Estimations of vertically averaged cloud water temperature using HSB data: simulated results

Bing Lin, Patrick Minnis, Yongxiang Hu, and Bruce Wielicki

NASA Langley Research Center

Hampton, VA 23681

CERES Science Team Meeting

Williamsburg, Virginia

January 24, 2001

Background

- Cloud vertical structure (e.g. top & bottom temperature) has important effects on surface longwave radiation.
- Recent studies show that high frequency microwave measurements have sufficient sensitivity on cloud water temperature.
- Humidity Sounder for Brazil (HSB) on Aqua will provide good opportunity to observe these properties globally.
- HSB channels: 150, 183±1,183±3, & 183±7 GHz.

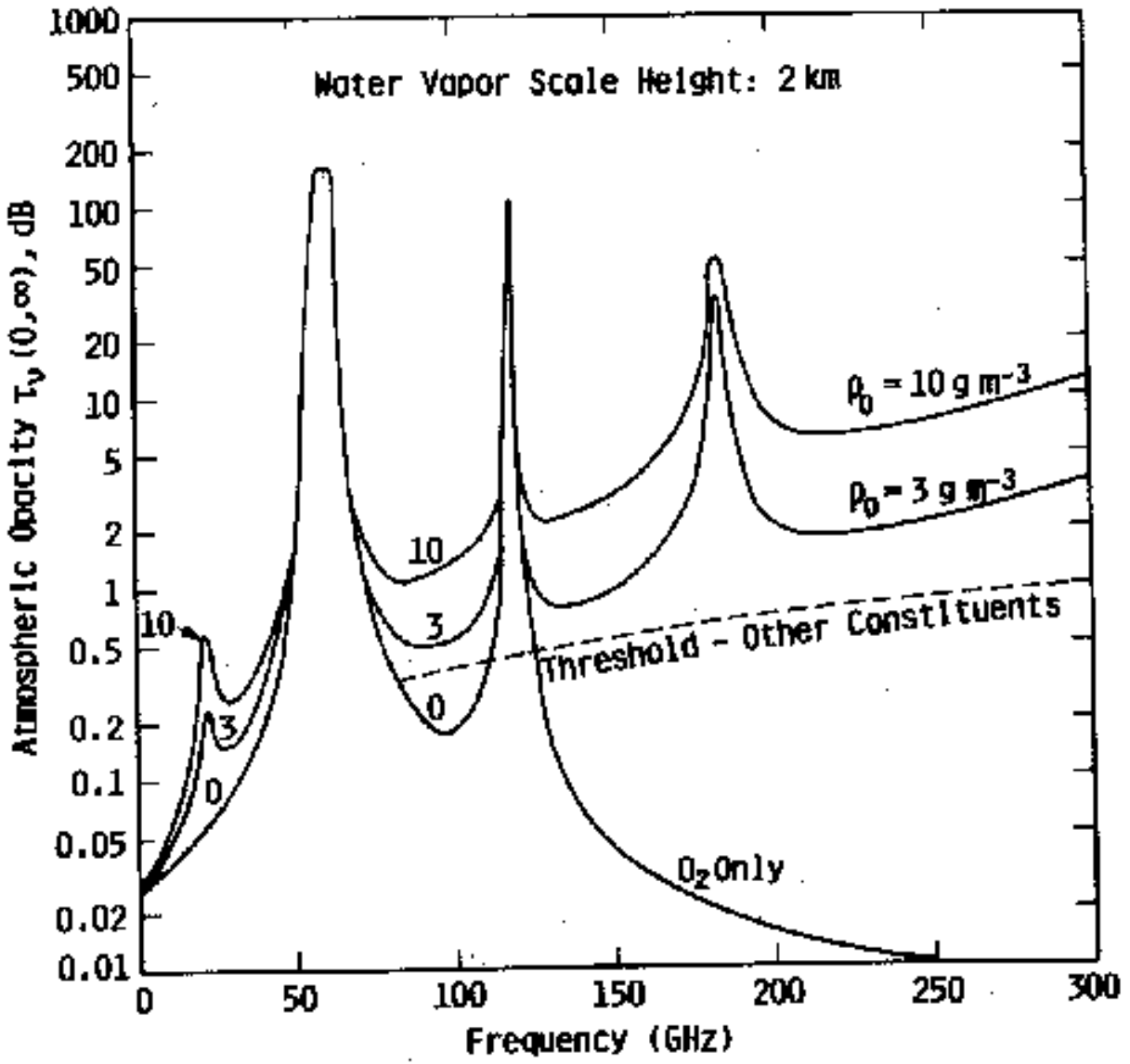
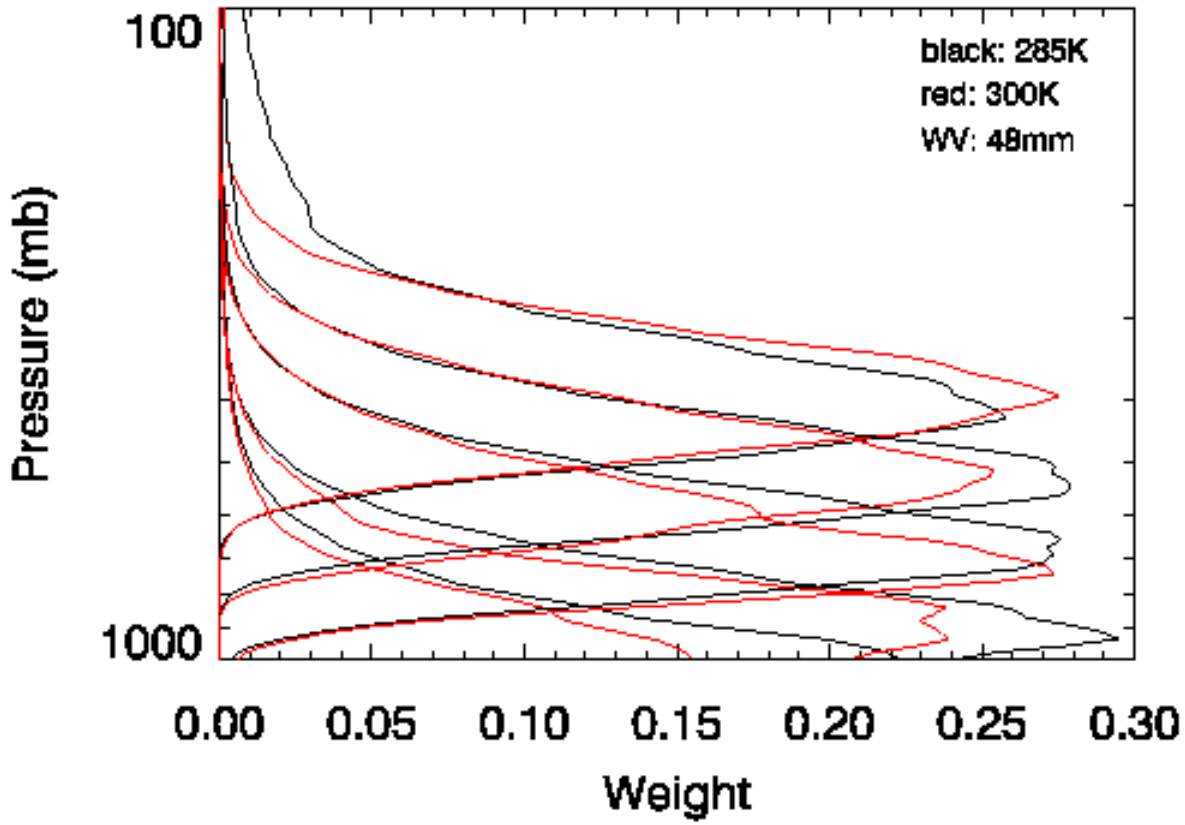
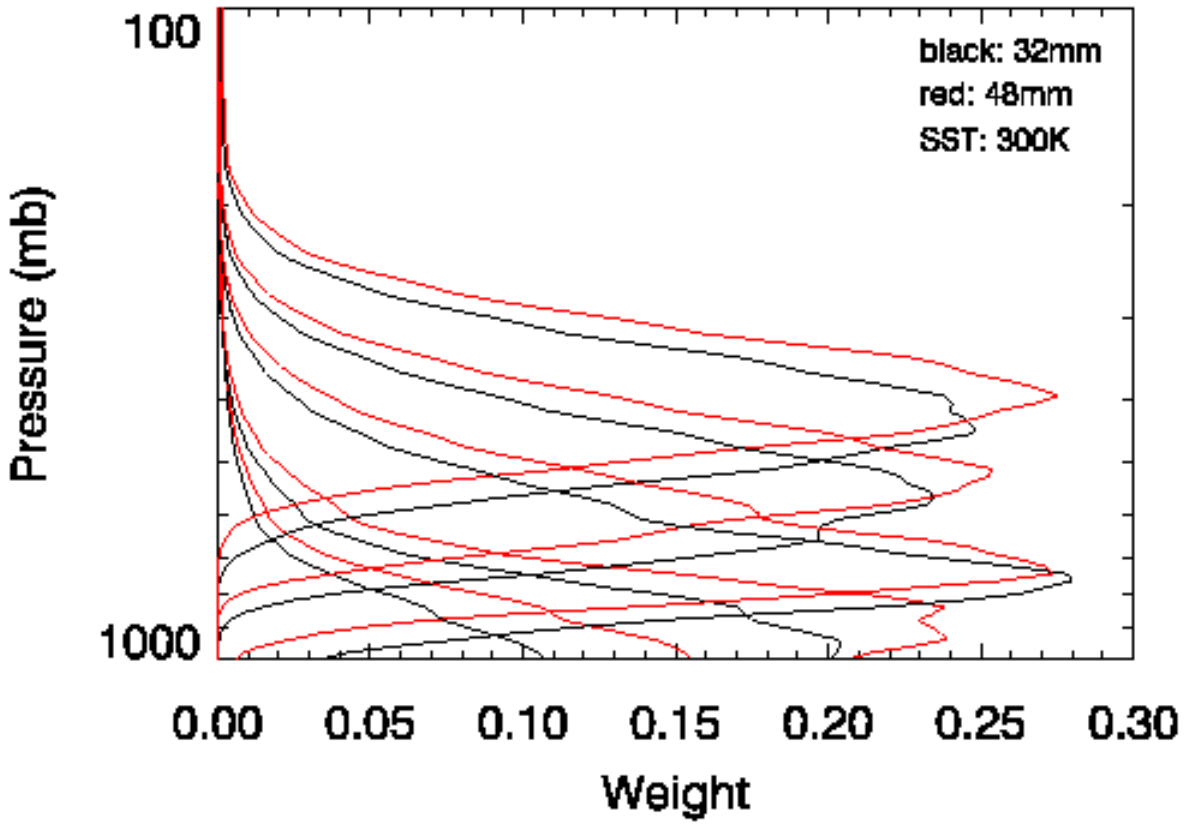


