RECENT PROGRESS IN THE DETERMINATION OF METEOROLOGICAL PARAMETERS FROM THE SATELLITES OF THE TIROS-N SERIES

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1. INTRODUCTION

The 3I (Improved Initialization Inversion) method has been designed for retrieving meteorological or climatic parameters from satellite vertical sounders and first applied to NOAA-7, the third of the Tiros-N operational weather satellites series. The 3I algorithm has already been described in some detail in several publications: Chedin and Scott (1984), Chedin et al. (1985), Scott et al. (1984), Wahiche et al. (1986). This approach to the radiative transfer equation problem directly pertains to pattern recognition theory as it has been shown by Chedin and Scott (1985). Recent developments and newer results have been presented at the last American Meteorological Society meetings held in Williamsburg (USA) in May 1986: P. Moine et al. (1986), N.A. Scott et al. (1986), J.F. Flobert et al. (1986) and A. Chedin et al. (1986). Reference will be made to these papers throughout this article which main purpose is to review the latest developments that have occurred in the 3I code and to present results recently obtained.

2. RECENT IMPROVEMENTS IN THE CLOUD DETECTION ALGORITHM

Retrieving meteorological parameters (temperature profile, composition, ..) from satellite data requires a method of cloud detection to get the clear radiances used in the inversion of the radiative transfer equation. Alternately, that pollution of infrared radiance by
Results of the "old" cloud detection algorithm.

Dark blue: cloudy over sea.
Blue: clear over sea.
Red: cloudy over land.
Yellow: clear over land.

Results of the "new" cloud detection algorithm. Same legend as the figure above.

Figure 2.1
clouds makes it possible to determine some characteristics of the cloud cover, such as cloud top heights or cloud amounts, which are essential parameters in climate models.

In Wahiche et al. (1986), the problems of detecting clouds and of retrieving cloud parameters were approached through the use of the data from the satellites of the Tiros-N series, and more particularly from the two instruments HIRS/2 (19 infrared channels and one visible) and MSU (4 microwave channels). In this paper was presented an algorithm for cloud detection, essentially based upon that described by McMillin and Dean (1982), except that it applied to infrared radiances not corrected for the satellite viewing angle. The advantage of this method is to avoid the noise introduced by the "limb" correction, which is particularly critical under cloud conditions.

The purpose of this section is to review the (sometimes substantial) modifications that have been brought to the cloud detection algorithm as it is described in the reference above (Appendix 1). Seven tests were considered:

2.1 Frozen sea test: no modification

2.2 Adjacent spot tests.

Comparisons between the central spot and each adjacent spot are made only if the difference between the percentage of water in the two fields of view is smaller than 0.3 and if the difference between the mean elevations is smaller than 250 m. The central spot is declared cloudy if at least one of the adjacent spots is such that:

$$T_{s_e}^{(adjacent)} - T_{s_e}^{(central)} > \ell$$

where $T_{s_e}$ is the estimated surface temperature and $\ell = 1.5 \text{ K over sea}$ and $\ell = 3 \text{ K over land}$. The central spot will remain clear only if at least one adjacent spot is such that:

$$| T_{s_e}^{(adjacent)} - T_{s_e}^{(central)} | < \ell$$
It must be noticed that new regressions have been designed for estimating the surface temperature. They now exclude channel 10 of HIRS-2 which may be strongly contaminated by the so-called "res-\[\text{b}t\text{rahlen}" effect over sand, resulting in an important decrease of the radiation measured.

2.3 Albedo test.

A spot is declared cloudy if $A > 15\%$ over sea and $A > 40\%$ over land. The latter limit has been adapted to desertic areas (sand), but still represents a problem for snow covered terrains (see Section 6).

2.4 Window channels test.

No modification to Wahiche et al. (1986) at night. For day time observations, no modification over sea, but the test is skipped if the albedo is greater than 0.2 over land. This modification avoids declaring cloudy snow or sand covered areas.

2.5 Interchannel regression tests.

Five regressions are predicting HIRS/2 or MSU channels from other channels. In the three first regressions, channels HIRS/2 nb. 7, MSU 2 and MSU 3 are predicted from channels 13, 14, 15, 16. In the two last ones, channels MSU 2 and MSU 3 are predicted from channels 3, 4, 5, 6, 7, 8. Regression 1 has been maintained. Regressions 2 and 3 have been suppressed as useless or too sensitive to solar flux contamination. The test limits for regressions 4 and 5 have been made more severe over sea: 1.5 K instead of 2 K.

