Operational processing of AVHRR data at DFD

Operationelle Prozessierung von AVHRR Daten am DFD

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Summary:

The German Remote Sensing Data Centre (DFD) of the German Aerospace Centre (DLR) has been receiving satellite data from the NOAA POES satellites in High Resolution Picture Transmission (HRPT) mode since November 1981 to serve the needs of the national and international user community. After reception of the AVHRR data a standardised pre-processing routine delivers calibrated and navigated data. These level 1 data are used for generating RGB - quicklooks overlaid with coastlines, and so-called media products showing wide parts of Central Europe in predefined annotated map projections. The level 1 data are also used for generating value-added products such as the "Normalised Difference Vegetation Index" of Europe, the sea surface temperature of European seas and the land surface temperature of Europe representing a day-time or night-time land surface temperature. For all value-added products different routines, such as automatic cloud masking using APOLLO software, precise geo-referencing, including land-sea mask and compositing, are necessary (level 2 data). The level 2 data are used for deriving daily, weekly and monthly level 3 products which are accessible by the internet using a user-friendly Web portal.

More than 65,000 scenes (as of May 2003) have been received since 1981 at Oberpfaffenhofen covering the station's visibility. Depending on the actual track (eastern, central and western) being received, the scenes cover different areas, reaching from Spitzbergen in the north to the Northern Sahara in the south and from the Central Atlantic in the west to Central Asia in the east.

This paper addresses aspects for daily operational processing, including the automatic supervision of the processing chain, for generating level 1 to 3 products , automatic failure identification and quality assurance. Future processing algorithms (automatic atmospheric correction, generation of cloud parameters and LAI time series), which are in a developmental stage, will also be discussed.

Zusammenfassung

Seit November 1981 empfängt das Deutsche Fernerkundungsdatenzentrum (DFD) des Deutschen Zentrums für Luft- und Raumfahrt (DLR) die Daten der NOAA POES Satelliten in HRPT Format. Damit will das DFD die Anforderungen der nationalen und internationalen Nutzergemeinschaft unterstützen.

Die Rohdaten des "Advanced Very High Resolution Radiometer (AVHRR)" werden nach dem Empfang mit standardisierten Routinen zu kalibrierten und navigierten Daten verarbeitet. Aus diesen sog. "level 1" Daten werden RGB-Quicklooks erstellt, denen Küstenlienien

überlagert sind. Ausserdem werden so genannte "Medienprodukte" generiert, auf denen ein großer Teil Europas in Kartenprojektion mit überlagerten Küstenlinien und Flußverläufen zu sehen ist. Die "level 1" Daten werden auch für die Erstellung von höherwertigen Produkten genutzt wie z.B. für den "Normalized Difference Vegetation Index (NDVI)", die Meeresoberflächentemperatur (SST) und die Tages- und Nachttemperatur der Landoberfläche. Um die höherwertigen Produkte ("level 3") zu berechnen, ist eine automatische Wolkenerkennung (APOLLO Software), eine präzise Navigation und Zuordnung der Pixel zu geographischer Länge und Breite und auch eine Maskierung in Land- ind Wasserflächen notwendig. Um tägliche, wöchentliche und monatliche "level 3" Produkte zu erstellen, sind unterschiedliche "Compositing" Algorithmen anzuwenden. Auf die "level 2 und level 3" Produkte kann über ein nutzerfreundliches Internetportal zugegriffen werden.

Mehr als 6400 Szenen (Stand Februar 2003) wuden seit 1981 am Standort Oberpfaffenhofen des DLR empfangen. Je nach Satellitenüberflug (östlich, zentral oder westlich) überdecken die Pässe Europa von Spitzbergen bis zur nördlichen Sahara, und vom Zentralatlantik bis Zentralasien.

Die Veröffentlichung beschreibt die operationellen Aspekte der täglichen Prozessierung zur Erstellung der "level 1" bis "level 3" Produkte einschließlich der automatischen Überwachung, der automatischen Fehlererkennung und Qualitätssicherung. Es werden auch zukünftige Prozessoren erwähnt wie z.B. die automatische Atmosphärenkorrektur, die Ableitung von Wolkenparametern und die Etablierung einer automatischen Harmonischen Analyse zur Erstellung einer lückenfreien, homogenisierten "Leaf Area Index (LAI)" Zeitreihe.

Introduction

Beginning in 1978, the AVHRR sensor (**A**dvanced **V**ery **H**igh **R**esolution **R**adiometer, http://eosims.cr.usgs.gov:5725/sensor_documents/avhrr_sensor.html) has flown on the National Oceanic and Atmospheric Administration's (NOAA) Polar Orbiting Environmental Satellites (POES; http://www2.ncdc.noaa.gov/docs/klm) measuring reflected and emitted radiation in four to six broad-band spectral channels from the visible to the thermal infra-red region. The NOAA-POES series are regarded as the backbone of the US meteorological program. The current POES series satellites are named simply NOAA-7 through NOAA-17 in order of launch. The program has evolved over several years starting in 1960 with TIROS. The philosophy of NOAA is to maintain at least two operational satellites in complementary orbits until 2010.

