THE "3I" PROCEDURE APPLIED TO THE RETRIEVAL OF METEOROLOGICAL PARAMETERS FROM NOAA-7 AND NOAA-8

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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 details in several publications: Chedin and Scott (1984), Chedin et al. (1985), Scott et al. (1984 a), Wahiche et al. (1984). This approach to the radiative transfer equation problem directly pertains to pattern recognition theory as it has been shown by Chedin and Scott (1985). The first purpose of the present paper is to present an overview of the 3I method: initialization of the inversion problem including cloud detection and cloud clearing, atmospheric temperatures retrieval, cloud parameters retrieval, atmospheric water vapor retrieval and surface temperatures retrieval. The second purpose of this paper is to discuss the results of two applications of the algorithm, one to NOAA-7 for the March 4-5, 1982 ALPEX (ALPine EXperiment) IOP (Intensive Observing Period) and the other to NOAA-8 (cyclogenesis over the United States, June 7, 1984). From the latter case, an interesting meteorological event, actually a "cold pool", has been detected along 90° longitude and between latitudes 35° to 40° (Section 4.2).

2. SURVEY OF THE 3I METHOD

The 3I procedure is a physico-statistical type method. It is a physical type method since it requires a theoretical simulation of atmospheric transmittances which directly enter the inversion process itself. It is a statistical type method since it relies upon an a priori knowledge of the observations (the brightness temperatures in each channel of the vertical sounder) as well as of the parameters (the atmospheric structure). This a priori knowledge is contained in a large data set, the TIGR (TOVS Initial Guess Retrieval) data set, created once and for all, and comprising for all possible observing conditions (viewing angle, surface pressure, surface emissivity) and for about 1200 atmospheric situations covering the whole globe, the transmittance profiles and associated brightness temperatures for each of the TOVS channels and the partial derivatives of these brightness temperatures with respect to such or such atmospheric parameter. Provided the observed brightness temperatures correspond to clear areas or have been properly "cleared", the 3I procedure follows two principal steps:
a) Retrieval of the initial guess solution: the observed clear column radiances are first used to retrieve the "best" initial guess solution in a statistical sense. The procedure makes use of the "TIGR" data set. The selected set of observed brightness temperatures is "compared" to each of the computed sets of brightness temperatures and the "closest" is retained. The distance between two sets is calculated in the axis system defined by the eigenvectors of the normalized brightness temperatures covariance matrix. This search for the closest archived situation may be carried out by considering either all the HIRS-2 and MSU channels or more restricted brightness temperature sets emphasizing such or such property in the atmosphere, for example: a set of channels almost insensitive to clouds.

b) The basis for the retrieval of the "exact" solution is a maximum probability estimation procedure aimed at minimizing the differences between the brightness temperatures associated with the initial guess and the observed ones. Use is made of the Jacobian associated with the retrieved initial guess, in the "TIGR" data set.

At present, the spatial resolution of the 3I algorithm is a compromise between the spatial resolutions of the two major sounders on board the NOAA's: HIRS-2 and MSU. Retrievals are made for boxes of 4 to 2 (according to the viewing angle) HIRS-2 spots by 3 HIRS-2 spots along the sub-orbital track. Such boxes approximately represent a surface of 100x100 km². However, in order to increase the density and check the coherence of the results, an oversampling is introduced along the sub-orbital track and one retrieval is produced every 100x30 km², two consecutive boxes sharing two scan lines (see, for example, Chedin and Scott, 1984).

A brief review of the essential aspects of the 3I method is presented in the following sections. References are made to existing publications when available.

2.1 Cloud detection

The cloud detection algorithm has been described by C. Wahiche et al. (1984, 1985). No modifications have been made to these presentations.

