# Status of WVMS $H_2O$ measurements

Gerald Nedoluha

Mike Gomez

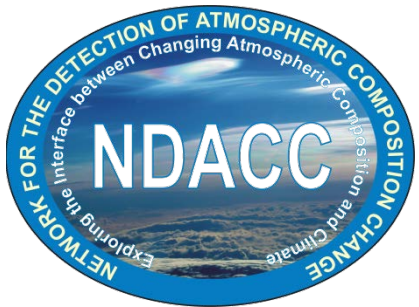




Table Mountain Jan. & Apr.

Mauna Loa Feb. & Aug.

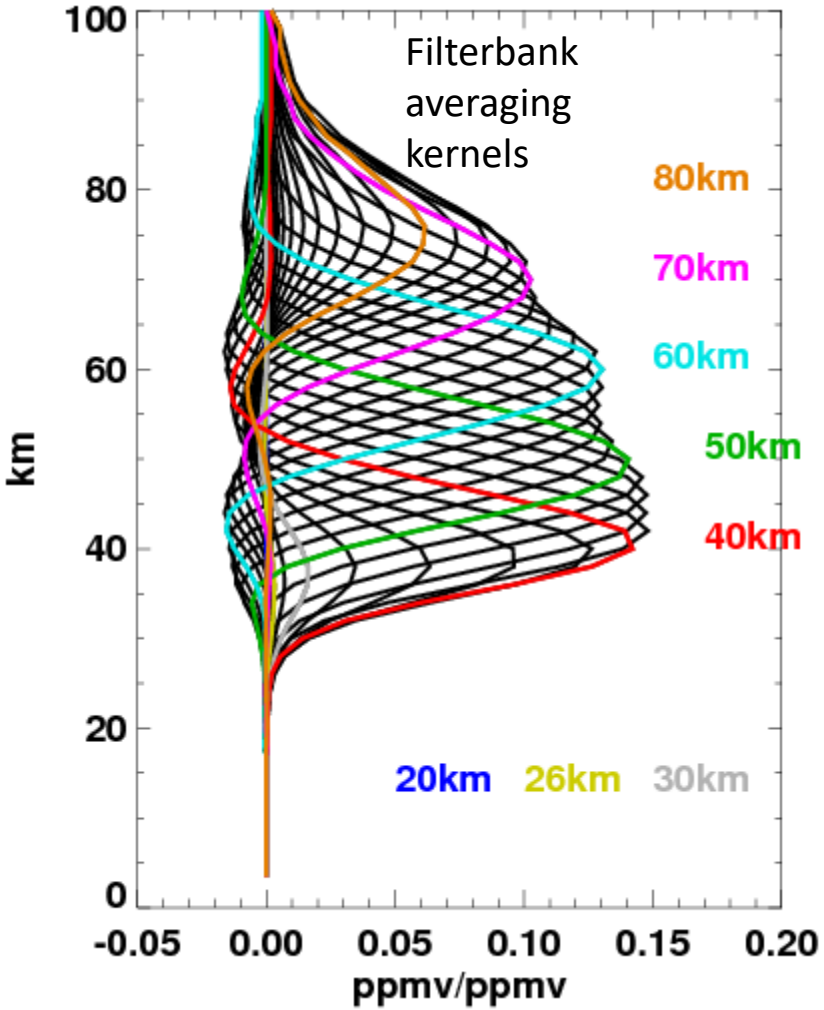
4 new WVMS instruments currently operating at 3 sites
Table Mountain: WVMS4 since 2010

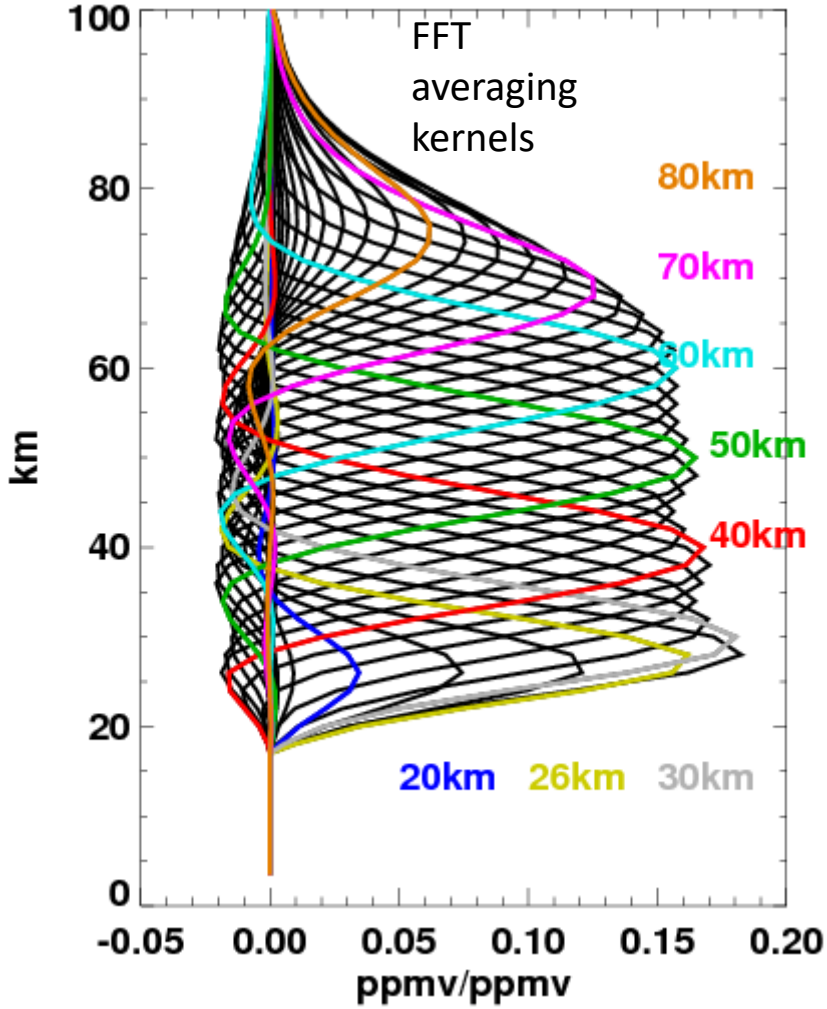
Mauna Loa:
WVMS3 replaced in 2010
WVMS5 (experimental)
WVMS6 (operational)

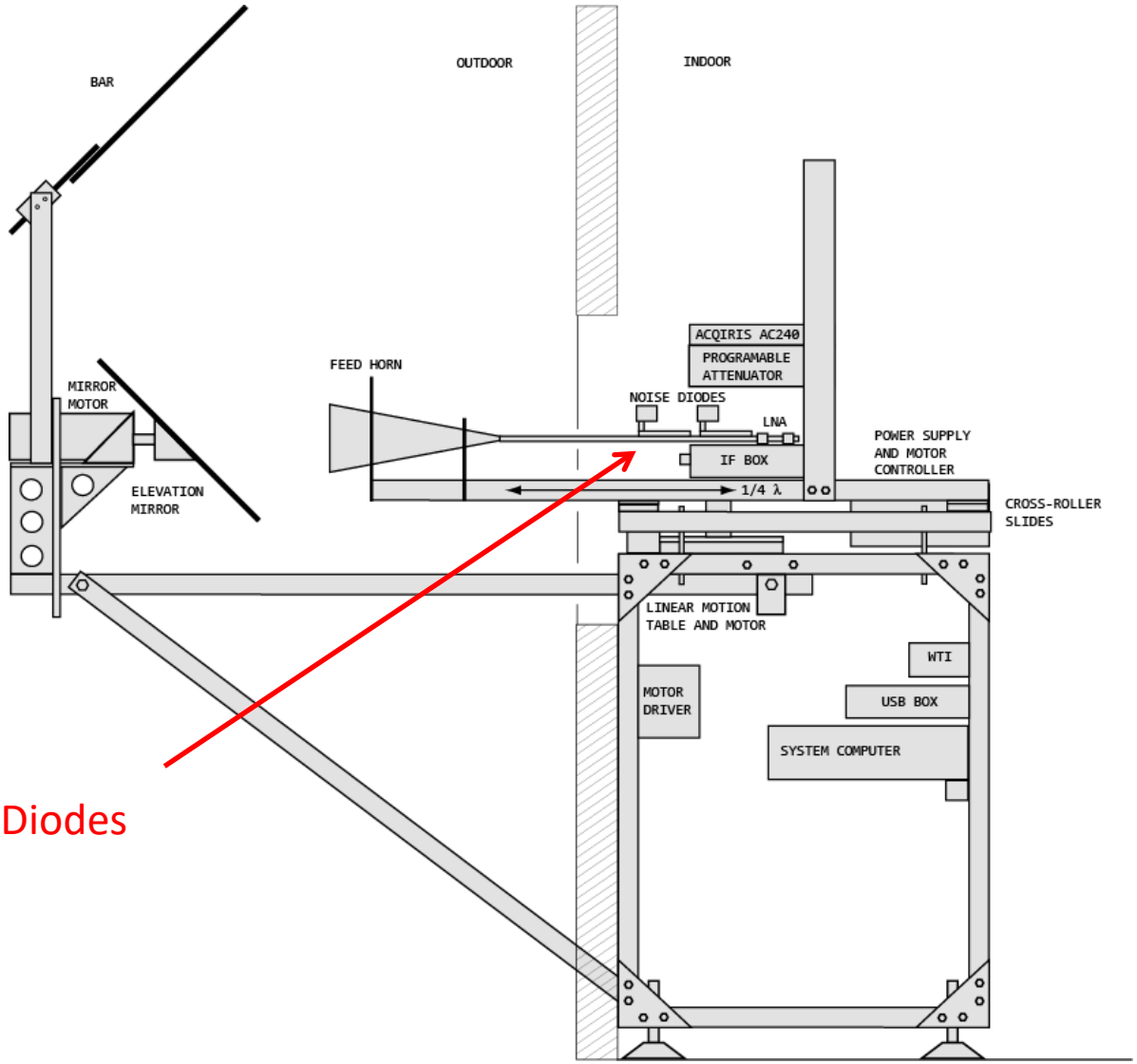
Lauder:
WVMS7 (replaced WVMS1 in 2011)

Lauder
May

•Can we extend the long-term mesospheric database at Mauna Loa in a consistent manner and still take advantage of the FFT spectrometer?
•FFT and Filterbank have similar sensitivity from 50km-80km.
•FFT is much more sensitive below 40km.
•Kernels vary somewhat from retrieval to retrieval depending on tropospheric optical depth.



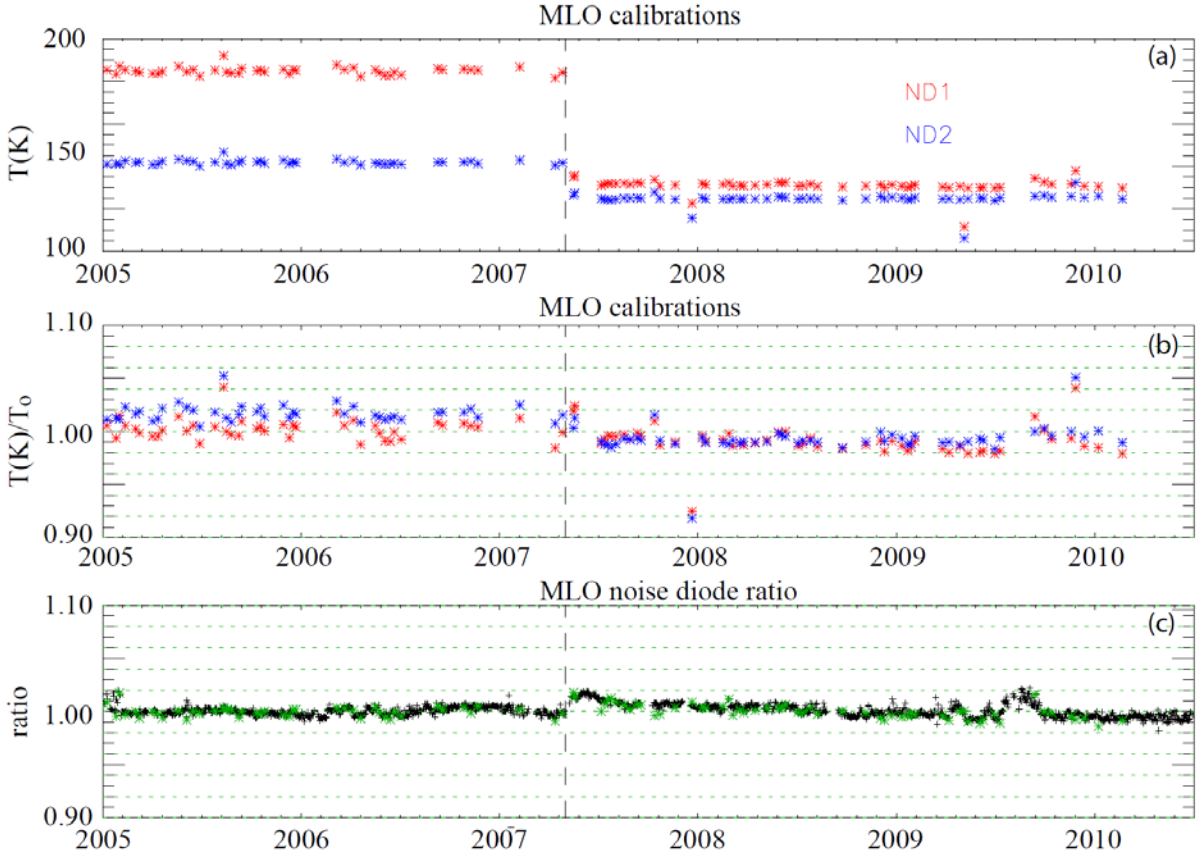






Noise Diodes

# Long-term consistency relies on consistency of noise diodes

## Jump in 2007 from replacement of waveguide couplers




**Top:** Calibrated temperature of primary noise diode (ND1) and secondary noise diode (ND2) on WVMS3, as obtained by an external hot-cold calibration.

