ATMOSPHERIC MOTION VECTORS HEIGHT ASSIGNMENT TECHNIQUES WITH METEOSAT 8

R. Borde and A. Arriaga

EUMETSAT, Am Kavalleriesand 31, 64295 Darmstadt, Germany

ABSTRACT

The height assignment is currently the most challenging task in the AMV extraction scheme. The main approach used for Meteosat was the so-called ‘WV-IRW intercept method’ for semi-transparent cases. Opaque cloud heights are calculated from the representative Equivalent Black Body Temperatures derived from the AMV target area.

The advent of Meteosat 8 provides many new opportunities for improve height assignment of AMVs. Indeed, the existence of a CO2 absorption channel at 13.4 µm on SEVIRI intrument enables to use simultaneously the IR/CO2 ratioing methodology in addition to the WV-IRW intercept technique to calculate the height of the AMV targets. Due to the existence of several Water Vapour and Infrared channels on SEVIRI, each method can be implemented in slightly different configuration, and finally, there are nearly 15 cloud top pressure schemes implemented in the MSG-MPEF. This paper presents a comparison of the results retrieved by some of these methods using Meteosat 8 data.

1. INTRODUCTION

The current Meteosat satellites operated by EUMETSAT form a 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 remains 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 approache used for the previous generation of Meteosat satellites was the so-called ‘WV-IRW intercept method’ (Niemann et al., 1993, Schmetz et al, 1993) for semi-transparent clouds. Opaque cloud heights are calculated from the representative Equivalent Black Body Temperatures (EBBTs) derived from the AMV target area.

The advent of Meteosat 8 provides many new opportunities to improve height assignment of AMVs. The existence of a channel at 13.4 µm on SEVIRI intrument, centred in the CO2 absorption band, enables to use simultaneously the IR/CO2 ratioing method in addition to the WV-IRW technique for height assignment. This method proposed by Smith and Platt (1979) has been successfully applied to the height attribution of AMVs from the GOES satellites (Menzel et al., 1983, Merill et al, 1991). Due to the existence of SEVIRI channels within several absorption bands for Water Vapour and carbon dioxide, each method can be implemented in slightly different configuration, and finally, there are nearly 15 cloud top pressure schemes implemented in the MSG-MPEF. Therefore the comparison of the cloud top pressure results from all these methods is important in order to increase the performance of AMV height assignment. This paper presents results of such a comparison for some of these methods, using Meteosat 8 data on 29 March.

2. TECHNIQUES DESCRIPTION

The cloud top temperature (CTP) should be derived from SEVIRI observations using a number of techniques. For optically thick clouds the CTP is derived from comparisons of the observed radiance to radiative transfer calculations for black clouds, like for Meteosat. The temperature profile forecast from the '*European Centre for Medium-Range Weather Forecast's* are used as ancillary data and compared to brightness temperatures calculated from infrared Meteosat channel at 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, the movement of opaque clouds is not usually 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 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 and the atmospheric layer below the cloud. In that case the altitude assigned to the corresponding AMV utilising the 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' (Niemann et al., 1993). For semi-transparent clouds, the CO2-slicing (Eyre and Menzel, 1989; Nieman et al., 1993) is also used with MET-8 observations due to the existence of a channel centred in the CO2 absorption band at 13.4 µm on the SEVIRI instrument.

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 IRW (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 the semitransparent cloud and a second pair from an adjacent cloud free area. These data are used in conjunction with forward calculations of the radiance at both spectral channels for opaque clouds at different levels in a given atmosphere represented by forecast profiles of temperature and humidity. The intersection of measured and calculated radiances will occur at clear sky radiances and cloudy radiances. The cloud top temperature is extracted from the cloud radiance intersection (Schmetz et al., 1993).

The general equation of the CO2 slicing technique is:

$$\frac{R_{cf}(CO_2)-R_{cd}(CO_2)}{R_{cf}(IR\nu)-R_{cd}(IR\nu)}=\frac{\varepsilon(CO_2)}{\varepsilon(IR\nu)}\frac{\left[R_{suf}(CO_2)-R_{bcd}(CO_2,P_c)\right]}{\left[R_{suf}(IR\nu)-R_{bcd}(IR\nu,P_c)\right]} \qquad (1)$$

Where R_{cf} and R_{cd} are respectively the cloud free and cloudy radiances, which are measured in the CO2 and Infrared bands by the SEVIRI instrument. R_{suf} and $R_{bcd}(Pc)$ are the surface radiance and the Planck blackbody radiance for a cloud at the level Pc in the atmosphere. These radiances are calculated with a radiative transfer model in the CO2 and Infrared bands. $\varepsilon(CO_2)$ and $\varepsilon(IR_\nu)$ are the emissivities in the two bands.

