Stable Retrievals down to 26km

Gerald Nedoluha

Mike Gomez

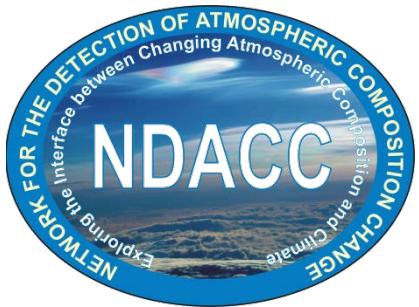
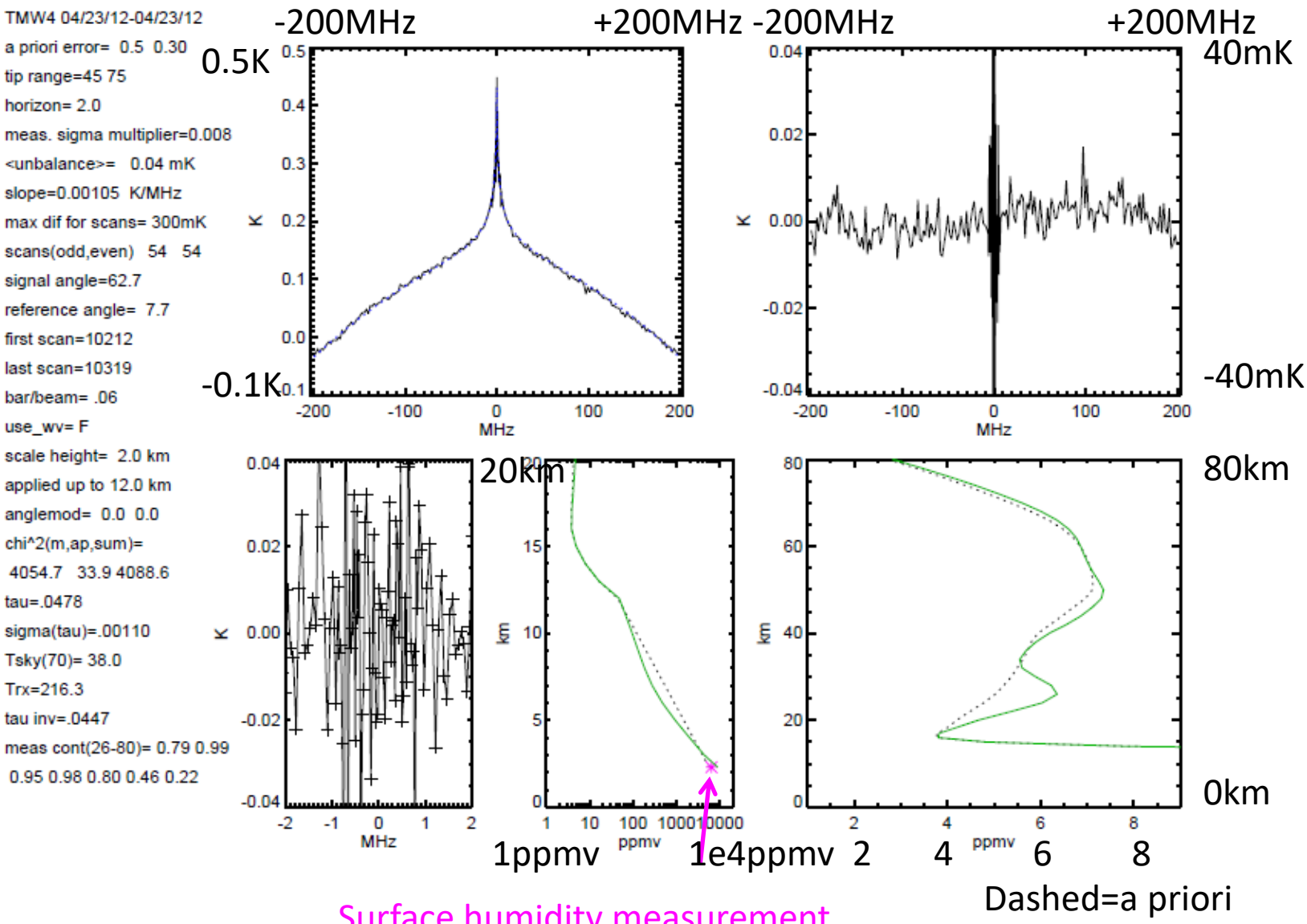
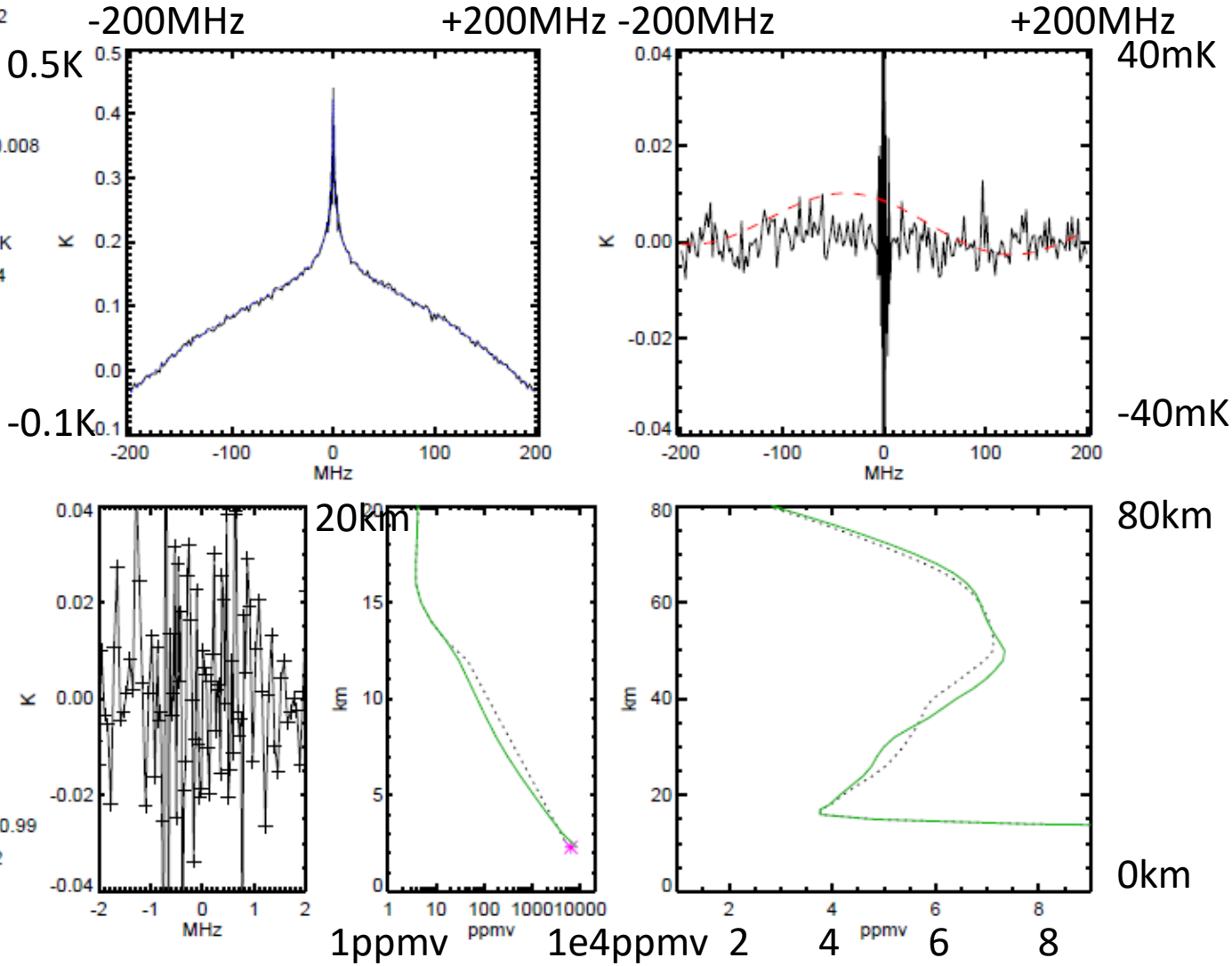


Table Mountain data from April 23, 2012. No baseline subtraction. No clear sign of a baseline problem, but there is a big bump in H_2O at 26km.



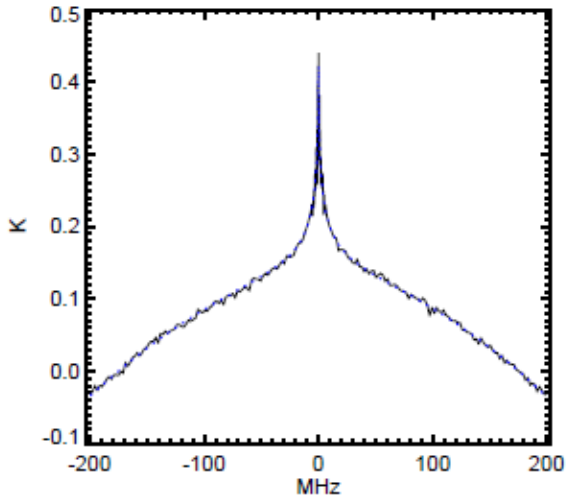
With the addition of the usual Table Mountain constant baseline term the 26km bump goes away.

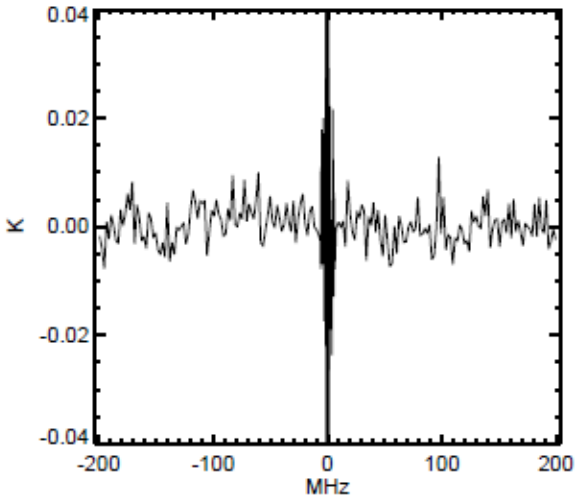
TMW4 04/23/12-04/23/12
a priori error= 0.5 0.30
tip range=45 75
horizon= 2.0
meas. sigma multiplier=0.008
<unbalance>= 0.04 mK
slope=0.00104 K/MHz
max dif for scans= 300mK
scans(odd,even) 54 54
signal angle=62.7
reference angle= 7.7
first scan=10212
last scan=10319
bar/beam= .06
use_wv= F
scale height= 2.0 km
applied up to 12.0 km
anglemod= 0.0 0.0
chi^2(m,ap,sum)=
3440.3 14.2 3454.4
tau=.0478
sigma(tau)=.00110
Tsky(70)= 38.0
Trx=216.3
tau inv=.0452
meas cont(26-80)= 0.79 0.99
0.95 0.98 0.80 0.46 0.22

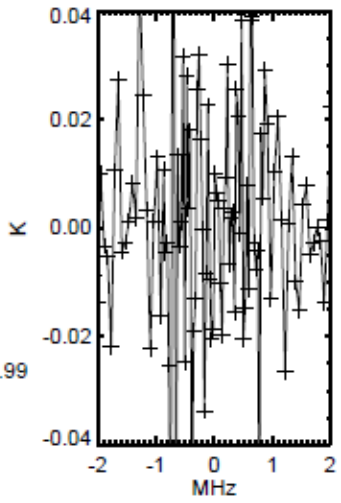


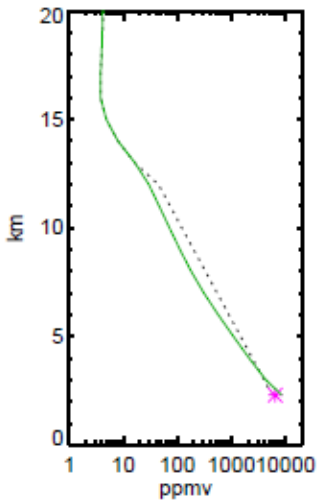
Now we have a nice looking retrieval.
Let's look at the 4 types of scans that make up this retrieval.

