Investigation of gas absorption models from 22 to 60 GHz observed at low water vapor concentrations and 530 hPa in the Atacama Desert in Chile

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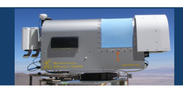
1. Campaign – RHUBC-II

- The Atmospheric Radiation Measurement (ARM) program conducted the second phase of the **R**adiative **H**eating in **U**nderexplored **B**ands **C**ampaign (RHUBC-II, Aug–Oct '09)
- Site at Cerro Toco (5320m), Chajnantor Plateau, Chile
- High-spectral-resolution radiance observations in spectral regions that are normally opaque at lower altitudes due to strong water vapor absorption
- Focus: Characterize and improve accuracy of water vapor (WV) absorption models (near-IR to sub-mm)

Figure 1: *RHUBC-II site*

2. Radiometer – HATPRO



- The microwave radiometer HATPRO-G2 (**H**umidity and **T**emperature **P**rofiler) [1] measures atmospheric radiation along the 22.24 GHz water vapor line and the O_2 absorption complex centered around **60 GHz**.
- **14** frequency channels: designed with sharply characterized band pass filters → high accuracy TB
- Observed and modeled TB along the oxygen complex are compared and used to evaluate O_2-absorption models.

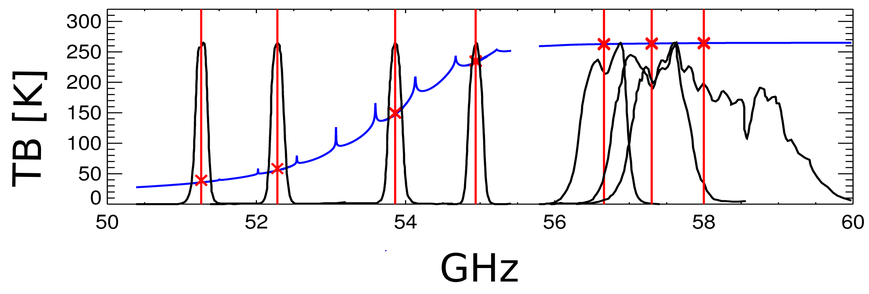


Figure 2: *Traces of band pass filters for the oxygen channels, mean spectrum calculated by the R98 model (input: 5 radiosondes on 09/13/09), HATPRO measurements (X) at nominal mid-frequencies.*

3. Model vs. Measurement

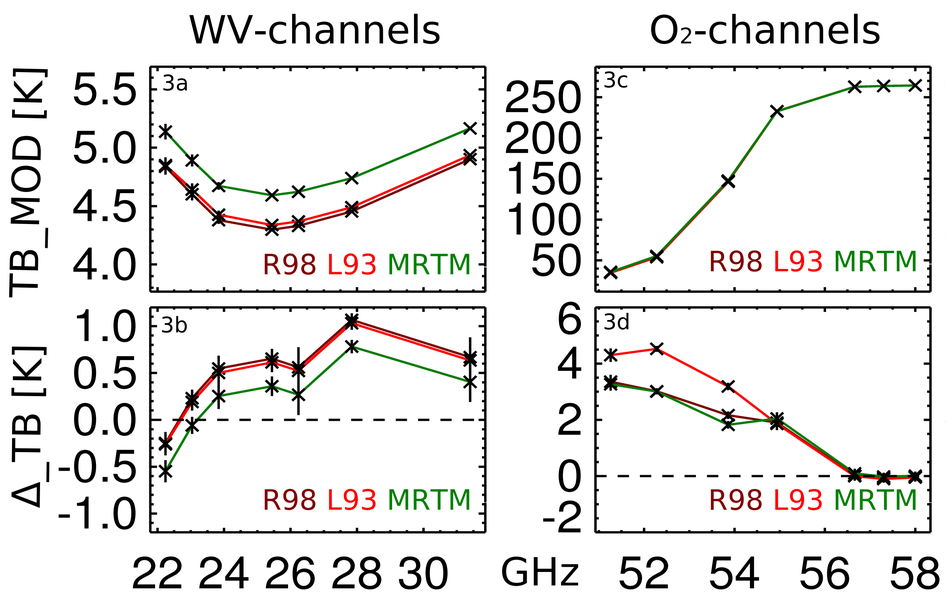


Figure 3: *TB_MWR: HATPRO measurement of TB. T_MOD: TB calculated at HATPRO's mid-frequencies using 5 radiosonde profiles on 09/13/09 as input for different absorbtions models:*
- *R98:Rosenkranz'98 [2]*
- *L93: Liebe'93 [3]*
- *MRTM: MonoRTM [4],*

Δ_TB=T_MWR-T_MOD, error bars: std.dev. of 5 radiosondes of 09/13/09.