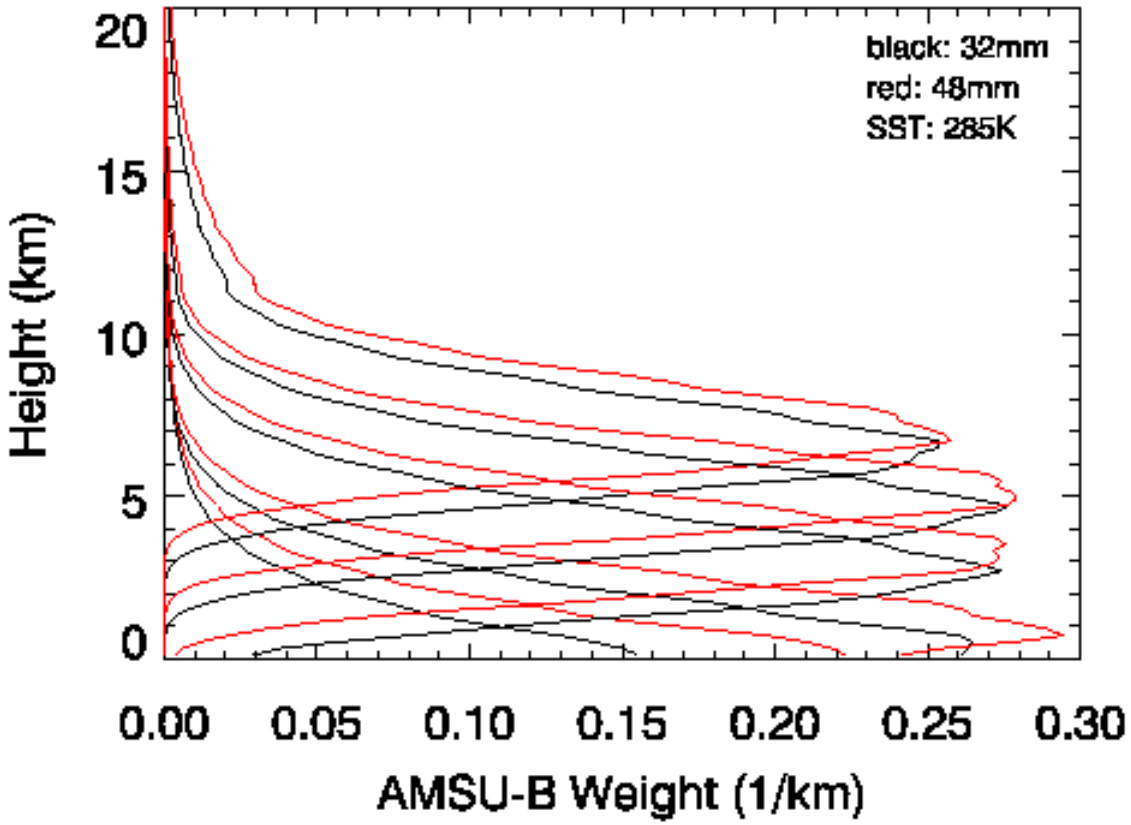
Fig. 17.8 Zenith opacity of the US Standard Atmosphere (1976 model) for surface temperature $T_0 = 288$ K and surface pressure $P_0 = 1020.5$ mbar for the moist atmosphere ($\rho_0 = 3$ and 10 g m^{-3}) and 1013 mbar for the O_2 atmosphere (from Smith, 1982).

