INTERNAL REPORT

SRT Site Monitoring: a comparison Between Radiometer and Radiosonde profiles

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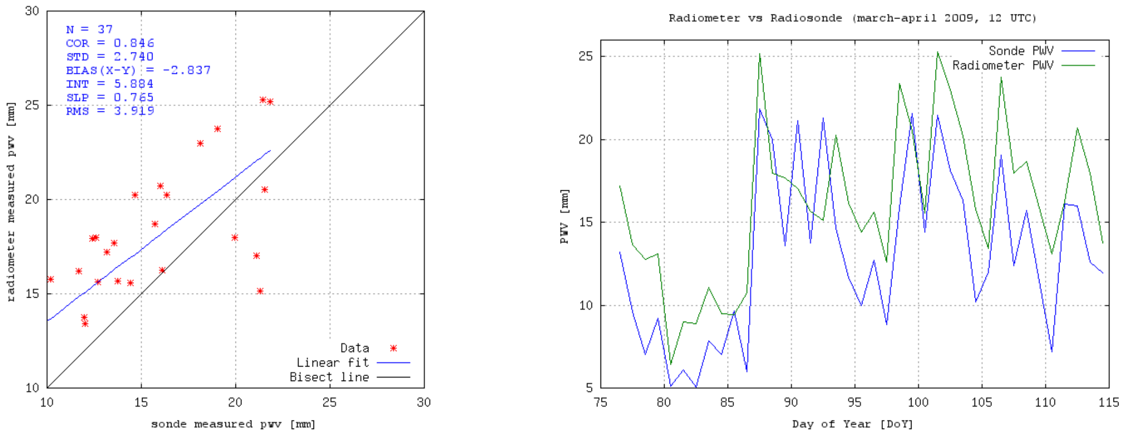
Introduction

Cagliari's astronomical observatory OAC located in Poggio dei Pini is in the process of buying a new profiling radiometer ($Radiometrics\ MP-3000A$ [1]) useful for the Sardinia Radio Telescope project. This instrument may perform azimuth-elevation scans of the atmosphere and it works in two microwave spectral regions: the K band ($\cong 20-30\ GHz$) and the V band ($\cong 50-60\ GHz$). The former is used mainly to retrieve integrated water vapour IWV and integrated liquid water ILW, while the latter is used to retrieve temperature profiles. Overall the radiometer has 35 frequency channels but at the moment we are using a standard radiometer procedure file that implements only 22 channels.
Since mid-March, the radiometer has been positioned on top of OAC's roof and is continuously measuring the afore mentioned geophysical quantities in the zenith direction.
It is interesting to note that a microwave radiometer actually measures sky emission in voltage units, but through calibration and an appropriate transfer function, measurements are usually expressed in brightness temperature units T_b. These units are more appropriate because they are directly related to the temperature at which the atmosphere is emitting at a given frequency and also with antenna and receiver noise. Output in terms of voltage units is named $level0$ data, while output in T_b units is named $level1$ data. In order to retrieve geophysical quantities, $level1$ measurements are taken as input for appropriately chosen retrieving techniques. The radiometer software is already equipped to retrieve geophysical quantities through a Stuttgart artificial neural-network simulator. A standard back-propagation algorithm is used for training, and a standard feed-forwards network is used for profile determination. Profiles are given on a 58 level vertical grid, as height increases resolution decreases and approaches climatological values above 7 km; geophysical output data is named $level2$ data.
The separation of data in different levels makes it so that a user may immediately have geophysical retrievals or he may create his own retrieval algorithms and estimate geophysical quantities starting with $level1$ type data; in this report, radiometer software retrievals were used.
In the paragraphs that follow we compare radiometer measured IWV with radiosonde measurements, the radiosondes are launched at the airport of Elmas, which is roughly 20 km away from OAC. In theory this distance is acceptable considering that radiosondes during their ascent can move horizontally by as much as 50 km from the initial launch position. Nevertheless, Elmas airport is located at sea level between the sea and a lagoon so measurements, especially in the first few hundred meters, are probably affected by unique local microclimate effects. In addition to this OAC is 200 m above sea level so in order to compare radiometer retrievals of IWV with radiosonde measurements, we must "clip-off" the first 200 m of radiosonde ascent measurements. We are still investigating whether this technique is acceptable or whether more sophisticated methods should be used.
For temperature profiles, once again we simply compare radiometer retrievals with sonde measurements, the same is true for relative humidity RH profiles. One should bear in mind that as height increases the radiometer retrieved geophysical profile resolution decreases especially after an altitude of 7 km. For T_b measurements we compare $level1$ radiometer measurements with model simulated T_b, the latter is obtained by taking the radiosonde profiles and using them as input for a radiative transfer model (in this case we used the $ARTS$ model [2]), with Rosenkranz parametrization for line and continuum absorption.
In the simulations of T_b, liquid water content of clouds was not simulated. This probably means that those frequency channels close to atmospheric windows and sensitive to liquid water (eg. 30 GHz) might not agree very well with radiometer measurements especially in the case of precipitation and heavy cloud cover.

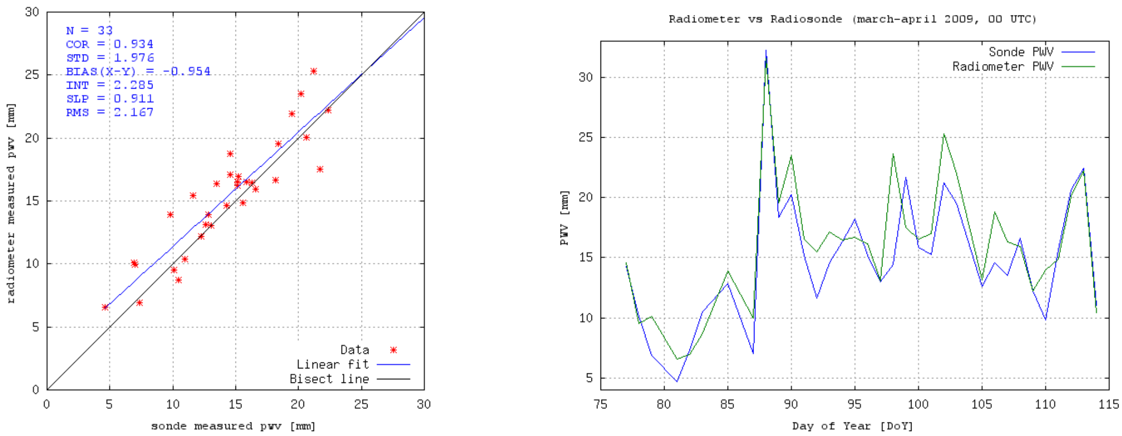
Integrated Water Vapour IWV

In this section, radiometer retrievals of IWV are compared with radiosonde measurements. In order to obtain a single IWV radiosonde measurement we have to integrate a whole relative humidity RH profile; as mentioned earlier the first 200 m are clipped-off. This is done to align vertically the radiometer location (alt. 200 m above sea level) with the radiosonde launch location (alt. 0 m above sea level). The comparisons are made at 12 UTC (representative of day time) and at 00 UTC (representative of night time) for the period March-April. As we may



