Comparison of Microwave Observations at 183 GHz

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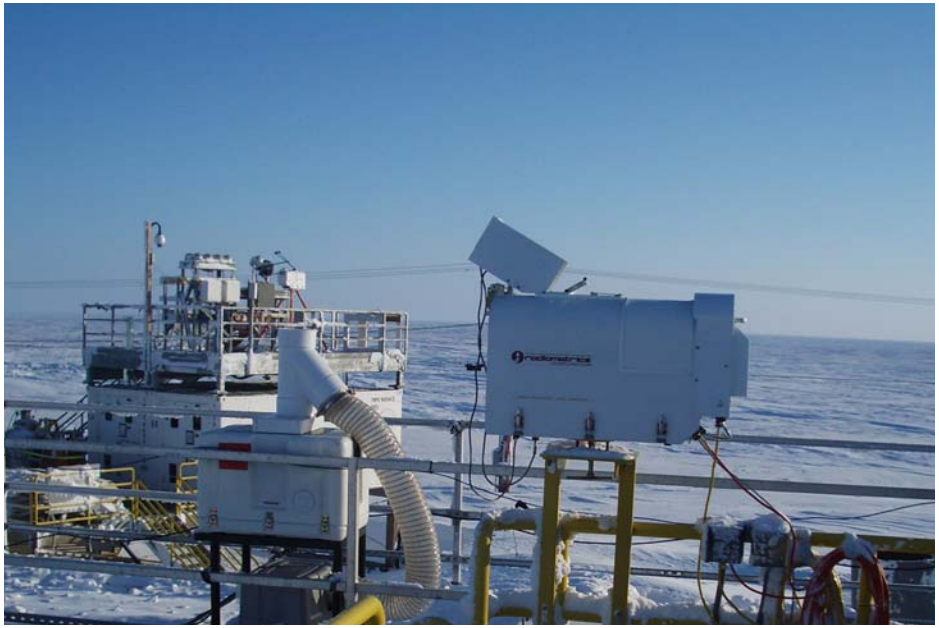
RPWG Workshop
Fall 2008
Princeton, NJ

ARM Atmospheric Radiation Measurement Program

Radiative Heating in Underexplored Bands Campaign (RHUBC 2007)



PI: D.D. Turner and E. Mlawer

Co-PIs: E.R. Westwater et al.

Period: February-March 2007

Location: ARM NSA, Barrow, Alaska

Note: Part of ARM contribution to IPY

Instruments:

1) Dual channel Microwave Radiometer (MWR)

2) 12-channel Microwave Radiometer Profiler (MWRP)

3) 27-channel Ground-based Scanning Radiometer (GSR)

4) 4-channel G-band Vapor Radiometer (GVR)

5) 15-channel 183 GHz Radiometer (MP183)

6) Extended-range Atmospheric Emitted Radiation Interferometer (AERI-ER) 400-1800 cm^{-1}

