COMPARISON OF TWO METHODS TO ESTIMATE THE CLOUD TOP TEMPERATURE AND PRESSURE FOR NOAA-AVHRR AND HIRS DATA

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ABSTRACT

We compared the AVHRR histogram and the radiation ratioing methods using NOAA data. The semi-transparent cloud top pressures retrieved with the radiance ratioing method applied with six different channel pairs were compared to each other and also to the results of the AVHRR histogram method. The retrieved cloud top pressures were validated with ground based lidar measurements. We conclude that the radiance ratioing method with the use of the 13.3\textmu m/11.1\textmu m and the 13.7\textmu m/11.1\textmu m channel pairs is the most adequate to retrieve semi-transparent cloud parameters.

1. INTRODUCTION

Within the SAF in support to Nowcasting and Very Short Range Forecasting (SAF NWC), a software is under development to extract cloud parameters (cloud mask and types, cloud top temperature and height) from MSG SEVIRI imagery. A part of this work is to choose the most appropriate method to estimate the cloud top temperature and pressure. The AVHRR histogram (Derrien et al., 1988) and the radiation ratioing methods (Menzel et al., 1983; Eyre and Menzel, 1989; Baum and Wielicki, 1994) were compared using NOAA-12, NOAA-14 and NOAA-15 data. The radiance ratioing method was applied to HIRS measurements. It gives the cloud top pressure in HIRS spots using pairs of HIRS channels. Table 1. contains the channel pairs used in the radiance ratioing method.

The AVHRR histogram method uses the results of a previous AVHRR processing, the detection of the semi-transparent cloud covered areas. Using the AVHRR 11\textmu m and 12\textmu m channel measurements of the AVHRR pixels in a HIRS spot covered by semi-transparent clouds the AVHRR histogram method calculates a semi-transparent cloud top temperature for the HIRS spots. Both methods need NWP vertical temperature and humidity profiles for data simulations. The French NWP model ARPEGE was used.

**Table 1. The channel pairs used in the radiation ratioing method**

<table>
<thead>
<tr>
<th>Ratio</th>
<th>Channel Pair</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>13.3\textmu m /11.1\textmu m</td>
</tr>
<tr>
<td>2</td>
<td>13.7\textmu m /11.1\textmu m</td>
</tr>
<tr>
<td>3</td>
<td>14.0\textmu m /11.1\textmu m</td>
</tr>
<tr>
<td>4</td>
<td>7.34\textmu m /11.1\textmu m</td>
</tr>
<tr>
<td>5</td>
<td>6.75\textmu m /11.1\textmu m</td>
</tr>
<tr>
<td>6</td>
<td>6.75\textmu m /7.34\textmu m</td>
</tr>
</tbody>
</table>

The cloud top pressures extracted from different channel pairs (retrieved by the radiance ratioing method) were compared to each other and to the results of the AVHRR histogram method and validated with ground based lidar measurements.

2. COMPARISON OF DIFFERENT METHODS FOR SEMI-TRANSPARENT ICE CLOUDS

During a five-month period the two methods were routinely used to retrieve cloud top pressure and temperature from AVHRR and HIRS data. Statistics were then calculated over sea and land for the spots
containing mostly (95\%) clear or opaque cloud covered or semi-transparent cloud covered AVHRR pixels. Two types of statistics were calculated. First we compared the retrieved semi-transparent cloud top pressures by the two methods. Then we compared the measured and simulated (using the retrieved cloud parameters) brightness temperatures to estimate the accuracy of the methods.

2.1. COMPARISON OF THE RETRIEVED SEMI-TRANSPARENT CLOUD TOP PRESSURES

The statistics on the difference of the semi-transparent cloud top pressure and temperature retrieved with AVHRR and radiance ratioing method are illustrated in Fig. 1. These statistics were made only for the HIRS spots containing mostly semitransparent cloud covered AVHRR pixels. The figure corresponds to data of NOAA-12, 14 and 15 satellites.

