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COMPARISON OF CLOUD HEIGHT ASSIGNMENT TECHNIQUES USING SEVIRI DATA

The height assignment is currently the most challenging task in the AMV extraction schemes with the advent of Meteosat Second Generation (MSG). There are many new opportunities to improve height assignment of AMVs. A CO_2 absorption channel at 13.4 μm on SEVIRI instrument enables to use simultaneously the IR/CO_2 ratioing methodology in addition to the semi-transparency technique for height assignment. The paper compares height assignment techniques using SEVIRI observation during the early phase of commissioning.

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1 INTRODUCTION

The current Meteosat satellites operated by EUMETSAT (EUropean organisation for the utilisation of METeorological SATellites) form an mandatory and integral part of the global meteorological satellite system. Atmospheric Motion Vectors (AMVs) are one of the most important products generally derived from all geostationary satellites, and especially from Meteosat at EUMETSAT, because they constitute a very important part of the observation data fed to Numerical Weather Prediction (NWP). The derivation of displacement vectors from Meteosat imagery data has been operational since the early 80's. The resolution of the current operational products is 160 km at the sub-satellite point. Some high-resolution products are also derived at a nominal resolution of 80 km.

The height assignment is currently the most challenging task in the AMV extraction scheme. Indeed, broken clouds, multilayered cloud targets, low-level targets (requiring cloud base height assignment) and height assignment of clear-sky targets do all require special attention. The main approach used for Meteosat was the so-called 'WV-IRW intercept method' (Nieman et al., 1993, Schmetz et al, 1993) for semi-transparent cases. Opaque cloud heights are calculated from the representative Equivalent Black Body Temperatures (EBBTs) derived from the AMV target area.

The advent of Meteosat Second Generation (MSG) provides many new opportunities to improve height assignment of AMVs. Existence of a CO_2 absorption channel at 13.4 µm on SEVIRI instrument enables to use simultaneously the IR/CO_2 ratioing methodology in addition to the semi-transparency technique for height assignment. This method proposed by Smith and Platt (1979) has been successfully applied to the height attribution of AMVs from GOES satellite (Menzel et al., 1983, Merill et al, 1991). Due to the existence of several water vapor and Infrared channels on SEVIRI, each method can be implemented in different channel configurations, such that there are nearly 15 cloud top pressure schemes implemented in the MSG-MPEF. Therefore the comparison of the cloud top pressure results for all these methods is important in order to increase the performance of AMVs height assignment. This paper presents early results of such a comparison using SEVIRI data on 24 February 2003. The paper compares height assignment techniques using SEVIRI observation during the early phase of commissioning.

2 TECHNIQUES DESCRIPTION

2.1 Height assignment with Meteosat data

For Meteosat the height assignment of opaque clouds is based on the IR cloud brightness temperature. The '*European Centre for Medium-Range Weather Forecasts'* forecast temperature profiles are used as ancillary data and compared to brightness temperatures calculated from infrared Meteosat channel 10.8 µm. The pressure level is determined as the level where the brightness temperature fits the forecast temperature. The pressure at that level is then considered as a good representation of an opaque cloud top pressure.

However, movement of opaque clouds is not usually very representative of atmospheric flow. Semitransparent clouds are often better tracers to estimate cloud motion vectors, because they show radiance gradients that can readily be tracked and they are likely to be passive tracers of the flow at a single level. Unfortunately, large errors in the height assignment occur for such clouds, since the satellite observed IR radiance contains great contributions of the surface or atmospheric layer below the cloud. In that case the altitude assigned to the corresponding AMV utilising brightness temperature method is generally lower than the real one. Corrections for semitransparency are possible using multichannel observations. With Meteosat imagery such correction is done with WV at 6.2 µm and IR at 10. 8 µm channels (Schmetz et al., 1993) using a technique referred as 'WV-IRW intercept method' (Nieman et al., 1993).

