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AVHRR DATA SET CURATION PROJECT

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AVHRR Master Data Set Handbook

Deliverable 16 (WP 7)

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1 Introduction

1.1 Purpose

The AVHRR user handbook gives the user some details about the content of the consolidated and harmonized data set archived at ESA facilities. The user will find information about the AVHRR sensor, the mission and coverage of Europe as well as the temporal distribution during the period 1981 – 2019. In the near future also the global 1-km AVHRR data set will be available in EO-SIP (see section 3.3). The format description for level L0, L1A and L1B gives a first overview about the structure of the data. Further information is available in the reference documents of NOAA.

1.2 Value of time series derived from AVHRR sensor

It is worthwhile to focus on remote sensing in climatology, as progress in this field has been very well documented by the IPCC in AR4 to AR5. Not only is there an increased likelihood of man-made changes documented, the increasing contribution of satellite remote sensing for the monitoring of global conditions are of particular importance to my work. The retrieval of essential climate variables (ECVs, defined by Global Climate Observing System (GCOS); *Figure 1*) with satellite data has now been proven as a viable, complementary source of information besides the use of ground measurements and climate model results. Many parameters can be monitored with satellite sensors, and to some extent, with an impressive degree of accuracy. However, this is only valid for the latest missions with good sensor calibration and stability. These data sets are a valuable contribution to monitor the changes on Earth and the atmosphere, but most systems in orbit have a short life time of approximately 5-10 years. The World Meteorological Organization (WMO) reported that a time series of at least 30 years is needed to retrieve statistically significant changes of ECVs. Considering that these are extended periods of time, only a limited selection of satellites and sensors can be used for global monitoring – one of these is the Advanced Very High Resolution Sensor (AVHRR) onboard of NOAA satellites (since 1978) and on the EUMETSAT platform Metop (since 2006).

The Essential Climate Variables

Domain	Essential Climate Variables	
Atmospheric (over land, sea and ice)	Surface:	Air temperature, **precipitation**, air pressure, surface radiation budget, wind speed and direction, water vapour.
	Upper air:	**Earth radiation budget (including solar irradiance), upper air temperature (including MSU radiances), wind speed and direction, water vapour, cloud properties.**
	Composition:	**Carbon dioxide**, methane, **ozone**, other long-lived greenhouse gases, **aerosol properties.**
Oceanic	Surface:	**Sea surface temperature**, sea surface salinity, **sea level, sea state, sea ice**, currents, **ocean colour (for biological activity)**, carbon dioxide partial pressure.
	Sub-surface:	Temperature, **salinity**, currents, nutrients, carbon, ocean tracers, phytoplankton.
Terrestrial	River discharge, water use, ground water, **lake levels, snow cover, glaciers and ice caps**, permafrost and seasonally-frozen ground, **albedo, land cover (including vegetation type), fraction of absorbed photosynthetically active radiation (fAPAR), leaf area index (LAI), biomass, fire disturbance, soil moisture.**	

Figure 1: Essential climate variables (ECV) defined by Global Climate Observing System (GCOS), WMO. Measurements of variables in bold type are largely dependent on satellite observations. Data sets from AVHRR sensor contribute significantly to these listed ECVs. Source: CEOS EO handbook – the important role of Earth observations http://www.eohandbook.com/eohb2011/climate_variables.html; access: October 17, 2019.

1.3 Executive Summary

The AVHRR user handbook gives an overview of the archived AVHRR data at ESA facilities. The archived data set is composed of the data holdings from University of Bern, Dundee Satellite Receiving Station and ESA. The data set is harmonized and consolidated to give the user one single format (NOAA AVHRR Level 1B) with additional meta- information and quality indicators in an EO-SIP container. The EO-SIP files were validated to proof the content of the EO-SIP files and check readability with different software packages. More than 235.000 AVHRR data sets are archived and accessible via ESA web interface.

1.4 References

EO-SIP Specialisation for AVHRR Products v1.1.pdf

Harmonised File Naming Convention v2_9.pdf
LTDP_ESA_UniBe_Deliverable_6_WP2.pdf

NOAA Technical Memorandum NESS-107.pdf
NOAA POD User's Guide, NOAA KLM User's Guide
ftp://ftp2.ncdc.noaa.gov/pub/data/satellite/publications/podguides/

https://www.ngdc.noaa.gov/wiki/index.php/NOAA_Processing_Levels

SeaShark - Detailed Design Document.pdf (SHK-DDD-001, Issue 2.0, 17 June 1999)

1.5 Definitions and Acronyms

AMSU	Advanced Microwave Sounding Unit
AMSU/MHS	Advanced Microwave Sounding Unit / Microwave Humidity Sounder
ARS	Archive Retrieval System
AVHRR	Advanced Very High Resolution Radiometer
CCI	Climate Change Initiative
CLASS	Comprehensive Large Array-data Stewardship System
EO	Earth Observation
ESA	European Space Agency
GCOS	Global Climate Observing System
HRPT	High Resolution Picture Transmission
LTDP	Long Term Data Preservation
Metop	Meteorological Operational Satellite (EUMETSAT)
NOAA	National Oceanic and Atmospheric Association
RSGB	Remote Sensing Research Group Bern
SHARP	Standard-family HRPT Archive Request Product
SIP	Submission Information Package
TBM	Terabit Memory
TIP	TIROS Information Processor
UniBe	University of Bern
WP	Work Package

2 Advanced Very High Resolution Radiometer (AVHRR)

2.1 Introduction

During the 1970s, the quality of the weather forecasts was far from that which we are familiar with today. This can be attributed to a combined lack of processing power, precise atmospheric models, and most importantly, the manual registration of meteorological data at the time. Ground based station data and relatively limited balloon soundings provided data for forecast models, which were characterized by coarse spatial and temporal resolutions.
To improve the situation, the National Oceanic Atmospheric Administration (NOAA) initiated a program that consisted of polar orbiting satellites to support the generation of weather forecasts with high spatial resolution images and capable of identifying cloud types and cloud distribution.
These data were highly valued by forecasters; for the first time, images from space with reasonable spatial resolution were used supporting the work of meteorologists. Consequently, the objective of the NOAA series was to deliver images on a regular basis, but not to use the data for quantitative investigations. The intended data application defines the Advanced Very High Resolution Radiometer (AVHRR)'s sensor design. For instance, onboard calibration for the VIS and NIR channels were not included, the orbit of the NOAA satellites was not stabilized, which results in an orbit drift with changing overpass times over the equator, and leads to variable solar illumination over AOIs throughout the lifetime of the satellite. Nevertheless, the four (five) spectral channels in VIS, NIR, and TIR, in addition to a spatial resolution of 1.1 km in nadir and high radiometric resolution of 10-bit, provides a very detailed view of clouds and the Earth surface – a milestone in satellite remote sensing. Furthermore, data transmission from the satellite to the ground was well documented and not restricted. Any interested organizations and universities could build a receiving station to acquire AVHRR data on a daily basis. In particular, the high temporal resolution enables new research topics to be explored by considering the Earth's atmospheric and surficial dynamics. It should be noted that the only publicly available satellite data sets during this time were Landsat images with a revisit period of 16 days. In mountainous areas or during the winter time, often characterized by persistent cloud cover, it was often only possible to obtain usable data about ground conditions after more than one month. Therefore, an alternative for the daily monitoring of ground-based changes or cloud/ fog dynamics offers new insights to understand processes and interactions between atmosphere and lithosphere.

2.2 Satellite missions

Before the launch of the first AVHRR, the VHRR was its precursor and was in orbit for some years. However, the quality that is required for long term monitoring was not sufficient for the VHRR and only partly achievable by AVHRR. The first AVHRR sensor was a four channel radiometer with a duplication of thermal channel 4. It was onboard of the TIROS-N satellite, which was launched in 1978. An improved version with two thermal channels (AVHRR/2) was carried on NOAA-7 (launched 1981) and continued in subsequent satellites until NOAA-14 (tables 1 and 2). The two thermal channels result in better retrieval accuracy of surface temperatures when the split-window technique is applied. With the launch of NOAA-15, the next generation of AVHRR sensors was installed. AVHRR/3 now has two channels in the SWIR spectrum (3A and 3B, tables 1 and 2) to improve cloud-snow discrimination. Both channels are automatically switched on the boundary between daylight and night data, since simultaneous operation is not possible. The following *Table 1* provides an overview of all satellites with AVHRR. It is remarkable that an old and not particularly sophisticated sensor is now onboard of the EUMETSAT Metop series and keeping the system operational until 2025. Within the framework of the Joint Polar Satellite Systems (JPSS), an agreement between NOAA, NASA and EUMETSAT included the decision to deliver three of the AVHRR sensors (manufactured by ITT Exelis, Indiana) to be mounted on Metop-satellites to continue the generation of unique time series until the end of their planned service period, which is expected for 2025 or some years later. In the end, more than 40 years of daily Earth observations will be available for long term studies to support climate change research activities. The "health" of these satellites is continually monitored and the data is publicly available on the Polar Orbiting Environmental Satellites (POES) web page (http://www.ospo.noaa.gov/Operations/POES/status.html).

Table 1: Launch dates and operational phases of the satellites with AVHRR sensor; temporarily inactive periods are listed in the column "Notes"; compiled 2019-09-14.

Satellite	Sensor	Slot	Launch	Operational	Notes
TIROS-N	AVHRR/1	PM	1978-10-13	1978-10-19 - 1980-01-30	
NOAA-6	AVHRR/1	AM	1979-06-27	1979-06-27 - 1986-11-16	inactive 1983-03-06 - 1984-07-02
NOAA-8	AVHRR/1	AM	1983-03-28	1983-05-03 - 1985-10-31	inactive 1984-06-22 - 1985-06-30
NOAA-10	AVHRR/1	AM	1986-09-17	1986-11-17 - 1991-09-16	
NOAA-7	AVHRR/2	PM	1981-06-23	1981-08-24 - 1985-02-01	
NOAA-9	AVHRR/2	PM	1984-12-12	1985-02-25 - 1988-11-07	
NOAA-11	AVHRR/2	PM	1988-09-24	1988-11-08 - 1995-04-11	AVHRR failure 1994-09-13
NOAA-12	AVHRR/2	AM	1991-05-14	1991-09-17 - 1998-12-14	
NOAA-14	AVHRR/2	PM	1994-12-30	1995-04-10 - N/A	
NOAA-15	AVHRR/3	AM	1998-05-13	1998-12-15 ongoing	
NOAA-16	AVHRR/3	PM	2000-09-21	2001-03-20 - N/A	3A deactivated since 2003-05-01
NOAA-17	AVHRR/3	AM	2002-06-24	2002-10-15 - N/A	
NOAA-18	AVHRR/3	PM	2005-05-20	2005-08-30 ongoing	3A deactivated since 2005-08-05
NOAA-19	AVHRR/3	PM	2009-02-06	2009-06-02 ongoing	3A deactivated since 2009-05-14
Metop-1	AVHRR/3	AM	2012-09-17	2013-04-24 ongoing	
Metop-2	AVHRR/3	AM	2006-10-19	2007-05-21 ongoing	
Metop-3	AVHRR/3	AM	2018-11-07	2019-07-03 ongoing	

The satellites are polar orbiting systems circling at an altitude of approximately 817 km, with a velocity of 8 km/s covering one swath of the globe in 101 minutes. Most of the time, two satellites were simultaneously in orbit, one known as morning satellite (AM) and a second known as the afternoon satellite (PM), which are related to the local solar time. The satellites provide two times coverage of the Earth's surface per day, thereby enabling the monitoring of highly dynamic elements in the atmosphere or on the surface (e.g. cloud movement or eddies in the ocean).

The afternoon satellites (PM) show a tendency to drift to later overpass times, whereas the morning satellites (AM) shift to earlier times (*Figure* 2). This orbit drift affects the retrieval of surface parameters in two ways. Firstly, the local solar illumination of a certain area changes over time and influences the reflectance values. If these changes are not corrected, i.e. by considering the bidirectional reflectance distribution function (BRDF), the retrieval of some ECVs may contain errors over time. Secondly, the diurnal cycle of surface temperature is measured by the radiometer later (PM) or earlier (AM) than the expected time, resulting in decreased temperatures of the same pixel over time.

