Overview of RHUBC-I Accomplishments: February - March 2007

PIs: David Turner (*Univ. Wisconsin*)

E. Mlawer (*AER, Inc.)*

RHUBC-I Concept & Results

Validate water vapor radiative processes in mid-to-upper troposphere using ground-based measurement - model intercomparisons.
High-quality radiometric measurements & atmospheric state profile

Assessment and improvement of MW spectroscopy around 183 GHz water vapor line in MonoRTM .

→ Release of Monortm v 3.3

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

→ PWV retrievals with ~2-4% uncertainty

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

→ Release of LBLRTM v11.6

183 GHz Spectroscopic Study

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

Published IEEE TGRS, November 2008

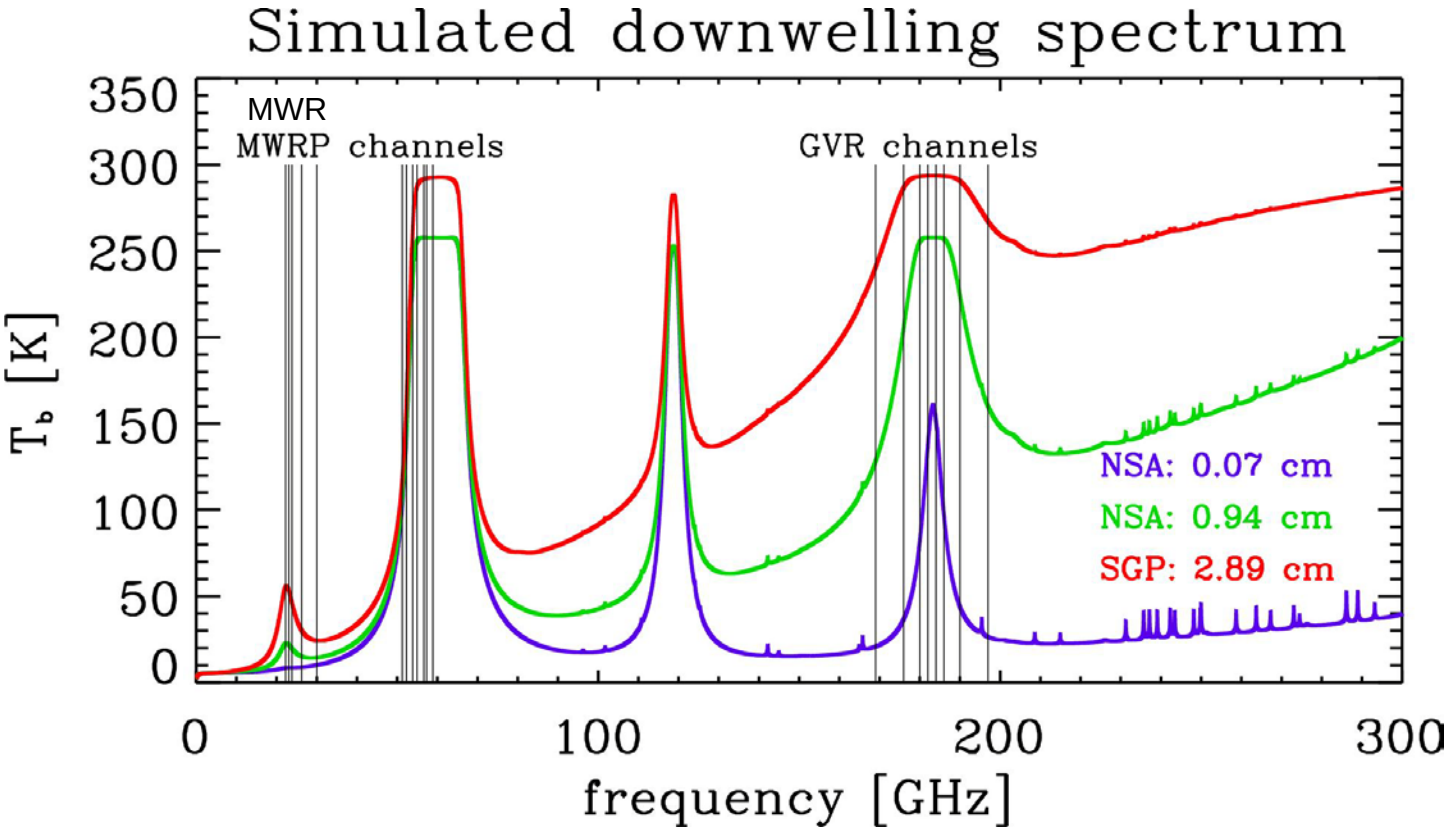
V. Payne, J. Delamere, S. Clough, K. Cady-Pereira, J. Moncet, E. Mlawer

(*AER, Inc.)*

R. Gamache

(*University of Massachusetts - Lowell)*

ARM Microwave Measurements

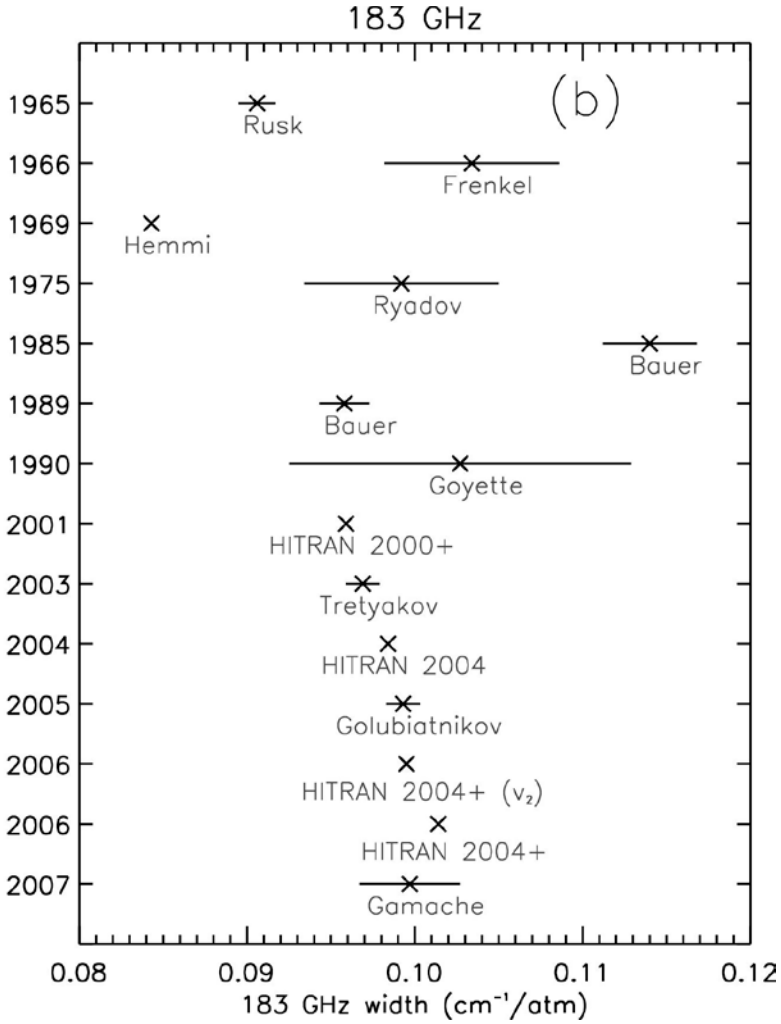


- 183 GHz line provides high sensitivity to water vapor at low PWV
- Importance for water vapor (PWV) and cloud liquid water measurements

RHUBC-I:
183 GHz Spectroscopic Parameters

MonoRTM Model

- Line intensity
  - Known to better than 1%
- Width
  - HITRAN 2000+ value ~5% different from most recent HITRAN update
  - ~3% PWV error at 0.2 cm PWV
- Temperature dependence of width
  - HITRAN 2000+: 0.64 (unrealistic)
  - HITRAN 2004+: 0.77

