Two Separate (But Related) Studies

Revised Microwave Water Vapor Continuum Values based on MWR, MWRHF and MP183 Measurements

Vivienne Payne, Eli Mlawer

AER, Inc.

Tony Clough

Clough Associates

Investigation of Far-Infrared Radiative Processes Using Measurements from the ARM North Slope of Alaska Climate Research Facility

Jennifer Delamere, Eli Mlawer, Vivienne Payne (*AER, Inc.)*

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Dave Turner (*U. Wisconsin*)

Robert Gamache (*U. Mass. Lowell*)

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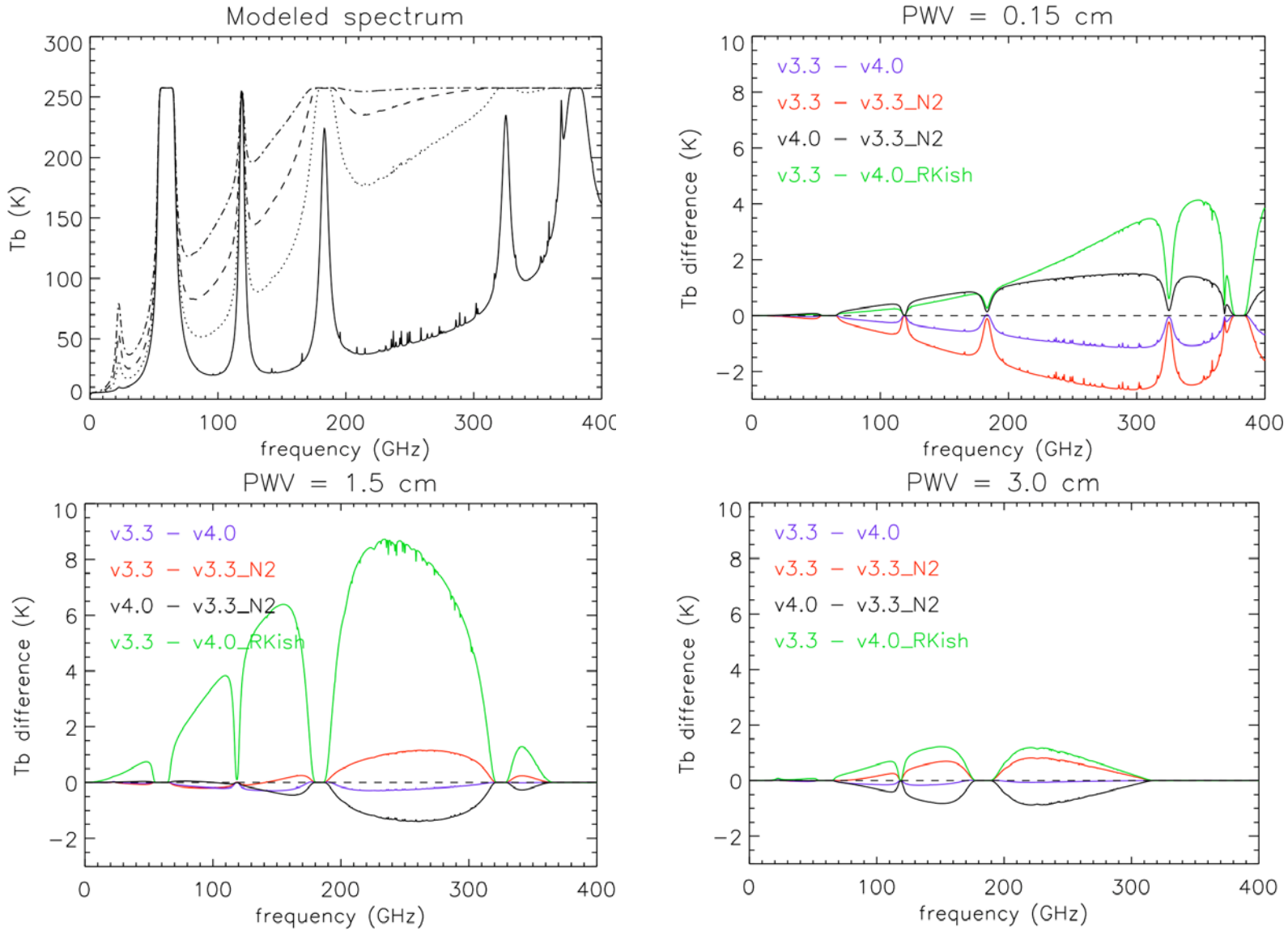
MonoRTM: Recent updates

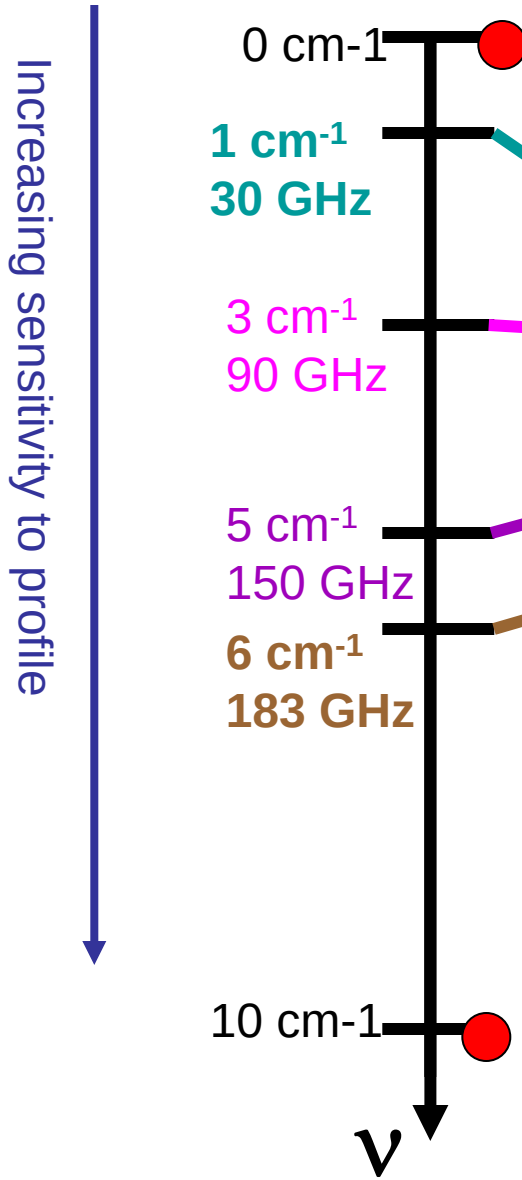
- MonoRTM v3.3 (2007)
  - Updated widths for 22 GHz, 183 GHz lines
  - 22 GHz: MWRP at SGP
  - 183 GHz: GVR at NSA (incl. RHUBC data)
- **MonoRTM v4.0 (2008)**
  - Can now be used at any wavelength
    - E.g. for monochromatic calculations at lidar frequencies
  - Now uses MT_CKD continuum
    - Consistent with LBLRTM
  - Corrected an error in the N_2 continuum

Differences between MonoRTM versions

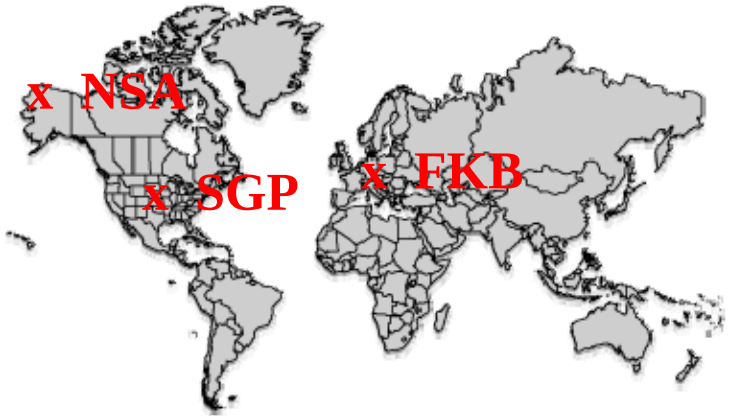


At higher PWV, v3.3-v4.0_Rkish goes negative due to increased influence of self continuum.

Measurements

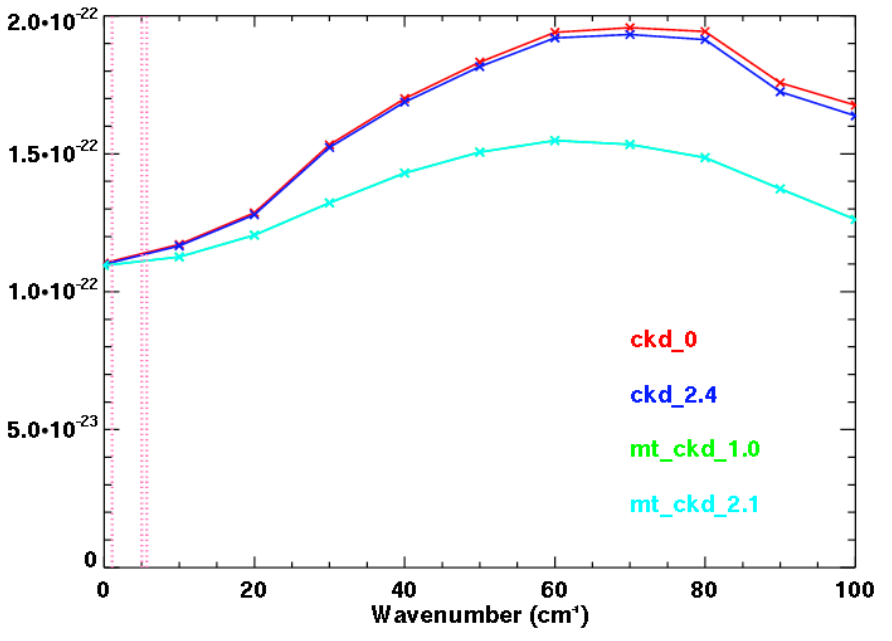


Instrument	Location	Dates	Max. PWV
MWR	SGP	1993-2008	5 cm
MWRHF GSR	COPS (FKB) NSA	06/07-01/08 03/04, 03/07	3 cm 1 cm
MWRHF	COPS (FKB)	06/07-01/08	3 cm
MP183	SGP	01/08-03/08	2 cm
GVR	NSA	01/07-present	2 cm

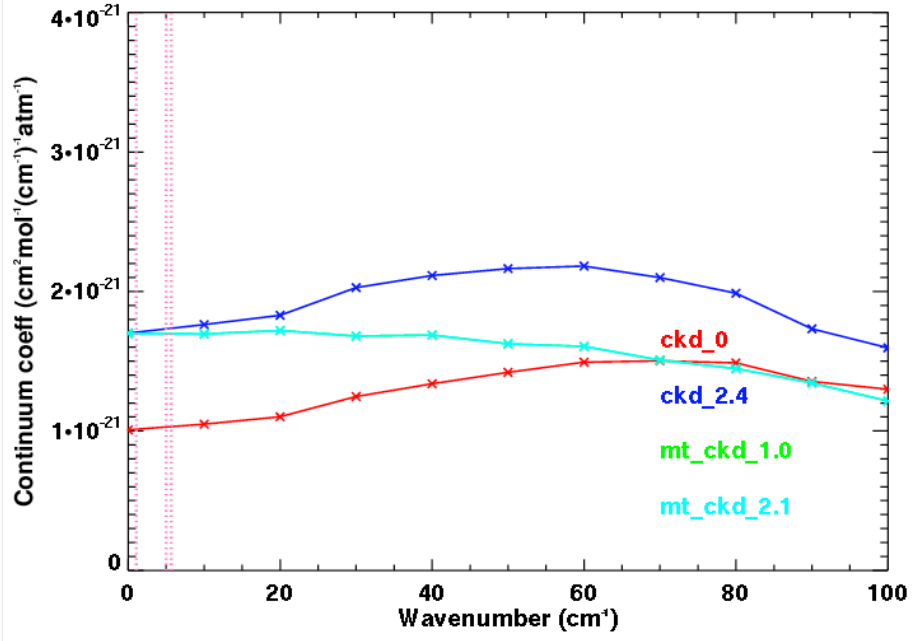


Water vapor continuum

Foreign



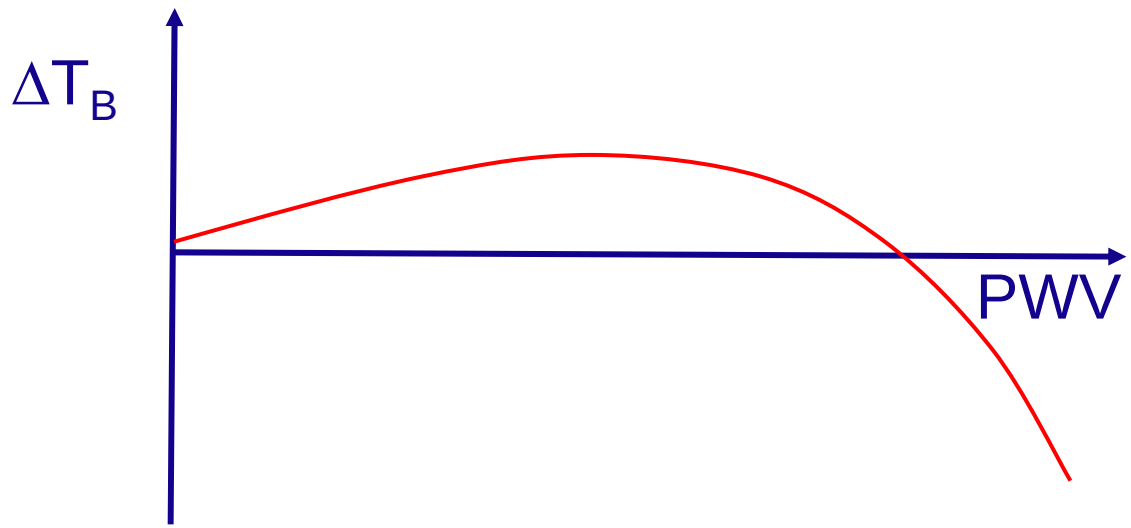
Self



Continuum uncertainty

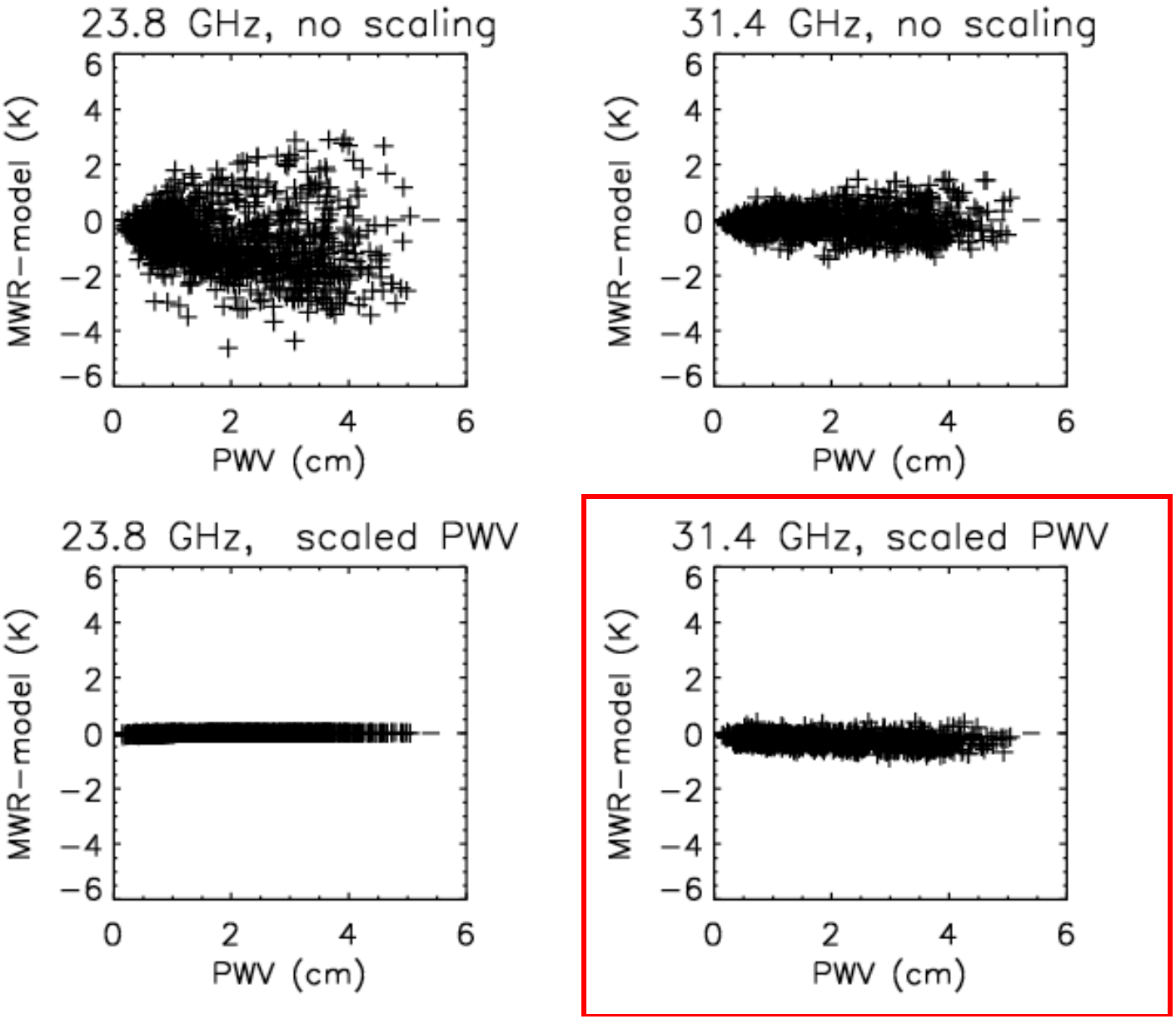
Extending the SGP MWR analysis

$$\Delta T_B = \underbrace{a\Delta X_{frg}(PWV)}_{\text{foreign}} + \underbrace{b\Delta X_{slf}(PWV)^2}_{\text{self}}$$