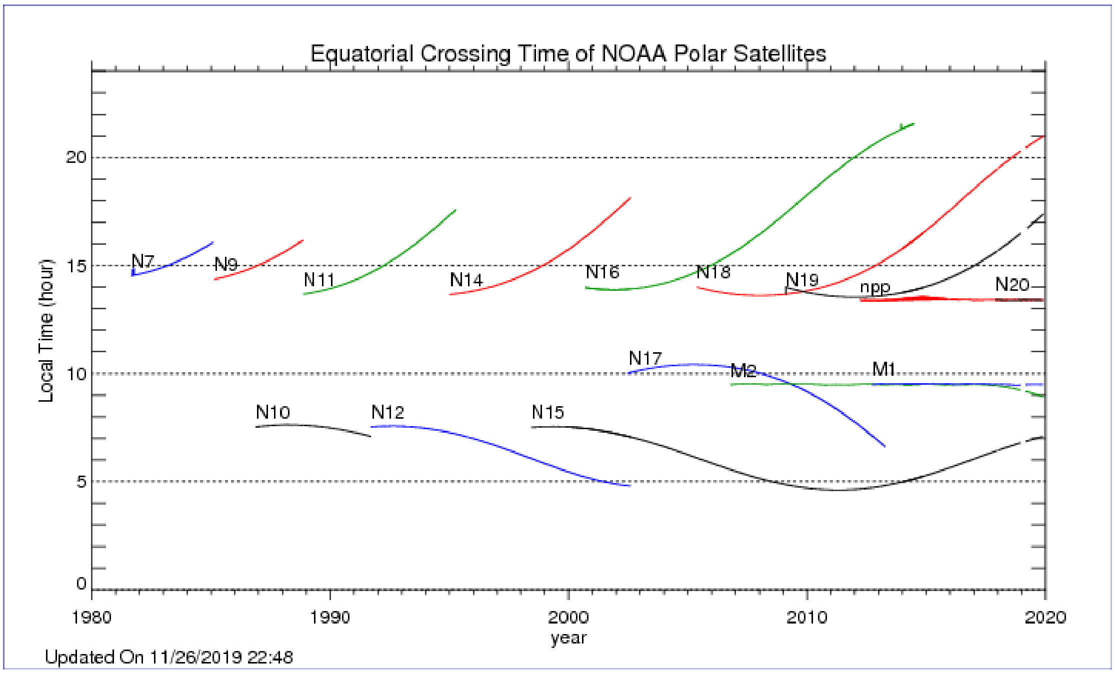

Figure 2: Orbit drift of NOAA and EUMETSAT Polar Satellites (N7 – N20, NPP and Metop-1, -2) changing the local overpass time; PM satellites drift to later times and AM satellites show a tendency for earlier overpasses; remarkably is the stable orbit configuration of Metop-1, Metop-2 and NPP. Source: http://www.star.nesdis.noaa.gov/smcd/emb/vci/VH/vh_avhrr_ect.php

2.3 Sensor description

The AVHRR is a five channel radiometer comprised of the solar, near infrared and thermal infrared spectra. A rotating mirror scans the Earth's surface, covering a swath 2700 km wide. The reflected and emitted EM-waves are split inside of the sensor to the VIS and NIR arrays and to the cooled thermal section (*Figure 3*). The signals are digitized with a 10-bit resolution and transmitted to ground stations. There is also an internal storage onboard to avoid loss of data for areas where no ground station is located.

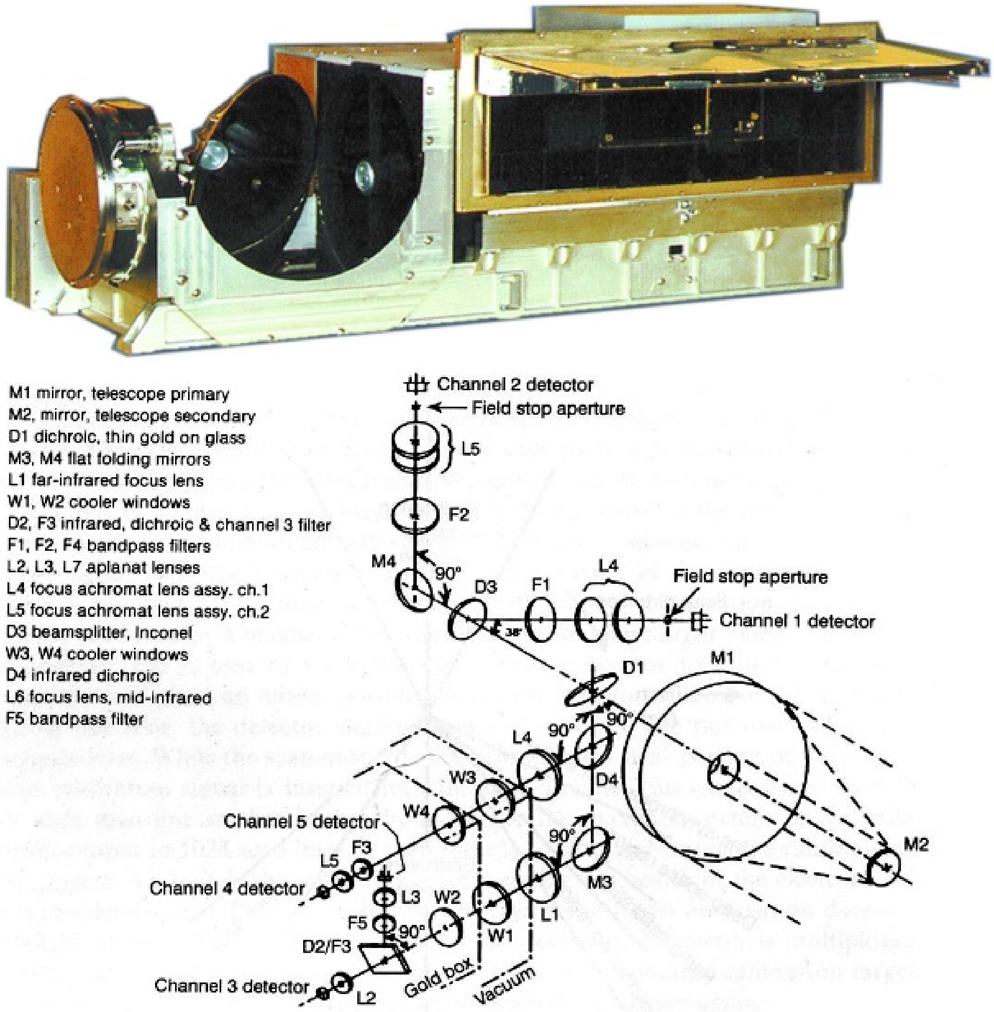

Figure 1.11 AVHRR optical subsystem five-channel version, AVHRR/2.

Figure 3: Picture of the AVHRR sensor (top) showing the main mirror and the telescope M1 and M2 and bottom: an exploding view of the optical subsystem (AVHRR/2), (Cracknell, 1997).

Table 2: AVHRR channel characteristics.

Channel	AVHRR/1	AVHRR/2	AVHRR/3	IFoV [mrad]
1	0.58 – 0.68 µm[1]	0.58 – 0.68 µm	0.58 – 0.68 µm	1.39
2	0.725 – 1.1 µm	0.725 – 1.1 µm	0.725 – 1.0 µm	1.41
3A			1.58 – 1.64 µm	1.30
3B	3.55 – 3.93 µm	3.55 – 3.93 µm	3.55 – 3.93 µm	1.51
4	10.5 – 11.5 µm	10.3 – 11.3 µm	10.3 – 11.3 µm	1.41
5	Ch4 repeated	11.5 – 12.5 µm	11.5 – 12.5 µm	1.30

The spatial resolution of 1.09 km is degraded when scanning the areas from nadir to the edges of the swath. The wide scanning angle of 110° results in a pixel size at the edges of approximately 4 km x 6 km, thereby blurring the image. Consequently, it is recommended that the scan angles of the data sets be limited to ± 40° to prevent ambiguous information from being generated due to enlarged pixels.

Throughout the development of the different AVHRRs, the band widths of the channels changed slightly, as well as the sensor response functions (SRFs). An example of channel 1 for AVHRR/2 (red) and AVHRR/3 (green) can be seen in *Figure 4*. It is evident that the normalized mean SRF between AVHRR/2 and AVHRR/3 shows a difference, which has to be considered and corrected for in the resultant time series. The NOAA-satellites are not stabilized in orbit in such a way that effectively maintains the equator crossing time constant.

Detailed information about all satellites and sensors is given in the NOAA POD User's Guide for all satellites until NOAA-14 and for all following systems, beginning with NOAA-15, in the NOAA KLM User's Guide. The documentation is available at ESA web page related to the European AVHRR master data set.

[1] TIROS-N: 0.55 – 0.90 µm

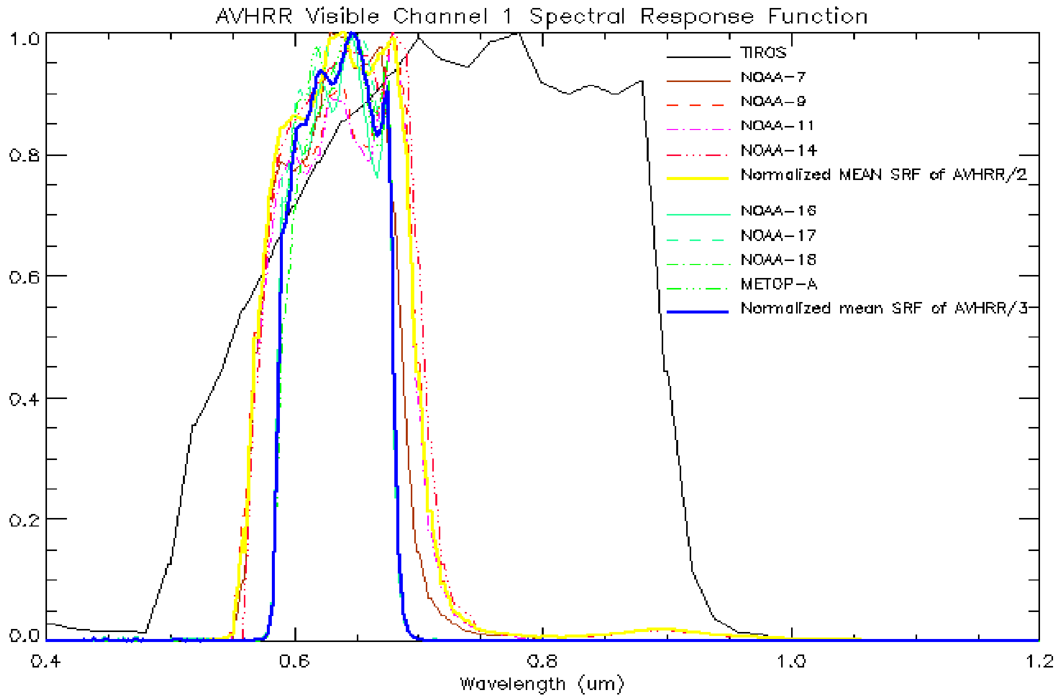

Figure 4: Spectral response functions of AVHRR/2 and AVHRR/3 for channel 1. Source: http://www.star.nesdis.noaa.gov/smcd/spb/fwu/homepage/AVHRR/spec_resp_func/meanAVHRRsrf.html

3 Data holding at ESA

The AVHRR data holdings at ESA are compiled considering three major AVHRR archives in Europe, namely University of Bern (including also the data archive of FU Berlin), Dundee Satellite Receiving Station and European Space Agency, Frascati. The different data sets were harmonized, consolidated and finally archived in the so-called EO-SIP containers. Detailed description of data formats and EO-SIP is given in chapter 4 *Data Formats*.

3.1 European Coverage

The European continent is very well covered due to the wide swath of AVHRR sensor (2.700km) and the distributed receiving stations located in Europe. University of Bern has a coverage from the North Cape to Northern Africa, Free University of Berlin reception was able to cover an area even far north and to the East. Whereas the station located at Dundee covers more the western area including the North Atlantic. All ESA stations cover whole Europe from the far north (station Tromsø) to southern tip of Europe (station Maspalomas).

3.2 Temporal Coverage by satellite and European station

More than 235.000 AVHRR data sets are now archived at ESA and available for the users. The consolidated and harmonized data set covers the years 1981 – 2019. The following tables and figures give an overview of the archived data sets.

Table 3: Overview of archived AVHRR data holdings with its origin (RSGB=University of Bern; ESA=European Space Agency; Dundee=Dundee Satellite Receiving Station).

Archive	Time Span	Satellites	Formats
RSGB	1989 – 2019	N10 – N12, N14 – N19, Metop-1, -2, -3	Standard HRPT, NOAA AVHRR Level 1B
ESA	1982 – 2012	N06 – N12, N14 – N18	SHARP-1 (CCT), SeaShark Archive Product
Dundee	1981 – 1988	N06 – N11	Standard HRPT

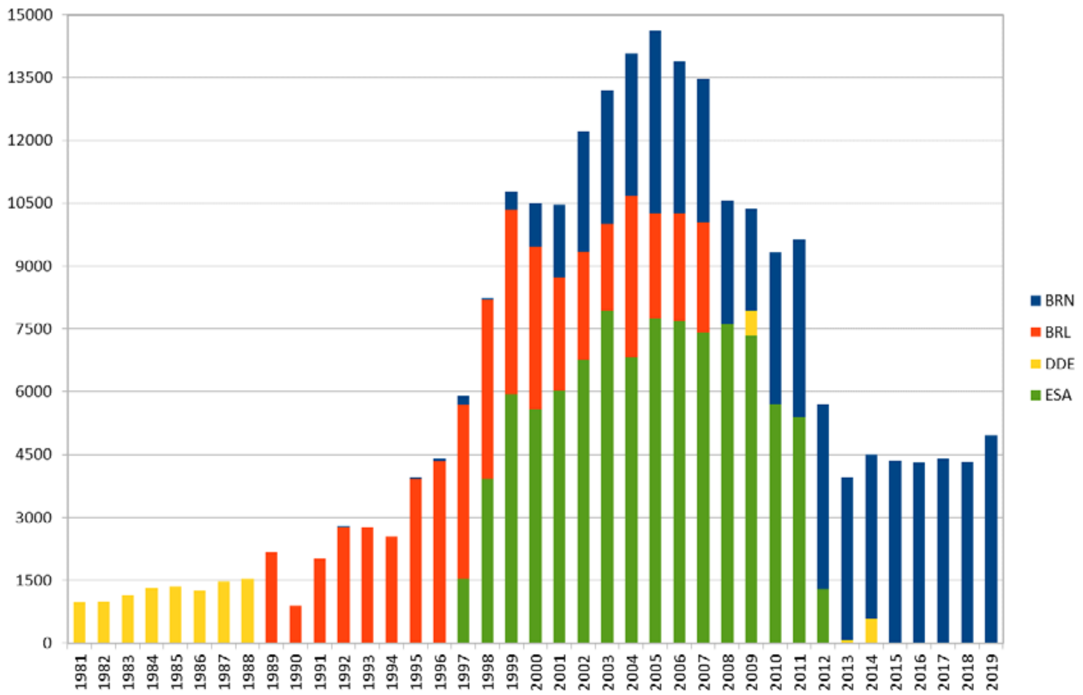

Figure 5: Amount of AVHRR data archived at ESA facilities with different origins.

