



The ESA missions and their Exploitation for Science and Applications Development



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Presentation Outline

1. Introduction
2. ERS-1 and 2 missions
3. ENVISAT mission
4. ESA-TPM missions
5. Earth Explorers
6. GMES & Sentinels
7. Conclusion

The challenge of global change

IPCC Report 2007

Model: *Global temperature increase between + 1.8 and 4.0 degrees until 2100*

- **Arctic:** ice-free as of 2nd half of the century
- **Sea level rise:** up to 48cm until 2100
- **Permafrost:** up to 90% melting until 2100, freeing high amounts of Methane gas
- **Precipitation:** decrease in arid regions and increase in wet areas
- **Storms and surges:** less in number but significantly stronger in intensity
- **Gulf Stream:** significantly weakened



Space-based EO contributes significantly to monitoring global change

EO Missions handled by EOP

Since 1977 1990 2000 2008 2015

Earthnet. European access to non-ESA missions:

Landsat, SeaWifs, NOAA, JERS, MODIS, ALOS, Proba, Bird, Scisat...

European users

METEOSAT
M-1, 2, 3, 4, 5, 6, 7

METEOSAT Second Generation
MSG-1, -2, -3

Meteo

in cooperation with EUMETSAT

METOP-1, -2, -3

GOCE

(Gravity and Ocean Circulation Explorer)

SMOS

ADM/Aeolus

SWARM

CryoSat 2 (Polar Ice Monitoring)

Earthcare

EE-7

Science

to better understand the Earth

Earth Explorers

ERS-1, -2

ENVISAT

Earth Watch

Sentinel 1

Sentinel 2

Sentinel 3

Sentinel 4-5

GMES in cooperation with EC

Applications Services

to initiate long term monitoring systems and services



ERS Missions



ERS mission overview

- 15 years of ERS-1/2 data in the archive
- (suitable for applications requiring long term series products)
- ERS-2 achieved 11 years in orbit in April 2006
- (was designed for 3 years nominal lifetime)
- Some problems with the platform
- (gyroscope in 2001, tape recorder in 2003)
- but all instruments still functioning well
 - engineering solutions have been developed:
 - new 'gyro-less' working mode
 - set up of a station network for Low Bit Rate data recovery
- Operations funding until 2008



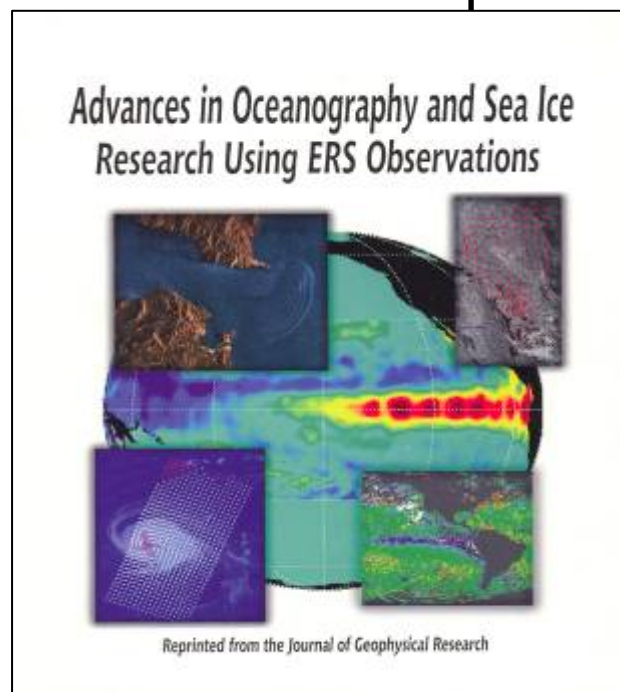
ERS-2 satellite and payload status

<i>Mission elements</i>	<i>Expected evolution</i>	<i>Comments</i>
Service Module	Good	Relaxed attitude control +/- 2deg, all other sub-systems with full redundancy. SPOT-1 platform flown for 17 years before de-orbiting.
Propulsion and Hydrazine	Excellent	1/3 of hydrazine has been consumed within 11 years
Payload Equipment Bay	Fair	Tape Recorders Failed , Realtime mission only with some 40% global coverage. Transmission Tube redundancy available.
SAR Image Mode	Excellent	
SAR Wave Mode	Excellent	
Scatterometer	Fair	Sub System on redundant side
RA & MWR	Excellent	
ATSR	Good	Scan Mirror problem has been overcome by patches on ground
GOME	Good	Calibration lamp problem overcome by using sun measurements
PRARE	Excellent	Reduced surface transponders covering North & South Poles and Europe only; no redundancy

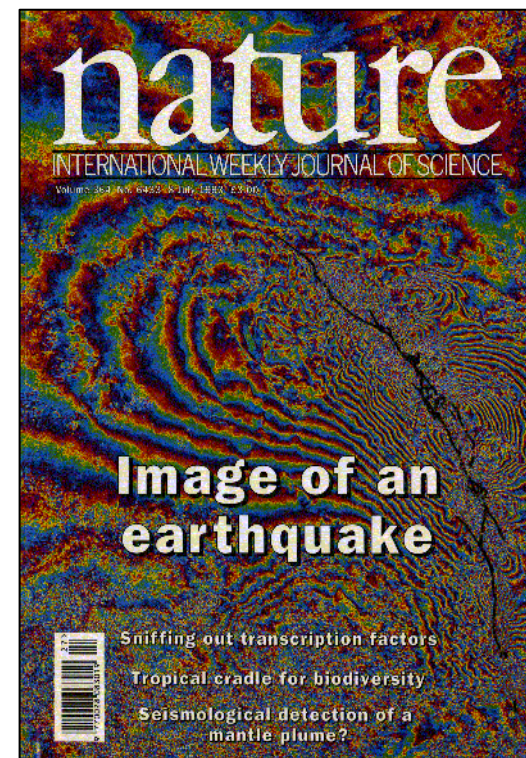
ERS Achievements - Science



ERS and Volcanic activities



ERS and SAR Interferometry



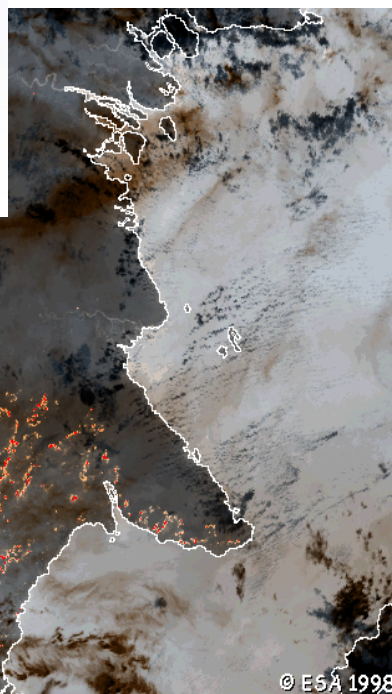
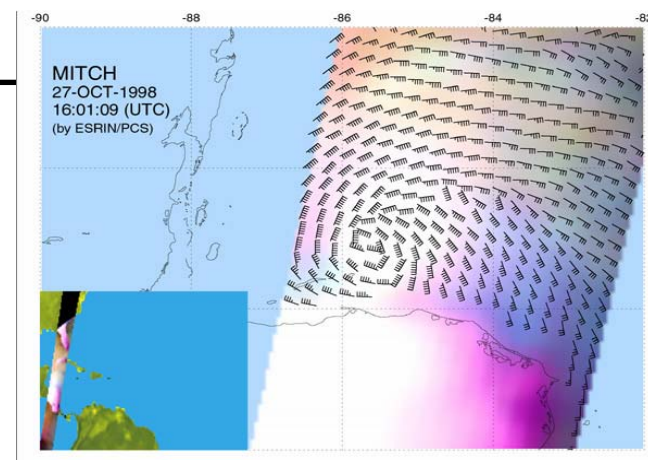
Oceanography and sea ice

ERS Achievements - Public Services

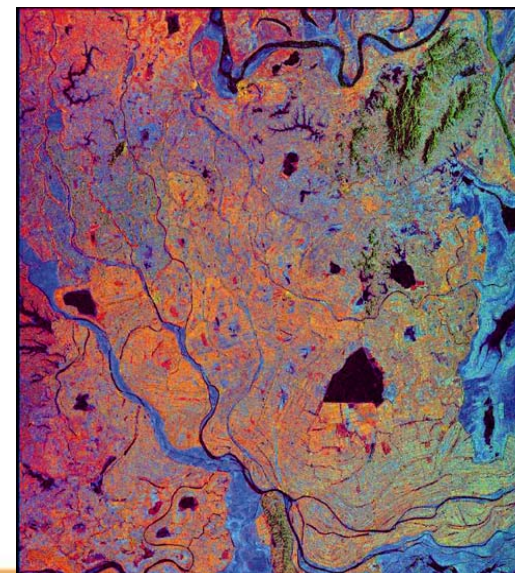


ERS contribution to the
International Charter
Space & Major Disasters

Better forecast
by ECMWF

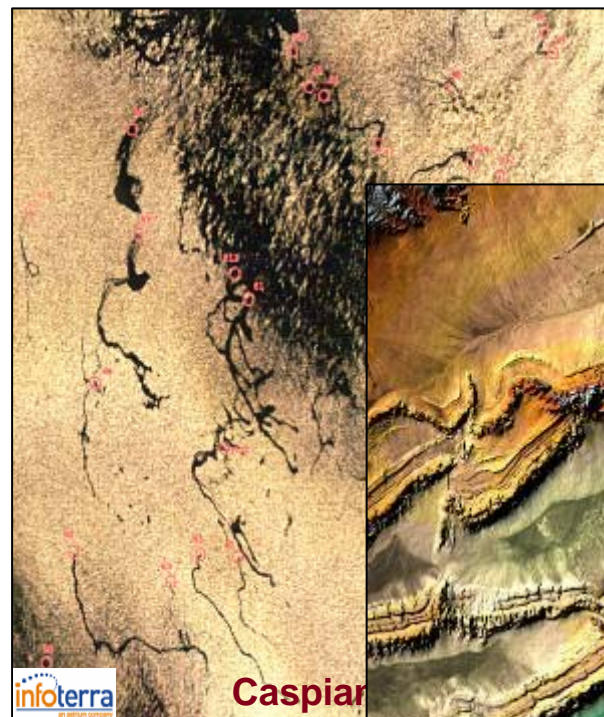


Fire detection
with AATSR

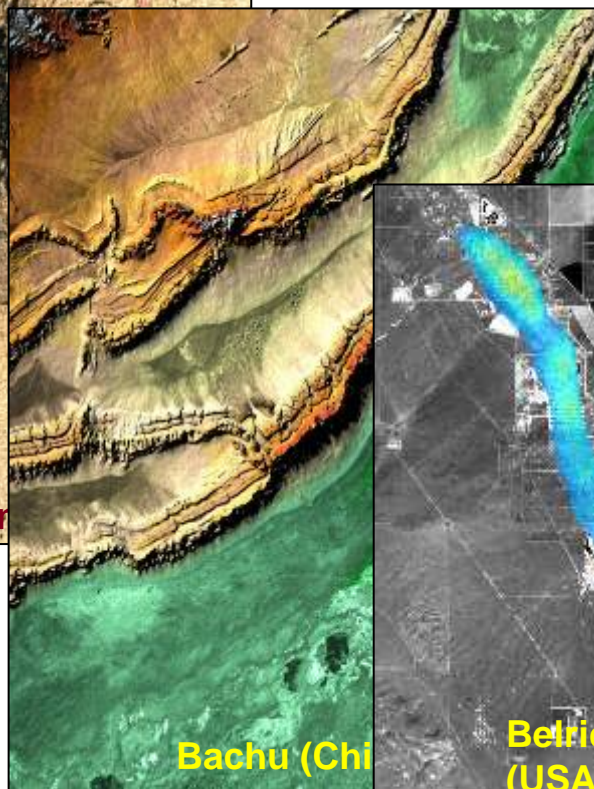


Flood
damage
assessment
Yangtse
river, 1998

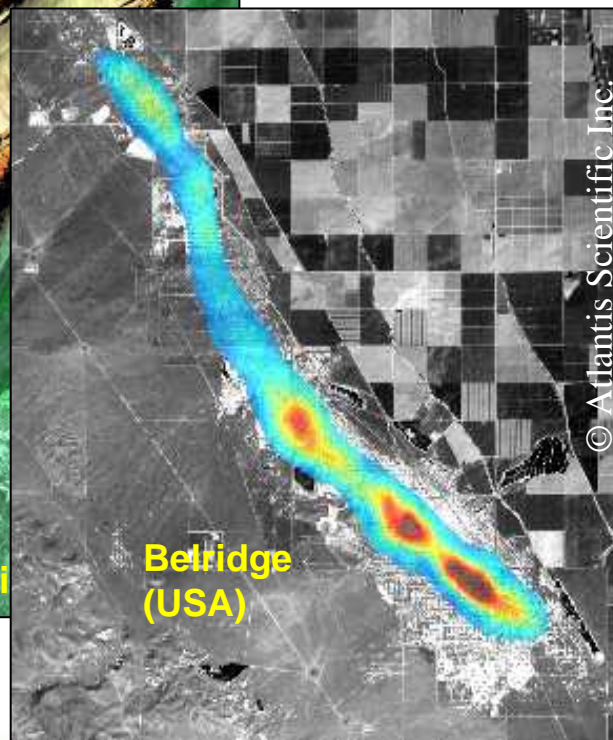
ERS Achievements - Commercial Services



Basin screening for
off-shore exploration

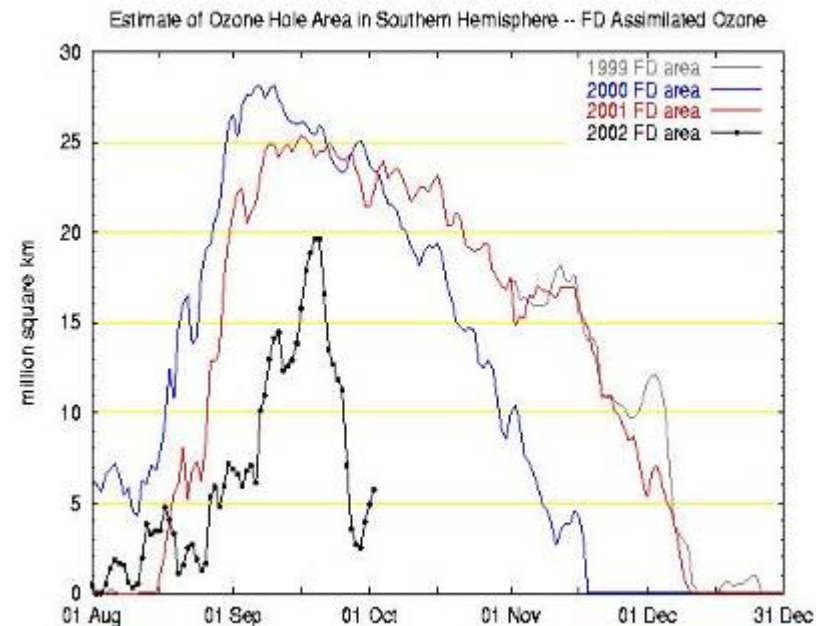
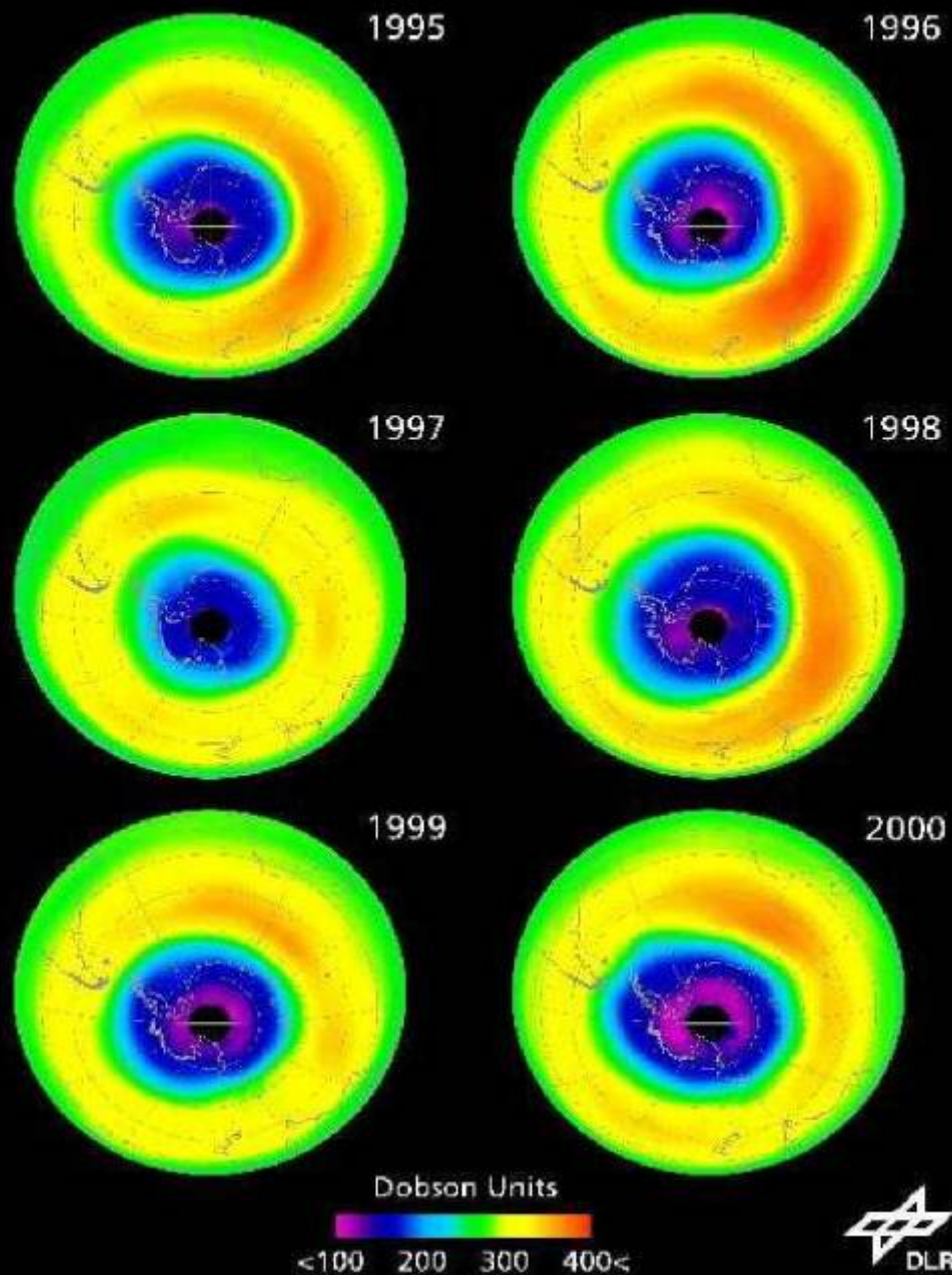


Digital Elevation Models
from Tandem InSAR



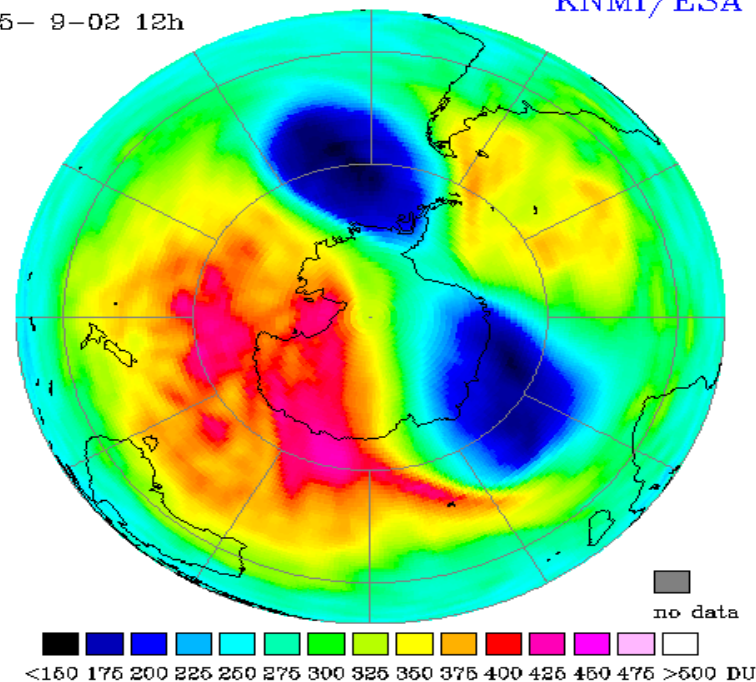
Mineral exploration
(oil fields deformation
rate)