All NOAA-POES satellites have a circular, sun-synchronous polar orbit with a nominal flight altitude of 833 km. The even numbered satellites cross the equator at local mean solar times of approximately 7:30 and 19:30, while the odd-numbered satellites cross the equator at local mean solar times of approximately 2:30 and 14:30.

The AVHRR sensor flown aboard TIROS-N, NOAA-6, NOAA-8 and NOAA-10 collected four spectral channels (AVHRR/1), the AVHRR sensor aboard NOAA-7, NOAA-9, NOAA-11, NOAA-12, NOAA-13 (was never operational, problems after launch) and NOAA-14 is collecting with five channels (AVHRR/2). With the operation of NOAA-15, a new version of the AVHRR sensor (called AVHRR/3) is in orbit. AVHRR/3 is a six channel instrument, with three of the channels located in the visible and near-infrared regions of the spectrum, having effective wavelengths around 0.63µm (channel 1), 0.86µm (channel 2), and 1.6µm (channel 3A for day-time operation), while the remaining three are located in the atmospheric window regions in the mid- and thermal infrared with effective wavelengths centred around 3.7µm (channel 3B for night-time operation), 10.8µm (channel 4), and 11.5µm (channel 5).

Another new feature of the AVHRR/3 of NOAA-15,16,17 is a split gain factor in order to increase the digital resolution for low albedo ranges from 0% to 25% by a factor of two for the channels 1, 2 and 3A. The resolution for the range between 25% and 100% is reduced.

Provision has been made for the transmission of five channels in the data format for all older and new satellites. Channel 5 contains a repeat of channel 4 data, when only four different channels are available (AVHRR/1). Currently, the AVHRR sensors on board NOAA-12, NOAA-15, NOAA-16 and NOAA-17 are in operational mode, however the sensor on board NOAA-14 severely degraded due to scan motor anomaly. NOAA-13 did not become operational due to a power failure after launch.

The AVHRR sensors are cross-track scanning systems covering a swath width of app. 2800 km with ~1 km spatial resolution in nadir direction. A fairly continuous global coverage is achieved using morning and afternoon satellites.

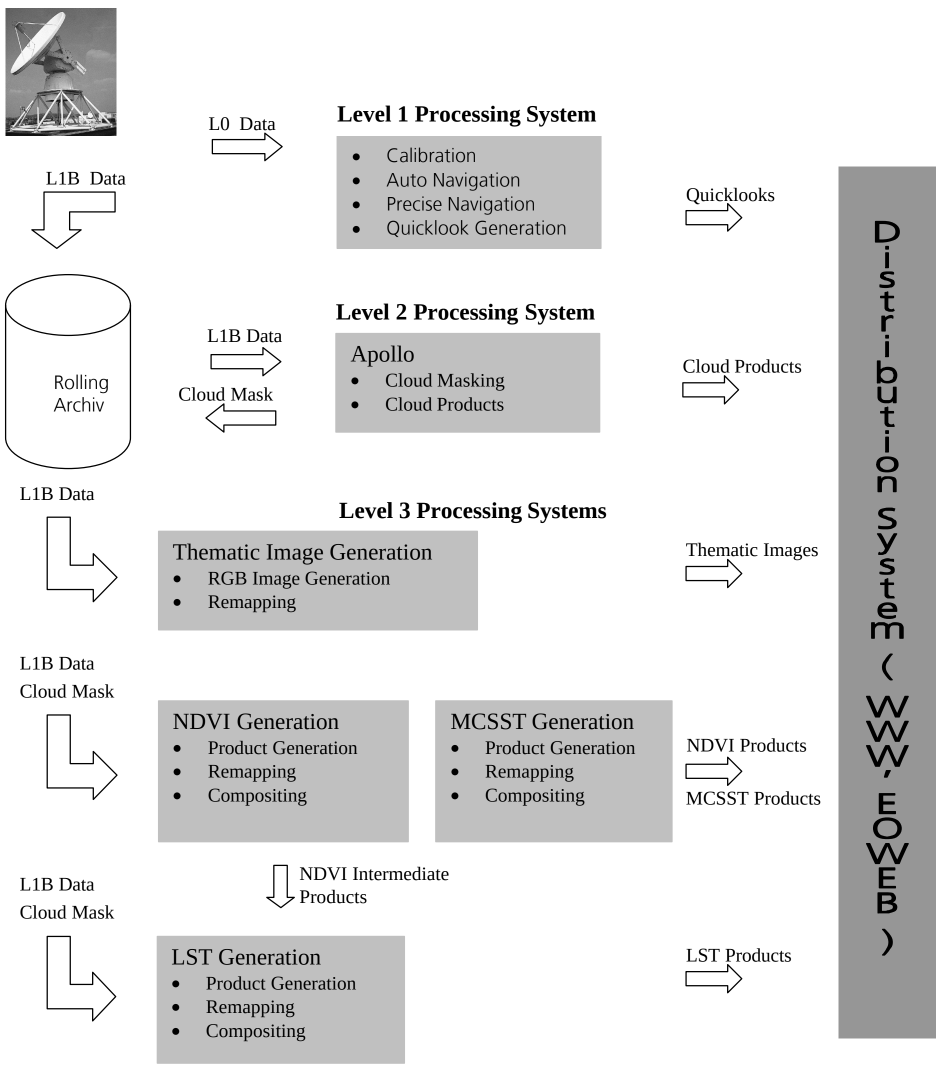

Figure 1: Overview of the NOAA-AVHRR processing scheme for generating operational products like quicklooks, level 1 and level 3 products. All products are available via different web user interfaces (GISIS, EOWEB or WWW)

