Performance of the Line-By-Line Radiative Transfer Model (LBLRTM) for Temperature and Species Retrievals:

IASI case studies from JAIVEx

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NASA Sounder Science Team Meeting

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Line-By-Line Radiative Transfer Model (LBLRTM)

- **Carefully validated using range of sensors, viewing geometries**
  - DoE Atmospheric Radiation Measurement (ARM) program
  - Satellite programs (NASA, NOAA, ESA, EUMETSAT)
- LBLRTM used to train fast codes for numerous applications
  - **Retrieval algorithms**
    - » E.g. Tropospheric Emission Spectrometer (TES) on NASA's Aura
  - **Radiance assimilation for numerical weather prediction**
    - » E.g. Community Radiative Transfer Model (Joint Center for Satellite Data Assimilation)
  - **Broadband radiative transfer models in GCMs - RRTM**
    - » Numerical weather prediction (e.g. ECMWF)
    - » Climate modeling (e.g. CAM)
    - » Planetary GCMs

LBLRTM package

- **Radiative Transfer Model: LBLRTM_v11.3**
- Continuum Model: **MT_CKD_2.1**
- Line file: **aer_v_2.1**
  - Based around HITRAN 2004 (+ updates)
    - » Specific exceptions made only for good reason and after rigorous validation

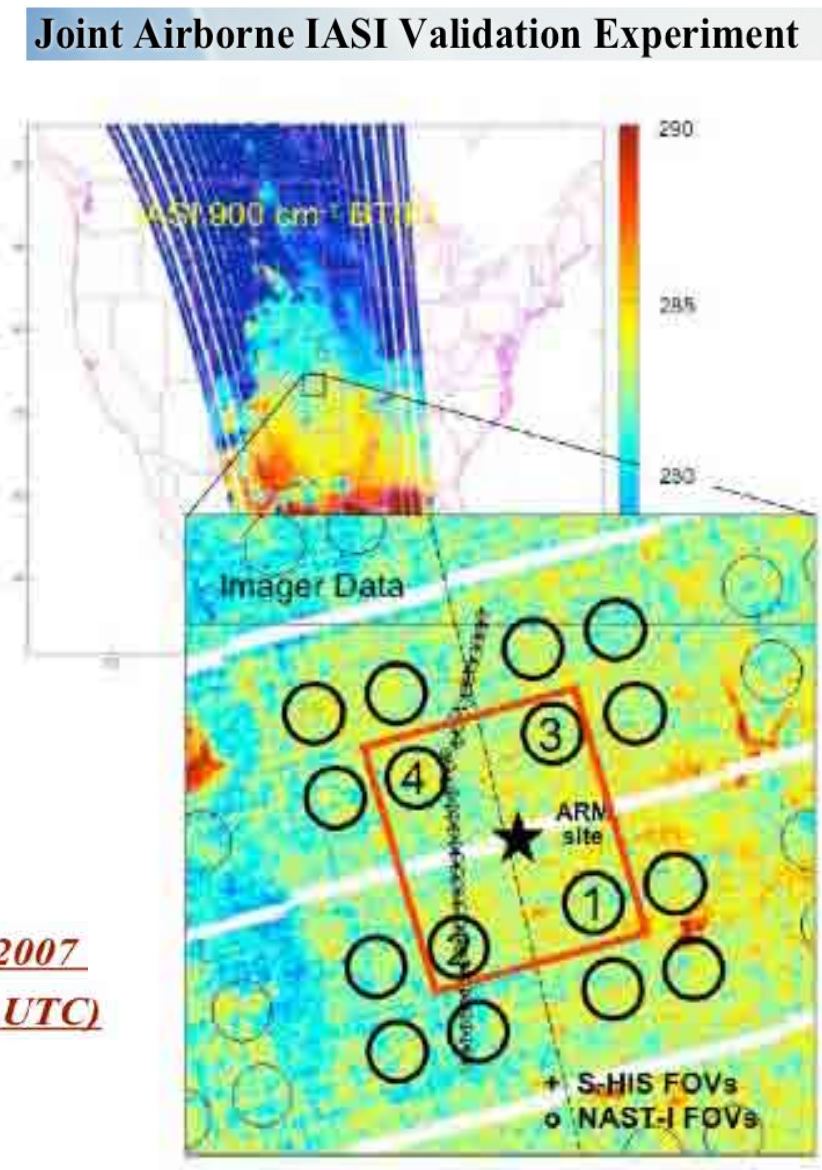
- Remaining uncertainties are associated with spectroscopy:
  - Line parameters
  - Line shape
  - Continuum

- This talk:
  - **CO_2 spectroscopy**
  - **H_2O spectroscopy**

IASI and JAIVEx

IASI

- **IFOV size at Nadir** **12 km**
- Spectral Range 645 to 2760 cm-1
- **Resolution (hw/hh)** **0.25 cm-1**
- Lifetime 5 years
- **Radiometric Calibration** **< 0.1 K**



JAIVEx 19 Apr 2007

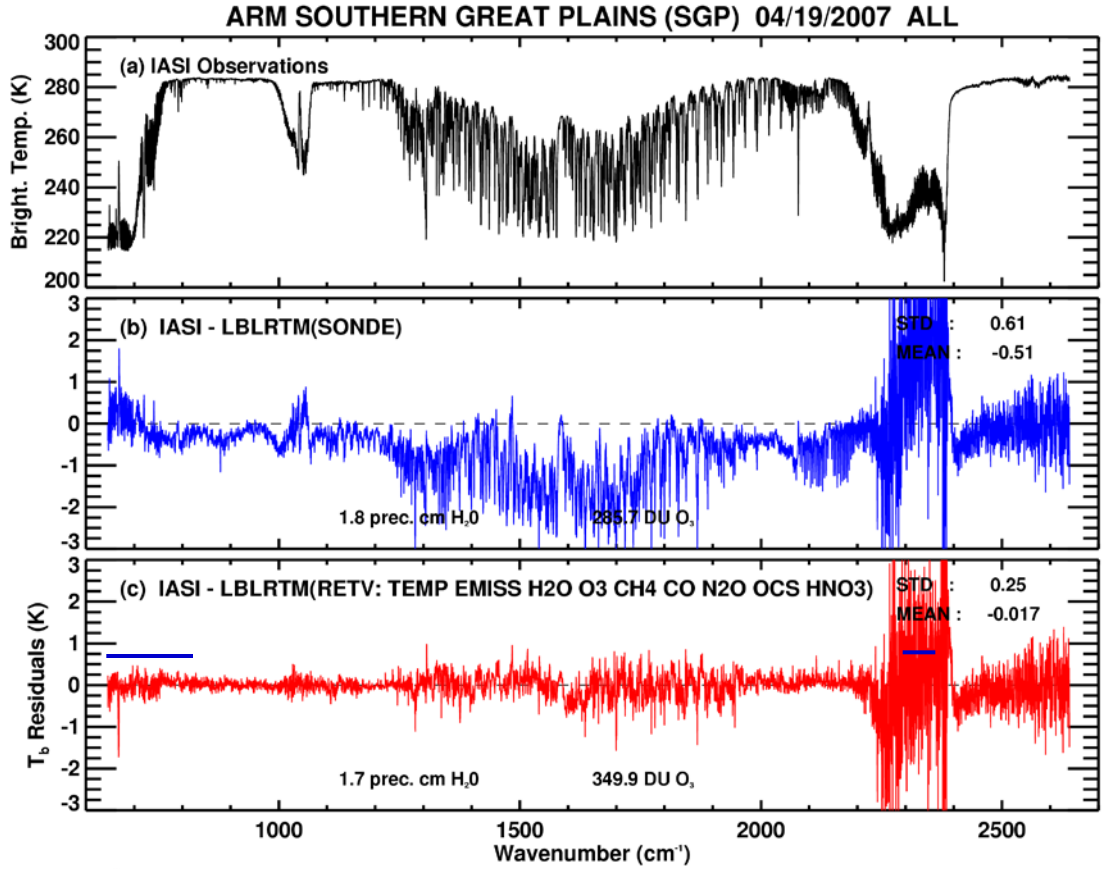
CART-site (03:35 UTC)

