Estimations of column cloud water amount over Arctic regions using ground-based thermal microwave and infrared measurements

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Background

- Recent studies show that polar regions have high sensitivity (or strong feedbacks) on climate change.
- Stratus clouds are important component for Arctic energetic systems.
- SHABA/ARM/FIRE-ACE experiment provided good opportunity to exam ground LWP estimates.
- The comparison between in situ aircraft and MWR measurements showed that ARM standard retrievals are too large by about factor of 2 for thin to moderate clouds.

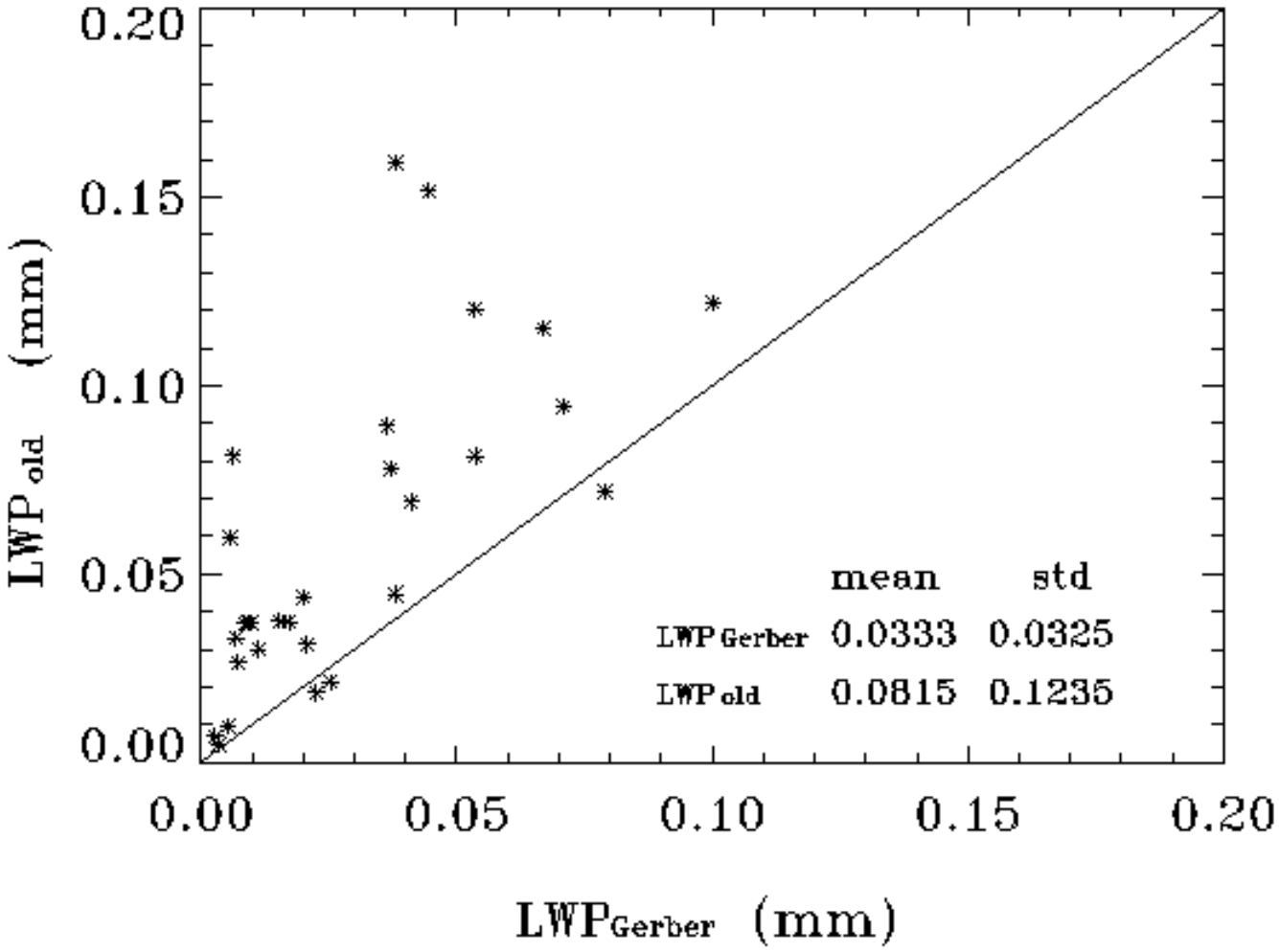
Data Sets

- FIRE ACE period: May ~ July 1998
- SHEBA towers reports: Ta, P, r.h.
- Lidar: cloud height Hc.
- Infrared thermometer (IRT): cloud temperature Tc
- MWR: 23.8 & 31.4 GHz for LWP & CWV retrievals
- In situ LWP measurements: aircrafts C-130 and CV-580

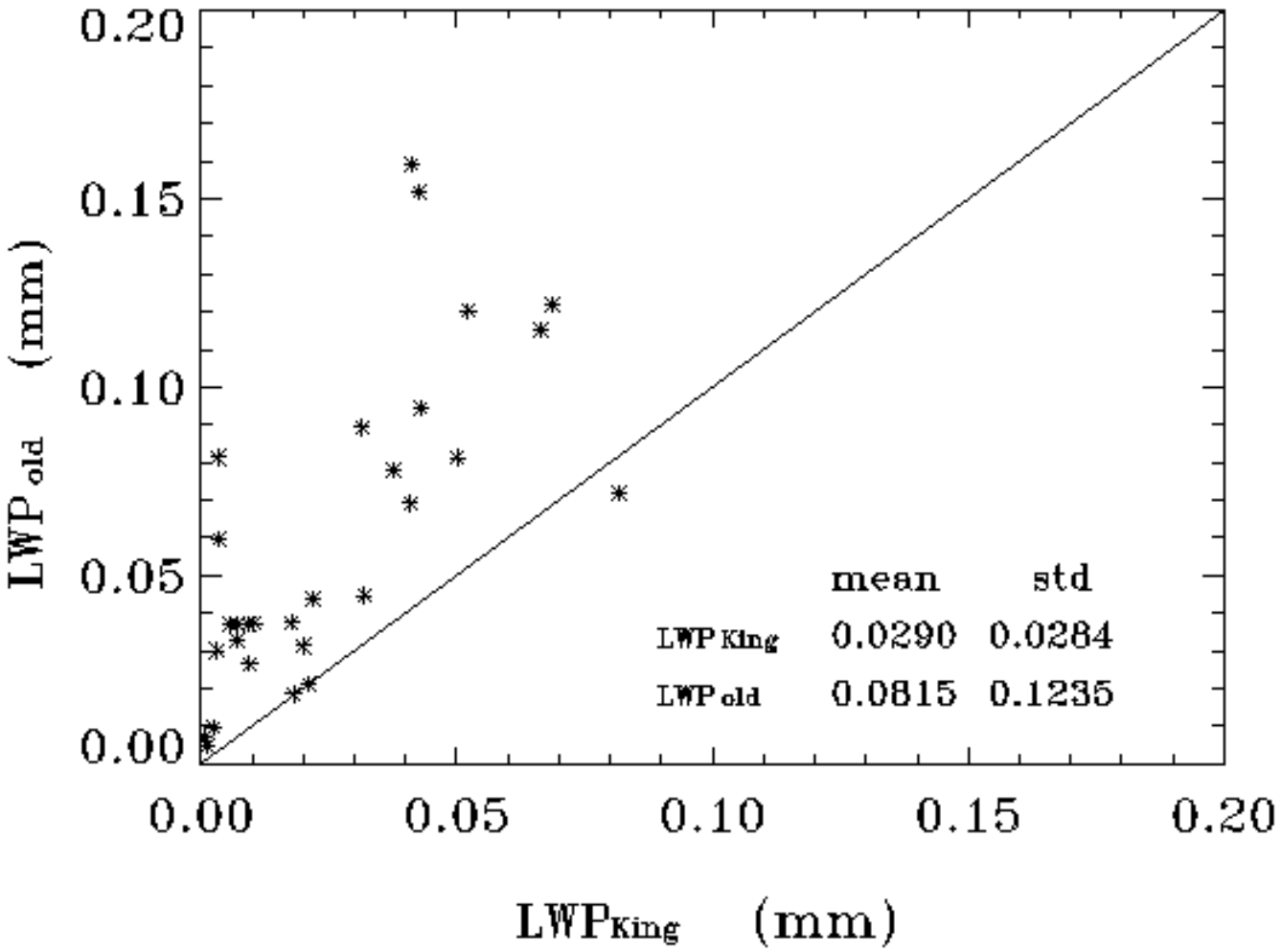
  Gerber PVM-100A & King Hot-Wire Probe
- Total 38 matched cases:

  extreme large LWP (>0.5mm): 4 cases

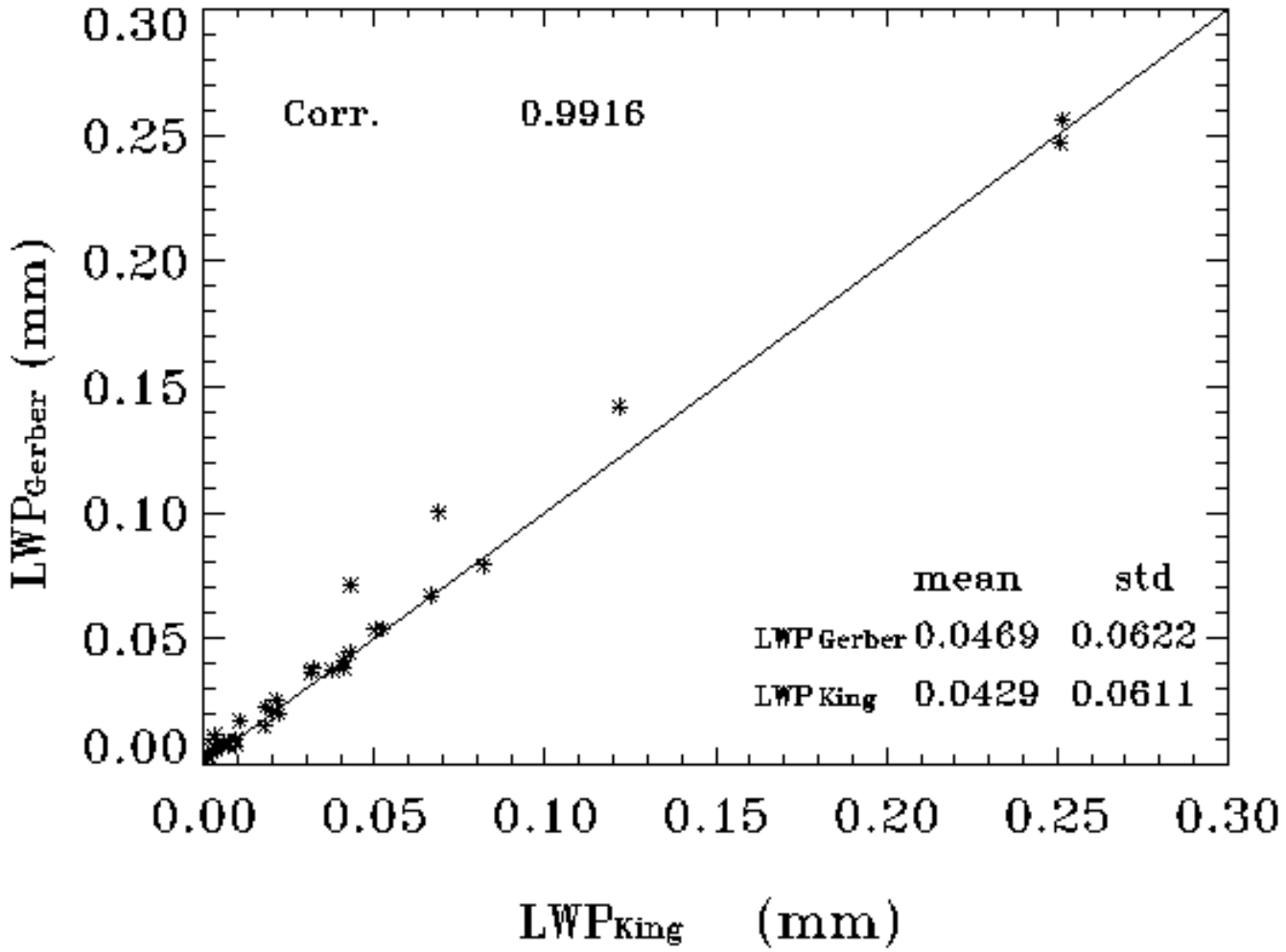
SHEBA/FIRE


0.20
0.15
0.10
0.05
0.00
LWP old (mm)
0.00
0.05
0.10
0.15
0.20
LWP Gerber (mm)
mean std
LWP Gerber 0.0333 0.0325
LWP old 0.0815 0.1235

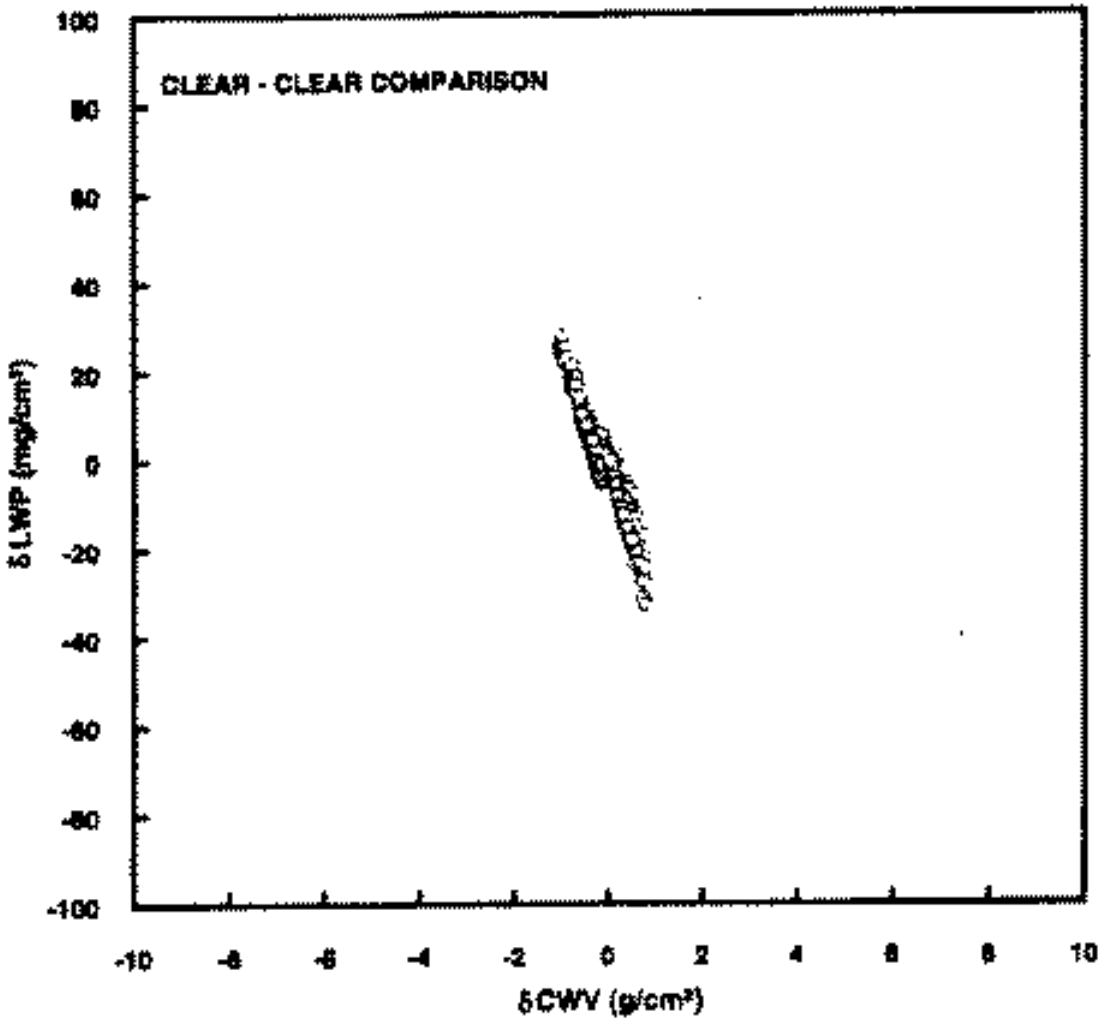
SHEBA/FIRE


0.20
0.15
0.10
0.05
0.00
0.00
0.05
0.10
0.15
0.20
LWP old (mm)
LWP King (mm)
mean std
LWP King 0.0290 0.0284
LWP old 0.0815 0.1235

SHEBA/FIRE


Corr. 0.9916
mean std
LWP Gerber 0.0469 0.0622
LWP King 0.0429 0.0611
LWPGerber (mm)
LWPKing (mm)
0.00
0.05
0.10
0.15
0.20
0.25
0.30

Lin & Rossow [1994]