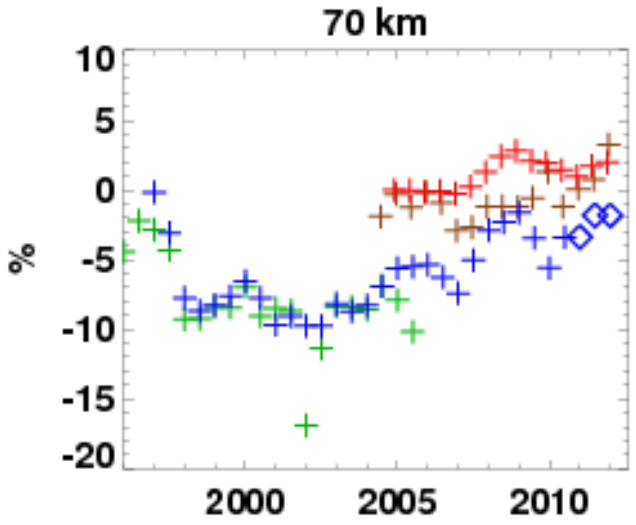
**Middle:** Normalized temperatures from top panel to better show correlation of external calibrations. => Variation in cals is primarily not caused by ND variations.

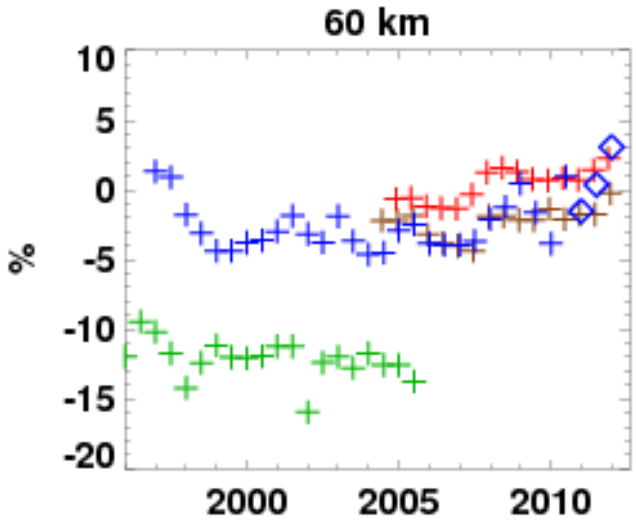
**Bottom:** Ratio of ND1/ND2 (normalized as in middle panel) from the external calibration. Daily median of the ratio of ND1/ND2 (normalized as in middle panel), as determined from the **internal noise diode comparison.**

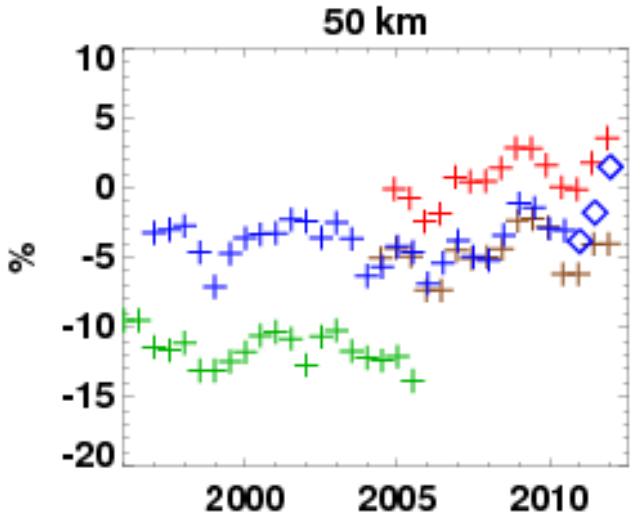
# WVMS5

Mauna Loa Hawaii (19.5°N, 155.6°W) Elevation 11,135 ft.

Transition to new instrument at Mauna Loa

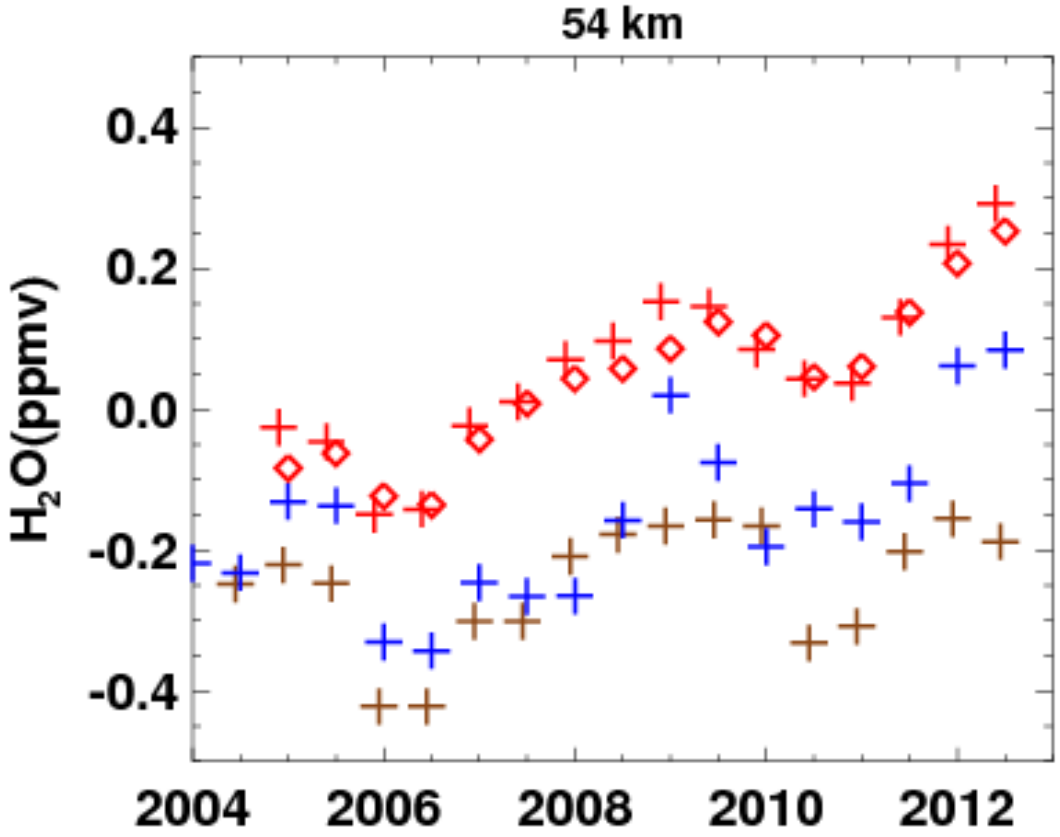



WVMS MLS ACE MIPAS
New WVMS(◇)

**At Mauna Loa: WVMS(+) MLS(+) ACE(+)**
**MLS(◇) (50S-50N; 0.46 hPa; not convolved)**




A single ground-based microwave site can do a pretty good job of tracking global changes in water vapor at this altitude.

# WVMS4

Table Mountain California (34.4°N, 242.3°E) Elevation 7486 ft.

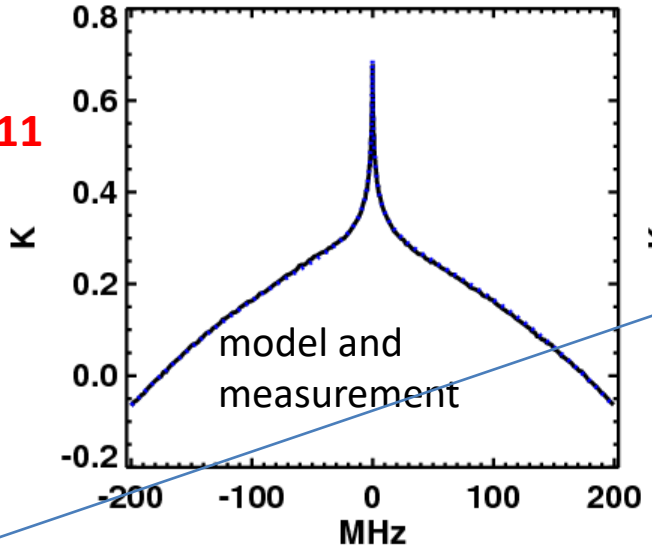
**Spectrum and retrieval from Table Mountain June 1-7, 2011**

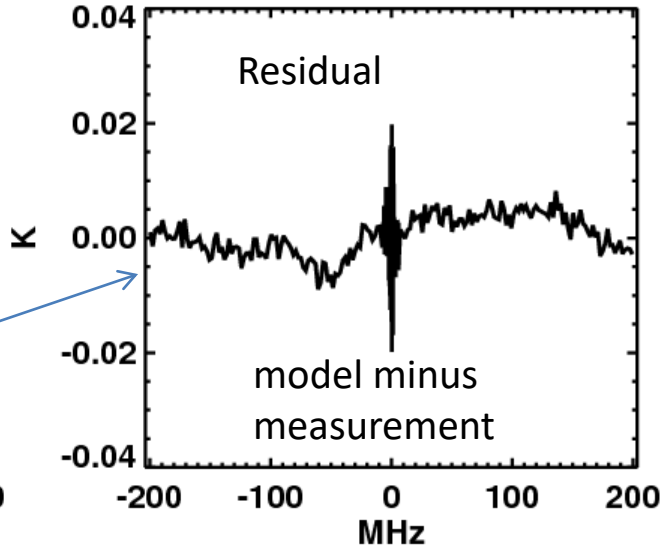
All microwave measurements have some instrumental baseline structure.

Getting a residual this clean over 400 MHz requires an incredible amount of work.

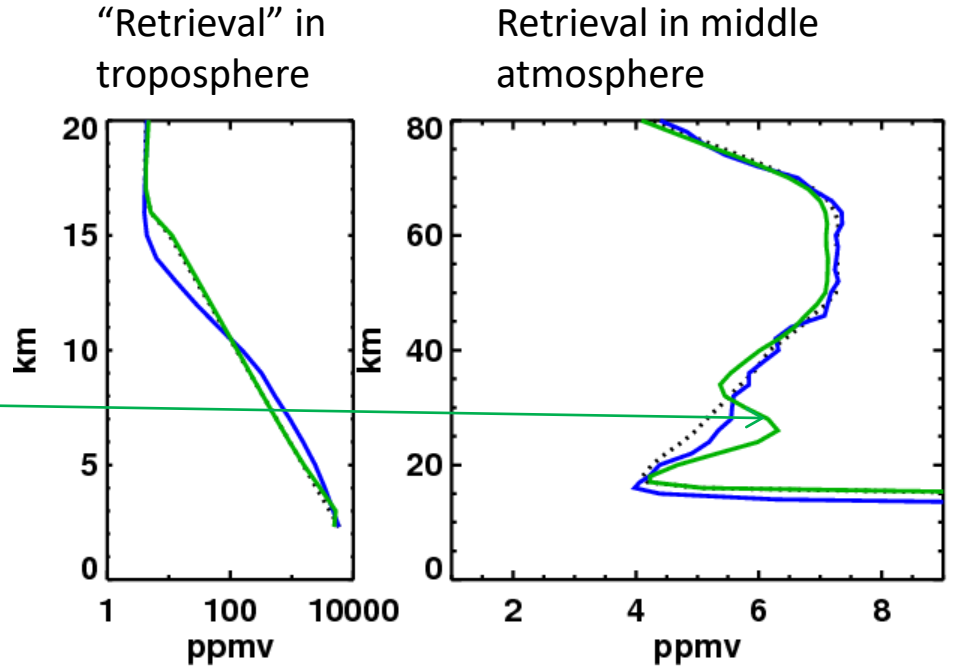
The effect of instrumental baseline structure on the retrieval increases with decreasing altitude.

If we assume in the retrieval that there is no instrumental baseline we get a bump in the retrieved profile at ~26km.

