Update on LBLRTM and MonoRTM development

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AER contributors to LBLRTM and MonoRTM development include:
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With contributions from Mark Shephard

Overview of AER RT Model Development

- Pace of LBLRTM, MonoRTM Development is Robust
  - LBLRTM v11.6
  - MonoRTM v4.1

    } Line file – aer_v2.2; Continuum – MT_CKD_2.4 — **June 2009**

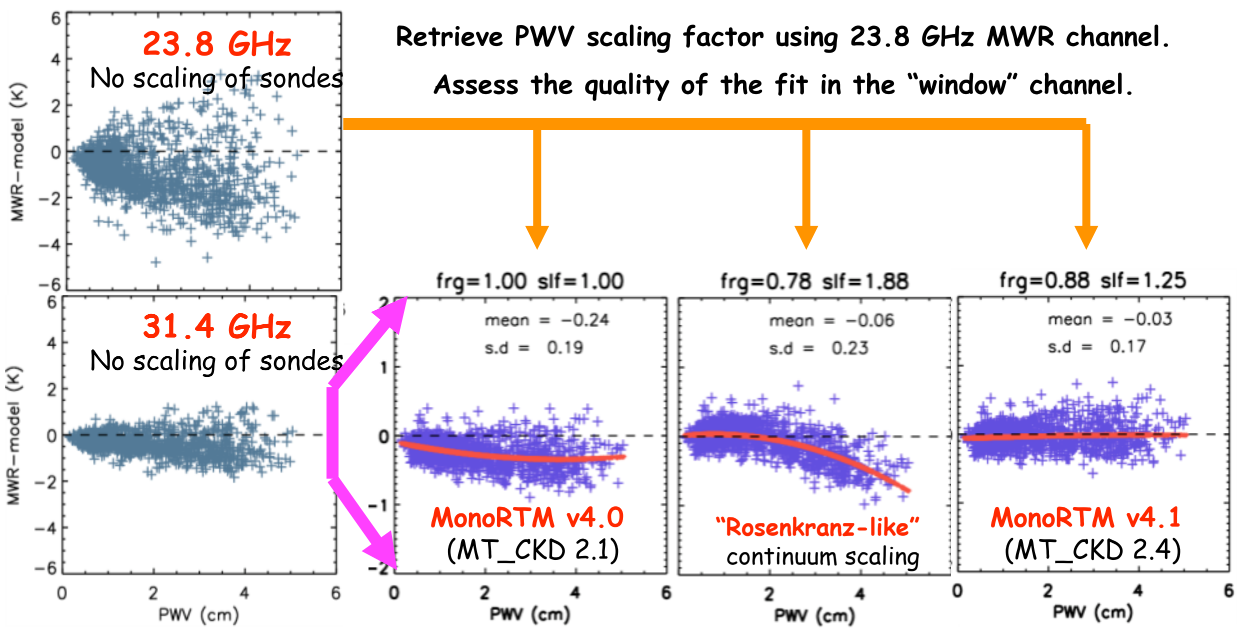
    - WV continuum modifications from ARM measurements in MW, far-IR
    - WV line widths, shifts, width temp. dep. (350-667 cm^{-1}) from Gamache
    - WV line intensities, positions, … from Coudert (10 to 2500 cm^{-1})
  - LBLRTM v11.7 – aer_v2.4, MT_CKD_2.5 — **January 2010**
    - CO_2 line positions, intensities (597-2500 cm^{-1}) from CDSD compilation
      - 1st order line coupling re-calculated using formalism of Niro et al. (2005)
    - WV shifts, width temp. dep. (436 to 2396 cm^{-1}) from Gamache
    - Modification of CO2 continuum coefficients from 2000-3000 cm^{-1}
    - Temperature dep. of CO_2 continuum absorption from 2386-2434 cm^{-1}
    - Modification of WV self continuum coefficients from 2000-3200 cm^{-1}
- RHUBC Field Campaign in Chile (2009 - AER co-leadership)
  - Goal: improve spectroscopy in strong WV bands

RHUBC Site in Atacama Desert

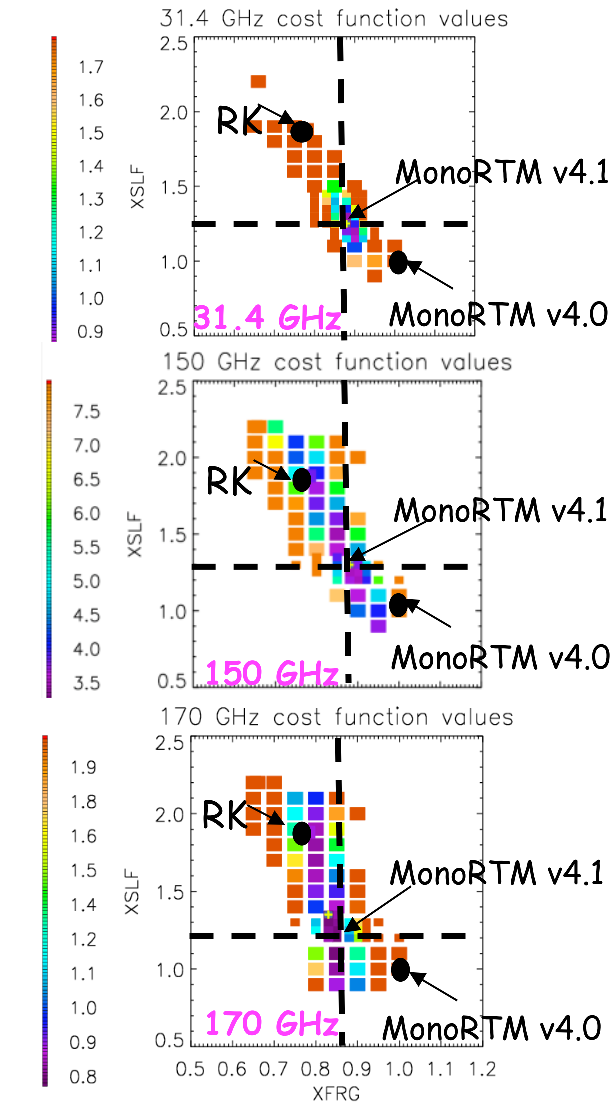
Water vapor: Self and foreign continuum in MW

Instrument	Location	Dates	Max. PWV
MWR	SGP	1993-2008	5 cm
MWRHF	COPS (FKB)	06/07-01/08	3 cm
MP183	SGP	01/08-03/08	3 cm

Retrieve PWV scaling factor using 23.8 GHz MWR channel.
Assess the quality of the fit in the "window" channel.

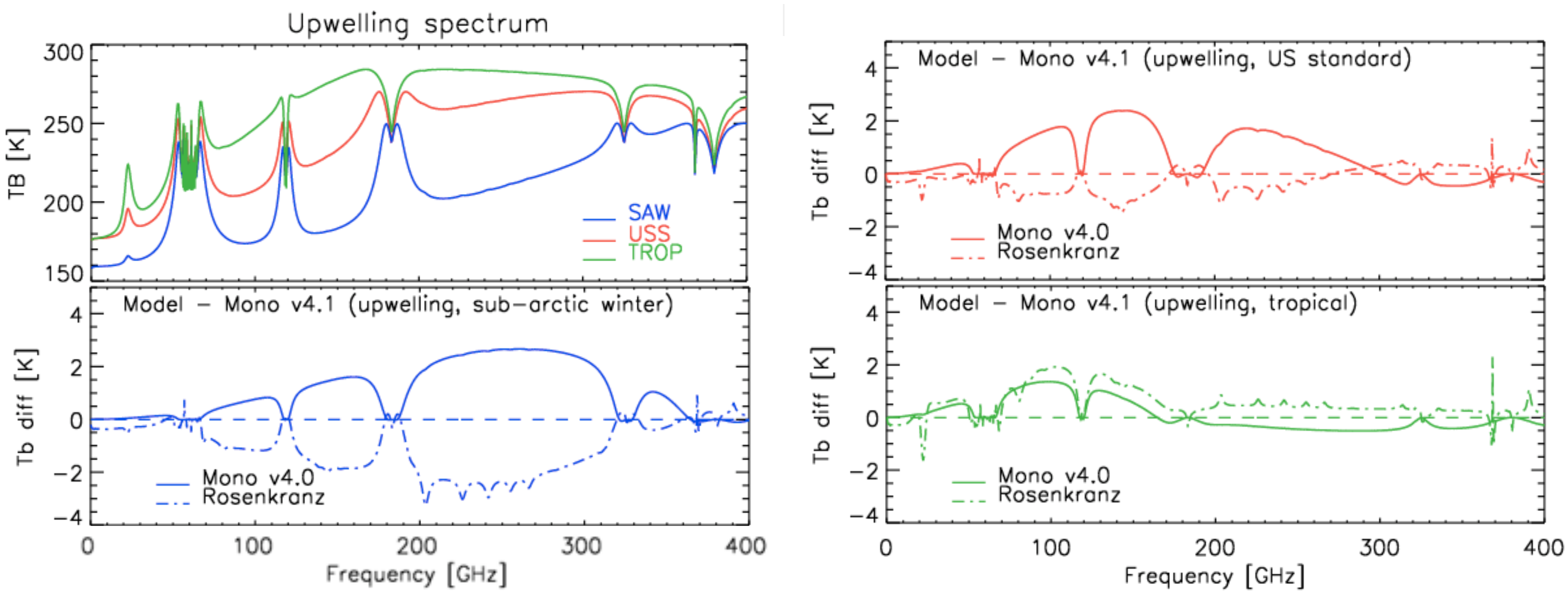


Cost function for window channels for self and foreign continuum scaling combinations



Consistent information from different instruments/frequencies!