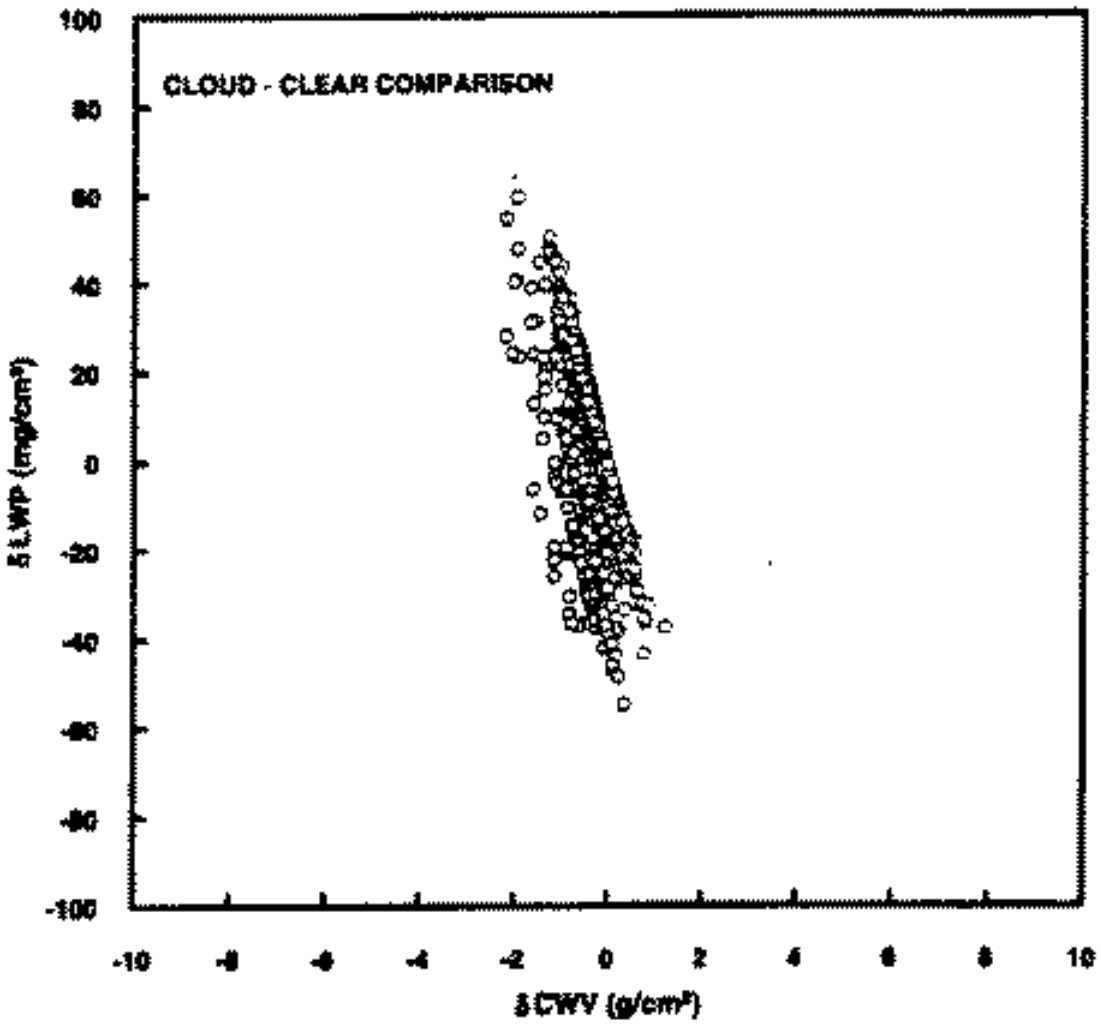


Figure 8. The δCWV versus δLWP (definition in text). (a) Clear sky cases where slope of best fit straight lines is approximately -30 mg/g. (b) Cloudy sky cases with almost the same slope.

Rosenkranz [1998]

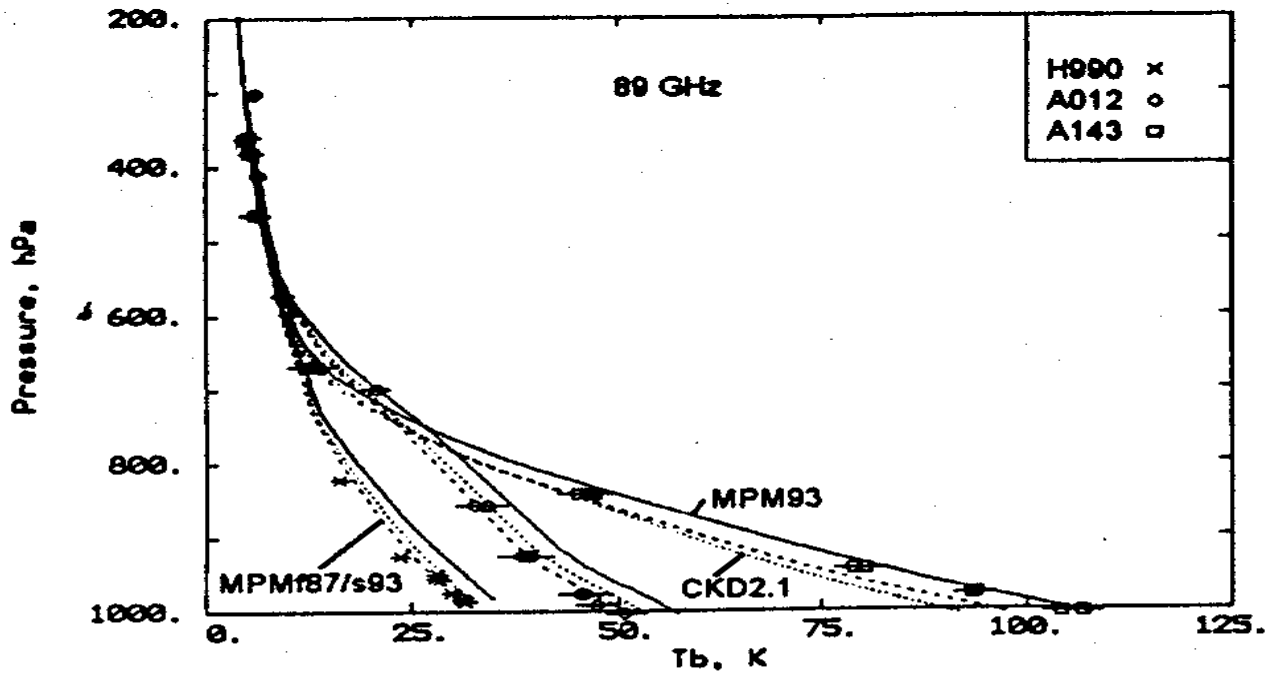


Figure 9. Near-zenith 89-GHz brightness temperatures measured by *English et al.* [1994], and calculations using three water vapor continuum models. The short horizontal lines through the data points are error brackets. H990 data are from northern Finland; A012 data are from the eastern Mediterranean; and A143 data are from near Ascension Island.

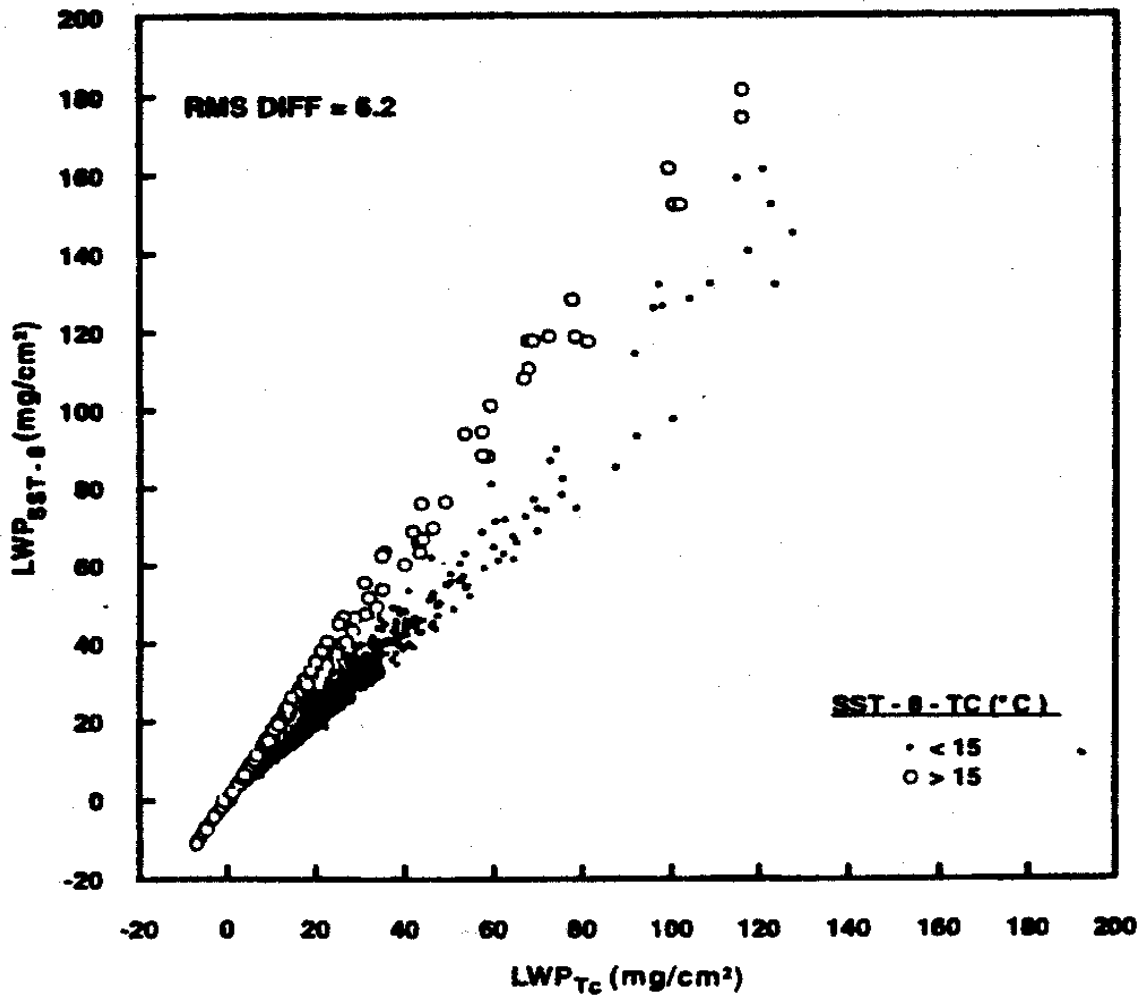
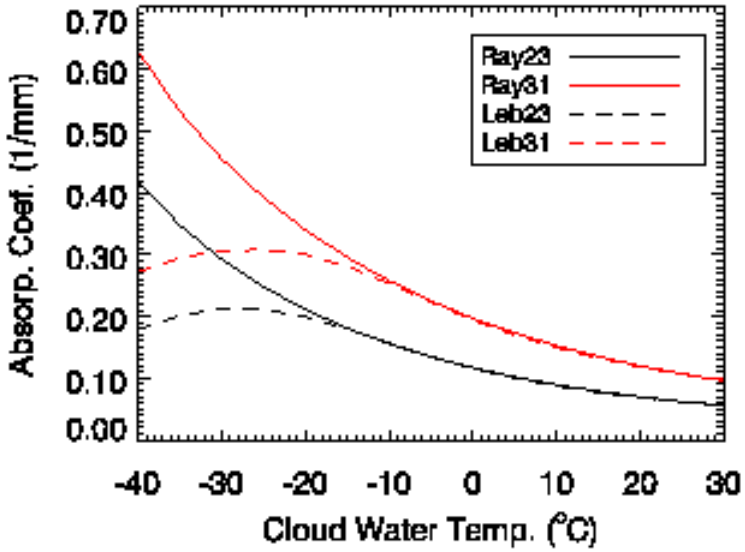
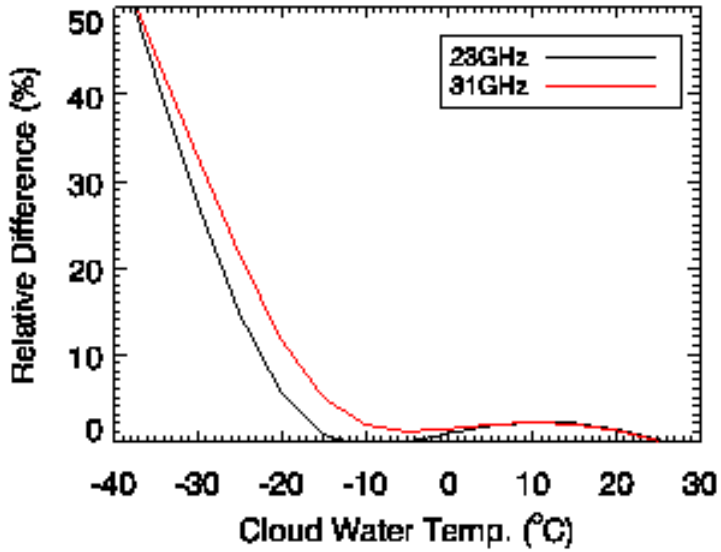