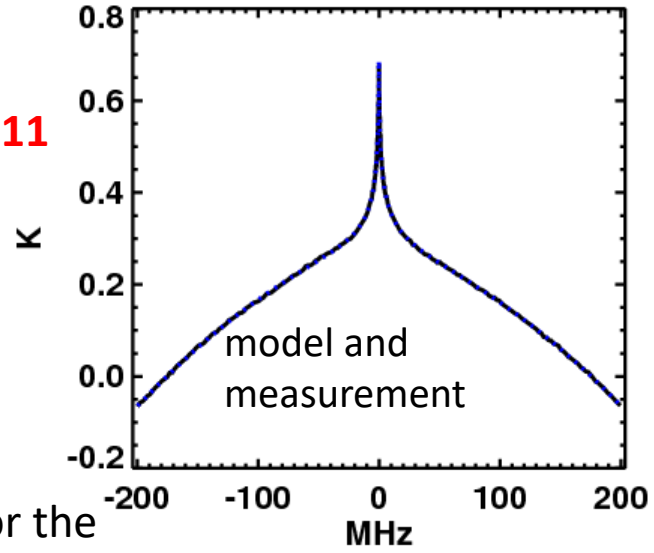


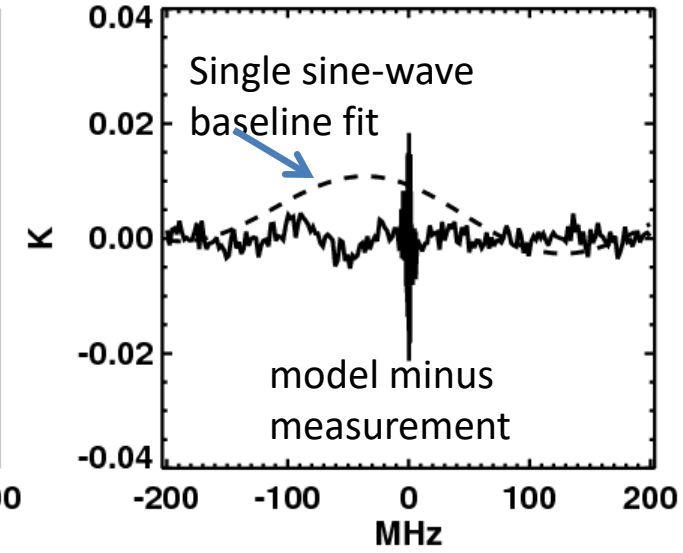




WVMS MLS (unconvolved)
a priori (dotted)



**Spectrum and retrieval from Table Mountain June 1-7, 2011**



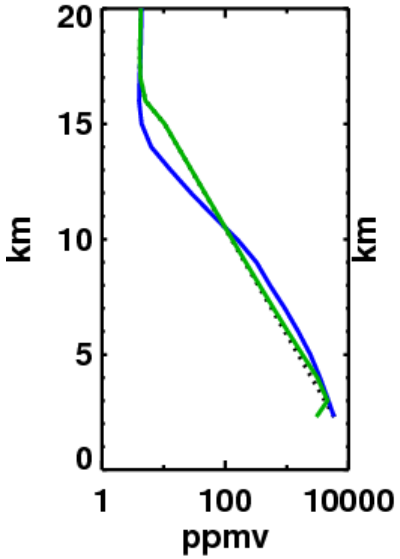




Now, fit a single sine-wave for the baseline term.

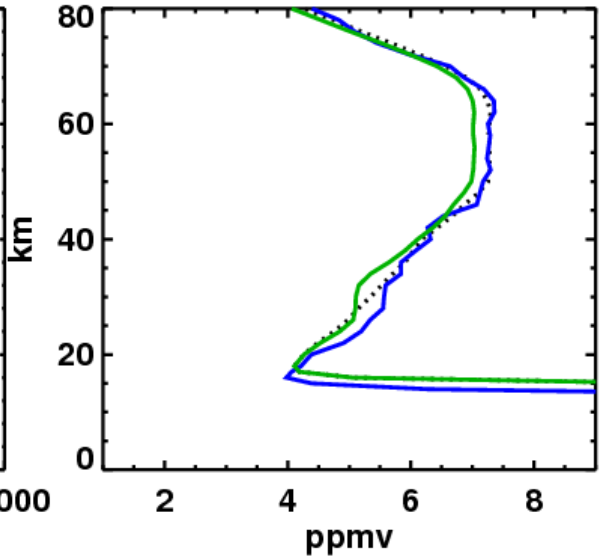
Retrieval looks good, but the measurement contribution to retrieval is only:
26km: 40%
30km: 41%

WVMS MLS (unconvolved)
a priori (dotted)

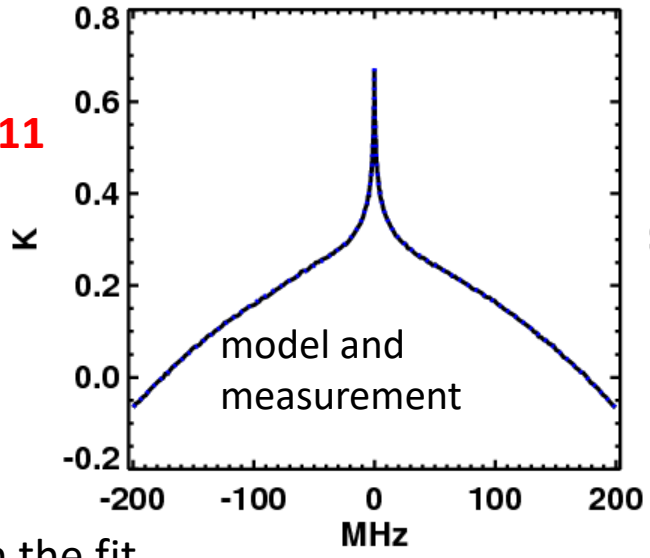
"Retrieval" in troposphere

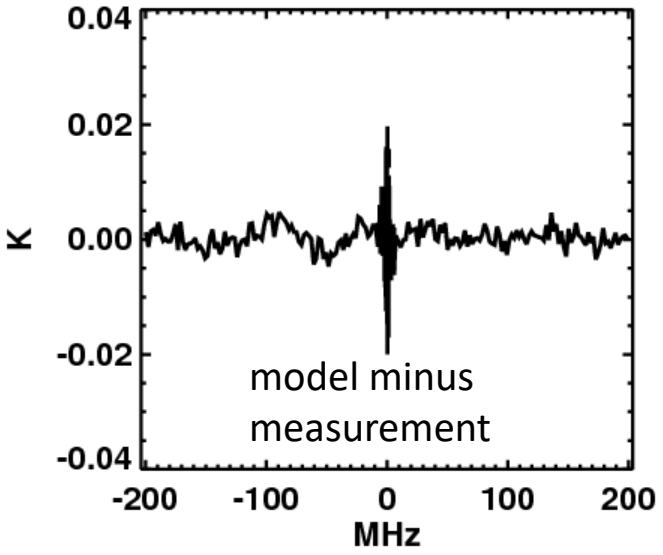



Retrieval in middle atmosphere



**Spectrum and retrieval from Table Mountain June 1-7, 2011**




Apply the baseline term from the fit to the measurements before retrieving.

Now the measurement contribution to retrieval is:

26km: 78%

30km: 93%

We have now "corrected" the measurement to make retrievals at 26km look good, so this is no longer an absolute measurement.

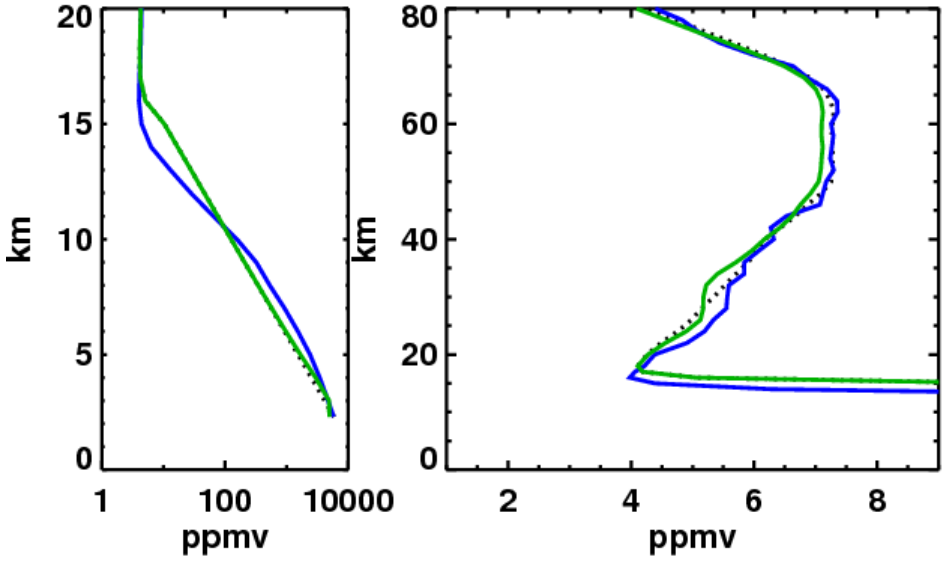
However, if the baseline is constant, we can now measure variations.

WVMS MLS (unconvolved)

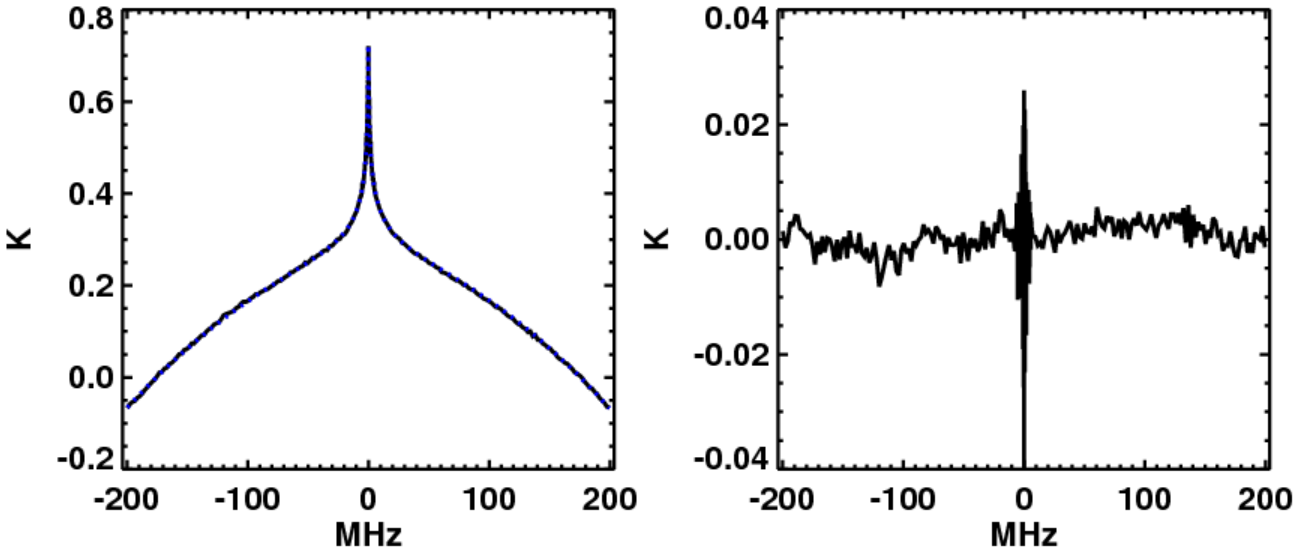
a priori (dotted)

"Retrieval" in troposphere

Retrieval in middle atmosphere



**Spectrum and retrieval from Table Mountain Dec. 11-16, 2010**

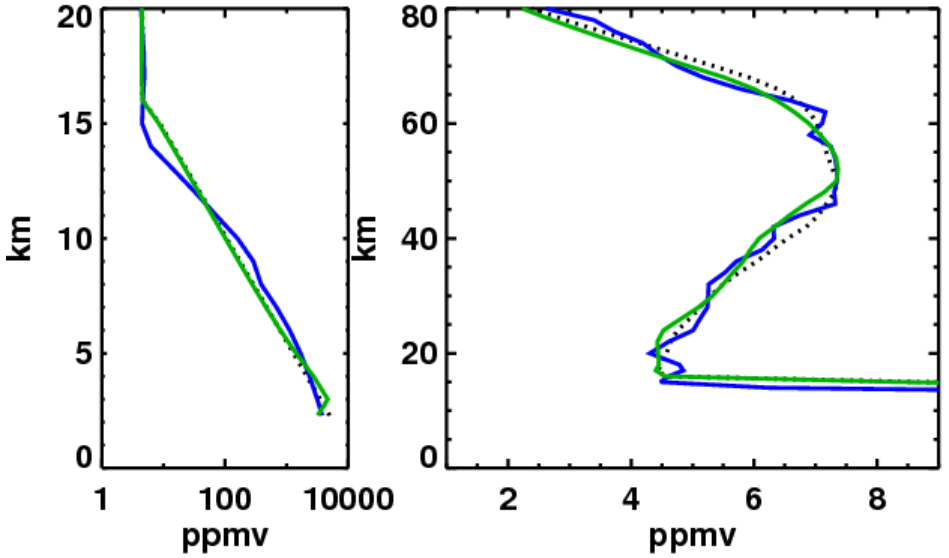



Apply the baseline term from the June fit to these December measurements before retrieving.
Now the measurement contribution to retrieval is:
26km: 89%
30km: 96%
Residual and retrievals look good using June baseline.
=> Constant baseline assumption is appropriate.