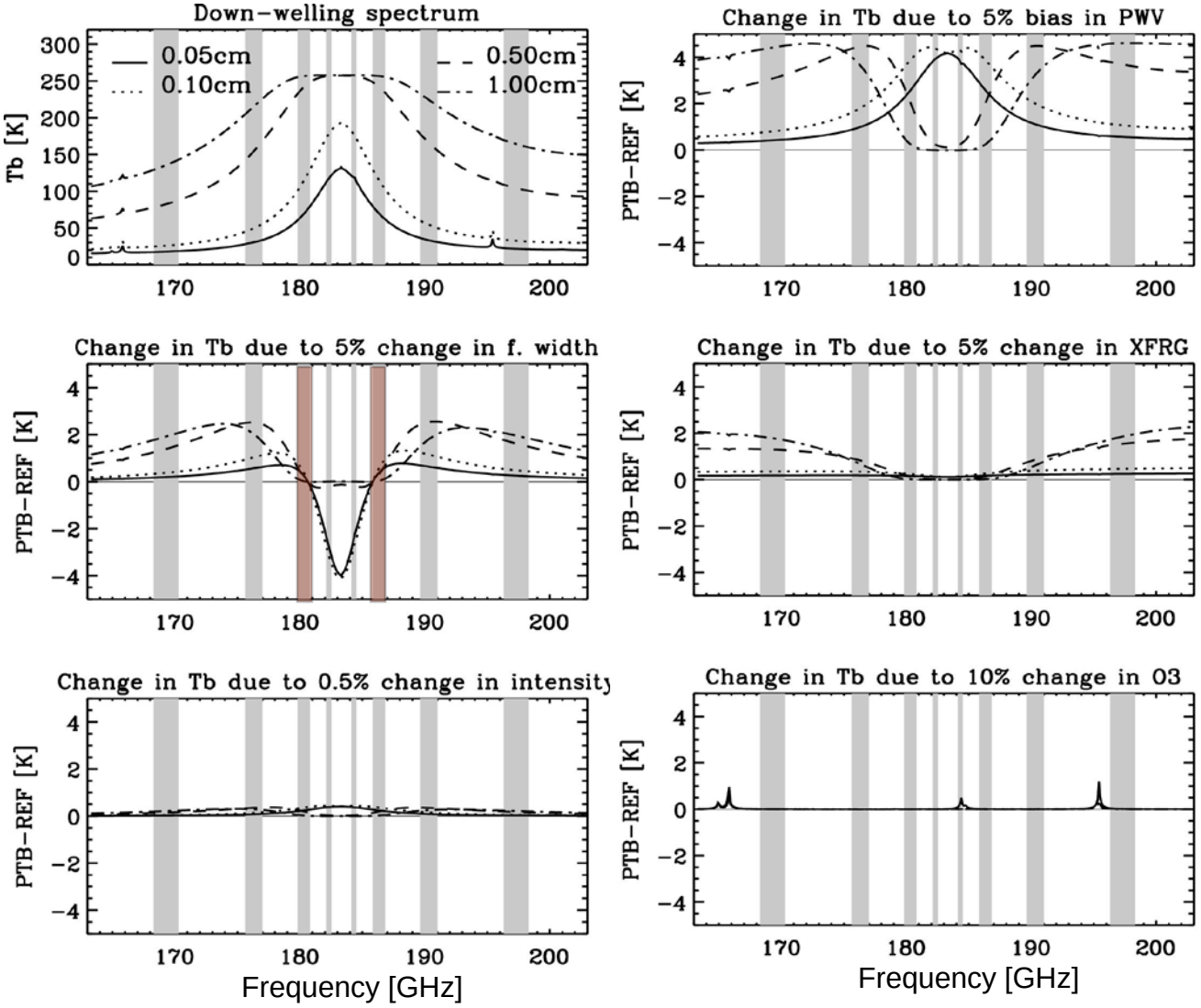


183.31 GHz Instrument

G-band Vapor Radiometer

- Continuous Operation at NSA
  - 183 ± 1, 3, 7, 14 GHz

Spectrum ☐Sensitivity



"Pivot point": +/-2 GHz

- 183+/-3 channel is least sensitive to the width
- Channels inside/outside pivot point crucial for obtaining information about width that is independent of PWV

Retrieval approach

Optimal Estimation Method (Iterative Approach)

- Assume that sonde represents tropospheric H2O profile shape well
- Use direct comparisons, determine offset for each channel
- Use 183 +/-3 GHz channel to obtain a first pass at a PWV scaling factor (-> *reduce scatter in residuals, work only in linear regime*)
- All channels used to obtain a first estimate of the width
- Use 183+/-7 channel to obtain a second pass at PWV scaling
- Re-retrieve the width

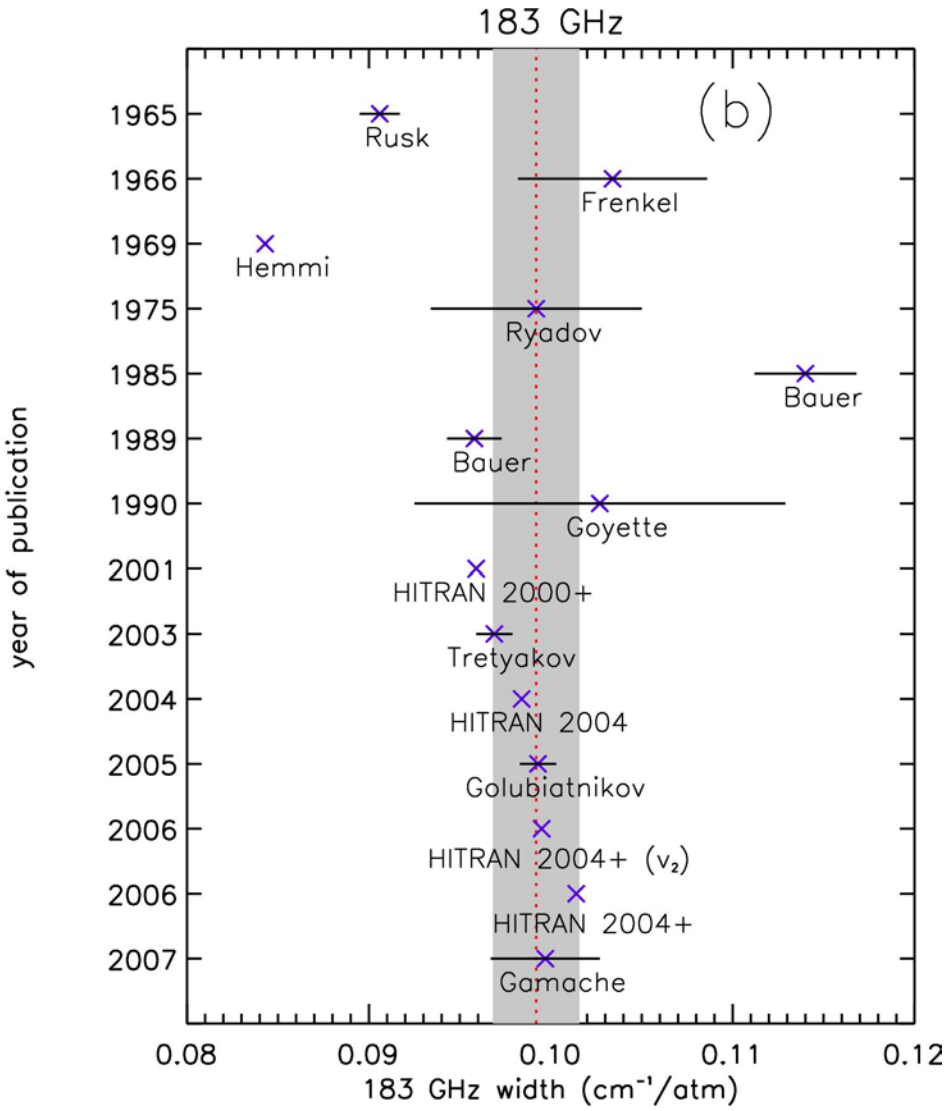
Summary of 183 Spectroscopy Paper

- GVR-based Width retrieval: 0.0992 cm^{-1}/atm ±0.0024

- CRB Calculations: 0.0997 cm^{-1}/atm

MonoRTM v3.3

http://rtweb.aer.com



183.3 GHz Instrument Comparison

Comparison of Ground-Based Millimeter-Wave Observations and Simulations in the Arctic Winter

Published IEEE, September 2009

Domenico Cimini

(*CETEMPS, Univ. of L'Aquila)*

F. Nasir, E. Westwater

V. H. Payne, D. D. Turner

E. Mlawer, M. Exner

M. Cadeddu

Three Different Radiometers

Estimated Accuracies:

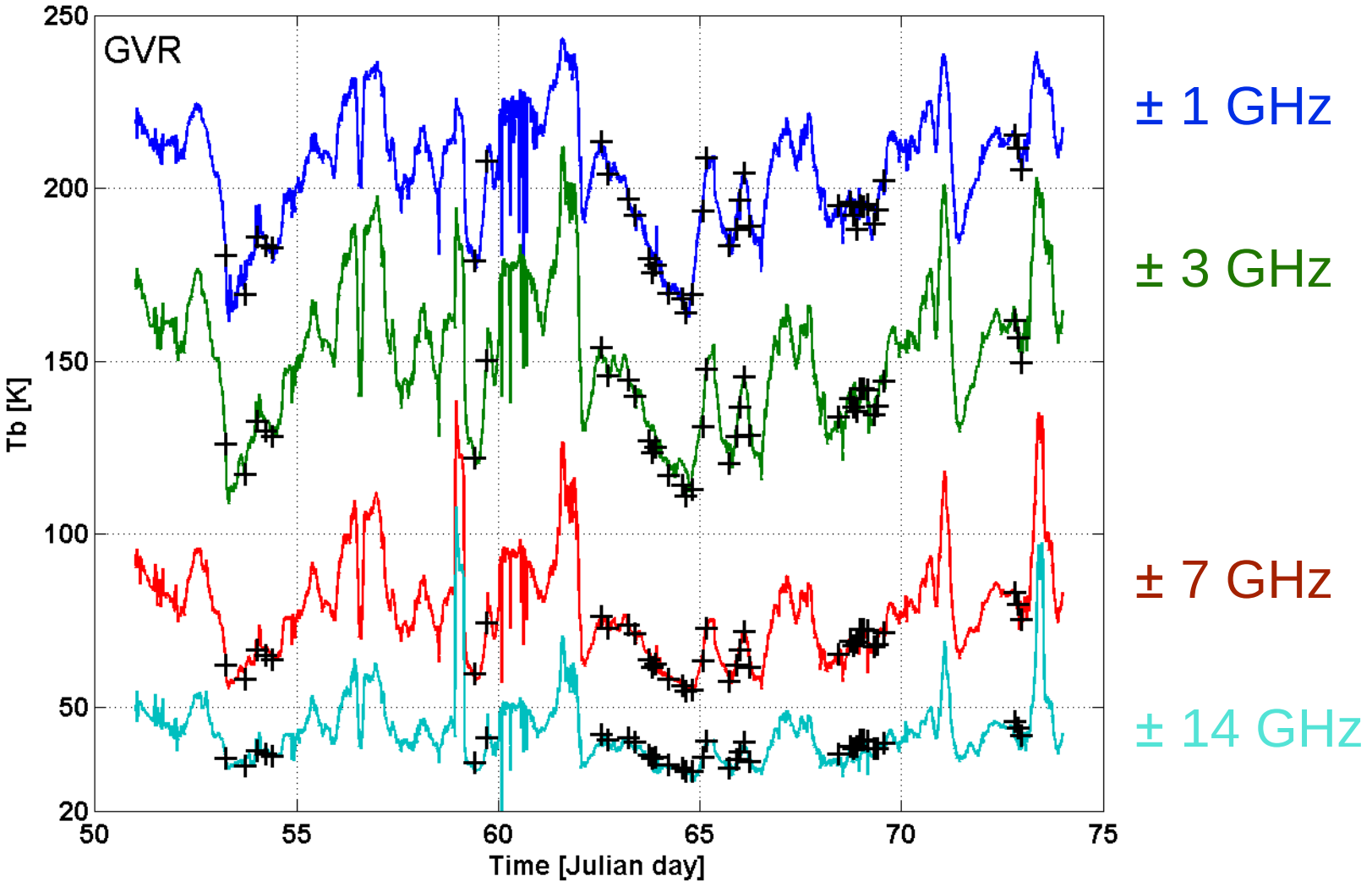
~1.5 K GSR

~2 K GVR

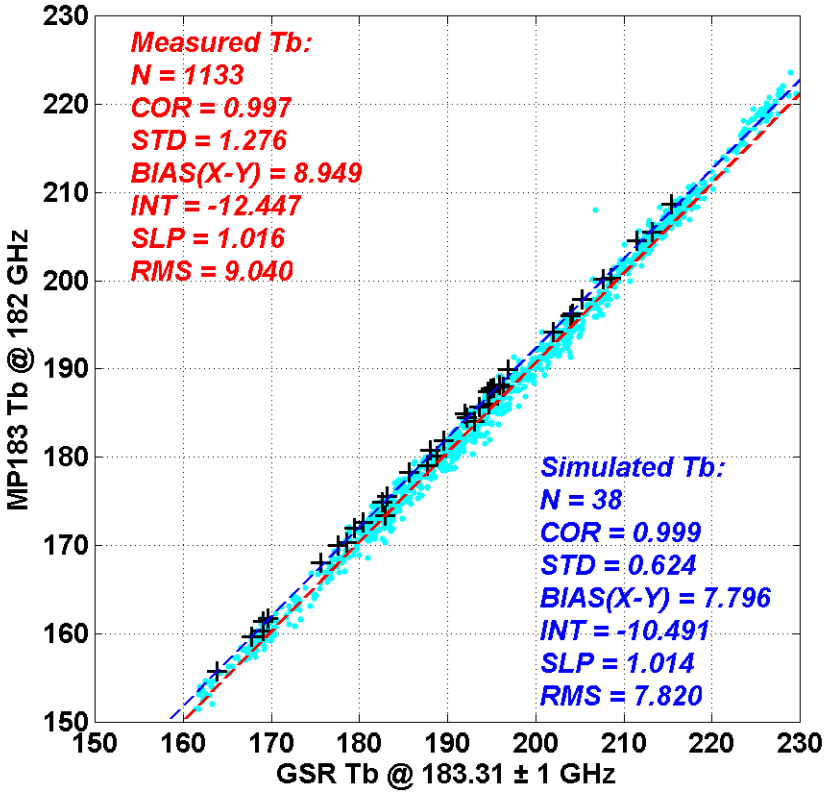
~1 K MP-183A

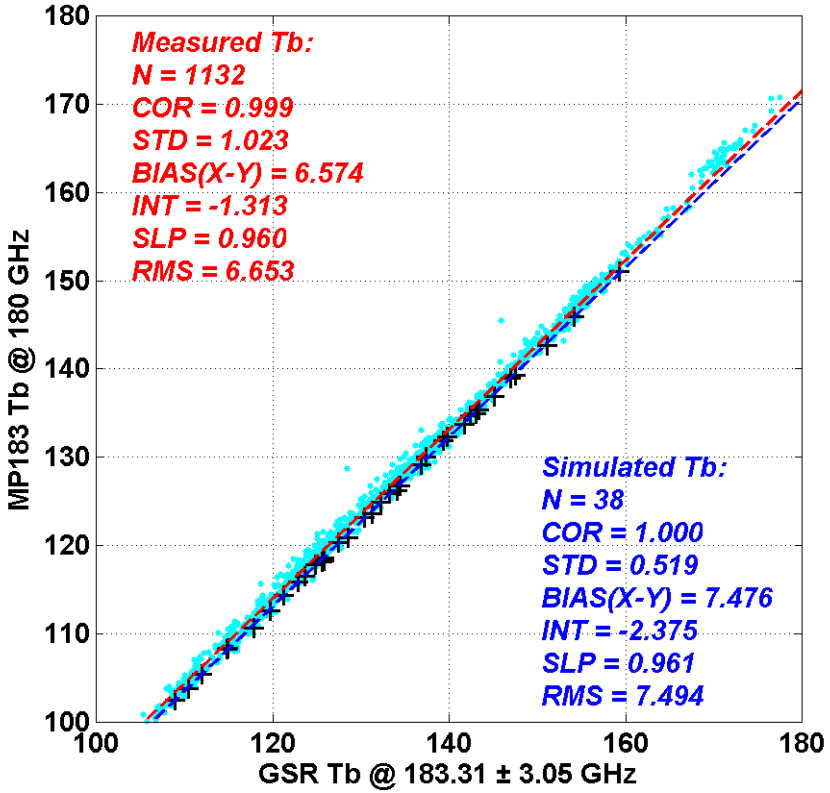
QuickTime™ and a
decompressor
are needed to see this picture.