Figure 7. Same as Figure 6 but with cloud liquid water temperatures set to 0°C in all clouds with cloud top temperature less than 0°C.


Ray23
Ray31
Leb23
Leb31
Absorp. Coef. (1/mm)
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
-40
-30
-20
-10
0
10
20
30
Cloud Water Temp. (°C)


23GHz
31GHz
Relative Difference (%)
50
40
30
20
10
0
-40
-30
-20
-10
0
10
20
30
Cloud Water Temp. (°C)

Radiative Transfer Model

- Two stream absorption and emission based microwave radiative transfer model [Lin et al. 1998].
- Water vapor absorption coefficients: Liebe [1989] (MPM89)
- Water absorption coefficients: Mie calculations using water refractive index of Ray [1972].
- Atmospheric temp., pres., cloud height from ARM surface measurements.

Radiative Transfer Model (cont.)

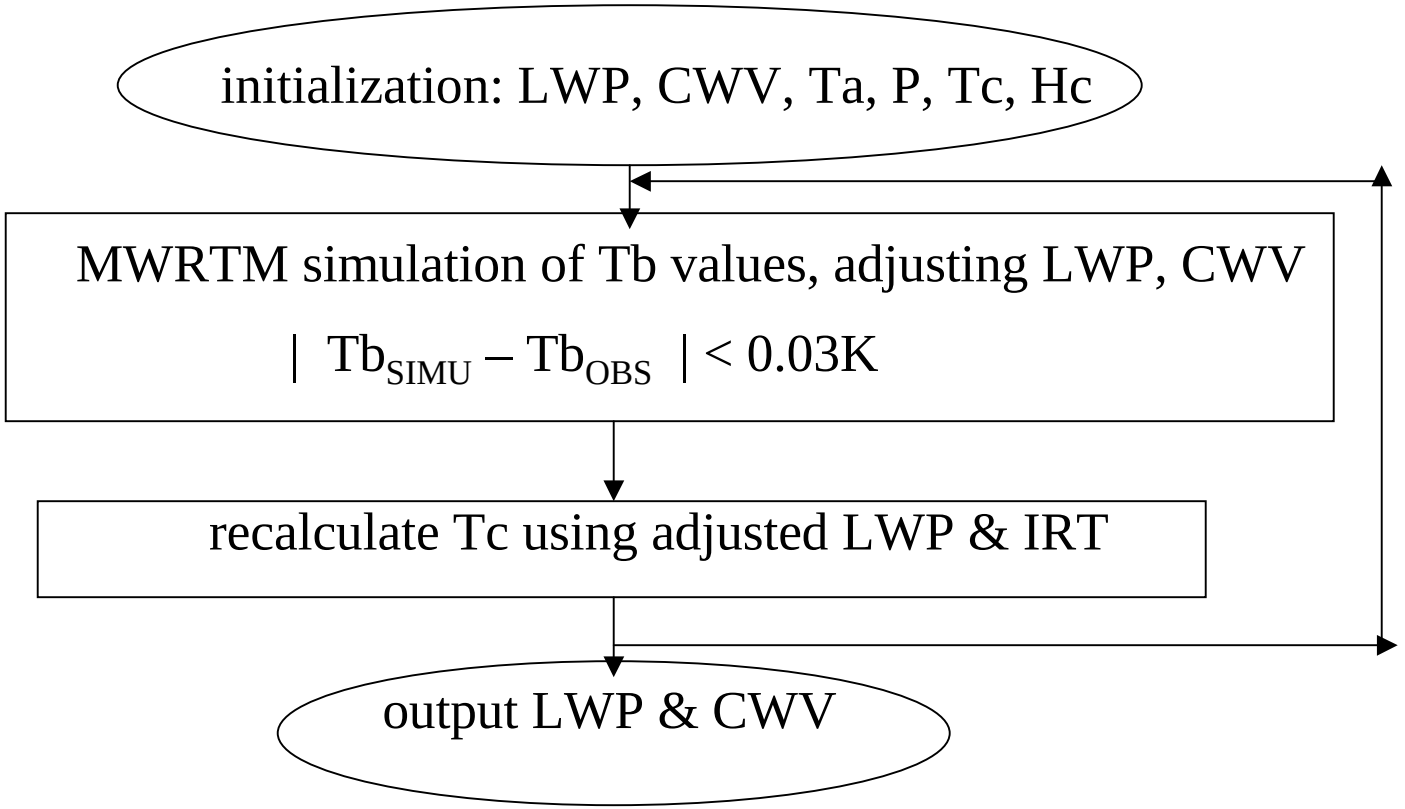
- Cloud temp.: IRT measurement

  $$R\text{cld} - R\text{clr} \approx (1\text{-}\exp(\text{-}\tau))B(Tc)$$

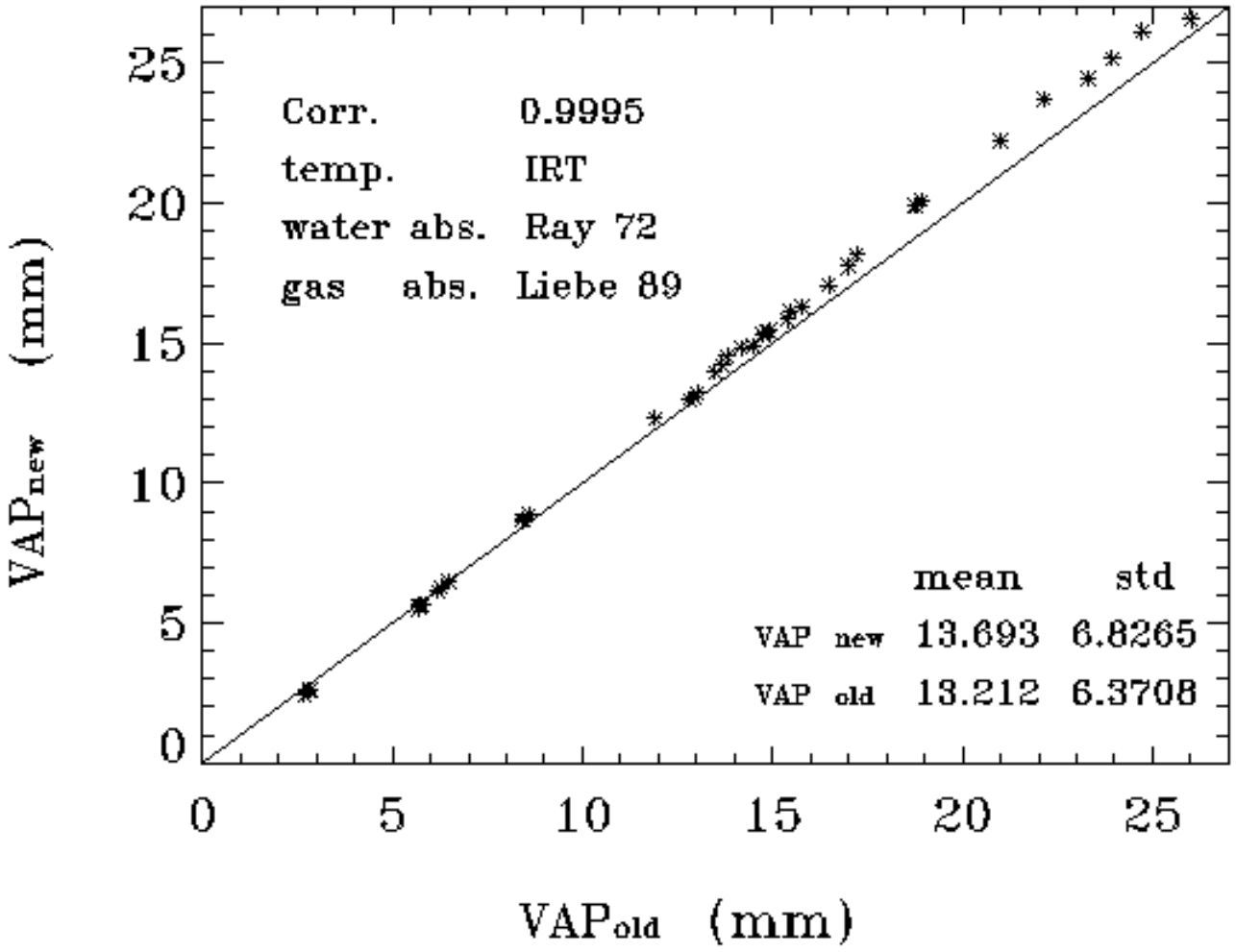
- *R*clr: IR radiative transfer model & *k*-distribution [Kratz et al. 1998].