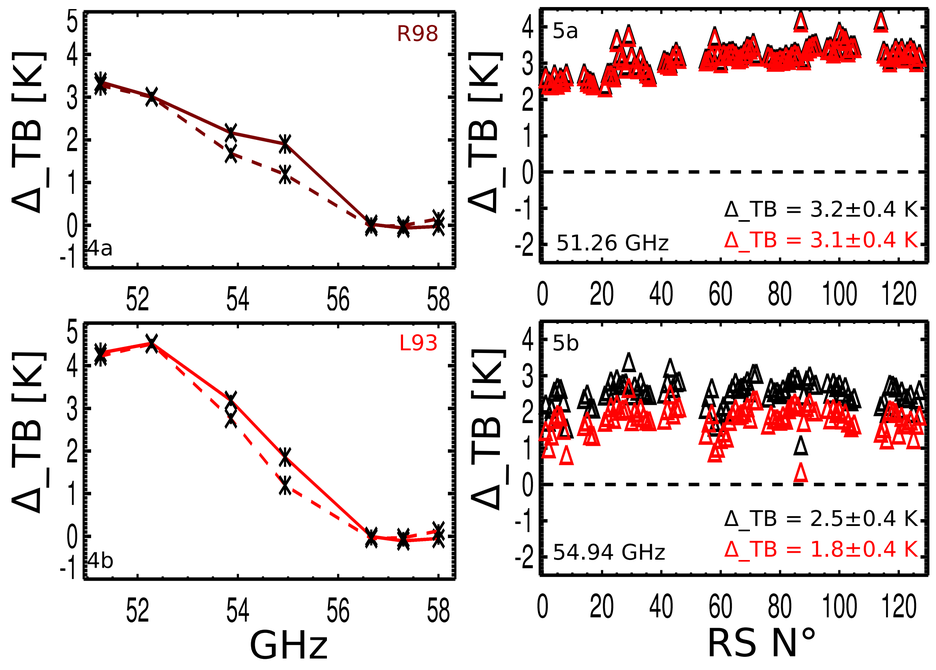


Figure 4: *TB differences between HATPRO measurements (TB_MWR) and modeled TB_MOD (from 5 radiosondes on 09/13/09, Fig. 2).* ***Solid:*** *TB_MOD is calculated at HATPRO's mid-frequencies,* ***dashed:*** *TB_MODs convolved with traces of HATPRO's band pass filters (Fig 2).*

Figure 5: *TB difference for 2 channels and all quality controlled clear sky radiosondes (model: R98, extension atmosphere: SDS, Fig 7), calculated at mid-frequencies, convolved with traces of band pass filters, Mean ± Stddev in numbers.*

- Measured TBs are compared to Tbs calculated with different absorption models. For the lower O_2-channels TBs differ up to **4 K (**Fig. 3).
- Convolving calculated Tbs with the traces of HATPRO's band pass filters (Fig. 2) make measured and modeled TBs more comparable. Differences are reduced by up to **1 K** for the most sensitive O_2-channels on the line's flank.
- The discrepancy between model an measurement at O_2-channels on 09/13/09 is representative for all RS lauched during the campaign (Fig. 5).

References:
[1] T. Rose et al: A network suitable microwave radiometer for operational monitoring of the cloudy atmosphere, Atmospheric Research 75, 2005
[2] H. J. Liebe et al, "Propagation modeling of moist air and suspended water/ice particles at frequencies below 1000 GHz" , presented at the AGARD 52nd Specialists Meeting Electromagnetic Wave Propagation Pane, 1993, Paper No 3/1-10
[3] P. W. Rosenkranz, "Water vapor continuum absorption: A comparison of measurements and models," Radio Science., 33, 1998
[4] S. A. Clough et al, "Atmospheric radiative transfer modeling: A summary of the AER codes," J. Quant. Spectrosc. Radiat. Transf., 91, 2005.
[5] Y. Han, E .R. Westwater: Analysis ans Improvement of Tipping Calibration for Ground-Based Microwave Radiometers, IEEE TGARS, 38(3), 2000