Direct Sonde Comparisons



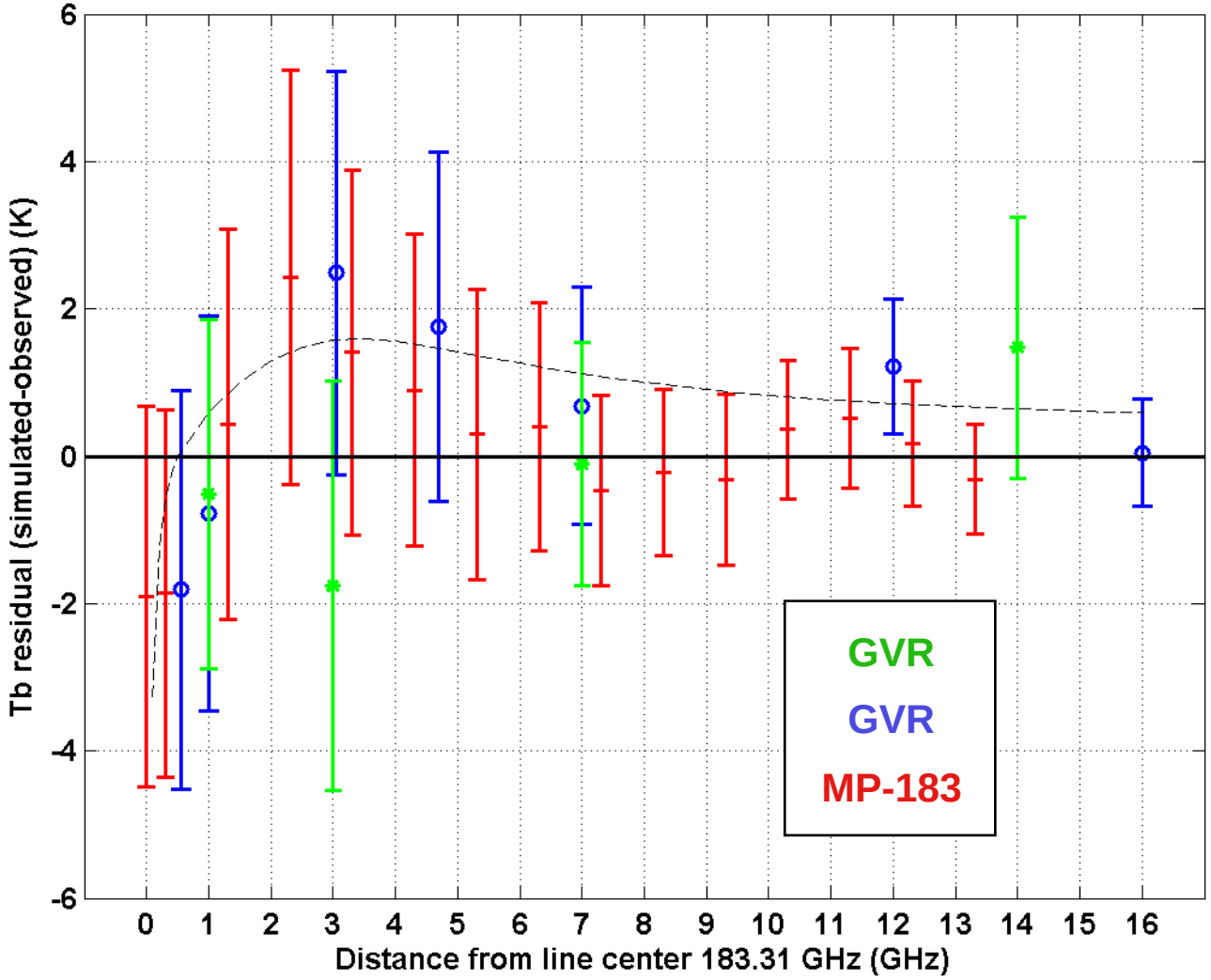
Cross-Validations





"the consistency between instruments allow IWV estimates within ~2-4% for dry conditions"

BT Residuals For Radiometers



Simulations with realistic sensor humidity uncertainty affecting the sounding in an opposite way at lower and upper levels (**5% drier/wetter above/below a reference level arbitrarily fixed to 3km**)

Summary of MW Radiometer Comparison Paper

- Deployed 3 very different 183 GHz microwave radiometers at NSA site for RHUBC-I
  - All three calibrated using different techniques

- Good agreement “spectrally” between the MP-183 and GSR; some differences with GVR

- MP-183 and GSR show consistent spectral residuals relative to calculations; most likely explanation is small bias errors in RS-92 radiosonde humidity profile that changes with height

NSA Far-Infrared Study

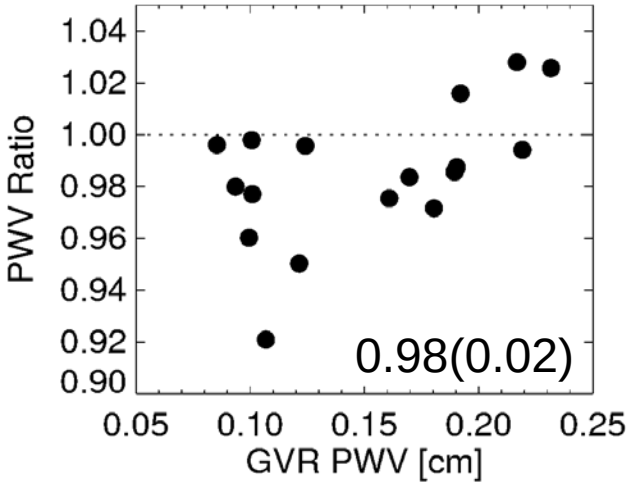
A Far-Infrared Radiative Closure Study In the Arctic: Application to Water Vapor

In Review, JGR, March 2010

J. Delamere, E. Mlawer, S. Clough, V. Payne
(*AER, Inc.)*
D. Turner
(University of Wisconsin)
R. Gamache
(*University of Massachusetts - Lowell)*

Far-IR Data Set

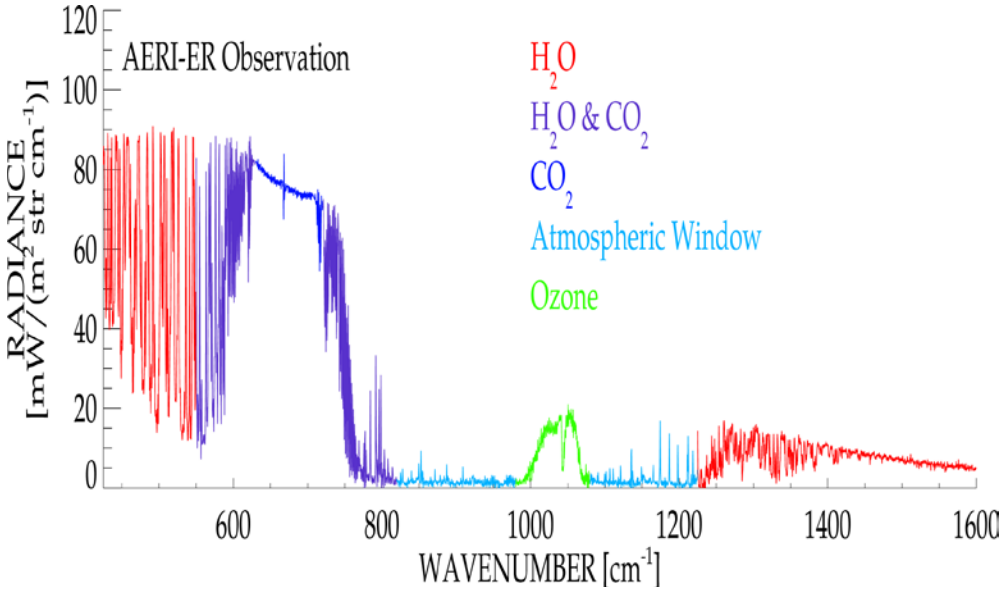
- Extended Range Atmospheric Emitted Radiance Interferometer:
  - Operating continuously at the NSA
  - Range 3.3 - 25 μm with 0.5 cm^{-1} resolution
  - 3-min (normal) or 20-s sky (rapid-sample) averages
  - Accuracy better than 1% ambient radiance
  - **Offset** applied to data
- Date range used: January - March 2007
  - 17 clear cases
- Atmospheric Profile
  - Radiosonde (T, RH)
  - PWV scaled to match GVR retrieval



Radiative Transfer Model (LBL06)

LBLRTM Model

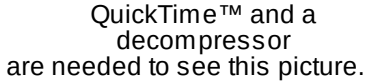
- Line intensities
  - HITRAN 2004 with Updates
- Widths
  - HITRAN 2004 with Updates
- WV Continuum
  - MT_CKD_2.1



Assess current spectroscopy down to 400 cm^{-1} using **AERI-ER measurements and LBLRTM calculations**

- PWV scaling factor retrieved from GVR

AERI-ER Correction



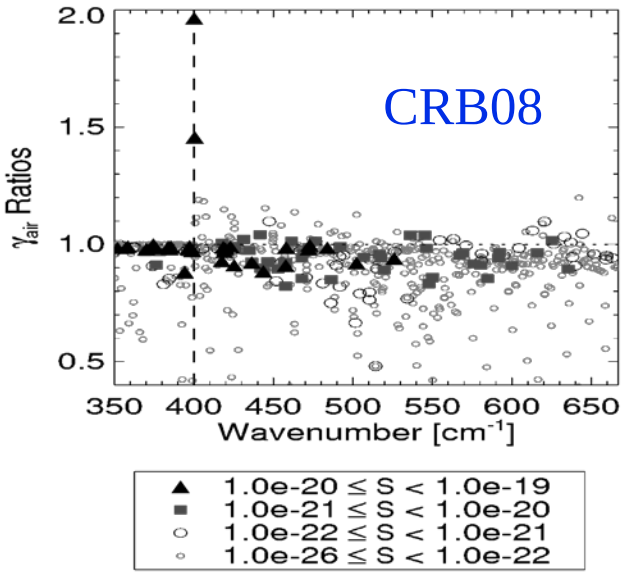
RHUBC-I LBL09 Modification

QuickTime™ and a
decompressor
are needed to see this picture.

Mean Residuals: LBL06: 0.84 (1.10)

LBL09: 0.16 (0.67)

Modifications to Line Parameters



& retrieval of widths for 42 lines

LBL09(HITRAN_2004) - LBL09; LBL09(CRB08) - LBL09

QuickTime™ and a decompressor are needed to see this picture.