Measurements at higher PWV (>3.0 cm) needed to constrain the self-broadened continuum

Scaling of PWV using MWR

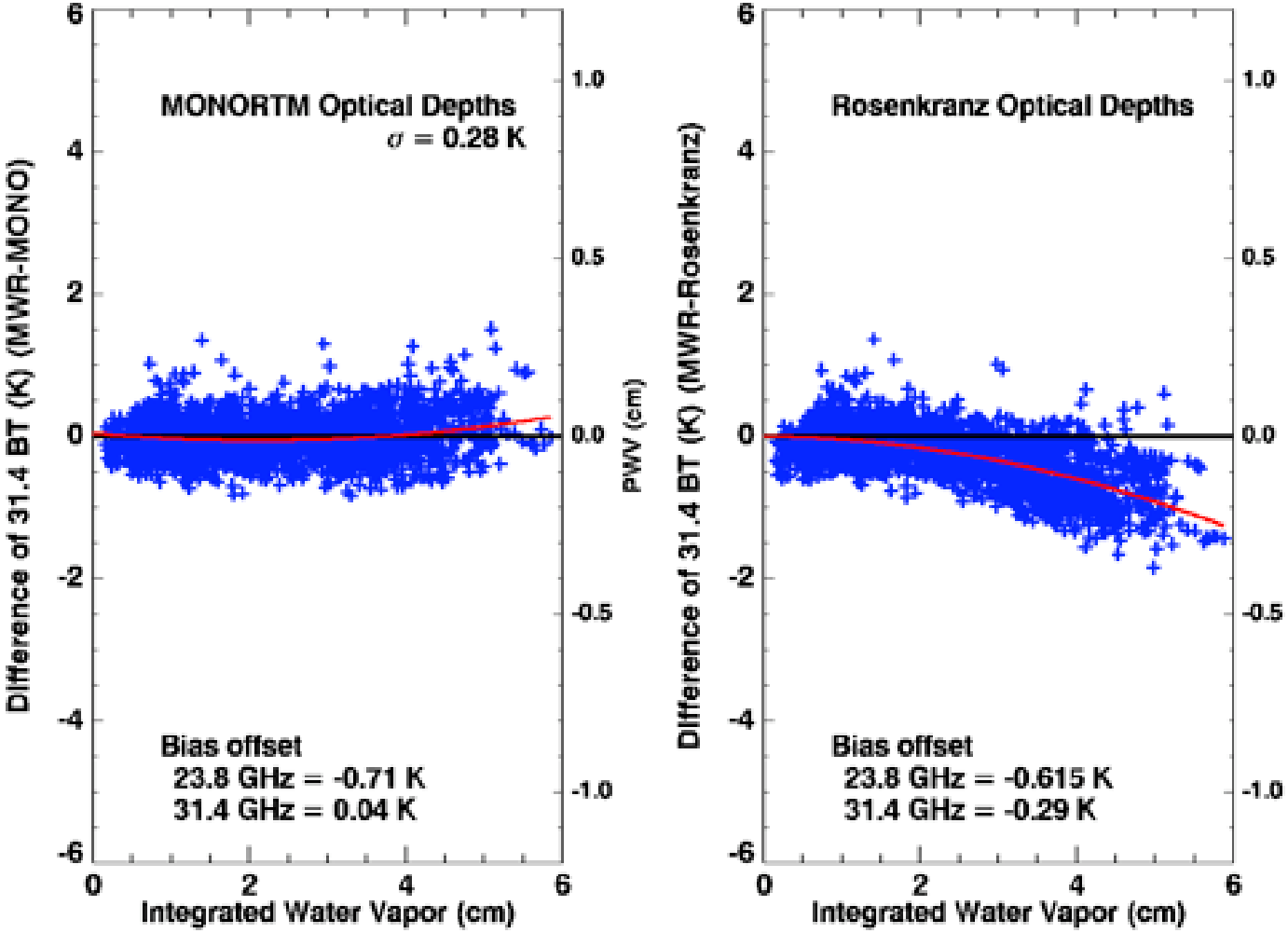


SGP MWR analysis

Karen Cady-Pereira, Tony Clough

2274 clear sky sondes, 1996-1998

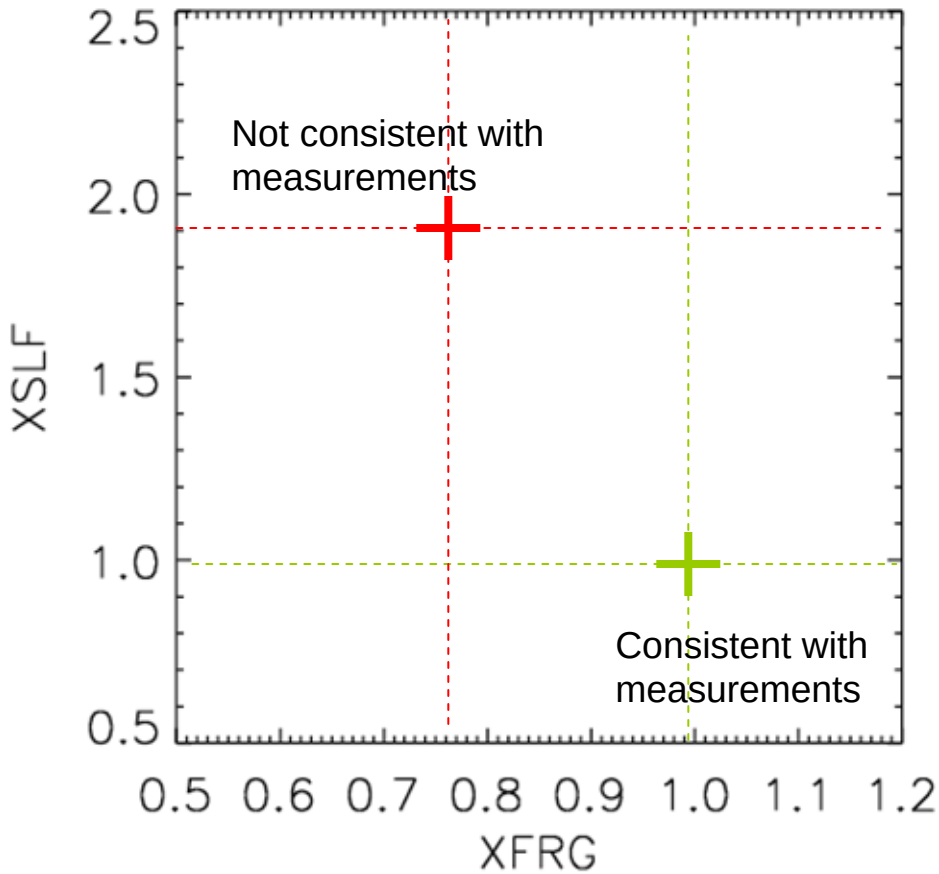
84 K



CKD_2.4 and Rosenkranz continua

31.4 GHz

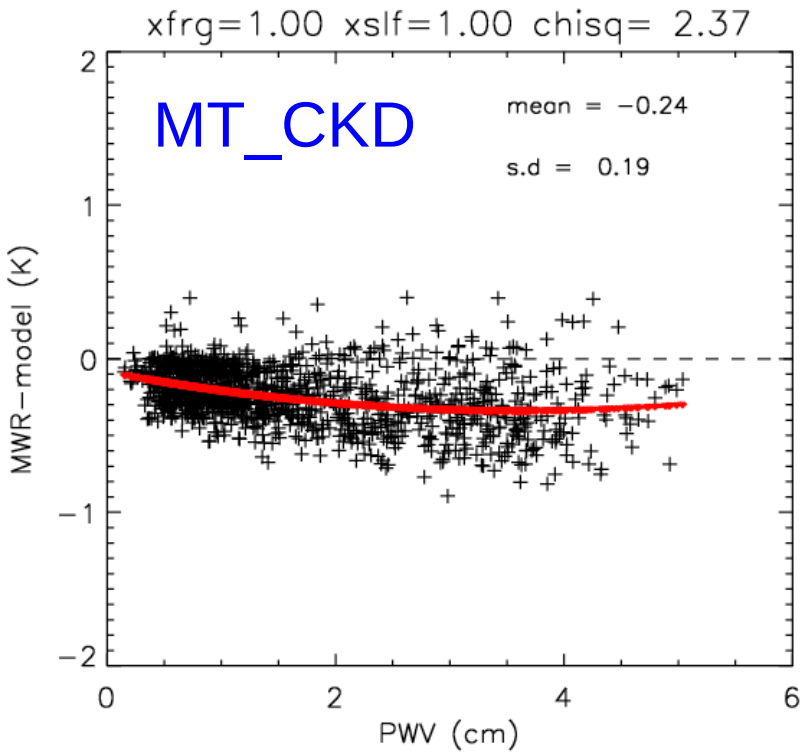
Continuum absorption relative to CKD_2.4



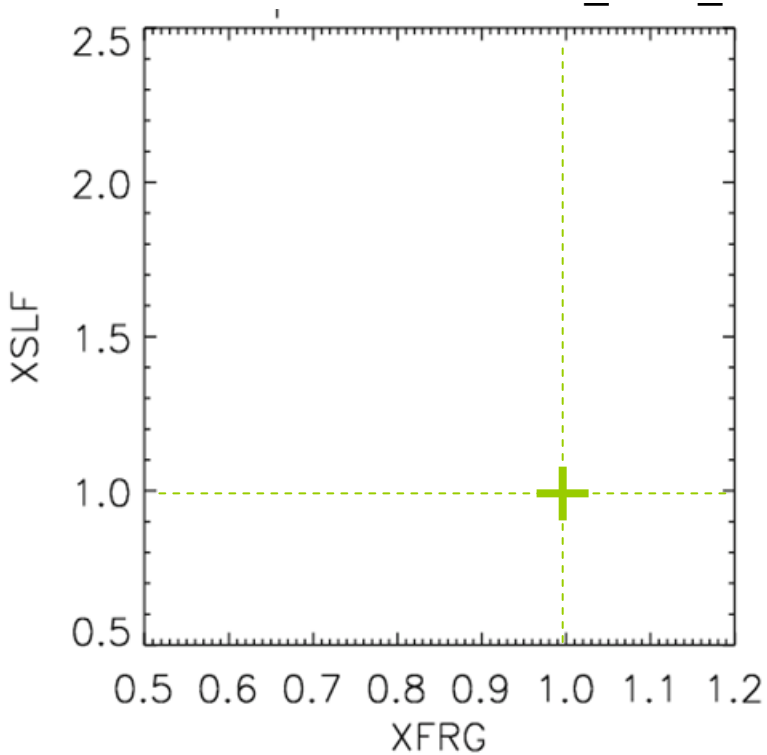
(Note that H_2O continuum was not the only difference between the MonoRTM and the Rosenkranz models for this 1996-1998 comparison…..)

