SP-452
October 2000

First MSG RAO Workshop

CNR, Bologna, Italy
17-19 May 2000

MSG05

European Space Agency
Agence spatiale européenne

SP-452
September 2000

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Organised by:

European Space Agency
and
EUMETSAT

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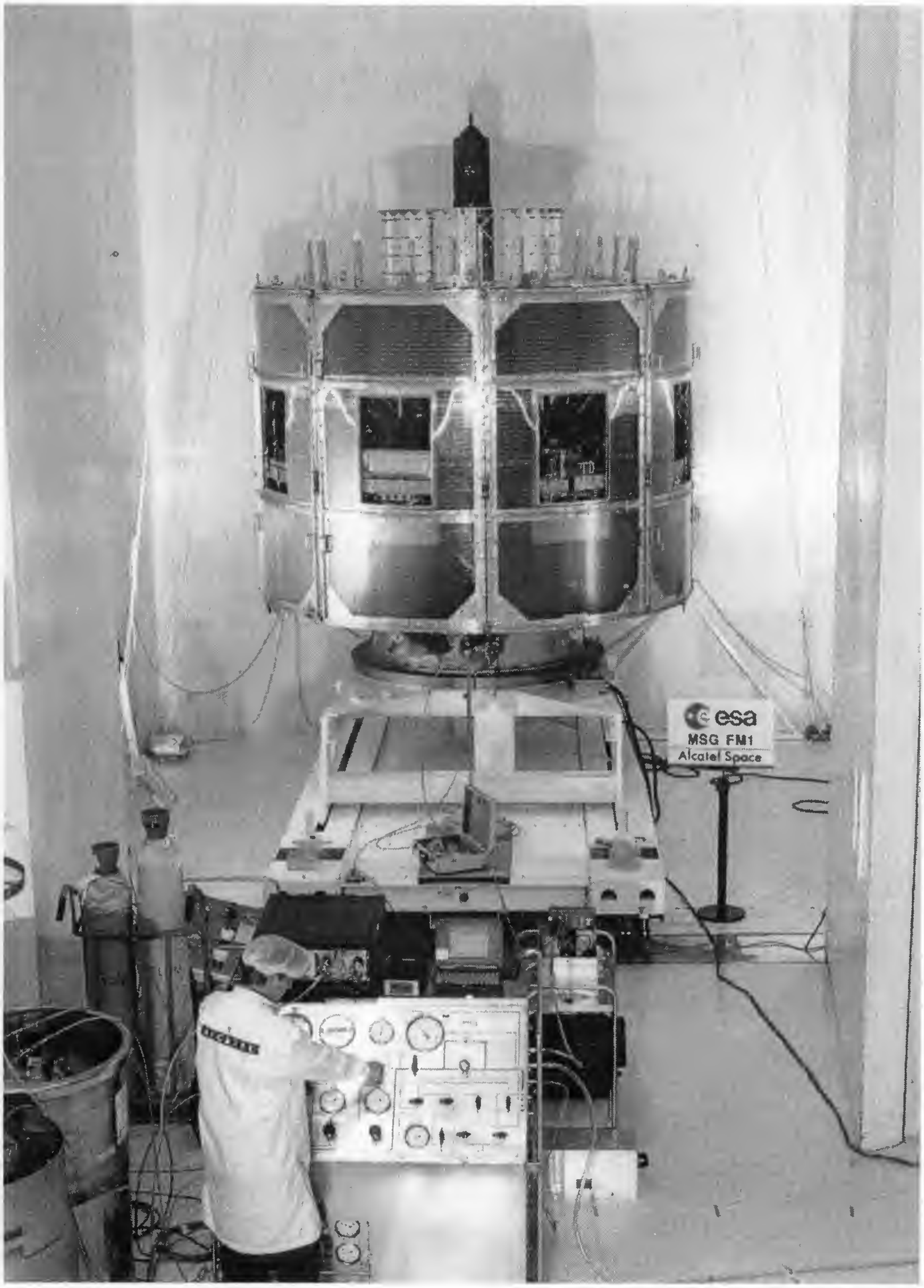

MSG During Balancing Tests
(courtesy: Alcatel Space Industries)

Contents

The MSG mission and the RAO

The MSG-RAO projects

The MSG mission and the RAO

FOREWORD

The Meteosat Second Generation (MSG) series will ensure the continuity of the Meteosat data and services, but will also provide improved observations in terms of spectral coverage, radiometric accuracy and data repeat rate. This represents an opportunity for research in many domains of Earth Sciences, not previously addressed by Meteosat.

The MSG Research Announcement of Opportunity (RAO) provides a structured framework for demonstrating the value of the MSG mission to innovative research in various Earth Sciences disciplines and for investigating the potential implications for the evolution of the operational services. The European Space Agency (ESA) and the European Organization for the Exploitation of Meteorological satellites (EUMETSAT) announced this opportunity to the worldwide scientific community in September 1998. Candidate Principal Investigators (PIs) were encouraged to submit research proposals using data from the MSG satellite series on:

- Innovative scientific investigations in areas such as
  - hydrology and land surface processes
  - atmospheric research
  - oceanography
  - climate research
- Calibration of MSG data and validation of geophysical products
- Investigation of new algorithms, including demonstration of new experimental products and of their value for research.

There were in total 43 projects jointly selected by ESA and EUMETSAT in November 1999, following a peer evaluation process initiated in February of the same year.

These projects involve about 190 researchers from ESA and EUMETSAT Member States including Belgium, Canada, Denmark, France, Germany, Italy, the Netherlands, Norway, Spain and the United Kingdom. Another 42 researchers belong to other countries including Botswana,

Workshop Objectives

Eva Oriol-Pibernat

MSG Mission Manager ESRIN

Via Galileo Galilei

00044 Frascati (I)

t: +390694180408;fax: +390694180402;email:eoriol@esrin.esa.it

Background

The Meteosat Second Generation MSG Research Announcement of Opportunity RAO has been released by ESA and EUMETSAT in 1999, after a first warning issued in September 1998, in order to promote the use of the new MSG satellites outside the operational meteorological user community. The variety and quality of the selected 43 proposals proves the usefulness of such joint initiative.

The MSG RAO Workshops

In the framework of the MSG RAO, a series of workshops will be organised which goal is to establish a structured dialogue and interactions among the MSG Principal Investigators (PIs) and ESA/EUMETSAT, respectively.

Each of these workshops will focus on a specific aspect, in addition to the necessary exchange of information.

Objectives of the Bologna Workshop

The focus of this first workshop was on the presentation of MSG features and of all selected RAO projects. It should serve as a starting point for continued interaction within the MSG RAO community (selected PIs and their co-Investigators, Co-Is).

The first MSG RAO workshop provided a forum for discussion among scientists, and ESA and EUMETSAT, leading to a continuous scientific co-operation. Requirements and possibilities with regard to data delivery were formulated and discussed at this workshop. In particular, PIs were asked to specify the minimal and nominal data requirements for the first year after the end of the MSG commissioning.

Specifically the objectives of this first MSG RAO workshop were:

- Presentation on MSG (mission, data, performance, products)
- Summary presentations of all selected RAO proposals;
- Synthesis of the major expected research results that will be possible thanks to MSG;

METEOSAT SECOND GENERATION: MISSION OBJECTIVES, PRODUCTS AND PLANS

Alain Ratier and Johannes Schmetz
EUMETSAT
Am Kavalleriesand 31, D-64295 Darmstadt, Germany

ABSTRACT: The mission, products and services of the new generation of European geostationary satellites, the so-called Meteosat Second Generation (MSG), are presented together with relevant programmatic background information. The MSG Programme covers a series of three identical satellites MSG-1, -2 and -3. It will provide a service over at least twelve years. Although, the mission is entirely justified by requirements from the operational meteorological user community, its capabilities offer a variety of opportunities for research in many disciplines, as demonstrated by the success of the Research Announcement of Opportunities jointly released by ESA and EUMETSAT.

1 INTRODUCTION

The meteorological community has been benefiting for more than two decades from the services of the current generation of Meteosat meteorological satellites, the first of which was launched in 1977. Meteosat image data are now an essential component of the Global Observing System and derived meteorological products are of great value to Numerical Weather Prediction (NWP), nowcasting and very short range forecasting (VSRF) and climate monitoring. The Meteosat Second Generation (MSG) system will significantly enhance the services and products that can be provided to the user community. It has been designed in response to more demanding user requirements that emerged from the continuously improved usage of current satellite data. As the current Meteosat, MSG will be spin-stabilised but will have far more capabilities, as a result of design and performance improvements and use of advanced technology. The following sections introduce the MSG mission objectives, system capabilities, products, services and current plans.

2 PROGRAMMATIC BACKGROUND

The MSG system is being developed to provide continuity of the current operational Meteosat system. Major improvements in terms of spectral channels, spatial resolution and temporal sampling will benefit the performances of nowcasting and Very Short Term Forecasting (VSRF) and Numerical Weather Prediction (NWP) systems. The MSG Programme covers a series of three identical satellites, MSG-1, -2 and -3, expected to provide observations and services over at least 12 years. Discussions have started at EUMETSAT Council level on a possible extension of the MSG Programme aimed at providing a two-satellite operational MSG service beyond 2013 (see Figure 1), based on the procurement of a fourth MSG satellite. Ultimately, with the implementation of the MSG and EUMETSAT Polar System (EPS), Europe will contribute to both the geostationary and polar orbiting components of the space-based Global Observing System of the World Weather Watch.

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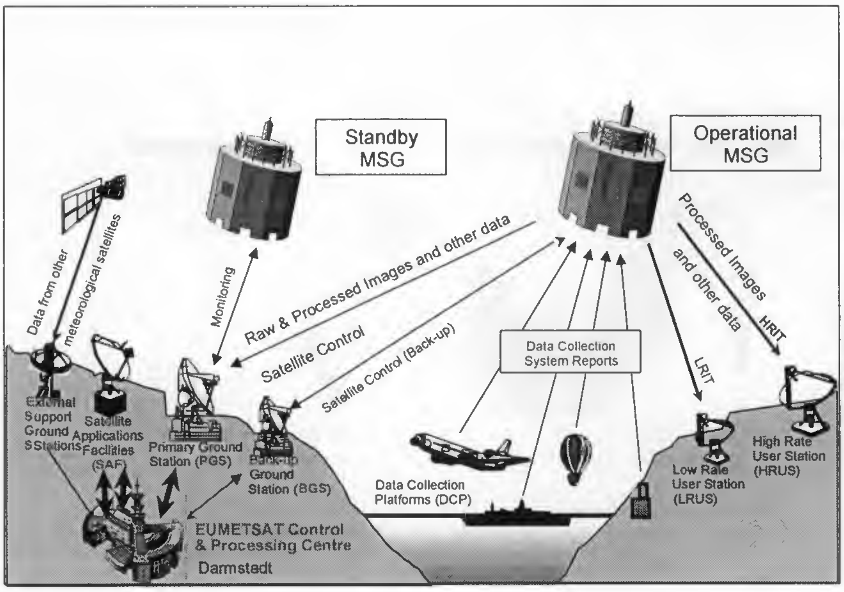

Figure 2: full MSG system and mission concept

The capabilities of the MSG system target major improvements in two disciplines of operational meteorology, Nowcasting and Very Short Term Forecasting (VSRF), and Numerical Weather Prediction (NWP). The former will benefit from about 20 times more data than Meteosat: the imaging frequency will be increased from 30 to 15 minutes, the ground resolution/sampling will increase by a factor of two in the two dimensions, and the number of spectral channels will be 12 instead of 3.

This will enable a better characterisation of rapidly evolving weather patterns, supported by improved discrimination between surfaces and clouds (window channels). More information will also be available from some infrared channels on the vertical structure of the atmosphere: pseudo-sounding will produce Global Instability Indices (GII), water vapour information will be available at two levels in the troposphere, and the 9.6 μ channel will document total ozone. The characteristics of the thermal IR channels are depicted in figures 3 and 4.

The HRIT/LRIT real time dissemination service and the dedicated software packages developed by the Satellite Application Facility (SAF) on Nowcasting and VSRF are an important complement to the enhanced satellite capabilities, as their distribution will enable operational users to derive further nowcasting products from SEVIRI basic imagery.

The main innovative features of the MSG satellites can be emphasised as follows:

i) The twelve spectral channels of the imager will observe the Earth-atmosphere system with a spatial sampling distance of 3 km (1 km for the High Resolution Visible channel), building a bridge to multi-spectral imagery from polar orbit and thus facilitating the amalgamation of geostationary and polar observations;

ii) The shorter repeat cycle of 15 minutes for full-disk imaging will provide unprecedented multi-spectral observations of rapidly changing phenomena (e.g. deep convection) and provide better and more numerous wind observations from the tracking of cloud features;

iii) Improvements also include an on-board blackbody calibration for the thermal IR channels and new methods for vicarious calibration of solar channels (at 0.6, 0.8, 1.6 and the broad band high resolution visible channel 0.4 – 1.1 μm);

iv) Improvements in satellite image navigation and inter-channel registration are also expected to benefit multi-spectral analyses commonly used for product derivation.

4 MSG GROUND SEGMENT

4.1 The MSG Ground Segment

The EUMETSAT multi-mission Ground Segment is composed of a set of central facilities, located at EUMETSAT headquarters, in Darmstadt, Germany, primary and back-up ground stations for satellite control and data acquisition and a geographically distributed network of so-called Satellite Application Facilities (SAFs) (see figure 5). The central facilities control the EUMETSAT satellites through the relevant Ground Stations, pre-process all data acquired from these satellites up to level 1.5. In the case of MSG, pre-processing is performed by the Image Processing Facility (IMPF, see Just, 2000, this issue). The responsibility for extraction of meteorological or geophysical (level 2) products is shared between the central Meteorological Product Extraction Facility (MPEF) and the network of SAFs. The multi-mission Unified - Meteorological Archiving and Retrieval Facility (U-MARF) (see Cadé, 2000, this issue) will archive all data and products generated centrally while the SAFs will archive products generated at their premises

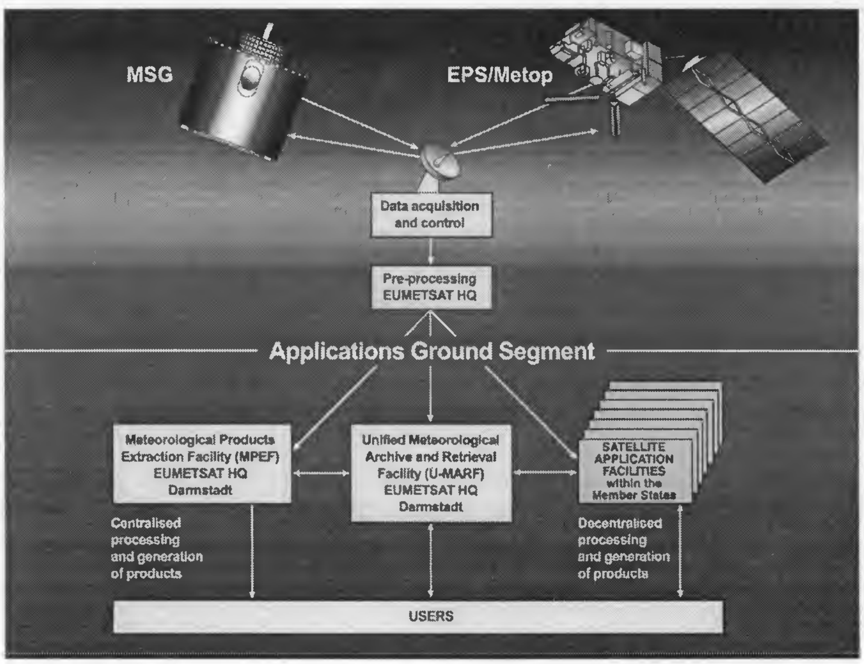

Figure 5: Overall architecture of the EUMETSAT multi-mission Ground Segment

MPEF processing starts with a pixel classification leading to an intermediate product called Scene Analysis. A key ingredient to the retrieval is a radiative IR forward model needed to help interpreting the observed IR radiances and to derive products (Tjemkes and Schmetz, 1997).

The Scene Analysis (SCE) is an intermediate, pixel-level product that is not disseminated. It is further used in the derivation of other products requiring either cloudy or clear pixels and provides at each repetition cycle:

- Identification of cloudy and clear pixels an a cloud mask;
- Identification of scene type for each pixel;
- Radiances at the top of the atmosphere.

The SCE algorithm is based on threshold techniques (e.g. Saunders and Kriebel, 1988).

The Cloud Analysis (CLA) is a disseminated product derived from the Scene Analysis results providing information about cloud cover, top temperature, top pressure/height, type and phase. Its extraction produces an intermediate (not disseminated) pixel level product necessary to support the generation of Atmospheric Motion Vectors (AMV). Lutz (1999) describes the extraction of the SCE and CLA products in detail.

The Cloud Top Height (CTH) is a derived image product providing the height of the highest cloud at a super-pixel resolution of 3x3 pixels with a vertical pseudo-resolution of 300 m. This product, intended for use in aviation meteorology provides also information about fog in the CTH processing segment. Both the CTH and the fog information are extracted from the intermediate pixel level CLA.

The Atmospheric Motion Vectors (AMV) are the most important products for NWP. Their extraction relies on conceptually validated ideas and methods. The tropospheric AMVs will be derived from cloud and water vapour motion using the 0.6 or 0.8 μm channels, the 10.8 μm channel and the 6.2 and 7.3 μm channels, respectively. The kernel algorithms will be to a large extent similar to those already widely in use, e.g. at EUMETSAT for Meteosat: a description of the basic method is given in Schmetz at al. (1993) and novel features are reported in Holmlund et al. (2000). Studies have shown that ozone observations at high temporal and spatial resolution (from the 9.6 μm channel) may also be used to provide information about winds in the upper troposphere and lower stratosphere (e.g. Riishojgaard, 1996). Therefore the capabilities to extract lower stratospheric displacement vectors from the ozone channel will also be exploited at Day 2.

The Global Instability Index (GII) is an air mass parameter indicating the stability of the atmosphere at a scale of about 30 km. It is derived on the full disk and disseminated. Together with the products from the SAF on nowcasting and VSRF, it will realise the motivation to use MSG for nowcasting. The idea for the GII was validated by successful applications and experience by NOAA/NESDIS with GOES lifted index products (e.g. Menzel et al., 1998). Two algorithms are currently foreseen i.e. a physical retrieval (Ma et al., 1999) and an artificial neural network. The latter has a lower performance overall but is computationally more efficient. This product is expected to be an experimental Day-1 product.

The Clear Sky Radiance (CSR) product gives radiances (in Wm-2 sr-1 (cm-1) -1) averaged over clear-sky pixels identified by SCE. The CSR is derived for each repeat cycle, though it is not disseminated that often (see Table 1). Operational NWP centres will assimilate CSR products in their analyses.

The Tropospheric Humidity (TH) product provides estimates of mean relative humidity in two tropospheric layers, i.e. Upper Tropospheric Humidity (HTH) between about 600 and 300 hPa (based on 6.3 μm clear sky radiances), and Mid-Tropospheric Humidity (MTH) between 850 and 300 hPa (based on 7.2 μm clear sky radiances). The algorithm follows the improved UTH retrieval presented in Schmetz et al. (1995).

The Total Ozone (TOZ) product uses the 9.6 μm channel, other SEVIRI channels and correlative data. It is derived with a regression algorithm described in Karcher and Blaison (1998) and prototyped by the SAF on Ozone Monitoring. Ozone observations will be used alone or assimilated into NWP models equipped with a suitable multivariate data assimilation system in which the forecast includes a prognostic equation for ozone.

6 ACCESS TO MSG DATA AND PRODUCTS

MSG image data and derived products can be accessed in quasi real time and in delayed off line mode.

6.1 Real time access

EUMETSAT-authorised users owning and operating MSG User Stations can access MSG image data (level 1.5) and selected products in real time from the MSG satellite, based on the MSG digital broadcasting/dissemination capabilities (see figure 2). Two types of User Stations are planned to be available from relevant industry, namely the High Rate User Stations (HRUS) and Low Rate User Stations (LRUS). These stations will acquire the High Rate Information Transmission (HRIT) and Low Rate Information Transmission (LRIT) digital data streams. As the contents of both data streams to be complementary and only partially redundant, industry is also expected to offer enhanced HRUS stations capable of acquiring both data streams.

Although the contents of the HRIT and LRIT data streams are still under discussion by EUMETSAT Delegate Bodies it is expected that all SEVIRI channels will be available at full space and time resolution as part of the HRIT data stream. A subset of channels would be available with reduced time sampling as part of the LRIT data stream, together with selected products.

The procurement of MSG User Stations (LRUS, HRUS or combined) is under the responsibility of the users. However, in order to guide users on relevant specifications, EUMETSAT has published on its Home Page the detailed design of the Prototype Stations developed as part of one MSG ground segment central facilities (the DADF) for monitoring purpose. Figure 6 depicts the typical breakdown of an HRUS station.

EUMETSAT will deliver the key unit for data decryption and relevant licences. Licenses are free of charge for all investigators selected under the MSG RAO and, more generally, for research use.
It should be noted that the European Commission (DGVIII) is supporting the acquisition of HRUSs over most of the African continent as part of its PUMA initiative.

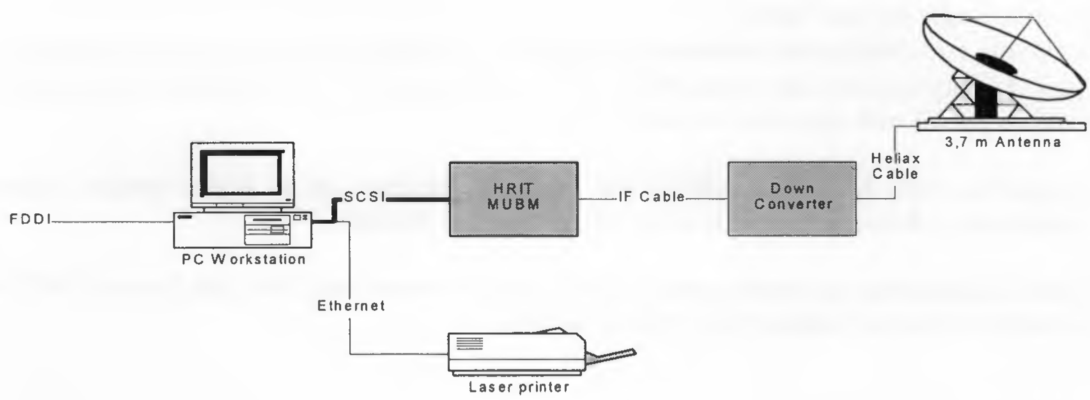

Figure 6: typical breakdown of a HRUS user station

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SEVIRI INSTRUMENT LEVEL 1.0 DATA

Paolo Pili
EUMETSAT
Am Kavalleriesand 31,
64295 Darmstadt, Germany

ABSTRACT: The main characteristics of the MSG SEVIRI instrument level 1.0 data are presented together with an overview of the SEVIRI image acquisition principle. Relevant performances of the SEVIRI instrument are also presented, as established from analysis of the test results of the Flight Model.

1 INTRODUCTION

The Spinning Enhanced Visible and Infrared Imager (SEVIRI) instrument is the main payload of the MSG satellite developed by Industry under the responsibility of ESA. The instrumental chain involves the instrument and the supporting facilities required for its characterisation and the ground facilities for its commanding and processing of its data. Taking into account the results of the recent tests of the SEVIRI Flight Model, this paper present the main characteristics and performances of the instrument and the level 1.0 data received from the satellite prior to pre-processing. The performances presented are at SEVIRI level and do not include some satellite flight dynamics corrections (e.g. the geometric performances do not include the satellite orbital effect). The purpose is to provide the information necessary to correctly understand and use the data delivered by the instrument.

2 SEVIRI SPECTRAL CHANNELS

Table 1 gives the SEVIRI spectral channels and the corresponding dynamic ranges (see ref. 1), with the following convention:

λ_{cen} is the nominal central wavelength in the channel

λ_{min} is the minimum wavelength of the outer template of the spectral response (e.g. 0.56μm in the plot of Figure 1 for channel VIS0.6)

λ_{max} is the maximum wavelength of outer template of the spectral response (e.g. 0.71μm in the plot of Figure 1 for channel VIS0.6)

Proceedings of the First MSG RAO Workshop, Bologna, 17-19 May 2000, ESA SP-452, October 2000

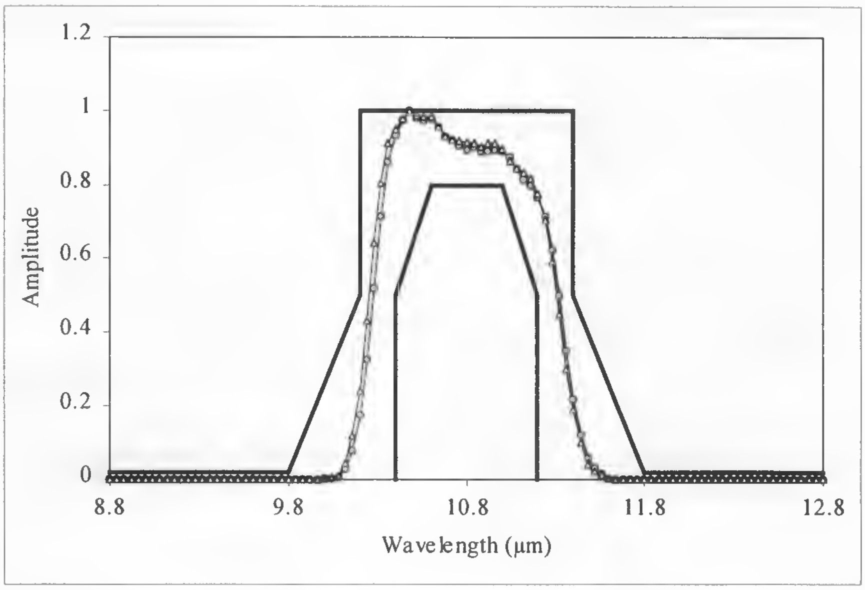


Figure 2: Example of SEVIRI spectral response (Channel IR10.8)
(Solid line is the specified template, dots are the FM values at 95K, triangles are for 85K)

3 IMAGE ACQUISITION PRINCIPLE

The MSG satellite is spins at a rate of 100 revolutions per minute. Each revolution lasts nominally 600 ms of which about 30 ms are dedicated to Earth viewing. The East-West scanning capability of SEVIRI (see ref. 1) is provided by the satellite spin. To ensure the necessary South-North coverage, a scan mirror is stepped from South to North in steps of 9 km. The full Earth disc is then covered in 15 minutes for the 12 spectral channels. The HRV provides also full-disc coverage in the North-South but only half-disc coverage in the East-West direction. Figure 3 shows the imaging principle. The SEVIRI nominal sampling distance is 3 km (1 km for HRV) at sub satellite point both in East-West and in North-South directions.

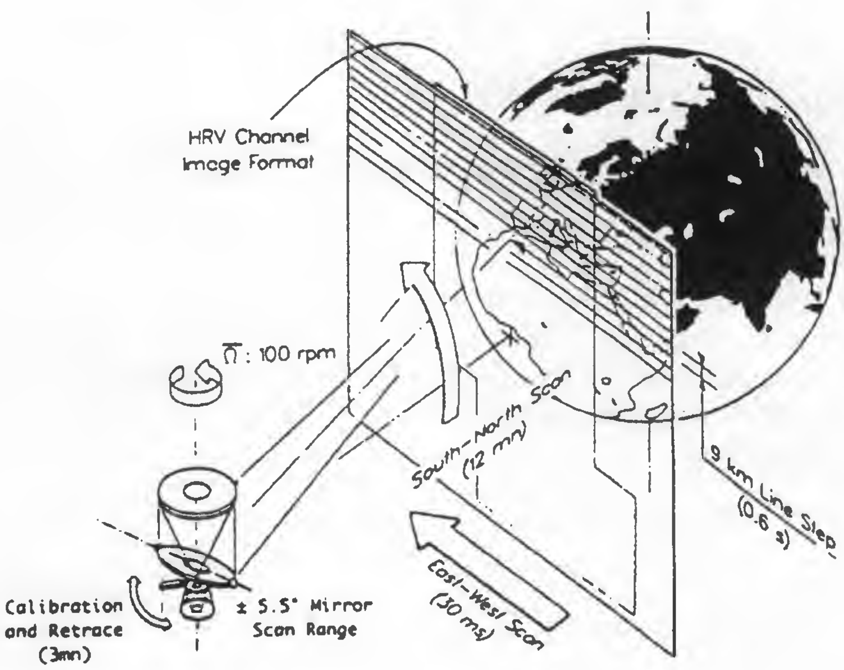


Figure 3: SEVIRI image acquisition principle

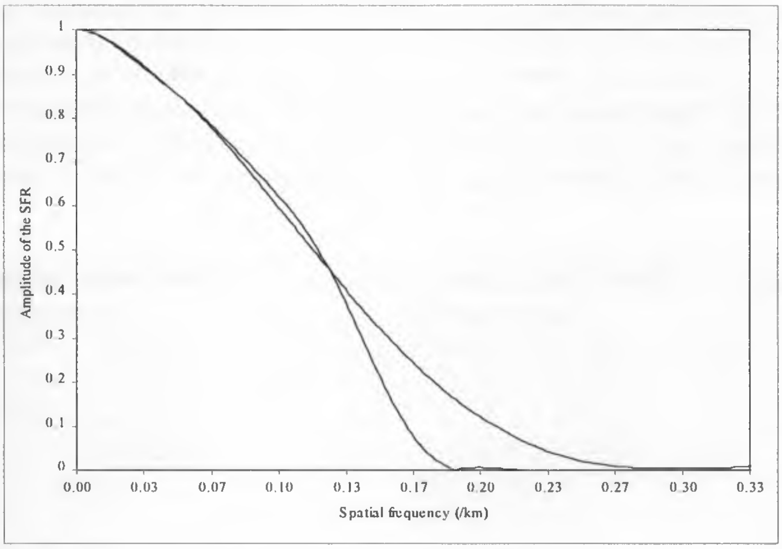


Figure 6: MTF curves for the VIS0.6 channel

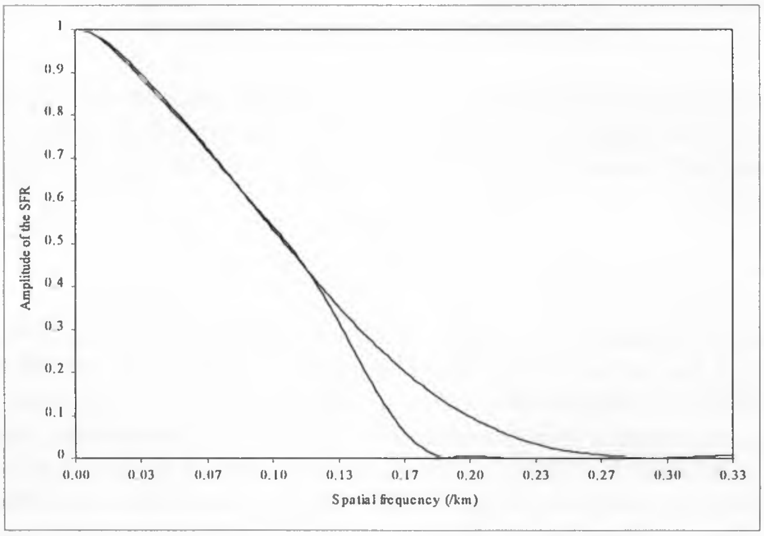


Figure 7: MTF curves for the IR10.8 channel

5 RADIOMETRIC PERFORMANCES

5.1 Short-term radiometric error

The short-term error requirement covers all contributors affecting the radiometry during one nominal repeat cycle (15 minutes duration) and accounts for the in-orbit conditions at End Of Life (EOL) (see ref. 2). These are essentially:

- Random Noise;
- Stability of the temperature of detectors;
- Crosstalk and straylight;
- Gain stability.

point within the optical path, this design feature being mainly driven by considerations on the feasibility and design complexity of a full pupil (500 mm diameter) calibration source with temperature uniformity. The on board calibration conceptual implementation is shown in Figure 8.

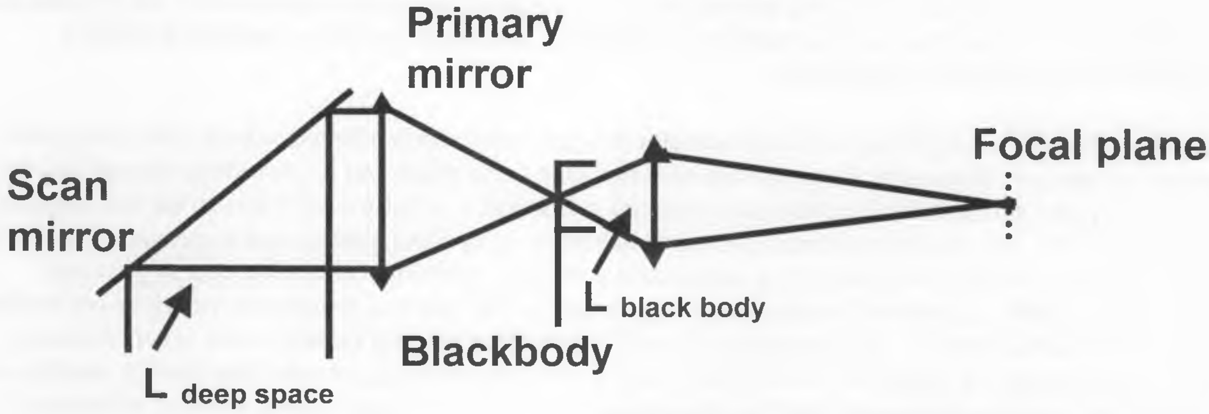


Figure 8: Schematic of the implementation of the SEVIRI on board calibration source

Although highly simplifying the instrument design, this implementation imposes a correction term in the determination of the instrument calibration coefficients. This is because the background radiance emitted by the fore optics (self emission of scan mirror, primary mirror and supporting structures) does not reach the detector when the on-board blackbody is moved into the optical path, whereas the background from these optical elements is present when calibrating on deep space. This asymmetry needs to be accounted for and corrected to avoid errors in the calibration coefficients. The effect has been analysed in detail by the SEVIRI manufacturer and a correction factor introduced in the classical calibration formulas to take into account the difference in the background flux between the acquisition of cold space and the acquisition of the on-board source. In order to allow the calculation of the correction factor, the on-board source can be heated up to a second temperature and the temperature of the front optics is monitored in flight to provide another necessary input to the model.

In summary, the SEVIRI calibration approach is based on classical deep space viewing and a known on-board black-body source, the temperature of which can be changed to determine a correction factor accounting for the different level of background flux when calibrating with the on-board source. The model has been tested on ground and a calibration error budget established in the frame of the SEVIRI on ground verification. Table 3 gives the results of this verification.

Channel	Calibration performances	Calibration requirements
IR3.9	0.35K at 335K	1.0K at 335K
WV6.2	0.29K at 300K	1.0K at 300K
WV7.3	0.29K at 300K	1.0K at 300K
IR8.7	0.41K at 300K	0.8K at 300K
IR9.7	0.54K at 310K	0.8K at 310K
IR10.8	0.53K at 335K	1.0K at 335K
IR12.0	0.53K at 335K	0.9K at 335K
IR13.4	0.49K at 300K	0.7K at 300K

Table 3: Comparison between calibration error requirements and performances as derived from the SEVIRI FM test results

	Measured co-registration error		Specified maximum co-registration error	
Group	**East-West (km at SSP)**	**North-South (km at SSP)**	**East-West (km at SSP)**	**North-South (km at SSP)**
VNIR channels	0.38	0.25	0.53	0.7
Warm channels	0.38	0.26	0.43	0.95
Window channels	0.37	0.46	1.39	1.39
Cold channels	0.39	0.61	1.48	1.7

Table 4: Comparison between inter-channel spatial registration requirements and performances

Table 5 demonstrates that stability of inter-channel spatial registration is very high for the SEVIRI FM. It should be noted however that the effect of eclipses as well as the satellite contribution are not included in the results.

		Measured co-registration stability		Required co-registration stability	
Group	**Stability period**	**East-West (km at SSP)**	**North-South (km at SSP)**	**East-West (km at SSP)**	**North-South (km at SSP)**
Warm channels	28 days	0.106	0.01	0.3	0.3
	7 days	0.027	0.003	0.3	0.3
	1 day	0.004	0.000	0.06	0.06
Cold channels	28 days	0.127	0.07	0.5	0.5
	7 days	0.032	0.018	0.3	0.3
	1 day	0.005	0.003	0.15	0.15

Table 5: co-registration stability: comparison between requirements and performances

7 OUTAGES

There are a few conditions on the MSG mission during which the SEVIRI data are expected to be not available. These are manoeuvres, eclipse, and decontamination of the passive cooler. Table 6 gives a comparison between requirements and expected performances.

	Expected performance	Requirement
Manoeuvres outages (hours per manoeuvre)	Less than 1 hour	Less than 3 hours
Eclipse outages (hours per eclipse)	Less than 1 hour	Less than 12 hours
Decontamination	To be estimated during commissioning	Less than 212 hours in the 1st year (96 hours in subsequent years)

Table 6: expected outages: comparison between requirements and performances

8 CONCLUSION

The SEVIRI performances as estimated from on ground tests of the SEVIRI Flight Model exceed specified specified requirements and give confidence in the in-orbit performances of the MSG system and in the quality and stability of the SEVIRI level 1.0 data. Additional information can be found on http://www.eumetsat.de and in the list of references.