2.6 Surface temperature test.

No modification.

2.7 Maximum value test.

No modification.

2.8 Hot surface test.

This new test has been introduced over land in the case of hot surfaces. A spot which has been declared cloudy is changed to clear if the HIRS/2 channel 8 brightness temperature is greater or equal to 300 K.

The comparison between the "old" and the "new" cloud detection algorithm is illustrated by Figure 2.1 and is particularly spectacular over desertic areas for which the "old" code was erroneous (restrahlen phenomenon affecting channel 10, albedo limit too low).
3. AUTOMATIC CLASSIFICATION OF AIR MASS TYPES (POLAR, MIDDLE OR TROPICAL) FROM NOAA SATELLITES OBSERVATIONS.

Knowledge of the air mass type observed is essential to retrieval methods, physical as well as statistical, the average profile of temperature being very different in each case (tropical, mid or polar type air).

The major role of a priori information for the satellite retrieval problem is explained by the nature of the observed radiances which integrate the atmospheric thermal structure over relatively thick layers. The principal use of that kind of information is here to specify the initial guess in the "31" (Improved Initialization Inversion) procedure as accurately as possible through a pattern recognition type approach. We present here a new approach for the searching of the closest element in the TIGR data set, which relies on an automatic classification of the air mass types using the measured brightness temperatures as descriptors. As in the former approach, the brightness temperatures are those of channels quite insensitive to clouds: HIRS/2 channels 1, 2, 3 and MSU channels 2, 3, 4.

In the former approach, the search for the closest element in the TIGR data set was made within the subset characterized (among other parameters such as angles of observations, surface elevations, surface emissivities) by the latitude of the satellite observations: three classes were considered: tropical \(< +30^\circ \); 30° \(< \text{mid latitude} \(< 60^\circ \); polar \(> 60^\circ \).

In case of incursions of "foreign" air masses within a given class of latitude (e.g. tropical (or polar) air masses into mid-latitude zones), this "latitude only" characterization of the sub-set turned out to be unsufficient. We thus developed a new approach based upon a more sophisticated clustering of the TIGR data set using the above brightness temperatures as descriptors.
The classification scheme we have adopted, is the "Dynamic Clusters Method"; its purpose is to separate the objects of a given set in disjoint classes - clusters - the elements of which have some given properties in common. It is based upon the notion of "strong patterns". The number of ending clusters which, in this method, has to be specified from the beginning, has been set to 5, in our case, featuring latitudes and seasons (winter, summer). For all the classification conditions - angle, surface pressure, ... - the same noteworthy results have been obtained: despite the pre-imposed number of 5 clusters, only 3 survived, corresponding exactly to the 3 initial groups of latitudes.

Results of this analysis have been applied to NOAA-7 observations over Europe of several relatively complex meteorological situations for which the forecast was particularly poor (see Moine et al., 1986) (Figure 3.1). With the purpose of experimentally validating the classification method described in the above reference, conventional analysis have been superposed on the maps obtained from the algorithm: surface or geopotential thicknesses (1000-500 mb) analyses. Figure 3.1 (top) illustrates these results for NOAA-7 orbit nb. 11664 of 09/27/1983. The map obtained from the classification shows an incursion of tropical air in an area including Spain, France and the south of Great-Britain: this can also be seen on the AVHRR picture (not shown here). On Figure 3.1 (bottom), NOAA-7 orbit nb. 12512, 11/26/1983, the classification gives, from North to South, an intrusion of polar type air mass down to 37ºN followed by mid-latitude then tropical type air masses. With a low at 975 mb associated with cold fronts and 90 km/h winds, the analysis corroborates the presence of polar air masses as indicated by our algorithm.

This classification scheme is used to improve the initial guess retrieval procedure: the closest element(s) is searched within the cluster to which the input pattern belongs.
Results of the classification algorithm. MORM-7 orbit nb. 11664, 27 September 1983, 14:35Z.

Blue: middle latitude type air masses (dark: land)
Red: tropical type air masses (dark: land)
1000-500 mb thicknesses analysis has been superimposed.

Results of the classification algorithm. MORM-7 orbit nb. 16512, 26 November 1983, 14:47Z.
Green: polar type air masses.
Blue and Red: see figure above.
The surface analysis of 26 November at 18:00Z has been superimposed.