(a) (b)

Figure 1: ***Day time comparisons of IWV (also known as PWV) between radiometer and radiosonde (a) scatter plot and (b) time series.***

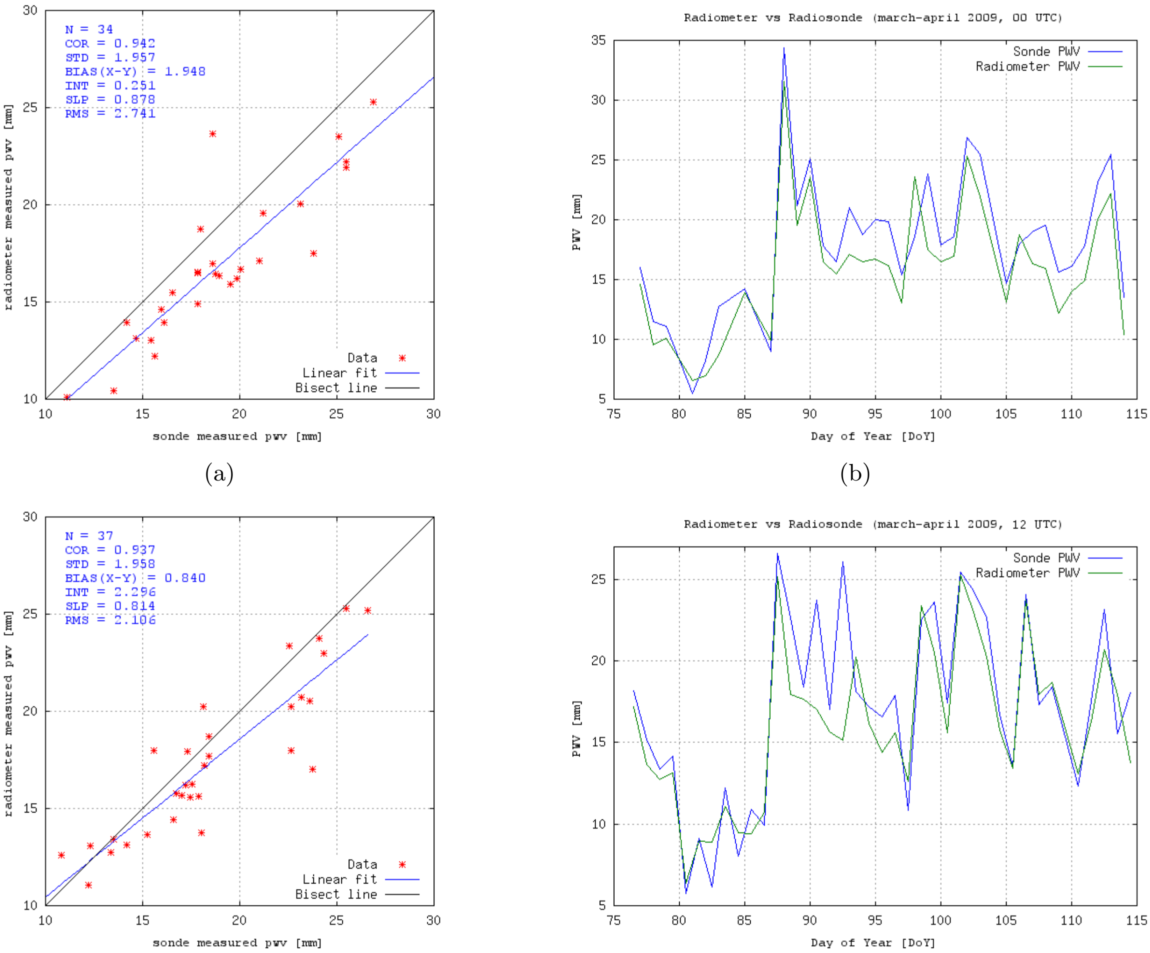


(a) (b)

Figure 2: ***Night time comparisons of IWV (also known as PWV) between radiometer and radiosonde (a) scatter plot and (b) time series.***

see from figure 1 and 2 radiosonde retrievals and radiosonde measurements are consistent with each other especially during night time. During day time radiosonde measured IWV appear to be systematically lower than radiometer retrievals. Maybe it is not correct to simply clip-off 200 m of radiosonde data in order to align vertically the radiosonde location with the radiometer location. This problem is more evident during day time than during night time, this could be due to higher atmospheric instability present in day time hours. Probably the less stable the atmosphere is the less correct the "clipping technique" is. In addition to this the Elmas airport radiosonde launch location is in a peculiar position in which a microclimate can easily develop.

In figure 3 we compare non-clipped radiosonde measurements with the radiometer retrievals, this is done to investigate further the clipping-off technique. The results seem more consistent



(a) (b) (c) (d)

Figure 3: ***Comparisons of IWV (also known as PWV) at night time (plots a and b) and at day time (plots c and d) between radiometer retrivals and radiosonde measurements***

with each other in this case than they did when we clipped-off 200 m of radiosonde data, especially during day time.

Temperature Profiles

The $MP-3000A$ radiometer may retrieve temperature profiles by using V band frequencies and display each profile on a vertical grid made up of 58 fixed nodes. The vertical grid is very dense at low altitudes and gets progressively less dense at high altitude, in fact after 7 km of altitude the resolution decreases and the radiometer retrieved temperature profiles approach climatological values. The radiosonde measured temperature profile was interpolated on the same vertical grid as the one described above, and the lower 200 m were clipped off.
Figures 4 and 5 illustrate a sample of comparisons between radiosonde measured temperature profiles and those retrieved with the radiometer at 12 UTC and at 00 UTC in the period March-April.

