Intercalibration of the Meteosat-7 Water Vapor Channel with SSM/T-2

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1. INTRODUCTION

There has been growing interest to quantitatively observe the upper tropospheric humidity (UTH) from space. Since the UTH is largely controlled by large-scale atmospheric circulations, geostationary satellites are of particular interest with their capability to observe the time variability of the UTH with high resolution. The European Meteosat satellites are part of a ring of geostationary satellites observing the tropical and mid-latitude regions of the earth in a regular manner with water vapor (WV) channel sensitive to the UTH field between about 500 and 200 hPa.

The current generation of Meteosat satellites does not have an adequate on-board calibration system providing absolute calibration. Instead vicarious calibration is used, which relies on radiosonde profile measurements in clear sky areas and radiative transfer calculations (Schmetz, 1989). Although this method has been improved continuously (van de Berg et al., 1995) it is prone to bias errors, primarily due to incorrect humidity measurements of the radiosonde systems (Gaffen et al., 1991).

One way to cross-check the accuracy of the operational vicarious calibration is to match up Meteosat observations with radiance observations from other satellites that are (1) sensitive to radiation exiting the same levels in the atmosphere as for the Meteosat WV channel, and (2) that are absolutely calibrated. While it would be obvious to utilize for this purpose satellite channels in the water vapor band around 6.3 μm, this paper describes results from a pilot study on the cross-calibration with well-calibrated microwave observations from Special Sensor Microwave Water Vapor Profiler (SSM/T-2) whose 183.3±1 GHz channel has weighting function very similar to the Meteosat WV channel -- see Fig.1.

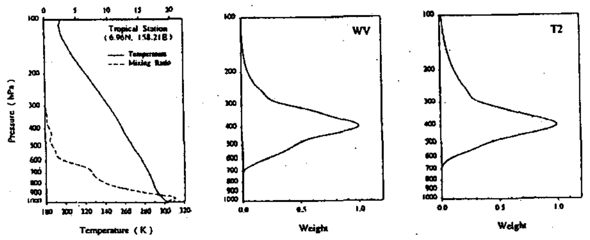

Fig. 1: Humidity and temperature profiles, and normalized weighting functions for a tropical station station of TIGR dataset. WV and T2 in diagrams represent Meteosat water vapour channel and SSM/T-2 183.3±1 GHz channel, respectively.

2. INTER-CALIBRATION PROCEDURES

The intercalibration can be summarized as follows:

- All Meteosat pixels with nearly equal viewing angles within an SSM/T-2 footprint (48 km resolution) are selected in an area of 30°N-30°S and 30°E-30°W, around the sub-satellite point of the geostationary Meteosat. Data are from 10 and 11 July 1998 and include eight SSM/T-2 overpasses.
- Each Meteosat pixel is examined for cloud contamination by applying a scenes analysis based on pixel-based threshold techniques (Lutz, 1999).
- clear-sky brightness temperatures (TB_{WV}) and corresponding counts (C_{WV}) of the Meteosat-7 WV channel are compiled by averaging over all Meteosat-7 pixels within a collocated SSM/T-2 scene.
- In total 947 pairs of TB_{WV} and TB_{T2} have been obtained for this pilot study.
- The transfer function between simulated brightness temperatures for Meteosat-7 WV channel and SSM/T-2 183.3±1 GHz channel is obtained using radiosonde temperature and moisture profiles in the TOVS Initial Guess Retrieval (TIGR) database (Scott et al., 1991) as inputs for both infrared and microwave transfer models. Profiles at latitudes higher than 60° are not included leaving a total number of 1615 simulations. This yields the following transfer function:

$$TB_{WV} = 50.07 + 0.77\, TB_{T2} \qquad (1)$$

The details of this intercalibration are found in a paper by Sohn et al. (1999).

3. RESULTS

From pairs of TB_{WV} and TB_{T2} it was noted that there is a strong linear relationship between two measurements with a correlation coefficient of 0.97, suggesting that Meteosat-7 measurements can be calibrated against SSM/T-2 microwave measurements The rms difference is about 5.4°K. On the other hand the linear relationship also suggests that UTHs from both measurements should be consistent with each other because the weighted upper-tropospheric relative humidity has a linear relationship with the logarithm of the WV channel brightness temperature (Soden and Bretherton, 1993), and with the logarithm of SSM/T-2 183.3±1 GHz brightness temperature (Spencer and Braswell, 1997).

Fig. 2 displays the scatter plot of simulated TB_{WV} versus TB_{T2}., yielding the relationship of Eq. (1).

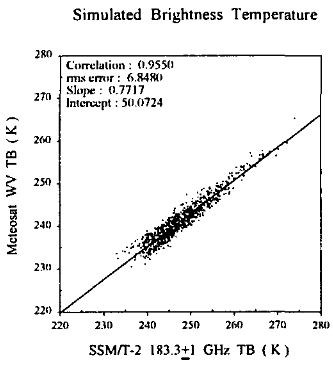

Fig.2:Scatterplot of simulated brightness temperatures for SSM/T-2 183.3±1 GHz channel and for Meteosat 7 water vapor channel.

Fig. 3 displays the scatter plot of the brightness temperature for Meteosat-7 estimated with Eq. (1) versus the observed Meteosat WV brightness temperatures using the operational calibration. Clearly there is bias, with brightness temperatures from the Meteosat-7 WV channel are overestimated by about 3°K, *suggesting that the current operational calibration* coefficient is biased high.

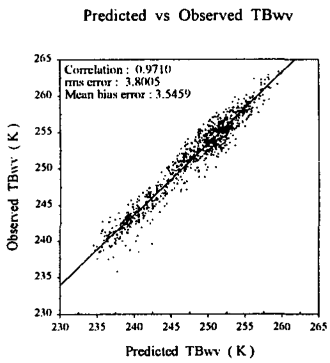

Fig. 3: Scatter plot of brightness temperature estimated from Meteosat water vapor channel and Meteosat brightness temperature calculated from SSM/T-2 183.3±1 GHz *measurements*.

Computed radiances are then compared to the corresponding Meteosat counts as shown in Fig. 4. The solid line is the best fit with correlation of 0.97. We obtain a new calibration coefficient with the value of 0.00899 Wm^{-2} sr^{-1} for the analysis period from June 10 to June 11, 1998 whereas the operational calibration coefficient was 0.01019 Wm^{-2} sr^{-1} until 0730 UT 11 July and was changed into 0.01032 Wm^{-2} sr^{-1} after 0930 UT 11 July. The relative difference between the operational value and the new coefficient estimated in this study suggests that the current Meteosat-7 operational calibration coefficient is biased high by about 12-13%. It is interesting to note that the intercept of the regression (zero radiance count) corresponds to the offset count of Meteosat-7 radiometer measured during space scans; this puts additional confidence on this inter-calibration with SSM/T2.

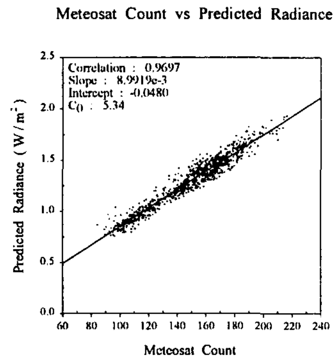

Fig. 4: *Scatterplot of predicted radiance and Meteosat* WV channel count. Radiance is derived from SSM/T-2 183.3±1 GHz brightness. Diagonal solid line is the best linear fit.

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