31.4 GHz residuals

1218 clear sky sondes, SGP, January 2005 to December 2007

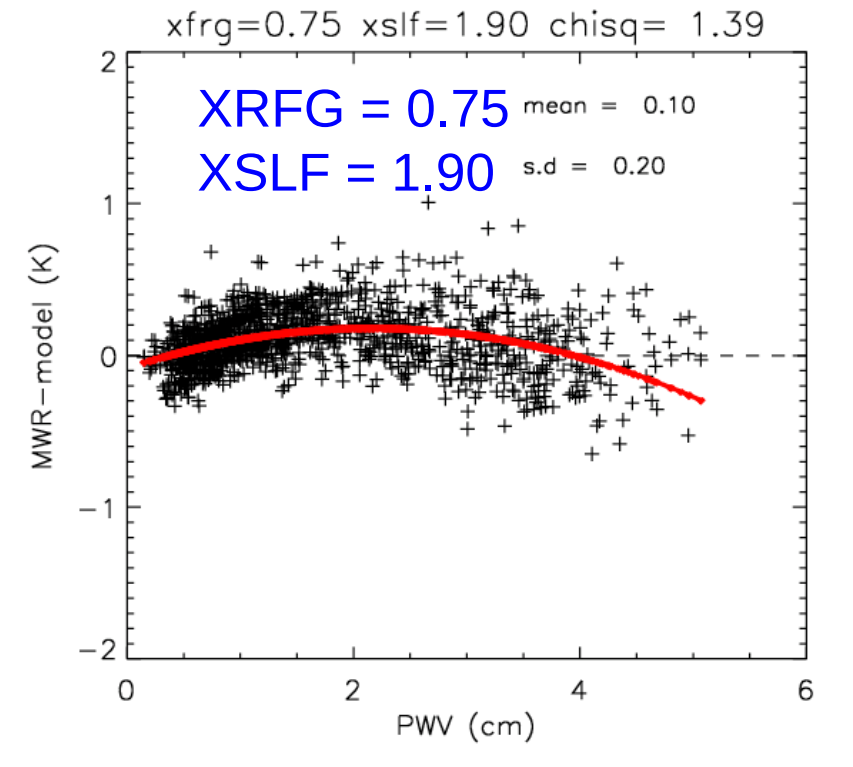


Continuum relative to MT_CKD_2.1

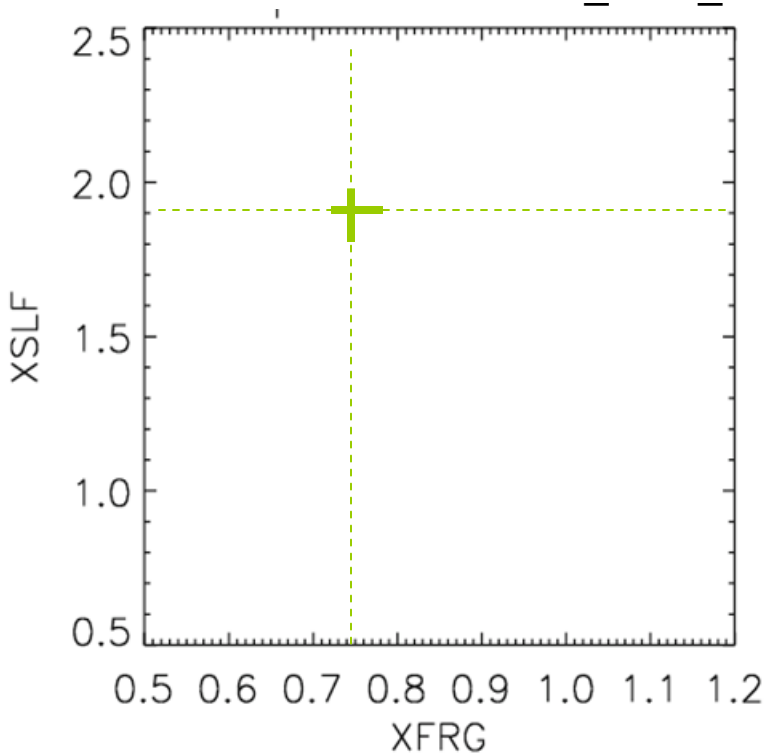


31.4 GHz residuals

1218 clear sky sondes, SGP, January 2005 to December 2007

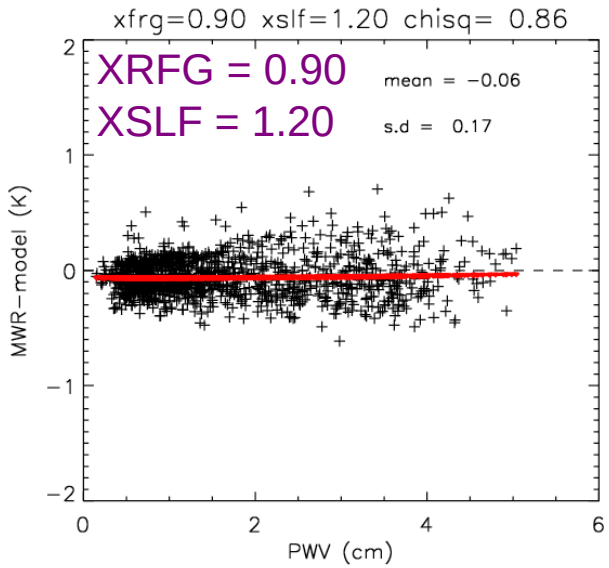


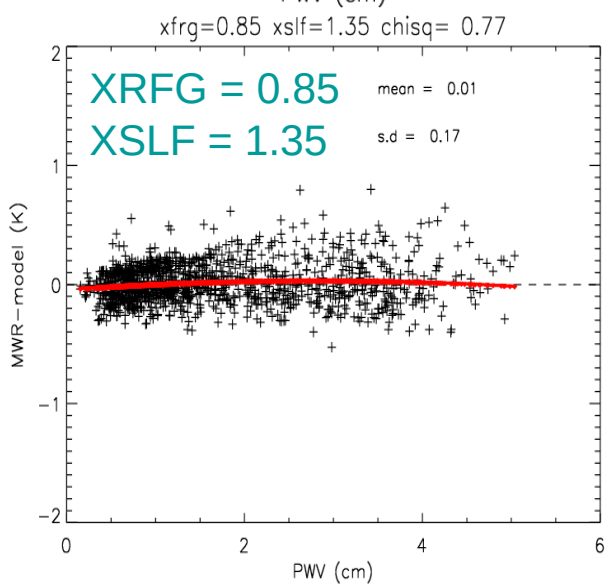
Continuum relative to MT_CKD_2.1



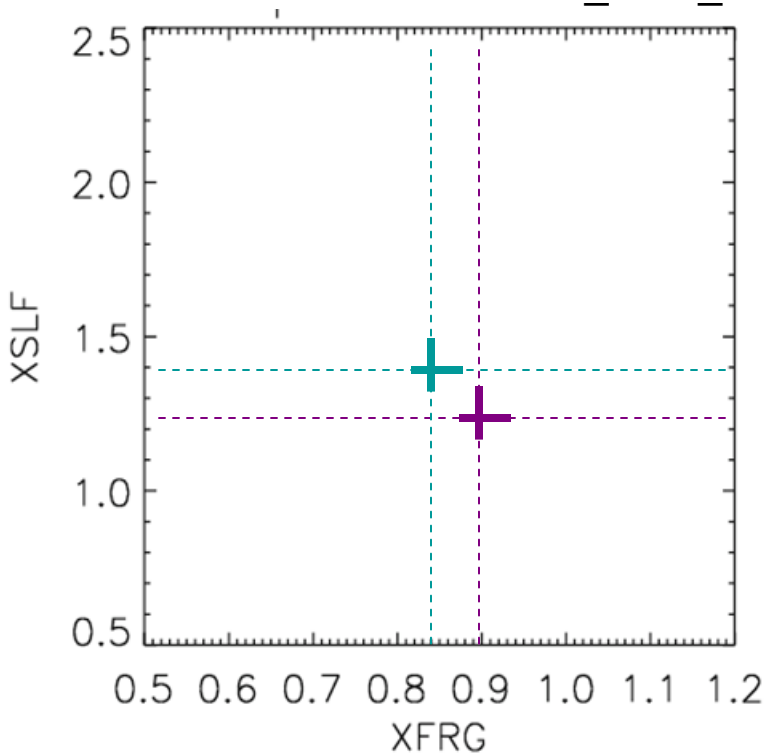
31.4 GHz residuals

1218 clear sky sondes, SGP, January 2005 to December 2007

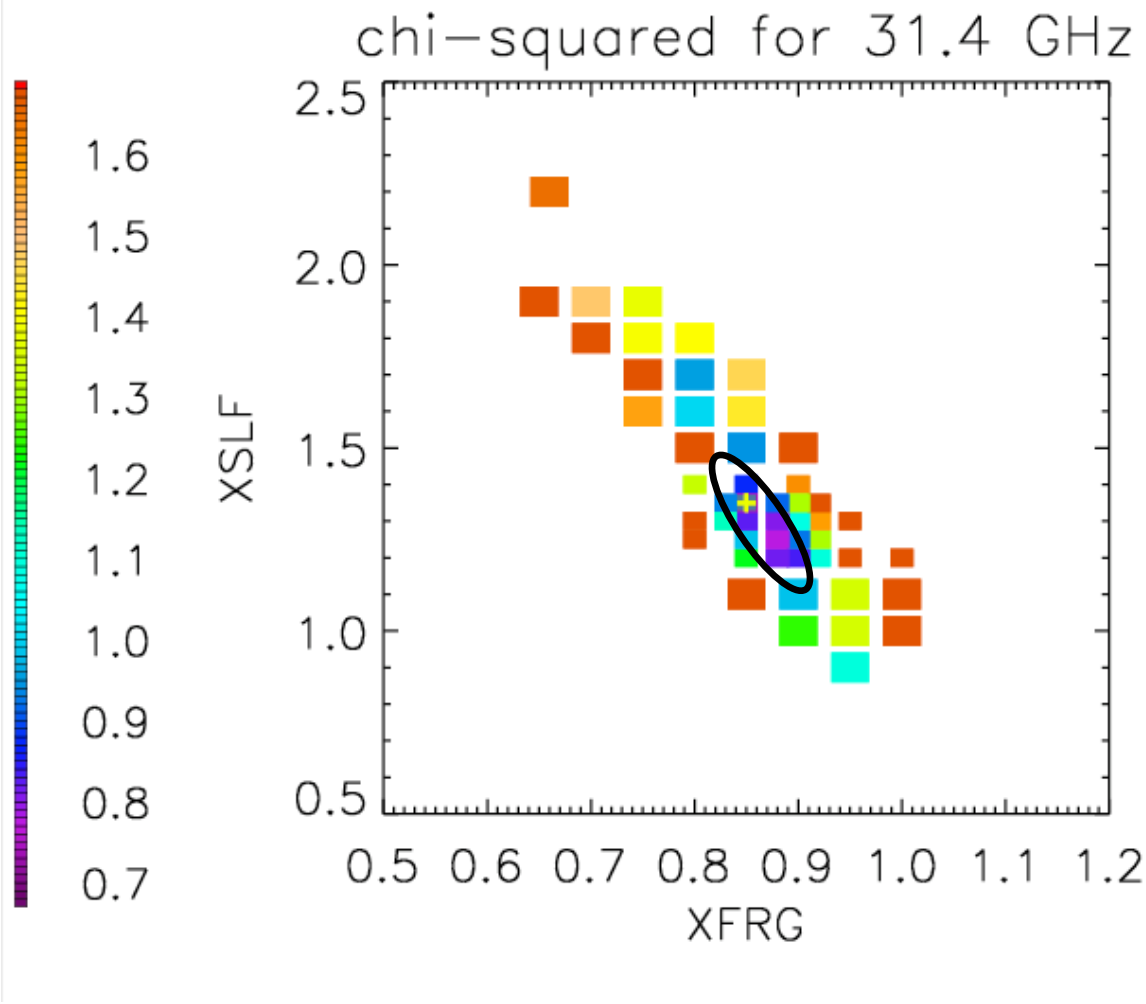




Continuum relative to MT_CKD_2.1



31.4 GHz chi-squared surface



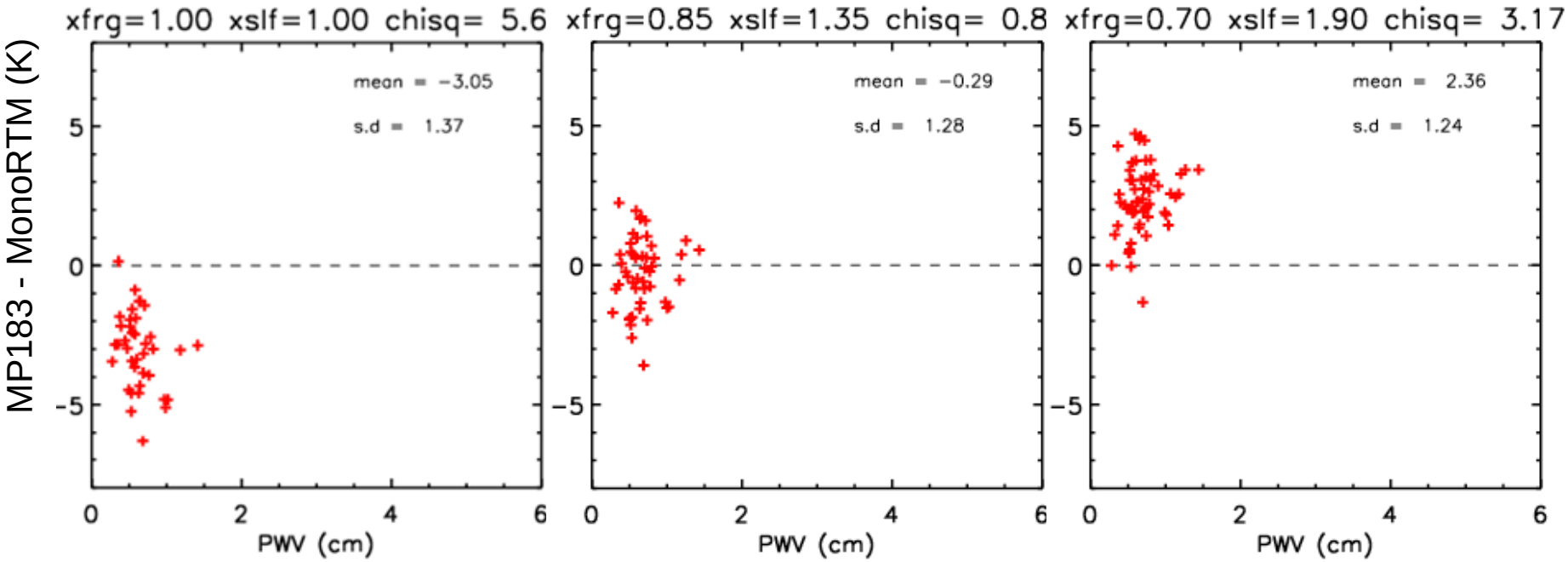
Uncertainty estimates:
+/-5 % on foreign
+/-20 % on self

170 GHz residuals

MP183 at SGP, 77 clear sky sondes, January to March 2008

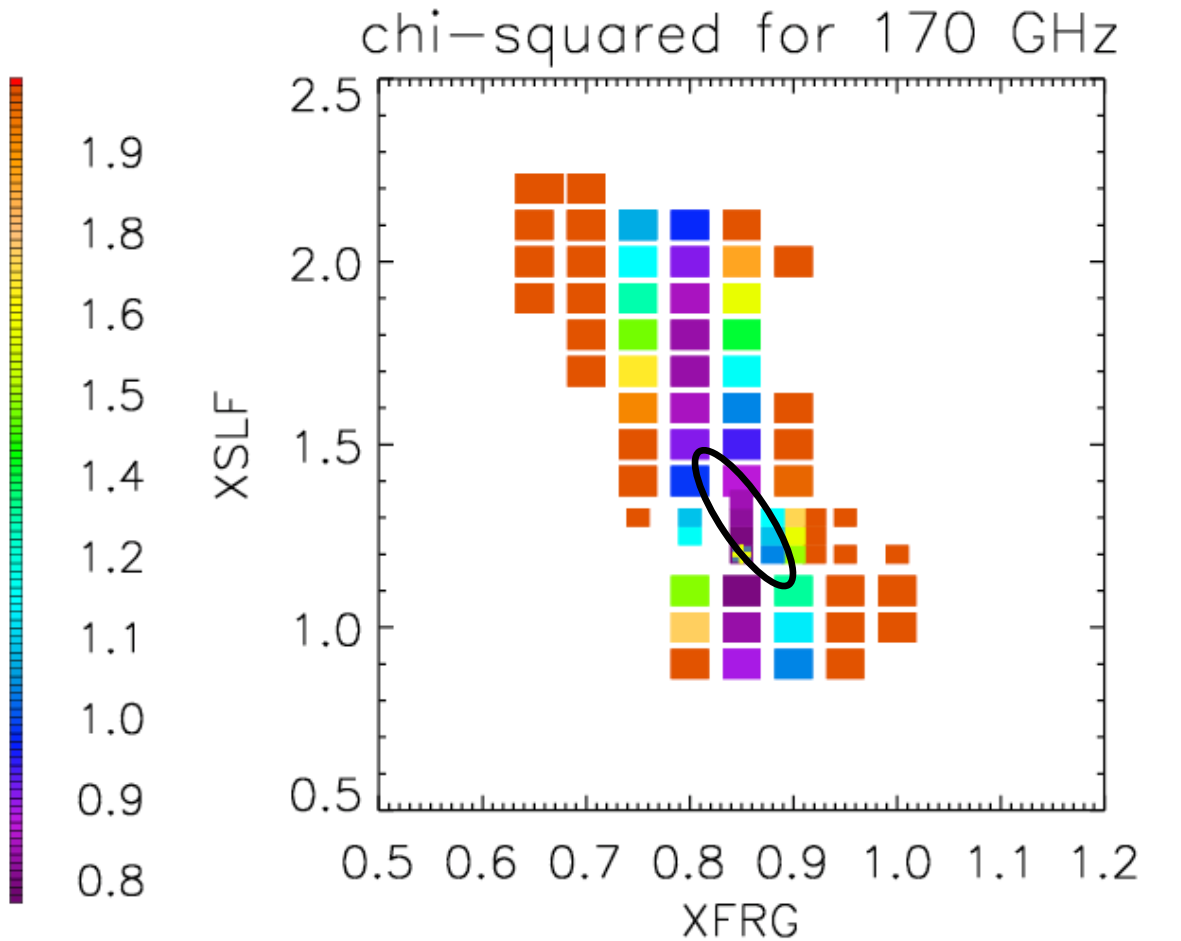
Retrieved PWV scaling factor based on MWR 23.8 GHz (no offset applied)

Thanks to Maria Cadeddu for making MP183 data available!