The left side of the equation 1 corresponds to SEVIRI observations, the right side to radiative transfer calculations. Assuming that the emissivities of the two channels are nearly the same, the cloud top pressure within the field of view can be specified as the ratio of cloudy and clear sky radiance differences. The observed ratio of differences is compared to a series of radiative transfer calculations at various cloud pressures Pc, and the tracer is assigned the pressure that best satisfies the observations.

In the present MSG-MPEF four different CTP retrieval techniques are implemented. Due to the existence of two water vapour channels centred at 6.2 and 7.3 µm) the water vapour intercept method (noted STC below) explore two different channel combinations. In total, there are 15 different CTP schemes implemented in the MSG-MPEF.

3. RESULTS

A comparison of some of these techniques was accomplished using the data from SEVIRI on 29 March 2004 at 1200 UTC and 1800 UTC. Priority issue was not to compare all methods between each other, but to compare the STC technique, which is currently used for Meteosat, to the CO2 slicing technique, which is used for GOES. Then, taking into account of the different configurations implemented for Meteosat 8, the results are presented for all the 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,
- CO2 slicing method using the channels at 10.8 and 13.4 µm,
- CO2 slicing method using the channels at 12.0 and 13.4 µm, and finally
- CO2 slicing method using the channels at 10.8, 12 and 13.4 µm.

Table 1 presents the mean of the retrieved cloud top pressure for all height assignment methods and the associated root mean square (RMS) about the mean, using SEVIRI data from the 29 March 2004 1200 UTC and 1800 UTC. Results are presented only for targets for which no method had failed. That corresponds to 15028 targets on a total amount of 23124 for the second data set (29 March 2004, 1800 UTC). As expected, the EBBT estimates show larger disagreement to results of all other methods. Many of the EBBT pressures are unrealistically low in the atmosphere, due to the semi-transparency of the selected high cloud tracers. Cloud top pressures calculated by the STC method using the water vapour channels at respectively at 6.2 and 7.3 µm are not in good agreement. The results of the STC method using the channel at 7.3 µm are on the average 50 hPa lower in the atmosphere, than those estimated using the channel at 6.2 µm. This difference is large considering that results were calculated using the same methodology. At the opposite, the three different configurations of the CO2 slicing techniques give average cloud top pressure with a difference lesser than 20 hPa between each other. Mean cloud top pressures calculated with the CO2 slicing methods are very close to those calculated by STC methods with the channel at 7.3 µm. Schreiner and Menzel (2002) showed that the height assignment of STC method was on average 80 hPa higher than the CO2 slicing cloud top pressure, using GOES-12 radiances (water vapour channel, infrared window channel and CO2 channel centred at 6.5, 10.7 and 13.3 µm respectively). The root mean square, which represents the deviation about the mean, is higher than 120 hPa for all these methods except for the STC method using the channel at 6.2 µm.

Method	**12:00 UTC**		**18:00 UTC**	
	Mean cloud top pressure (hPa)	**RMS deviation (hPa)**	**Mean cloud top pressure (hPa)**	**RMS deviation (hPa)**
EBBT	563	143	527	142
STC 10.8-6.2 µm	310	107	286	98
STC 10.8-7.3 µm	350	121	320	124
CO2 10.8-13.4 µm	352	148	322	143
CO2 12.0-13.4 µm	371	143	337	139
CO2 10.8-12.0-13.4 µm	358	146	327	140

Table 1. Mean cloud top pressure and RMS deviation calculated for all height assignment methods using SEVIRI data from the 29 March 2004 12:00 and 18:00 UTC.

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 2 presents the correlation coefficients of the results obtained from two different techniques.

