PROSAT - A SYSTEM FOR METEOROLOGICAL SATELLITE DATA PROCESSING AT THE SWEDISH METEOROLOGICAL AND HYDROLOGICAL INSTITUTE

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1. INTRODUCTION - MAIN IDEA AND PURPOSE OF PROSAT

During the 70's and the first half of the 80's the use of picture information from weather satellites at the Swedish Meteorological and Hydrological Institute (SMHI) consisted of pictures received in an analogue way. The pictures were in many ways of great value to the forecaster but the analogue information had a number of rather serious drawbacks (e.g. geometric correction was not possible) that put some restrictions to the usefulness of the image information.

The urgent need of geometrically corrected pictures and the fact that multispectral processing of digital satellite image data could extract very useful information about clouds, precipitation and other meteorological parameters (e.g. shown by Liljas, 1982), led to the definition of the PROSAT system (PROSAT = PROcessing system for meteorological SATellite data). The requirements for PROSAT were in general terms formulated as follows:

1. Automatic scheduling and reception of digital image data from the METEOSAT and NOAA satellites should be performed.

2. Pictures should be produced automatically and presented on standard geographical areas in near real time.

3. The procession system should allow multispectral processing of satellite data (all 5 channels for the NOAA satellite) and be able to produce derived pictures from such processing within 30 minutes after reception.

4. The system should have a capability to allow both operational use and research.

The main development and installation of PROSAT took place between 1984 and 1986 and the system went operational during 1987. The main contractor was ERICSSON RADAR ELECTRONICS AB which delivered the system in cooperation with TERAGON-CONTEXT AB (responsible for the image processing hardware and basic software), the SWEDISH SPACE CORPORATION (responsible for software for data reception and geometrical operations) and SMHI.

2. MAIN SYSTEM COMPONENTS

In figure 1 an overall system overview of PROSAT is given.

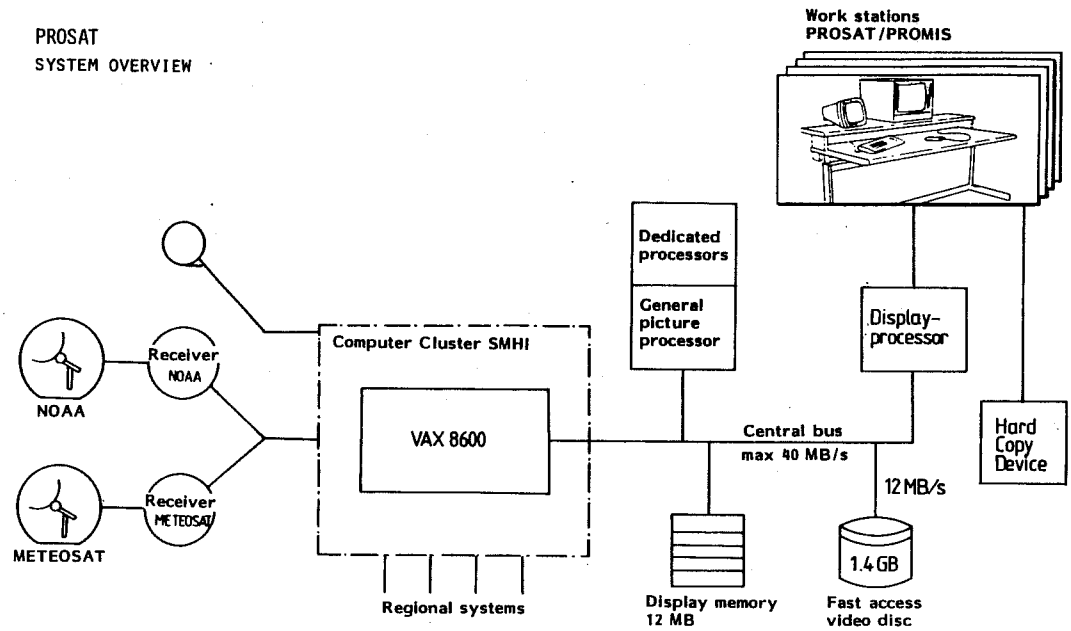

Figure 1. A system overview of PROSAT.