ERS2-GOME Total Ozone Column Monthly Mean September

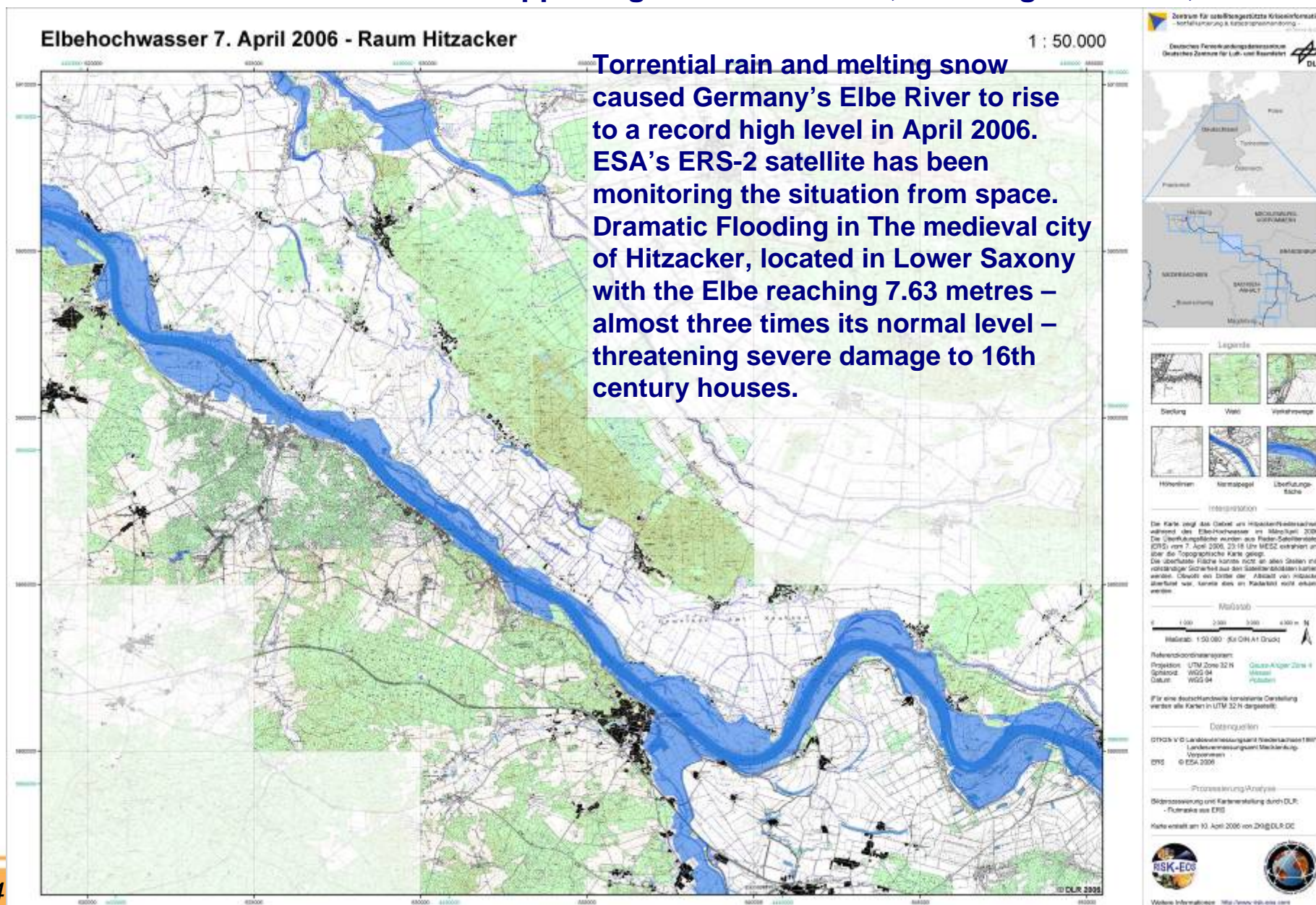


Assimilated GOME total ozone
25- 9-02 12h

KNMI/ESA



ERS-2 supporting Charter Call 117, Flooding river Elbe, Germany





ENVISAT Mission



ENVISAT mission

- ❑ **Largest European satellite & largest worldwide EO satellite:**
 - unique combination of 10 instruments addressing land, ocean, ice and atmosphere studies,
 - instruments working nominally, except MIPAS instrument
- ❑ **Satellite OK with long-term operations capabilities:**
 - 65 % of fuel available (about 5 years)
- ❑ **78 different types of data products**
 - but many more geophysical parameters
- ❑ **250 Gigabytes of data products generated per day**
- ❑ **Nominal lifetime (5 years) ends in March 2007**
 - but operations funding until end 2010





ENVISAT satellite and payload status

Mission elements	Expected evolution	Comments
Service Module	Excellent	
Propulsion and Hydrazine	Fair	Main limiting factor of the mission
Payload Equipment Bay	Excellent	
ASAR	Fair	Sub-system on redundant side
MERIS	Excellent	
AATSR	Excellent	
RA-2	Fair	Recent anomaly with altimetric range measurement On ground correction tables
MWR	Good	
DORIS	Fair	Instrument on redundant side
SCIAMACHY	Excellent	
MIPAS	Bad	Progressive mechanical degradation in non redundant part. Used on campaign basis.
GOMOS	Fair	Instrument on redundant side. New operations scenario is satisfactory.

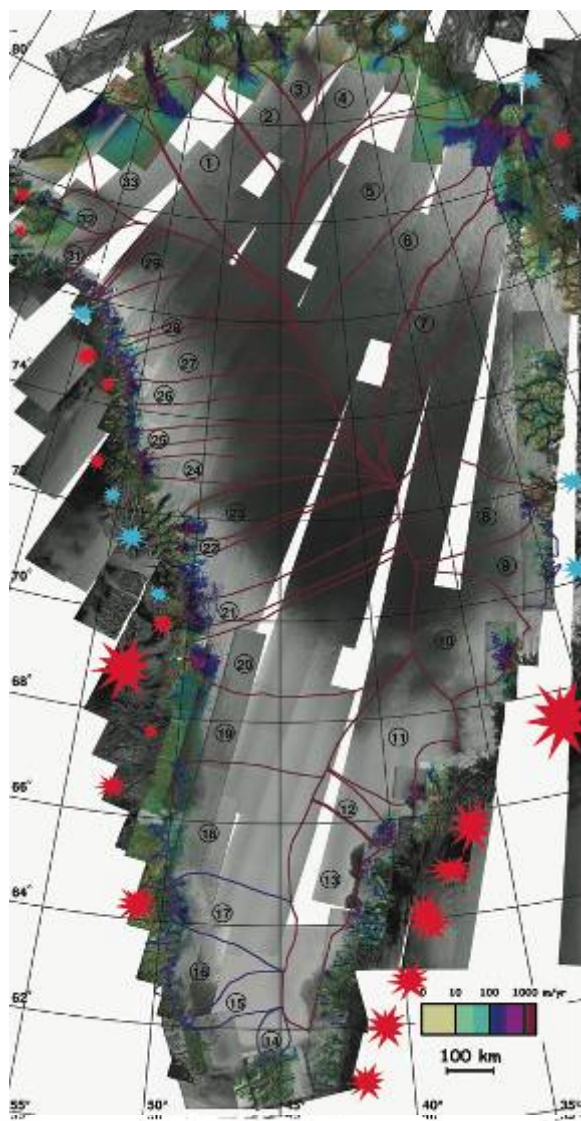


Envisat Symposium: Major Scientific results

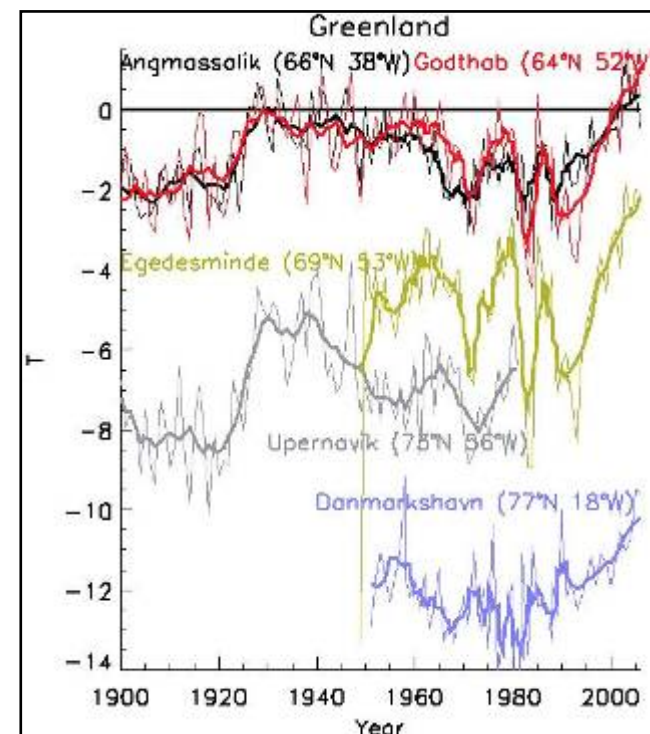
- ❑ **Land ice:** Quantification of increased velocity of glaciers in Greenland , Antarctica, and observation of Greenland ice melting process (ERS/Envisat SAR)
- ❑ **Oceanography:** Confirmation of sea level rise of ~3 mm/year and first time observation regional variations in the Arctic region (ERS/Envisat Altimetry)
- ❑ **Land subsidence:** Quantification of the subsidence of the major dikes in the Netherlands from space (Envisat SAR)
- ❑ **Atmosphere:** First global measurement of greenhouse gases with evidence of fast growing CO2 concentration and strong CH4 seasonal variation (Envisat)
- ❑ **Land resources:** Long term monitoring of vegetation in relation to terrestrial carbon (Envisat/ERS (A)ATSR and MERIS)
- ❑ **Oceanography:** First long term observation of origin and propagation of swell from space (ENVISAT SAR wave mode)

→ Remark: the above first five major results are **related to Climate Change**

Greenland mass balance 1996-2005



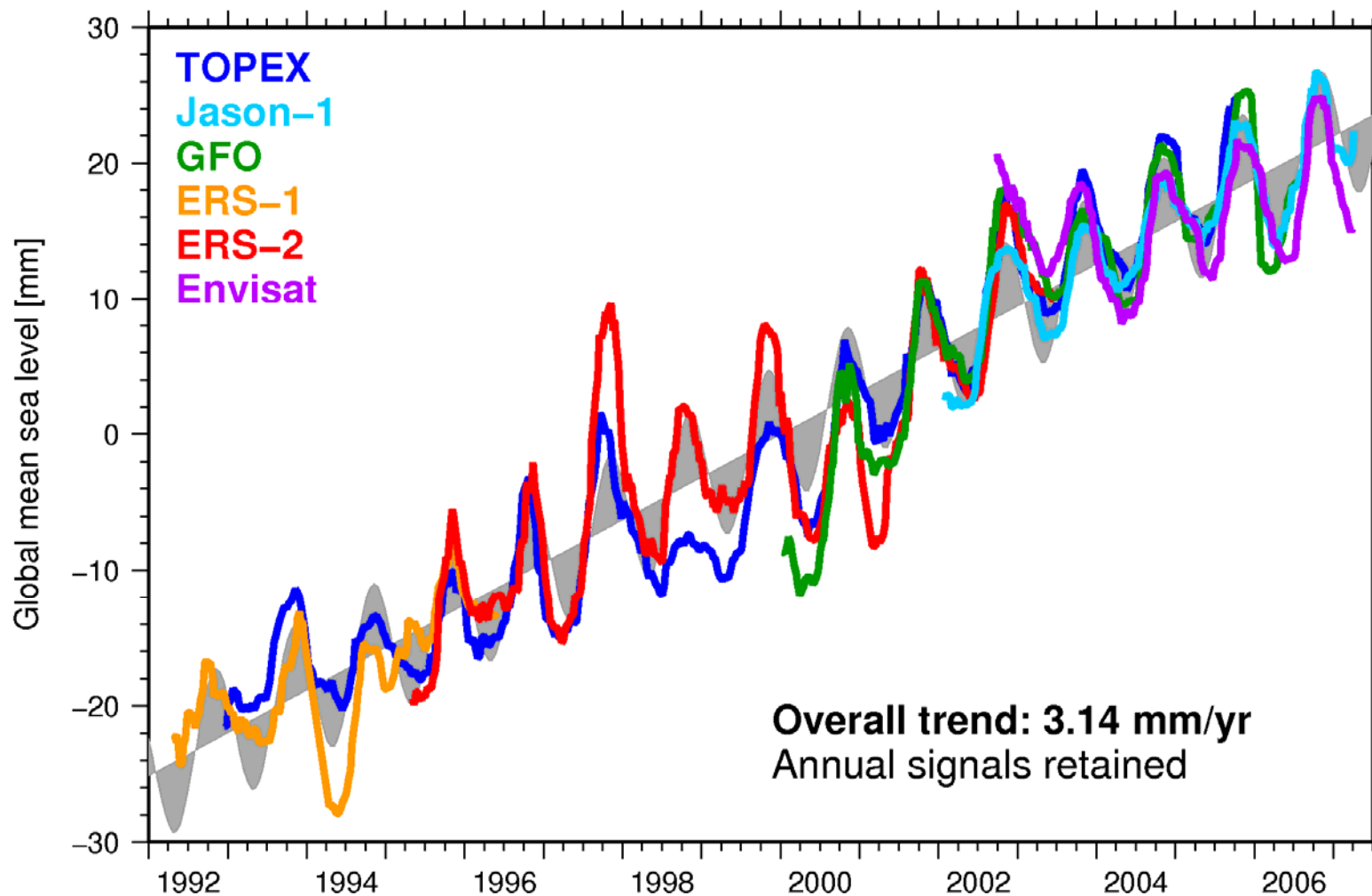
- Mass deficit:
- 83 ± 30 Gt/yr in 1996
- 205 ± 37 Gt/yr in 2005
- 2/3rd of loss due to dynamic thinning.



“Greenland’s contribution to sea level rise has been doubling between 1995 and 2005” – Eric Rignot, JPL

Changes in the Velocity Structure of the Greenland Ice Sheet, Science vol. 311 no. 5763, pp. 986-990
Courtesy of Rignot & Kanagaratnam,

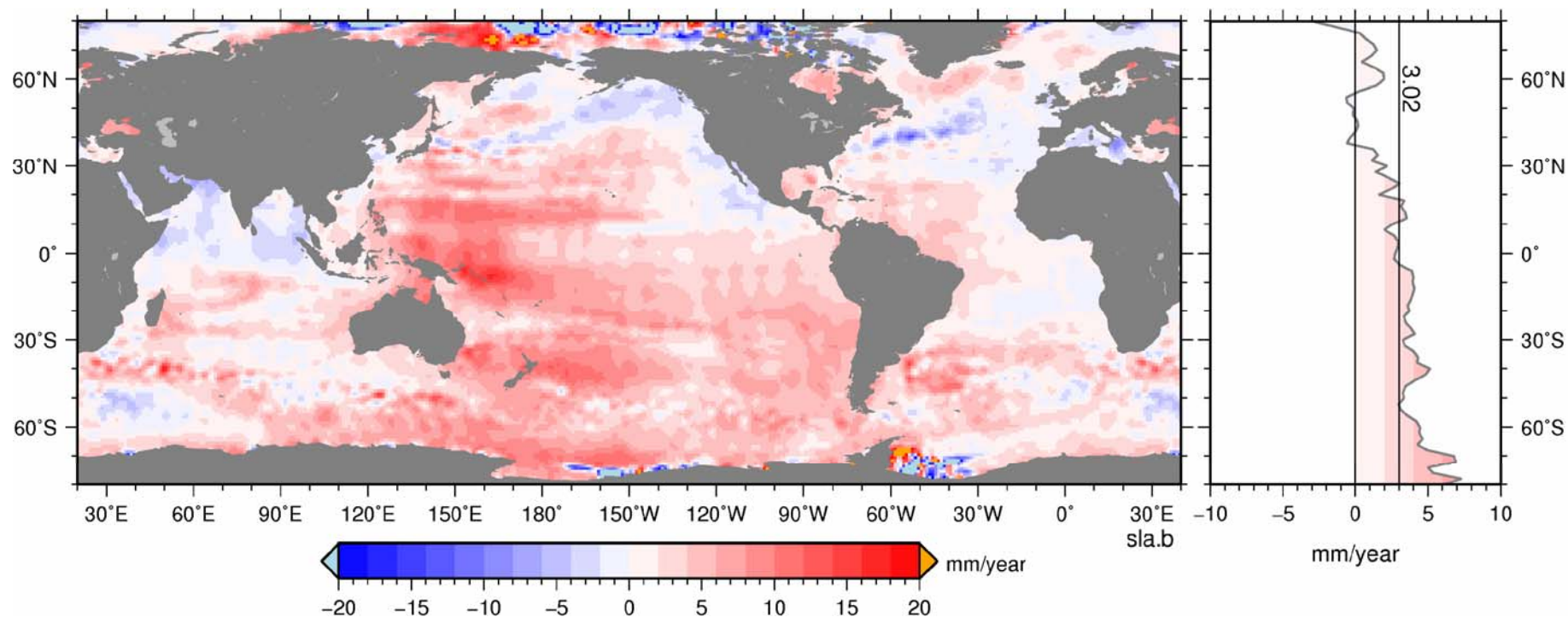
Global Sea Level Change



Global sea level change from ERS-1, ERS-2, ENVISAT altimetry
Courtesy of Remko Scharroo Altimetrics LLC, Cornish, NH

Local Sea Level Change

- ERS-1/2, Envisat (Apr 1992 – Mar 2007)
 - Very consistent features
 - All latitudes show sea level rise, except around 45°N
 - Sea level drop confined to N-Indian Ocean, Kuroshio, Gulfstream

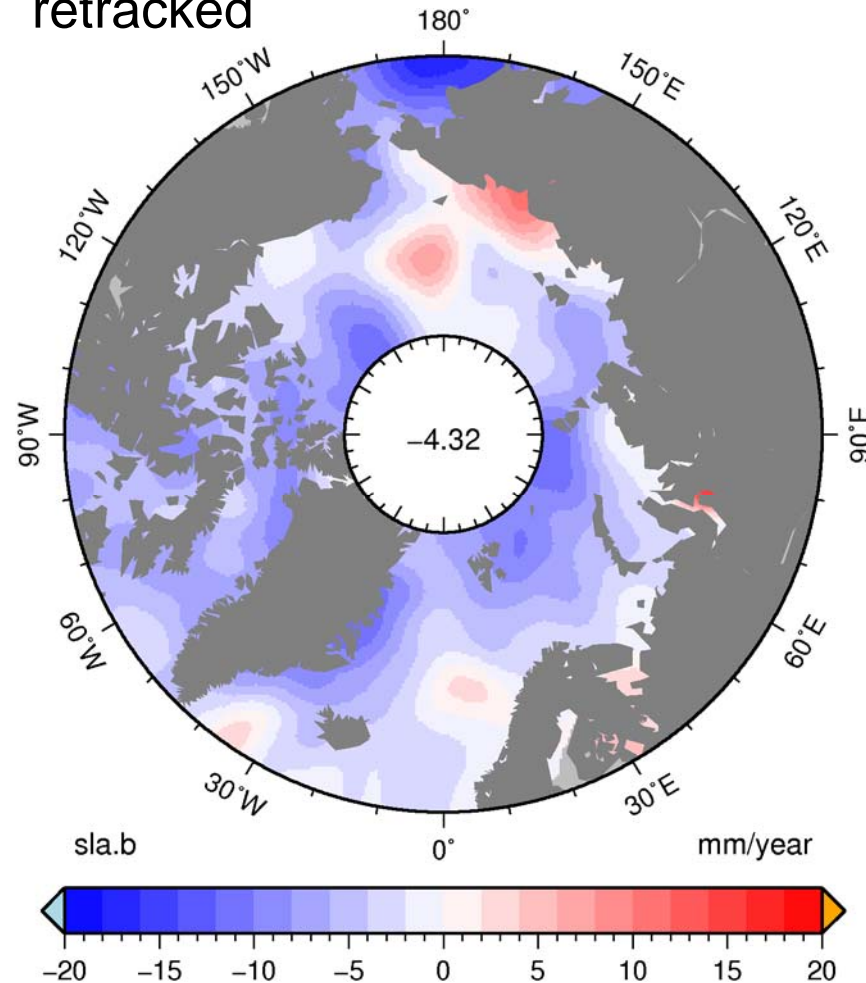


Arctic sea level change from ERS-2 altimetry

*Courtesy of Remko Scharroo Altimetrics LLC, Cornish, NH
Andy Ridout and Seymour Laxon
Centre for Polar Observation & Modelling, University College London, UK*