SEVIRI LEVEL 1.5 DATA

Dieter Just
EUMETSAT
Am Kavalleriesand 31,
64295 Darmstadt, Germany

ABSTRACT: A number of radiometric and geometrical corrections must be applied to the SEVIRI level 1.0 data, before they can be used for the generation of meteorological products. These corrections transform the Level 1.0 data into Level 1.5 data. This paper describes these corrections and the main characteristics of Level 1.5 data in terms of projection, size, resolution, coverage and quality. In addition, the two major Level 1.5 data formats used for archiving and dissemination are shortly described.

1 INTRODUCTION

The Meteosat Second Generation (MSG) system will enter into operation in 2002 following commissioning with the MSG-1 satellite. The MSG SEVIRI (Spinning Enhanced Visible and Infrared Imager) instrument features several improvements compared with its Meteosat predecessor (Ratier and Schmetz, 2000, this issue). These improvements are required to meet the expectations of the meteorological user community. Some of them are sizing factors for data processing, one of the key functions of the MSG ground segment. These are in particular:

- The shortening of the repeat cycle for image data acquisition from 30 to 15 minutes;
- The increase in the number of channels from 3 to 12;
- The reduced sampling distance of 3 km for all channels except for the High-Resolution Visible (HRV) channel which is sampled at 1 km.

The SEVIRI data stream will be continuously transmitted from the MSG satellite to the Primary Ground Station (PGS) located in Usingen, Germany. It will be sent from there to the EUMETSAT Image Processing Facility (IMPF) located in Darmstadt, via a land communication link.

The IMPF checks the completion and consistency of the received data packets and performs radiometric and geometric corrections of the image. The resulting image data, called Level 1.5 data, is then sent to:
- the Meteorological Product Extraction Facility (MPEF) for product extraction;
- the Unified Meteorological Archiving & Retrieval Facility (U-MARF) for archiving, and
- The Data Acquisition and Dissemination Facility (DADF), for dissemination to users via the MSG satellite.

The MSG Data Acquisition and Dissemination Facility (DADF) is preparing the Level 1.5 data for up-link to the MSG satellite via the PGS and further dissemination to user stations via the dissemination channels of the MSG satellite.

2 TRANSFORMATION OF LEVEL 1.0 INTO LEVEL 1.5 DATA

The main function of the IMPF is to apply geometric and radiometric corrections to the SEVIRI Level 1.0 data. The definition and characteristics of Level 1.0 data are presented in Pili, 2000, this issue. Such corrections are necessary to remove perturbations caused by imperfections in the image acquisition process. The corrected image is the so-called Level 1.5 data. As a result of the correction process, Level 1.5 images are provided in a standard projection, i.e. the geostationary projection, which allows an easy geo-location of (which depends on the scan angle) and column N of the selected tie point is first determined in the SEVIRI instrument reference frame. The look vector is then transformed into a reference frame fixed with respect to the Earth. When the look vector is known in this frame the intersection of the extended look vector with the Earth surface is determined. Once the longitude and latitude of this intersection point is known it can be mapped easily into the geostationary reference frame, i.e. the Level 1.5 reference grid. The spacing between tie points is close enough to allow a simple interpolation to derive the Level 1.0 grid location for every Level 1.5 pixel positioned between a set of four tie points. This procedure is applied first in the East-West direction and then North-South. The East-West interpolation corrects also for detector offsets (relative to the centre detector), spin variations and jitter. After calculation of the Level 1.0 grid location, the corresponding pixel count value is derived by means of an interpolation filter with a kernel size of up to eight pixels. Various interpolation filter types are selectable in the IMPF, e.g. a cubic spline or a truncated Shannon function. It is also possible to modify the East-West and North-South Modulation Transfer Functions in this step, East-West for every detector and North-South for every channel. The kernel size of the interpolation filter will be increased in this case. Some special treatment has to be applied to the HRV channel because of its different size, coverage, and sampling distance.

3.1 Geostationary Projection and Geographical Coverage

The projection used for all MSG channels has not changed from the current Meteosat: Level 1.5 images are mapped in the standard geostationary projection as seen from an ideally aligned satellite/instrument at zero degree longitude and latitude (see figure 2).

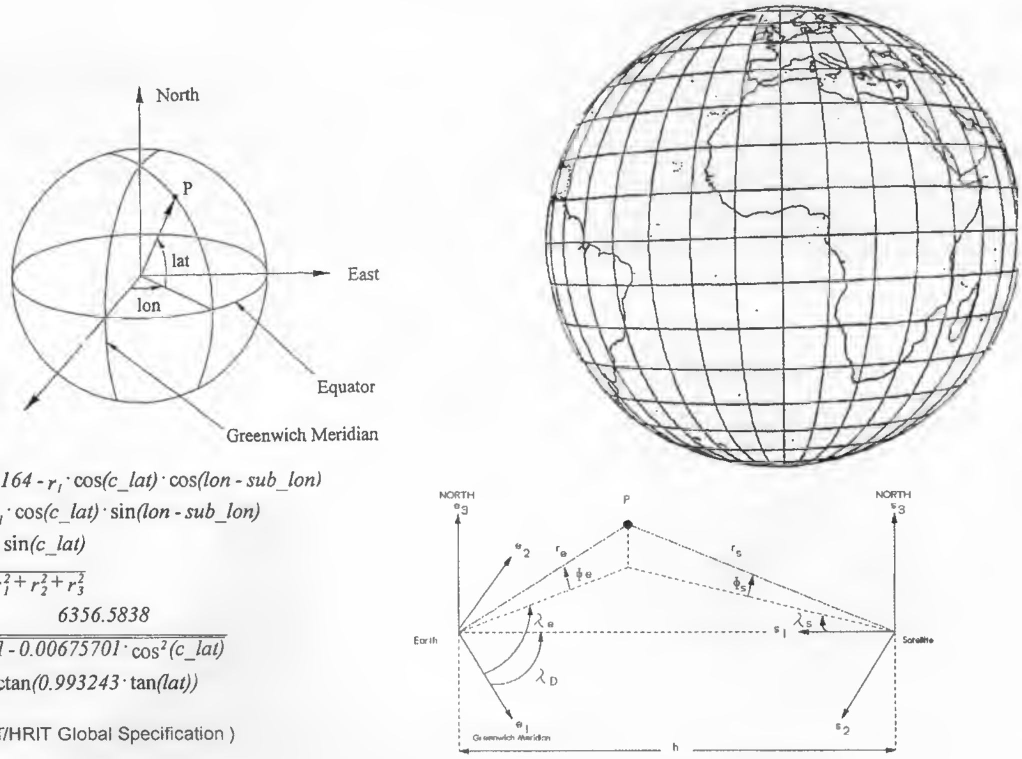


Figure 2 –Geostationary Projection

The use of a constant projection grid to which all images are mapped allows every user to easily geo-locate each Level 1.5 pixel (Ref.1). In addition, multi-channel products can be derived in a straightforward manner because all channels are presented in the same grid. However, due to the increased HRV resolution and reduced sampling spacing (1 km SSP versus 3 km SSP), a non-HRV pixel covers an array of 3x3 HRV pixels.

The precise evaluation of the image resolution requires knowledge of the Point Spread Function (PSF). Figure 4 displays the result of a simulation of the PSF (in km SSP units) for the non-HRV channels that takes into account the most important effects that limit the resolution, e.g. the detector size/shape and the on-board anti-aliasing filter. The detector is the limiting factor for the resolution. Therefore wavelength-dependent effects (e.g. diffraction) are of second order. As SEVIRI acquires images in constant angular steps, the on-ground resolution varies according to the geographical location on Earth as shown in figure 5.

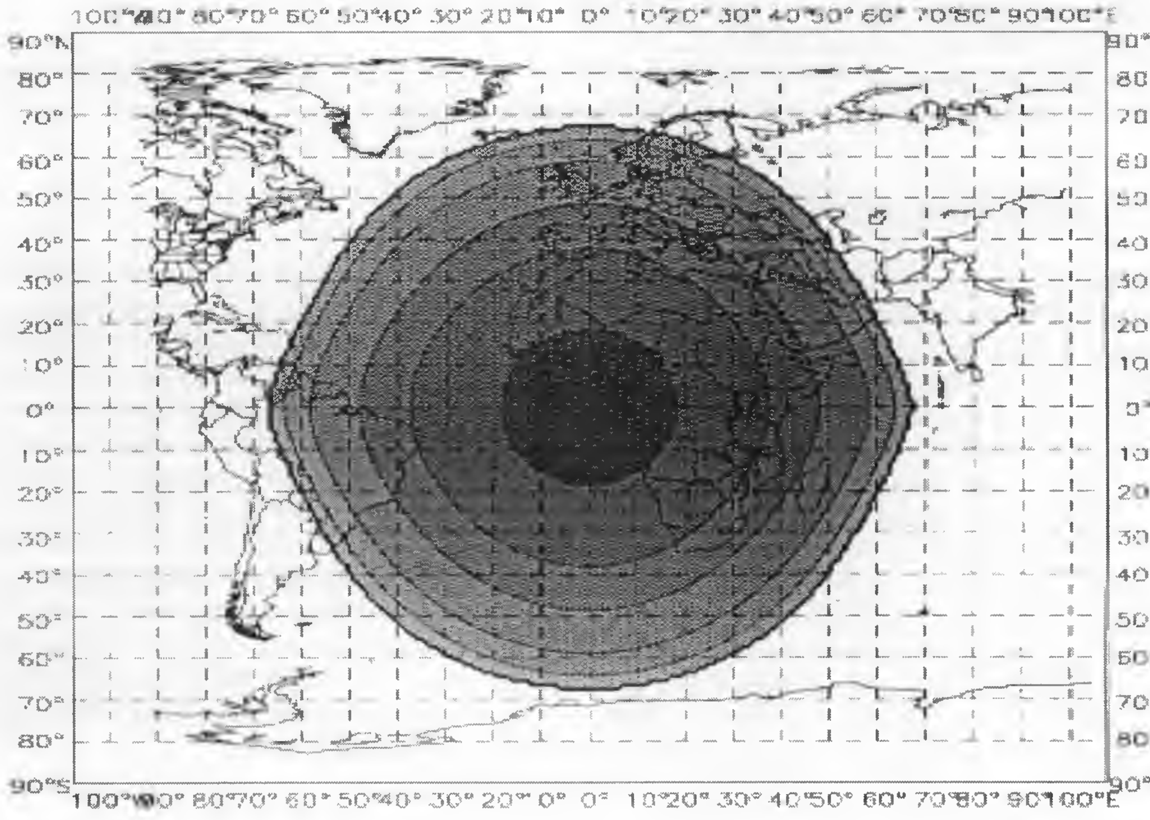


Figure 5: On-ground resolution as a function of geographical location on Earth. The darkest grey corresponds to a resolution of 3.1 km and the lighter greys to 4, 5, 6, 8 and 11 km, respectively.

3.3 Geometric quality

In order to assess the geometric quality of the achieved corrections, quality parameters are derived for every image.

The absolute accuracy is the RMS value (over one image) of the absolute pixel position with respect to its ideal position. It is derived using landmark deviation measurements with respect to a precise digital map. The absolute RMS error is required to be less than 3 km.

The relative accuracy is the RMS of the positional variation of a pixel relative to the previous image. It is a measure of stability of the image navigation. It is especially important for tracking displacement of features (e.g. clouds) and is measured by tracking the displacement of landmarks from one image to the next. The RMS error is required to be less than 1.2 km.

The relative accuracy within 500 (resp. 16) pixels is the variation of the positional error within 500 (resp. 16) pixels in both the East-West and North-South directions. It is an indicator of local deformations within an

The final radiance values are then mapped to the Level 1.5 dynamic range (0-1023) by multiplication of a scaling factor. The latter is provided as part of the 1.5 auxiliary parameter records and allows every user to retrieve the true radiance values from the 1.5 counts by a simple linear relation:

$$\text{Physical Units} = \text{Cal\_Offset} + (\text{Cal\_Slope} \,.\, \text{Pixel Count})$$

All corrections, including the scaling into the Level 1.5 dynamic range, are calculated and stored in one look-up table ("generation of Level 1.0 conversion function" in figure 6) applied to Level 1.0 data ("requantise level 1.0 data" in figure 6). The look-up table is up-dated with every repeat cycle.

5 LEVEL 1.5 DATA FORMAT

5.1 Native Level 1.5 Format

The level 1.5 image is transferred for further archiving or dissemination as a continuous sequence of packets providing the data from the full Earth disk (full scan) or a part of the Earth disk (partial scan), corresponding to one repeat cycle. Each repeat cycle contains heading and trailing information, and in between, the actual level 1.5 image data on a line by line basis. All ancillary information on the image is captured in the format header and trailer.

Data corresponding to one full repeat cycle comprise (Ref.3):

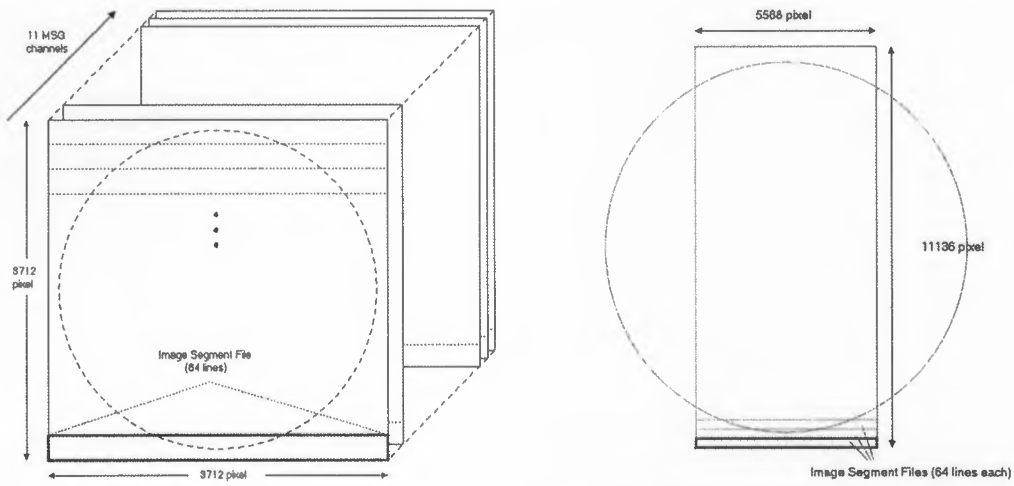
- the repeat cycle header packet;
- the repeat cycle image packets, organised by lines. Each line is in turn split into line header data and line image data. In case of a full Earth scan (nominal repeat cycle), there are 3712 lines of 3712 10-bit pixels per IR/VIS channel and 3 x 3712 (=11136) lines of 5568 10-bit pixels for the HRV channel;
- the repeat cycle trailer packet containing processing data and statistics, imaging platform data and quality information for the repeat cycle.

Data corresponding to one reduced scan are structured in the same way, except that fewer lines are generated due to the reduced geographical coverage. The repeat cycle header packet contains a description of all relevant acquisition and processing conditions of the present repeat cycle, e.g. number of lines, position of the HRV South and North scans within the grid, etc. Figure 7 shows a graphical representation of the data sequence. The concatenation of all packets of a repeat cycle constitutes the "native Level 1.5 data format". The native format is used in the U-MARF archive (see Cadé, 2000, this issue). However, other data formats can be made available.

field. Secondary headers can be provided, if necessary, to further specify the data content. Figure 8 shows a graphical presentation of the basic HRIT/LRIT file structure.

Figure 8 – HRIT/LRIT File structure

The HRIT/LRIT format then specifies further the transmission protocol down to the physical layer.
It is important to note that the "native Level 1.5 data format" of one repeat cycle, including its header, image data and trailer, is not sent in one HRIT/LRIT file but in different HRIT/LRIT files. Also, image data of one repeat cycle are sent over several files in order to meet timeliness requirements. Each image is segmented into files of 64 lines of the same channel for this purpose. Figure 9 shows a schematic of image segment files for non-HRV and HRV channels.



The eleven '3 km channels' will be split into 58 image segments.

The HRV channel will be split into 174 segments.

Figure 9 – HRIT/LRIT Image segmentation files

The image data may be subjected to compression (lossless for HRIT and lossy for LRIT) and encryption. However, de-compression/de-cryption is performed at the user stations making the encoding transparent to users. More details on the MSG mission specific HRIT/LRIT format can be found in Ref. 4.

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U-MARF FACILITY AND SERVICES

F. Cadé
EUMETSAT
Am Kavallerisesand 31
D-64295 Darmsdadt, Germany

ABSTRACT: This paper describes the capabilities and services expected from the EUMETSAT Unified Meteorological Archiving and Retrieval Facility (U-MARF) currently under development. This facility will be the central repository of all EUMETSAT data and centrally derived products. It will also provide users with on-line retrieval capability using web-based interfaces. The data delivery mechanisms considered by EUMETSAT to support potential Meteosat and large volume MSG data requests from the MSG RAO investigators are also presented.

1. INTRODUCTION

The current Meteosat radiometer provides 1.8 Gbytes of data every day in three spectral bands cumulating to more than 650 Gbytes per year. Due to the enhanced spectral and temporal capabilities of SEVIRI (see Ratier and Schmetz, 2000, this issue) more than 30 Gbytes of level 1.5 data will be generated daily, representing more than 10 Tbytes per year. Hence, in the context of the scientific exploitation of these data, issues related to delivery media, storage cost or batch processing should not be underestimated. Past experience has shown that fast and customised archive retrieval systems were seldom realised without causing limitation to the maximum amount of retrieved data per order. Additionally, the MSG mission has been primarily designed to serve the purpose of operational meteorology, with focus on near real-time services and processing of frequent off line requests for small data volume.

The Unified Meteorological Archiving and Retrieval Facility (U-MARF) currently under development will be the central repository of all EUMETSAT data and centrally derived products. It will furthermore provide users with on-line information, search and ordering services using standard web-based interfaces. Product delivery will be performed on-line (electronic delivery) or off-line on physical media.

An overview of the Facility is presented hereafter in section 2, followed by an introduction to the U-MARF standard services in section 3. An analysis of the MSG RAO data requests is presented in section 4, together with possible delivery scenarios tailored to large data requests from MSG PIs. Section 5 summarises the outcome of relevant discussions at the first MSG RAO Workshop.

2. U-MARF OVERVIEW

2.1. Development approach and schedule

The procurement of the U-MARF was initiated in 1997 following a decision of the EUMETSAT Council to develop a multi-mission, incremental archiving and retrieval facility, including on-line web-based user access capability and supporting all EUMETSAT programmes, i.e. :

- The Meteosat Transition Programme (MTP), including historical archive from METEOSAT 1 to 6;
- The Meteosat Second Generation (MSG);
- The EUMETSAT Polar System (EPS).

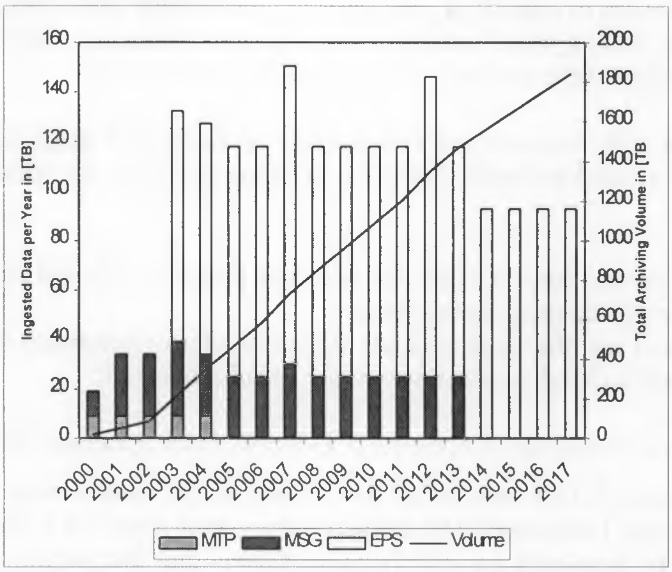

Figure 2: U-MARF archive ingestion and accumulation.

Whereas the migration of the MTP data will represent an archive sizing of about 45 Terabytes, the U-MARF will have to archive 25 Terabytes of SEVIRI level 1.0, 1.5 and 2.0 data per year, which represents a total of about 300 Terabytes for the entire MSG mission. With the extension to EPS services, the volume of the archive will reach the 1.5 PetaBytes of data.

3. THE U-MARF STANDARD SERVICES

The U-MARF is being designed in order to provide users with automated fast delivery services and to offer a maximum of flexibility in terms of selection of delivery media, spectral bands, geographical areas, and selection of repeat cycles within time periods. The U-MARF standard services will be described in the U-MARF User Handbook, scheduled to be available by the end of 2000. These services will be accessible from the EUMETSAT home page (www.eumetsat.de). They can be basically classified into U-MARF core services and auxiliary services.

The core services include:

- Information and Guide services aiming at providing users with general information and documents (about the U-MARF services, the products characteristics, the file format, etc.);
- Product search services allowing users to search for archived products and to obtain information on the selected products (these services correspond to the Inventory and Browse services in the former CEOS Catalogue definition);
- Ordering and Follow-up services allowing users to order the previously selected products.

The auxiliary services support the aforementioned core services and include User Registration and User Administration. Last but not least, a Help Desk service will complement all the automated services listed above.

The U-MARF on-line retrieval capability mission will be fulfilled by the Product search and Ordering services. The search services aims at providing user-friendly access to the catalogue of the data and products actually archived. Two types of searching mechanisms are proposed:

Gigabytes for typical periods of full retrieval of the SEVIRI 1.5 images (i.e.all Level 1.5 repeat cycles, full window, 12 channels). The table also presents the requested number of tapes (DAT and DLT).

Period of retrieval	Sizing	Number of DAT tapes	Number of DLT tapes
1 month of data	900 Gbytes	75	18
3 months of data	2700 Gbytes	225	54
6 months of data	5400 Gbytes	450	108
12 months of data	10.8 Tbytes	900	216

Table 1: Sizing of SEVIRI Level 1.5 data retrieval request.

Such a sizing raises concerns with respect to operational constraints, both on EUMETSAT and on the user side, for the capability of managing and processing such data sets, and also with respect to the current limitation from the user services. Last but not least, a trade-off is required between the volume of the data retrieval request and the delivery time.

In order to by-pass this limitation, EUMETSAT plans to offer, in addition to the U-MARF standard services (restricted to 1000 products orders; i.e. 2 weeks of full resolution SEVIRI level 1.5), the possibility of generating pre-defined bulk orders, but without the flexibility of services available with the standard user services.

4.2 Access to Meteosat data

4.2.1. Standard ordering mechanism

The transcription and transfer of Meteosat data into the new U-MARF facility will require at least 3 years of work. Therefore, access to Meteosat archived data, proposed in the context of the MSG-RAO, will be handled by the existing Meteorological Archive and Retrieval Facility (MARF). This service is described in the MARF User Handbook available at http://www.eumetsat.de/en/area2/publications/marf_td06.pdf. The current ordering mechanism foresees the restriction of any single order to 1500 images. Computer routines that convert Meteosat pixel coordinates into geographical coordinates are available in the MARF User Handbook, and software for computing the sun angles is available on demand.

4.2.2. Potential improvements

It is planned to remove the current limitation for the PIs who have requested access to a large amount of Meteosat data. It is therefore suggested to make two specific years of data available: one before the launch of MSG, i.e. 1999, and one after the end of commissioning. It is not foreseen to have this option available for additional years since the utilisation of Meteosat data is not the main purpose of the MSG-RAO. This option includes the following image characteristics:

- Meteosat rectified images full disk, uncalibrated. Calibration coefficients are available at the following URL: http://www.eumetsat.de/en/area3/mpef/calib.html;
- Three channels, visible, water vapour and infrared, available separately.
- 48 slots/day (limited to slot 12 to 36 for the VIS band).
- Periods: quarterly distributed.
- Delivery format:
  - OpenMTP;
  - HDF; this format is not yet available, but EUMETSAT is currently investigating this option.
- Delivery medium: DLT tapes.

The data retrieval requests expressed in the framework of the MSG RAO is an opportunity for EUMETSAT to capture end users needs of the research community and to anticipate the verification of the adequacy of the current system requirements and design to meet expectations of off-line users.

Discussions on the standard U-MARF user services have taken place during the first MSG RAO Workshop and shown, overall, a good adequacy of the system towards these needs. In particular the results of questionnaires provided to the PIs established that the standard delivery mechanism could satisfy about 30 % of the data requests. This corresponds to PIs who intend to use the flexibility of the U-MARF user services to select specific samples of Level 1.5 repeat cycles, sometimes combined with a spectral band selection or a geographical subsetting over Europe or Africa.

However, the workshop has also highlighted areas for improvement in order to better address needs raised from the scientific community, such as the use of additional distribution format (especially HDF), or the need to distribute support software providing further auxiliary information. The MSG RAO data retrieval requests definitely confirmed the need of the U-MARF to answer to large data retrieval requests. These could be fulfilled via a subscription mechanism for a limited number of pre-defined orders. About 70% of the PIs have expressed interest in this solution.

Beyond the use of the U-MARF off-line retrieval, the use of EUMETSAT High Rate User Station (HRUS) is however recommended for PIs intending to process or reprocess on a systematic basis largore MSG datasets. The PIs are also invited to analyse the feasibility and implications of managing large datasets at their premises, before ordering such datasets. The information available in this paper is expected to provide useful preliminary indications in this respect.

GERB Data and Products

Peter M Allan, Rutherford Appleton Laboratory
Chilton, Didcot, UK

The GERB-1 instrument has been designed to make very accurate measurements of the total radiative energy output of the Earth in order to monitor the diurnal cycle and to validate climate models. It makes two broad band measurements of the radiance, measuring the total radiance in the range 0.35μm - 40 μm and the short wave radiance in the range 0.35 μm to 4 μm. The long wave results are obtained by subtracting the short wave from the total. As well as the basic science drivers mentioned above, GERB data products will be used in a variety of studies, as described by other papers in this volume.

The GERB instrument will be mounted on the outside of the MSG satellite, so will be operating under the mechanically challenging environment of a constant 17g acceleration. The science requirements on the accuracy of the filtered radiance measurements are 1.0% in the SW and 0.5% in the LW. In order to achieve this accuracy, the detector views the Earth, a black body source and an optical calibration source on each rotation of MSG. The detector used in GERB is a 256-pixel array arranged in the N-S direction. A full Earth image is built up by stepping the array in the E-W direction with a 'de-spin' mirror. The SW image is built up by stepping the detector in one direction with the SW filter in the beam and then the 'total' image is built up by stepping the detector in the opposite direction with the SW filter removed. Thus a N-S strip of the Earth is measured on each rotation of the MSG satellite and a complete Earth image is obtained in 262 rotations, or just over 2.5 minutes. This is to be contrasted with the SEVIRI arrangement where an E-W strip is measured on each rotation of MSG and an image is built up over 15 minutes.

Due to the fact that GERB requires 262 rotations to build up a complete image of the Earth, combined with the fact that the rotation rate of MSG can vary by up to 1%, the GERB data products cannot be fit into an exact 15 minute repeat cycle. The nominal repeat time for GERB radiance products is 15 min 43 sec (6 x 262 x 0.6 sec), but this depends on the actual rotation rate of MSG. The longer repeat cycle of GERB means that the relative start time of the products shifts in time and comes back into step after about 3 hours. In order to make it easy to select the GERB data file that most closely matches a given SEVIRI image, GERB radiance data files are labelled with the time of the matching SEVIRI 15-minute time slot. However, the data file contains precise details of the times during which the data were taken. The consequence is that if you are not concerned with details of changes within a 15-minute period, simply selecting the matching data file will be perfectly adequate. If you are interested in changes on a timescale of 15 minutes or less, you will need to delve into the file to obtain the details of the times.

Data Processing Chain

Raw GERB data will be received at RAL and processed to generate two science products; the averaged (in time), rectified (on to a standard grid), geolocated product and the non-averaged, non-rectified, geolocated product. These are called the ARG and NANRG products, respectively. The ARG product is the one that should normally be used as it is necessary to average over more than one Earth scan in order to achieve an acceptable signal to noise ratio. The NANRG products

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ERS and Envisat plans

Jean Pierre Guignard
Head Ground Segment Engineering Division
Department of Applications
ESA ESRIN Frascati Italy

This paper intends to present the status of both the ERS and Envisat Missions, with emphasis on the Envisat features of interest to the MSG RAO Principal Investigators.

ERS Situation

Till March 10th 2000, both ERS-1 and ERS-2 have been operated in the 35-day repeat cycle. On March 10th, a failure of the attitude control system ended the ERS-1 Mission; It is noticeable that a satellite designed for a 2-year lifetime (with consumables planned for 3 years), lasted 9 years!

ERS-2 continues providing operational services for both SAR and Low Bit Rate data, but the ERS-2 strategy is being reviewed to extend the its lifetime as much as possible.

Since Feb 2000, ERS-2 is operated in mono-gyro mode (to preserve the lifetime of the 3 gyros) and all platform sub-systems are working normally.
The hydrazine still available should permit nominal operations up to end of 2003.

Preparations are underway for the ERS/Envisat Symposium to be held in Goteborg on 16-20 October 2000. This major event will permit the gathering of 600 of 700 scientists involved with using ERS data and preparing themselves to the launch of Envisat.
The web site for registration and paper submission is open and further details may be found on the ESA WEB sites (e.g. Earthnet On Line at www.esrin.esa.it).

The Envisat system

Satellite Configuration and Envisat Orbit

A direct injection of the satellite by the ARIANE 5 launcher on the selected Sun Synchronous orbit is planned

The selected reference orbit is very similar to the one used for ERS:

- Mean altitude of 799.79 km,
- 14 11/35 orbits per day
- Repeat cycle of 35 days (501 orbits).
- 10:00 a.m. mean local solar time at the descending node
- Ground track maintained within ±1 km from nominal (same orbit ground track as currently for ERS-2)

Solid State Recorder

Is has been decided to replace the standard tape recorders with two solid state recorders, offering the possibility to record high rate instruments such as ASAR and/or Meris. Each solid-state recorder SSR has a capacity of 60 Gbits end of life (EOL) (70 Gbit/s beginning of life BOL) allowing for 10 minutes of ASAR HR or 41.5 minutes of MERIS FR being recorded.
The flexibility in managing the mission is much improved by using the dynamic partitioning of the memory.

Mission Scenario

The mission scenario is based on distinguishing 2 types of missions: a global mission and a regional one.

1. The global Mission operation includes all ENVISAT-1 instruments which have global coverage objectives; it implies a continuous operation of the low rate instruments with on board recording of all instrument data;

The data recorder playback is occurring at least once per orbit to ensure the availability of the Fast Delivery products within less than 3 hours from observation; a systematic processing of all acquired data is implemented.

The global mission strategy is defined in the **High Level Operation Plan (HLOP)** that has been approved by the program participants.

2. The Regional Mission includes:

   - All ASAR operation modes including low rate modes (GMM and Wave mode)
   - The MERIS Full Resolution (FR) mode

The data rates involved imply either real time transmission or recording using one of the solid-state recorders. The data acquisition is based on user requests while again the strategy for handling the user requests is defined in the HLOP.
The data acquisition assumes the combined use of the ESA X band stations and/or the Ka-band link via ARTEMIS as implemented at ESRIN; it is eased by the fact that the simultaneous operation of Ka and X band channels is possible.

Ground Segment Architecture

The Ground Segment includes two main parts:

- The FLIGHT OPERATIONS SEGMENT (FOS): composed of the Flight Operations Control Center (FOCC) located at ESOC and the associated command and control stations.
- The PAYLOAD DATA SEGMENT (PDS) ensuring the payload data acquisition, processing, archiving and all user interfaces and services; It is split into two main centers (Payload Data handling System: PDHS): Kiruna (receiving data using an X-band reception chain) and ESRIN (receiving data using a Ka-band antenna from the data relay satellite Artemis).

In addition, the Kiruna center includes a facility to consolidate (e.g. remove overlap between orbits) all the low rate data and archive them (Low rate archiving center: LRAC).

Envisat Ground Segment status/events

While the launch of the satellite is planned to occur in June 2001, both the PDS and FOS elements are nearing completion:

- Payload Data Segment (PDS):

The full testing of the PDS V2 version (including the complete deployment in Kiruna and ESRIN) took place from December 99 to March 2000 and has been successfully concluded.
A new version (V3) is currently under development to cope with a new version of the satellite to ground interface, the addition of the 2 solid state recorders and the need to upgrade to a new version of the IBM operating system (IBM AIX 4.3). The version targeted for January 2001 will include the implementation of the final processing algorithms.

- Flight Operation Segment (FOS):

The Flight Operation Control Center (FOCC) is already under use and the Satellite Reference Data Base under completion (this database contains the results from all satellite flight model characterization measurements).

Envisat Data Products

A complete list of the 74 ESA products has been defined. Most of the products are SAR related (26). In all cases a product is associated with a type of processing (Systematic or On Request), a dissemination mode, a time delivery requirement, a center or station providing the service and an algorithm development scheme.

Various quality levels are defined:

- Raw Data as received from the satellite (serial data stream, no demultiplex)
- Level 0: data reformatted and time ordered (i.e. featuring no overlap) in a computer compatible format
- Level 1b: geolocated engineering calibrated product (Near Real Time and Offline)
- Level 2: geolocated geophysical product (Near Real Time and Offline

The Envisat Products List and their related characteristics are obtainable from the Envisat WEB site (http://envisat.estec.esa.nl)
Each product (whatever the quality level is) is based on using only one Data Product Format. Each product consists of one file only and this file systematically includes the following elements:

- MPH — Main Product Header
- SPH — Specific product header
- SQADS — Summary Quality Auxiliary Data Set
- LADS — Localization Auxiliary Data Set
- MDS — Measurement Data Set(s) as many as necessary
- ADS — Auxiliary Data Set(s) as many as necessary
- GADS — Global auxiliary data Set(s), for auxiliary data not timely related to the MDS record time entries

All Data sets are filled with Data Set Records (DSR), and each DSR starts with a time entry;
The product headers are in an ASCII format using a well-defined structure:

KEYWORD and PARAMETERS

Earth Observation in the Fifth Framework Programme

By Michel Schouppe

European Commission (EC)
Research DG (DG RTD)
Biodiversity and global change Unit (DI.1)
Michel.schouppe@cec.eu.int

The Meteosat Second Generation (MSG) programme opens new opportunities for Research and Technological Developments (RTD) in Earth observation. This programme will produce a unique data set over Europe and Africa, thanks notably to improved spectral coverage, unique imaging frequency and increased space sampling. It will allow long term provision of data from 2002 till 2012, a pre-condition for moving towards new operational applications. The MSG potential is strengthened by Eumetsat initiatives to establish a co-ordinated and dedicated research community.

Considering such a perspective, it is the interest of the scientific community to be aware of RTD opportunities in Earth observation and to know how Eumetsat and EC RTD efforts complement each other. MSG-RAO is mainly mission-driven. The Fifth Framework Programme follows both a problem-solving approach through its key actions and a market-driven approach in the specific case of generic Earth observation. The focus is therefore on both the user and the multidisciplinary nature of the research. Principal Investigators from the MSG Research Announcement for Opportunity (MSG-RAO) might get free access to MSG data whilst Community funding could cover up to 50 % of the personnel, travel, computing and consumable costs of a research project. The latter funding is of course subject to the Fifth Framework Programme (FP5) rules with respect to submitting, evaluating and selecting proposals.

There are a number of opportunities for supporting Earth observation related research within FP5. Research activities having a space component can be co-funded under budgets allocated to various key actions or generic lines of the four thematic programmes[1] of FP5 (1999-2002). The main opportunities lie in the Environment sub-theme of programme 4, called '*Energy, Environment and Sustainable Development*' (EESD). This paper concentrates on (a) the generic line on Earth observation[2] and (b) the European component for Global Observing Systems[3], a component of the key action '*Global Change, Climate and Biodiversity*'.

The objectives of these two areas correspond to those of the MSG-RAO. The first area (a) aims to develop the Earth observation market for new operational products and services and by so doing, expand the use of Earth observation to make it more cost effective and to enlarge the customer base. The second area (b) aims to extend the European capacity to observe our global environment.

[1] Programme 1 : '*Quality of Life and Management of Living Resources*'
Programme 2 : '*Information Society Technologies*'
Programme 3 : '*Competitive and Sutainable Growth*'
Programme 4 : '*Energy, Environment and Sustainable Development*'.

[2] The generic line on Earth observation corresponds to area 7.2 in the work programme. It is entitled '*Development of generic Earth observation technologies*'.

[3] The European component for Global Observing Systems[3] corresponds to area 2.4 in the work programme.

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The MSG-RAO projects

MSG validation of level 1 and level 2 cloud products from ENVISAT-MERIS and aircraft observations

Jürgen Fischer, Ralf Bennartz, René Preusker
Institute for Space Sciences
Free University of Berlin, Berlin, Germany
e-mail: fischer@zedat.fu-berlin.de

Jean-Louis Brenguier, Lothar Schüller
Meteo-France CNRM/GMEI/MNP
Centre National de Recherche Meteorologique, Tououse, France

Abstract

Objective of the research is the validation of SEVIRI calibration and cloud products. Level 1b calibration will be examined in conjunction with a cloud experiment which is proposed within the European Commission's Framework Programme V. The experiment is planned to take place in spring 2002 over the North Sea and Belgium. It consists of simultaneous in-situ cloud microphysical and remote sensing aircraft observations of cloud systems performed by the French and German research aircrafts. Direct intercomparisons of SEVIRI data with remotely sensed aircraft and MERIS data will allow to quantify the accuracy of SEVIRI´s calibration. Validation of retrieved cloud parameters will be achieved by long-term comparisons of MSG with ENIVSAT-MERIS data. MPEF and SAF cloud products as specified in the SEVIRI science plan (e. g. cloud mask, cloud type, cloud top height) will undergo a detailed evaluation with independent data and approaches. MERIS will allow to independently estimate cloud top pressure from back-scattered solar radiation in the near infrared and it's comparably high spatial resolution will allow to examine processes on the sub-scale of the MSG resolution. In addition to the cloud products defined in the SAFs and MPEF, we will also derive and evaluate cloud optical thickness and cloud albedo from both MSG and MERIS.