From level 0 data to "value - added" level 3 products

The following section describes, in detail, the methods employed at DFD to process level 0 data (raw data) into value-added level 3 products such as sea surface temperature, land surface temperature and "Normalised Difference Vegetation Index" using the TeraScan software from SeaSpace Corporation (http://www.seaspace.com/). Further operational software and scripts are developed by DFD.

An overview of the operational NOAA-AVHRR processing scheme of DFD is given in Figure 1. The operational routines are based on the work of DECH ET AL. (1998). After reception of the AVHRR data, a pre-processing routine delivers calibrated and auto-navigated data. These level 1 data are used for generating RGB - quicklooks overlaid with coastlines and a so-called media product which is a subset showing wide parts of Central Europe („Central Europe"). The level 1 data are also used for generating value-added products such as the „Normalised Difference Vegetation Index" of Europe, the sea surface temperature of European seas and the land surface temperature of Europe representing a day-time or night-time land surface temperature. For all value-added products, different routines such as cloud masking, geo-referencing, including land-sea mask and compositing are necessary (level 2 data). The level 2 data are used for deriving daily, weekly and monthly level 3 products which are accessible via the internet (http://eoweb.dlr.de).

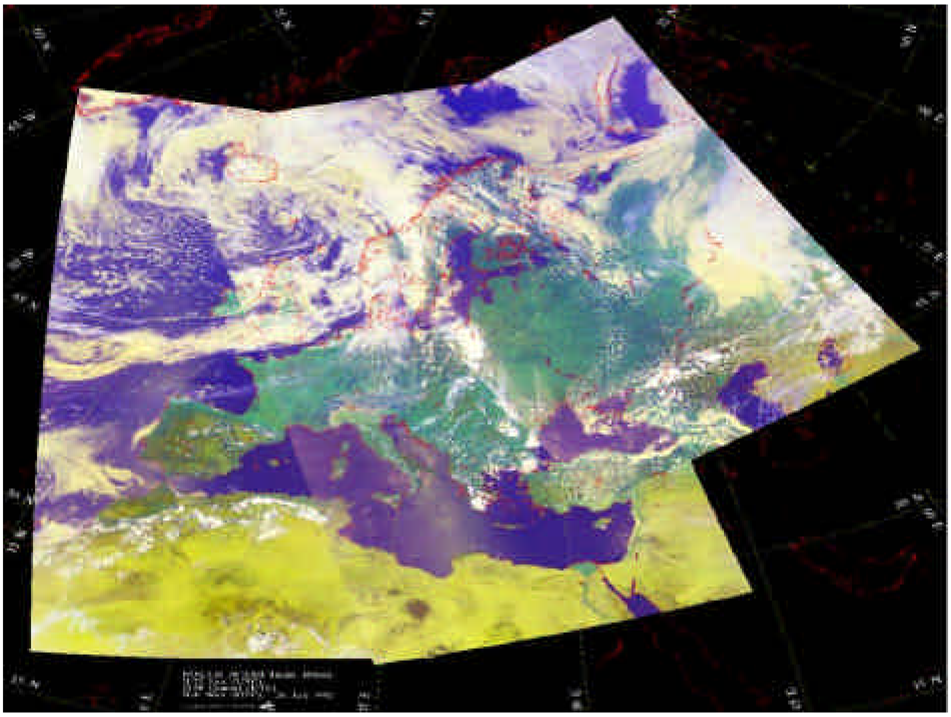

Figure 2: Geographical coverage for AVHRR data reception from Oberpfaffenhofen, Germany

The total image size of one pass depends on the time of visibility of the spacecraft and varies from day-to-day and from pass-to-pass. A "long" acquisition, e.g. a "central" pass, may contain up to 5600 lines and covers about 7150 km in north-south direction. 2048 pixels are digitised for every scan line resulting in a pass width of about 3000 km. The geometric resolution of the instrument is ~ 1.1 km at nadir and is reduced to ~ 6 km close to the pass edges due to the wide swath width and the earth curvature. The wide scan angle of the AVHRR means that the local time for pixels at the eastern and western edges of the swath can vary by more than an hour. Due to the fact that the NOAA satellites do not complete an integral number of orbits per day, the same pixel will be imaged at local times varying up to ± 50 minutes for successive days, a phenomenon called phasing.

Level 1B data processing

Inputs are level 0 HRPT Data, which are collected in a directory after acquisition. As soon as a level 0 raw data file arrives in this directory, the generation processor automatically runs determining the records, extracting the AVHRR data from HRPT data stream, calibrating the data, and lastly performing the auto navigation. The quality of the auto navigation is interactively checked and manually corrected if necessary (Precise Navigation). Level 1B data are calibrated and navigated data in such called "satellite" projection.