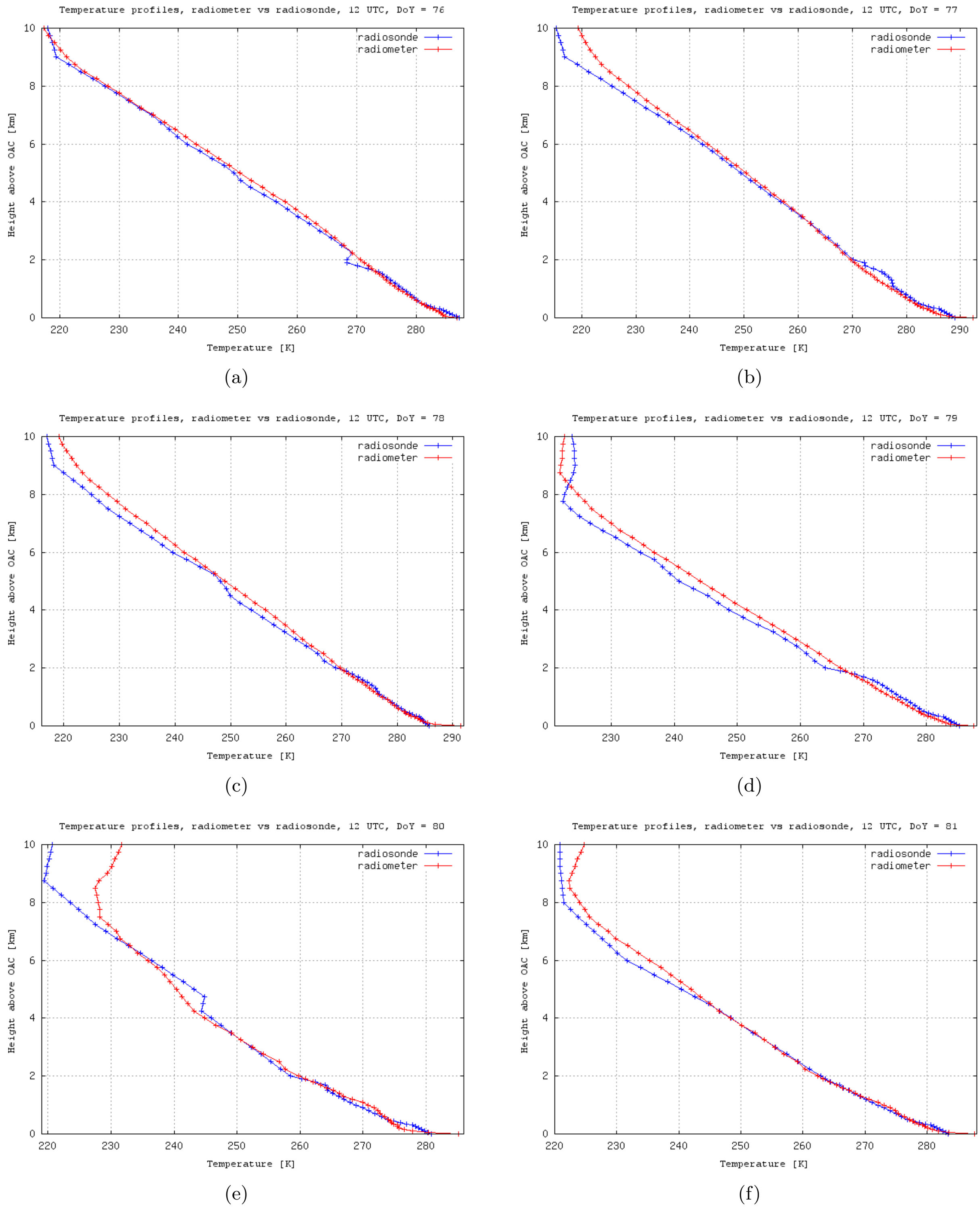
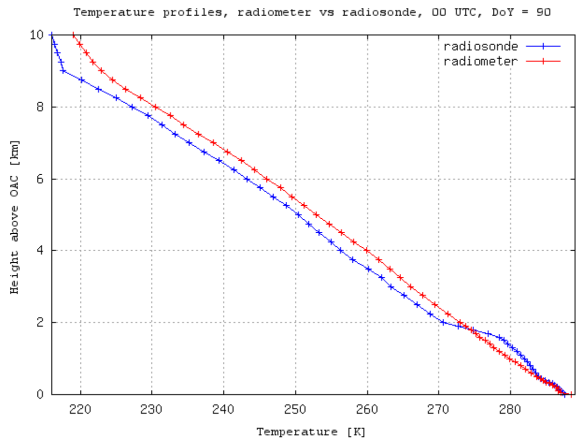
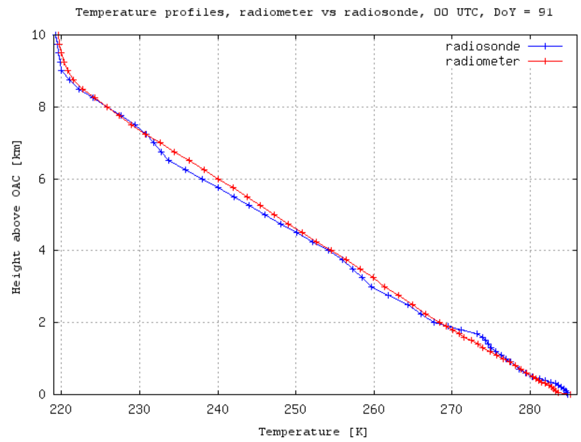