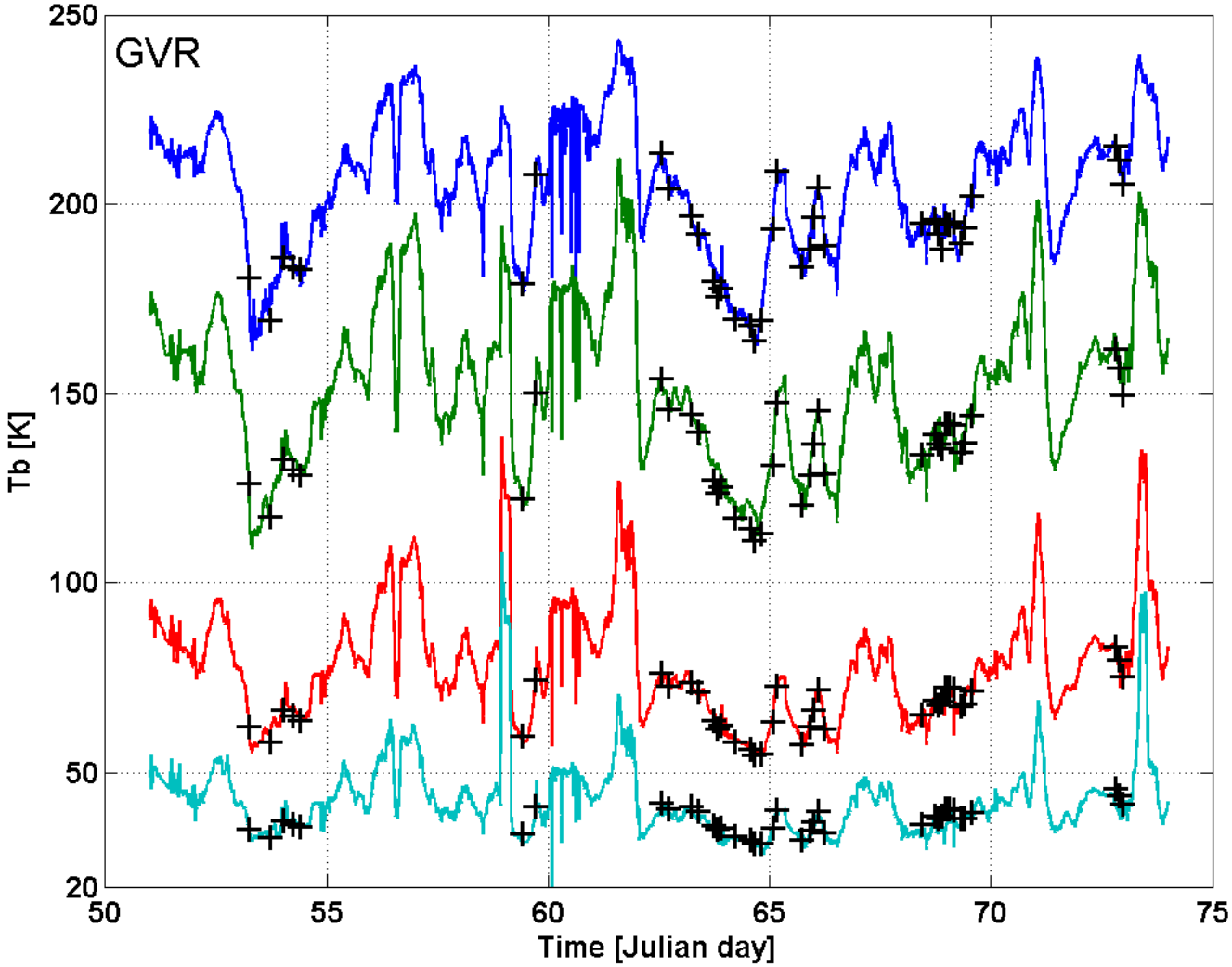
7) TAFTS 80-700 cm^{-1}

Cimini et al., submitted to IEEE TGRS, 2008.

Three Very Different Radiometers

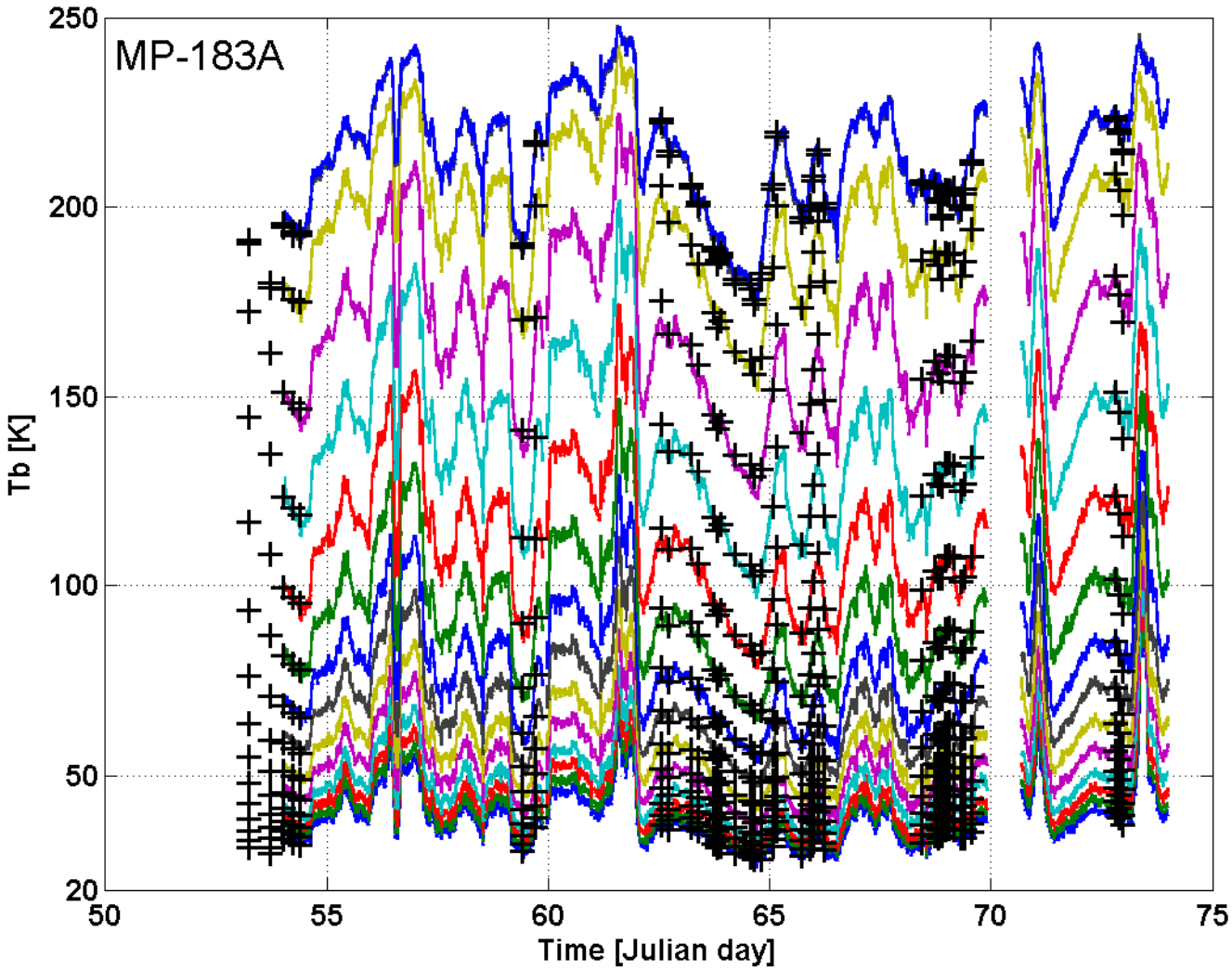
- GVR
  - ARM's operational G-band radiometer
  - 4 double-sideband channels at ±1, 3, 7, 14 GHz from line center
  - Calibrated with views of hot and ambient loads
- MP-183
  - Frequency tunable, single-sideband radiometer
  - 15 channels used in RHUBC-I, from 170-183.31 GHz
  - LN2 calibration
- GSR
  - 27 channel radiometer from CU
    - 7 double-sideband channels around 183 GHz at: ± 0.55, 1.0, 3.05, 4.7, 7, 12, and 16 GHz from line center
  - Calibration using hot and ambient BB views and tip curves for less opaque channels

