USE OF TOVS SOUNDINGS AND METEOSAT IR DATA TO MONITOR CLOUD TOP HEIGHT

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ABSTRACT

Cloud top height maps using Meteosat IR data are routinely produced at the Italian Meteorological Service. TOVS soundings have been used to improve the spatial consistency of height assignment of cloud tops. The experiment has been carried out by comparing cloud top temperatures obtained from TOVS retrievals with those derived from Meteosat images. The results are shown and the assessment of consistency between the two set of data are discussed. Three techniques of application of TOVS soundings to establish the cloud height from cloud top temperature obtained by Meteosat IR data are shown.

1. INTRODUCTION

Cloud top heights can be obtained from the infrared imagery of satellite by making use of the relationship between the radiance measurements collected by the satellite, and the temperature of the cloud emitting that radiation. It is assumed that the cloud behaves like a black body and has an emissivity close to unity.

By comparing the cloud top temperature obtained in this way with the actual temperature profile measured by radiosonde, the cloud top height can then be determined. The accuracy of the height estimation depends strongly on the accuracy of the assumption that the cloud has an emissivity close to unity.

Cumulus and cumulonimbus clouds do have an emissivity of unity, but with layered stratus clouds the deviation from black body behaviour is noticeable and with semi-transparent cirrus clouds is substantial.

So the determination of cloud top height by this method can only be applied to cumulus cloud type or, with less accuracy, to stratostratus cloud types.

However this product, which is available half-hourly from Meteosat every 30 minutes, has proven to be very useful for nowcasting purposes and particularly for air navigation assistance, allowing forecasters to detect at a glance locations and heights of the most active storm clouds.
The production of cloud top height maps is operational at the
Italian Meteorological Service since 1985 (De Leonibus and Pagano,
1985), where a forecaster can select interactively a sub-frame area
around a particular radiosonde station. Using the latest sounding
from this station, the satellite temperature field is converted into
heights. Over the sub-frame area the heights are sliced up to 8
levels and colour coded.

The processed sub-frame is then presented on a TV screen as a
colour "window" within the wider black and white satellite image
which preserves the overall cloud pattern (fig. 1, from EUMETSAT,

![Fig. 1 Cloud top height analysis, Italy Centre - 89.09.27 11:00 UTC, RDS Rome 12:00 UTC](image)

However, apart from the already mentioned physical problems due
to emissivity, the application concerned is valid as long as the
radiosounding utilized for converting temperatures into heights is
representative of the air mass in the sub-frame. This limits the
applicability of the method for frames far in space and time from
the available radiosoundings, usually spaced 500-600 km, carried out
every six hours at the best, and only over land.

Hence the possibility of using TOVS-derived vertical profiles, to
improve spatial and temporal consistency for the height assignment
of cloud tops has been investigated.

Indeed satellite soundings would allow the production of cloud
top height maps even over areas poor of radiosoundings and over the
sea and, since they are time-interleaved with the ground-based ones,
a better representation of cloud structure during evolving situa-
tions.
The retrievals have been performed making use of the ITPP-4 software package, running on a microVAX 3800 computer. The retrieval scheme uses the regression first guess included in the package without external surface data.

2. ASSESSMENT OF THE METHOD

An assessment of the possibility of replacing or complementing radiosonde observations with TOVS-derived vertical profiles is necessary because the application is designed to be used in cloudy areas, therefore just where ITPP-4 is less performing. On the other hand, the product is addressed mainly to the detection of cumulus clouds, more often associated to broken or scattered cloud coverage, making it possible to retrieve a vertical profile within the area concerned.

To verify the reliability of the method, the following tests have been performed:

2.1. Radiosoundings vs the nearest TOVS profile

Within each frame of the scene considered, the correlations between radiosoundings and the nearest available TOVS profile for high (>6000 m), medium (3000 to 6000 m) and low levels (<3000 m) have been computed. The result showed correlation values of 0.95 for high levels, 0.97 for medium levels and 0.38 for low levels. This result justify the use of TOVS profiles for producing Cloud Top Height maps to be utilized in a qualitative way by the forecasters, mainly for medium and high clouds. As it is expected ITPP retrievals are less performing at the low levels (below 3000 m), due to the poor vertical resolution in the lower troposphere and the strong influence of the surface effects.

2.2. Radiosoundings vs mean profile

The same correlations, as described in the previous point, have been computed, replacing the nearest TOVS profile with the averaged profile in the frame considered. The number of profiles used for building the average depends on the cloudiness and on the geometry of the TOVS pass. Usually it ranges between 5 to 25 with a mean value of 15. The results showed correlation values of 0.95 for high levels, 0.94 for medium level and 0.49 for low levels. Although the use of a single profile could produce a more correct "punctual" representation, CTH maps obtained by means of a mean profile within a frame would allow a lesser dependence on the position of the
actual profile, with a stabilizing effect in the total frame.

2.3. Dependence on cloudiness

For high and medium levels a statistics of retrieved profiles vs cloudiness have been analyzed, showing that about 90% out of the total number of retrieved profiles, considered as "first neighbour", were classified as "clear" profiles (cloudiness less than 33%), and only a few were classified as "cloudy" (cloudiness between 34 and 66%) or "overcasted" (cloudiness more than 67%). The high percentage of "clear" profiles, even for mostly cloudy frames, confirms the applicability of the method, because of the high probability of having soundings in the frame less contaminated by clouds.

3. EXAMPLES OF APPLICATION

As an example of the application described, two CTH maps, processed using different profiles for temperature-height conversion are here presented in figg. 2 a.,b.,c.,d., 3 a.,b.,c.,d. The frames are relative to a disturbance crossing Italy on 3 dec 1992. All types of clouds are present in the scene and refers to a Meteosat IR image over Italy at 14.00 UTC. Radiosounding taken at 12.00 UTC were used, together with retrieved TOVS profiles from the 13 hours passage.

