Analysis of Measurements from the RHUBC-II Campaign

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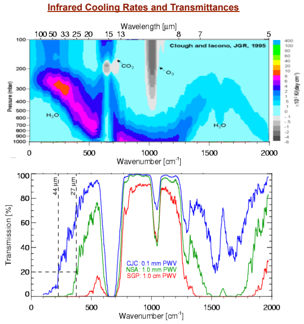
The Radiative Heating in Underexplored Bands Campaign in Chile (RHUBC-II)

Infrared Cooling Rates and Transmittances



Radiative cooling in the upper troposphere is dominated by water vapor in the far-IR (~300 cm^{-1}). Surface spectral measurements under typical conditions (bottom panel, red) provide no information about the associated radiative processes, while those in very dry locations do (bottom, blue).

Motivation:

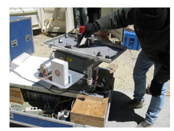
- Mid- and upper-tropospheric radiative cooling have important atmospheric effects
  - e.g. impacts vertical motions of the atmosphere
- Occurs primarily in water vapor absorption bands that are opaque at the surface
- Approximately 40% of the OLR comes from the far-IR

Need to validate water vapor absorption models in these normally opaque bands.

To address this gap in our knowledge, we need:

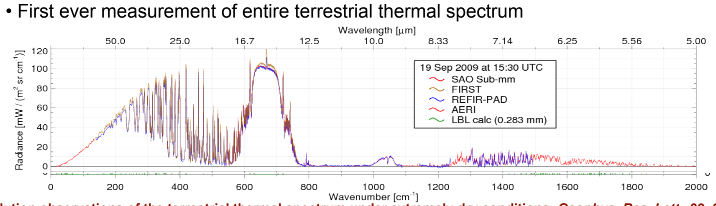
- Spectrally resolved measurements in these bands
- A very dry location so the bands are not opaque
- Good characterization of the water vapor field above the spectral measurements

Ultimate goal: Improved RT code (RRTM) in dynamical models



RHUBC-II Campaign – ARM Program, July – November 2009

- Cerro Toco (5350 m), Atacama Desert, Chile -- extremely low water vapor
- Key Instruments
  - Vaisala **RS-92** radiosondes – 144 launches
  - G-band Vapor Radiometer Profiler (**GVRP**) – 15 channels on side of 183.3 GHz WV line
  - **SAO FTS** – zenith radiance from 300-3500 GHz (resolution 3 GHz)
  - NASA LaRC Far-IR Spectroscopy of the Troposphere (**FIRST**) – 100-1600 cm^{-1} (res. 0.6 cm^{-1})
  - CNR (Italy) Radiation Explorer in the Far-IR (**REFIR-PAD**) – 100-1400 cm^{-1} (res. 0.5 cm^{-1})
  - U. Wisc. Atmospheric Emitted Radiance Interferometer (**AERI**) – 550-3000 cm^{-1} (res. 0.5 cm^{-1})
  - Absolute Solar Transmittance Interferometer (**ASTI**) – 2000-10000 cm^{-1} (res. 0.96 cm^{-1})
- First ever measurement of entire terrestrial thermal spectrum

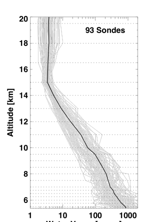


Turner and Mlawer, The Radiative Heating in Underexplored Bands Campaigns (RHUBC), *Bull. Amer. Met Soc.*, 91(7), 911-923, 2010; Turner et al., Ground-based high spectral resolution observations of the terrestrial thermal spectrum under extremely dry conditions, *Geophys. Res. Lett.*, 39, 2012.

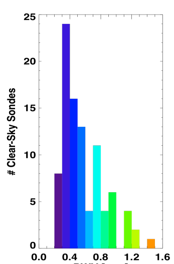
RHUBC-II Best Estimate Water Vapor Profiles

Sonde Measurements During RHUBC-II

Sondes provide an initial water vapor field; an adjustment to correct biases in Vaisala (RS92) RH measurements was determined by Miloshevich et al. (2009)

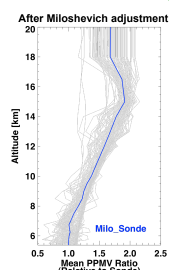


Individual and average water vapor profiles measured by RHUBC-II sondes.