2.1 The host computer

The system is managed and controlled by a host computer, in this case av VAX 8600 computer. In general, the image processing hardware doesn't need a host computer of this size (a smaller computer could also be used). The fact that PROSAT-products should be used together with other information in meteorological databases (such as radar pictures, observations from automatic and manual stations etc.) led to an integration of the system on one of the main computers which means that the PROSAT system, as installed at SMHI, is not a totally free stand-alone system.

The host computer controls and supervises the operations that are performed by PROSAT. This is done both by following a predefined schedule and by use of a message system that triggers and ends processes. The

operations typically performed by the host are preparation and control of reception of satellite data, preparation for calibration and geometric transformation, initiation of product generations and administration of files. Practically no image processing is performed by the host computer but is done by the image processing system (described in section 2.3).

For this reason, one of the most important tasks for the host is to order and instruct the image processing system to execute the picture generation.

The host also distributes a subset of satellite pictures on fast telecommunication links to regional forecasting offices.

2.2 Satellite data reception system

The left part of figure 1 shows the satellite data input part of PROSAT. The schedule for reception of data is prepared by the host computer by using the NOAA TBUS telegrams (delivered on GTS) with orbital data for the NOAA satellites and a fix table for the transmission of METEOSAT images.

The reception of the digital HRPT data stream from the NOAA polar orbiters is handled by a system consisting of a 2.4 meter DATRON antenna and a MICRODYNE receiver. Positioning of the antenna is done automatically by an auto tracking procedure.

Reception of the digital PDUS data stream from METEOSAT is performed by a TECHNAVIA 4 meter antenna and a TECHNAVIA receiver.

The received data from either the NOAA satellites or METEOSAT is then transferred by an AYDIN bit synchronizer and an ERICSSON frame synchronizer to storage at full digital resolution on a VAX disk.

As is indicated in figure 1 it is also possible to ingest satellite data on tapes for research purposes. PROSAT can handle several foreign tape formats and it is naturally also possible to store received data on tapes.

2.3 Image processing system with workstations

In figure 1 the image processing system is presented as the components to the the right of the host computer. For the image processing a TERAGON 4000 system is used. It is connected with and controlled by the host computer by a specific operating system (working in the VAX/VMS environment) which serves as an interface between the host and the image processors. The operating system enables several parallel PROSAT applications

to be executed. It also administrates the use of a virtual picture memory in the system, which means the image processing when necessary can temporarily use disk capacity to extend the needed primary picture memory (commented on below).

The components of the TERAGON 4000 system is connected with a multiplexed bus that enables quick parallel data transfers. The maximum data transfer rate is 40 MByte per second.

Three main image processors is responsible for all image processing. It is the general picture processor, a set of dedicated picture processors and the display processor. All processors use and share the primary picture memory that at present is 16 MByte (could be extended).

A very important component is an IBIS video disk with a total storage of 1.4 GByte. The disk serves as the storage of all operationally needed products and the maximum data transfer rate from the disk is 12 MByte per second. If PROSAT had been a stand-alone system the access and display of images in general would have been instantaneous but with the present system, where the host computer is shared with other non-PROSAT applications, the access times of individual pictures varies between 1 and 5 seconds. The video disk also supports the handling of picture sequences due to the fast data access. Another important task for the disk is to serve as the virtual picture memory. This means that image processing of images that are very big and with several layers is performed in a rational way and it could also be done by parallel mutually independent processes.

The general picture processor handles all picture processing but it can when necessary use the attached set of dedicated picture processors which performs all processing that require neighbourhood operations (such as resampling and filtering). The dedicated processors in PROSAT consists of 4 parallel pipeline processors (mainly used in parallel to speed up operations like filtering or multispectral classification) and a resampling pipeline processor (used for geometrical operations). The display processor controls the last step when a picture is about to be displayed on one of the PROSAT workstations.

