TOVS processing at KNMI

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Background

As part of the modernisation project for the Dutch forecasting office, a fully automatic guidance system has been designed, aiming at numerical forecasts for a period 24-30 hour ahead. This so-called "Automatic Production Line" (APL) is currently being built around a fine-mesh, limited-area version of the ECMWF gridpoint model (FMLAM), implemented locally on a CONVEX type array-processor. The designers of the APL came to the conclusion that the usefulness of a forecast for the operational meteorologist is getting rapidly less when the update interval increases above around 1/6 to 1/8 of the forecast period. Therefore the update cycle for the APL system has been fixed at 3 hours, requiring forecast availability around 2 hours after analysis time.

For a realistic meteorological performance of the system, it was deemed necessary to use as much satellite-observed upper-air information as possible. Or, in other words, every pass of the polar orbiters with the TOVS instrument package has to be analysed in terms of atmospheric parameters, preferably within 1 hour after the time of satellite overpass.

Satellite processing

Therefore the local HRPT reception station, already operational for the AVHRR cloud imagery since 1980, was extended with a VAXstation/GPX processor for real-time data-storage, TIP-data extraction and digital AVHRR processing. The TIP data files (HIRS and MSU data are stored in separate files) are subsequently transferred to a VAXstation 3200 processor for further processing. This data-handling scheme consists of several preprocessing steps, which have been modelled after the ITPP pre-processing programs PRETIP, PREING and INGTOV. These programs have been redesigned in such a way as to allow unattended, automatically scheduled processing. The inversion scheme has been taken from the 3I system, again redesigning the I/O structures in such a way, that the full processing chain can be triggered from the orbital information extracted from the TBUS messages received routinely over the GTS telecommunication network.

This whole scheme is planned to enter a pre-operational test phase by the end of September 1989, including the transfer of the TOVS/3I results (basically thickness data to start with) to the FMLAM running on the CONVEX processor (see fig. 1).

Impact studies

Once the system is in the air, impact studies will be performed, comparing the model output with and without satellite data in an objective/statistical way, but also by presenting the resulting forecast fields in a "double blind" testmode to experienced operational forecasters to assess the added value of satellite data in the forecasting process. In the future it is planned to provide the duty forecaster also with direct satellite analyses and other products, in a form yet to be developed (thickness maps, vorticity charts, or other products).

The precise way in which the impact study will be done is still a bit open, since in impact studies a whole series of questions can be asked, each with its own right:

- where do we measure impact: in the analysis, after model initialization, or in the forecast and after what time period?
- where and when do we apriori expect an impact of satellite observations in the NWP process, if any?
Relevant properties of TOVS data stem from the spectral and spatial resolution of the instruments used and from the processing done on the raw radiance data. Furthermore the physics of remote sensing of the atmosphere is basically involved:

- RS observations of the atmosphere, being radiance measurements, apply to finite air volumes of at least 1-2 km thick and 20-60 km across (110-320 km for MSU data).
- at most 8 pieces of vertical information for the troposphere and at most 4 pieces of vertical information in the stratosphere can be expected. Probably not more than 8-10 independent pieces of information is a better estimate for the whole atmosphere.
- for water vapour contents not more than 3 independent values are available in the vertical.

This implies that little vertical detail can be expected from satellite observations, but considerably more resolution in the horizontal; especially gradients will be quite reliable if the data are carefully processed. Here we have to give special attention to the error correlation statistics of satellite data, since these are vital ingredients in current analysis schemes. If these error correlation matrices are incorrectly specified, no positive impact of the satellite data can be expected, or -even worse- a negative impact, depending on implementation details.

In all our impact studies we have to keep in mind that we are measuring the response of one particular model system (analysis, initialization and forecast) to satellite data and that this response can at times depend quite strongly on the way this model system has been implemented or the way or form in which the satellite data are presented to the model's analysis scheme.

In view of the above considerations we expect to see impacts in model forecasts in those meteorological situations, where mesoscale systems are an active part of the current weather situation, i.e., in situations where the horizontal resolution of the satellite data can resolve the gradients in the relevant weather systems. This also implies, that at least for the relatively well-observed northern hemisphere we expect to see positive impacts of TOVS products where and when such short-lived mesoscale phenomena are important in understanding the short-range weather evolution.

**Future plans**

Our future work will mainly concentrate on 3 main themes:

- better understanding of the characteristics of satellite observations and better exploitation of their information contents. To this end we will look into the "error structure" around retrieved situations. This is based on the understanding that any inversion or direct assimilation scheme sooner or later call on some iterative algorithm, thus raising the question "how close must the initial guess be to the real situation?". Fig. 2 illustrates this idea in a qualitative way: if the "error" is a fairly peaked function of some measure of "distance from the real situation" (bold line) then the constraints on the closeness of the initial guess are a good deal less stringent than in the case where the error is only weakly dependent on the "distance" or has significant minima in the neighbourhood of, but different from the true situation (thin line).
  Better understanding in this area will help solving questions of selection of initial guess profiles, will give better insight in the problems with linear and non-linear approximations in direct-radiance-analysis and might answer questions around error covariance and error correlation matrices, a vital ingredient in current analysis schemes.

- Enhancements of the 3I system, drawing on our own experience with AVHRR imagery data, especially directed towards refined cloud detection schemes and towards better detail in the atmospheric boundary layer.
  We will soon start research on physical parameterizations in the FMLAM and future HIRLAM models for those processes which can be initialized in the model by using satellite radiances. Special attention will be paid to liquid water and cloud schemes in HIRLAM-type models, both for forecasting and for climate research.
Fig. 1 Satellite reception and processing infrastructure at KNMI
Fig. 2 Error structures as a function of "distance from the true situation"
THE TECHNICAL PROCEEDINGS OF THE FIFTH INTERNATIONAL
TOVS STUDY CONFERENCE

Toulouse, France

July 24-28, 1989

Edited by A. CHEDIN

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January 1990