2.2 Initialization of the inversion problem

This important problem, at the basis of the 3I algorithm, has been discussed in details in Chedin and Scott (1984), Chedin et al. (1985) and Chedin and Scott (1985). In the latter reference, initialization of the retrieval process from the 3I method is presented and discussed within the frame of pattern recognition theory, an approach allowing important features of an observation to be simply detected and classified. In this reference, comparisons have been made between initialization fields (for example thickness iso-contours) and "final" fields resulting from the inversion process, displaying a remarkable agreement.

2.3 Cloud clearing

The procedure for retrieving the initial guess solution in the proper sub-set of the TIGR data set (the one corresponding to the observation conditions: viewing angle, surface pressure and emissivity) is
direct in case of clear areas, while two steps are required for not clear areas (see Chedin et al., 1985). In the first step, comparisons are made between the observations and the archived brightness temperatures on the basis of a restricted set of channels, in principle insensitive to clouds. Operational forecasts of the temperature at the lowest level are also included in this proximity search. From this preliminary initial guess is started the cloud clearing algorithm based upon the so-called "Ψ-method" (Chedin and Scott, 1984; Chedin et al., 1985). Following this method, a cleared infrared brightness temperature is obtained by adding to the initial guess value of the channel considered, the difference between the observed and the initial guess values of a microwave channel, almost insensitive to clouds and peaking approximately at the same level. The Ψ-method is applied to channels 3, 4, 5, 6, 14 and 15. Contrary to the well known N× method (Smith, 1968), which used at least two spots to eliminate the effects of the clouds, the Ψ-method only uses one spot and consequently avoids the assumption that the difference in radiance for a given channel in the two spots is only due to a variation of the amount of clouds of the same type (same height in particular). The result is that the N× method is subject to noise when this assumption does not hold.

The strong correlation between the initialization of the inversion process and the cloud clearing technique must also be pointed out: the quality of the initialization and that of the cleared brightness temperatures are directly connected.

2.4 Temperature inversion algorithm

Three important characteristics of the inversion scheme must be recalled:

1) The basis for the retrieval of the "exact" solution is a maximum probability estimation procedure aiming at finding the solution the most likely consistent with the observations. Use is made of the Jacobian associated with the retrieved initial guess, in the "TIGR" data set. See Chedin et al. (1985).

2) Since it starts from an optimum initial guess, which is the situation the closest to the observed situation among those archived in the TIGR data set, the 3I method aims at estimating the difference between the parameters and their values for the closest situation rather than the parameters themselves (or the difference between the parameters and their mean or climatological values).

3) The 3I procedure produces an initial guess solution of high quality which may start a physical type inversion method requiring only one iteration (one matrix inversion) to get an accurate final solution. To the best of our knowledge, this method, developed in 1983 (see Chedin and Scott, 1984), has been the first single-iteration - or direct - physical method.
2.5 Cloud parameters retrieval: the "coherence of effective cloud amounts" method

Considering a partially cloudy field of view (cloud amount N), the radiance measured by the satellite in channel \(i\) can be expressed as (Smith, 1968):

\[
I_{m_i} = (1 - N \varepsilon_i) I_{Cl_i} + N \varepsilon_i I_{Cd_i}(P_C)
\]  
(1)

where \(I_{Cl_i}\) is the clear radiance, \(I_{Cd_i}(P_C)\) the radiance arising from a black cloud at level \(P_C\) and \(\varepsilon_i\) the cloud emissivity. \(N \varepsilon_i\) is called the "effective cloud amount" in channel \(i\). From Eq. (1), \(N\) and \(\varepsilon_i\) cannot be reached separately. The use of Eq. (1) (written for several channels) to determine \(N \varepsilon_i\) and \(P_C\) requires knowledge of \(I_{Cl_i}\) and the function \(I_{Cd_i}(P_C)\). These values can be reached from the TIGR data set. More precisely, the TIGR data set provides an estimation of \(I_{Cl_i}\) and of \(I_{Cd_i}(P_C)\) in all HIRS/2 channels, for a set of cloud levels \(P_C\) (23 values from the surface to 200 mb) and for all the possible conditions of observations.