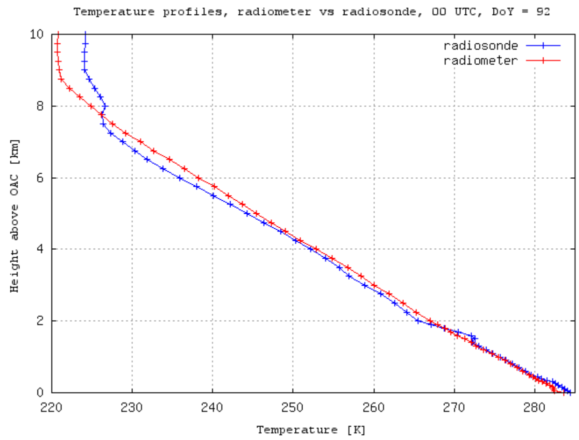
Figure 4: ***Day time comparison between radiometer retrived temperature profiles and radiosonde measured ones.***



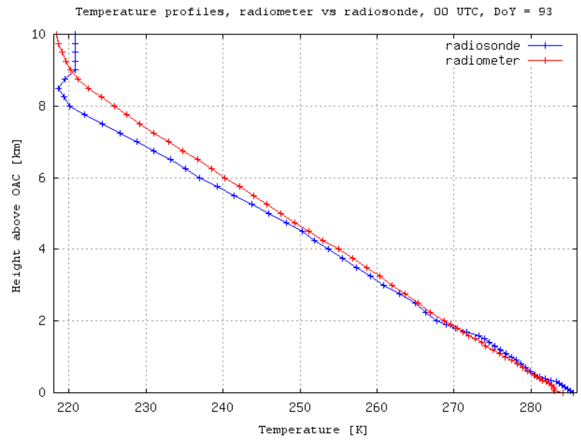
(a)



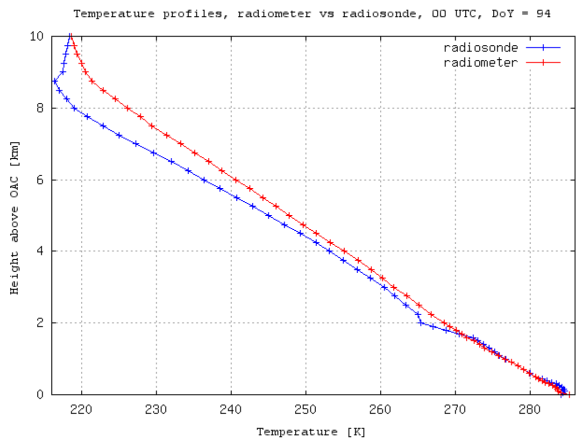
(b)



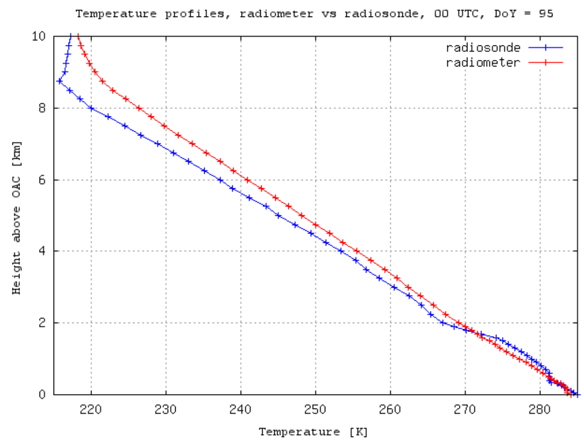
(c)



(d)



(e)



(f)

Figure 5: ***Night time comparison between radiometer retrieved temperature profiles and radiosonde measured ones.***

In both cases (night and day) radiometer retrievals and radiosonde measurements seem to be consistent with each other especially at lower altitudes. As expected, as height increases the differences between measurements also increase. One thing to note though is that the radiometer retrieved temperature profiles seem to be heavily smoothed out, while the radiosonde profiles show finer vertical detail. This might be due to the particular retrieval algorithm used by the radiometer software, maybe by applying different algorithms to $level1$ data we might be able to retrieve temperature profiles with finer vertical detail. Finally, no significant differences seem to exist between the accuracy of night time retrievals and day time ones.

Relative Humidity Profiles

In theory the $MP-3000A$ radiometer should be able to measure also relative humidity profiles, for the period March-April we compared all of these radiometer retrieved profiles with radiosonde measured ones, as usual the first 200 m of the radiosonde measurements were clipped-off. Figure 6 shows some of these comparisons, clearly there is no agreement what so ever between radiometer retrievals and radiosonde measurements. This is true for all the period under examination (day and night), it seems as the radiometer isn't able to retrieve RH profiles. Maybe this is due to the fact than many channels available in the K band were not used in the standard procedure file and so the neural network did not have enough information to perform good RH profile retrievals. It is also possible that the neural network algorithm hasn't been trained accordingly. In future months we will investigate this problem further.

