AN INTEGRATED RECEIVING AND PROCESSING UNIT FOR MSG, NOAA AND TERRA/AQUA DATA

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ABSTRACT

The cooperation of VCS Engineering and the Laboratory for Climatology and Remote Sensing (LCRS) at Marburg University (Germany) resulted in the integration of different satellite receiving and processing systems based on improvements of the existing hard and software design at Marburg Satellite Station (MSS). In a joint-venture between VCS and LCRS the algorithms for Level 1b / 2a products for MSG SEVIRI, NOAA AVHRR (VCS) and Terra/Aqua MODIS developed at LCRS are integrated into the VCS software package 2met! (Linux/Windows). Even though higher level operational products of the LCRS (implemented in Fortran and Java) are not part of 2met! yet, its modular architecture allows for the easy integration of further components.

1. INTRODUCTION

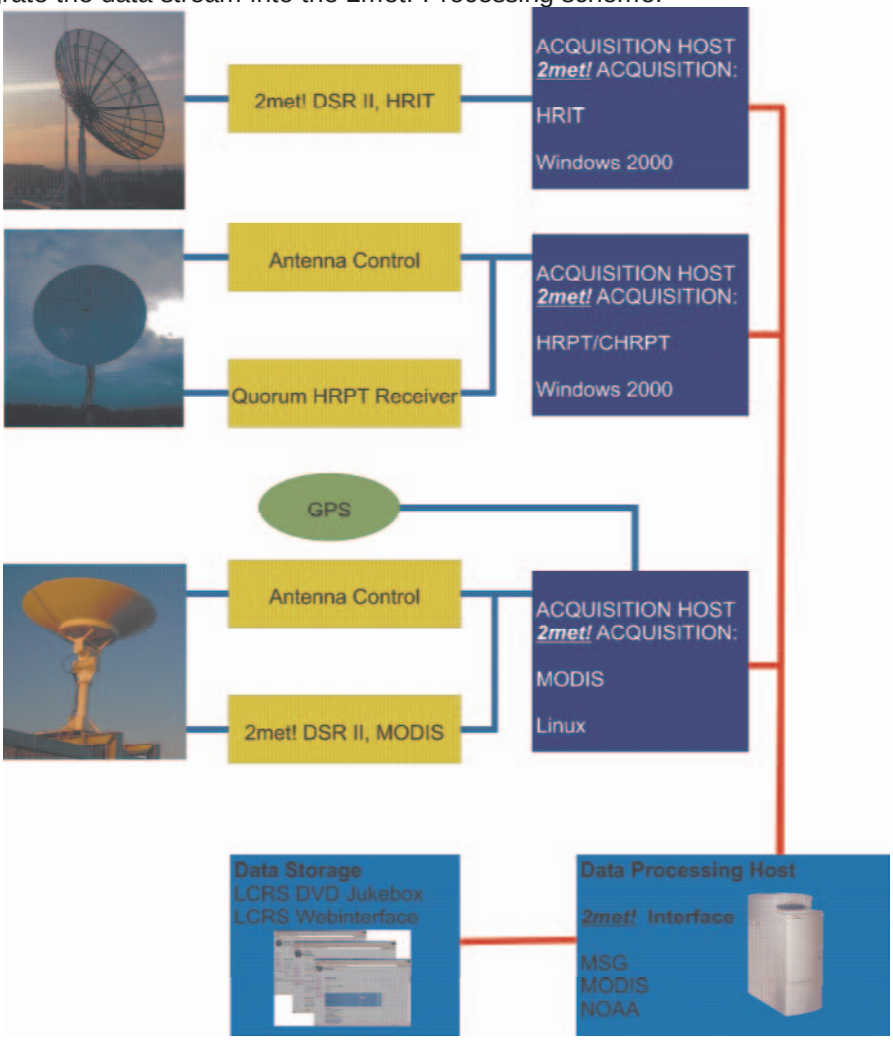
A ground segment (Marburg Satellite Station, MSS) for the reception of high resolution weather satellite data is in place at the Laboratory of Climatology and Remote Sensing (LCRS) in Marburg, Germany. The MSS comprises three receiving stations for different systems: NOAA-HRPT, MSG-HRUS and TERRA/AQUA. All stations have been in operation since December 2001. All received image data is transferred via a LAN to the LCRS data processing and archiving facility. A metadata base of received and archived images is available on the LCRS web page which can be also contacted for any data request. Due to both the significant increase of data amounts and the online demand on operational products a concept for the large-scale integration of the data processing chains was developed in a joint venture project between LCRS and VCS. The two main objectives of VCS are the hardware-based integration of the original Quorum NOAA AVHRR receiving station into the MSG ground segment and the development of software modules to integrate higher level products into the reception and processing work flow. Based on the development of an adapted control unit the NOAA AVHRR reception is performed by a standard industrial PC which transmits the data stream to the MSG processing engine. Due to some extensions of the existing software libraries of the 2met! package it is possible to process the NOAA AVHRR data using this standard processing environment. The objectives of LCRS are the development and implementation of higher level