Figure 3.1
4. RECENT RESULTS IN THE RETRIEVAL OF ATMOSPHERIC OR SURFACE PARAMETERS FROM THE 3I CODE

The 3I retrieval algorithm explicitly takes into account the physical and statistical aspects of the phenomena involved and offers specific answers to the three following essential problems:

a) to enter the inversion process with an initial guess close to the final solution,

b) to acquire clear equivalent radiances through an appropriate cloud clearing algorithm, and

c) correlative to derive high density retrievals even in case of heavy cloudiness.

Within the frame of the International TOVS Study Conference ITSC, I and II, held in Austria (August 1983, February 1985), the 3I method has already demonstrated its capability to produce accurate temperature soundings (Le Marshall, 1985). These first encouraging results must however be complemented by further systematic comparisons with either collocated radiosoundings data or operational analyses. Moreover, recent improvements brought to the 3I code (introduction of an air-mass classification scheme; refinement of the initial guess retrieval procedure; modification of the surface temperature estimation method; review of the rejection tests, etc..) have led us to reassess its accuracy. This has been done, or is in progress, for several sets of observations, and, in particular for the "bench-mark" set made of NOAA-7 orbits of an ALPEX IOP (March 4-5, 1982).

4.1 Atmospheric temperatures and thicknesses

The basic statistics (mean, rms) generated from the atmospheric soundings are given: a) for temperatures at the standard levels; b) for geopotential thicknesses obtained from the retrieved temperatures by vertical integration.

The observed sets are either RAOB data or analyses from ECMWF.
The colocations between RAOB and satellite soundings are accepted within the following constraints: (1°×1°) latitude longitude distance; 2 hours in time; measurement of temperature available up to 100 mb and of dew point temperature up to 400 mb. The colocations with the analyses are obtained through a spline interpolation procedure at the satellite sounding points.

A two step rejection procedure is applied to the 31 retrievals. The first step consists in analyzing the differences between the satellite observations and the first guess solution resulting from the initialization through the TIGR data set. A concept of distance between the two situations, globally or channel by channel, is at the basis of this step. The second step consists of a simple 2-D "horizontal" filtering procedure. For a given pressure level, each retrieval, labeled (i,j), i being the scan line number and j being the box number along a scan line (ranging from 1 to 19; see Chedin et al., 1985a), is first compared to the mean of the "adjacent" retrievals comprised in an array (i±3, j±1). If the difference is larger than 1.8K (a value which has been empirically determined on the basis of various trials), the retrieval (i,j) is rejected. A second test concerns the number of available retrievals within the above array: if this number is smaller than 20, the test limit is changed from 1.8K to 1.3K. Each pass is explored twice: i and j increasing and i and j decreasing. As soon as a retrieval has been detected as "bad", it is no longer included in the process. Results are shown on Figure 4.1 and Table 4.1 (statistics in temperature) and Figure 4.2 (statistics in geopotential thicknesses).

Figure 4.1 is for the ALPEX orbit (daytime) nb. 3586 of March 4, 1982. For the standard levels between 1000 mb and 70 mb, this figure gives the biases and r.m.s. errors: (A) without filtering; (B) with the 2-D filtering technique; (C) no filtering, but rejection of any retrieval such that the difference between the retrieved temperature at a given pressure level and the corresponding ECMWF's analysis value is larger (smaller) than the mean over the sample plus (minus) two times the standard deviation (2σ procedure). The initial number of retrievals, prior to any rejection is 1236 giving a percentage of rejections of about 5% for the case (B).
Figure 4.1  Biases and rms errors between the 3I retrievals and the ECMWF analysis.
ALPEX I0F ; March 4, 1982 ; orbit nb. 3586.
......: no rejection ; ———: 2-D filtering ;
----------: 2σ procedure.
Table 4.1 presents the same type of results for the two day-time orbits 3586 + 3587. The original number of retrievals is 2393 and the percentage of rejections is close to 7 % for the case (B).

Table 4.1 Biases and rms errors between 31 retrievals (temperatures) and ECMWF analyses. ALPEX 1OP of March 4, 1982. Orbits nb. 3586 + 3587.