Methods	EBBT	STC 10.8-6.2	STC 10.8-7.3	CO2 10.8-13.4	CO2 12.0-13.4	CO2 10.8-12.0-13.4
EBBT	-	0.53	0.55	0.51	0.54	0.53
STC 10.8-6.2	0.53	-	0.80	0.77	0.81	0.79
STC 10.8-7.3	0.55	0.80	-	0.83	0.86	0.85
CO2 10.8-13.4	0.51	0.77	0.83	-	0.96	0.99
CO2 12.0-13.4	0.54	0.81	0.86	0.96	-	0.98
CO2 10.8-12.0 -13.4	0.53	0.79	0.85	0.99	0.98	-

Table 2. Correlation coefficient of results obtained from two different techniques. Results have been calculated using SEVIRI data from the 29 March 2004 1200 UTC.

The three different configurations of the CO2 slicing methods have a very good correlation between each other, with a correlation coefficient greater than 0.96. Table 1 showed that these methods give the same mean cloud top pressure within a range of 20 hPa, in spite of the great RMS scatters. Thus, these three configurations can be considered as equally well suited for the height assignment of cloud motion vectors. As an example, Figure 1 shows a scatter plot of the pressure obtained by the CO2 slicing method using channels 10.8 µm and 12 µm, versus the pressure obtained by the CO2 slicing method using only the channel 10.8 µm. The correlation coefficient is close to 0.96 and the bias is around 15 hPa.

The correlation between the two different configurations of the STC method is not as good as expected, as shown in Figure 2. The correlation coefficient is close to only 0.8, and the bias is near 33 hPa. It is interesting to note on the Figure 2 that the correlation between the two configurations is better for high level targets, and it becomes worse and worse when the clouds are lower in the atmosphere. The STC method using the channel 6.2 µm generally overestimates the height comparing to the STC using channel at 7.3 µm. There is presently no clear explanations for this difference, and more detailed investigations are needed to understand it.

Two examples of correlation between the STC methods and CO2 slicing techniques are presented on the Figure 3. The results of the CO2 slicing technique using the IR channel at 10.8 µm are presented on the left as function of the STC method using the channel at 6.2 µm, on the right as function of STC method using the channel at 7.3 µm. The correlation coefficient is higher for the second comparison (STC 7.3), close to 0.83. and the bias is very low, only to 2 hPa. On the first plot, it can be noted like on the Figure 2, that the correlation between the two methods looks worse and worse when the targets are located lower in the atmosphere. That is not the case for the STC method using channel at 7.3, which remains quite correctly correlated with the results of the CO2 slicing method for all heights.

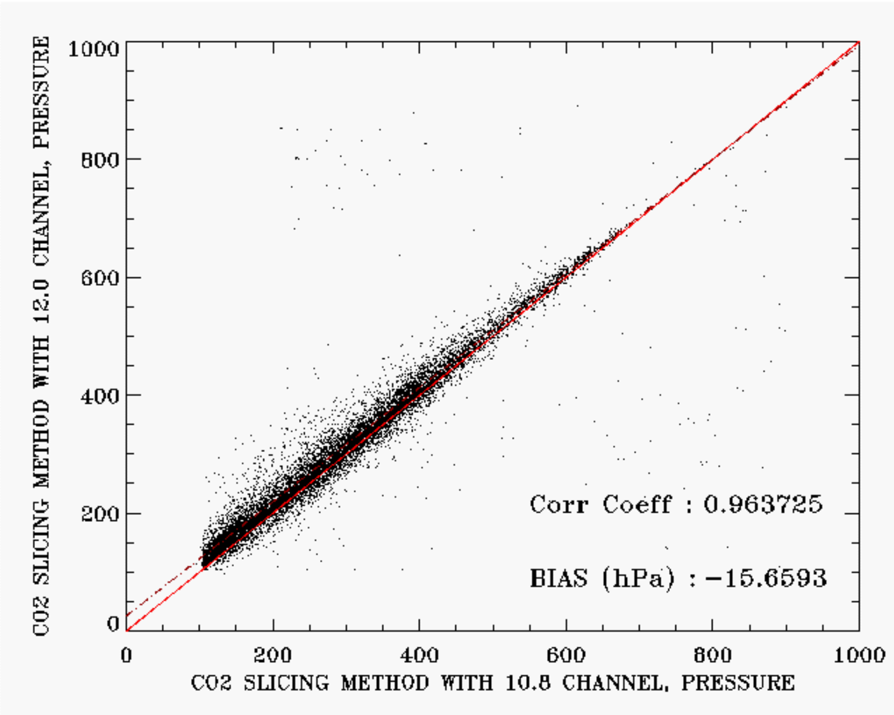


Figure 1: Pressure calculated by CO2 slicing method using channel 10.8 µm and 12 µm, versus the pressure calculated by the CO2 slicing method using only the channel 10.8 µm. SEVIRI data from the 29 March 2004 1200 UTC.