satellite data products. Currently, cloud type maps, maps of the distribution of microphysical cloud properties and precipitation estimates are available. Due to the fact that most of the algorithms are multi-sensor compatible the integration of NOAA AVHRR, Terra/Aqua MODIS and MSG SEVIRI processing schemes into the 2met! Software concept acts as an efficient base for the coupling of commercial technical data processing and operational calculation of scientific algorithms.

2. THE MARBURG SATELLITE STATION (MSS)

2.1 NOAA-HRPT stations and applications

The stations consists of a tracking-antenna (elevation - azimuth) with a feed, a downconverter, a tracking interface and processing PCs. The PCs are operating under a DOS/Windows environment. Currently, data of NOAA-12, 14, 15, 16 and 17 are being captured. System time and Kepler elements are regularly updated via internet. The station in Marburg was manufactured by UKW-Technik GmbH. Data are submitted to the robot archive and stored as UKW generic raw data. VCS Engineering has devoloped the necessary 2met! libraries to integrate the data stream into the 2met! Processing scheme.



1. The technical conception of the Marburg Satellite Station

2.2 MSG-HRUS station and applications

The MSG-HRUS (High Rate User Station) receiving station was manufactured by VCS Engineering and consists of the following elements:

(a) 3,6 m fixed mesh-grid antenna with feed and HRIT downconverter
(b) Digital Satellite Receiver (VCS 2met!-DSRII, HRIT type) based on the global LRIT/HRIT specifications of the Co-ordination Group for Meteorological Satellites
(c) Dell data processing workstation (Windows 2000-based system).

The computation of Level 1b products (calibration, geo-referencing, gridding) is performed by the VCS software (2met! Software for Windows NT) which is installed on the processing workstation.

2.3 TERRA/AQUA Station and data processing chain

The receiving station at MSS is designed for TERRA/AQUA “Direct Broadcast Mode”. The system consists of the following:

(a) 2.8 m two-axis (X-Y) tracking antenna and X-band feed, Cassegrain-Reflector and downconverter
(b) GPS receiver for time-tagging for high-accuracy antenna tracking
(c) Receiver with DPSK-demodulator, Viterbi-decoder and bit-/frame synchronizer
(d) Tracking Control PC-system (Windows-DOS PC Workstation)
(e) PC Workstation (LINUX) with interface card for data processing up to Level 1b. Processing of the raw data stream to Level 0 PDS-data (Production Data Set
(f)) is provided by the aquisition software which includes Reed Solomon Decoding and re-assembling of the raw telemetry data.

3. THE 2met! ACQUISITION AND PROCESSING CORE

3.1 ACQUISITION XRIT

The 2met! ACQUISITION XRIT software which is used at the MSS, is based on the DADF Reference User Station developed for EUMETSAT. This implementation uses the 2met! DSRII. The software therefore has to perform the Reed-Solomon decoding and the frame synchronisation.
The 2met! ACQUISITION XRIT software package performs the decryption and decompression on the data in real-time. All assembled, decrypted and decompressed files, including all intermediate files, are stored in an online buffer directory on the local system disk for a configurable time. The 2met! ACQUISITION XRIT software includes monitoring functionality with regard to the reception quality of data. The Data stream monitor displays quality data in real time, this includes information on:

- the satellite link status
- Besides the RF input level the monitoring systems displays also the logs the state of Carrier PLL, bit synchroniser PLL, Viterbi Decoder Node Synchronisation and the frame synchroniser.
- the actual and long term bit error rate