| Pressure | Bias (K) | | | | RMS (K) | | |
|----------|----------| | | | | | | | |
|          | (A)      | (B) | (C) | | (A) | (B) | (C) |
|----------|----------| | | | | | | | |
| 1000     | -1.21    | -1.14 | -1.12 | | 2.02 | 1.92 | 1.90 |
| 850      | 0.14     | 0.05  | 0.03  | | 1.65 | 1.45 | 1.33 |
| 700      | 0.11     | 0.07  | -0.04 | | 1.59 | 1.48 | 1.33 |
| 500      | -0.37    | -0.36 | -0.42 | | 1.75 | 1.67 | 1.58 |
| 400      | -0.24    | -0.19 | -0.09 | | 1.79 | 1.69 | 1.52 |
| 300      | 0.33     | 0.34  | 0.34  | | 1.81 | 1.77 | 1.57 |
| 250      | -0.12    | -0.15 | -0.23 | | 1.75 | 1.71 | 1.48 |
| 200      | -1.02    | -1.03 | -1.05 | | 2.51 | 2.37 | 2.29 |
| 150      | -1.37    | -1.36 | -1.41 | | 2.20 | 2.15 | 2.06 |
| 100      | -1.06    | -1.05 | -1.08 | | 1.48 | 1.48 | 1.43 |
| 70       | -0.58    | -0.57 | -0.63 | | 1.49 | 1.49 | 1.38 |
| Items    | =2386    | =2229 | =2270 | | =2386 | =2229 | =2270 |

(A) Statistics without filtering
(B) Statistics with rejections from the 2-D horizontal filtering code.
(C) Statistics with the 2σ elimination procedure and no filtering.

Figure 4.2 illustrates the results for the thicknesses (statistics for the 1000-500 mb : bias : -1.02 dam ; rms = 2.38 dam ; std. dev. = 2.15 dam).
Figure 4.2 Biases and rms errors between 31 retrievals (thicknesses) and ECMWF analyses. ALPEX 1OP, March 4, 1982; orbits nb. 3586 + 3587.
1.2 Water vapor fields and surface temperature

Retrievals of water vapor amounts are made for three layers delimited by the levels 1000 mb, 800 mb, 500 mb and 300 mb in addition to the total amount of precipitable water vapor. Following the temperature profile retrieval, the brightness temperatures associated with the initial guess are corrected for the deviations between the initial temperature profile and the final solution giving rise to the initial guess for water vapor and surface temperature retrievals. Four HIRS/2 channels are presently used: 8, 10, 11 and 12 for the day-time observations and 18, 10, 11 and 12 for night-time observations. A ridge type estimation procedure is used:

$$\Delta \theta = (X'X + \gamma I)^{-1} X' \Delta Y$$

where $X$ ($X'$, transpose of $X$) is the matrix of the partial derivatives of the brightness temperatures with respect to relative humidities and surface temperature, $\Delta Y$ the difference between observed (cleared) brightness temperatures and the initial guess (corrected as explained above), $\Delta \theta$ the difference between the final and initial values of the parameters considered, $\gamma$ a smoothing parameter (Lagrangian multiplier).

Table 4.2 gives recent results which show a significant improvement, particularly concerning the number of items entering the statistics (much less rejection), over those presented in Chedin et al. (1985b).

Figures 4.3 and 4.4 display (with the same limitation as for Table 4.2: N< $\leq$ 30%) total precipitable water vapor fields for the two day time orbits (3586 and 3587: Fig. 4.3) and the two night time orbits (3594 and 3595: Fig. 4.4).

Surface temperatures are physically retrieved simultaneously with water vapor. Comparisons have been made with in-situ measurements (ships of opportunity) for orbits 3587 (day) and 3595 (night) on one hand, and with AVHRR retrieved SST's for orbit 3587, on the other hand. Results are given in Table 4.3 for clear situations.
Table 4.2  3I retrieved humidities versus radiosonde data. Clear and partially cloudy areas (up to NE ≤ 30%) are considered. March 4-5, 1982; NOAA-7 observations over Europe (4 passes).

<table>
<thead>
<tr>
<th>Layer (mb)</th>
<th>Bias</th>
<th>Rms</th>
<th>Nb. of items</th>
</tr>
</thead>
<tbody>
<tr>
<td>300 - 500</td>
<td>-0.03</td>
<td>0.21</td>
<td>79</td>
</tr>
<tr>
<td>500 - 800</td>
<td>-0.04</td>
<td>0.19</td>
<td>81</td>
</tr>
<tr>
<td>800 - 1000</td>
<td>-0.03</td>
<td>0.18</td>
<td>79</td>
</tr>
<tr>
<td>U_TOT</td>
<td>0.05</td>
<td>0.20</td>
<td>78</td>
</tr>
</tbody>
</table>

1 Relative humidity
2 Total content in g cm⁻²
Mean total content of the sample: 0.85 g cm⁻²

Figure 4.3  3I retrieved total precipitable water vapor above 1000 mb in mm for clear and partially cloudy areas (NE ≤ 30%). March 4, 1982.
Figure 4.1  See legend of Figure 4.3. March 5, 1982.