As shown in *Figure 5* the early years (1981 – 1988) are covered only by Dundee Satellite Receiving Station (yellow) continued by Freie Universität Berlin (red). ESA recordings (green) in the Master Data Set are available since 1997 followed by University of Bern (blue) until the end of 2019. The y-axis shows the number of data sets per year including some redundancy.

Figure 6 gives the same overview of the AVHRR images available as L1B EO-SIP from the ESA archives, but detailed by satellite.

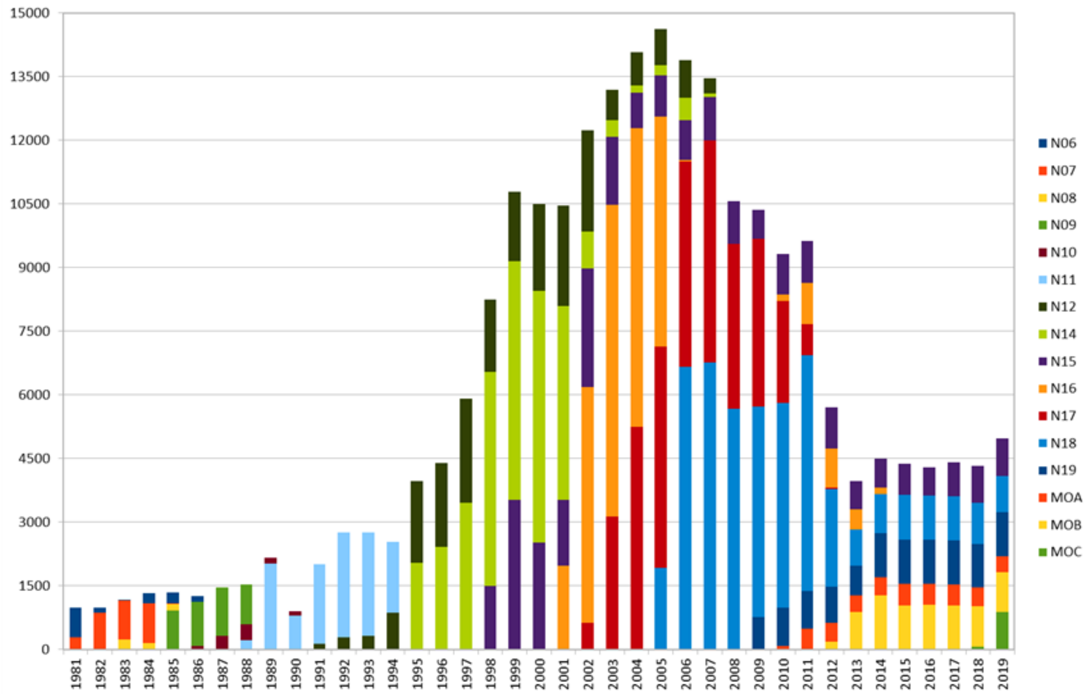

Figure 6: AVHRR L1B EO-SIP, archived at ESA, detailed per year and satellite.

The following *Figure 7* shows the temporal redundancy of the AVHRR swaths received simultaneously be different stations from the year 1997 onwards. Visualized are the orbits covered by two or more files in the archive for the different satellites (NOAA-6 to NOAA-19 and Metop-A to -C). This redundancy explains the high amount of data sets from 1997 to 2011 covering Europe. Hence, the user can select the best image for their own needs.

As shown in *Table 4* and its visualization in *Figure 8*, only for the years 1990 and 1991 a major data gap of approx. 300 days could not be closed so far. The outage of the Berlin station caused the gap. Due to a hardware issue at the Bern station a minor gap of 54 days occurred in 2013. All other years are useable for the generation of time series of ECVs for analysis of climate induced changes. The periods of deactivated scanner or any subsystem on the NOAA satellites is documented in *Table 1*.

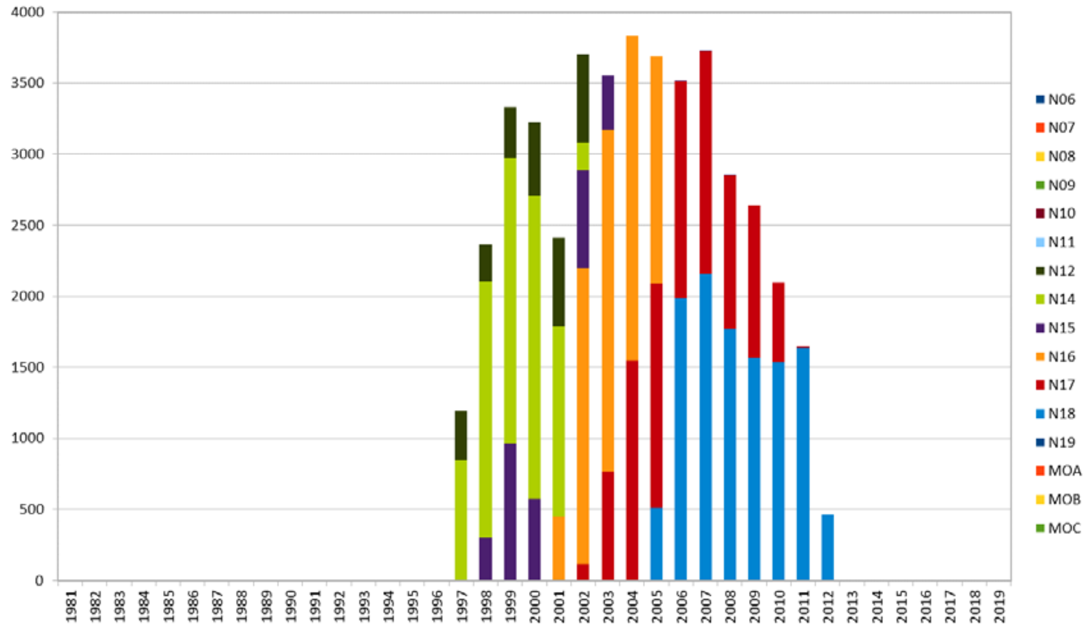

Figure 7: Number of orbits covered by two or more files in the Master Data Set.

Table 4: Number of dates per year indicating the availability of files archived as EO-SIP files at ESA facilities. Column '0' depicts the number of dates no data are available for; column '1' shows the number of dates for which exactly one file is available for; column '>1' shows the number of dates with the availability of 2 or more files.

year	0	1	>1
1981	0	8	357
1982	1	9	355
1983	0	2	363
1984	0	0	366
1985	0	1	364
1986	0	1	364
1987	0	0	365
1988	0	0	366
1989	32	4	329
1990	231	2	132
1991	75	1	289
1992	2	2	362
1993	0	0	365

year	0	1	>1
1994	6	1	358
1995	4	0	361
1996	1	1	364
1997	0	0	365
1998	0	0	365
1999	0	0	365
2000	0	0	366
2001	0	0	365
2002	0	0	365
2003	0	0	365
2004	0	0	366
2005	0	0	365
2006	0	0	365

year	0	1	>1
2007	0	0	365
2008	0	0	366
2009	0	0	365
2010	0	0	365
2011	0	0	365
2012	1	1	364
2013	54	1	310
2014	0	0	365
2015	0	0	365
2016	0	0	366
2017	0	0	365
2018	0	0	365
2019	0	0	365

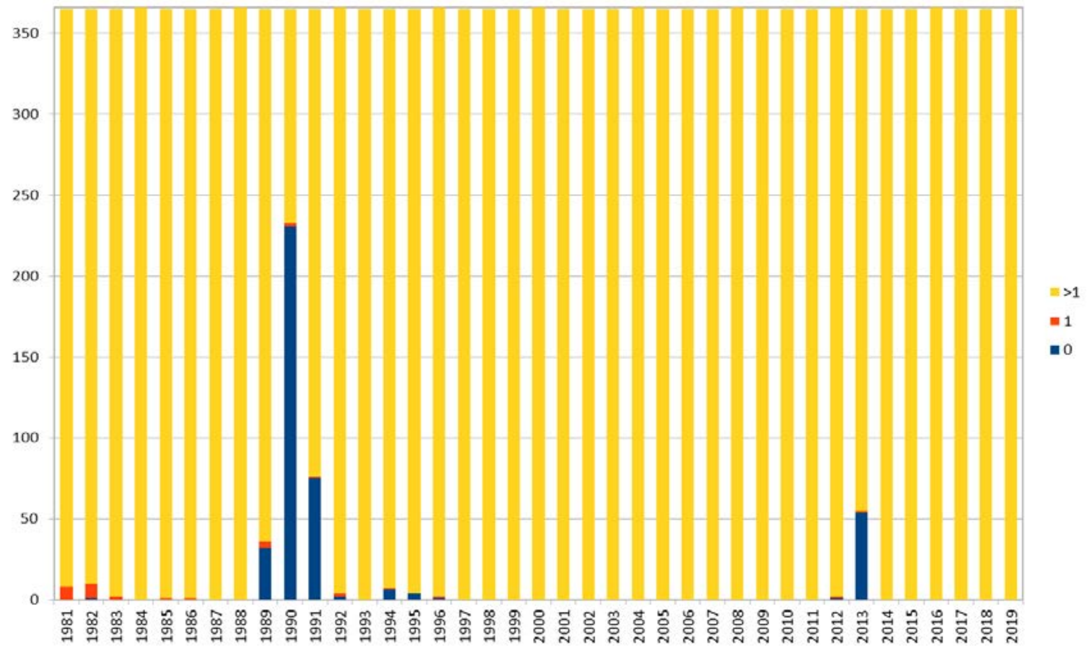

Figure 8: Availability of archived EO-SIP files at ESA facilities, a visual representation of table 4. Yellow bars indicate the number of days with more than one recording per day; red bars show the number of days with exactly one file per day; blue bars indicate the number of days without any data.

3.3 Global 1-km AVHRR data set

Also the global AVHRR data set in 1-km spatial resolution is archived at ESA facilities. It was a coordinated activity from many space agencies to receive and archive all data from the years 1992 – 1999. This data set is available as NOAA level 1b file but not as EO-SIP with all included meta-files and quality indicators. In addition, the pre-processed global 1-km data set by USGS is now also available at ESA facilities.

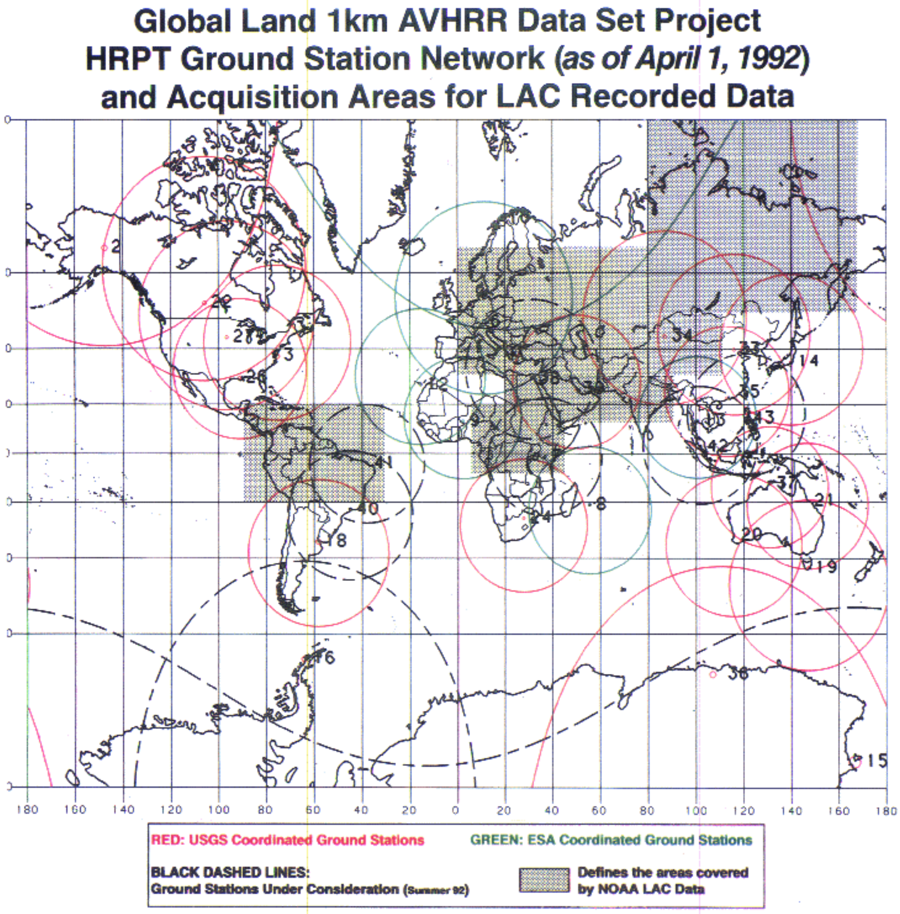

Figure 9: Coverage of the global 1-km AVHRR data set (1992-1999).