Radiometric Calibration

The radiometric calibration of the AVHRR data is done in accordance with methods described in "Techniques for Data Extraction and Calibration of TIROS-N/NOAA Series Satellite Radiometers for Direct Readout Users" (LAURITSON & NELSON, 1979).

The raw digital counts for channels 1 and 2 are calibrated into technical albedo values. As there is no on-board calibration for solar channels 1 and 2, major problems arise in calibrating the data. For retrospective NOAA-11 AVHRR data processing, time-adjusted coefficients are used to consider the degradation of the sensor sensitivity over time (TEILLET & HOLBEN, 1994). For NOAA-14 AVHRR, post-launch updated calibration coefficients provided by NOAA/NESDIS (RAO & CHEN 1997) were applied. For NOAA-16 AVHRR data only pre-launch coefficients are available. Due to a dual gain response for channel 1 and 2, Piecewise Linear (PWL) calibration coefficients are needed in order to increase sensitivity.

The thermal infrared data (channels 3, 4, and 5) are converted from raw counts to radiances with a linear relationship that is based on the raw count value associated with cold space (roughly 3 degrees Kelvin) and the raw count value associated with the temperature of an onboard target (approximately 300 degrees Kelvin). A slight nonlinearity in channels 4 and 5 is corrected using a quadratic function of radiance. Lastly, the infrared radiances are converted to temperature using the inverse Planck function.

Auto Navigation/Precise Navigation

After calibration, the earth locations of this data set are also automatically computed using the latest satellite orbit elements and a sensor model. Satellite orbit elements updated once a day by ftp except weekends or public holidays in the US, are supplied routinely by the SeaSpace Corporation. The images are correlated with land/sea masks (World Databank (WDB) or Digital Chart of the World (DCW) data bases) to provide more precise navigation. Appropriate coastline areas with significant features are selected in 1deg × 1deg boxes and checked for cloudiness by applying several spectral tests. For the remaining cloud free boxes, a cross correlation algorithm between the satellite image chips and the reference coastline is used. Based on the yielding vector array the satellite's yaw, pitch, and roll angles are adjusted and so the assignment of each pixel to the geographical latitude and longitude is done. The accuracy of the earth location is typically 1-2 pixels of the AVHRR resolution, this means accuracy better than 2 kilometres. But if the orbital elements are not up-to-date, the satellite navigation elements can be displaced by as much as 10 km.

Therefore an interactive quality control by the operator is needed, which involves a visual display of one or more channels of the navigated and calibrated AVHRR data on a colour screen. The location of several readily identifiable land/water boundaries are displayed as an overlay on the monitor, and compared with the actual ones according to the earth reference data computed from the orbit elements, spacecraft clock time, and the pointing angle of the

AVHRR scanner. Interactive routines are used to bring the reference overlays into exact alignment with the actual land/water points of the AVHRR data. This is done by first adjusting the spacecraft clock time, which is known to be inaccurate by ± 0.5 seconds, sometimes as much as 1 second. A one second clock error translates to a 6.6 km location error along the satellite. Following the spacecraft clock time correction, another set of corrections is made for adjusting the attitude control system of the spacecraft. The system for maintaining the pitch, roll, and yaw angle is accurate to about 0.2 degrees, which translates to about 2 pixels in the AVHRR data.

Quick look generation

After calibration and navigation an RGB quicklook is generated for each pass using appropriate channels depending on being a day- or night-time pass.

Digital browse quicklooks can be accessed via world wide web. Quicklooks after December 7, 1994 show a combination of AVHRR channels 1-2-4 (RGB) for day-time data (minimum sun zenith angle as threshold) and a combination of channels 5-4-3 (RGB) for night-time data. The data are re-navigated using actual orbital-elements provided by NOAA ("two-line-elements"), resampled to a nadir ground resolution of ~ 6 km, panorama-corrected against distortions due to the earth curvature, brightness and contrast-enhanced, and superimposed with a coastline (WDB-II) in red. No sun-angle correction is performed, in order to provide the user an "informative" view of the brightness conditions in the solar channels 1 and 2.

Level 2 data processing

Cloud masking and products

Clouds in satellite imagery can be considered either as obstacles or objects of interest and are thus qualitatively and quantitatively classified. In either case it is necessary to identify and separate cloudfree from cloudy pixels such that macro- and micro-physical cloud parameters can be determined from cloudy radiances while calculations such as SST, LST or NDVI are derived from cloudfree radiances. Methods for detecting clear sky and cloudy radiances and to derive optical properties of clouds from fully cloudy AVHRR pixels are provided through the APOLLO (AVHRR Processing scheme Over cLouds Land and Ocean) software package (SAUNDERS & KRIEBEL 1988, KRIEBEL et al. 1989, GESELL 1989). APOLLO was initiated by a joint effort of the UK Meteorological Office and DLR´s Institut für Physik der Atmosphäre. It has since been continuously improved and extended at DFD together with that institute. Among several attempts to establish AVHRR data processing schemes (e.g. COAKLEY & BRETHERTON 1982, LILJAS 1984, ARKING & CHILDS 1985), APOLLO was the first to make use of all five AVHRR channels during day-time and to discretise all AVHRR pixels into four different groups called cloudfree, fully cloudy, partially cloudy (i.e. neither cloudfree nor fully cloudy) and snow/ice-contaminated, before deriving physical properties. Within APOLLO, clouds are further discretised into three layers according to their top temperature, and further a distinction between (thin) ice clouds and water clouds is made. After these classifications are made for the pixels, cloud parameters such as the fractional coverage, top temperature, optical depth, liquid/ice water path and IR emissivity can be derived. Figure 3 shows a night-time example of an APOLLO cloudmask together with a colour-composite of the channels 3, 4 and 5.