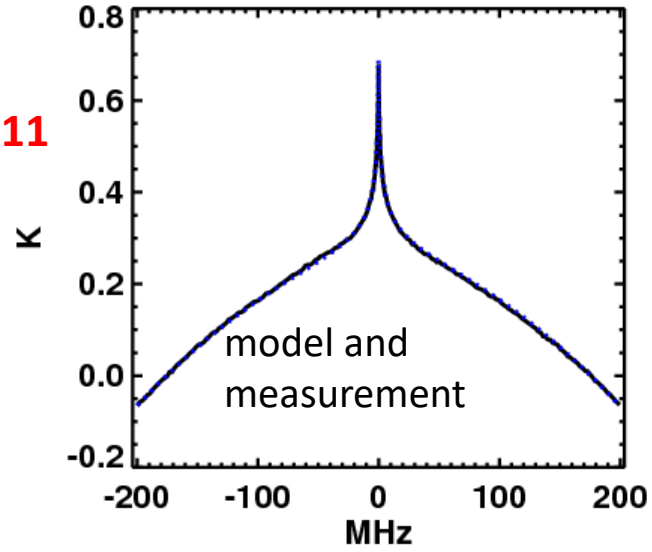
WVMS MLS (unconvolved)
a priori (dotted)

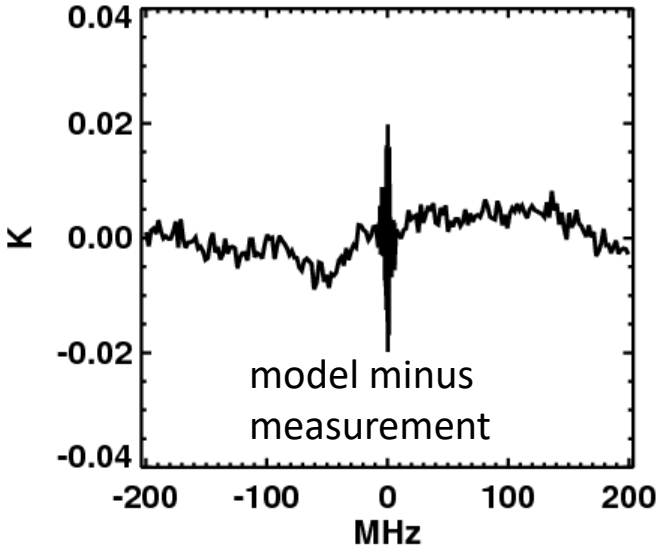
"Retrieval" in troposphere

Retrieval in middle atmosphere



**Spectrum and retrieval from Table Mountain June 1-7, 2011**



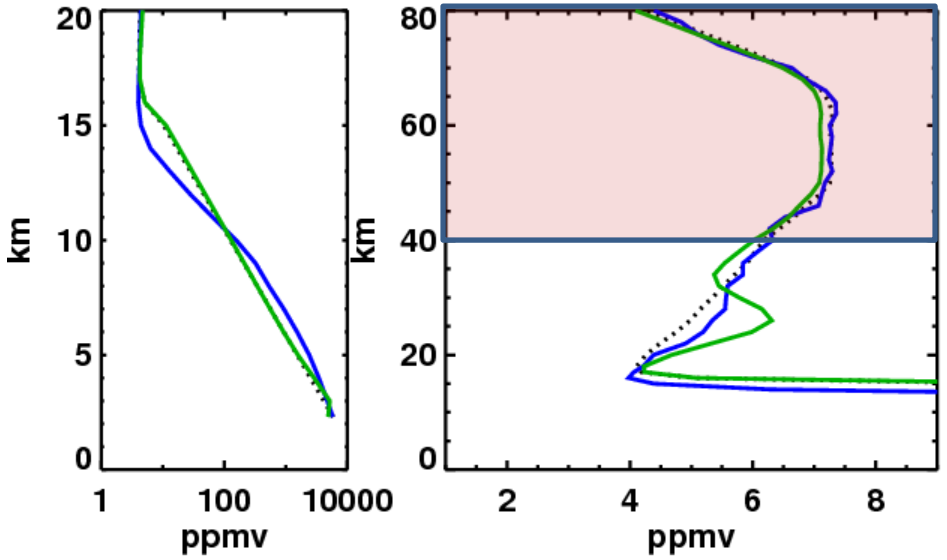

Note how insensitive the measurements above ~40km are to this baseline correction. (Compare with next slide)

Previous WVMS retrievals with filterbanks never went below 40km.

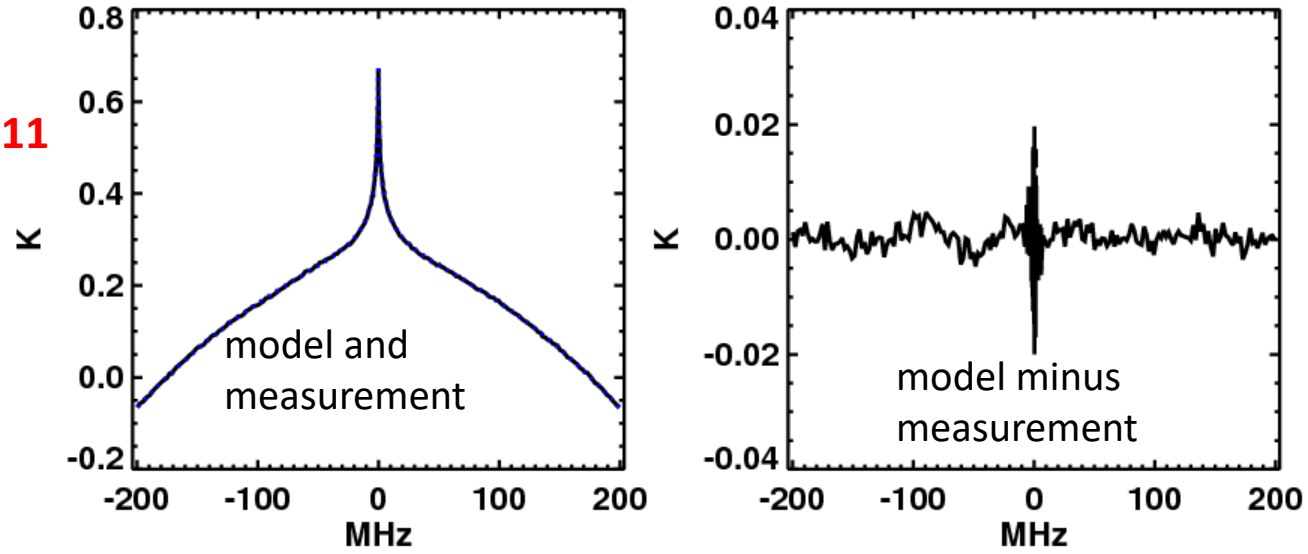
WVMS MLS (unconvolved)
a priori (dotted)

"Retrieval" in troposphere

Retrieval in middle atmosphere



**Spectrum and retrieval from Table Mountain June 1-7, 2011**



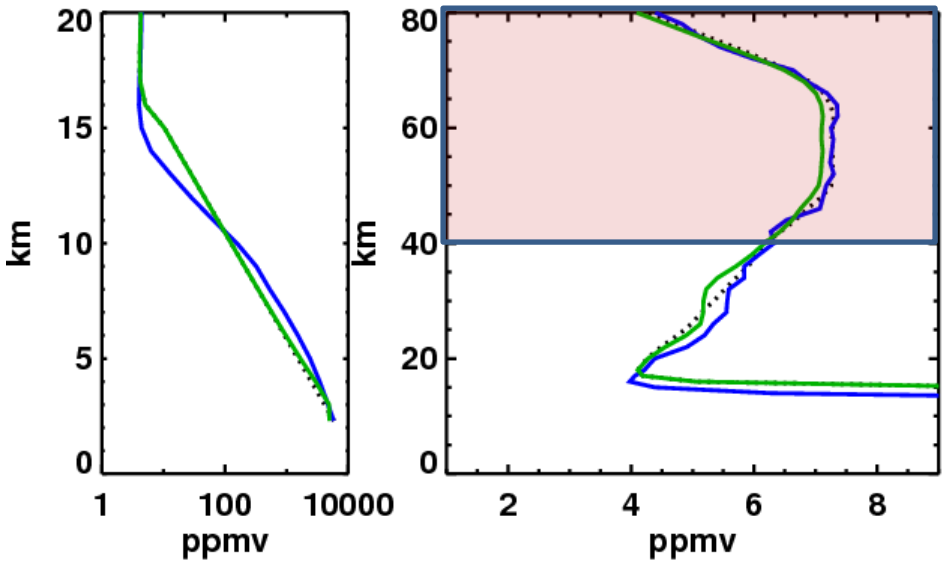

The "next slide"

WVMS MLS (unconvolved)

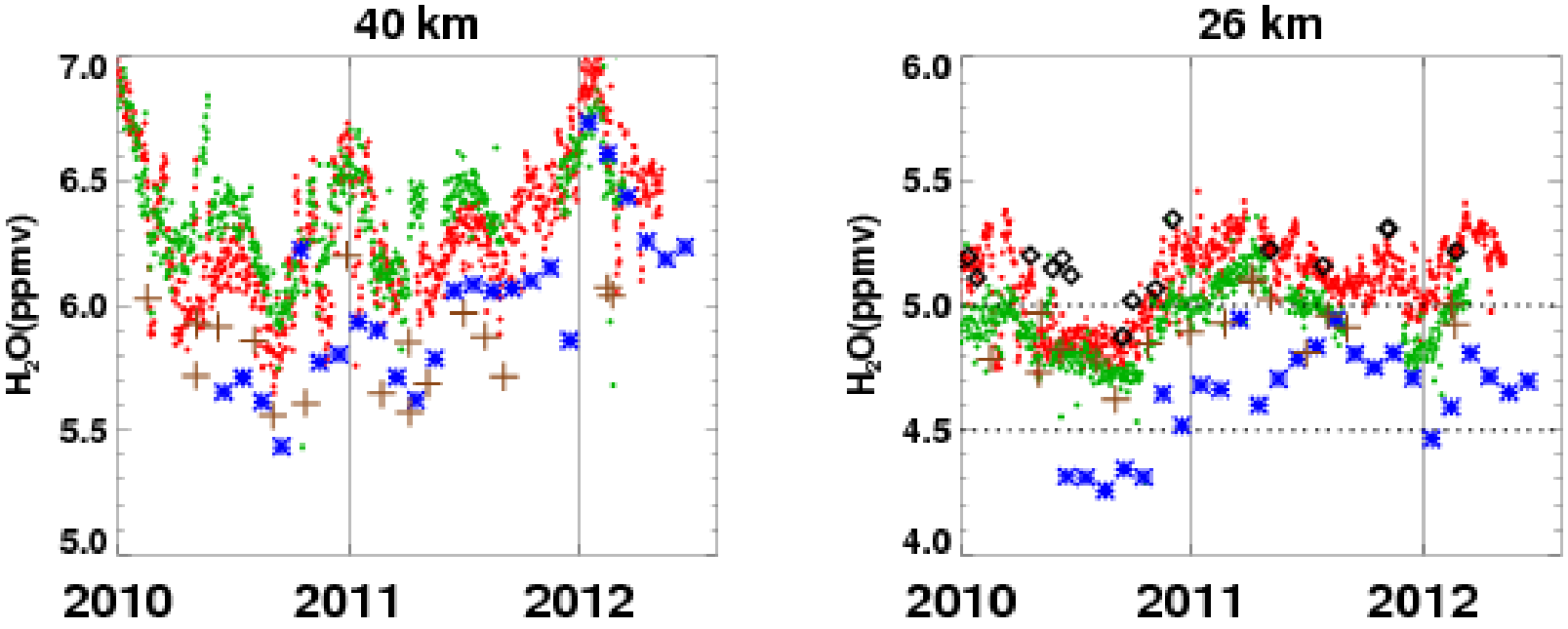
a priori (dotted)

"Retrieval" in troposphere

Retrieval in middle atmosphere



# Table Mountain since 2010




WVMS MLS ACE MIPAS Boulder Balloons

# WVMS6

Mauna Loa Hawaii (19.5°N, 155.6°W) Elevation 11,135 ft.