The WV-IRW intercept height assignment is based on the fact that radiances in one spectral band observing a single cloud layer vary linearly with the radiances in another spectral band as a function of cloud amount in the field of view. Thus, a plot of Water Vapour radiances (6.2 µm) versus IR window (10. 8 µm) radiances in a scene of varying cloud amount is nearly linear. The operational Meteosat correction method employs two simultaneous radiance observations in both IR and WV channels, where one pair of radiance is from semitransparent cloud and a second pair from an adjacent cloud free area. These data are used in conjunction with forward calculations of radiance for both spectral channels for opaque clouds at different levels in a given atmosphere specified by a numerical weather prediction of temperature and humidity. The intersection of measured and calculated radiances will occur at clear sky radiances and at the opaque cloud radiances. The cloud top temperature is extracted from the cloud radiance intersection (Schmetz et al., 1993).

1.2 Height assignment with SEVIRI

The main payload of MSG will be the Spinning Enhanced Visible and InfraRed Imager (SEVIRI). SEVIRI is a multi channel imager, which nominally operates on a 15 minutes repeat cycle. The definition of the channels is shown in Table 1.

The cloud top temperature should be derived from SEVIRI observations using a number of techniques. For optically thick clouds the CTP is derived from comparison of the observed radiance to radiative transfer calculations for black clouds, like for Meteosat. For semi-transparent clouds, the CO_2-slicing (Eyre and Menzel, 1989; Nieman et al., 1993) or the water vapor intercept method can be used.

In the CO_2 slicing technique, a cloud height is assigned with the ratio of the deviation in observed radiances from the corresponding clear air radiances for the infrared window and the CO_2 (13.4) channel. The clear and cloudy radiance differences are determined from SEVIRI observations and radiative transfer calculations. Assuming the emissivities of the two channels are nearly the same, the cloud top pressure within the field of view can be specified through the ratio of cloudy and clear sky radiance differences. The observed differences are compared to a series of radiative transfer calculations with various cloud pressures, and the tracer is assigned the pressure that best satisfies the observations.

Channel	Range[µm]
01: VIS0.6	0.56 - 0.71
02: VIS0.8	0.74 - 0.88
03: NIR1.6	1.50 - 1.78
04: IR3.9	3.48 - 4.36
05: WV6.2	5.35 - 7.15
06: WV7.3	6.85 - 7.85
07: IR8.7	8.30 - 9.10
08: IR9.7	9.38 - 9.94
09: IR10.8	9.80 - 11.80
10: IR12.0	11.00 - 13.00
11: IR13.4	12.40 - 14.40
12: HRV	0.5 - 0.9

Table 1. MSG SEVIRI spectral channels

In the present MSG-MPEF four different CTP retrieval techniques are implemented. Due to the existence of several water vapor (6.2 and 7.3 µm) and Infrared channels vapor (10.8 and 12.0 µm), water vapor intercept method (noted STC in the following) can explore four channel combination. In total, there are approximately 15 different CTP schemes implemented in the MSG-MPEF.

1.3 Results

A comparison of these techniques was accomplished with the data from SEVIRI on 24 February 2003 at 12:00h. Height assignments were made with all following methods:
- EBBT method using the channel at 10.8 µm,
- STC method using the channels at 10.8 and 6.2 µm,
- STC method using the channels at 10.8 and 7.3 µm,
- CO_2 slicing method using the channels at 10.8 and 13.4 µm,
- CO_2 slicing method using the channels at 12.0 and 13.4 µm, and finally
- CO_2 slicing method using the channels at 10.8, 12 and 13.4 µm.

Table 2 presents mean cloud top pressure for all height assignment methods and the associated root mean square (rms) about the mean. Results are presented only for targets for which none methods have failed. That corresponds to 7924 targets out of a total amount of 23280. The scatter is due both to the natural variability in the cloud height as well as technique inaccuracy. As expected the EBBT estimates show larger disagreement with results of all other methods. Many of the EBBT pressures are unrealistically low in the atmosphere, due to the semi-transparency of the high clouds tracers selected. Cloud top pressures calculated by STC method using the water vapor channels at 6.2 and 7.3 µm respectively are not in good agreement. The height assignments using the channel at 7.3 µm are on the average 70 hPa lower in the atmosphere than those estimated from the channel at 6.2 µm. On the contrary the three different configurations of the CO_2 slicing technique give average cloud top pressure with a difference less than 30 hPa between each other. Average height assignments calculated with CO_2 slicing method are located between the results calculated by the two STC methods. It is noted that a good agreement between the STC method using the 6.2 water vapor channel and the CO_2 slicing using the 13.4 and 10.8 channels. Schreiner and Menzel (2002) showed that the height assignment of STC method was on average 80 hPa higher than the CO_2 slicing cloud top pressure, using GOES-12 radiances (water channel, infrared channel and CO_2 channel centered at 6.5,10.7 and 13.3 µm respectively). The root mean square, which represent the deviation about the mean, is higher than 130 hPa for all these methods except for the STC method using the channel at 6.2 µm.