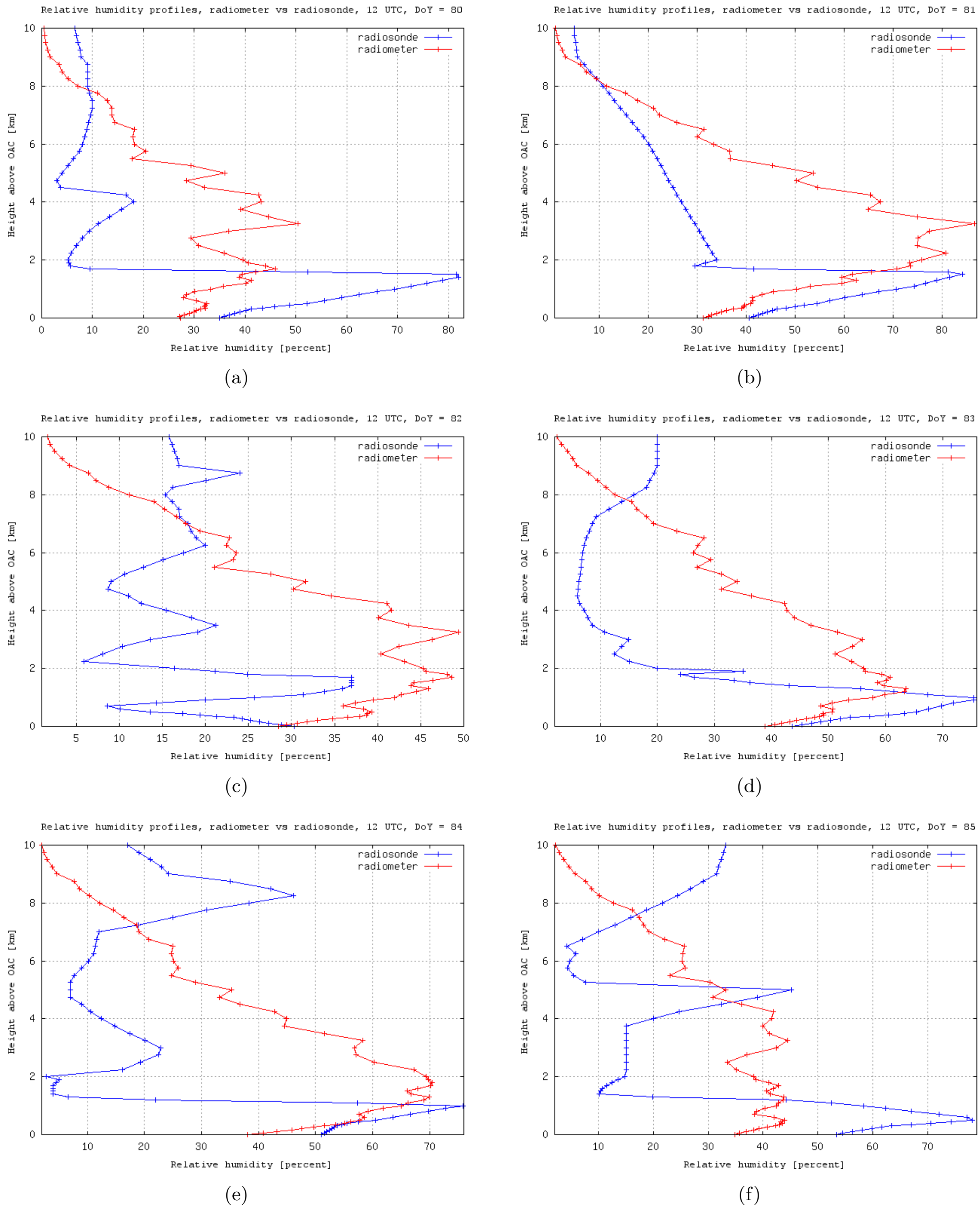


Figure 6: ***Day time comparison between radiometer retrived relative humidity profiles and radiosonde measure ones.***

Brightness Temperature Tb

As mentioned earlier, the radiometer measures sky brightness emission at different frequencies in terms of brightness temperature T_b. Figures 7 and 8 show the time series of all channels available at day time (12 UTC) and at night time (00 UTC) for the period March-April 2009.

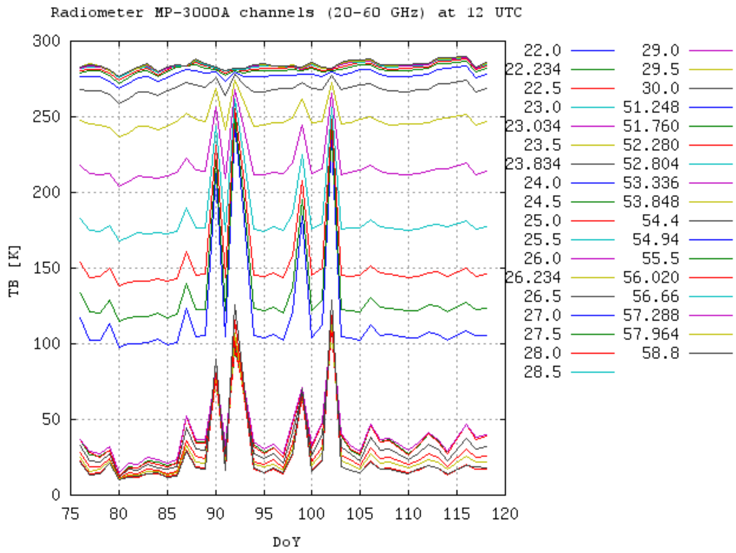


Figure 7: ***Time series of radiometer T_b at all channels during day time.***

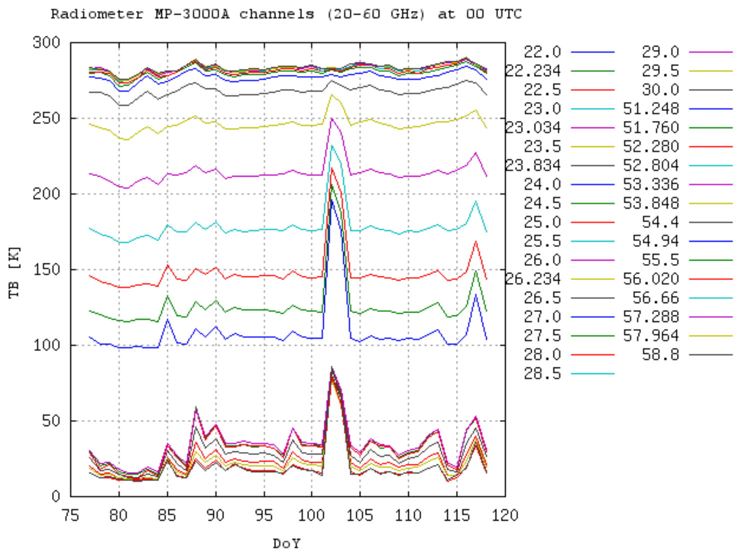


Figure 8: ***Time series of radiometer T_b at all channels during night time.***

We compared for each frequency channel the radiometer $level1$ measurements with T_b simulated with a radiative transfer model ($ARTS$) that used as input radiosonde profiles, we set the platform height at 200 m in order to be consistent with the real radiometer altitude. Cloud liquid water was not included so it is reasonable to imagine that channels far away from resonant absorption lines will show some bias.

