NOAA15 SOUNDING PROFILES RETRIEVED WITH THE ICI SCHEME

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1. INTRODUCTION

The ICI sounding scheme developed at CMS/Météo-France (Lavanant, 1997) for the processing of HRPT NOAA data has been updated to take into account the new AMSU Noaa15 channels and the same software is now able to process TOVS and ATOVS data. The new version is interfaced with the 'Atovs and Avhrr Preprocessing Package' (AAPP) level1d files and operationally performs retrievals at CMS for the two satellites since August 1998.

Several code updates have been included in the release and are presented in a first stage of this paper: it mainly concerns the interfaces, the way to take into account the micro-wave surface emissivities and the guess selection. Noaa15 statistics of retrieval errors for the 7 last months of operational runs are then presented for temperature.

2. ICI ADAPTATION FOR ATOVS

2.1 Software interfaces

The ICI software is simultaneously operational for TOVS and ATOVS; a routine is called at the start of the process to initialize all the charts required in the course of the software in relation to the satellite (e.g.: channels involved in the process) and to select routines to processes that are specific to each satellite (e.g.: surface emissivity, channel clearing).

The software is now interfaced with AAPP (Klaes, 1997) output level1d files. The main data of AAPP level1d files are located, calibrated and mapped (MSU or AMSU on HIRS grid) observations. The three pieces of information of AAPP level1d files resulting from the AVHRR cloud mask (Lavanant, 1999) are used: mean clear cover in HIRS fov, skin surface temperature (AVHRR split-window) when part of the AVHRR pixels mapped in the ellipsis are clear, the forecast air surface temperature (on land) or a climatology on the skin surface temperature (on sea) when the situation is cloudy. Two informations items extracted from the AMSU pre-processes are also considered: a type of surface in terms of μ-waves and a clear/cloudy/precipitating flag.

The clear cover is used to allocate a cloud class to the situation:
For TOVS, a situation is ‘clear’ if the clear cover is greater than 90%, ‘partly-cloudy’ for a cover between 90 and 30% and otherwise ‘cloudy’. For ‘partly-cloudy’ situations, a cloud clearing of tropospheric channels is activated.

For ATOVS, the cloud class depends on the AVHRR cloud mask but also on the AMSU preprocessing results. A situation is ‘clear’ if the IR cover is greater than 90%, ‘partly-cloudy’ if it is less than 90% with a ‘clear’ micro-wave flag, ‘cloudy’ when the micro-wave flag is cloudy. The situation is not processed if the AMSU radiation is diffused by hydrometeors (e.g. precipitation). The cloud clearing stage is not applied for ATOVS: cloudy and partly-cloudy situations are treated in terms of IR in the same way: just the stratospheric IR channels are considered.

Two coding routines are now available for reading the NWP analyses and forecast files in ASCII or in GRIB format. Concerning forecast data, ICI TOVS version 1 reads two values at the surface, the sea pressure and the air temperature at 1000hpa level. The software can run without but they largely improve the accuracy of the retrieved temperature profile over all the levels, as inversion is done by considering all channels together. In the ATOVS ICI version 2, the forecast wind module at 10m is also acquired. It is used for computing the micro-wave surface emissivities over sea.

Depending on their requirements, users avail of four result coding routines that can read the binary ICI output file and are activated on request:

1. an ASCII coding routine can read inversion files or co-location files. It codes the satellite data and the profile on RTTOV levels. The profile is a retrieval in case of inversion files or an observation (radio-sonde, analysis) in case of co-location files.
2. an AAPP level2 format coding can be used to compare the results of various sounding models.
3. a SATEM coding is currently used for transmitting thickness onto layers to NWP models.
4. a GRIB coding is particularly useful to display the inversion fields on levels onto meteorological terminals.

2.2 Surface emissivities

2.2.1 IR channels

On sea, the IR surface emissivity depends on the frequency, the scanning angle, the wind speed, the salinity and the sea temperature. In the ICI software, emissivity is classified in charts for the different sounder channels, according to the scanning angle, and for an average wind speed and surface temperature, by using the values given in *Masuda*, 1988. We intend to take soon into account a range of wind speeds and surface temperatures.

On land, emissivity is always considered to a constant and set to 1.
2.2.2 μ-wave channels

On sea, a default value of 0.6 is taken when no other data is available (e.g. for MSU). However, emissivity is greatly affected by the wind speed (because of the formation of small waves on the sea surface), the skin surface temperature, the foam, the scanning angle and the channel polarization. Values ranging from 0.4 to 0.7 can be observed. The FASTEM routine of English, 1998 is implemented in ICI and estimates the micro-wave emissivities of the sea surface on the basis of the input surface temperature from level1d file and wind module forecast.

On land and for TOVS, two constant values, 0.85 and 0.95 (the second for altitudes over 1000m) are allocated in ICI. For ATOVS, the type of surface in terms of μ-waves from AAPP pre-processes is used to allocate an average value to emissivity according to the nature of the ground. The values used are extracted from Noaa report (Wark, 1996). These values, even though useful and important for using the channels that can see the surface in certain conditions (e.g. high altitudes) are not precise enough for a routinely use of the surface viewing channels. In particular, emissivities largely depend on the scanning angle. That is why a development is under way for using a rolling emissivity atlas integrated in the monitoring task of ICI. For that purpose, after retrieval and for clear situations in terms of AVHRR cloud mask, we compute the micro-wave surface emissivities for AMSU-A surface channels, by using the retrieved profile and the observations. These values are archived with geographical position and scanning angle to create an atlas, input of the retrieval scheme for future runs. A study of the usefulness of this atlas is expected in the next months. If nothing else is available, the AMSU land emissivity climatology developed by Prigent, 1998 from SSMI observations should be used.