Combined Data

- Aqua (PM orbit): HSB + MODIS (+ AMSR)
- HSB Cross-track scan (±50°, total 90 pixels).
- FOV: 1.1º (16.3 ~ 25.4 km)
- Column water vapor
- IR: cloud top temperature Tc, cloud cover
- VIS: cloud cover, optical depth
- AMSR: cloud liquid water amount, SST, wind speed


100
1000
Pressure (mb)
black: 285K
red: 300K
WV: 48mm
0.00
0.05
0.10
0.15
0.20
0.25
0.30
Weight


100
1000
Pressure (mb)
black: 32mm
red: 48mm
SST: 300K
0.00
0.05
0.10
0.15
0.20
0.25
0.30
Weight

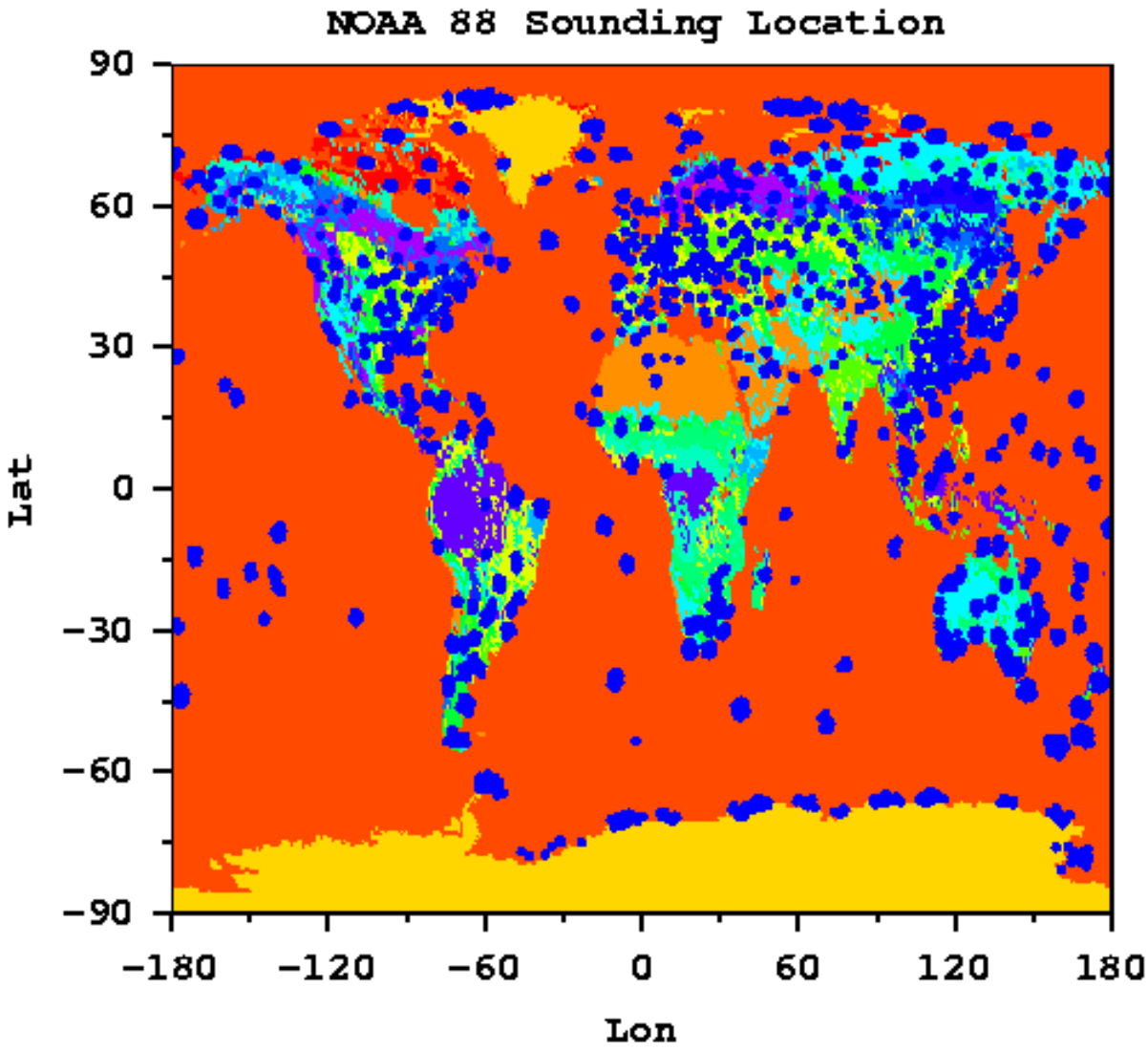

black: 32mm
red: 48mm
SST: 285K
Height (km)
20
15
10
5
0
0.00
0.05
0.10
0.15
0.20
0.25
0.30
AMSU-B Weight (1/km)

Atmospheric Profile for Simulation

- McClatchey et al. (1972): Tropical, midlatitude summer, US standard and midlatitude winter.
- NOAA 1988 radiosonde measurements :

  clear & cloudy conditions
- Cloud water amount:

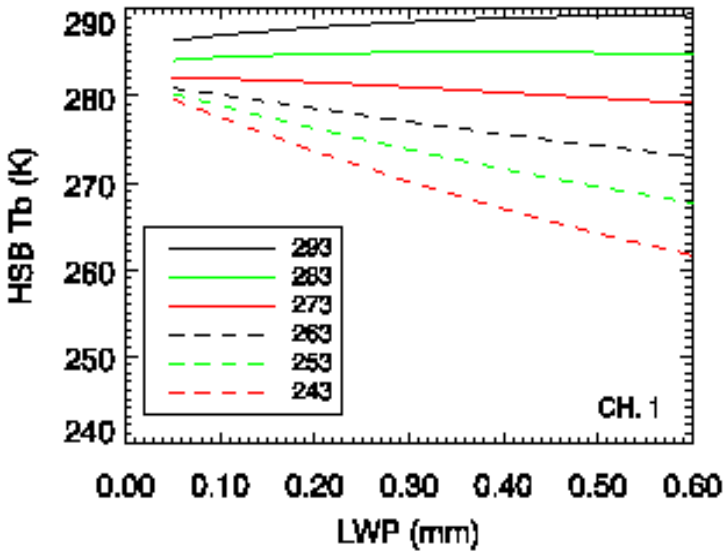
  Minnis et al. (1995) and random values
- Random sea surface wind speed

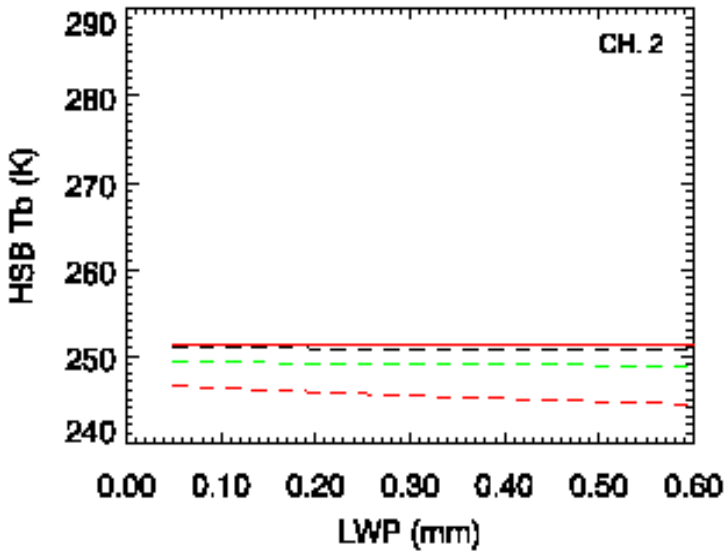

NOAA 88 Sounding Location
90
60
30
0
-30
-60
-90
Lat
-180
-120
-60
0
60
120
180
Lon