- Confidence in MP183 from RHUBC

170 GHz chi-squared surface



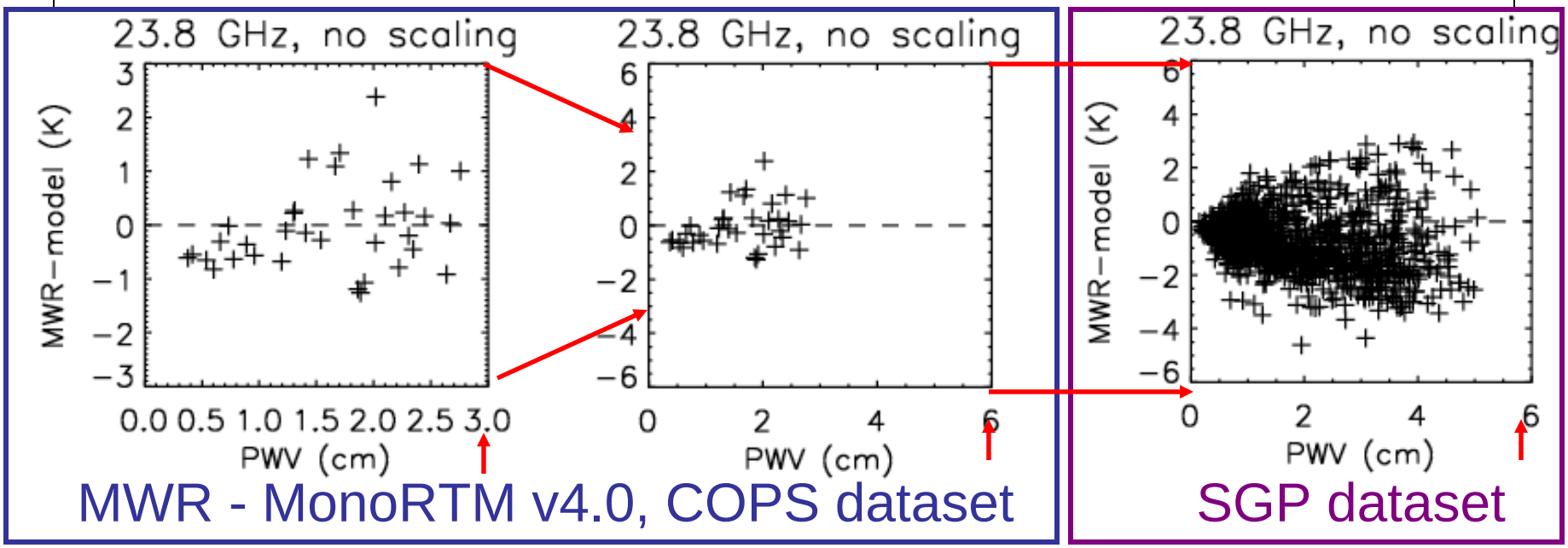
Consistent with 31.4 GHz continuum scaling factors!

Self-broadened continuum poorly constrained due to limited PWV range

COPS dataset

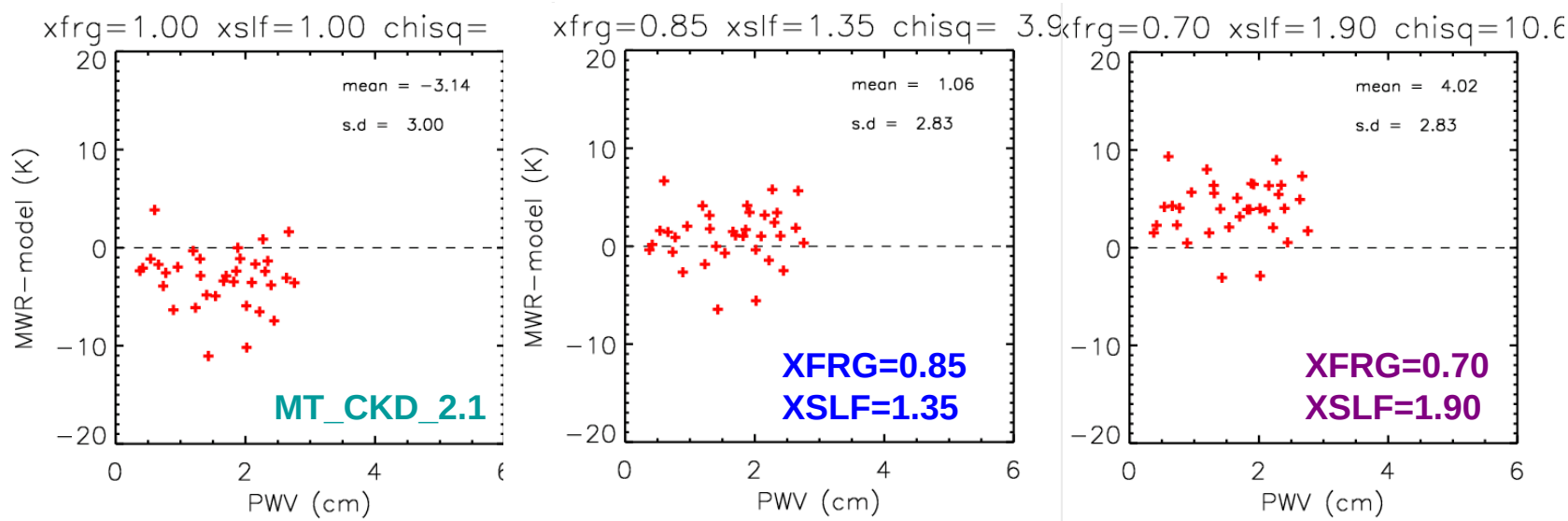
June to December 2007

- MWR (23.8, 31.4 GHz)
- MWRHF (90, 150 GHz)
- 35 clear-sky sondes (provided by D. Turner)
- Determination of instrument offsets
  - Particularly problematic due to limited clear sky data
  - Evidence for need for MWR offsets is limited

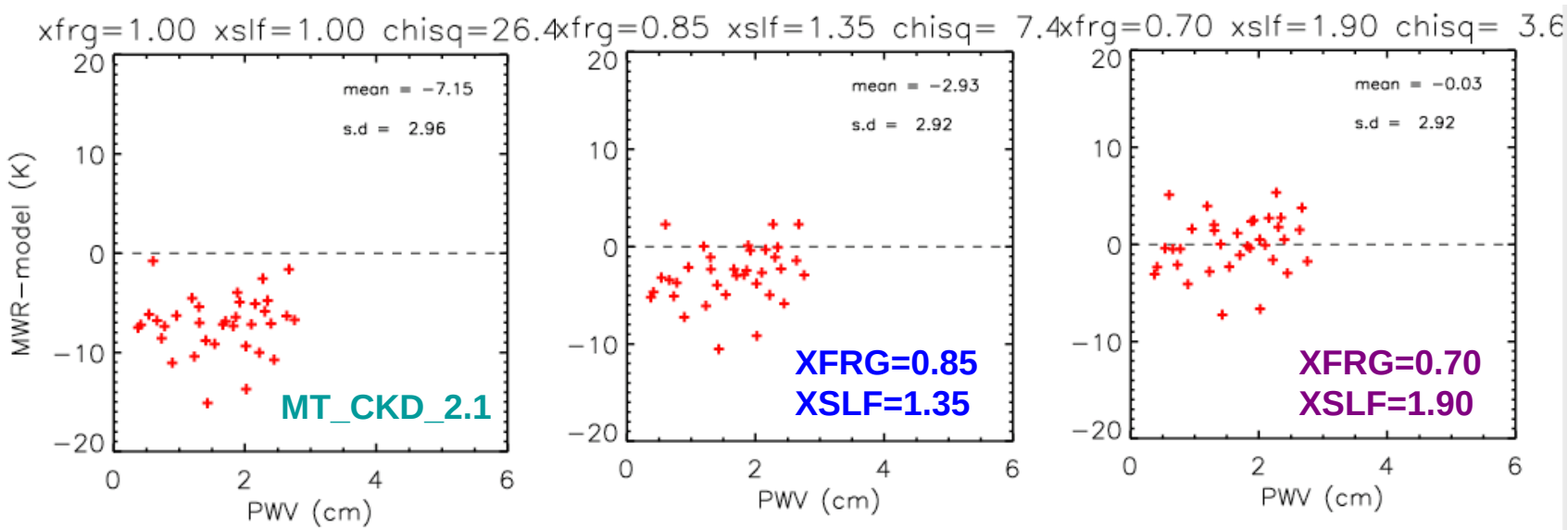


150 GHz residuals

Zero MWR offset

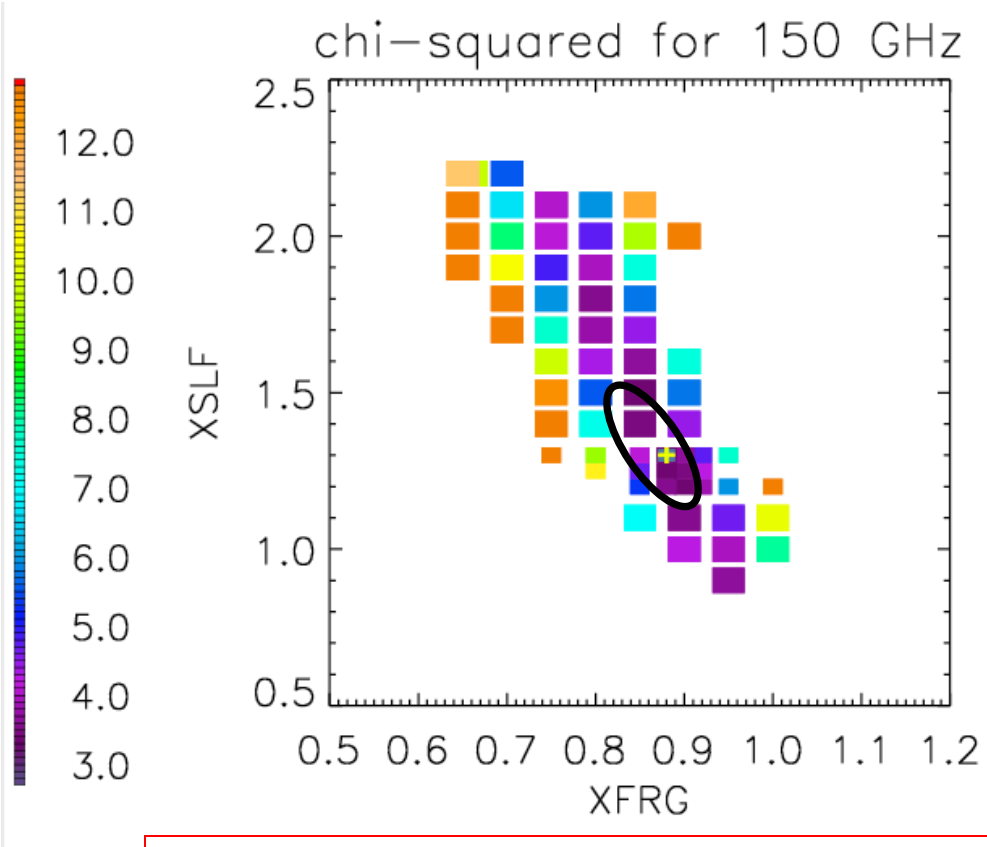


1.0 K MWR offset

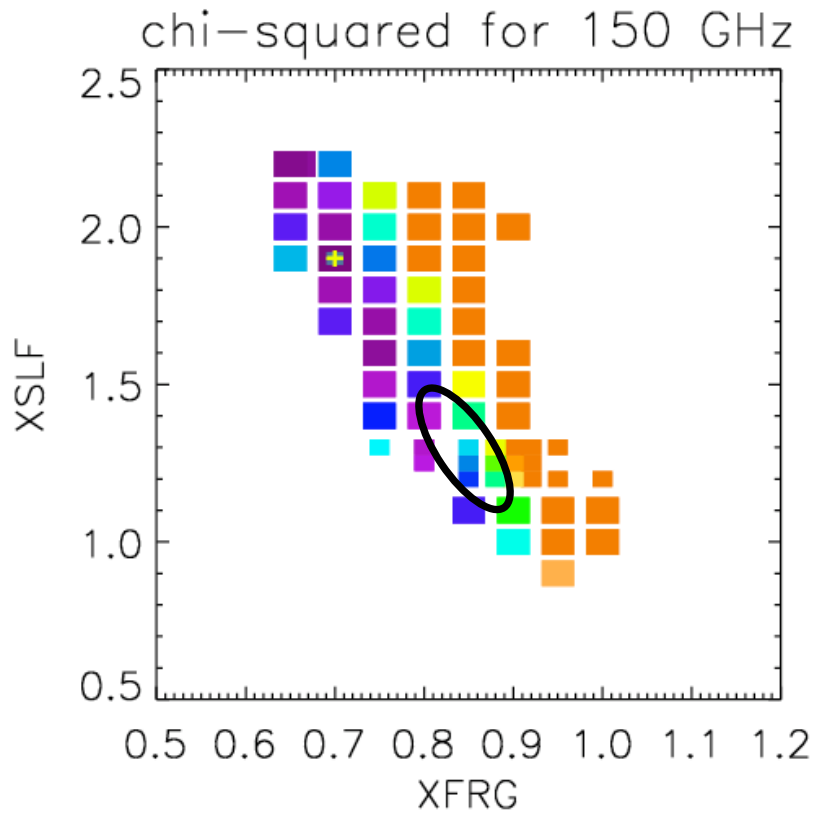


150 GHz chi-squared surface

Zero offset for MWR



1.0 K offset for MWR

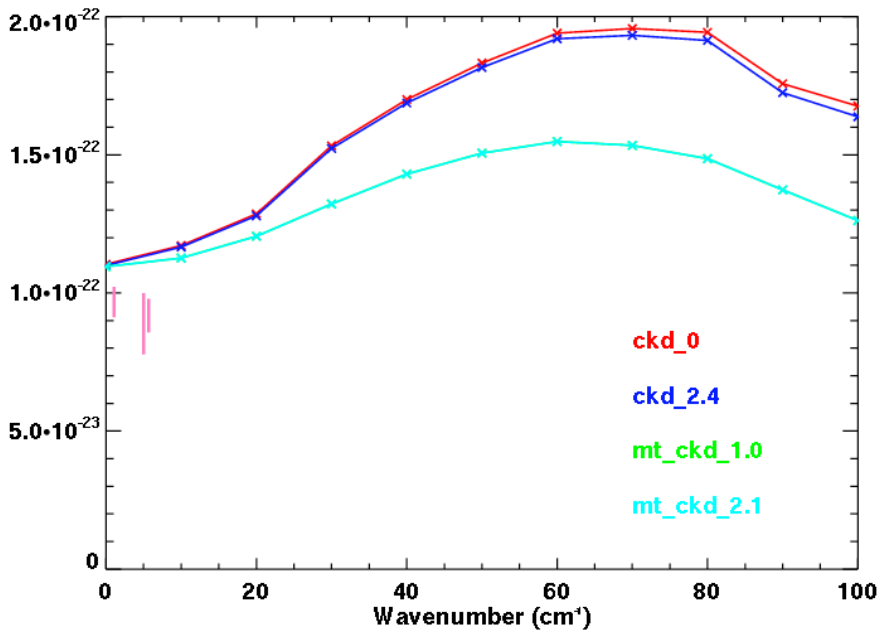


Consistent with 31.4 and 170 GHz if no offset is applied to the MWR

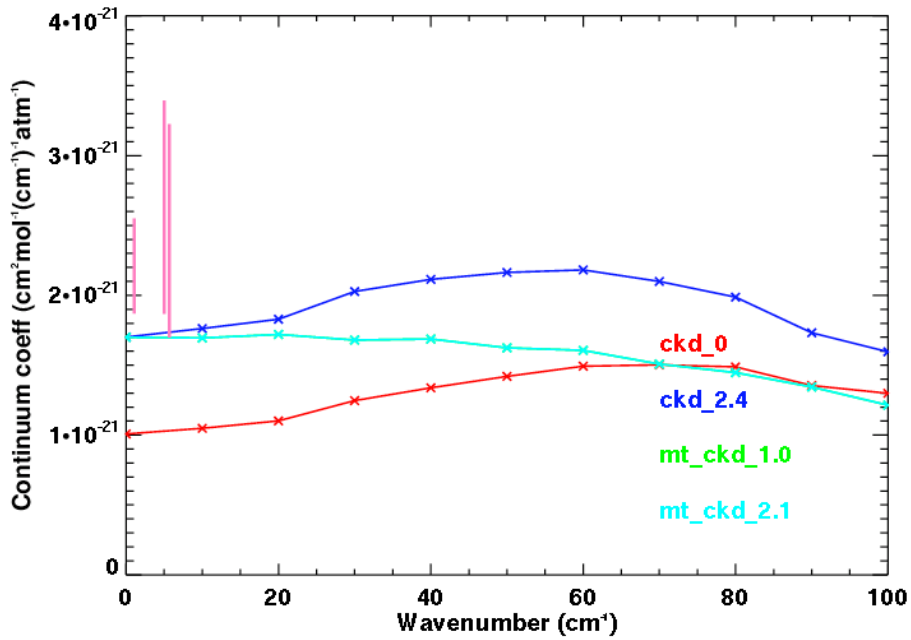
Water vapor continuum:

Constraints from microwave measurements

Foreign



Self



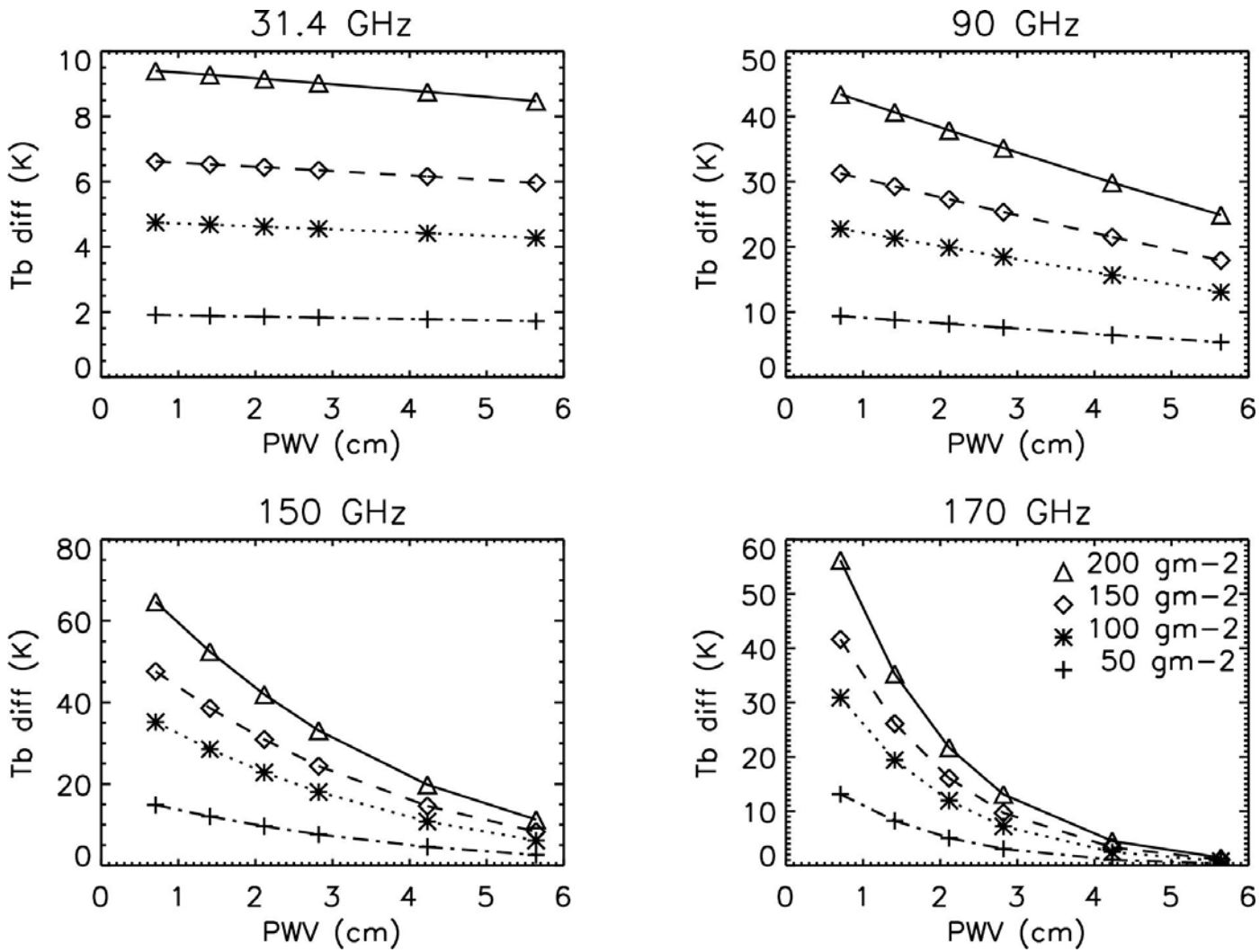
Continuum has limited spectral variation between 0-10 cm-1 (0-300 GHz)

No changes between MT_CKD 1.0 and 2.1 in this spectral region

Pink bars indicate constraints from ARM measurements

Additional constraint from balance between self and foreign

Cloudy minus clear-sky differences



Differences in inferred LWP (gm^{-2})

(MonoRTM v3.3 minus scaled v4.0, assuming fixed PWV)

31.4 GHz

PWV (cm)	XFRG 0.90 XSLF 1.20	XFRG 0.75 XSLF 1.80
0.15	-0.54	0.57
1.5	4.9	11
3.0	7.2	7.0

90 GHz

PWV (cm)	XFRG 0.90 XSLF 1.20	XFRG 0.75 XSLF 1.80
0.15	-0.90	1.0
1.5	8.3	17
3.0	12	12

Negative values due to N_2 error in v3.3

150 GHz

PWV (cm)	XFRG 0.90 XSLF 1.20	XFRG 0.75 XSLF 1.80
0.15	-1.3	2.2
1.5	15	30
3.0	21	21

170 GHz

PWV (cm)	XFRG 0.90 XSLF 1.20	XFRG 0.75 XSLF 1.80
0.15	-1.6	3.4
1.5	16	32
3.0	21	21

Summary

- **SGP MWR dataset provides tightest constraints on continuum**
  - Largest range of PWV
  - Largest number of available clear-sky sondes
  - Longest-running dataset (confidence in calibration)
- **Evidence of need for a continuum update**
  - Water vapor continuum scaling factors:
    - **(0.85, 1.35) to (0.90, 1.20) for foreign, self**
  - MonoRTM v4.1 impending (< 1 month)
- Impact on LWP retrievals to be determined
  - **Expect impact to be greatest for CLOWD cases**

Investigation of Far-Infrared Radiative Processes Using Measurements from the ARM North Slope of Alaska Climate Research Facility

J. Delamere, **E. Mlawer**, V. Payne (*AER, Inc.)*

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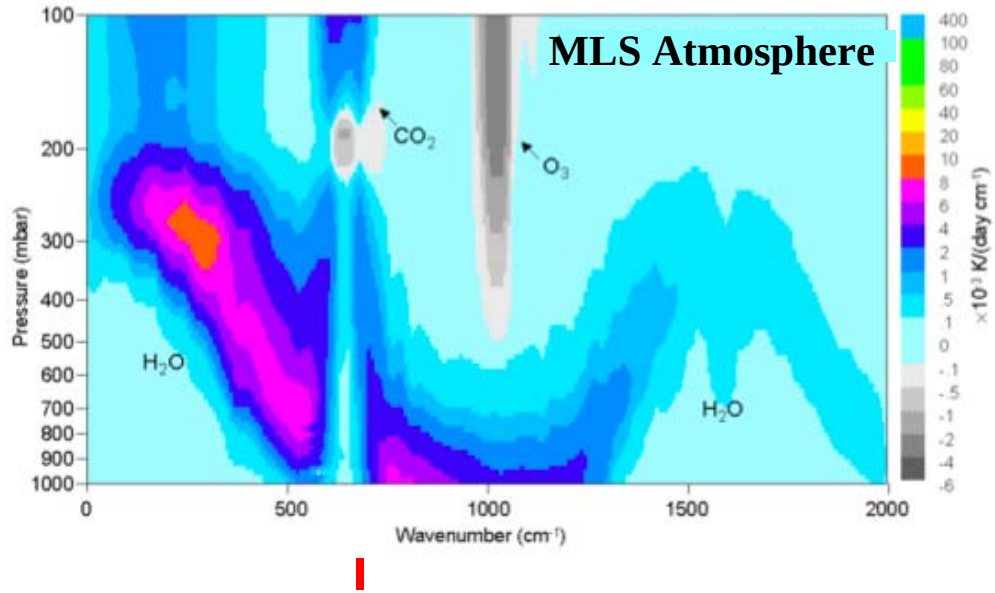
R. Gamache (*U. Mass. Lowell*)

Why the Far-IR?

Cooling Rate Calculation



Clough & Iacono (1995)

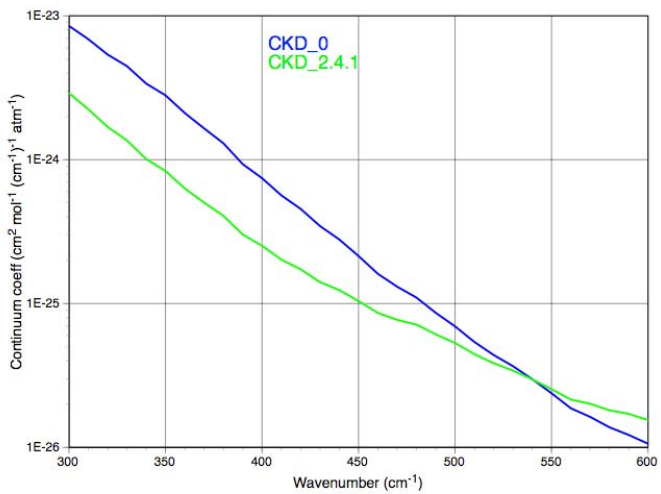
- Maximum cooling occurs in the far-IR (10 to 650 cm^{-1}, $\lambda > 15\ \mu m$)
- Up to 40% of the OLR occurs in far-IR

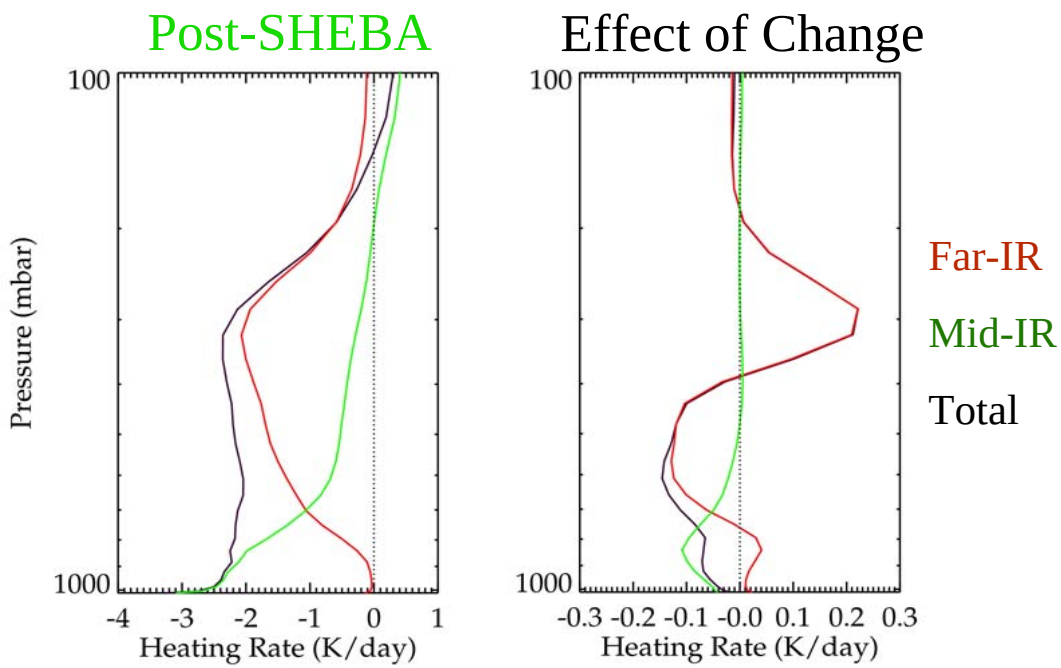
So important but significantly understudied…..

The SHEBA Experience

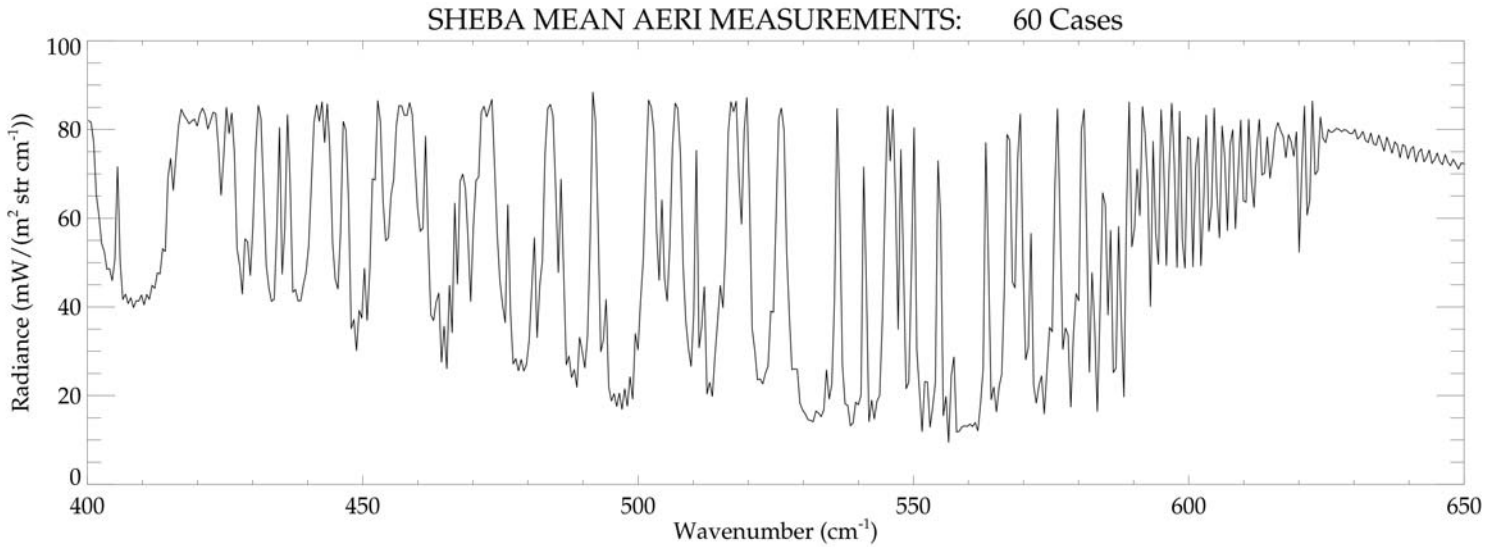
- Collocated far-IR radiance measurements (AERI) and atmospheric profiling instruments deployed in the Arctic in 1997

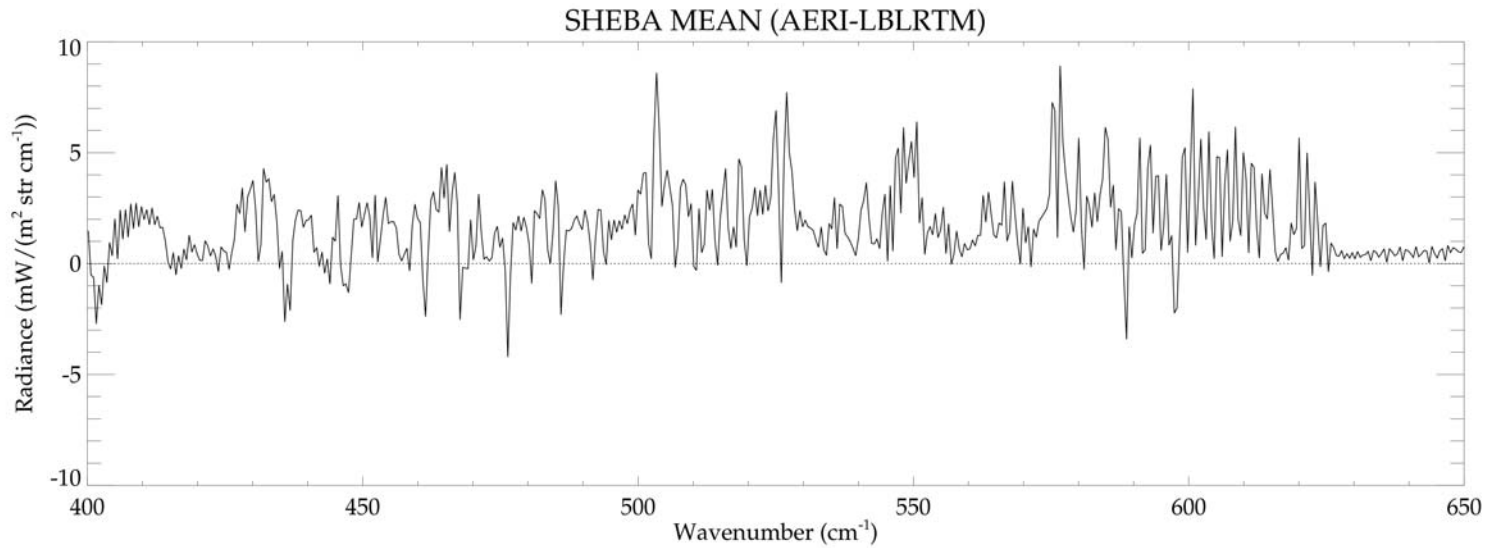
- 4 cases from October used to adjust foreign water vapor continuum model (*Tobin et al., JGR, 1999*)