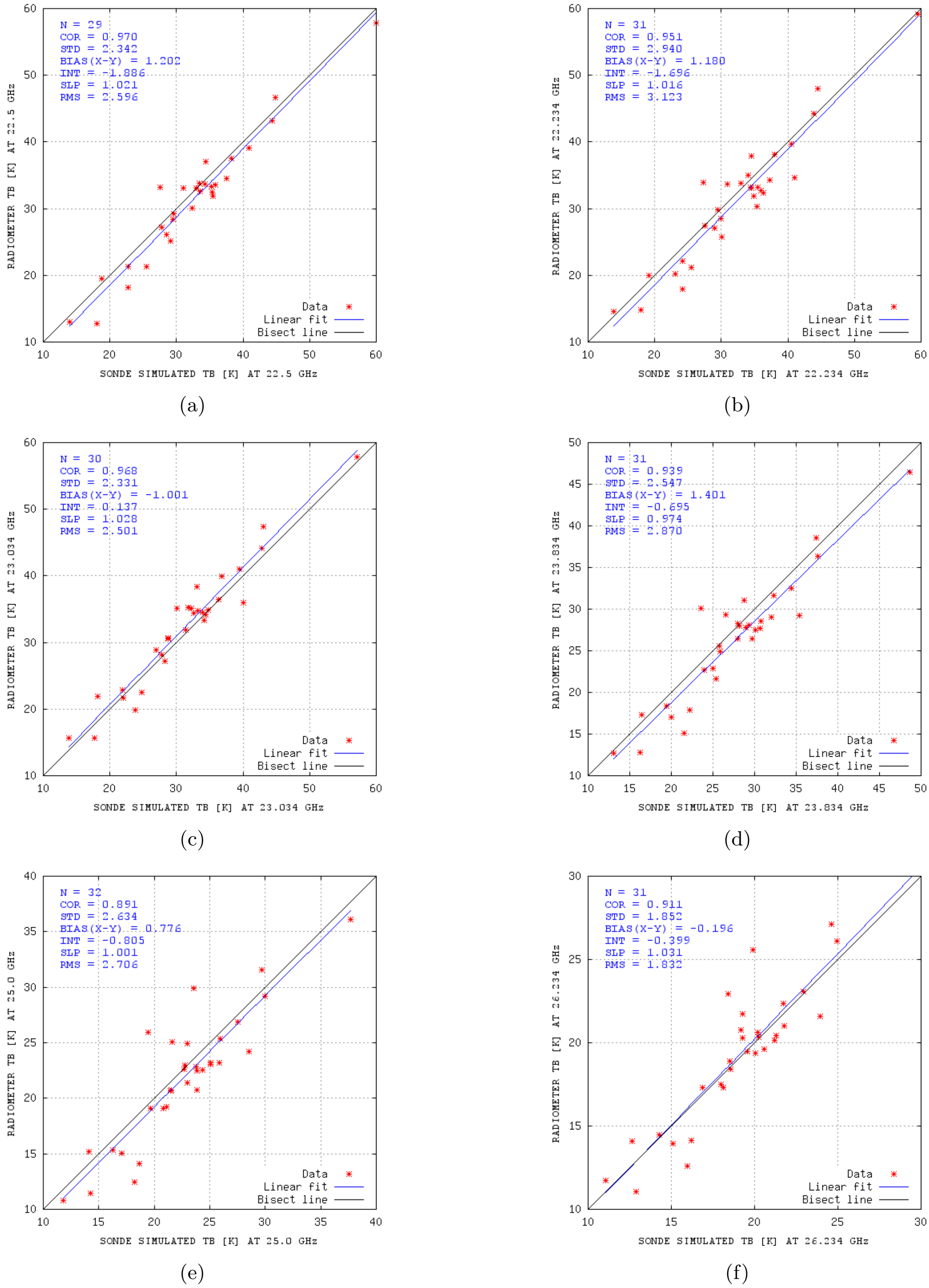


Figure 9: ***Night time comparison between radiometer measured T_b and model simulated through radiosonde input T_b (channels 22-26 GHz).***