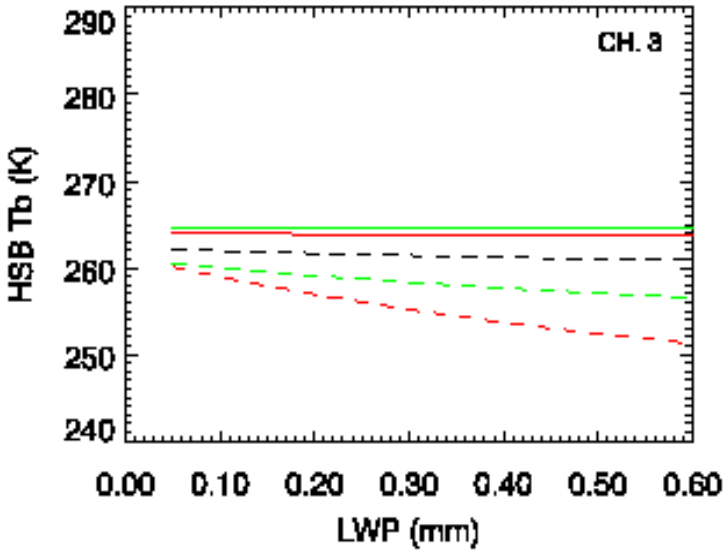
Radiative Transfer Model

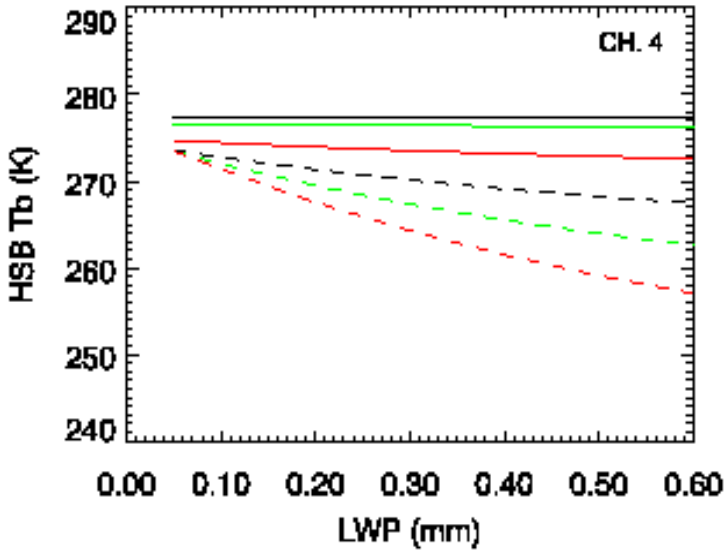
- Two stream absorption and emission based microwave radiative transfer model [Lin et al. 1998].
- Water absorption coefficients: Mie calculations using water refractive index of Ray [1972].
- Surface emissivity: SST, WS, salinity and whitecap

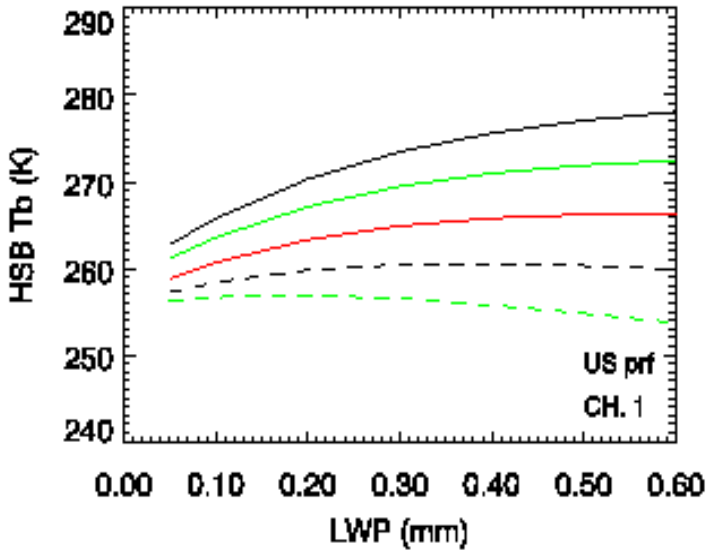
  Cox & Munk slope statistics
- Water vapor absorption coefficients: Liebe [1989] (MPM89), line-by-line calculation

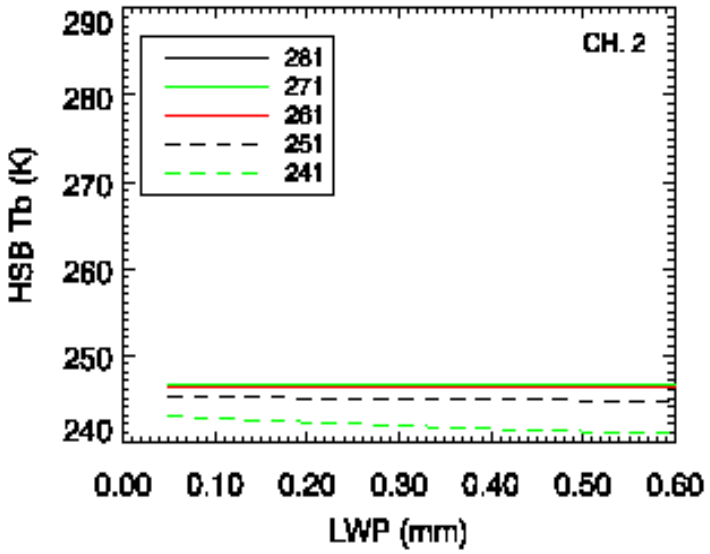

HSB Tb (K)
290
280
270
260
250
240
293
283
273
263
253
243
CH. 1
0.00 0.10 0.20 0.30 0.40 0.50 0.60
LWP (mm)

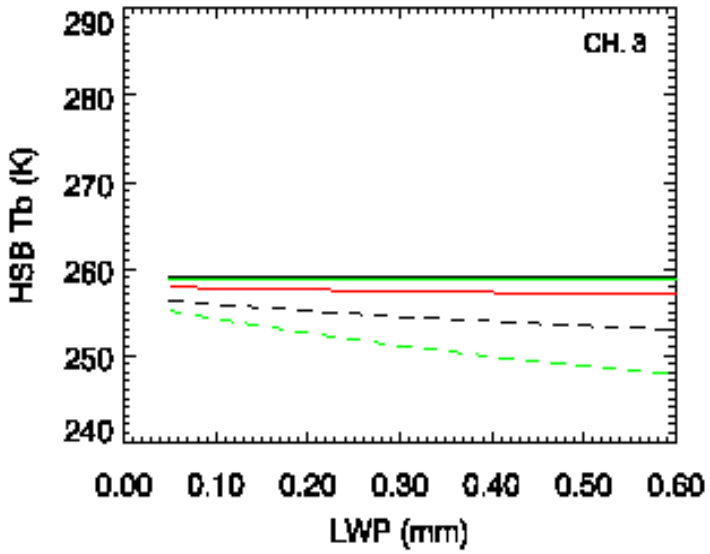

HSB Tb (K)
290
280
270
260
250
240
CH. 2
0.00 0.10 0.20 0.30 0.40 0.50 0.60
LWP (mm)