I. Project description

A. Calibration and validation of level 1b data.

Similar to the calibration of the Meteosat visible channel, SEVIRI VIS/NIR channel calibration relies on external targets, such as large desert areas with a presumably constant surface albedo. Although this technique is well established and has proven to provide stable long-term calibration, the SEVIRI science plan outlines that an initial absolute calibration of the SEVIRI requires additional efforts, namely dedicated aircraft calibration campaigns and comparisons with other satellites.

In the framework of a proposed cloud/radiation experiment FUB and Meteo-France will perform such an experiment. FUB will perform airborne spectrometer measurements of cloud systems over the North Sea with its own spectrometers casi and FUBISS. The former is an imaging spectrometer with a swath width of 2 km and a spatial resolution of 4 m at 3 km aircraft altitude and up to 19 programmable channels in the VIS/NIR. The latter one is a nadir-looking spectrometer with a spectral coverage between 200 and 2400 nm and a respective spectral resolution of 3 nm (VIS) and 10 nm (NIR). Meteo-France will carry out the in-situ measurements, which will give insight in the microphysical properties of clouds, namely the vertical distribution of cloud liquid water and ice as well as droplet concentration.

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VIS/NIR. The latter one is a nadir-looking spectrometer with a spectral coverage between 200 and 1700 nm and a respective spectral resolution of 3 nm (VIS) and 10 nm (NIR).

1. Derivation of cloud optical thickness and cloud albedo from MERIS and MSG

The cloud albedo α_c and cloud optical thickness δ_c will be estimated from measurements of the MERIS channel centred at λ=753.75nm and for MSG using VIS0.6 and VIS0.8. An adequate algorithm is established to transform the radiance measurements into hemispherical quantities by integration over viewing angles, since clouds do not reflect the sunlight isotropically. The algorithm suggested here accounts for the angular distribution of reflected solar radiation by radiative transfer simulations. The radiative transfer model MOMO (Matrix Operator Model) is used to solve the forward problem, *i.e.* the derivation of satellite sensor signals (radiances) by simulating the transfer of solar radiation through the atmosphere for given parameters. Additionally, MOMO calculates the spectral albedo at the atmospheric model layer boundaries.
Inferring the optical properties from measured satellite radiances is called the inverse problem. This problem will be tackled by a polynomial approach where the cloud albedo and optical thickness are related to a polynomial function of the radiance to be measured. In order to improve the algorithm, the selection of the coefficients for polynomials depends on parameters that are specified *a priori*, either from external data or empirically derived from climatological data sets. This includes surface albedo as the most important parameter.

2. Cloud top pressure from MERIS

Cloud top height will be an operational MPEF and SAF product which we will compare to MERIS estimates of cloud top pressure. The relation between cloud top pressure and temperature can be established using e. g. ECMWF analysis fields to obtain information about the vertical layering of the atmosphere.
The cloud top pressure retrieval of the MERIS is based on backscattered radiation in the O_2A-absorption band. The extinction of radiation due to gaseous absorption depends on the absorber mass and on the absorption coefficients within the radiation path. Regarding satellite measurements at wavelengths in the absorption bands of atmospheric gases, the backscattered radiance decreases if the photon path within the atmosphere increases. Therefore, the relation between radiances within and outside absorption bands contains information on the absorber mass penetrated by the photons. For a well mixed absorbing gas like oxygen, the total absorption is linear with the total photon path length. The vertical profile of the cloud differently affects the radiances within and outside the oxygen absorption band. While radiances in window channels depend only on total optical thickness, radiances within the absorption band are also related to the vertical distribution of liquid water. Photons penetrating into deeper cloud layers have a higher probability of becoming absorbed. Since penetration depth varies with cloud microphysical properties, a large number of radiative transfer simulations has been performed to establish a database with variable clouds and their associated radiances. This database has been inverted using neural networks. The inversion has a theoretical accuracy of about 25 hPa.

3. Cloud classification

A cloud classification solely based on cloud optical depth and cloud top pressure will be applied. Similar to the ISCCP cloud classification nine different classes of clouds and one cloud-free class will be distinguished. Weekly and monthly averages and variances of cloud frequency, cloud optical depth, and cloud top pressure will be provided for each class and both, MERIS and MSG. Within

USE OF THE MSG SEVIRI CHANNELS IN A COMBINED SSM/I, TRMM AND GEOSTATIONARY IR METHOD FOR RAPID UPDATES OF RAINFALL

V. Levizzani[1], P.P.Alberoni[1,2], P. Bauer[3], L. Bottai[4], A. Buzzi[1], E. Cattani[1], M. Cervino[1], P. Ciotti[5], M. J. Costa[1], S. Dietrich[6], B. Gozzini[4], A. Khain[7], C. Kidd[8], F. S. Marzano[5], F. Meneguzzo[4], S. Migliorini[4], A. Mugnai[6], F. Porcù[9], F. Prodi[9], R. Rizzi[1], D. Rosenfeld[7], L. Schanz[10], E. A. Smith[11], F. Tampieri[1], F. Torricella[1], J. F. Turk[12], G. A. Vicente[13], and G. Zipoli[4]

[1]*CNR – Institute of Atmospheric and Oceanic Sciences, via Gobetti 101, I-40129 Bologna, Italy*
Tel.: +39-051-639-9578, Fax: +39-051-639-9649, e-mail: v.levizzani@isao.bo.cnr.it
[2]*ARPA – Regional Meteorological Service, viale Silvani 6, I-40122 Bologna, Italy*
[3]*European Centre for Medium-Range Weather Forecasts, Shinfield Park, Reading RG2 9AX, United Kingdom*
[4]*Laboratory for Meteorology and Environmental Modeling (LAMMA), via Einstein 35/B, I-50013 Firenze, Italy*
[5]*Univ. of L'Aquila, Dept. of Electrical Engineering, Monteluco di Roio, I-67040, Italy*
[6]*CNR – Institute of Atmospheric Physics, Area della Ricerca Tor Vergata, via Fosso del Cavaliere 100, I-00133 Roma, Italy*
[7]*Hebrew University of Jerusalem, Institute of Earth Sciences, Jerusalem 91904, Israel*
[8]*Univ. of Birmingham, School of Geography and Environmental Sci., Edgbaston, Birmingham B15 2??, United Kingdom*
[9]*Univ. of Ferrara, Dept. of Physics, via Paradiso 12, I-44100 Ferrara, Italy*
[10]*German Aerospace Centre (DLR), DFD-KA/NV, D-51170 Köln, Germany*
[11]*NASA, Global Hydrology and Climate Center, 977 Explorer Blvd., Huntsville, AL 35806-2807, USA*
[12]*Naval Research Laboratory, 7 Grace Hopper Av. Stop 2, Monterey, CA 93943-5502, USA*
[13]*Raytheon ITSS, Distributed Active Archive Center, NASA-GSFC, Code 902.2, Bd. 32, S150D, Greenbelt, MD 20771, USA*

ABSTRACT

The METEOSAT Second Generation (MSG) Spinning Enhanced Visible and Infrared Imager (SEVIRI) twelve channels significantly amplify the capabilities of sensing cloud microstructure and precipitation forming processes from a geostationary platform. A potential exists for improved instantaneous rainfall measurements from space, especially when combined with passive microwave (MW) measurements (Levizzani et al., 1999). A near real-time adjustment of the thermal infrared (IR) co-localized with MW-based rainrates is operationally very promising. Numerical weather prediction (NWP) model data need to be incorporated within the rapid-update scheme in order to accommodate orographic precipitation, a common error source. Rainfall and humidity assimilation, and microphysical parameterizations for Local Area Models (LAM) are studied as well as verification of model output. Tests of the real time rainrates are planned in the operational environment, e.g. nowcasting and hydrogeological disaster management, and for the evaluation of the attenuation effects on K-band satellite telecommunication. Operational use over large areas is envisaged.

INTRODUCTION

IR and visible (VIS) satellite rainfall estimates have long since been available and suffered from the difficulty in associating cloud top features to precipitation at ground level (Levizzani, 1999). They were used for climate purposes or combined with radar measurements for nowcasting (e.g. Porcù et al., 1999; Amorati et al., 2000). Physically-based passive MW methods were developed mainly using data from the Special Sensor Microwave/Imager (SSM/I) and are based on several different physical principles (Smith et al., 1998). Limitations of MW algorithms include the relatively large footprint and the low earth orbits not suitable for most of the operational strategies. Combined MW and IR algorithms using SSM/I radiometric data have normally been focused on monthly averages over wide areas, although their need for instantaneous estimations was recognized already some time ago (e.g. Levizzani et al., 1996). Recently blended MW and geostationary IR techniques have been proposed oriented towards rapid-update operational use over large areas and data assimilation into NWP models (Turk et al., 1997, 1999; Vicente et al., 1998). An example is shown in Figure 1.

insufficient number of passages. The effective radius (r_e) of the particles and the cloud optical thickness are extracted and used for radiative transfer calculations that define the cloud type and improve its characterization. Precipitation forming processes are inferred using also data from AVHRR and the Tropical Rainfall Measuring Mission (TRMM) VIS and IR Sensor (VIRS).

Microphysically "maritime" clouds grow in very clean air with small cloud condensation nuclei (CCN) and droplet concentrations, which produce very efficient coalescence and warm rain processes. "Continental" clouds normally grow, on the contrary, in polluted air having large CCN and droplet concentrations, i.e. the coalescence is relatively inefficient. The better knowledge of cloud microstructure and precipitation forming processes will facilitate the development of a new generation of improved passive MW rainfall algorithms. The importance of the cloud characterization method has recently been demonstrated by observing the effects of forest fire (Rosenfeld, 1999; see Figure 2) and urban pollution aerosols (Rosenfeld, 2000) in inhibiting precipitation formation processes.

MICROWAVE RAINFALL ESTIMATION METHODS

Many methods have been proposed for detecting rainfall from MW satellite sensors. Simple methods using polarization corrected brightness temperatures (e.g. Kidd, 1998) have been proposed together with more physical approaches that rely upon microphysical characterization by

- stratifying clouds into different microphysical types and examining how much of the variability in the bias of MW rainfall estimation is explained by the microphysical characterization;
- developing a library of passive MW signatures from different cloud types, and
- using a microphysical cloud classification for improving cloud radiative transfer modeling based on statistical multivariate generators of cloud genera.

The scheme of Mugnai et al. (1993) and Smith et al. (1992) is a good example of such methods, especially in the very complex environment of severe storm microphysics. An outlook into combining VIS/IR and advanced MW observations is given by Bauer et al. (1998). Cloud modeling and MW radiative transfer has been recently applied to stratiform rainfall by Bauer et al. (2000). Panegrossi et al. (1998) have shown the importance of testing the physical initialization and the consistency between model and measurement manifolds.

COMBINED MULTISPECTRAL AND MW METHODS

The cloud microphysical information, when combined with MW measurements, can lead to greatly improved satellite based rainfall measurements, specially from clouds in the extra tropics and over land. The study concentrates on exploiting data from SEVIRI in the VIS, near IR and water vapor (WV) for cloud characterization and screening within a rapid cycle of rainfall estimation based on SSM/I, TRMM MW Imager (TMI) and geostationary IR data. Two are the main research lines:

1. Develop new MSG-MW rainfall algorithms incorporating the observed cloud microstructure and precipitation forming processes. State of the art cloud and radiative transfer modeling will be included and serve the purpose of cloud and rainfall type discrimination.
2. Introduce such methods into rapid update rainfall cycles for near real time rainfall estimations over oceans and land with the widest possible area coverage. Mid-latitude Europe, the Mediterranean basin, North Africa, the Middle East and equatorial and tropical African regions are the main targets for operational and climatological applications. Applications to the Mediterranean basin have been reported by Meneguzzo et al. (1998).

APPLICATIONS

Data assimilation procedures that improve current analysis schemes for LAMs especially for cloud and humidity characterization are at hand. Most important are the sensitivity to the orography and the modeling of moist processes (e.g. Buzzi et al., 1998). Cloud parameterization using information from multispectral methods is foreseen as a main goal. Extensive rainfall model output verification is

Combined use of MSG and POLDER for cloud property retrievals and their effect on radiation.

Geneviève Sèze,
Laboratoire de Meteorologie Dynamique du CNRS
Université P. et M. Curie- Tour 15- BP99- 4,pl Jussieu
75252 Paris Cedex 05, France
Tel: 33 1 44 27 27 99, Fax: 33 1 44 27 62 72
seze@lmd.jussieu.fr

J.C. Buriez, F. Parol, J. Riedi, C. Vanbauce, M. Vesperini
Laboratoire dOptique Atmosphérique,
Université des Sciences et Technologies de Lille,
59655 Villeneuve dAscq Cedex, France

P. Couvert,
Laboratoire des Sciences du Climat et de l'Environnement
C.E.Saclay
91191 GifsurYvette cedex, France

ABSTRACT

POLDER (POLarisation and Directionality of the Earth's Reflectances) will be aboard the ADEOS 2 platform scheduled to be launched in 2002. In this proposal, the consistency between the SEVIRI and POLDER cloud detection and analysis schemes will be investigated. The total precipitable water content fields will be compared. The multidirectional POLDER measurements will be used to investigate the impact of the radiance-to-flux conversion on the TOA shortwave flux estimate from GERB.

I Objectives

Cloud amount and cloud properties are key parameters of the climate system. They need to be monitored adequately for us to understand present climate and further climate change. In this proposal, in order to improve cloud property retrieval, a comparative study of MSG (Meteosat Second Generation) and POLDER (POLarisation and Directionality of the Earth's Reflectances) data will be performed.

As a component of a new generation of instruments designed for Earth's observation, the POLDER radiometer was on board the polar orbiting ADEOS 1 platform from August 1996 to June 1997. POLDER 2 will be on the ADEOS 2 platform, launch of which, initially scheduled at the end of 2000, is deferred until 2002. This instrument consists of a CCD matrix detector, a rotating wheel carrying spectral filters and polarizers, and a wide field-of-view lens. When the satellite passes over a target, up to 14 different images are acquired in eight narrow spectral bands of the visible and near-infrared spectrum. The elementary pixel size is 6 km x 7 km. Cloud phase and cloud top pressure are retrieved from the polarisation capability, which is the most original characteristics of POLDER. Moreover, the multidirectional capability allows for checking schemes of cloud optical thickness retrieval and can be used to investigate the impact of the radiance-to-flux conversion on the TOA shortwave flux. The multi-spectral measurements, using two differential absorption techniques allow to estimate a mean cloud pressure and the integrated water vapour content.

hand, weaknesses of the LMD cloud classification scheme based on the METEOSAT VIS and IR radiances and their spatial variances were also pointed out. For high and homogeneous clouds, comparison of POLDER measurements in the oxygen A-band and METEOSAT IR radiance helped in the interpretation of the retrieved cloud pressure (Vanbauce et al., 1998). Distribution of the POLDER cloud thermodynamic phase and pressure inside the METEOSAT LMD cloud type classification was investigated. (Goloub et al., 2000)

These comparisons will be pursued during the preliminary phase, in particular to interpret the cloud pressure and cloud phase retrievals in case of thin clouds, multi-layered systems and small cumulus clouds. Following the technique developed for METEOSAT, some GOES data will also be compared with POLDER data. In particular, the split window is expected to help the detection of thin cirrus and the interpretation of anomalies found between the POLDER cloud phase and METEOSAT cloud types. Comparisons with ATSR2 data are also undergoing to investigate the contribution of the 1.6 um channel. Moreover, following the methodology developed in a previous comparative study between METEOSAT cloud map and SPOT cloud cover index, the DALI SPOT catalogue will be used. This catalogue gives for each registered SPOT scene a cloud cover index and the associated quick look if needed. This will help to check the efficiency of METEOSAT and POLDER to detect small cumulus over land.

When ADEOS2-POLDER and MSG-SEVIRI data will be available, these previous studies will be continued with the new data sets, for several 10-day periods covering the four seasons. The first step will consist in the comparison of the visible radiances, to check the spatial and temporal registration but also the calibration. MSG data will be projected on the full resolution POLDER grid, or on the POLDER "ERB, Clouds and Water Vapour" grid. Note that in the operational POLDER "ERB, Clouds and Water Vapour" line (Buriez et al., 1997), the various cloud parameters are retrieved for each full-resolution pixel and for each direction, and then gathered at the scale of super-pixels of 60 km x 60 km (expected to be 20 km x 20 km for ADEOS2-POLDER).

The consistency between POLDER and SEVIRI cloud detection results will be checked. To help in the interpretation of discrepancies, the LMD cloud classification method will be applied to SEVIRI data. POLDER and SEVIRI schemes are mainly based on a series of sequential tests. Agreements and disagreements between the two detection schemes will be studied as a function of the behaviour of these tests. For SEVIRI, the quality flag will be used ; for POLDER, intermediate results of the cloud detection scheme will be required. A good knowledge of the main differences in cloud detection between POLDER and SEVIRI will be a key step for the following studies.

The MSG cloud type analysis will be confronted to POLDER cloud products such as the Rayleigh pressure (derived from polarisation at 0.443 um), the Oxygen pressure (derived from absorption in the oxygen A-band), the thermodynamic phase (derived from polarisation at 0.865 um) and the optical thickness (derived from reflectance at 0.670 um). The LMD cloud type classification will be used again to better interpret the results that will be found.

To further understand the results, a finer comparison using the POLDER directional values of these parameters and the SEVIRI radiance measurements will be performed for some case studies focusing on the cloud phase and the cloud top height. Special emphasis will be given to thin cirrus, multi-layered systems and small cumulus cloud fields. Use of simultaneous data from Global Imager (GLI) which will be onboard ADEOS2, data with a spatial resolution of 250 m, multi-spectral characteristics close to SEVIRI, and a perfect time coincidence with the POLDER data will allow to better understand the results of the POLDER-SEVIRI comparison. AATSR data with its two viewing directions will allow to test the impact of directional measurements for the 1.6 um channel. As in the preliminary phase, detection of small cumulus over land will be checked using the SPOT cloud cover index. Some SPOT scenes will be analysed in the aim to study the small-scale heterogeneity and relate it

Remote Sensing of Clouds and Precipitation from MSG Data

P. Wendling [1], H. Mannstein[1], M. Kästner [1], R. Meerkötter [1], B. Mayer [1]
R. Büll [1], G. Gesell [2], S. Hacker [1], P. Meischner [1]
Th. Hauf [3], T. Inoue [4]

[1] Deutsches Forschungszentrum für Luft- und Raumfahrt (DLR)
Institut für Physik der Atmosphäre
D-82234 Wessling

[2] Deutsches Forschungszentrum für Luft- und Raumfahrt (DLR)
Deutsches Fernerkundungsdatenzentrum
D-82234 Wessling

[3] Universität Hannover
Institut für Meteorologie und Klimatologie
D-30419 Hannover

[4] Meteorological Research Institute
Tsukuba-Ibaraki, Japan

1. Objectives

Clouds have a strong impact on the large scale circulation and on climate due to their direct effects on the radiation field and via phase changes on the thermodynamic state of the atmosphere. There is a need to further improve the parameterization of clouds in climate and weather models. In addition, long time series of cloud observations are needed to determine trends of cloud variations. Within the project we propose to contribute on three areas of work:

- An existing cloud detection scheme (APOLLO) is modified for the use of MSG data in order to determine cloud parameters.

- An MSG based time series of cloud parameters is established for Europe and compared to part of an ongoing 15 years cloud climatology based on NOAA AVHRR HRPT data in order to estimate a possible bias of the latter. The cloud products will also be used to support the analysis of icing conditions in clouds within the framework of a new diagnosis and warning system for aircraft icing environments. Further, in specific cases air traffic induced cloudiness (contrails) will be studied with respect to its transition to cirrus and its effect on the radiation budget.

- An upscaling of areal precipitation using data from the DLR polarization radar and MSG is envisaged and the results are compared to data of a new recording rain gauge network. Further, studies of tropical convective rain situations are carried out using MSG and TRMM data in order to determine differences in the spectral signatures for raining clouds in the midlatitudes and the tropics.

The project duration will be 3 years starting with 01012001. For the first year data acquisition and development of algorithms is planned. During the remaining 2 years detailed data analysis will be carried out. Reports will be delivered every 6 months and results will be presented on the workshops.

Address of principal investigator: Peter Wendling, DLR, Institut für Physik der Atmosphäre,
D-82234 Wessling, Phone: 49-8153-282546, Fax: 49-8153-281841, E-mail: peter.wendling@dlr.de

The proposed case studies require full resolution radiances, but not for the whole time period. The proposed time series require full resolution products, delivered off-line. But to compare the two independent processing chains with the two algorithm packages which are linked to a certain extent, full resolution radiances are required for the whole time period. This can be achieved either by HRIT/HRUS or by a continuous data transmission line. As it turned out, the latter is much more expensive. Hence, HRIT/HRUS is required.

2.3 Areal Precipitation from MSG Data

It is intended to apply the new cloud detection scheme to MSG data in order to get a cloudmask, cloud optical depth, liquid water path, cloud top temperature and cloud IR-emissivity. MSG promises an improvement to derive the precipitation rates at ground for larger areas. The increased number of IR channels and the higher repetition rate of images are supposed to intensify their use for the estimates of precipitation. However, ground based radar measurement are much more precise than satellite data algorithms, but they have a limited field of view. The determination of precipitation based on conventional weather radar measurements is accurate up to about 30% if the system is properly calibrated. However, polarimetric methods improve that accuracy either by measuring the differential reflectivity to determine the spectra of rain drops or by measuring the differential propagation phase. Different measuring strategies are necessary for different rain types like stratiform or convective rain. The ground based DLR radar POLDIRAD is able to measure very exact rainfall rates with accuracies distinctly below 30% (Hagen et al., 1999). Further, ground based recording rain gauges support these radar measurements of rainfall rates. A new dense network is on the way to be installed in Bavaria in the next three years. Rainfall data from this network with high temporal resolution will be used for comparisons, too. The precipitation estimates using MSG data are compared to the radar results within the optimum measurement area of the DLR radar. After this validation an extrapolation to regions outside of the range of the DLR radar is planned (upscaling). These upscaled MSG based precipitation estimates are verified with ground based rain gauge recordings. We will further use TRMM (VIRS, PR) and coincident MSG SEVIRI data in order to study the spectral signatures of raining clouds in the tropics and their differences compared to those of clouds in midlatitudes.

3. Results and Deliverables

- An innovative algorithm for cloud detection and the retrieval of cloud properties will be derived and applied to establish time series of cloud properties.
- Temporal means and variances are the first results, further diurnal cycles and seasonal cycles will be observed. Cloudiness trends will be looked at, though it is open how many years such time series must comprise. The comparison with SAF results will reveal whether there are significant differences in the algorithms and will give hints to improvements.
- For several cases of contrail induced cloudiness the radiation budget at the top of the atmosphere will be determined as well as studies of the growth of contrails with transition into cirrus cloud.
- As to the forecasting of aircraft icing conditions the information gain obtained with MSG data will be shown for different synoptic situations and icing scenarios.
- The anticipated results and deliverables are case studies of validations for estimates of areal precipitation by stratiform and convective clouds based on comparisons of radar-rain gauge, MSG-radar, and MSG-rain gauge data. An accompanying result will be the discrimination of raining and non-raining clouds for convective cloud situations in the tropics and its difference to that one in midlatitudes.

Validation and exploitation of MSG ozone imaging for synoptic and mesoscale processes observation

Fernand Karcher,
Météo-France, Centre National de Recherches Météorologiques
31057 Toulouse-Cedex 1, Tel. (33) 561079349, fernand.karcher@meteo.fr

Participants :
Y. J. Orsolini, NILU, Kjeller
H. Kelder, KNMI De Bilt
C. Camy-Peyret, LPMA/CNRS Paris
M. Weber, IFE Bremen

Satellites in geostationary orbit have an expanding potential to image ozone in the infrared, in the same way as they currently do for water vapour, or cloud cover. For example, synoptic total ozone information from the US weather satellite GOES-8 is now routinely provided real-time. In Europe, the launch of Meteosat Second Generation (MSG), will provide a new observing capability that can be fully exploited for ozone imaging. Such synoptic ozone imaging at unprecedented spatial and temporal resolution, will provide a wealth of information on meteorological processes, and on the ozone layer. The production of synoptic ozone maps over Europe and the Atlantic in particular, will be a novel tool for European meteorologists who will be able to validate the weather analysis (air masses and potential vorticity charts) using direct comparisons with independent observations of the total ozone field.

The proposal is aimed at preparing an optimal use of the information contained in the Meteosat Second Generation (MSG) ozone channel observations.

The objectives are :

- To refine the existing algorithms for better treatment of cloudy conditions
- To validate the MSG Total Ozone measurements with existing ground-based and other satellite observations,
- To demonstrate its ability to document atmospheric situations of particular meteorological and/or chemical interest, at scales from some hundreds to some tens of kilometres,
- To derive Ozone displacement winds that are of potential use in future data assimilation systems for numerical weather prediction.

Objective 1 : To refine the existing algorithms for better treatment of cloudy conditions

Previous work and comparisons of total ozone columns derived from the TOVS instruments showed that the methods used so far and deriving the ozone column from observations in the 9.7 micron band have to be refined in high cloud conditions.
One specificity of the ozone measurement is that the measured 9.7 micron radiance combines a signature of the ozone column (through its absorption properties) and a signature of the surface and cloud properties that constitute the dominant source of infrared light. MSG and its capabilities to document in detail the surface and clouds will allow a step further in the observation of ozone. On one side a better processing of the perturbing effect of clouds on the ozone measurement is expected, on the other side, new methods to estimate tropospheric ozone in specific meteorological conditions will be tested. In the framework of our activities within the Satellite Application Facility for Ozone, radiative transfer simulations of various cloud conditions were performed and some cloud correction could be tested. A validation using real MSG observations and a detailed analysis of the real cloud characteristics at the same resolution are still necessary. To increase the interpretation capabilities, the

Work package 2 : Validation and interpretation of the MSG total ozone images using ground-based and satellite observations

Task A : Using other existing (GOME, TOMS) or future (ENVISAT) satellite data (i.e. at moderate horizontal scale)
Task B : Modelling of ozone fine-scale transport using meteorological analyses. Characterization of modelled ozone structures. Comparisons with observed MSG structures in order to understand their origin.
Task C : Comparison with data assimilation results
Task D : Demonstrating the impact of ozone imaging on the understanding of meteorological processes : fronts, tropical processes, convection, mini-holes.

Work package 3 : Ozone wind derivation

Task A : Set up a maximum correlation displacement wind algorithm
Task B : Accuracy and efficiency of the wind algorithm with respect to size and height of structures
Task C : Parallel detection of moving structures in modelled total ozone

Data Requirements :

The project will need full disk, full resolution SEVIRI Level 1.5 data, and SEVIRI Level 2 products for 4 different days, in different seasons. These data will be used for all workpackages together with data from other satellites : ERS-2/GOME, ENVISAT/SCHIAMACHY. The 96 slots of each of the 4 days are required to observe atmospheric motions, in day and night conditions. There is no special requirement concerning the dates in the first year of SEVIRI exploitation.
Local MSG data (over France) corresponding to the IASI-Balloon flight, or to specific episodes of interest for the ozone field will be acquired through the Météo-France High Rate User Station.

Total Ozone Retrieval from MSG-SEVIRI Data by Means of Neural Networks
- Algorithm Development, Calibration, Validation and Real Time Application -

Anton Kaifel, Martin Müller
Center for Solar Energy and Hydrogen Research
Hessbrühlstr. 21c, 70565 Stuttgart, Germany
Tel. 0711/7870-238, Email: anton.kaifel@zsw-bw.de

Executive Summary

A new approach for total ozone retrieval from SEVIRI data based on neural networks (NN) will be developed and evaluated on a three-year data set. The total ozone product will be supplied to other research teams for climate and forecast model improvements and validation. A software module will be set up to retrieve total ozone in real time for utilization in operational processing schemes (e.g. EUMETSAT and/or national meteorological services).

A similar approach for multi-year global TOVS data yielded an accuracy of 12 Dobson Units (DU) for all atmospheric conditions (clear/cloudy, day/night) compared to ground truth. Spectral sensitivity of IR SEVIRI channels is about equal to corresponding TOVS channels. Therefore, retrieval of total ozone columns has an expected accuracy of about 12 DU with this instrument. Four main tasks of the project can be identified:

A) Development of a NN total ozone retrieval scheme based on simulated SEVIRI data including sensitivity analysis of NN input data. A set of simulated IR SEVIRI data for all different atmospheric conditions including expected variations in the future will be used for training and testing the new NN retrieval scheme.

B) In parallel to A, the currently available NN model for total ozone retrieval from TOVS data will be extended to ATOVS NOAA 15 satellite data and near real time processing of global TOVS and ATOVS data is set up. This data will be used for collation with SEVIRI data in task C.

C) Evaluation, validation and improvement with other satellite (TOVS, GOME, TOMS) and ground truth ozone data: After launch of MSG, all available ozone satellite and ground measurement data will be collocated with SEVIRI data. The NN model of phase A will be tested, further improved and optimized by training the NN with collocated data. At the end of the task the NN model for total ozone retrieval from SEVIRI data will be evaluated by processing two years of full disk coverage SEVIRI data and validating the generated ozone product.

D) Development of real-time software module: A software module will be set up for operational real-time application and implemented at the local ZSW receiving station. This includes D1) performance specification set up and software development, D2) implementation and off-line test and D3) real-time implementation into operational scheme. Subtask D2 and D3 are each followed by an extensive validation phase with other satellite and ozone ground truth data.

The generated 3 year total ozone product contains the diurnal cycle of total ozone with high temporal resolution for the whole coverage of SEVIRI data. So far no other satellite instrument is able to retrieve similar information and therefore the knowledge about the diurnal ozone cycle and its dynamical behavior is very sparse. This project will close this lack of knowledge and can additionally be used to improve chemical and dynamical climate and forecast models and to better understand ozone dynamics.

Approach

The four different tasks of the project are described below. Task A and B are carried out in parallel.

Task A) MSG Study Phase

This phase will start before launch of MSG and therefore simulated data from the MSG RT-model SYNSATRAD (Tjemkes et al, 1998) are used. A set of simulated IR SEVIRI data for all different atmospheric conditions including expected variations in the future is generated. As much as possible, the influence of various cloud types together with variations of the ground emissivity on the outgoing radiance at the top of the atmosphere is taken into account. This huge data set of SEVIRI radiances or brightness temperature data is divided in two independent data sets. One is used for training the NN and the other one for independent testing of the total ozone retrieval. Various configurations for feed forward NNs will be trained in order to find the network architecture with best performance and generalization ability on test data.

As input parameters for the NN not only the SEVIRI IR channel data are used. Other relevant data e.g. solar zenith angle, elevation and instrument parameters like scan angle (E-W, N-S) can be taken into account. Previous studies with TOVS data have shown the NN to be able to carry out corrections for line of sight (LOS). If the LOS of the TOVS instrument is supplied as input no significant dependency of ozone retrieval accuracy from TOVS LOS can be found (Kaifel et al., 1999).

Extensive sensitivity studies of the input parameters will follow the first training and test cycles of NNs based on simulated data. They have to be carried out in order to check the accuracy which can be achieved with an given calibration and noise level of the SEVIRI data.

Task B) TOVS Ozone Phase

The only satellite instrument able to retrieve total ozone during day and night time with daily global coverage is the TOVS instrument. Currently two instruments, TOVS and its advanced follow-on ATOVS, are operational on NOAA 14 and NOAA 15, respectively.

In parallel to task B the currently available NN model for total ozone retrieval from TOVS data will be extended to ATOVS. The generated total ozone data will be used for collocation with SEVIRI data in task C. The ZSW is transferring all operational TOVS and ATOVS Level 1b data from the NOAA Satellite Active Archive (SAA) every night over the internet. Therefore it is possible to process the global TOVS/ATOVS data in such a way that the ozone products are available in the morning. This is important for task C and D in order to validate the total ozone product derived from SEVIRI data.

Task C) Application, Validation and Improvement Phase

Evaluation, validation and improvement with other ozone data. During the first two years after launch of MSG all available ozone ground measurement and ozone data from other satellite instruments (TOVS, GOME, TOMS) within the MSG full disk of view will be collected and collocated with SEVIRI data. The NN model based on simulated data of phase A will be tested and improved by further training of the NN with collocated ozone data. A second optimization for the NNs will be done using the same algorithms already adapted to the NNs for ozone retrieval.

Finally, a NN model for total ozone retrieval from SEVIRI data will be ready for operational implementation.

Task D) Real Time Implementation and Validation Phase

A software module for operational real-time application will be developed and first implemented at the ZSW local HRUS receiving station. After extensive validation and optimization the NN scheme can be delivered to EUMETSAT, national meteorological services (NMS) or ozone research facilities for implementation in the operational scheme of meteorological product generation.

Exploiting the GERB/SEVIRI synergy for data validation, new algorithm development and scientific applications (Prop. 138, 142 & 143)

J.E. Harries[✈], R.Mossavati[✈], E. Lopez-Baeza[#], S.Dewitte[+], N. Clerbaux[+], G.L. Smith[%],
P. Allan[✓], M.Bates[✓], J. Muller[⊥] and R. Stuhlmann[∀]
✈ Imperial College of Science Technology and Medicine
Space and Atmospheric Physics, London SW7 2BZ, UK
Tel: +44 20 75947663, *Fax:* +44 20 75947900
Email: **r.mossavati@ic.ac.uk**

University of Valencia, Spain
+ RMIB, Brussels, Belgium
% NASA-Langley Research Center, USA
✓ Rutherford Appleton Laboratory, UK
⊥ EUMETSAT, Germany
∀ GKSS, Germany
and the GERB International Science Team (GIST)*

Introduction

The GERB International Science Team (GIST) are proposing a series of investigations to monitor changes in the climate and ERB, and many of the factors which affect it, by exploiting the excellent performance of the SEVIRI/GERB instruments in synergy with, and validated by, data from other satellites. Improved models of climate processes may result from these investigations.

Much of the preparatory work necessary for the investigations envisaged is already underway .The enhanced spatial and temporal resolutions available with the SEVIRI/GERB data will allow new, as well as improved data products and monitoring of clouds and ERB parameters to be undertaken.

Preliminary results will be reported at the workshops specified in the RAO, at regular GIST meetings, and in periodic reports as requested by ESA/EUMETSAT. Final results will be published in refereed scientific journals. The following is extended abstracts for the 3 MSG-RAO proposals submitted on behalf of the GIST.

Calibration/Validation (ID 138)

The first four objectives concern the core validation and the last two are intended to maximise the synergy between GERB and the operational multispectral imaging instrument (SEVIRI) aboard MSG. The broad objectives of the validation program are:

1. Validate GERB filtered radiances to 0.52% in the SW (0.3–4 μm) and to 0.3% in the LW (4-30 μm);
2. Validate GERB unfiltered radiances to 1% in the SW (0.3–4 μm) and 0.5% in the LW (4-30 μm);
3. Validate BRDF's used by GERB;
4. Validate GERB TOA and GERB compatible surface fluxes and corollary data;
5. Obtain calibration of SEVIRI SW radiometric channels (0.6,0.8,1.6 micron) with absolute accuracy better than 5%;
6. Verify stability of SEVIRI channel calibration and spectral response (for 0.6 and 0.8 micron channel) in time.

Validation of higher level products (vegetation, cloud/aerosol etc) is considered to be an external scientific activity.

* A list of the GIST members who have contributed indirectly to this work can be found in Appendix 1.

The project is planned to cover a three-year period. There will be six months of preparation during which algorithms will be developed as far as possible in the absence of data from MSG, one year of investigation with new data from MSG, one year of solidifying algorithms and testing, and a final six months for reporting of results and documenting deliverables. Results will be reported at workshops and will be published in the literature.

Science Applications (ID 143)

There are several key objectives contained within this proposal, reflecting the broad range of interests and expertise of the investigating team. In particular, as the GERB International Science Team, we are keen to exploit our unique understanding of the GERB instrument to best realize its potential in conjunction with complimentary information from contemporaneous Earth observation data sources. Given the range of planned studies, it is convenient here to list the objectives under appropriate headings, noting that there will necessarily be some overlap between certain areas.

1. Earth Radiation Budget (ERB) Studies
Here one key aim will be to characterise the temporal and spatial variability of the ERB on all scales within the region covered by MSG. Initially we will be concerned mainly with identifying the dominant processes driving diurnal variability, but this will be extended to monthly, seasonal, and interannual time-scales as the length of the data record increases. Particular attention will be paid to the role of clouds within the ERB, including cloud feedbacks, and such features as tropical convection, sub-tropical marine strato-cumulus, and mid-latitude storm tracks. The temporal resolution of GERB and SEVIRI will permit detailed investigations into the water vapour greenhouse effect and the water vapour feedback question, with the spectral coverage of GERB allowing a direct assessment of the importance of the far infra-red portion of the terrestrial spectrum on the ERB. A further area of interest will be the study of the impact of aerosols on the ERB, notably wind-blown dust from the Saharan and other deserts and aerosols generated by biomass burning. Building on previous studies for clear-sky conditions, the effect of clouds on net shortwave radiation at the surface will also be investigated, as will the relationship between net surface radiation and soil heat flux.