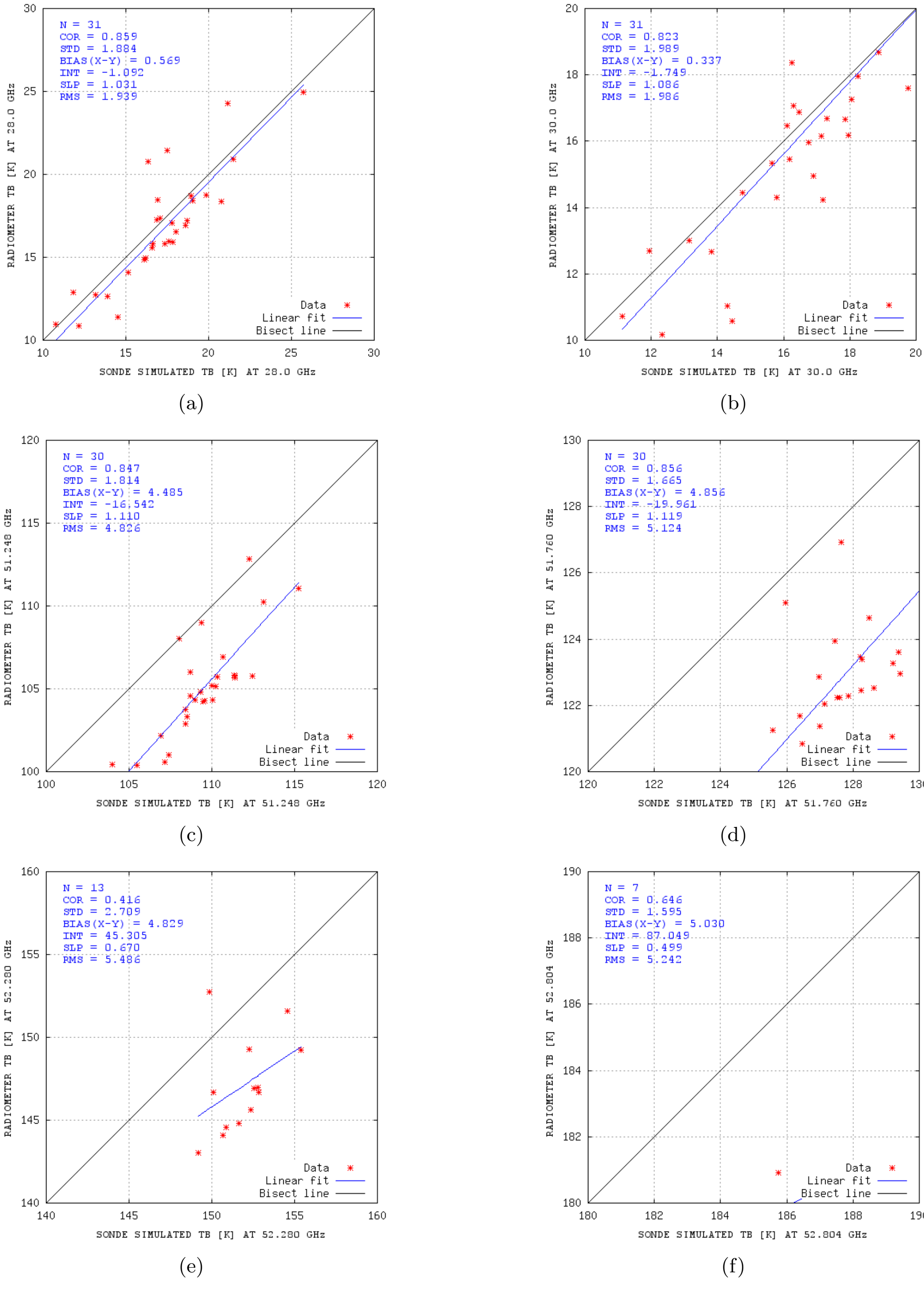


Figure 10: ***Night time comparison between radiometer measured T_b and model simulated through radiosonde input T_b (channels 28-52 GHz).***

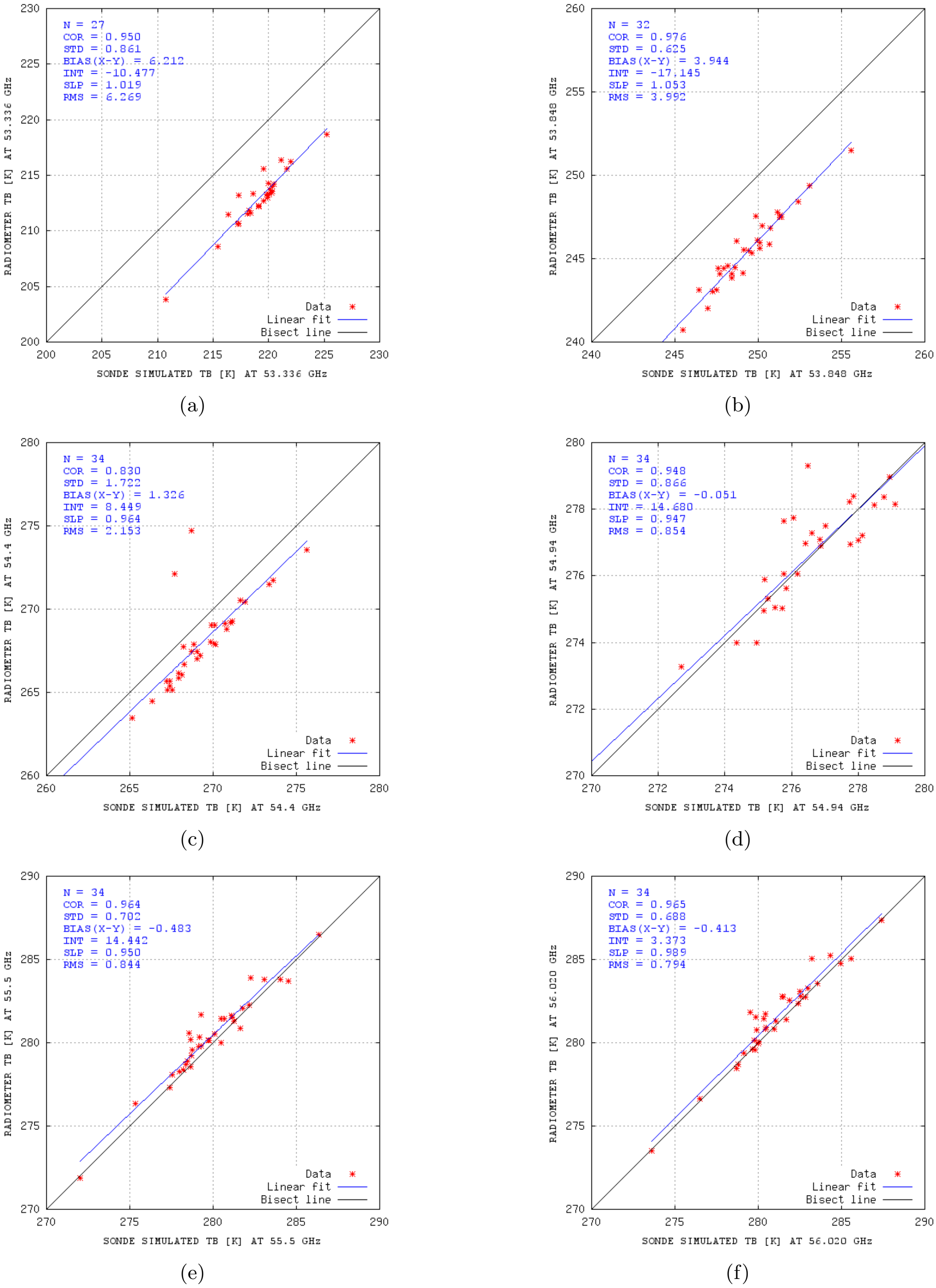


Figure 11: ***Night time comparison between radiometer measured T_b and model simulated through radiosonde input T_b (channels 53-56 GHz).***

