MSG VALIDATION: AN ONGOING PROCESS

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ABSTRACT

With the dissemination of METEOSAT 8 products a new era in satellite imagery interpretation has begun. Users are eager to assess the added value of the imagery and its derived products. The method of quantitative assessment is the comparison to other observations.

In January 2004 the EU funded CLOUDMAP2 project ended. One of the objectives of CLOUDMAP2 was the creation of a database of cloud parameters derived from different observation techniques either space-borne or ground-based. For successful completion of this objective these cloud parameters have to be validated by inter-comparison. Here the comparison is concentrated on the cloud top height (CTH).

The object of this study is to assess the quality of the SAF-NWC (www.meteorologie.eu.org/safnwc) cloud products by comparing them to other cloud observation methods. Early SAF-NWC products (from September 2003 onwards) are derived by Meteo-France and were kindly provided by CMS-Lannion to the CLOUDMAP2 consortium. The SAF-NWC products are compared to collocated observations of the MODIS (MODerate resolution Imaging Spectroradiometer, modis.gsfc.nasa.gov) instrument flying on the Terra satellite. Over Europe the MODIS and the SAF-NWC products are compared to radar observations performed at the Chilbolton site (UK).

In both comparisons the SAF-NWC CTH compare well with the MODIS and radar observations. It is shown that the SAF-NWC CTHs show a dependency on latitude and on cloud type.

1. INTRODUCTION

The CLOUDMAP2 project aimed to produce and exploit value-added remote sensing data products for macroscopic (e.g. cloud-top height) and microscopic (e.g. cloud droplet radius) cloud properties and water vapour distributions to characterise sub-grid scale processes within Numerical Weather Prediction Models (NWP) through validation and data assimilation. More and detailed information can be found at www.cloudmap.org.


During the project the Meteo-France group in Lannion working on the SAF-NWC products was contacted. They agreed to provide early products based on the MSG imagery during the commissioning phase. From these products the cloud top height is compared in this paper to MODIS cloud top pressure product provided by Plymouth Marine Laboratory and to 94 GHz radar cloud top height provided by Rutherford Appleton Laboratories. However, MSG was still in the commissioning phase and the SAF-NWC software used to
extract MSG cloud products (version v0.1) was different from the first operational software version (v1.0) to be released in June 2004. The results should therefore be evaluated as a first indication of the performance the Cloud top height [CTH] product of the SAF-NWC products.

2. DATA AND METHOD

MODIS versus SAF-NWC products

MODIS cloud top pressure and cloud coverage products were processed in near real time at the Plymouth Marine Laboratory using radiances collected at the Dundee receiving station (for more information; www.npm.ac.uk/rsg/projects/cloudmap2). The cloud top pressures are obtained using a CO₂-slicing method (Menzel and Strabala, 1997). The comparison required the conversion of MODIS cloud top pressure into cloud top height. Data from the HIRLAM NWP model, locally run at KNMI were used for the conversion.

Due to a limitation in the data amount to be transferred from Lannion to KNMI a limited set of times (11:00 hr and 12:00 hr GMT) and of cloud products were selected for the comparison: cloud coverage, cloud type, and cloud top height. The area of interest for this study was Europe and the Northern Atlantic.

There is a significant difference in pixel size between MODIS and MSG. MODIS has a pixel size of 1 km by 1 km whereas MSG pixels covers a 3 km by 5 km area in the region of interest. The difference in viewing geometry hampered the comparison of cases with partial cloudiness; observation angle differences can differ by more than 50 degrees in the area of interest. To facilitate the interpretation of the results, the comparison was restricted to the cases having a high coverage (larger than 75% in the SAF-NWC products and larger than 90% in the MODIS results).

As cloud type information was available and also the latitudinal information of the satellite, the dependency of the CTH results on these parameters are also investigated.

Radar versus SAF-NWC products

Ground based observations were performed at the Chilbolton-site in the United Kingdom located at 51.1°N, 1.43W. More detailed information about the radar and other equipment at this site can be found at http://www.rcru.rl.ac.uk/weather/cloudradar.htm.

For the comparison, the 94 GHz radar cloud top heights (CTH) were processed using the method of Clothiaux et al. (1999).

Comparison between ground based and satellite data required the definition of a collocation window in both spatial and temporal dimensions. The collocation window was chosen to be small in both time and space. This limited collocation space decreased the chance of erroneous collocation occurrences between satellite and radar observations caused by cloud displacement observed from space. Despite the small collocation window, there is a significant difference in volume of air sampled from space [10¹² m³] versus the volume of air sampled by the radar [10⁴ m³].

Information from the satellite pixels is used when the pixels have a footprint in latitude and longitude fitting into a rectangular box of 0.2 by 0.2 degree around the radar station. For the comparison to SEVIRI the calculated observation time of the Chilbolton site is used as center of the time window.