Arctic Sea level change

retracked



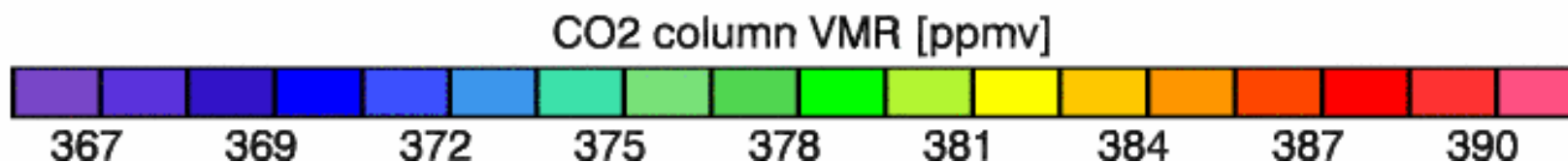
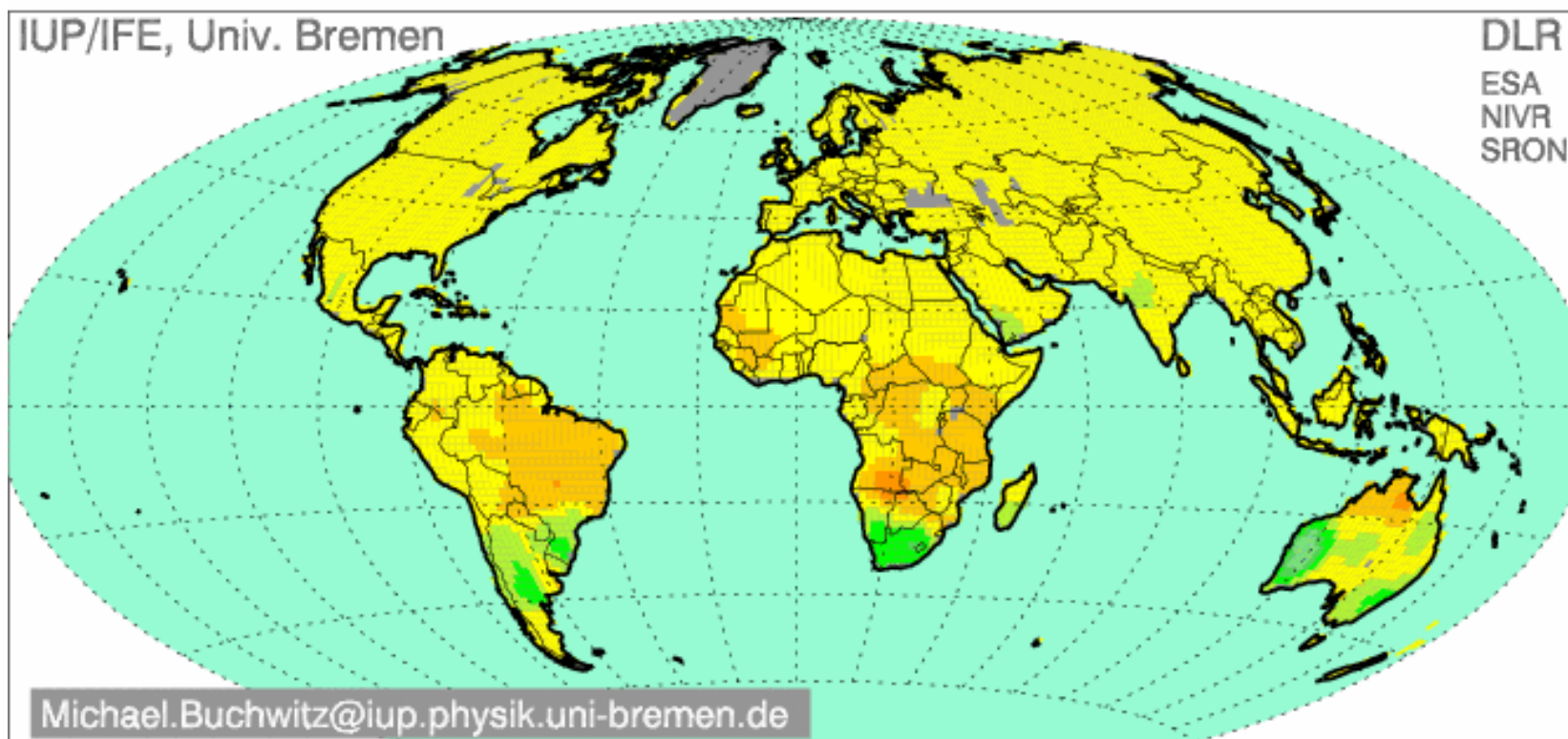
- Arctic sea level change from ERS-2 (1995 to 2003)
 - Scientists have retrieved arctic sea level data in ice infested regions
 - Highest sea level in September is consistent with maximum fresh water
 - Arctic sea level drops by 4 mm/yr
 - Small part due to Glacial Isostatic Adjustment
 - Trend consistent with observations

Arctic sea level change from ERS-2 altimetry

*Courtesy of Remko Scharroo Altimetrics LLC, Cornish, NH & Andy Ridout, Seymour Laxon
Centre for Polar Observation & Modelling, University College London, UK*

Global Monitoring of Carbon dioxide

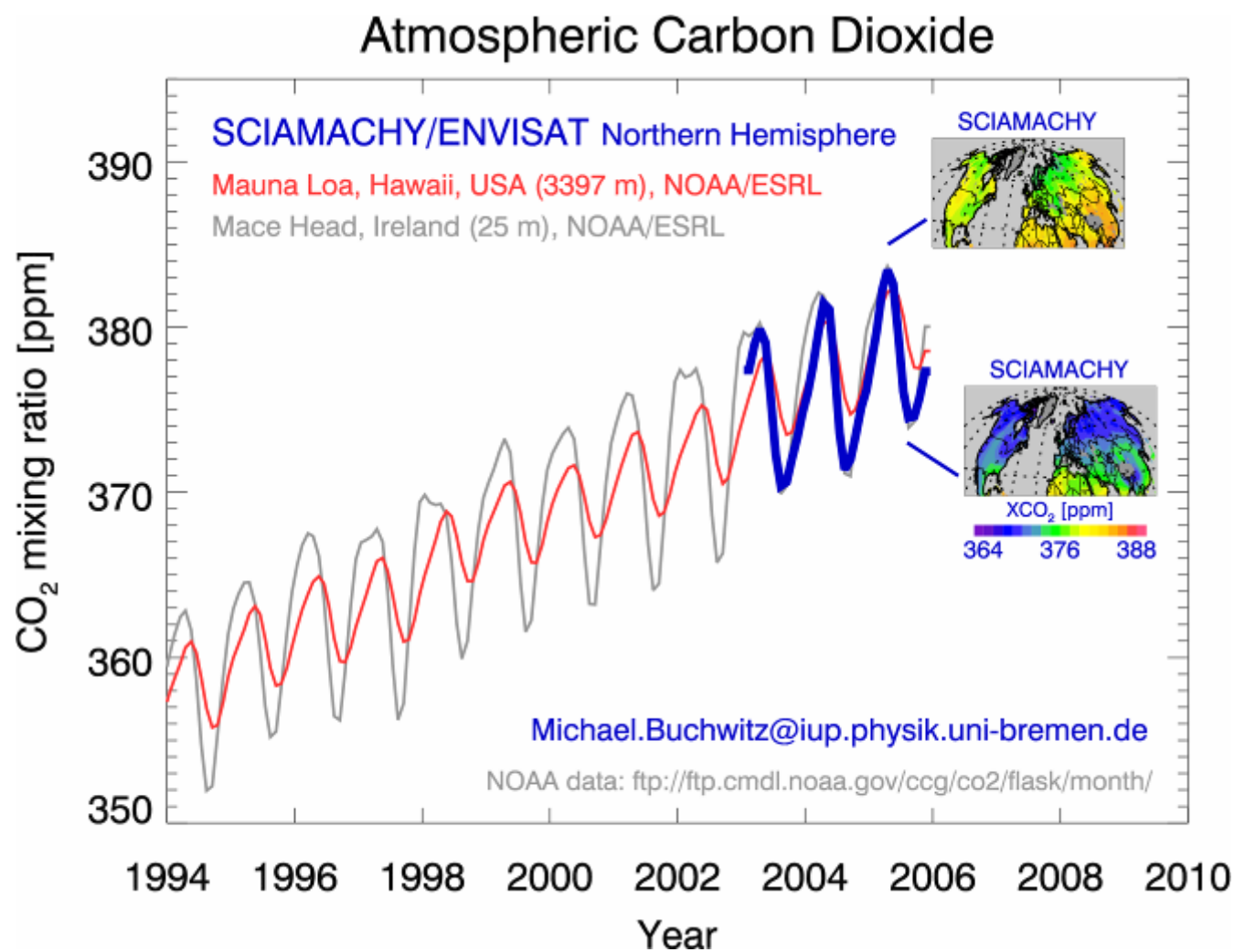
Carbon dioxide SCIAMACHY(WFMDv1.0)/ENVISAT 2005 12



Three Years of SCIAMACHY Carbon Dioxide Averaged Mixing Ratio Measurements
Courtesy of Michael Buchwitz University Bremen



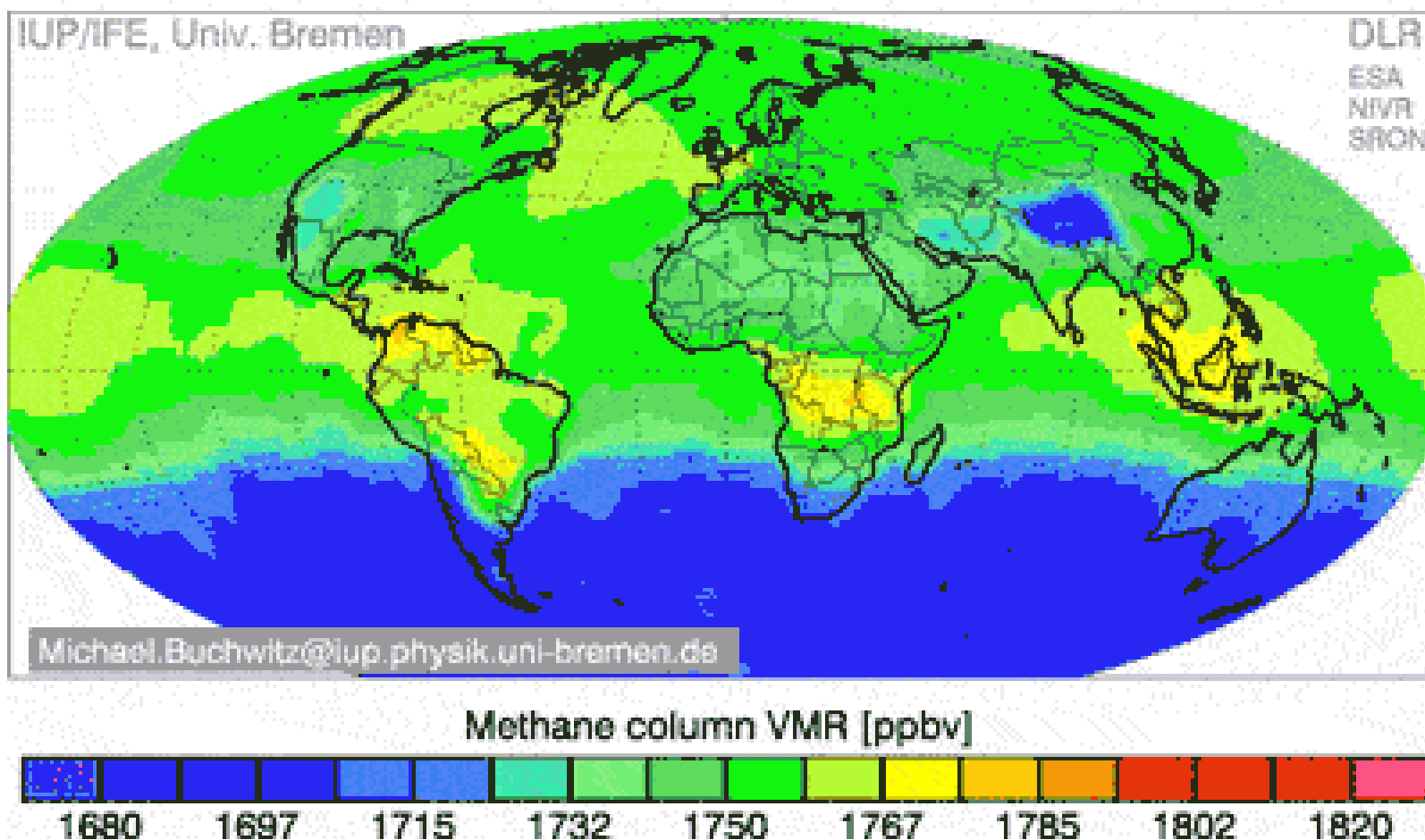
SCIAMACHY carbon dioxide (CO₂) columns





Global Monitoring of Methane

Methane SCIAMACHY(WFMDv1.0)/ENVISAT 2003 01

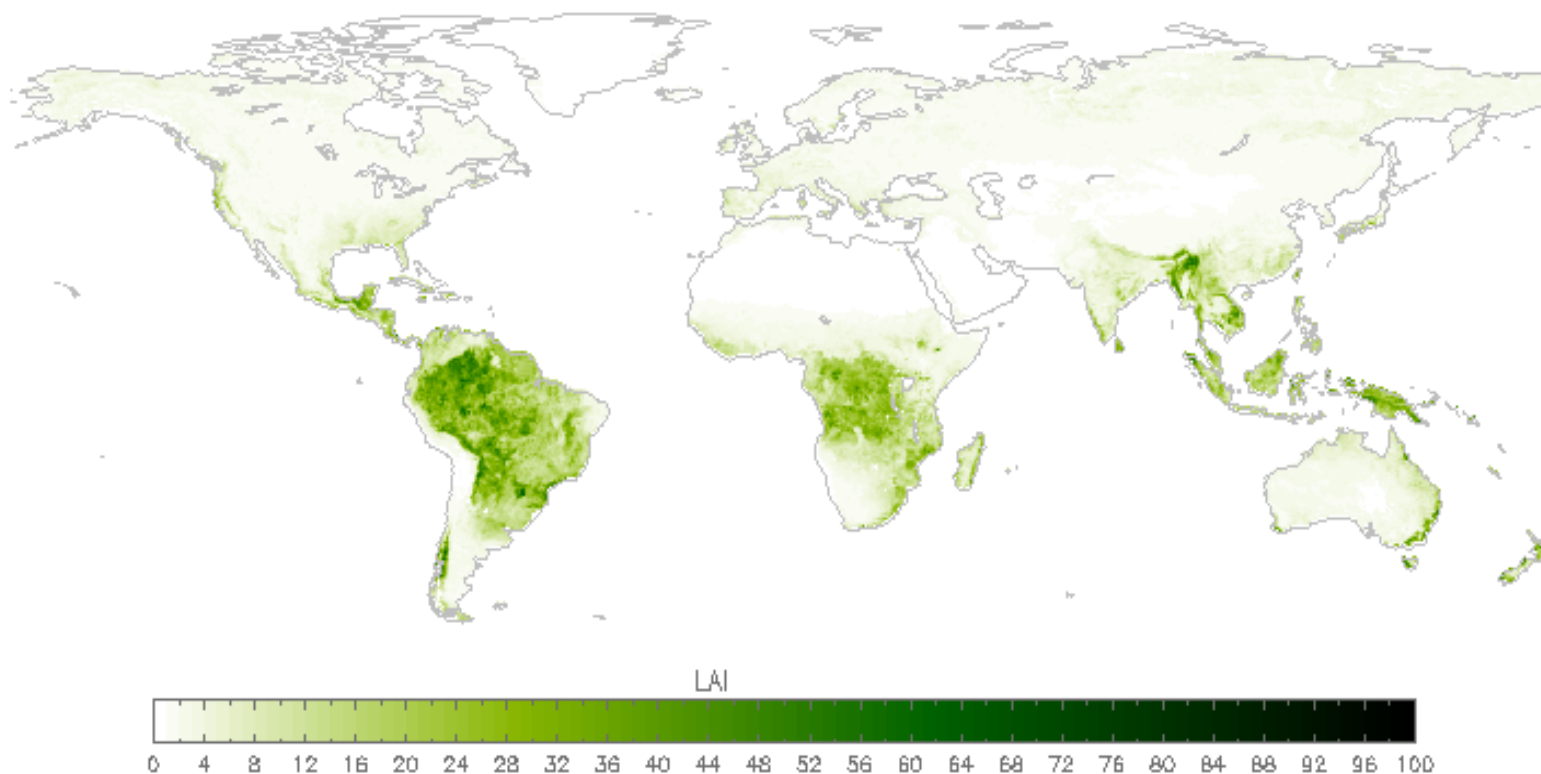


Three Years of SCIAMACHY Methane Column Averaged Mixing Ratio Measurements
Courtesy of Michael Buchwitz University Bremen



Leaf Area Index for global terrestrial carbon studies

January 1999



4 years 1999 to 2002 measurements with ATSR-2, AATSR, MERIS, VEGETATION

*Courtesy of Deng, F. et al , 2006, **Algorithm for global leaf area index retrieval using satellite imagery**, IEEE Transactions on Geoscience and Remote Sensing, 44(8), 2219-2229.*



Earth Explorers

Living Planet Programme

Earth Explorers – Core Missions

- **ESA-led missions to cover the primary research objectives of the Explorer's program:** *Earth interior, physical climate, geosphere & biosphere, atmosphere & marine environment*

GOCE

Earth gravity field
and Geoid
measurements

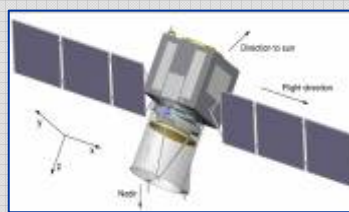
Launch: 2007



ADM-Aeolus

Windspeed
vectors
measurements

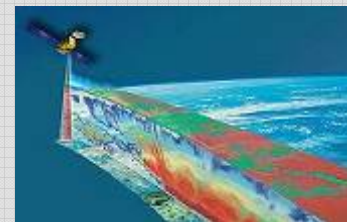
Launch: 2009



EarthCARE

Clouds, Aerosols
& radiation
measurements

Launch: 2012+





ESA's Gravity Mission

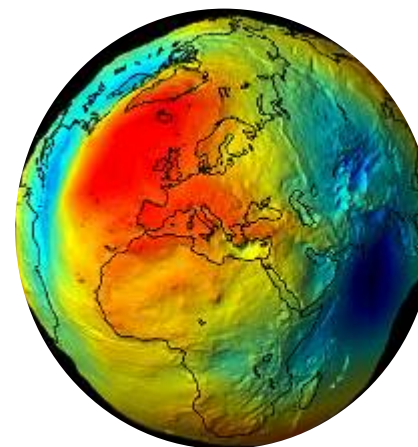


ESA's Gravity Mission

The Gravity field and steady state Ocean Circulation Explorer

Its objectives are to improve understanding of:

- global ocean circulation and transfer of heat
- physics of the Earth's interior (lithosphere & mantle)
- sea level records, topographic processes, evolution of ice sheets and sea level change





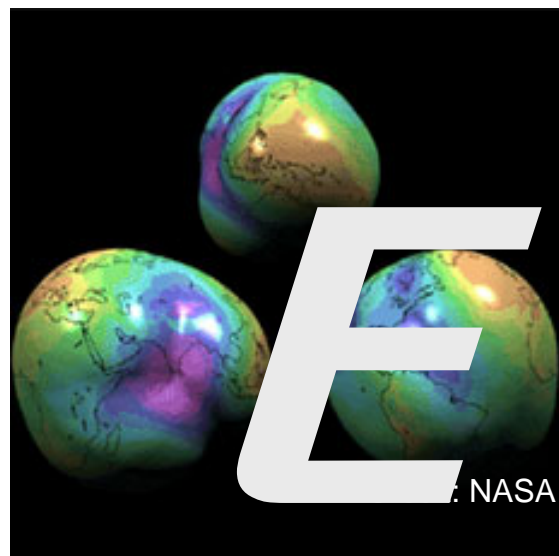
ESA's Gravity Mission

Expected Scientific Output

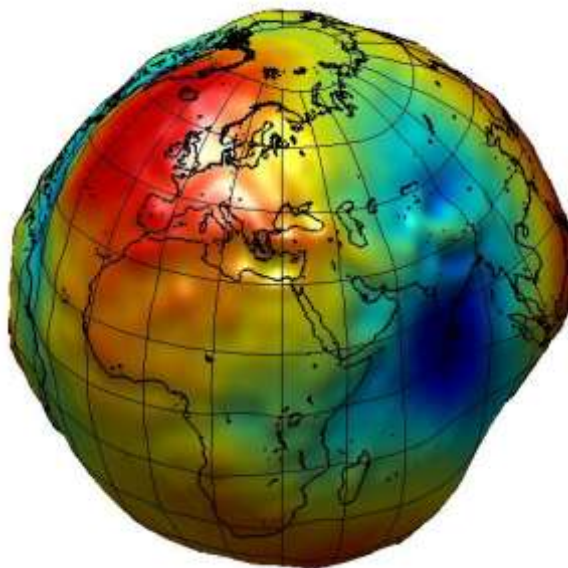
- measurements of the **physics of the Earth's interior** including geodynamics associated with the lithosphere, mantle composition and rheology, uplifting and subduction processes
- **estimate of the marine geoid** for the quantitative determination of absolute ocean currents and their transport of heat and other properties (*in combination with satellite altimetry*)
- a better **global height reference system** for datum connection, which can serve as a reference surface for the study of topographic processes
- estimates of the **thickness of the polar ice sheets** through the combination of bedrock topography derived from gradiometry and ice-sheet surface topography from altimetry

ESA's Gravity Mission

Examples of Scientific Applications



Gravity field map



Global geoid model
*improved understanding of
ocean circulation and energy
distribution*



Global unification
of height systems

ESA's **Wind** Mission

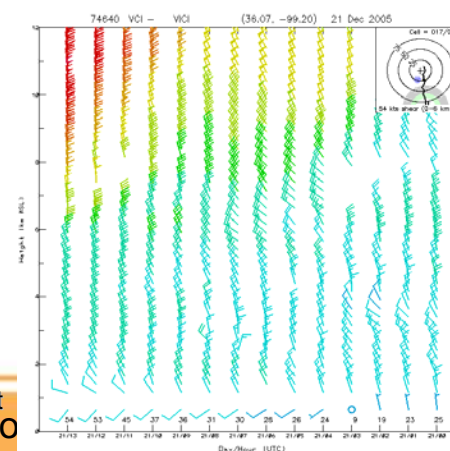


ESA's Wind Mission

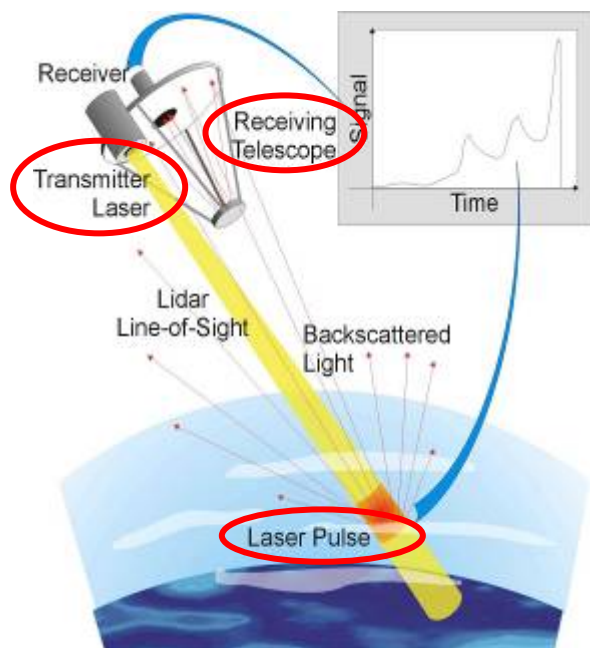
The Earth Explorer Atmospheric Dynamics Mission

Objectives of the ADM-Aeolus mission:

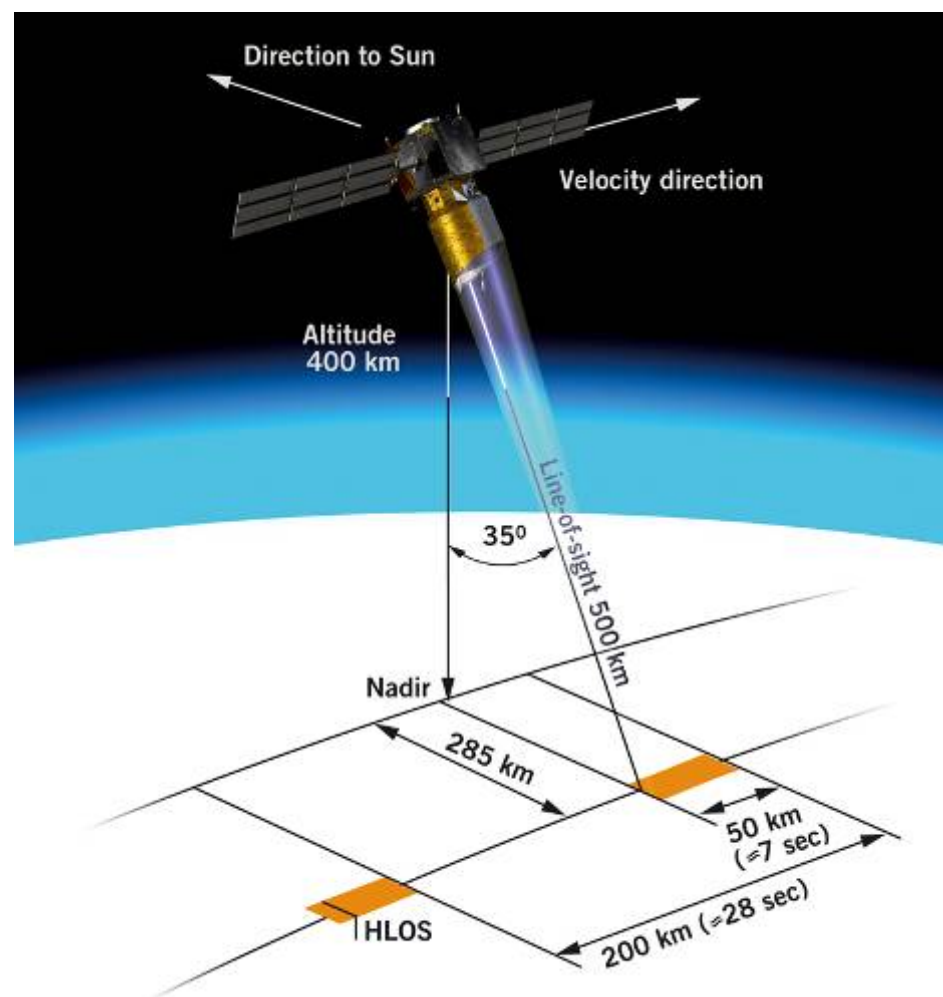
- to provide global observations of wind profiles from space
- to improve the quality of weather forecasting
- to enhance our understanding of atmospheric dynamics and climate processes



Measurement Concept



- Backscatter signal
- Winds are derived from Doppler shift of aerosols **and** molecules along lidar line-of-sight

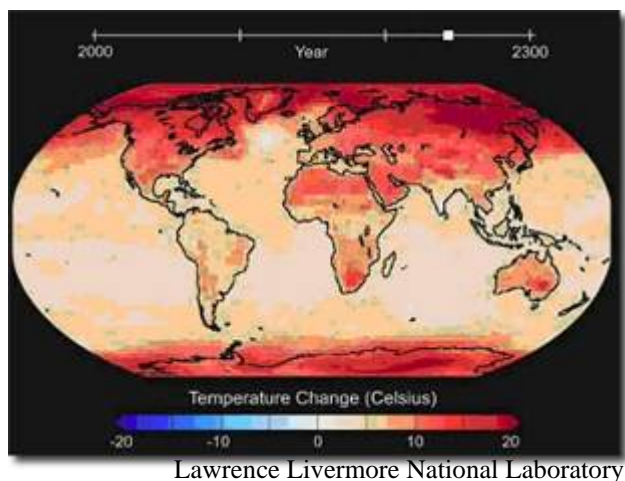


ESA's Wind Mission

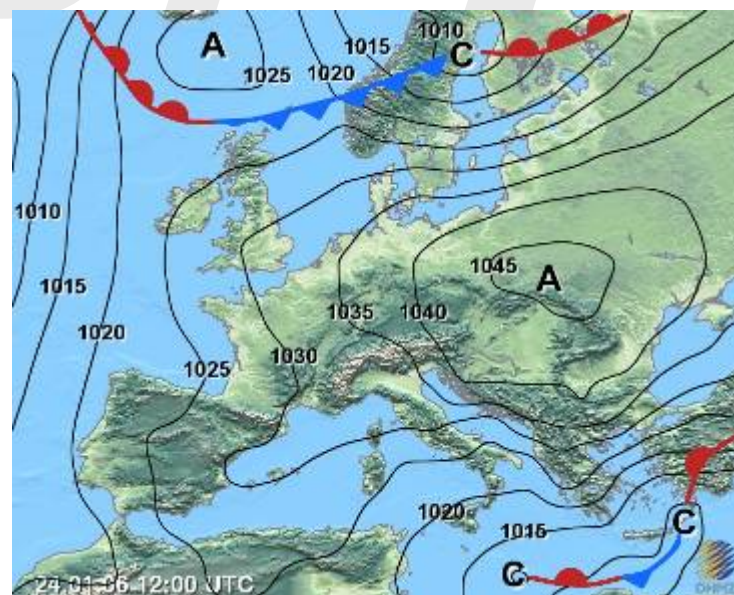
Expected Scientific Output

- measurements of **global three-dimensional wind fields**, giving a more accurate picture of the Earth's global energy budget
- data of **global atmospheric circulation** and related features (precipitation systems, El Niño, Southern Oscillation phenomena), distribution of atmospheric constituents like ozone or aerosol, and stratosphere/troposphere exchange
- Better modelling, and a greater understanding, of **tropical dynamics**; better estimates of the position and intensity of tropical cyclones
- Significant improvement of **short range forecast** of synoptic events; small-scale details of intense wind events will improve for short-range forecasts because of the earlier detection of their development.

Examples of Scientific Applications



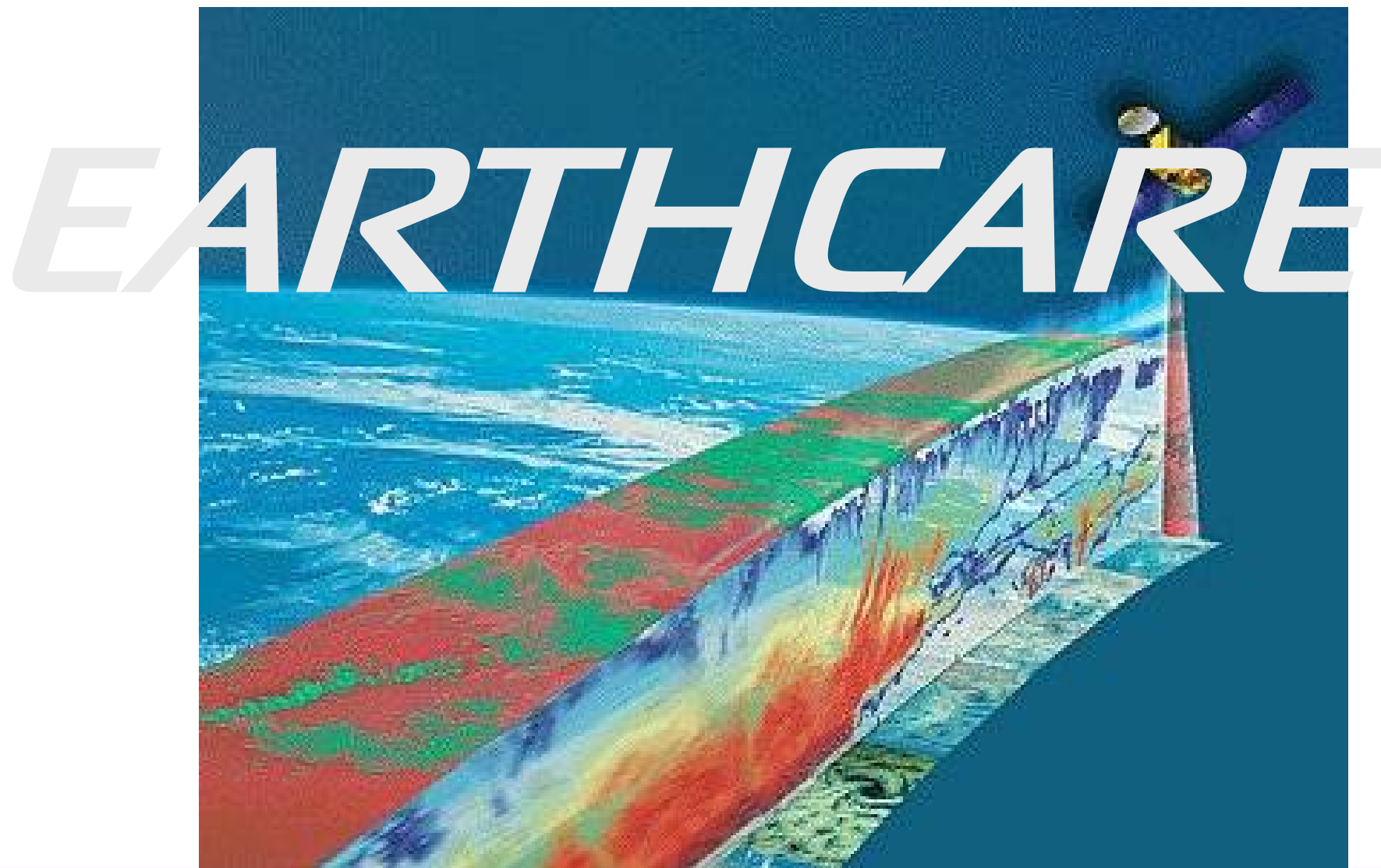
Improved Earth
climate models



Progress in numerical weather
prediction and better operational
forecasting



ESA's **Cloud & Aerosol** Mission



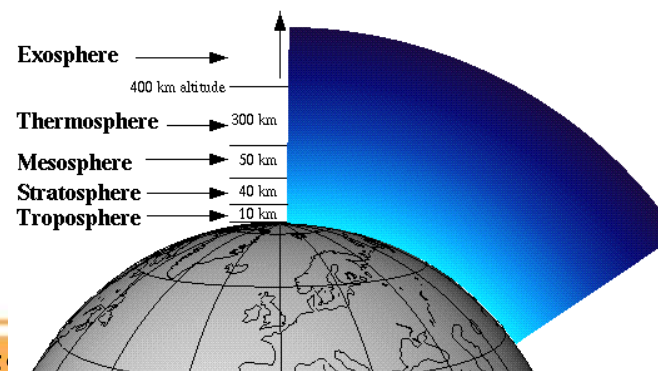
ESA's **Cloud & Aerosol** Mission

The Earth Clouds, Aerosols and Radiation Explorer

EARTHCARE

EarthCARE is a joint European (ESA) – Japanese (JAXA) mission with the objective:

- to quantify and thus improve understanding of cloud-aerosol-radiation interactions
- to include such parameters correctly and reliably in climate and weather prediction models

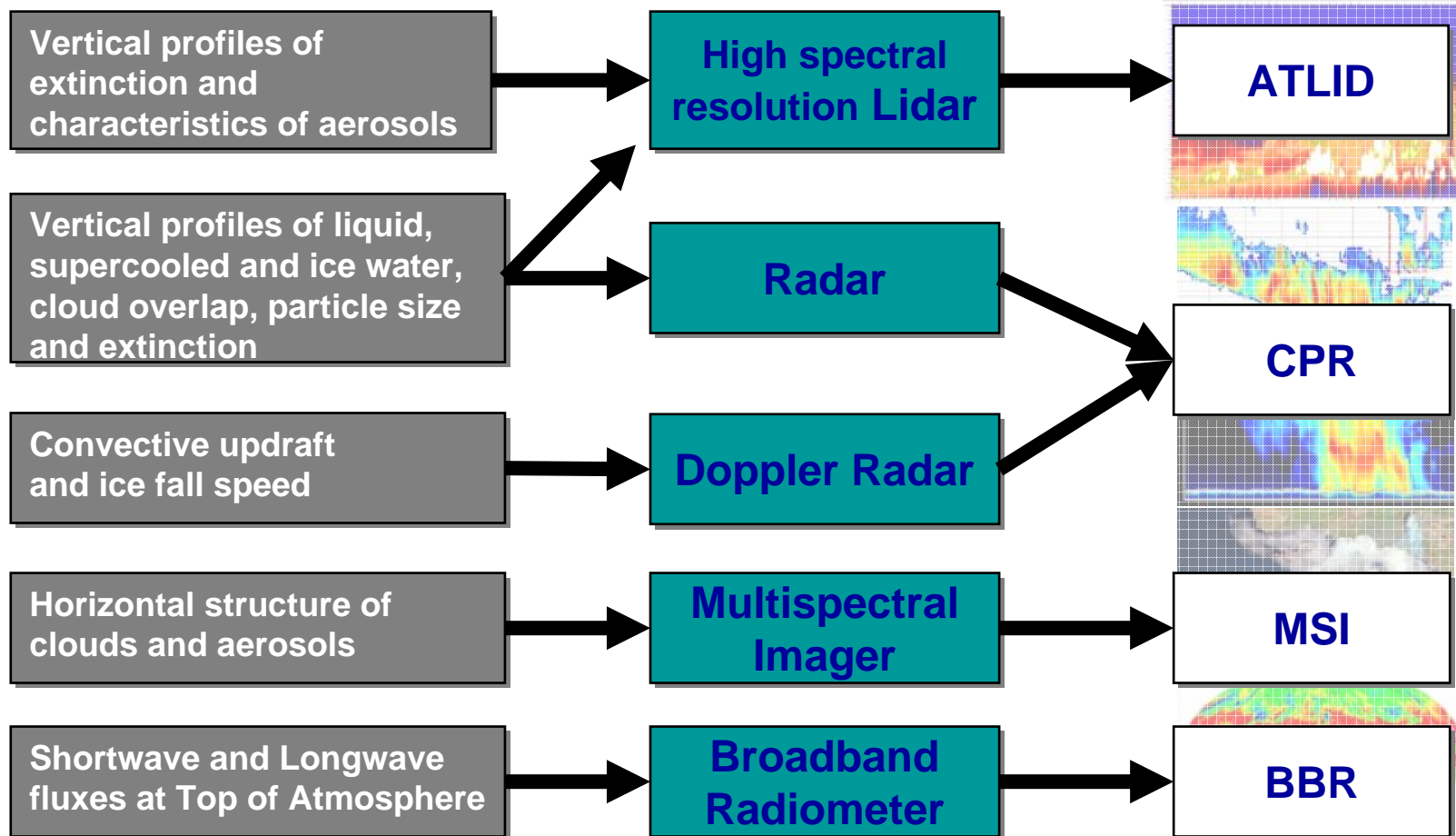




Atmospheric data

Techniques

EarthCARE instruments



Temperature and humidity from operational analysis

ESA's **Cloud & Aerosol** Mission

Expected Scientific Output

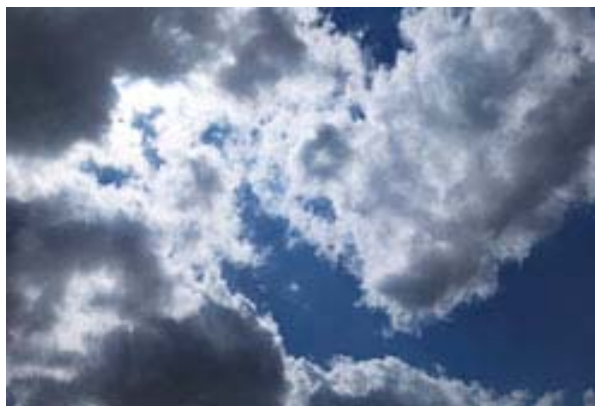
EARTHCARE

- Vertical **profiles of natural and anthropogenic aerosols** on a global scale, their radiative properties and interaction with clouds
- Vertical **distribution of atmospheric liquid water and ice** on a global scale, their transport by clouds and radiative impact
- Cloud overlap in the vertical, cloud-precipitation interactions and the **characteristics of vertical motion within clouds**
- The **profiles of atmospheric radiative heating and cooling** through a combination of retrieved aerosol and cloud properties

ESA's **Cloud & Aerosol** Mission

Example of Scientific Applications

EARTHCARE



More reliable climate predictions and better weather forecasts through the improved representation of processes involving clouds, aerosol and radiation

Living Planet Programme

Earth Explorers – Opportunity Missions

- **Smaller missions with specific targets:** *Instrument provision to other programmes, research and technology demonstration (incl. new observing techniques)*

SMOS

Soil moisture and ocean salinity measurements

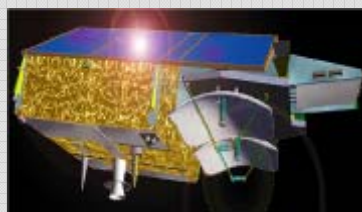
Launch: 2008



Cryosat-2

Ice elevation and ice thickness measurements

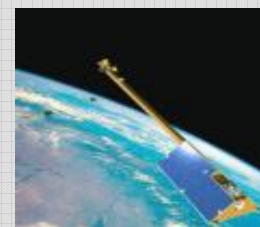
Launch: 2009



SWARM

Earth magnetic field & Earth core dynamics meas.