Interactive use of PROSAT pictures operationally and for development purposes is performed at four PROSAT workstations. Every workstation con-

sists of a colour monitor, an alpha-numeric terminal and a digitizer table equipped with a mouse. Hard copy equipment (a thermal colour printer and a videoprinter) is attached to the workstations.

3. PICTURE CONCEPT IN PROSAT AND STANDARD PICTURE OPERATIONS

The use of a virtual picture memory means that, in practice, there are no limitations on picture sizes handled by PROSAT. The only restriction is that, when working interactively at a workstation, due to the size of the colour screen, the operator can not see the full picture if it is very big (though, zooming and other operations can solve this problem). At present the colour screen has a resolution of 575 lines and 725 pixles. The system also allows use of image structures consisting of several image layers. When performing multipectral processing, a concept of multi layer structures is used.

The concept of colour compositing of image layers (use of red, green and blue 8 bit layers) is widely used in PROSAT. This allows presentation of multispectral information in a very efficient way. For example, all 5 NOAA channels could be presented in 2 pictures. Essential information, as time, satellite, map and grid information, is presented in overlays.

The system allows a wealth of picture operations. Some of those are:

* zooming,
* moving of pictures on the screen,
* quick comparasions of pictures,
* sequences,
* merging and mosaics of pictures,
* contrast operations (both fixed and picture related),
* false colouring,
* conversion of pixel bit sizes,
* geometrical resampling,
* filter procedures (single- or multi layer arithmetic, logical or basic convolution operations),
* multispectral training and classification (box, minimum distance and maximum likelihood methods),
* pixel read-back,
* graphical operations (drawing of figures, writing of symbols and text).

4. OPERATIONAL USE OF PROSAT IN WEATHER FORECASTING

The operational forecasters in Sweden have been using PROSAT since autumn 1988. In designing PROSAT much effort has been put on making the system user friendly and the products suitable for operational usage.

4.1 Areas for picture presentation

All meteorological picture products are presented in standard geographical areas in polar stereographic projection as shown in figure 2. These are: the European area (EURO - approx. resolution 8 km), the Scandinavian area (SCAN - approx. resolution 4 km) and the southern and northern Swedish areas (SSWE + NSWE - approx. resolution 1 km). In addition, two areas in mercator projection, describing the sea waters surrounding Sweden, has been defined for use in marine forecasting.

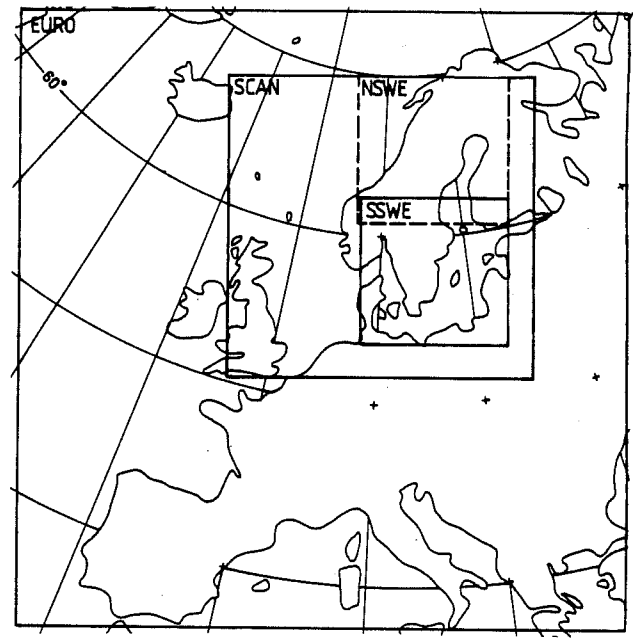

Figure 2. Standard geographical areas for meteorological products.