IASI/LBLRTM Validation

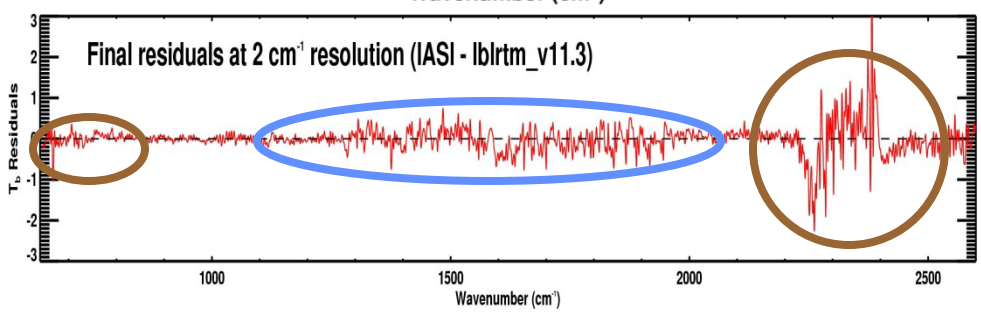
IASI

SONDE

RETV



Residuals at "AIRS-type" resolution



Focus areas of ongoing research: H_2O and CO_2 spectroscopy

What is 'Truth'?

- **Spectral Residuals are Key!**

- **Consistency within a band system**
  - **ν_2 band to investigate consistency for H_2O**

- **Consistency between bands**
  - **IASI ν_2 and ν_3 bands to investigate consistency for CO_2**

- **Consistency between species**
  - **TES: temperature from O_3 and H_2O consistent with CO_2 ; N_2O**

- **Consistency between instruments**

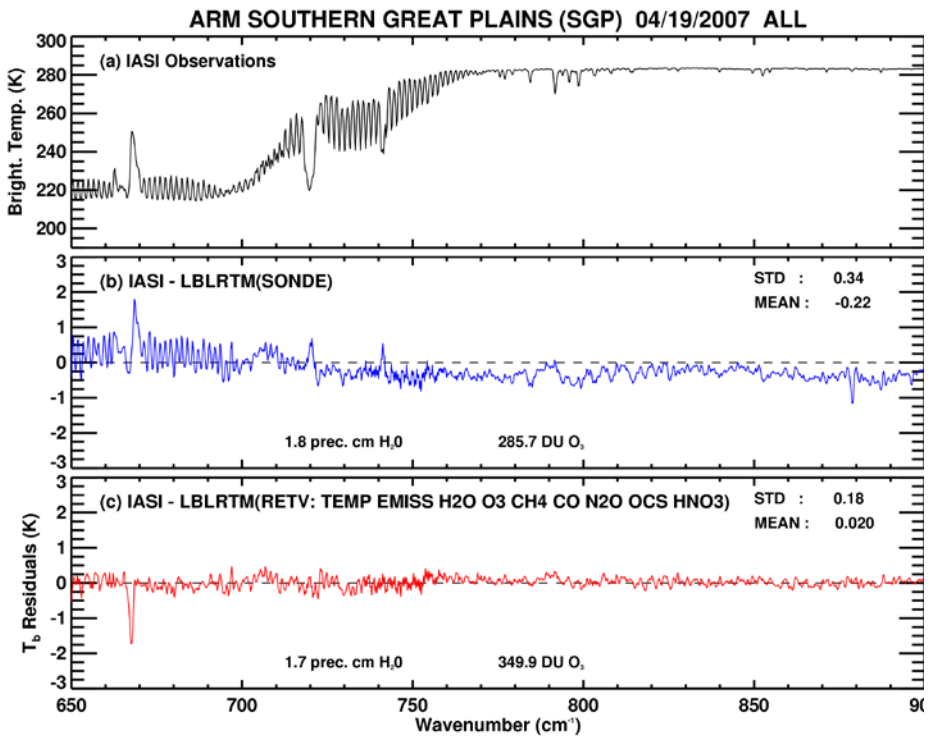
- IASI	- TES	- NAST-I
- AIRS	- MIPAS	- AERI
- ACE	- SHIS	

Line parameters for carbon dioxide

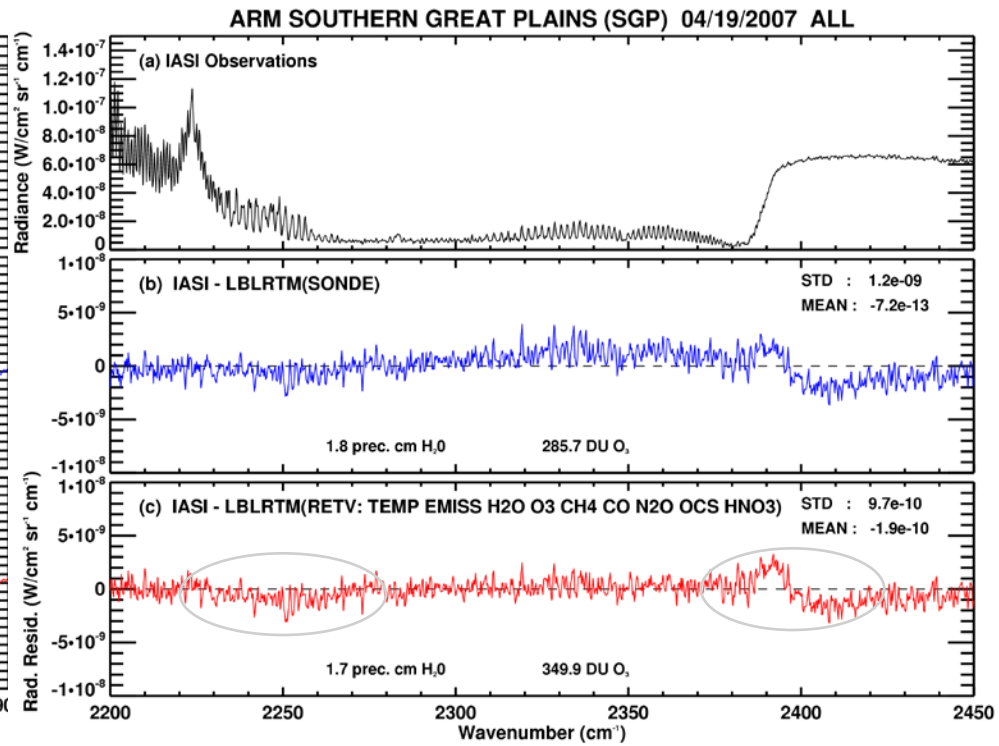
- **Current CO_2 parameters**
  - **HITRAN** strengths, widths etc
  - P, Q and R branch line coupling coefficients based on **Niro et al. (2005)**
    - » Jean-Michel Hartmann's group
  - Implementation of Hartmann's line coupling scheme was a major improvement!
- **CO_2 line strengths/positions from method of Tashkun et al. (1999)**
  - Implemented for the MIPAS forward model (Flaud et al., 2003)
- **Implementation of new parameters in LBLRTM (not yet released)**
  - Required re-calculation of line coupling parameters
  - Some work needed to get Hartmann's scheme to use alternative parameters
  - Recently completed, comparisons performed with AIRS and IASI data
  - **Results: Improved consistency across spectral regions**