Launch: 2009+



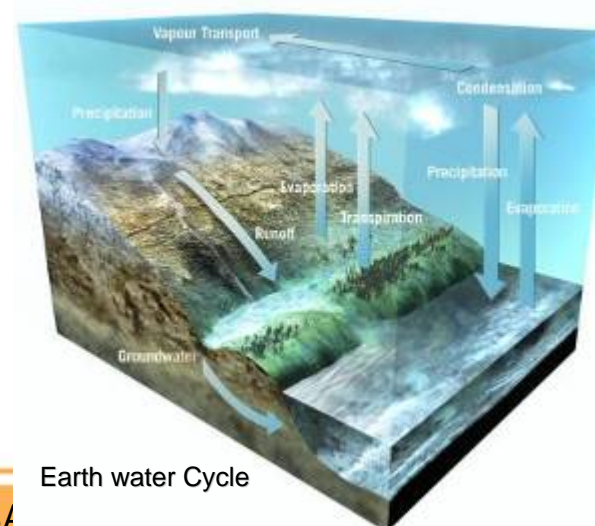
ESA's **Water** Mission



The Soil Moisture and Ocean Salinity Mission

Its objectives are to:

- Provide global maps of soil moisture and ocean salinity for hydrological studies
- Advance our understanding of the freshwater cycle
- Add to the improvement of climate, weather and extreme-event forecasting



Earth water Cycle

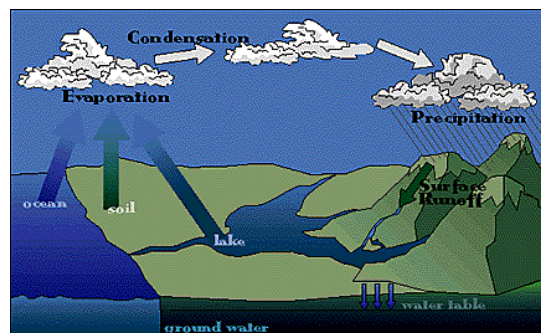
Expected Scientific Output

- Global monitoring of soil moisture over land surfaces with specified accuracy, sensitivity, spatial resolution, spatial coverage and temporal coverage
- Global monitoring of surface salinity over the oceans with specified accuracy, sensitivity, spatial resolution, spatial coverage and temporal coverage
- Improvement of the characterisation of ice and snow covered surfaces

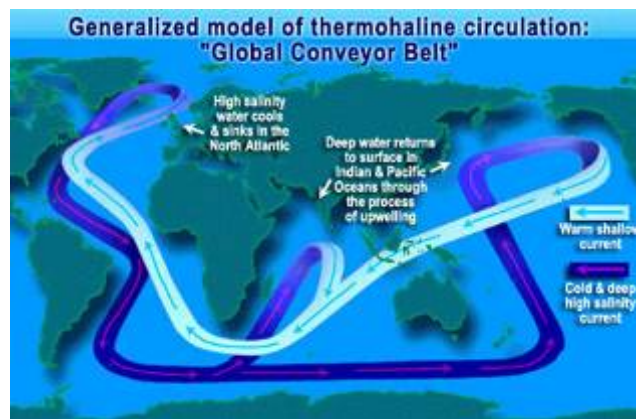
In order to:

- advance climatological, oceanographic, meteorological, hydrological, agronomical and glaciological science
- assess the potential of such measurements to contribute to improving the management of water resources

Examples of Scientific Applications



Improved models
of the global water
cycle



Monitoring and
modelling of ocean
circulation



Improved
management of
water resources

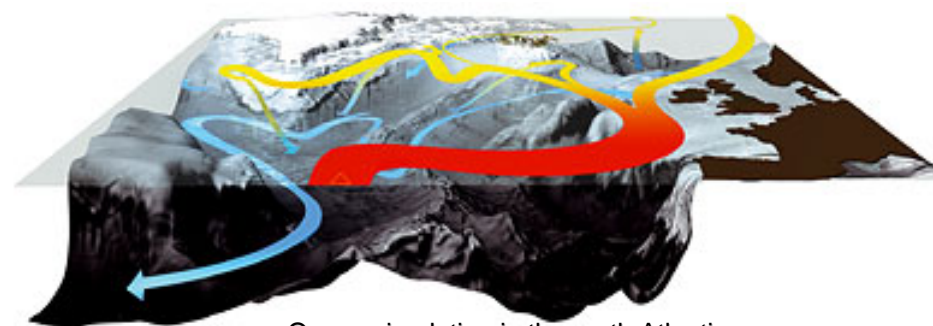
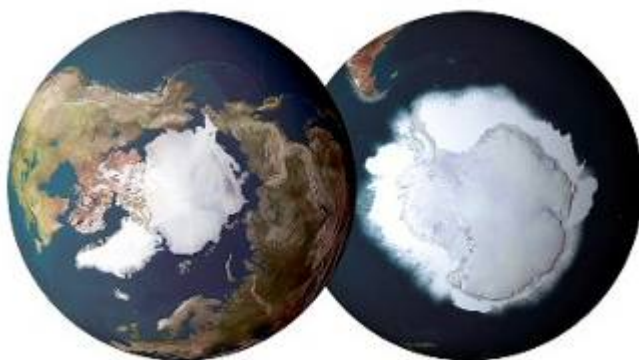
ESA's Ice Mission



Cryosat – the ice mission of ESA

Its objectives are to improve understanding of:

- Thickness and mass fluctuations of the Earth's continental ice shields and marine ice cover
- To quantify rates of thinning and thickening of ice due to climate variations



Ocean circulation in the north Atlantic

Expected Scientific Output

- regional **trends in Arctic perennial sea-ice thickness and mass**
- Determination of the **contribution of Antarctic and Greenland ice sheets to mean global sea level rise**
- the **seasonal cycle** and inter-annual variability of Arctic and Antarctic sea-ice mass and thickness
- the variation in the thickness of the Earth's **ice caps and glaciers**

ESA's **Magnetic Field** Mission



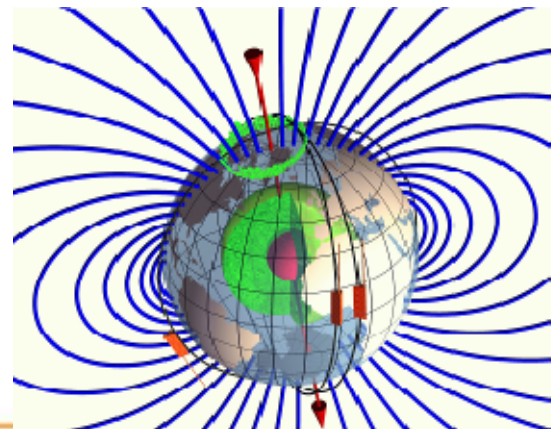


ESA's Magnetic Field Mission

The Earth's Magnetic Field and Environment Explorers

Its objectives of the SWARM constellation are:

- To provide the best-ever survey of the Earth's geomagnetic field and its variation in time
- To Use of the data obtained to gain new insight into the Earth's interior and climate





ESA's **Magnetic Field** Mission

Expected Scientific Output

- provide the **best-ever survey of the geo-magnetic field** and its temporal evolution
- gain **new insights into the Earth system by improving the understanding of the Earth's interior and climate**
- measurement of the strength, variation and direction of the magnetic field, complemented by precise navigation, accelerometer and electric field measurements



Six new Earth Explorer missions selected for further study



1. **BIOMASS** – to take global measurements of forest biomass.
2. **TRAQ** (TRopospheric composition and Air Quality) - to monitor air quality and long-range transport of air pollutants.
3. **PREMIER** (PRocess Exploration through Measurements of Infrared and millimetre-wave Emitted Radiation) – to understand processes that link trace gases, radiation, chemistry and climate in the atmosphere.
4. **FLEX** (FLuorescence EXplorer) – to observe global photosynthesis through the measurement of fluorescence.
5. **A-SCOPE** (Advanced Space Carbon and Climate Observation of Planet Earth) – to improve our understanding of the global carbon cycle and regional carbon dioxide fluxes.
6. **CoReH2O** (Cold Regions Hydrology High-resolution Observatory – to make detailed observations of key snow, ice and water cycle characteristics.



GMES & GEOSS

GMES

Global Monitoring for Environment and Security (GMES)



European autonomy in data sources for environment
and security monitoring

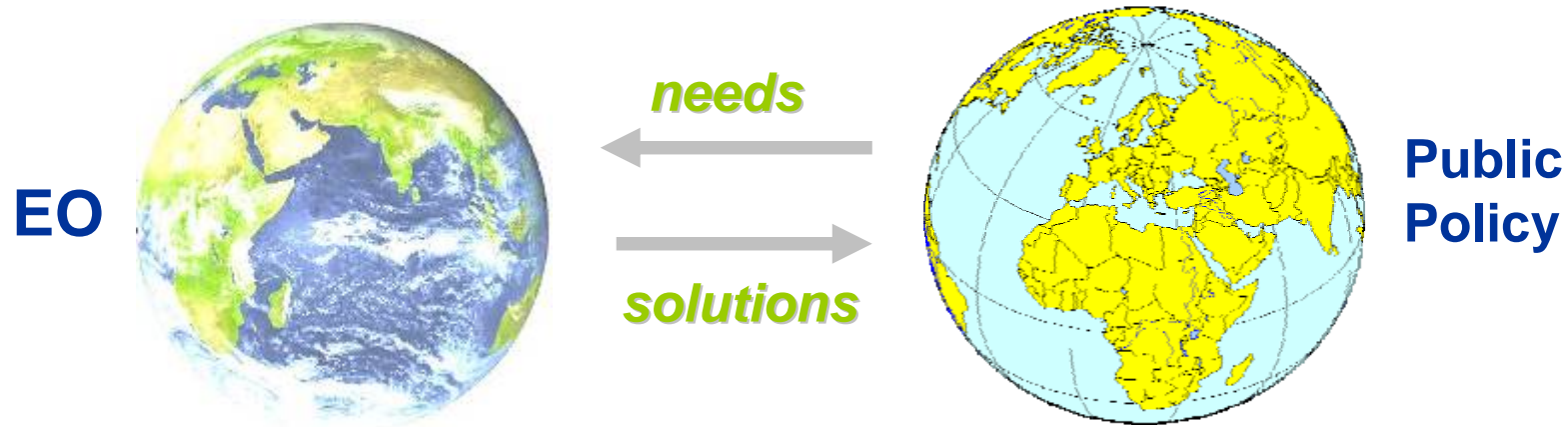
and

The European contribution to the Global Earth
Observation System of Systems (GEOSS)

GMES



Global Monitoring for Environment and Security



A joint initiative of ESA and the European Union

“to respond to the need to establish, by 2008, a European Capacity for Global Monitoring of Environment and Security to support the public policy maker’s need for global access to reliable, accurate and up-to-date information on issues of environment and security”

EC Communication COM(2001)264, 15 April 2001

From research to services

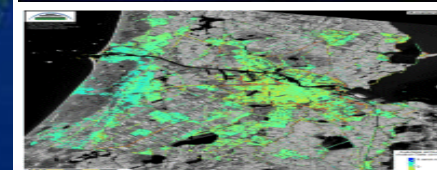
GMES Services

Prime objectives:

- Support European policies on environment and security
- Future EO operational systems to benefit Europe's citizens

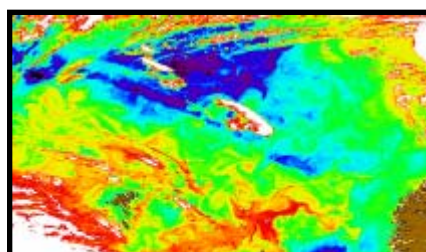
GMES services must fulfill:

- Availability
- Reliability
- Affordability

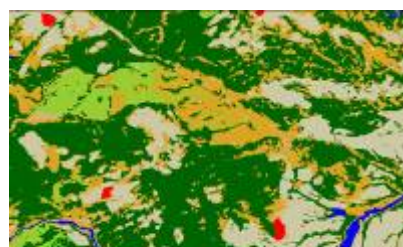


Services

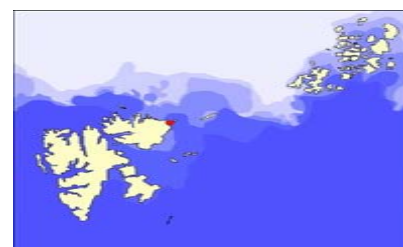
Initial GMES Services



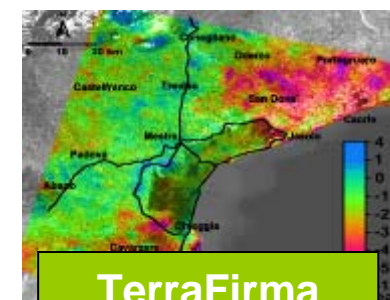
MARCOAST



Forest Monitoring



PolarView



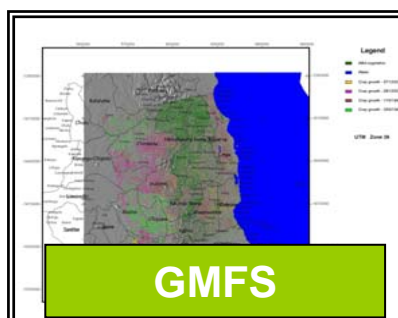
TerraFirma



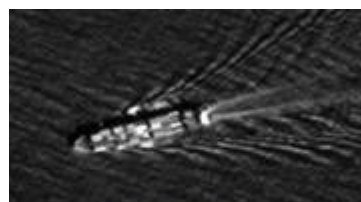
RISK-EOS



GSE Land



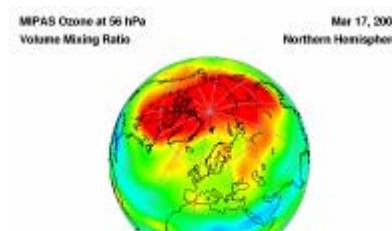
GMFS



MARISS



RESPOND



PROMOTE

**100 M€ by ESA
MS**

**Period 2003-
2008 (2009)**

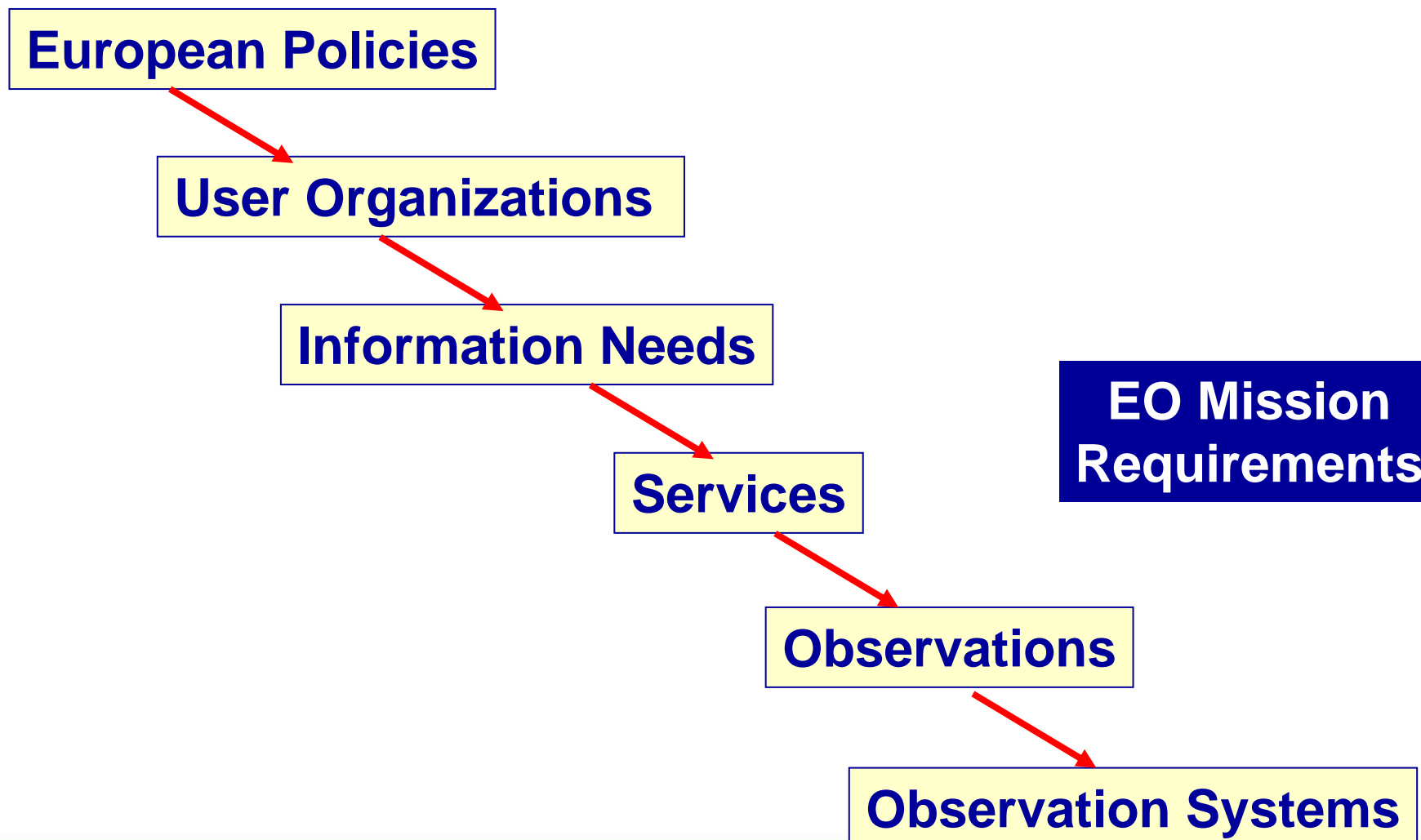
**300+ user
organisations**

**EC has
invested
another 100 M€**

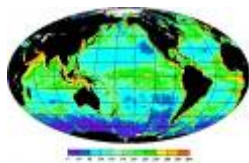
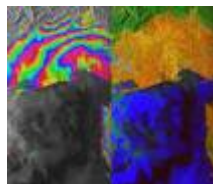