Brightness temperature differences



Notes

- Key differences between MonoRTM and Rosenkranz
  - WV continuum
  - Width of 22 GHz line is 5% lower in MonoRTM
- RSS has recently readjusted their water vapor continuum to remove bias in CLW retrieval (Meissner and Wentz, *personal communication*). RSS and AER continua are now close together at 37 and 89 GHz (RSS model not valid above 89 GHz)

Consistency across Mid-infrared Regions

Mean residuals from 36 ARM TWP cases using Tobin et al. best estimate sonde profiles.

Profile inputs from AIRS Phase I val. supplied by L. Strow and S. Hannon (UMBC).

LBLRTM

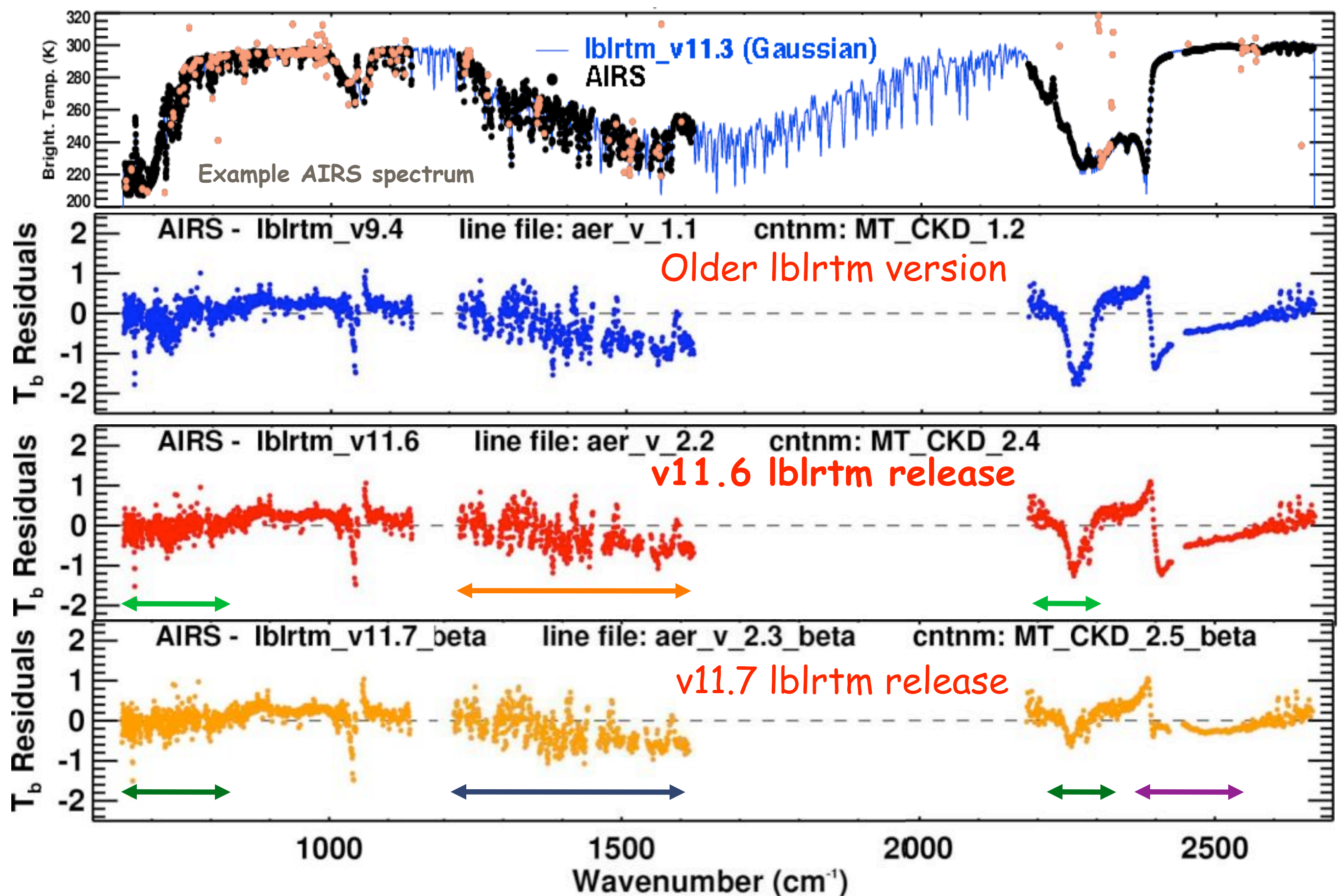
CO_2 line coupling
Application of Niro et al. (2005)

H_2O line positions and strengths
Coudert et al. (2008)

CO_2 line positions and strengths
Tashkun et al., (1999)
Already in use by MIPAS team (Flaud et al., 2003)

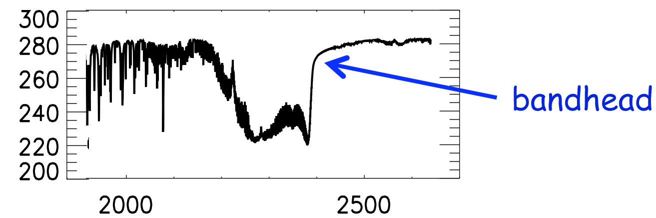
H_2O shifts, T-dep. of widths
Gamache (personal comm.)

CO_2/H_2O continuum
(LBLRTM v11.7 release)



Significant improvements to consistency between spectral regions!

CO_2 v3 bandhead (2385-2600 cm^{-1})



- Contributors to optical depth
  - N_2 continuum (collision-induced)
    - Good accuracy for N_2-N_2 and N_2-O_2 (Lafferty et al., 1996)
    - Small uncertainty due to lack of knowledge of N_2-H_2O
  - CO_2
    - Large uncertainty due to rapid decline of OD at ~2385 cm^{-1} and lack of knowledge of line shape
    - Effects of line coupling need to be accounted for in CO_2 continuum
  - H_2O
    - Self-continuum dominates
    - Very weak absorber in MT_CKD formulation
  - Aerosols – unknown role