3.1. Italy North-West

Fig. 2a. shows a cloud top height map over the North Western part of Italy produced by means of the Milano Linate radiosounding (marked in white on the picture). The map displays a nearly overcasted area with medium high clouds and topped by a couple of thunderstorm nuclei embedded in it, reaching the tropopause level (9741 m).

Fig. 2b. shows the same map obtained by replacing the Milano radiosounding with the nearest available TOVS profile. It can be seen that the overall structure of the cloud patterns is unchanged and that the correspondance is optimal for clouds with tops at all levels and well inside the estimated error for TOVS. This is evaluated as the standard deviation between the single profile and the mean of the profiles in the surrounding frame. This method has been chosen to account for the space variability of retrievals and give the confidence of the analysis. A little discrepancy is experienced at the tropopause level; this is connected with the difficulty, for ITPP, to detect the tropopause level correctly. The TOVS profile overheats the atmosphere at that level and therefore produces more high tops.
Fig. 2c. is obtained by replacing the TOVS profile nearest to Milano with the profile nearest to the frame centre. This would be obviously the most correct representation for the central part of the frame, with performances downgrading towards the edges. As before an error derived from the standard deviation of profiles in the frame has been associated to the central one. In this specific case the two maps of fig. 2b. and 2c. have been built using the same profile, due to the high cloudiness coverage, therefore they are identical! Only the associated error is different, making reference to different areas.

Fig. 2d. shows the same frame obtained by replacing the single sounding with an averaged profile in the frame. As before the overall cloud pattern is maintained, with a "stabilizing" effect for the atmospheric profile, mainly in stormy areas, as can be seen from the highest top structures.

3.2. Italy Centre-East

Fig. 3a. shows a CTH map over the Central-Eastern part of Italy, produced using the Brindisi radiosounding. The frame is half covered with medium and low clouds. To be noticed that the radiosounding utilized is located on the very edge of the frame.

Fig. 3b. shows the same frame, but obtained by means of the TOVS profile nearest to Brindisi. The optimal correspondence between the two CTH maps is confirmed, with temperature values at reference levels always within the confidence interval.

Fig. 3c. is obtained by using the TOVS profile nearest to the centre of the frame. Also in this case the cloud pattern is preserved, mainly for medium level clouds, where it can be seen a slight difference in the low clouds, due to the changing of location and, in any case to the poor validity of the method for lower clouds.

Fig. 3d. shows the CTH maps, obtained by means of a mean profile, averaged among 30 samples. Because of a high number of available satellite soundings, the mean is very close to that of fig. 3c., more representative of the whole frame than that of fig. 3b.

4. CONCLUSIONS

Cloud top height maps obtained from Meteosat IR imagery are an operational product at the Italian Meteorological Service. The production of these maps is based on the use of ground based radiosoundings, to convert black-body temperatures into heights. However the coarse resolution, in space and time, of the radiosonde network limits the accuracy of the product.
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Fig. 2a  Cloud top height analysis, Italy North-West 92.12.03 14:00 UTC, RDS Milan 12:00 UTC.

Fig. 2b  As Fig. 2a. NOAA-11 pass: 92.12.03 13:43 UTC. Nearest TOVS retrieval to Milan (42.86 N, 8.98E)

Fig. 2c  As Fig. 2b. TOVS retrieval nearest to the centre of the frame (42.86N, 8.98E)

Fig. 2d  As Fig. 2b. Average TOVS retrieval in the frame.

Fig. 3a  Cloud top height analysis, Italy Centre-East 92.12.03 14:00 UTC, RDS Brindisi 12:00 UTC.

Fig. 3b  As Fig 2a. NOAA-11 pass: 92.12.03 13:43 UTC TOVS retrieval nearest to Brindisi (40.73N, 17.87E)

Fig. 3c  As Fig. 3b. TOVS retrieval nearest to the centre of the frame (41.19N, 16.05E).

Fig. 3d  As Fig. 3b. Average TOVS retrieval in the frame.
To complement ground based soundings, TOVS-derived temperature profiles have been utilized, to allow the production of CTH maps also over the sea and at times interleaved with synoptic hours.

Preliminary tests performed over several frames have shown the correspondence of radiosounding-derived CTH maps with TOVS-derived ones, with the highest correlation for similar altitude levels and the possibility of using satellite retrievals also in near overcasted areas.

Differences in temperature values, hence in height assignment between the two methods are within the confidence interval associated with TOVS profiles and, in any case, mostly negligible for an application based rather on the representation of the overall structure of the cloud field than on the exact cloud height determination. This is rather more hampered by the departure of clouds from a black-body behaviour.

Comparison between maps produced with different methods have shown that maps carried out by means of TOVS data have the best performance for medium levels clouds (usually with tops ranging from 3000 to 6000 m). Some discrepancies are due to the poor determination of tropopause level by ITTP at the lowest levels, because of the influence of the determination of the surface temperature.

Further refinements of the method can be applied, but the above presented results have confirmed that the experiment performed has shown the applicability of satellite-derived CTH maps for a qualitative representation of the cloud structure. Quantitative utilization of cloud top heights is possible, mainly for cumulus clouds, taking into account the limit of variability as derived from the confidence interval.

The application described, however, represents an example of possible integration of data coming from different satellites, such as Meteosat and NOAA, and a useful tool for nowcasting and flight assistance.

5. REFERENCES


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TECHNICAL PROCEEDINGS OF

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