GMES Space Component

System specifications derived from end user needs



Sentinel Missions

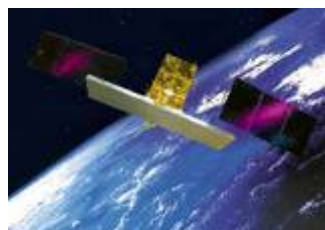


- **Sentinel 1 – SAR imaging**
 - All weather, day/night applications, interferometry, ocean/ice/land
- **Sentinel 2 – Superspectral imaging**
 - Continuity of Landsat, SPOT - type of data for land mapping
- **Sentinel 3 – Ocean monitoring**
 - Wide-swath ocean color, surface temperature and land mission & radar altimeter
- **Sentinel 4 – Geostationary atmospheric**
 - Atmospheric composition monitoring, trans-boundary pollution
- **Sentinel 5 – Low-orbit atmospheric**
 - Atmospheric composition monitoring

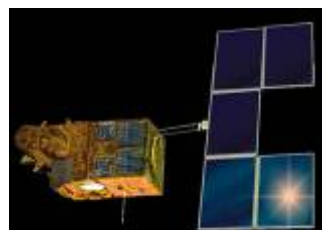
Sentinels provide continuity of ERS, ENVISAT, SPOT missions

GMES: Joint Infrastructure

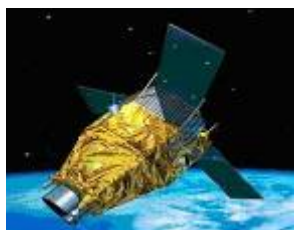
National, Eumetsat and Third Party Missions will also contribute to GMES



CosmoSkymed



SPOT



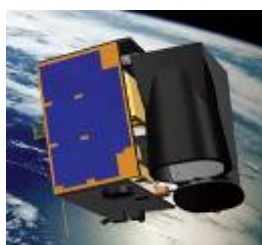
Pleiades



Jason-2



Radarsat



TopSat



Terrasar-X



RapidEye



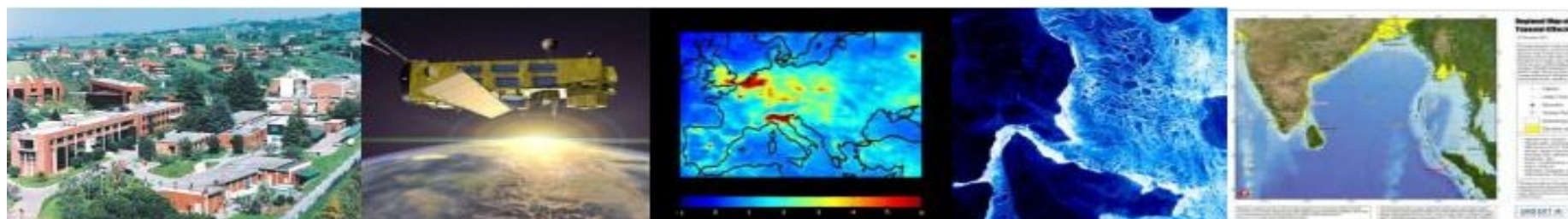
UK-DMC



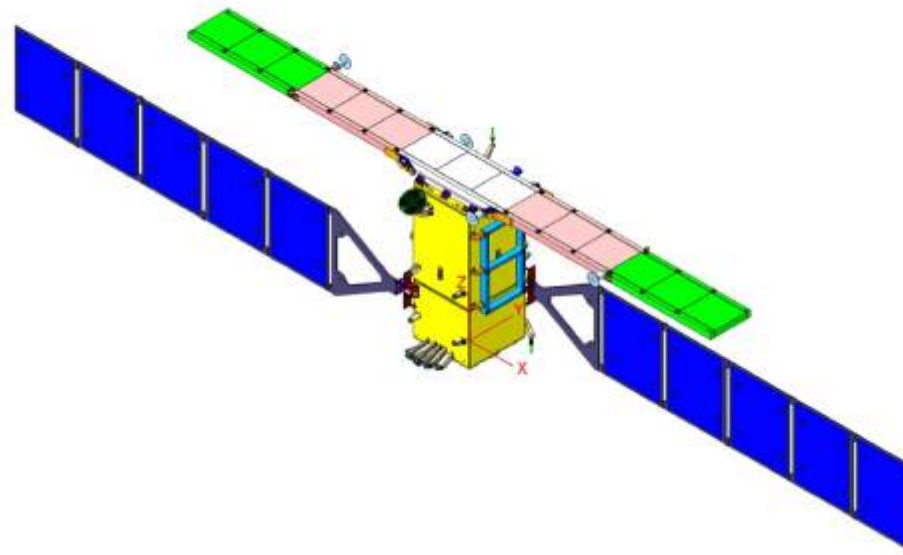
METOP



GMES Space Component Sentinel-1, -2 and -3



Sentinel-1



- European Radar Observatory: C-band Synthetic Aperture Radar
- Main operational mode: SAR imaging (Interferometric Wide Swath)
- Prime task: Continuity of operational SAR applications including interferometry



Sentinel-1 Services (1)

GMES Consolidated Service	Sentinel-1 Contribution
Polar Environment Services	<ul style="list-style-type: none"> •Glacier and Snow Monitoring •Iceberg Monitoring •Sea Ice Monitoring •Oil Discharge Monitoring •Near Shore Ice Complex •Land Monitoring •Lake Ice Monitoring •River Ice Monitoring
Marine & Coastal Environment	<ul style="list-style-type: none"> •Sea surface winds, currents & waves •Oil spill information services (surveillance, drift forecasting) •Ship detection services for fisheries and security
Land Information Services	<ul style="list-style-type: none"> •Basic Land Cover •Soil Sealing Map
Forest Monitoring Services	<ul style="list-style-type: none"> •Green house gas reporting •Sub-National Forest Information Updates •Mapping and Monitoring of Disturbances (Clearing, Fires) •Land Cover & Forest Indicators

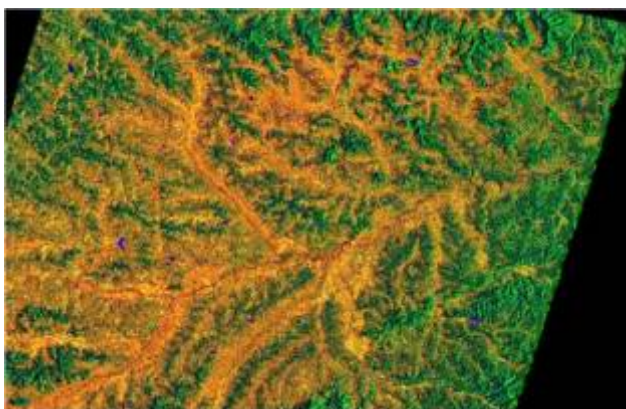


Sentinel-1 Services (1)

GMES Consolidated Service	Sentinel-1 Contribution
Geo-hazard Risk Management	<ul style="list-style-type: none"> •Historical measurements of ground motion: subsidence risk •Subsidence and landslide monitoring (tunnelling project, water table change) •Geological engineering
Flood and Fire Risk Operational Information Services	<ul style="list-style-type: none"> •Flash flood early warning •Floods rapid mapping •Flood risk analysis
Food Security Information	<ul style="list-style-type: none"> •Mapping ploughing time and acreage •Mapping planting time and acreage •Mapping cultivated area at harvest/during growing period
Humanitarian Aid	<ul style="list-style-type: none"> •Rapid mapping for out-of-area crises operation •Cartography for development and reconstruction planning



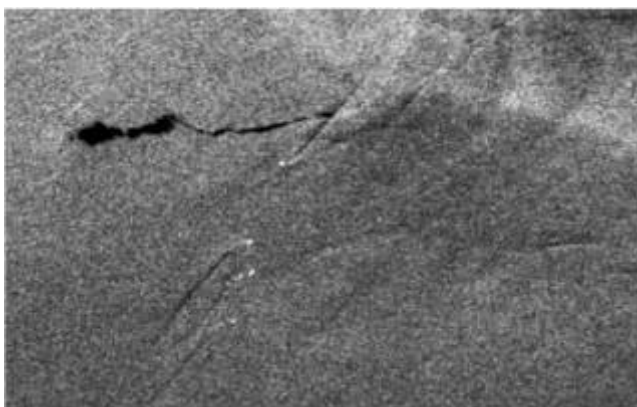
Examples of Services



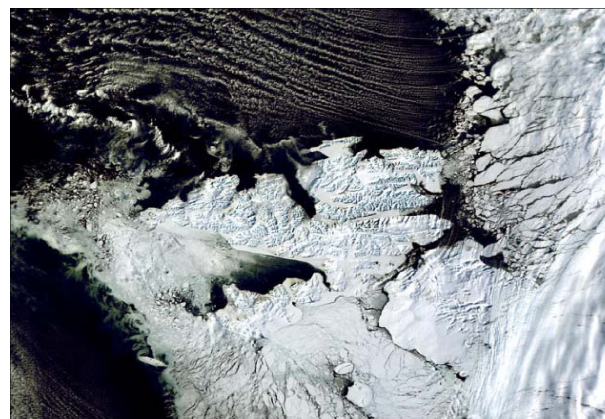
Forest mapping by radar (ERS-1 & -2)



Radar-based flood mapping



Radar observation of ships and pollution

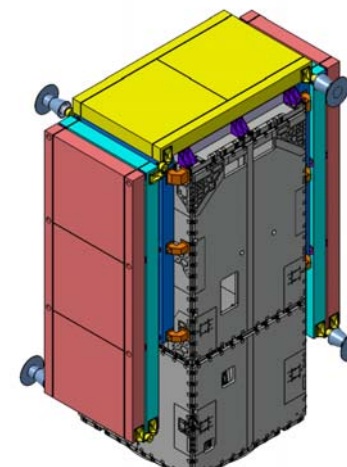
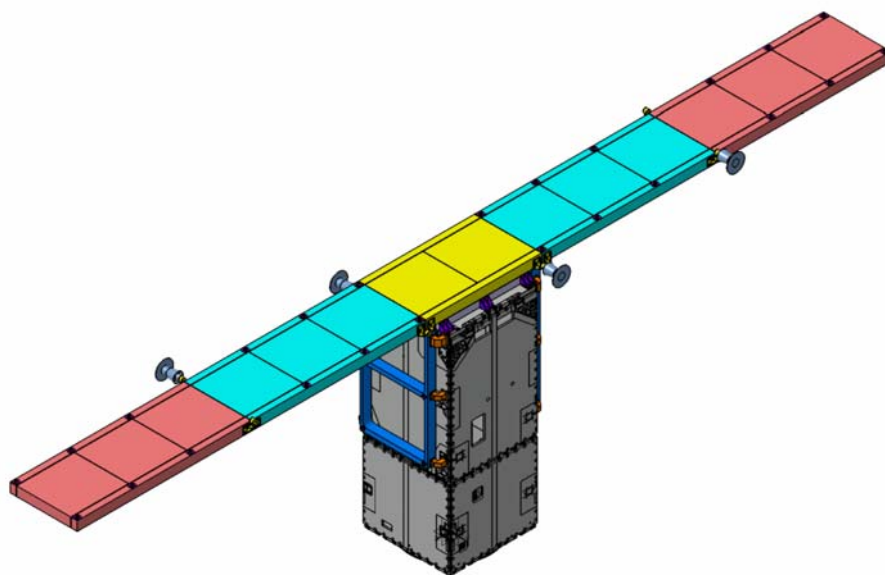


Sea ice monitoring



Sentinel-1 Antenna Configuration

SAR antenna and Solar Array in flight configuration and stowed



***Present Status: start
Phase B2***



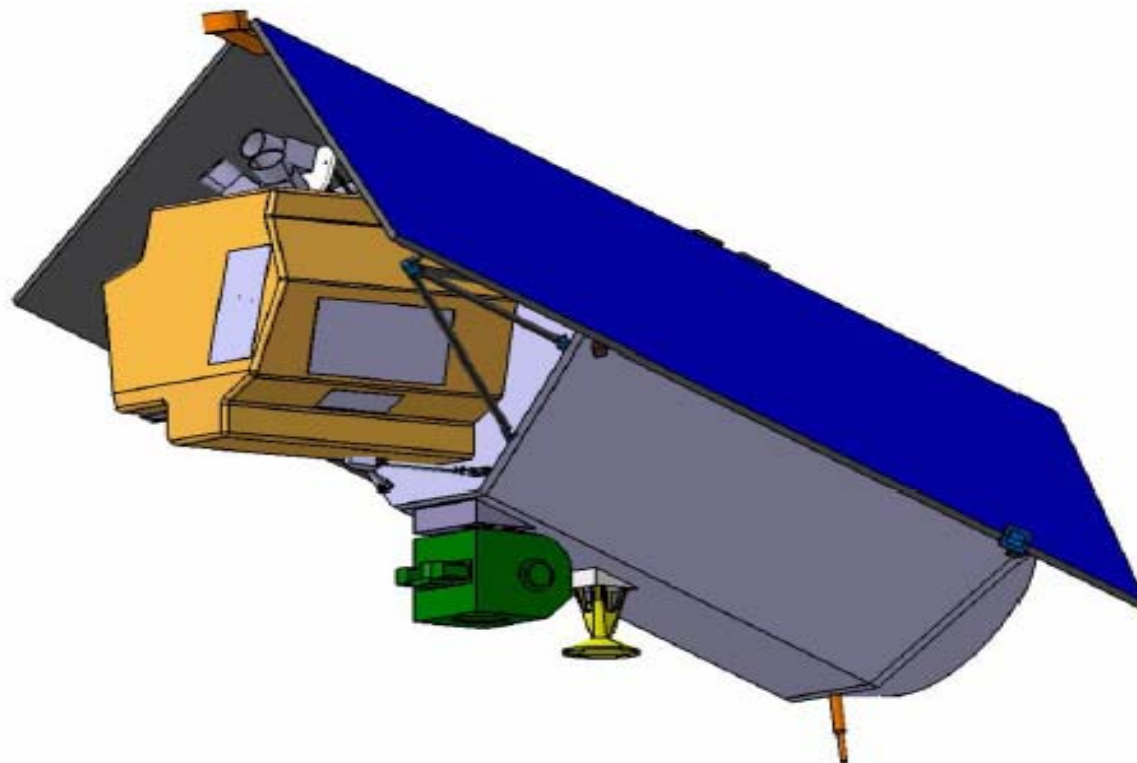
Spacecraft Budgets

- **Mass** 2.1 ton
- **Power** 6 kW
- **Antenna size** 10 x 1.4 m
- **Fuel** > 10 years
- **Downlink rate** ~ 500 Mbps (X band)
- **Center frequency** same as Radarsat 2
- **S-1 revisit period:** 12 days
- **Phase A/B1 activities** completed
- **System Requirement Review** completed
- **Launch date** June 2011

S1 Payload

Orbit: 12 d (06:00 LTDN)	ASAR : 35 d (10:00 LTDN)
<u>Stripmap Mode (SM)</u>	
Swath: 80 km	comparable to ASAR
Resolution: 5x5 m (1L)	better than ASAR capability
<u>Extra-wide Swath Mode (EW)</u>	
Swath: 400 km	same as ASAR
Resolution: 25x100 m (3L)	better than ASAR capability
<u>Wave (WV)</u>	
Swath: 20x20 km	better than ASAR
Resolution: 20x5 m	better than ASAR
<u>Interferometric Wideswath Mode (IW)</u>	NEW MODE (BASELINE)
Swath: 240 km	
Resolution: cell area	comparable to ERS
Sensitivity, Ambiguity, Radiometric performance	comparable to ASAR
No separate AP mode but dual-pol capability in all modes without performance reduction	

Sentinel-2



***Configuration
resulting from
Phase A/B1***

- Multispectral imaging
- Continuity of Landsat, SPOT & Vegetation-type data
- Continuity to services for multi-spectral high-resolution optical observations over global terrestrial surfaces



Sentinel-2 Services

GMES Initial Service	S-2 Features
Global Change - Land	mapping services for monitoring urban areas in Europe (urban sprawl, urban planning modelling & forecasting, changes in urban land use, environmental monitoring and enforcement of urban planning discipline)
Land cover & Land use change	Comprehensive information services for European users with respect to mainly European policies (Water, Soil, Integrated Coastal Zone Management, Urban Environment, Spatial Development)
Forest Monitoring	Forest area / forest area change map Forest type map Forest fragmentation
Food Security early warning	Support to Crop and Food Supply Assessment Agricultural mapping Crop Yield assessment
Humanitarian Aid	Appropriate and reliable application of geographic information for humanitarian organisations
Risk Management (flood and fires)	Monitoring of floods, forest fires, volcano eruptions, subsidence and landslides



Sentinel-2 Examples of Services



Anatolian Plateau, Turkey (SPOT-2)

MS 20m, panchromatic 10m



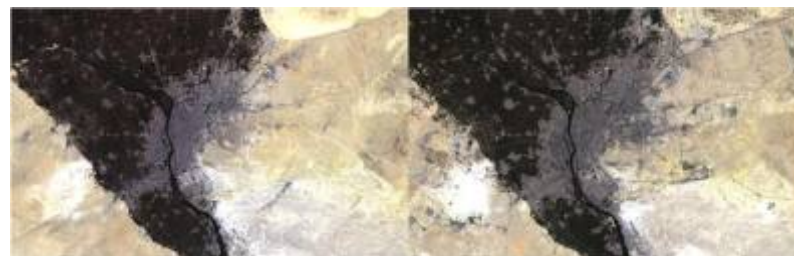
Mokpo, South Korea (FORMOSAT-2)

MS 8m, panchromatic 2m



Swains Atoll, American Samoa (PROBA)

MS 20m

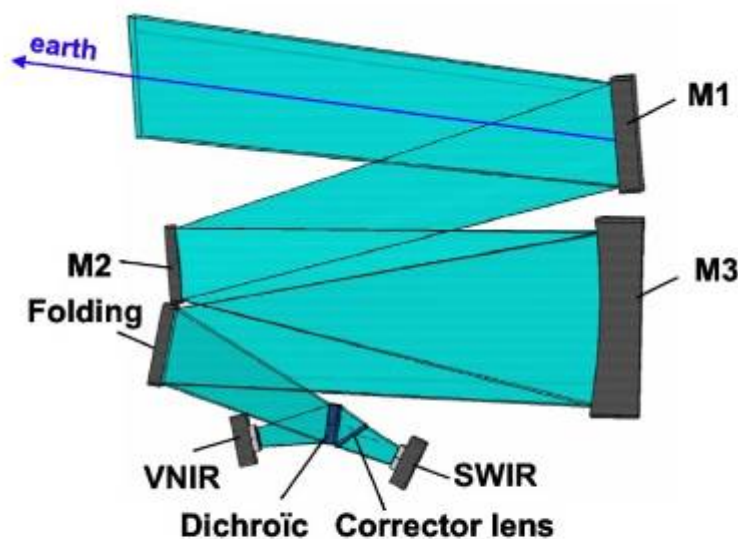
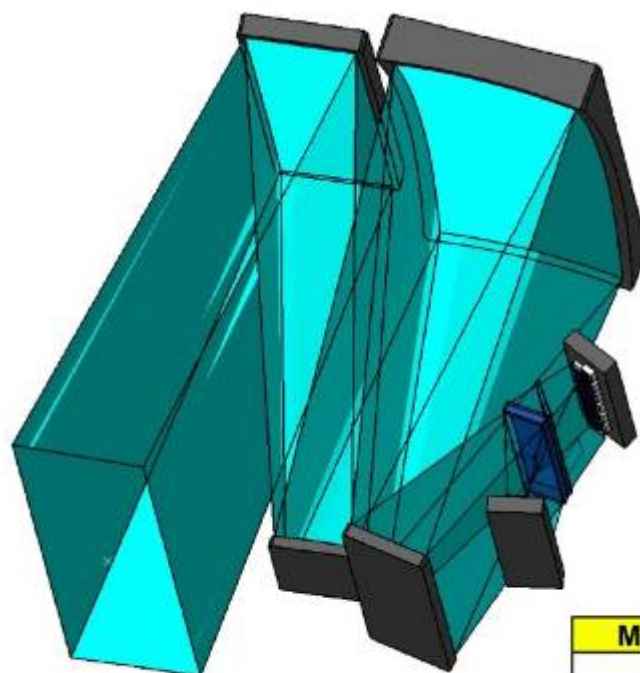