At DFD, all the physical methods provided by APOLLO are embedded, together with statistical and mathematical ancillary functions, into a complex scheme (KRIEBEL et al 2003) which is part of the NOAA-16 operational processing chain and a so-called European Cloud Climatology (ECC). Within the NOAA-16 processing chain, APOLLO delivers a simple cloud mask which separates cloudfree from cloud- snow- and ice-contaminated pixels.

APOLLO is automatically started as soon as the precise georeferencing is available on the rolling archives server. All subsequent processors which need a cloud-clearing start immediately after APOLLO has finished its cloudmask. The ECC is a long-term open-ended project which up to now consists of about 10,000 processed AVHRR scenes, i.e. cloud parameters for the last 13 years are already stored in the DFD´s archives. The ECC will be continued retrospectively back to 1986 and into the future as long as AVHRR data are available at DFD. The ECC-data are to be analysed continuously and time-series are to be derived in the future.

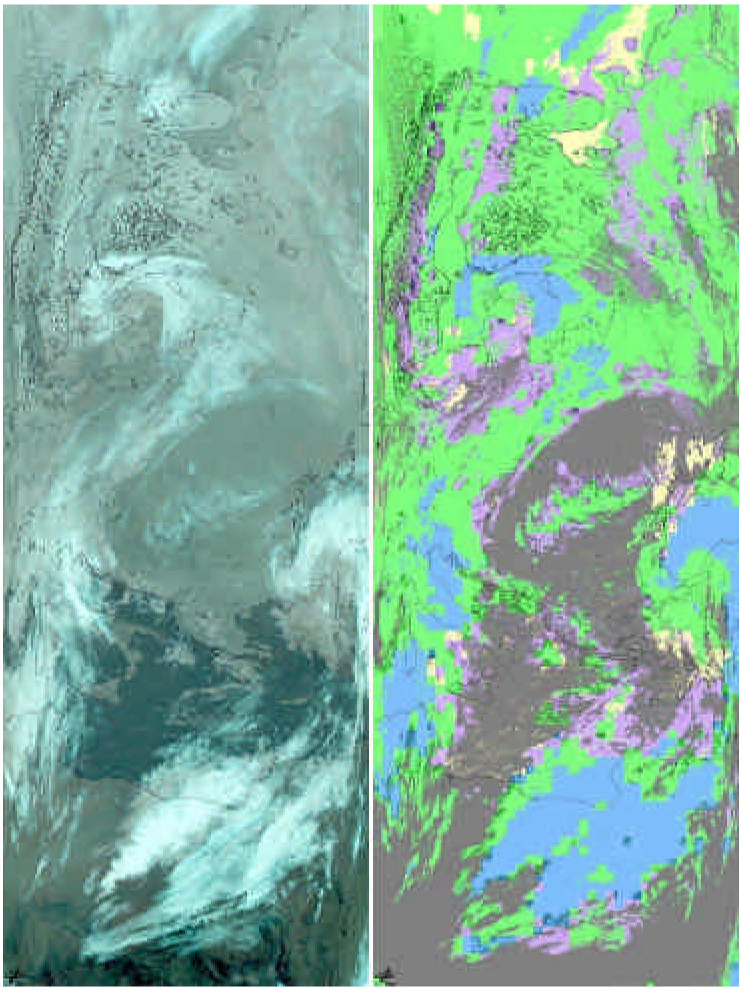

Figure 3: Example of NOAA-16 AVHRR from April 3rd, 2003, 01:01 UT, where left is the colour-composite from channels 3, 4 and 5 and right is a colour-coded APOLLO cloudmask. Low-level clouds are indicated in yellow, mid-level in green, high-level in blue and (thin) ice clouds in lilac. The brightness of the colours is a measure for the fractional coverage (brightest = 100%, darkest = 0%). The grey colour means cloudfree.

Level 3 data processing

Inputs for these processing steps are level 1B data (calibrated, navigated data) and level 2 data (cloud masks in "satellite" projections). Outputs are 3 value-added products: NDVI of Europe, the MCSST (Multi-Channel Sea Surface Temperature) of European Seas in 3 areas and the LST of Europe on a daily, weekly and monthly basis and thematic subsets for several selected areas.

Generation of NDVI

The NDVI has proven to be very useful in measuring and mapping the density of green vegetation because it partially compensates for changing illumination conditions, surface slope and viewing aspect, all of which are factors that strongly affect observed radiances.