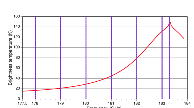
Water vapor column amounts (PWV) measured by radiosondes during RHUBC-II. (The PWV for US Standard atmosphere is 14.3 mm.)

Sonde Bias Adjustment



For a typical profile, the Milo. correction leaves the near-surface H_2O unchanged and increases it higher up. The effect on PWV is a net increase of ~10%.

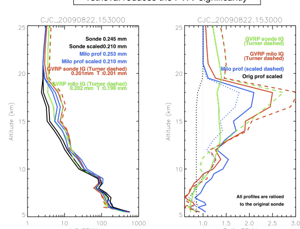
Using GVRP Measurements on the 183.3 GHz H_2O Line to Improve H_2O Profiles

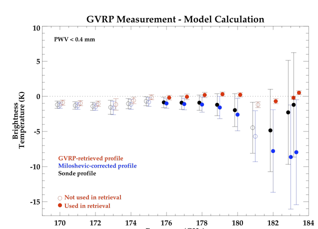


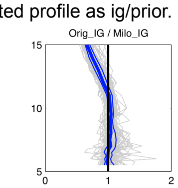
Calculated brightness temperatures and GVRP channel centers

The Miloshevich et al. study does not pertain to the RHUBC-II conditions and sonde batches. GVRP measurements can provide an accurate H_2O column amount and limited information on profile. We have performed two sets of profile retrievals using the optimal estimation approach: one using the raw sondes as initial guess/prior for each case, and the other with the Milo adjusted profile as ig/prior.

Retrieval example: For 8/22, 1530, the retrieval reduces the PWV significantly





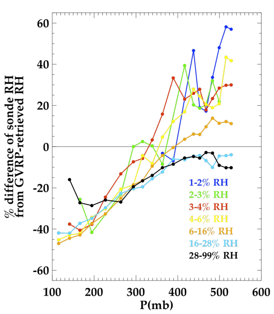


The ratio of the two retrieved H2O VMR profiles are a test of whether the retrieved profiles are independent of ig/prior. The median (thick line) and interquartile values of these ratios are close to unity below 12 km.

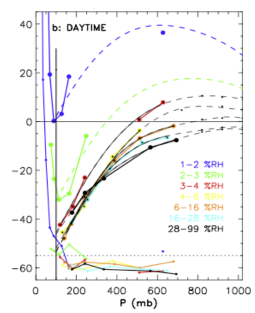
Analysis of Sonde Biases

The biases in sonde RH values determined by the retrieved profiles are compared to those in Miloshevich et al. A similar pattern is found, but the RHUBC-II sondes have a greater moist bias for P > ~400 mb.

This study



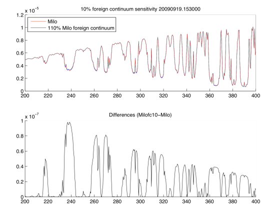
Miloshevich et al. Fig 9b



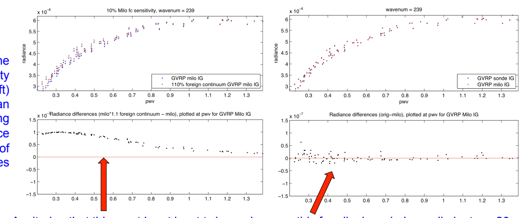
Impact on Radiances Determines How Much Profile Uncertainty Is OK

It is important to restrict this analysis to cases for which the profile uncertainty is not large enough to prevent determining key spectroscopic parameters. A good metric is the sensitivity of the radiances with respect to a 10% change in the H_2O foreign continuum in microwindows in the far-IR. A case is eliminated if the difference between radiances computed in these microwindows using the profile from the sonde-based retrieval and those from the Milo-based retrieval is comparable to the radiance sensitivity to the continuum change.