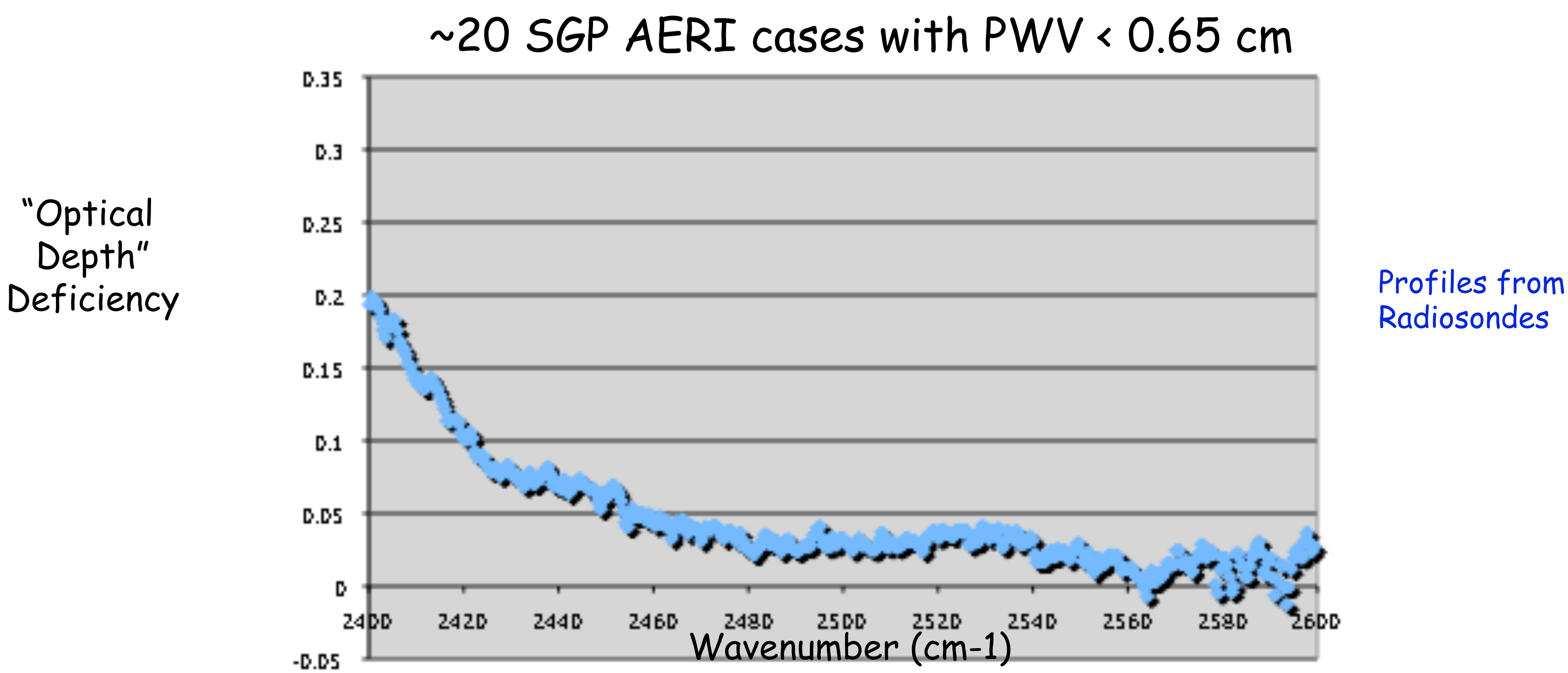
- Challenge – Large sensitivity of Planck function to temperature (compared to mid-IR)

Starting point for study - Observations indicate that LBLRTM v11.6 optical depths are too small in this region

Atmospheric Emitted Radiance Interferometer (AERI)

- Ground-based, zenith view
- 550-3000 cm^{-1}
- Spectral resolution ~ 0.5 cm^{-1}
- Uncertainty ~ 0.4 mW m^{-2} sr^{-1} cm^{-1}
- Developed at University of Wisconsin
- Deployed for ~15 years at ARM Southern Great Plains (SGP) site

Positive AERI - LBLRTM residuals

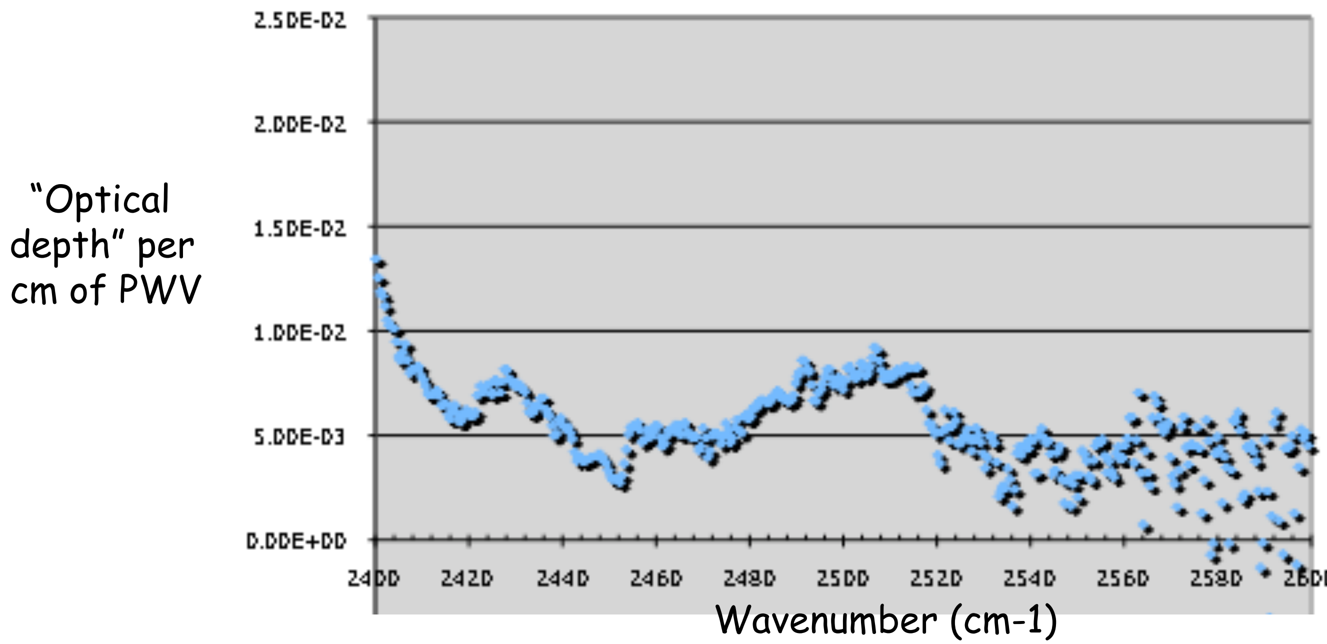


- "Optical depth" deficiency obtained by analyzing radiance residuals and assuming a missing evenly-mixed emitter radiating at $T = \frac{1}{2}(T_{surf} + T_{CG})$

  Analysis for illustration only

- Difficulty in determining zero line (aerosols, instrument effects)

Including higher PWV AERI cases



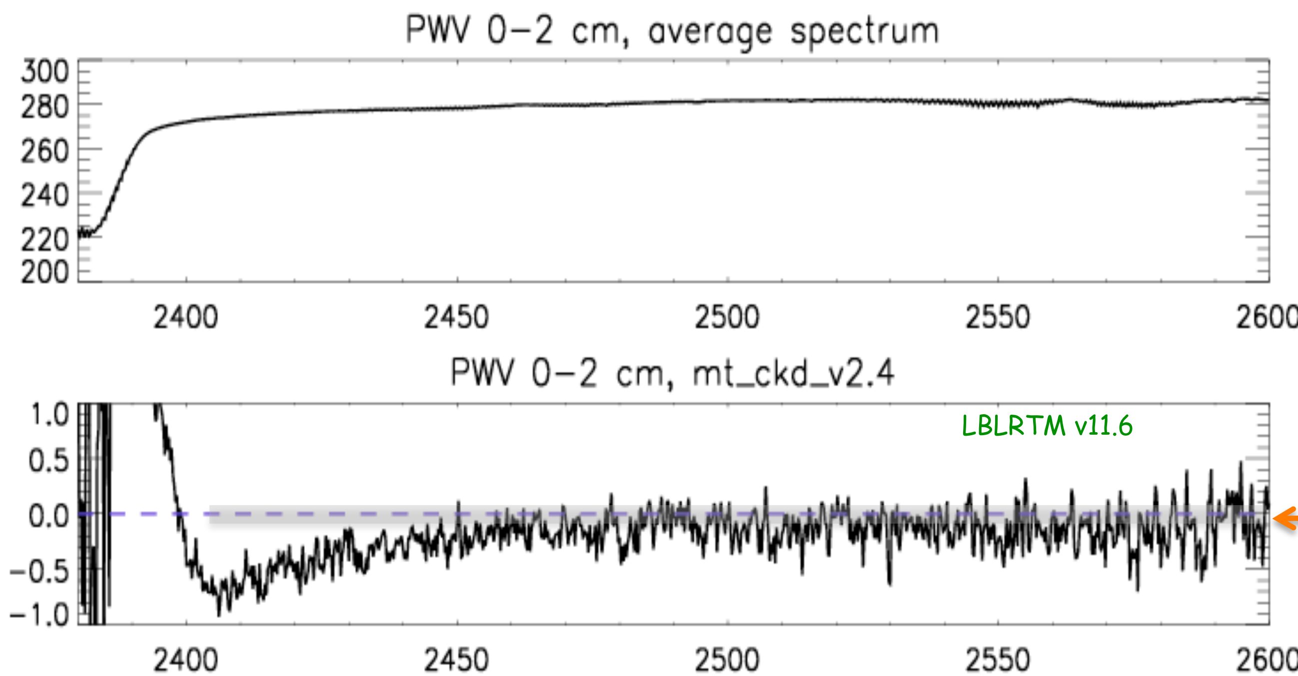
> 200 cases

- Assume:
  - CO2 OD deficit is as on previous slide
  - 2-layer atmosphere with
    - upper layer with CO2 emitting at $T = \frac{1}{2}(T_{surf} + T_{CG})$
    - lower layer H20 absorbing and emitting at T_{surf}