2. Evaluation of Numerical Models
Given the results from part 1, one critical objective will be to assess the degree to which current numerical models, in particular the three dimensional models used in climate simulation and numerical weather prediction (NWP), correctly match the climatology seen over the MSG region. GERB and SEVIRI products will be used to test the model performance in selected regions at high temporal resolution to provide an insight into the physical realism of the parameterisation schemes used to simulate cloud and land surface processes. A quite distinct proposal involves the testing of forward models which are used to simulate the radiation budget from operational or other products (e.g. ISCCP, re-analyses).

3. Meteorological Exploitation
One aim here is to use the SEVIRI and GERB radiometers to monitor night cooling and then help 'nowcast' the formation of radiative fog, a meteorological phenomenon which is very difficult to model and forecast, and which can have major socio-economic repercussions for many European regions. A separate application, related to (2), involves the assessment of NWP performance in near real-time using merged GERB and SEVIRI data. This will be the first time that radiation budget information has been used to evaluate the performance of an NWP model during the forecast process.

Data Requirements

MSG and METEOSAT	ESA	others
GERB data: continuous in near real time	ATSR-2 on ERS and/or AATSR on ENVISAT: one or more periods of one month of spectral radiance data (1 overpass per day) in the METEOSAT field of view	CERES on TRMM/TERRA/AQUA: 6-8 overpasses per day of TERRA

CERES AND GERB VALIDATION STUDIES

G. Louis Smith[1] and M. G. Mlynczak[2]
1. Virginia Polytechnic Institute and State University
Langley Research Centre, NASA Mail Stop 420
Hampton, Virginia USA 23681
2. Atmospheric Sciences Division
Langley Research Centre, NASA Mail Stop 420
Hampton, Virginia USA 23681

1. INTRODUCTION

The Geosynchronous Earth Radiation Budget GERB instrument aboard the MeteoSat Second Generation Satellite will provide measurements every 15 minutes of the MeteoSat region of the Earth for Outgoing Longwave Radiation OLR and for Reflected Solar Radiation RSR. There are 2 Clouds and Earth Radiant Energy System CERES instruments on the TERRA spacecraft in Sun-synchronous orbit whose results can be compared to those of GERB. The AQUA spacecraft is scheduled to be placed in orbit and in early 2001 should be providing data from 2 more CERES instruments. A major part of CERES validation is comparison of results from the various CERES instruments and also with the Earth Radiation Budget Experiment Wide field-of-view radiometers aboard the Earth Radiation Budget Satellite. The latter comparisons provide a link with the ERBE data set, to give a continuity of Earth radiation measurements. Comparisons will place GERB on the same Broadband Radiometric Scale of satellite measurements as ERBE and CERES. Figure 1 shows the Earth radiation budget record over the years.

There are several steps which produce a sequence of data products, each of which needs to be validated. From the instrument counts and the calibrations the radiances are computed. Next, the radiances are used to compute the radiant fluxes, which involves accounting for the anisotropy of the radiation leaving the "top of the atmosphere," by use of bidirectional reflectance distribution functions BRDFs. The fluxes are computed then for grid regions, which are 1 degree in latitude and longitude. Finally, daily averages are computed. The comparison of products between GERB and CERES for each of these steps will now be described. Typically, the comparison of 2 data sets improves the products from both. For comparison studies, the measurements should be taken as close together in time as possible. For GERB, this is no problem. The CERES measurements will always be taken within 7.5 minutes of a GERB measurement.

2. RADIANCES

The instrument measures total and shortwave radiances at the detector. These radiances differ from the radiances entering the instruments due to the spectral response of the instrument, so we denote them as filtered radiances. From the filtered radiances, the longwave and shortwave The unfiltered radiances which entered the instrument are computed, which we denote as unfiltered radiances. GERB uses an array of 256 detectors, each of which views a narrow latitude band. The unfiltered radiances from each of these detectors should be compared to unfiltered radiances from the CERES instruments. Because of the anisotropy of reflected solar radiation, the ray which is observed by GERB should be close in angle to the ray observed by CERES. CERES instruments operate primarily in one of 3 scan modes, each of which impose constraints on the observation of a ray by both the GERB and by CERES. The sampling of radiances measured by both instruments is now considered for each CERES scan mode.

For mapping the radiative flux from the Earth, a CERES instrument scans cross-track, as shown in Fig. 2. The rays which are viewed by CERES lie in a plane which is normal to the TERRA orbit plane and moves with the spacecraft as it goes around its orbit. The only ray which is observed by GERB and CERES is the ray along the intersection of the orbit planes of the MSG and the TERRA spacecraft. It is the nadir ray from each spacecraft as they cross, which is at 10:30 local solar time and 10:30 GMT.

which describes the variation of albedo with solar zenith angle. GERB data will provide information for validating the CERES time interpolated and averaged data products.

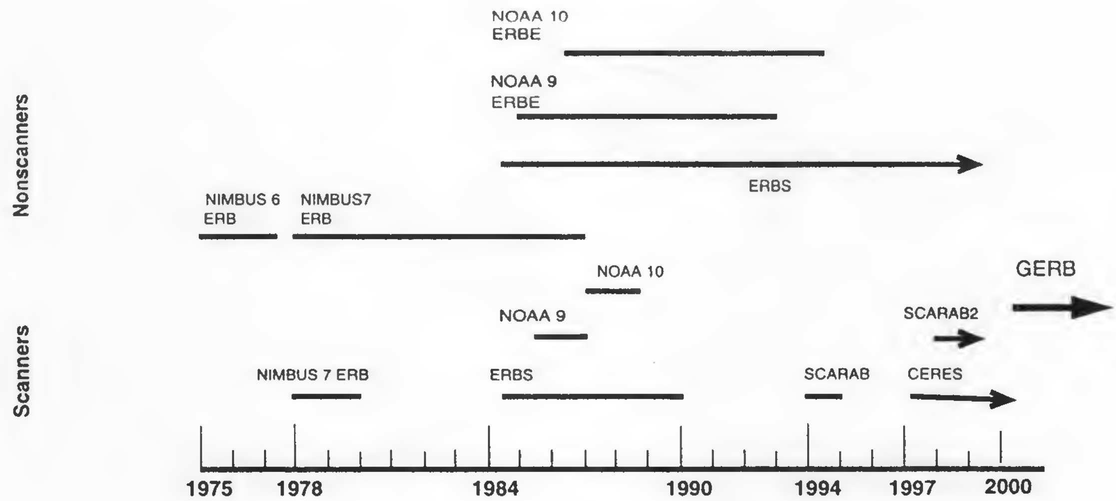

Figure 1. Earth Radiation Budget data sets.

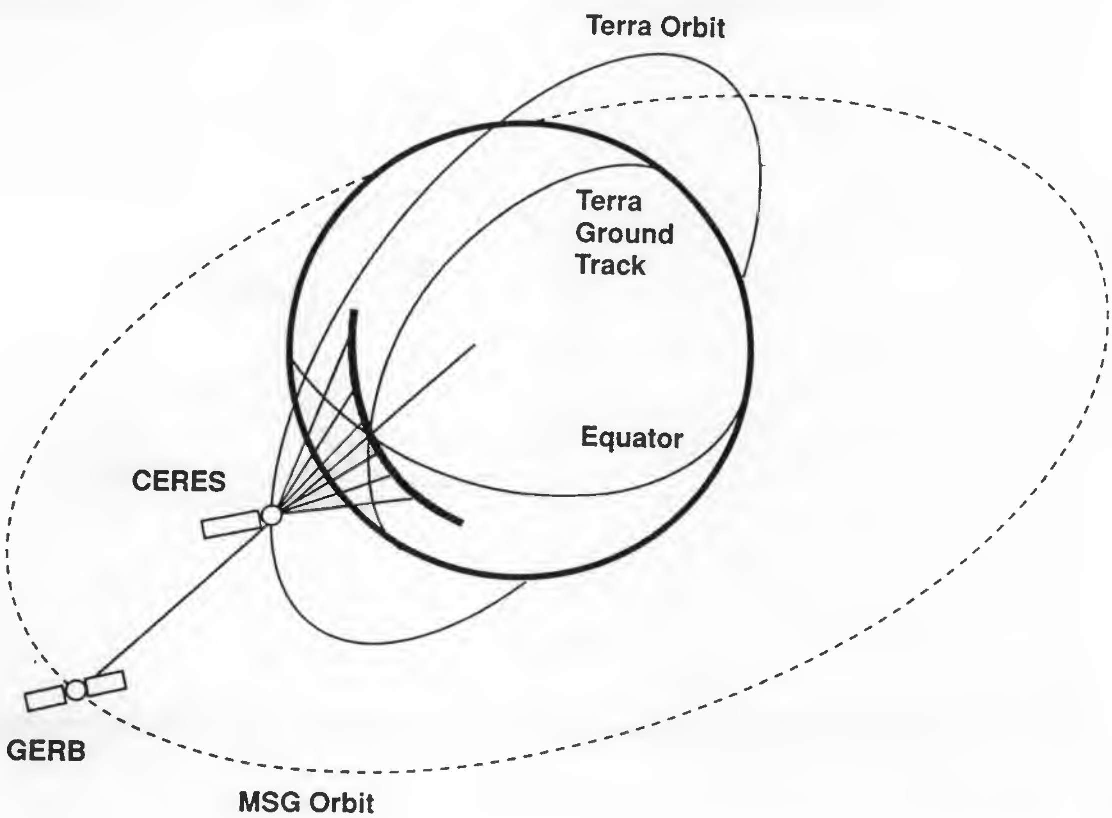

Figure 2. CERES and GERB simultaneous radiance measurements for CERES scanning cross-track.

Far-Infrared Radiative Transfer Studies with GERB Data

M. Mlynczak[1], D. Kratz[1], C., Mertens[2] & G.L. Smith[3]
[1] NASA Langley Research Center,
[2] G & A Technical Software, Hampton Virginia
[3] Virginia Polytechnic and State University

1.0 Science Discussion

The radiative balance of the troposphere, and hence climate, is influenced strongly by radiative cooling associated with emission of infrared radiation by water vapor, particularly at far infrared (far-ir) wavelengths greater than 15 μm and extending out beyond 50 μm, and principally due to the pure rotation band which includes both line and continuum absorption. The distribution of water vapor and associated radiative forcings and feedbacks are well-recognized as major uncertainties in understanding and predicting future climate. However, despite this fundamental importance, water vapor far-infrared emission (spectra or band-integrated) has rarely been directly measured from space or airborne platforms. Operational satellites typically observe the mid-infrared only to about 15 μm, sufficient to measure emission from the bending modes of the carbon dioxide molecule for remote sensing of the temperature profile. For purposes of water vapor profiling the strong 6.3 μm band has been used exclusively since the early 1970's.

The role of water vapor cooling in the far-ir was brought into prominence by the work of *Clough et al.* [1992] and of *Sinha and Harries* [1995]. The radiative cooling is dramatically illustrated in Figure 1 from *Mertens et al.*, [1999] which shows the spectral cooling rate in the troposphere (K/day/cm^{-1}) from 10 to 2500 cm^{-1} (1000 to 4 μm) from the surface (1000 mb) to 100 mb (approximately 16 km altitude). The cooling rates are calculated for clear sky using the Intercomparison of Radiation Codes in Climate Models (ICRCCM) midlatitude summer atmosphere with the temperature and water vapor profiles from *Ellingson et al.* [1991] and the ozone profile is as reported by *Anderson et al.* [1986]. The green-colored band between about 1300 and 2100 cm^{-1} is represents the cooling by the vibration-rotation bands of water vapor in the mid-infrared. Between 100 and 500 cm^{-1}, as indicated by the blue colors, is the strong radiative cooling by water vapor in the far-ir due to rotational and continuum emission. This figure clearly illustrates that far-infrared emission by water vapor is responsible for cooling the atmosphere from the surface to around 200 mb. The bulk of the free troposphere is cools radiatively in the far-ir portion of the spectrum.

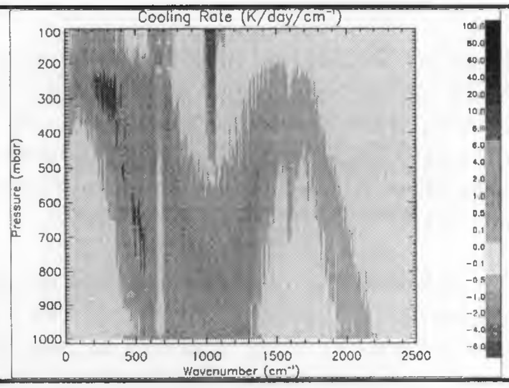

Figure 1. Spectral cooling rate profile for water vapor, carbon dioxide, and ozone from 10 to 2500 cm^{-1} (100 to 4 μm), in units of K/day/cm^{-1} multiplied by a factor of 10^{-3}.

1.1 Prior, Existing, and Planned Far-IR Measurements

To date, few sensors capable of measuring the terrestrial far-ir emission have flown. The IRIS-A and IRIS-B instruments, flown on Nimbus-3 and Nimbus-4 in 1969 and 1970, measured the far-ir emission out to 400 cm^{-1} (25 μm) with a resolution of 5.0 and 2.8 cm^{-1}, respectively. In addition, the SIRS-B instrument also on Nimbus-4 included six channels to measure the rotational band of water vapor between 18 and 35.7 μm. In hindsight, these sensors all suffered because of their large fields-of-view (nominally 100 km for IRIS and 150 km for SIRS) which made it nearly impossible to isolate clear fields-of-view. The large fields-of-view were required to achieve sufficient signal-to-noise with the detector technology then available. One primary reason that the far-ir has remained unobserved from space is that in order to attain smaller IFOVs cryogenic devices to cool the focal plane were required. Reliable cooler technology has recently residual TOA flux between 15 and 30 μm. Similarly, we can use these calculations to obtain a CERES residual TOA flux between 15 and 100 μm. The difference between the CERES 15-100 μm residual and the GERB 15-30 μm residual is the TOA flux between 30 and 100 μm.

Once the TOA residuals between 15 and 30 μm and 30 and 100 μm are computed, we will compare these directly with first principles radiative transfer calculations. Specifically, we will use the AIRS-derived temperature and moisture fields to compute TOA fluxes in these 2 spectral regions and will compare with the derived residuals. Minor species such as ozone that have a weak signature in the far-ir will be included in the computations as well. Ozone profiles will be taken from the Upper Atmosphere Research Satellite (UARS) if still operating or we will use the UARS climatology. We propose to use the LINEPAK and BANDPAK radiative transfer routines [*Marshall et al.*, 1994; *Gordley et al.*, 1994]. These radiative transfer codes have compared excellently with those used in the ICRCCM studies [*Mertens et al.*, 1999]. We will also use a correlated-k distribution model of *Kratz et al.* [1998].

It is not sufficient to simply compare the GERB-derived and CERES-derived far-ir residuals with the radiative transfer calculations without an assessment of the uncertainties in the derived residuals and in the radiative transfer calculations. The derived residuals will have errors due to calibration and measurement noise, although these should be small given the high level of accuracy to which the GERB and CERES instruments are calibrated. Of perhaps greater concern is uncertainty in the TOA fluxes in the 15-30 μm and 30-100 μm interval computed by radiative transfer models. Uncertainties in the AIRS-measured temperature and water vapor, and in the far-ir spectroscopy will lead to uncertainties in the calculated TOA fluxes. We will conduct a full error analysis in both the derived residuals and the computed TOA fluxes in the spectral intervals of the residuals. All results (differences between derived and computed TOA residuals) will be presented in light of this error analysis. We have conducted similar error analyses in our studies of the stratospheric heat budget [*Mertens et al.*, 1999; *Mlynczak et al.*, 1999].

1.3 Science Applications

The task proposed above offers the only way to assess, on a nearly global basis, our present understanding of far-infrared radiative transfer associated with water vapor. This is a first-order study that will give us basic information on a key component of atmospheric energetics. The results of this study will serve to build the science case for future spectral measurements of the Earth's far-ir emission, thereby complimenting the nascent TAFTS and REFIR programs.

It is also our goal to compare the results of this study with OLR as computed in numerical general circulation models. Typically, parameterizations of far-ir emission in such models is crude, and in some instances, non-existent. This comparison should spur improved parameterizations, and thus, better numerical models, if successful.

1.4 Closure

We have proposed a nearly global study of terrestrial far-ir emission using the only available space-based measurements sensitive to far-ir emission. Our approach is to compute far-ir residuals, differences between measured broadband TOA fluxes and computed mid-ir fluxes, the latter being computed from very accurate, simultaneously-measured temperature and moisture profiles. We have proposed to conduct a full error analysis of the far-ir residuals including all measurement and spectroscopy uncertainties. Over time this approach will give us an excellent assessment of our understanding of far-ir radiative transfer associated with water vapor, and hence, of a key element of atmospheric energetics and the climate system.

1.5 Task Schedule

This study will be carried out under separate funding provided by the National Aeronautics and Space Administration. The above will be proposed to NASA by GERB co-investigator M. Mlynczak of the NASA Langley Research Center. It is estimated that a level of effort of one post-doctoral researcher will be requested in this proposal to NASA.

This task will nominally begin on January 1, 2001, after GERB is checked out in orbit and data begin to flow routinely and the EOS Aqua payload is launched. The basic task breakdown is given below.

Validation, Calibration, and Improvement of Cloud and Radiation Parameters Using MSG SEVIRI and GERB with CERES, MODIS, GOES, and Triana Data

P. Minnis, D. F. Young, T. P. Charlock, K. J. Priestley, T. Wong
NASA Langley Research Center
Hampton, Virginia USA

D. P. Duda, N. G. Loeb
Hampton University
Hampton, Virginia USA

J.-J. Morcrette
ECMWF
Reading UK

Abstract for the First MSG RAO Workshop
Bologna, Italy, 17-19 May 2000

1. INTRODUCTION

The Clouds and Earth's Radiant Energy System (CERES; *Wielicki et al.* 1998) is designed to measure the global radiation budget at a gridded resolution of 1° x 1° using broadband scanning radiometers on up to three satellites in polar or mid-inclined orbits. CERES also derives cloud properties from high-resolution imagers to help interpret the CERES radiances and determine the relationship between clouds and the radiation fields. The combination of cloud properties and broadband radiative fluxes should provide the most accurate dataset to date for monitoring the global radiation budget and for constraining General Circulation Model (GCM) climate calculations. Because of orbital limitations, only a few local times are sampled by any given satellite. Although 3-hourly geostationary narrowband data are used to improve the interpolation of CERES measurements to fill unsampled hours (*Young et al.* 1997), the most accurate method is measure the radiation field each hour. The cloud properties are also interpolated to the unsampled hours to enable computation of the surface and atmospheric radiation budgets. Accurate quantification of the errors due to interpolation and sampling is critical for defining the constraints that can be imposed on GCM computations.

Cloud macro- and microphysical properties are key factors for determining the effect of clouds on radiation in the atmosphere and the relationship between the atmospheric hydrological cycle and the radiation budget. Determination of surface radiative characteristics is also critical for interpreting the cloud effects. Recent advances in geostationary satellite sensors now permit the derivation of cloud optical depth, phase, and particle size and the determination of surface emissivity, temperature, and spectral albedo over the complete diurnal cycle. The Geostationary Earth Radiation Budget (GERB) and the Spinning Enhanced Visible and Infra-Red Imager (SEVIRI) on the upcoming Meteosat Second Generation (MSG) will enable the combination of all of these parameters together at high spatial and temporal resolutions. Additionally, there are a variety of new scientific studies that can be performed using MSG with other satellites.

emissivities (*Smith et al.* 1999) derived from AVHRR and VIRS data. Because of changes in the soil moisture during the day, the emissivity may vary diurnally and the albedo may change from morning to afternoon. We will use the high temporal and spatial resolution of SEVIRI to derive more accurate versions of surface spectral emissivity and albedo maps. The results will be related to vegetation type, each other, and precipitation patterns.

e. Anisotropic directional model (ADM) validation

The fixed view of the MSG requires a quantification of retrieval errors due to the viewing angle. New ADMs for BB and NB radiance corrections are becoming available from CERES and POLDER and MISR, respectively. These models are crucial for predicting clear SEVIRI radiances and converting GERB radiances to flux. We will assess the uncertainties in GERB fluxes due to ADM errors by matching all relevant CERES footprints with contemporaneous GERB pixels. The errors in predicted clear-sky radiances and derived optical depths will be evaluated by comparing the CERES cloud retrievals from VIRS and MODIS with the corresponding SEVIRI products described above. These matched data comparisons will be especially valuable for determining the anisotropic error in LW due to shadowing of the surface (e.g., *Minnis and Khaiyer* 2000).

f. NWP model validation and assimilation

The European Center for Medium-range Weather Forecasting (ECMWF) numerical weather prediction model is presently geared toward direct assimilation of radiances. With the availability of near-real time cloud products, it may be possible to use them to improve weather forecasts. We will attempt some experimental assimilation of the satellite-based physical quantities (e.g., clouds and cloud water path) to test their impact on the ECMWF predictions. These same products will be used to evaluate the ECMWF output. Satellite-derived, land skin temperatures will also be compared to their ECMWF counterparts to estimate the prediction errors.

g. Contrail life cycles

Heavy air traffic occurs over large parts of the MSG FOV causing a significant number of contrails and substantial radiative forcing (*Minnis et al.* 1999b). While static, young linear contrails have been studied, little is known about their lifetimes and spreading over Europe. Previous studies using GOES data over the United States show that contrails can increase in coverage by more than four times due to spreading (*Minnis et al.* 1998b). Statistics of linear contrail conversion to cirrus clouds will be derived using sequential SEVIRI images initialized with MODIS data.

h. Cirrus particle shape

Cloud particle habit, an important parameter relating the hydrological cycle and radiation budget, may be determined from multi-angle views with one view from near-backscattering direction because phase function depends on particle shape. Water droplet phase functions are very distinct from ice. The Triana imager always views from 165-178°, while SEVIRI view varies from 60–180°. Thus, matched SEVIRI and Triana data will be used to estimate effective particle shape in cirrus clouds. The SEVIRI retrieval will be performed for a variety of particle shapes. The results will be used to predict the reflectances at the Triana view. The particle shape can be estimated by finding the result giving the best match between the SEVIRI-predicted and the Triana-observed reflectances.

3. CONCLUDING REMARKS

The MSG data can be used to attack a wide variety of remote sensing problems that could not be addressed with earlier instruments because of poor spectral, spatial, or temporal sampling.

An investigation into the spatio-temporal and spectral sampling characteristics of satellite-borne sensors for improved climate model validation

G.J. Robinson (PI), I. Astin, C. Godsalve, J.J. Settle

Environmental Systems Science Centre (ESSC)
The University of Reading, Reading RG6 6AL, England
(tel:+44 118 931 8742, fax: +44 118 931 6413, e-mail: gazza@mail.nerc-essc.ac.uk)

A. Slingo, R.P. Allan
Hadley Centre for Climate Prediction and Research (HC)

1 Introduction

Earth Observation (EO), because of its long-term synoptic capability, should arguably provide the best means of measuring global climate change. Over the past few decades numerous satellites have been launched, which have undoubtedly improved our understanding of the interaction between radiation and the earth's surface and atmosphere, and have led to the development of quantitative methods to detect climate change. However, their use for estimating changes over time is still hampered by two fundamental problems: the comparison of measurements made by different satellites and inadequate knowledge of the atmosphere (*i.e.* the physical structure of clouds and the distribution of water vapour). Both factors contributed to the recent scientific controversy concerning possible EO-based measurements of temperature change in the upper stratosphere, which is still unresolved, and the short-wave anomaly, which illustrates our incomplete knowledge of the effects of clouds on radiation. Clearly, considerable work remains before EO can be fully effective in this area.

The CLAUS (Cloud Archive User Service) EU Framework IV project, which is establishing a long-term time series of global brightness temperature data for use in GCM validation, has highlighted the limitations of current satellites for producing reliable long term global data-sets. Problems with calibration of the various sensors used are evident in products from the International Satellite Cloud Climatology Project (ISCCP), from which CLAUS obtains its input data. The CLAUS work has also shown that the ISCCP level B3 source data used have insufficient spatial and temporal resolution to allow the structure and evolution of cloud systems to be studied properly. Other errors in the calibrated ISCCP data have also been found, which introduce artefacts into the CLAUS data-set. These are especially noticeable when combining data from polar orbiting satellites with that from near-limb observations from geostationary satellites. This shows as occasional spurious peaks in cloud cover statistics at the semi-diurnal sampling frequency of the polar orbiting satellites. Difficulties with the correction of limb darkening effects have also demonstrated the need for better understanding of the relationship between radiation and cloud structure. Currently, CLAUS is only using the thermal IR (11-13μm) channel: further difficulties are to be expected with data from other channels, particularly those for water vapour (6.2, 7.3μm).

This proposal aims to help address these problems by developing a set of models and other tools to improve the use of EO in atmospheric General Circulation Model (GCM) validatation, which in turn will lead to more reliable estimates of climate change due to natural and anthropogenic events. The approach combines theoretical modelling and analysis of observational data. Our intention is to use existing work wherever possible, both within and outside the two organisations involved. The novel nature of this project lies in meeting the three objectives collectively, which will produce a useful and reliable set of sampling algorithms, developed for processing the ISCCP data, to the Meteosat 1999 TIR (and eventually SEVIRI) data to produce regional (*i.e.* MSG coverage area) higher resolution versions (5 km and 3 km respectively) of the CLAUS data-set. These data will then be sub-sampled and averaged to reproduce the sampling characteristics of the source ISCCP data used by CLAUS. Knowing the statistical properties of the SEVIRI data will then enable us to assign error values to the lower resolution CLAUS data, and to decide whether higher resolution data are required in future products (*e.g.* global water vapour distribution).

2.2 Radiative Transfer Study

The common theme in the three sub-tasks that comprise this study is the BRDF behaviour of clouds, which will affect the interpretation and comparison of SEVIRI and GERB data - particularly at shorter wavelengths. This work is especially important, since the spectral sampling component will provide a useful check on the proposed use of the more accurately calibrated GERB sensors to calibrate SEVIRI.

Existing BRDF work at ESSC and elsewhere will be used to develop detailed models of BRDF behaviour of clouds over the spectral range of interest. Observational data from SEVIRI and GERB will be combined with data from other polar orbiting sensors to test the radiance to flux conversion algorithms, and also to improve the parameterisations of the synthetic cloud models developed in the sampling study.

The main aim of this study is to develop suitable models of radiance to flux conversion for interpreting observations of clouds. Much work has been done in the area of atmospheric Radiative Transfer (RT): it not our intention to replicate this. Instead, the best and most appropriate existing techniques will be adopted, and modified as necessary, for use in this study. One of the greatest sources of uncertainty in atmospheric RT is the physical structure of clouds. Various models have been developed elsewhere which, along with assumptions about the micro-physical properties of clouds, have had varying degrees of success in reproducing measurements (space-borne, air-borne and land-based). The measurement process is itself a subject that requires far more study because of angular effects (*i.e.* BRDF) caused by the reflection properties of clouds and other atmospheric components. Satellites such as MSG and the new polar orbiting satellites, equipped with multi-spectral, multi-look angle sensors, will provide an excellent opportunity to investigate these problems in depth.

Our approach in this study will be to select one, possibly two, suitable atmospheric RT models and apply these to the synthetic cloud models described earlier to investigate three related issues:

1) limb darkening/BRDF: this will involve using the cloud models, coupled with RT models, to predict TOA radiances for comparison with observations from geostationary (Meteosat, SEVIRI) and near-nadir observations from polar platforms (ATSR series, CHRIS, *etc.*). This will be carried out at a number of wavelengths, corresponding to the satellites used.

2) spectral response functions: we will look at the effect of spectral response functions on measured radiance values at the same nominal wavelength from different sensors. The reason for doing this is that the CLAUS work has revealed (as yet) unexplained discrepancies between observed limb darkening effects from the Meteosat series and other satellites (*e.g.* GOES).

3) spectral sampling: we will investigate methods of converting, *i.e.* integrating, multiple narrow-band observations from SEVIRI to produce equivalent broad-band values for comparison with direct broad-band observations from GERB. We intend to investigate this problem in depth using the RT models developed earlier, coupled with the synthetic cloud models and/or UM output. The results will give an estimation of the likely errors involved in the integration procedure.

Algorithm Improvement for Novel Applications in Earth Science Research

MSG RAO Proposal #167

Kristina B. Katsaros,
Director, NOAA/Atlantic Oceanographic and Meteorological Laboratory, 4301 Rickenbacker Causeway,
Miami, FL 33149-1026, Phone: 305-361-4300, FAX: 305-361-4449, E-mail: katsaros@aoml.noaa.gov

and

Rachel T. Pinker, Department of Meteorology, University of Maryland, College Park, MD 20742,
Phone: 301-405-5380, FAX: 301-314-9482, E-mail: pinker@atmos.umd.edu

Objectives of the Proposal:

The objective of this project is to initiate research on new algorithms and products that will be applicable for the subtropical and tropical Atlantic Ocean. The total energy budget over the Atlantic Ocean will be evaluated as accurately as possible. Net radiative fluxes, both SW and LW, are part of this budget, the SW being the dominant part. The radiative fluxes will be derived form the new sensors of the MSG satellites. Adding the radiative fluxes to the latent and sensible heat fluxes estimated by multi-sensor techniques using independent microwave radiometer and scatterometer observations will complete the surface energy budget. For validation of the derived fluxes data collected by the Atlantic Oceanographic and Meteorological Laboratory data center will be used.

Planned Activity

We plan to produce research quality estimates of the surface energy budget for the Atlantic Ocean using MSG. We build on experience with METEOSAT observations for estimating the surface and top-of-the-atmosphere radiation budgets at several temporal and spatial scales, and in modeling and evaluating the heat budgets over the oceans from a wide range of satellite observations (ERS-2, SSM/Is, NSCAT). The most important forcing component of this budget is solar radiation, which is very sensitive to temporal variability. Diurnally resolved observations will become available from the MSG. To transform the observations into radiative fluxes will require improving or modifying existing methods by incorporating observations from SEVIRI and GERB and use of results to become available from the MPEF and SAF. It is anticipated that information on atmospheric parameters (e.g., precipitable water, aerosols) will become available from other MSG investigators or from independent sources. Validation data for components of the budget will be available from the AOML data center. The proposed work with MSG data will bridge the historic surface radiative fluxes and new fluxes thereby extending the climatic records. The proposed work will demonstrate the value of the new satellite mission for atmospheric, oceanographic and climate research; contribute to the calibration and validation of the new products; combine data from both the SEVIRI and GERB radiometers and various microwave sensors; and serve for cross validation of algorithms to be developed by the European scientists.

Approach and Methods

The turbulent energy fluxes across the air-sea interface are currently being evaluated by K. Katsaros in collaboration with colleagues at the Institut Francais de Recherche pour l'Exploitation de la Mer (IFREMER), France, a project that is ongoing and will be continued through several satellite generations. The net heat budget will be used in ocean circulation studies, water mass formation, climate variability studies, and a host of other potential projects. The satellite evaluations will also contribute to evaluation of sea surface temperature and radiation measurements on a proposed buoy network in the tropical Atlantic. Details of deployment and schedules are being discussed between U.S., French, and Brazilian scientists. The new observations from the suite of sensors on the MSG mission, SEVIRI and GERB, will facilitate resulting fluxes will be compared to similar products based on ship data, numerical model estimates, and individual buoy time series for quality evaluation. The one-year analysis will contribute to the information needed for determining methods for future long-term climate variability data collections from satellites.

- Similar work will continue after the launch of the MSG, using observation from SEVIRI and GERB for the radiative fluxes, and new generations of microwave scatterometers and radiometers for the turbulent heat flux estimates.

Deliverables include peer-reviewed articles on (1) the algorithms and (2) the distribution and variability of the energy flux terms over the Atlantic Ocean plus a CD-ROM atlas of our results is expected to be delivered at the end of the project. At least the meta-data will also be posted on the AOML World-Wide Web site.

Work Plan

During 1999 and 2000 we plan to work with METEOSAT and GOES data to obtain surface radiative fluxes over the Atlantic Ocean at 0.5 degree spatial resolution, and daily time scale, to be compatible with other input parameters to models of the total energy budget. The values of the radiation budget in gridded form will be transferred to the Remote Sensing Group at AOML for incorporation into oceanographic studies of the tropical Atlantic circulation, and heat content transformation of warm core eddies. The complementary data on evaporation rate (latent heat flux), sensible heat and momentum fluxes are being calculated employing scatterometer data from NSCAT and in 2001 supposedly by QuikSCAT, as well as microwave radiometer data. This work is collaborative with IFREMER (France) and may involve the ESA scatterometer data from ERS-2 and the ASCAT from METOP. These data are not requested through this RAO (access is available to the P. I. via her membership on the NASA NSCAT and QuikSCAT teams).

Details of the work plan for the period when data from the MSG will be available: After evaluation of the preliminary results and approach as applied for the 1997 period, development of modifications to the SW algorithm for SEVERI and GERB observations, as well as development of an SST algorithm and a net LW algorithm, and modifications for the new microwave instruments will be done during the first year. This later work is pending availability of funding for these activities from U.S. sources.

Data Requirements

MSG and Meteosat Data

Level 1.5 data from SEVIRI and GERB will be required on half hourly time scale in all 12 SEVIRI channels and two GERB channels for the Atlantic Ocean between 45EN and 45ES. Similar data would be required over land to match all IGBP land classifications (or as will be available from ENVISAT). This is needed, so the current n/b transformations can be tested and benefit the work based on narrowband observations, ongoing in the United States.

ESA Data

All ESA data such as ERS-2 scatterometer and METOP ASCAT data are already available through membership in the U.S. Scatterometer Team and through collaborations with European colleagues at IFREMER (France).

Other Data and Facilities

There is no direct need to use numerical forecast models, but we intend to analyze National Center of Environmental Prediction (NCEP) flux results for comparison. K. Katsaros, as a NOAA employee in the

Synergistic investigation of ocean, atmosphere and land processes, using data from GERB, SEVIRI and other sensors.

David Llewellyn-Jones, Eric Bradshaw, Sean Lawrence, Glyn Spencer,
Earth Observation Science, Space Research Centre, University of Leicester, University Road, Leicester, LE1 7RH, UK.

Tel: +44 116 252 5238
Fax: +44 116 252 5262
Email: dlj1@le.ac.uk

Dominic Kniveton,
Department of Geography, University of Leicester, University Road, Leicester, LE1 7RH, UK.

and

Neil Arnold.
Radio And Space Plasma Physics, Department of Physics and Astronomy, University of Leicester, University Road, Leicester, LE1 7RH, UK.

Introduction

Calling on the inter-disciplinary expertise within Earth Observation Science and the Physics and Geography Departments at the University of Leicester, our proposal is to use available satellite data to synergistically investigate the variations in flux over tropical ocean and land and to monitor the formation of tropical cloud formations. This will allow us to measure the diurnal and annual variation in Earth Radiation Budget (ERB) parameters with greatly enhanced accuracy and to examine the relationship between cloud development, precipitation efficiency and solar activity. By identifying regions of deep convective cloud, we will identify sources of atmospheric gravity waves, the flux of which can be input into a GCM to better model equatorial flows in the stratosphere.

A series of three investigations is proposed utilising the data and data products from GERB and SEVIRI. The objectives and approach behind each one are outlined below together with an indication of the anticipated results that may be obtained.

Description of the investigations proposed.

Investigation 1 (Llewellyn-Jones, Bradshaw, Lawrence)

The objectives of the first study are to investigate the diurnal variation in fluxes observed over the tropical Atlantic Ocean and equatorial African continent to develop new data assimilation techniques and relate these fluxes to the mean, time-averaged fluxes employed in ERB calculations. The diurnal and annual variation of certain ERB parameters will also be investigated.

The ERB is the balance between incoming radiation from the Sun and the reflected and scattered solar radiation added to that emitted by the Earth to space as thermal infra-red radiation. Although the effect of clouds on this budget can be quite large (100 W/m2 compared with 240 W/m2 for the fluxes), factors which can affect climate change can have as small an influence as ~4 W/m2. Therefore it would be ideal to measure the components of the ERB to as high an accuracy as possible (~1 W/m2). This should be achievable with the GERB instrument.

The investigation into fluxes over the tropical ocean and equatorial land at the enhanced time resolution offered by GERB will enable the diurnal variation of these quantities to be accurately measured for the first time and will lead to enhanced understanding of the different components of the electric field and enhancement of the rate of coalescence of cloud droplets to raindrops. In both cases a key parameter is the precipitation efficiency, the ratio of precipitated water to cloud water. Precipitation efficiency is influenced by a number of parameters other than electrostatic charge, including the inter-related cloud parameters of cloud type, height and development phase through the instability and moisture content of the air mass of the cloud. In turn these parameters are related to surface moisture and heat fluxes.

Solar activity varies over time scales of hours to millennia. In both the 'electrostatic charge' and 'cloud microphysical' mechanisms, the influence of solar activity is manifested through the scattering of magnetic discontinuities in the interplanetary medium by the solar wind resulting in variations in cosmic ray intensities at the Earth's surface. The purpose of this part of the proposal is to investigate these theories further by examining the relationship between cosmic ray intensity and precipitation efficiency for different cloud types, heights and development phases. Precipitation and cloud water data used to calculate precipitation efficiencies will be retrieved from passive and active microwave data from the Tropical Rainfall Measuring Mission (TRMM) Microwave Imager and Profiling Radar. Cloud and ancillary precipitation parameters will be obtained from MSG SEVIRI. Cosmic ray data will be obtained through the Solar-Terrestrial Physics division of the National Geophysical Data Center. In addition, it is proposed to use TRMM data and the GPROF algorithm to investigate the influence of variations in cosmic ray intensity on hydrometer profiles for different cloud development phases, heights and types.

