EUMETSAT

AVHRR Factsheet

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Document Change Record

Issue / Revision	Date	DCN. No	Summary of Changes
1	06/10/2010		Initial version.
1A	04/09/2015		Changes to document reflect PVRB 30/01/2015 approval of release for AVHRR Winds Level 2 products.
1B	07/09/2015		Section 3.6 deleted and new content added.
1C	01/12/2015		Changes made per request of CA Manager Marine applications: • added paragraph on derivation of AMV from cloud tracking • Noted that NDVI generation has been discontinued at EUMETSAT.

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1   INSTRUMENT DESCRIPTION

The Advanced Very High Resolution Radiometer (AVHRR) instrument operates at 6 different channels simultaneously, but only 5 channels are transmitted to ground. As a high-resolution imager–approximately 1.1 km near-nadir– its main purpose is to provide cloud and surface information about the following:

- cloud coverage,
- cloud top temperature,
- surface temperature over land and sea,
- vegetation or snow/ice.

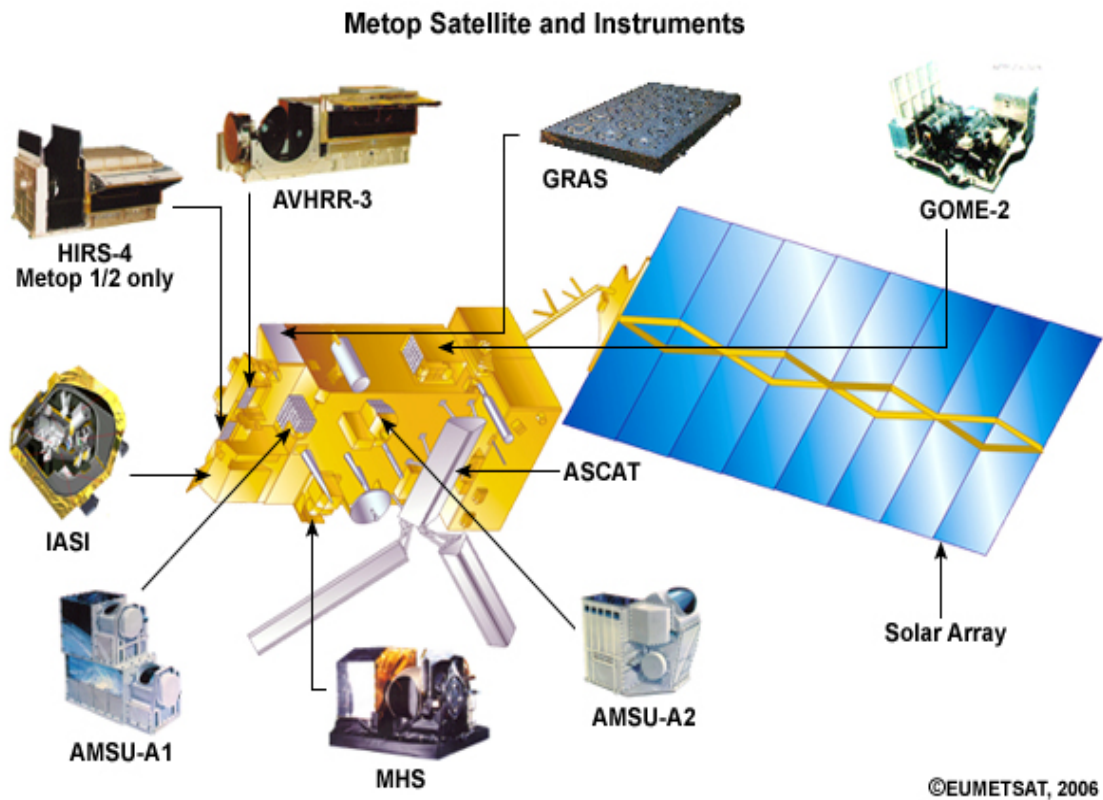In addition, AVHRR products serve as input for the level 2 processing of IASI and ATOVS.

Figure 1: Instrument package on Metop-series satellites. The AVHRR instrument is pictured at top left.