- Optical depth: $\tau \approx 0.5\ \tau_{\mathbf{VIS}} = 75LWP$

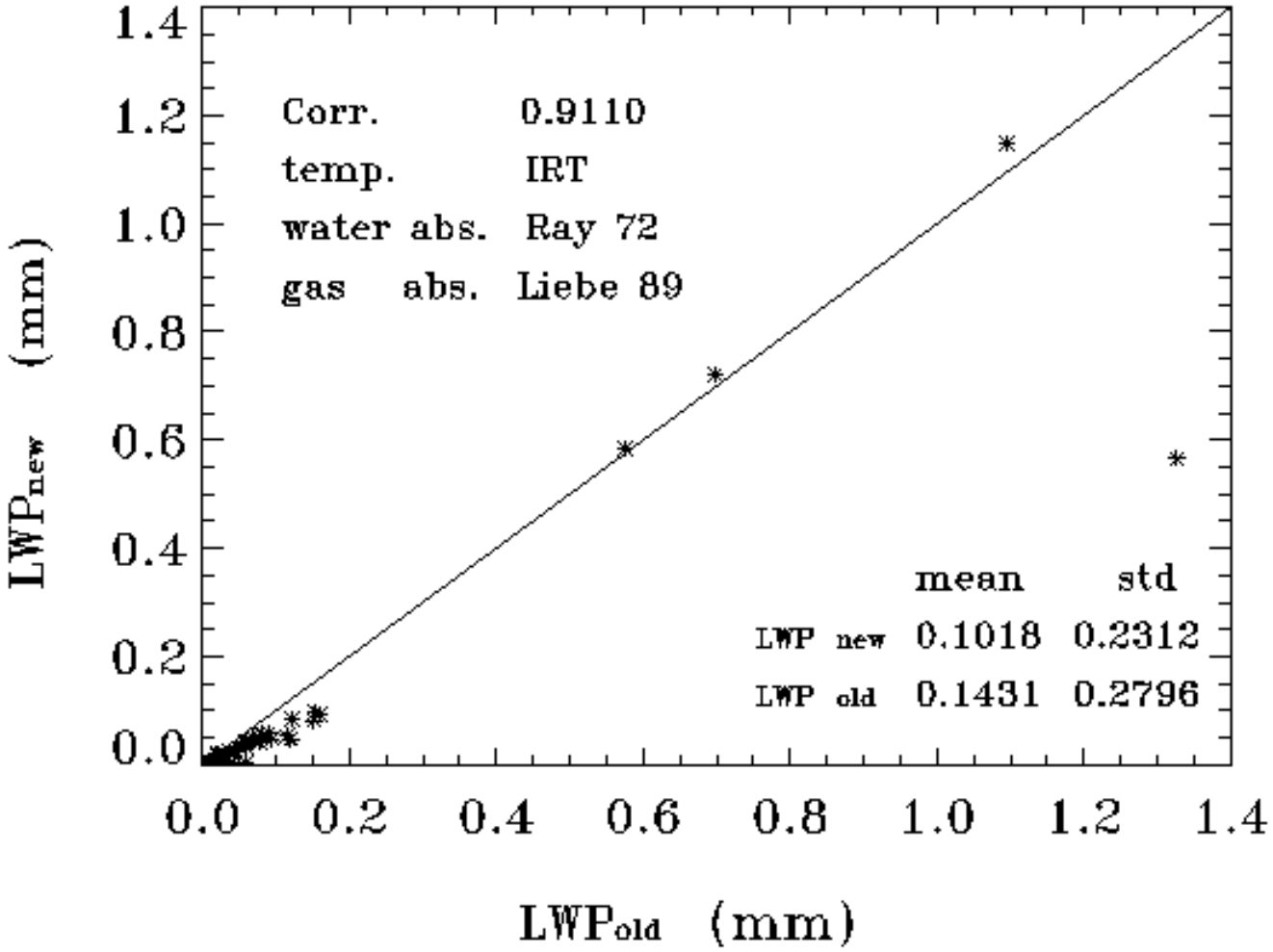
Retrieval Scheme



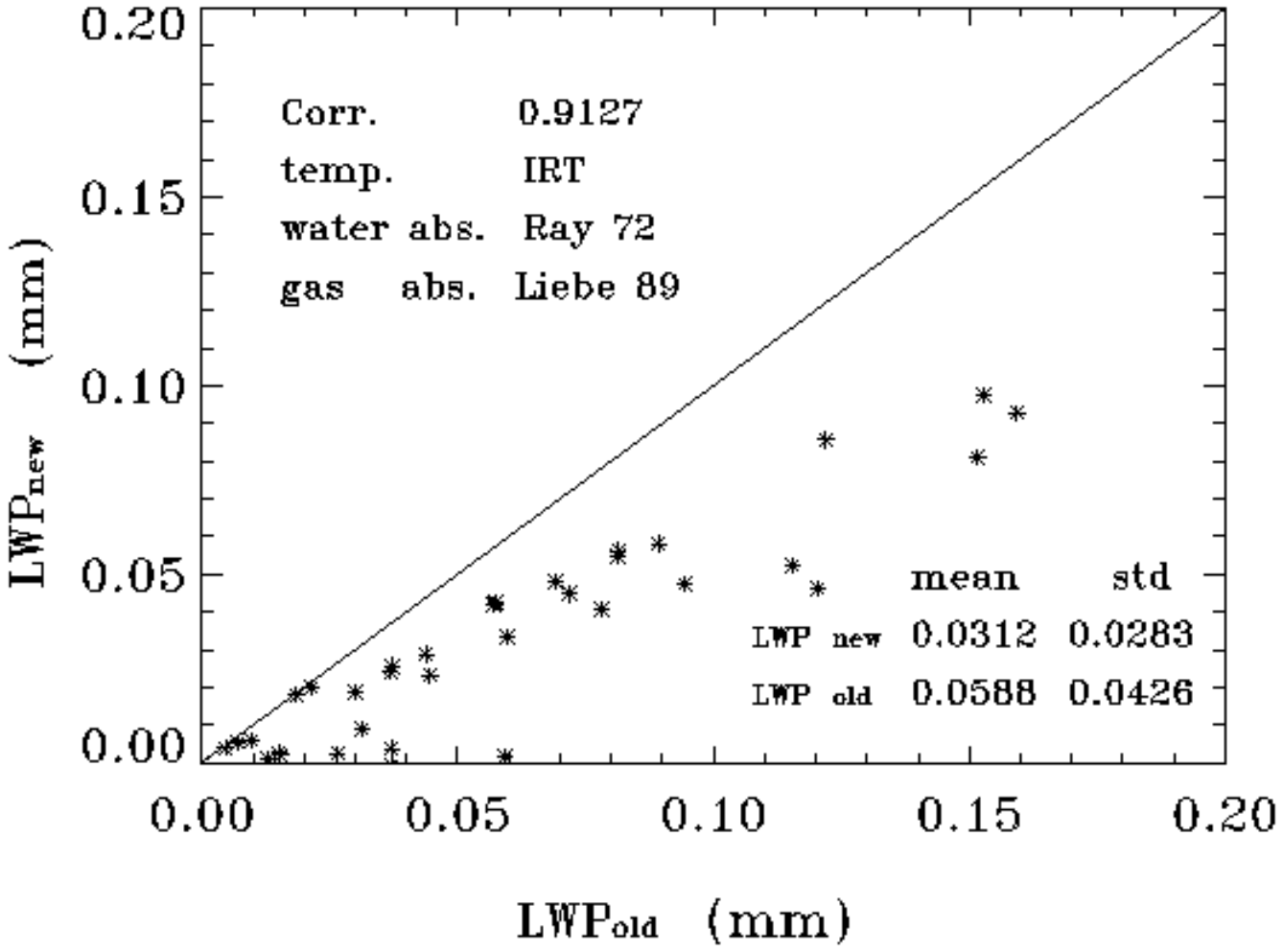
SHEBA/FIRE


Corr. 0.9995
temp. IRT
water abs. Ray 72
gas abs. Liebe 89
mean std
VAP new 13.693 6.8265
VAP old 13.212 6.3708
VAPnew (mm)
VAPold (mm)
0
5
10
15
20
25

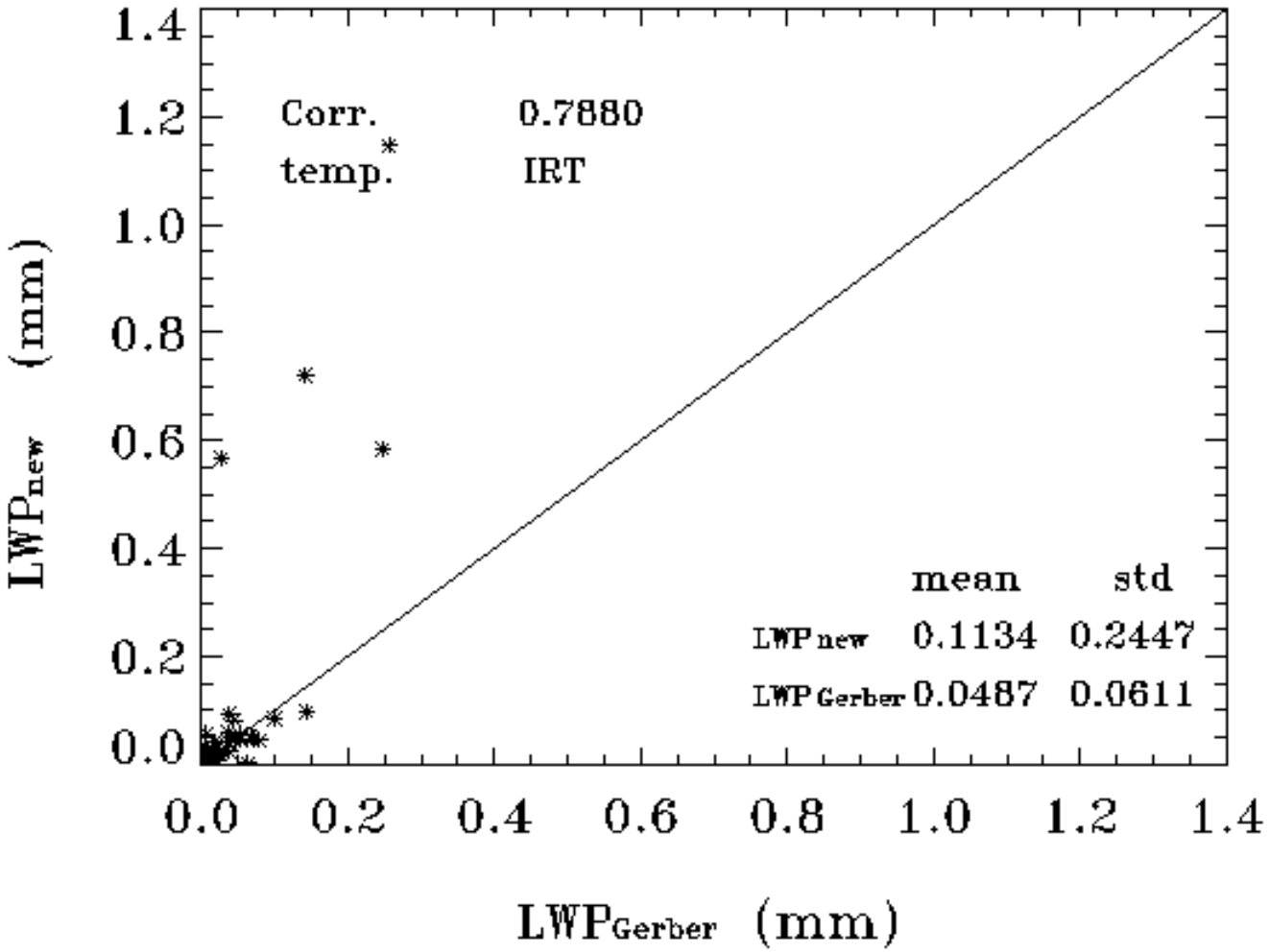
SHEBA/FIRE


Corr. 0.9110