More than 30.000 data files covering the land areas of the world from 1992 – 1999 are archived at ESA. This data set will be very valuable to compare the retrieval accuracy of ECVs based on AVHRR GAC data (4km spatial resolution).

Table 5: Number of AVHRR data in Level 1A and Level 1B format from the global 1-km activity stored at ESA facilities.

Level	NOAA 11	NOAA 14	Total
1A	8679	22933	31612
1B	8664	22933	31597

4 Data formats

4.1 Input format description L0, L1A

The contributors Bern, Berlin, and Dundee provided the input data as HRPT Level 0 files. The data were incorporated in both the L0 and L1A EO-SIP data sets.
HRPT Level 0 data consist of minor frames of 11090 10-bit words. Each 10-bit word is stored in two 8-bit bytes on disk. Each minor frame corresponds to one AVHRR scan line covering a ground swath of approximately 3000 km. The video data comprises 5 interleaved channels, each 2048 pixel wide. As well as video data, each minor frame contains sync, telemetry and TIP data. The total length of a HRPT Level 0 minor frame is 22180 bytes, starting with a 12 bytes sync header, followed by administrative, telemetry and finally the actual AVHRR data:

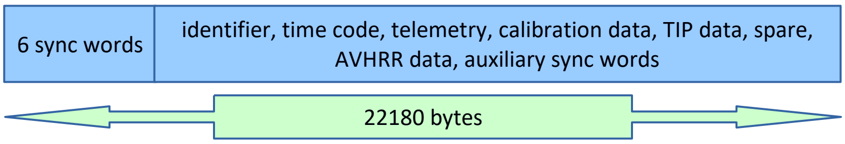

Figure 9: Basic HRPT minor frame format.

A major frame is made up of three minor frames. For the AVHRR/1 and AVHRR/2 sensors the TIP data are updated at the major frame rate, i.e. the TIP data in minor frames 2 and 3 are identical to those in minor frame 1. For the earlier AVHRR/3 satellites NOAA-15 to -17 the TIP and AMSU data are updated at the major frame rate, TIP data in minor frame 1 and backfilled in minor frame 2, AMSU data in minor frame 3. For the latest AVHRR/3 satellites NOAA-18 and -19 the TIP and AMSU/MHS data are updated at the major frame rate, TIP data in minor frames 1 and 2, AMSU/MHS data in minor frame 3.
The detailed descriptions for the various HRPT Level 0 formats and their differences can be found in:

- NOAA Technical Memorandum NESS-107: Section 3.3 HRPT Format (for AVHRR/1 and /2)
- NOAA KLM User's Guide: Section 4.1.3.1 HRPT Minor Frame Format for NOAA KLM (for AVHRR/3 on NOAA-15 to -17)
- NOAA KLM User's Guide: Section 4.1.3.2 HRPT Minor Frame Format for NOAA -N, -N’ (for AVHRR/3 on NOAA-18 and -19).

The data from the ESA holdings were provided as SeaWiFS and AVHRR Level 1 Archive Products. The format of the AVHRR imagery file deviates slightly from HRPT Level 0, the leading 6 sync words were replaced by a 16-bit word for scanline flags, another 16-bit word for the day of year, and a 32-bit word for the time of day in milliseconds. A minor frame in this format takes up 22176 bytes:

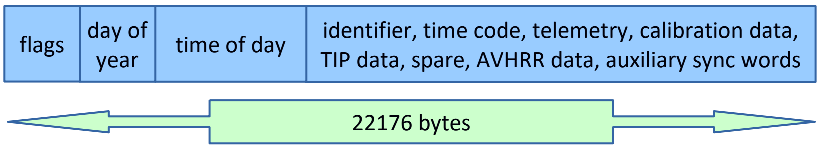

Figure 10: HRPT minor frame format in an ESA AVHRR Level 1 Archive Product.

The complete format is specified in Section 5.4 of the SeaShark - Detailed Design Document and includes the auxiliary files like navigation and calibration data, catalogue and quicklook files etc. The format definition of the AVHRR imagery file can be found in Table 5-6 of the same chapter. The files are considered as processing level 1A. As such they are directly and without modification transferred to the Level 1A EO-SIP data set. Level 0 EO-SIPs were not produced from the ESA data.

4.2 Level 1B EO-SIP

The European AVHRR Master Data Set is provided as Level 1B EO-SIP files to the user. This section gives a terse overview of their file and data structure. The entire L1B EO-SIP format is detailed in the document EO-SIP Specialisation for AVHRR Products.

Each AVHRR L1B EO-SIP contains a single AVHRR image as the EO product, accompanied by the product metadata, a browse image from AVHRR channel 4, a quality report file, and an information file about the SIP creation. *Table 6* showcases the components of an AVHRR L1B EO-SIP. The description of the format and content of the EO product follows in Section 4.3 NOAA AVHRR Level 1B Format. A detailed explanation of the quality report can be found in Chapter 5 Quality information.

Table 6: Components of an AVHRR Level 1B EO-SIP.

Component	**File name within the EO-SIP**
EO product	N11_RPRO_AVH_L1B_1P_19890803T120502_19890803T122046_004415.TAR
Product metadata	N11_RPRO_AVH_L1B_1P_19890803T120502_19890803T122046_004415.MD.XML
Quality report	N11_RPRO_AVH_L1B_1P_19890803T120502_19890803T122046_004415.QR.CSV
Browse image	N11_RPRO_AVH_L1B_1P_19890803T120502_19890803T122046_004415.BI.PNG
SIP information file	N11_RPRO_AVH_L1B_1P_19890803T120502_19890803T122046_004415.SI.XML

The product metadata are outlined in an XML file. An incomplete list of the metadata includes:

- the start and end dates and times of the AVHRR scene
- satellite name and mission
- orbit number and direction
- acquisition station
- quality status
- the four-corner footprint of the image.

The complete definition of the metadata content is part of the EO-SIP Specialisation for AVHRR Products. A copy of the high-level schematic view can be found in Annex A in this document. Annex B showcases the detailed content of an AVHRR L1B EO-SIP metadata file.

The EO-SIP file name follows the ESA PDGS Harmonised File Naming Convention (Harmonised File Naming Convention v2_9.pdf). It uses a file name pattern with fixed and variable parts:

```
<identifier>_RPRO_AVH_L1B_1P_<starttime>_<endtime>_<orbit>_v0100.ZIP
```

To depict the variable parts here they are enclosed in brackets, whereas the fixed parts are written as-is. *Table 7* lists the variable elements of the file name including sample values. The complete file name composed of the sample values would be:

```
N09_RPRO_AVH_L1B_1P_19920411T032844_19920411T033638_005501_v0100.ZIP
```

Table 7: Variable elements in an AVHRR EO-SIP file name.

File Name Element	Description	Example(s)
<identifier>	3-character satellite identifier	N09 (for NOAA-9) MOA (for Metop-A)
<starttime>	Start date and time in the 15-character ISO 8601 format	19920411T032844
<endtime>	End date and time in the 15-character ISO 8601 format	19920411T033638
<oooooo>	6-digit orbit number	005501

4.3 NOAA AVHRR Level 1B Format

The EO product in an AVHRR Level 1B EO-SIP consists of a non-compressed TAR archive with a NOAA AVHRR Level 1B file and its MD5 checksum as content. The AVHRR data file is called *image.l1b*, the checksum file *image.md5.* Prior to the archiving step both files were put in a folder named after the EO-SIP file minus the version number. *Table 8* lists the components of the EO product.

The NOAA Level 1B format combines the raw AVHRR data stream from the processing levels 0 or 1A with ancillary information including calibration coefficients and georeferencing parameters in a single file. Contrary to other definitions for processing level 1B the ancillary data in NOAA L1B files, in particular the calibration information, are not applied to the AVHRR measurements. Also, Earth location data are available only for 51 anchor points per scanline and need to be interpolated to geolocate the other pixels.

Table 8: Content of the Level 1B EO product

Component	Directory / file name within the EO product
AVHRR data	N11_RPRO_AVH_L1B_1P_19890803T120502_19890803T122046_004415/image.l1b
Checksum	N11_RPRO_AVH_L1B_1P_19890803T120502_19890803T122046_004415/image.md5

The file *image.l1b* in the L1B EO-SIP has the following structure:

- 1 archive header record
- 1 data set header record
- *N* data records.

Depending on the AVHRR sensor generation the type of the archive header and the size of data record differ. *Table 9* provides a list for those differences. The data set header record has the same size as the data records.

Table 9: Differences in the Level 1B formats per sensor generation.

Sensor generation	Header type	Header size	Data record size	Format date
AVHRR/1 and /2	TBM	122 bytes	14800 bytes	1994-11-15
AVHRR/3	ARS	512 bytes	15872 bytes	2005-04-28

Over time the format definitions of the data set header records changed; in the case of AVHRR/3 even a change in the data record format was implemented. For the user's convenience those changes are not represented in the L1B files of the EO-SIPs. Instead all AVHRR/1 and /2 L1B files from the EO-SIPs have the same format which is described in the NOAA POD User's Guide in the tables *2.1.1-1. TBM Header Record Format*, *2.0.4-2. Data Set Header record format for AVHRR* and *3.2.2.1-1. Format of LAC/HRPT data record*. The AVHRR/3 data from the satellites NOAA-15 to -19 and from the EUMETSAT Metop satellites are structured as in format version 3, defined in the tables *8.3.1.2-1. Format of ARS Header Record*, *8.3.1.3.2.2-1. Format of LAC/HRPT Data Set Header Record*, and *8.3.1.3.3.2-1. Format of LAC/HRPT Data Record for NOAA-N* of the NOAA KLM User's Guide. The software which was used in the LTDP project to convert the AVHRR/3 Level 1A data to the NOAA AVHRR Level 1B format did not bump the version number to 5 as the associated changes do not apply for processing facilities other than the NOAA CLASS archive.

5 Quality Information

5.1 Validation of the EO-SIP files

A validation procedure was implemented and performed on a subset of the L1A and L1B Master Data Sets. The EO-SIP files were tested for completeness and correctness. The tool to perform the validation was developed independently from the EO-SIP processor suite to increase the fidelity of the results.

The validation tool screened the content of the EO-SIP files for the five components from Table *6*. A first test checked if the SIP file included all components. Then the EO product was extracted, its MD5 checksum computed and verified to check both the integrity of the EO product and the correctness of the packing and unpacking procedures.

The next verification step ensured that the SIP metadata file contained the correct values for dates, times, orbit number, pass direction, and satellite number. Those data are critical as they are also used to build the SIP identifiers and filenames.

The final test checked the footprint in the SIP metadata file to be complete and containing five coordinate pairs. The first and the last coordinates need to be identical to form a closed polygon, which was also verified.

The validation procedure was applied to a total of 7256 EO-SIP files from the L1A and L1B Master Data Sets for the year 2004. The AVHRR data came from five different satellites, including AVHRR/2 and AVHRR/3 data. The images were recorded at three different locations. All EO-SIP files passed the automatic consistency test.

Before the final integration into the ESA dissemination platform the ESA Heritage Team performed additional tests to guarantee the compatibility of the EO-SIP files with the platform requirements.

5.2 Quality of AVHRR data

5.2.1 The quality report file

Every L1B EO-SIP file contains a quality report file (QR). The entries consist of single lines with the name and values of the quality property, separated by commas. At the end of the QR two sections about quality flags and gaps contain lists of values. *Table 10* lists the properties available in a QR file.

The property *stage* indicates the operational phase of the satellite. Valid values are:
- commissioning
- primary
- secondary.

The property *channels* lists the active AVHRR channels active in the recording. For AVHRR/1 data channel 4 is listed twice; channel 5 was not available, therefore the data from channel 4 were duplicated. For AVHRR/3 data both channels 3A and 3B may appear in the list simultaneously if the satellite crossed the boundary between daylight and night.

Table 10: Properties of the quality report file.

Property	Description
stage	operational stage of the satellite
quality	overall data quality
channels	list of the AVHRR channels
barcode	flag if a barcode pattern was detected
gaps	flag if missing scan lines were detected in the core area of the AVHRR image
clock error correction	time shift in seconds in relation to the satellite clock
geo-correction	flag if a landmark-based geo-correction is applied
source	source EO-SIP
parts	number of parts of the source data
md5sum	MD5 checksum of the EO product
quality flags	quality bitfield(s) taken from the AVHRR L1B file
gap list	a list of ranges where data are missing in the AVHRR image

The fields *clock error correction* and *geo-correction* are typically set to *0* resp. *no* unless the data are from the Dundee archive. Those recording were delivered with adjusted clock and satellite attitude.