WVMS6

WVMS5

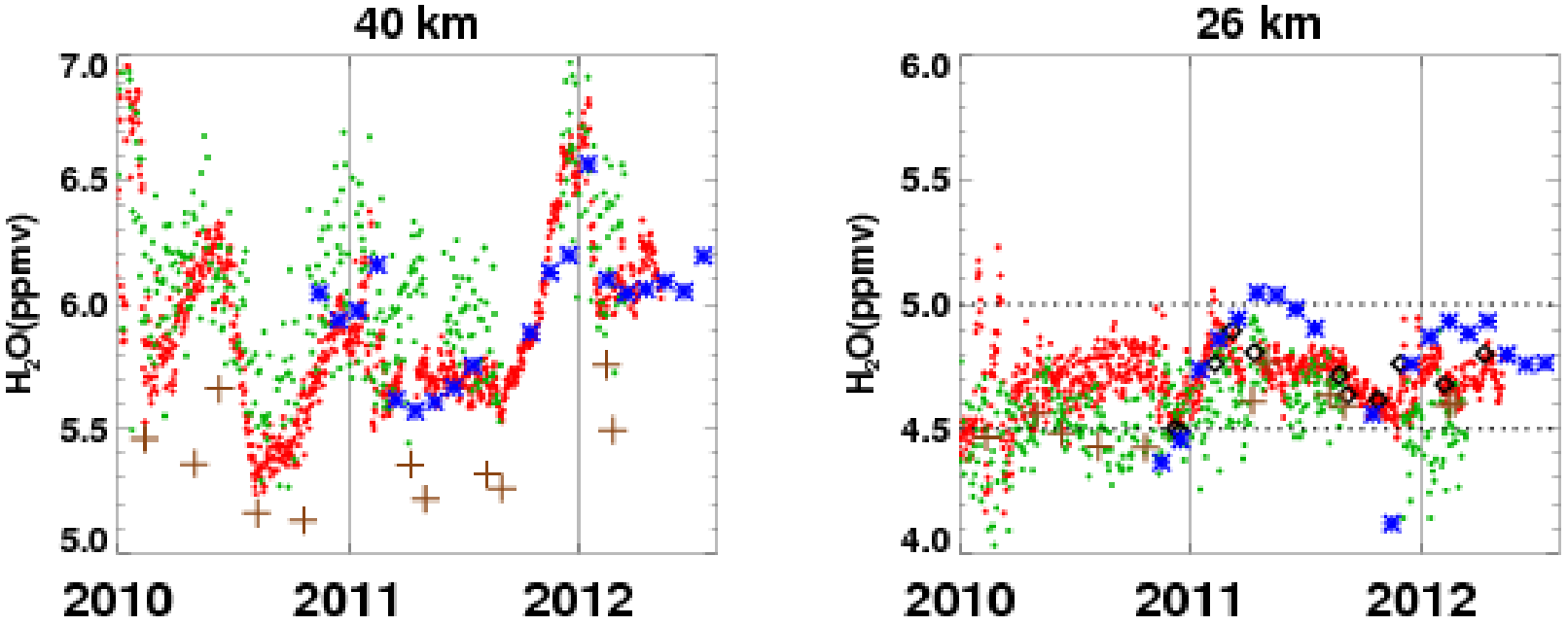
WVMS6 is now the long-term instrument with the best feedhorn.

Mauna Loa NDACC
microwave building

## Mauna Loa since 2010 (good feedhorn)

- There was a baseline change in November 2011
- The constant baseline term was recalculated

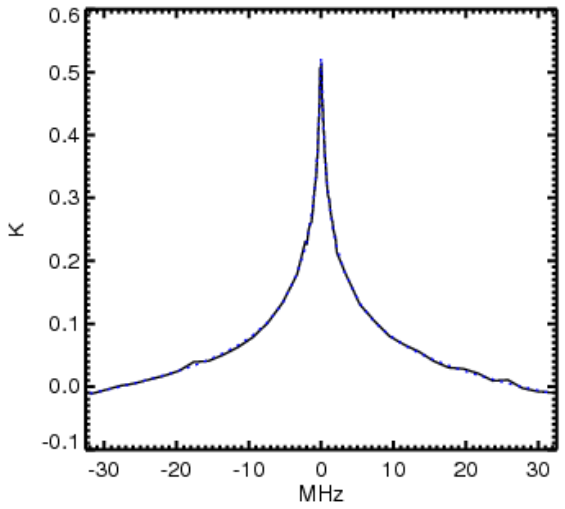
=> 26km data before and after November 2011 are not directly comparable.

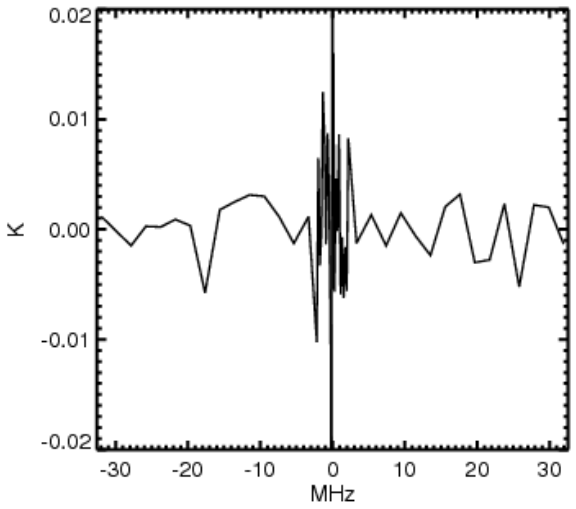


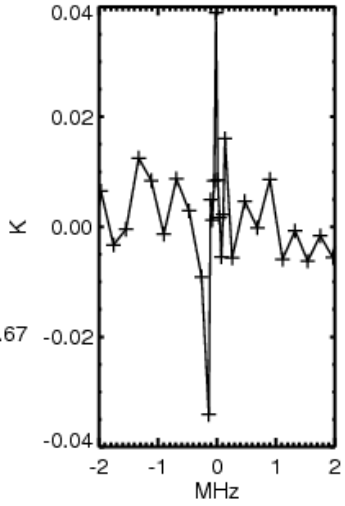

MLS MIPAS ACE WVMS Balloons (Hilo)

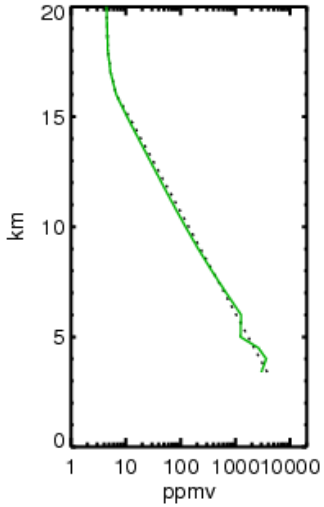
# WVMS5 (Univ. of Navarra feedhorn)– inner 60 MHz only

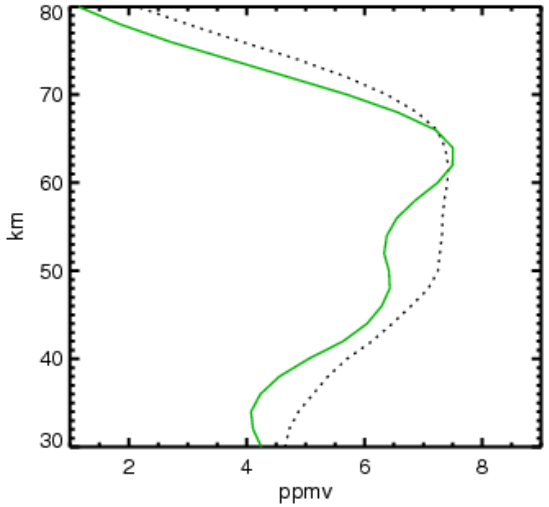
MLW5 11/01/12-11/01/12
a priori error= 0.5 0.30
tip range=45 75
horizon=-1.0
meas. sigma multiplier=0.008
<unbalance>= 0.11 mK
slope=0.00248 K/MHz
max dif for scans= 300mK
scans(odd,even) 40 40
signal angle=75.1
reference angle= -3.2
first scan=18070
last scan=18149
bar/beam= .09
scale height= 2.0 km
applied up to 15.0 km
anglemod= 0.0 0.0
chi^2(m,ap,sum)=
999.3 66.7 1066.1
tau=.0327
sigma(tau)=.00053
Tsky(70)= 25.2
Trx=180.1
tau inv=.0340
meas cont(26-80)= 0.28 0.67
1.00 0.90 0.95 0.80 0.54



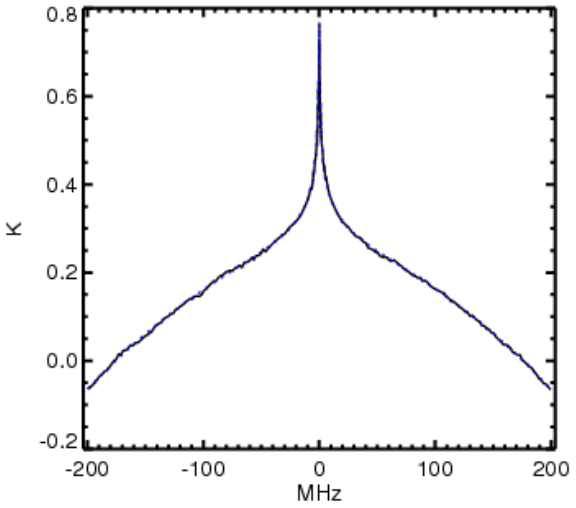



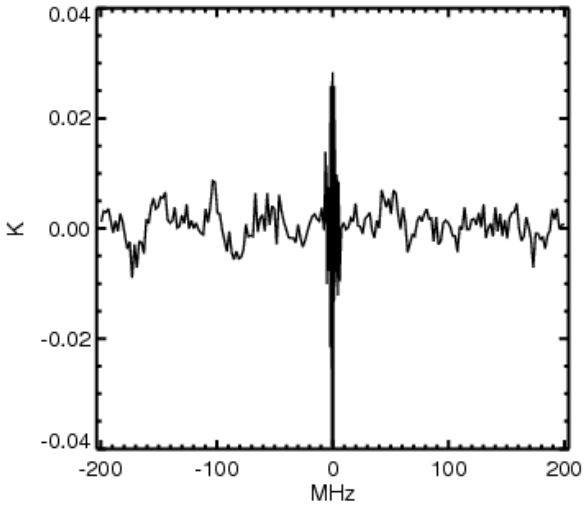



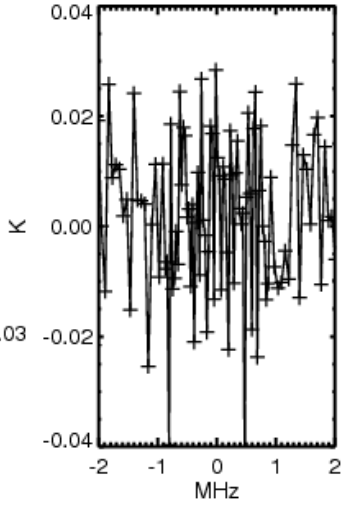



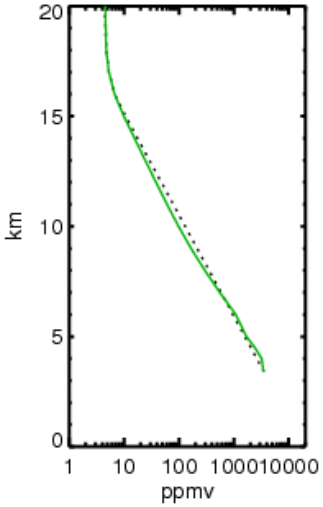
# WVMS6 – 400 MHz

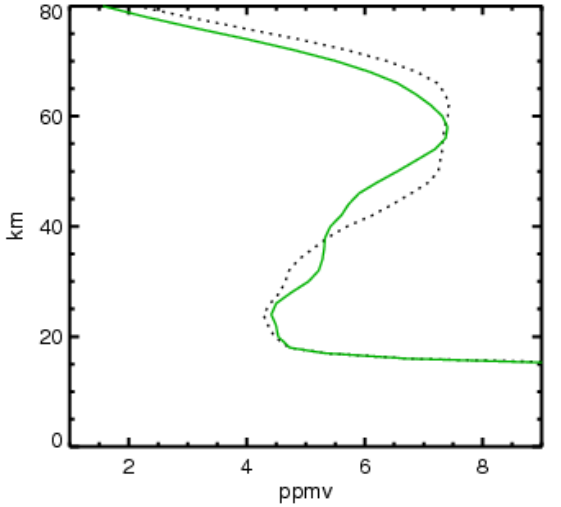
MLW6 11/01/12-11/01/12
a priori error= 0.5 0.30
tip range=45 75
horizon=-1.0
meas. sigma multiplier=0.008
<unbalance>= -0.06 mK
slope=0.00111 K/MHz
max dif for scans= 300mK
scans(odd,even) 41 40
signal angle=72.9
reference angle= -5.0
first scan=22561
last scan=22641
bar/beam= .07
scale height= 2.0 km
applied up to 15.0 km
anglemod= 0.0 0.0
chi^2(m,ap,sum)=
3128.1 39.4 3167.5
tau=.0305
sigma(tau)=.00048
Tsky(70)= 24.8
Trx=194.6
tau inv=.0315
meas cont(26-80)= 0.92 1.03
0.93 0.96 0.97 0.78 0.50