NDVI values are calculated using the technical albedo of channel 1 and 2 according to the following equation, *RED* stands for albedo values in channel 1 and *NIR* for those in channel 2:

$$NDVI = \frac{(NIR - RED)}{(NIR + RED)}$$

The NDVI product is a fixed grid map with 1.1 km resolution in a stereographic projection (figure 4). The total size of the final map is 4100 samples by 4300 lines. The data from three daily afternoon passes over Europe are processed to a daily NDVI map. Based on the daily NDVI values weekly and monthly composites are processed in which maximum value compositing technique is applied.

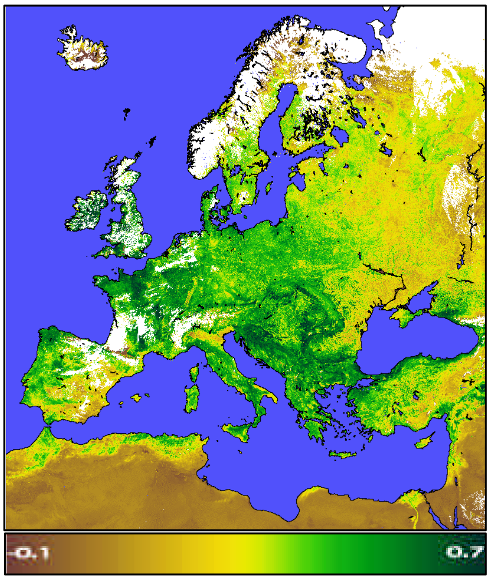

Figure 4: Weekly maximum value NDVI composite for Europe (5th - 11th May, 2003); clouds are masked out (white)

The NDVI range is scaled between -0.1 and 0.7 with a radiometric resolution of 0.0031546 (depends on 10-bit-coding). Value of –0.1 is stored for water, clouds are masked out and set to bad value.

Generation of Sea Surface Temperature maps (MCSST)

The need for accurate sea surface temperature fields has been receiving increasing attention, primarily due to its importance in understanding variability in the oceans' climate. When compared to any other type of measurements, satellite SST measurements are attractive due to their global, repeated coverage.

For the derivation of the sea surface temperature (SST) product, eliminating cloud and other atmosphere-induced effects, is very important because clouds obscure the sea surface and therefore the satellite measures cloud top brightness temperatures rather than SSTs.

The McClain algorithm (MCCLAIN et al. 1985) is applied for processing the SST. This algorithm is based on a so called 'split window technique' that takes advantage of the differential absorption in the thermal region. The two infrared channels of AVHRR (channel 4 and 5) account for the differential absorption of the atmosphere, mainly for water vapour that could lead to a significant drop in derived brightness temperatures, depending on the climatic region. The formula applied is the following:

MCSST = A*T4 + B*(T4-T5) + C*(T4-T5)*(SEC(sza)-1) + D*(SEC(sza)-1) + E

For the calculation of the sea surface temperature, the sun zenith angle (sza) must be known as well as the AVHRR measured temperatures in channel 4 and 5 (T4, T5). The coefficients A,B,C,D and E are day/night specific and sensor dependent. They are derived from extended statistics of empirical buoy measurements and provided by NOAA and SeaSpace Corporation, respectively.

Different MCSST map products of Europe are produced, each with 1.1 km resolution and using a Mercator projection:

1) The Mediterranean and Black Seas (2048 lines/ 4096 samples) presented in figure 5
2) The North Sea, the Baltic Sea and the North-Eastern Atlantic (2500 lines/ 3900 samples) and
3) Atlantic around Madeira and the Canary Island (2200 lines/ 1350 samples)

To register the images from the satellite projection into the final grid-map a nearest neighbour resampling technique is applied.

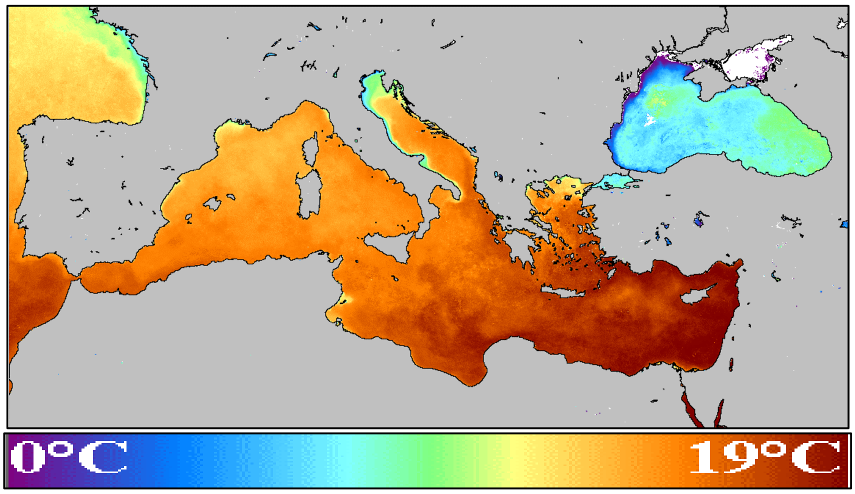

Figure 5: Monthly Sea Surface Temperature (SST) for the Mediterranean Sea (February 2003); clouds are masked out (white)

Generally a daily MCSST composite consist of 3 day-time and 3 night-time single passes. Compositing technique is maximum MCSST. From these daily composites weekly and monthly MCSST products are derived by averaging MCSST values.