The averaged (in time and space) CTH were then compared. The SAF-NWC algorithm uses MSG [METEOSAT 8] observations to derive a Cloud Mask and a cloud type, and an estimate of cloud top temperature. The Cloud Mask and type information, NWP profile information and cloud top temperature are used for the determination of the cloud top height.

3. RESULTS

MODIS Cloud top height versus SAF-NWC MSG SEVIRI CTH

The SEVIRI instrument is calibrated in the commissioning period of the MSG. Since September 2003 the SEVIRI data is of such quality that MF could use it to extract products. Presented here are the comparison of
CTH between MODIS and SEVIRI for the period September till December 2003. In Figures 1 and 2 the frequency distributions are given and Table 1 summarizes the statistics.

Figure 1. Frequency distribution for September [left] and October [right] 2003 of the derived cloud top heights over the area under study of the SAF-NWC MSG SEVIRI (straight red line) and MODIS PML CTH (black line). Please note that the bin size is 400 m for the SAF-NWC results and 800 m for the PML-MODIS results.

Figure 2. Frequency distribution for November 2003 [left] and December 2003 [right] of the derived cloud top heights over the area under study of the SAF-NWC MSG SEVIRI (straight red line) and MODIS PML CTH (black line).

The comparison shows a tendency by the SAFNWC to overestimate lower CTH values in comparison to the MODIS CTH. This has been noted before De Valk et al, 2003. The significant different statistical results obtained for December can be partially attributed to the low number of comparisons and to the unfavourable solar illumination in this month. MODIS Terra also experienced some direct broadcast anomalies during December 2003 which resulted in no data being processed after 3 December 2003. The passes were replaced by MODIS Aqua which suffer from a direct broadcast cutoff around 52N for the ascending (daytime) passes.
A more detailed study showed a dependency of the results on the latitude and on the cloud type. As an example the latitudinal dependency of the frequency distribution is shown for September in Figure 3. At higher latitudes the SAF-NWC overestimates CTH. This could partially be due to the unfavorable viewing angle of SEVIRI. At lower latitudes an underestimation of CTH occurs.

The dependency of the frequency distribution on cloud type is further explored and given in Figure 4.

![Figure 3](image_url) Figure 3. Frequency distribution at different latitudes for September 2003 of the derived cloud top heights over the area under study of the SAF-NWC MSG SEVIRI (straight red line) and MODIS PML CTH (black line). From top right (Latitude lower than 40°) to bottom left (latitude larger than 70°) the images are given in steps from 5°.

The Figure shows significant differences between the MODIS and SEVIRI distribution for low and medium high clouds. This can be attributed to the change in technique in the MODIS procedure to derive CTH. Omission of the two cloud types results in a more favorable comparison (last figure in Figure 4).

A detailed study for October and November showed similar results to the September case and are therefore not presented here. The October and November results show that the cases with semitransparent clouds over lower clouds also had a significant difference between the MODIS and SEVIRI results.
Figure 4. Frequency distribution for different cloud types for September 2003 of the derived cloud top heights over the area under study of the SAF-NWC MSG SEVIRI (straight red line) and MODIS PML CTH (black line).

From top to bottom: First row: Very low clouds; low clouds; medium clouds; Second row: high opaque clouds; very high opaque clouds; high semitransparent meanly thick clouds; Third row high semitransparent thick clouds; high semitransparent over low and medium clouds. The last figure of the third row is a comparison between MODIS and SEVIRI with the omission of the low and medium clouds. (statistics for the last figure: bias –90m, standard deviation 2073 m, number 1484047).
MODIS CTH versus SAF-NWC SEVIRI CTH  

<table>
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<tr>
<th></th>
<th>Bias [m]</th>
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<tr>
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<td>−210</td>
<td>2025</td>
<td>194757</td>
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<tr>
<td>October</td>
<td>−200</td>
<td>2261</td>
<td>152347</td>
</tr>
<tr>
<td>November</td>
<td>−386</td>
<td>2319</td>
<td>256772</td>
</tr>
<tr>
<td>December</td>
<td>−1080</td>
<td>2649</td>
<td>532402</td>
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Table 1. Statistics for the MODIS versus SAFNWC MSG CTH for September till December 2003. The MODIS overpasses within the time window of 10:40 till 12:20 hr GMT are used in the comparison.

SAF-NWC MSG SEVIRI CTH versus Chilbolton 94 Ghz radar

For September till December 2003 the satellite observations were compared to radar observations made at the Chilbolton site. The results are given in frequency distributions in Figure 5 for SEVIRI. In Figure 6 a direct comparison between radar and satellite is given. The statistics are summarized in Table 2.