Table 4.3  3I retrieved SST's (3I) compared to either ships of opportunity measurements or to AVHRR retrieved SST's (T. Phulpin).

<table>
<thead>
<tr>
<th>Orbit nb.</th>
<th>Measurements</th>
<th>m</th>
<th>σ</th>
<th>rms</th>
<th>nb.items</th>
</tr>
</thead>
<tbody>
<tr>
<td>3587 (day)</td>
<td>3I - ships</td>
<td>-0.65</td>
<td>1.03</td>
<td>1.22</td>
<td>173</td>
</tr>
<tr>
<td>3587 (day)</td>
<td>3I - AVHRR</td>
<td>0.11</td>
<td>0.91</td>
<td>0.91</td>
<td>289</td>
</tr>
<tr>
<td>3595 (night)</td>
<td>3I - ships</td>
<td>-0.51</td>
<td>0.77</td>
<td>0.92</td>
<td>256</td>
</tr>
</tbody>
</table>

The negative bias between 3I retrieved SST's and ships measurements has also been observed by other groups working on the same situation. Quantitatively, these results are in agreement with other more extensive and less local (space and time) studies. TOVS SST's should probably be improved when HIRS-2 is equipped with a split window capability (NOAA-1).
5. EXTENSION OF THE RETRIEVALS TO THE UPPER STRATOSPHERE:
PROCESSING OF THE SSU DATA

Rocket soundings and meteorological or research satellites are the main sources of temperature data in the upper stratosphere. Rocket soundings give measurements of pressure and temperature up to about 80 km and allow good description of planetary waves perturbations and of sudden events like the stratospheric warmings to be derived. Temperature profiles, up to about 90 km, may also be derived from lidar measurements of the atmospheric density.

Satellite soundings instruments (aboard SME, NIMBUS, the TIROS-N series) produce atmospheric temperatures retrieved from radiance measurements in the 15 μm spectral region. On board the Tiros-N series, the Stratospheric Sounding Unit (SSU) allows retrieval of vertical temperature profiles to be accurately done between approximately 30 and 50 km. A twice daily global coverage is obtained from one platform.

Retrieving temperature in this altitude range is somewhat simpler than in the troposphere due to the absence of clouds, the extremely low amount of water vapor and the absence of surface contamination. This makes a purely statistical retrieval approach much more attractive than in the troposphere or lower stratosphere. This is the way we have chosen for processing the SSU data.

To establish the relation between satellite observations and atmospheric temperatures (or thicknesses), we have made use of data sets provided to us by the British Met. Office in Bracknell. Several days of observations have been selected for both NOAA-7 and NOAA-8 for the whole northern hemisphere. The predictors are the brightness temperatures of channels 1, 2, 3 of SSU; 1, 2, 3 of HIRS/2 and 4 of MSU. The predictands are the geopotential thicknesses for the layers 100-20 mb, 100-10 mb, 100-5 mb and 100-1 mb issuing from the Bracknell's analysis at a relatively low spatial resolution (2 x 2 SSU spots; see Figure 5.1).
The regressions allow the predictands to be accurately reproduced: no biases and the standard deviations are less than 0.3% (in percentage) for tropical and mid-latitudes, less than 0.5% for polar latitudes except for the layer 5–2 mb (obtained from 100-5 and 100-2) where it amounts to a maximum of 0.75%.

![Figure 5.1](image)

Figure 5.1  HIRS/2 and SSU scan patterns projected on earth.

5.1 Application to European scenes.

The statistical scheme described above has been applied to several passes of NOAA-7 over Europe, between September and December 1983. Figures 5.2 to 5.4 show the results obtained for the two successive passes on December 28 at 14:17Z and 15:58Z. They illustrate the thickness charts for the layer 20–10 mb (Figure 5.2), 10–5 mb (Figure 5.3) and 5–2 mb (Figure 5.4). Holes in those charts are due to the
reduced width of the scanning pattern of SSU (see Figure 5.1). Figure 5.5 is for the layer 2-1 mb and displays the air density (inversely proportional to temperature) in $10^3$ g/dm$^3$. The spatial resolution is

**Figure 5.2** Retrieved thicknesses for the layer 20-10 mb for December 28, 1983. Two NOAA-7 passes at 14:17Z and 15:58Z.
that of the 31 boxes: 100 x 100 km², a number close to the SSU resolution. The figures show a rather disturbed situation for the highest layers, with strong undulations of the iso-lines. At the

Figure 5.3  See legend of Figure 5.2.  Layer 10-5 mb.
latitude of France, a cold area is apparent, extending northwest over Atlantic. For the two lowest layers, the situation is quieter with temperatures increasing from north to south.