GVR Tb time series



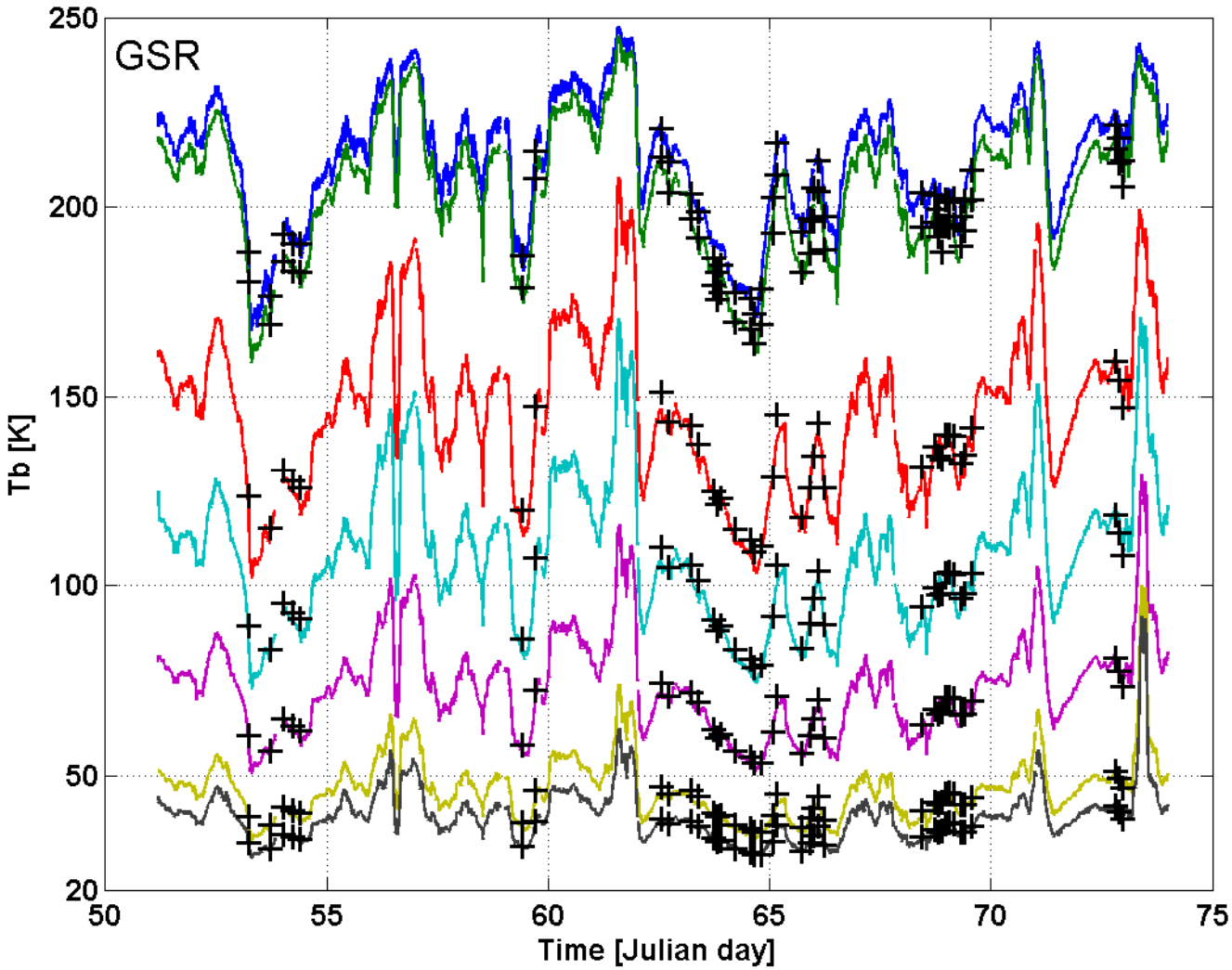
+ MonoRTM calculation

MP-183A Tb time series



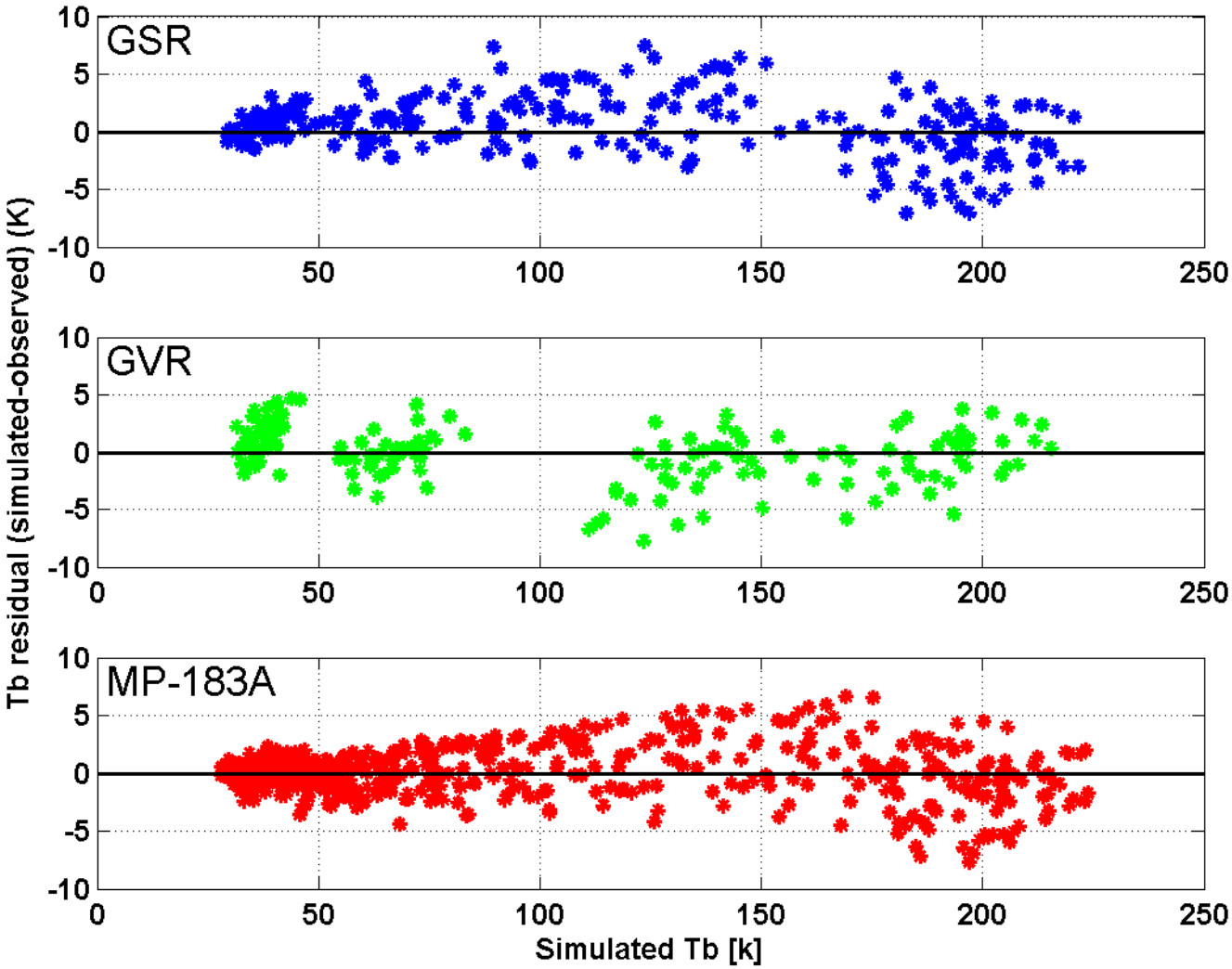
+ MonoRTM calculation

GSR Tb time series

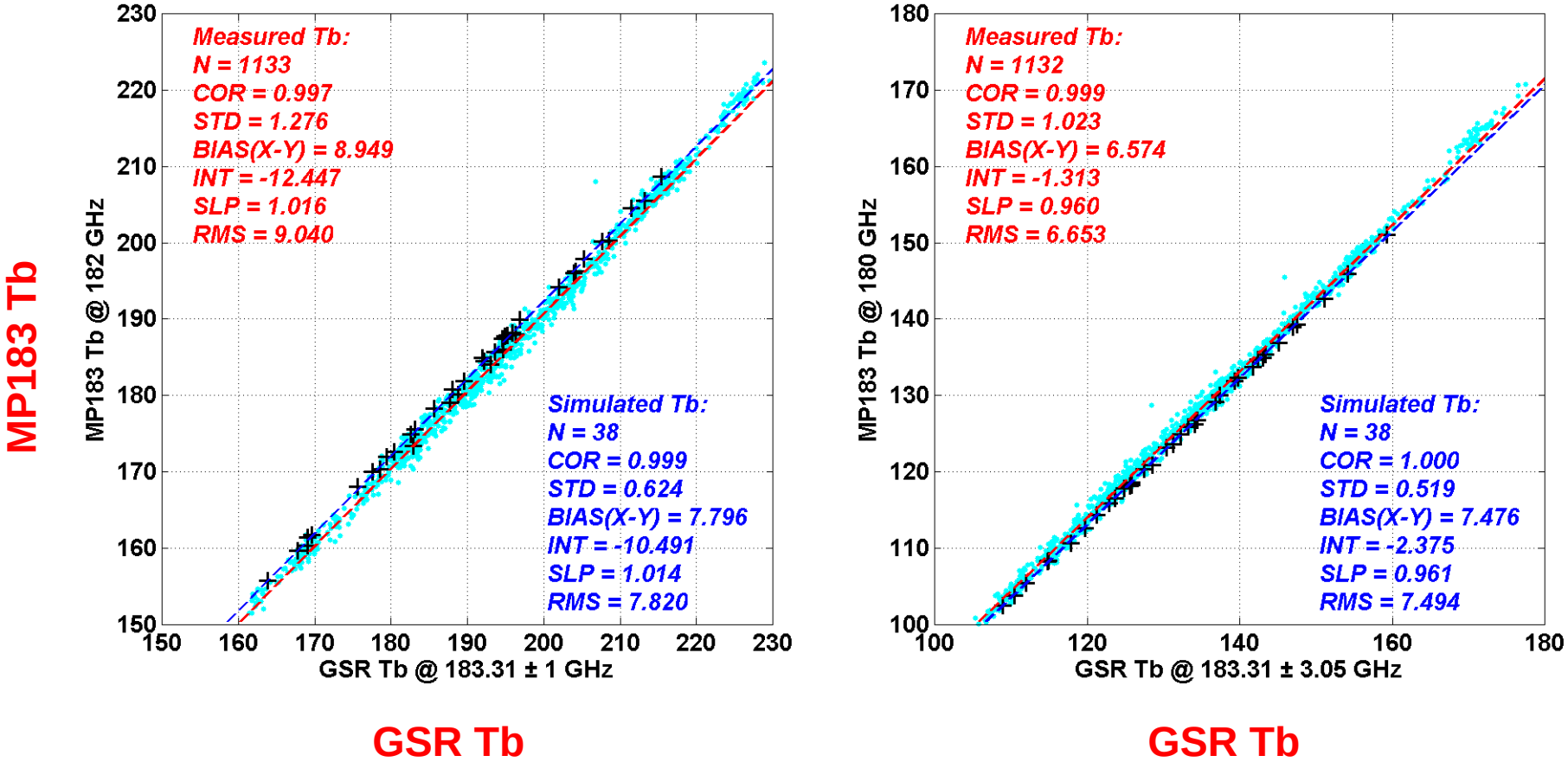


+ MonoRTM calculation

Tb residuals (calc - obs) wrt Tb



Cross-validation between GSR and MP-183A



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

Cimini et al., Comparison of ground-based millimeter-wave observations in the Arctic winter, submitted to IEEE TGRS, 2008.