2 TECHNICAL DESCRIPTION

The AVHRR/3 is a six-channel scanning radiometer providing three solar channels in the visible/ near-infrared region and three thermal infrared channels. The AVHRR/3 has two one-micrometre wide channels between 10.3 and 12.5 micrometres. The instrument utilises a 20.32 cm (8 inch) diameter collecting telescope of the reflective Cassegrain type. Cross-track scanning is accomplished by a continuously rotating mirror directly driven by a motor. The three thermal infrared detectors are cooled to 105 K by a two-stage passive radiant cooler. A line synchronisation signal from the scanner is sent to the spacecraft MIRP processor which in turn sends data sample pulses back to the AVHRR.

The spectral channels of AVHRR/3 are not exactly the same as AVHRR/2, and include an additional channel 3a in the near infrared (NIR). AVHRR/3 has six spectral channels between 0.63 and 12.00 micrometres: three in the visible/near infrared, and three in the infrared. Channel 3 is a split channel: channel 3a is in the solar spectral region (1.6 µm); channel 3b operates in the infrared 3.7 µm.

Although AVHRR/3 is a six-channel radiometer, only five channels are transmitted to the ground at any given time because channels 3a and 3b cannot operate simultaneously. The data from the six channels are simultaneously sampled at a 40-kHz rate and converted to 10-bit binary form within the instrument. The data samples from each channel are output in a non-continuous burst of ten space samples, 2048 Earth samples and ten internal calibration target samples per scan.

The following table summarises the spectral characteristics of AVHRR/3.

Channel	*Central wavelength (µm)*	*Half power points (µm)*		*Channel noise specifications*
			S/N @ 0.5% reflectance	NEdT @ 300K
1	0.630	0.580 - 0.680	9:1	-
2	0.865	0.725 - 1.000	9:1	-
3a	1.610	1.580 - 1.640	20:1	-
3b	3.740	3.550 - 3.930	-	<0.12 K, 0.0031 mW/(m^2 sr cm^{-1})
4	10.800	10.300 - 11.300	-	<0.12 K, 0.20 mW/(m^2 sr cm^{-1})
5	12.000	11.500 - 12.500	-	<0.12 K, 0.21 mW/(m^2 sr cm^{-1})

Table 1: Spectral characteristics of AVHRR/3.

AVHRR/3 is an across-track scanning system with a scan range of ±55.37° with respect to the nadir direction. The field of view (IFOV) of each channel is approximately 1.3 milliradians (0.0745°) leading to a square instantaneous field of view size of 1.08 km at nadir for a nominal altitude of 833 km. The scanning rate of 360 scans per minute is continuous (1 scan every 1/6 second). There are 2048 Earth views per scan and per channel for a swath width of about ±1447 km (sampling time of 0.025 ms). The sampling angular interval is close to 0.944 milliradians (0.0541°). The distance between two consecutive scans is approximately equal to 1.1 km.

Characteristics	Value	Unit
Scan direction	East to West (northbound)	-
Scan type	Continuous	-
Scan rate	0.025	ms
Sampling interval (duration)	0.1667	s
Sampling interval	0.0541	degrees
Pixels/scan	2048	-
Swath	±55.3	degrees
IFOV	0.0745	degrees
IFOV type	Square	-
IFOV size (nadir)	1.08	km
IFOV size (edge) - across track	6.15	km
IFOV size (edge) - along track	2.27	km
Scan separation	1.1	km

Table 2: Nominal scanning characteristics of AVHRR/3.

2.1   Applications in meteorology

Day and night cloud mapping is the main application of AVHRR data in meteorology, especially at high latitudes where data from geostationary satellites are severely distorted due to Earth curvature. The AVHRR/3 Level 1b contains basic cloud map information necessary for the processing of higher-level ATOVS and IASI products.

Other important applications of AVHRR in meteorology are in combination with information from the ATOVS sensors (HIRS, AMSU-A and MHS) flying on the same platform. Together, these systems provide a suite of infrared and microwave channels that can be used to profile atmospheric temperature and humidity. Such meteorological applications include interpreting cloud top temperatures and heights for predicting and monitoring storms, differentiating ice, water, shadow and other aspects of clouds, deriving polar winds from monitoring cloud motions, water vapour content of the lower atmosphere, and the study and monitoring of tropical cyclones. Finally, surface radiative fluxes are an essential geophysical parameter for climatological studies which can be derived from AVHRR data.