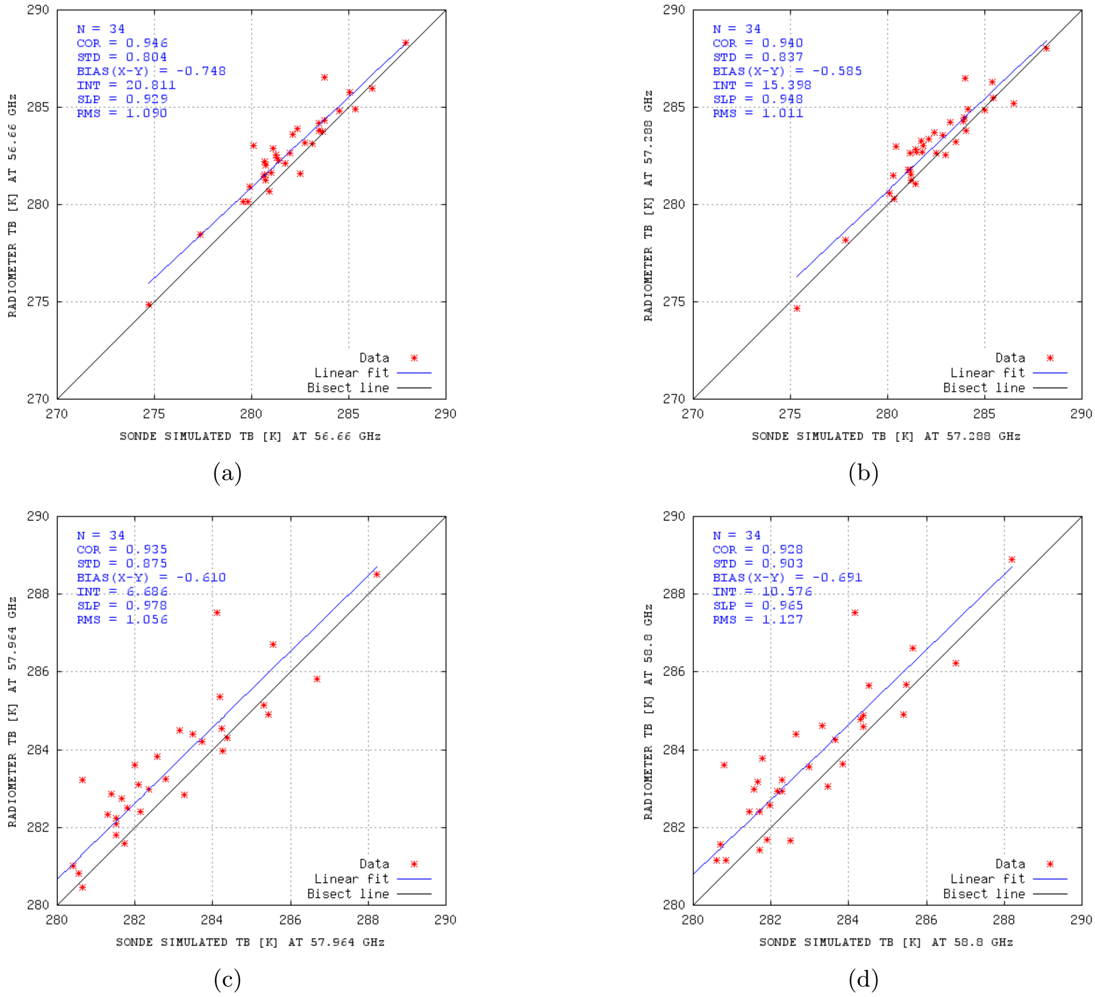


Figure 12: ***Night time comparison between radiometer measured T_b and model simulated through radiosonde input T_b (channels 56-58 GHz).***

In this initial period of observation we had 22 out of the 35 radiometer channels operational: 22.234, 22.5, 23.034, 23.834, 25.0, 26.234, 28.0, 30.0, 51.248, 51.760, 52.280, 52.804, 53.336, 53.848, 54.4, 54.94, 55.5, 56.02, 56.66, 57.288, 57.964, 58.8. Figures 7 and 8 give a rough idea of the order of magnitude in units of T_b measured by the different frequency channels.

Figures 9 and 12, show comparisons only at night time but the analysis that follows is valid also for day time considering that the results are not much different. Whilst observing figures 9 and 12, one must keep in mind that we are comparing a limited set of values and good statistics will be available only as the data set increases.

Most channels show reasonably good agreement with simulations especially those close to resonant absorption of gasses. The 30 GHz channel is sensible to liquid water, which as said before wasn't simulated by the transfer model and in fact as T_b temperature increase due probably to the presence of liquid water in clouds, the radiometer seems to have higher values than those shown by the model (fig. 10b). In addition it can be seen from the plot but also from the root mean square error value RMS, that values are highly scattered around the mean value, this may be due to the fact that liquid water wasn't considered in the transfer model.

However there are some comparisons, mainly in the 51-53 GHz band that are not acceptable and can't be explained simply by the absence of liquid water in the transfer model. These discrepancies must be investigated further. They may be due to incorrect absorption parametrization, maybe the oxygen and water vapour continuum aren't well represented in the transfer model. Maybe these errors are due to interference between some unknown artificial radio source close to OAC and the radiometer receiver.

Conclusions

The initial 40 days of radiometer observations and comparisons with radiosonde measurements have produced some interesting results.
Integrated water vapour IWV retrievals seem to be quite consistent with radiosonde measurements. The reasonably small discrepancies that were noticed may be due to the fact that the radiosonde location is at 20 km away from the radiometer location and at a different altitude (200 m lower). In addition to this, the radiosonde location is in between the sea and a lagoon and so it might be subject to a peculiar microclimate. In future we may get the chance to perform radiometer measurements in the exact same location as the radiosonde launch location, this should simplify the comparison between radiometer retrievals and radiosonde measurements.
Temperature profile retrievals seem highly consistent with radiosonde measurements especially in the lower troposphere. Though comparisons are satisfactory, radiometer retrievals seem to be highly smoothed out to a degree where vertical information is often lost when compared with radiosonde temperature profiles. In future we will try out different retrieval algorithms to check whether finer profile detail can be achieved.
Relative humidity RH retrievals are not consistent with radiosonde measurements, we are not sure whether it is due to the fact that the radiometer simply can't retrieve RH profiles or whether not enough K band channels were used for the retrieval. The problem may also be caused by not appropriate neural network training. In future we will use all radiometer channels to retrieve RH profiles and we will try to improve the neural network training.
Radiometer brightness temperature measurements were compared with model simulated ones. Results are usually satisfactory considering that liquid water was not modelled but there is a frequency band (51-53 GHz) in which results are not consistent. This may be due to a external radio source that interferes with the radiometer receiver or it may be due to bad parametrization of continuum oxygen absorption in the transfer model, this problem needs to be investigated further.

References

[1] Satellite Atmospheric Science Group, 2009: ARTS - Atmospheric radiative transfer simulator.
http://www.sat.ltu.se/arts/, last accessed 06/05/2009.

[2] Radiometrics corporation, 2009: MP-3000A Temperature, Humidity and Liquid Profiler. http://www.radiometrics.com/, last accessed 06/05/2009.