The synergistic use of MSG SEVIRI data and products with TRMM data allows the investigation of these relationships at a temporal scale consistent with transient disturbances in cosmic ray intensity, called Forbush decreases, and incorporating key cloud parameters affecting precipitation efficiency. In addition to the investigation proposed here, it is envisaged that information on precipitation efficiencies related to cloud parameters will be of interest to the wider climate modelling, atmospheric and hydrological research communities.

Anticipated results

From Investigation 1, the diurnal and annual variations of fluxes over the tropical Atlantic Ocean and the equatorial African continent will be available for the first time and this will allow the measurement of the diurnal and annual variations of the cloud forcing parameter. An enhanced capability in assimilating GERB data to include atmospheric analysis fields (ECMWF) and detailed cloud parameters from SEVIRI is also envisaged as a product of this investigation. This, in conjunction with data from clear sky scenes over known land and ocean, will allow better understanding of the different contributions to the Earth radiation budget, in particular the contribution from different cloud types should be available.

From the second investigation in the proposal, results will include details of the spatial and temporal variations in the deep convection cloud regions with a view to assessing the source mechanisms for atmospheric gravity waves. The climatology of these deep convection regions will become available, with studies of the geographic, diurnal and seasonal variability. Comparison of these convection regions can then be made with GCM-simulated convection regions leading to an empirical estimation of the tropical distribution of gravity wave fluxes as a function of location, time of day and season. Finally, an assessment of the improvements in the 'skill' of numerical weather prediction and climate analysis on the basis of these results can be made and the impact of these clouds on the middle atmosphere and possible contributions to the Quasi-Biennial Oscillation can be examined.

Through the synergistic use of TRMM and MSG SEVIRI data, precipitation efficiencies for different cloud types, heights and development phases will be obtained from the third investigation in this proposal. This will enable information to be gained on the relationship between variations in the above and cosmic ray intensities which may, in turn, increase our knowledge of the theories relating solar variability and changes in atmospheric dynamics.

In flight absolute calibration of the visible channel of Meteosat Second Generation using Rayleigh scattering over oceans

Jean-Marc Nicolas[1], Pierre-Yves Deschamps[1], Olivier Hagolle[2]

[1] Laboratoire d'Optique Atmospherique, USTL, Bâtiment P5
59655 Villeneuve d'Ascq, FRANCE
Tel : 33 3 20 43 67 08
Fax : 33 3 20 43 43 42
email : nicolas@loa.univ-lille1.fr

[2] Centre National d'Etude Spatial , 18 avenue Edouard Belin
31401 Toulouse Cedex 4, FRANCE

Our objective is to propose an absolute calibration method for the VIS 0.6 channel of SEVIRI using atmospheric rayleigh scattering over oceans. That signal can be accurately computed and compared to the sensor output. The level of signal of that kind of target is low but more than sufficient. Preliminary computations show that it is between 3 % to 9 % of maximum dynamic of the instrument. The aerosol contribution will be evaluated using the near and short wave infrared channels centred at 0.8 and 1.6 micron. Other contributions like water reflectance or sun-glint will be minimised by data selection. Long-term calibration control is then possible all over the lifetime of the sensor.

The main uncertainties for such a method is the aerosol contributions. Maritime aerosols can be accounted for using VIS 0.8 and 1.6 bands. But the variability of continental aerosols needs to carefully discard such situations by areas selection. Apart from aerosols variability, other uncertainties like sun glint, gaseous absorption or water leaving radiance should be accounted for. The use of POLDER1 monthly synthesis will be helpful for areas selection.

1. Approach and method

In-flight calibration for sensors in the visible and near-infrared is possible using natural, earth targets. Usually those methods rely on some land areas known for their stability and homogeneity like desert sand or rocky plateau. This approach has many drawbacks such as the difficulties to measure ground reflectance, the difficulties to correct the continental dust effects or the scale problems for low-resolution radiometers like MSG. Another way is to cross-calibrate the target instrument with another spatial or aircraft one. This approach can be really useful but rely entirely on the calibration of the other instrument.

Another way, successfully applied to AVHRR and POLDER1, is to use the Rayleigh scattering over ocean as the target and to compare it pixel to pixel to exact computation of this signal for the given geometric and geophysical conditions. That is the approach we intend to apply to MSG. We will show that precision within the noise of the sensor can be obtained with some carefulness. The nominal method does not rely on any in-situ measurements. However, during the first year we can validate the method using the SIMBAD and SIMBADA radiometers deployment.

Formulation :

Let's use the normalized radiance defined as :

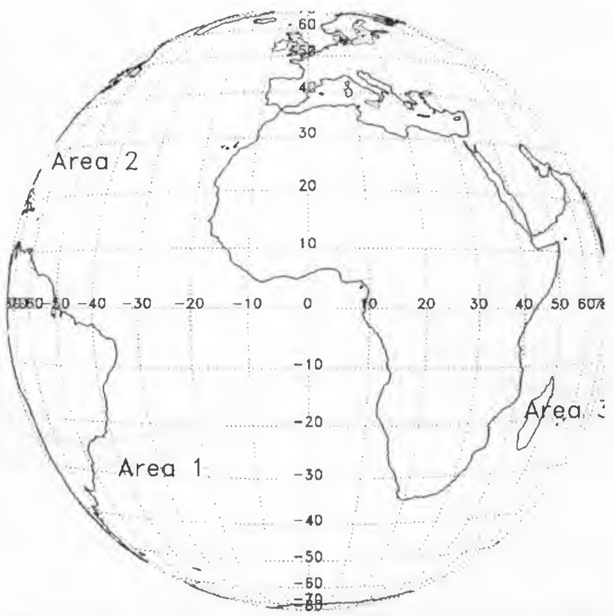

Figure 1. Selected areas for calibration (based on aerosol climatology)

3. Preliminary signal simulation

For each area we consider standard conditions : maritime aerosols, clear waters, standard pressure, low but steady wind (table 1.)

Geophysical conditions	*value*
Date	21 mars (equinoxe)
Aerosol model	maritime
Aerosol optical thickness	0.05
Maximum solar zenith angle	75 °
Wind speed (Cox & Munk model)	7.5 m/s
Chlorophyll	0.05 mg/m3
VIS 0.6 rayleigh optical thickness	0.054

table 1. Geophysical conditions for simulations

We computed the evolution of the TOA signal as seen by SEVIRI (figure 2.) along the day supposing that the delay between each sequence is 15 minutes. If we consider in a first approach that central wavelength is representative of the whole spectral band (in real data processing, convolution should be achieved other the spectral band), we can write that :

1 DC = 0.00098 (normalize radiance)

The level of the signal is small (from 3 % to 9 % of maximum dynamic range) but it can be accurately computed (within 1 DC of precision). It should be noticed that we stop the simulation for solar zenith angle above 75 ° (below 15 ° other the horizon) because radiative transfer codes become less accurate. But some specific corrections should allow us to compute signal for solar angle up to 85 °. That kind of investigation is new for molecular scattering calibration.

Calibration of SEVIRI with ATSR-2 and AATSR

D. Smith

The SEVIRI 0.6μm, 0.8μm, 1.6μm, 11μm and 12μm channels will be calibrated against the ATSR-2 and AATSR, using data from desert scenes, deep convection clouds and clear-sky ocean scenes.

The project will commence when MSG data becomes available using data from the start of the mission.

The comparison between SEVIRI and ATSR-2/AATSR will use the results from radiative transfer calculations to allow for the differences in the spectral responses.

The result will be improved calibration coefficients for SEVIRI. These will be available approximately one year after the start of the MSG mission.

The calibration drift of the SEVIRI short wavelength channels will be monitored using desert scenes. A correction table will produced and updated for the duration of the MSG mission.

Detailed Description

Objectives:

The aim of this proposal is to improve the calibration of SEVIRI using data from ATSR-2 and AATSR.

Data from large area desert scenes and tropical, deep convection clouds will be used to derived calibration coefficients for the 0.64μm, 0.8μm and 1.6μm channels.

The long-term stability of the SEVIRI short wavelength channels will be monitored using the ATSR-2 and AATSR visible calibration systems as the reference.

Compare SEVIRI against ATSR-2 and AATSR 10.8μm and 12μm top-of-atmosphere brightness temperatures.

Approach and Methods:

Introduction

The integrity of geophysical parameters derived from satellite data will depend on the calibration accuracy of the instrument. This has been addressed for SEVIRI by the use of an on-board blackbody target for the infrared (cold) channels and pre-launch calibration tests. However, the calibrations will drift with time as a result exposure of the optical systems to exhaust contamination from the launch and the harsh space environment (Rao and Chen, 1995). In order to maintain the calibration it is necessary to monitor any immediate changes and long term drifts.

The traditional approach to verifying the calibration of such instruments is to make coincident measurements of a scene with the satellite and ground and/or aircraft based instruments (Abel et al, Slater et al). Although essential, such campaigns are expensive to

Although the desert scenes to be used are uniform over a large area, and are temporally stable, the measured top of atmosphere radiance varies significantly with viewing angle. This does present a problem because most of these sites are typically between 20°N-30°N. Because of the limited viewing geometry, it will not be possible to make co-angular comparisons. However, the BRDFs of these sites are being derived from POLDER measurements and it is hoped that these will used to transfer the ATSR-2/AATSR calibrations to SEVIRI. Comparisons between ATSR-2 and POLDER are currently being done, and the initial results look promising.

The dual view of ATSR will allow 11μm and 12μm comparisons to be made at two local zenith angles. In addition, measurements will be taken for both day and night time images.

The result of comparing the top-of-atmosphere reflectances and brightness temperatures will allow gain and offset corrections to be made for SEVIRI.

In addition to the absolute calibration of SEVIRI, the long-term stability of the instrument will also be monitored. Here the long-term stability of the large area desert scenes will be employed. In order to derive drift rates for SEVIRI it is necessary to allow for the non-isotropic behaviour of the sites. The effect of this can be reduced by using data from a limited range of Sun zenith angles, the satellite zenith angle being fixed. A simple model of the bi-directional reflectance properties is made for each site and the data will be normalised to this function. Data from ATSR-2/AATSR will be used to monitor any seasonal variations in the scenes that may influence the calibration.

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Results and Deliverables:

Top of atmosphere reflectances and brightness temperatures for selected test sites from ATSR-2/AATSR and SEVIRI at MSG start of mission.

MSG IMPROVED CAPABILITIES FOR MARINE AEROSOL CHARACTERIZATION

Cyril Moulin[1], François-Marie Bréon[1], Fabienne Maignan[1], Jean Poitou[1], and Didier Tanré[2]

[1] *Laboratoire des Sciences du Climat et de l'Environnement, CEA-CNRS, C.E. Saclay - bât. 709, 91191 Gif-sur-Yvette, France*
tel: (33 1) 69 08 71 20; fax: (33 1) 69 08 77 16; cyril.moulin@cea.fr
[2] *Laboratoire d'Optique Atmospherique, USTL-CNRS - bât. P5, 59655 Villeneuve D'Ascq, France*

ABSTRACT

Our objective is to make use of the improved MSG capabilities to perform a complete characterization of the aerosols in the marine atmosphere and to investigate the potential of an operational aerosol product. First, our mineral dust load retrieval method (hereafter refered to as African dust method) will be adapted from the Meteosat solar band (VIS) to the 0.8 μm band of MSG to continue the survey of the African dust export over the Atlantic and the Mediterranean. Then an improved method based on the combined use of the 0.6, 0.8 and 1.6 μm bands will be developed to extend the inversion (hereafter refered to as marine aerosol method) to other marine aerosols such as sulfates from pollution or biomass burning aerosols. We will also explore the possibility of extracting pertinent information on African dust from the various infrared (IR) bands, e.g., on the particle size and on the altitude of the dust layer.

INTRODUCTION

Despite their important contribution to the Earth radiative budget, aerosols are poorly known at the global scale and are only partially taken into account in climate models. Because of the strong variability of aerosol sources, distributions and optical properties, satellite observations are well adapted to provide the climate community with useful aerosol data sets. MSG spectral bands offer new opportunities to study the aerosols over the oceans within its field of view.

We have used for almost ten years the Meteosat VIS band to retrieve the African dust load (Dulac *et al.*, 1992; Jankowiak and Tanré, 1992). The method was applied to every noon images from the ISCCP-B2 archive since 1983 (Moulin *et al.*, 1997a). This unequaled data set enables us to show a general increase of the export of African dust between 1983 and 1994 and to generate the first monthly climatology of African dust loads over the Atlantic and the Mediterranean (Moulin *et al.*, 1997c). Our first objective is to develop a similar method for the 0.8 μm band of MSG to extend our climatology. The use of this band should lead to significant improvements since it enables to avoid some important sources of uncertainty (sea surface contribution, gazeous absorption bands). The better digitization should also improve the accuracy of the retrievals.

However, several other aerosols are present in the marine atmosphere, with different optical properties and radiative impact. Our second objective is to extend the African dust method to these aerosols, in order to generate maps of both aerosol load and type from MSG images. In particular, we seek to differentiate desert dust from the Sahara and Sahel, biomass burning aerosols from subtropical Africa and pollution aerosols downwind of Europe. To achieve this, we will make use of the three solar bands to retrieve the spectral signature of the aerosol reflectances derived after correction of both molecular and surface contributions. This spectral dependence is

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depth is directly computed from the aerosol reflectance via a Look Up Table (LUT). For a given geometry and aerosol type, the LUT provides a direct relationship between the reflectance and the optical depth. These LUTs will be computed once and for all using the radiative transfer model.

The African dust method will be applied to low resolution images equivalent to the ISCCP-B2 format (i.e., 1 pixel over 10). This spatial resolution is suitable for dust monitoring and will warrant the continuity with the existing Meteosat data-base. For the marine aerosol method, we will use a better resolution, depending on our computer facilities (e.g., 1 pixel over 3). Contrary to the African dust method that is expected to be operational quickly, the marine aerosol method will require a test period. We will first select a set of images displaying different representative situations such as pollution plumes from southern Europe over the Mediterranean or biomass burning smokes off subtropical Africa to set up the aerosol characterization. During this period, we will define the number of aerosol types to include in the LUTs.

Finally, we will use sunphotometer measurements made in coastal areas or in islands to validate our estimates. To achieve this, we will make use of the AERONET network (Holben *et al.*, 1998). Several instruments are routinely operated in both Atlantic and Mediterranean regions. Atlantic sites such as Dakar and Sal Island are particularly suitable to validate the African dust method, while the Mediterranean sites are perfectly adapted to the marine aerosol method since particles in this region may vary from pollution to mineral aerosols. Another source of "comparison data" will be POLDER 2 which should be launched on ADEOS 2 in late 2000. We are deeply involved in the POLDER program (Deschamps *et al.*, 1994) and we will have a free and fast access to the data. The POLDER marine aerosol algorithm was already applied to POLDER 1 data (1996-1997) and showed very good accuracy in terms of both aerosol optical depth and type retrievals (Goloub *et al.*, 1999).

APPROACH TO USE MSG INFRARED BANDS

Our scientific approach of the characterization of the African dust from IR bands will be to work on a few selected cases. Indeed, the innovative aspect of this research as well as the number of required bands (both solar and infrared) prevents to schedule an early operational processing. We will thus select a few intense dust events over the Atlantic and order the corresponding full MSG imagery. The first step will be to carefully look at all IR bands to observe the perturbations related to the dust plume. We expect to observe a clear signal at 3.8 μm and hopefully also a perturbation at 8.7, 10.8 and 12.0 μm. In parallel, we will perform intense radiative transfer computations in these spectral domains to determine the parameters which affect the IR signals. Indeed, it is well known that the altitude of the dust layer has a strong impact on the intensity of the perturbation in the infrared. However some other parameters, such as the mineral dust size distribution and refractive index, may also be very important. For example, recent modeling showed that the sign of the net dust radiative forcing over the oceans may change with the refractive index in the infrared. We will thus have to test the importance of these different parameters with respect to the measured signals.

Depending on these results, we will develop inversion methods to process IR images. To retrieve the African dust plume characteristics using the radiative transfer model, we will first remove the sea surface contribution and impose the dust optical depth. The later will be derived from the solar band inversion. The surface emission in every band will be computed from the sea surface temperature (SST). Since African dust plumes may bias the SST estimates from the standard MSG algorithm, we plan to infer the SST from clear days close to the "dusty" period. These parameters will be used to run the radiative transfer model on each clear-sky pixel affected by the dust plume. On the one hand, the thermal IR bands should enable us to retrieve the dust

Dust in Africa using the Infrared Difference Dust Index (IDDI). Expected progress in dust detection, dust cycle description, and African climate, through the improved resolution and multi-channel facilities of SEVIRI

Michel Legrand, Laboratoire d'Optique Atmosphérique, Université de Lille-1, 59655Villeneuve d'Ascq, France
Phone (33) 3 20436646 – Fax (33) 3 20434342 – Email legrand@loa.univ-lille1.fr

Scope of the proposal :

- Utilization of the improved resolution and the multichannel facilities of SEVIRI to make a new improved multichannel IDDI
- Development of a methodology for a high-resolution characterization of the source emission
- Extension of the daily series of IDDI images to investigate long-term changes of dust production and atmosphere loading
- Investigation on the natural and man-made origin of the dust production. Analysis of the interactions between dust and the main components of the African climate

1 - The Infrared Difference Dust Index (IDDI)

The key milestone of this proposal is the development of an improved Infrared Difference Dust Index (IDDI). The current IDDI is a product developed at the LOA, designed to climatological applications. It is closely adapted to the data delivered by geostationary satellites. It is defined as the decrease of thermal infrared outgoing radiance involved by the presence of dust and measured with the IR channel of METEOSAT. It is relevant over land in the middle of the day.

The figure included shows the steps of image processing giving rise to an IDDI image. The Original Image (OI) is a raw IR image from Meteosat, radiometrically corrected (a mask is added over the ocean); NW Africa is covered by clouds. The Reference Image (RI) is a clear (no clouds) and clean (no dust) image derived from an OI series. The Difference Image (DI) obtained by subtracting the OI from the RI, displays only the atmospheric pattern of clouds (especially over NW Africa) and dust (thick plume around the central Sahel). The IDDI image is obtained from the cloud masking operated on the DI.

The IDDI product gave rise to the following applications (published articles are available) :

- Realization of a dust climatology over northern Africa, currently from 1983 to 1999;
- Identification of the Saharan and Sahelian sources of dust, retrieved properties of dust emission from these sources (wind speed threshold), validation of a physical model of dust emission;
- Analyses of the interactions between dust and the main other components of the climate. A well-known problem in the scope of these studies is the persistent drought affecting the Sahel.

The IDDI allows the detection of dust sources. This property of the IDDI was used, in conjunction with surface windspeed data, to determine the threshold for dust emission of some sources (validated by in situ measurements). This procedure will be automated and applied to the pixels of the whole Sahara-Sahel area in order to map emission thresholds at a high-resolution.
The improved IDDI will be used for this study. So it needs the SEVIRI Level 1.5 Data reported in the previous section 2.

4 - Extension of the daily series of IDDI images to investigate long-term changes of dust production and atmosphere loading

A climatology of dust over Africa covering the period from April 1983 to April 1999 has been realized with the daily series of IDDI images from METEOSAT. We propose to extend this series by including the MSG data, taking care to realize at best the compatibility between MSG and the former Meteosat. This long time series is designed to investigate long term changes of dust production and atmospheric dust loadings.

This climatology needs the SEVIRI Level 1.5 Data reported previously (section 2) in association with METEOSAT data requested as follows:

- Meteosat Image Data (first generation)
- Processing level: Rectified
- Area: Full disk area
- Meteosat data required for the period: 04-1999 - 04-2002, then restricted to a year.

Comment: the period of a year data METEOSAT will necessarily overlap the production of SEVIRI data (after the commissioning), and the images should be obtained according the same geometry.

5 - Investigation on the natural and man-made origin of the dust production. Analysis of the interactions between dust and the main components of the African climate

The phase of the project concerned with interactions between dust and climate will have three objectives:

(i) The extent to which dust mobilisation in the semi-arid regions is controlled by land-surface properties (including man-made changes), as opposed to the regional-scale climatology, will be assessed. This will go some way towards resolving the contentious issues of the relationships between climate change and land degradation in the region.

(ii) The contribution of Saharan and Sahelian sources to the regional and global dust budget will be tentatively estimated by using the improved IDDI, in order to assess claims that, due to land degradation, the Sahel has become a more important dust source than the Sahara.

(iii) The impact of dust on the thermal structure of the atmosphere and on the regional circulation will be assessed, with regard to the extent to which dust modulates the processes that produce rainfall in the Sahel region.

Aerosol/Cloud Effects: Implication on the Radiation Budget and Atmospheric Correction

Rolf Stuhlmann[1], Andreas Macke[2], Roland Doerffer[1], and Knut Dammann[1]

[1]GKSS Forschungszentrum, Max-Planck-Strasse, D-21502 Geesthacht, Germany
Phone: +49 4152 87 1543, Fax: +49 4152 87 2020, e-mail: stuhlmann@gkss.de;
[2]Institute for Oceanography at the University of Kiel, Duesternbrooker Weg 20, D-24105 Kiel, Germany
Phone: +49 431 597 3875, Fax: +49 431 565 876, e-mail: amacke@ifm.uni-kiel.de

SUMMARY

The project is to achieve the following objectives: 1) determine properties of aerosol and clouds over ocean areas, 2) determine changes in the radiation budget (top of the atmosphere and surface) in relation to these properties, 3) improve and test atmospheric correction algorithms for aerosol and thin cirrus clouds for ocean remote sensing 4) determine the photosynthetic active radiation (PAR) over oceans. Narrow-band visible channels of SEVIRI will be used to determine the optical depth and size parameter of aerosol and clouds using algorithms similar to those of Nakajima (aerosol) and Kriebel (clouds), implemented at GKSS for use with AVHRR data. The radiation budget at the top of the atmosphere will be that derived from GERB measurements. The top of the atmosphere radiation budget and the aerosol and cloud products, together with atmospheric profiles obtained from analysis or standard profiles will be used to determine the radiation budget and PAR at the surface. As result, it is expected that possibly some information on the direct and indirect effect of aerosols on climate can be derived as a contribution to the Global Aerosol and Climatology Project (GACP). Algorithms for atmospheric correction for ocean remote sensing, developed at GKSS for MERIS, will be tested with SEVIRI. Because of the higher temporal and spectral resolution of SEVIRI, these algorithms will be improved by better distinguishing between effects of aerosol and thin cirrus. In the pre-launch phase, data of NOAA-AVHRR and ScaRaB will be used to substitute SEVIRI and GERB. Existing algorithms will be used as a baseline and will be adapted for MSG data. After launch, these new versions will be improved, tested and applied using MSG data. For the BALTEX intensive observation period (Jan/Feb 2002), products will be made available off line to the BALTEX user community. Results are reported on Science Team workshops, project reports and in the scientific literature.

OBJECTIVES

Atmospheric aerosols could, by reflecting solar radiation directly and by changing cloud optical properties indirectly, play an important role in global climate change. This potential effect of aerosols on climate is recognized by the Intergovernmental Panel on Climate Change (IPCC) as being one of the largest sources of uncertainty in understanding of long term climate change. First investigations to study aerosol optical thickness together with broadband reflected short wave radiation at Top-of-Atmosphere over cloud free oceans for a thirteen years (1981 - 1993) period was done by LL Stowe (WCP, 1998). He found an aerosol forcing ranged from about -40 Wm^{-2}, cooling in the tropics to about +20 Wm^{-2}, heating at mid-latitudes. A disadvantage related to this study is, that the broad band reflected flux was derived from the narrow-band AVHRR measurements by applying a fixed, aerosol independent conversion algorithm. Since narrow to broadband conversion strongly depends on the spectral properties of the reflected radiation, it is expected that the narrow to broadband conversion parameters will change for different aerosol loading, which could not be taken into account so far. Meteosat Second Generation (MSG), for the first time, offers a continuos data set of narrow and broadband measurements, co-located, co-aligned and simultaneously and therefore will be excellent spectral resolution of MSG SEVIRI data make it an excellent candidate as a data source. For Ocean remote sensing in general, existing algorithms of atmospheric correction do not distinguish between the contamination of clear sky ocean scenes by aerosols or thin cirrus clouds. The algorithms derived at GKSS for the MERIS instrument will be modified for the use with SEVIRI data to give an improved information on aerosols and thin cirrus clouds in the atmosphere.

APPROACH

The approach to meet the above described scientific objectives is straight forward and will be based on already existing algorithms developed for application to operational satellite data as NOAA AVHRR for narrow-band radiances and ScaRaB for broad-band radiances. Basically, these have to be methods to derive aerosol properties as optical thickness and an index on aerosol particle size distribution, cloud scene identification, and cloud properties as optical thickness, phase and index on size distribution of cloud particles, surface radiation budget and PAR, and atmospheric correction for ocean remote sensing. Fig. 1 is an example of the combined analysis of ScaRaB and AVHRR data to derive a relation between aerosol optical depth and reflected shortwave flux at the top of the atmosphere. In addition, complex radiative transfer algorithms are necessary to realistically model three dimensional distribution of scattered cloud fields with internal inhomogeneous microphysics including ice and water phase. Before "Day 1" (end of MSG commissioning phase), these algorithms will be implemented and applied to NOAA AVHRR and ScaRaB data at GKSS and the University of Kiel. The major task here will be to test these algorithms for a transition to the SEVIRI and GERB measurements and to modify these algorithms for a final application to the MSG data after "DAY 1". As part of the today research program at GKSS and the University of Kiel, most of these necessary algorithms, listed above, are already implemented or in preparation to be implemented. For instance, as contribution to the Global Aerosol Climatology Project, where GKSS and the University of Kiel are co-operating as members of the International Aerosol Radiative Forcing Science Team selected by the World Climate Research Programme in conjunction with NASA, the two channel algorithm of Nakajima for aerosol detection has been implemented in 1999 and is now in its test phase. For detection of cloud pixels and cloud properties the APOLLO algorithm of Kriebel and Saunders where implemented and is applied in a quasi operational mode for cloud studies within the Baltic Sea Experiment (BALTEX) over Europe and also the Mackenzie River Experiment (MAGS) in Canada. As part of the work done within the ScaRaB project, cloud information and radiation budget measurements are combined and used for validation of the Regional atmospheric BALTEX model. For this purpose, derived cloud information from the high spatial resolution AVHRR measurements (about 1km) is aggregated for a corresponding low resolution (about 60km) ScaRaB pixel by weighting the AVHRR results with the ScaRaB point spread function. As partner of the German weather service, GKSS has already started to develop algorithms to determine also the incoming solar- and downwelling terrestrial radiation at the surface. To study the effect of microphysical and macrophysical cloud structure on interaction with radiation and consequences for remote sensing and regional scale modelling, at the University of Kiel, a Monte Carlo radiative transfer scheme was developed to simulate multiple scattering of cloud distributions close to reality. The single scattering properties of ice particles within this model are derived by a ray tracing program. Information on internal and external cloud structures of clouds as input to this model are taken from in-situ measurements carried out by GKSS with a set of PMS particle probes detecting aerosol and cloud particles within a size range from 0.1 to 6400 micro meter. In addition, the internal structure of clouds is also measured by a 95GHz cloud radar at GKSS, whenever possible in combination with the GKSS particle probes attached to a research aircraft. As part of the research done at GKSS in relation to the MERIS instrument onboard of ENVISAT, algorithms are developed for atmospheric correction for ocean remote sensing. A major step in improving atmospheric correction models is to distinguish between aerosols and thin cirrus clouds, since their scattering properties of radiation are totally different. GKSS already started to put up a sun photometer for measuring atmospheric aerosol loading on the island of Helgoland. It is planned at GKSS to take also measurements of incoming solar radiation, PAR, and downwelling terrestrial radiation on the island of Helgoland as ground truth measurements. Because the sun photometer measurements of GKSS are included into the NASA Aerosol Robotic Network (AERONET), GKSS has also access to all measurements taken at the other sites of the AERONET. It is assumed that by adapting the

A fog monitoring scheme based on MSG data

JÖRG BENDIX[1]
Faculty of Geography, University of Marburg, Deutschausstr. 10, 35032 Marburg (Germany), Tel.: ++49-6421-2824266, e-mail: bendix@mailer.uni-marburg.de

1. Introduction

Air quality is not only affected by men-made emission but also by the prevailing weather situation. Fog[2] represents one of the most dangerous meteorological situation because the pollutants remain near the ground and cannot disperse. Pollutants can also be incorporated within fog droplets and deposited on the surfaces exposed to the atmosphere in high concentrations. Hence, epidemiological studies have shown a clear relationship between fog occurrence and human health and ecological studies have revealed that polluted fogs cause severe damages to forests and vegetation, to materials and structures and to aquatic systems by acidification of the surface waters. In the case of a valley fog, the needed key parameters for pollution studies are schematically presented in Figure 1. A stable inversion layer of variable geometrical depth and width is formed which limits the vertically and horizontally exchange of polluted air. The degree of stability within the fog layer controls the magnitude of vertical exchange of polluted air as well as the uncoupling of the synoptic wind field from the boundary layer drainage flow, which is generally weak during such weather conditions. Vertically extended fog layers delay fog clearance due to the reflected solar irradiance at the fog top and hence, fog can persist over several days with a continuous increase in concentration of air pollutants.

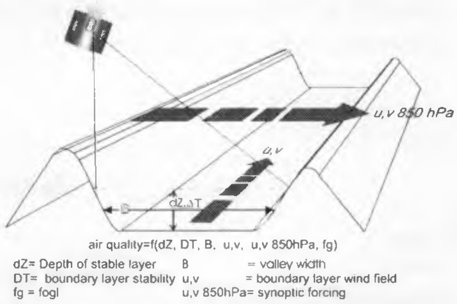

Figure 1: Key parameters which are related to air quality studies

The inability of meteorological models to accurately predict fog properties, the difficulty of reconstructing fog properties from ground based measurements (which are also time-consuming and expensive), recommend as a unique solution the use of satellite data within pollution studies. Hence, a tool for monitoring fog events based on MSG data will be developed and validated in order to derive the following key parameters: ***(1)*** Fog occurrence as a spatial tracer for temperature inversions, ***(2)*** fog geometrical depth as a tracer for the available air exchange volume, ***(3)*** fog optical and microphysical properties (optical depth, liquid water content LWC, effective radius r_e) as a tracer for the delay in fog/inversion clearance (persistence) as well as for pollutant deposition and ***(4)*** time of fog clearance as a tracer for the persistence of the critical weather situation. The final monitoring scheme will be extensively calibrated/validated by means of synoptic observations and time synchronous *in situ* observations of key parameters which will be obtained by special field experiments of the participating co-investigators.

2. Development of the monitoring scheme

The basic methodological outline of the scheme is summarised in figure 2. Extensive in situ-observation, field surveys, the integration of European SYNOP data as well as numerical model results

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[1] Co-Investigators are: Dr. S. Fuzzi, Institute of Atmospheric and Oceanic Science, CNR-Bologna; Prof. Dr. F. Wieneke, Institute of Geography and Dr. M. Sachweh, Institute of Meteorology, University of Munich.

[2] For the purpose of pollution studies, fog cannot be simply defined by visibility <1 km. In this paper, fog means a cloud which covers basins and river valleys and is partially lying on the ground (at least on the slopes of the surrounding terrain). Elevated ground is, however, partially situated above the fog layer within the fog-limiting temperature inversion.

in reflectance at 0.64 and 1.64 µm can be realized during daylight due to the different optical properties of fog and haze in these spectral bands (PILEWSKY & TWOMEY 1987). Validation of the resulting fog mask is performed by manual/GPS-based mapping of fog boundaries in the field (river valleys and pre-Alpine basins) simultaneous to MSG scan times.

2.2 Fog optical and microphysical properties

The second part of the monitoring scheme is the determination of fog optical depth, liquid water path and effective radius as a function of fog albedo. An important pre-condition is the adaptation of a numerical weather prediction model (NWP ARPS, XUE *et al.* 1995) to the central study area in the spatial resolution of MSG by using digital data of topography, land cover and by realising an interface between ARPS and European SYNOP and TEMP data. The proposed method is restricted to the MSG spectral band at 0.64 µm and therefore to daylight conditions with sun elevations ~>5°. Hence, it is only applicable to pixels which are proven as fog contaminated during part one (fog detection) of the monitoring scheme. The proposed approach is as follows (Fig. 3, right): **(1)** Raw counts are calibrated and radiometric corrected. Atmospheric correction is performed by assimilating atmospheric profiles from the NWP scheme ARPS which is operated on the basis of soundings and SYNOP / TEMP data. **(2)** The resulting fog top reflectance is then converted into spectral fog albedo by eliminating the albedo of the underlying surface accounting for the spectral albedo under cloud free conditions which is retrieved for every month from MSG. Cloud albedo is directly related to optical depth, liquid water path and r_e by means of the parameterization approach which is described in BENDIX (1995[1]). Fog properties has to be carefully validated against *in-situ* observations and possibly, the retrieval method has to be tuned. The transfer scheme will be operated with realistic fog droplet size and liquid water conditions provided by co-investigators 1 and 2 in order to related spectral fog albedo to these quantities more accurate and hence, to adjust parameterisation assumptions to foggy conditions (HU & STAMNES 1993).

2.3 Fog geometry (top and base height)

The extraction of fog top heights from the fog image has to be operated by means of supplementary data (Fig. 4a, left). Fog top height is generally calculated by superimposing the MSG-based binary fog mask onto a Digital Elevation Model (DEM) (BACHMANN & BENDIX 1993). A fog rim image has been calculated from the binary fog mask which is superimposed onto the DEM and the rim elevations are extracted and interpolated for the whole fog covered area. Validation of the calculated fog top heights has to be performed using SODAR measurements and soundings at several observation sites as well as field mapping of fog boundaries. More problematic is the determination of fog base height (BENDIX 1995[2]). An appropriate algorithm does not exist until today because satellite radiances as MSG-SEVIRI are not directly suitable for columnar retrievals. If a fog layer represents uplifted or ground fog depends not only on condensation level but also on wind speed near the ground. It is obvious that the entire meteorological situation has to be evaluated to estimate fog base height. Extensive statistical investigations in order to find a proper relation especially between fog base height and satellite-retrieved properties will be performed by on of the co-investigators. The following approach which is based on the statistical function and the assimilation of NWP data is proposed (Fig. 4 b, left). **(1)** Routine meteorological data of wind speed, air temperature and humidity are calculated by means of the assimilated NWP model for every fog covered pixel. **(2)** These values, satellite retrievals from part 2 (LWP, optical depth) and part 3 (maximum fog thickness) are used to calculate fog base height for every fog covered pixel by applying the statistical relation. Even if no estimate of the accuracy can be given in advance, at least it is expected to get a reliable measure for the probability of ground fog.

2.4 Nowcasting of fog clearance

The approach for the nowcasting of the time of fog clearance with MSG is based on the numerical model of PETKOVŠEK which has already been successfully applied to selected spring/autumn fog situations on the basis of NOAA-AVHRR data (REUDENBACH & BENDIX 1998) but has proven to need further improvement. Intended improvements profits from the assimilation of NWP results and

Application of Fourier and wavelets series to model land surface evaporation

Massimo MENENTI[1], Gerbert ROERINK[2], Wout VERHOEF[3],
Zhao Liang LI[1] and Bart v.d. Hurk[4]
1 = Universite Louis Pasteur, Illkirch, France
2 = ALTERRA, Wageningen University and Research, The Netherlands
3 = National Aerospace Laboratory (NLR), The Netherlands
4 = Royal Netherlands Meteorological Institute (KNMI), The Netherlands

ABSTRACT The investigation aims at exploiting the unique temporal frequency provided by MSG to develop improved algorithms for the study of land surface processes. The approach proposed comprises four steps:

a) determine dominant frequencies in time series of SEVIRI observations using a Fast Fourier Transform image – oriented algorithm;
b) determine a model of the time series using a harmonic analysis image – oriented algorithm (HANTS) and separate cloud and land observations;
c) use the land multi- spectral observations to determine land surface albedo and temperature;
d) use land surface albedo and temperature to estimate land evaporation using two different methods: the Surface Energy Balance Index (SEBI) and the heating rate method;

The two methods to estimate land evaporation require information about the Atmospheric Boundary Layer (ABL). This will be extracted from data sets generated with four Dimensional Data Assimilation systems (4DDA).

INTRODUCTION

Land evaporation is a biophysical variable relevant to several application of MSG data: food security, large area hydrology and vegetation monitoring. Soil moisture initialization has a significant impact on the performance of NWP models. Estimations of land evaporation provide a measure of water availability and have been used as a proxy for soil moisture in this context. MSG will provide two basic observables for heat-balance based estimations of land evaporation: surface temperature and albedo. Clouds is major bottle-neck in methods aiming at estimating land evaporation with space-based observations in the optical region. The very high temporal sampling rate of MSG, however, provides an excellent opportunity to overcome this difficulty.

The approach proposed comprises the following steps:

1. Cloud screening of SEVIRI observations at full temporal resolution using a combination of algorithms for time series analysis of satellite data.
2. Atmospheric correction using a split-window algorithm, observations in the IR3.8 channel for temperature-emissivity separation and a simple two-streams RT model in combination with observations of visibility for reflectance measurements.
3. Modeling of diurnal evolution of surface temperature using the irregularly spaced land-observations selected after step 1 and the results of the time series analysis.
4. Use of 4DDA data sets to characterize the Atmospheric Boundary Layer (ABL).
5. Estimation of land evaporation using two methods which combine ABL variables with land surface temperature and albedo.
6. Comparison of the two methods against each other and measurements of latent heat flux at e.g. the LITFASS site or other experiments.
7. Use of the selected algorithm to produce fields of estimated land evaporation for a large area (Europe and/ or part of Africa).
8. Case study on NWP initialization using these results.

and 2 is only used when the exponent of 2 is odd, in which case still one step with radix 2 is necessary. Actually in the implemented version the number $N/2$ is factored, because real data of length N can be transformed with a complex FFT of length $N/2$.