The property *source* links the L1B EO-SIP with its source, typically the L1A EO-SIP. The field *parts* indicates how many files the data were sourced from. It is usually set to 1 unless the data were recovered from CEOS SHARP-1 volumes. In this case an AVHRR image was split up into blocks of 1440 scan lines and needed to be re-assembled.

The field *md5sum* contains the checksum of the EO product within the L1B SIP, i.e. the TAR archive as described in section 4.2.

The remaining properties *quality flags*, *barcode*, *gaps*, *gap list*, and *quality* are explained in more detail in the following subsections.

5.2.2 Quality flags

The section *quality flags* contains a list of the scan lines with non-empty quality indicator fields in the NOAA AVHRR L1B file. It differs depending on the AVHRR generation.

For AVHRR/1 and /2 it is a copy of bytes 9 and 10 from "Table 3.1.2.1-2. Format of quality indicators" in the NOAA POD User's Guide; *Table 11* displays the excerpt.

For AVHRR/3 the Quality Indicator Bit Field and the Scan Line Quality Flags originating from "Table 8.3.1.3.3.2-1. Format of LAC/HRPT Data Record for NOAA-N (Version 5, post-November 14, 2006, all spacecraft)" are put to the *quality flags* field in the QR. *Table 12* shows the definitions per bit for the Quality Indicator Bit Field. *Table 13* describes the Scan Line Quality Flags.

Table 11: Quality indicators for AVHRR/1 and /2 data.

Byte	Bit	Description
9	7	FATAL FLAG - Data should not be used for product generation
	6	TIME ERROR - A time sequence error was detected while processing this frame
	5	DATA GAP - A gap precedes this frame
	4	DATA JITTER - Resync occurred on this frame
	3	CALIBRATION - Insufficient data for calibration
	2	NO EARTH LOCATION - Earth location data not available
	1	ASCEND / DESCEND - AVHRR Earth location indication of ascending (=0) or descending (=1) data
	0	P/N STATUS - Pseudo Noise (P/N) occurred (=1) on the frame, data not used for calibration computations
10	7	BIT SYNC STATUS - Drop lock during frame
	6	SYNC ERROR - Frame Sync word error greater than zero
	5	FRAME SYNC LOCK - Frame Sync previously dropped lock
	4	FLYWHEELING - Flywheeling detected during this frame
	3	BIT SLIPPAGE - Bit slippage detected during this frame
	2	CHANNEL 3 SOLAR BLACKBODY CONTAMINATION (SBBC) INDICATOR 0 = no correction 1 = solar contamination corrected
	1	CHANNEL 4 SBBC INDICATOR 0 = no correction 1 = solar contamination corrected
	0	CHANNEL 5 SBBC INDICATOR 0 = no correction 1 = solar contamination corrected

If the bitfields are empty, i.e. set to zero for every scan line in the AVHRR L1B file this section remains empty as well. Note that these quality flags depend on the hardware and software of the receiving station, they are not part of the recorded level 0 data stream. Especially for archived AVHRR/1 and /2 data this information is available only on rare occasions.

Table 12: Quality Indicator Bit Field for AVHRR/3 data.

Bytes	Bit(s)	Description
25-28	Quality Indicator Bit Field *(if a bit is on (=1), the statement is true)*	
	31	do not use scan for product generation
	30	time sequence error detected within this scan
	29	data gap precedes this frame
	28	insufficient data for calibration
	27	earth location data not available
	26	first good time following a clock update (nominally 0)
	25	instrument status changed with this scan
	24	bit sync dropped lock during frame (NOAA) or <zero fill> (Metop)
	23	frame sync word has errors (NOAA) or <zero fill> (Metop)
	22	frame sync returned to lock (NOAA) or <zero fill> (Metop)
	21	frame sync word not valid (NOAA) or <zero fill> (Metop)
	20	bit slip occurred during this frame (NOAA) or <zero fill> (Metop)
	19-9	<zero fill>
	8	TIP parity error detected (NOAA) or <zero fill> Metop
	7-6	reflected sunlight detected ch 3B (0=no anomaly; 1=anomaly; 3=unsure)
	5-4	reflected sunlight detected ch 4 (0=no anomaly; 1=anomaly; 3=unsure)
	3-2	reflected sunlight detected ch 5 (0=no anomaly; 1=anomaly; 3=unsure)
	1	resync occurred on this frame (NOAA) or <zero fill> Metop
	0	Pseudo-noise occurred on this frame (NOAA) or <zero fill> Metop

Table 13: Scan Line Quality Flags for AVHRR/3 data.

Byte(s)	Bit(s)	Description
29		Scan Line Quality Flags [<Reserved>] (zero fill)
30		Scan Line Quality Flags [Time Problem Code] (If a bit is on (=1), the statement is true. All bits off implies the scan time is as expected.)
	7	time field is bad but can probably be inferred from the previous good time
	6	time field is bad and can't be inferred from the previous good time
	5	this record starts a sequence that is inconsistent with previous times (i.e., there is a time discontinuity); this may be associated with a spacecraft clock update. (see bit 26, Quality Indicator Bit Field)
	4	start of a sequence that apparently repeats scan times that have been previously accepted
	3-0	<zero fill>
31		Scan Line Quality Flags [Calibration Problem Code] (If a bit is on (=1), the statement is true. These bits complement the channel indicators; all bits set to 0 indicate normal calibration.)
	7	scan line not calibrated: all IR channels failed calibration
	6	scan line marginally calibrated: one or more IR channels marginally calibrated, or one or more, but not all, IR channels failed calibration
	5	scan line not calibrated: bad or insufficient PRT data
	4	scan line marginally calibrated: marginal PRT data
	3	some uncalibrated channels for this scan line (i.e., one or more, but not all, IR channels failed calibration)
	2	no visible calibration due to either the presence of MIRP pseudo-noise in place of AVHRR data (NOAA only) or calibration processing turned off
	1	<zero fill>
	0	scan line was not calibrated because of satellite maneuver (Metop) or <zero fill> (NOAA)
32		Scan Line Quality Flags [Earth Location Problem Code] (If a bit is on (=1), the statement is true. All bits set to 0 imply the earth location was normal.)
	7	not earth located because of bad time; earth location fields zero-filled
	6	earth location questionable: questionable time code (see time problem flags above)
	5	earth location questionable: marginal agreement with reasonableness check
	4	earth location questionable: fails reasonableness check
	3-2	<zero fill>
	1	not earth located because of satellite in-plane maneuver (Metop) or <zero fill> (NOAA)
	0	not earth located because of satellite out-of-plane maneuver (Metop) or <zero fill> (NOAA)

Figure 10 displays an extract of a NOAA-15 image with a large amount of noisy scan lines at the start of the recording. Excerpts of the section *quality flags* in the corresponding QR indicate that at least some of the affected scan lines may be identified by their quality flags, as seen in *Figure 11*.

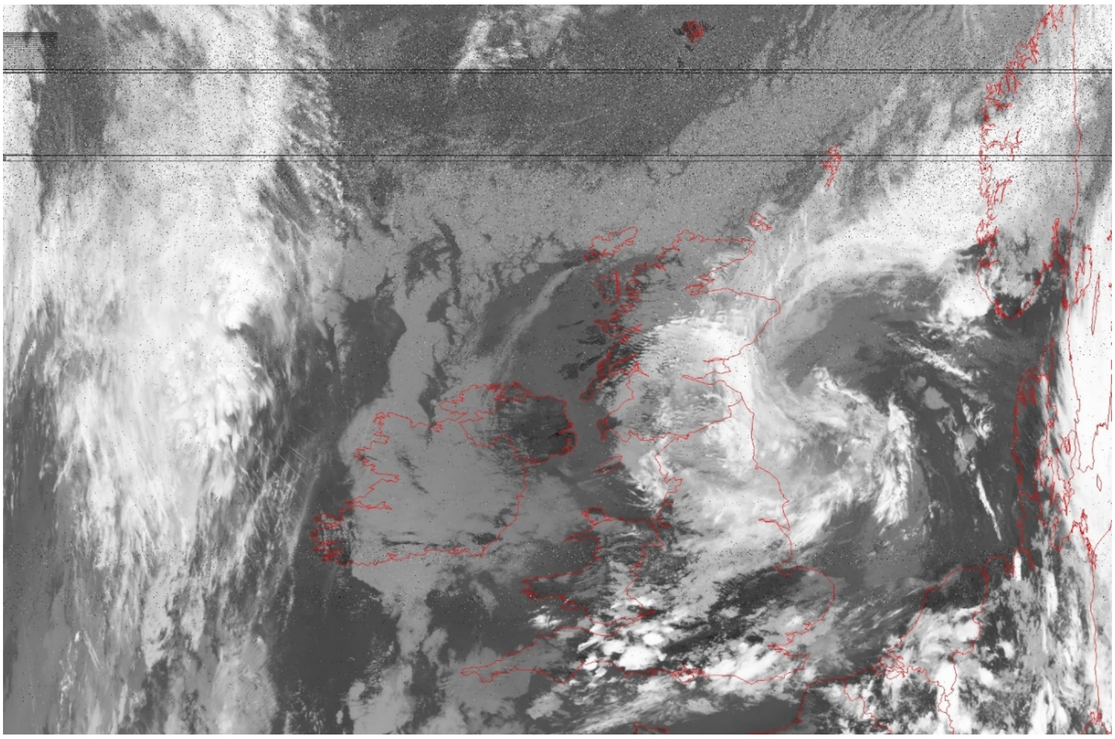

Figure 10: NOAA-15, 2016-06-17, noise at the start of the recording.

```
:,quality flags
1,0X00800000,0000000000
4,0X00800000,0000000000
7,0X00800000,0000000000
9,0X00800000,0000000000
…
100,0X00800000,0000000000
101,0X00800000,0000000000
102,0X10800000,0X00001000
103,0X10800000,0X00001000
104,0X10800000,0X00001000
105,0X10800000,0X00001000
…
272,0X10800000,0X00001000
273,0X10000000,0X00001000
274,0X10800000,0X00001000
275,0X10000000,0X00001000
276,0X10000000,0X00001000
277,0X10000000,0X00001000
…
422,0X10800000,0X00001000
423,0X10800000,0X00001000
424,0X00800000,0000000000
425,0X00800000,0000000000
426,0X00800000,0000000000
…
```

Figure 11: Excerpt from the field quality flags in the QR.

5.2.3 Bar code and wave patterns

Erroneous behavior of the AVHRR scan motor on various platforms led to issues in the form of waved or bar code patterns. As an example the NOAA status page reported for NOAA-16:

- 2004-01-04: [The] AVHRR Scan Motor and synch delta at significantly elevated levels, imagery exhibiting wave patterns.
- 2004-01-14: [The] current surged to maximum reported value (305 mAmps). Imagery began showing bar code patterns shortly thereafter.

Figure 12 shows an extract from a NOAA-16 recording on 2004-01-08 affected by a wave pattern. In *Figure 13* the area within the yellow square was magnified to detail the wave pattern at the edge of the AVHRR image.

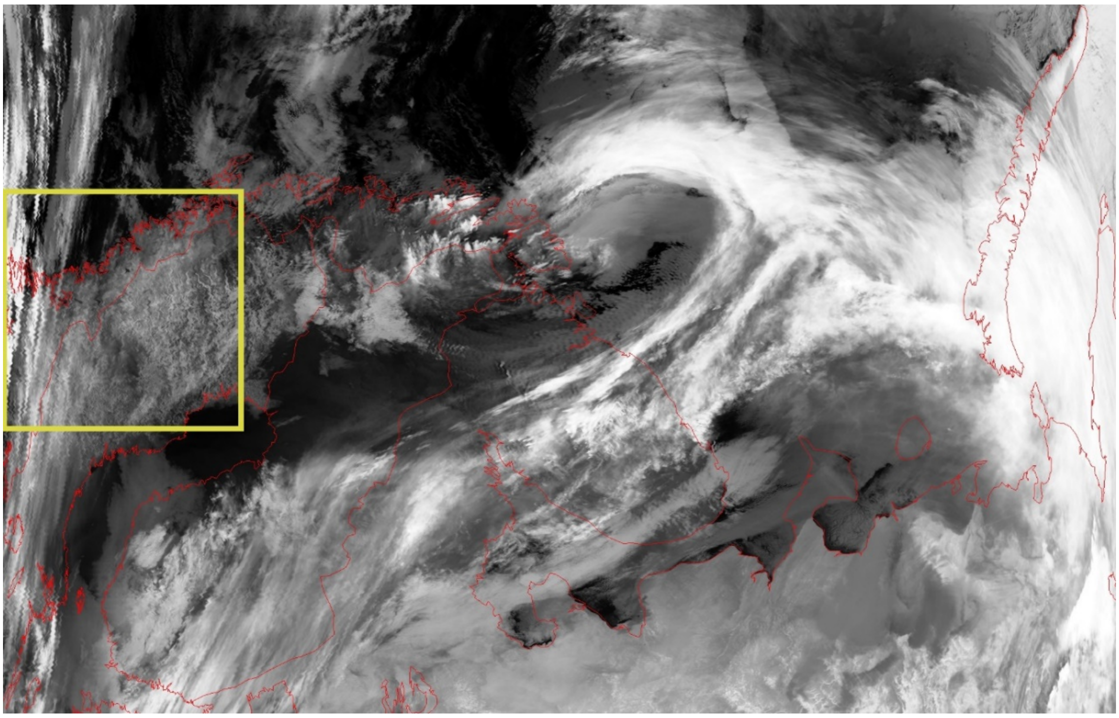

Figure 12: NOAA-16, 2004-01-08, wave pattern at the left edge of the image.