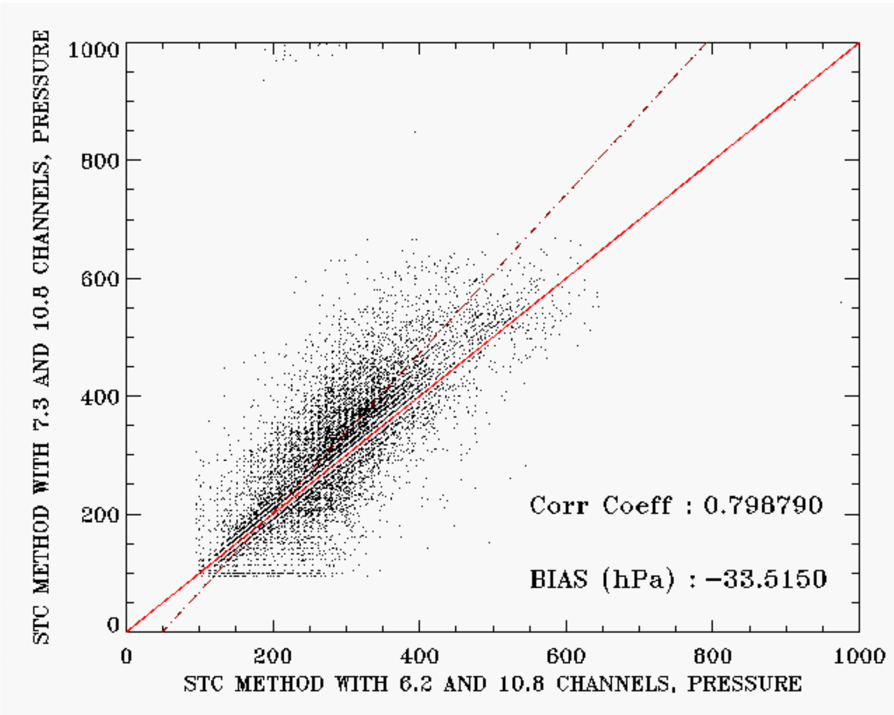
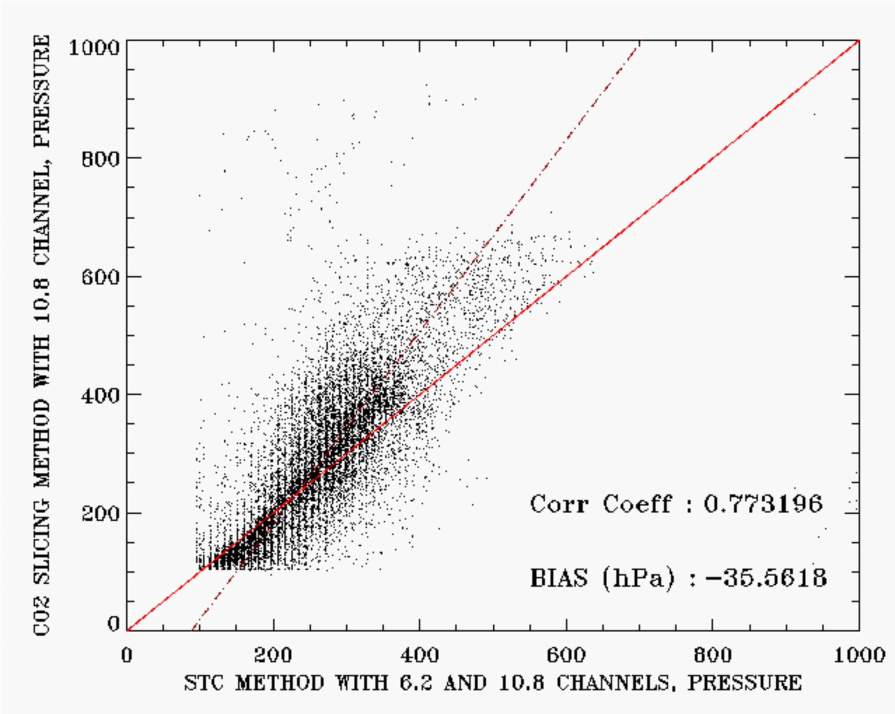