  Look at slope of any OD deficit with respect to PWV
- Features: Reasonably flat with non-negligible OD; odd-looking bump ~ 2500 cm-1

IASI Analysis

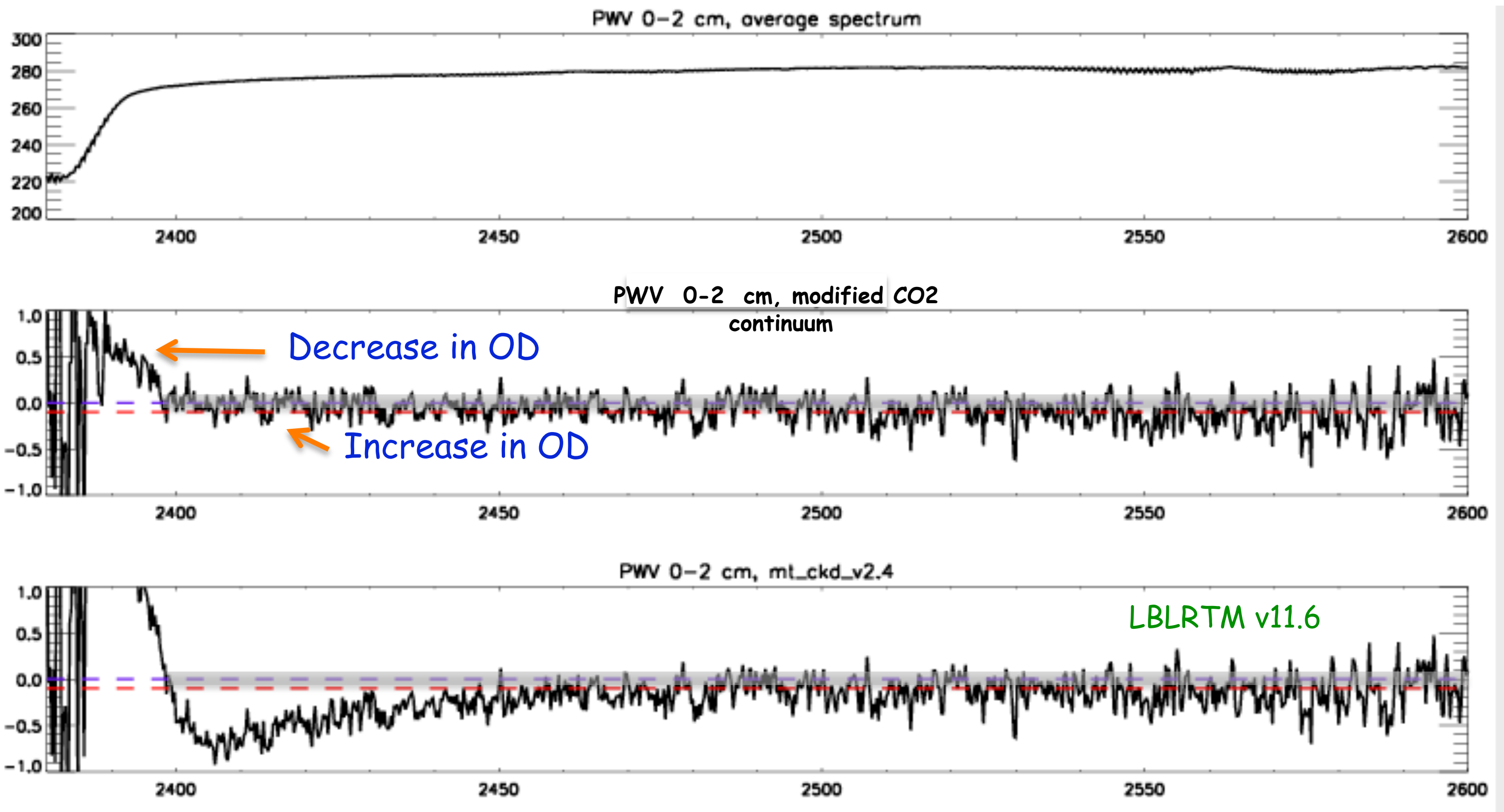
Average of many cases (nighttime, over ocean, low observer angle)
- ECMWF profiles (provided by M. Matricardi)



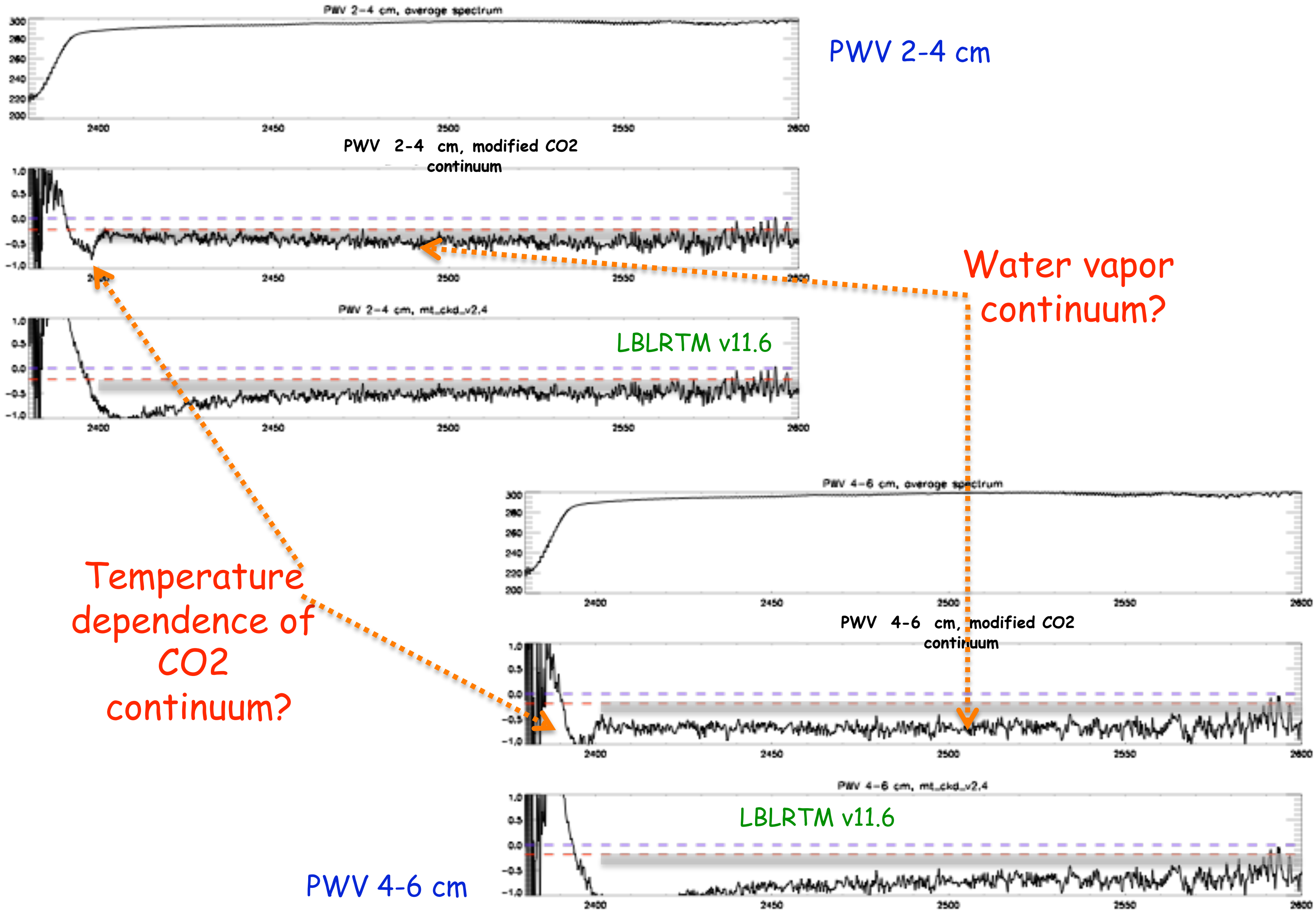
Zone of agreement determined from spectral region of similar brightness temperature near CO2 v2 band + instrumental uncertainty