CO_2: Issues with HITRAN parameters

CO_2 ν_2



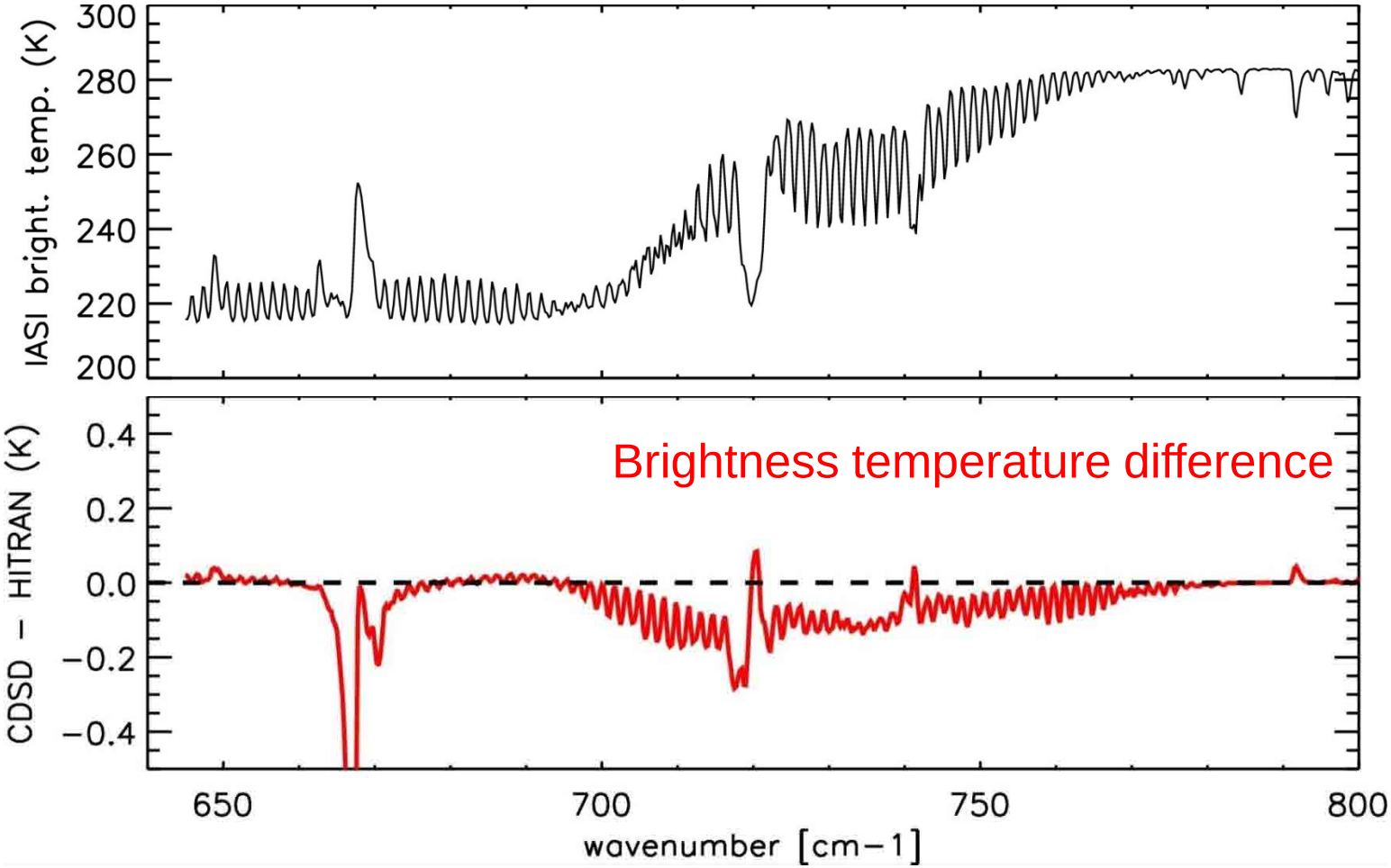
CO_2 ν_3



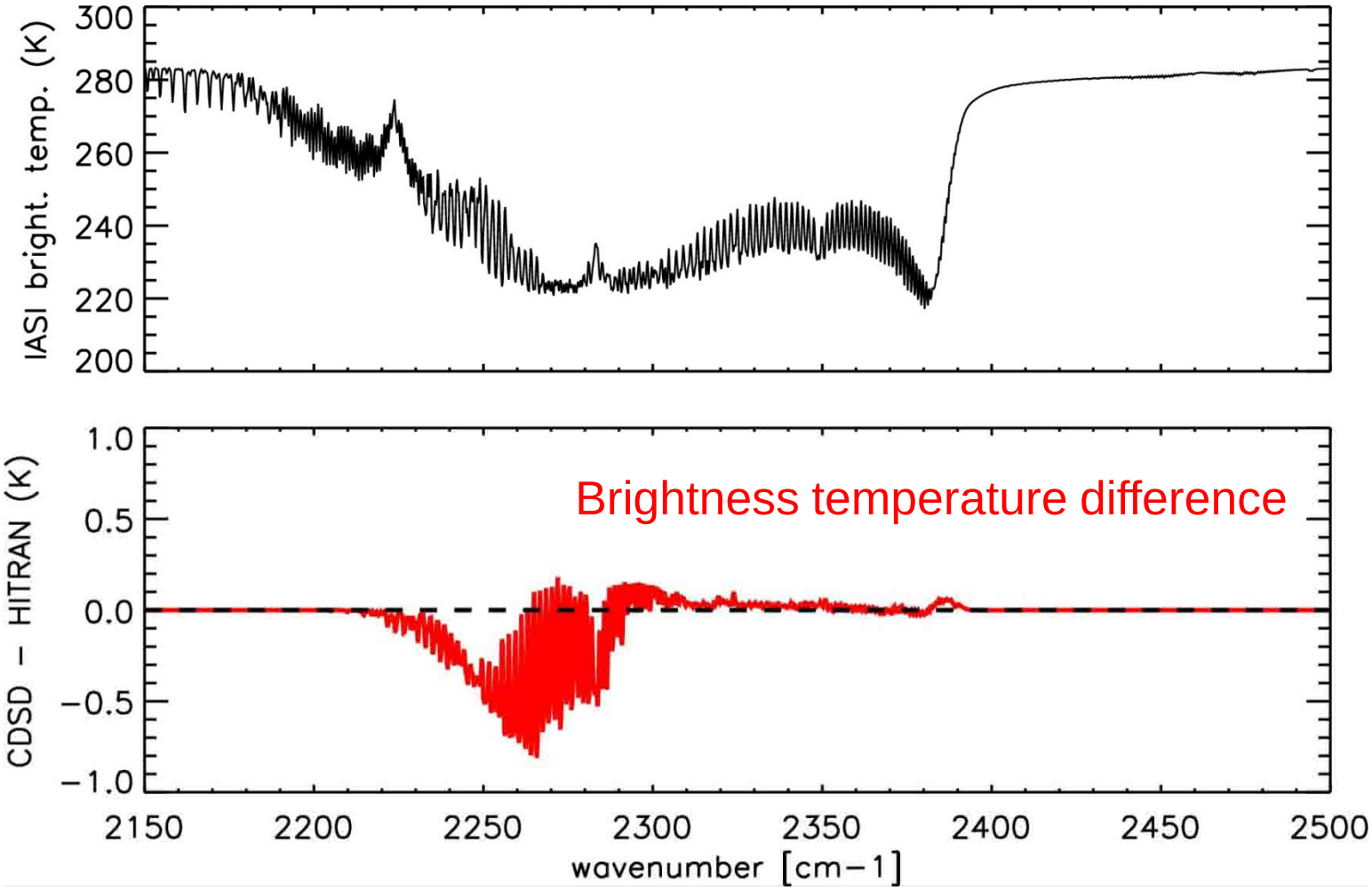
Importance of CO_2 spectroscopy:

- Temperature retrievals
- Trace gas retrievals (through impact of temperature retrievals)
- CO_2 retrievals (directly)

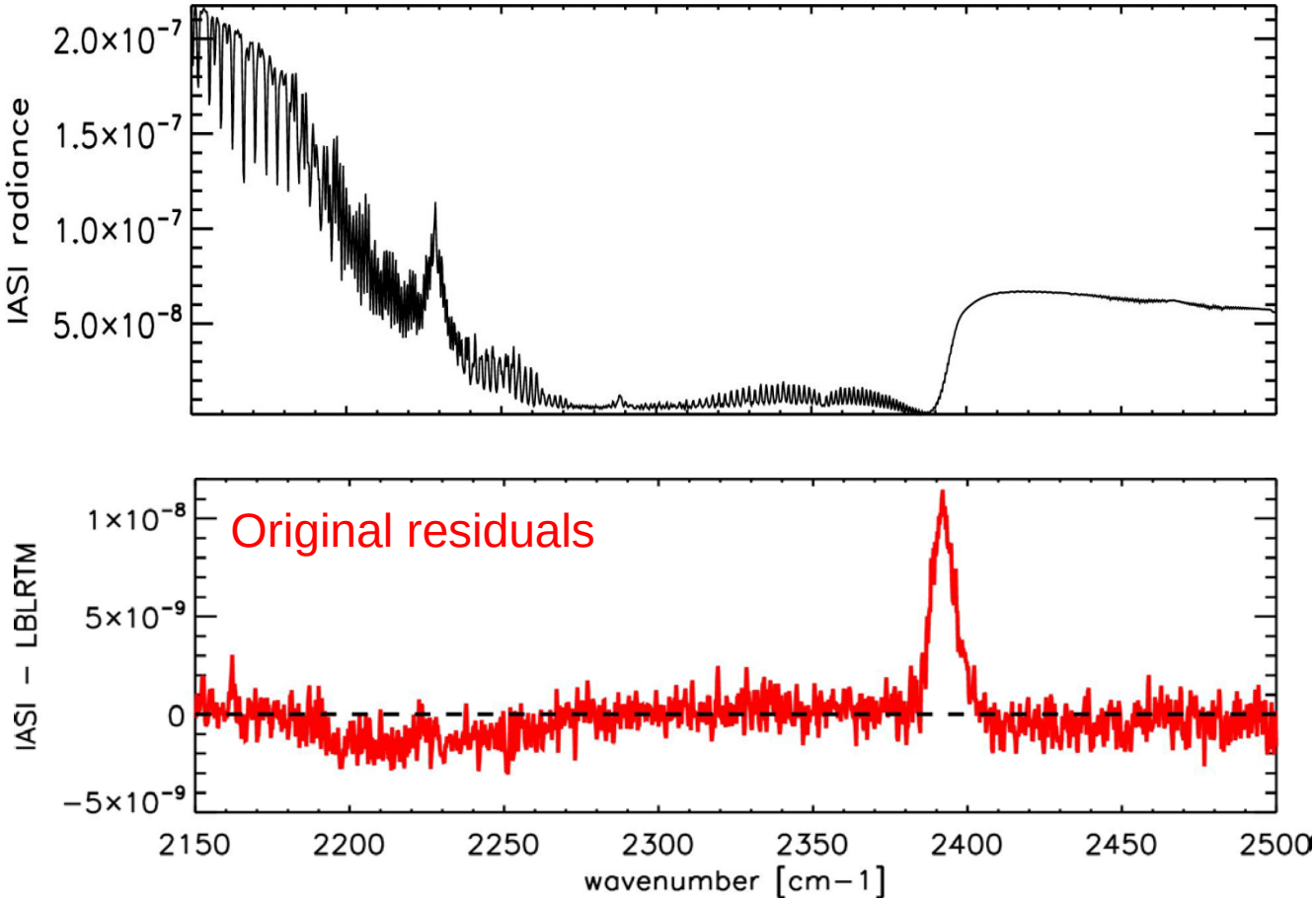
Impact of Tashkun (CDSD) line parameters in CO_2 ν_2