EUMETSAT derives Atmospheric Motion Vectors (AMV) operationally from the AVHRR instruments on METOP satellites. The latest derivation scheme relies on being able to define a target point based on a fixed processing grid. Around each grid location, an optimum target location based on statistical properties of the suggested location is extracted. This target is 28 × 28 pixels, which corresponds to 30 × 30 km^2 for the AVHRR instrument. Only cloudy targets are used to derive the

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baseline products. The concept of target and search areas is shown in Figure 3. For each possible target location the entropy, contrast, and number of cloudy pixels are computed. Furthermore, using a 3×3 area, a standard deviation is calculated and attributed to each pixel. Suitable targets should have enough variability such that the tracking procedure will be able to lock onto the identified features. To be a suitable target for AMV use, the target also has to contain a sufficient (more than 10) number of pixels with a high standard deviation.
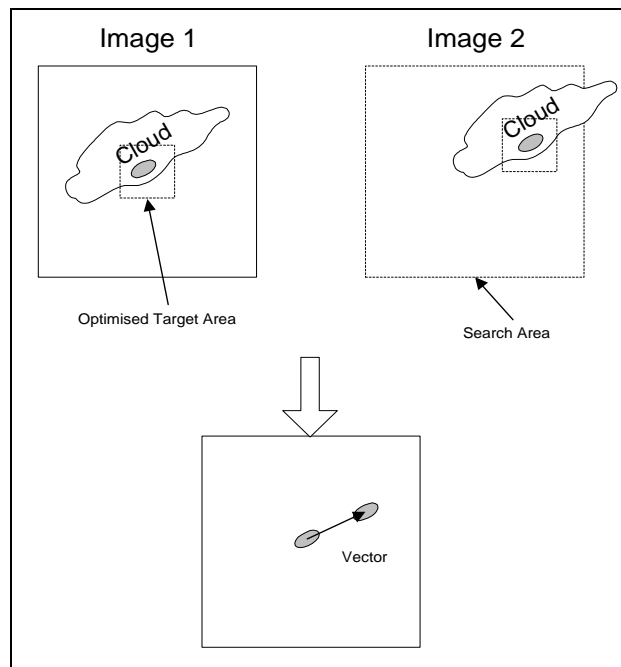

Figure 2: Target and Search Areas

2.2   Applications in terrestrial sciences

AVHRR's frequent day/night synoptic coverage and high horizontal resolution are features that make the system unique for the study of land surface.

In the area of monitoring terrestrial vegetation, the AVHRR-derived NDVI has proven to be a very robust and useful quantity to monitor vegetation, land cover and climate. The index has been produced and utilised globally and regionally. The NDVI is related to the health of the vegetation growth, and has therefore been used for drought forecasting, crop growth monitoring and to map forest fire fuel potential.

Multi-channel imagery from the AVHRR has also proven to be useful in snow-cover mapping. The frequent coverage of the AVHRR is again the prime advantage in being able to distinguish clouds from snow cover with their similar albedo signature. Combined with topographic relief information, snow cover from AVHRR can be converted to snow-water equivalent to give an estimate of the amount of water reserve represented by the winter snow pack.

3 AVHRR PRODUCT DESCRIPTIONS

3.1 AVHRR Level 1b Products

AVHRR Level 1b products measure and report on the following:

- Radiances
- Cloud information (cloud-top temperature and cloud mask)
- Normalised Density Vegetation Index (NDVI)

For internal EUMETSAT use, the data undergo further processing in ATOVS level 2 and IASI processors. Level 1b products feature cloud mapping during both daylight and night-time hours. AVHRR/3 data are transmitted via EUMETCAST (Level 1B product).

The visible (VIS), Near InfraRed (NIR) and InfraRed (IR) channels of AVHRR provide cloud information for the ATOVS sensors (HIRS, AMSU-A and MHS), which provide temperature and humidity profiles.