No test to detect wave patterns was developed or performed on the AVHRR data in EO-SIP files of the European Master Data Set.

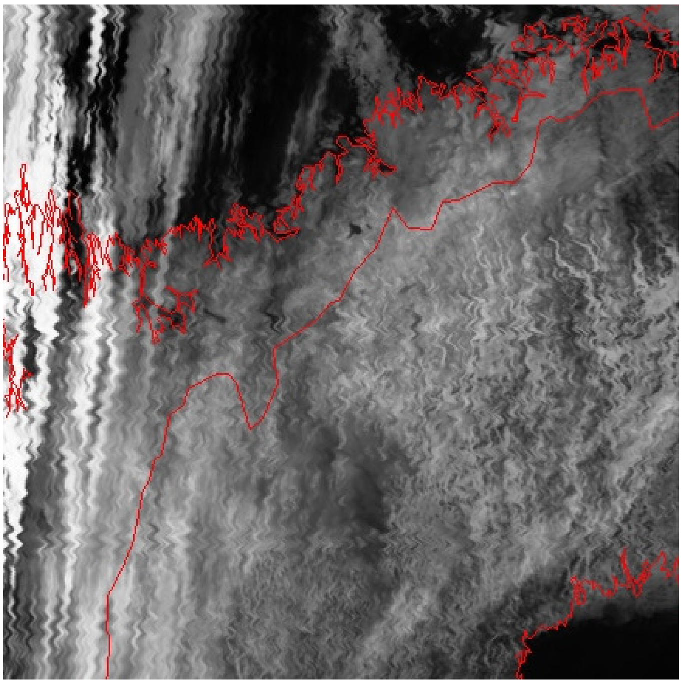

Figure 13: Magnified view of the yellow square from Figure 12, demonstrating the wave effect of the scan motor issue.

Figure 14 displays a sample recording with a bar code pattern. The AVHRR imagery was sent on 2004-01-16 from NOAA-16, two days after the second status message from NOAA. The pattern stopped in the lower part of the image data.

Other satellites like NOAA-14 and NOAA-17 showed the same symptoms, typically towards the end of their lifetime. Information about the periods when the sensors exhibited bar coded data is sparse and incomplete. Therefore, a heuristic approach was developed and implemented to automatically detect bar code patterns and to fill the QR field *barcode*.

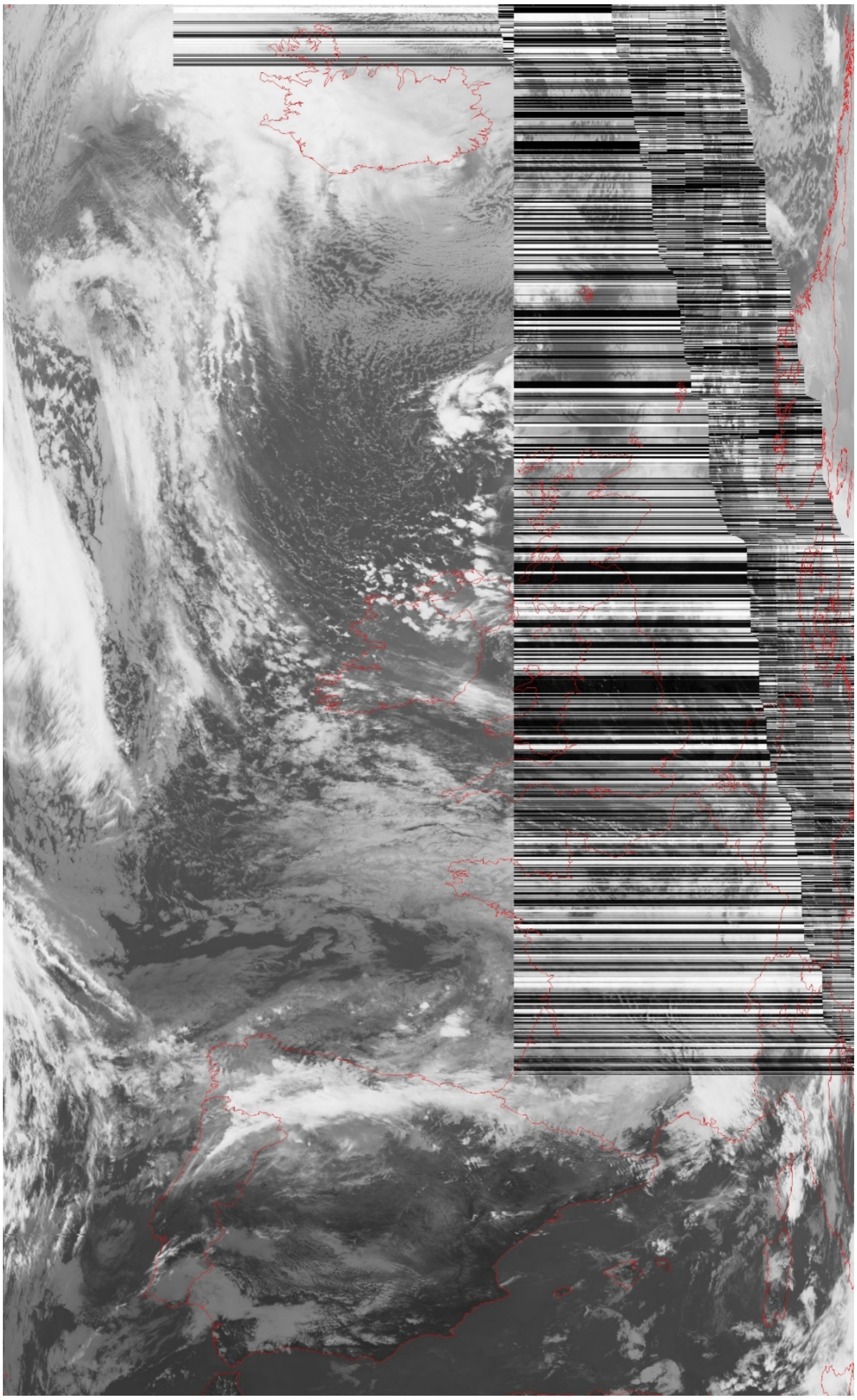

Figure 14: NOAA-16, 2004-01-16, bar code patterns over major parts of the AVHRR imagery.

Typically, the edge of the bar code is located in almost the same column over a considerable amount of scan lines, showing a distinctly vertical line. The test tries to identify such a vertical pattern in an AVHRR channel 4 image. First it computes the maximum difference between two neighbors in the same scan line. Second it creates and sorts a histogram to find the cluster spots with the maximum differences. If the top 6 bins combined are above a threshold of 16% the test assumes to have found a vertical pattern and sets the *barcode* flag in the QR file to *yes*.

Due to the variety of the form the bar code pattern can take the test fails in a number of cases. If the edge of the pattern moves along the scan lines the test often returns a false negative result. Such an example is shown in *Figure 15*.

The test fails with a false positive if the edge of a large cloudy area runs almost vertically over an extended area of the recording. *Figure 16* shows two areas with a yellow border which could possibly trigger the bar code detector into a false alarm. Coastlines may have the same effect, although rarely.

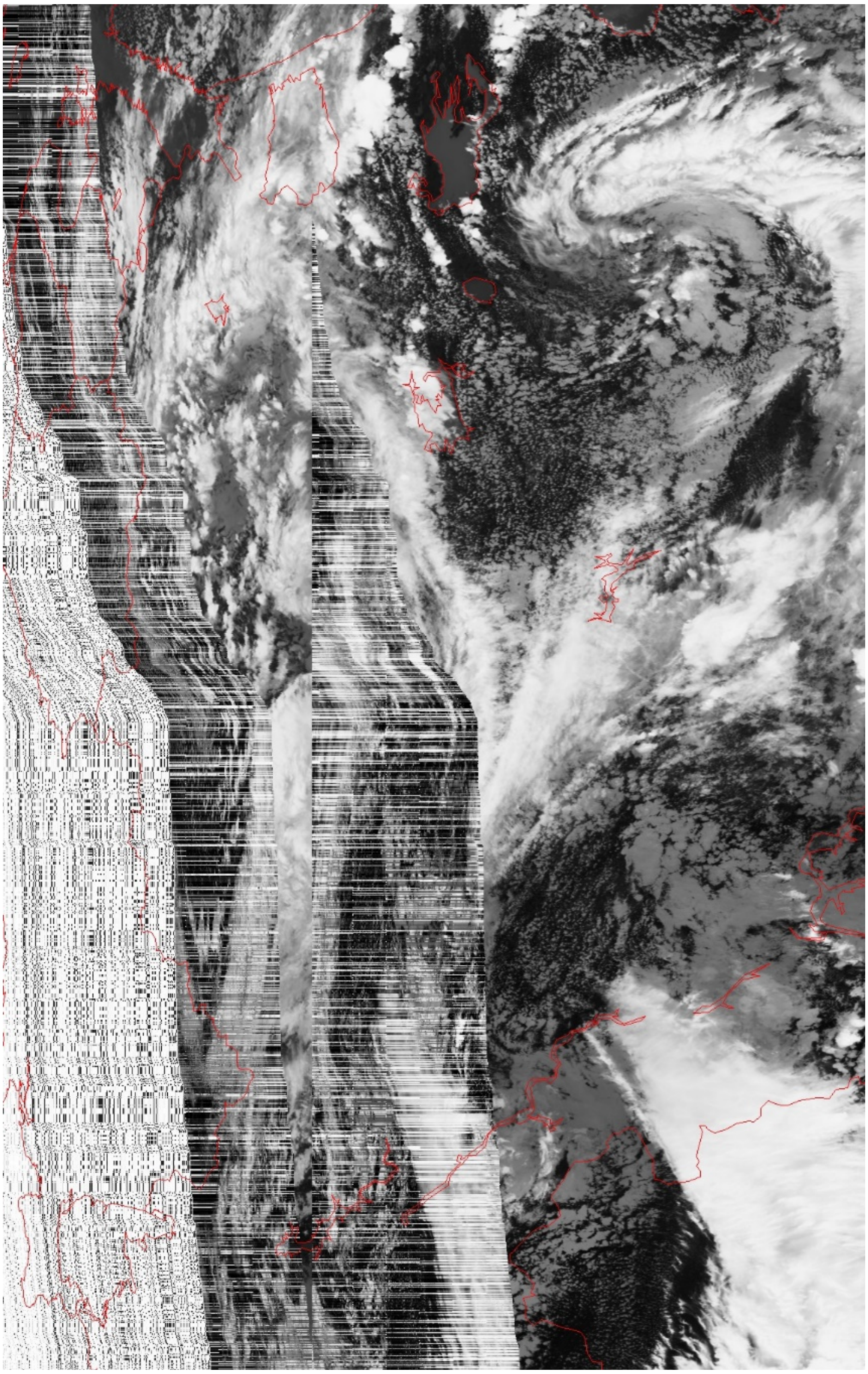

Figure 15: NOAA-16, 2004-05-20, bar code pattern with floating edges, failing the bar code test to identify the pattern.