Cairo, Egypt - in 1984 left, 2005 right (LANDSAT)

MS 30m, panchromatic 15m

MSI Overall Optical Configuration

- Optical configuration of the Multi Spectral Instrument
- TMA (three mirror anastigmat) design: VNIR/SWIR split via dichroic

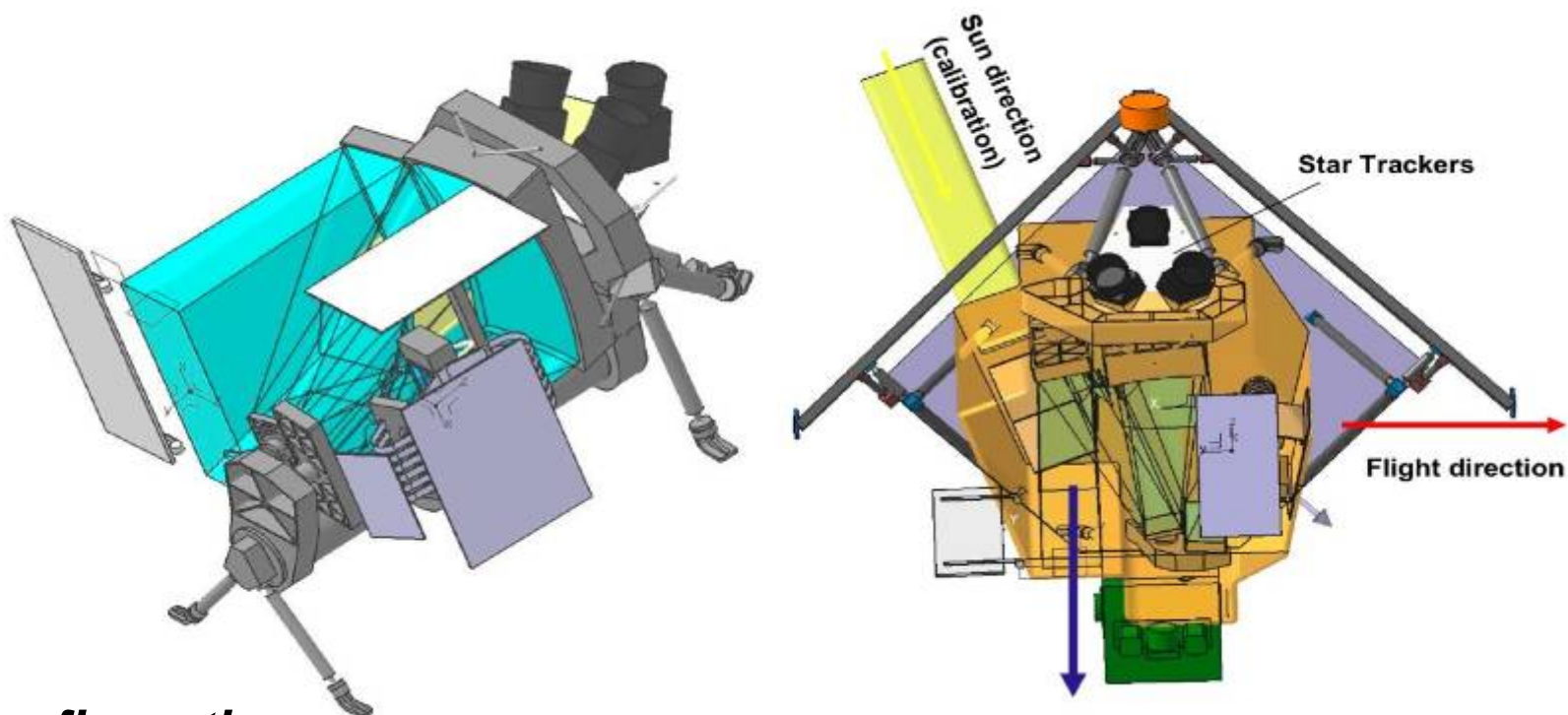


Mirrors	Size (mm ²)
M1	184 x 480
M2	152 x 124
M3	315 x 625
Folding	130 x 360

**Configuration
resulting from
Phase A/B1**

MSI Overall Configuration

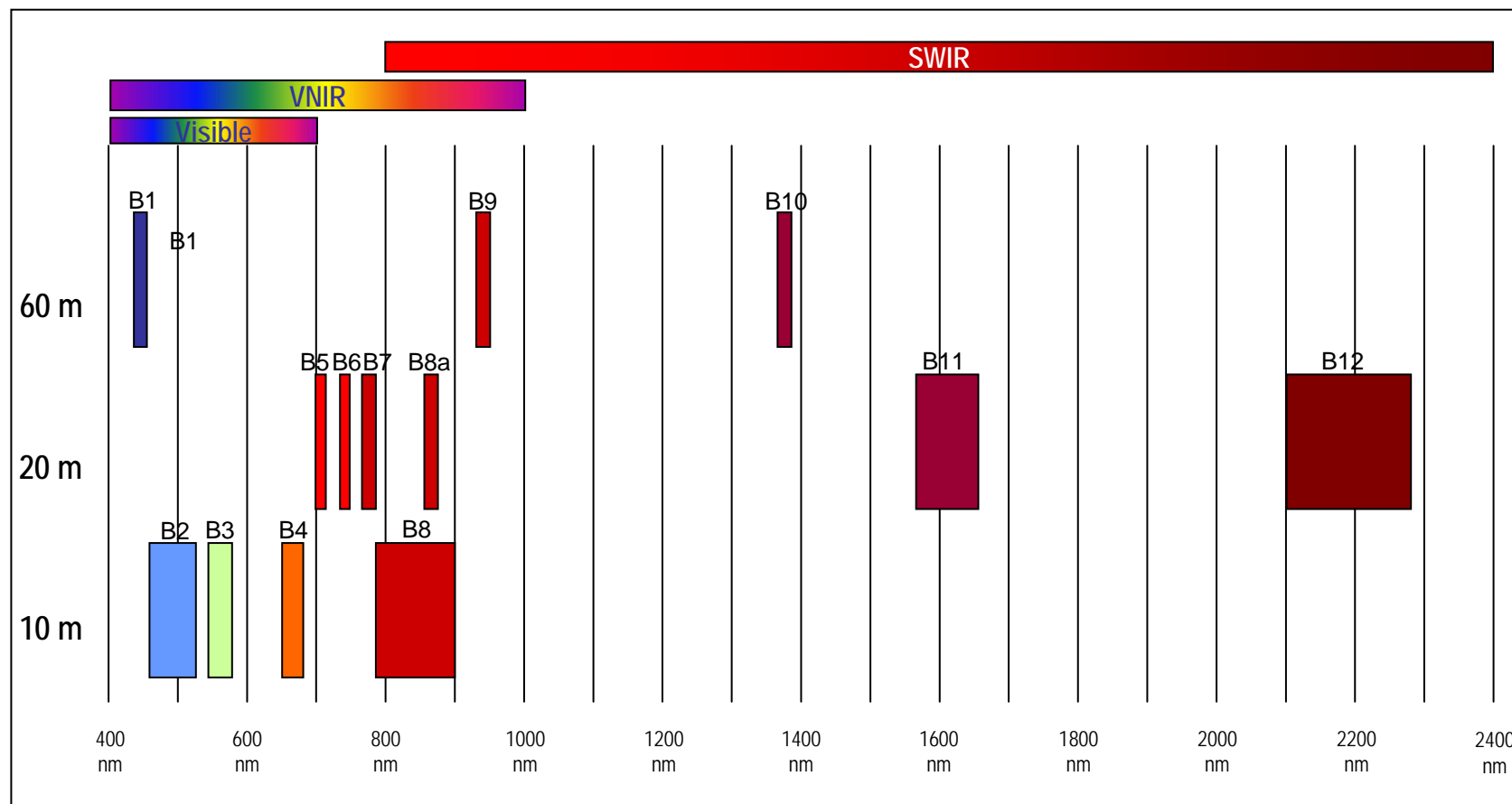
- Possible design and accommodation of the Multi Spectral Instrument



***Configuration
resulting from
Phase A/B1***



Sentinel-2 Spectral Bands



13 spectral bands versus spatial sampling distance



Spectral Coverage

- As shown in the previous chart, the MSI's spectral coverage has been evolved to provide
 - 4 Bands @ 10 m resolution
 - 6 Bands @ 20 m
 - 3 Bands @ 60 m
- This evolution has been driven by the following mission goals:
 - enhanced continuity to Spot and Landsat
 - spectrally narrow bands for better feature identification
 - channels in the red-edge spectral domain addressing vegetation,
 - dedicated channels for improved atmospheric corrections and cirrus cloud detection



Sentinel-2 Spectral Bands

(Wavelength nm/Width nm/SSD m)

MSI spectral bands	Mission objective	Measurement or Calibration
B1(443/20/60), B2(490/65/10) & B12(2190/180/20)	Aerosols correction	Calibration bands
B8(842/115/10)/B8a(865/20/20), B9(940/20/60)	Water vapour correction	
B10(1375/20/60)	Cirrus detection	
B2(490/65/10), B3(560/35/10), B4(665/30/10), B5 (705/15/20), B6(740/15/20), B7(775/20/20), B8(842/115/10)/B8a(865/20/20), B11(1610/90/20), B12(2190/180/20)	Land cover classification, Leaf chlorophyll content, leaf water content, LAI, FAPAR, snow/ice/cloud, mineral detection.	Land measurement bands

LAI (Leaf Area Index) & FAPAR (Fraction of Absorbed Photosynthetically Active radiation) are 2 key biophysical variables

In comparison, SPOT5 bands: 4 multi-spectral channels + 1 panchromatic channel between 0.49 um and 0.69 um.



Instrument Features

- Swath: 285 Km
- 13 Bands @ 10-60 m resolution
- Radiometric Resolution 12 bit
- Onboard calibration
- Pushbroom technology
- VNIR (Very Near Infrared) focal plane: CMOS or CCD
- SWIR (Short-wave Infrared) focal plane: cooled MCT (Mercury Cadmium Telluride) detector hybridised on CMOS read-out circuit
- Shutter provided for launch contamination and sun view



Mission Aspects

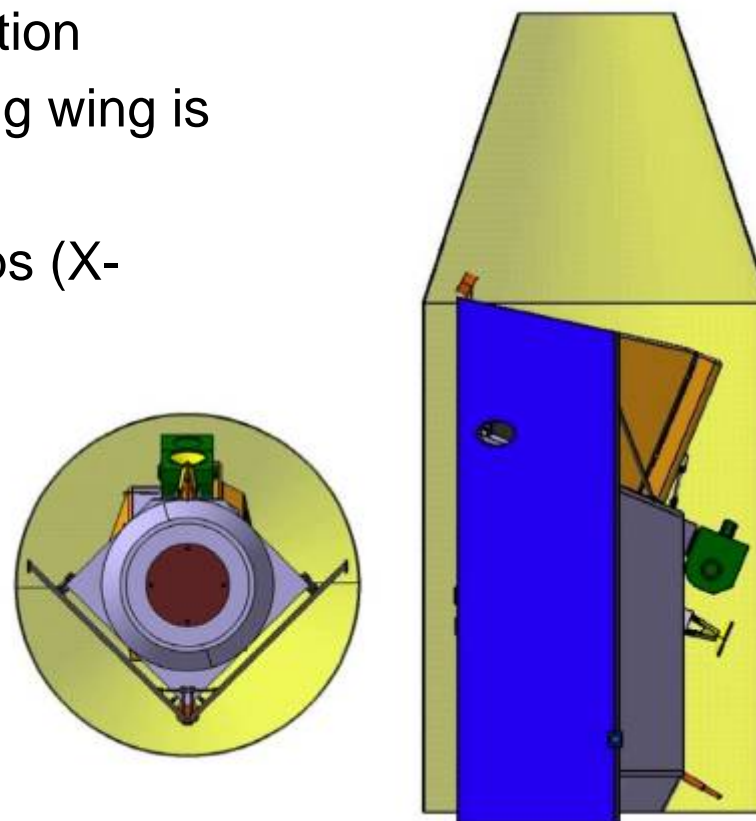
- Coverage:
- Aim is to provide full land coverage (-56° to $+83^{\circ}$)
- With 2 operational satellite, a 5 day revisit time is achieved (\ll Landsat (16d) or Spot (26d))
- This then should provide global cloud free products every 15-30d
- A roll-tilt manoeuvre capability has been included in the design, allowing a more rapid (1-3d) access for disaster monitoring
- Processing/Distribution
- Accurate geo-location ($<20\text{m}$) will be produced automatically
- Automatic data processing for pre-defined areas/time windows, made available on-line for subscribing users



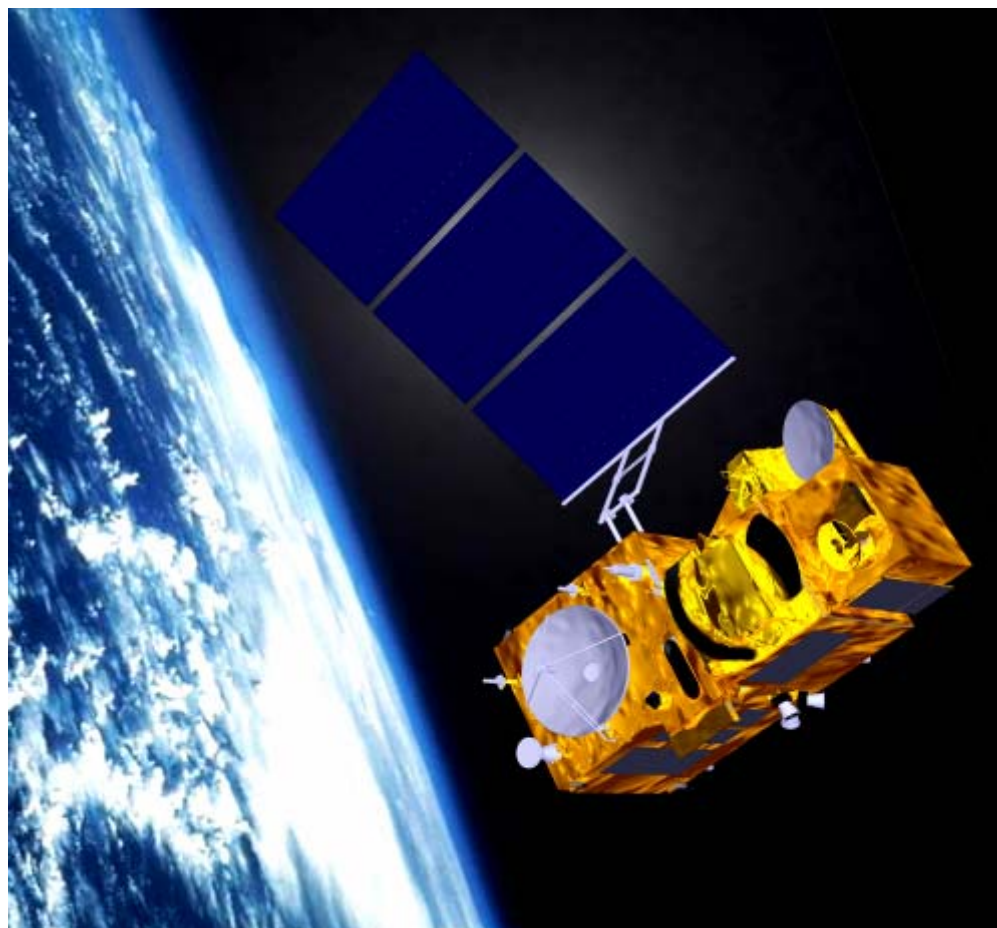
Sentinel-2 Key Features

- Mass 1000 kg
- Power 1175 W (GaAs Triple Junction Cells, Li-Ion Battery)
- Body-mounted solar array configuration
- (roof) versus deployable/rotating wing is under discussion
- Downlink rate about 450 Mbps (X-band)
- 2 TB Memory: lossy compression (wavelet technology)
- Near-polar sun synchronous orbit with 14 +3/10 rev/day
- (10:30 LT DN)
- Launcher class: Vega

Configuration resulting from Phase A/B1



Sentinel-3



- Consistent, long-term collection of remotely sensed marine and land data
- Operational ocean state analysis, forecasting and service provision
- Advanced Radar Altimeter concept
- Multi-channel optical imager (VIS, IR)



Sentinel-3 Marine Services

GMES Initial Service	S-3 Features
Marine and Coastal Environment	sea-surface topography mesoscale circulation water quality sea-surface temperature wave height and wind sediment load and transport eutrophication
Polar Environment monitoring	sea-ice thickness ice surface temperature
Marine Security	ocean-current forecasting water transparency wind and wave height
Global Change - Ocean	global sea-level rise global ocean warming ocean CO ₂ flux



Sentinel-3 Land Services

GMES Initial Service	S-3 Features
Global Change - Land	forest cover change mapping soil degradation mapping
Land cover & Land use change	land use mapping Vegetation indices
Forest Monitoring	forest cover mapping
Food Security early warning	regional land-cover mapping drought monitoring
Humanitarian Aid	land use mapping
Air Pollution (local to regional scales)	aerosol concentration
Risk Management (flood and fires)	burned scar mapping fire detection



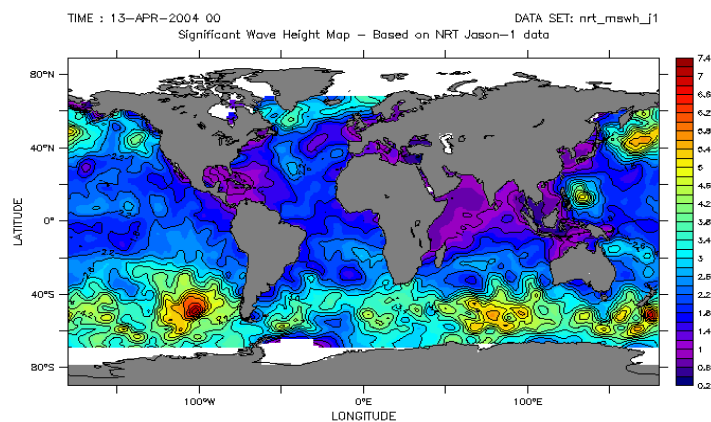
Sentinel-3 Examples of Services



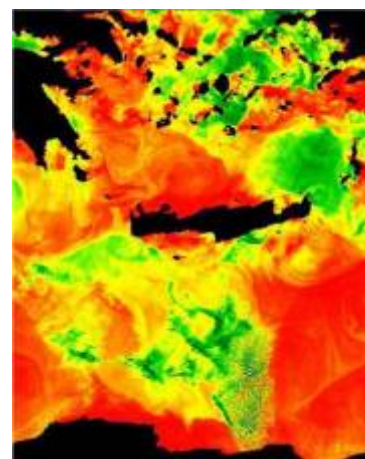
Ireland, Plankton bloom (ENVISAT)



Australia - bushfire plumes at top right (ENVISAT)