3.1.1 Radiances

Two examples of AVHRR radiances data returned are shown in Figure 3 and Figure 4. Not each pixel is plotted. They cover about 100 minutes of data and were received from Metop-A orbit 1940 from 5 March 2007.
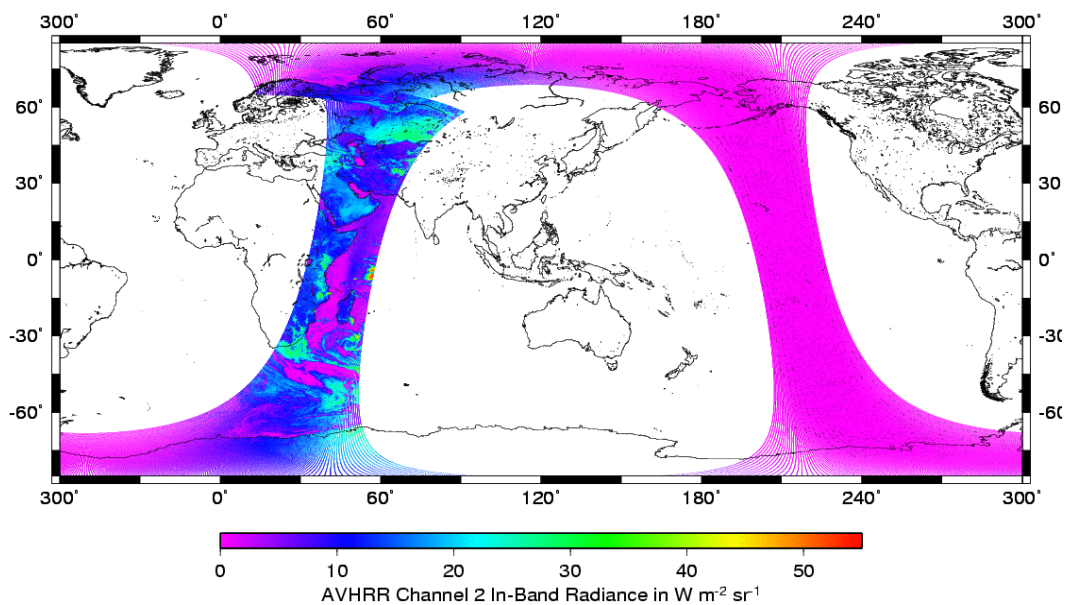

Figure 3: AVHRR radiances, Channel 2 (0.85 µm).

Note: For visible (VIS) channels shown in, surface and cloud properties can only be derived for the daylight side of the orbit.
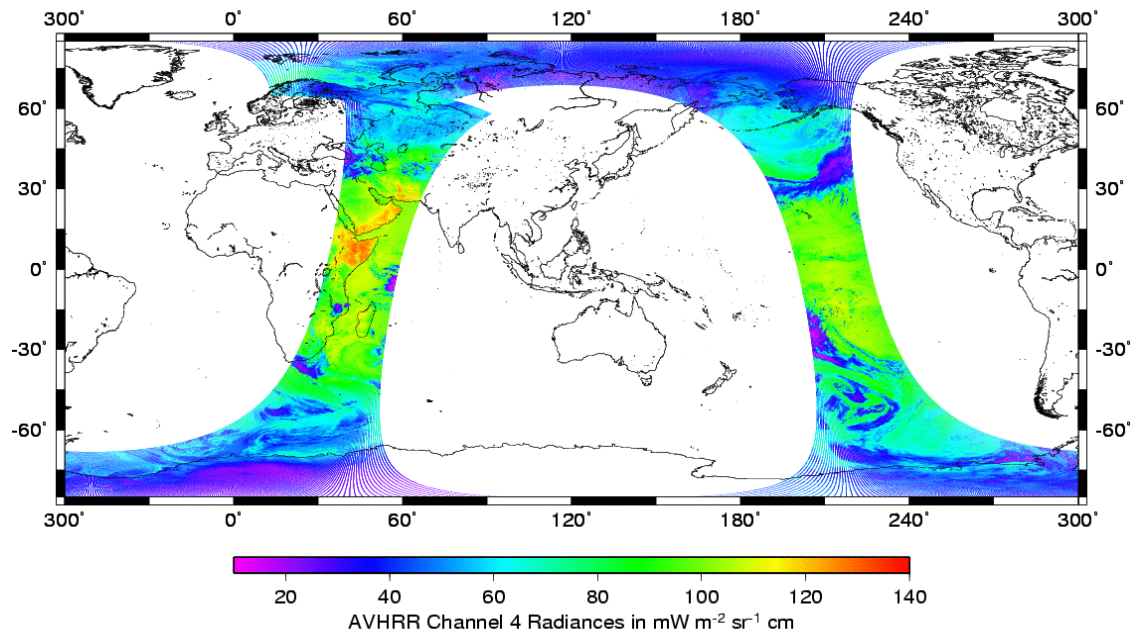
Figure 4: AVHRR Radiances, Channel 4 (11 μm).

Note: In addition to cloud coverage, this infrared (IR) window channel provides information about the surface temperature distribution in cloud-free conditions.

