

Analysis of radiosonde measurements by ground- and satellite-based simultaneous observations during the Water Vapor IOP 2004 experiment

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RATIONALE

• Very accurate measurements of atmospheric Water Vapor (WV) are needed to improve our understanding of the radiation energy budget.

• Measurements during extremely dry conditions, as during the winter in polar regions, are particularly difficult, because of the lack of sensitivity of conventional instruments to such low amounts of WV.

• The Environmental Technology Laboratory (ETL) of the National Oceanic and Atmospheric Administration (NOAA) has developed a new instrument, the Ground-based Scanning Radiometer (GSR), and conducted a Water Vapor Intensive Operational Period (WVIOP) in March/April 2004 at the Atmospheric Radiation Measurement (ARM) Program site in Barrow, AK, USA.

INSTRUMENT	PLATFORM	CHANNELS	RANGE
MWR	GWT	2	23-31 GHz
MWRP	GWT	12	22-58 GHz
GSR	GWT	25	50-382 GHz
AERI-ER	GWT	5436	400-3020 cm ⁻¹
MODIS	NASA AQUA	36	620-14385 nm
AIRS	NASA AQUA	2378	649-2665 cm ⁻¹
AMSU-B	NOAA-17	5	89-183 GHz
RADIOSONDE	GWT, DPX, NWS	-	-

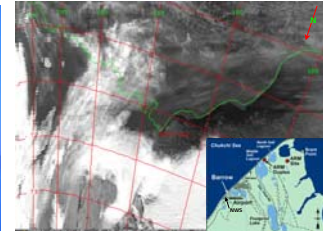


Table 1. List of the instruments considered in this analysis. MWR, MWRP, GSR, and AERI-ER are ground-based instruments located at the ARM Great White (GWT) site. MODIS, AIRS, and AMSU-B are satellite-based instruments. The radiosondes were launched from three separated sites (see Figure 2).

Figure 1. The experimental set-up on the ARM GWT deck during the WVIOP2004. The microwave radiometers (ARM MWR and MWRP, NOAA/ETL GSR) are circled in red.

Figure 2. MODIS (AQUA) image of the North Slope of Alaska. The location of the ARM duplex (DPX), the GWT, the NWS, and the city of Barrow are indicated in the inset (from www.arm.gov).

GOALS

The goals of the WVIOP2004 experiment include:

- To access the accuracy of radiosonde humidity profiles in Arctic environment
- To demonstrate the performances of recently developed technology at NOAA/ETL
- To compare micro- vs. mm-wave radiometric sensitivity to low WV amounts
- To obtain data for atmospheric absorption model studies at frequencies ranging from microwave to infrared wavelengths.

Concerning the radiosonde study, four radiosondes (Vaisala RS90-A) per day were launched from the ARM duplex (DPX) site during the WVIOP2004. Occasionally, three different radiosonde packages (Vaisala RS90-A, Meteolabor Snow White, and Sippican AIR VIZ) were attached at the same balloon and launched at the same time. Moreover, two radiosondes (Sippican AIR VIZ) per day were independently launched at the National Weather Service (NWS) facility, while one (Vaisala RS90-A) at the ARM GWT site, as part of NWS and ARM operational routines. Thus, in a few cases we had five independent radiosonde measurements at the same time (see Figure 3). Note that significant differences were found in the humidity profiles.

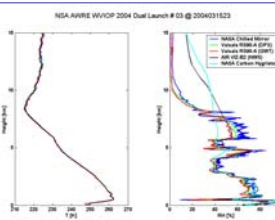


Figure 3. A case of multi-radiosonde launch. Three out of five were attached at the same balloon and launched from DPX, while the other two were launched at NWS and GWT sites. Significant differences were found in the humidity profiles.

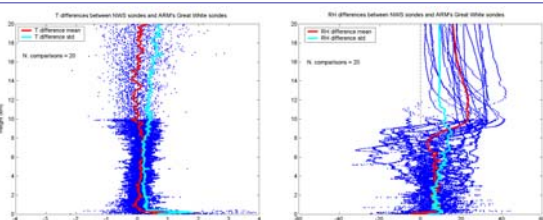


Figure 4. Difference in temperature (left) and relative humidity (right) profiles for the entire set of simultaneous soundings launched at NWS and GWT sites. Mean value (red) and standard deviation (cyan) are overimposed. Temperature differences in the lower levels are likely due to the heat island caused by the city of Barrow. Note about 20% RH bias for levels higher than 10 km.