4. Error Source - Radiosonde Profiles

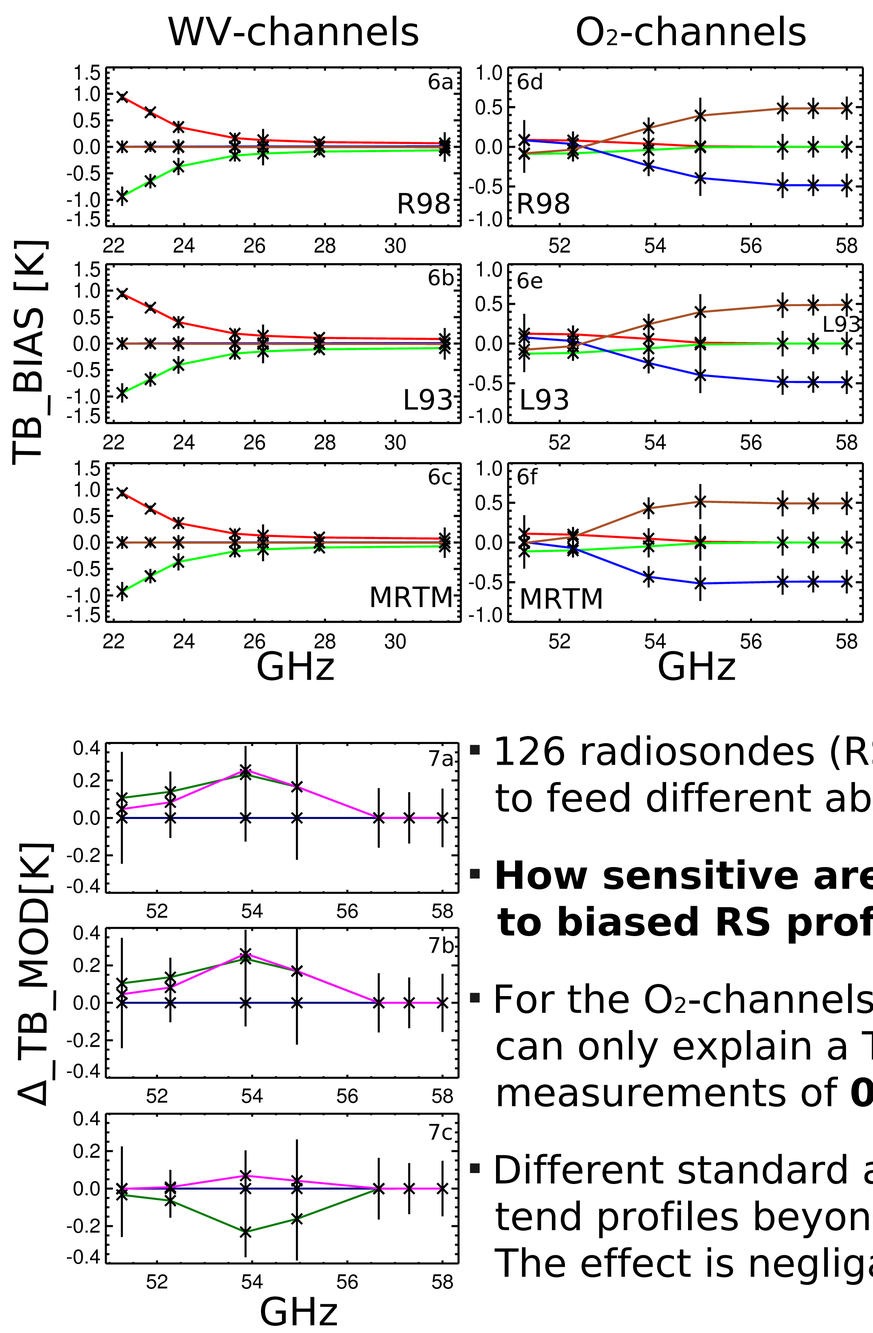


Figure 6: *RS profiles were modified in four ways: q=0, q=2*q_RS, T = T_RS + 0.5 K, T = T_RS - 0.5 K, TB_BIAS = TB_MOD (T_RS, q_RS) – TB_MOD(T, q), plotted for HATPRO channels and different absorption models.*

Figure 7: differences between TB_MODs resulting from different extension atmospheres: Mean atmosphere, Payerne (CH), Standard atmosphere tropical/dry stratosphere. Reference: Standard atmosphere subtropical/dry stratosphere (SDS), error bars: std.dev. of 5 RS of 09/13/09.

- 126 radiosondes (RS) were collected to feed different absorption models.
- **How sensitive are modeled TBs to biased RS profiles?**
- For the O_2-channels biased profiles can only explain a TB difference to measurements of **0.5 K** (Fig. 6).
- Different standard atmospheres extend profiles beyond the tropopause. The effect is negligable (Fig. 7).

5. Outlook

- HATPRO was operated in a continuous elevation scanning mode. A tipping curve procedure [5] will be applied to recalibrate the transparent oxygen channels (51.26 GHz and 52.28 GHz). This allows to asses the initial absolute liquid nitrogen calibration.
- Measured and modeled brightness temperatures show a difference of several Kelvin for the lower O_2-channels. O_2 absorption models will be evaluated in the microwave spectrum around 60 GHz, once uncertainties from RS and radiometer calibrations are well characterized.

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