3.1.2   AVHRR Surface and Cloud-Top Temperatures

The image in Figure 5: shows the AVHRR Surface and Cloud Top Temperatures in Kelvin. For pixels assigned as cloud free, the surface temperature is computed by means of a split-window technique. In the case of channel 3b availability, the temperature is computed by means of a triple window technique. Different sets of regression coefficients for land and sea, and day and night are used. For pixels detected as cloudy, the difference between brightness temperature channels 4 and 5 is used to discriminate between pixels covered by optically thick clouds and pixels covered either by optically thin clouds or adjudicated as partially cloudy. For the latter two classes of pixels, no representative surface or cloud top temperature can be retrieved; therefore they are plotted as black areas. For pixels covered by optically thick clouds, the brightness temperature of channel 4 is considered as a reasonable cloud top temperature.

The AVHRR Surface and Cloud Top Temperatures are part of processing for the Scenes analysis function, and go into the processing of AVHRR-based level-2 products.
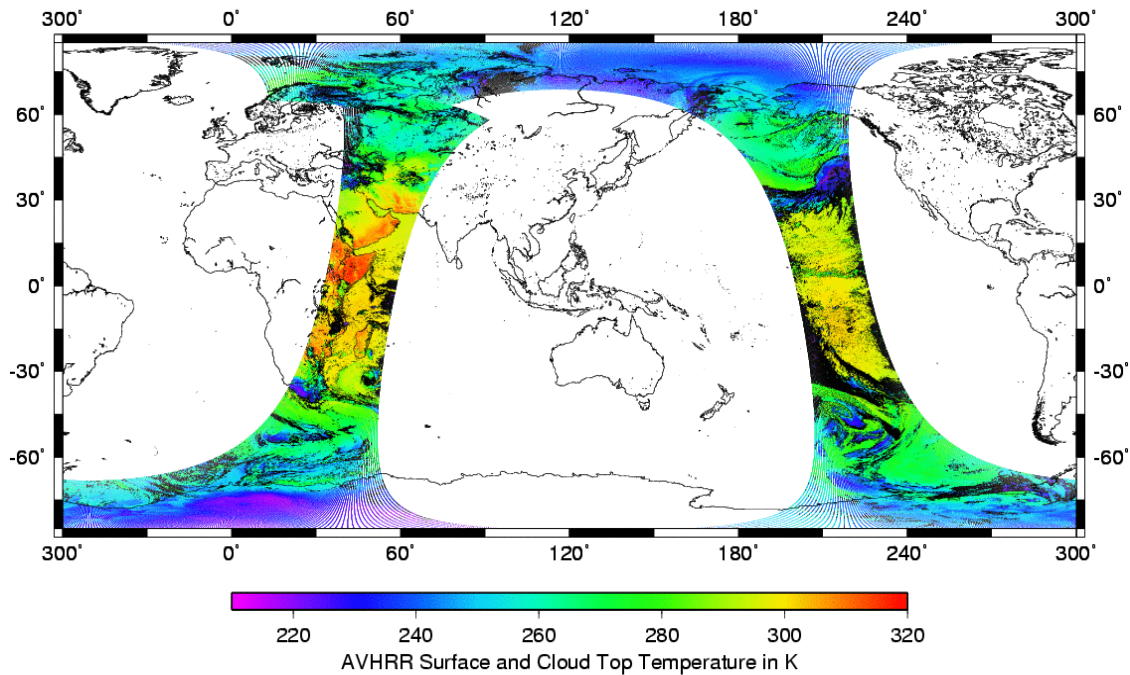
Figure 5: AVHRR Surface and Cloud Top temperatures.

3.1.3   AVHRR Cloud Mask

The image in Figure 6 shows a cloud mask processed from AVHRR data on a global scale. The areas shaded orange show pixels that are assigned as cloud free, the magenta colour shows cloud-contaminated areas. The western branch of the orbit was recorded during night time whereas the branch showing the overpass over Africa and Europe shows the results of the cloud detection scheme under daylight conditions.