temp. IRT
water abs. Ray 72
gas abs. Liebe 89
mean std
LWP new 0.1018 0.2312
LWP old 0.1431 0.2796
LWP_new (mm)
LWP_old (mm)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4

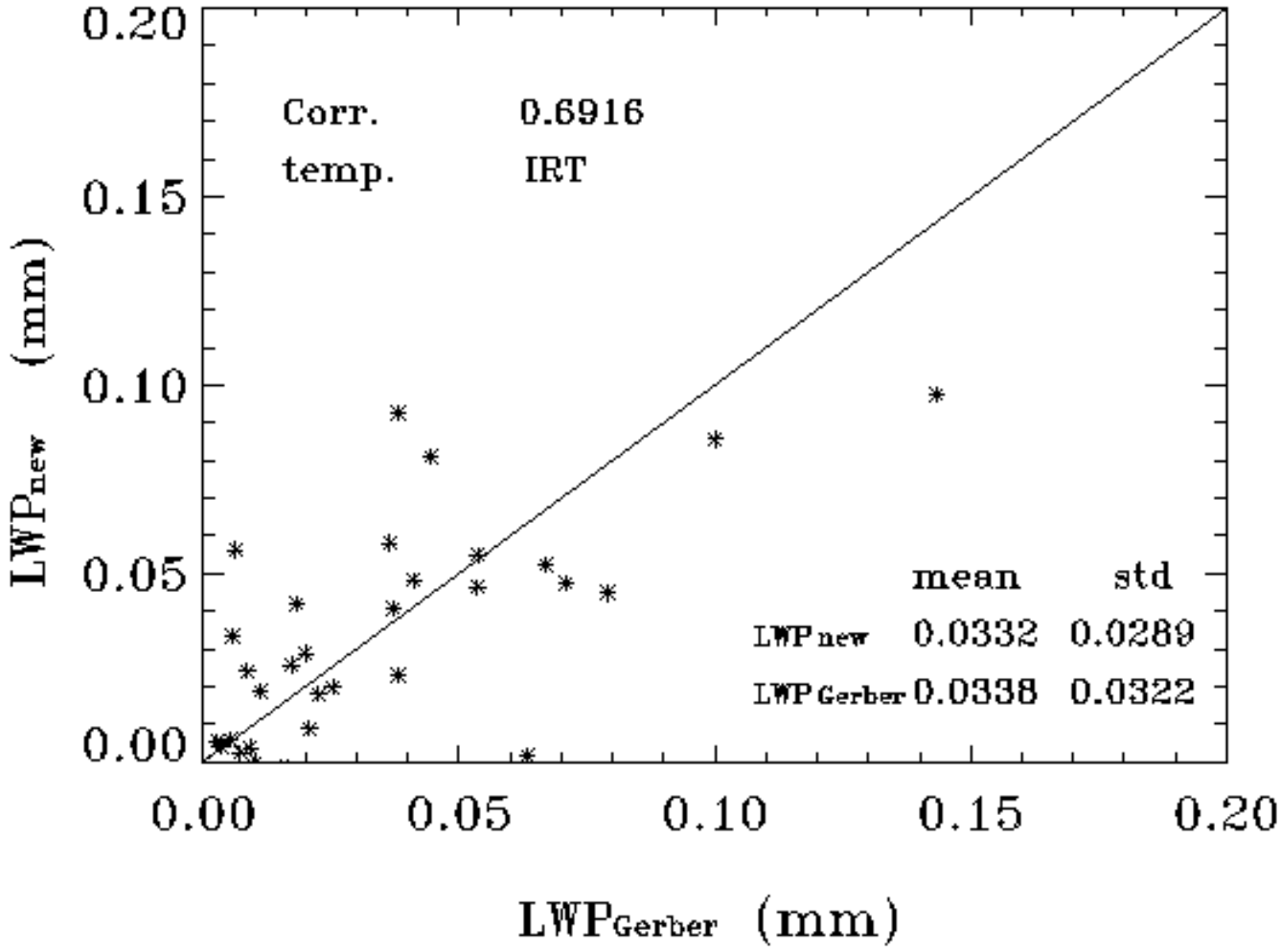
SHEBA/FIRE


Corr. 0.9127
temp. IRT
water abs. Ray 72
gas abs. Liebe 89
mean std
LWP new 0.0312 0.0283
LWP old 0.0588 0.0426
0.00
0.05
0.10
0.15
0.20
LWPnew (mm)
LWPold (mm)