![Graph showing AVHRR-Radiance Comparison](image)

Fig 1. Comparison of semi-transparent ice cloud top pressure and temperature retrieved with the AVHRR histogram method and the radiance ratioing method. The latter method was applied with six channel pairs (see Table 1.) The square symbols with the solid line bars and the circle symbols with the dashed line bars correspond to mean and rms values over sea and over land respectively. Statistics are computed on a five-month period (Dec. 1998- Apr. 1999).

Analysing the statistics we have found the following:

- The AVHRR histogram method gives on average 10 - 50 hPa lower cloud top pressures than the ratioing techniques. The radiance ratioing technique, applied to various HIRS channel pairs, gives similar results (average values within 20hPa), except for the 7.43\(\mu\)m/11.1\(\mu\)m pair (ratio 4) for which larger retrieved pressures are obtained.
- The averaged differences between results obtained with the radiance ratioing techniques and the AVHRR histogram methods are satellite-dependent: 20hPa difference is observed for the 7.43\(\mu\)m/11.1\(\mu\)m pair (ratio 4) between NOAA-12 and NOAA-15.
- The differences between the cloud top pressure retrieved with the radiance ratioing technique and the AVHRR histogram show large rms, about 50hPa (60hPa for NOAA-12).
- The radiance ratioing method gives a definite cloud top pressure for 2-3 times more spots if the 13.3\(\mu\)m/11.1\(\mu\)m, 13.7\(\mu\)m/11.1\(\mu\)m or the 14.0\(\mu\)m/11.1\(\mu\)m channel pairs (ratio 1-3) are used as for the other ratios.

2.2. COMPARISON OF THE MEASURED AND THE SIMULATED BRIGHTNESS TEMPERATURES

We have estimated the accuracy of the two methods by using the retrieved cloud parameters to simulate brightness temperatures in all HIRS channels and compare it with the measured ones (Fig. 2). An error in the cloud height estimation induces an error in the simulated brightness temperatures: systematic errors lead to a bias in the statistics, whereas random errors increase the associated rms. The simulation uses the satellite retrieved cloud top temperature, emissivity and forecast ARPEGE vertical temperature and humidity profiles. In Fig. 2 we can compare the mean and rms values of the brightness temperature differences not only for
semitransparent clouds (where the cloud parameters are retrieved by the ratioing method and the AVHRR histogram method) but also for opaque clouds and clear areas (where the cloudfree area detection and the opaque cloud pressure are retrieved from AVHRR imagery). (Note that the difference of the simulated and measured brightness temperature do not show always the error, the simulation might be quite good also with an erroneous cloud top pressure because an error in the height estimation leads to an error in the emissivity (computed using T11μm brightness temperature) and both errors may compensate themselves in the HIRS simulation.)

Fig. 2. Comparison of measured and simulated brightness temperatures for HIRS channels at 14.5μm (peaking at 100hPa), 14.2μm (peaking at 400hPa), 14.0μm (peaking at 600hPa) and at 13.7μm (peaking at 900hPa). The simulations use: forecast ARPEGE vertical temperature and humidity profiles; semitransparent cloud top pressure and emissivity retrieved with the radiance ratioing technique applied to six HIRS channel pairs and the AVHRR histogram method. The square symbols with the solid line bars and the circle symbols with the dashed line bars correspond to mean and rms values over sea and over land respectively. Statistics are computed on a five-month period (Dec. 1998- Apr. 1999).