4.2 Operational meteorological products

The products are mainly of three types: black and white pictures, colour composite pictures and false coloured pictures. On the whole, most pictures are in the form of colour composites because of the usefulness for presenting multispectral information. The following picture information is at present (december 1989) produced by PROSAT:

METEOSAT:

1. IR overview (black and white, area EURO and SCAN).

2. VIS + IR overview (composite, areas EURO and SCAN).

NOAA:

1. IR overview - channel 4 (black and white, area EURO).

2. VIS + IR - channels 1, 2 and 4 (composite, areas EURO, SCAN, NSWE and marine areas).

3. IR - channels 3, 4 and 5 (composite, areas SCAN, SSWE, NSWE and marine areas, calibrated to brightness temperatures).

4. CLASSIFICATION (false coloured, areas SSWE and NSWE, presented both as cloud type classification and precipitation analysis).

All product generation is performed by background processes in PROSAT. In the future the operational products will be extended to include classifications on areas EURO and SCAN, cloud top temperature/height pictures and sea surface temperature pictures. Also products derived from processing of TOVS-data is planned to be presented.

Pictures derived from multispectral classification are based on processing of calibrated data from all 5 AVHRR channels. The classification model is a multidimensional box model depending on season and existing sun elevations in the AVHRR scene. It has been developed within the Swedish PROMIS project (see Strandberg, 1990) at SMHI. The model processes for the SSWE area a multi layer structure consisting of approximately 7 MByte of pixel data. For a complete description of the model, see Karlsson and Liljas (1990).

A product generation of METEOSAT pictures is done within 5 minutes after reception. Due to the much larger amount of data and the larger number of products, a complete NOAA product generation takes approximately 40 minutes after reception. However, the products needed quickly in weather forecasting are naturally produced first. This means that overwiev pictures on the EURO area and full resolution pictures on areas SSWE and

NSWE (including classification products) are available after approximately 20 minutes. All operational products from the last two days are stored on the video disk. This database is continuosly updated. No long term storage (more than temporary case study data) are performed in the system. In the future this is likely to be introduced and the first products to be stored will be classifications and extracted data from classifications and extracted data from classifications on reduced resolution grid fields.

4.3 Management of PROSAT by the forecaster

In order to make the system easy to handle for an operator, a special menu system have been developed. It is based on input on the alphanumeric text teminal and the wide use of functional keys minimizes all writing on the terminal. The operator can order pictures either by pressing functional keys for direct choice of the latest available picture of a specific type, or by choosing products in a tree structure that allows presentation of pictures from the last two days. Basic image handling functions are also handled by direct functional keys or by selection in a tree structure. The operator can on the text terminal screen follow the data flow in the system by inspection of messages displayed continuosly. Thereby he or she can control what is going on in PROSAT and in advance plan for the optimal use of the incoming picture data.

5. OPERATIONAL EXPERIENCE OF PROSAT

PROSAT has been running operationally since autumn 1987 and all the operational products listed om section 4.2. have been produced since early spring 1989. In general, the system has satisfactory fulfilled the requirements listed in section.1. In some parts it has performed better than was originally specified (e.g. multispectral classification is executed in less than 15 minutes after reception). As the design and procurement of the system was somewhat delayed, the final system turned out to be more modern (e.g. large image memories realized the use of colour composites and large multispectral structures of data). The receiving part of PROSAT has proven to be quite robust and no major interruptions have occured. Product generation by the image processors has also been executed successfully and when problems have occured service has been

carried out quickly. The problems that in periods have arisen have been caused by the fact that PROSAT is not a stand-alone system but sharing the host computer with many other processes. Due to an increasing load to the host computer, product generations sometimes suffer of time delays and the access of pictures at the workstations could also be delayed by this. Much work is carried out to optimize the use of the host computer and to ensure that PROSAT is given high priority.

The development of PROSAT has also been important for the development of systems for display of an integrated set of meteorological pictures (from satellite, weather radar, observations from automatic and manual stations, forecast fields, meteorological analyses etc.) and for production of forecasts distributed to various customers. The basic image processing hardware and software (the TERAGON 4000 system) have formed a base for the development of such systems. The Swedish PROMIS system (see Strandberg, 1990) is an example of this kind of systems used at SMHI. For PROMIS, the PROSAT system also serves as a very important source of data.

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