The cloud detection scheme consists of a sequence of threshold tests where an actually measured physical value (e.g. brightness temperatures, brightness temperature differences and/or target reflectance factors) is compared against a value expected under cloud free conditions. This value can either be computed from forecast data or from climatological databases. If the difference between the actual value and the expected value is larger than a distinct threshold, the pixel is assigned to be cloud contaminated. Test sequences and thresholds depend on channel availability, surface conditions and solar zenith angle. In addition, over water surfaces the variability in brightness temperature of neighbouring pixels is used as a test criterion (standard deviation tests). The cloud detection is performed for each individual pixel and the results are stored in the AVHRR level 1b product. The AVHRR cloud mask is used as input for the processing of AVHRR-based level 2 products.
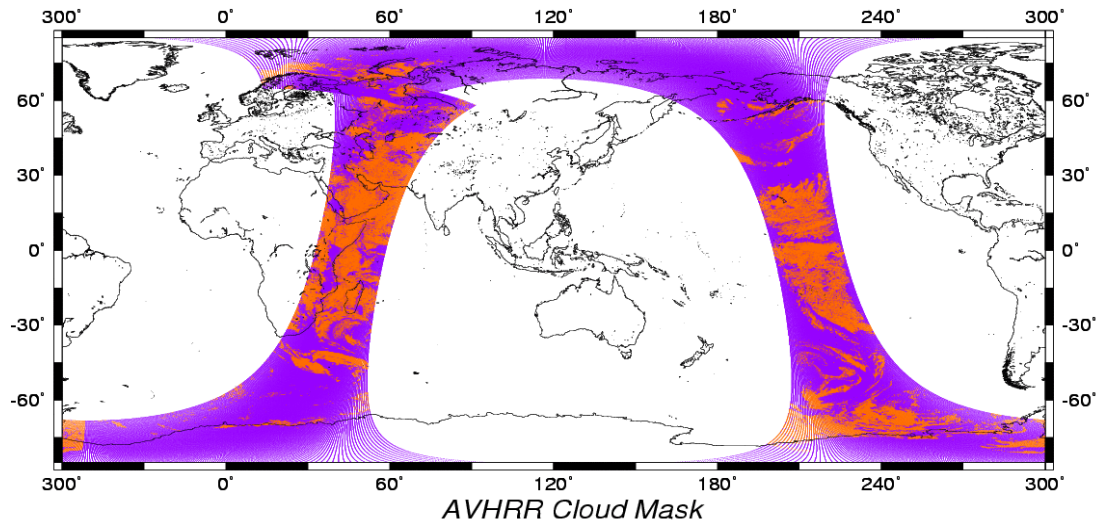
Figure 6: Retrieved cloud mask, where not each pixel is plotted. The data covers about 100 minutes of data, processed from Metop-A: Orbit 1940 on 5 March 2007.

3.1.4   Normalised Density Vegetation Index (NDVI) and Geolocation information

Using AVHRR/3 solar channels 1 and 2, the top-of-the-atmosphere NDVI is derived, which can be used to monitor vegetation and land-cover. This product can then be used to monitor drought and crop growth, and to map forest fire potential.

Note: As of December 2014, the generation of the NDVI product has been discontinued at EUMETSAT.

3.2   AVHRR Level 2 products

The various Satellite Application Facilities (SAFs) are responsible for many AVHRR level 2 products. There are eight EUMETSAT SAFs which provide users with operational data and software products, each SAF for a dedicated user community and application area. The SAFs directly linked to the AVHRR instrument and derived products are the Ocean and Sea Ice SAF (OSI SAF) and the Land Surface Analysis SAF (LSA SAF). The AVHRR instrument contributes significantly to products derived along with data from the IASI instrument.

AVHRR level 2 products have a vast range of applications in meteorology, oceanography, Earth sciences and climatology. Meteorological applications include deriving cloud top heights and temperatures, and differentiating ice, water, and clouds, as well as monitoring cloud motions to derive polar winds. Each of these applications is registered as a separate product in the EUMETSAT range, and each product has its own Product User Manual. See the SAF web sites for these product user manuals and other documentation. These SAF sites are also listed in Section 4.

Besides immediate meteorological uses, AVHRR products are increasingly valuable in climatology and long-term climate data studies. One product is the Multi-channel Sea Surface Temperature (SST) product, which is the main geophysical parameter used in meteorological and oceanographic

applications. Infrared AVHRR imagery has proved very useful in mapping mesoscale ocean features in terms of their SST signatures. AVHRR imagery can also be used to compute sea ice concentration and ice edge location. The frequent coverage of AVHRR multi-channel imagery is also extremely useful in snow cover mapping; they make it possible to distinguish clouds from snow cover during daytime conditions. Due to its manifold applications, AVHRR/3 data are also useful for generating high-resolution long-term climate data sets.