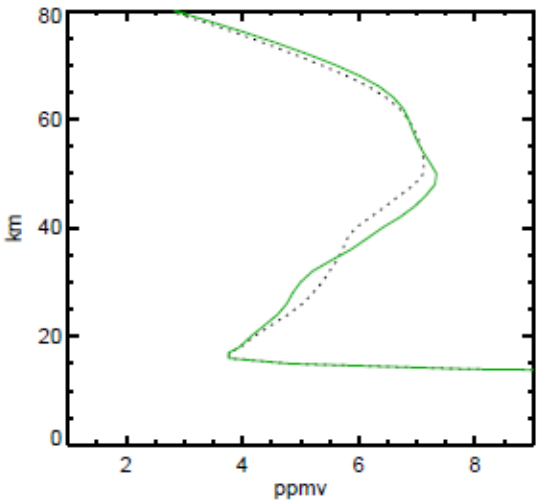
TMW4 04/23/12-04/23/12
a priori error= 0.5 0.30
tip range=45 75
horizon= 2.0
meas. sigma multiplier=0.008
<unbalance>= 0.04 mK
slope=0.00104 K/MHz
max dif for scans= 300mK
scans(odd,even) 54 54
signal angle=62.7
reference angle= 7.7
first scan=10212
last scan=10319
bar/beam= .06
use_wv= F
scale height= 2.0 km
applied up to 12.0 km
anglemod= 0.0 0.0
chi^2(m,ap,sum)=
3440.3 14.2 3454.4
tau=.0478
sigma(tau)=.00110
Tsky(70)= 38.0
Trx=216.3
tau inv=.0452
meas cont(26-80)= 0.79 0.99
0.95 0.98 0.80 0.46 0.22

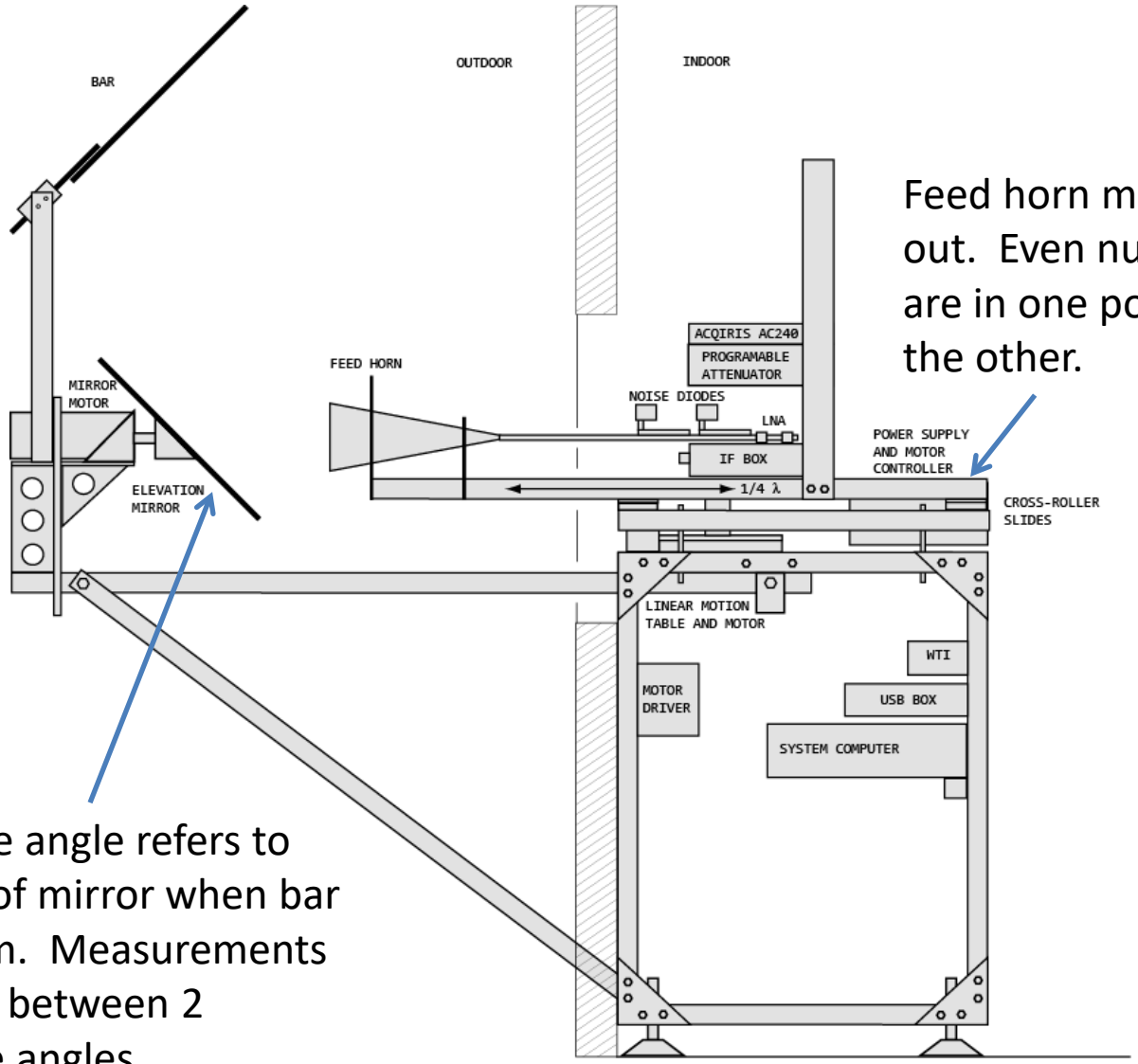










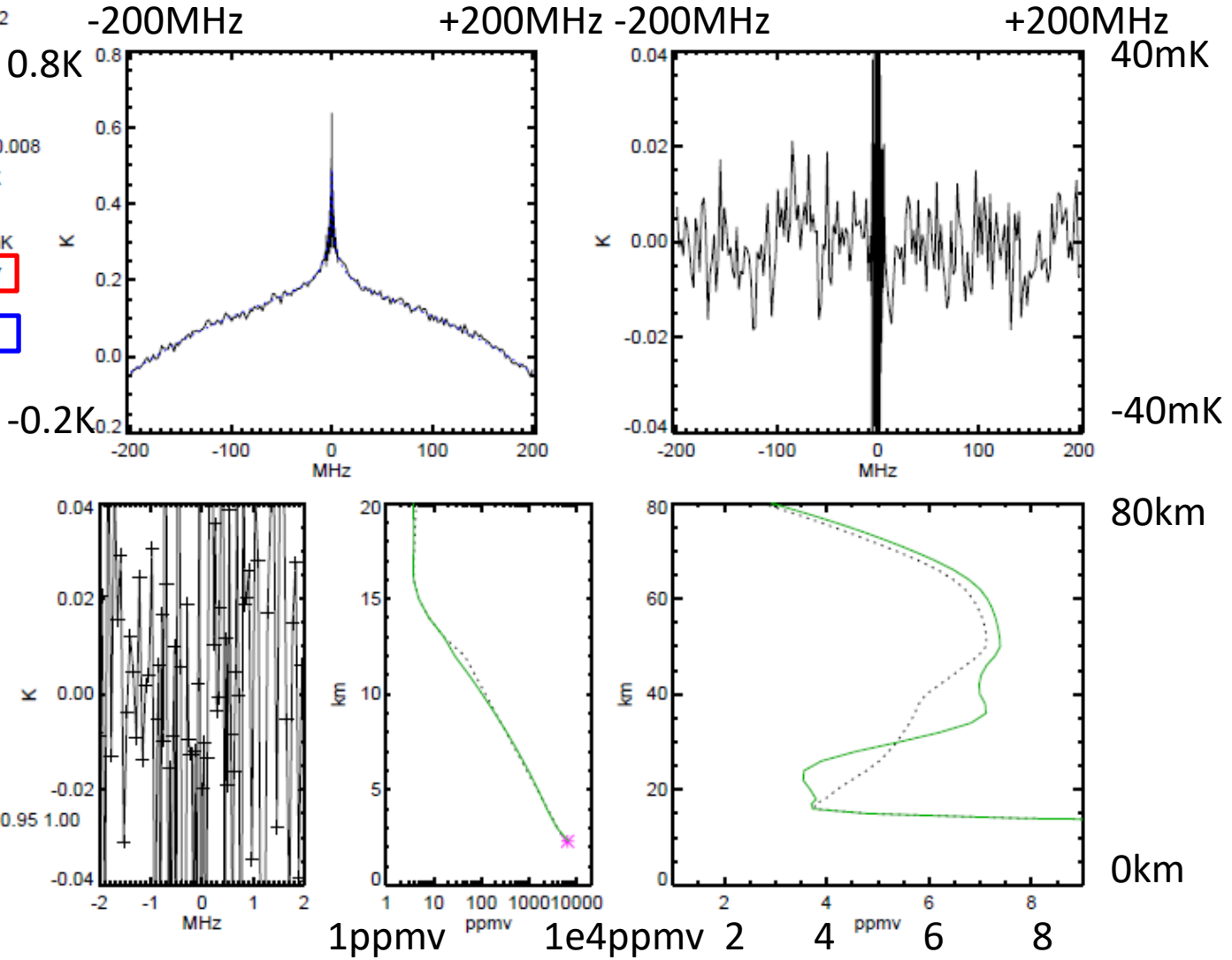


Feed horn moves λ/4 in and out. Even numbered scans are in one position, odd in the other.

Reference angle refers to position of mirror when bar is in beam. Measurements alternate between 2 reference angles

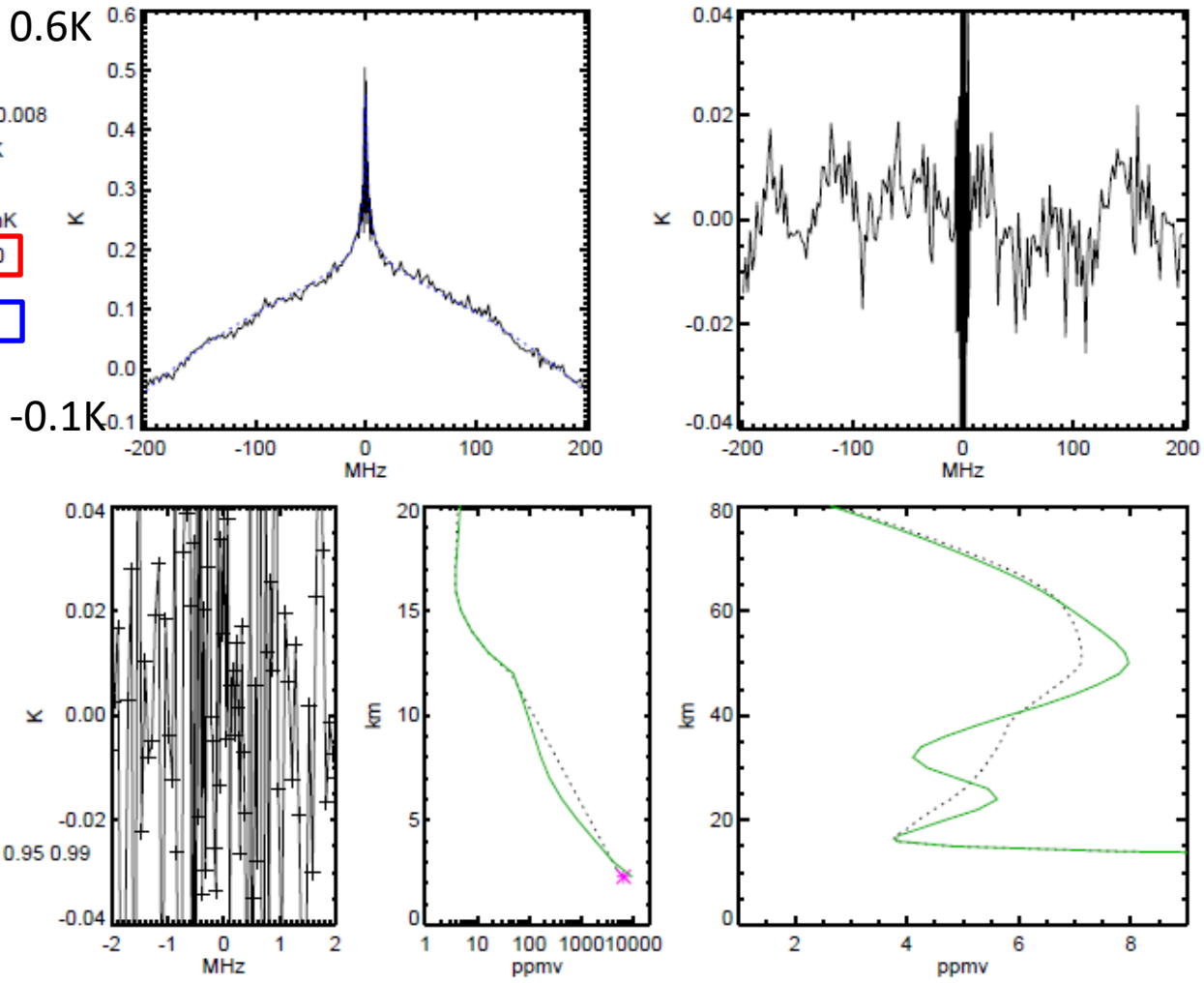
"Even" scans describe a specific feed horn position.
These are taken at reference angle=7.2°