The output of the NLR version of the FFT algorithm consists of $N/2+1$ amplitudes (including the zero frequency) and $N/2-1$ phases (the zero and the maximum frequency have zero phase).

Harmonic Analysis and screening of image data

The Harmonic ANalysis of Time Series (HANTS) algorithm considers only the most significant frequencies expected to be present in the time profiles (determined, for instance, from a preceding FFT analysis), and applies a least squares curve fitting procedure based on harmonic components (sines and cosines) (Verhoef, 1996). For each frequency the amplitude and phase of the cosine function is determined during an iterative procedure. Input data points that have a large positive or negative deviation from the current curve are removed by assigning a weight of zero to them. After recalculation of the coefficients on the basis of the remaining points, the procedure is repeated until the maximum error is acceptable or the number of remaining points has become too small.

The HANTS algorithm offers greater flexibility in the choice of frequencies and the length of the time series than the FFT algorithm. Also it is relatively easy to exclude certain images from the time series, since the samples are not required to be equidistant in time. The price paid is a processing time of roughly ten times that of the FFT, but this is still acceptable (approx. ten hours for a series of 36 images of 1536 x 2800 pixels on a work station, if two frequencies are selected). However, thanks to the removal of obvious errors, the computed amplitudes and phases at the selected frequencies are much more reliable than with the direct FFT algorithm.

Fig. 1 shows an example of how the HANTS procedure works. Fig. 1a shows the original and HANTS reconstructed NDVI time series for a point in Northern France (arable farming). Iteration stopped when 14 out of the 36 original NDVI values were rejected, i.e. classified as cloud affected data points. The remaining 22 values have a maximum negative deviation from the curve smaller than the FET (=0.05 NDVI units). Fig. 1b shows the Fourier components of the 3 different frequencies from which the cloud free profile is reconstructed.

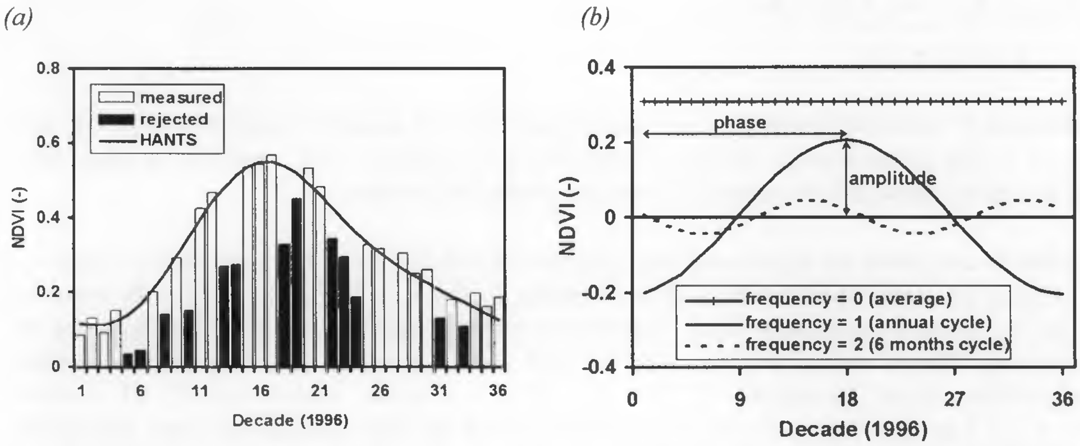

***Fig. 1** Example of HANTS: Original cloud affected and reconstructed cloudfree NDVI time series (a) and the different Fourier components from which the cloudfree profile is reconstructed (b). The arrows represent these values for the annual component (frequency = 1).*

The HANTS algorithm has been applied in two case studies with time series of METEOSAT images. The first one tests its ability to detect, characterize, remove and replace cloud-affected pixels in long time series of METEOSAT VIS and IR channels. The second case study is an attempt to correlate phase velocity (derived from METEOSAT WV channel) to the wind speed (derived from weather prediction model) energy between H and E (LE in ***Figure*** 3 can be determined by the length of the arrows (***Figure*** 4). The magnitude of the individual fluxes can then be easily calculated because the added length of the two arrows equals (Q^*-G_0).

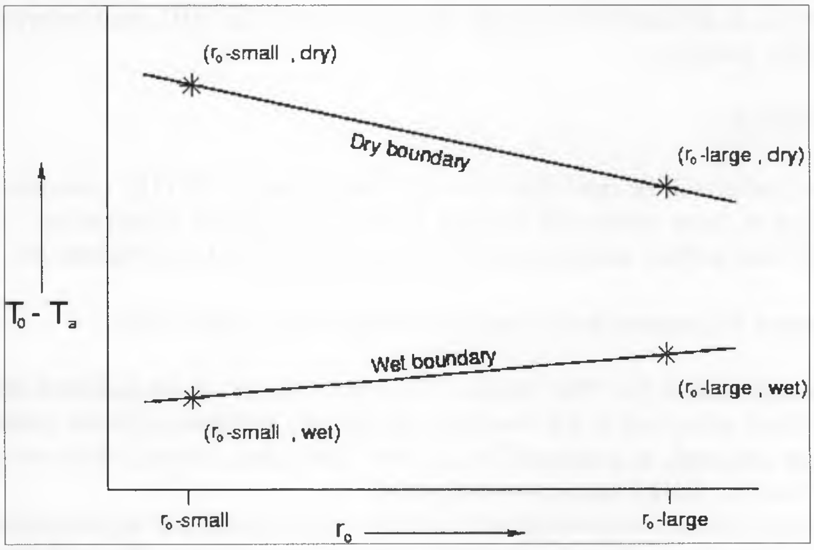

Figure *3Principle behind the SEBI algorithm: The Penman-Monteith equation is used to calculate wet and dry boundaries in the r_0–(T_0-T_a) diagram.*

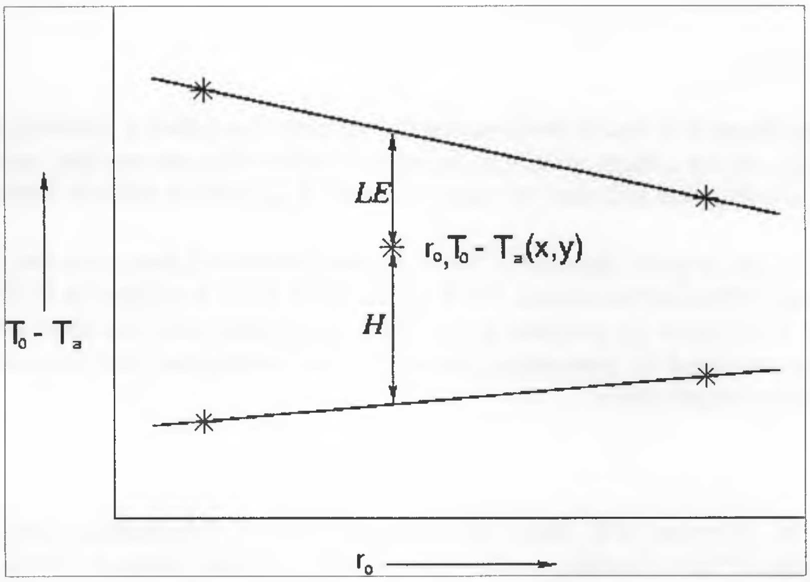

Figure *4Every pixel in the satellite image can be positioned in the r_0–(T_0-T_a) diagram. The relative magnitude of the sensible and latent heat flux can be determined from the relative length of the arrows.*

The Heating Rate Method

The Two – Source Time Integrated Model (TSTIM) proposed by Anderson et al. (1997) combines two different and independent estimates of the latent and sensible heat flux densities:

a) use of a dual – source parametrization of heat transfer at the land – atmosphere interface in combination with observations of land surface and albedo at one time of the day and
b) use of ABL profiles to compute the heat balance of the ABL;

Development and Validation of New Surface Temperature Retrievals, Cloud Classification Algorithms and an Evaluation of the Diurnal Cycle
(An Extended Project Abstract)

J. J. Simpson,
Scripps Institution of Oceanography
University of California, San Diego
9500 Gilman Drive, MS-0237
La Jolla, CA 92093
(858) 534-2789
jsimpson@ucsd.edu

A. R. Harris
United Kingdom Meteorological Office

C. J. Merchant
University of Edinburgh

M. J. Murray
Rutherford Appleton Laboratory

M. R. Allen
Oxford University

Abstract

The objective of this project is to develop new geophysical products for the scientific exploitation of MSG data. This will be achieved by adopting a multi-step approach, starting with sensor characterization, calibration and noise removal. Next, new methods for scene classification (particularly cloud/surface discrimination) will be developed in accordance with the requirements of the geophysical product. Thirdly, new retrieval methods for surface temperature and other geophysical products will be developed and validated. Finally, the new products will be combined with modeling and ancillary data to examine the nature of the diurnal cycle of cloud cover and surface temperature in relation to the radiation budget. Results of each step of the study will be reported to EUMETSAT/ESA via the PI workshops, interim and final reports and the referenced literature.

I. INTRODUCTION

Diurnal variability in the temperature structure and heat content of the upper ocean occurs over all seasons and has large dynamic range (see table of reported observations in Dickey and Simpson (1983)). In the ocean, maximum isothermal penetration lags maximum surface heating. The corresponding thermal response is such that the heating occurs at a greater rate than cooling, which results in an asymmetric diurnal temperature wave (Shonting, 1964). The diurnal variability over land is generally even more complex, a function of landform, surface cover type (and hence emissivity), and other factors. This diurnal variability also directly effects variability in the exchange of heat and moisture between the air-sea and air-land interfaces.

Diurnal studies of both sea surface and land surface temperature based on new products derived from MSG-SEVIRI data, other satellite data sets, *in situ* observations and model simulations will be conducted. Research in new scene classification and geophysical parameter retrieval algorithms will also be conducted. Attention will be paid to careful calibration/validation of products derived from the new algorithms. The combination of high temporal resolution provided by the geostationary platform and improved quality products (*e.g.*, sea surface temperature (SST), land surface temperature (LST), cloud cover) provided by the new instruments and retrieval algorithms should yield new information on the high frequency variability and dynamical responses in the air-sea and air-land systems.

II. OVERALL PROJECT OBJECTIVE

This project focuses on the design, implementation and validation of new algorithms for the robust retrieval of marine, atmospheric and terrestrial products from data taken by advanced geostationary instruments (MSG-SEVIRI), augmented with other remotely-sensed data (*e.g.*, ATSR family of sensors, GERB). Diurnal variability studies in selected regions will be performed using a combination of derived satellite products, *in situ* observations and modeled results. These studies are designed to take maximum data (LeMarshall *et al.*, 1999). Moreover, it is important to exercise as much of the dynamic range of a sensor as possible. Therefore, cross-calibration with sensors such as AATSR on Envisat (and ATSR-2 on ERS-2, if still operational) would be of particular benefit, because those instruments are calibrated to an extremely high standard.

If one accepts the validity of the other data source (*e.g.,* AATSR brightness temperatures), then it is simple to demonstrate the degree of concurrence by a variety of metrics. However, any change in, for example, calibration coefficients, should also be attributed to a physical mechanism. If this is done, then recalibration may be extended with confidence in time, space and dynamic range. Otherwise, the applicability of the calibration may be limited in all these aspects, requiring much more frequent calculation. A secondary measure of success will be in the comparison of equivalent geophysical products formed from multiple sensor coincidences. This does not have the restriction of requiring correction for differing pathlengths as these are already accounted for in the retrieval process. For example, the SST retrieved from AATSR should be very accurate and will therefore provide a reference for the SST retrieved from SEVIRI data. Although this approach has the retrieval process (atmospheric model, etc.) included, if the same model is used for both sensors then the effect of this can be minimized. The stability of SST, particularly at night, should mean that SST retrievals for the entire AATSR pass can be used. Specific relevant publications by investigating team members on the topic of calibration and sensor noise removal include LeMarshall *et al.* (1999), Simpson *et al.* (1998a), Frouin and Simpson (1995) and Simpson and Yhann (1994).

The identification of clouds is part of the retrieval process and the investigating team has considerable expertise in the development and application of cloud detection in satellite data. The geophysical product being retrieved governs the characteristics required of the cloud detection. Team members have been developing highly adaptive image segmentation procedures (*e.g.,* Simpson *et al.*, 2000a, Simpson *et al.* 1998b, Simpson and Gobat, 1995a,b, Yhann and Simpson, 1995) which are now both fast and accurate. Cloud identification over land is an extremely difficult task which has now been tackled with considerable success using both GMS and GOES data over continental land masses. Complications include the diurnal evolution of both underlying temperature and cloud height/type, leading to significant problems with traditional threshold-based schemes. The latest approach comprises a hybrid segmentation / neural network based classification scheme. Tasks will include optimization of the input vector components and adjustment of the neural network specification to handle the output, depending on the nature of the end product.

Validation of the results of cloud classification is notoriously difficult due to the lack of independent data. Recently, however, Simpson *et al.* (2000c) present independent LIDAR observations to validate one of their new approaches to cloud detection; agreement level is at 95%. This degree of objective agreement is encouraging, especially given the navigation uncertainties and the time differentials between the satellite data and the LIDAR observations. A proxy measure, however, is appropriate for certain applications. As an example, if the geophysical product is SST, then the success of the cloud identification may be gauged by the accuracy of the product when compared with *in situ* data (*e.g.*, drifting buoys). In this case, success criteria would include metrics such as regional distribution and quantity of successful retrievals as well as their accuracy.

Surface temperature (ST) retrievals will use detailed forward modelling of surface properties, atmospheric transmission and instrument characteristics to define a retrieval scheme capable of coping with conditions of atmospheric water vapor and aerosol loading likely to be encountered. This strategy has been applied with considerable success to SST retrieval from ATSR (Merchant *et al.*, 1999)

SEVIRI channels at 10.8, 12.0 and (at night) 3.9 μm are those which are most obviously relevant to ST retrieval, but, in addition, use of channels at 8.7, 6.2, 7.3 and 13.4 μm may allow better correction for atmospheric effects. The 8.7 μm channel will help make retrievals more robust to aerosol contamination. The water vapour channels will allow for correction of water vapour related non-linearities which degrade the performance of AVHRR-like 'split window' retrievals in wet atmospheres; the CO_2 channel at 13.4 μm may also contribute, although its radiometric accuracy may be inadequate.

MSG RAO proposal ID 144. Solar flux derivation using MSG-SEVIRI measurements

A.Rublev[1], A.Uspensky[2], A.Trotsenko[1], N.Chubarova[3]

[1] Russian Research Centre KURCHATOV INSTITUTE
(Kurchatov sq., 1. Moscow 123182. Russia
Phone:7-095-196-7687 Fax:7-095-194-1994 rublev@imp.kiae.ru)
[2] Scientific Research Centre Planeta-Roshydromet
[3] Meteorological Observatory of Moscow State University

Summary
The proposed activity will be devoted to the development of methodology and a Software Package (SP) for computationally efficient evaluation of the solar radiation fluxes using SEVIRI measurements as input data. The capability to estimate the angular dependence of the solar outgoing radiances (both spectral and integral) will be also investigated.

The software will be based on regression-type relationships between the solar radiative fluxes (and/or radiances) and atmosphere bulk parameters (primarily, cloud and aerosol characteristics, water vapour and ozone content) that can be reliably extracted from the SEVIRI measurements. The above relationships will be derived using corresponding reference database that should be generated with an accurate radiative transfer model based upon the combination of the 3D Monte-Carlo and line-by-line methods. The SP implementation is expected to contribute in areas of cloud radiative forcing research, radiation budget studies, global climate change and NWP. It will also allow to perform the cross validation of SEVIRI data and GERB measurements.

It is assumed that the SP accuracy characteristics and a scope of possible applications will be determined through validation studies involving existing datasets of the ground-based measurements of the solar radiative transfer parameters (primarily direct and diffuse fluxes) and synchronised satellite observations available from SEVIRI/MSG, MVIRI/METEOSAT, AVHRR/NOAA, Imager/GOES.

Objectives
As a result of the project performance the following objectives will be attained:
- To derive solar fluxes and outgoing radiances dependencies on essential optical and meteorological parameters.
- To design an efficient computational procedure to evaluate the solar fluxes and outgoing radiances in SEVIRI spectral channels for different atmosphere states. The fast radiative transfer model developed at Kurchatov Institute in context of the IASI/METOP studies is assumed to be used for the IR spectral channels.
- To develop the relationships between the downward / upward solar fluxes and bulk atmospheric parameters that can be retrieved from SEVIRI measurements and to assess the statistical spread of the relationships resulted from the uncontrollability of certain atmosphere and the stochastic structure of broken clouds.
- To validate the developed relationships using existing ground-based downward flux measurements (including UV spectral range) and the synchronised satellite observations (AVHRR, GOES, MVIRI).
- To assess the confidence levels of spatial variability of the surface biologically active UV irradiance stipulated by a stochastic structure of the broken cloudiness.

It must be stressed, that the objectives listed above to a certain extent can be also reputed as relevant project subtasks.

Approach and Methods
The modern methods for operative assessment of the solar radiative fluxes using satellite images are typically based on the interpolations of the reference radiances and/or fluxes pre-calculated for a plane-parallel cloud layer model. The drawbacks of the above methods application to the broken-cloud conditions

content. The interpolation procedure also included angular dependent corrections for the aerosol type and ozone total content. The exercise was performed for 140 pre-selected observation session and demonstrated good agreement of the calculated and measured downward fluxes. The detailed description of the above results is accessible via Internet (see the first reference at section Bibliography at http://www.imp.kiae.ru/crdf/).

The first experience in application of the above approach for evaluation of solar downward fluxes in cloudy conditions (using the AVHRR based cloud parameter retrievals as input data) has shown a need to develop special service software to flexibly manage the reference data in multi-dimensional parameter space of the cloudy atmosphere. For this purpose correspondent database and service software have been developed. This software hereafter referred to as UMMS (Universal Measurements Modelling Software) enables to efficiently evaluate the vertical profiles of solar (both upward and downward) fluxes and outgoing radiances in conditions of single-layer (both uniform and broken) cloudiness and thus can be reputed as prototype one to that proposed for development.

The UMMS database covers 111 spectral intervals within 2-5 μm range; 7 reference values of cloud amounts (from 0. to 1); 7 values of cloud extinction coefficient (from 0 to 80 km-1); 5 gradations of solar zenith angle cosine (0.25-0.85), 5 reference levels of surface spectral albedo (0.-0.8) within each of 111 spectral bands. The reference data has been computed for the standard mid-latitude summer temperature, humidity and trace gas profiles and aerosol model (including continental and 75% H_2SO_4 model for 0-12 and 12-20 km layers, respectively, with cloud aerosol optical thickness at 0.55 μm equal to 0.226). Cloud bottom height is fixed at 1 km. The reference data on outgoing radiances includes 56 zenith viewing angle gradations correspondent to those adopted in ERBE angular radiation models and one zero azimuth angle (correspondent to the opposite-to-Sun direction) (for more details see J.Suttles et al., NASA RP-1184, 1988). The system enables to evaluate the solar fluxes for user specified spectral band (or channel) at 37 atmosphere levels from 0 to 100 km, as well as respecting outgoing radiances at selected viewing angle. For the spectrally integral (0.2-5 μm) solar fluxes and outgoing radiances the numerical errors of the interpolation procedure (respecting the direct calculation) have magnitudes less than 0.5 % and 5 % respectively. For the narrower spectral bands the accuracy is evidently lower.

The on-line versions of the above systems are accessible via Internet (http://www-litms.imp.kiae.ru, online tools) both for cloudless atmosphere and under clouds conditions.

The UMMS system has been validated using the surface downward flux measurements in 0.2-5 μm and 0.30-0.38 μm spectral bands performed during several dozens of observation sessions at MO MSU coupled with synchronised AVHRR measurements. The intercomparison results have shown the applicability of the synergetic use of the UMMS and AVHRR-based cloud parameter retrievals for estimating the area-averaged downward fluxes within the above spectral bands. Furthermore the described approach has been also applied in context of the UV downward radiation level estimates. Relevant methodological details and the results of the method validation against synchronised ground-based measurements (14 summer time days) are presented at http://www.imp.kiae.ru/crdf/ (see reference # 4 in Section Bibliography). The intercomparison gives less than 20 % r.m.s. disagreement between the calculated and observed values. We believe that the obtained discrepancy evidently represents the top estimate of the methodological error. It can be shown that the primarily source of the above disagreement was the uncontrollable spatial discontinuity of the cloud field but not the inherent accuracy of the exploited models and algorithms. For reasons given, in order to provide more careful validation of the proposed approach (i.e. to consider diverse geographical regions, seasons, multi-layer cloudiness, etc.) it is assumed to involve already existent data of synchronised satellite and ground-based measurements available from at least 3 independent datasets: MO MSU + AVHRR/NOAA; Atmospheric Radiation Measurements Enhanced Shortwave Experiments
(CAGEX database)+Imager/GOES; SUVDAMA project UV measurements + MVIRI/METEOSAT.

After the end of the MSG satellite commissioning phase, authors are also going to use the data of ground-based measurements, that will be provided on some stations of Baseline Surface Radiation Network. They

Energy-Specific Solar Radiation Data from MSG: The HELIOSAT-3 Project

Marion Schroedter, Detlev Heinemann[1], Hermann Mannstein[2], Lucien Wald[3]

Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR)
Deutsches Fernerkundungsdatenzentrum (DFD)
Oberpfaffenhofen, D-82234 Weßling, Germany
phone: ++49-8153-28-2896, fax ++49-8153-28-1445
e-mail: Marion.Schroedter@dlr.de
www: http://www.dfd.dlr.de

[1] Universität Oldenburg, Abteilung Energie- und Halbleiterforschung
[2] DLR, Institut für Physik der Atmosphäre [3] Armines / Ecole des Mines de Paris

Abstract

Solar energy technologies such as photovoltaics, solar thermal power plants, passive solar heating/cooling systems and daylighting in buildings are expected to continue their very rapid growth. In this context the availability of reliable solar radiation data is of high economic value both for planning and operating these systems.

HELIOSAT-3 aims the quantification of surface solar irradiance in cloudfree and cloudy situations and additional energy-specific parameters as direct normal irradiance, angular distribution of diffuse irradiance, illuminance, photosynthetically active radiation (PAR), and solar cell response over Europe and Africa using the enhanced capabilities of MSG. Emphasis will be on clouds, water vapor, aerosols and ozone and their influence on surface solar irradiance. All methods will be developed with respect to an operational use and in close connection with potential users.

Introduction

Solar energy technologies play a major role in most scenarios for a sustainable global development. Their high potential to contribute to a reliable and durable global energy supply is widely known and confirmed by the current strong increase in the utilisation of e. g. photovoltaics, solar thermal systems for heating and cooling, and daylighting applications in buildings. This is supported by the current EU policy which aims to double the contribution of all renewable energies during the period 1995-2010. Following the EU White Paper "Energy for the Future: Renewable Sources of Energy", the expected increases during this period are by a factor 16 (solar thermal) to 100 (photovoltaics).

To achieve these goals and to accelerate the market penetration of solar energy, improvements in both technological domains (e.g. to increase efficiency, to achieve mass production) and in the operation of solar energy systems are necessary. Detailed knowledge of the fluctuating energy source "solar radiation" is an issue of strategic importance for optimum system performances. Main limitations regarding the availability of high-quality solar radiation data have been identified:

- Uncertainty of regional solar energy potential estimates is too high if based on interpolated ground measurements. This holds especially for non-industrialised regions.
- Spatial and temporal resolution of available data sets is too low for reliable estimation of system performance at a given site.
- Solar energy specific information (direct normal irradiance, angular distribution of diffuse irradiance, spectrally filtered data, spatial structure) is commonly not available at all.

This lack of information frequently results in an incorrect system sizing, non-optimum site selection, unreliable system performance, or unnecessary use of conventional energy sources.

During the last decade attempts have been made to include satellites in the derivation of solar surface irradiance data. (Cano et al., 1986; Beyer et al.,1996) These methods are based on the strong

- Solar-thermal power plants: Hourly data of direct normal irradiance and information on the temporal variability of irradiance will be exemplarily used for planning and operation of thermal concentrating devices.
- Exploitation of daylight in buildings: Global illuminance data and its angular distribution is needed to achieve an optimized use of daylight. Therefore, data filtered with the CIE photopic vision response curve and the directionality of diffuse radiation will be supplied and used in demonstation examples.

Retrieval of Atmospheric Parameters

Extensive experience in the retrieval of clouds, water vapour, aerosols and ozone will be brought into the project by the German Remote Sensing Data Center (DFD) and the Institute of Atmospheric Physics (IPA) of the German Aerospace Center (DLR).

Split window channels in the VIS and IR have successfully been used for cloud detection in NOAA/AVHRR (Gesell, 1989; Kriebel et al., 1989) and ERS-2/ATSR. This method will be adapted to MSG. The high repetition rate of MSG allows the successive development of surface properties maps, like the thermal diurnal cycle and bi-directional reflectance and therefore, allows a better detection of clouds. Cloud optical depth, liquid and ice water path, cloud top temperature, emissivity and effective cloud droplet radius will be retrieved.

Split window algorithms for the water vapor content use the difference of brightness temperatures in two channels as a measure for the differential absorption of water vapor. Conventionally, knowledge about the temperature profile is indispensable but often not available. A more promising approach is given through the transmission ratio method (Kleespies & McMillin, 1990): Two pixels are used to eliminate the air temperature dependence. The pixel pair can be obtained as one pixel measured at two times. Due to the temporal resolution of MSG the diurnal cycle can be monitored and it provides the necessary difference in the surface temperature between both pixels. DFD generates TOVS and ATOVS water vapour column measurements operationally and will compare these with the MSG results. Secondly, MSG and ENVISAT-SCIAMACHY retrieved water vapor will be compared.

The Global Aerosol Data Set climatology (GADS, Koepke et al., 1997) based on ground measurements will be used to create an aerosol parametrisation scheme for the surface solar irradiance algorithms. DFD has developed the satellite retrieval scheme SYNAER (Synergetic Aerosol Retrieval, Holzer-Popp et al., 2000) for aerosol optical depth and aerosol type over land and ocean. SYNAER will be adapted to MSG and tested in the solar irradiance algorithms.

Ozone columns are retrieved operationally at DFD from ERS-2/GOME (Loyola et al., 1998) and in future from ENVISAT-SCIAMACHY. Using a Kalman filter approach, global maps of ozone columns can be determined for the exact time of MSG images (Bittner et al., 1997) and used in the retrieval of surface solar irradiance.

Retrieval of Surface Solar Irradiance and Energy-Specific Parameters

The semi-empirical HELIOSAT method (Cano et al., 1986; Beyer et al., 1996), which is currently operated at Ecole des Mines (EdM) and the University of Oldenburg (Department of Energy and Semiconductor Research, EHF), will serve as the basis for the development of a MSG scheme HELIOSAT-3. It will be enhanced by the calculation of atmospheric parameters influencing solar irradiance, as described above. Calculating shortwave radiative transfer will be the major task, and a discrete ordinate algorithm will be used to derive look-up-tables for predefined sets of atmospheric and geometric conditions. Direct and diffuse surface irradiance components will be separated. Knowledge of direct irradiance is essential for, e.g., the operation of solar thermal power plants. To serve the needs of daylighting applications, directional properties of solar irradiance and their parameterization will be delivered.

MSG allows deriving spectrally selective data: illuminance (daylight), photovoltaic cell response, and photosynthetically active radiation (PAR). The filter-like responses will be calculated with radiative transfer models. A parameterization of the atmospheric influences will be performed for each.

Spatial variability of irradiance is an important issue for an efficient integration of solar energy into electricity grids and will be described by the structure of the surface radiation field on different scales.

Mapping surface UV irradiance and actinic flux over Europe

Jean Verdebout
European Commission - Joint Research Centre - Space Applications Institute
21020 Ispra (VA) Italy
Tel: + 39 0332 785034, Fax: + 39 0332 785461, email: jean.verdebout@jrc.it

Objectives

The project objectives are:

- to insure the continuity and consistency of surface UV irradiance maps previously developed using METEOSAT/ERS-2 data to MSG/ENVISAT based products
- to improve the surface UV irradiance maps by taking advantage of the new capabilities of the SEVIRI and SCIAMACHY instruments
- to prototype and test satellite derived information on the actinic flux, as input to the photochemical module of an ozone pollution model

The surface UV irradiance maps were developed to serve a number of applications: impact studies of UV radiation on human health and the environment and in general documentation of the changes in the surface UV intensity over Europe during the last two decades. Presently, the maps are generated using METEOSAT data (to estimate the cloud optical thickness), GOME total column ozone (or TOMS for pre-GOME years), ground measurements and model outputs (e.g. visibility observations, snow cover). The maps quality has been assessed against ground measurements and the results are encouraging. Most potential users of these maps have expressed the need for documenting the long-term changes in the surface UV radiation. To meet this requirement it is crucial to insure the continuity and consistency of the maps as the data sources change (i.e. changing from GOME to SCIAMACHY, from METEOSAT to MSG); hence the first objective. The quality assessment work has also pinpointed a number of situations where the map quality should be improved. These are linked to the presence of snow on the ground (making the cloud identification difficult) and to geometrical conditions (wintertime, high latitudes) where the low METEOSAT signal impacts the reliability of the result. In this respect, the additional spectral bands and the higher dynamic of SEVIRI offer the opportunity to improve the results. The potential of MSG to better discriminate ice and water clouds and to more accurately estimate the cloud top height are also features that can a priori be exploited to refine the cloud description. Exploring and implementing these potential improvements constitute the second objective of the proposal. A proposal to the ESA ENVISAT-AO has also been selected which aims at improving the map quality by exploiting GOME and SCIAMACHY spectral information.

The third objective is related to a new institutional activity of the Space Applications Institute (SAI), which aims at developing space derived information to help in the preparation, implementation and monitoring of the European legislation in the field of Air Quality. It will be conducted in close collaboration with the Environment Institute (EI) of the Joint Research Centre, already supporting the regulatory actions of DGXI by means of ground measurements and modelling exercises. The SAI project includes the prototyping and testing of space derived information on the actinic flux as input to the photochemical module of a pollution model routinely used by EI. The actinic flux is used in combination with the molecular concentrations and cross sections to estimate the kinetics of the photochemical processes leading to the build up of ozone pollution. Technically, the estimation of the actinic flux is very similar to that of irradiance but the application has specific requirements: the data sets. However, the operation of the old and new instruments may not overlap in time. In this case, the consistency check will need to be based on cases with similar surface and atmospheric conditions and comparison with ground measurements. The success criterion is the consistency between the MVIRI/GOME and SEVIRI/SCIAMACHY maps.

With regard to the improvement of the UV irradiance map, the first priority will be to implement a better discrimination of snow and clouds. In a first approach, this can be done by using the 1.6 µm SEVIRI band signal to resolve the snow/cloud ambiguity when generating the effective surface albedo baseline map. This is presently done with the thermal infrared METEOSAT band; the higher contrast at 1.6 µm should improve the reliability of the result. The use of MSG total column ozone will also be investigated. With its enhanced multi-spectral capability SEVIRI also offers the opportunity to refine the description of the atmosphere, in particular of the clouds characteristics. So far, the only cloud UV LUT entry is the "cloud water thickness"; all other characteristics (type, droplet radius, height) are fixed. SEVIRI allows a better estimation of the cloud type and height; these two parameters could be made additional entries of the UV LUT. This can a priori be implemented by directly using level 2 SEVIRI products or by including the retrieval of these additional characteristics from the level 1.5 data in the overall UV map processor. The first approach is simpler and is a priori preferred but its feasibility depends on the detailed characteristics of the level 2 products and on their availability. The second approach would imply to perform radiative transfer calculations in the various SEVIRI spectral bands, first to assess the sensitivity of the signals with respect to the atmospheric and surface parameters and then to build a SEVIRI multi-spectral LUT for the retrieval itself (inversion procedure). The possibility of retrieving aerosol characteristics can also be investigated. However, the retrieval of cloud and aerosol characteristics is not the main object of this proposal and it is hoped that the UV mapping algorithm will benefit from the research conducted by other projects more focused on these topics. In parallel, it is also intended to investigate the possibility of refining the aerosol description by using SCIAMACHY spectral data and or the MERIS aerosol product. This part of the work has been included in a proposal to the ESA ENVISAT AO and is not further described here. The success criterion is the improvement of the accuracy of the satellite derived surface UV irradiance.

The work related to the third objective is already planned as part of the institutional workprogramme of JRC-SAI. The methodology for generating the actinic flux is very similar to that for the surface irradiance. The main difference resides in the UV LUT, which will then content the vertical resolved spectral actinic flux computed with the UVspec code. The selection of the entry parameters will also be slightly different; in particular it will include a series of tropospheric aerosol vertical profiles. For this application, the GOME/SCIAMACHY total column ozone data will be substituted by the MSG ozone product, if this latter one has a higher temporal sampling frequency. The actinic flux information must indeed be provided with at rapid intervals as the ozone pollution builds up in the afternoon. The generated information will be tested as input to a photochemical ozone pollution model. This model presently uses ground measurements of the radiation. The usefulness of the satellite-derived information will be tested by comparison and by running the model for well-documented test cases. The success criteria are the quality of the model results.

Surface, Clouds, and Aerosol Retrievals (Project #130)

Bernard Pinty and Michel M. Verstraete

Space Applications Institute,

EC Joint Research Centre, TP 440,

I–21020 Ispra (VA), Italy

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1 Introduction

The main purpose of this surface albedo project is to design, implement and evaluate an operational algorithm to document the radiative properties of terrestrial surfaces on the basis of the Meteosat Second Generation (MSG) data. This particular project is an outgrowth of an existing project with similar objectives but exploiting the older Meteosat data archive. Because of the state of development of this latter project, and the similarity with the previous one, this document will outline how the current algorithm works. The specific algorithmic modifications that are expected to enhance this approach for MSG will be briefly covered at the end of this contribution.

The objectives of the project are (1) to derive reliable and accurate distributions of land surface albedo over Europe and Africa, (2) to study the properties and dynamics of land surfaces by characterizing their brightness and anisotropy, and (3) to simultaneously estimate the aerosol optical depth over land at the same scale and resolution as the above surface products. A by-product of this algorithm will also be a high performance cloud mask based on the specific spectral and directional properties of clouds.

Additionally, this algorithm must meet a few design constraints including (1) the generation of land surface albedo and Bidirectional Reflectance Factor values at the full Meteosat resolution, and (2) the production of codes which can be easily inserted into the existing EUMETSAT processing system.

Land surface albedo $A(z_0, \Omega_0)$ (also known as the surface directional hemispherical reflectance (DHR) is defined as follows:

$$A(z_0, \Omega_0) = \frac{E^{\uparrow}(z_0, \Omega_0)}{E^{\downarrow}(z_0, \Omega_0)}$$

where z_0 stands for the surface level, Ω_0) represents the direction of incoming (solar) radiation, $E^{\uparrow}(z_0, \Omega_0)$ stands for the outgoing radiation flux and $E^{\downarrow}(z_0, \Omega_0)$ is the incoming irradiance.

to allow a significant fraction of all computations to be made in advance, but the decrease in floating point calculations is traded-off against increased memory requirements of the LUT.

The discretization of the LUT with respect to independent and dependent variables is of course crucial, because simulating conditions that never occur imposes useless computing before hand and unnecessary searches during inversion, and too high a discretization may lead to the frequent identification of multiple solutions. In addition, the level of discretization may be expanded or reduced to provide better accuracy where needed or to avoid equivalent solutions. This being said, more realistic or complex algorithms (in particular coupled models) may be used to generate the LUT than with more traditional approaches.

Last but not least, the failure to match a set of measurements, at a predefined level of accuracy, with any entry in the LUT may indicate that the observed system does not correspond to any of the ones assumed during the creation of the LUT, and may serve to discriminate undesirable situations (e.g., clouds). Alternatively, additional geophysical situations can be included in the LUT.

In practice, the selection of the solution consists in selecting, amongst an identified set of possible solutions, the surface and atmospheric conditions that best account for the angular variability in the observations. This can be achieved through a modular program design, which has been implemented as four different modules with the following functionalities:

- Data Screening Module (DSM): Get and calibrate MFG data, screen clouds
- Atmospheric Scattering Module (ASM): Inversion of a coupled surface-atmosphere model against MFG data, accumulation of possible solutions
- Data Interpretation Module (DIM): Select the most probable solution, compute statistics, quality flags, report basic daily products (albedo, aerosol optical thickness @550 nm, surface anisotropy, flags)
- Space-time Averaging Module (SAM): Generate 10-day composites of surface and atmospheric products at full and reduced resolutions

3 Future plans

As explained before, this algorithm was initially developed to retrieve surface albedo from existing archive of Meteosat data. The purpose ofthis project is to extend this approach to the MSG instrument, specifically taking advantage of the improved spectral resolution in the red and near-infrared spectral domains and the higher temporal sampling of the instrument.

This algorithm will deliver the same geophysical products as the existing MFG project, *i.e.*, surface albedo and BRFs, effective aerosol optical thickness as well as detailed cloud and cloud shadow covers, with a *greater accuracy*, and at the *full spatial resolution* of MSG. This project thus ensures, in principle, product continuity over a long time period.

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The development and application of MSG SEVIRI satellite sea surface skin temperature (SSST) observations.

C J Donlon, C Merchant, W Eifler, D. Llewellyn-Jones, P. Minnett, I S Robinson, T J Nightingale and G Wick.