The method is based upon the consideration of a plausible variation of the cloud emissivity \(\varepsilon_C(\nu)\) with frequency. From the conclusions of a study by Yamamoto et al. (1970), we assume that \(\varepsilon_C(\nu)\) is roughly constant in the longwave region (5 channels: 4 to 8) and in the shortwave region (5 channels: 13, 14, 15, 18, 19), and, moreover, that the shortwave value is slightly lower than the longwave one. The algorithm can be divided into two steps:

1) Selection, among the initial set of 23 pressure levels, of a sub-set of plausible cloud top levels.

A level is plausible if the following test is verified: we consider the function:

\[
S(P_C) = \sum_{(i,j)} \left[ \frac{I_{m_i} - I_{Cl_i}^2}{I_{m_j} - I_{Cl_j}^2} - \frac{I_{Cd_i}(P_C) - I_{Cd_j}(P_C)}{I_{Cd_i}(P_C) - I_{Cd_j}(P_C)} \right]^2
\]  
(2)

for \((i,j) = (4,5), (5,6), (6,7)\)

where \(I_{Cl_k}^2\) and \(I_{Cd_k}(P_C)\) are respectively the estimations of \(I_{Cl_k}\) and \(I_{Cd_k}(P_C)\). Eq. (2) derives from Eq. (1), written for each pair of channels considered, after \(N \varepsilon_i\) has been eliminated.

The test consists in verifying that \(S(P_C)\) is close to its minimum value \(S_{\min}\). In the pairs of adjacent channels technique, the cloud top level \(P_C\) would be the one for which \(S(P_C) = S_{\min}\). Here the test limit is: \(S(P_C)/S_{\min} \leq 5\).

2) Tests on the coherence of effective cloud amounts.

For each plausible cloud level \(P_C\), corresponding values of \(N \varepsilon_i\) are computed in each channel from Eq. (1). This step is itself divided into two parts:
. Elimination of obviously impossible levels: various tests are carried out, in each spectral region, to make sure that the individual values $N_{\xi_i}$ are not too much scattered, and that both mean values (respectively $N_{\xi_{lw}}$ and $N_{\xi_{sw}}$ for the longwave and the shortwave region) are comprised between 0 and 1, and that $N_{\xi_{sw}}$ is slightly lower than $N_{\xi_{lw}}$.

. Choice of the final cloud top level: the ratio of the standard deviation of the effective cloud amounts $N_{\xi_i}$ by the mean value $N_{\xi_{lw}}$ in the longwave region must be minimum, which ensures the smallest scattering.

For daylight observations, shortwave channels cannot be used because of their contamination by reflected solar radiation. In that case, a simplified algorithm is applied, in which all tests using shortwave channels are excluded.

The algorithm has been validated on synthetic data and compared, favourably in particular for low clouds, to those obtained by Wielicky and Coakley (1981) with the pair of adjacent channels technique. Knowledge of the cloud parameters makes it possible to "clear" all the channels influenced by the clouds and not corrected by the $\Psi$-method. More details are given in Wahiche et al. (1985).

2.6 Water vapor and surface temperature retrievals

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.

Because of the difficulty in retrieving accurate water vapor amounts from TOVS, two different methodologies are presently experienced. The first one is a simultaneous physical inversion of the water vapor amounts and of the surface temperature. The second relies upon regressions obtained from the TIGR data set which main interest is to comprise all possible conditions of observations (viewing angle, surface parameters, ...) as well as a large representative sample of atmospheric situations.

1) Simultaneous physical inversion of water vapor and surface temperature.

Four HIRS/2 channels are presently used: 8, 10, 11 and 12 for the day-time observations and 18, 10, 11, 12 for night-time observations. A ridge type estimation procedure is used:

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

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), $\Delta \beta$ the difference between the final and initial values of the parameters considered, $\gamma$ a smoothing parameter (Lagrangian parameter).
2) Regressions from the TIGR data set.