TMW4 04/23/12-04/23/12
a priori error= 0.5 0.30
tip range=45 75
horizon= 2.0
meas. sigma multiplier=0.008
<unbalance>= -0.07 mK
slope=0.00114 K/MHz
max dif for scans= 300mK
scans(odd,even) 0 27
signal angle=64.1
reference angle= 7.2
first scan=10212
last scan=10319
bar/beam= .06
use_wv= F
scale height= 2.0 km
applied up to 12.0 km
anglemod= 0.0 0.0
chi^2(m,ap,sum)=
4525.2 55.0 4580.2
tau=.0480
sigma(tau)=.00220
Tsky(70)= 38.2
Trx=216.2
tau inv=.0476
meas cont(26-80)= 0.72 0.95 1.00
0.88 0.57 0.27 0.12



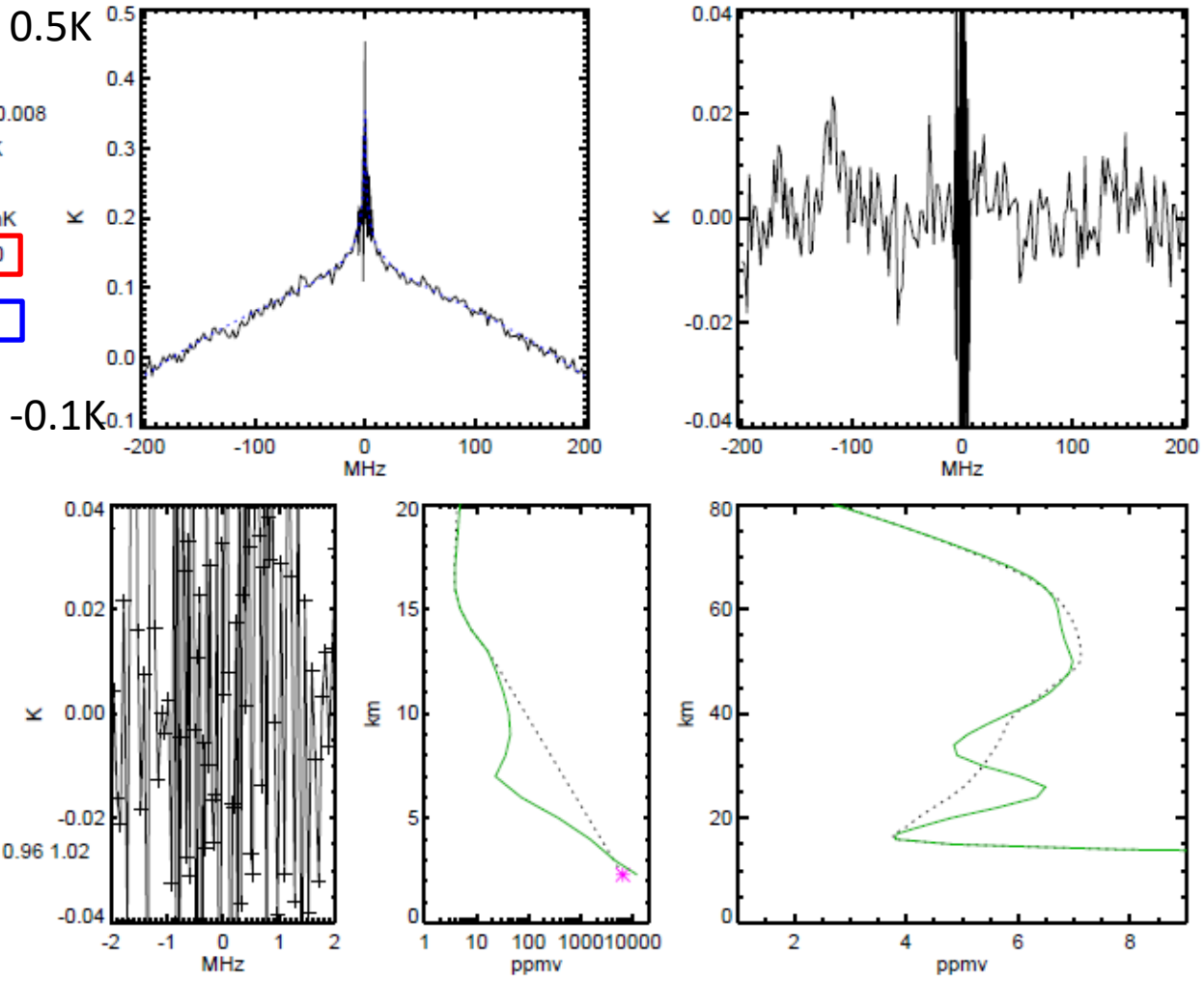
Odd scans taken at reference angle=7.2°

TMW4 04/23/12-04/23/12
a priori error= 0.5 0.30
tip range=45 75
horizon= 2.0
meas. sigma multiplier=0.008
<unbalance>= 0.07 mK
slope=0.00118 K/MHz
max dif for scans= 300mK
scans(odd,even) 27 0
signal angle=64.4
reference angle= 7.2
first scan=10213
last scan=10319
bar/beam= .06
use_wv= F
scale height= 2.0 km
applied up to 12.0 km
anglemod= 0.0 0.0
chi^2(m,ap,sum)=
5412.0 56.4 5468.4
tau=.0476
sigma(tau)=.00222
Tsky(70)= 37.9
Trx=216.4
tau inv=.0432
meas cont(26-80)= 0.72 0.95 0.99
0.89 0.59 0.28 0.12



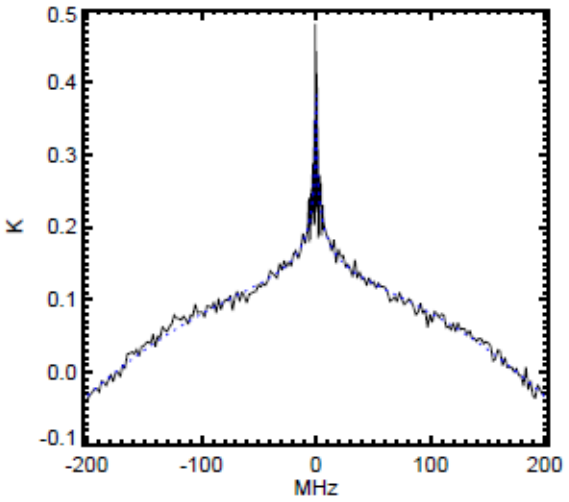
Odd scans taken at reference angle=8.1°

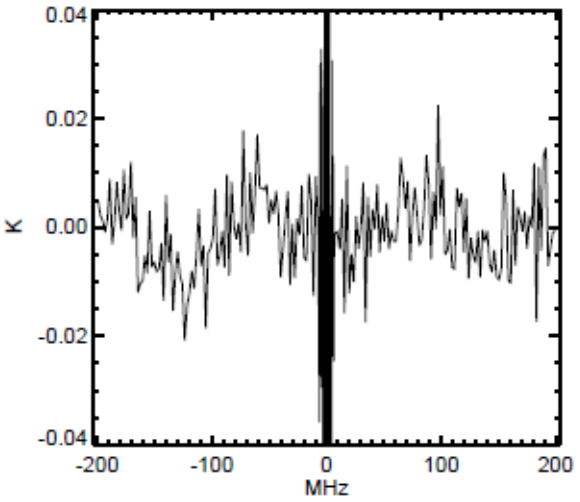
TMW4 04/23/12-04/23/12
a priori error= 0.5 0.30
tip range=45 75
horizon= 2.0
meas. sigma multiplier=0.008
<unbalance>= 0.15 mK
slope=0.00096 K/MHz
max dif for scans= 300mK
scans(odd,even) 27 0
signal angle=60.8
reference angle= 8.1
first scan=10215
last scan=10319
bar/beam= .05
use_wv= F
scale height= 1.8 km
applied up to 12.0 km
anglemod= 0.0 0.0
chi^2(m,ap,sum)=
5022.1 57.0 5079.1
tau=.0480
sigma(tau)=.00221
Tsky(70)= 38.2
Trx=216.1
tau inv=.0411
meas cont(26-80)= 0.71 0.96 1.02
0.85 0.53 0.24 0.10

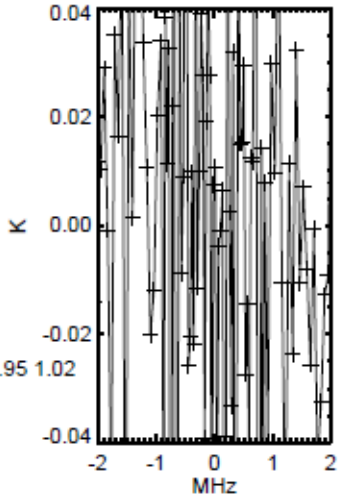


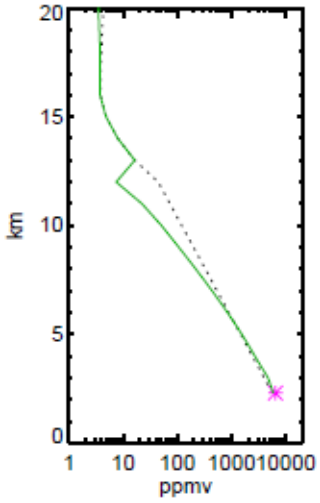
Even scans taken at reference angle=8.1°

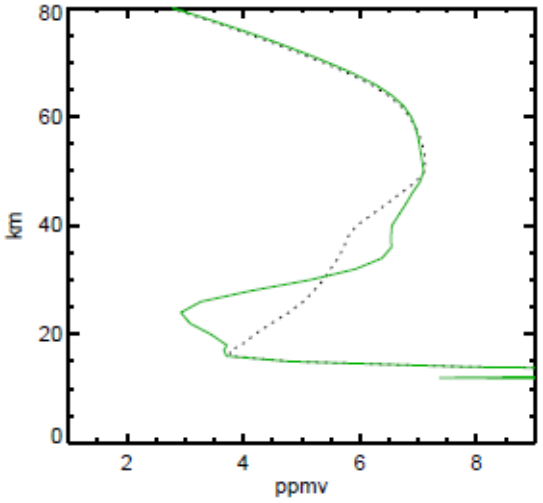
TMW4 04/23/12-04/23/12
a priori error= 0.5 0.30
tip range=45 75
horizon= 2.0
meas. sigma multiplier=0.008
<unbalance>= -0.01 mK
slope=0.00089 K/MHz
max dif for scans= 300mK
scans(odd,even) 0 27
signal angle=61.0
reference angle= 8.1
first scan=10214
last scan=10319
bar/beam= .05
use_wv= F
scale height= 2.0 km
applied up to 12.0 km
anglemod= 0.0 0.0
chi^2(m,ap,sum)=
4654.0 55.6 4709.7
tau=.0473
sigma(tau)=.00219
Tsky(70)= 37.6
Trx=216.4
tau inv=.0479
meas cont(26-80)= 0.70 0.95 1.02
0.84 0.52 0.23 0.10







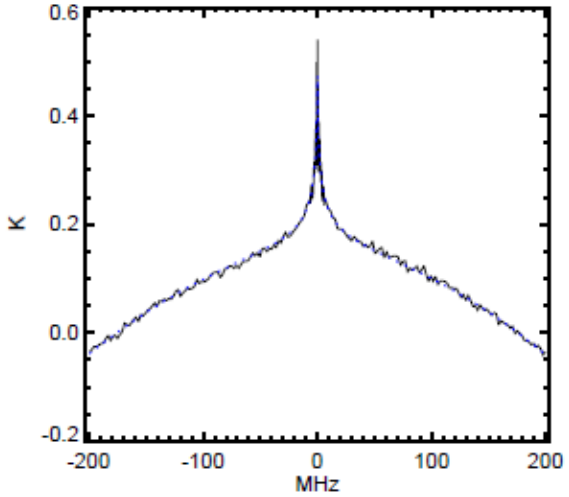


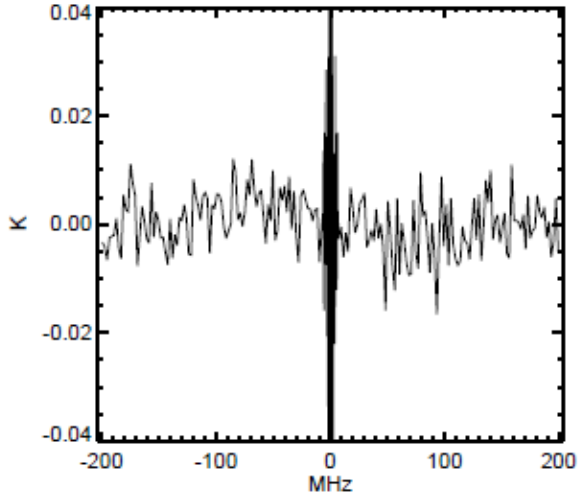


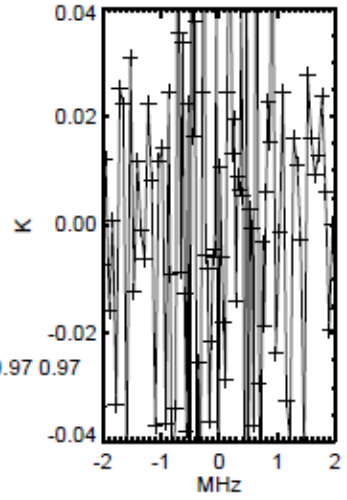
Clearly we need to add together the scans taken in the two positions separated by λ/4. How much do the reference angles matter now?