C J Donlon
CEC-JRC Space Applications Institute
Marine Environment Unit
Ispra, TP442
I-21023
Italy
(t): +39 0332 786353
(f): +39 0332 789648
(e): craig.donlon@jrc.it

Abstract

The primary objective of the proposed work is to develop and demonstrate new MSG SEVIRI Sea Surface Skin Temperature (SSST) data products that will constitute a high temporal resolution data framework for monitoring European ocean areas including the coastal zone. The need for high-resolution SST products that properly account for skin temperature effects has been identified by several groups including the Global Ocean Data Assimilation Experiment (GODAE) and numerical weather prediction agencies. In this context, the MSG SEVIRI radiometer provides a new generation of multi-spectral, geostationary infrared imaging capability that is particularly tuned to European area, capable of providing an unrivalled and comprehensive record of SSST for the entire European ocean region at high spatial resolution (~4km) with a temporal resolution of better than 3 hours. The main objective of this proposal is to develop a data framework in which (a) MSG SEVIRI SSST algorithms may be developed via radiative transfer modelling techniques and (b) pilot SSST data products and applications can be demonstrated. We propose to work in 4 main regions of interest:

1. The subtropical high pressure regions of the NW African upwelling region and Azores for clear sky and aerosol contamination studies. Dynamic SSST imagery including significant diurnal variability is characteristic of this region which is required for the development of temporal cloud detection techniques.
2. European coastal waters for investigation of coastal zone SSST dynamics.
3. The N Atlantic for the development/validation of problematic "extreme high latitude" SSST algorithms.
4. The tropical Atlantic Ocean for "diurnal surface-cloud-radiation interaction" studies to be matched with the PIRATA moored array in situ measurements.

Any region may require limited extension to benefit from specific in situ validation campaigns not dedicated to MSG SEVIRI validation studies. In addition to SSST data products, we propose a Daily Stratification Index (DSI) data product family incorporating (but not limited to) stratification anomaly maps, extent of stratification modulation (SM), correlation of SM with biological activity, onset time of SM, oceanic overturn time, digital video loops of SM patch dynamics, and afternoon cloud development-SM correlation maps. In situ validation data derived from new autonomous shipboard infrared radiometer systems deployed on ships of opportunity will be used to validate the MSG products complemented by existing in situ infrastructure (including radiometers and the PIRATA array). The proposed work will ensure the effective co- ordination, exploitation and synergistic integration of complementary data including satellite, in situ and, ocean-atmosphere models within the MSG project.

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Data assimilation for regional water balance studies in arid and semi-arid areas (Case study: the Volta basin upstream the Akosombo dam in Ghana)

Peter A. Troch
Wageningen University

Abstract

Accurate quantification of the water balance components is of vital importance for adequate water resources management in all parts of the world. In arid and semi-arid regions this need is even more pronounced due to the existing conflicts in water use and the anticipated shortage of water for further development of the region. In industrialized countries a dense network of in-situ hydro-meteorological observation stations provide the necessary data to evaluate these water balance components. In developing countries situated in arid and semi-arid regions of the world the installation of such dense networks is often hampered by economic reasons and the availability of specialized personnel to operate and maintain these networks. Basic research is therefore needed to overcome the needs for such in-situ observation networks. One obvious alternative is the development of estimation procedures based on remotely sensed information of the Earth's surface and lower atmosphere.

The objective of this research proposal is to improve the methods to estimate the regional water balance in arid and semi-arid regions of Africa by means of the synergetic use of remotely sensed land surface and lower atmosphere characteristics (Meteosat Second Generation SEVIRI Level 2 and SAR data), in-situ observations, distributed modeling of water and energy balances, and data assimilation procedures. The developed methodology will explicitely account for spatial organization of state variables (such as soil moisture) and surface fluxes (such as precipitation and evapotranspiration). The test site is the Volta basin in Ghana, upstream the Akosombo dam. The expected results are 1) improved water and energy balance models to compute catchment-scale fluxes and 2) innovative river basin management tools based on data assimilation.

The problem of accurately estimating components of the regional water and energy balance by means of remote sensing information has received a lot of attention recently. Bastiaanssen et al. (1998a, 1998b) have developed a surface energy balance algorithm for land based on remote sensing information. This algorithm allows to estimate the spatial variation of most essential hydro-meteorological parameters empirically and requires only limited field information. At the same time distributed water balance models for regional scale applications have been extended to include remote sensing information of the land surface (Troch et al., 1996, Troch et al., 1999). In order to solve important water resources management problems in arid and semi-arid regions it is important that regional water and energy balance models based on remote sensing information are developed. Given the uncertainty involved in both remote sensing information and regional water and energy balance models, it is crucial that data assimilation methods are applied to improve the accuracy of these management tools (Hoeben and Troch, 1999).

This proposed research will explore the possibilities of using Meteosat Second Generation (MSG) data, in synergy with data from other ESA Earth Observation satellites, to improve our capabilities to estimate the regional water balance in arid and semi-arid regions of Africa. The starting point of this research is the regional water balance equation, on one hand:

$$\Delta S = P - ET - Q$$

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Both the water and the energy balance models discussed above can rely on input data provided by the MSG satellite system. Instantaneous precipitation rates or precipitation indeces from VIS/TIR geostationary imagery are directly usable by the distributed water balance model. The parameterization of the SEBAL model will benefit highly from the multi-spectral observations available at 15-minute intervals and with changing illumination conditions (for instance to define the bi-directional reflectance).

In addition to the MSG derived surface parameters and driving forces of the water and energy balance, information from SAR sensors will be employed to further parameterize the distributed models, including soil moisture status, canopy characteristics and vegetation moisture status.

The forward link between the water balance model and the energy balance model is the estimated spatial soil moisture pattern. This pattern can be compared to soil moisture indeces derived from the Apparent Thermal Inertia (ATI). ATI can be estimated from frequent observations in the thermal infrared associated to changing solar radiation during the day, thus providing an immediate possibility to validate the water balance model. Spatial patterns in ATI can also be compared to soil moisture patterns derived from SAR sensors such as on board of the ERS-1/2 and Envisat satellites. Multi-temporal image analysis of SAR images allows for the determination of soil moisture patterns, as recently demonstrated by Troch et al. (1999).

Model derived and remotely sensed state variables and parameters of the water and energy balance need to be combined in a computationally efficient way. One such procedure makes use of data assimilation. In Earth sciences basically three different data assimilation strategies are applied:

a. Direct insertion
b. Nudging
c. Statistical interpolation

It is the main focus of the proposed research to investigate the efficiency of these data assimilation procedures to improve our estimation of the regional water balance.

The test site is the Volta basin in Ghana. The Akosombo dam on the Volta river in Ghana has created an artificial lake covering an area of approx. 8400 km^2. The dam provides hydropower (max. supply of 1063 MW), water for irrigation, and drinking water for Ghana, Burkina Faso, Togo, Benin, and Cote d'Ivoire

Proper management of the available water from the Akosombo dam is vital for the further development of the area. Water supply to the dam is changing due to evolution in land use, climate and upstream water use. The accurate estimation of current day water balance of the Volta river is therefore crucial to predict trends in water availability.

Ground truth data consist of several years of hydro-meteorological observations (Meteo Services Dept., Hydrological Services Dept., and Volta River Authority). The Water Research Institute has issued several reports covering water resources, maps and plans for water management. Also the Soil Research Institute and the Volta Basin Research Project (University of Ghana) have collected substantial land and water resources data concerning the basin.

Monitoring the hydrological cycle of Southern Africa for operational applications: Development of algorithms for improved estimation of surface and atmospheric water fluxes from Meteosat Second Generation satellite data

Martin Todd,
School of Geography, University of Oxford,
Mansfield Road, Oxford, OX1 3TB, UK
Tel +44 1865 271915, Fax+44 1865 271929,
martin.todd@geog.ox.ac.uk

(From 1/9/00 Department of Geography, University College London, 26 Bedford Way, London, UK.
m.todd@geog.ucl.ac.uk)

V. Djepa, Dept. of Applied Physics and Electronic & Mechanical Engineering, University of Dundee, UK
T. Dawson, Environmental Change Institute, University of Oxford, UK
D.I.Grimes, TAMSAT, Department of Meteorology, University of Reading, UK
D.R. Kniveton, Department of Geography, University of Leicester, UK
F. Lucio, Instituto Nacional de Meteorologia de Mozambique
A. Manague, National Water Division of Mozambique
M. Muchinda, Zambian Meteorological Department
W. Sakala, Zambezi River Authority, Zambia

1. Introduction

The climate of much of Southern Africa (SA) experiences high variability at frequencies from intra-seasonal (1,2) through inter-annual (3) to decadal and beyond (4). Rainfall is a vital resource in SA largely because of the dependence on rain-fed agriculture, but also because other operations e.g. electricity generation and tourism, are sensitive to rainfall variability. There are potentially great benefits therefore, to be gained from research leading to more effective ecosystem and water management.

Real time satellite data has long provided information for management practices, including agricultural planning, hydroelectric power management, flood forecasting, and drought and food security monitoring, e.g. FAO ARTEMIS and USAID/FEWS. There have been initiatives to develop hydrological models driven by Meteosat data, e.g. the USAID Nile Forecast System (5,6,7) and the Khartoum Flood Warning System (8). This project will build on this experience, but ultilising new information from MSG.

The utility of existing Meteosat data in these applications has always been limited by a lack of information on a number of key hydrological processes within the catchment, relating to the processes of water and energy exchange between land and atmosphere. Accurate estimation of precipitation is problematic if based solely on satellite optical data. Estimation of surface evapo-transpiration is hindered by a lack of information on surface temperature, humidity, wind speed, surface solar radiation, as well as on soil and vegetation. Hydrological models often incorporate climatological mean values for parameters that are known to be highly variable.

Evaporation from wetland areas is an important hydrological component but is poorly understood. Studies in Eastern Africa have shown the evapo-transporation estimates to be far lower than expected (9). In addition, real-time information on water and energy fluxes has operational applications in wetland management and conservation measures.

The project has 3 levels of objectives. The primary objective is to advance our ability to monitor and model the hydrological cycle in meso-scale catchments (greater than 1000km^2) using MSG data. Second, this will

1 will be split evenly for ANN calibration and validation (by comparison with daily rainfall estimates from the project rain gauge network and the WCRP GPCP project). In the event of a failure of the TRMM (or follow on) system, SSM/I data will be used.

2.2.2 Surface evapo-transpiration (Et)

(a) Modified Penman-Monteith approach
This technique is based upon a data component (land-cover class) of the International Satellite Land Surface Climatology Project (ISLSCP) (17), and the fraction of vegetation cover/LAI estimated by NDVI from the ATSR-2 (Along Track Scanning Radiometer) on board ESA's ERS-2 spacecraft. The model for estimating land surface temperature from the ATSR-2 will be adapted from a split-window equation (18) (spectral domain) where the land surface emissivity will be determined using the Vegetation Cover Method (VCM) (19).

(b) Two-source physical model for heat exchange method
In this method, cloud cover, surface albedo (α) and surface temperature (Ts) and emissivity (e) are retrieved from the visible (0.6μm and 0.8μm) and TIR (11μm and 12μm) channels of MSG SEVIRI, using MODTRAN code, in considering of information on atmospheric water vapour and ozone. The spectral characteristics and high temporal frequency of SEVIRI observations uniquely provide this information. Surface net radiation is then calculated using ECMWF radiative transfer code, incorporation these estimates of surface and atmospheric characteristics (20). By inverting the heat transfer equations over wet and dry surfaces (and linearly interpolating for all pixels) air temperature (Ta) is derived. ET from the canopy is estimated from Priestly-Taylor approximations (Norman et al., 1995), whilst sensible and latent heat fluxes from the soil surface are derived from the energy balance equation. Finally, ET from the canopy/soil system is determined as a residual of the basic energy balance equation

2.3 Hydrological model development

2.3.1. Rainfall-runoff modelling for catchments (a) and (c)

The aim is to develop a model that can be used for operational river flow forecasting for flood warning and for general river management. The model will be based on the Pitman model, specifically developed for use in southern Africa. Model inputs are daily rainfall and Et estimates, output is daily runoff and river flow. Changes in water storage capacity will be estimated using a 2-bucket empirical model, simulating soil (based on the soil and NDVI characteristics) and ground water storage. The resulting run-off will be routed through the catchment based on surface elevation. The model will be calibrated using a combination of a) rainfall estimates (derived from historic Meteosat imagery and rain gauge data) and river flow data from 1994-2000 b) rainfall and Et estimates from MSG described above from the project first year. Data from the second and third years will be used for validation. The model will provide flow forecasts from rain events or probabilistic seasonal forecasts from historic rain data. Establishing the source of errors in modelled flow can be problematic. A comparison of satellite rainfall with independent gridded gauge rainfall fields will provide a partial solution. A 'lumped' one-dimensional hydrological model fails to utilise spatial information on Et and rainfall provided by MSG. However, a distributed model at full pixel resolution may suffer inaccuracies in the rainfall and Et fields. We will run the model with varying degrees of distribution to determine the optimum spatial scale.

2.3.2. Surface water budget modelling for wetland site (b)

Daily rainfall estimates, vegetation cover and evaporation estimates as detailed in Section 2.3 will provide inputs to a soil moisture model. The modelled results of inundation and soil moisture will be compared with wetland areas identified by an algorithm based on the diurnal surface temperature range from SEVIRI TIR data.

Assessment of biophysical and hydrological variables in semiarid West Africa based on MSG data and numerical modelling

MS Rasmussen*, I Sandholt*, K Rasmussen*, R Fensholt*, J Qi#, A Tourè³, C Watts∀, J Gratuza Payan∃

* Institute of Geography, University of Copenhagen, Øster Voldgade 10, DK-1350 Copenhagen K, Denmark, phone: +45 35 32 25 00, fax: +45 35 32 25 01, email: msr@geogr.ku.dk
# Dep. of Geography, Michigan State University, East Lansing, MI, USA
³ Centre de Suivi Ecologique, Fann Residence, Dakar, Senegal
∀ Instituto del Medio Ambiente del Estado de Sonora (IMADES), Reyes y Aguascalientes, Col San Benito, Hermosillo, Sonora, Mexico
∃ Instituto Tecnologico de Sonora, Sonora, Mexico

Introduction

The project focuses on the development of models to characterize vegetation and hydrological conditions in the semiarid to subhumid environment in West Africa. This will be done using primarily SEVIRI data from the MSG, however, data from MERIS, AATRS, ASAR all from ENVISAT will be used along with ancillary data. The long term perspectives of the study are to contribute to global assessment of water and carbon budgets and to improve tools for regional natural resource management and early warning. The study is a continuation of the ongoing research on using NOAA-AVHRR data as the primary data source for net primary production (NPP) assessment and hydrological modelling in the Senegal River basin. Other related activities have been remote sensing of crop yield forecasts, active fire mapping, rainfall estimation and long term monitoring of vegetation conditions.

The main issue of the present study is to improve the assessment of NPP as well as the assessment of variables relevant to the hydrological modelling. Important parameters are leaf area index, growth efficiency coefficients, vegetation and soil moisture contents. Addressing these subjects necessitate a high standard of basic EO data processing such as the problems of reliable operational corrections for atmospheric conditions and anisotropy and how to handle data composition and aggregation, including cloud screening methods. The present team seeks partners among the other Primary Investigators to assist dealing with these problems.

Net primary production

Operational assessment of NPP can be done using the semi biophysical production efficiency model (PEM) using optical EO data from the AVHRR (Prince, 1991 and Rasmussen 1998). Here the NDVI is used as a measure of the fraction of absorbed photosynthetically active radiation (fPAR) to assess NPP, however, it provides an estimate of the potential rather than the actual production. Methods to account for production limiting factors are needed as well as measures to handle the in-between and within years variation in environmental and climatic variations. Existing methods to assess water stress are the Ts / NDVI relationship or the derived dryness index (see below), other methods have exploited the summations of surface temperature (Rasmussen 1998). It appears that the surface temperature is a crucial parameter when trying to assess vegetation water stress. Opposed to the vegetation index, the surface temperature changes more radically over short time periods and consequently there are reasons to believe that by improving the temporal resolution of data, as is the case with time-series of SEVIRI data, these fluctuations can be captured.

Some authors have shown that the information in the mid-near infrared can be used to assess vegetation water contents (Boyd et al 1999). Using the IR 1.6 and IR 3.9 from SEVIRI to characterize water content in the vegetation will be tested. It is the aim to assess water stress along with other pertinent variables describing the efficiency coefficient γ, to be used in the PEM. Recently Nouvellon et al. (2000) have shown that the variation in γ is a function of water stress, temperature, leaf aging and processes and respiration and change in the energy allocation pattern. Again temperature appears to be a critical parameter. Leaf aging can be assessed from the time since emergence of the vegetation derived

The present team will specially encourage and welcome collaboration with other MSG PI teams on solving these pertinent operational issues.

Data needs

The present authors have been awarded the status of primary investigators (PI) on ENVISAT data as well. The two PI projects were originally jointly scheduled for three years, with field campaigns in Senegal and EO data acquisitions for the 2001 and 2002 growing seasons. However, with the delay in the launch of ENVISAT, the team proposes to begin working with the MSG data for the 2001 growing season and then subsequently obtain data from both MSG and ENVISAT as planned for the two consecutive seasons 2002 and 2003 in order to investigate the anticipated synergy between MSG and ENVISAT sensors for a minimum of two growing seasons. Consequently additional MSG data for a third year (04-2003 - 04-2004) is kindly being requested.

Data Requirements:

SEVIRI Level 1.5 Data - near real-time processing of SEVIRI raw imagery, geometrically and radiometrically corrected data

Spectral channels:	Multispectral imagery: 11 channel(s); HRV data, Southern area: Cantered
Area:	Full disk area
Data required for the period:	04-2001 - 04-2004
Data delivery:	Off line (UMARF)

ENVISAT

Instrument:	MERIS, AATSR, ASAR
Data required for the period:	04-2002 - 04-2004

ERS

Data required for the period:	04-2001 - 06-2002 (to replace ASAR)
Data type:	SLC

Study area:

MSG, MERIS and AATSR:
Top left Latitude (deg min) / Top left Longitude (deg min): 17° 00'/ -17° 00' Bottom right Latitude (deg min) / Bottom right Longitude (deg min):13°00'/-13°00'

ERS and ASAR:
Top left Latitude (deg min) / Top left Longitude (deg min): 17° 00'/-16° 00' Bottom right Latitude (deg min) / Bottom right Longitude (deg min):15°30'/-14°00'

Veterinary Decision Support in Africa: Improving degree-day assessment for better forecasting of the nasal bot fly, *Oestrus ovis*

S. Flasse [1], A. Perryman [1], P. Hutchinson [2] & B. Kohrs [3]

[1] Natural Resources Institute, University of Greenwich,
Medway University Campus, Central Avenue, Chatham Maritime, Kent ME4 4TB, UK
Tel: +44 1634 883221, Fax: +44 1634 883232
Email: s.p.j.flasse@gre.ac.uk

[2] Namibian Meteorological Services, Private Bag 13224, Windhoek, Namibia
Tel: +264 61 208 2169, Fax: +264 61 208 2197
Email: weather@iafrica.com.na

[3] Veterinary Services, Private Bag 12022, Windhoek, Namibia
Tel: +264 61 208 7500, Fax: +264 61 208 7779

Summary

The Directorate of Veterinary Services in Namibia issues timely warnings about the likelihood of infestation of small stock by the nasal bot fly, *Oestrus ovis*. The emergence of *O. ovis* puparia is directly dependent on the number of degree-days above a particular threshold soil temperature. Meteosat images are used to provide accumulated temperature degree-days. Meteosat Second Generation data has the potential to increase the temporal and spatial precision of information provided to the veterinary department and hence to improve warnings issued to Namibian farmers.

Introduction

Infestation of small stock (i.e. sheep and goats) by the larvae of the nasal bot fly *Oestrus ovis* L. (Diptera: Oestridae), affects farmers in many parts of the world. Female flies deposit larvae in the nostrils of their small-stock hosts. The number of larvae per head can exceed 30 at peak times, but falls to as low as one or two at other times of the year. Later the larvae leave the nasal passages and drop into the soil into which they burrow and pupate. When puparial development is completed, the adult flies emerge and mate. Larvae are again deposited in host animals approximately two to three weeks after emergence.

Infestation by this parasite larvae can cause constant irritation that results in sneezing, excessive secretion of mucus from the nostrils and difficulty in breathing. This seriously affects the well-being of infected animals as it leads to a reduction in feeding activity (Zumpt, 1965). A less extreme, though economically significant, problem arises because olfaction in infected rams may be impaired, making them less able to detect oestrus in and impregnate receptive ewes (Biggs *et. al.*, 1998).

The *Oestrus ovis* puparia develop at shallow depths in the soil and the timing of emergence is directly dependent on climatic conditions, specifically the number of degree-days above a particular threshold soil temperature.

The Directorate of Veterinary Services of the Ministry of Agriculture, Water and Rural Development of Namibia issues warnings to farmers in the south of the country about the likelihood of infestation of small-stock by the nasal bot fly, *O. ovis* just before the most severe period of fly strike. Farmers can then combat the problems caused by *O. ovis* by treating their stock with larvicides shortly after larvae have been deposited around and into the nostrils. Optimising the timing of treatment would avoid wasting drugs and money.

This work aims to improve the precision (timing and location) of warnings issued by the veterinary department in Namibia on the risk of infection of small stock by *O. ovis* just before the most severe period of fly strike. These warnings currently incorporate information from

$$BTDD = \frac{\sum_{0}^{24} BTDH_i}{24} \qquad (3)$$

and the soil degree-days are computed using equation (1), where *BTDD* replaces DD_{air}. Finally, the soil degree-days are incorporated into the cumulative degree-day image. It is possible at any stage to view the cumulated degree-days graphically or in tabular form.

Limitations and Constraints

While the potential of this approach for a veterinary application has been demonstrated, the precision and reliability of the information provided to farmers is limited by the nature of the Meteosat data, particularly by the accuracy of land surface temperature measurements, the accuracy of degree-day calculable due to cloud cover and missing data. In addition, soil temperature assessment must also be improved. The accuracy of warnings is approximated to be about one week late compared to field conditions.

Meteosat Second Generation (MSG) Opportunity

MSG offers improved temporal resolution that will allow more complete accumulation of data, every 15 minutes instead of 30 minutes, for degree-day estimation. Additionally the higher spatial resolution will allow more precision in location of geographical variations and more accurately located warnings.

The addition of several thermal infrared channels on MSG will allow the application of split window techniques for determining land surface temperature, which should improve accuracy and precision of degree-day estimation. Other new channels should contribute to better detection of problematic cloud.

The intended provision of standardised good basic products such as land surface temperature, cloud masks and soil moisture should facilitate the use of MSG data for extended applications such as degree-day estimation.

All these features of MSG should help provide more precise information to decision makers and hence improved warnings to farmers of likely *O. ovis* outbreaks and allow more effective control of this pest.

The proposed project will take advantage of the new MSG capabilities to move to an operational and reliable approach. The project has two main phases, research and implementation. These phases are linked by the field campaign to collect supporting data. The final output will be an operational tool to predict potential outbreaks of *O. ovis*.

The research phase involves examination of the main component of the prediction system, that is, estimation of soil temperature and subsequently degree-day. The precision of these inputs will be assessed. The implementation phase involves development of operational software and in-country testing. The precision and usefulness of products will be assessed. More detail is given as a diagram, *see Figure 1 overleaf*.

Conclusion

The nasal bot fly, *Oestrus ovis*, is a serious pest affecting farmers in Namibia. By using data from Meteosat it is possible to alert farmers to the risk of infestation and allow them to implement control measures. An experimental system to automatically produce degree-day information and provide warnings is in operation in Namibia. When Meteosat is replaced by MSG there is an opportunity to improve the quality and precision of information being provided to help farmers combat *Oestrus ovis*.

The techniques and methodology used in this study are sufficiently generic to be applicable in other countries affected by *Oestrus ovis*. Degree-day information could similarly be found useful for other applications, for example in examination of agricultural growth.

Improving Relevant Information for Local Fire Management Strategies in Africa

S. Flasse [1], A. Perryman [1], J.-M. Grégoire [2], J.-B. Vickos [3], J. Tel [3] & D. Dambe [4]

[1] Natural Resources Institute, University of Greenwich,
Medway University Campus, Central Avenue, Chatham Maritime, Kent ME4 4TB, UK
Tel: +44 1634 883221, Fax: +44 1634 883232, Email: s.p.j.flasse@gre.ac.uk

[2] Global Vegetation Monitoring Unit, Space Applications Institute TP 440,
Joint Research Centre, 21020 Ispra (Va), Italy
Tel: +39.0332.78 92 15, Fax: +39.0332.78 90 73, Email: jean-marie.gregoire@jrc.it

[3] Programme Regional de Gestion de l'Information Environnementale (PRGIE),
Bangui, Central African Republic
Fax: +236 - 612 823 or 236 615 741, Email: Parn@intnet.cf

[4] Botswana Department of Meteorological Services (BDMS),
PO Box 10100, Gaborone, Botswana
Tel: +267 35 62 81, Fax: +267 35 62 82, Email: bots.met@info.bw

Summary

Local management of fires is an important issue in Africa. Satellite data such as NOAA-AVHRR have been extensively used to monitor fire activities and impacts at a global scale, as well as in real-time at local scales. New features of the Meteosat Second Generation (MSG) satellite include a 1.6μm channel, 15 minutes temporal resolution, accurate geo-location, multiple illumination angles. These features provide an opportunity to improve the quality of the fire related information provided, such as vegetation moisture assessment (fire risk), active fire detection and burned areas. In collaboration with African departments, the proposed project will adapt existing active fire detection and burned area detection techniques, and assess and document the resulting information. The aim is to determine recommendations on the use of MSG data for local fire management units.

Introduction

Vegetation fire affects most of the world's population, many ecosystems and climate. The continuing rise in the world's population results in a corresponding increase in pressure on vegetation resources. Fire monitoring has shown that large areas of Africa burn every year (Dwyer, *et al.*, 2000). Negative effects of large, uncontrolled fires include damage to property, threat to life, damaged forest, changed vegetation ecology, increased land degradation and wildlife and livestock mortality. Over time such fires can consume vast areas of vegetation causing significant biomass loss and the release of large amounts of gases and aerosols. However, fire can also be beneficial. The vegetation types and ecosystems in many African countries have evolved with fire as a major shaping force and many rangeland vegetation types require fire to maintain health and species diversity. With the appropriate frequency, timing and extent of burning, fires can have many positive effects including promoting species diversity and controlling bush encroachment. Fire is extensively used as a range management tool throughout southern Africa for maximising rangeland productivity.

While now recognised as a global issue, fire management has to be improved locally to realise the best trade-off between its beneficial usage to support livelihoods in a sustainable way and its impact on global resources and climate. In Botswana for example, the Ministry of Agriculture and other government departments have recently put fire management on their agendas as a priority and are developing policies to improve knowledge on the potential problem and strategies to tackle the issues. It is recognised that many issues need to be addressed such as improving knowledge on fire and wildland ecology; the use of fire as a range management tool; the socioexcellent basis for change detection. The fifteen minute temporal coverage offers the most nearly complete data set to monitor the diurnal cycle of fire in Africa. In addition the capacity to collect images throughout the day, as the solar incidence angle changes, produces a data set with multi-angle illuminations. This allows retrieval of surface parameters that could potentially be very useful, such as the Meteosat Surface Albedo (MSA) recently developed by the STARS group of the Global Vegetation Monitoring Unit.

The aim of this project is to apply and adapt current knowledge to MSG, to assess the relevance of MSG, and its advantages and limitations for operational input into local fire decision support systems. The research will focus on areas representative of many African ecosystems, in Botswana and Central African Republic. Priority will be given to the type of information directly useful in-country. The main topics focussed on in this research are active fire detection and burnt area detection with MSG. Although not covered in detail in this proposal, current research on the detection of vegetation moisture content indicates that the MSG channel at 1.6 μm could prove useful in vegetation moisture assessment and therefore for fire risk assessment.

Active Fire Detection

Existing AVHRR algorithms for active fire detection involve the use of the mid-infrared channel at around 3 μm, which is the peak emission wavelength for blackbodies of fire-like temperature. Application of contextual tests, designed to compare potential fire pixels to the temperatures in the immediate surroundings, can be used to overcome the confusion that can occur in discrimination between hot land surfaces and fires in Africa. The new channels available on MSG should allow direct extension of existing active fire detection with AVHRR (Pilar *et al.*, 1999) and GOES (Prins and Mentzel, 1994).

MSG active fire detection algorithms will be developed and tested against ground observations and other remote sensing sources for assessment and validation. The detectability of active fires within MSG image pixels will be investigated as part of the proposed field campaign. Previous work included setting controlled burns to test fire size detectability within AVHRR 1.1 x 1.1 km pixels. These tests showed that fire fronts of about 50 m long by 2 m wide produce enough effect that pixels in AVHRR images can be identified as containing active fires. Field data will also be used as part of a fire detection validation exercise. The limitations of the MSG pixel size will be investigated and documented.

As cloud (effective detection and masking of) is a limitation on active fire detection, cloud masking techniques developed for MSG data will be evaluated as part of the fire detection work.

Burnt Area Documentation and Detection

Automatic detection of burnt areas is an on-going research topic (Barbosa *et al.*, 1999; Trigg, 1998; Flasse, 1999). An operational methodology that is robust over large areas and multiple ecosystems has yet to be developed. Various existing techniques for burn scar detection with AVHRR and ATSR (Along-Track Scanning Radiometer) will be adapted and applied to MSG data.

Particular attention will be given to the potential of new features provided by MSG. The potential for use of the 1.6 μm channel data will be evaluated. The combination of precisely co-registered MSG images together with the availability of images every fifteen minutes should produce a data set capable of detecting sudden changes in land cover and the progression of fires (Boschetti, 2000). The increased quantity of data that can be easily analysed as a time series will be particularly relevant when cloud cover increases towards the end of the dry season while fires are still abundant.

The new generation of products resulting from inversion of a coupled bidirectional reflectance surface-atmosphere model should provide an interesting new type of information at canopy level, free from atmospheric and bidirectional effects. The utility of the recent Meteosat Surface Albedo product will be evaluated and similar products from MSG will be investigated as far as is possible. Of particular interest are the vegetation canopy parameters retrieved through inversion.

FOREST FIRE DETECTION AND ESTIMATION OF FOREST FIRE RISK INDEX FROM SEVIRI SYNTHETIC IMAGES

José-Luis Casanova, Abel Calle, Federico González Alonso* and Alfredo Romo
Remote Sensing Laboratory, University of Valladolid, SPAIN
*** Remote Sensing Laboratory, INIA, Madrid, SPAIN**
jois@latuv.uva.es

INTRODUCTION

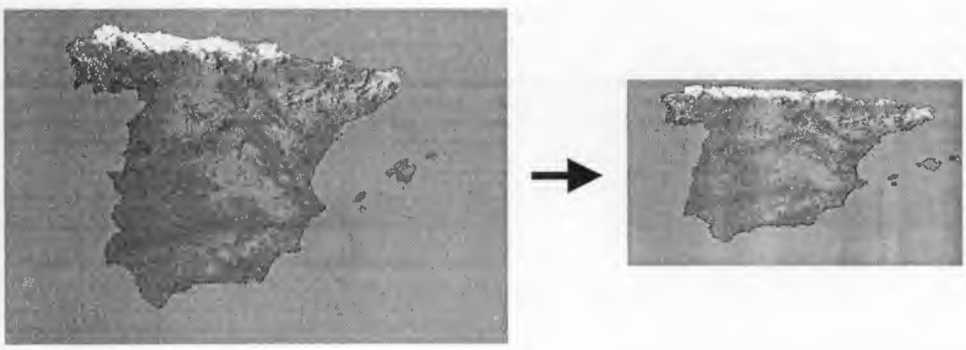
The goal of this work is to develop and set up algorithms for the detection of forest fires using SEVIRI images as well as to estimate forest fire risk using the same images. To do this synthetic SEVIRI images have been generated from NOAA-AVHRR images and a bidirectional reflectance has been used to eliminate the solar component reflected in the middle IR. Results show that large fires can be detected using SEVIRI images as well as even "small fires" of around 1 ha or less. Likewise, it is possible to establish a fire risk map based on an indicator of the evolution of the vegetation and an indicator of its humidity.

GENERATION OF SYNTHETIC SEVIRI IMAGES

SEVIRI sensor images have been generated using images from the NOAA-AVHRR sensor which have been corrected geographically. These NOAA images were resampled to a spatial resolution of 1x1 km^2, in UTM 30 N projection. The SEVIRI images are obtained in turn through a resampling process using the *nearest neighbour* criteria and applying the geometric conditions imposed by the sensor.

The satellite is considered to be in the position (long, lat) = (0,0) and the sub-satellite resolution 3x3 km^2, equivalent to an IFOV value of 8.383e-5 rad., taking a nominal distance of the satellite to be 45164.0 km and the value of the earth equatorial radius. The co-ordinates of the points of the SEVIRI image have been obtained from trigonometric relations that use 0.314 rad. as the FOV (*Field Of Vision*) value, equivalent to total coverage of the earth's disc from the distance of the satellite. In addition, the flattening effect of the earth's surface has also been applied.

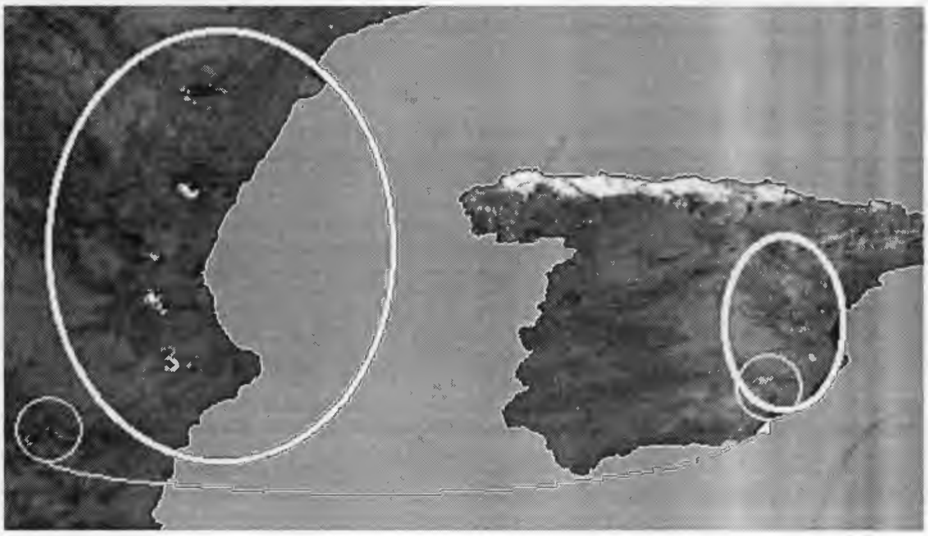
The result of the resampling can be seen in the following NOAA-AVHRR and SEVIRI figures:



CORRECTION OF THE BIDIRECTIONAL REFLECTANCE

The algorithm for the detection of forest fires will be applied throughout the whole day, meaning that it is necessary to correct the non-Lambertian reflectance of the earth's surface since use will be made of images taken at different times of the day and therefore with a variable sun-satellite geometry. To carry out correction of the bidirectional reflectance of the ground and obtain the normalised hemispherical reflectance

The results can be seen in the following figure, in which it can be observed how some fires have been reproduced with greater clarity due to the grouping caused by the reduction in spatial resolution.



The fires shown in these figures correspond to "large fires". However, an analysis has also been made of the possibility of detecting "small fires", called "beginnings", of less than one hectare. To do this, the detection limits of NOAA images have been calculated and a simple proportionality has been established between the size of the pixels.

The previous algorithm has been applied to fires which occurred in July 1993 in Spain, and once the beginnings were located, the Dozier (1981) method was applied. This method is based on the fact that when a fire starts emission in the middle IR increases proportionally much more than in the thermal IR. It may then be considered that:

$$L_3\ (T_3) = p.L_3(T_F) + (1-p).L_3(T_V)$$

$$L_4(T_4) = p.L_4(T_F) + (1-p).L_4(T_V)$$

where 3 and 4 correspond to the MIR and TIR channels, F indicates fire, V, vegetation, and p is the fraction of the pixel which is burning. By applying this algorithm to different fires, we have been able to see that the smallest fires which may be detected are around 600 m^2. If the proportionality established by the Dozier procedure is fulfilled, since SEVIRI pixels are approximately 15 times larger than NOAA pixels, fires of around 9000 m^2 may be detected, in other words less than one hectare. However, by means of multitemporal analysis which at the moment cannot be applied and by using a refined Dozier method, the lower detection limit is expected to be much smaller.

ESTIMATION OF FOREST FIRE RISK

Since 1995 the LATUV, Remote Sensing Laboratory of the University of Valladolid, has been providing daily estimations of forest fire risk for European Mediterranean regions over the summer. To do this, several indicators have been developed which are eventually fused into a single index which ranges from the value "0, no risk", to "4, extreme risk". The indicators used reflect the evolution of the vegetation as well as ground humidity (González et al., 1997).

High Temperature Thermal Activity from MSG SEVIRI: Volcanoes and Fires

M J Wooster*[1] , D.A. Rothery[2], M. Coltelli[3], M.F. Buongiorno[4]
[1]King's College London, [2]Open University,
[3]Instituto Internazionale de Vulcanologia, [4]Instituto Nazionale di Geofisica

*Department of Geography, King's College London, Strand, London WC2R 2LS
Tel: + 44 207 8482577, Fax: + 44 207 848 2287, email: martin.wooster@kcl.ac.uk

Background

The 1980s were the worst decade for volcanic disasters this century, with 24000 - 28000 fatalities associated with two particularly devastating Latin American eruptions alone. Similarly the occurrence of large wildfires, such as those in Indonesia in 1997-98, has in recent years become a matter of increased public and scientific concern. In terms of volcanic hazards, the location of active and potentially active volcanoes is relatively well known. However, despite advances in the technology available for ground-based monitoring, with over 500 active volcanoes and an average of 50 eruptions occurring annually, traditional ground-based monitoring fails to keep the majority of these targets under surveillance. Infrared measurement from satellites is one method that may assist the monitoring process, by observing heat output from active volcanoes and by monitoring the status of persistent volcanic plumes and volcanic eruption clouds. Similarly such techniques can also be used to locate actively burning fires, and potentially to estimate certain of the fire parameters that may be of use in scientific studies of biomass burning, for example the fire size and intensity.