Example: Continuum Sensitivity for a Single Case



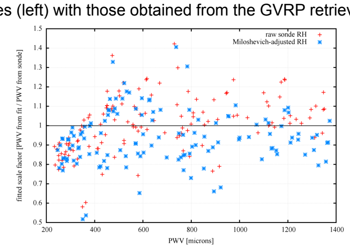
For most cases, the continuum sensitivity in microwindows (left) is a lot greater than the corresponding radiance difference due to choice of retrieved profiles (right).

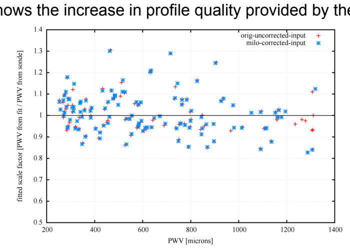


A criterion that this must be at least twice as large as this for all microwindows eliminates ~20 cases.

Analysis With the Sub-millimeter Radiance Measurements

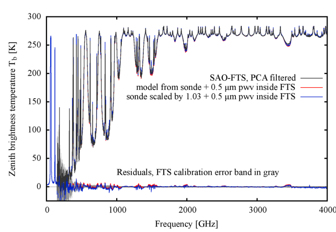
For each SAO-FTS measurement, a scale factor for the H_2O profile can be derived that provides the best match between the measurement and a corresponding model calculation. Comparing the scale factors obtained with the pre-retrieval profiles (left) with those obtained from the GVRP retrievals shows the increase in profile quality provided by the retrieval.

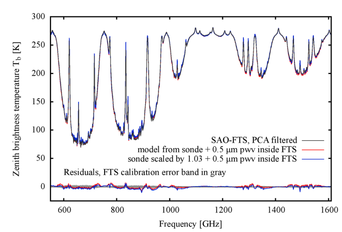




For this case, a small scaling factor is needed so there is not much difference in the measurement-calculation residuals when the retrieved profile is used vs. the scaled retrieved profile. The overall small residuals suggest that there are no major issues with spectroscopy in the sub-millimeter region, including the foreign water vapor continuum.

Example: Brightness Temperature Differences (SAO-FTS – Calculation) for a Single Case

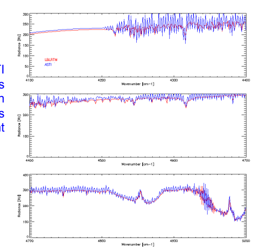




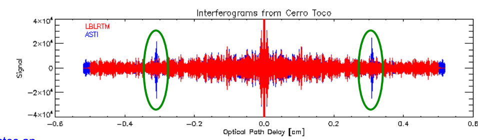
Preliminary Near-IR Closure Study: ASTI vs. LBLRTM

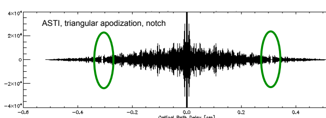
The ASTI did not perform well in the harsh Andean environment. It was possible to obtain a lamp calibration on only one day, 10/17/09. Calibrating the sky spectra has involved a number of challenges.

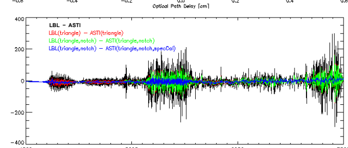
A comparison of ASTI radiance measurements assuming no apodization with LBLRTM calculations results in significant measurement-calculation differences.



A comparison of the ASTI and LBLRTM interferograms indicates an anomalous features for the ASTI (above). Manually creating a "notch" in the interferogram (middle) fixes the issue with a negligible loss of information. It is then possible to do a spectral calibration. A comparison in spectral space (below) shows the overall improvement.







With this ASTI calibration, the ASTI-LBLRTM differences begin to look more reasonable. Our analysis of water vapor continuum absorption in this near-IR band can now go forward.