Regressions for the relative humidities of the three above mentioned layers and for the surface temperature are derived from the TIGR data set. The sets of channels used to predict the relative humidities for the layers 300–500 mb, 500–800 mb and 800–1000 mb are respectively: 4, 5, 6, 11, 12 and 15 for the first layer; 5, 6, 7, 10, 11, 12 and 15 for the second; 5, 6, 7, 10, 11, 14 and 15 for the third one. The surface temperature is predicted from three regressions using the sets of channels: 8, 10, 11, MSU2, MSU3 for the first one; 8, 10, 18 and MSU2 for the second one; 8, 10, 11, 19, MSU2 and MSU3 for the last one. If we denote respectively by T(8), T(18) and T(19) the three values provided by these regressions, the surface temperature is obtained from T(8) for day time observations and from 0.5 T(8) + 0.25 T(18) + 0.25 T(19) for night time observations. More details are given in Wahiche (1984).

2.7 Microwave surface emissivity

Microwave surface emissivity is an important parameter bearing information on the type of the surface (ice monitoring in particular). It is directly extracted from the measurements in the first channel of the microwave sounding unit, a window channel (see Wahiche, 1984).

3. APPLICATION OF THE 3I ALGORITHM TO NOAA-7

The 3I procedure briefly described in the preceding sections was first applied to the ALPEX (ALPine Experiment) IOP for March 4–5, 1982. Satellite data were prepared by NOAA/NESDIS Development Laboratory, Madison (USA). They represent 4 satellite passes: March 4, orbits Nbs. 3586 and 3587 at 12h00 and 13h45 respectively; March 5, orbits Nbs. 3594 and 3595 at 2h05 and 3h45 respectively. Each pass is made of approximately 70 to 80 scan lines. Forecasts data were obtained, for the same period, from ECMWF, Reading (GB). Results have been reported in the references already quoted. They were obtained from the first version of the TIGR data set, comprising at that time 398 atmospheric situations of middle latitude type. The new version of the TIGR data set, rapidly described in Section 2, comprises 1207 atmospheric situations, distributed in 525 polar, 545 mid-latitude and 137 tropical situations. A significant improvement over previous results has been obtained as shown in the next section.

3.1 Comparison between the 3I results and conventional data

For the period considered, a preliminary assessment of the quality of the 3I procedure can be made by comparing retrievals to the available radiosounding measurements. These data were obtained from ECMWF. Results of this comparison between radiosondes and retrievals are illustrated on Fig. 1.

On this figure, we have used the standard levels stratification for the sake of simplicity in comparing with other algorithms. One of the most salient features of this figure is the good quality of the retrievals in the lower part of the troposphere (500-1000 mb). The agreement
is significantly better than what we obtained from the first version of TIGR. The peak at about 250 mb for the clear boxes with the new TIGR, also noted by other authors (see Smith, 1984) is under investigation. The most striking point is the decrease of the number of boxes automatically rejected by the inversion algorithm: 32 boxes for the first TIGR and only 16 now, over a total of 171 radiosondes available. The improvement issuing from the new TIGR is also illustrated on Figures 2-5 presenting geopotential thicknesses and thermal winds derived from the retrieved thermal structure, with the first TIGR data set (Figs. 2 and 4) and with the new TIGR data set (Figs. 3 and 5). The spatial coherence appears greater on the latter two and the number of rejections is clearly smaller. The quality of the initialization is illustrated by comparisons between the initial and final thickness iso-contours fields. Fig. 6 presents the thickness iso-contours field obtained from the retrieved solutions (that of Fig. 3) and may be directly compared to Fig. 7 which presents the same field derived from the initial guess solutions.

The general appearance of the initialization field of Fig. 7 is already remarkably close to that of Fig. 6.