Impact of Tashkun (CDSD) parameters in CO_2 ν_3 region



CO_2 ν_3 spectral region: Spectroscopic improvements

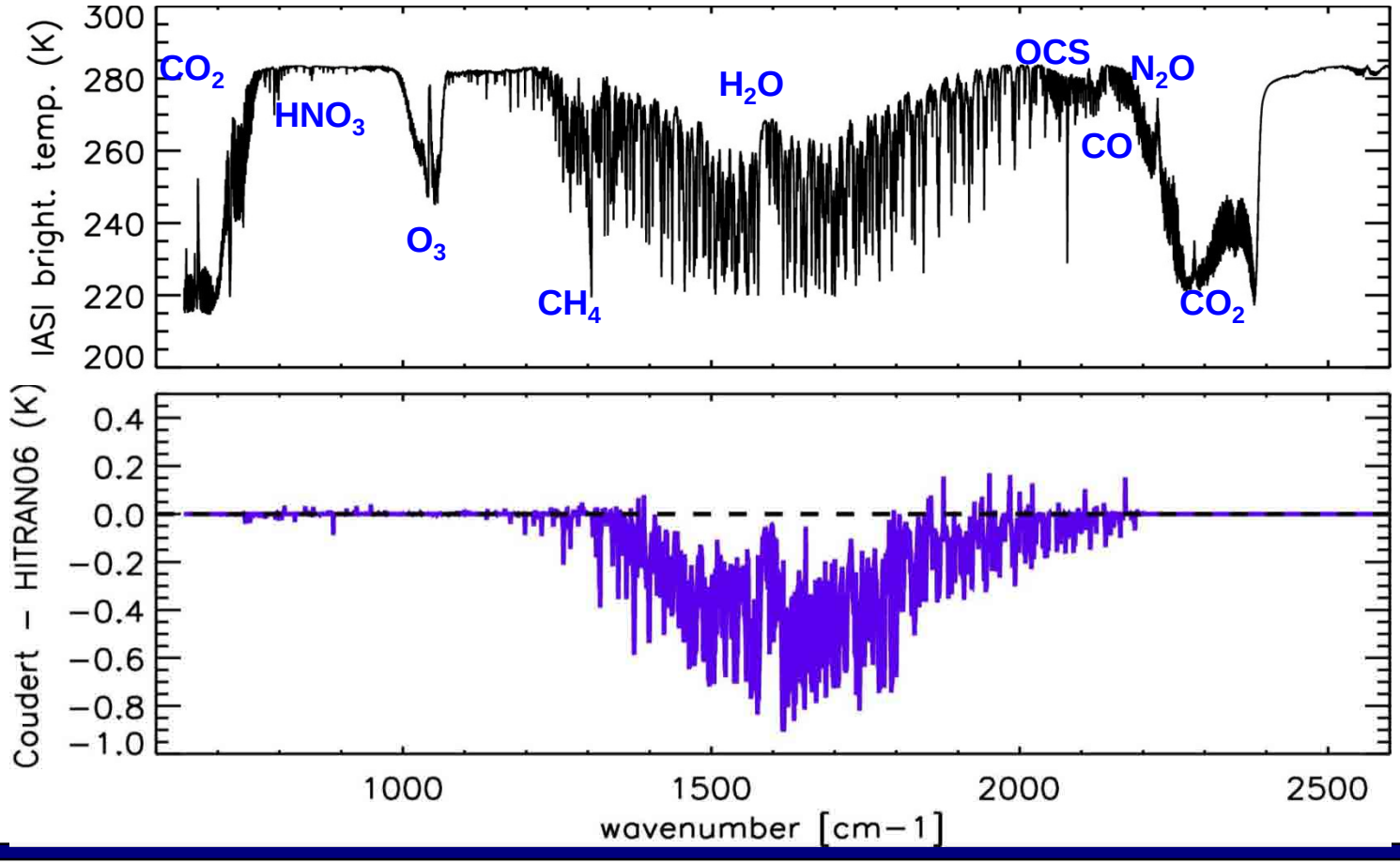


Water vapor spectroscopy

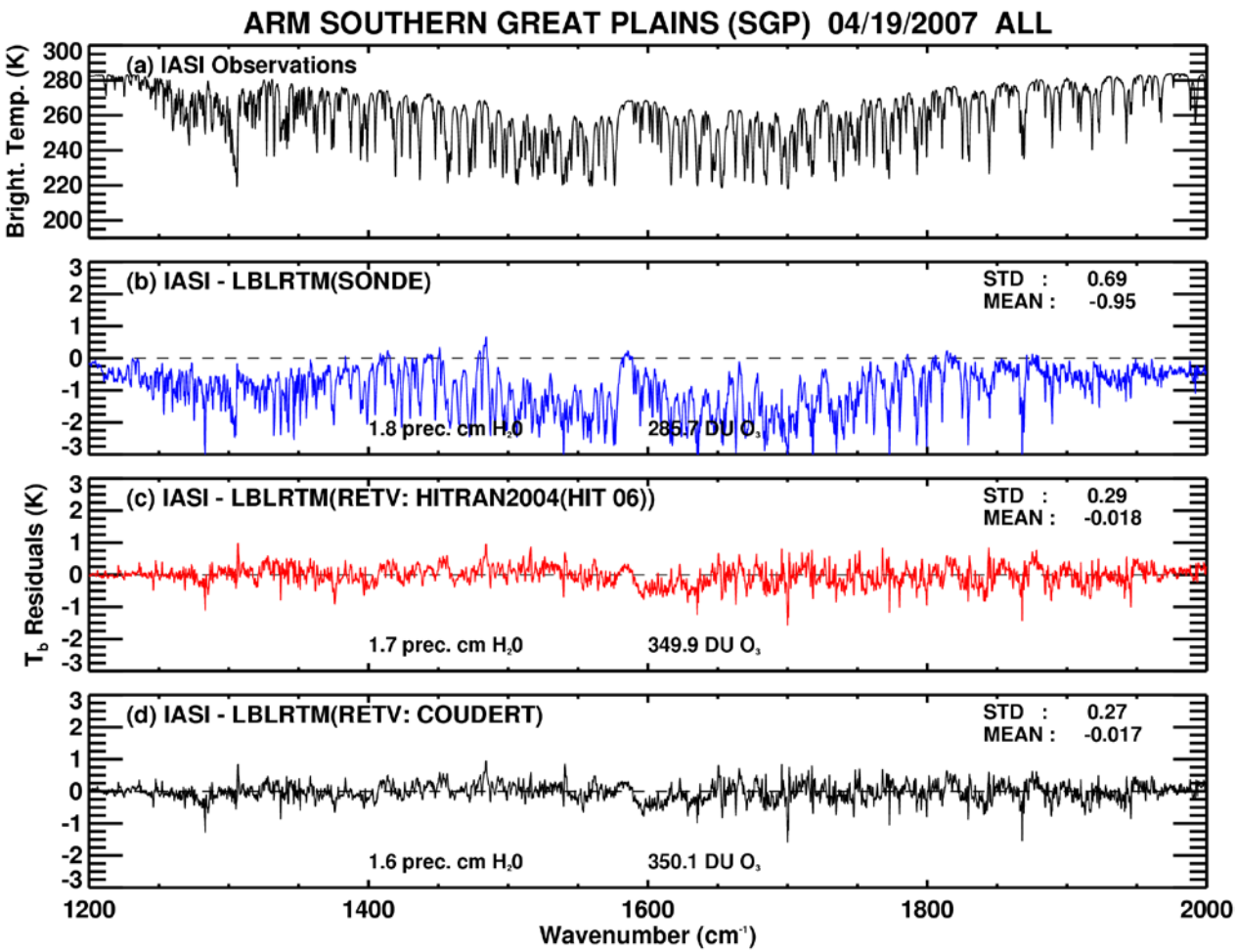
- **Current water vapor line strengths/positions used by LBLRTM:**
  - HITRAN 2004 (+ 2006 updates)
  - From an analysis by Bob Toth (JPL)
- **Coudert et al. (2008), J. Mol. Spec.**
  - Some new measurements
  - Some re-fitting of available measurements
  - **Strengths of stronger lines are ~5-7 % weaker than HITRAN 2004**
  - **Toth is working on a re-analysis**
    - » New analysis indicates his strengths are within 1 % of Coudert's
- **Validation of Coudert parameters at AER**
  - Primarily using IASI data, also AIRS
  - Provides some confidence in the Coudert parameters
  - Shephard et al., (2009) ACPD
- **Future work:**
  - Assessment of temperature dependences for widths from Bob Gamache (UMass)

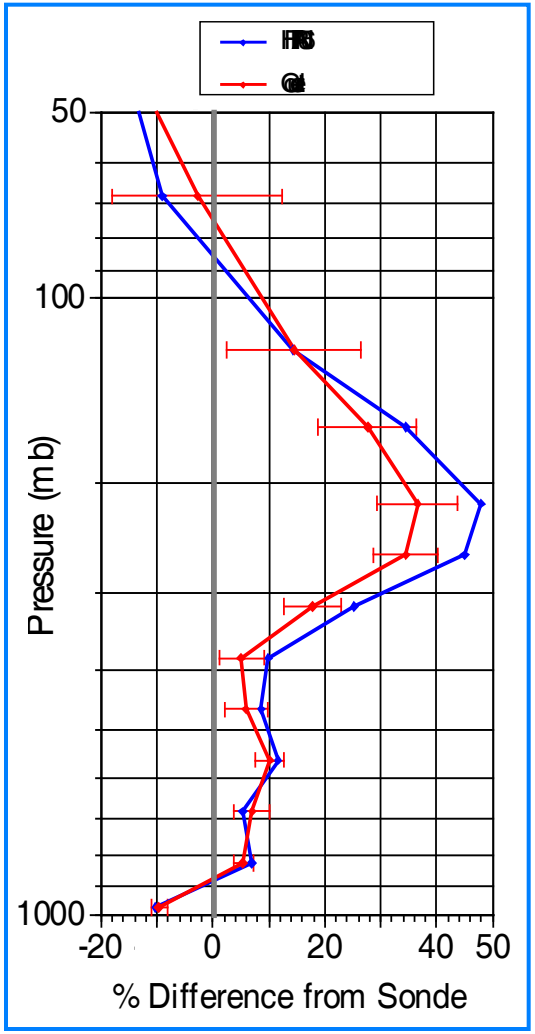
Line parameters for H_2O

- **Changes in H_2O parameters have an impact throughout the spectrum**
  - Potential to influence other species retrievals as well as H_2O



Water Vapor ν_2 Region : Impact of Coudert Intensities





~10 % diff in upper trop!