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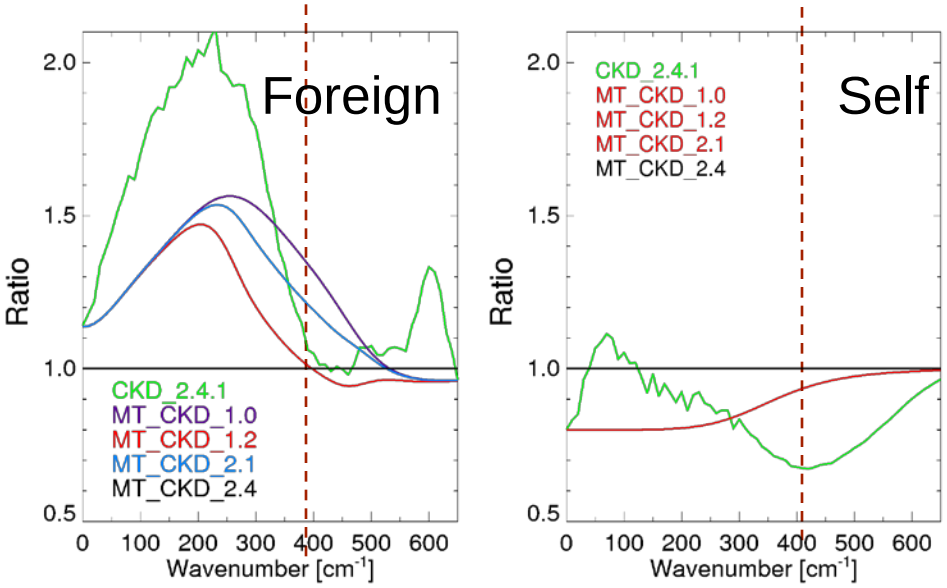
Modifications to WV Continuum

Ratio:

$$\frac{\text{Model X}}{\text{(mt\_ckd\_2.4)}}$$



LBL06(MT_CKD_1.2) ; LBL07 (MT_CKD_2.1) - ; LBL99(CKD_2.4) - LBL09

QuickTime™ and a
decompressor
are needed to see this picture.

QuickTime™ and a
decompressor
are needed to see this picture

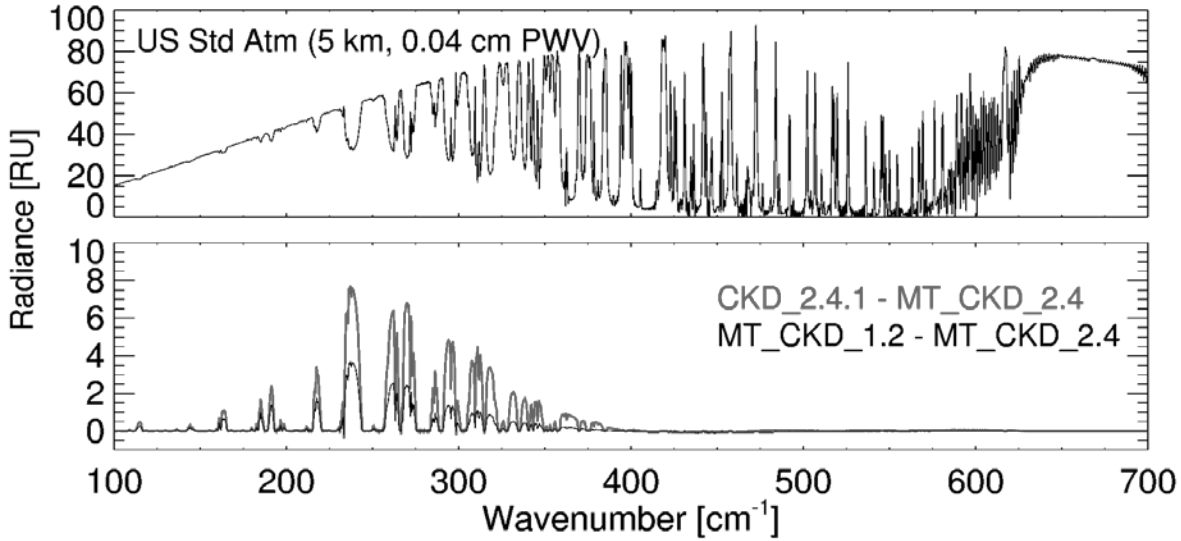
Summary of Far-IR Paper

- Using 17 well-defined cases (with GVR-scaled water vapor column), modified:

  Water Vapor Continuum Model (MT_CKD_2.4)

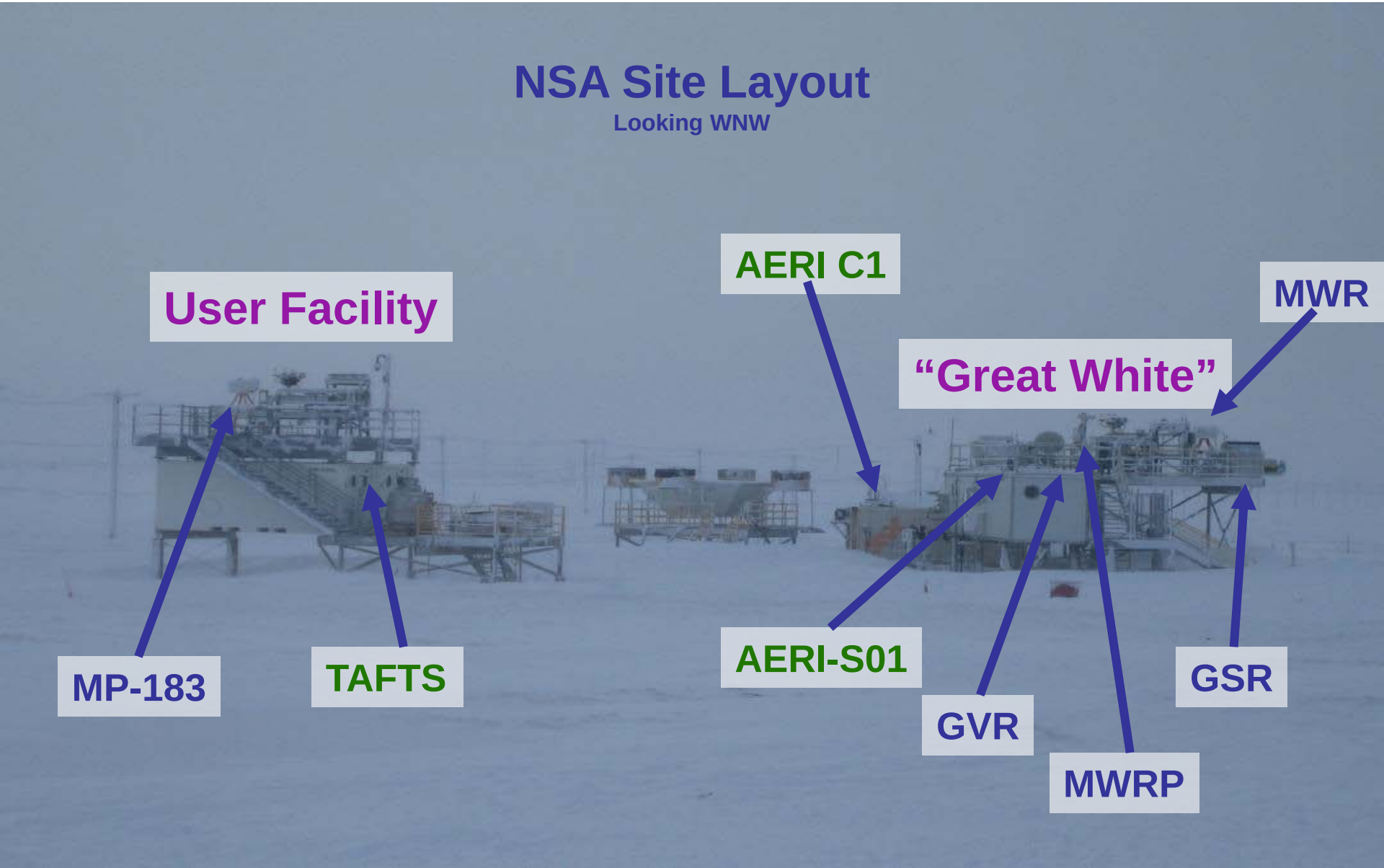
  Line Parameter Database (aer_v_2.4)