A similar conclusion comes from Figs. 8 and 9 which present the same type of results for the two night-time passes and for the atmospheric layer comprised between 850 mb and 700 mb, a layer much thinner than the vertical resolution associated with an infrared sounder. Fig. 8 is for the retrieved field when Fig. 9 is for the initialized field.

Results illustrated on Figs. 2-9 have been obtained using as a proximity criterion for selecting the initial guess solution among the situations archived in the TIGR data set an average minimum distance classifier as explained in Chedin and Scott (1985).

![Figure 1](image-url)

RMS error of retrieved mean layer temperature (standard levels) compared to collocated radiosondes for the ALPEX IOP, March 4-5, 1982.
Fig. 2 Thermal winds and thicknesses between 1000 and 500 mb for the two day-passes - orbits 3586 and 3587 - of March 4, 1982. Areas where data are missing are either regions where the calibration of the radiometer occurred or regions where the rejection tests have a significant impact. Winds are in m/s; thicknesses are in dam minus 500. "Old" TIGR data set.
Fig. 3  Thermal winds and thicknesses between 1000 and 500 mb for the two day passes - orbits 3586 and 3587 - of March 4 1982. Areas where data are missing are either regions where the calibration of the radiometer occurred or regions where the rejection tests have a significant impact. Winds are in m/s; thicknesses are in dam minus 500. "New" TIGR data set.
Fig. 4  Thermal winds and thicknesses between 1000 and 500 mb for the two night passes – orbits 3594 and 3595 – of March 5, 1982. Areas where data are missing are either regions where the calibration of the radiometer occurred or regions where the rejection tests have a significant impact. Winds are in m/s.; thicknesses are in dam minus 500. "Old" TIGR data set.
Fig. 5  Thermal winds and thicknesses between 1000 and 500 mb for the two night passes - orbits 3594 and 3595 - of March 5, 1982. Areas where data are missing are either regions where the calibration of the radiometer occurred or regions where the rejection tests have a significant impact. Winds are in m/s.; thicknesses are in dam minus 500. "New" TIGR data set.
Figure 6  Retrieved thickness iso-contours field for the same passes as for Figure 3.

Figure 7  Thickness iso-contours field corresponding to the initial guess solution for the same passes as for Figure 3.
Figure 8  Retrieved thicknesses for the two night-time passes (in dam) and for the layer 850-700 mb.

Figure 9  Initialized thicknesses for the same passes as for Figure 8.
3.2 Results for the relative humidities and surface temperatures

The two methods described in Section 2.6 have been applied to the retrieval of relative humidities (and total water vapor contents) and of surface temperature.

1) Simultaneous physical inversion

Table 1 presents the results of a comparison between both the initial guess solutions and the final solutions and radiosondes measurements for the 4 NOAA-7 passes, for the relative humidity retrievals. Table 2 presents similar results for surface temperature retrievals over sea.

Although being a very preliminary basis (the samples are too limited, in number, in time and in space), Table 1 does not reveal important problems with the initialization. The accuracy of the retrievals corresponds to what is usually reported from NOAA satellites observations.

The main problem which comes out from Table 2 is the important negative bias for the initial solution, also seen for the final solution. Since no satisfactory explanation could be given to these biases, we have compared these results to those obtained for one pass (March 4) by the French Meteorological Office from AVHRR observations (Personal Communication, July 1984, T. Phulpin and P. Leborgne, CMS Lannion, France). These results show the same bias, even a little larger, which could find its origin in the data base (archived by ECMWF, Reading, GB) itself. The encouraging result is the standard deviation decrease from the initial guess to the final solution. If the latter is satisfactory, the former is acceptable and does not reveal a very big problem with the initialization.

2) Regressions from the TIGR data set

Tables 3 and 4 present similar results obtained from the regressions described in Section 2.6. The numbers in these tables compare well with those of Tables 1 and 2. If we only consider day time statistics with a relatively large number of items, the results coming from the regressions appear slightly better (smaller bias for clear sky conditions). It is however clear that more experience is required with a much larger (both in time and in space) and more accurate observation data base. In any case, the quality of the atmospheric temperature retrievals low in the atmosphere indicate that the two components of the radiances, atmospheric and surface, have been well disentangled.