The investigation of the differences of measured and simulated brightness temperatures in the HIRS channels shows that:

- The random errors are larger than the systematic errors.
- The simulation is less accurate in the water vapor channels.
- The retrieving is less accurate if the 7.34μm/11.1μm channel pair is used.
- Statistics of simulated minus measured brightness temperatures for semi-transparent clouds present higher rms when the AVHRR histogram method is used, which indicates that this technique induce higher random errors than the radiance ratioing techniques.
- The random error induced by the ratioing method (if the 15μm CO₂ absorption band channels and 11μm window channels are used, i.e. ratio 1-3) is similar (or less) as for opaque clouds retrieved from AVHRR imagery. This means that the random errors induced by it is rather small.
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- As expected, statistics for channel 14.5mm (peaking at 100hPa and therefore nearly insensitive to clouds) are nearly the same for cloud-free and cloudy (opaque or semi-transparent) situations.

3. VALIDATION WITH GROUND BASED LIDAR MEASUREMENTS

The lidar measurements were made in Lannion (France) at the ENSSAT Atmospheric Propagation Laboratory with a Rayleigh-Mie Yag Lidar. It operates at 0.532μm with a range of 0-40km in cloud free atmosphere. The lidar measurements give the top height (in km) of thin cloud layers. The lidar can see the cloud top only if the cirrus layer is thin. The cloud top pressure is obtained assuming a standard atmosphere. For some situations, two (and even three) cirrus layers could be observed: an averaged top pressure together with the minimum and maximum top pressure were used in the comparison.

Those satellite and lidar measurements were selected which were coincident or less then 90 minutes separated them. The semi-transparent cloud top pressures are retrieved for each HIRS F.O.V around Lannion, using the radiance ratioing and AVHRR histogram techniques. For each tested technique, two values were used in the comparison: 1. the retrieved cloud pressure of the HIRS F.O.V collocated over Lannion; if this value is not available, the retrieved cloud top pressure corresponding to the higher retrieved emissivity within the 3*3 HIRS F.O.V around Lannion is retained; 2. the retrieved cloud pressure averaged over 5*5 HIRS F.O.V around Lannion. Fig 3. shows the satellite retrieve cloud top pressures and the lidar measured cirrus layers for 17 dates.

The comparison of the satellite retrieved cloud top pressures and the lidar derived minimum and maximum of the cirrus cloud layers shows that:

- The best fit between lidar and satellite cloud pressure is obtained with the radiance ratioing technique applied to the 11.1μm window IR & 13.7μm channels (ratio 2).

- All techniques overestimate the cloud top pressure: the averaged difference between satellite and lidar pressure takes values from 20hPa (for the ratioing technique applied to 11.1μm & 13.7μm) up to 100hPa for the AVHRR histogram technique, with rms from around 50-60hPa (100hPa for the radiance ratioing technique using the 7.34μm water vapour channel). Note that the on average only 20hPa overestimation is a very good result. For thin semitransparent clouds the retrieved pressure is normally not the cloud top pressure but it corresponds to a point somewhere inside the cloud (depending on the cloud emissivity).

- The AVHRR histogram technique gives the least reliable results. The histogram retrieval technique is not adequate for very thin cirrus clouds.

- The radiance ratioing technique using the 11.1μm window IR & 7.34μm water vapour channel (peaking at approximately 700hPa) can be applied only in few cases, and gives the larger scatter. This must be due to the fact that the 7.34μm simulation is not accurate, due to the water vapour vertical profile uncertainty.

4. CONCLUSION

The radiance ratioing method with the use of the 13.3μm or 13.7μm or 14.0μm and the 11.1μm window channels is more adequate to retrieve semi-transparent cloud parameters than the AVHRR histogram method. The best are the channel pairs 13.3μm/11.1μm and 13.7μm/11.1μm. They give the greatest number of successful retrievings, with the smallest errors. For very thin cirrus clouds the parameter retrieved with the 13.7μm/11.1μm. channel pair is the most reliable.
Fig. 3. Comparison between satellite retrieved and lidar measured cloud top pressures. The red symbols correspond to the cloud top pressure retrieved over Lannion, the green one near Lannion and the vertical bars correspond to the cirrus layer (minimums and maximums) observed with the lidar.

REFERENCES


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