3.2.1   AVHRR wind products

Tracking the motion of clouds between successive AVHRR images of the same location allows the extraction of several AVHRR wind products. These products differ in their coverage footprint (as shown in Figure 7), the timelines, the number of images used, and the number of satellites used for the product extraction.

Single Metop polar wind Product. This is the oldest AVHRR wind product extracted at EUMETSAT. It is extracted from one Metop satellite, uses two images and the coverage is limited over polar regions. Since the launch of Metop B satellite, this product has been extracted from both Metop A and Metop B satellites. The temporal gap between the two consecutive images is approximately 100 minutes.

Dual Metop global coverage wind Product. The extraction of this product required two Metop satellites flying on the same orbit. The wind extraction is done by using image pairs taken successively by the two satellites Metop A and Metop B. The global coverage is ensured by two complementary products, one using Metop A as the first image of the pair (denoted as Metop A/B), one using Metop B as the first image of the pair (denoted as Metop B/A). The temporal gap between the two consecutive images is approximately 50 minutes.

Triplet mode polar wind Product. The extraction of this product required two Metop satellites flying on the same orbit and 3 consecutive images. The coverage is then limited to polar areas. Two different products are extracted, one using Metop A as the first image of the triplet (denoted as Metop A/B/A) the second one using Metop B as the first image (denoted as B/A/B). The use of triplet of images allows temporal consistency check between the two intermediate wind vectors extracted from the two consecutive pair of images, as it is usually done in the Atmospheric Motion Vectors (AMV) extraction scheme from geostationary satellites. The temporal gap between two consecutive images is approximately 50 minutes, but the timeline necessary for the whole extraction is approximately 100 minutes.
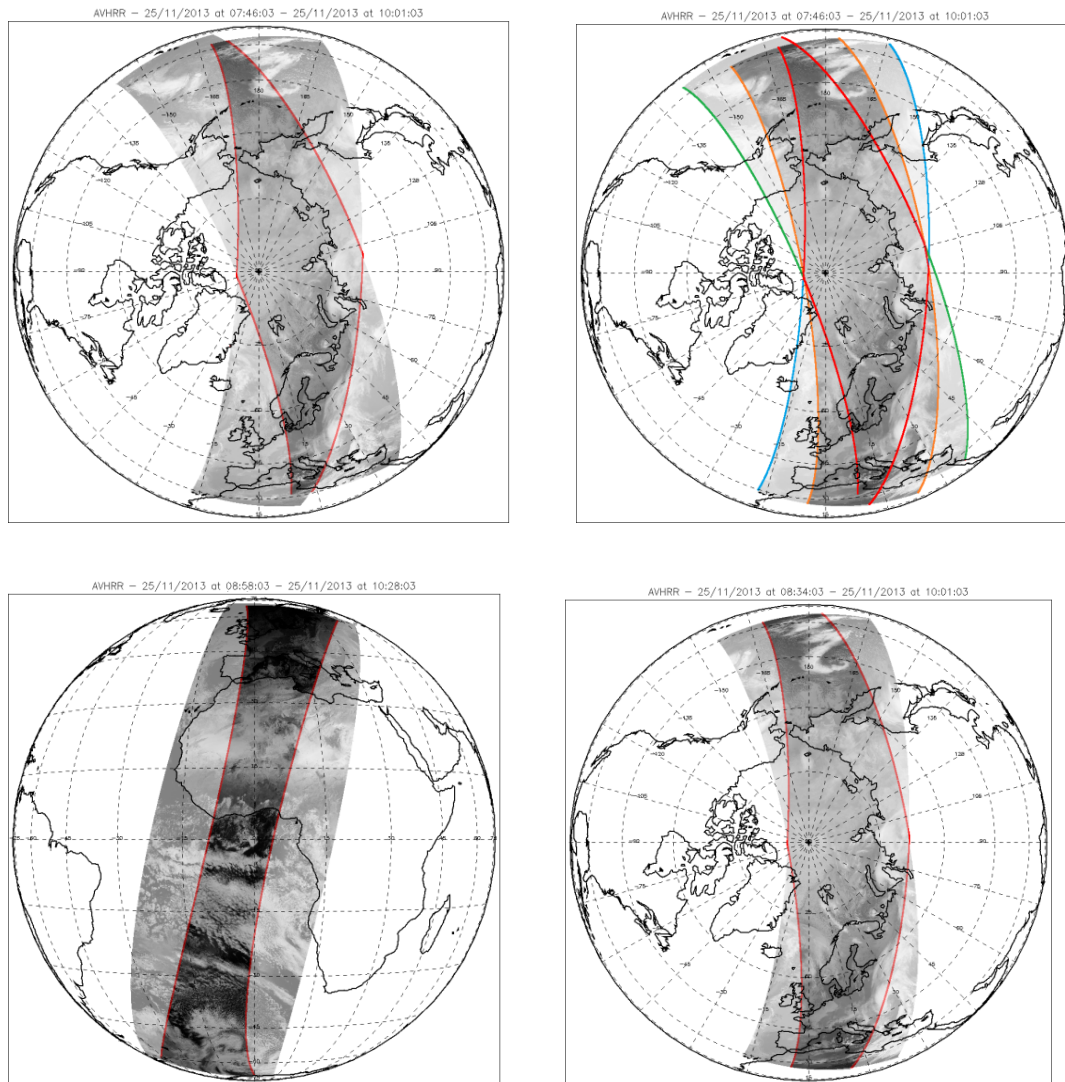
Figure 7: Overlapping areas where AVHRR winds products are extracted. Single Metop wind product over North Pole (top left) and triplet mode over North Pole (top right). The bottom row plots dual Metop global coverage wind product on the full MSG disk area (left) and over the North Pole (right).