Statistics of clear sky Tb residuals (simulated minus observed)

GSR

CHN (GHz)	BIAS (K)	STD (K)	RMS (K)	COR	P(1)	P(0) (K)
183.31 ± 0.55	-1.81	2.74	3.25	0.98	0.98	5.06
183.31 ± 1	-0.78	2.72	2.79	0.98	0.99	2.72
183.31 ± 3.05	2.49	2.78	3.70	0.98	1.00	-2.96
183.31 ± 4.7	1.76	2.40	2.95	0.97	1.02	-3.35
183.31 ± 7	0.68	1.63	1.75	0.97	0.97	1.30
183.31 ± 12	1.22	0.93	1.53	0.97	0.94	1.29
183.31 ± 16	0.05	0.74	0.73	0.97	0.93	2.27

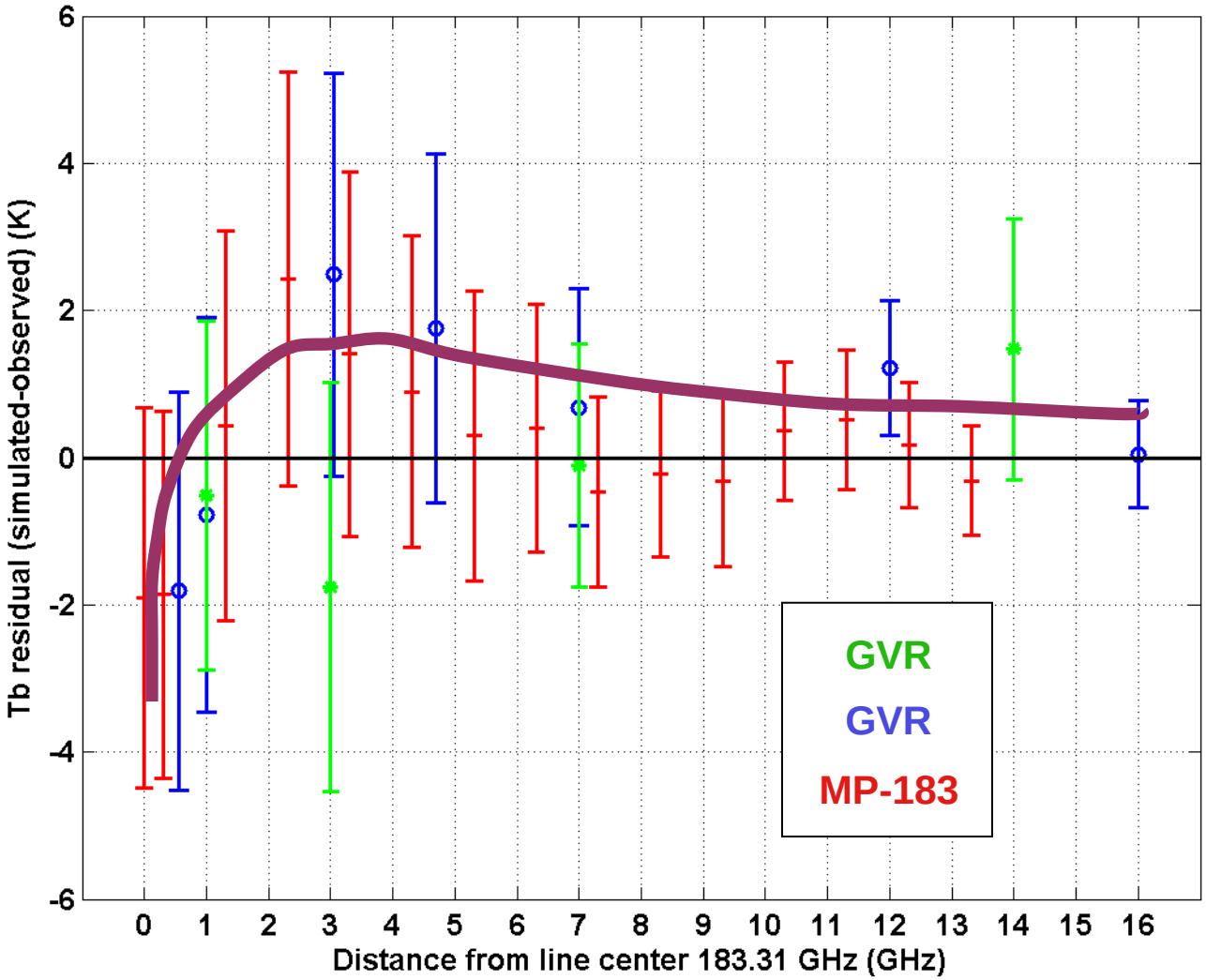
GVR

CHN (GHz)	BIAS (K)	STD (K)	RMS (K)	COR	P(1)	P(0) (K)
183.31 ± 1.0	-0.51	2.40	2.42	0.98	0.93	13.49
183.31 ± 3.0	-1.76	2.81	3.29	0.98	0.89	15.96
183.31 ± 7.0	-0.11	1.67	1.66	0.97	0.90	7.02
183.31 ± 14.0	1.47	1.79	2.30	0.86	0.74	8.34