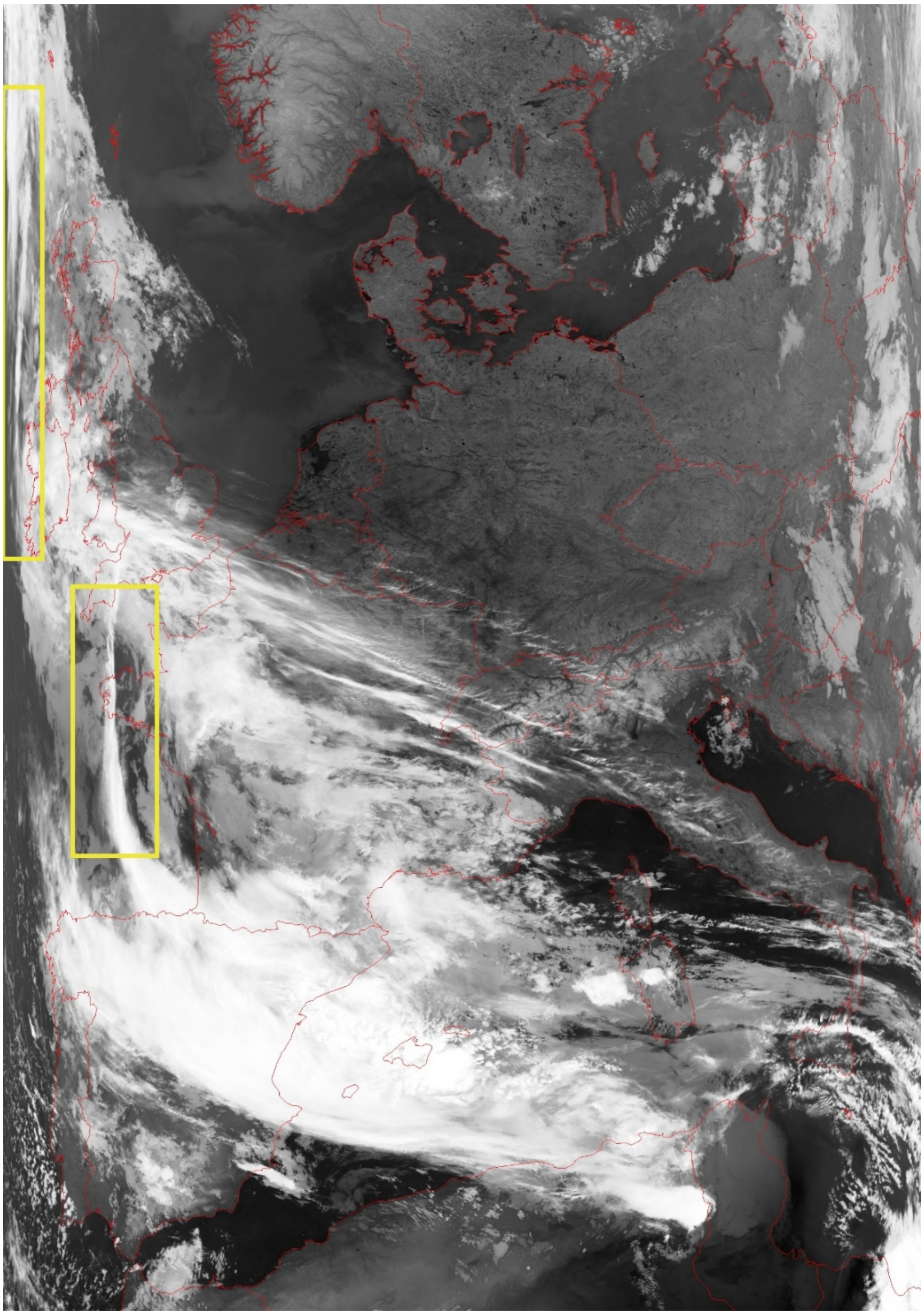

Figure 16: NOAA-18, 2008-05-10, the bar code detector falsely identified cloudy areas as edges of a bar code pattern.

5.2.4 Gaps

Several reasons can lead to missing scan lines in an AVHRR image. Most often the data reception got interrupted due to a reduced signal strength or an issue with the hardware and software at the station. The QR field *gaps* indicates if missing scan lines occur in the AVHRR scene.

Because of the decreasing signal strength the start and the end of a recording are prone to be affected by unusable or missing signals. Core areas have been defined as a counter measure. For AVHRR/1 and /2 scenes gaps in the first and last 5% of the recording do not count for the *gaps* flag, keeping 90% as the core area. For AVHRR/3 images the core area consists of 94%, leaving out the first and last 3% of the data.

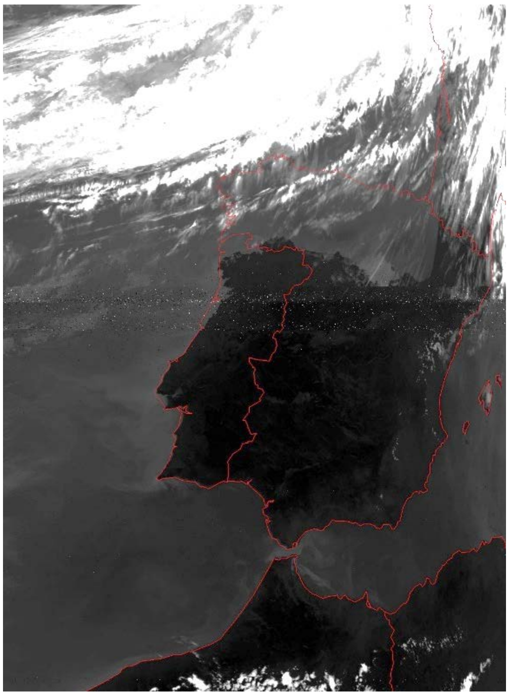

Figure 17: NOAA-11, 1992-08-16, gaps in the core area; quicklook made from AVHRR channel 4 in the L1B file.

Excerpt from the quality report file describing the areas where data are missing. Note that the quality flags are not available for the NOAA-11 data.

```
quality,degraded
…
gaps,yes
…
:,gap list
736,743,24
757,765,14
772,776,10
788,799,88
799,803,39
824,826,8
827,829,15
3998,4002,11
4047,4053,20
```

If gaps occur in the core area, the QR field *gaps* is set to *yes*. *Figure 17* showcases a NOAA-11 recording with gaps over the Iberian Peninsula. The missing scan lines occur in the core area of the image. The shifted coastlines (red) indicate the issues with the data as well as the northbound direction of the pass.

With the help of the listed gaps in the QR missing scan lines should be re-inserted before the processing of the data. *Figure 18* demonstrates that the NOAA-11 image can be calibrated and properly ortho-rectified even though the L1B file lacked the data.

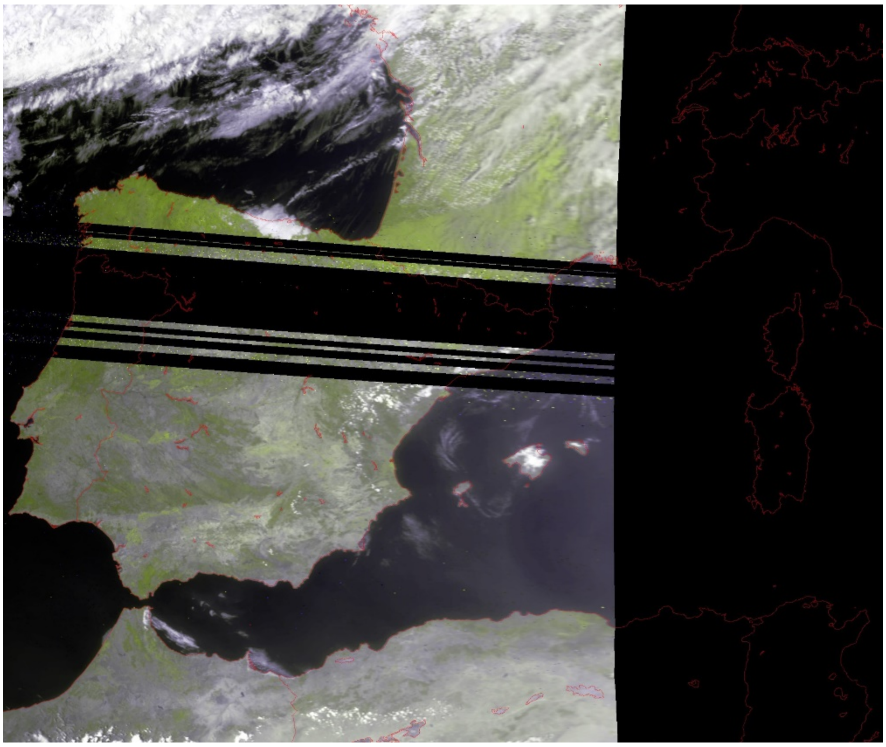

Figure 18: False colour representation of the calibrated and ortho-rectified AVHRR data from Figure 17 after the missing scan lines were re-inserted.

If gaps occur only outside of the core area they are listed in the QR, see the following subsection *5.2.5 Gap list*, and the QR field *gaps* is set to *no*. The sample in *Figure 19* demonstrates such a case.

5.2.5 Gap list

The routine which detects missing scan lines prints a list of the areas that should be inserted before the data are processed. The SIP processor appends this list at the end of the QR to the section *gap list* as comma separated triplets with

- the index of the last existing scan line before the gap
- the index of the first existing scan line after the gap
- the number of scan lines in between.

The indexing begins at 0 as the first scan line in the AVHRR image. The scan line numbers given in gap list tie to the index in the AVHRR recording and do not take into account inserted scan lines from a former gap.

A sample gap list with two problematic areas could look like:

```
:,gap list
4972,4975,4
4977,4978,2
```

The first gap starts at the scan line with index 4973 – the 4974th scan line in the AVHRR file – and ends at scan line 4974. Both scan lines need to be removed and replaced by a total of 4 blank scan lines. For the second gap no scan lines need to be removed, but two blank scan lines need to be inserted between scan line numbers 4977 and 4978.

If scan lines need to be removed from the start or the end of an image the index -1 is used, for example:

```
:,gap list
-1,5,5
4632,-1,7
```

At the start of the scene the scan lines with the indices 0 to 4 need to be removed or replaced by blanks, at the end the last seven scan lines beginning with index 4633 need to be cut.

Figure 19 shows the extract of a NOAA-19 north-bound pass with noisy data near the end of the recording. The noise showed up not only in the quality flags, but also caused a defective timeline recognized by the gap detector. The only gap in the recording lies outside of the core area, so the overall quality of the image is still considered as nominal even though the gap list is not empty.

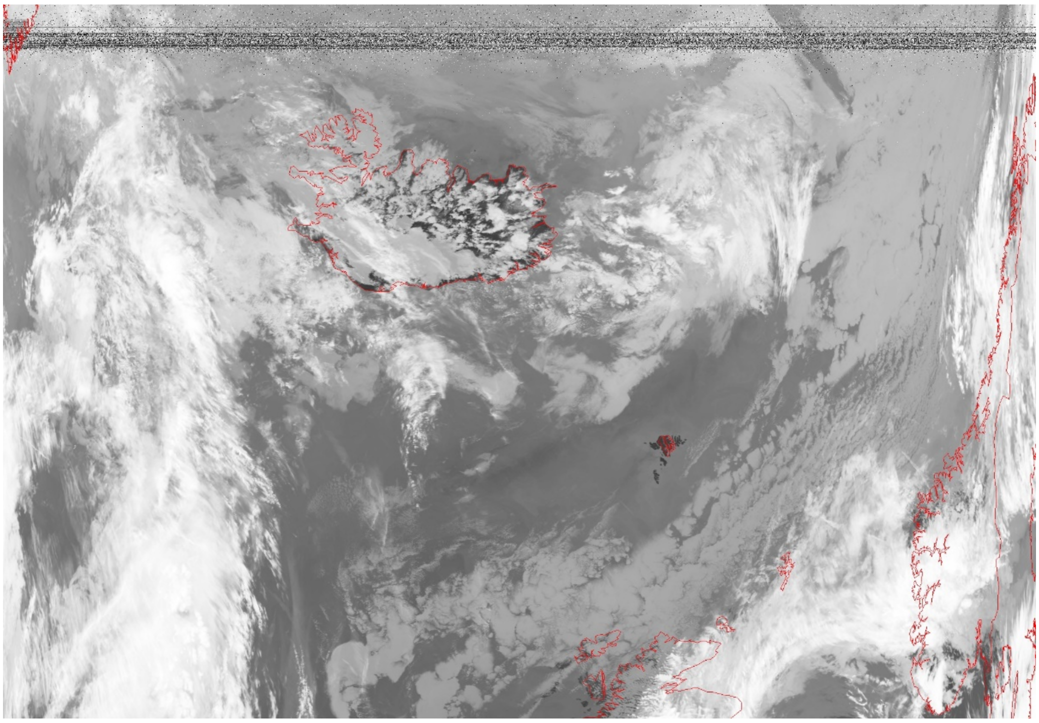

Figure 19: NOAA-19, 2016-06-17, north-bound pass with gaps outside the core area.

Excerpt from the quality report file with the quality flags marking the noise data:

```
quality,nominal
…
gaps,no
:,quality flags
…
4667,0X10800000,0X00001000
4668,0X10000000,0X00001000
4669,0X10800000,0X00001000
4670,0X10800000,0X00001000
4671,0X10800000,0X00001000
…
4716,0X10800000,0X00001000
4717,0X10800000,0X00001000
4718,0X10800000,0X00001000
4719,0X10800000,0X00001000
4720,0X10800000,0X00001000
4721,0X10800000,0X00001000
…
:,gap list
4669,4718,49
```

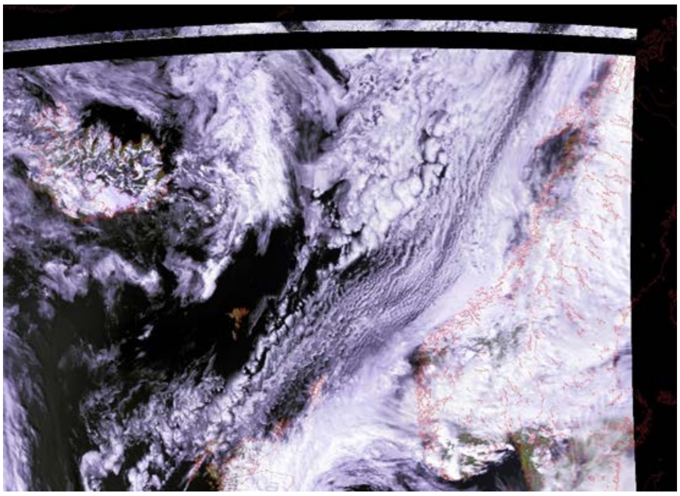

Figure 20: Calibrated and ortho-rectified data from Figure 19 with blank scan lines replacing a part of the noise data.