- RHUBC-II will provide information to validate continuum below 400 cm^{-1}



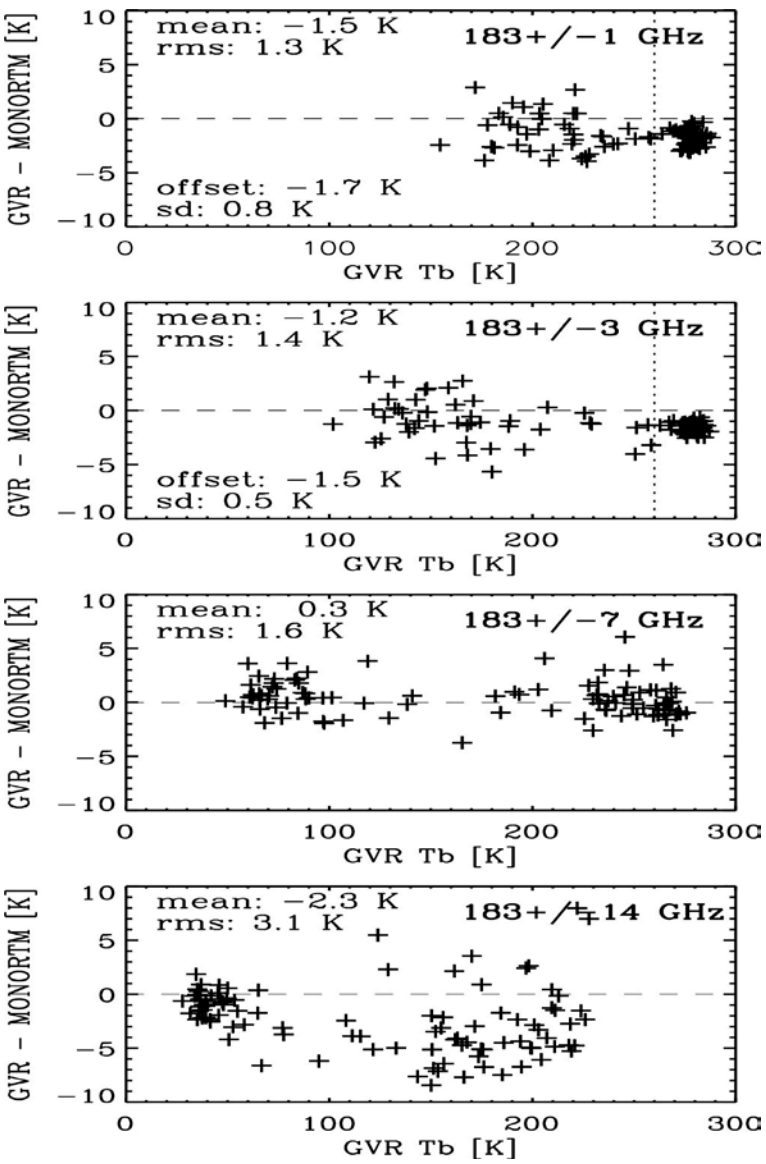
Additional Slides

NSA Instruments (2007 RHUBC)