MP-183

CHN (GHz)	BIAS (K)	STD (K)	RMS (K)	COR	P(1)	P(0) (K)
183.31	-1.91	2.61	3.21	0.98	0.95	12.73
183	-1.86	2.53	3.11	0.98	0.98	6.73
182	0.43	2.69	2.68	0.98	0.98	3.97
181	2.42	2.85	3.71	0.98	0.99	-0.60
180	1.41	2.51	2.85	0.98	0.96	6.74
179	0.90	2.15	2.30	0.98	1.01	-1.70
178	0.29	1.99	1.99	0.97	1.00	-0.61
177	0.40	1.70	1.73	0.97	0.99	0.02
176	-0.47	1.31	1.38	0.98	0.99	1.23
175	-0.50	1.98	2.01	0.94	1.00	0.41
174	-0.32	1.18	1.21	0.97	1.02	-0.83
173	0.36	0.95	1.00	0.98	1.03	-1.67
172	0.52	0.97	1.08	0.97	0.97	0.78
171	0.18	0.86	0.87	0.97	0.99	0.13
170	-0.31	0.75	0.81	0.97	1.00	0.37

Tb residuals (calc - obs) wrt frequency

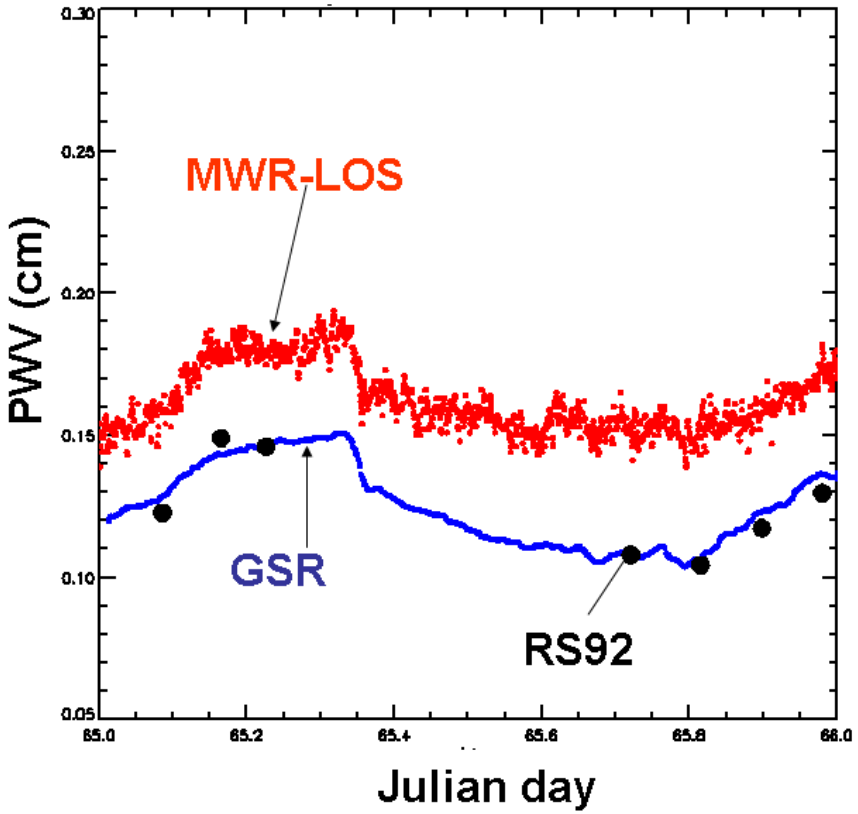


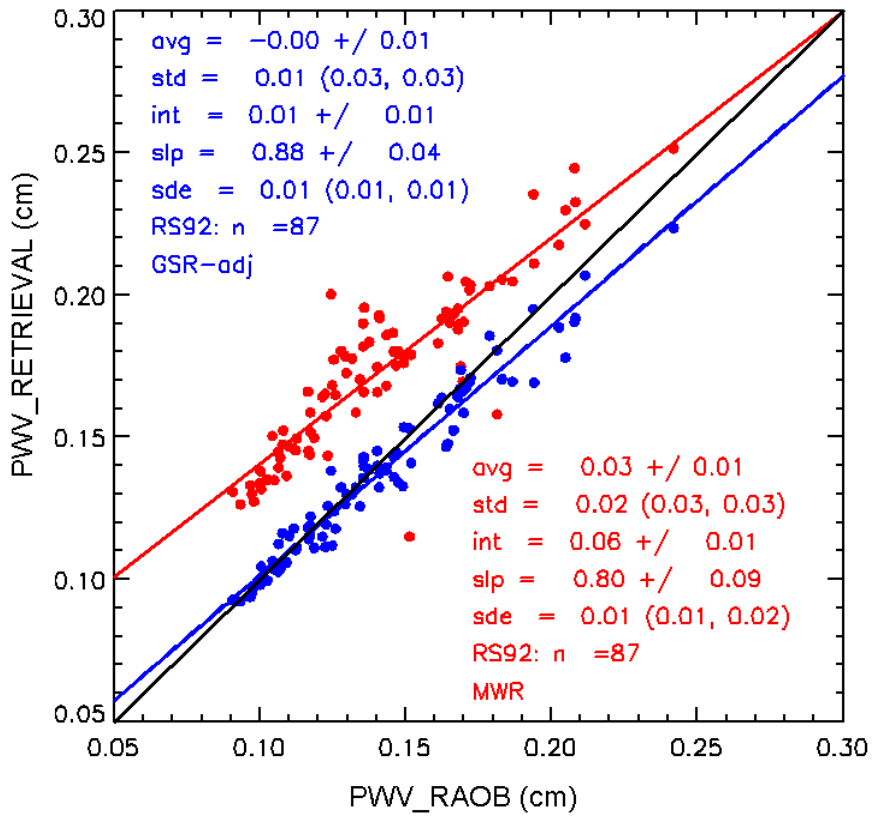
Simulations with realistic sensor humidity uncertainty affecting the sounding in an opposite way at lower and upper levels (**5% drier/wetter above/below a reference level arbitrarily fixed to 3km**)

Summary

- 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
  - Anecdotal support: Miloshevich, Vömel, et al. are about to submit a paper that shows similar height-dependent bias in RS92 using a variety of techniques

PWV estimated from GSR data (piecewise linear method)





“the GSR provided unprecedented accuracy in PWV retrievals of 0.1 mm rms (6.2 %)”

Westwater E. R., D. Cimini, et al., “Deployments of Microwave and Millimeter-wave Radiometers in the Arctic”, Proceedings of Microrad 2008.