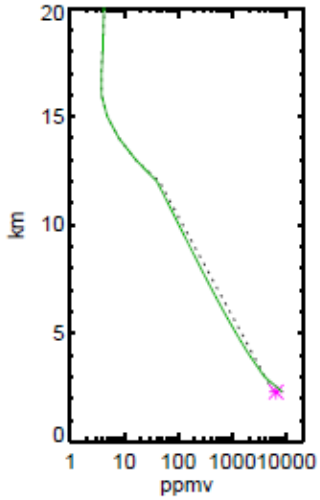
First, reference angle =7.2°

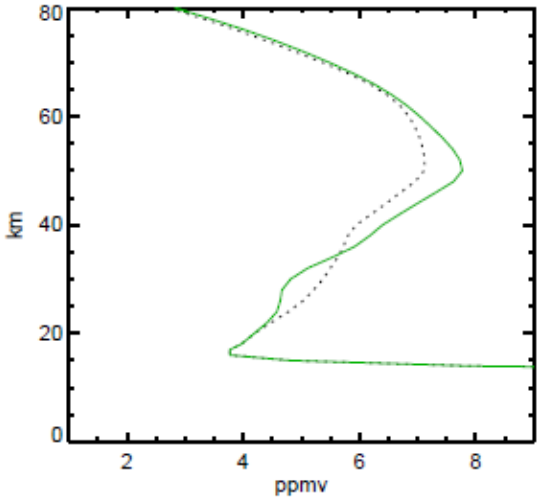
TMW4 04/23/12-04/23/12
a priori error= 0.5 0.30
tip range=45 75
horizon= 2.0
meas. sigma multiplier=0.008
<unbalance>= 0.00 mK
slope=0.00116 K/MHz
max dif for scans= 300mK
scans(odd,even) 27 27
signal angle=64.2
reference angle= 7.2
first scan=10212
last scan=10319
bar/beam= .06
use_wv= F
scale height= 2.0 km
applied up to 12.0 km
anglemod= 0.0 0.0
chi^2(m,ap,sum)=
3945.6 20.3 3965.9
tau=.0478
sigma(tau)=.00156
Tsky(70)= 38.0
Trx=216.3
tau inv=.0455
meas cont(26-80)= 0.77 0.97 0.97
0.95 0.72 0.38 0.17





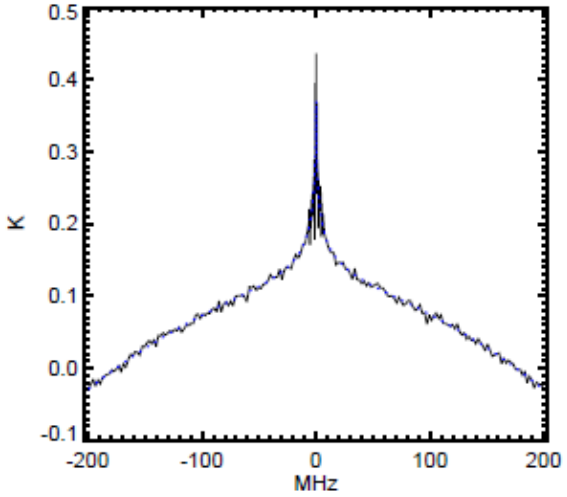


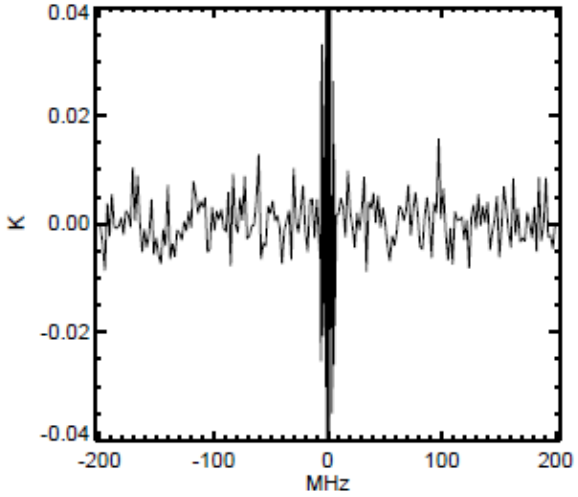


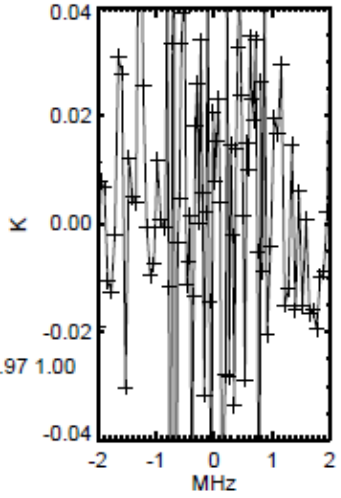


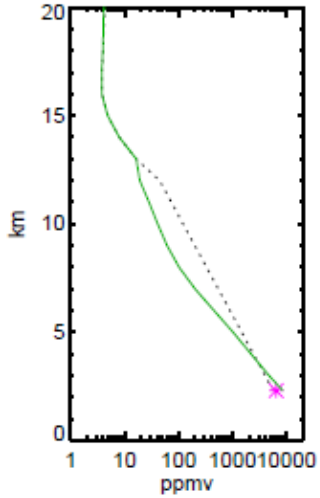
Now, reference angle =8.1°
Neither profile looks unreasonable, but they are different.

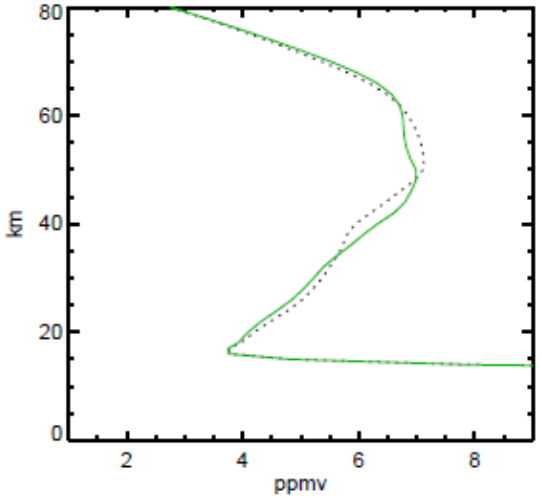
TMW4 04/23/12-04/23/12
a priori error= 0.5 0.30
tip range=45 75
horizon= 2.0
meas. sigma multiplier=0.008
<unbalance>= 0.07 mK
slope=0.00093 K/MHz
max dif for scans= 300mK
scans(odd,even) 27 27
signal angle=60.9
reference angle= 8.1
first scan=10214
last scan=10319
bar/beam= .05
use_wv= F
scale height= 2.0 km
applied up to 12.0 km
anglemod= 0.0 0.0
chi^2(m,ap,sum)=
3624.5 13.7 3638.2
tau=.0477
sigma(tau)=.00156
Tsky(70)= 37.9
Trx=216.3
tau inv=.0448
meas cont(26-80)= 0.74 0.97 1.00
0.93 0.66 0.33 0.15





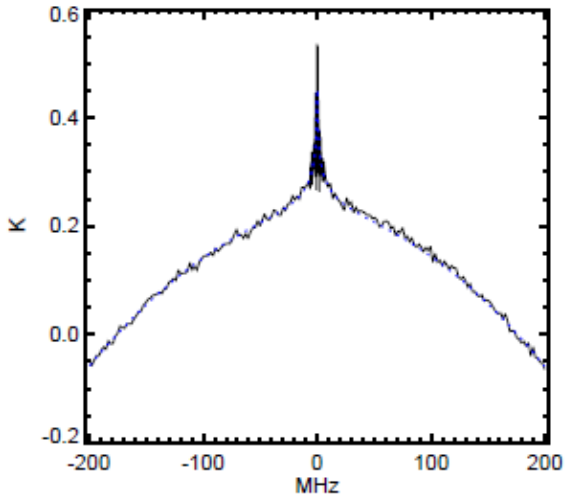


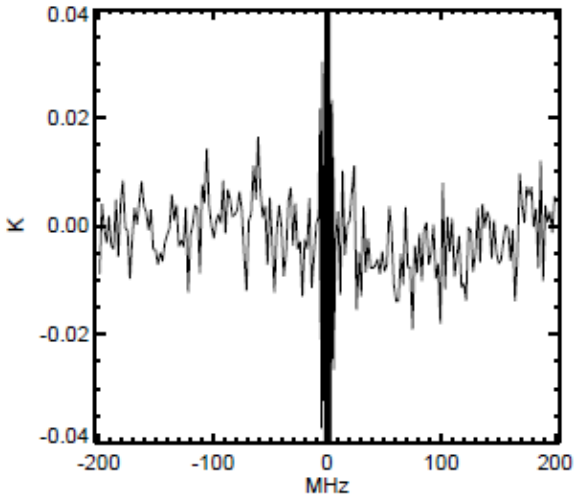


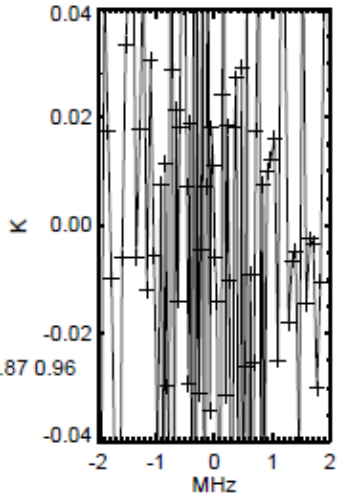


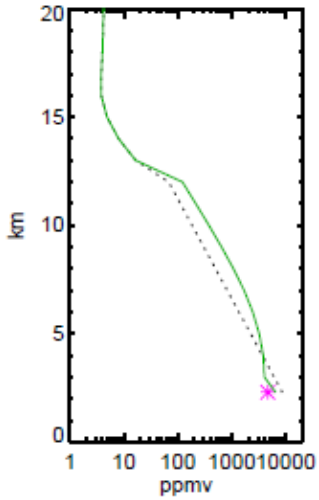
The same two reference angles on the next day

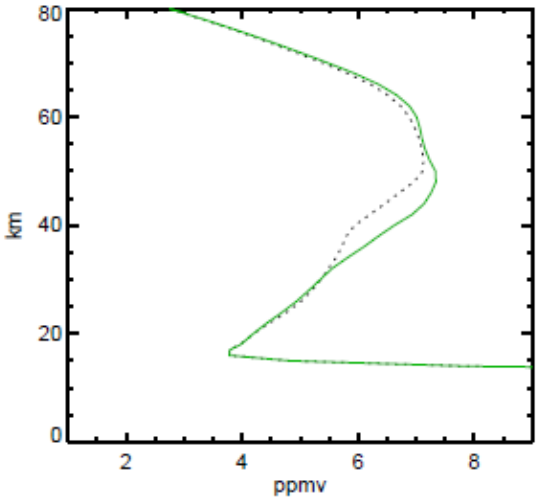
TMW4 04/24/12-04/24/12
a priori error= 0.5 0.30
tip range=45 75
horizon= 2.0
meas. sigma multiplier=0.008
<unbalance>= 0.02 mK
slope=0.00129 K/MHz
max dif for scans= 300mK
scans(odd,even) 25 25
signal angle=60.1
reference angle= 7.2
first scan=10320
last scan=10433
bar/beam= .07
use_wv= F
scale height= 2.0 km
applied up to 12.0 km
anglemod= 0.0 0.0
chi^2(m,ap,sum)=
5019.6 28.0 5047.6
tau=.0699
sigma(tau)=.00329
Tsky(70)= 53.1
Trx=217.4
tau inv=.0753
meas cont(26-80)= 0.62 0.87 0.96
0.81 0.51 0.23 0.10