IASI residuals are consistent with idea of missing 'dry' OD

Empirical adjustment of CO2 continuum



Including higher PWV IASI cases



Temperature dependence of CO_2 v3 band

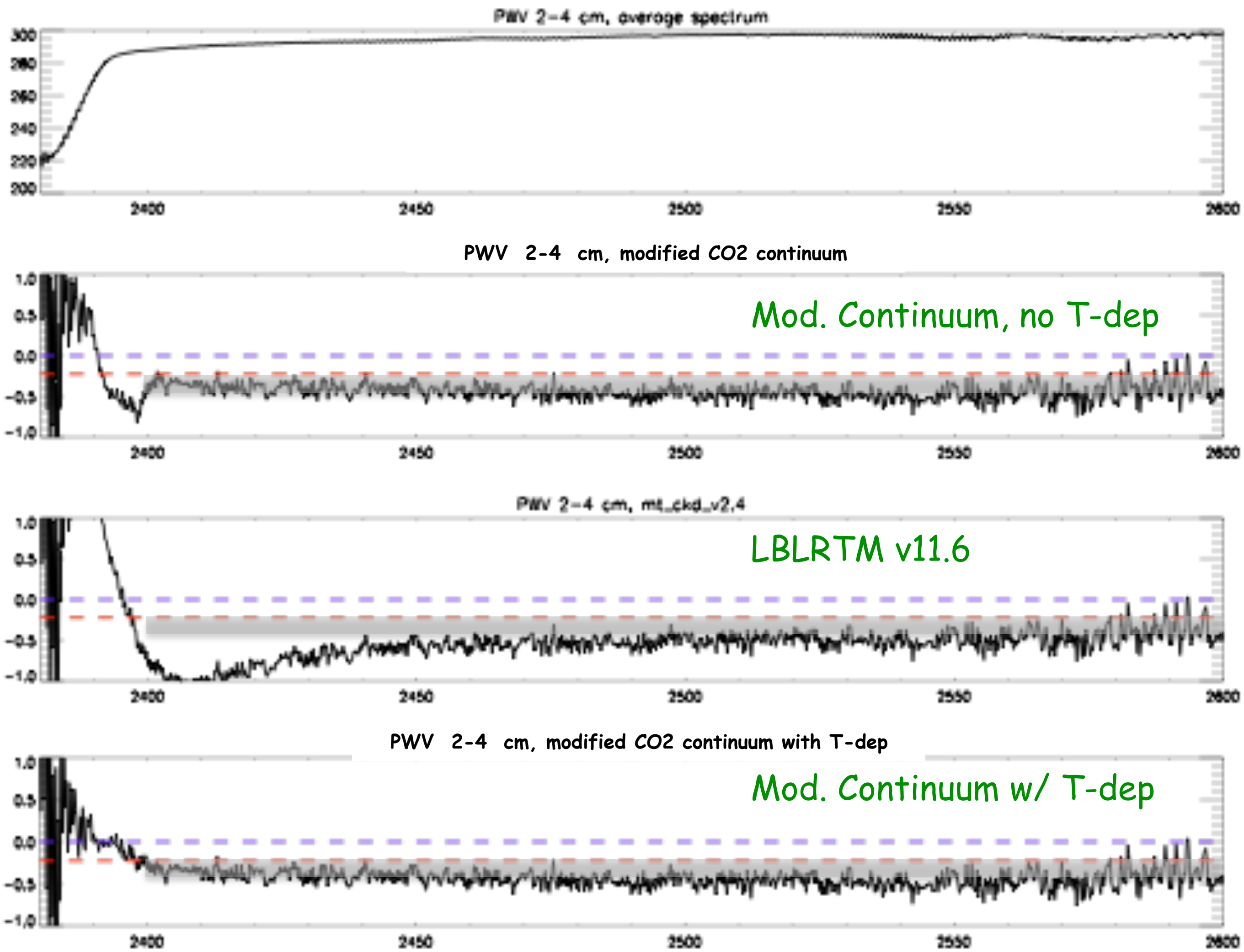
Temperature dependence in CO2 v3 band in LBLRTM v11.6/ MT_CKD_2.4

- Line contribution
  - handled with appropriate temperature dependence
  - first-order line coupling stored at 4 temperatures (340K, 296K, 250K, 200K)
- Continuum coefficients
  - computed based on **296K** line coupling coefficients **only**

Evaluate for MT_CKD_2.5

- Compute continuum coefficients at 4 line coupling temperatures – look at residuals with no empirical adjustments

Including temperature dependence of CO_2 continuum

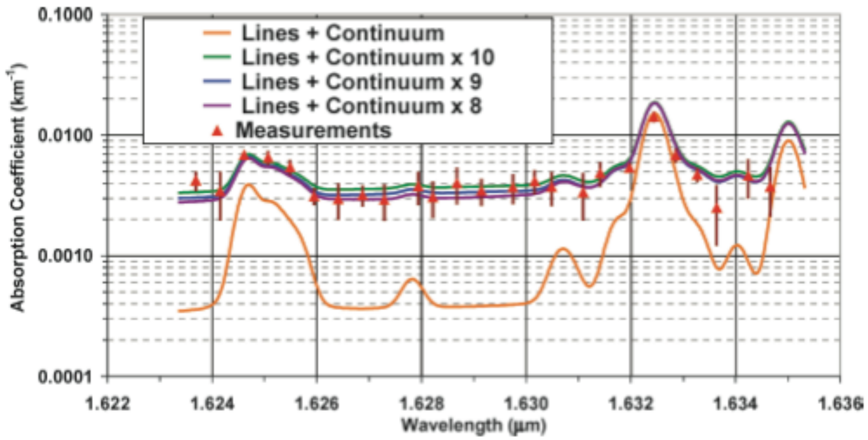


PWV
2-4 cm

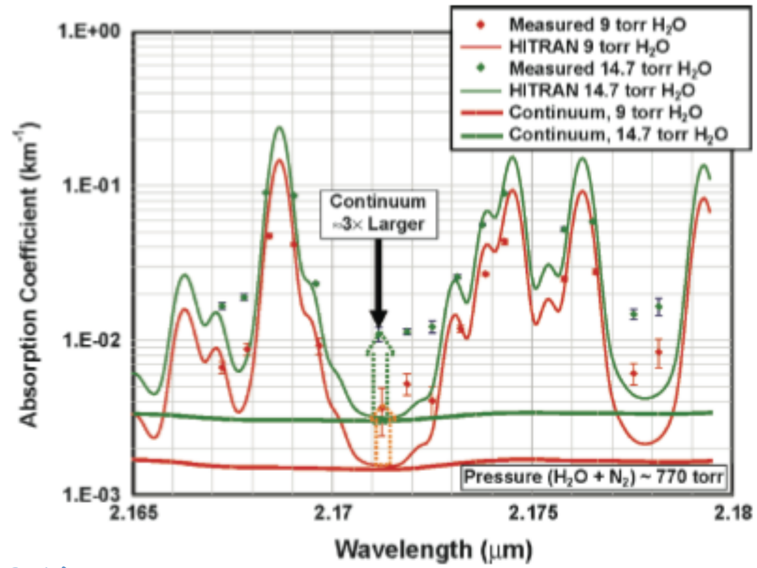
Similar improvement for IASI cases with 4-6 cm of PWV

WV Self Continuum in Near-IR

Lab measurements: MT_CKD self continuum too low in near-IR window regions

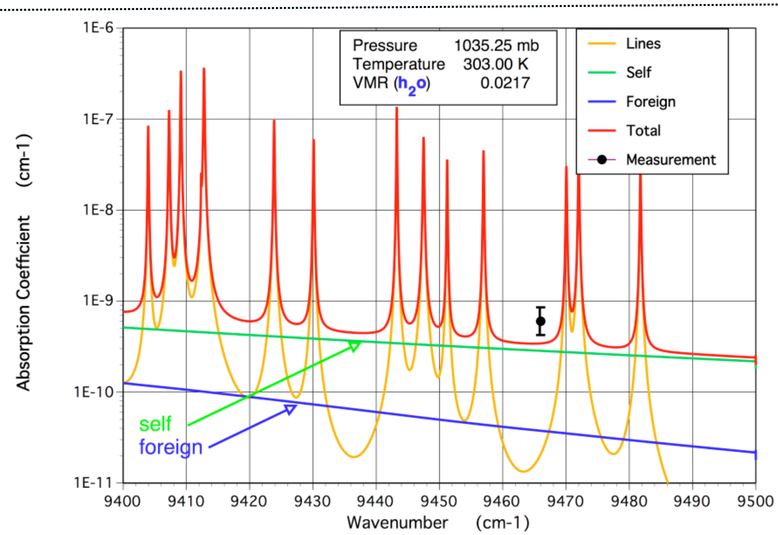


Increase of 6-9x needed ~6140 cm-1



Bicknell et al. (2006)