Consistency across spectral regions

Mean residuals from 36 ARM TWP cases: Profile inputs from AIRS Phase I val. supplied by L. Strow and S. Hannon.

LBLRTM

CO_2 line strengths

Tashkun et al. (1999)

CO_2 line coupling

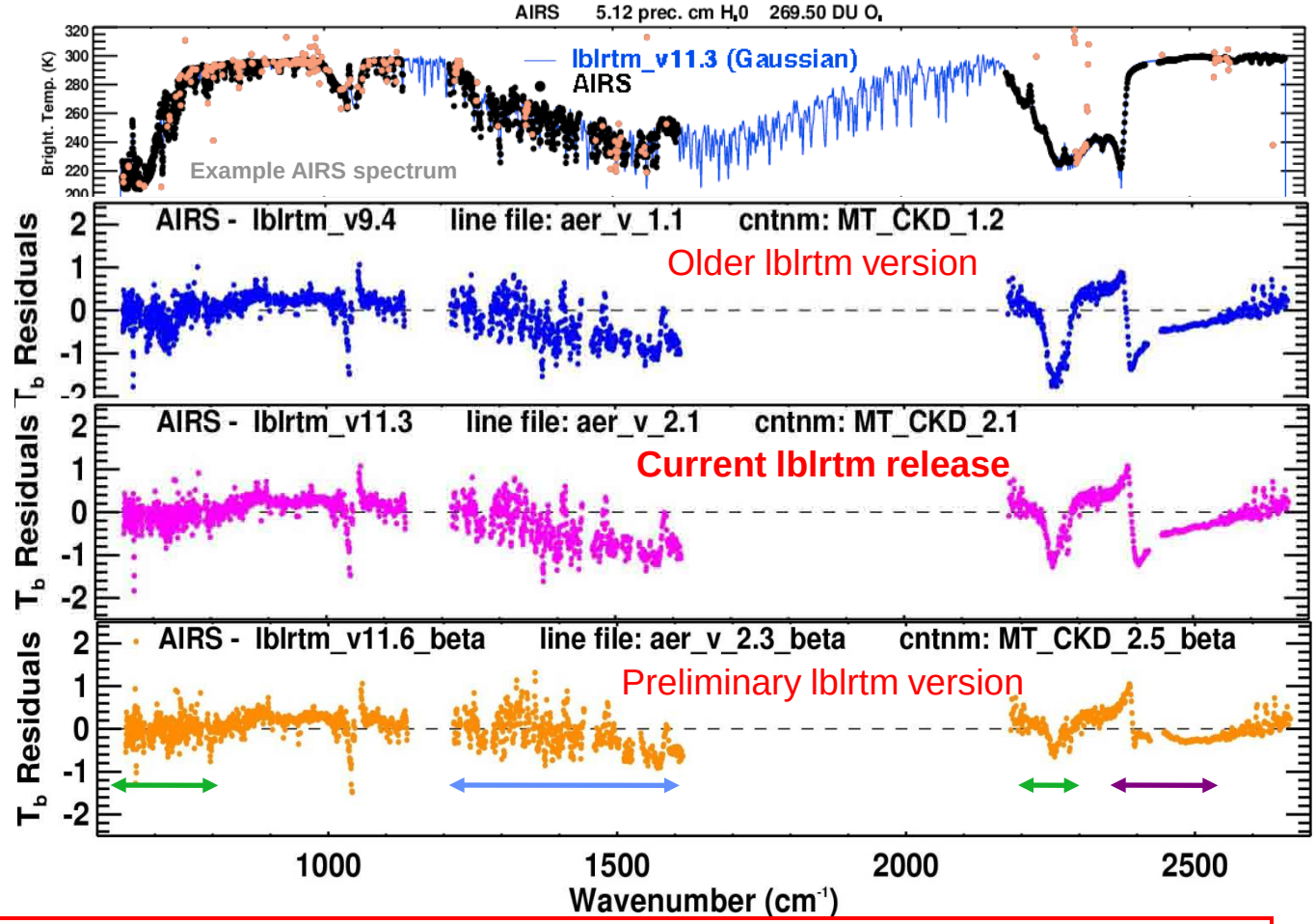
Application of Niro et al. (2005) code to Tashkun line parameters

CO_2 continuum

Empirical correction constructed using ARM ground-based interferometer meas.
Future improvements will focus on the physics of the line coupling in this region

H_2O line parameters

Coudert et al. (2008)



Significant improvements to consistency between spectral regions!

Summary

- **Carbon Dioxide:**
  - Line coupling is key
  - Relaxation matrix needs adjustment

    and/or
  - Duration of collision effects need to be included
  - CO_2 continuum requires modification
  - ν_2 and ν_3 approaching consistency

    Tashkun line parameters currently being evaluated
  - ν_2 667 cm^{-1} Q-branch not yet consistent

- **Water Vapor:**
  - Coudert line parameters being adopted

    Internal consistency is not necessarily conclusive
  - Residuals are larger than IASI noise
  - Line coupling, widths and shifts ?