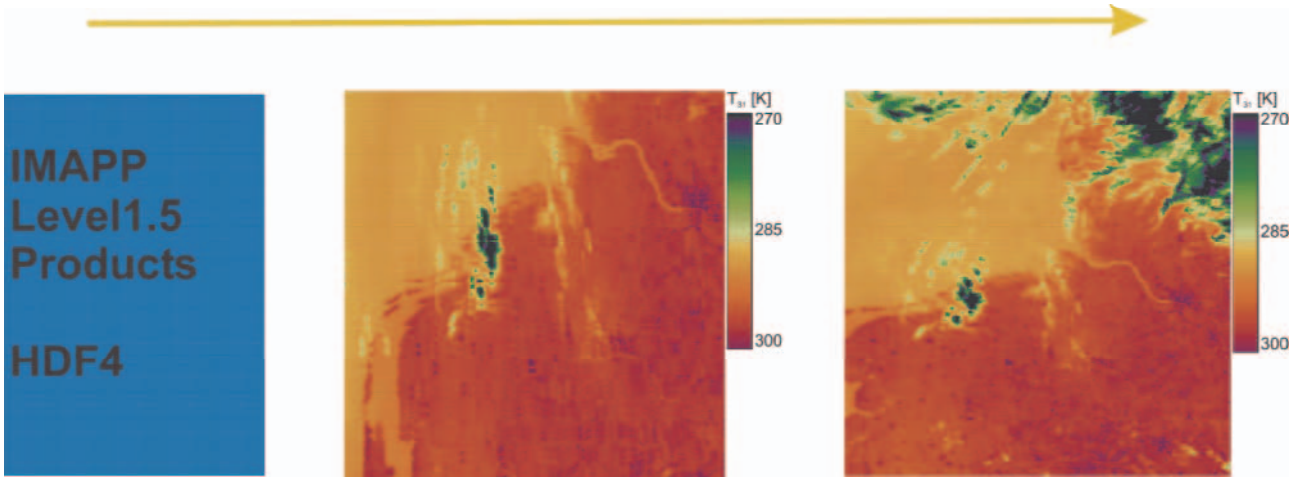
3.2 HRPT ACQUISITION Software

The 2met! ACQUISITION HRPT is the software for the polar orbiting satellites NOAA KLM, FENG YUN, METOP and its successors. It consists of a scheduler which sets up all automatic background tasks such as tracking (optional), data reception and data processing and a data acquisition part which collects the data from the front-end. The acquisition part performs the CCSDS processing required for METOP and the frame synchronisation as well as the decryption in case of METOP data. It interfaces to the 2met! DSR II or alternative to an unsynchronised data stream from the UKW HRPT Receiving Unit via a TCP/IP connection. Further processing like the calibration of the AVHRR instruments will be performed by the 2met! PROCESSING package on the algorithms developed for the NOAA satellites. The software will then

perform the frame synchronisation, the Reed Solomon decoding and the source packet reconstruction. These processed data will be sent to the 2met! PROCESSING software.

3.3 MODIS ACQUISITION Software

The MODIS acquisition software basically reads the data from the receiver via the EDT high speed interface board and performs the CCSDS processing to the MODIS Level 0 format which is later processed by the IMAPP software running on the processing hosts. Pass Prediction and scheduling is performed by the same software used within the HRPT reception system. Therefore features like the flexible conflict resolution also exist for the MODIS system. The acquisition software automatically controls the receiver and tracking system.
The MODIS Level 0 files generated by the Acquisition software are processed by the IMAPP software and the LCRS IMAPP Extension package MOPS. The MOPS software is partially integrated into the 2met! PROCESSING software in so far as the MOPS programs are started by the PROCESSING background software (figure 2).



2. The panel shows the IMAPP extension module. After finishing the IMAPP standard processing (left) the geometric properties of the imagery is like the brightness-temperature calibrated band 31 before bow-tie correction (center). The feature doubling can clearly be seen at the off-shore islands. Right figure shows the same band after bow-tie correction and projection. The projection can be done for all MODIS resolutions. The 250m and 500m band projection is done using bilinear interpolated latitude/longitude files. Corresponding sun and satellite angles are also bilinear interpolated to fit the desired resolution.

The software tool MOPS for Terra-/Aqua-MODIS is designed for ordinary PC platforms (Nauss et al. 2003a). Its modular architecture presents an easy to update / easy to extend system which consists of pre-/post-processing and product modules. The pre-processing takes care of the conversion from PDS to HDF format, extraction of band- and geo-data from HDF to flat-binary format and radiative / thermal calibration. The post-processing projects the data to a cartesian grid like UTM. A similar processing scheme based on the VCS 2met! Software is under construction for MSG.