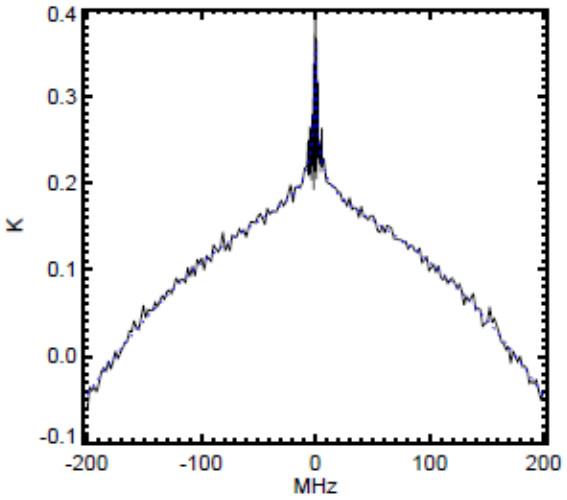


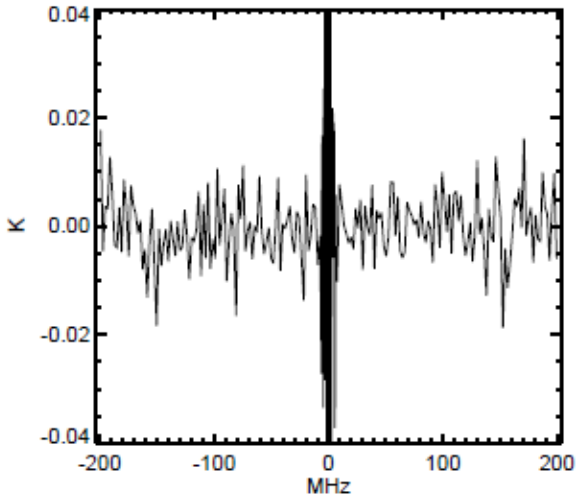


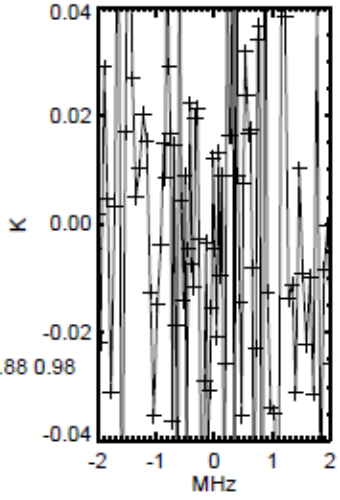


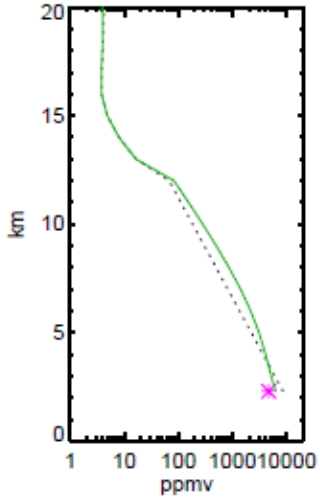


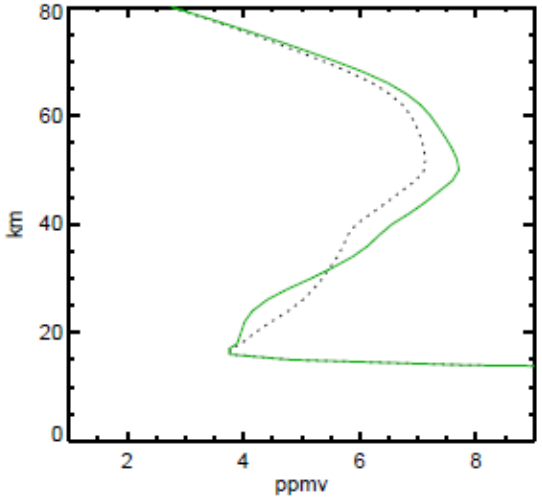
TMW4 04/24/12-04/24/12
a priori error= 0.5 0.30
tip range=45 75
horizon= 2.0
meas. sigma multiplier=0.008
<unbalance>= 0.02 mK
slope=0.00101 K/MHz
max dif for scans= 300mK
scans(odd,even) 24 24
signal angle=56.2
reference angle= 8.1
first scan=10322
last scan=10433
bar/beam= .06
use_wv= F
scale height= 2.0 km
applied up to 12.0 km
anglemod= 0.0 0.0
chi^2(m,ap,sum)=
3969.7 30.0 3999.7
tau=.0699
sigma(tau)=.00329
Tsky(70)= 53.2
Trx=217.4
tau inv=.0752
meas cont(26-80)= 0.61 0.88 0.98
0.76 0.44 0.19 0.08



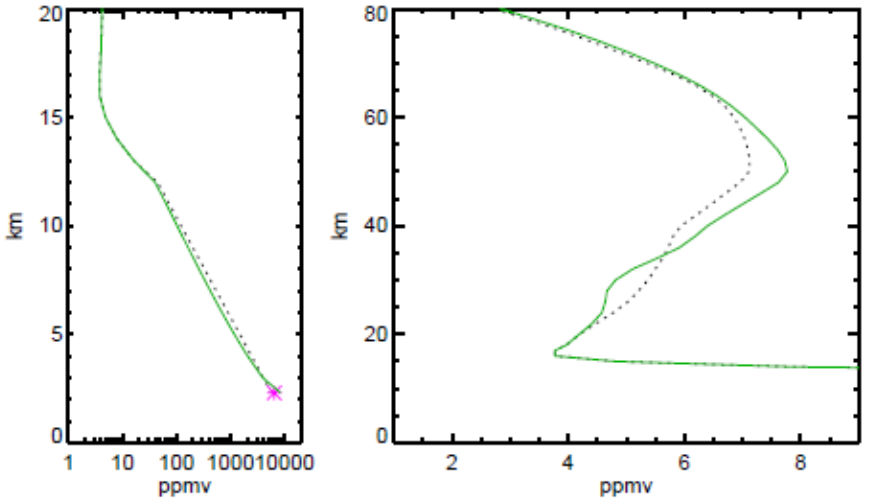




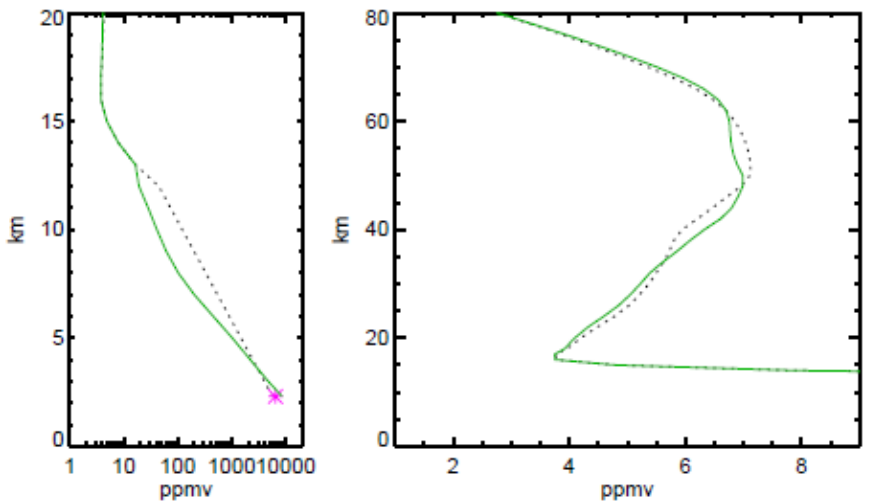




7.2°, 4/23

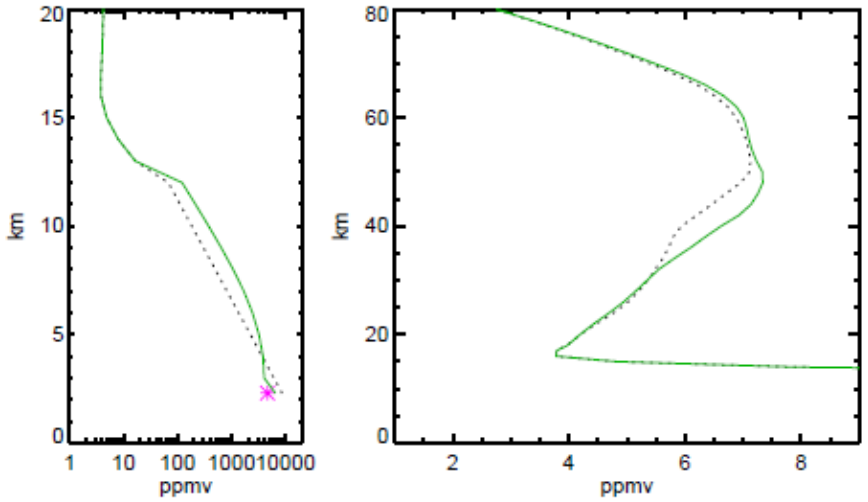


8.1°, 4/23

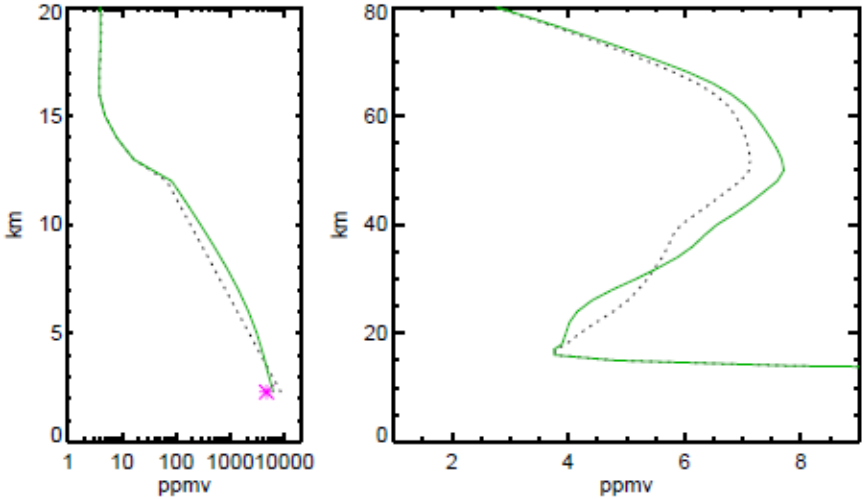


These plots provide an estimate of the error in a daily measurement. Note that there is no clear consistent offset between scans at the 2 reference angles.

7.2°, 4/24

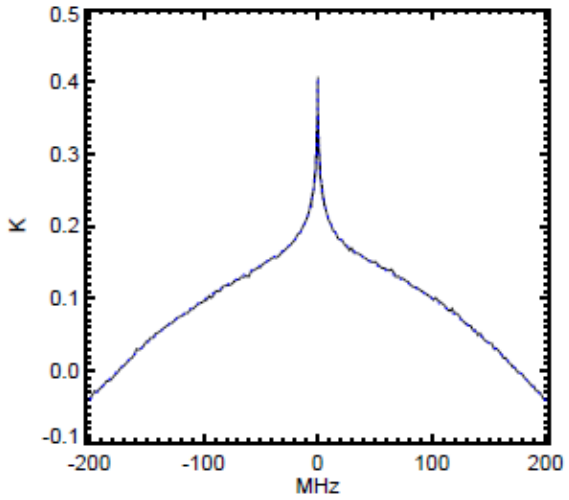


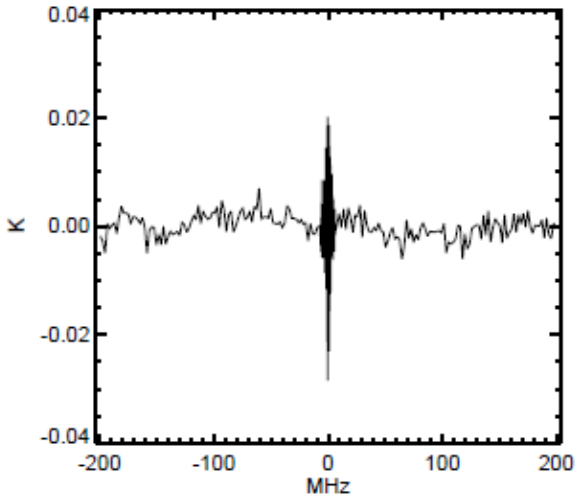
8.1°, 4/24

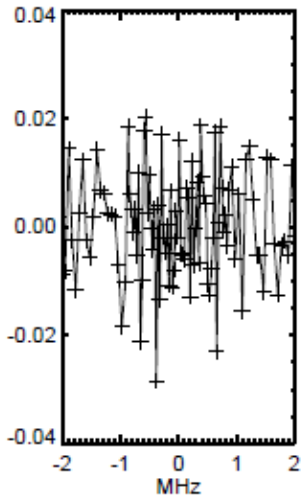


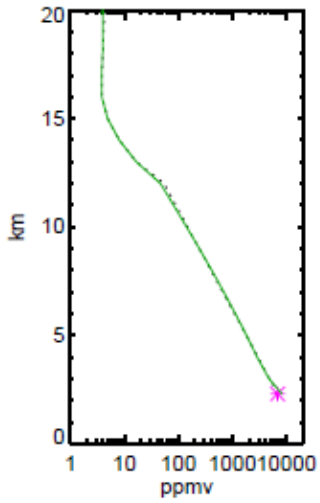
Both reference angles for a full week.