Method	Mean cloud top pressure (hPa)	Standard deviation (hPa)
EBBT	594	238
STC 10.8-6.2 µm	292	93
STC 10.8-7.3 µm	365	139
CO2 10.8-13.4 µm	302	136
CO2 12.0-13.4 µm	333	151
CO2 10.8-12.0-13.4 µm	315	139

Table 2. Mean cloud top pressure and RMS deviation calculated for all height assignment methods using SEVIRI data from the 24 February 2003

In addition to the mean height assignment and RMS scatter for each technique, it is interesting to know how these methods are correlated between each other. Table 3 presents the correlation coefficient (upper) and RMS (in hPa) for all height assignments using a method with respect to those using another method. This last value represents the deviation of one technique with respect to the other.

The three different configurations of CO_2 slicing methods have a very good correlation between each other, with a correlation coefficient greater than 0.9. The table 2 has shown that these methods give the same mean height assignments within a range of 30 hPa, in spite of the great RMS scatters. Then, these three configurations could be reasonably considered as equivalent for the height assignment of cloud motion vectors.

The correlation between the two different configurations of the STC method is not very good. The correlation coefficient is close to only 0.71, explaining only about 50 % of the variance, and the difference between the two mean cloud top pressure close to 70 hPa. Results obtained from the channel at 6.2 µm are not as good as expected. This could be explained because the dynamic range of counts of SEVIRI instrument in this channel is currently only about 200 counts. Improvement of the dynamic range in this channel should benefit the estimation of cloud top pressure with the STC method.

Then the correlation between STC method using channel at 6.2 mm and CO_2 slicing techniques are poor as well, with correlation coefficients close to 0.6. The correlation between STC method using the channel at 7.3 mm and CO_2 slicing techniques is better, with correlation coefficient close to 0.8.

Methods	EBBT	STC 10.8-6.2	STC 10.8-7.3	CO_2 10.8-13.4	CO_2 12.0-13.4	CO_2 10.8-12.0-13.4
EBBT	-	0.52 107	0.75 158	0.54 132	0.64 152	0.59 140
STC 10.8-6.2	0.52 107	-	0.71 96	0.52 81	0.51 85	0.53 83
STC 10.8-7.3	0.75 158	0.71 96	-	0.75 119	0.78 128	0.78 122
CO_2 10.8-13.4	0.54 132	0.52 81	0.75 119	-	0.90 136	0.97 135
CO_2 12.0-13.4	0.64 152	0.51 85	0.78 128	0.90 136	-	0.96 142
CO_2 10.8-12.0-13.4	0.59 140	0.53 83	0.78 122	0.97 135	0.96 142	-

Table 3. Correlation coefficient and RMS (in hPa) for all height assignments using a methods with respect to those using another method. Results have been calculated using SEVIRI data from the 24 February 2003

3 CONCLUSION

This study presents early results about comparison of several height assignment techniques using SEVIRI data. The results are based on SEVIRI data from the early commissioning phase processed with the SEVIRI prototype software (not the operational software). The classical EBBT method for opaque clouds has been tested, both with the STC intercept technique and the CO_2 slicing method. The H_2O intercept technique has been considered for 2 different configurations due to the presence of two water vapour channels on SEVIRI instrument (6.2 and 7.3 μm). CO_2 slicing method has been tested for three different configurations. The results show the STC intercept technique and the CO_2 slicing method for inferring the heights of semi-transparent cloud elements produce quite similar results, within a range of 60 hPa. All CO_2 slicing configurations are well correlated with each other and give the same results within a range of 30 hPa. The correlation between the two different STC techniques is poor, and the mean cloud top pressure difference between these two configurations is close to 70 hPa. The poor performance of the STC method using the 6.2 μm channel could due to dynamic range currently be limited to less than 8 rather than 10 bits.
These first results will be further verified and analysed through more extensive investigations in the future.

4 REFERENCES

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