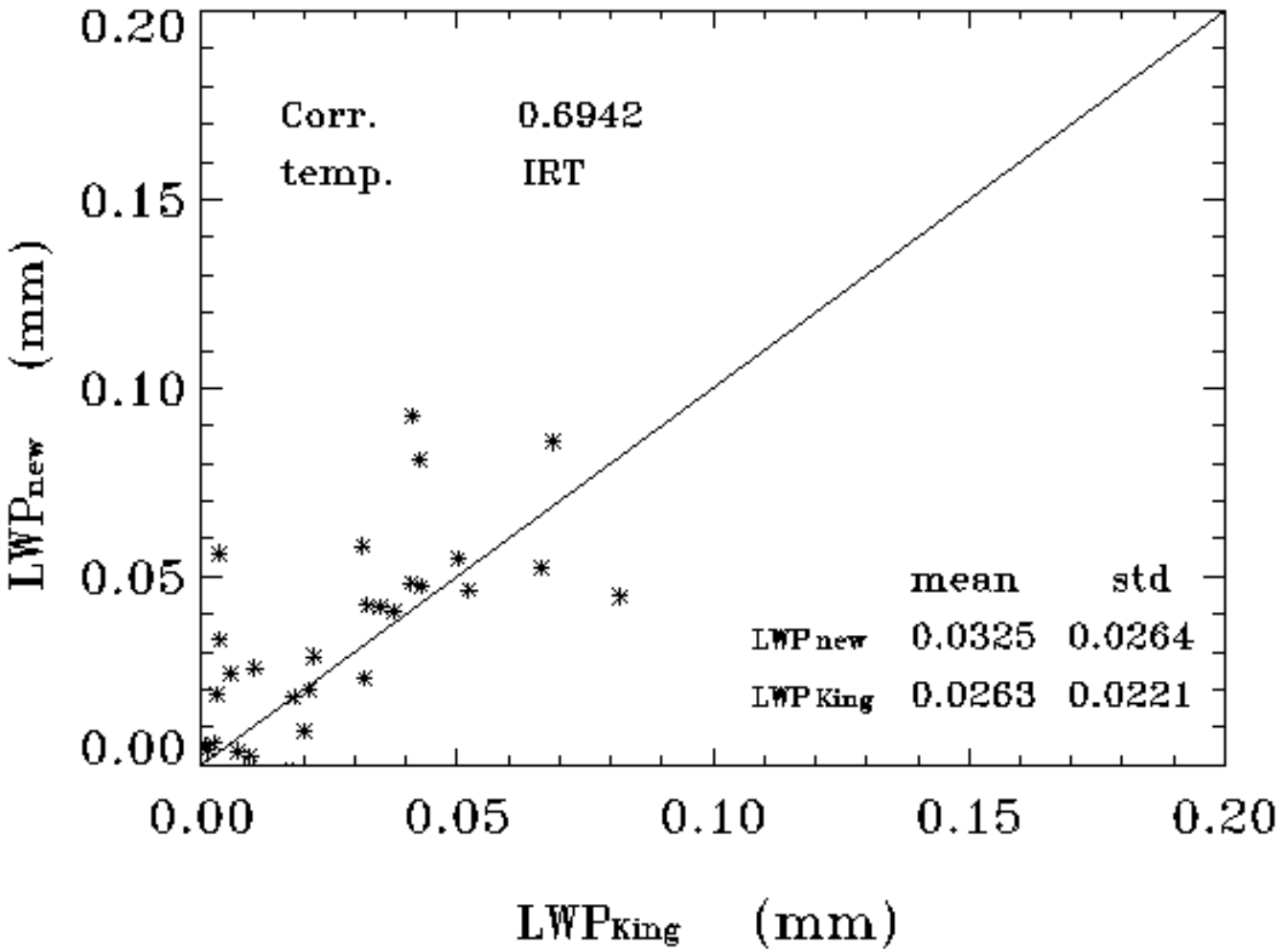
SHEBA/FIRE


Corr. 0.7880
temp. IRT
mean std
LWP new 0.1134 0.2447
LWP Gerber 0.0487 0.0611
LWP new (mm)
LWP Gerber (mm)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4

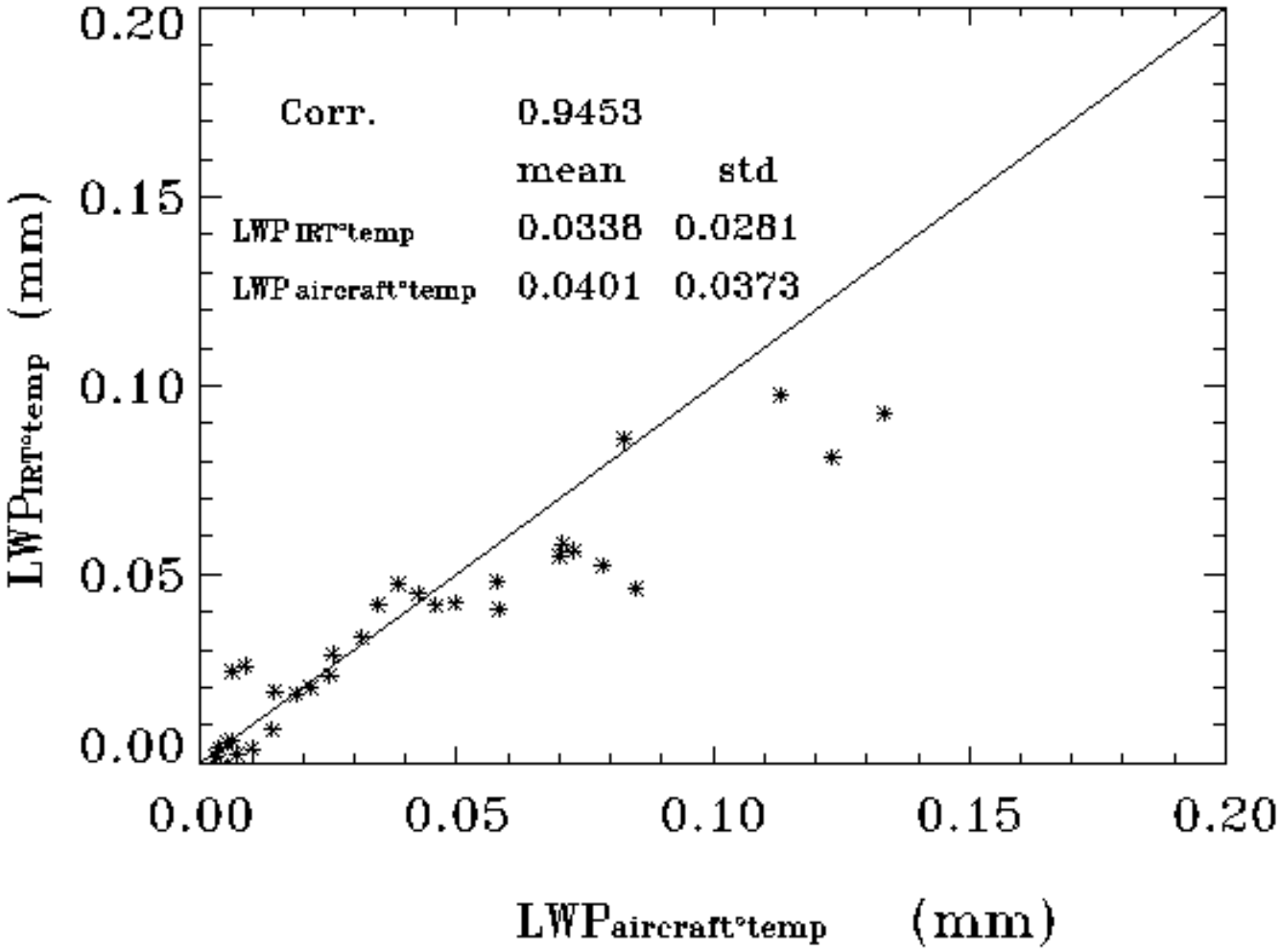
SHEBA/FIRE


Corr. 0.6916
temp. IRT
mean std
LWP new 0.0332 0.0289
LWP Gerber 0.0338 0.0322
LWPnew (mm)
LWPGerber (mm)
0.00
0.05
0.10
0.15
0.20