4. APPLICATION OF THE 3I ALGORITHM TO NOAA-8

The 3I procedure has been applied to one orbit of NOAA-8, a morning overpass covering the central United States and Gulf of Mexico on June 7, 1984. It is very interesting to notice that a tornado devastated Barneveld (Wisconsin) later in the evening. Satellite data have been prepared by CIMSS, Madison, and comprise approximately 80 scan lines. For the same period, the LFM (Limited Finemesh Model) predicts have also been obtained from CIMSS.
Table 1  Water vapor inversion: statistics for the initial solutions and the retrievals compared to radiosondes measurements (ALPEX IOP, March 1982). Clear areas and partially cloudy areas (up to 50%) are considered

<table>
<thead>
<tr>
<th></th>
<th>Initial solution</th>
<th>Retrieval</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (o-c)</td>
<td>s.d.</td>
</tr>
<tr>
<td>RH300-500mb</td>
<td>-0.11 0.20 53</td>
<td></td>
</tr>
<tr>
<td>RH500-800mb</td>
<td>-0.12 0.22 54</td>
<td></td>
</tr>
<tr>
<td>RH800-1000mb</td>
<td>0.04 0.16 51</td>
<td></td>
</tr>
<tr>
<td>U_total</td>
<td>-0.03 0.27 54</td>
<td></td>
</tr>
</tbody>
</table>

1 Percent relative humidities.
2 In g.cm\(^{-2}\). Mean over the sample: 0.9 g.cm\(^{-2}\).

Table 2  Surface temperature inversion over sea: statistics for the initial guess solutions and the retrievals, compared to ships of opportunity measurements (ALPEX IOP, March 1982). Not clear areas include up to 50% cloud amounts.

<table>
<thead>
<tr>
<th></th>
<th>Clear</th>
<th>Clear + Not clear</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (c-o)</td>
<td>s.d.</td>
</tr>
<tr>
<td>Initial solution</td>
<td>Night</td>
<td>-2.9</td>
</tr>
<tr>
<td></td>
<td>Day</td>
<td>-3.5</td>
</tr>
<tr>
<td>Retrievals</td>
<td>Night</td>
<td>-1.3</td>
</tr>
<tr>
<td></td>
<td>Day</td>
<td>-1.6</td>
</tr>
<tr>
<td>RH, 200-500mb</td>
<td>1</td>
<td>-0.07</td>
</tr>
<tr>
<td>RH, 500-800mb</td>
<td>1</td>
<td>-0.07</td>
</tr>
<tr>
<td>RH, 800-1000mb</td>
<td>1</td>
<td>-0.008</td>
</tr>
<tr>
<td>U, total</td>
<td>2</td>
<td>-0.006</td>
</tr>
</tbody>
</table>

1 Percent relative humidities
2 In g.cm\(^{-2}\). Mean over the sample: 0.9 g.cm\(^{-2}\)

|Table 4 Surface temperature regressions over sea: statistics for the retrievals compared to ships of opportunity measurements (ECMWF Reading archives; ALPEX IOP, March 1982).|
|-----------------|-----------------|-----------------|
|Clear| Clear + Not clear|
|Mean (c-o)| s.d.| n\(\text{stat}\)| Mean (c-o)| s.d.| n\(\text{stat}\)|
|Night| -1.1| 1.0| 11| -0.94| 1.00| 16|
|Day| -0.1| 1.4| 72| -0.60| 2.30| 99|
4.1 **Validation of the transmittance/radiance model**

Accurate computation of transmittances and raddiances (brightness temperatures) for the TOVS channels and the atmospheric situations in TIGR are an essential condition to correctly retrieving meteorological parameters from the 3I method.