**Figure 5.4** See legend of Figure 5.2. Layer 5-2 mb.
5.2 Application to a situation of "sudden stratospheric warming"

Applying the model to a rather unusual situation of strong sudden stratospheric warming (which may exceed an amplitude of 50°C) is a good way of testing its ability to retrieve out-of-statistics situations.

The major stratospheric warming of February 22-23, 1984 over Norway has been extensively studied during and after the WINE (Winter in Northern Europe) campaign. Corresponding NOAA-8 observations were provided to us by the British Met. Office (Bracknell). The most spectacular results are those concerning the highest layer, between 2 and 1 mb and are illustrated by Figure 5.6 which displays the mean layer temperatures in °C. Temperatures of 24°C are observed which are to be compared to a normal value of -30°C at the latitudes of Norway, for example. The warming also strongly affects lower layers. These results are in good agreement with the analysis, made by the Stratospheric Group in Berlin (K. Petzoldt; private communication, 1986), which shows a strong warming on February 23rd over Andoya (north of Norway). Taking into account the fact that our study concerns the 22nd of February and that the warming was moving westward, the two analyses are in good concordance. The relatively high spatial resolution of the present analysis brings into evidence numerous interesting mesoscale features, sometimes curiously correlated (at least apparently) to features corresponding to much lower layers (see P. Moine, Thesis, for more details).

Very preliminary comparisons between SSU retrievals and either rocket or lidar soundings have shown a small negative bias (SSU minus sounding) of the order of 1-2°C and a standard deviation of 2-3°C.

Coupled with the 31 results, the SSU retrieved temperature profiles provide a continuous description of the atmospheric thermal structure from the surface to about 50 km.
6. 3I OVER POLAR LATITUDES THROUGH THE MIZEX (Marginal Ice Zone Experiment) CAMPAIGN

From May to August 1984, an international experiment, MIZEX, has been conducted in the Fram Strait, an area between Greenland and Svalbard, aiming at a better understanding of the processes that govern the advance and retreat of the ice margin. A multidisciplinary team of over 200 scientists and technicians was supported by seven research ships, eight meteorological and remote sensing aircrafts, four helicopters. Numerous in-situ data are thus available in conjunction with satellite observations from NOAA-7 and NOAA-8, which may be used for studies of the interactions between sea ice and atmosphere.

As a starting point, three days of the MIZEX campaign have been selected: July 1st and 2nd, and August 5th, 1984, and NOAA-7 observations obtained from the Chr. Michelsen Institute (Norway). HIRS/2 and MSU data were calibrated and navigated by CMS Lannion.

Application of 3I to these latitudes requires that some modifications be made to the code, particularly concerning the cloud detection algorithm; discrimination between sea ice and low clouds is a well known problem. We are approaching it through the coupling between HIRS/2 and MSU (mostly the window channel MSU-1) on the one hand and between HIRS/2 and AVHRR on the other. Knowledge of precise surface conditions from the MIZEX in-situ data base is of great importance for the validation of the algorithms retained.

Very preliminary results are presented on Figures 6.1 and 6.2. Figure 6.1 is a reproduction of AVHRR, channel 2, observations for August 5, 1984 (NOAA-7). Greenland is at the bottom left of the figure. For the same scene, Figure 6.2 displays the 3I retrieved 1000-500 mb thickness chart. Quantitatively, the numbers compare well with those of the European Meteorological Bulletin which, however, are much smoother than the 3I contours.
Figure 6.1 AVHRR channel 2 picture over Fram Strait. August 5, 1984: 12:36Z Bottom left: the Greenland coast.
This work will continue with the analysis of additional scenes from MIZEX and with NOAA-9 observations from the new international programme ARCTEMIZ (Arctic Experiment on Marginal Ice Zones).

This research is conducted in close cooperation with Laboratoire d'Océanographie Dynamique et Climatologie (Dr. J.C. Gascard) and with Laboratoire d'Optique Atmosphérique in Lille (Dr. C. Kergomard).