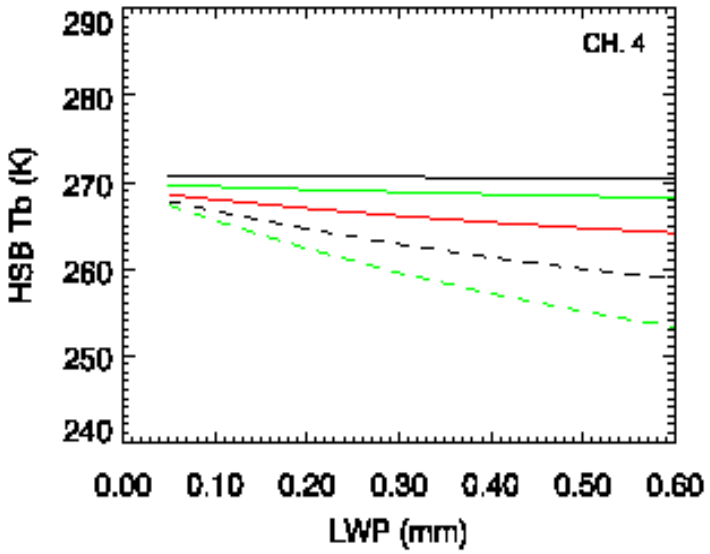

HSB Tb (K)
290
280
270
260
250
240
CH. 3
0.00 0.10 0.20 0.30 0.40 0.50 0.60
LWP (mm)


HSB Tb (K)
290
280
270
260
250
240
CH. 4
0.00 0.10 0.20 0.30 0.40 0.50 0.60
LWP (mm)

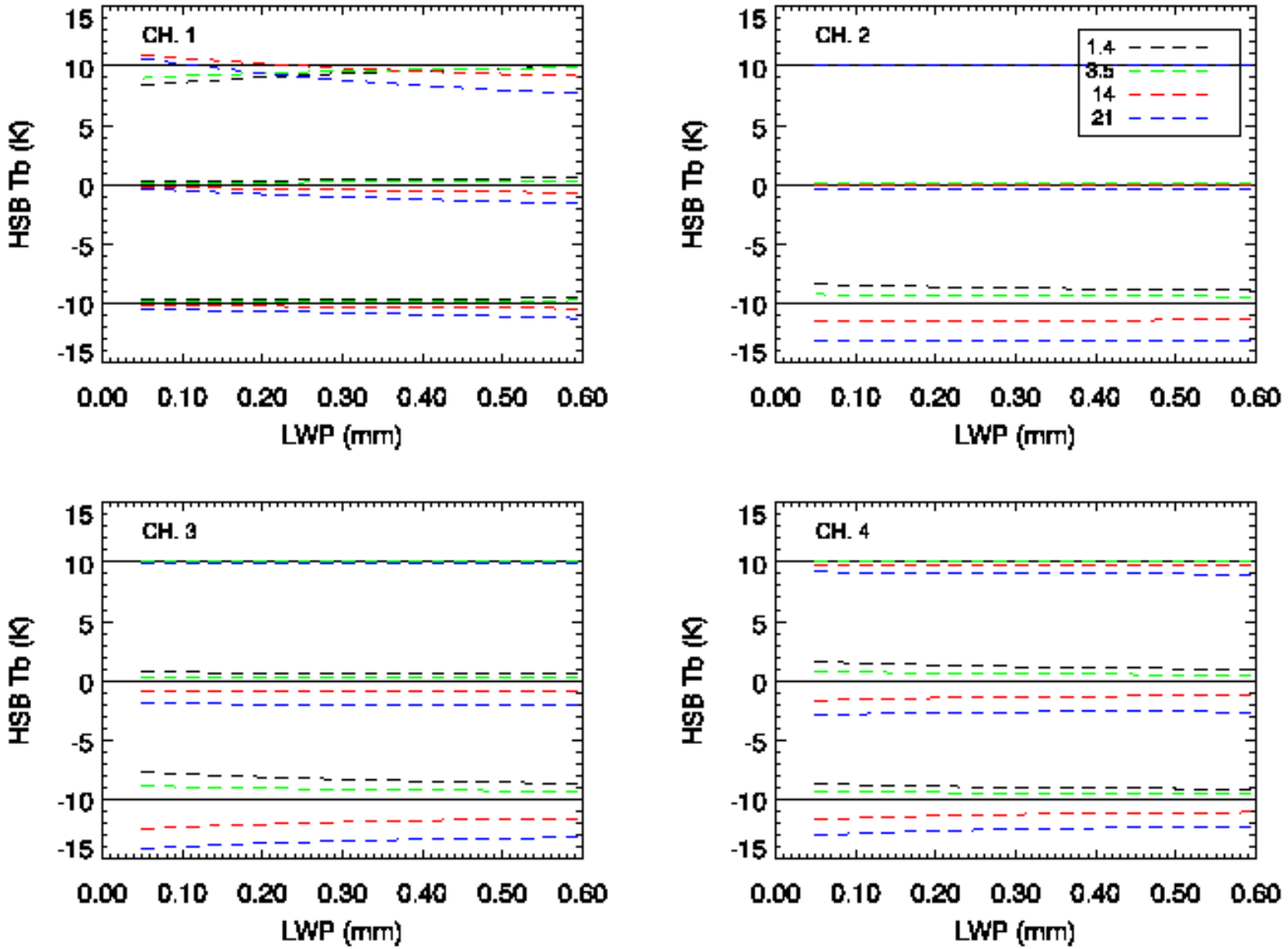

HSB Tb (K)
290
280
270
260
250
240
0.00
0.10
0.20
0.30
0.40
0.50
0.60
LWP (mm)
US prf
CH. 1


HSB Tb (K)
290
280
270
260
250
240
0.00
0.10
0.20
0.30
0.40
0.50
0.60
LWP (mm)
CH. 2
281
271
261
251
241

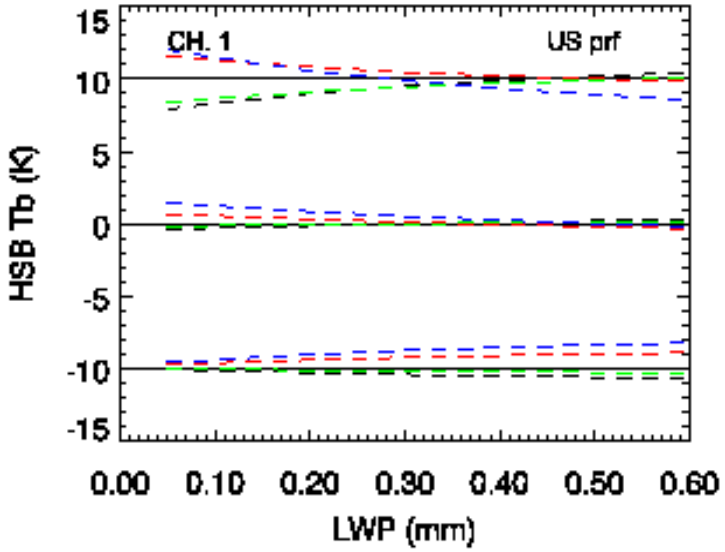

HSB Tb (K)
290
280
270
260
250
240
0.00
0.10
0.20
0.30
0.40
0.50
0.60
LWP (mm)
CH. 3