Use is made of the fast line-by-line model "4A" (Automatized Atmospheric Absorption Atlas; Scott and Chedin, 1981), properly validated against TOVS - radiosonde matched data for the satellite of interest, here NOAA-8. Two types of matched data have been considered. The first file was extracted from the NOAA/NESDIS DSDV files: 240 matchups covering the periods Summer 1983 and Winter 1983-1984 corresponding to night time observations over land or sea for polar, middle and tropical latitudes. The second file was produced by CMS/Lannion: 16 situations (over sea; day and night; middle latitudes; winter) with an accurate estimation of the surface temperature, a parameter essential to an accurate validation of transparent channels. Radiances originally produced by 4A were transformed owing to the \( \gamma-\delta \) procedure (see, for example, Scott et al., 1984a) to constrain the biases between observations and computations to zero. The mean values of the \( \gamma \) and \( \delta \) factors are, respectively, 1.02 and -0.3. Their standard deviations are 0.03 and 0.5. The TIGR data set (1207 situations) for NOAA-8 is based upon these results.

4.2 **Geopotential thicknesses and thermal winds for NOAA-8 observations over Central United States and Gulf of Mexico (June 4, 1984).**

Figure 10 presents geopotential thicknesses and thermal winds for the NOAA-8 orbit considered and for the layer 1000-500 mb. Over a total of 1254 possible retrievals, 1080 were declared acceptable, the rejections representing 16.6%, a relatively small fraction if one considers the meteorological situation characterized by an extended and relatively heavy cloudiness (see Fig. 11 which reproduces the corresponding channel 2 AVHRR picture). Figure 12 presents the associated thickness iso-contours field. Figures 13 to 24 present similar results for other atmospheric layers. The quality of the initialization is illustrated on Figures 25 and 26 which display thermal winds and thickness iso-contours for the layer 1000-500 mb and for the initialization field, which may be directly compared to Figs. 10 and 12.

With the a priori knowledge of the fact that a tornado devastated some areas in the state of Wisconsin (Barneveld, in particular), these results appear interesting since they seem to bring into evidence a cold pool along 90° longitude and between latitudes 35° and 40°. This phenomenon appears on both the thermal wind charts (Fig. 10, for example) and on the iso-contours field of Fig. 12 (minimum at 570 dam): the almost symmetrical isotherms about the low center are characteristical. The forecast of the violent meteorological event which occurred a few hours after the satellite pass could have benefited from the results of the inversion algorithm.
Figure 10

Thermal winds and thicknesses between 1000 and 500 mb, for the June 7, 1984, NOAA-8 pass over Central U.S.

Figure 12

Retrieved thickness iso-contours field for the same pass as for Fig. 10.
Figure 21  See legend of Fig. 10.  850-500 mb.

Figure 22  See legend of Fig. 12.  850-500 mb.
Figure 23  See legend of Fig. 10.  500-300 mb.

Figure 24  See legend of Fig. 12.  500-300 mb.
Figure 25

Thermal winds and thicknesses between 1000 and 500 mb derived from the initial solution (retrieved solution on Figure 10).

Figure 26

Initial solution thickness iso-contours field for the case presented on Figure 12.
5. CONCLUSION

For both the ALPEX case (NOAA-7) and the Central US overpass by NOAA-8, the 3I algorithm has demonstrated its capability to retrieve quite accurately large scale features as well as small scale events. The spatial resolution of the 3I method combined with a small number of rejections (bad retrievals) even for relatively cloudy situations lead to a high density of retrievals. The strong coupling of physics and statistics, from an "educated" data set - the "TIGR" data set -, ensures a good spatial coherence.

The next step, recently started, will consist in merging as far as possible the AVHRR data, currently processed by the CMS Lannion, to the TOVS data, resulting for clear and partly cloudy areas, in an important improvement in the spatial resolution. This is the principal aim of the "4I" method: Improved Initialization Inversion with Imagery.
REFERENCES


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