OBSERVATIONS OF WATER VAPOR PROFILES OVER NORTHERN FINLAND BY SATELLITE AND BALLOON BORNE INSTRUMENTS

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Abstract

Accurate in situ measurements of water vapor were made by the cryogenic frost point hygrometer (CFH) over northern Finland during February-August 2009. The CFH measurements were started prior to the overpass times of the EUMETSAT MetOp-A satellite. Thus we obtained a series of near-coincident measurements of water vapor in the upper troposphere that can be used to validate satellite borne measurements. The operational level 2 data of the Infrared Atmospheric Sounding Interferometer (IASI) showed no significant bias in comparison to the CFH measurements in the troposphere as an average of the clear sky cases. We also discuss the accuracy of RS92 radiosonde water vapor measurements based on the earlier comparison flights of the RS92 and the CFH instrument.

INTRODUCTION

Confidence in satellite observations is based on independent validation measurements. Sodankylä in northern Finland (67.4° N, 26.6° E) is among the sites that have actively participated in satellite data validation campaigns during the recent years. A large data set of ground based measurements suitable for satellite data validation was collected during the Atmospheric Sounding Campaign of the EUMETSAT Polar System (EPS) in Sodankylä, Finland in summer 2007 (Aulamo et al., 2009). Recently another atmospheric sounding campaign took place in Sodankylä motivated by the need to obtain accurate water vapor profiles over land surface including the snow-cover period. During both campaigns we used cryogenic chilled mirror hygrometers (CFH) that are capable of accurate measurements of water vapor in the upper troposphere (Vömel et al., 2007). In addition we made comparisons flights with RS92 radiosondes in order to investigate the differences in radiosonde humidity relative to the CFH in the upper troposphere.

WATER VAPOR SOUNDINGS

The CFH water vapor sonde launches in spring and summer 2009 in Sodankylä were timed to the clear sky periods and secondly to the EUMETSAT Metop-A (Meteorological Operational) satellite overpass times. We were interested in performing comparisons with the Infrared Atmospheric Sounding Interferometer (IASI) water vapor soundings on board the Metop-A satellite. Table 1 gives the summary of the sonde launches and distances to the IASI measurement.
Table 1: Summary of the CFH sonde launches in Sodankylä during year 2009, IASI overpass times and distances between IASI measurement location and the sonde at the elevation of 400 hPa are also shown.

The location of sonde can vary due to the variability in wind profile; therefore our goal was to select the IASI measurements that were the closest to the sonde location. The drifts of the balloon are illustrated in Figure 1 for each individual case. Although the balloon drifts were larger in the stratosphere, the measurements taken at 400 hPa were relatively close to the balloon launch site. The goal in this work was to compare our soundings to the operational level 2 product of IASI. The IASI products were those processed at the EUMETSAT Central Facilities in Darmstadt and they were obtained from the EUMETSAT Unified Meteorological Archiving and Retrieval Facility (UMARF). All IASI sounding products used in this study are operational products of version 4.3.

![Figure 1: Flight paths of the sondes (solid lines), 400 hPa locations (stars) and nearest IASI pixel centres (circles).](image-url)
RESULTS OF WATER VAPOR COMPARISONS

Results of the water vapor comparisons are shown for each individual case (Figure 2). CFH soundings (gray) and IASI L2 water vapor profiles (red) are from year 2009. IASI data is from the closest measurement relative to the sonde location at 400 hPa. The dashed red lines indicate one standard deviation of the IASI retrieval. CFH soundings were averaged to the IASI layers and all comparisons were made between the CFH average and the corresponding IASI value. The IASI products used here contained only the variance for each layer and did not provide the averaging kernels.

Figure 2: CFH soundings (gray) and IASI L2 water vapor profiles (red) from year 2009. IASI data is the closest measurement relative to the sonde location at 400 hPa. The dashed red lines indicate one standard deviation of the IASI retrieval. CFH soundings were averaged to the IASI layers (black solid line).
In most cases we found satisfactory overall agreement between the CFH and the IASI profile measurement, but clearly the IASI level 2 products tend to smooth the humidity layers in the troposphere. Large differences in water vapor mixing ratio were seen at the level of 200-400 hPa during February and April 2009 over Sodankylä (Figure 2, upper panel). These differences cannot be explained by significant differences in measurement location or in time of the measurements (Table 1).

The corresponding temperature soundings (Figure 3) suggest that the tropopause altitude in the in situ measurements is generally in agreement with the IASI temperature profile, but in one case (February 25, 2009) there is a significant difference in tropopause altitude (Figure 3, upper left).

Figure 3: Temperature soundings (gray) and IASI L2 temperature profiles (red) corresponding to the water vapor soundings in figure 2. IASI data is the closest measurement relative to the sonde location at 400 hPa. The dashed red lines indicate one standard deviation of the IASI retrieval. Temperature soundings were averaged to the IASI layers (black solid line).
SUMMARY AND DISCUSSION

In summary of all soundings performed in year 2009 we did not find significant biases between the sonde and IASI level 2 data in tropospheric water vapor (Figure 4) and temperature (Figure 5). The CFH soundings needed for accurate water vapor measurements in the upper troposphere are relatively difficult to perform in comparison to the operational radiosondes and therefore one might think about obtaining much larger data sets by the RS92 sondes. Previous work has shown that the RS92 sondes are among the most accurate operational radiosondes (Miloshevich et al., 2006). No significant bias in night-time humidity measurements was found by Suortti et al. (2008); however the daytime soundings may have dry bias in the upper troposphere due to the solar heating of the sensor boom (Vömel et al., 2007b).

Figure 4: Summary of all IASI/CFH comparisons over Sodankylä in year 2009: average water vapor differences (IASI-CFH) in ppmv (red) and one standard deviation of the differences (blue).

Figure 5: Summary of all IASI/CFH comparisons over Sodankylä in year 2009: average temperature differences (IASI-SND) in K (red) with one standard deviation (blue) per IASI pressure level.
Relative difference between RS92 and the CFH humidity profiles during daytime flights in Sodankylä from June to August 2007. The new model of RS92 sonde is using aluminized coating of the sensor attachment, which reduces the radiation dry bias (left). Relative difference between the two RS92 models is also shown (right).

In Sodankylä we performed seven daytime flights during June-August 2007 with multiple sensors in each balloon payload. These payloads included the CFH instrument and two models of the RS92 radiosonde. The “new model” of the RS92 used an aluminized coating of the sensor attachment, which reduced the solar radiation induced dry bias. The “old model” of the RS92 was without the new coating material. Based on these comparisons empirical bias correction can be derived, which depends on the altitude and this correction can be applied on the new and the old model of the RS92 sonde relative humidity under daytime measurements. For the new type of RS92 sondes the radiation bias correction can be calculated by:

$$C_{rad}(P) = -0.01376\ln(P)^2 + 0.3018\ln(P) - 0.445,$$

where $P$ is pressure in hectopascals. The corrected RH values can be derived as

$$RH_{corr} = RH/C_{rad},$$

where RH is the uncorrected relative humidity measured by the improved model of the RS92. Similar bias corrections can be applied to the relative humidity profiles measured by the other models of the RS92.

REFERENCES