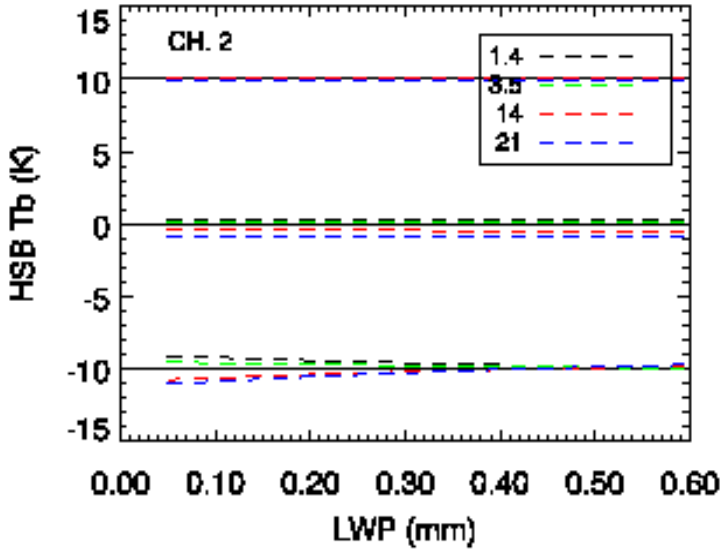

HSB Tb (K)
290
280
270
260
250
240
0.00
0.10
0.20
0.30
0.40
0.50
0.60
LWP (mm)
CH. 4