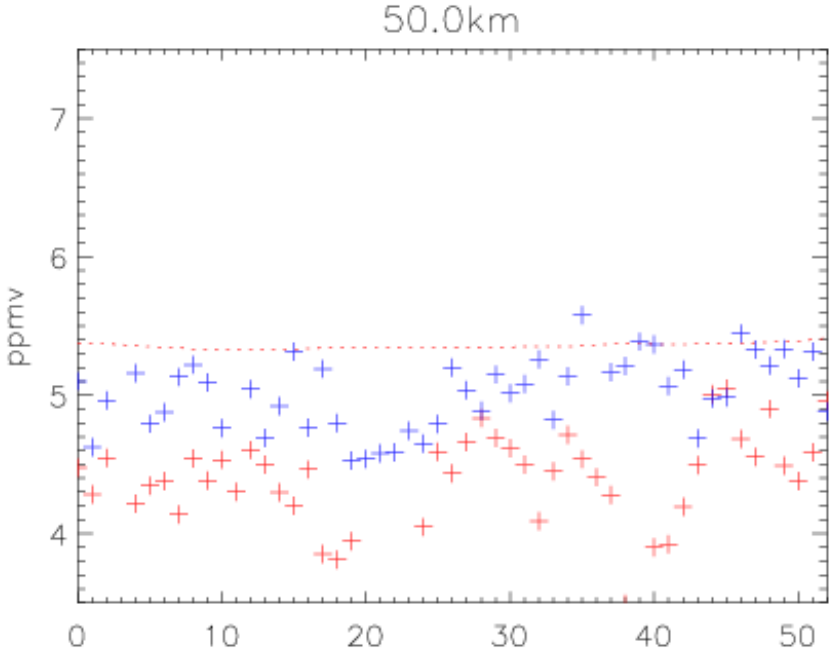


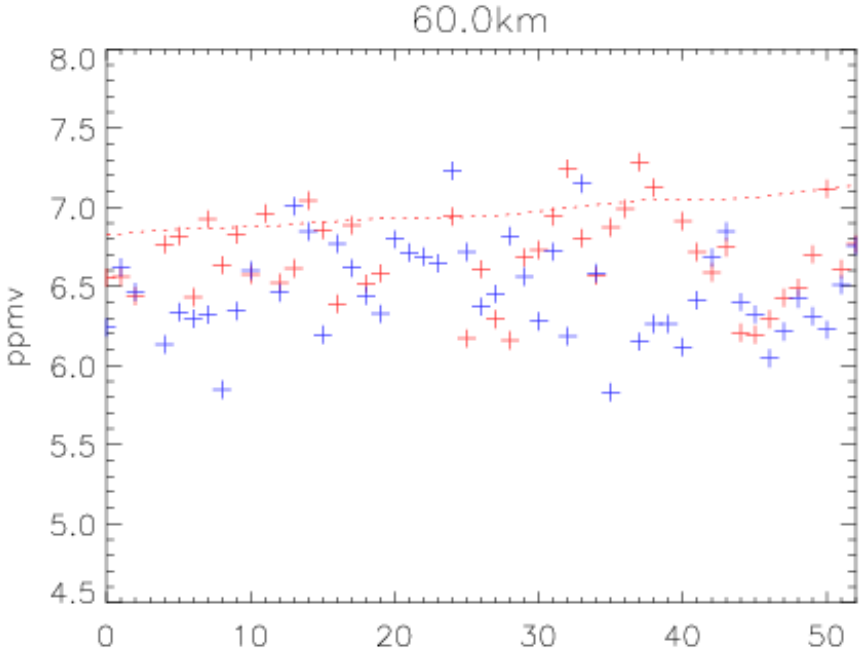



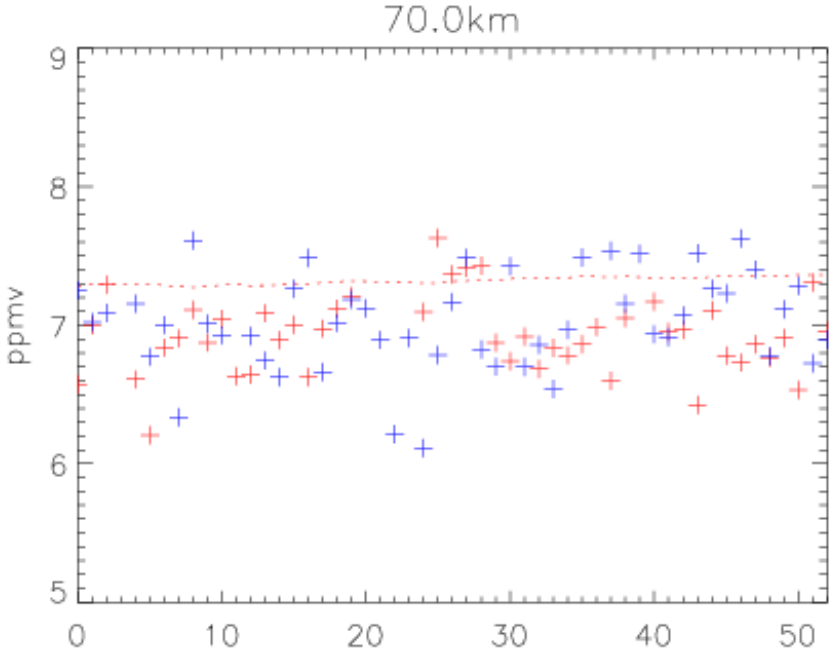





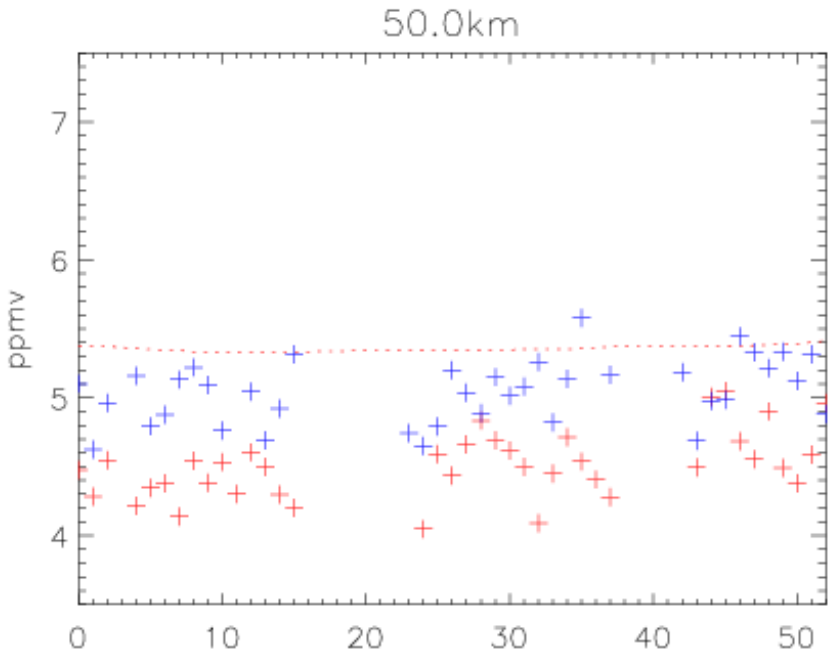



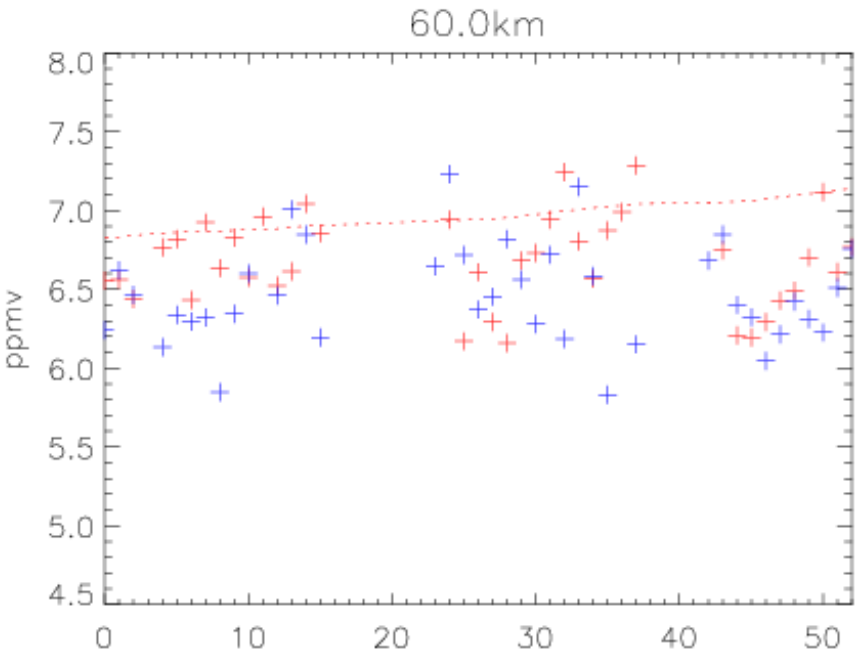

Days since Sept. 16, 2012



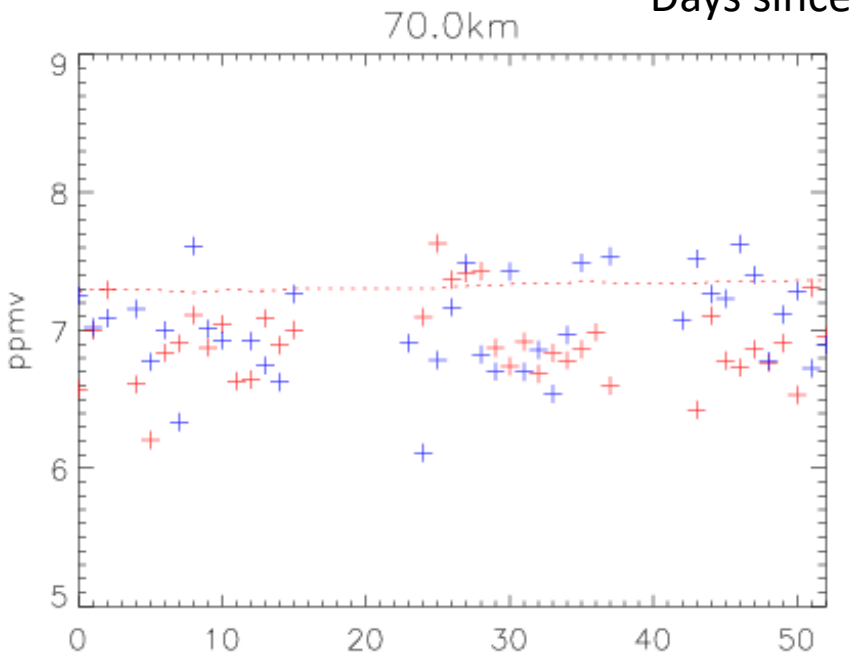

WVMS5
WVMS6

Dashed line is a priori (for both)




Days since Sept. 16, 2012; $\tau$<0.06




WVMS5
WVMS6

Note correlation of low 50km measurements with $\tau$>0.06

# WVMS1

Lauder New Zealand (45.0°S, 169.7°E) Elevation 1214 ft. (1993-2011)

# WVMS7

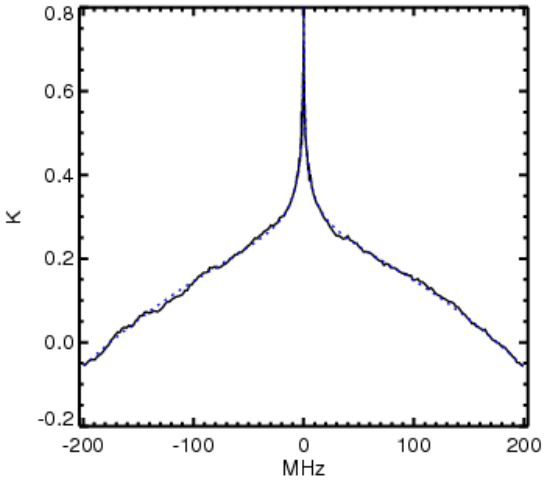
Lauder New Zealand (45.0°S, 169.7°E) Elevation 1214 ft. (2011-Present)

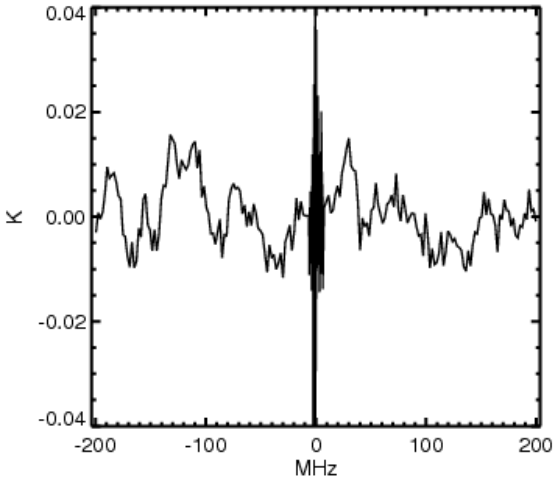

# Lauder

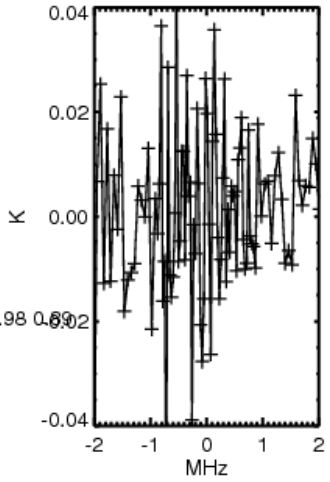
June 30 (Austral winter), low tau, full FFT