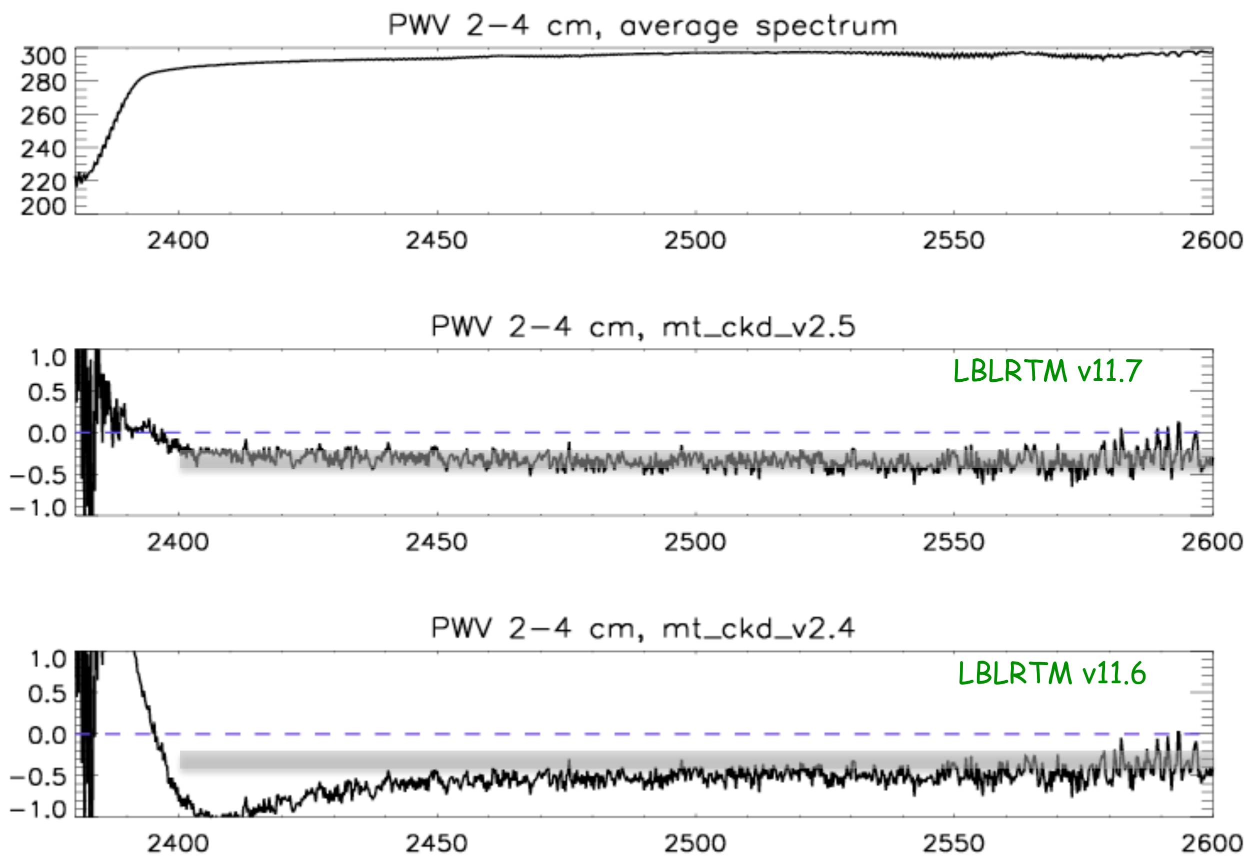
Increase of 2-4x needed ~4610 cm-1



Fulghum and Tilleman (1991)