Figure 2: Pressure calculated by STC method using channel 10.8 µm and 7.3 µm, versus the pressure calculated by the STC method using the channel 10.8 µm and 6.2 µm. SEVIRI data from the 29 March 2004 12 00 UTC.



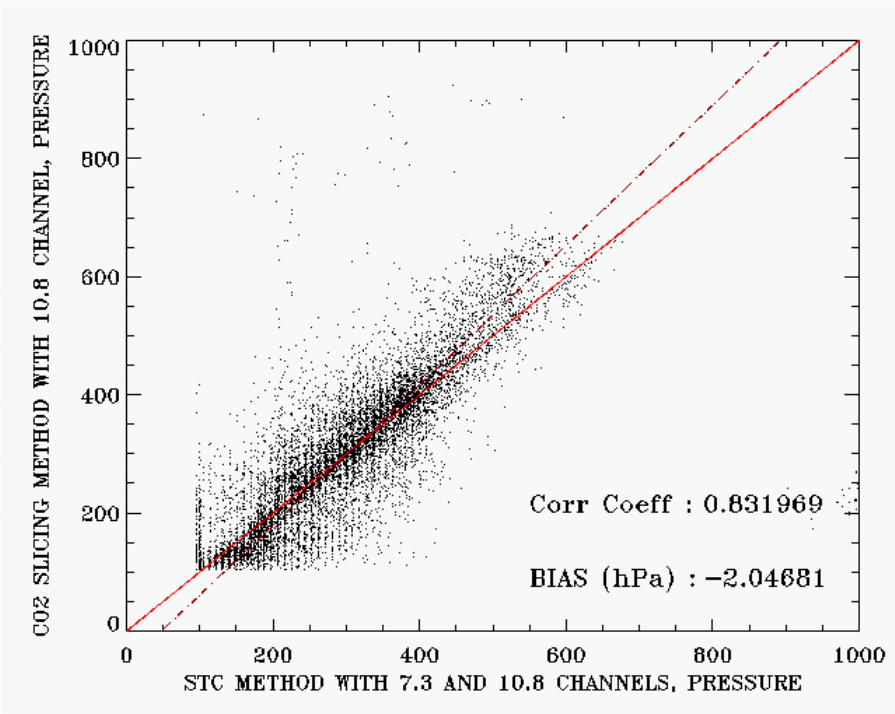


Figure 3: Pressure calculated by CO2 slicing method using channel 10.8 µm, versus the pressure calculated by the STC method using the channel 6.2 µm (upper), using the channel at 7.3 µm (lower). SEVIRI data from 29 March 2004 1200 UTC.

4. CONCLUSION

This study presents the results from the comparison of several height assignment techniques using Meteosat 8 data. The classical EBBT method for opaque clouds has been tested, both with the STC intercept technique and the CO2 slicing method. The STC intercept technique has been considered for 2 different configurations due to the presence of two water vapour channels on the SEVIRI instrument (6.2 and 7.3 µm).

The CO2 slicing method has been used for three different configurations, using the IR channel at 10.8, at 12 and both together respectively. The results show the STC method using channel at 7.3 and the CO2 slicing methods for inferring the heights of semi-transparent cloud elements produce quite similar results, within a range of 20 hPa. Correlation coefficients are greater than 0.8, and biases lesser than 15 hPa. The STC method using channel at 6.2 µm generally overestimates the cloud top height with respect to all other methods, and this overestimation increases when the clouds are lower in the atmosphere. All CO2 slicing configurations are well correlated between each other and give the same results within a range of 20 hPa. The correlation between the two different STC techniques is poorer as expected, and the mean cloud top pressure difference between these two configurations is close to 50 hPa.

More extensive and detailed investigations are needed in the future in order to understand these results, and especially those from the channel at 6.2 µm.

5. REFERENCES

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