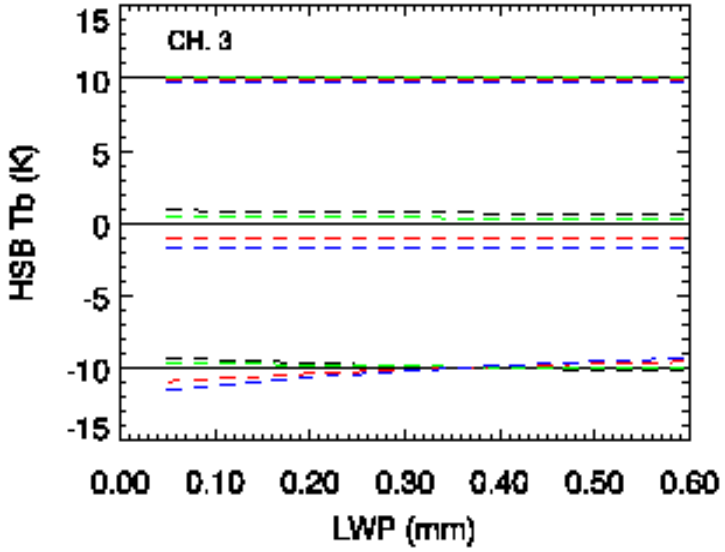
Thickness tests: Hc=1, 4, 7km

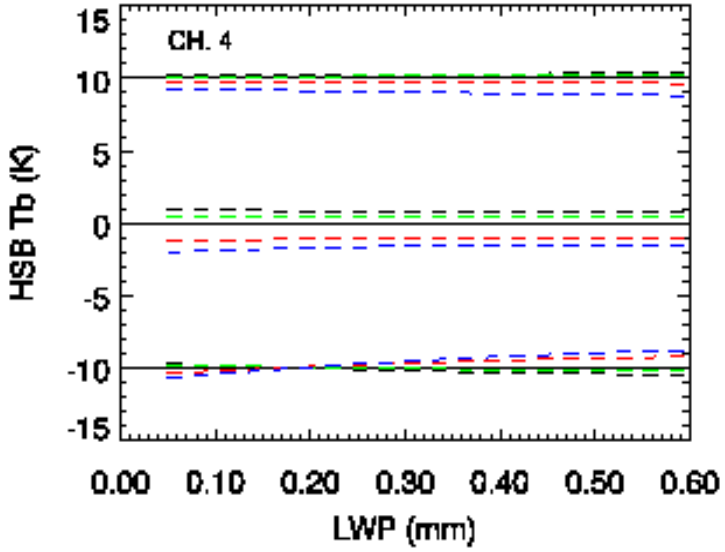


Thickness tests: Hc=1 ,4, 7km



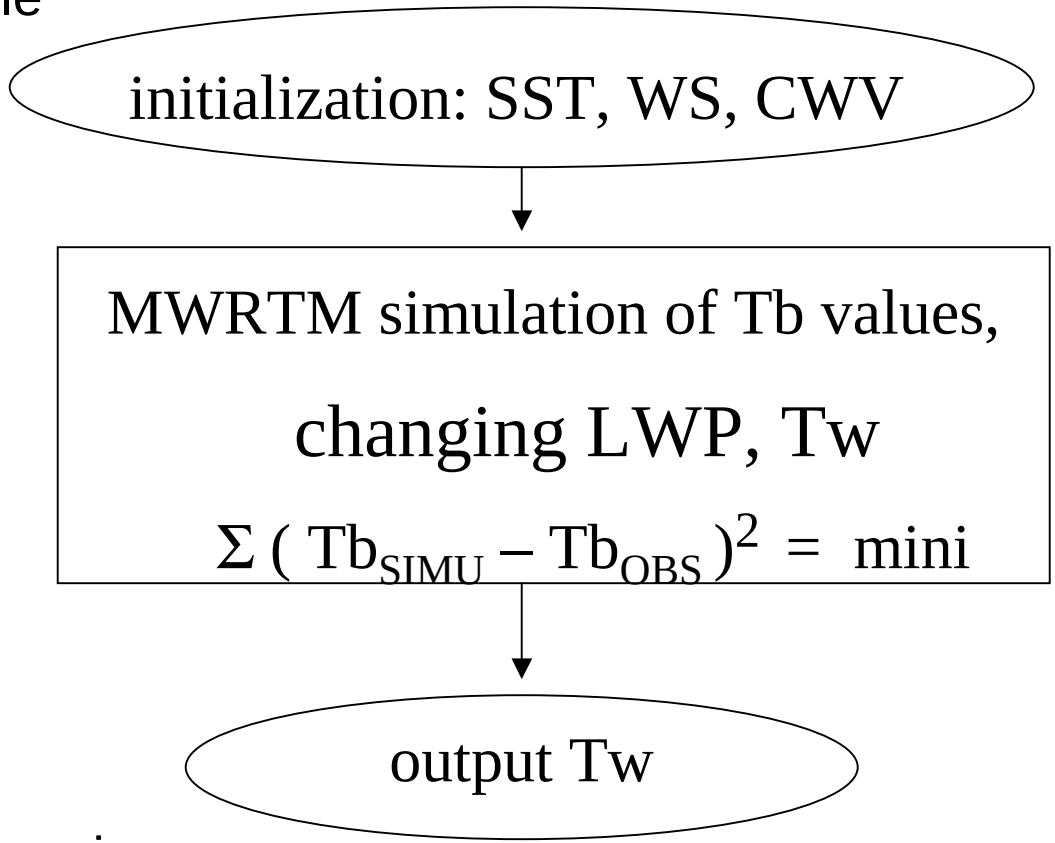




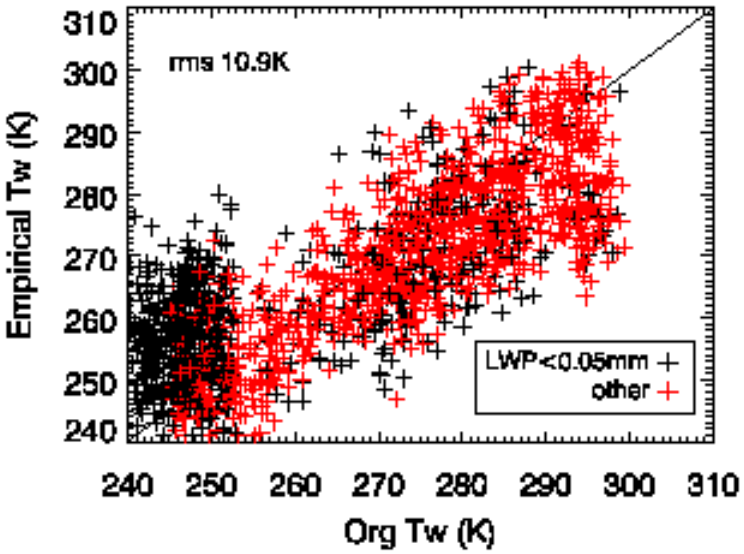


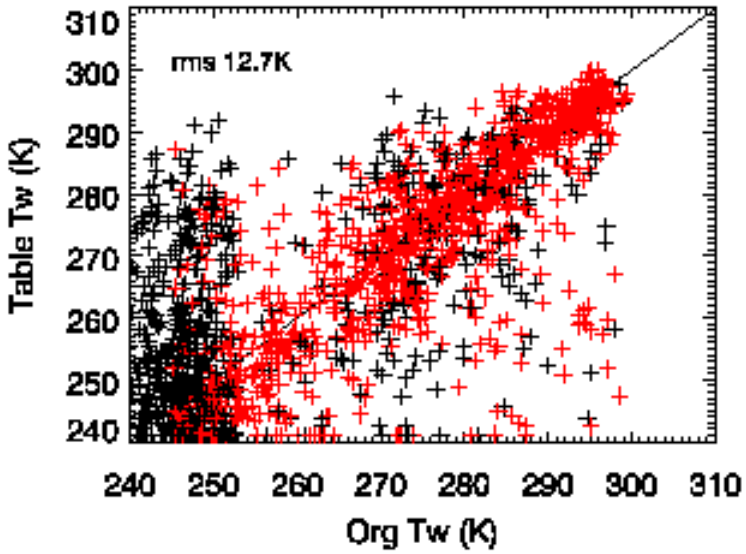
Retrieval Scheme

1.Lookup table

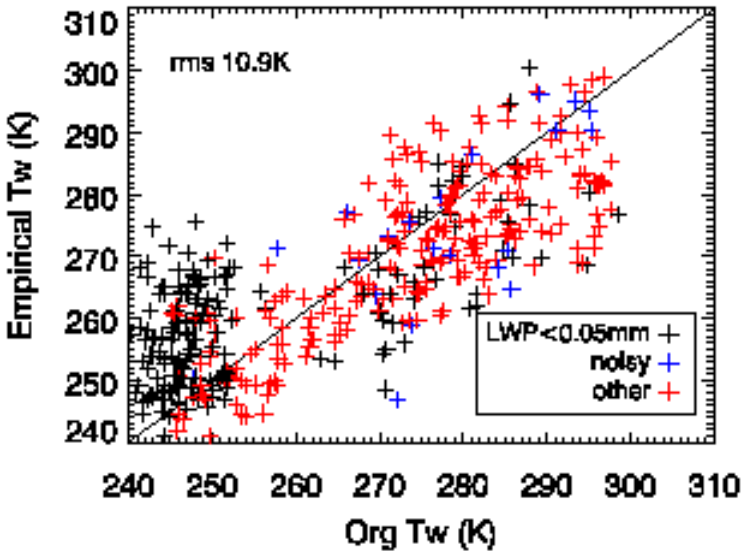


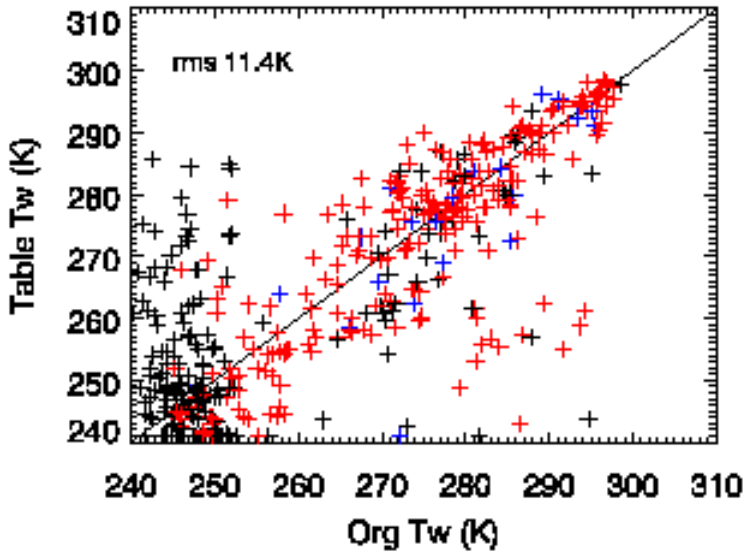
2. Linear regression


rms 10.9K
LWP<0.05mm
other
Empirical Tw (K)
Org Tw (K)
240
250
260
270
280
290
300
310