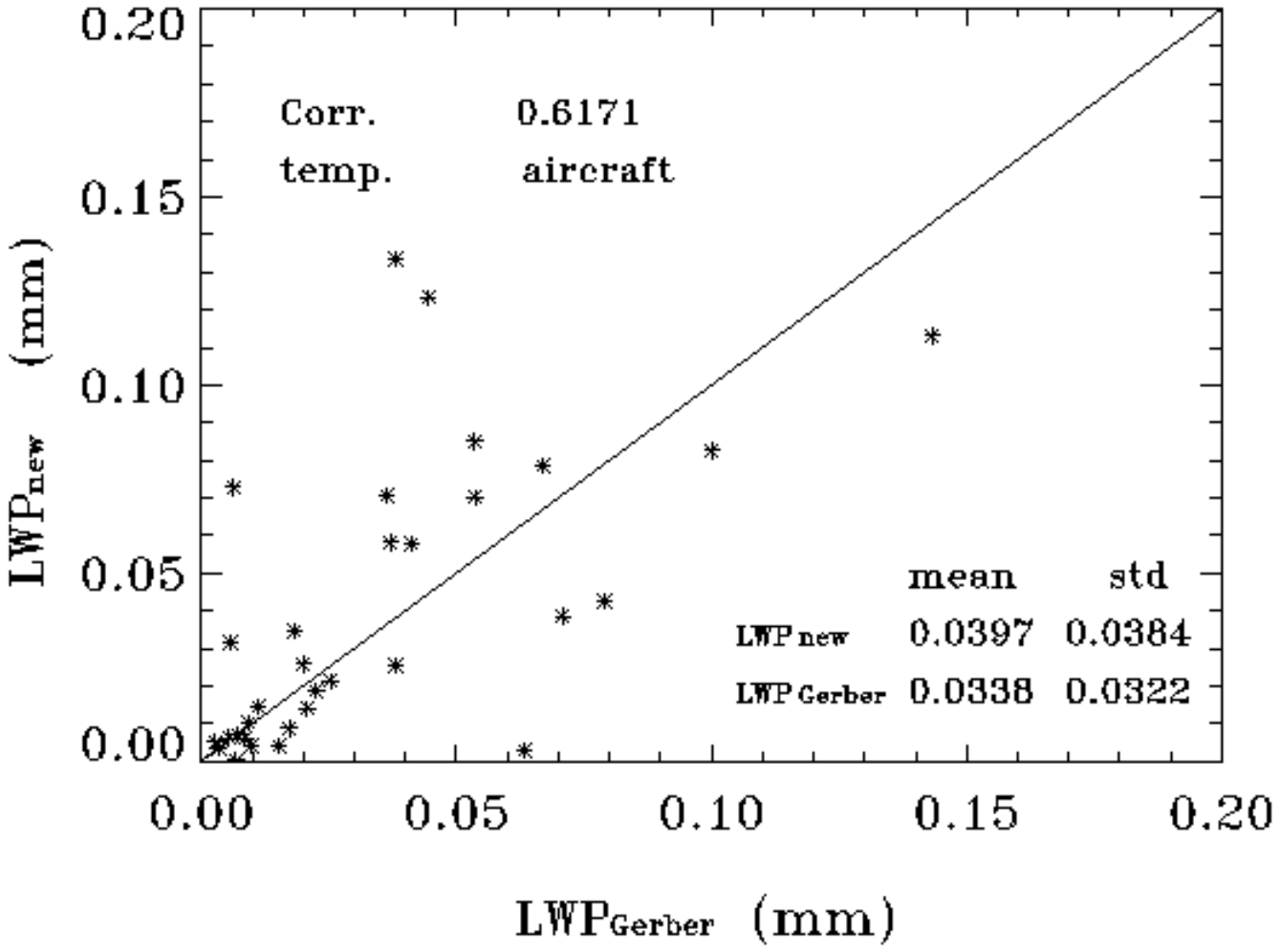
SHEBA/FIRE


Corr. 0.6942
temp. IRT
mean std
LWP new 0.0325 0.0264
LWP King 0.0263 0.0221
LWP new (mm)
LWP King (mm)
0.00
0.05
0.10
0.15
0.20

SHEBA/FIRE


Corr. 0.9453
mean std
LWP IRT*temp 0.0338 0.0281
LWP aircraft*temp 0.0401 0.0373
LWPIRT*temp (mm)
LWPaircraft*temp (mm)
0.00
0.05
0.10
0.15
0.20

SHEBA/FIRE


Corr. 0.6171
temp. aircraft
mean std
LWP new 0.0397 0.0384
LWP Gerber 0.0338 0.0322
LWPnew (mm)
LWPGerber (mm)
0.00
0.05
0.10
0.15
0.20

Conclusions

- For microwave LWP retrievals, it is critical to accurately account for cloud water temperature, water vapor amount, and water vapor absorption coefficients, as discussed by Lin et al. [1998] and Lin and Rossow [1994].
- Current algorithm significantly reduces the bias error comparing with standard ARM method, and gives LWP retrievals consistence with aircraft in situ measurements. This algorithm should be applicable to clouds in other ARM sites.
- Improvements in water and vapor absorption coefficients may be needed.

Rosenkranz [1998]

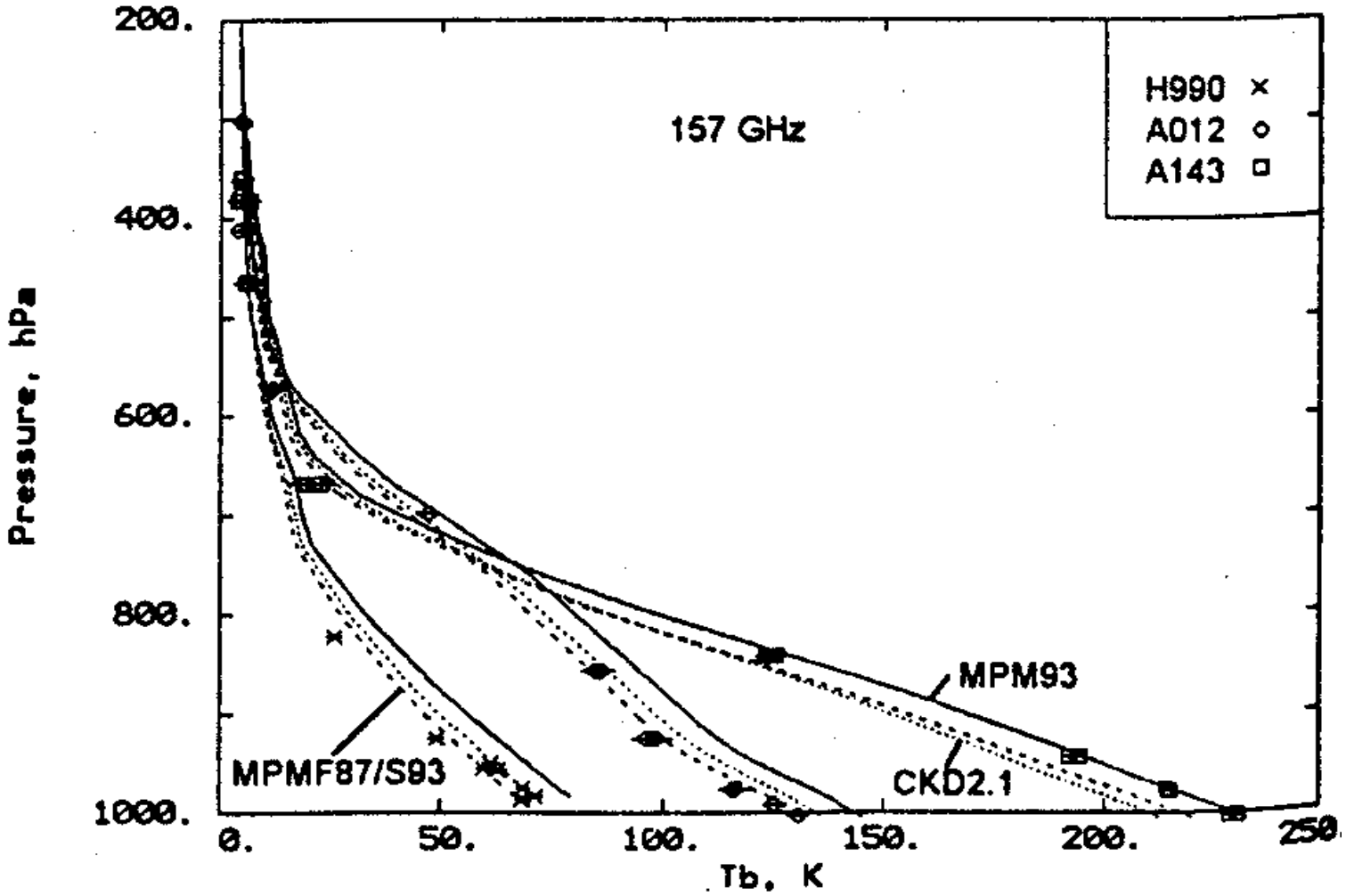


Figure 10. Same as in Figure 9, except at 157 GHz.