For well over a decade infrared measurements from Earth orbiting satellites, taken at high spatial resolution, have been known to be suited to detecting thermal anomalies associated with active volcanoes and vegetation fires (e.g. Rothery *et al.*, 1988; Oppenheimer *et al.*, 1991), but these data are limited for routine monitoring due to their relatively poor temporal frequency. More recently attention has turned to use of lower spatial resolution instruments since these offer the possibility of higher temporal frequencies. Data from the Advanced Very High Resolution Radiometer (AVHRR) 3.7 μm channel was found capable of detecting small, high temperature targets (e.g. Matson and Dozier, 1981; Oppenhiemer, 1989; Robinson, 1991), though measurements were frequently saturated over such phenomena and was thus limited for quantitative work. This led to the Along Track Scanning Radiometer (ATSR) sensor being investigated, with the shortwave infrared band (1.6 μm) allowing non-saturated volcanic thermal data to be collected and in some cases compared to discharge rates of volcanic products (e.g. Wooster and Rothery; 1997a; 1997b; Wooster and Kaneko, 1998a). ATSR has been shown to be similarly effective in studies of active fires (e.g. Antikidis *et al.*, 1998). The current project intends to expand upon this existing research capability by investigating the complementary use of geostationary MSG SEVIRI data in the monitoring and assessment of thermal anomalies associated with active volcanoes, and also with vegetation fires. SEVIRI provides data that is extremely complementary to that obtained from ATSR (and AVHRR), most notably by providing data at an enhanced set of infrared wavelengths and at a temporal resolution increased by more than two orders of magnitude. Within the MSG footprint there are active volcanoes on the European and African mainland and on islands in the Mediterranean, Atlantic and Indian Oceans. These volcanoes can all be targeted for study using SEVIRI data, as can the large, annually active fires that occur in the many of these regions. At the very minimum the occurrence of vegetation fires must be assessed in order that any volcano monitoring operation does not mistake biomass burning for increased volcanic activity. Already data from the imager onboard the US NOAA Geostationary Operational Environmental Satellite, which can be considered somewhat similar to SEVIRI, is being used to monitor volcanic and fire activity in the America's (Harris *et al.*, 1997). The enhanced sensor capabilities of SEVIRI suggest such phenomena can be similarly monitored in Europe and Africa using the high repetition frequency obtainable from MSG's geostationary orbit.

Proceedings of the First MSG RAO Workshop, Bologna, 17-19 May 2000, ESA SP-452, October 2000

be effective in the study of the gas and aerosols contained in volcanic eruption clouds (Mt. Pinatubo, Nevado del Ruiz, El Chichon, Mauna Loa). However, the satellites used for atmospheric studies have generally been characterised by sensors that do not have the necessary spectral and spatial resolution to study SO_2 concentration in tropospheric plumes emitted by continuous volcanic degassing. The MSG SEVIRI instrument potentially offers such a capability, using techniques related to those airborne and ground-based techniques that have already been used to retrieve SO_2 concentration maps and relative fluxes for the Etna (Relamuto *et al.*, 1994 and Teggi *et al.*, 1999) and Kilauea volcanoes (Realmuto *et al.*, 1997). Again, the repetitiveness of the geostationary satellite observations is the main advantage offered by the MSG system, as opposed to alternative methods of measurement.

Finally, in addition to the concentration of volcanic gasses, meteorological thermal infrared satellite data have already been shown to have the capability to investigate the characteristics of actual eruption clouds. These characteristics include the clouds spatial extent and rate of spread, the cloud top height, and under certain circumstances even the distribution and characteristics of silicate particles within the cloud itself (Prata, 1989). For larger eruption clouds MSG data should provide these capabilities at a previously unavailable temporal resolution, this being important for hazard mitigation purposes since silicious eruption clouds pose a considerable hazard to national and international air traffic.

In summary the proposed project aims to investigate all three applications of MSG imagery relevant to the monitoring of volcanic activity, namely thermal anomalies, SO_2 concentration in persistent tropospheric plumes, and the characteristics of volcanic eruption clouds. Where appropriate the use of certain of these techniques to the study of large vegetation fires, particularly the thermal monitoring methods, will also be investigated.

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Posters

Studies of upper tropospheric processes including the radiation budget

Robert S. Harwood
Hannah L. Clark, Mark J. Filipiak, Hugh C. Pumphrey

University of Edinburgh

Abstract

Meteosat Second Generation (MSG) data will be used for two connected strands of research. The first strand is to enhance the on-going studies of meteorological processes near the tropopause by using MSG cloud and profile measurements. These studies involve calculation of particle trajectories in the region of the tropical tropopause. To obtain the vertical velocities for these trajectories diabatic heating rates need to be calculated. MSG data will be used to improve the specification of cloud and water vapour fields required in these calculations. In addition the cloud fields will be used to indicate where convective mixing processes affect the trajectories.

The second strand will combine high horizontal resolution MSG data with high vertical resolution EOSMLS data to improve estimates of the radiation budget. EOSMLS is an improved version of the highly successful UARSMLS instrument. UARSMLS proved successful in measuring water vapour in the upper troposphere and lower stratosphere. EOSMLS has been designed with greatly improved capabilities for such measurements. EOSMLS will be launched on the EOS Aura satellite in December 2002.

Objectives

Our objectives relate to two separate but closely linked themes

- studies of near tropopause processes, principally in the tropics, especially those related to trans-tropospheric exchange - this is described in section 2
- symbiotic studies with the Microwave Limb Sounders on which the PI and Co-Is are official NASA Co-Is on the instrument team - described in section 3.

Transport across the tropopause

Hypothesis to test:

A proper understanding of the stratosphere in general and the ozone layer in particular, requires a full understanding of the processes by which source gases for the catalysts of ozone destruction, enter the stratosphere, and by which the reservoir or sink species leave it.

The stratosphere can be split into two regions, the `middle-world' in which the isentropic surfaces intersect the tropopause, and the `over-world' in which they do not (Holton et al, 1995). All air

EOS MLS is being built by a team at the Jet Propulsion Laboratory lead by Dr. Joe Waters. A group at the University of Edinburgh comprising the authors contributes to the science team and has a particular responsibility for some aspects of the retrieval algorithms, quality control of the retrieved product and scientific exploitation of the data for some species.

EOS MLS measures many species, including temperature, pressure, O_3, H_2O, CO, N_2O, HNO_3, HCl, ClO, HOCl, BrO, HO_2, SO_2, HCN and cirrus ice at various heights (depending on species) from the mid-troposphere to the mesopause and beyond. Measurements can be obtained even in the presencse of clouds. Of these the water vapour and cirrus ice measurements are the most important in the context of the present study.

Use of MSG measurements

The measurements from this instrument on a polar-orbiting satellite will give water vapour from mid-troposphere to upper stratosphere and beyond, but with a rather different sampling regime than Meteosat. Being a limb sounder MLS has much higher vertical resolution than MSG but inferior horizontal resolution. There are three ways we shall use the data from both satellite instruments symbiotically:

(i) By cross-validating and combining MLS and MSG estimates of upper troposphere humidity.

(ii) By using MSG cloud data to improve our understanding of the cloud detecting abilities of MLS.

(iii) By calculating outgoing longwave radiation (OLR) using MLS and MSG upper troposphere humidities and comparing the results with OLR measured by GERB.

MLS scans vertically along the orbital track, measuring a profile every every 165 km. As the scans overlap, the retrieval process will use tomographic techniques, returning a 2-dimensional slice around an orbit. There is clearly much to be gained by studying similar slices derived from suitable sampled MSG data. Each can be regarded as providing a constraint on the other for validation purposes, alternatively it may be possible to combine the information from both to produce cross-sections of higher combined vertical and horizontal resolution than either can achieve alone. We shall investigate the extent to which this can usefully be done.

We shall then use the combined profiles with radiative transfer codes to calculate outgoing long wave radiation, which will then be compared with the GERB measurements to ensure as a consistency check on the entire dataset. That forms the second aspect of our symbiotic study. We will use radiation code from the models of the UK Universities Global Atmospheric Modelling Project to calculate OLR.

Although MLS radiances are affected by both emissions and scattering from upper tropospheric cloud particles, the retrieved values are insensitive to the cloud and humidities can be determined in the presence of cloud. In addition cloud ice content can be retrieved (Waters, 1999). As the third part of the symbiotic study, we shall use MSG as a sanity check that retrieved ice amounts are qualitatively consistent with the cloud field. In addition we shall use it to monitor the extent to which retrieved MLS profiles flagged as `bad' are in cloudy areas and hence likely to be caused by improper handling of cloud effects by the MLS retrieval code.

Classification and storing of Meteosat Second Generation images and short-term prediction of flood hazards

Paolo Gamba, Stefano Nativi, Sandro Zappatore[~]
CNIT – Italian Consortium for Telecommunications
[~]CNIT – Genoa Research Unit, Department of Computer, Communications and System Science, University of Genoa,
Via Opera Pia 13, I-16145 Genoa, Italy, tel: +39-010-3532990, fax: +39-010-3532154, e-mail: zap@dist.unige.it

Objectives:

The activity is aimed at both the classification and analysis of the received data (in order to recognize and track the various kinds of clouds) and the evaluation of sea surface temperature.

The final goal is the estimation and the short-term prediction of the meteorological parameters in the Mediterranean basin that potentially could be associated with flood hazards.

The global process can be organized into the following three main tasks:

a) Within the first task, different techniques devoted to a complete shape oriented analysis of satellite images will be studied and compared. The goal is to implement a set of modules that are expected to extract significant objects, such as regions associated with high rate terrestrial zones, from an almost-raw (level 1.5) satellite image, together with their significant features.

Then this information will be delivered as an input to a shape analysis algorithm, whose results will serve for clouds time-evolution study, clouds classification and, possibly, shape-based forecasting.

b) The second task is aimed at the motion estimation and prediction of a group of selected clouds, that potentially can be associated with high rain-rate terrestrial regions, as reported by a rain-gauge network. More in detail, the corresponding clouds in an image sequence will be detected by a process that will take great advantage of the short MSG repetition time.

The motion parameters of each interesting cloud will be estimated by means of two different possible approaches and then a prediction of the cloud evolution will be performed by using a set of interpolating functions that take into account some physical constraints derived from the orography of the considered basin.

c) Finally, some techniques will be developed to integrate IR and microwave multispectral data for enhance the estimation of meteorological parameters in the Mediterranean region. More in detail, the proposed approach will combine different sources of remote sensing information - microwave and infrared imagery - as acquired by sensors on-board polar and geostationary satellites, to better understand the spatial and temporal variations of interesting meteorological variables in the Mediterranean basin.

The goal is to estimate the sea surface temperature (SST) using MSG infrared data in two consecutive acquisitions, closest to the passage of the SSM/I instrument on-board of the DMSP polar satellites: the short MSG repetition time (15 mins) makes such comparison very reliable. In the southern part of the Mediterranean is also possible to make a data fusion with the closest passage of the TMI instrument on-board the TRMM satellite. The microwave estimation of atmospheric temperature and water vapour profiles - in absence of clouds – is improved by resampling the obtained information at a common spatial resolution via ordinary image processing techniques.

Otherwise, when clouds are present, it is possible to compare the infrared cloud top temperature and the microwave derived temperature atmospheric profile to infer - for every sea pixel of the considered scene – the cloud top height: in this way, a better cloud liquid water estimate may be obtained.

Approach and Methods:

The activity of the group will be organized in four main phases, each of them will be focused on the development of efficient techniques for:

- the extraction and shape analysis of the significant objects from MSG imagery;
- the establishment of the correspondences between the selected clouds identified on consecutive IR images;
- the motion estimation and short-term prediction of the selected clouds;

every pixel through an accurate modelling of atmospheric absorption and emission of sea surface and atmosphere in the microwave spectral range. In particular, a numerical monochromatic polarised plane-parallel radiative transfer code over sea has been developed for a non-scattering atmosphere in local thermodynamical equilibrium. Such forward model gives the brightness temperature in both linear polarisations in microwave spectral region for every atmospheric layer and, in particular, at the top of the atmosphere. An exponential water vapour and a piecewise linear temperature atmospheric profile are supposed and sea surface wind effects are taken into account. Input data for this forward model are therefore: the surface atmospheric temperature water vapour and dry pressure value, the atmospheric temperature lapse rate, the water vapour scale height, the sea surface wind speed and direction and the sea surface temperature whose value can be evaluated as seen in the previous section, in clear sky conditions.

A non-linear inversion technique, based on the Levenberg-Marquardt Method, can be applied to the forward model and to satellite microwave multispectral imagery acquired by SSM/I and/or TMI radiometers: starting from a first-guess set of physical parameters, an estimation of maximum-likelihood values of the parameter-set is given for every pixel.

In presence of clouds, a less constrained estimation of the parameter-set is still possible, but now the model has also to deal with the cloud liquid water content value. In this case, the retrieved atmospheric temperature profile gives a relationship between atmospheric temperature and height: measuring the infrared brightness temperature (directly linked to cloud top temperature) using MSG data, it is possible to estimate cloud top height that can be used to increase the accuracy of the cloud liquid water content value determined via inversion technique.

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Conclusions, recommendations and discussion

The Need for GERB Data and Products

Peter M Allan, Rutherford Appleton Laboratory
Chilton, Didcot, UK

Based on the talks given at this workshop, it is possible to categorise the needs that the speakers have expressed for GERB data products, and to say whether there will be any problems in meeting them.

Some speakers need particular products for a specific range of times, others need all of the radiance products for the lifetime of a project, and some only need data products when another satellite such as Terra is directly below MSG. Some people need the products quickly (within a few hours), while others want to be able to extract the products from an archive. The GERB ground segment is designed to handle all of the requests that have been presented at this meeting and should not have a problem in satisfying the needs that have been described in a timely manner.

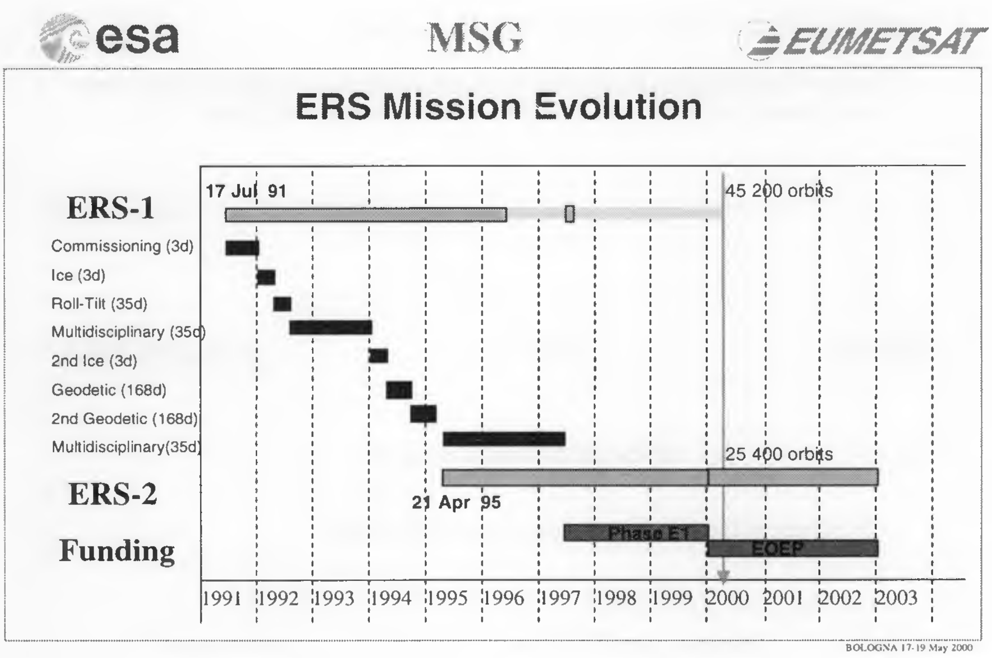
However, needs do change and there can be hidden assumptions, so it is worth stating where problems could arise.

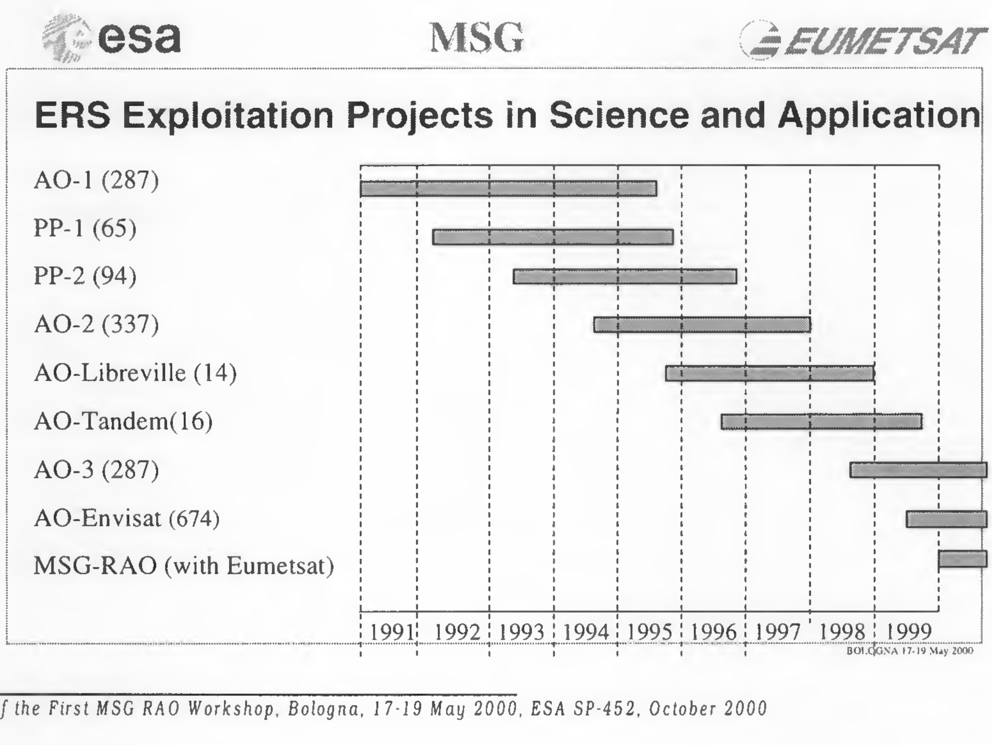
- The high-resolution flux products that RMIB will generate will not be archived. They will be available from RMIB for a period of approximately one month, but they will not be available after this time. To date no one has asked that they be made available for a longer time.
- The GERB ground segment is not designed to provide the ultimate in reliability with redundant systems. It will operate automatically and has many features designed to handle the type of problems that can be foreseen. Nevertheless, in order to keep costs down, the requirement on fixing problems that prevent the continuous flow of data is that they will normally be addressed on the next working day.

The GERB ground segment is designed to provide a flexible means of obtaining GERB data products. However, if anyone feels that they might have new and demanding requirements, please contact the author at the above address or by e-mail at p.m.allan@rl.ac.uk

ERS and ENVISAT Data Requirements for MSG RAO

S. Jutz
Earth Observation Applications Department
Directorate of Application Programmes
ESRIN/ESA
Ph: +39-06.94180659, Fax:+39-06.94180612, sjutz@esrin.esa.it





esa MSG EUMETSAT

ENVISAT Data Requirements

5 projects not covered by AO ENVISAT:

•*AATSR/MERIS: AO_ID 143,152:*
please specify in more detail your requirements

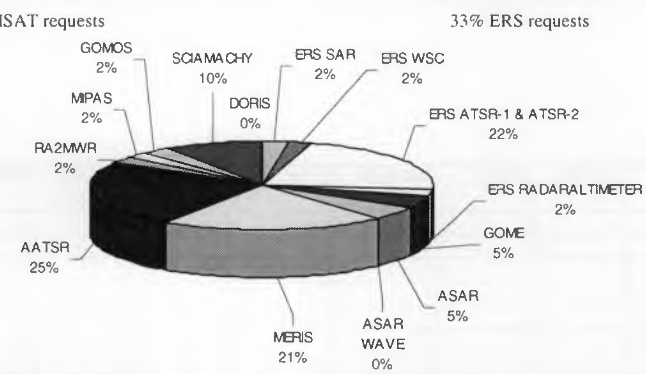
• *GOMOS/MIPAS/SCIAMACHY: AO_ID 158, 160*

• *SAR: AO_ID 176*

• *one additional project (141) asks for MERIS data not specified in RAO proposal*
• *proj. 140 requires additional AATSR + MIPAS data over Africa (not incl. in ENVISAT AO)*

esa MSG EUMETSAT

RAO ERS/ENVISAT DATA REQUIREMENTS



ERS SAR	ERS WSC	ERS ATSR & ATSR-2	RA1	GOME	ASAR	ASAR WAVE	MERIS	AATSR	RA2	MIPAS	GOMOS	SCIAMACHY	DORIS
1	1	9	1	2	2	0	9	10	1	1	1	4	0

THE ERS/ENVISAT DATA POLICY

The "Category of Use"

- ***Category 1 Use (Research& applications development)***
  - "Research and *applications development* use in support of the mission objectives, including research on long term issues of Earth system science, research and development in *preparation for future operational use*, certification of receiving stations as part of the ESA functions, and ESA internal use"
- ***Category 2 Use (Operational and commercial use)***
  - "All other uses which do not fall into category 1 use, including operational and commercial use"

esa MSG EUMETSAT

ERS LBR FD Products

- free of charge
- contact ESA EO Help Desk (eohelp@esrin.esa.it) for registration and password

Product type	**Instrument**	**Data Dissemination**	**online availability**
UWI	Scatterometer	GTS/ftp	2 weeks on ftp_dir
UWA	SAR Wave mode	GTS/ftp	2 weeks on ftp_dir
URA	Radaraltimeter	GTS/ftp	2 weeks on ftp_dir
GBT,GSST, ASST	ATSR-2	ftp (from Tromsoe)	5 days

BOLOGNA 17-19 May 2000

esa **MSG** EUMETSAT

ERS SAR Products

Product type	Medium type	Temporal/ spatial coverage	Media output	Category 1 use price (EURO)
PRI	CD Exabyte 8500	1 frame	1 CD 1 cassette	150
RAW	CD Exabyte 8500	1 frame	1 CD 1 cassette	100
SLC-I	CD Exabyte 8500	1 frame	1 CD 1 cassette	200
SLC	CD Exabyte 8500	1/4 frame	1 CD 1 cassette	100
GEC	CD Exabyte 8500	1 frame	1 CD 1 cassette	200
GTC	CD Exabyte 8500	1 frame	1 CD 1 cassette	300

esa **MSG** EUMETSAT

ESA Earth Observation Missions

ESA/Third Party Missions	*off-line Catalogue DESCW*	*on-line Catalogue Earthnet*	*Quicklooks on-line*	*Online Data (file server)*
ERS / SAR	X	X	X	
ERS / SWM	via Order Desk			X
ERS / WSC	via Order Desk			X
ERS / ALT	via Order Desk			X
ERS / ATSR-1	X	X	X	
ERS / ATSR-2	X	X	X	X
ERS / GOME	via Order Desk			X
ERS TANDEM	X	X	X	
JERS / SAR	X	X		
JERS / OPS	X	soon avail	soon avail	
Landsat / TM	X	X	X	
Landsat / MSS	X	soon avail		
NOAA / AVHRR	via Order Desk	X	X	
Nimbus / CZCS	via Order Desk	soon avail	soon avail	
IRS-P3 / MOS	via Order Desk	soon avail	soon avail	

Archived also: Seasat, MOS(MESSR,MSR,VTIR),HCMM

Workshop summary and recommendations

Yves Govaerts
EUMETSAT
Am Kavalleriesand 31
D-64295 Darmstadt
Germany

This first MSG RAO workshop gave the opportunity to selected Principal Investigators to present their projects. Among these projects, the use of SEVIRI data for atmospheric process monitoring represents a natural heritage from Meteosat data exploitation. The improved characteristics of SEVIRI open however new avenues in terms of innovative or more accurate products. Projects focusing on climate monitoring will take advantage of the duration of the MSG mission but also its continuity with respect to the Meteosat one. Spectral similarities between the SEVIRI and NOAA/AVHRR instruments contribute also to these advantages. The SEVIRI ozone channel has triggered several studies on ozone winds, ozone total column retrieval. As can be expected from the availability of GERB data, several projects will focus on Earth radiation budget related studies. Comparisons between GERB products and TERRA/CERES are foreseen, offering the possibility to investigate the impact of the diurnal cycle on radiative flux estimations. Over land surfaces, the retrieval of aerosol load is suggested using infrared channels over the desert areas while the solar channels will be used to retrieve simultaneously surface anisotropy properties and aerosol load. Catchment hydrology or, more generally, surface atmosphere interactions will benefit from the diurnal cycle observation as provided by SEVIRI. In this context, the use of four-dimensional data assimilation techniques in surface energy balance models is proposed. Last but not least, several projects will be dedicated to the vicarious calibration of SEVIRI solar channels with an expected accuracy better than 5%.

A second important issue that has been addressed during the workshop concerns the data delivery mechanisms required to serve the needs of the scientific community. Processing and archiving issues resulting from the large data volume generated by the MSG instruments should indeed not be underestimated. Data requests and delivery mechanisms have therefore been analysed in the light of the data requirements of each selected proposal and the actual technical performance of the EUMETSAT archiving system. The only potential problems that have been identified concern large volume delivery of Meteosat and SEVIRI level 1.5 data. The design of the SEVIRI archive system has inherited the Meteosat ordering feature, i.e., the support of operational meteorological applications. This translates into a fast delivery time for a limited number of images with a fully customisable ordering mechanism. While this delivery mechanism should satisfy most of the project data requests, the access to several months of data has been requested by several PIs. To overcome the ordering limitation for such request, a new delivery mechanism referred to as "predefined order" has been proposed to the PIs of the MSG RAO. Feedback on the data format has been requested too during the workshop. 29 in 43 PIs (i.e., 67%) reply to this enquiry.

Proceedings of the First MSG RAO Workshop, Bologna, 17-19 May 2000, ESA SP-452, October 2000

SEVIRI Level 2.0 Data		
Request SEVIRI level 2.0 data	16	55
AMV	5	31
CLA	9	56
CTH	8	50
IDSAC	4	25
IDSB1	4	25
IDSB2	4	25
CSR	9	56
HPI	6	38
TH	8	50
CDS	6	38
CLM	13	81
TOZ	6	38
Day/Night selection	8	50
Repeat cycle sub-sampling selection	4	25
HDF	11	69

Table 3: Results of the SEVIRI level 1.5 data request form

The workshop offered also the possibility to the PIs to raise general remarks concerning the RAO organisation or the SEVIRI data delivery. There are summarised hereafter:

1. EUMETSAT to work out a clear statement on which data can be provided through the predefined ordering mechanism;
2. EUMETSAT to provide for research use processing software to read the SEVIRI native format and to classify SEVIRI images.
3. EUMETSAT to consider:
   - an early delivery of SEVIRI archive level 1.5 and 2.0 data during commissioning phase for CAL/VAL activities;
   - setting up a facility for reprocessing SEVIRI data and products;
   - operational implementation of MSG RAO algorithms and products as a long term goal;
   - the distribution of cloud products at a high spatial resolution;
4. EUMETSAT to use the relevant research outcome from RAO to foster SAF development;
5. ESA/EUMETSAT to seek discussions with the EU to avoid detrimental effects of launch delay on funding of MSG RAO projects within FP5;
6. ESA/EUMETSAT to encourage the reprocessing of GERB products;
7. PIs to agree on common data sets and periods to facilitate comparisons of different algorithms output and the exchange of calibration and validation results;
8. ESA/EUMETSAT to facilitate this exchange of information through the establishment of email lists or a dedicated Web server restricted to the PIs.

Overall conclusions

Eva Oriol-Pibernat & Yves Govaerts

In the framework of the MSG RAO, a series of workshops will be organized which goal is to establish a constructive dialogue and interactions among the MSG Principal Investigators and ESA/EUMETSAT, respectively. The first dedicated workshop focused on the presentation of MSG features and of the selected RAO projects. The MSG RAO long-term objectives were presented, as well as updated information on the MSG mission and relevant plans. ESA provided updated information concerning the ERS and Envisat missions. Representatives from RAL (for GERB) and the EC (regarding 5th FWP plans) contributed with relevant technical information and plans.

A unique plenary session provided the scientists with the opportunity to know all aspects of research covered by the projects. It created a very good atmosphere and fostered interesting discussions. The establishment of a co-operative structure between RAO researchers was only partially addressed during the first workshop.

The follow-on activities will essentially be based on electronic day-to-day interactions with ESA/EUMETSAT designated points of contact, using ESA-developed WEB-based tools and ESRIN and EUMETSAT respective help desks. Electronic briefing notes will be distributed to PIs prior to MSG-1 launch with information on detailed planning of the commissioning phase and updated information on day-1 data and products.

The second MSG RAO workshop is currently foreseen to take place one year after the launch of MSG-1. It will provide the opportunity to present commissioning results and to review PI activities with focus on capability to access, read and process the MSG data.

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List of Participants

ALLAN Peter
Rutherford Appleton Laboratory
Chilton
Didcot OX11 0QX
UNITED KINGDOM
Tel.: +44 (1235) 445723
Fax: +44 (1235) 445848
e-mail: p.m.allan@rl.ac.uk

BENDIX Jörg
Institute of Geography
University of Marburg
Deutschhausstr. 10
35032 Marburg
GERMANY
Tel.:
Fax:
e-mail: bendix@mailer.uni-marburg.de

BRIGGS Steve
ESA/ESRIN
Via Galileo Galilei
00044 Frascati
ITALY
Tel.: +39 06 941 801
Fax: +39 06 94180280
e-mail: sbriggs@esrin.esa.it

BUONGIORNO M. Fabrizia
Istituto Nazionale di Geofisica
Via di Vigna Murata 605
00143 Roma
ITALY
Tel.: +39-6-51860439
Fax: +39-6-5041181
e-mail: buongiorno@ing.rm.it

CABOT François
CNES
18, Avenue Edouard Belin
31401 Toulouse
FRANCE
Tel.: +33- 561 27 33 04
Fax: +33 561 27 31 67
e-mail: francois.cabot@cnes.fr

CADÉ Franck
EUMETSAT
Am Kavalleriesand 31
64295 Darmstadt
GERMANY
Tel.: +49-6151-807-517
Fax: +49-6151-807-7
e-mail: cade@eumetsat.de

CASANOVA José-Luis
University of Valladolid
Prado de la Magdalena S/N
47071 Valladolid
SPAIN
Tel.: +34-983-423130
Fax: +34-983-423130
e-mail: jois@latuv.uva.es

COLTELLI Mauro
CNR Istituto Internazionale di Vulcanologia
Piazza Roma, 2
95123 Catania
ITALY
Tel.: +39-095 448084
Fax: +39-095-435801
e-mail: colt@iiv.ct.cnr.it

HARWOOD Robert
Edinburgh University
Dept of Meteorology, King's Bldgs
Edinburgh EH9 3JZ
UNITED KINGDOM
Tel.: +44-131-650 5095
Fax: +44-131-650 5780
e-mail: r.harwood@ed.ac.uk

INGMANN Paul
ESA/ESTEC
Keplerlaan 1
2201 AZ Noordwijk
NETHERLANDS
Tel.: +31 71 5654459
Fax: +31 71 5655675
e-mail: pingmann@estec.esa.nl

JUST Dieter
EUMETSAT
Am Kavalleriesand 31
64295 Darmstadt
GERMANY
Tel.: +49-6151-807-539
Fax: +49-6151-807-555
e-mail: just@eumetsat.de

JUTZ S
ESA/ESRIN
Via Galileo Galilei
00044 Frascati
ITALY
Tel.:
Fax:
e-mail:

KAIFEL Anton
Center for Solar Energy and Hydrogen
Reseach (ZSW)
Hessbruehlstr. 21c
70565 Stuttgart
GERMANY
Tel.: +49-711-7870-238
Fax: +49-711-7870-200
e-mail: anton.kaifel@zsw-bw.de

KARCHER Fernand
Meteo-France
CNRM, 42 avenue Coriolis
31057 Toulouse Cedex
FRANCE
Tel.: +33 561079349
Fax: +33 561079610
e-mail: fernand.karcher@meteo.fr

KATSAROS Kristina
Atlantic Oceanographic and Meteorological
Laboratory
4301 Rickenbacker Causeway
Miami, Florida 33149
USA
Tel.: +305-361-4300
Fax: +305-361-4449
e-mail: katsaros@aoml.noaa.gov

LEVIZZANI Vincenzo
Institute of Atmospheric and Oceanic Sciences,
ISAO-CNR
via Gobetti 101
40129 Bologna
ITALY
Tel.: +39-051-639-9578
Fax: +39-051-639-9649
e-mail: v.levizzani@isao.bo.cnr.it

MOSSAVATI Ruzbeh
Imperial College, Physics Dept.
Blackett Laboratory
Prince Consort Road
London SW2 2BZ
UNITED KINGDOM
Tel.: +44-171-594-7663
Fax: +44-171-594-7663
e-mail: r.mossavati@ic.ac.uk

MOULIN Cyril
Laboratoire des Sciences du Climat et de l'Environnement, CEA-CNRS
C.E. Saclay - bat. 709
91191 Gif-sur-Yvette
FRANCE
Tel.: +33 1 69 08 71 20
Fax: +33 1 69 08 77 16
e-mail: cyril.moulin@cea.fr

NATIVI Stefano
University of Florence
Via Opera Pia 13
16145 Genova
ITALY
Tel.: +39 0574 602532
Fax: +39 0574 602515
e-mail: nativi@pinet.ing.unifi.it

NICOLAS Jean-Marc
Laboratoire d'Optique Atmospherique
USTL, Bâtiment P5
59655 Villeneuve D'Ascq
FRANCE
Tel.: +33 3 20 43 67 08
Fax: +33 3 20 43 43 42
e-mail: nicolas@loa.univ-lille1.fr

ORIOL-PIBERNAT Evangelina
ESA/ESRIN
Via Galileo Galilei 32
00044 Frascati
ITALY
Tel.: +39 06 94180408
Fax: +39 06 94180402
e-mail: eoriol@esrin.esa.it

OTTENBACHER Andreas
ESA/ESTEC
Keplerlaan 1
2201 AZ Noordwijk
NETHERLANDS
Tel.: +31 71 5654580
Fax: +31 71 5654801
e-mail: aottenba@estec.esa.nl

PERGOLA Nicola
IMAAA-CNR
C. da S. Loja
85050 Tito Scalo (PZ)
ITALY
Tel.: +39 0971 427268
Fax: +39 0971 427271
e-mail: pergola@imaaa.pz.cnr.it

PIETRAPERTOSA Carla
IMAAA-CNR
C. da S. Loja
85050 Tito-Scalo
ITALY
Tel.: +39 09 71427242
Fax: +39 0971427271
e-mail: pietra@imaaa.pz.cnr.it

SCHOUPPE Michel
EC-DGXII
Rue de la Loi 200
1049 Brussels
BELGIUM
Tel.: +32 (2) 2960618
Fax: +32 (2) 2960588
e-mail: Michel.Schouppe@cec.eu.int

SCHROEDTER Marion
Deutsches Zentrum fuer Luft- und Raumfahrt (DLR) e.V. - Deutsches Fernerkundungsdatenzentrum (DFD)
Oberpfaffenhofen
82234 Wessling
GERMANY
Tel.: +49-8153-28 2896
Fax: +49-8153-28 1445
e-mail: Marion.Schroedter@dlr.de

SEZE Genevieve
Laboratoire de Meteorologie Dynamique du CNRS
Universitee P. et M. Curie- Tour 15- BP99-4,pl Jussieu
75252 Paris Cedex 05
FRANCE
Tel.: +33 1 44 27 27 99
Fax: +33 1 44 27 62 72
e-mail: seze@lmd.jussieu.fr

SIMPSON James
Scripps Institution of Oceanography
9500 Gilman Drive
La Jolla CA 92093-0237
USA
Tel.: +1-619-534-2789
Fax: +1-619-534-5602
e-mail: jsimpson@ucsd.edu

SMITH David C.
Rutherford Appleton Laboratory
Chilton
Didcot, Oxfordshire OX5 1DH
UNITED KINGDOM
Tel.: +44 (0)1235 446573
Fax: +44 (0)1235 445848
e-mail: d.l.smith@rl.ac.uk

SMITH G. Louis
VPI - Virginia Polytechnic Institute & State University, Langley Research Centre
Mail stop 420
Hampton, Virginia 23681
USA
Tel.: +1-757-864-5678
Fax: +1-757-864-7996
e-mail: g.l.smith@larc.nasa.gov

STUHLMANN Rolf
GKSS Forschungszentrum
Max-Planck-Strasse
21502 Geesthacht
GERMANY
Tel.: +49 4152 87 - 1543
Fax: +49 4152 87 - 2020
e-mail: rolf.stuhlmann@gkss.de

TODD Martin
School of Geography, University of Oxford
Mansfield Road
Oxford OX1 3TB
UNITED KINGDOM
Tel.: 44 1865 271915
Fax: 44 1865 271929
e-mail: martin.todd@geog.ox.ac.uk