Increase of ~3x of continuum at 9465 cm-1

Use near-IR values to create new self continuum fit

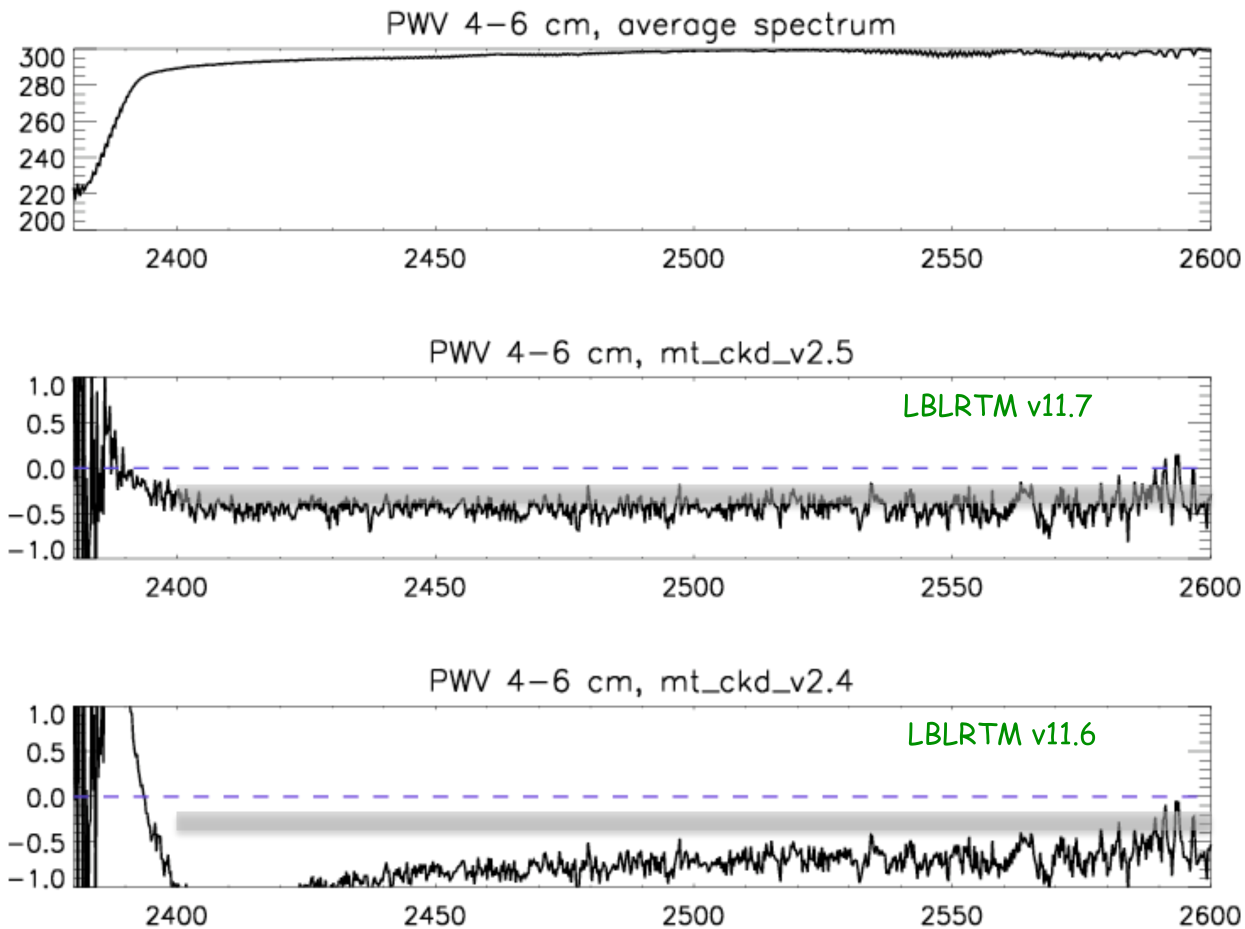


PWV
2-4 cm

New self-continuum coefficients generated from 2000-3000 cm^{-1}

- Scaling of H_2O self continuum by ~5-7 improves fit in window region

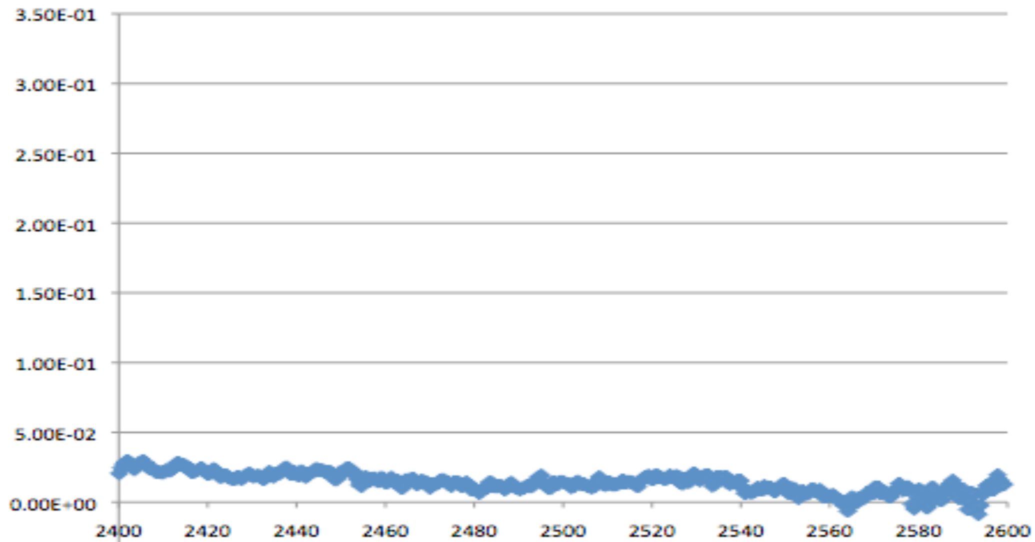
Impact of new self continuum values



PWV
4-6 cm

Back to the AERI data set

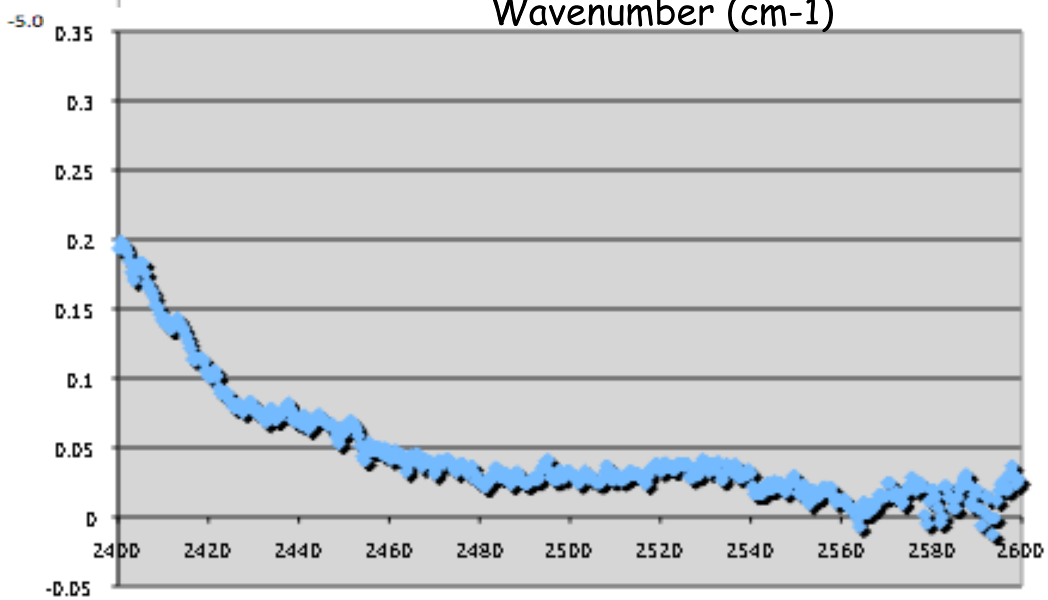
First, the 'dry' OD deficiency (using cases with PWV < 0.65 cm)



Wavenumber (cm-1)