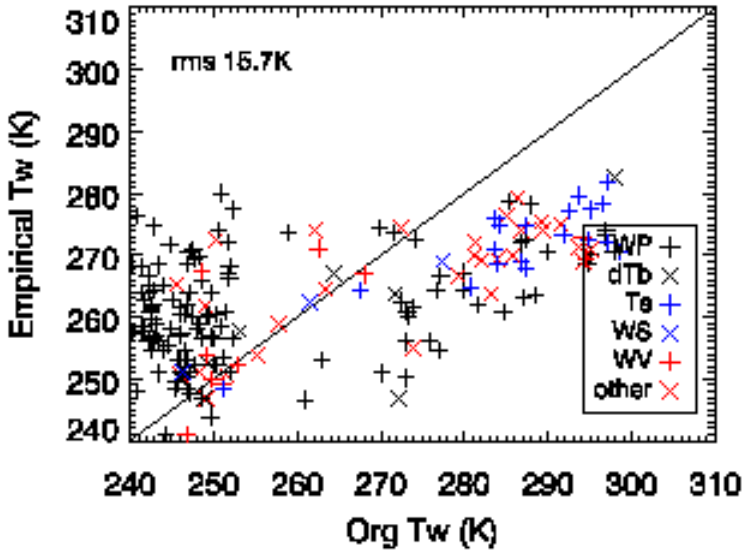

rms 12.7K
Table Tw (K)
Org Tw (K)
240
250
260
270
280
290
300
310

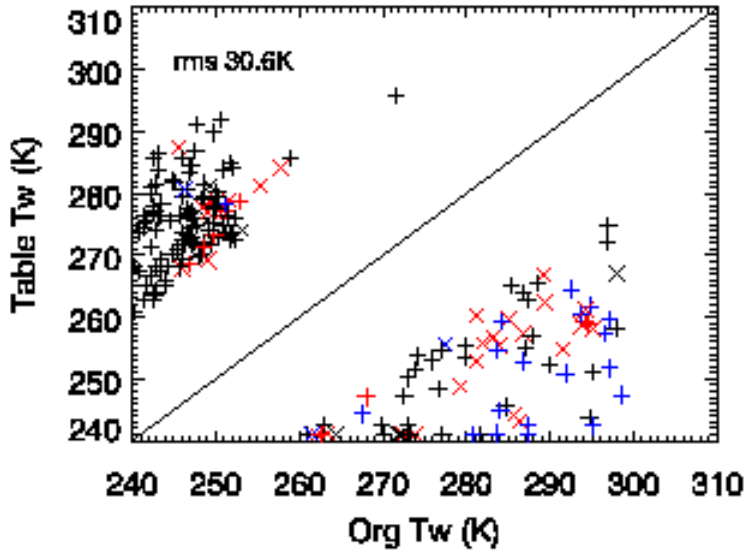
noises in parameters < 1σ



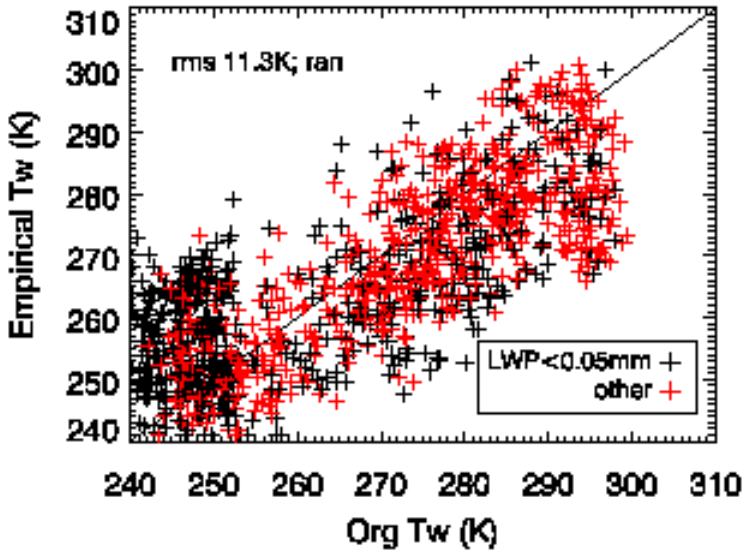


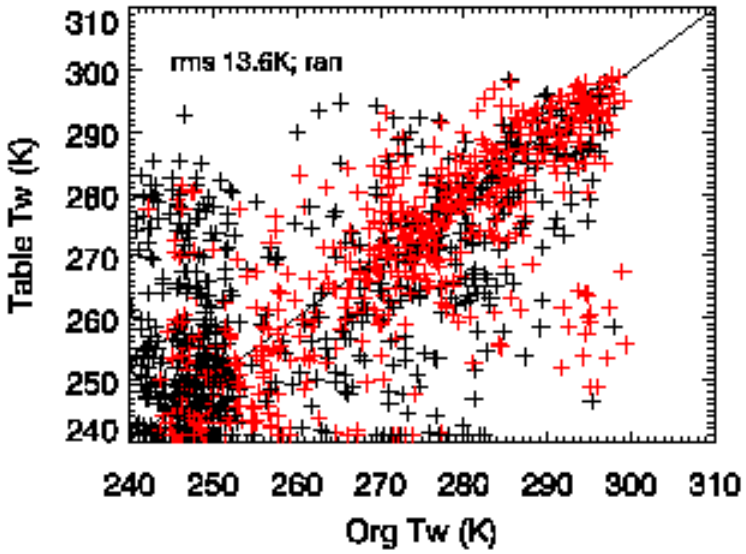
‘bad’ data


rms 15.7K
Empirical Tw (K)
Org Tw (K)
WP
dTb
Ts
WS
WV
other
240
250
260
270
280
290
300
310

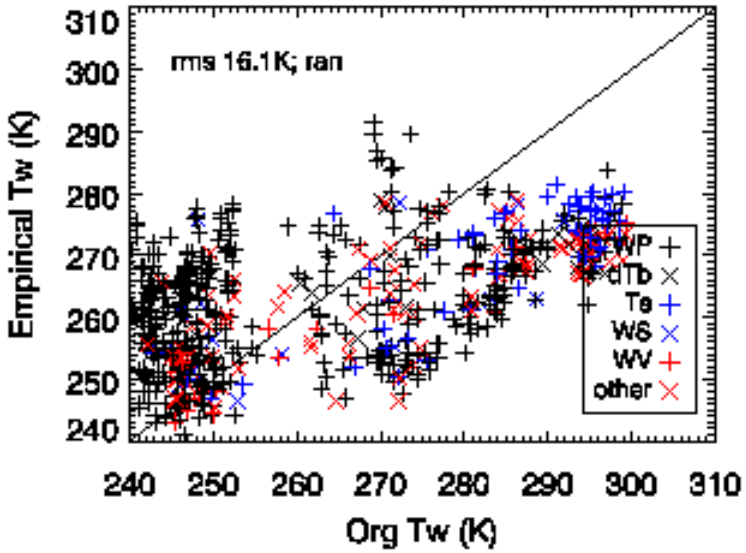

rms 30.6K
Table Tw (K)
Org Tw (K)
240
250
260
270
280
290
300
310

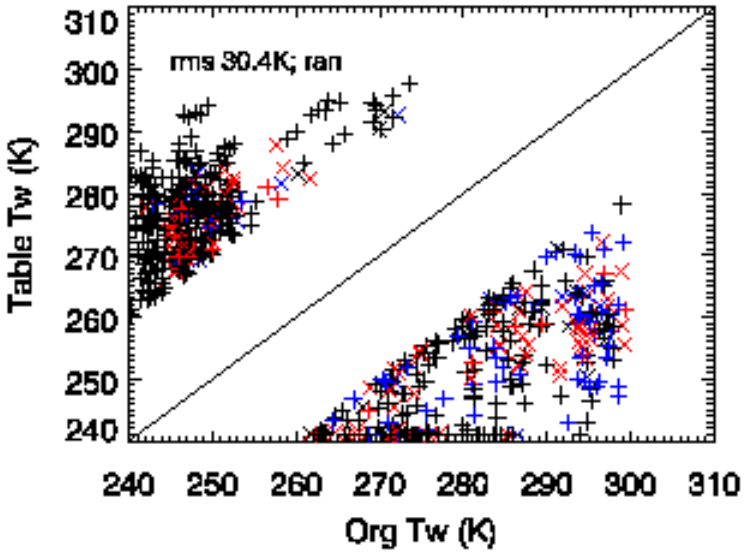
Random LWP simulation





Random LWP simulation





Conclusions

- The HSB Tb values are considerably affected by both LWP and cloud water temperature. From low to high moderate thick (0.1mm) clouds in US standard profile, the Tb changes are about 5 and 10K at 150 and 183±3 GHz, respectively. For thick clouds (0.5mm), these values increase to ~ 10 and 20K, respectively.
- For the clouds with the same averaged cloud water temperature, the Tb differences are generally small (within ~2K) if cloud physical thickness is less than 3km.

Conclusions (cont')

- The RMS errors in cloud vertically averaged temperature are about 9~ 13K for the simulated NOAA 1988 data set.
- Retrievals using 2-channel lookup table have about the same accuracy as those from empirical method.
- Combined with IR cloud top measurements, cloud base temperature may be estimated with RMS errors about the same as the mean water temperature.
- More study on physical retrieval is needed.