5.2.6 Nominal vs. degraded quality

The field *quality* from *Table 10* can have the values *nominal* or *degraded*. It is determined by the outcome of the bar code test and the gap detection routine. The data quality is marked as nominal unless at least one of the following conditions apply:

- the field *barcode* is set to *yes*
- the field *gaps* is set to *yes*
- the fields *barcode* and *gaps* are set to *no*, but the gap detector could not find a way to repair the timeline of the AVHRR image by removing and inserting scan lines. This is an extremely rare case and indicates a file which should not be used at all to process and analyze data.

In general, the quality of the AVHRR data is good enough to be used for the generation of ECVs. However, the age of the sensor design shows when the user needs to gather quality information about the data. Checksums are missing completely in the data transmission due to memory constraints leaving the user on their own to detect questionable data. The varied reception setups, hardware and software handled issues differently, and the lack of a unified system led to the loss of quality information especially for data from the AVHRR/1 and /2 satellites. Artifacts caused by a desynchronized mirror, reduced signal strength and many more are not detected or marked in the data stream.

The gap detector repairs and completes reliably the AVHRR data based on the timestamps of the scan lines. The bar code detector however delivers only a best effort assumption about a possibly degraded quality caused by a bar code pattern. Therefore, the user should consider the *quality* property in the QR with care; when in doubt the quicklook image within the EO-SIP may give an additional impression before processing and analyzing the data.

6 Recommendation for Users

6.1 Access via ESA interface

The European AVHRR Master Data Set is available via ESA standard data access web sites.

6.2 Usability of the AVHRR data

The AVHRR level 1B files provided as EO-SIP are a valuable source to generate long time series of many different Essential Climate Variables (ECVs) but require a careful and precise pre-processing. This includes the calibration of channel 1, 2 and 3A, which have no on-board calibration source but also the proper calibration of the thermal channels 3B, 4 and 5. Furthermore, some effort is needed for precise geocoding including orthorectification of the AVHRR data to guarantee a geocoding accuracy of better than 1/3 of pixel as required by GCOS. After these steps, the data can be used to retrieve snow cover extent, albedo, fire activity, aerosol optical depth, vegetation dynamics, lake surface water temperature and many more. University of Bern developed many algorithms for the retrieval of ECVs during the last years and compiled long time series. Further information on the usability of AVHRR data are available at:
https://www.geography.unibe.ch/research/remote_sensing_group/publications/index_eng.html

Annex A: AVHRR Metadata Schematic Representation

This annex is a copy of Figure 3-2: AVHRR Metadata Schematic Representation from the document EO-SIP Specialisation for AVHRR Products, pages 10ff. It presents a high-level schematic view of the metadata content in an AVHRR L1B EO-SIP.

Based on the full set of identified elements and attributes, a high-level but complete schematic representation of the Metadata XML file is reported in Figure 3-2.

This notation is applicable in the following figure:

- This is a container of other elements
- **This is a container of actual metadata**
- This is a mandatory element for the standard which is left empty by this specification
- **[This is an optional element]**
- This is an optional block of elements

eop:EarthObservation Root element of the metadata representation tailored for GENERIC EO Products
- om:phenomenonTime Time coverage of the product
  - gml:TimePeriod Time coverage of the product as a period
    - **gml:beginPosition Start date and time of the product**
    - **gml:endPosition Stop date and time of the product**
- om:resultTime Time when the sensing data has become available
  - gml:TimeInstant Identifiable position in time
    - **gml:TimePosition Date and time of data availability**
- om:procedure Procedure used to sense the data
  - eop:EarthObservationEquipment Equipment used to sense the data
    - eop:platform Platform description
      - eop:Platform Nested element for platform description
        - **eop:shortName Satellite name**
        - **eop:serialIdentifier Serial number of the satellite**
    - eop:instrument Instrument description
      - eop:Instrument Nested element for instrument description
        - **eop:shortName Sensor name**
    - eop:sensor Sensor description
      - eop:Sensor Nested element for sensor description
        - **eop:sensorType Sensor type**
        - **eop:operationalMode Sensor operational mode**
        - **eop:resolution Sensor resolution**
    - eop:acquisitionParameters Acquisition parameters
      - eop:Acquisition Acquisition description
        - **eop:orbitNumber Orbit number**
        - **eop:orbitDirection Orbit direction**
        - **eop:ascendingNodeDate UTC Date and Time at ANX**
        - **eop:ascendingNodeLongitude Longitude at ANX**

```
                                   eop:pitch Pitch angle
                                   eop:roll Roll angle
                                   eop:yaw Yaw angle
     om:observedProperty Observed property (empty)
     om:featureOfInterest Observed area
          eop:Footprint Footprint description
             eop:multiExtentOf Footprint representation structure, coordinates in posList
                    gml:MultiSurface
                           gml:surfaceMember
                                   gml:Polygon
                                          gml:exterior
                                                 gml:LinearRing
                                                        gml:posList Footprint points
     om:result Observation result
             eop:EarthObservationResult
                    eop:browse
                           eop:BrowseInformation
                                   eop:type
                                   eop:referenceSystemIdentifier
                                   eop:filename
                                          ows:ServiceReference Browse Image filename
                                                 ows:RequestMessage Download request (empty)
                    eop:product
                           eop:ProductInformation
                                   eop:filename
                                          ows:ServiceReference DIP package filename
                                                 ows:RequestMessage Download request (empty)
                                   eop:size Product size
eop:metaDataProperty Observation metadata
             eop:EarthObservationMetaData
                    eop:identifier Product identifier
                    eop:acquisitionType Type of acquisition
                    eop:productType Product type
                    eop:status Status of the product
             eop:downlinkedTo Downlink information
                    eop:DownlinkInformation
                           eop:acquisitionStation Acquisition station
             [eop:productQualityStatus] Product quality check result
             eop:productQualityReportURL Quality Report file name
             eop:processing Data processing information
                    eop:ProcessingInformation
                           eop:processingDate Processing date and time
                           eop:processingLevel Processing level
                           eop:nativeProductFormat Native product format
             eop:vendorSpecific Product specific attribute
                    eop:SpecificInformation
                           eop:localAttribute Attribute Name: sourceSIP
                           eop:localValue Attribute value
```

Annex B: Example of an AVHRR L1B EO-SIP metadata file

The content of a metadata file from an AVHRR Level 1B EO-SIP is shown below. The NOAA-17 data were recorded on the ESA station Matera, Italy. The full name of the EO-SIP is:

N17_RPRO_AVH_L1B_1P_20100112T093223_20100112T094516_039252_v0100.ZIP

The metadata file in the XML format is part of the EO-SIP content and is called:

N17_RPRO_AVH_L1B_1P_20100112T093223_20100112T094516_039252.MD.XML

Some lines in its content were split to accommodate the constraints of the word processor and to improve the readability.


```
<eop:EarthObservation
    xmlns:gml="http://www.opengis.net/gml/3.2"
    xmlns:eop="http://www.opengis.net/eop/2.1"
    xmlns:om="http://www.opengis.net/om/2.0"
    xmlns:ows="http://www.opengis.net/ows/2.0"
    xmlns:xlink="http://www.w3.org/1999/xlink"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    gml:id="N17_RPRO_AVH_L1B_1P_20100112T093223_20100112T094516_039252_1">
  <om:phenomenonTime>
    <gml:TimePeriod
        gml:id="N17_RPRO_AVH_L1B_1P_20100112T093223_20100112T094516_039252_2">
      <gml:beginPosition>2010-01-12T09:32:23Z</gml:beginPosition>
      <gml:endPosition>2010-01-12T09:45:16Z</gml:endPosition>
    </gml:TimePeriod>
  </om:phenomenonTime>
  <om:resultTime>
    <gml:TimeInstant
        gml:id="N17_RPRO_AVH_L1B_1P_20100112T093223_20100112T094516_039252_3">
      <gml:timePosition>2010-01-12T09:45:16Z</gml:timePosition>
    </gml:TimeInstant>
  </om:resultTime>
  <om:procedure>
    <eop:EarthObservationEquipment
        gml:id="N17_RPRO_AVH_L1B_1P_20100112T093223_20100112T094516_039252_4">
      <eop:platform>
        <eop:Platform>
          <eop:shortName>NOAA</eop:shortName>
          <eop:serialIdentifier>17</eop:serialIdentifier>
        </eop:Platform>
      </eop:platform>
      <eop:instrument>
        <eop:Instrument>
          <eop:shortName>AVHRR</eop:shortName>
        </eop:Instrument>
      </eop:instrument>
      <eop:sensor>
        <eop:Sensor>
          <eop:sensorType>other: AdvancedVeryHighResolutionRadiometer</eop:sensorType>
          <eop:operationalMode codeSpace="urn:esa:eop:NOAA:AVHRR:operationalMode">
              HRPT</eop:operationalMode>
          <eop:resolution uom="m">1090</eop:resolution>
        </eop:Sensor>
```

```
      </eop:sensor>
      <eop:acquisitionParameters>
        <eop:Acquisition>
          <eop:orbitNumber>39252</eop:orbitNumber>
          <eop:orbitDirection>DESCENDING</eop:orbitDirection>
          <eop:ascendingNodeDate>2010-01-12T09:00:37Z</eop:ascendingNodeDate>
          <eop:ascendingNodeLongitude uom="deg">177.982</eop:ascendingNodeLongitude>
          <eop:pitch uom="deg">0.00000000</eop:pitch>
          <eop:roll uom="deg">0.00000000</eop:roll>
          <eop:yaw uom="deg">0.00000000</eop:yaw>
        </eop:Acquisition>
      </eop:acquisitionParameters>
    </eop:EarthObservationEquipment>
  </om:procedure>
  <om:observedProperty xsi:nil="true" nilReason="inapplicable"/>
  <om:featureOfInterest>
    <eop:Footprint
        gml:id="N17_RPRO_AVH_L1B_1P_20100112T093223_20100112T094516_039252_5">
      <eop:multiExtentOf>
        <gml:MultiSurface
            gml:id="N17_RPRO_AVH_L1B_1P_20100112T093223_20100112T094516_039252_6">
          <gml:surfaceMember>
            <gml:Polygon
                gml:id="N17_RPRO_AVH_L1B_1P_20100112T093223_20100112T094516_039252_7">
              <gml:exterior>
                <gml:LinearRing>
                  <gml:posList>67.092201 -19.268322 22.429611 -19.444046 18.466150
                      7.302216 58.817890 37.022400 67.092201 -19.268322</gml:posList>
                </gml:LinearRing>
              </gml:exterior>
            </gml:Polygon>
          </gml:surfaceMember>
        </gml:MultiSurface>
      </eop:multiExtentOf>
    </eop:Footprint>
  </om:featureOfInterest>
  <om:result>
    <eop:EarthObservationResult
        gml:id="N17_RPRO_AVH_L1B_1P_20100112T093223_20100112T094516_039252_8">
      <eop:browse>
        <eop:BrowseInformation>
          <eop:type>QUICKLOOK</eop:type>
          <eop:referenceSystemIdentifier
              codeSpace="urn:esa:eop:crs">Unknown</eop:referenceSystemIdentifier>
          <eop:fileName>
            <ows:ServiceReference xlink:href=
                "N17_RPRO_AVH_L1B_1P_20100112T093223_20100112T094516_039252.BI.PNG">
              <ows:RequestMessage/>
            </ows:ServiceReference>
          </eop:fileName>
        </eop:BrowseInformation>
      </eop:browse>
      <eop:product>
        <eop:ProductInformation>
          <eop:fileName>
            <ows:ServiceReference xlink:href=
                "N17_RPRO_AVH_L1B_1P_20100112T093223_20100112T094516_039252_v0100.ZIP">
              <ows:RequestMessage/>
            </ows:ServiceReference>
          </eop:fileName>
          <eop:size uom="bytes">73666560</eop:size>
        </eop:ProductInformation>
      </eop:product>
    </eop:EarthObservationResult>
```

```
  </om:result>
  <eop:metaDataProperty>
    <eop:EarthObservationMetaData>
      <eop:identifier>
          N17_RPRO_AVH_L1B_1P_20100112T093223_20100112T094516_039252
      </eop:identifier>
      <eop:doi>10.5270/AVH-f1i8784</eop:doi>
      <eop:acquisitionType>NOMINAL</eop:acquisitionType>
      <eop:productType>AVH_L1B_1P</eop:productType>
      <eop:status>ARCHIVED</eop:status>
      <eop:downlinkedTo>
        <eop:DownlinkInformation>
          <eop:acquisitionStation
              codeSpace="urn:esa:eop:facility">MTI</eop:acquisitionStation>
        </eop:DownlinkInformation>
      </eop:downlinkedTo>
      <eop:productQualityStatus>NOMINAL</eop:productQualityStatus>
      <eop:processing>
        <eop:ProcessingInformation>
          <eop:processingDate>2019-06-03T07:14:27Z</eop:processingDate>
          <eop:processingLevel>1B</eop:processingLevel>
          <eop:nativeProductFormat>NOAA-1B</eop:nativeProductFormat>
        </eop:ProcessingInformation>
      </eop:processing>
      <eop:vendorSpecific>
        <eop:SpecificInformation>
          <eop:localAttribute>source</eop:localAttribute>
          <eop:localValue>
              N17_RPRO_AVH_L1A_1P_20100112T093223_20100112T094516_039252_v0100.ZIP
          </eop:localValue>
        </eop:SpecificInformation>
      </eop:vendorSpecific>
    </eop:EarthObservationMetaData>
  </eop:metaDataProperty>
</eop:EarthObservation>
```