The output files format and content are identical for all these products. They can be identified by the name of the output files.

3.2.2   AVHRR AMV Level 2 Product Naming Convention

The AVHRR AMV level 2 products follow the product naming convention detailed in the AVHRR Product Format Specification

The INSTRUMENT_ID is AVHR.
The PRODUCT_TYPE is AMV.
The PROCESSING_LEVEL depends on the process mode:

- 02 for legacy products (product format v1);
- 2A for AMV products derived from a single AVHRR sensor;

- 2D for AMV products derived from AVHRR sensors on two satellites;
- 2T for AMV products derived from AVHRR sensors on two satellites with Triplet mode activated.

The SPACECRAFT_ID refers to the satellite platform of the AVHRR data used. For 2D and 2T modes, it refers to the most recent data.

The AVHR_AMV BUFR product format is common to the MSG-SEVIRI derived windBUFR product format. It uses the BUFR standard 3 10 014 Satellite derived wind sequence. It is completed by quality information sequences.

4   REFERENCES AND PRODUCT ASSISTANCE

Title	EUMETSAT Reference Number
AVHRR Level 2 Polar Winds Product Generation Specification	EUM/OPS-EPS/SPE/08/0346
AVHRR Level 2 Polar Winds Product Format Specification (PFS)	EUM/OPS-EPS/SPE/08/0338
AVHRR Global Winds Product Validation Report	EUM/TSS/REP/10/3478
A Direct Link between the feature Tracking and Height Assignment of Operational EUMETSAT Atmospheric Motion Vectors	doi.org/10.1175/JTECH-D-13-00126.1

All of the reference documents listed above are on the EUMETSAT Technical Documents page.

www.eumetsat.int > Satellites > Technical Documents > METOP/NOAA Global Data Services >
> GDS-Metop > AVHRR

EUMETSAT Satellite Application Facilities (SAFs) maintain documentation for selected products on their separate web pages, which you can access from the main EUMETSAT web page. Choose SAFS from the **EUMETSAT FOR** bar. You will be directed to the general SAF pages maintained by EUMETSAT. The table below lists some dedicated SAF web pages.

SAF Name	website
Support to Nowcasting and Very Short Range Forecasting (NWC SAF)	http://www.nwcsaf.org/HD/MainNS.jsp
Climate Monitoring (CM SAF)	http://www.cmsaf.eu/EN/Home/home_node.html
Numerical Weather Prediction (NWP SAF)	http://nwpsaf.org/
Ozone & Atmospheric Chemistry Monitoring (O3M SAF)	http://o3msaf.fmi.fi/
Ocean and Sea Ice (OSI SAF)	http://www.osi-saf.org/

Information about the service status of EUMETSAT satellites and the data they deliver is the web page:

www.eumetsat.int > Data > Service Status

To get answers to any questions about data delivery, registration or documentation, contact the EUMETSAT User Service Help Desk:

Telephone: +49 6151 807 3660/3770
e-mail: ops@eumetsat.int