Post-SHEBA Far-IR Residuals





Radiative Heating in Underexplored Bands Campaign (RHUBC)

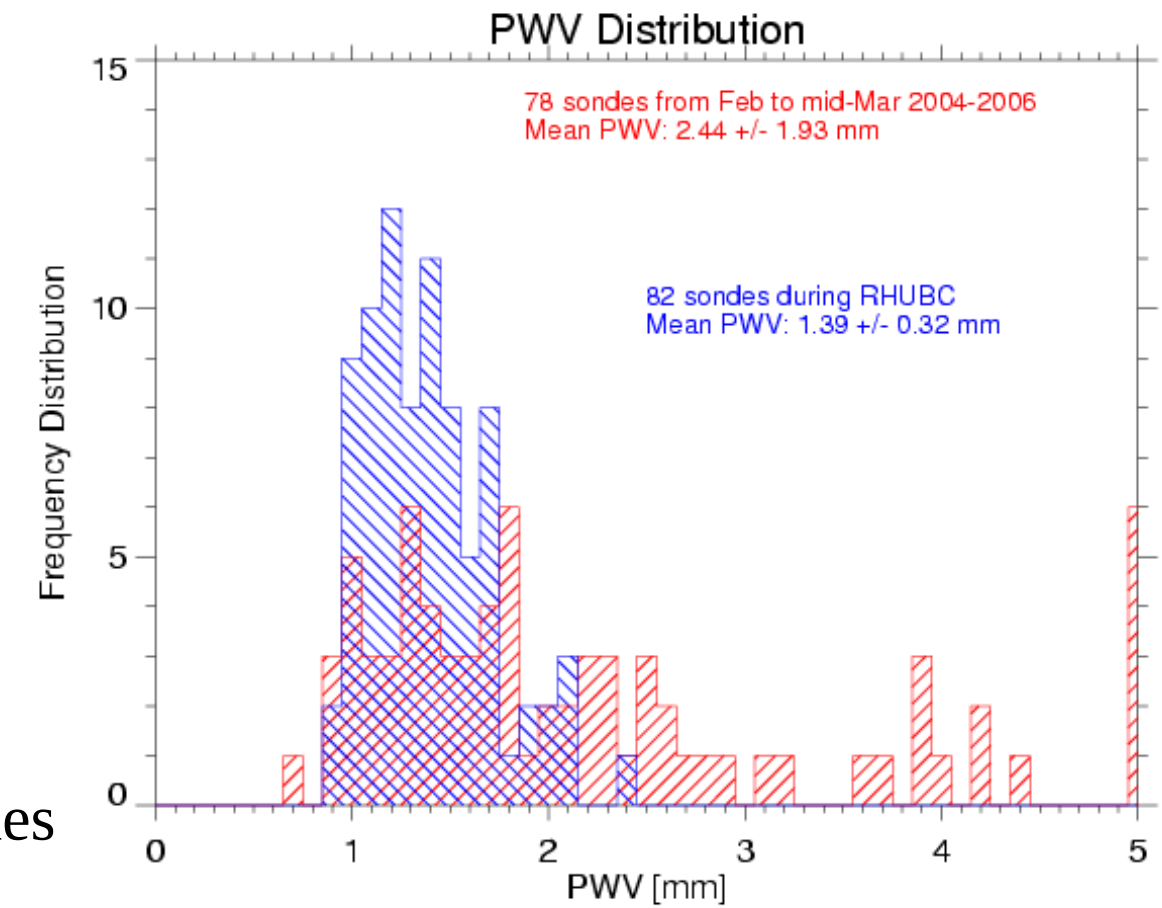
Microwave (MW) measurements v. radiative transfer model (MonoRTM) comparisons @ 183 GHz.

Assessment and improvement of MW spectroscopy in MonoRTM.

Improved estimates of total atmospheric water content (PWV) from a MW retrieval algorithm with improved MonoRTM.

Far-IR measurements v. model (LBLRTM) comparisons using MW-retrieved PWV estimates. Assess and improve far-IR spectroscopy.

ARM North Slope of Alaska Facility

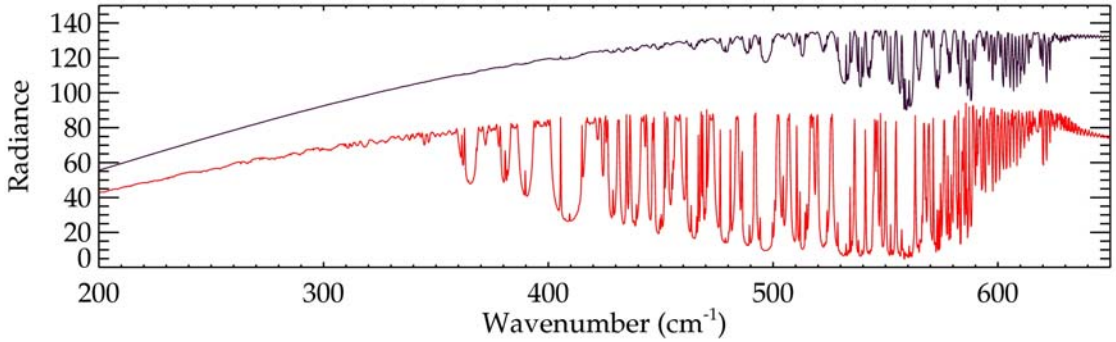


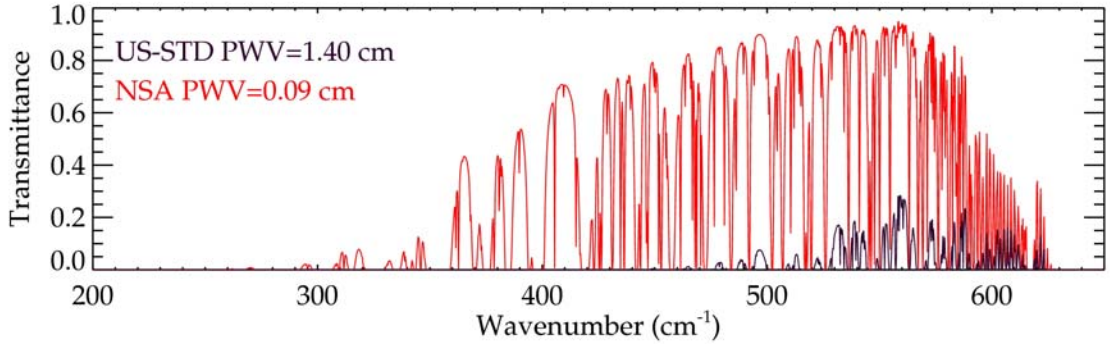
- Daily radiosonde launches
- Continuous operation of AERI
- Continuous operation of 2 microwave radiometers: 23.8 & 31.4 GHz (since 1998) and 183 GHz (since 2006)

RHUBC - Phase 1

RHUBC-I: North Slope of Alaska
Feb-March 2007

Principal Investigators: David Turner and Eli Mlawer





Retrieval of 183 GHz Width: Results

- G-band Vapor Radiometer:
  - 4 double sideband channel

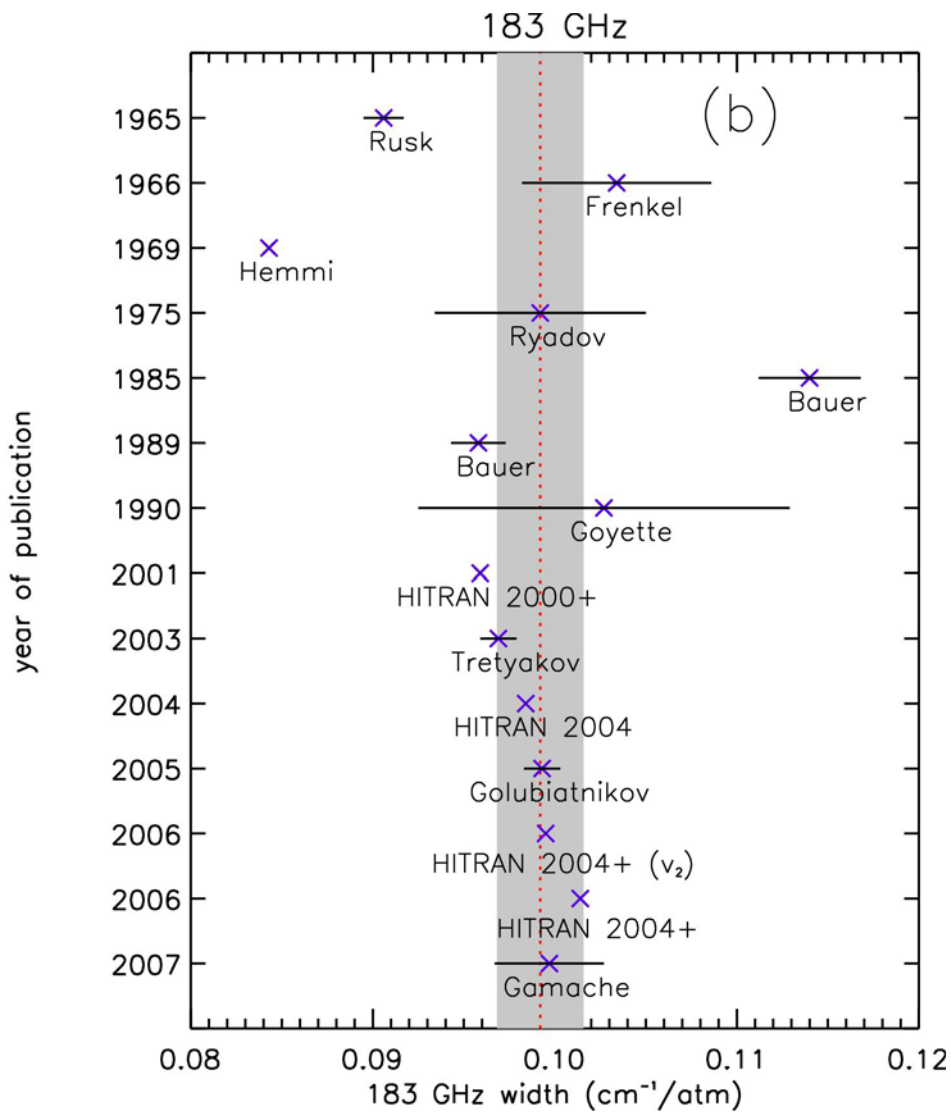
  183+/-1, 3, 7, 14 GHz
- GVR-based width retrieval:
  0.0992 cm^{-1}/atm(± 2.5 %)
- CRB calculations (Gamache):
  0.0997 cm^{-1}/atm (± 3 %)

Air-broadened Half-Widths of the 22 GHz and 183 GHz Water Vapor Lines

(Accepted IEEE TGRS, 2008)

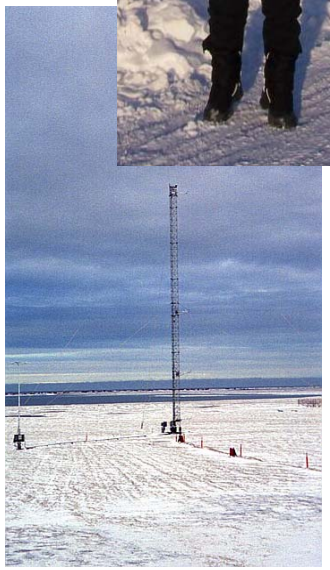
V. Payne, J. Delamere, S. Clough, K. Cady-Pereira, J. Moncet, E. Mlawer (*AER, Inc.)*

R. Gamache (*U. Mass - Lowell)*



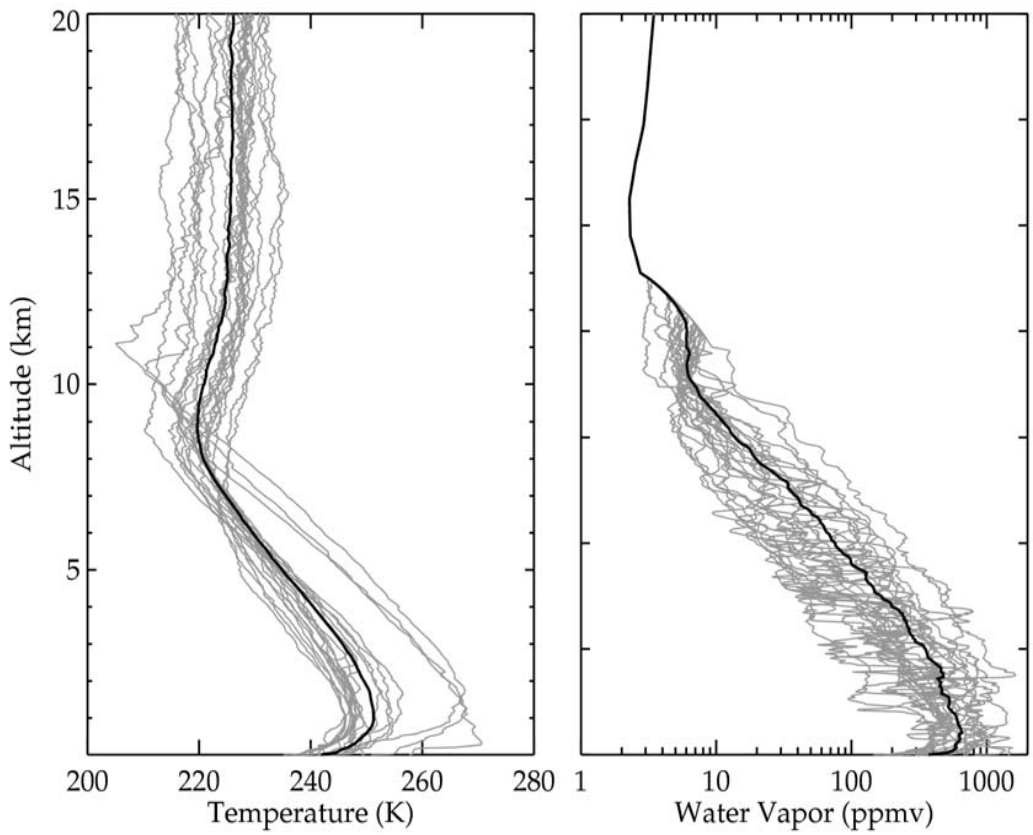
Creating the Atmospheric Profile

Radiosonde Profile
(T,WV)