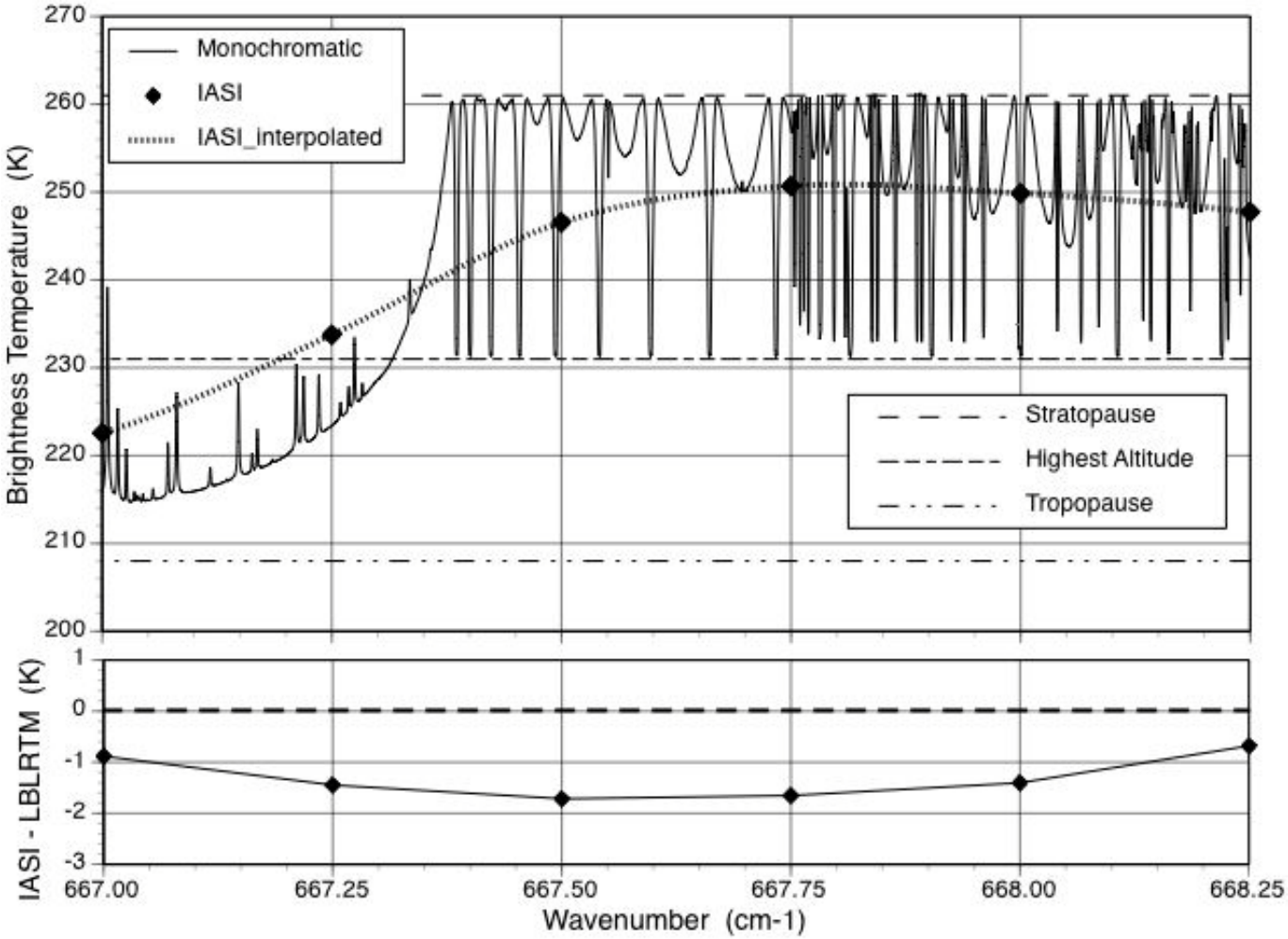
- **LBLRTM package is publicly available at http://rtweb.aer.com**

- **Contact me if you are interested in the following related research:**
  - **Microwave/sub-mm spectroscopy**
    - » H_2O line widths and continuum
  - **Far-IR spectroscopy**
    - » H_2O line parameters and continuum
  - **Upcoming field campaign at extremely low water vapor amounts**
    - » 0.1 mm column water vapor!
    - » Ground-based measurements in spectral regions normally opaque from the ground
    - » Evaluate H_2O spectroscopy within bands, especially far-IR
  - **RRTM (AER flux and heating rate code)**

vpayne@aer.com

Backup slides

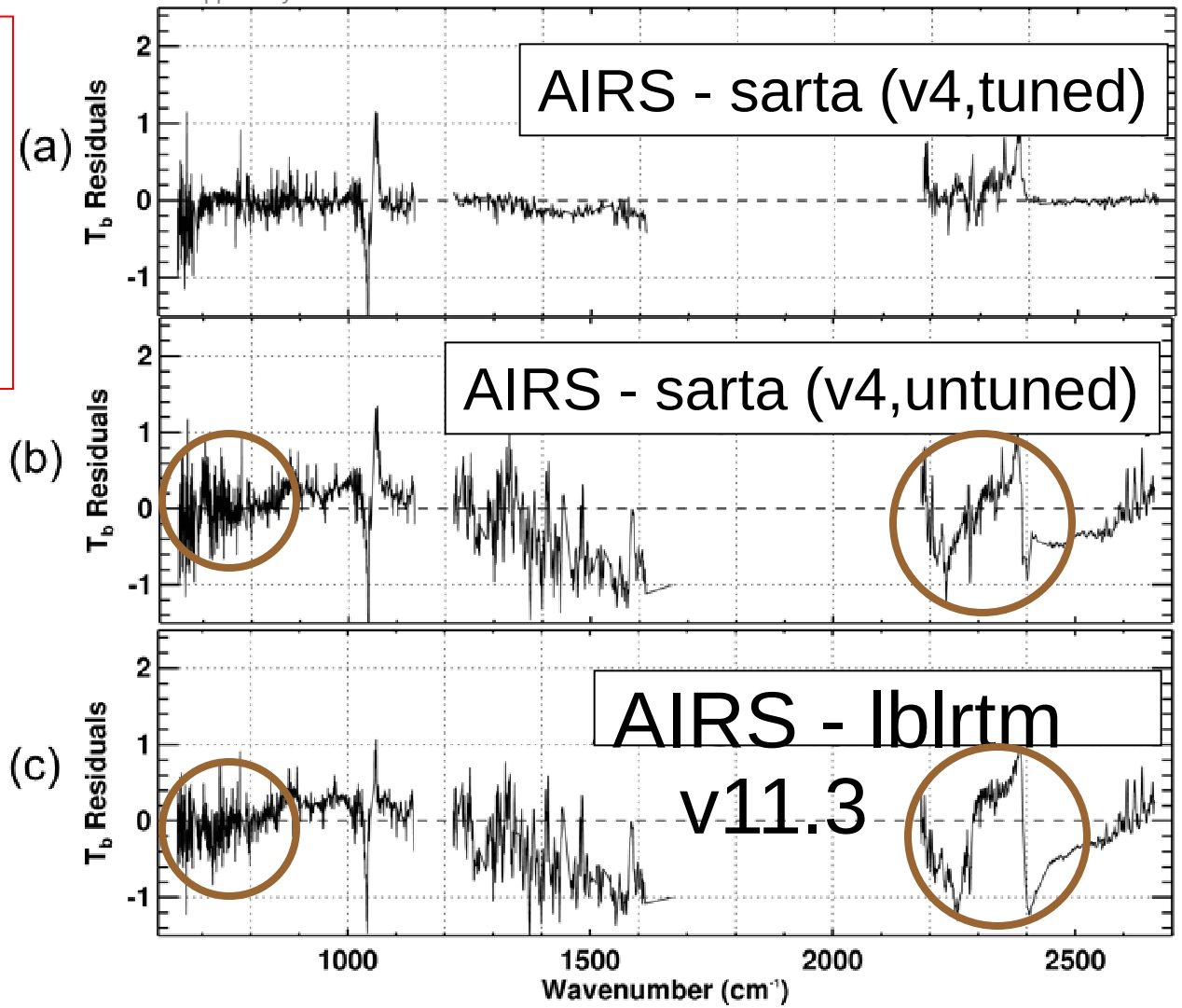
CO_2 Q-Branch: 667 cm-1



AIRS residuals

- Consistency for CO_2:
  - **Issues are with spectroscopy**
  - Not RT calculation
  - Not instrument

Mean residuals from 36 ARM TWP cases: Profile inputs and SARTA results from AIRS Phase I val. supplied by L. Strow and S. Hannon.