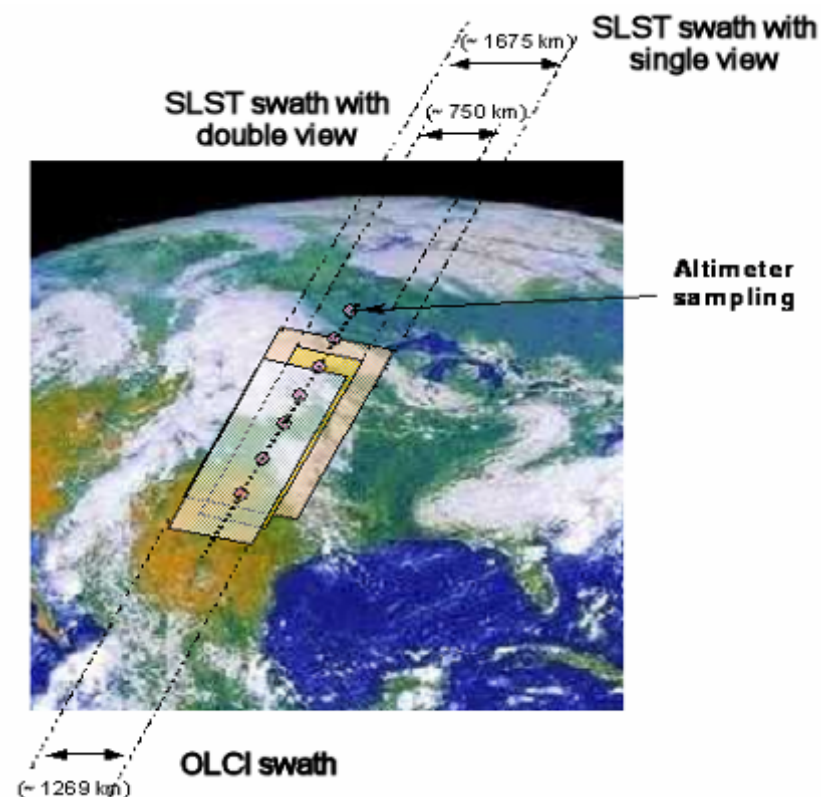
Significant Wave Height Map (JASON-1)



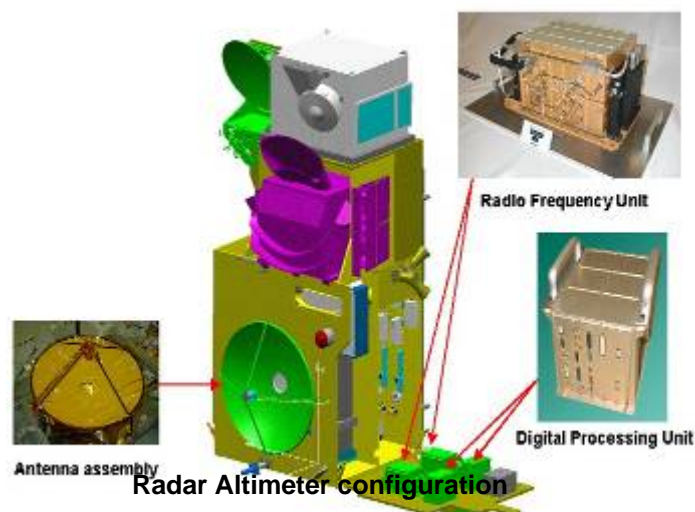
**Sea surface
Temperatures
Around Crete
(ENVISAT)**

Sentinel-3 Payload Complement

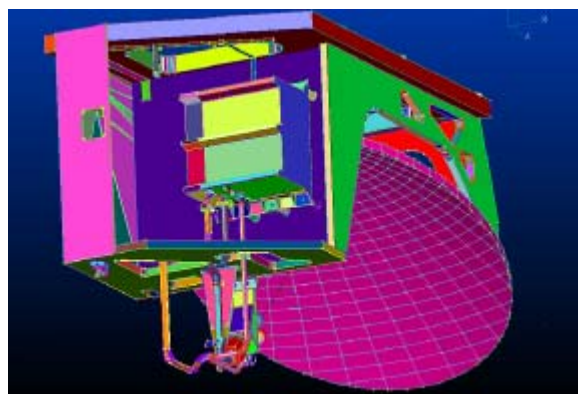
- Topography Mission
 - Bi-frequency Synthetic Aperture Radar Altimeter
 - Microwave Radiometer (Bi- or Three-frequency)
 - Precise Orbit Determination (POD) including
 - GNSS Receiver
 - Laser Retro-Reflector
- Optical Payload
 - Ocean and Land Colour Instrument (OLCI)
 - Sea and Land Surface Temperature (SLST)



Topography instruments overview



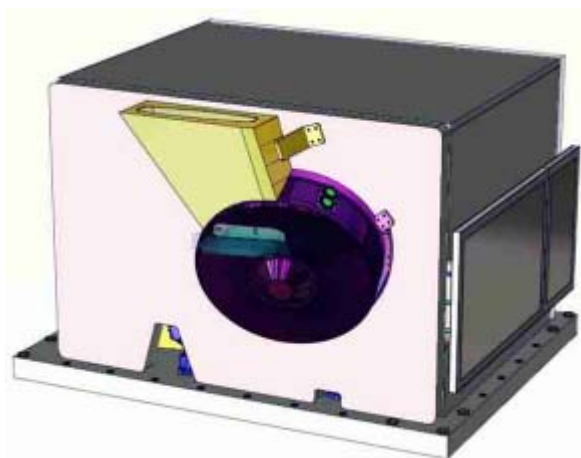
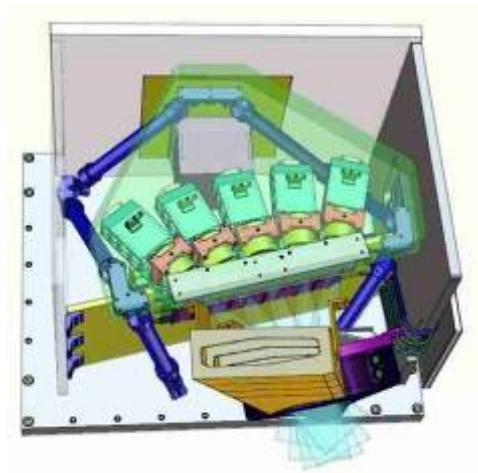
- Radar Altimeter
 - Heritage from CryoSat & Jason
 - Ku & C-band (for ionosph. correct.)
 - New features: SAR mode and open-loop tracking
 - ⇒ Improved monitoring of coastal ocean, ice surfaces and in-land water



Microwave Radiometer overview

- Microwave radiometer
 - 23.8 / 36.5 (/ 18.7) GHz
 - Path correction accuracy: 1.4 cm
- Precise Orbit Determination
 - High accuracy GPS (+Galileo) receiver
 - 2 cm accuracy (radial)

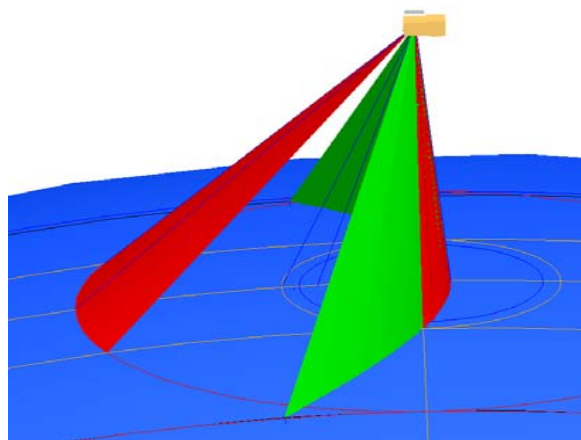
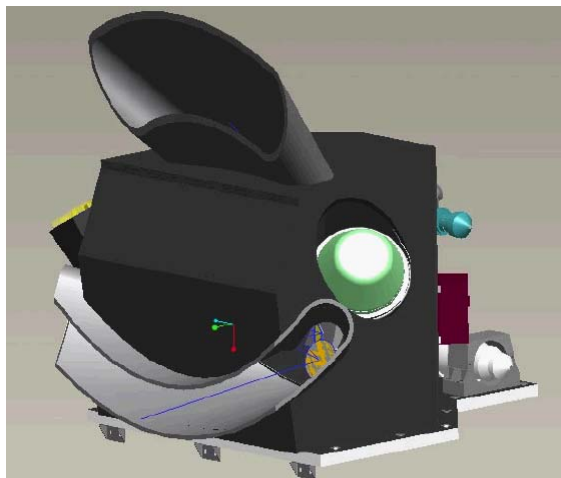
OLCI Overview



**Configuration
resulting from
Phase A/B1**

- Heritage from MERIS
- Pushbroom type imager spectrometer
- 5 cameras, 16 programmable spectral bands (incl. channels for MERIS & VGT legacy products)
- Low polarisation < 1%
- Sun Glint free configuration by design
- Swath covered by SLST for atmospheric correction
- Resolution optimized for observation with full resolution over Coastal/Land
 - Land 300 m
 - Coastal Ocean 300 m
 - Open Ocean 1.2 km

SLST Overview



**Configuration
resulting from
Phase A/B1**

- Heritage from AATSR, dual-view (nadir and backward) required for aerosol corrections:
 - Nadir swath $>74^\circ$ (1300 km min up to 1800 km)
 - Dual view swath 49° 750 km
 - Nadir swath covering OLCI
- 9 spectral bands:
 - Visible : 555 – 659 – 859 nm
 - SWIR : 1.38 – 1.61 – 2.25 μm
 - TIR : 3.74 – 10.85 – 12 μm
- One IR channel used for co-registration with OLCI

Mission Performance

- Revisit time (optical observations):
 - Full performance is met with 2 satellites. Significant improvement wrt to Envisat achieved with 1 satellite: wider instrument swath and optimised orbit.
 - Vegetation products, with approx. 1-day revisit are derived from OLCI (visible/NIR bands) and SLST (SWIR bands) over the overlapping part of their swaths.

		Revisit at Equator	Revisit for latitude > 30°	Requirement
Ocean Colour (sun-glint free)	1 Satellite	< 3.8 days	< 2.8 days	< 2 days
	2 Satellite	< 1.9 days	< 1.4 days	
Land Colour (and vegetation)	1 Satellite	< 2.2 days	< 1.8 days	< 2 days (goal 1 day)
	2 Satellite	< 1.1 day	< 0.9 day	
SLST dual view	1 Satellite	< 1.8 days	< 1.5 days	< 4 days
	2 Satellite	< 0.9 day	< 0.8 day	



Mission Performance (cont'd)

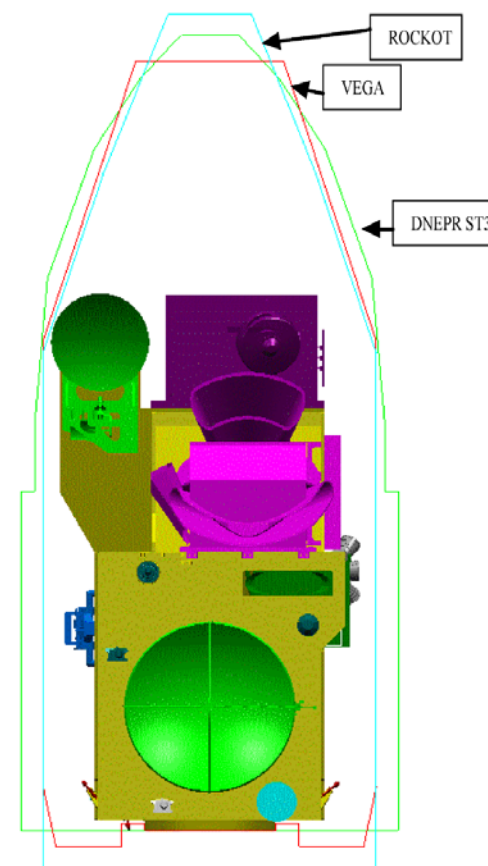
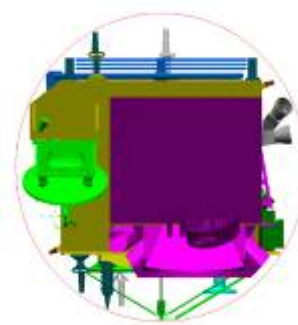
- Ocean Topography:

Error type	Value
<i>Altimeter random</i>	<i>1.3 cm</i>
<i>Sea model</i>	<i>2.0 cm</i>
<i>Ionosphere</i>	<i>0.7 cm</i>
<i>Dry troposphere</i>	<i>0.7 cm</i>
<i>Wet troposphere</i>	<i>1.4 cm</i>
Total range error (rms)	3.0 cm
POD (rms)	2.0 cm
Sea Surface Height (rms)	3.6 cm

- Products
 - Near Real Time L2 optical and topography products, available within 3 hours following acquisition.
 - Highest quality, Non-time critical L2 products, available within 1 month.

Sentinel-3 Key Features

- Mass 1270 kg
- Power 1100 W
- Downlink rate about 300 Mbps (X-band)
- Near-polar frozen sun synchronous orbit,
- 14 +7/27 rev/day (10:00 - 10:30 LT DN)
- 27 days repeat cycle
- Launcher class: Vega



***Configuration
resulting from
Phase A/B1***



Status of Sentinels 1-3

- Sentinel-1
 - Phase B2 start: April 2007
 - Critical Design Review: March 2009
 - Launch: November 2011

- Sentinel-2
 - Phase B2 start: October 2007
 - Critical Design Review: Mid 2010
 - Launch: April 2012

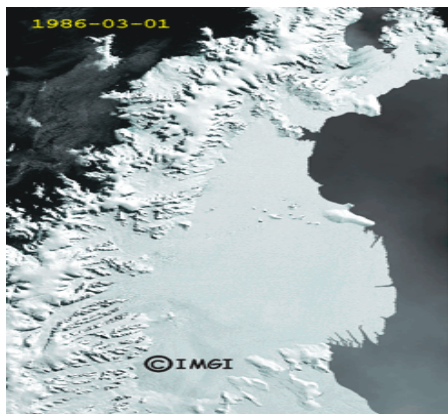
- Sentinel-3
 - Phase B2 start: October 2007
 - Critical Design Review: February 2010
 - Launch: August 2012



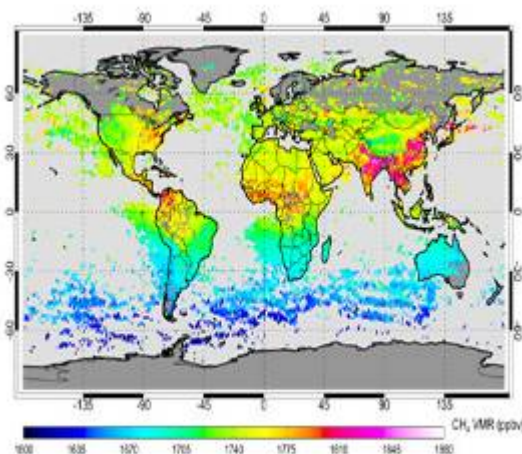
Conclusion

Monitoring Climate Change from space

*Collapse of the Larsen Ice Shelf
(Envisat, courtesy Univ. Innsbruck)*



*Global Concentration of Methane
(Envisat, courtesy KNMI)*



Warming signs from space

Accelerated global warming and sea-level rise (ERS, Envisat, Sent-3)

- * Faster rate of global sea-level rise (about 3.1mm/yr since 1993)
- * Warming of the global ocean and lower atmosphere

Melting of ice and snow (ERS, Envisat, Cryosat, Sent-1, Sent-2)

- * Shrinking of Arctic sea-ice cover (about 2.7%/dec. decline since '78)
- * Breakup of Antarctic ice shelves
- * Decrease in snow extent in both Hemispheres
- * Retreat of Mountain glaciers

Understanding global change processes

Understanding Radiative Forcing

- * Earth Radiation budget (MeteoSat, EarthCare)
- * Monitoring of clouds and aerosols (EarthCare)

Quantifying the Carbon Cycle

- * Monitoring Greenhouse Gases concentration (Envisat, Metop, Sent-4/5)
- * Monitoring carbon stocks in vegetation & plankton (Envisat, ERS, Sent-2/3)

Validation and forcing of coupled climate models

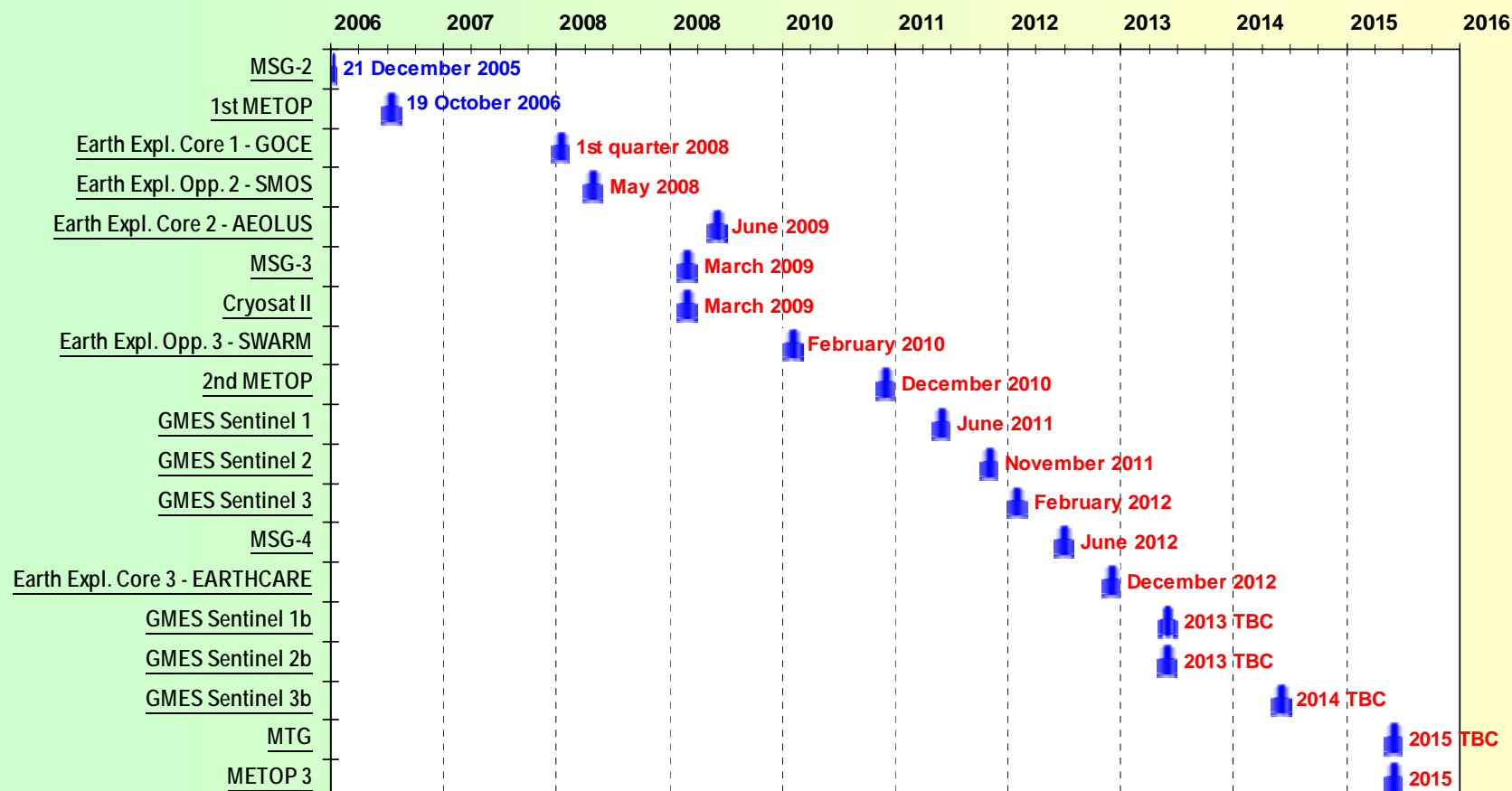
Monitoring “tipping-point” of abrupt climate change

- * Greenland icecap (Envisat, Cryosat, Sent-1)
- * Ocean circulation (conveyor belt) (GOCE, SMOS)



EOP overall launch schedule

D/EOP Overall Launch Schedule



Earth Explorer Nr. 7, Sentinel-4 and -5: launch dates tbd



THANK YOU