From the set of radiosondes launched simultaneously at NWS and GWT sites (Figure 4), we compute the mean value and the standard deviation of the differences in temperature and humidity profiles. The bias in the temperature profile is within 0.25 K, except for the first 500 m, where local effects due to environmental conditions might be important. On the other hand, above 10 km, NWS were found to be more moist than GWT by about 20% in relative humidity (RH).

PRELIMINARY RESULTS

UPPER TROPOSPHERIC/STRATOSPHERIC HUMIDITY CHANNELS

To investigate the effect of bias in Figure 4, we consider selected channels that show a strong response to humidity changes in the upper troposphere and lower stratosphere. Figure 5 shows weighting functions for selected AIRS, GSR, and MWRP channels.

COMPARISON WITH GROUND-BASED INSTRUMENTS

Down- and up-welling brightness temperature (Tb) have been simulated from DPX, GWT, and NWS radiosonde measurements using most recent versions of radiative transfer models (MW: Rosenkranz 2003, IR: LBLRTM). Comparison between radiosonde simulations and ground-based measurements are shown in Figure 6. Note that NWS show large differences (5-10 K) at 22.235 and 183±3 GHz, but agree better with channels that are more sensitive to the integrated WV content (23.8, 31.4, 183±15 GHz).

COMPARISON WITH SATELLITE-BASED INSTRUMENTS

Figure 7 shows a comparison between AIRS measurements and simulations from a NWS radiosonde. Differences ranging from 0 to 5 K were found in the selected upper tropospheric/stratospheric channels (cyan circles). Statistics and scatter plot of simulated vs. measured Tb show better agreement with GWT.

SUMMARY AND FUTURE WORK

The WVIOP2004 radiosonde experiment pointed out a major issue in the upper tropospheric humidity soundings. Preliminary results seem to indicate that NWS radiosondes might be biased above 10 km, although further investigation is needed (as, for example, including all the instrument in Table 1). Such an error source needs to be taken into account into the study of radiative and climate models, as well as in the satellite measurements cal/val.

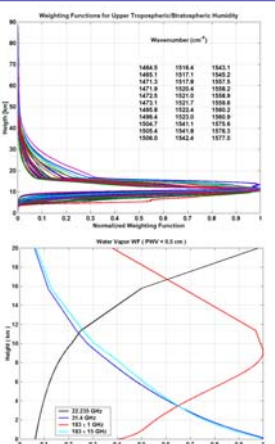


Figure 5. Weighting Functions for AIRS upper tropospheric/stratospheric humidity sounding channels (top) and selected MWRP and GSR channels (bottom).

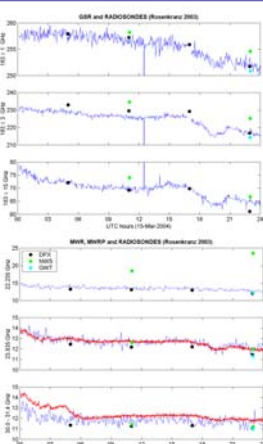


Figure 6. 24-hour time series of simulated and measured Tb at selected GSR, MWR, and MWRP channels. 22.235, 183 ± 1, and 183 ± 3 GHz are more sensitive to upper tropospheric humidity, while 23.8, 31.4, and 183 ± 15 GHz to integrated WV content.

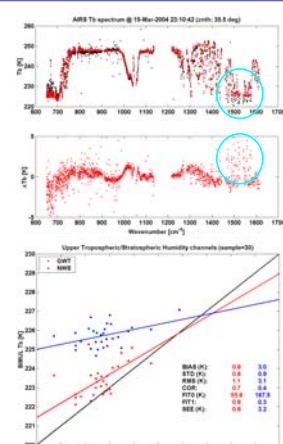


Figure 7. Top: Measurements (black) and NWS simulations (red) of AIRS Tb spectrum. Middle: difference between the two. Bottom: scatter plot and statistics of simulated (blue: NWS; red: GWT) minus measured Tb considering only upper tropospheric humidity channels.

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