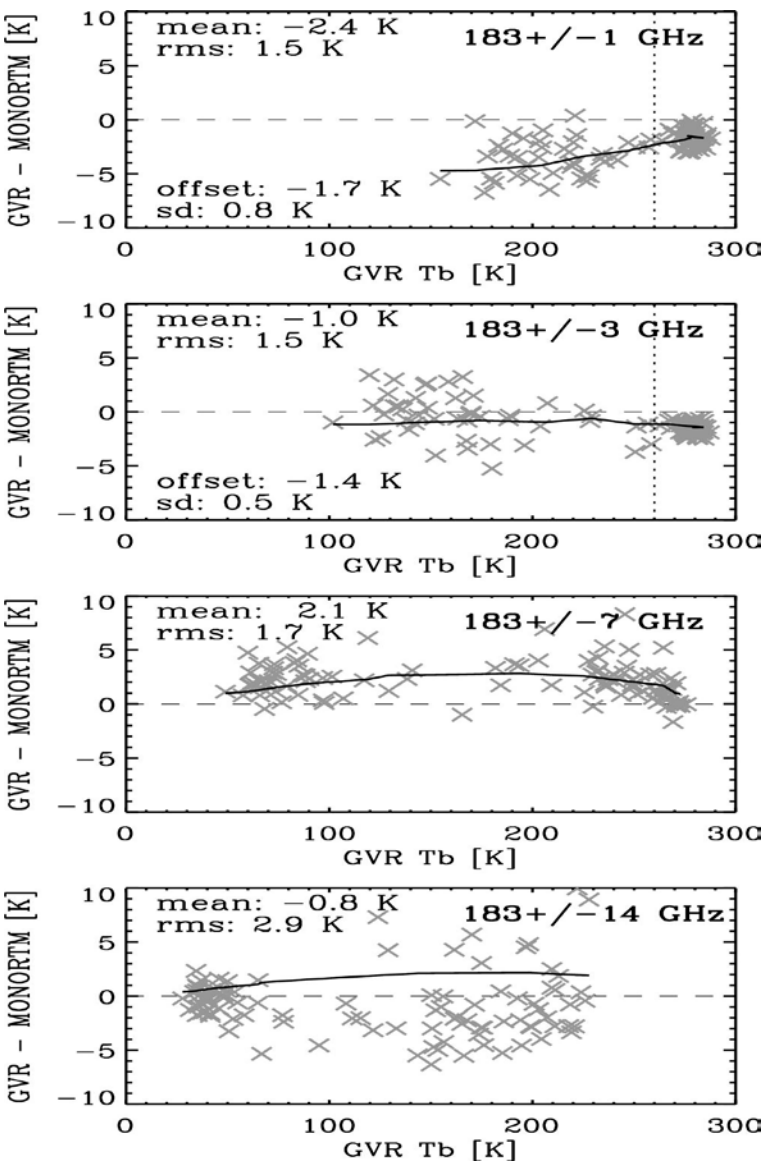


Direct Sonde Comparisons

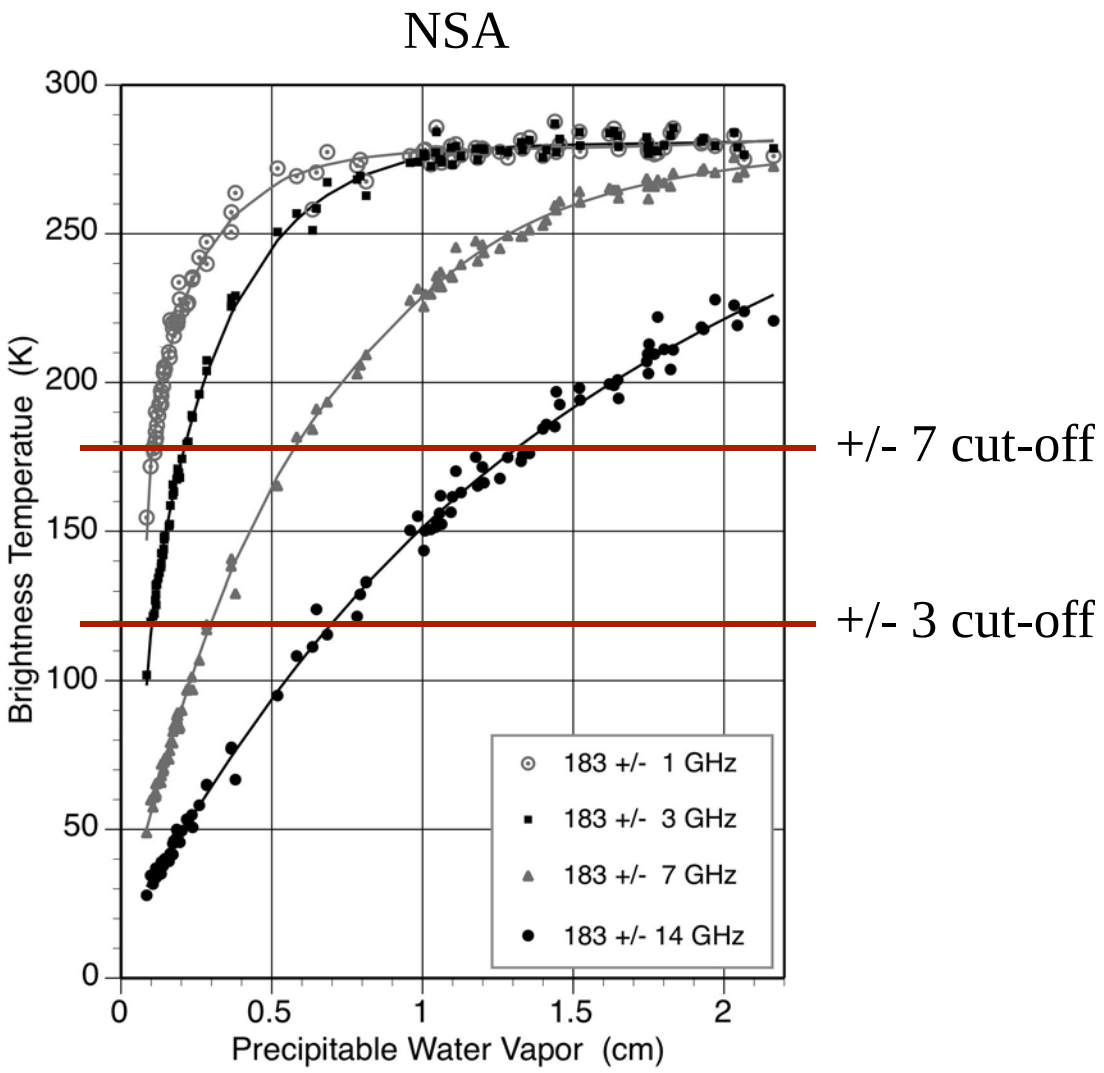
Hf_wdth = 0.0989



Hf_wdth = 0.95*0.0989

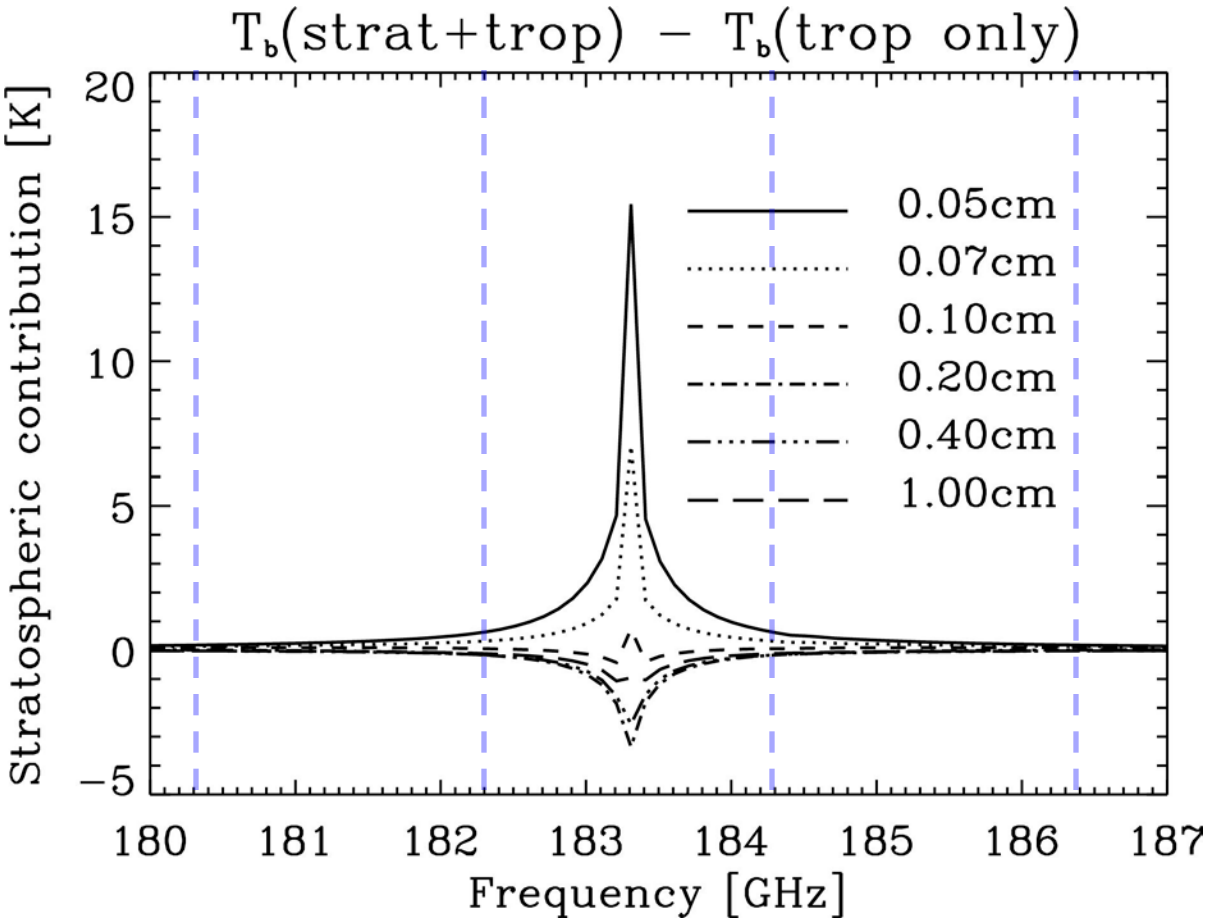


Response of Tb to PWV

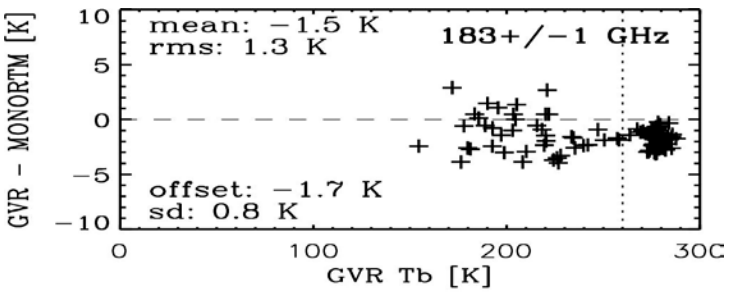


Sensitivity to the Stratosphere

- Sensitivity to stratosphere is small at GVR channel frequencies

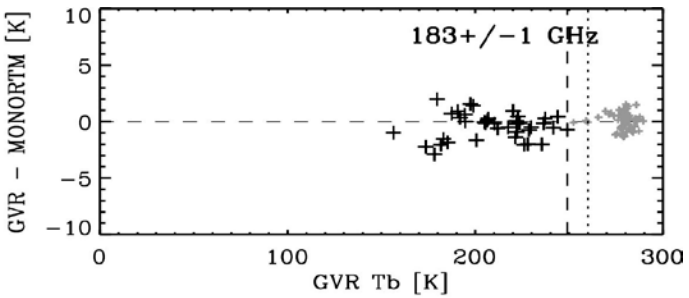


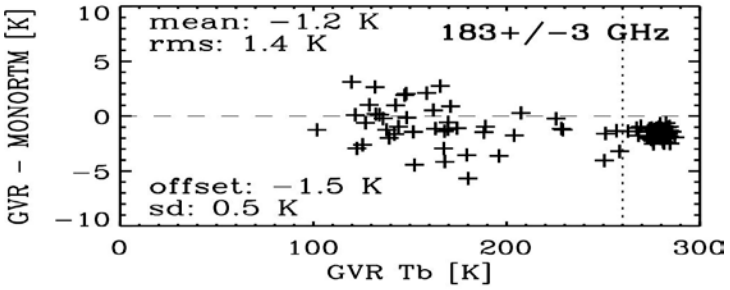
Half-Width Retrieval Result



After retrieval:
mean: −0.4 K
rms: 1.1 K

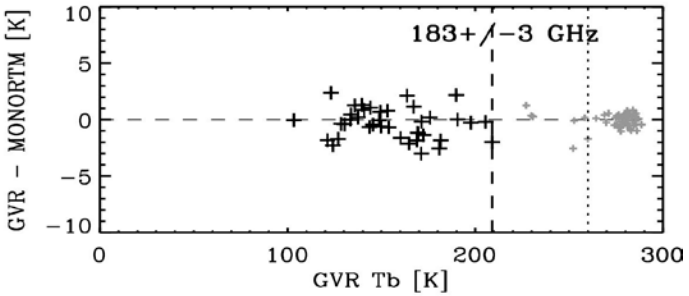
Original:
mean: −1.3 K
rms: 1.8 K

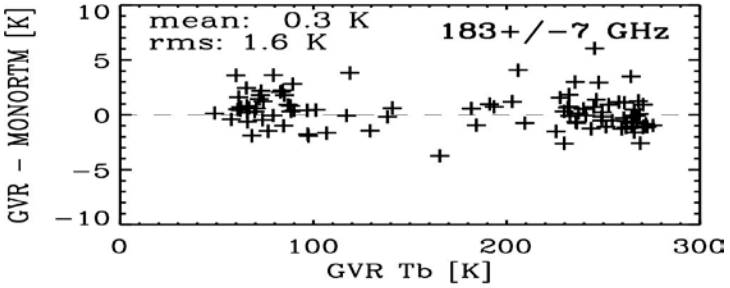




After retrieval:
mean: −0.3 K
rms: 1.3 K

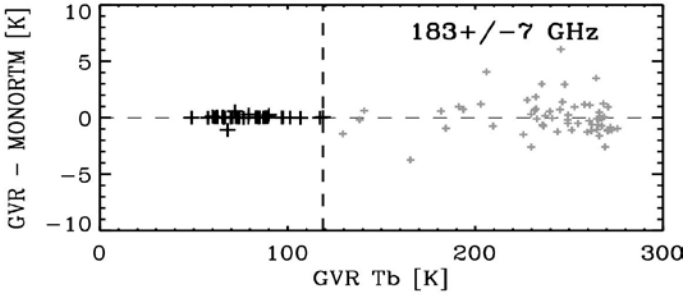
Original:
mean: −0.8 K
rms: 2.1 K

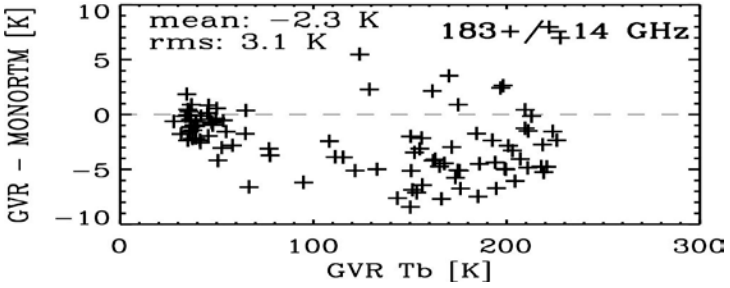




After retrieval:
mean: 0.0 K
rms: 0.2 K

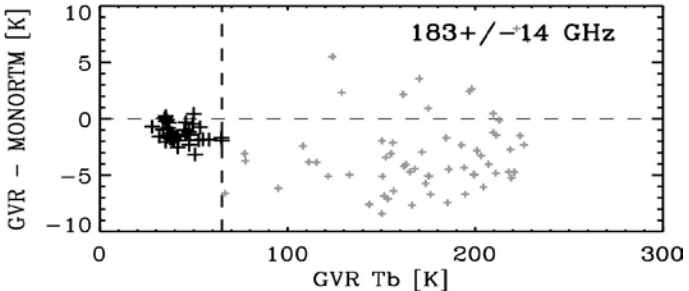
