Radiative Closure in the Far-Infrared: Results from RHUBC-I

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Why Study the Far-Infrared?

• The far-IR (λ > 15 μm) is an important component of the overall radiation budget of the Earth, accounting for approximately half of the outgoing infrared radiation to space.

• Dominated by the pure rotation band of water vapor, the maximum mid-to-upper tropospheric cooling also occurs in the far-IR.

• Cirrus scattering properties not well validated in far-IR.

• The opacity of the lower atmosphere has precluded extensive investigations of water vapor and cirrus cloud optical properties in the far-IR, leaving large uncertainties in climate model calculations.

The RHUBC Concept

1. Collect high-resolution, downwelling radiance measurements in the far-IR in cold, dry conditions; collect collocated measurements of the atmospheric state.
2. Calculate the downwelling surface radiance.
3. Compare the measurements to the model calculations.

✓ *Validate and refine the water vapor spectroscopy*

✓ *Evaluate modeled optical properties of ice clouds.*

✓ *Incorporate improvements into GCM-appropriate radiative transfer models (e.g. RRTM).*

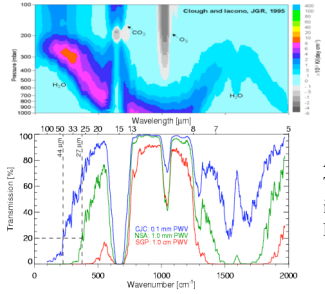
The RHUBC facts

• Radiative Heating of Underexplored Bands Campaign (RHUBC)
  - PIs: Turner and Mlawer
• RHUBC-I, North Slope of Alaska ARM site, Feb 22 - Mar 14, 2007
  - Opportunity to evaluate 3 millimeter wave (183 GHz) radiometers
• RHUBC-II, Chajnantor Chile, Aug 1 - Oct 30, 2009
  - Include a near-IR component to investigate other strong WV absorption bands

• Key Spectral Instruments
  - AERI-ER (3.3 - 25 μm) [I, II]
  - TAFTS (15 - 125 μm) [I only]
  - FIRST (5 - 100 μm) [II only]
  - ASTI (1.0 - 4.0 μm) [II only]

• Key Water Vapor Instruments
  - Vaisala RS-92 radiosondes [I, II]
  - GVR (183.31 GHz) [I, hopefully II]
  - GSR (183.31 GHz) [I, hopefully II]
  - MP-183 (183.31 GHz) [I, II]

Dependence of Transmission on Water Vapor Amount



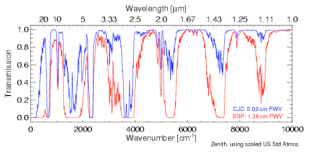
Spectral Cooling Rates with Altitude

Atmospheric Transmission in Thermal and Far Infrared

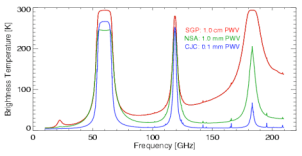
Transmission of the atmosphere in many parts of the spectrum depends on amount of water vapor (PWV)

Range of PWV
RHUBC-I (obs): 0.95 - 3.0 mm
RHUBC-II (anticipated): 0.01 - 1.0 mm

Atmospheric Transmission in Near Infrared

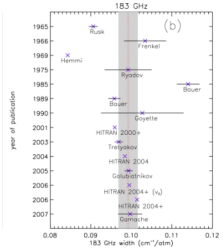


Microwave and Millimeter-wave Brightness Temperatures



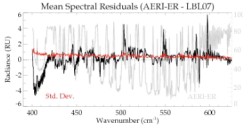
Clear Sky Results: NSA, Jan-Mar 2007

Validation of Half-width of 183.3 GHz Water Vapor Line



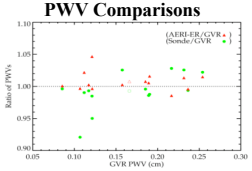
The air-broadened half-widths of the 183 GHz lines from various sources. The vertical dotted line represents the value obtained in our analysis, while the shaded bar represents the error bounds for this value.

Mean Observed - Calculated Residual



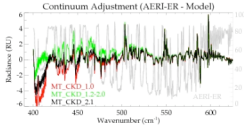
Calculations from the current model package LBL07 (LBLRTM v11.3, MT_CKD_2.1, updated line parameter database aer_v_2.2 - based on HITRAN) are compared to AERI-ER measurements.

PWV Comparisons



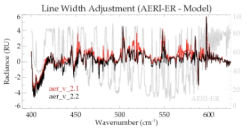
Consistency between 3 different PWV retrievals.

Changing WV Continuum Model



Over the last 5 years, the water vapor continuum model has been revised as new data sets became available.

Changing WV Spectral Line Widths

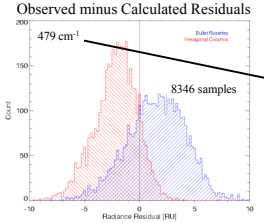


New WV air-broadened half-widths (black) are available. Modest improvements from the previous HITRAN values (red) are obtained.

Cirrus Results: NSA, Jan-Mar 2007

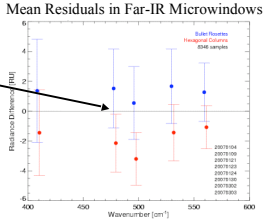
Approach:
• Retrieve optical depth and R_{eff}
• Use only 10-13 μm obs in retrieval
• Assume bullet rosettes or hexagonal columns
• Evaluate 'closure' in the far-infrared

Observed minus Calculated Residuals

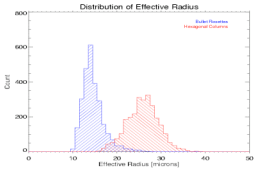


Neither habit results in good closure at 479 cm^{-1}…

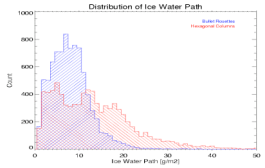
Mean Residuals in Far-IR Microwindows



…or in any of the far-IR microwindows



Significant difference in distribution of retrieved R_{eff}



Differences in the distribution of retrieved IWP

Impact on the surface and TOA radiative flux for wavelengths > 15 μm