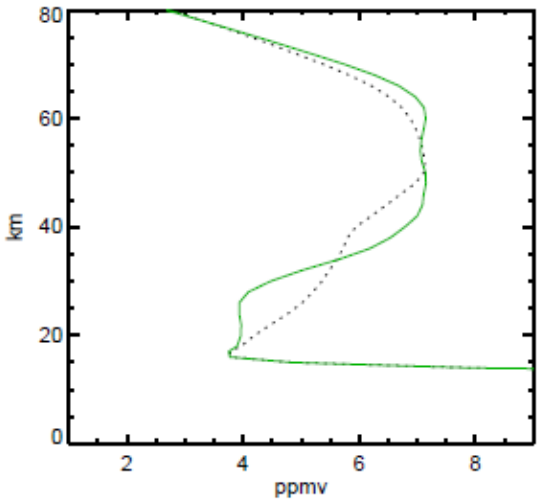
TMW4 04/21/12-04/27/12
a priori error= 0.5 0.30
tip range=45 75
horizon= 2.0
meas. sigma multiplier=0.008
<unbalance>= 0.00 mK
slope=0.00109 K/MHz
max dif for scans= 300mK
scans(odd,even) 341 339
signal angle=60.8
reference angle= 7.7
first scan= 9978
last scan=10721
bar/beam= .06
use_wv= F
scale height= 2.0 km
applied up to 12.0 km
anglemod= 0.0 0.0
chi^2(m,ap,sum)=
2206.9 33.4 2240.3
tau=.0570
sigma(tau)=.00200
Tsky(70)= 44.1
Trx=215.9
tau inv=.0568
meas cont(26-80)= 0.75 0.96
0.91 0.94 0.92 0.66 0.37





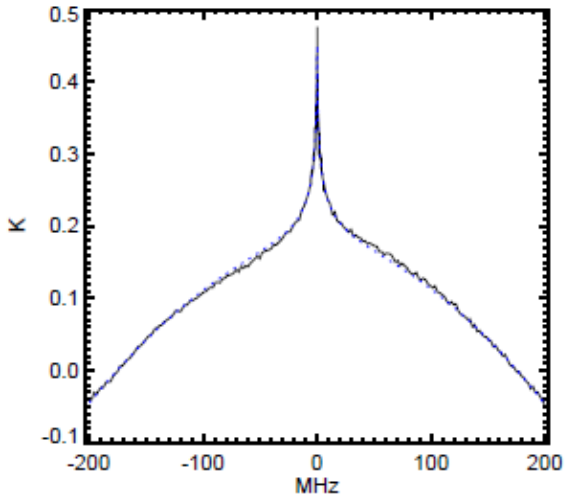


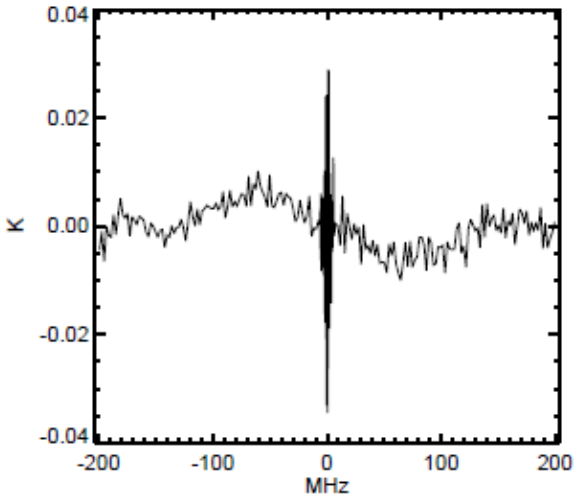


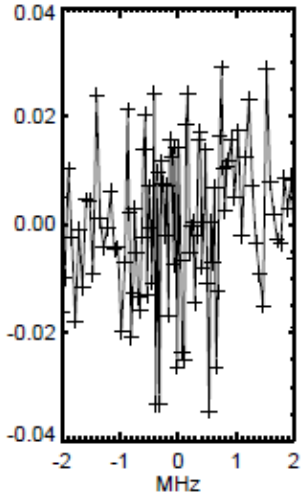


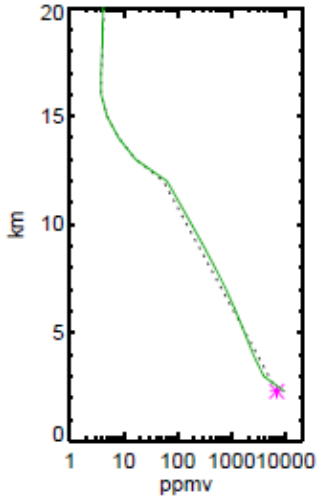
Reference angle=7.2°

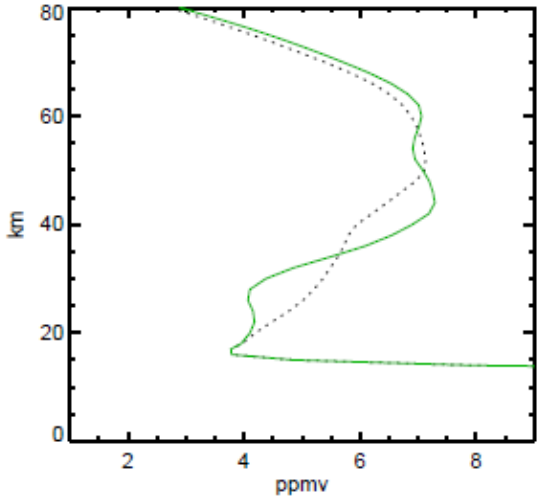
TMW4 04/21/12-04/27/12
a priori error= 0.5 0.30
tip range=45 75
horizon= 2.0
meas. sigma multiplier=0.008
<unbalance>= 0.00 mK
slope=0.00120 K/MHz
max dif for scans= 300mK
scans(odd,even) 171 170
signal angle=62.4
reference angle= 7.2
first scan= 9980
last scan=10721
bar/beam= .07
use_wv= F
scale height= 2.0 km
applied up to 12.0 km
anglemod= 0.0 0.0
chi^2(m,ap,sum)=
3656.0 37.0 3692.9
tau=.0571
sigma(tau)=.00282
Tsky(70)= 44.2
Trx=215.9
tau inv=.0557
meas cont(26-80)= 0.76 0.95
0.90 0.94 0.88 0.58 0.31





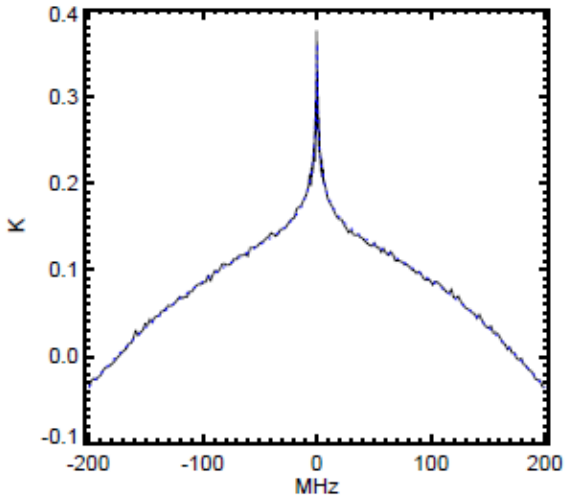


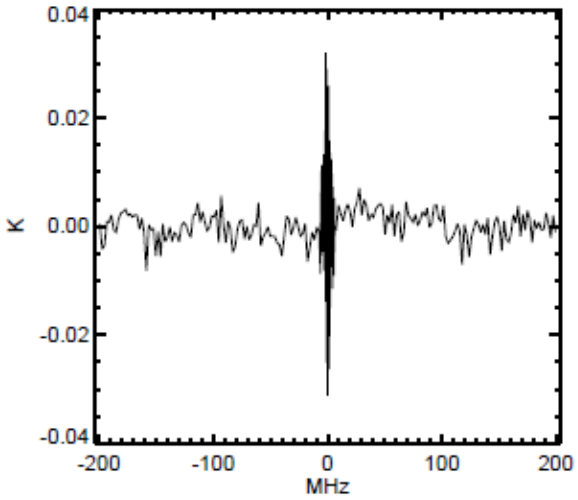


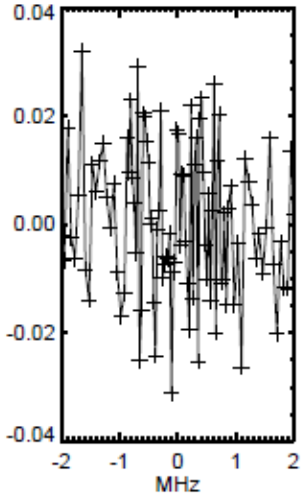


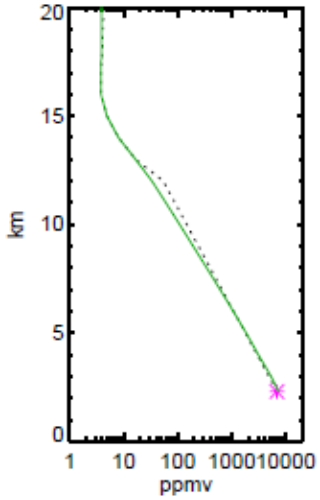
Reference angle=8.1°

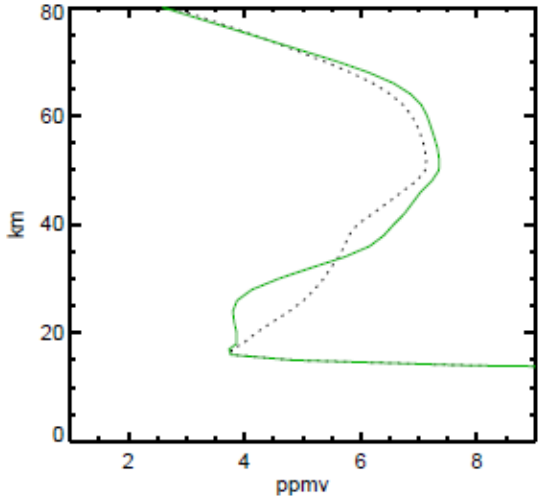
TMW4 04/21/12-04/27/12
a priori error= 0.5 0.30
tip range=45 75
horizon= 2.0
meas. sigma multiplier=0.008
<unbalance>= 0.01 mK
slope=0.00097 K/MHz
max dif for scans= 300mK
scans(odd,even) 170 169
signal angle=58.9
reference angle= 8.1
first scan= 9978
last scan=10721
bar/beam= .05
use_wv= F
scale height= 2.0 km
applied up to 12.0 km
anglemod= 0.0 0.0
chi^2(m,ap,sum)=
2582.9 29.6 2612.5
tau=.0568
sigma(tau)=.00281
Tsky(70)= 44.0
Trx=215.9
tau inv=.0573
meas cont(26-80)= 0.74 0.96
0.93 0.96 0.86 0.54 0.27





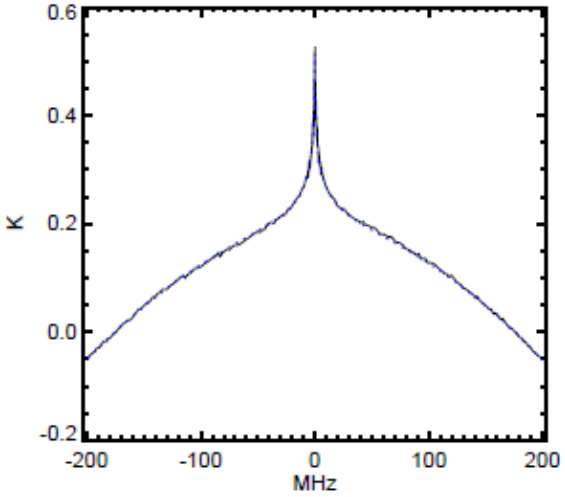


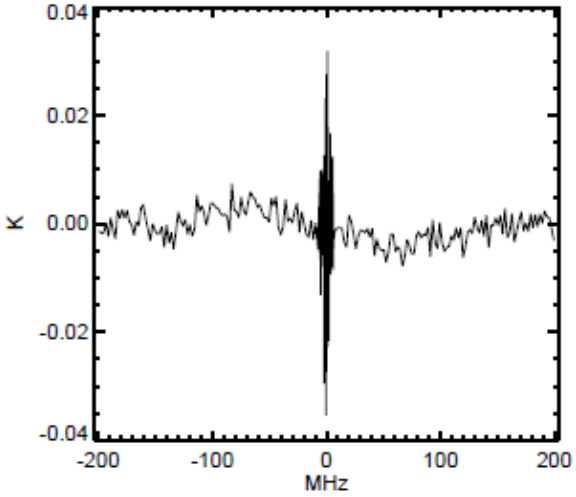


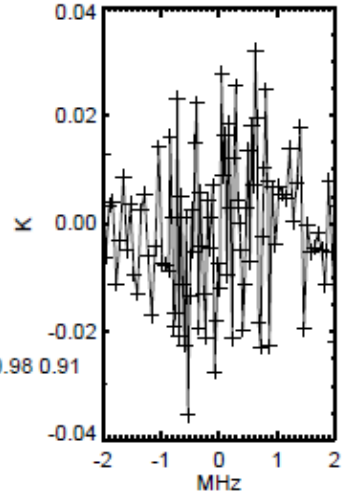


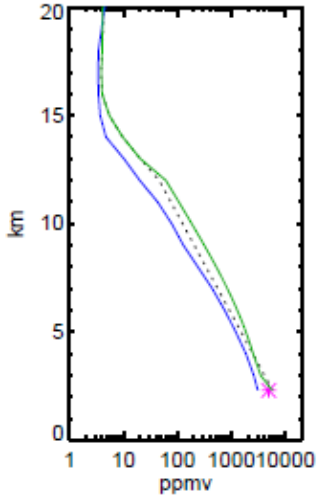
Now for the following week.
Reference angle=7.2°