Original:
mean: 0.7 K
rms: 1.5 K



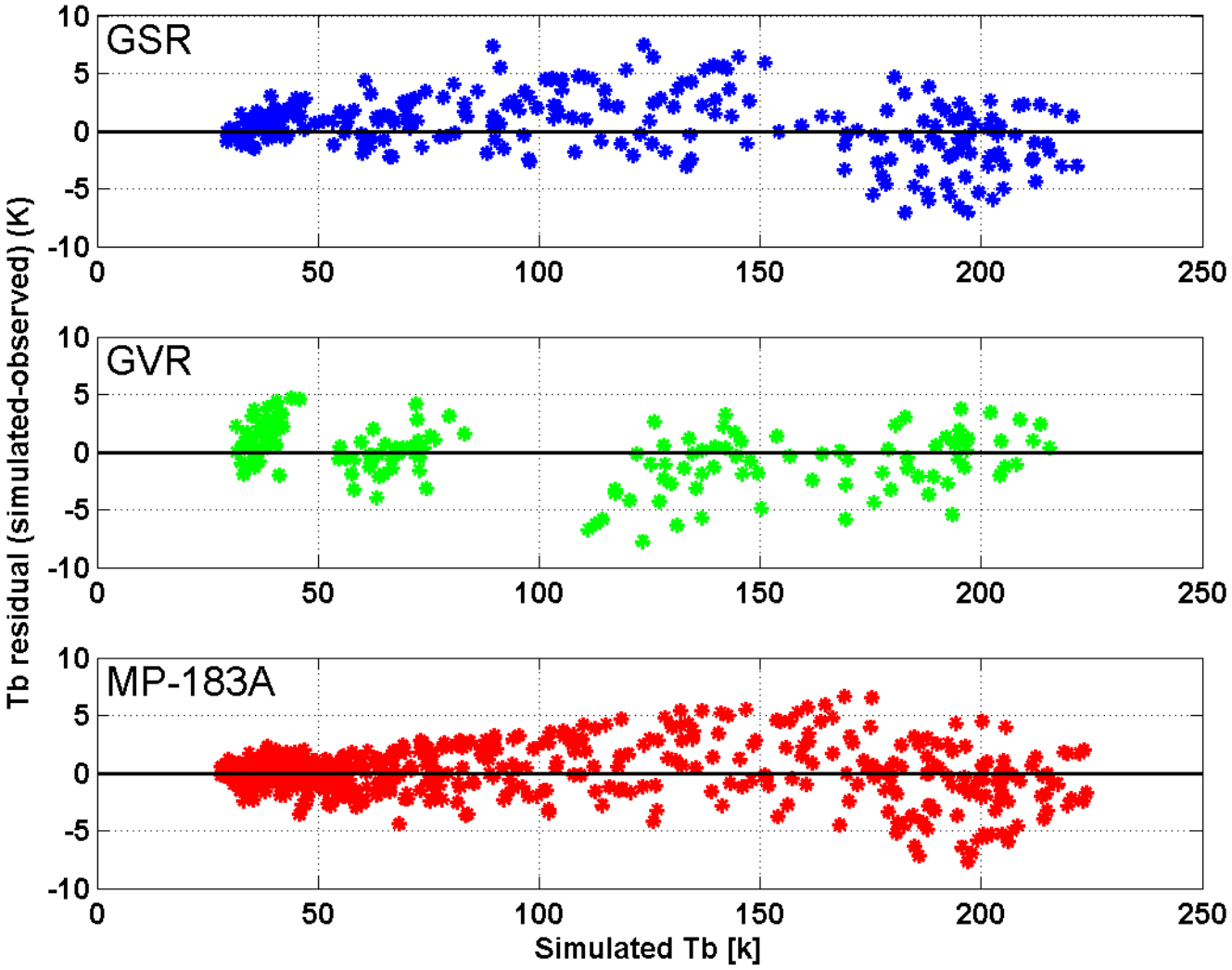


After retrieval:
mean: −1.3 K
rms: 0.8 K

Original:
mean: −1.0 K
rms: 1.2 K



BT Residuals For All Channels



Direct Sonde v. GVR Comparisons

G-band Vapor Radiometer

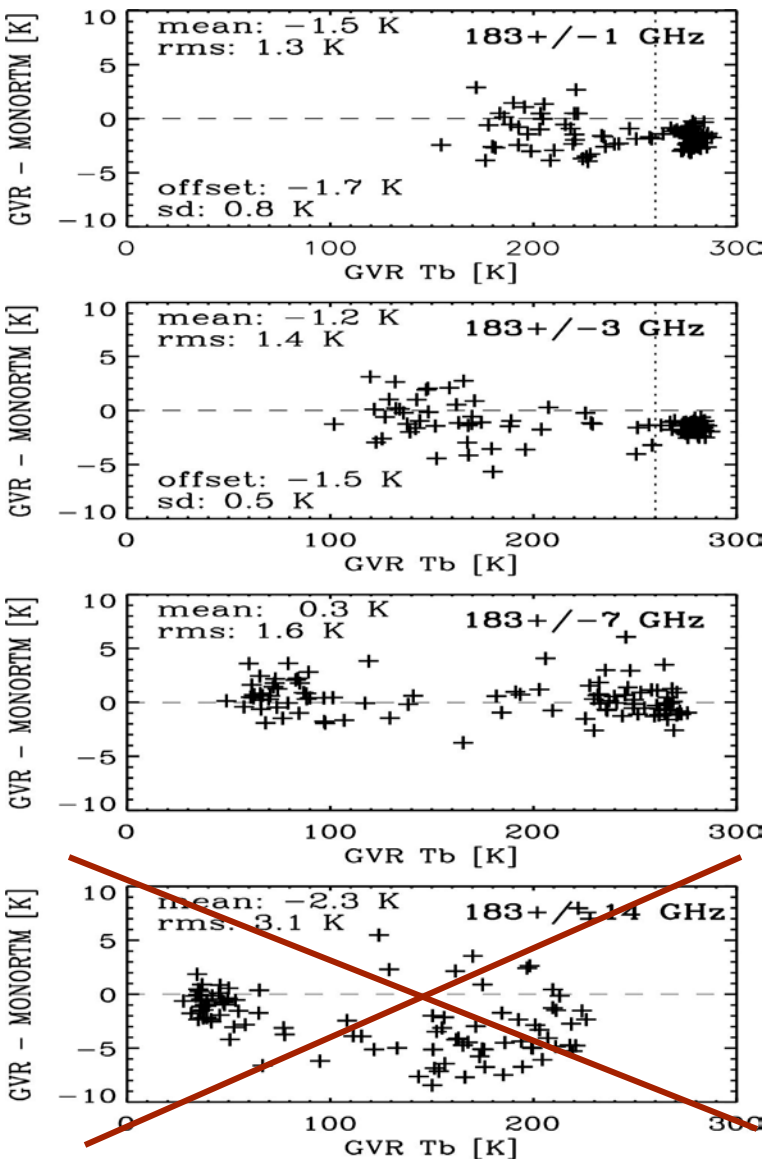
- Continuous Operation at NSA
- 183 ± 1, 3, 7, 14 GHz

January to October 2007

– Liquid-free conditions

GVR measurements averaged for 35 minutes

Vaisala RS-92 radiosondes provide atmospheric state information



GVR Retrieval Results

- GVR-based Width retrieval: 0.0992 cm^{-1}/atm

Error source	Contribution
Random retrieval error	0.1 %
1 K temperature uncertainty	0.3 %
3 % continuum uncertainty	0.6 %
10 % column ozone uncertainty	0.02%
1.5 % PWV uncertainty	1.5 %
Water vapor profile shape uncertainty	0.4 %
1 K GVR calibration uncertainty	1.6%
Total	2.4 %