Statistics of clear sky Tb residuals between independent channel pairs
bold: observed (sample>1000) plain: modeled (sample=38)

CHN PAIR (GHz)	BIAS (K)	STD (K)	RMS (K)	COR	P(1)	P(0) (K)
GVR 183±1	**0.09**	**2.02**	**2.02**	**0.99**	**0.92**	**15.42**
GSR 183±1	-0.22	0.08	0.23	1.00	1.00	0.22
MP-183A 182	**8.95**	**1.28**	**9.04**	**1.00**	**1.02**	**-12.45**
GSR 183±1	7.80	0.62	7.82	1.00	1.01	-10.49
GVR 183±3	**-6.30**	**2.17**	**6.67**	**0.99**	**0.93**	**15.17**
GSR 183±3	-2.44	0.14	2.44	1.00	1.00	1.65
MP-183A 180	**6.56**	**1.02**	**6.65**	**1.00**	**0.96**	**-1.31**
GSR 183±3	7.48	0.52	7.49	1.00	0.96	-2.37
GVR 183±7	**-3.02**	**1.98**	**3.61**	**0.98**	**0.99**	**3.80**
GSR 183±7	-1.76	0.19	1.77	1.00	1.03	-0.05
MP-183A 176	**5.14**	**1.49**	**5.35**	**0.99**	**0.93**	**-0.46**
GSR 183±7	6.26	0.69	6.30	1.00	0.90	0.41
GVR 183±14	**-1.80**	**1.85**	**2.58**	**0.92**	**0.99**	**2.26**
GSR 183±16	-2.81	0.36	2.83	1.00	1.11	-1.07
MP-183A 170	**1.02**	**0.80**	**1.30**	**0.98**	**1.04**	**-2.43**
GSR 183±16	1.44	0.11	1.45	1.00	0.96	-0.24
MP-183A 182	**8.67**	**2.47**	**9.01**	**0.99**	**1.07**	**-23.33**
GVR 183±1	8.01	0.70	8.04	1.00	1.01	-10.66
MP-183A 180	**12.91**	**2.05**	**13.08**	**0.99**	**1.02**	**-15.30**
GVR 183±3	9.91	0.64	9.93	1.00	0.95	-3.92
MP-183A 176	**7.93**	**1.86**	**8.14**	**0.98**	**0.89**	**-0.50**
GVR 183±7	8.02	0.88	8.07	1.00	0.87	0.45
MP-183A 170	**2.51**	**1.63**	**2.99**	**0.93**	**0.87**	**2.55**
GVR 183±14	4.25	0.47	4.28	1.00	0.87	0.70