Figure 5. Frequency distribution for September till December 2003 of the derived cloud top heights over the area under study of the SAF-NWC MSG SEVIRI (straight red line) and Chilbolton radar best estimate CTH (black line).

Figures 5 and 6 indicate that the radar does not observe clouds with a CTH higher than 10,000 m. In Table 2 the second line shows the statistics when the SAF-NWC CTH higher than 10 km are omitted.
In the direct comparison of Figure 6 the minimum and maximum values are given as a box around the average value. This representation shows the span of the occurring values within the collocation space which would not be reflected by the standard deviation.

A closer examination of cases with a large difference between maximum and minimum values showed that multilayer clouds cause these differences. By reducing the time window used for the radar observations from 300 seconds to 180 seconds the statistics of the comparison improved. Still in some cases multilayer clouds were unavoidable even with a reduction of the time window.

<table>
<thead>
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<th>September December 2003</th>
<th>Bias [m]</th>
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<td>Radar versus SAF-NWC SEVIRI CTH</td>
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<td>33</td>
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<td>Radar versus SAF-NWC SEVIRI CTH &lt;10 km.</td>
<td>190</td>
<td>1913</td>
<td>28</td>
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</table>

Table 2. Statistics for the MODIS versus SAFNWC MSG CTH for September till December 2003. Radar collocation period is 180 seconds. The second line shows the results for the comparison with omission of the SAF-NWC results higher than 10 km.

4. CONCLUSIONS

As part of the CLOUDMAP2 Project a comparison was performed between the SAF-NWC derived cloud top height (CTH) and the CTH derived from ground-based radar and polar orbiting TERRA MODIS. A number of
problems had to be solved before the comparisons could be made. Those problems were collocation in both time and space, differences in viewing geometry, and, differences in pixel sizes.

The comparison between the SAF-NWC MSG and PML MODIS cloud top heights was performed for September 2003 till December 2003. The SAF-NWC overestimates the CTH of lower clouds. The results were remarkably good considering that SEVIRI is still in commissioning phase. The SAF-NWC products are foreseen to become operationally available as soon as June 2004. A detailed study of CTH frequency distribution as function of latitude showed that for mid-latitudes the comparison is better than the frequency distribution of the complete data set in Figure 1 and 2 suggests. For low latitudes the SAF-NWC SEVIRI based products even show a slight underestimation of the CTH in comparison to MODIS CTH. For Northern latitudes the reverse occurs, SAF-NWC SEVIRI based products show an overestimation of the CTH in comparison to MODIS CTH. As the number of observations at the Northern latitudes dominate the distribution the general comparison shows an overestimation by SAF-NWC.

Possible causes for this phenomena:

- An underestimation of the atmospheric contribution to the observed brightness temperature. The atmospheric path increases significantly when observing higher latitudes from a geostationary orbit.
- Collocation error. A high cloud at high latitudes can be attributed to wrong latitude due to the slanted view.

The underlying NWP model can then determine an incorrect CTH. (Not shown here but in images of the differences between the SEVIRI CTH and the MODIS CTH a clear collocation effects was visible especially at cloud edges, which were more pronounced in the North). A parallax correction of MODIS and SEVIRI observations would improve the collocation.

Another detailed study on the dependency of CTH on cloud type showed that the largest differences in frequency distributions between SEVIRI CTH and MODIS CTH occur for the low and medium high clouds.

This phenomenon is related to the change in technique for the MODIS CTH retrieval at around 4 km., where the CO₂ slicing technique is replaced by a technique based on brightness temperatures. Neglecting the medium and low clouds showed a remarkable improvement in the comparison.

The cloud type study further confirmed the difficulty to assign CTH to semi-transparent cloud above lower clouds; this is not shown here.

The comparison between Chilbolton 94 Ghz radar CTH and the SAF-NWC MSG cloud top heights was performed for September till December 2003.

The SEVIRI CTH and the radar frequency distributions show a good agreement; especially for the upper cloud layer at around 8 km. The radar observations miss the CTH greater than 10 km. Also the straightforward comparisons between radar and satellite CTH in figure 6 indicate a good correlation between SEVIRI CTH. However the number of comparisons is (still) too low to enable firm conclusions, and the statistics are affected by the occurrence of multilayer clouds.

5. ADDRESSES AND REFERENCES

Some references within this paper are done through relevant web addresses:

- www.cloudmap.org
- www.eumetsat.de
- www.arm.gov
- www.noaa.goens.gov
- www.meteorologie.eu.org/safnwc
- www.arm.gov/docs/sites/sgp/sgpsiteindex.html
- www.npm.ac.uk/rsdas/projects/cloudmap2
- modis.gsfc.nasa.gov