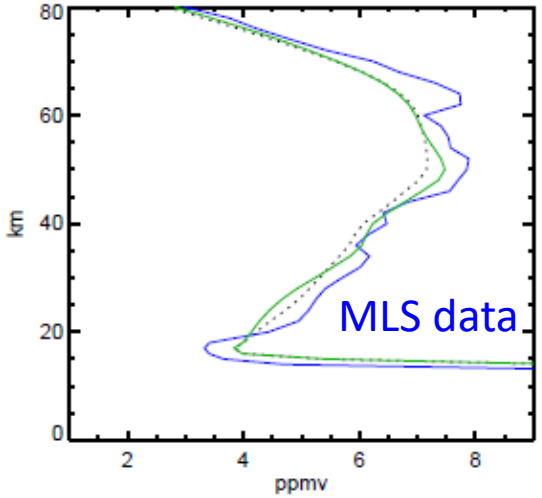
TMW4 04/28/12-05/04/12
a priori error= 0.5 0.30
tip range=45 75
horizon= 2.0
meas. sigma multiplier=0.008
<unbalance>= -0.04 mK
slope=0.00116 K/MHz
max dif for scans= 300mK
scans(odd,even) 204 205
signal angle=64.7
reference angle= 7.2
first scan=10724
last scan=11540
bar/beam= .06
use_wv= F
scale height= 2.0 km
applied up to 12.0 km
anglemod= 0.0 0.0
chi^2(m,ap,sum)=
3262.5 7.6 3270.1
tau=.0490
sigma(tau)=.00226
Tsky(70)= 38.4
Trx=215.2
tau inv=.0508
meas cont(26-80)= 0.81 0.98 0.91
0.94 0.93 0.67 0.37





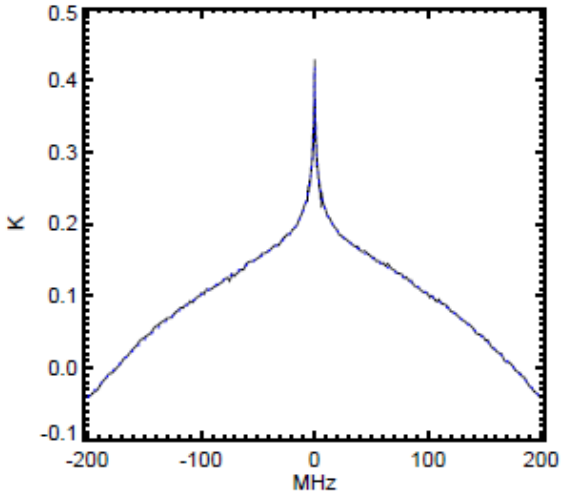


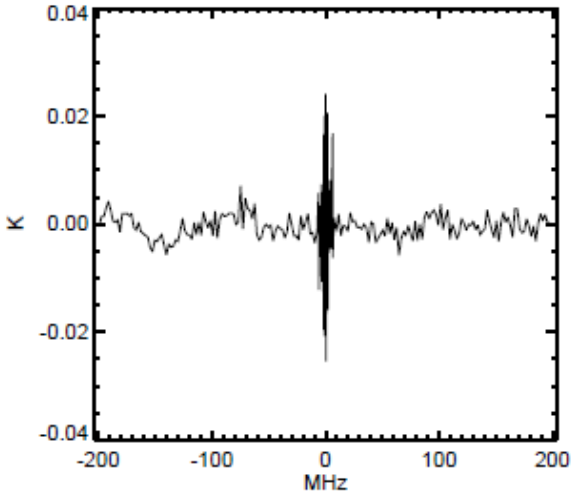


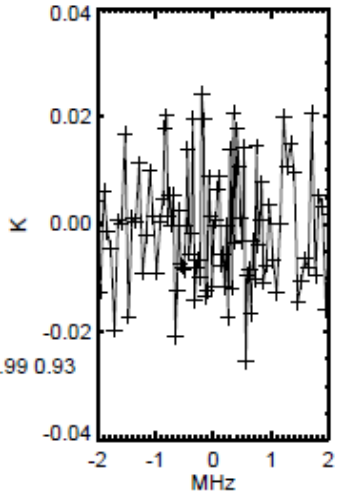


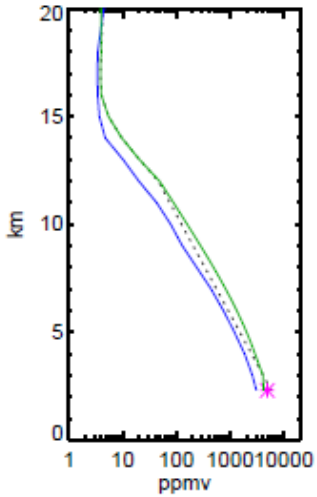
For the following week.
Reference angle=8.1°

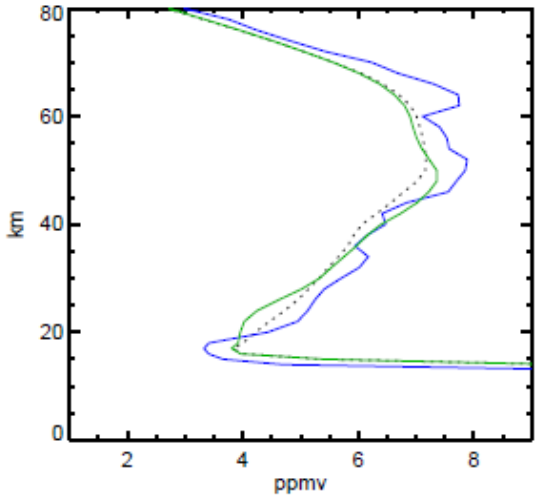
TMW4 04/28/12-05/04/12
a priori error= 0.5 0.30
tip range=45 75
horizon= 2.0
meas. sigma multiplier=0.008
<unbalance>= -0.04 mK
slope=0.00093 K/MHz
max dif for scans= 300mK
scans(odd,even) 205 205
signal angle=61.2
reference angle= 8.1
first scan=10722
last scan=11540
bar/beam= .05
use_wv= F
scale height= 2.0 km
applied up to 12.0 km
anglemod= 0.0 0.0
chi^2(m,ap,sum)=
2892.4 10.4 2902.8
tau=.0490
sigma(tau)=.00226
Tsky(70)= 38.5
Trx=215.2
tau inv=.0524
meas cont(26-80)= 0.80 0.99 0.93
0.96 0.92 0.62 0.33



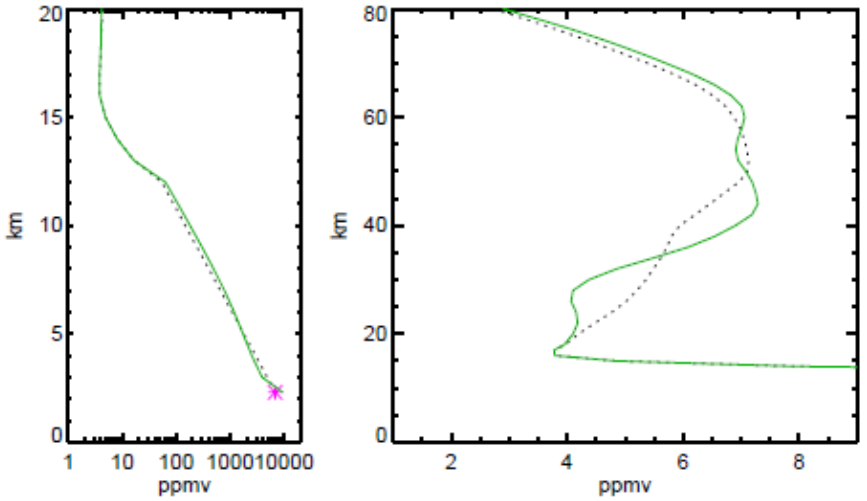




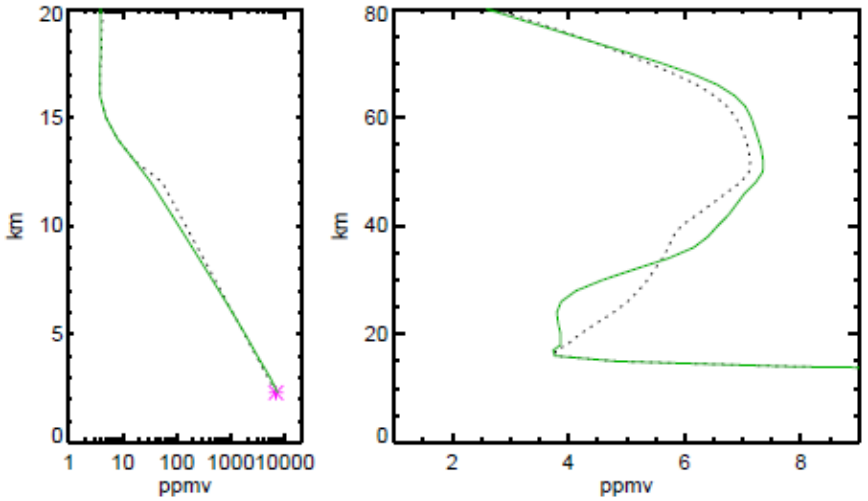




7.2°, 4/21-4/27

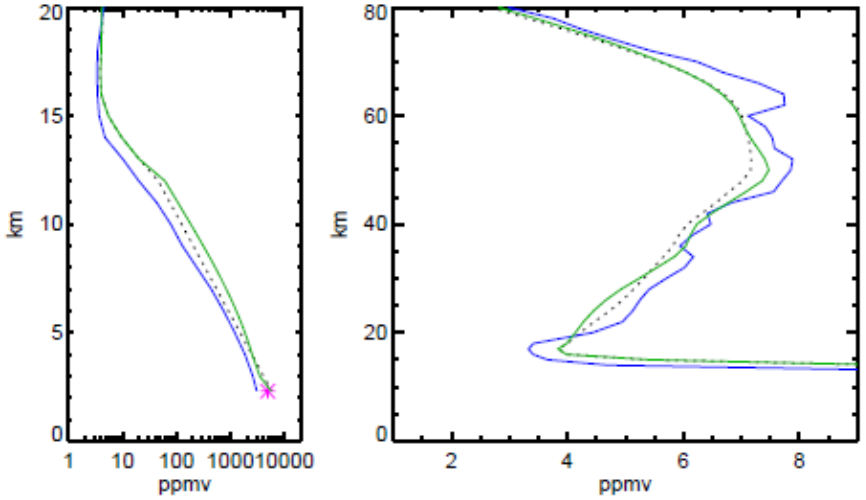


8.1°, 4/21-4/27

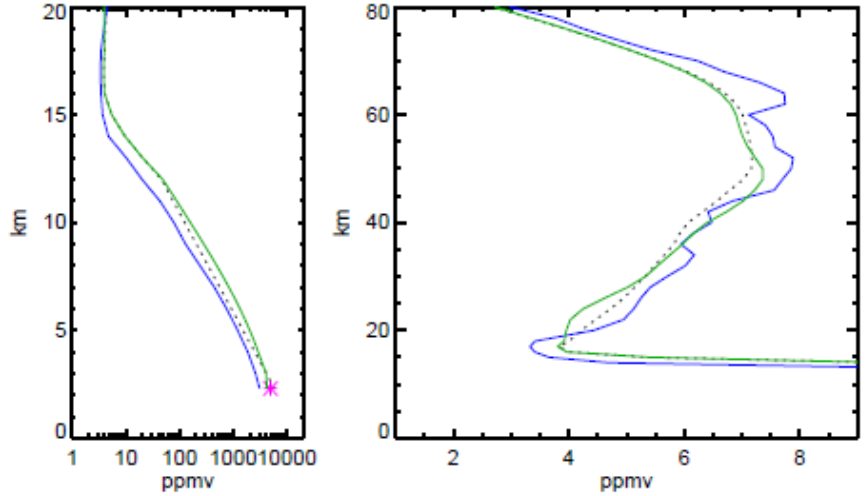


Reference angle clearly matters – but some large changes from week-to-week are apparent at both angles.