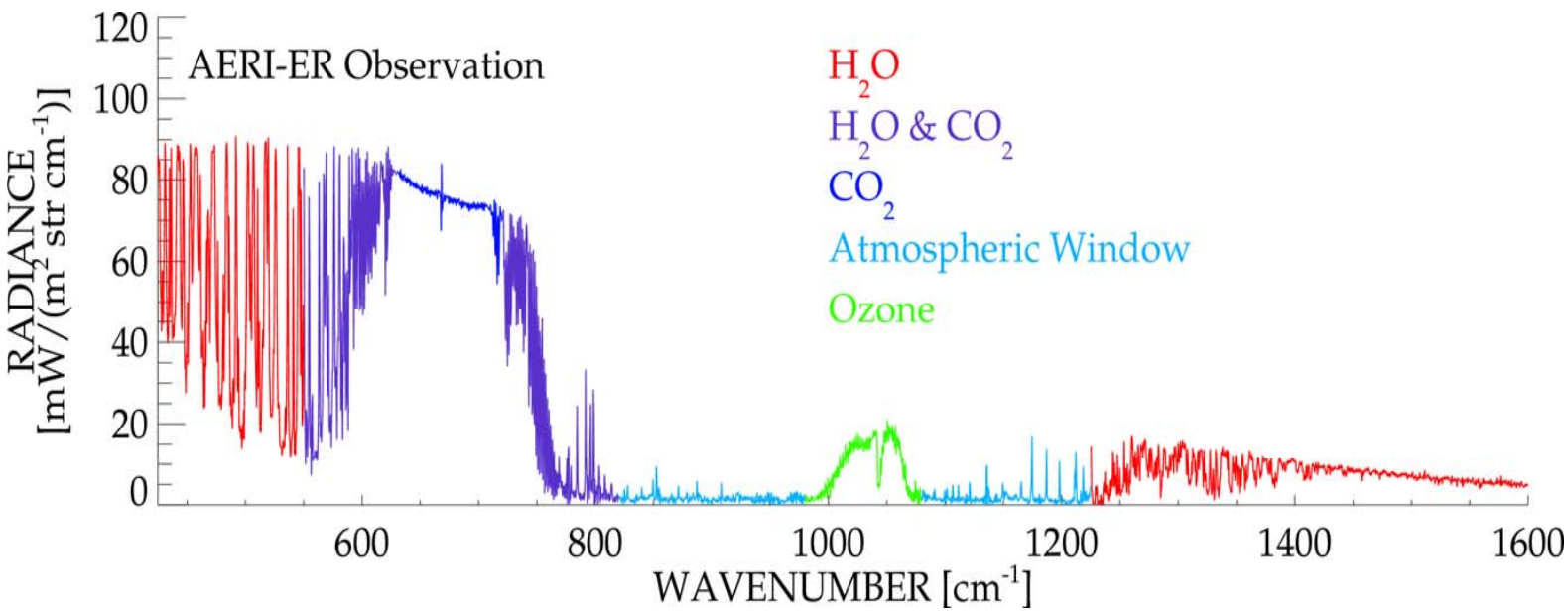
Surface Met
Data
+ Climatology

Utilized "scaled-sonde"
approach with 183.31 GHz
GVR PWV retrievals
(Payne et al., 2008)



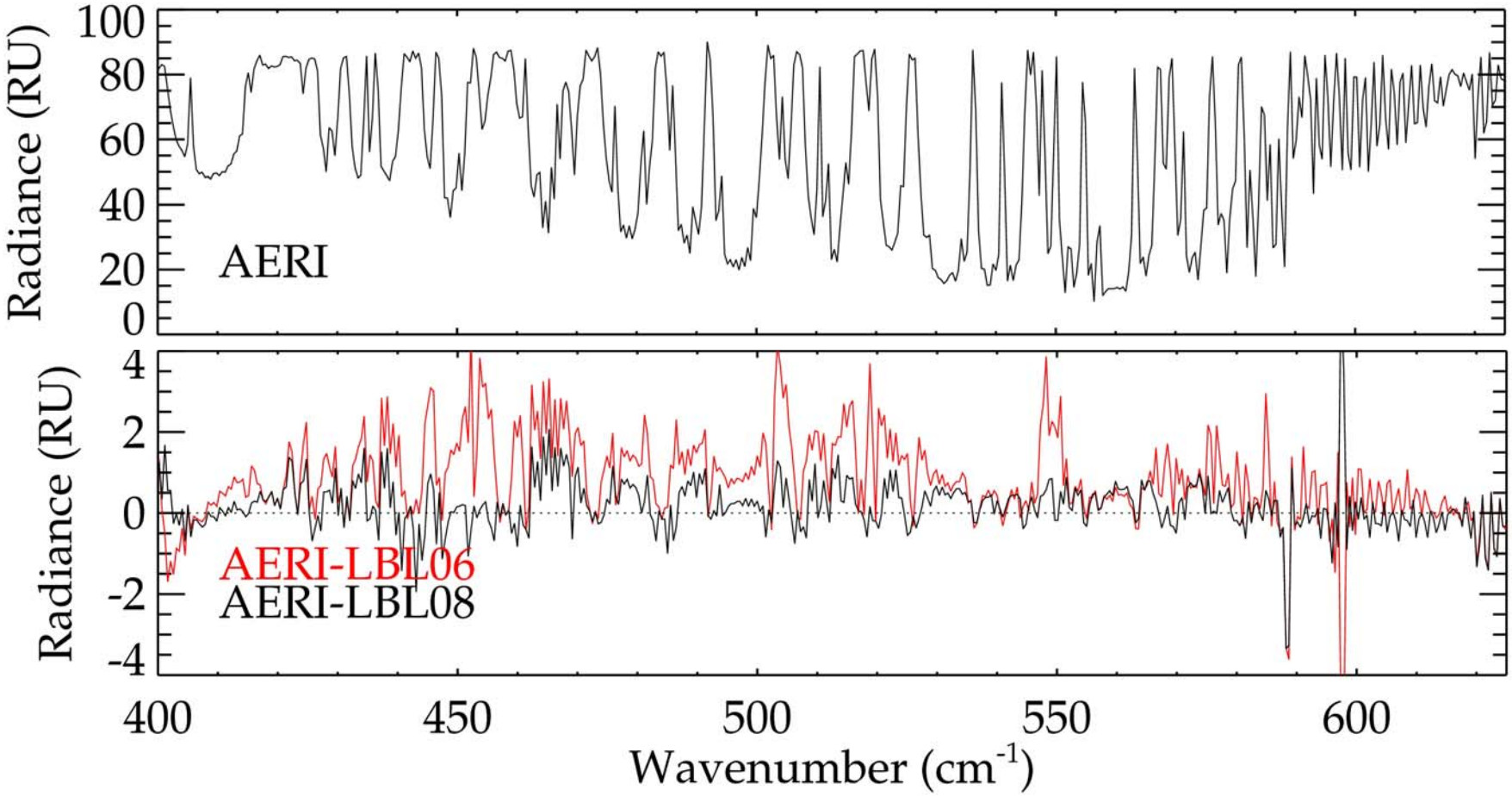
AERI-ER at NSA

- Extended Range Atmospheric Emitted Radiance Interferometer:
  - Operating continuously at the NSA
  - Range 3.3 - 25 µm with 0.5 cm^{-1} resolution
  - Calibrated with two internal reference blackbodies traceable to NIST standards
  - Accuracy better than 1% ambient radiance
  - **Corrections** are applied to data (~ 1 RU)



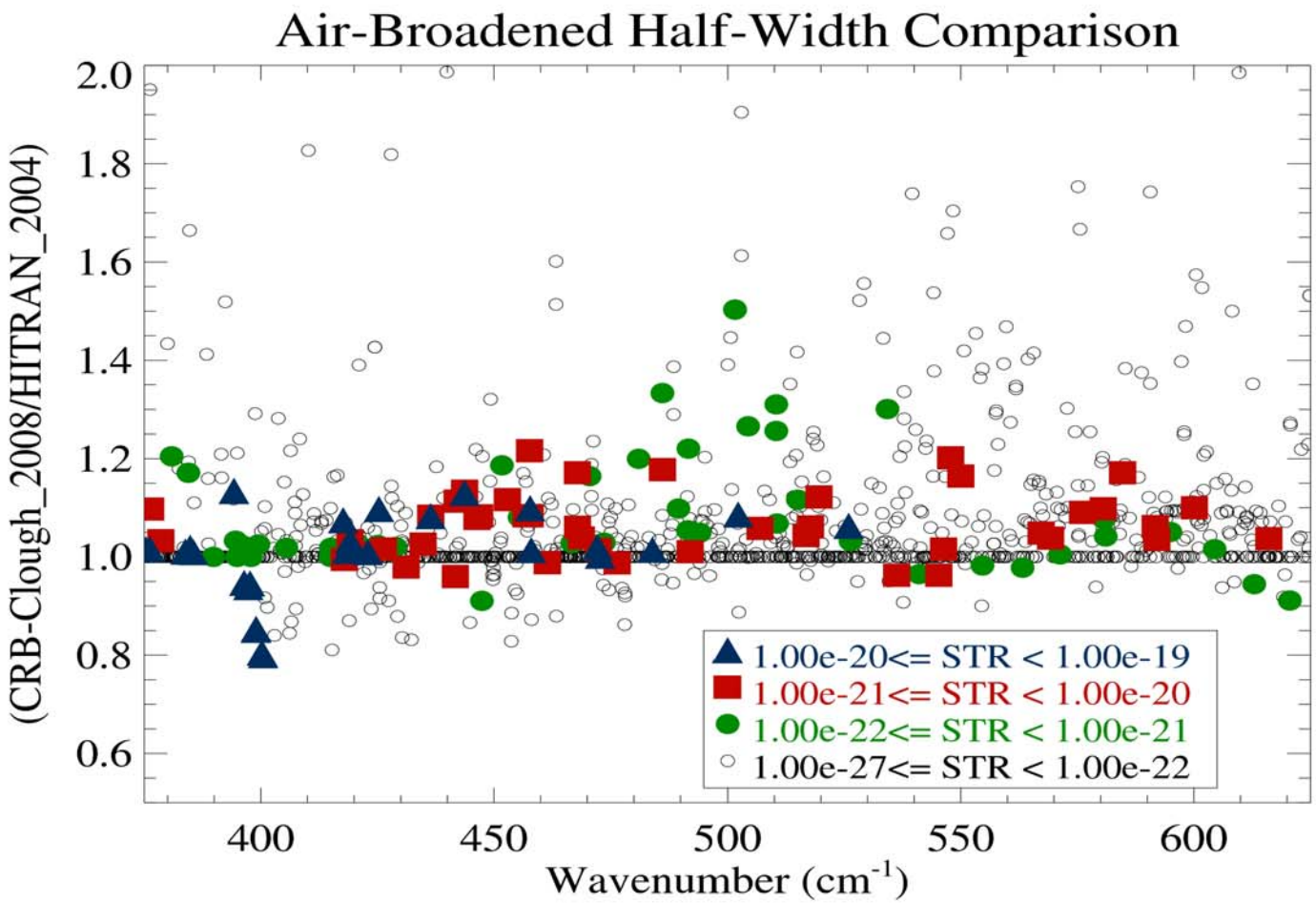
LBLRTM Far-IR Update

- LBL06: LBLRTM v10.3, HITRAN04 w/updates, MT_CKD_1.2
- LBL08: LBLRTM v11.5, New strengths (Coudert 2008) & widths (CRB & Clough), MT_CKD_2.4

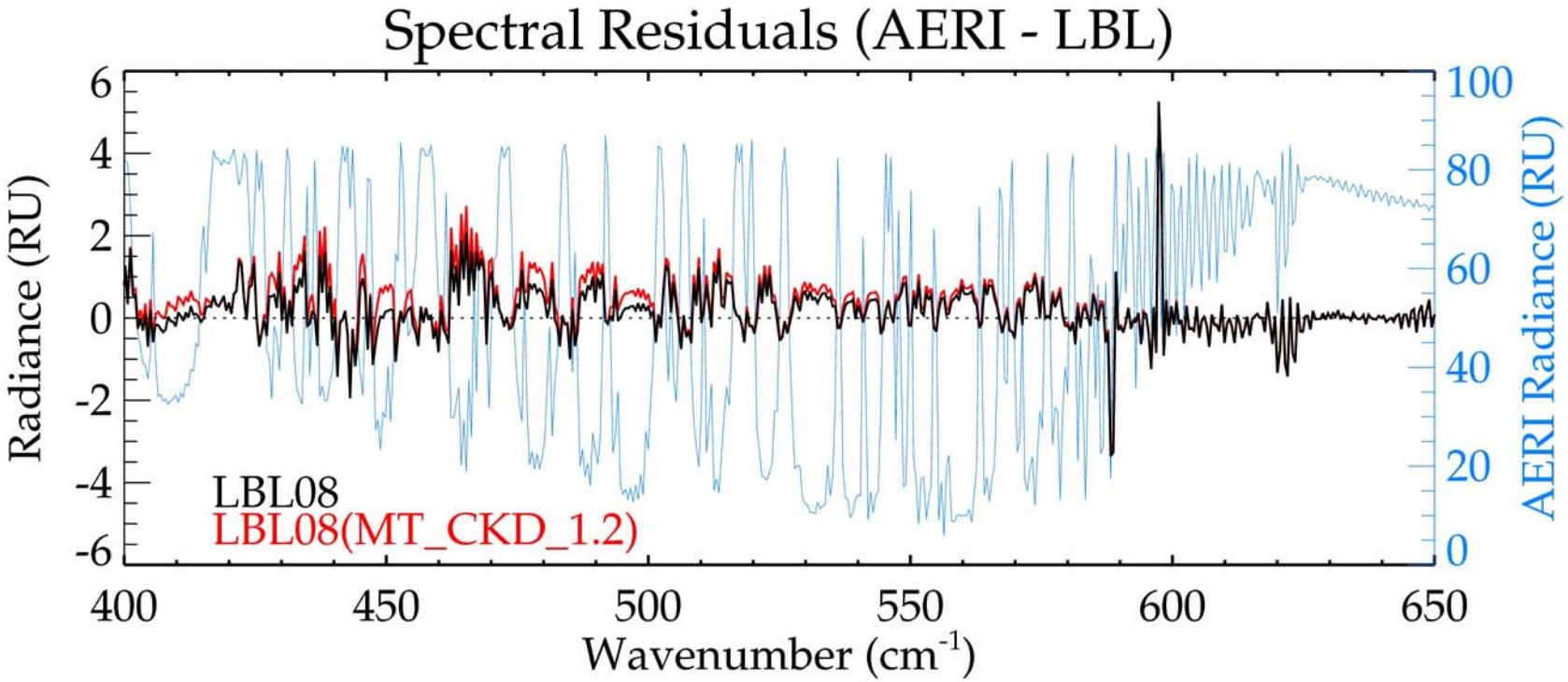


Half-Width Adjustments

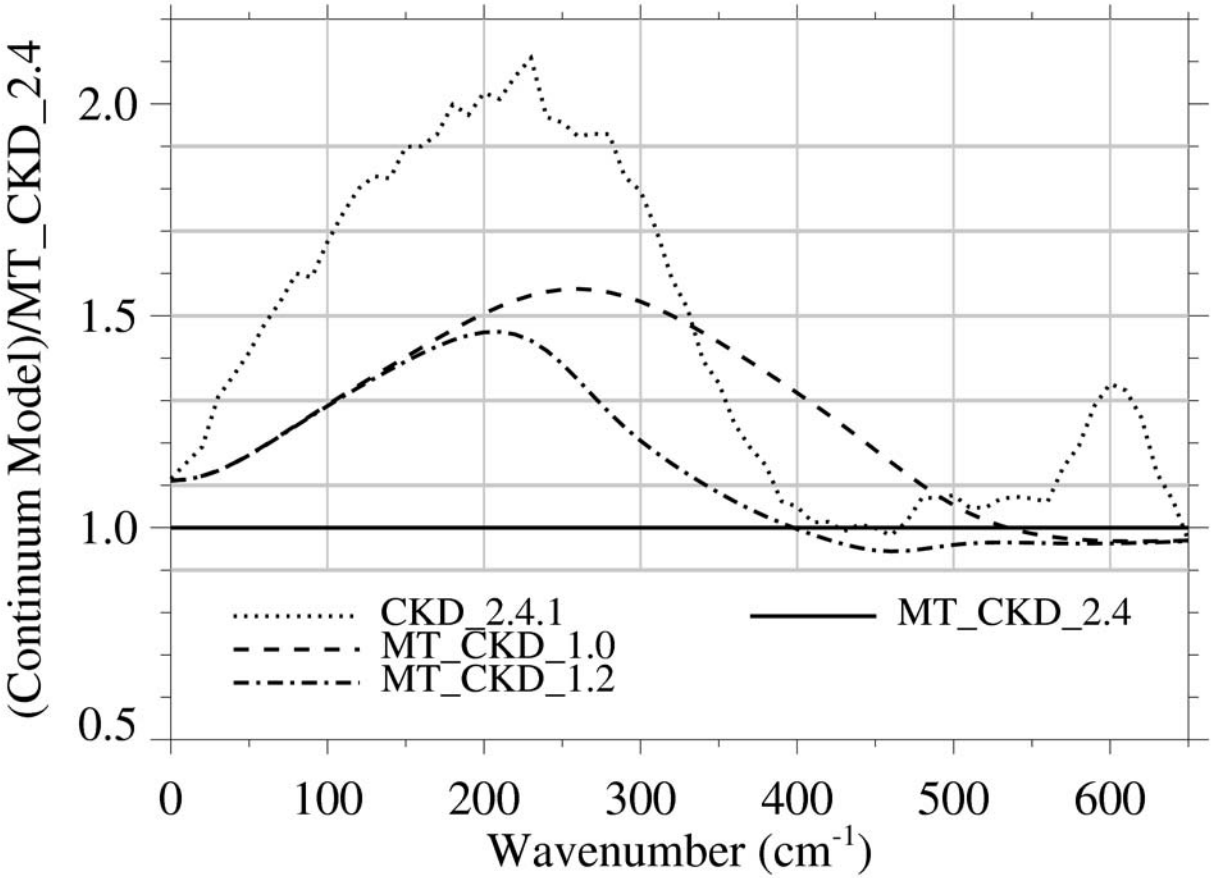
- Update HITRAN 2004 line parameters
  - -New CRB calculations for air-broadened half-width, temperature dependence of the width, and line shift; Additional width retrievals from S. Clough