3.4 The *2met!* PROCESSING module

2met! PROCESSING is the production tool within the *2met!* environment. It handles the data from all acquisition packages to execute further steps of processing. In the proposed system it will perform all tasks beyond the level 0 processing of the data.
It allows for the integration of new algorithms without modifying the existing executables. The tools performing the tasks are in fact single executable programs which can be used without the background

processing. This feature allows using them from the viewer tool for interactive processing of satellite images as well. The main tasks are:

- Navigation and Calibration of HRPT - Data
- Reprojection of satellite image data
- Housekeeping for image files
- Landmark Correction

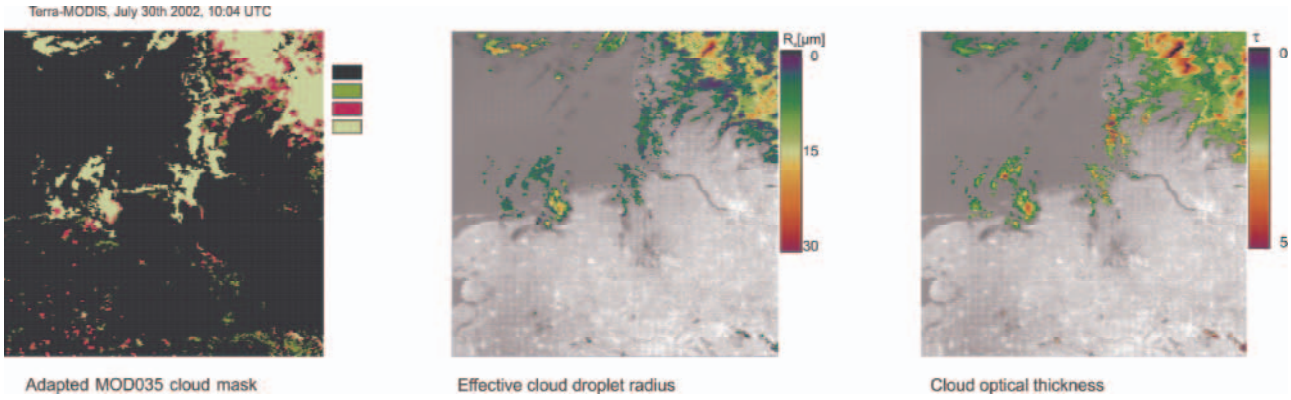
One feature of this package relevant to the requirements is the pipeline mode in which products are processed. This mode allows to feed the data through all processing steps in a chain simultaneously. The resulting product will be ready very shortly after all data required for that particular product have been received. Even if products are chained - if one product is the input for another one - they will be processed in the pipeline mode. This feature is essential for fast product availability.

4. OPERATIONAL ALGORITHMS FOR HIGHER LEVEL CLOUD PRODUCTS

The operational processing scheme run at the LCRS for the retrieval of cloud microphysical properties or cloud types and precipitation estimates respectively are integrated into the 2met! Processing scheme. Two examples are given here.

4.1 Modis Product Line

Up until now the basic processing steps including decoding of satellite raw data, calibration, geolocation and projection are included the 2met! Processing environment. The retrieval runs in an MS Windows environment based on modular pre-processing by MOPS. Cloud properties (effective cloud droplet radius, optical thickness, geometrical thickness and liquid water path) of day-time data are retrieved based on an adapted version of an algorithm by T. Nakajima, T. Y. Nakajima and K. Kawamoto with look-up tables for Terra-/Aqua-MODIS and MSG respectively. For night-time data an infrared technique developed at the LCRS is used taking into account near-infrared and infrared radiances. Up to now the processing chain is run for Terra-/Aqua-MODIS. With the end of the Meteosat-8 commissioning phase it will also be available for MSG.