7.2°, 4/28-5/4

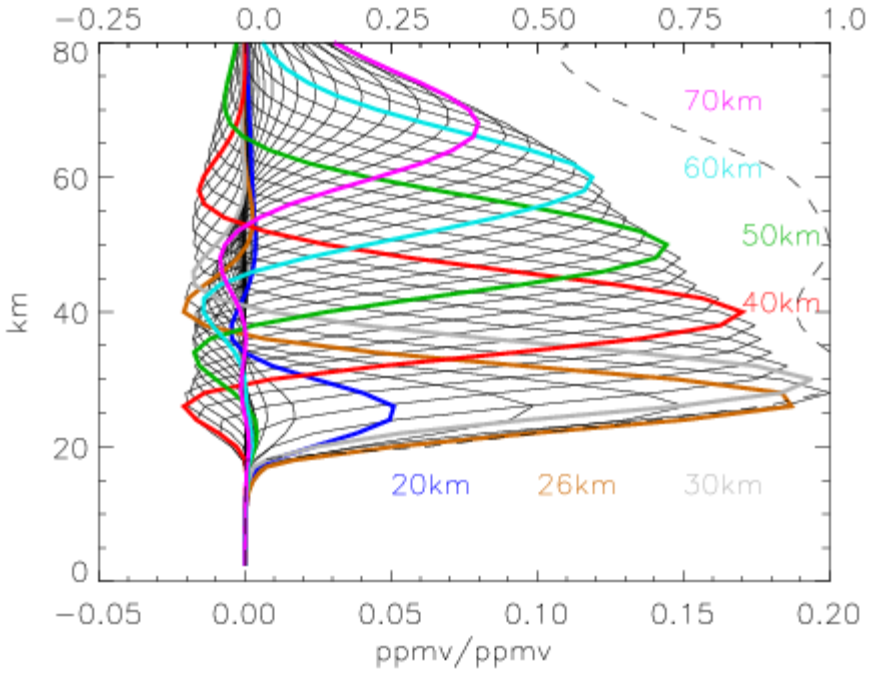


8.1°, 4/28-5/4



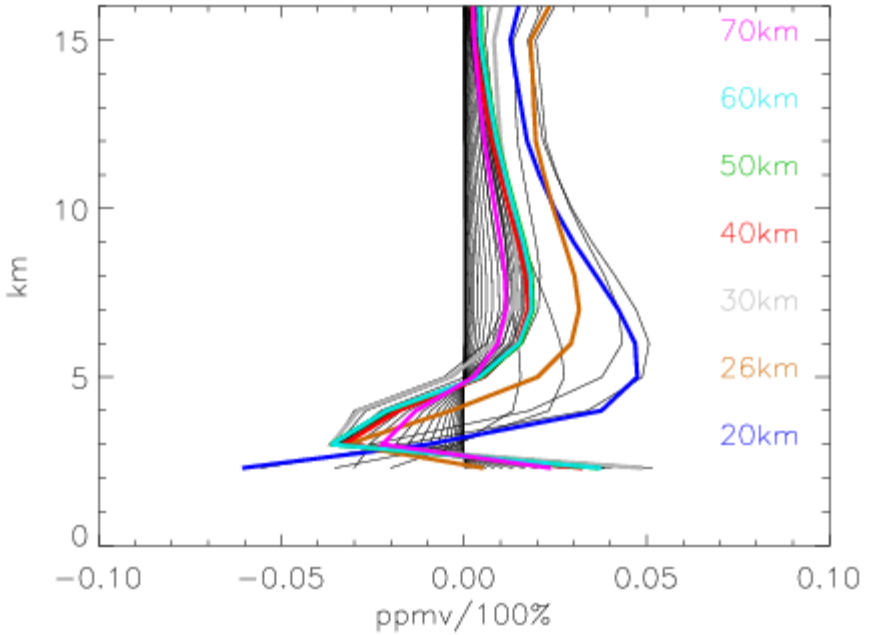
Retrieval steps

1. Add together spectra from desired period:
   a) For retrievals above ~70km use ~1 week
   b) For retrievals in mid-stratosphere use ~6 hour integrations.
2. Use tipping measurements to calculate an average tropospheric optical depth for the average spectra
3. Calculate a tropospheric a priori profile based on this tipping measurement. Assume a 2 km scale height up to some reasonable altitude (~15km). A priori uncertainty in troposphere is much larger than in middle atmosphere – tuning required.
4. Subtract the slope from the spectrum.
5. Add a constant baseline term to the spectrum. This is a single sine wave with a given amplitude, period, and phase – none of which are allowed to vary.
6. Run the retrieval from surface to 100km. Modify a priori scale height and "tropopause height" and try again if retrieval has trouble – but this is probably a sign of a baseline problem.
7. Compare retrieved tropospheric optical depth with that derived from tips. If it is very different (usually $|tau_{inv}-tau_{tip}|>\sim0.005$) then modify tropospheric profile. Watch for systematic differences.

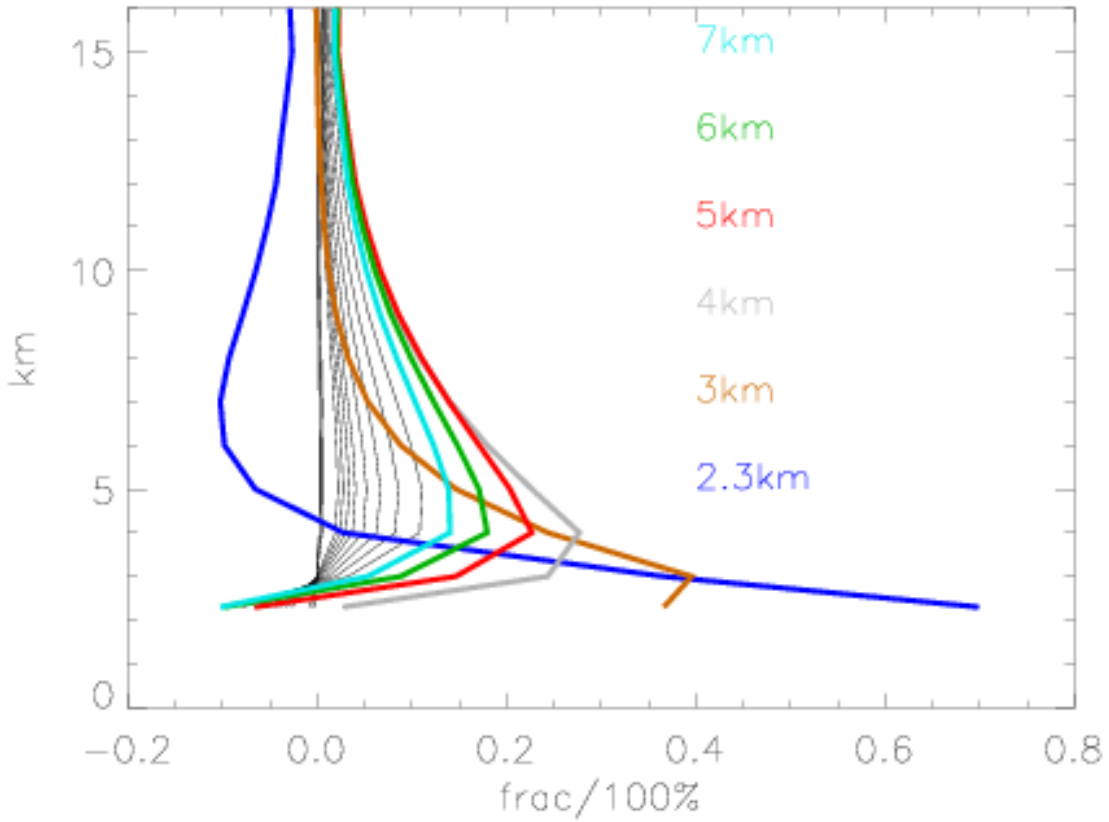


Measurement sensitivity for 24 h of WVMS measurements on 28 January 2009.

Each curve shows the response of the retrieval at the indicated altitude (shown for 17–100 km) to 1 ppmv perturbations from 0 to 80 km. The dashed curve (axis label at top) indicates the contribution of the measurement to the mixing ratio profile.

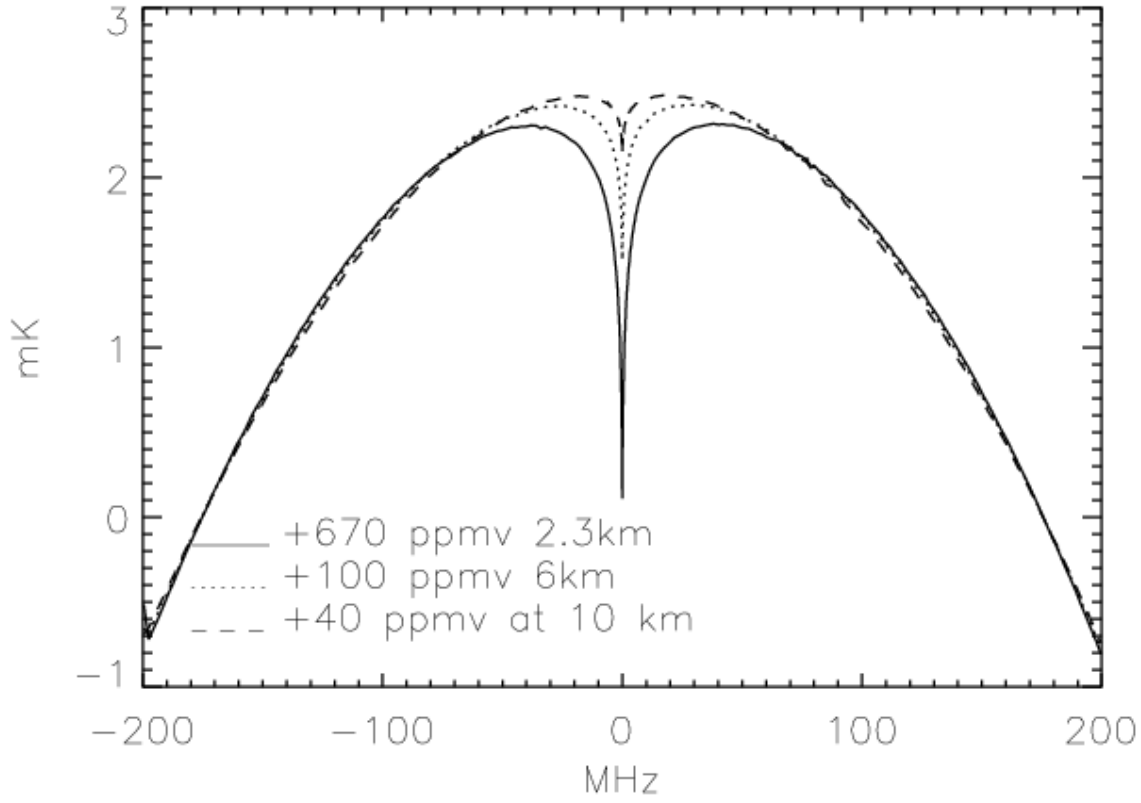


The sensitivity of the 17–100 km retrievals to perturbations of 100% at each altitude from 0 to 16 km.



Sensitivity of the retrievals for 24 h of WVMS measurements on 28 January 2009. The response is calculated from the surface to 18 km for perturbations of 100% at each altitude from 0 to 16 km.

The effect of adding water vapor at different altitudes on the spectrum used in the WVMS retrieval.



The shape of the change in emission resulting from adding water vapor at these 3 altitudes is nearly indistinguishable, but 670 ppmv has a much larger effect on the optical depth, and therefore causes much more absorption of the narrow middle atmospheric signal.

Retrieving for long-term variations

- In order to get good information about small but long-term changes the a priori contribution should be minimal. Retrievals are not necessarily optimized to get the "best guess" for that particular time period.
  - This means that individual retrievals should be noisy
  - Variations on short timescales often not geophysically meaningful

- For **26km retrievals** we currently use only 6-hour integrations which have a sensitivity >75% at 26km. This eliminates 6-hour periods with high tau and with large baseline waves from a wet bar.
  - Some scans which look reasonable are probably still affected by the wet bar
  - Show the monthly **median** of these retrievals to ensure that a few bad scans do not cause a problem