Foreign Continuum Adjustments



Foreign Continuum Adjustments in Microwave and Far-IR



Backup slides……

Summary of Far-IR Study

- Suite of 22 optimal cases established
  - PWV values from radiosondes scaled to agree with 183 GHz retrievals

- Initial adjustment to MT_CKD continuum released (MT_CKD_2.1)

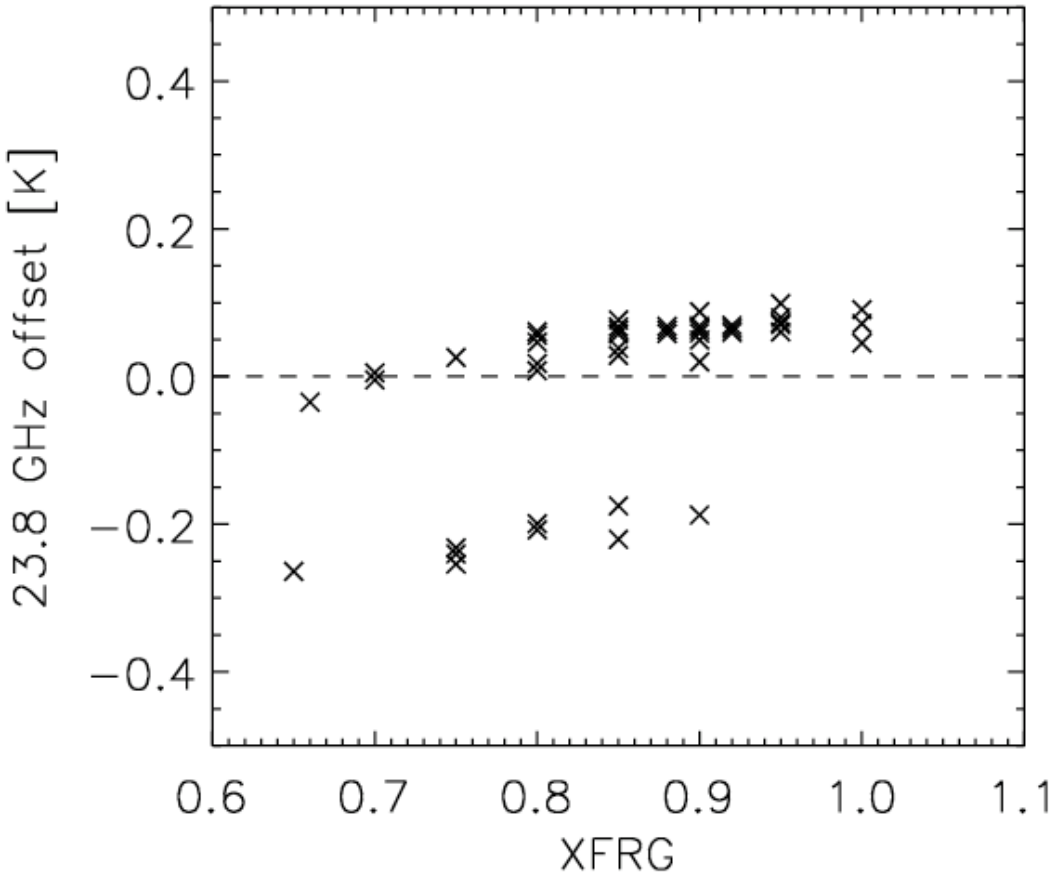
- Improved spectral residuals result from use of newly calculated CRB line widths and additional width retrievals (Clough) relative to HITRAN 2004+ widths

- Improved water vapor continuum fit ready (MT_CKD_2.4)

- Upcoming….updated calculations available from L. Coudert (intensity,position) and R. Gamache (width)

SGP MWR offsets

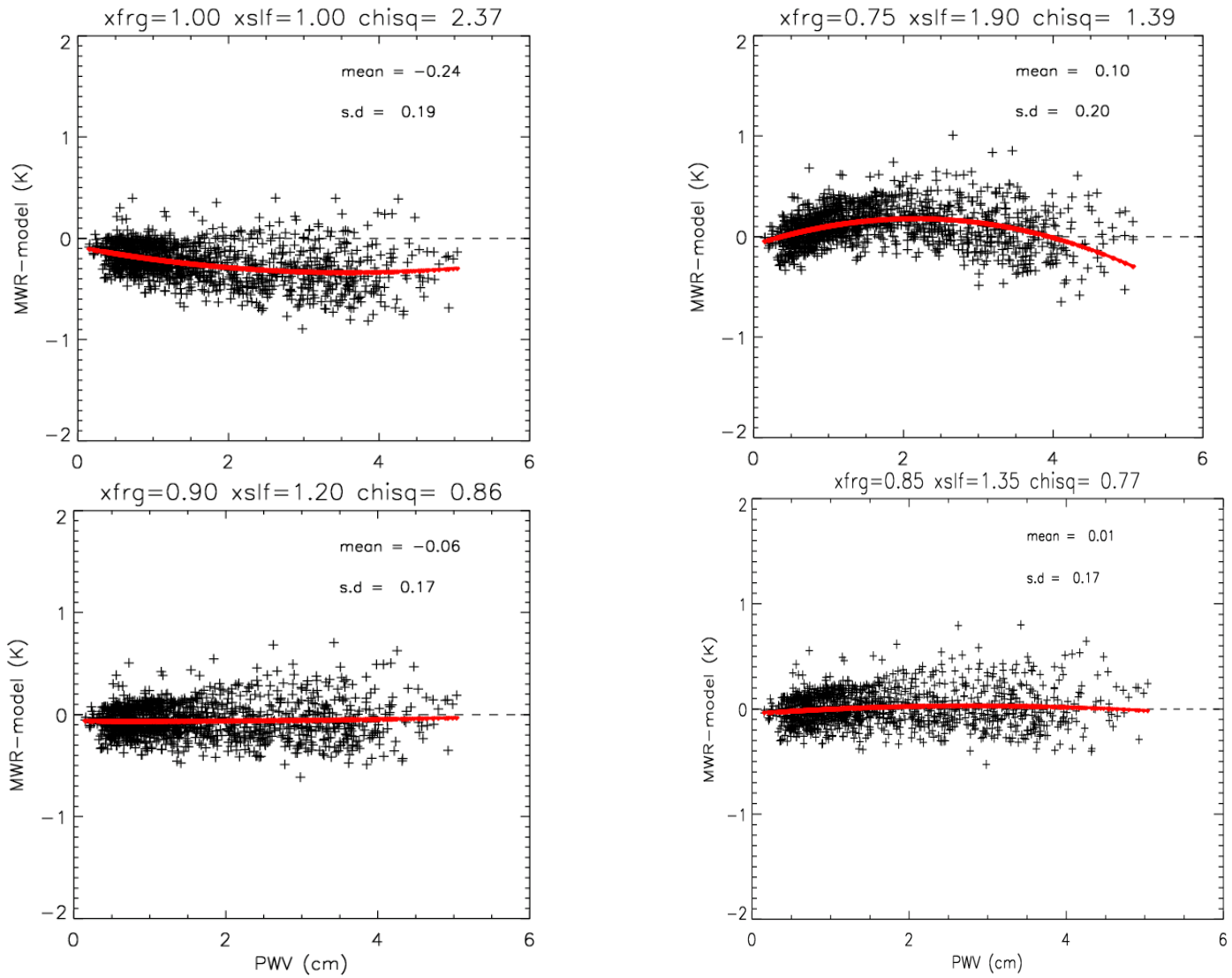
23.8 GHz offset based on unscaled sondes:
obtained by fitting 2nd order polynomial through zero PWV



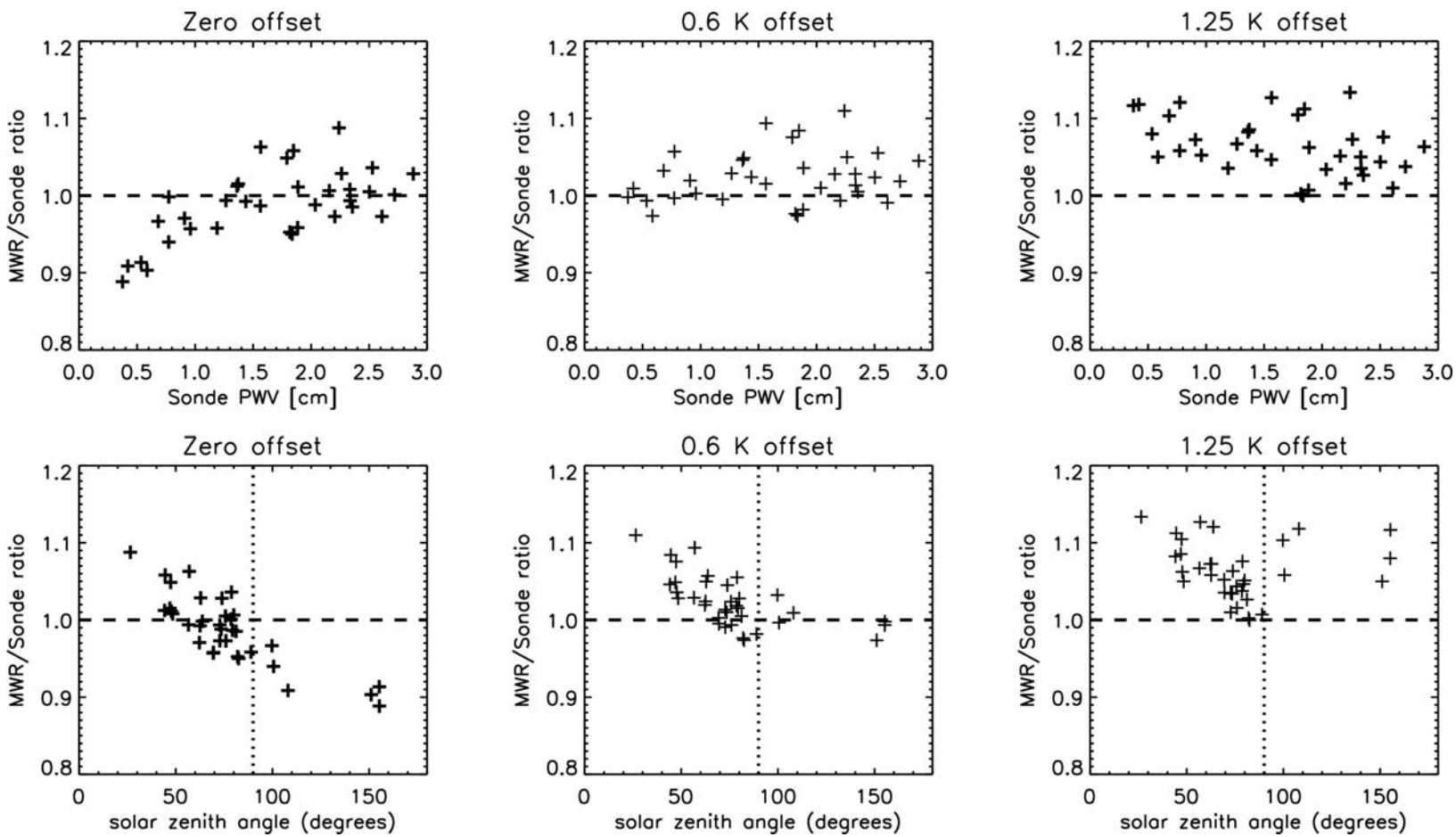
Estimate of 23.8 GHz offset uncertainty: 0.1 K

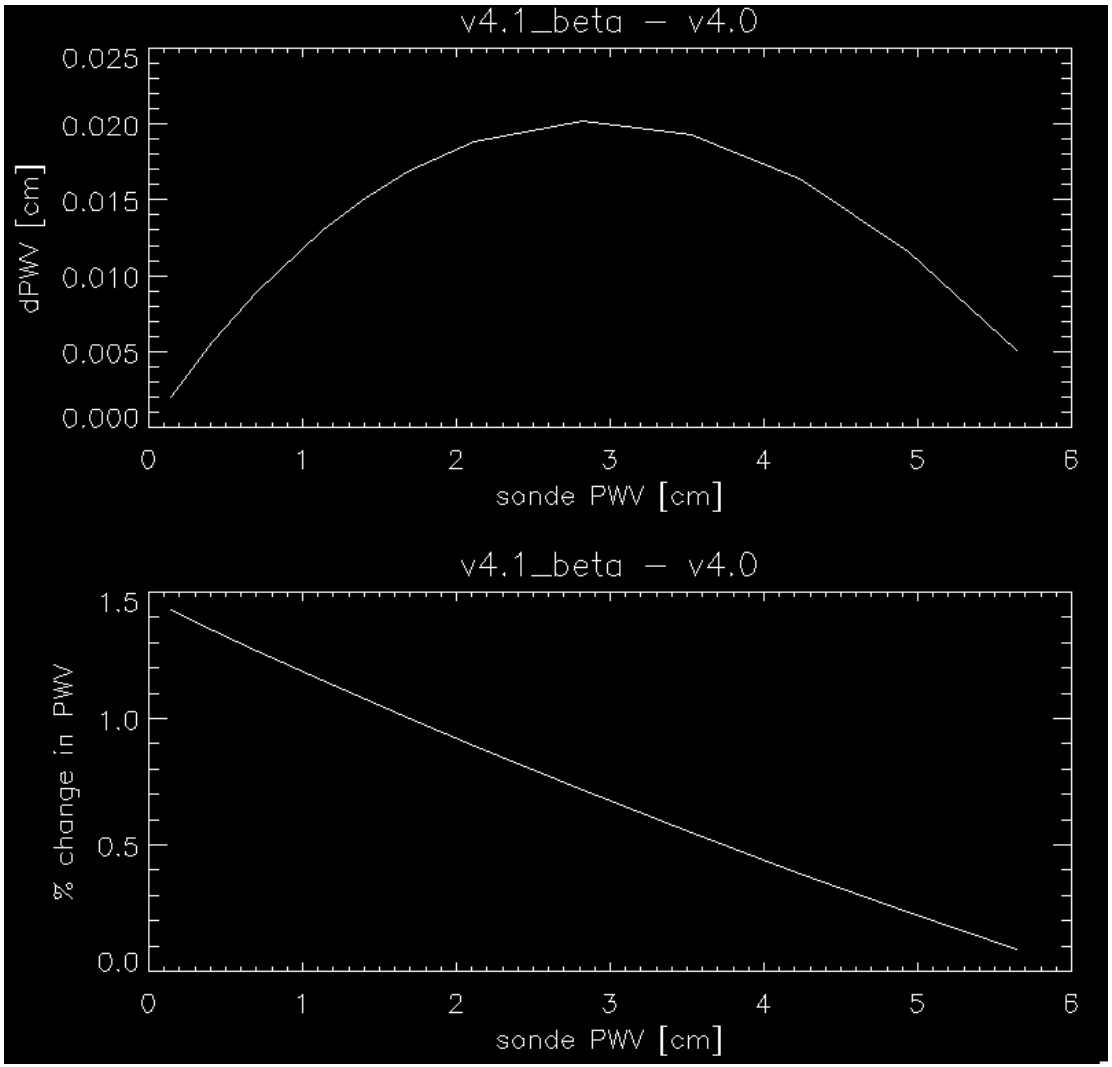
31.4 GHz residuals

1218 clear sky sondes, SGP, January 2005 to December 2007



23.8 GHz offset for COPS dataset



Limited number of cases insufficient to assess appropriateness (or otherwise) of offset

Impact of 0.85, 1.35 continuum scaling on PWV retrievals from 23.8 GHz