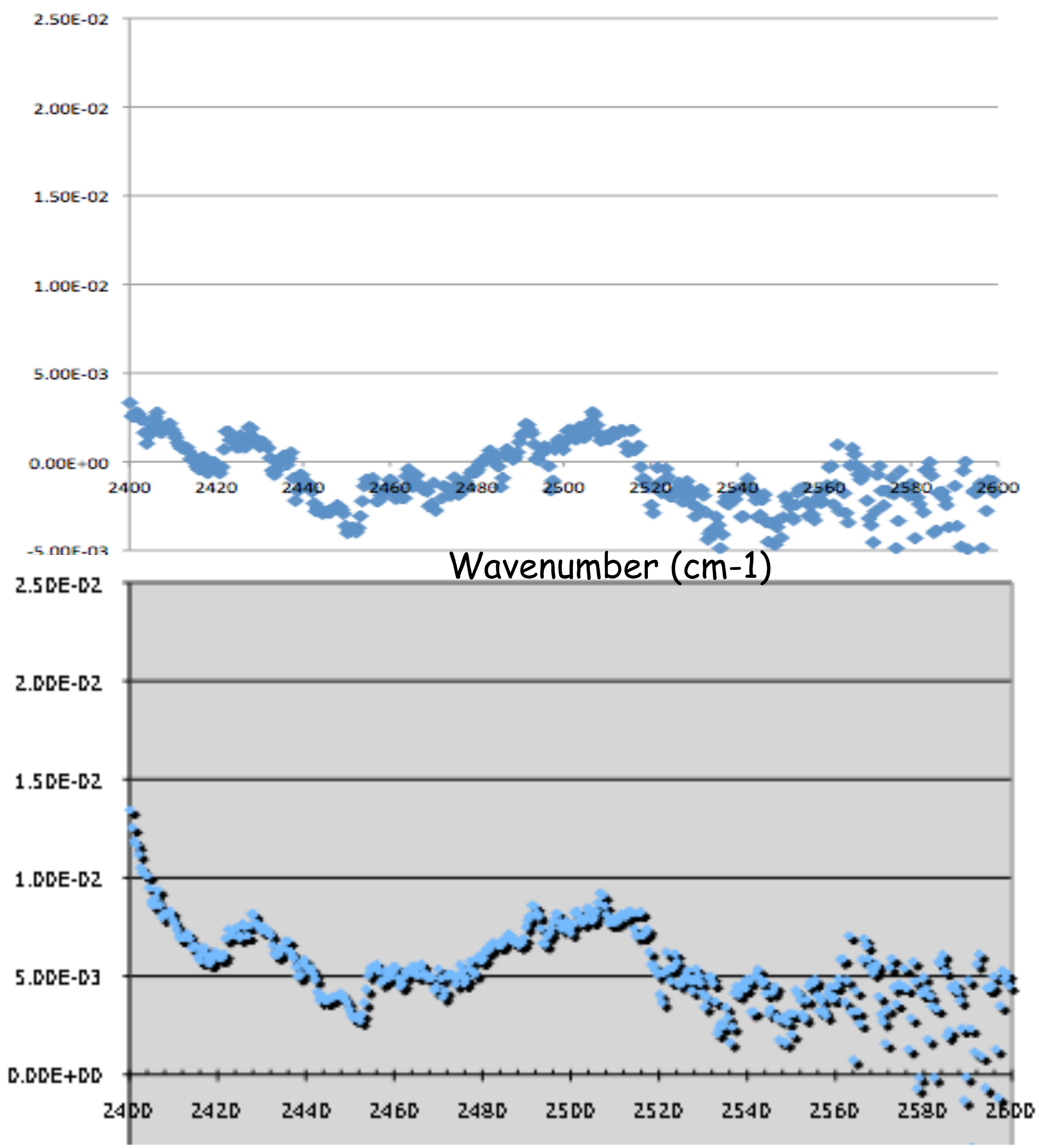
LBLRTM_v11.7

"Optical Depth" Deficiency



LBLRTM_v11.6

Slope of OD deficiency with respect to PWV



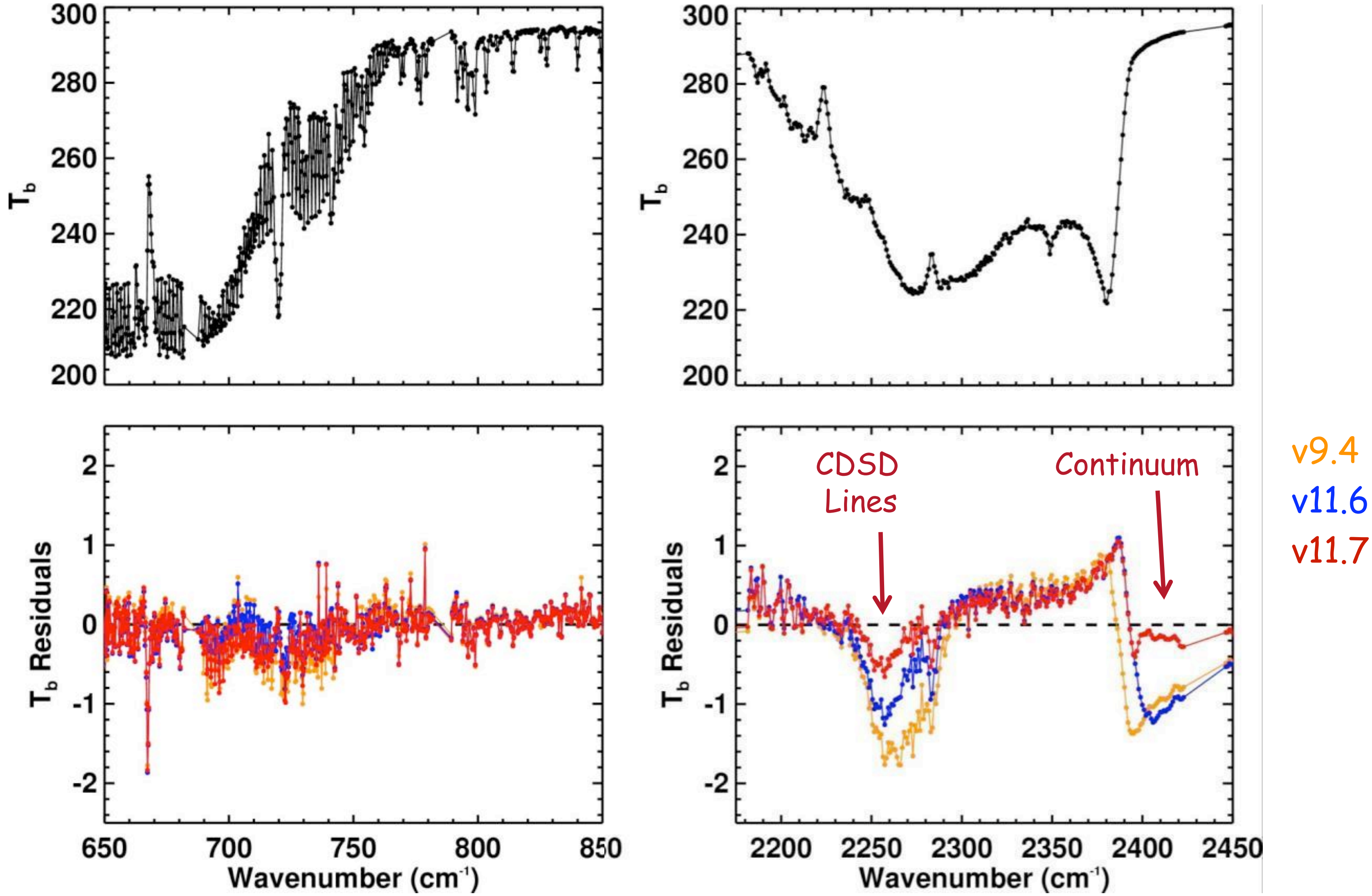
"Optical depth" per cm of PWV

LBLRTM_v11.7

LBLRTM_v11.6

AIRS data: Consistency between v2 and v3

Mean residuals from 36 AIRS ARM TWP cases using Tobin et al. best estimate sonde profiles (Input profiles supplied by L. Strow and S. Hannon).



LBLRTM: future plans

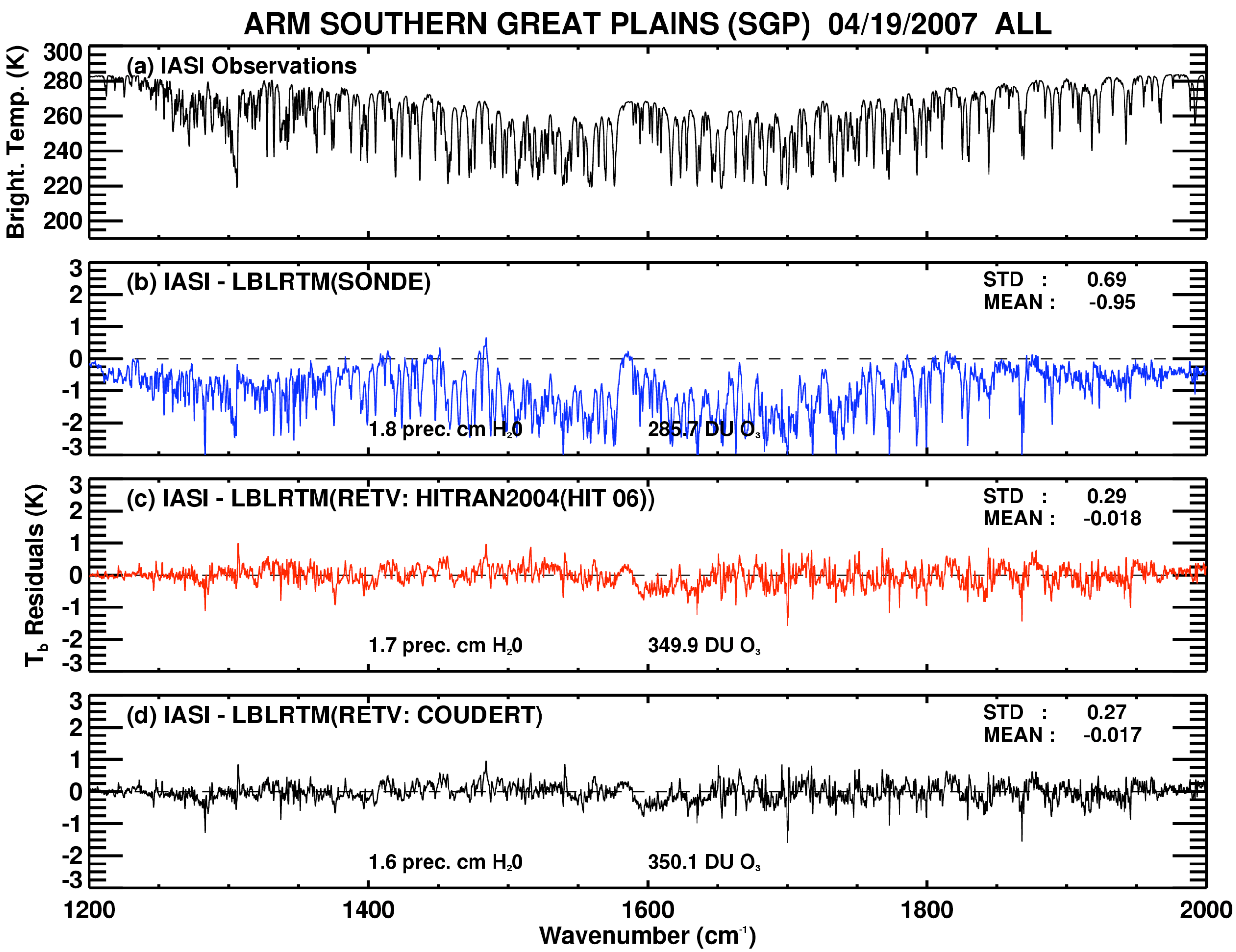
- NLTE:
  - Added flexibility to accept user specified isotopes and NLTE bands (hard coded in current release) in special JCSDA release (April 2010)
- Future:
  - Test with larger set of IASI/RAOB match ups and adjust atmospheric profiles using the radiometric measurements in selected spectral regions
  - CO_2 667 cm^{-1} Q-branch (treatment of line coupling)
  - CH_4 line coupling
  - H_2O v_2:
    - Line widths (R. Gamache, U. Mass Lowell)
    - Local continuum adjustment
    - HITRAN 2008 evaluation

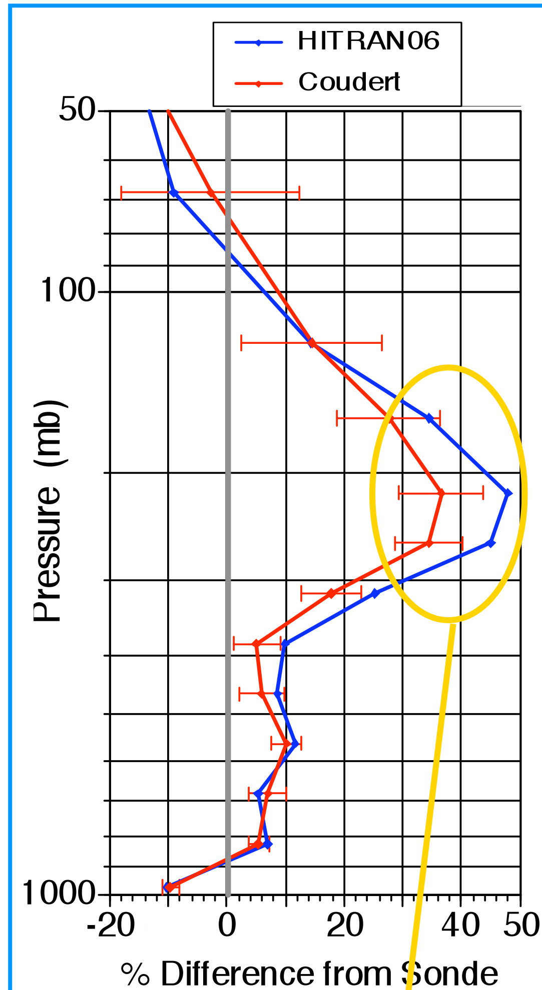
AER RT models available at http://rtweb.aer.com

Extra slides

Water Vapor ν_2 Region : Impact of Coudert Intensities

IASI measurement from JAIVEx campaign





~10 % diff in upper troposphere

Tony Clough and Mark Shephard (Shephard et al., ACP, 2009)