The MCSST values are stored between 0.125 and 31.75 degrees Celsius (°C) with a radiometric resolution of 0.125°C. The 0°C value is reserved for land, while clouds are stored as bad values.

Generation of LST

Land surface temperature (LST) is an important factor controlling most physical, chemical, and biological processes on earth. LST is generally controlled by the surface energy balance, atmospheric state (wind, humidity), thermal properties of the surface and subsurface mediums. Numerous factors determine the accuracy of the LST retrieval from satellite thermal data, including sensor radiometric calibration, atmospheric correction, surface emissivity correction, characterisation of spatial variability in land cover, and the combined effects of viewing geometry, background, and fractional vegetative cover.

The technique used at DFD for estimating the land surface temperatures from thermal infrared NOAA AVHRR data is also a so-called “Split-Window” method. This technique is based on the differential absorption effects in two infrared bands situated close to each other in order to estimate atmospheric water vapour content (channels 4 and 5 of AVHRR are closely related).

The temperature is derived using an empirical relation of the form:

$$T = a_0 + \sum a_i * T_i$$

where T is the land surface temperature and T_i are the brightness temperatures in two thermal infrared channels. The coefficients a_0 and a_i are dependent on the atmospheric state and on the surface emissivity. Unlike sea surface, where the emissivities are quite similar in the thermal infrared channels, land surface emissivities depend on the type and condition of the land surface. In addition, the emissivities are wavelength-dependent. If neglected, these variations introduce large errors in the calculated LST.

The BECKER & LI algorithm (1990) is applied for processing LST over Europe at DFD.

$$T_{Becker\&Li} = 1.274 + (T_4 + T_5) * ½ * [1 + 0.15616 * (1 - \varepsilon) / \varepsilon - 0.482*\Delta\varepsilon/\varepsilon^2] +$$

$$(T_4 - T_5) * ½ * [6.26 + 3.98 * (1 - \varepsilon) / \varepsilon + 38.33 * \Delta\varepsilon / \varepsilon^2]$$

where

$$\varepsilon = (\varepsilon_4 + \varepsilon_5) / 2$$

$$\Delta\varepsilon = (\varepsilon_4 - \varepsilon_5)$$

$$T_0 = 273.15$$

For estimating the surface emissivity $\varepsilon(\lambda)$ the relationship given by VAN DE GRIEND et al. (1993) is applied:

$$\varepsilon_4 = 1.0094 + 0.047 * \ln(NDVI)$$

$$\Delta\varepsilon = (\varepsilon_4 - \varepsilon_5) = 0.01$$

NDVI here stands for the 10-day NDVI maximum composite value based on the daily composites operationally generated at DFD.

Under the assumption that the emissivity remains nearly constant within a period of ten days, the 10-day composite is a suitable input parameter to reduce cloud contamination effects and to take into account the effects caused by angular viewing conditions of the sensor.

The LST product is a fixed grid map with 1.1 km resolution in a stereographic projection (figure 6). The total size of the final map is 4100 samples by 4300 lines. Within 24 hours, day-time and night-time LST’s are calculated. In general, from 3 day-time single passes or 3 night-time single passes the products are generated. Compositing technique for daily day-time LST is maximum NDVI value and for daily night-time LST maximum LST value. Weekly and monthly day-time or night-time LST composites are also obtained by averaging daily day-time or daily night-time LST values respectively.

The LST range is scaled between –39.5°C and +87°C with a radiometric resolution of 0.5°C. Value of –40°C is used for water, and clouds are masked out as bad values.

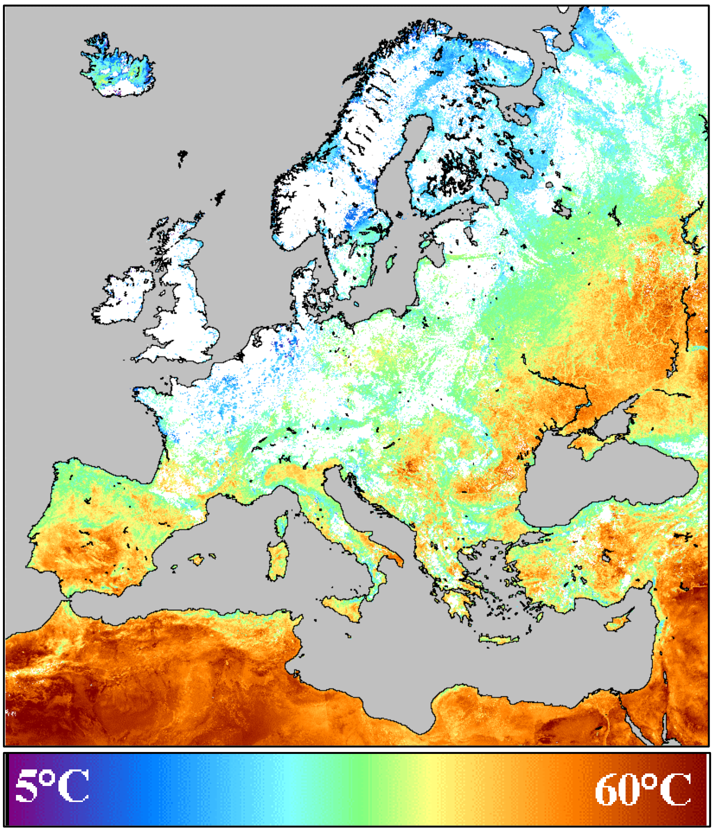

Figure 6: Weekly Land Surface Temperature (LST) composite (19th - 25th May, 2003); clouds are masked out (white)