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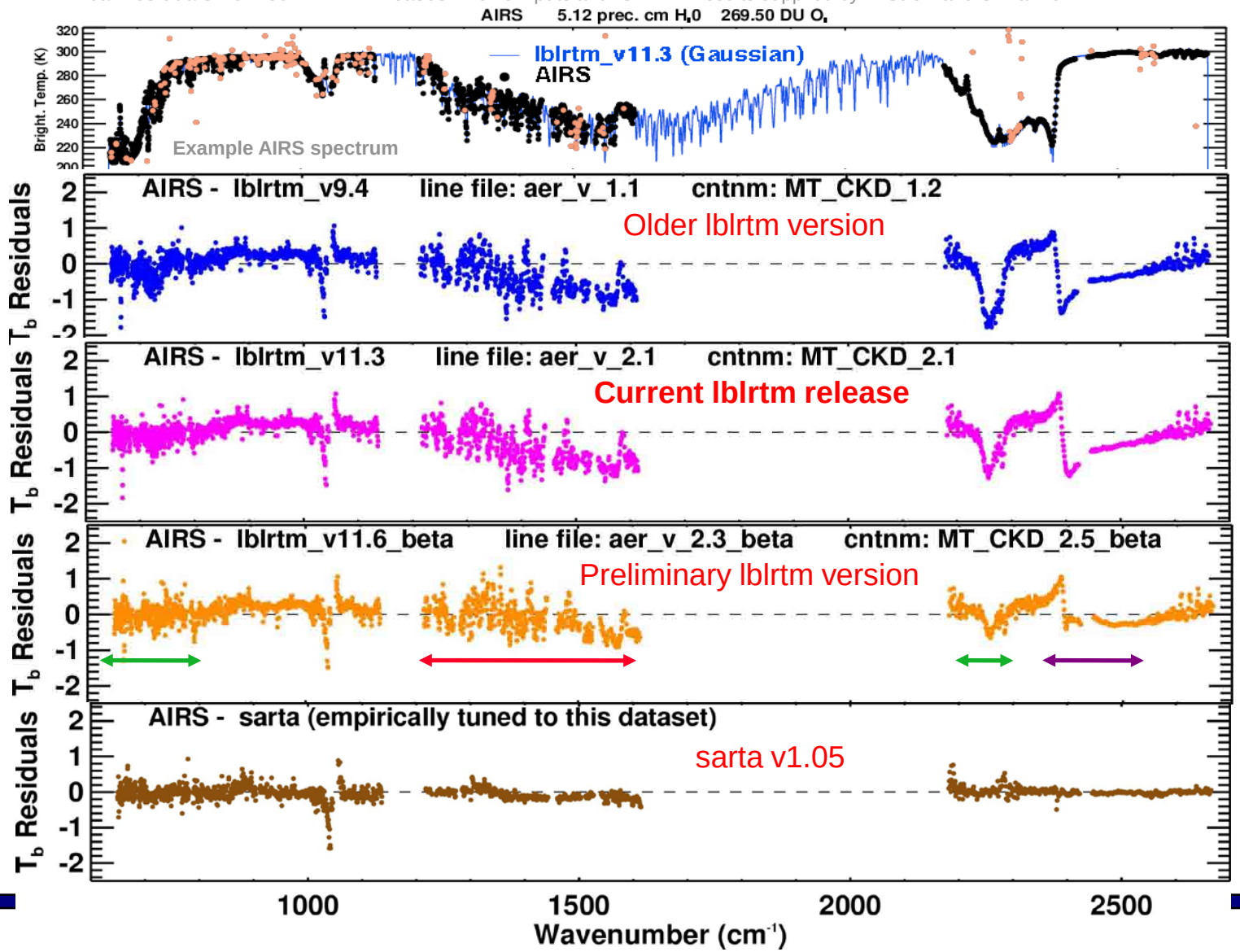
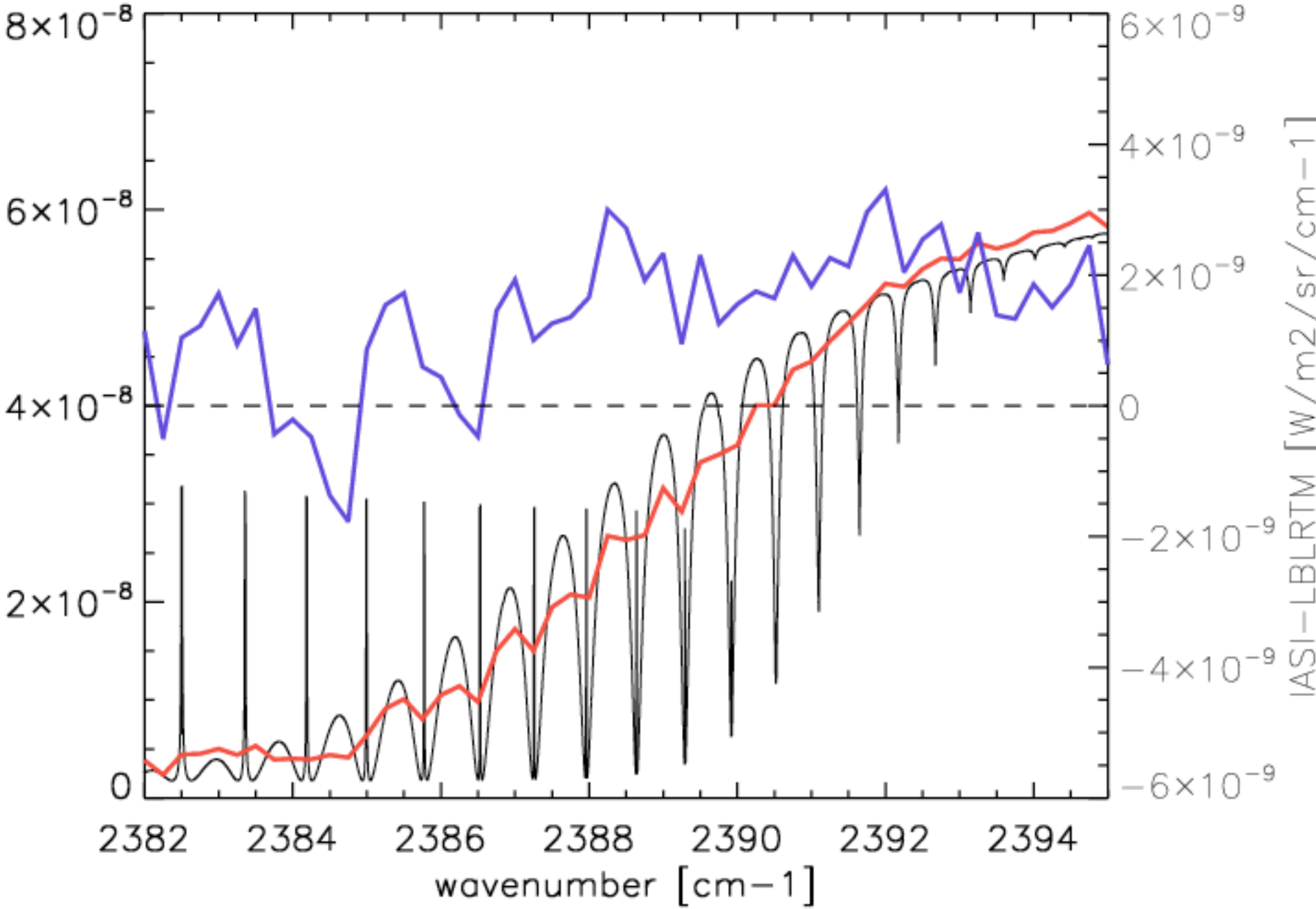
AIRS/LBLRTM/SARTA results for TWP dataset

Mean residuals from 36 ARM TWP cases: Profile inputs and "SARTA" results supplied by L. Strow and S. Hannon.




8×10⁻⁸
6×10⁻⁸
4×10⁻⁸
2×10⁻⁸
0
6×10⁻⁹
4×10⁻⁹
2×10⁻⁹
0
−2×10⁻⁹
−4×10⁻⁹
−6×10⁻⁹
IASI−LBLRTM [W/m2/sr/cm−1]
2382
2384
2386
2388
2390
2392
2394
wavenumber [cm−1]