Figure 6.2 31 retrieved 1000-500 mb thicknesses for August 5, 1984: NOAA-7 observations over Fram Strait. Notice the low, east of Greenland.
7. PRELIMINARY RESULTS OF THE PROCESSING OF NOAA-7 OBSERVATIONS OVER EUROPE DURING ALPEX (March 16-17, 1982).

Within the frame of the activities of the International TOVS working Group of the IRC (International Radiation Commission), NOAA-7 observations over Europe, during the IOP (Intensive Observing Period) of the international campaign ALPEX (ALPine EXperiment) of March 4-5, 1982, have served as a reference for intercomparing the results of retrieval algorithms from various groups. NOAA-8 observations over the Central United States and Gulf of Mexico have then been added to this "bench-mark", for an interesting pre-tornadic situation (June 7, 1984). A new series of NOAA-7 observations during ALPEX could possibly be of interest to the TOVS group, those of March 16-17, 1982, with an interesting low, north of Great Britain.

Figure 7.1 AVHRR, channels 2 and 3 pictures for March 1982.

002: NOAA-7
Figures 7.1 to 7.6 display the results we have obtained for three situations: orbit 3557 of March 16 at 14:43Z; orbits 3763-3764 of March 17 at 3:00Z and orbit 3771 of March 17 at 14:32Z.

**1000 - 500 mb thicknesses (dam) and thermal winds (m/s).**

**Figure 7.2** 1000-500 mb thermal winds retrieved from the 31 algorithm. March 16, 182, 14:43Z. NOAA-7.
Figure 7.3  1000-500 mb retrieved thicknesses.
M.B. The retrieval algorithm used here is a slightly different version of
the standard one which makes use of operational forecasts of the
temperatures and geopotential heights at 1000 mb in the seeking of
the initial guess solution within the TIGR data set, through a
pattern recognition type approach. In the presently used version, the
"satellite-only" 31 version, no "foreign" ancillary data of any kind
have been used in the initialization process (as well as, a fortiori,
in the retrieval process itself, in which such data are never used).

Figure 7.4  1000-500 mb thermal winds retrieved from the 31 algorithm.
March 17, 1982. 3:00Z. NOAA-7. The restricted coverage by
orbit 3763 (right) is due to a lack in the archives.
Figure 7.5  1000-500 mb 31 retrieved thicknesses.  
March 17, 1982.  3:00Z.  NOAA-7.
Figure 7.6  1000-500 mb 3I retrieved thicknesses.  
<table>
<thead>
<tr>
<th>Channel</th>
<th>Sea clear 147 items</th>
<th>Land clear 337 items</th>
<th>Cloudy 696 items</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( \bar{m} ) (c-o)</td>
<td>( \sigma )</td>
<td>( \bar{m} ) (c-o)</td>
</tr>
<tr>
<td>3</td>
<td>-0.78</td>
<td>1.02</td>
<td>-0.42</td>
</tr>
<tr>
<td>4</td>
<td>-0.26</td>
<td>0.53</td>
<td>-0.01</td>
</tr>
<tr>
<td>5</td>
<td>0.11</td>
<td>0.63</td>
<td>0.66</td>
</tr>
<tr>
<td>6</td>
<td>0.15</td>
<td>0.67</td>
<td>0.93</td>
</tr>
<tr>
<td>13</td>
<td>0.42</td>
<td>0.43</td>
<td>-0.45</td>
</tr>
<tr>
<td>14</td>
<td>-0.10</td>
<td>0.43</td>
<td>-0.31</td>
</tr>
<tr>
<td>15</td>
<td>-0.98</td>
<td>0.69</td>
<td>-0.86</td>
</tr>
<tr>
<td>MSU 2</td>
<td>0.46</td>
<td>0.51</td>
<td>0.91</td>
</tr>
<tr>
<td>MSU 3</td>
<td>0.06</td>
<td>0.11</td>
<td>0.02</td>
</tr>
<tr>
<td>MSU 4</td>
<td>0.04</td>
<td>0.23</td>
<td>-0.08</td>
</tr>
</tbody>
</table>

**Table 8.1** Statistics (\( \bar{m} = \) mean ; \( \sigma = \) standard deviation) for the differences between TOVS observations (c) and corresponding brightness temperatures computed from 31 retrievals using the 3R code (c). ALPEX orbit nb. 3586, March 4, 1982 at 12:00Z.