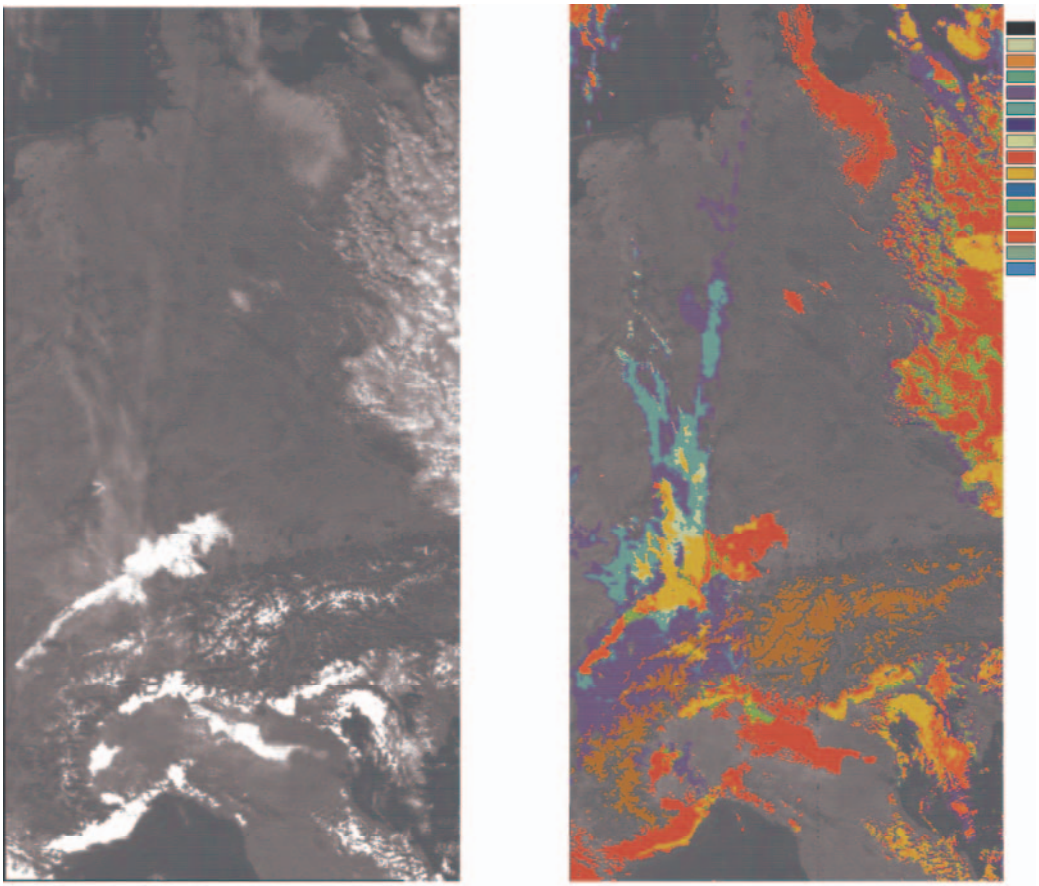
3. MOD035 MODIS cloud-mask (Ackermann et al. 1998) (left) July 30th 2002 10.04 UTC in comparison to operationally derived cloud properties (centre & right). The nominal thresholds for each cloud test are addapted to values suitable for Europe and northern Africa. Operationally derived distribution of the effective cloud droplet radius (centre) and cloud optical thickness (right).

The example shows these basic steps and two transcend operational products of the LCRS that controlled by the 2met! core module. For daytime data this is done by means of an adapted version of the GTR code (Nakajima et al. 1995 and Kawamoto et al. 2000) which was originally designed for NOAA-AVHRR. Look-up

tables have been re-calculated by means of radiative transfer calculations with respect to the spectral response functions of MODIS bands 1, 20 and 31. The program requires some ancillary data sets such as maps of ground albedo for bands 1 and 20 in order to eliminate contaminations of TOA cloud reflectance due to the underlying surface, especially for semi-transparent clouds. These maps have been calculated from a set of atmospherically corrected (6S-code) and nearly cloud-free MODIS scenes by using the minimum composite technique.
For night time data a multi-spectral technique has been developed using data at 3.9µm, 8.5µm, 31µm and 32µm (Nauss et al. 2003b).

4.2 NOAA Product Line

The widely used NOAA-AVHRR imagery is used to produce standard products like the NDVI or cloud type classifications. The latter is performed for both day and night overpasses by applying several threshold tests which also include ancillary terrain information. The classification scheme generally follows the logic of the APOLLO-method by Saunders and Kriebel (1988) and Kriebel et al. (1999) for both day and night application. Existing tests were modified and additional tests have been introduced. For the remaining tests of the APOLLO scheme, thresholds have been carefully adjusted (Bendix et. Al. 2003).



4. The upper panel shows the albedo image (left) and the operationally derived cloud classification mask (right)

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