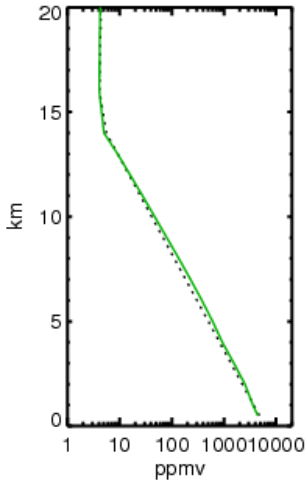
This retrieval looks reasonable, but conditions are not always this optimal (τ=.0436)

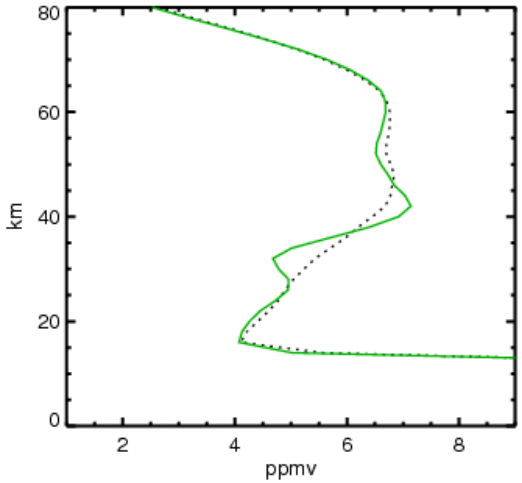
NZW7 06/30/12-06/30/12
a priori error= 0.5 0.30
tip range=45 75
horizon= 3.0
meas. sigma multiplier=0.01
<unbalance>= -0.05 mK
slope=0.00288 K/MHz
max dif for scans= 300mK
scans(odd,even) 42 42
signal angle=75.3
reference angle= 1.3
first scan= 9232
last scan= 9315
bar/beam= .12
scale height= 2.0 km
applied up to 15.0 km
anglemod= 0.0 0.0
chi^2(m,ap,sum)=
13326.0 10.013336.0
tau=.0436
sigma(tau)=.00014
Tsky(70)= 34.6
Trx=210.6
tau inv=.0451
meas cont(26-80)= 0.91 0.98 0.89
0.93 0.96 0.68 0.40



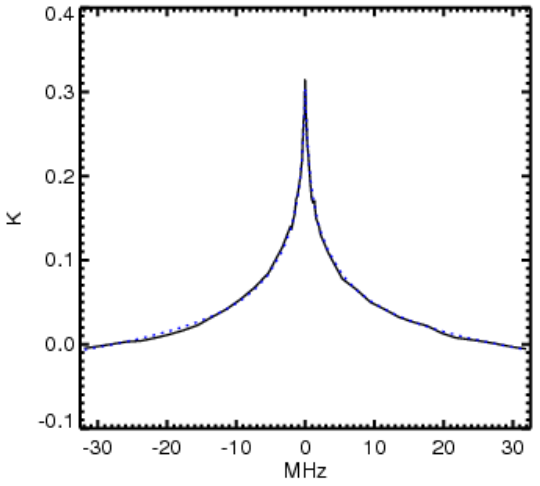



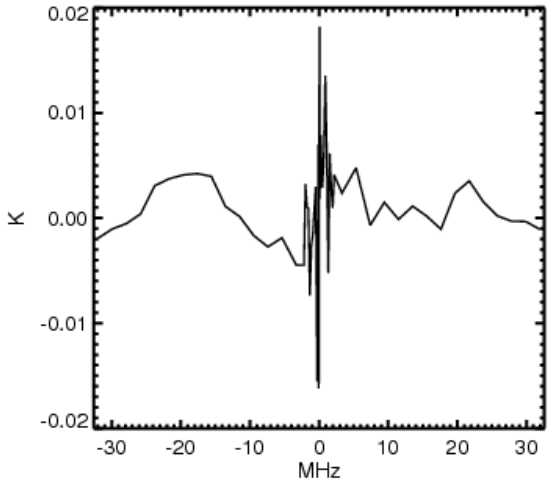



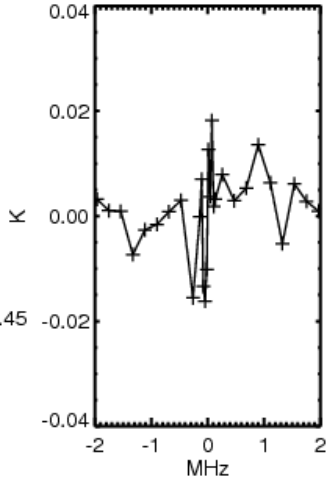



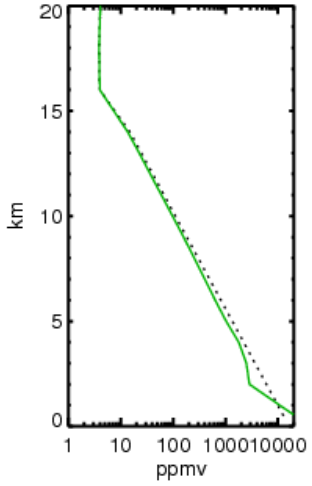
# Dec. 1-6, 2012 (τ=.1047). Only middle ~60 MHz. Constant MLO apriori

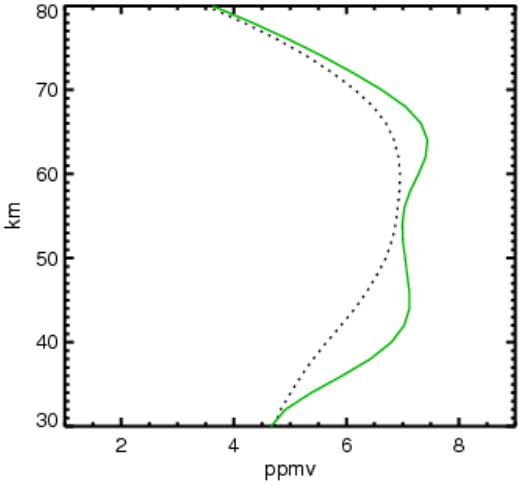
NZW7 12/01/12-12/06/12
a priori error= 0.5 0.30
tip range=45 75
horizon= 3.0
meas. sigma multiplier=0.008
<unbalance>= 0.17 mK
slope=0.00338 K/MHz
max dif for scans= 300mK
scans(odd,even) 203 203
signal angle=65.7
reference angle= 1.3
first scan=21213
last scan=21640
bar/beam= .14
scale height= 2.0 km
applied up to 15.0 km
anglemod= 0.0 0.0
chi^2(m,ap,sum)=
2221.2 43.5 2264.7
tau=.1047
sigma(tau)=.00470
Tsky(70)= 74.9
Trx=216.3
tau inv=.0951
meas cont(26-80)= 0.18 0.45
0.87 0.75 0.73 0.54 0.30



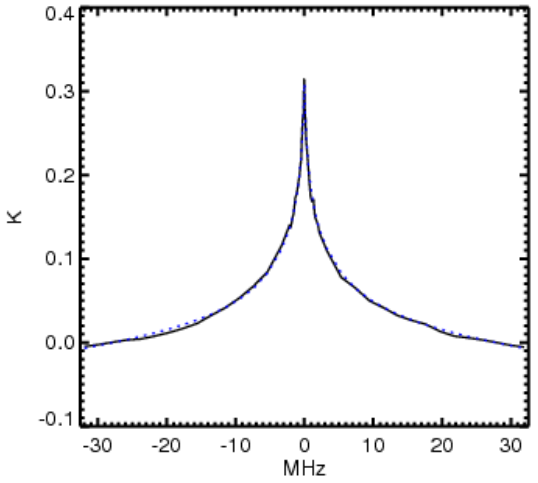



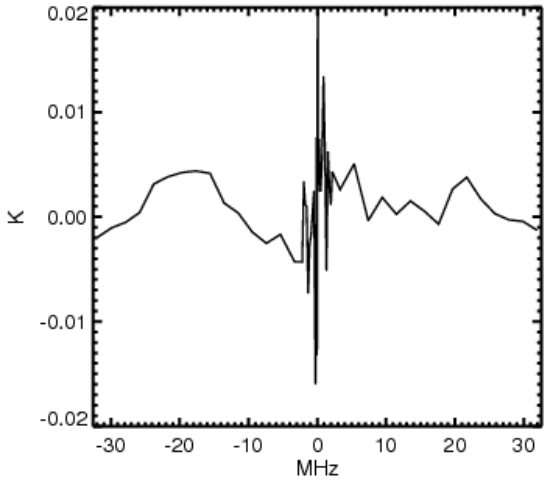



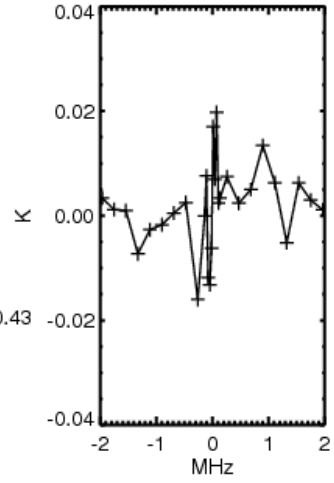



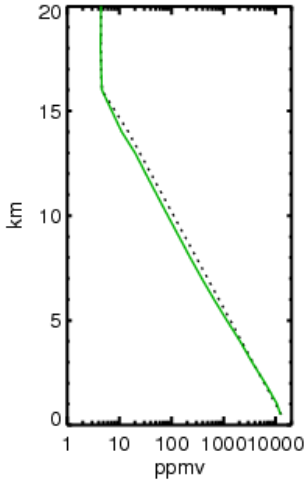
# Dec. 1-6, 2012 (τ=.1047). Only middle ~60 MHz. Variable apriori

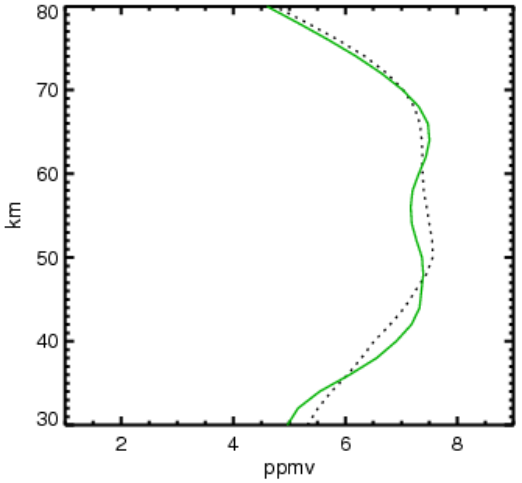
NZW7 12/01/12-12/06/12
a priori error= 0.5 0.30
tip range=45 75
horizon= 3.0
meas. sigma multiplier=0.008
<unbalance>= 0.17 mK
slope=0.00322 K/MHz
max dif for scans= 300mK
scans(odd,even) 203 203
signal angle=65.7
reference angle= 1.3
first scan=21213
last scan=21640
bar/beam= .14
scale height= 2.0 km
applied up to 15.0 km
anglemod= 0.0 0.0
chi^2(m,ap,sum)=
537.1 6.7 543.9
tau=.1047
sigma(tau)=.00470
Tsky(70)= 74.9
Trx=216.3
tau inv=.1041
meas cont(26-80)= 0.18 0.43
0.81 0.71 0.68 0.48 0.26



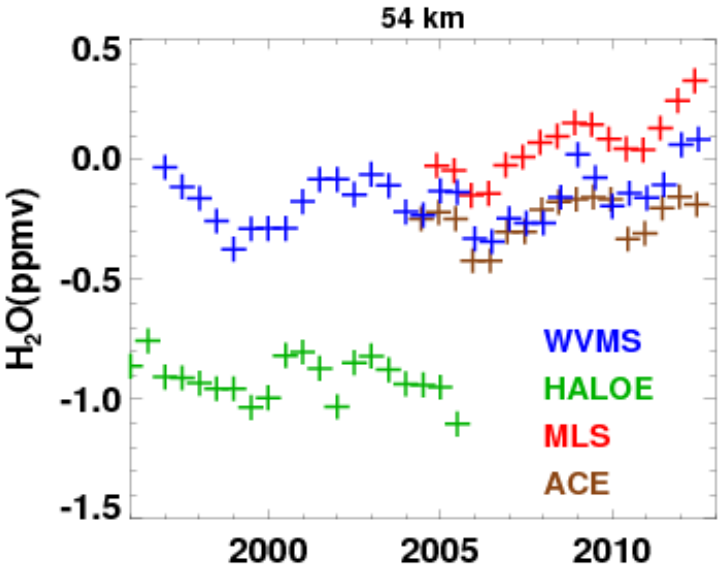



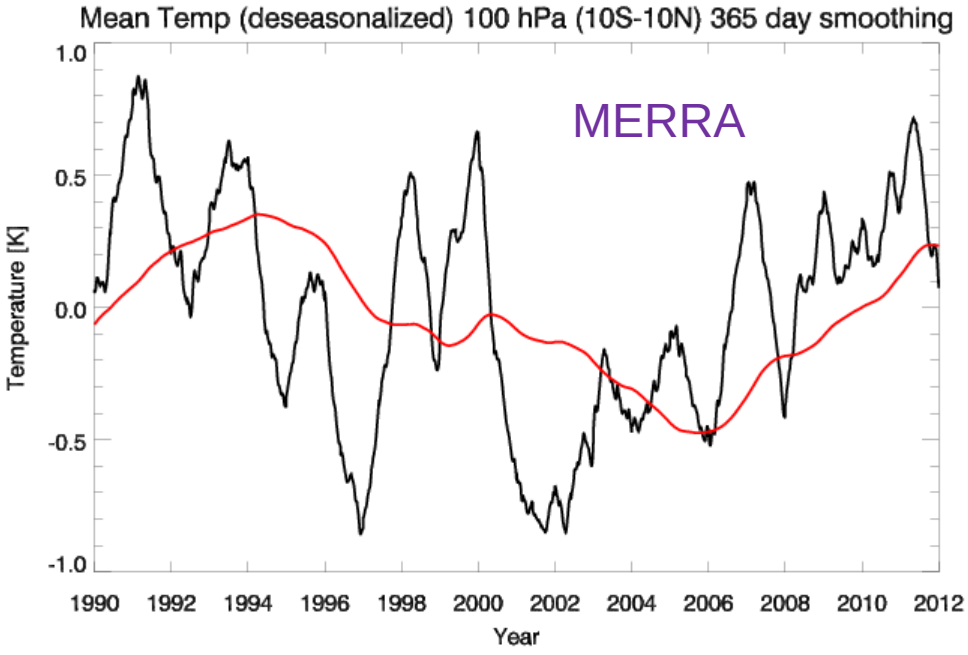
With the exception of 2009, the highest annual average $H_2O$ values in the WVMS Mauna Loa are in 1996 and 2012.