<table>
<thead>
<tr>
<th>Channel</th>
<th>Sea clear 313 items</th>
<th>Land clear 339 items</th>
<th>Cloudy 538 items</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( \bar{m} ) (c-o)</td>
<td>( \sigma )</td>
<td>( \bar{m} ) (c-o)</td>
</tr>
<tr>
<td>3</td>
<td>-0.40</td>
<td>1.05</td>
<td>-0.54</td>
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<tr>
<td>4</td>
<td>-0.12</td>
<td>0.42</td>
<td>-0.17</td>
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<tr>
<td>5</td>
<td>0.22</td>
<td>0.48</td>
<td>0.36</td>
</tr>
<tr>
<td>6</td>
<td>0.39</td>
<td>0.60</td>
<td>0.52</td>
</tr>
<tr>
<td>13</td>
<td>0.48</td>
<td>0.38</td>
<td>0.52</td>
</tr>
<tr>
<td>14</td>
<td>-0.01</td>
<td>0.42</td>
<td>-0.02</td>
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<tr>
<td>15</td>
<td>-0.61</td>
<td>0.73</td>
<td>-1.10</td>
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<tr>
<td>18</td>
<td>0.25</td>
<td>0.24</td>
<td>0.07</td>
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<tr>
<td>MSU 2</td>
<td>0.11</td>
<td>0.56</td>
<td>0.42</td>
</tr>
<tr>
<td>MSU 3</td>
<td>0.08</td>
<td>0.14</td>
<td>0.12</td>
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<tr>
<td>MSU 4</td>
<td>0.02</td>
<td>0.38</td>
<td>-0.21</td>
</tr>
</tbody>
</table>

**Table 8.2** Same legend as Table 8.1. ALPEX orbit nb. 3595, March 5, 1982 at 03:45Z.
input and the initial guess are minimized through the use of the partial derivatives matrices also archived in TIGR. More details are given in Floquet et al. (1986). This reference also presents results of comparisons between the 4A and the 3R models when applied either to synthetic data from the TIGR data base or to real observations from files regularly archived by NOAA/NESDIS (the so-called DSDV files).

An interesting application of the 3R fast model consists in applying it to 3I retrievals of atmospheric profiles and to compare the results to the real TOVS observations. This has been done, in a first step, for those channels which are mostly sensitive to temperature and for two orbits of the ALPEX IOP of March 4-5, 1982 : nb. 3586 (day) and 3595 (night). The results are given in Tables 8.1 and 8.2 for 10 channels (11 at night since channel 18 for HIRS/2 is not contaminated by solar flux). The observations have been splitted into 3 categories: clear over sea, clear over land and cloudy. In the latter case, observations are replaced by the cloud-cleared values obtained through the ψ-method (see Chedin et al., 1985). A part from channel 3, for which retrievals do not extend high enough to cover the associated weighting function, the results are satisfactory. However, some of the biases are relatively large (channel 15 for example) and should be studied into more details.

This application of the 3R code is in progress and will be extended soon to water vapor sensitive channels. We also intend to include the 3R model in the automatic rejection procedure which removes "bad" retrievals from the final 3I products. A retrieval would be declared as bad if the differences between the observed brightness temperatures and those computed from the retrieved profiles using 3R exceed a certain limit value.
CONCLUSION

From the 1st International TOVS Study Conference (ITSC) held in Igls, Austria, 1983, the SL method has demonstrated its capability to accurately derive atmospheric parameters. Quantitative intercomparisons studies using ECMWF analyses and colocated RAOB data have been made (J. Le Marshall, ITSC-II).

The SL algorithm has been recently revised:

- optimization of the cloud detection algorithm, owing to, among other things, a better handling of the surface characteristics (quality of the terrain);

- improved specificity in the search for the closest element(s) in the TIGR data set owing to an optimized description of the air mass types;

- optimization of the surface temperature estimation method;

- optimization of the rejection tests based upon an improved filtering of the results;

- extension of the temperature profiles to the upper stratosphere owing to the use of the SSU data.

Newly derived results, using this revised version of the SL code, have been submitted for comparisons studies (ITSC-III). They concern: temperature profiles, geopotential heights at standard pressure levels, cloud amounts, cloud-top pressure and temperature, $H_2O$ content profiles, geostrophic winds.
The already demonstrated quality of the results (ITSC-II) has led us to extend the intercomparison studies to impact studies on the forecasts (Chedin et al., 1986a) and to the treatment of the satellite observations over polar regions.

Moreover, we have developed a very fast radiance calculation scheme (3R) to answer the effective utilization of satellite radiances directly in the numerical weather prediction schemes.

The ongoing development of this work is the combination of TOVS and AVHRR data and to prepare the processing of the coming AMSU data.
REFERENCES


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