![Figure 1: RTTOV3 brightness temperature deviations for noaa15.](image-url)
In fact, as we need to test the accuracy of the \( \mu \)-wave emissivities before introducing them in the ICI package, the emissivities are presently set to the default values (sea, land). Figure 1 shows the statistics of computed brightness temperatures - observations for Noaa15 and a 10 days period, in bias and standard deviation. The channels in black are presently used in the operational context because of their small standard deviation. The \( \mu \)-wave surface channels are not used.

2.3 Guess selection

The guess profile is selected by comparing the sounder observations (after applying RTTOV forward model biases and if necessary cloud clearing) with computed brightness temperatures for a set of profiles (representing atmospheric conditions for the acquisition area and the date considered).

At CMS in the operational context, the retained profiles are analyses of the ten passed fields at 00H supplied by the French NWP center and sampled at a 10*10 degree pitch so that a minimum independence is possible between profiles. The data set is reviewed every day so as to avail of a rolling library as representative as possible of the meteorological conditions for running day.

However, it is also possible to use one of the two worldwide static climatological library available with the ICI package: TIGR2 (Chedin, 1985) and NESDISPR (NOAA/CIMSS).

In the ICI version1, brightness temperatures and total transmittance for each profile, and each channel and corresponding Tb covariance matrixes were computed off-line and archived.

In this ATOVS release, upwards and downwards radiances are now computed and archived instead of brightness temperatures and the synthetic brightness temperatures are computed in real time for each new observation with surface temperature and emissivity values adapted to the situation.

The corresponding Tb covariance matrix of the library are then computed in real time for each observation with the new set of brightness temperatures.

These modifications have been implemented because the \( \mu \)-wave surface emissivities are so variable with surface conditions that Tb for surface viewing channels can differ from several tenths of degrees with a same atmospheric profile.

3. ATOVS RETRIEVALS ACCURACY

Figure 2 shows for Noaa15 and over sea, the RMS of errors between retrievals and 'in-situ' profiles since the beginning of operational runs at CMS. Lower figure corresponds to clear situations, the upper one is for all IR cloud covers greater than 10%. Statistics were computed at a 10 days and on the 40 RTTOV3 working levels. Blue colors are for RMS values less than 1K, green resolution colors between 1K and about 1.8K, browns/yellows show values less than 2.5K and reds afterwards. The main comments are the followings: results are better in summer than in winter and for clear
situations. In troposphere the errors on levels are never more than 1.5K for clear observations but can reach 2.5K for cloudy situations in winter. As we don’t presently use the noaa15 surface micro-wave channels, the noaa15 and noaa14 (not shown) statistics are quite similar in the troposphere.

Figure 2: RMS of error on RTTOV3 levels between temperature retrievals and radiosonde and analyses profiles since beginning of noaa15 operational runs.

We still observe with Noaa15 a seasonal effect in the stratosphere but very less dramatic than for Noaa14. See for example the comparison of the statistics between noaa14 and noaa15 on figure 3, for the same 10 day period and area: we have a much greater standard deviation for noaa14 layer 10-30hpa than for Noaa15, thanks to AMSU 11 and 12 which sound atmospheric layers around 10hpa whereas we don’t use noaa14 SSU channels. We expect to solve the stratospheric deviation in the next months by using the ECMWF analysis profiles for creating the initial profile library when they will go up 0.1hpa. This will avoid a climatological extrapolation of the profiles, which is an important source of errors in the ICI software. On Figure 3, the results were computed on the layers involved in the French NWP model and are of course better than the same statistics on levels; we have everywhere about 1K in standard deviation for non cloud contaminated data.

Figure 4 shows the variation of the statistics for 10 ranges of the viewing angle secant. Secant 1 corresponds to nadir and 10 to the two edges of the passes together. The results are for the November-December period and level 500hpa. The full line is the mean error, the dash curve the standard deviation and the boxes the number of collocations (see right scale). The bias curve displays a
scanning angle variation, specifically for high angles. The present ICI version is running with a RTTOV biases correction based on predictors: channel observations (number depends on TOVS or ATOVS) and linearly with the zenithal angle. The linear variation with the viewing angle is in fact insufficient and we need to update the predictors.

![Graphs showing temperature profiles](image)

**Figure 3**: Comparison of Noaa14 and Noaa15 retrieval statistics for the same 10 days period and area.

![Graph showing retrieval statistics](image)

**Figure 4**: retrieval statistics function of the secant of the viewing angle.

## 4. NEXT DEVELOPMENTS

Exportation:

The ICI package, that has been described in this paper, is (or is being) implemented in other HRPT stations than CMS/Météo-France. See first validation results for Hungary acquisitions in *Borbas*, 1999. A complete ICI documentation (scientific description, software architecture) is now available.
for users (Lavanant, 1999). The exportation of the ICI release number 2 package will continue during the next months and we intend to create a web site on which each foreign team, having implemented the ICI package, will put their validation results with a common graphic tool. It is an easy way for CMS to verify that the software is well working all the year in other climatological areas. The set of graphic routines will be based on the freeware ‘Generic Mapping Tool’ (GMT) and will be distributed with the package. It is also planned to implement as soon as possible RTTOV5 in place of the current RTTOV3 version, in order to supply users with a consistent package with last developments on RTTOV.

The main scientific developments in the future months will be:
- to develop an accurate inversion for retrieving humidity profiles, by better processing water vapor channels HIRS 11, 12 and AMSU (AMSU/B when a correction of interference will be implemented in AAPP)
- to study the impact of variable micro-wave surface emissivities on retrievals and if correct implement in ICI package the atlas on land
- to improve the tuning scheme (forward model biases..)
- to supply the ICI software with ECMWF analysis fields instead of French analyses. We expect by this way to remove the problem of profile extrapolation.

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