Generation of Thematic Images (e. g. "Central Europe", CE)

Five-channel NOAA-16 image subsets in standard Mercator projection are created daily for several areas such as “Central Europe” and allow user-specific applications. The data sets are navigated, calibrated, registered and scaled to a user-friendly 8-bit data format. Coastlines and state boundaries are overlaid.

Product access

Datasets in HRPT formats are stored on different media in the DFD archives. Older data are stored on HDDT analogue tapes and some on digital CCT. Since 1990 all datasets are stored digitally on tape archives. Users can get data either in a DLR-specific "DFD" format which contains the complete datastream (AVHRR, TOVS, DCS, etc.) as well as raw HRPT and NOAA LAC format on various distribution media (CD ROM, tape, ftp etc.).

Subsets of AVHRR acquisitions stored in the ESA-Earthnet SHARP format (Standard-family HRPT Archive Request Product) can also be ordered at the DFD. The AVHRR scenes in SHARP format contain 4 minutes of acquisition, thus 1440 lines.

In 1993, the operational delivery of daily, weekly and monthly MCSST products started. Value-added products as the daily, weekly and monthly NDVI have been available since mid-1994. Since 1995, the land surface temperature (LST) has been available as weekly and monthly day- and night-maps. Most products are available with a delay of one day except after weekends and holidays through DFD’s Intelligent Satellite Information System (ISIS) or

EOWEB. ISIS software can be downloaded and installed on a PC or workstation (http://isis.dlr.de).

The new EOWEB interface (http://www.eoweb.de) will run on any browser supporting Java 1.1.3, LiveConnect, JavaScript, so that the Java Swing libraries/applets are supported. With EOWEB, online transfer is possible for the products:

1) NOAA AVHRR Central Europe
2) NOAA AVHRR SST
3) NOAA AVHRR LST and
4) NOAA AVHRR NDVI.

The thematic maps SST, LST and NDVI consist of one layer in 8-bit resolution. The data format can be selected by the user (GIF, TIFF, Sun Raster or HDF4). Due to the great data volume of the thematic products, a very high compression rate can be achieved for on-line transfer. The quicklooks are stored in JPEG format and can be downloaded. All products are also available off-line and can be sent on CD on request.

New products

In early 2003, an experimental processor for routine correction of atmospheric disturbances was set-up. The atmospheric correction is based on the "Simplified Method of Atmospheric Correction" (SMAC) (RAHMAN & DEDIEU 1994). Inputs to the pre-operational processor include atmospheric products from other operational DFD processors. Water vapour is derived operationally from NOAA-TOVS data and interpolated for AVHRR coverage and spatial resolution. Ozone absorption is corrected using level-3 data derived operationally in near-real time at DFD from ERS-2 Global Ozone Monitoring Experiment (GOME). This level-3 data is derived using Kalman filter techniques for spatial and temporal interpolation. The aerosol content and type are not yet derived from remote sensing data and therefore set to default values.

Our first results show that the integration of different remote sensing data sources needs precise data management and highly sophisticated quality control. Nevertheless, routinely atmosphere-corrected AVHRR data (channel 1 and 2) may become a better basis for long-term monitoring of the land environment.

In order to use the AVHRR products more efficiently for climate change research (e.g. modelling the net primary productivity of land vegetation), an operational processing chain is under development for generating homogenised yearly time series of the NDVI. Applying the Harmonic Analysis (HA) to the noisy and missing data NDVI composites gives a smoothed and interpolated data set suitable as input for different models. Our first results show that missing data gaps of up to 20 weeks duration, which are typically observed for boreal forests during winter time, can be interpolated with good results. This new processor will be tested in the near future with a NDVI data set covering one year and entire Europe. Based on the smoothed NDVI data set, the LAI time series will be derived using the algorithm of SELLERS et al. (1996).

Conclusion

Since November 1981 the German Remote Sensing Data Centre (DFD) of the German Aerospace Centre (DLR) has been receiving AVHRR satellite data to serve the needs of the national and international user community. The operational processing of AVHRR data at DFD has now delivered a 10-year time series of the Sea Surface Temperature (SST) covering the European seas. With this dataset a first climatological record with 1 km resolution is archived and can be accessed by users via the internet. Also, the 9 years operational processing of AVHRR data to derive the Normalised Difference Vegetation Index (NDVI) and the Land Surface Temperature (LST) has brought up a valuable dataset for climatological investigations.

All products are currently accessible free of charge through DFD's electronic interfaces ISIS and EOWEB.

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