Sensitivity of saturation variations near cold-point tropopause temperature is ~0.6 ppmv/K

Variation in mean of previous 5-years 100 hPa temperature is ~0.6K => $H_2O$ variation ~0.36 ppmv.

Solar cycle effect at 54km <1% Lower altitudes have more variations from $CH_4$ oxidation.



End

# Dec. 1-6, 2012. Only middle ~60 MHz. Constant MLO apriori

NZW7 12/01/12-12/06/12
a priori error= 0.5 0.30
tip range=45 75
horizon= 3.0
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<unbalance>= 0.17 mK
slope=0.00338 K/MHz
max dif for scans= 300mK
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reference angle= 1.3
first scan=21213
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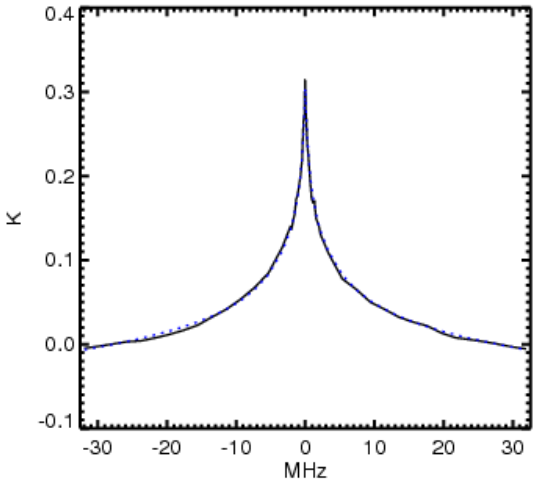
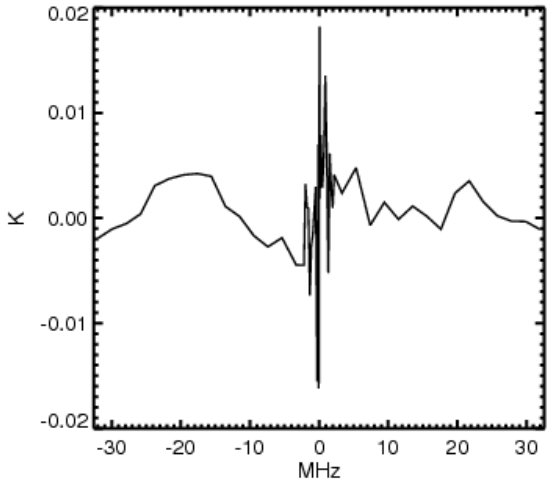
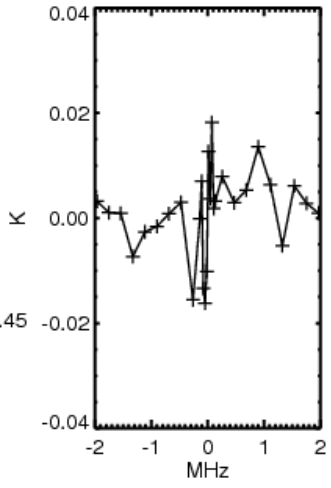
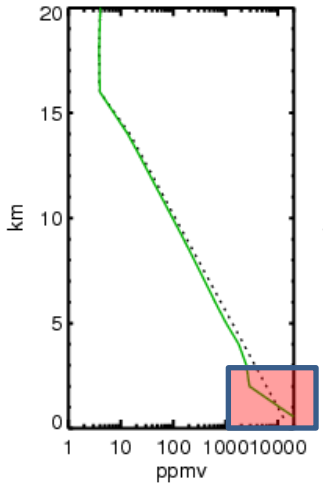
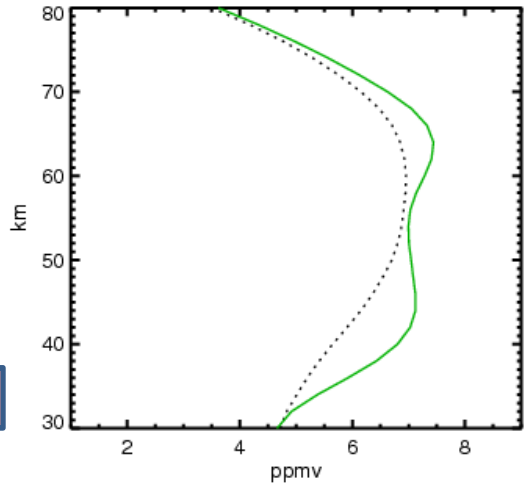
bar/beam= .14
scale height= 2.0 km
applied up to 15.0 km
anglemod= 0.0 0.0
chi^2(m,ap,sum)=
2221.2 43.5 2264.7
tau=.1047
sigma(tau)=.00470
Tsky(70)= 74.9
Trx=216.3
tau inv=.0951
meas cont(26-80)= 0.18 0.45
0.87 0.75 0.73 0.54 0.30



# Dec. 1-6, 2012. Only middle ~60 MHz. Variable apriori

NZW7 12/01/12-12/06/12
a priori error= 0.5 0.30
tip range=45 75
horizon= 3.0
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slope=0.00322 K/MHz
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chi^2(m,ap,sum)=
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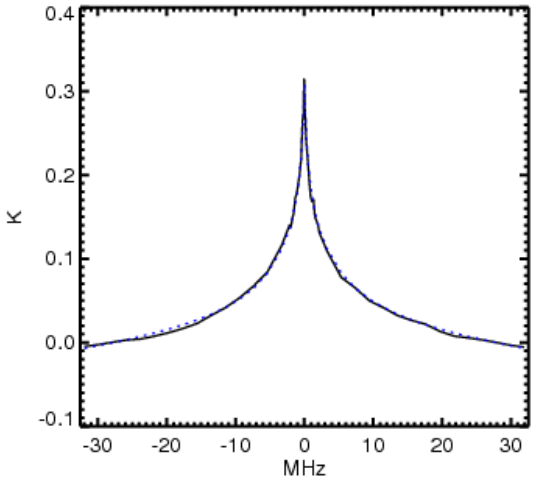
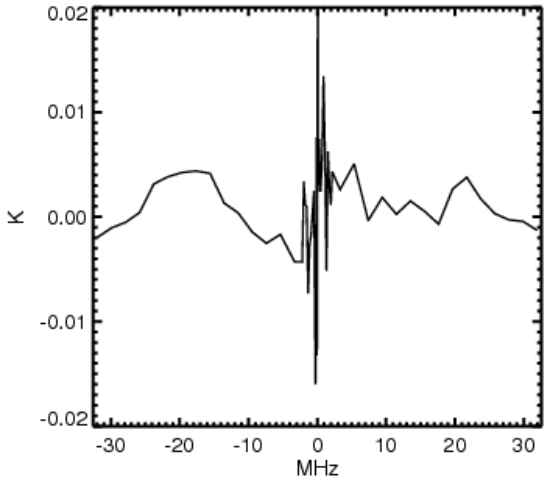
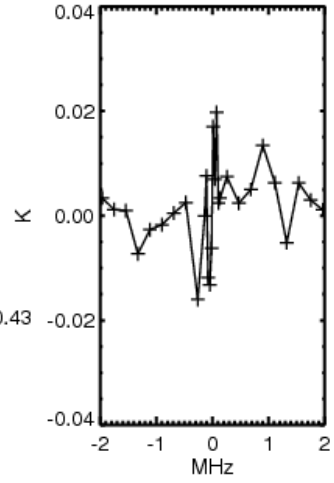
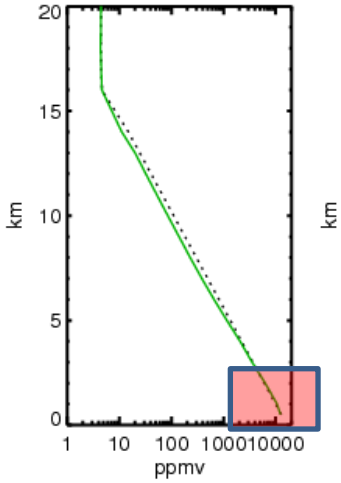
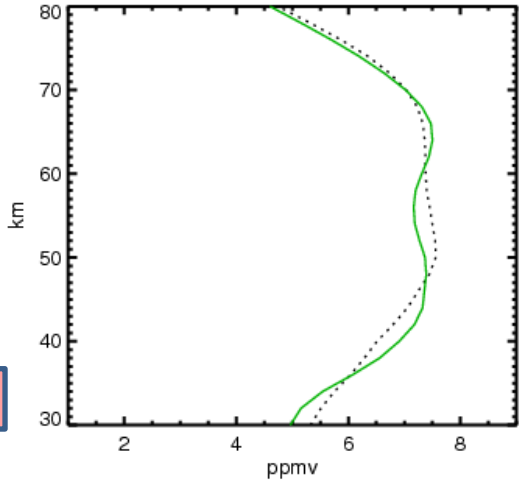
tau=.1047
sigma(tau)=.00470
Tsky(70)= 74.9
Trx=216.3
tau inv=.1041
meas cont(26-80)= 0.18 0.43
0.81 0.71 0.68 0.48 0.26



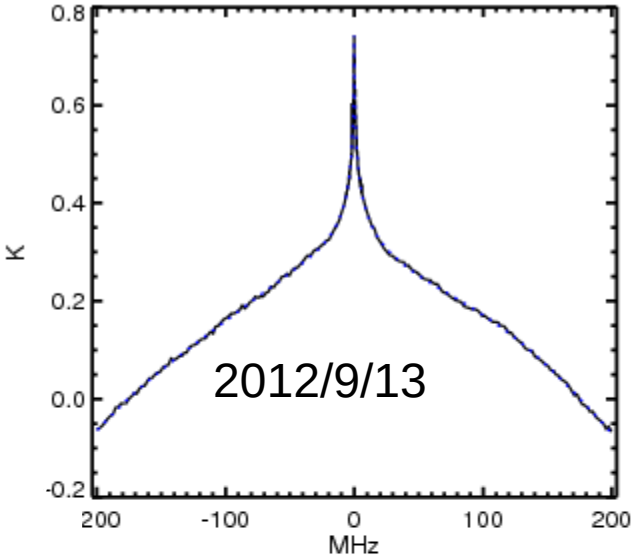



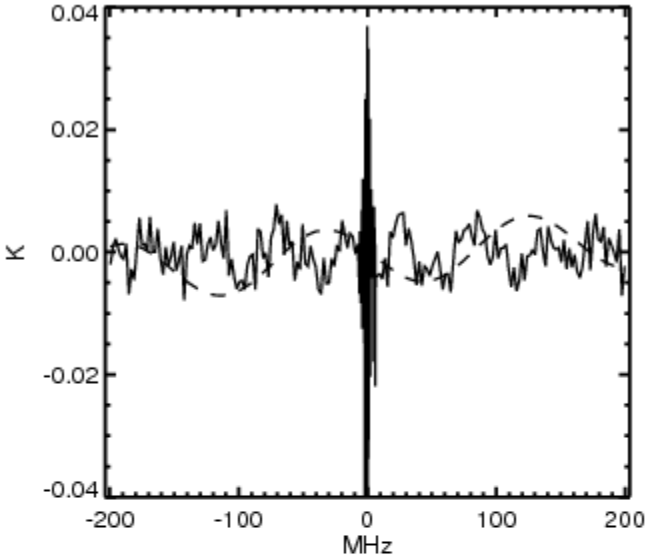



# New WVMS7 instrument deployed at Lauder




We are working to determine whether it is possible to extend the useful altitude range of the retrieval with this new instrument.