- Instruments:
  - HALOE
    - 1991-2005
  - POAM III
    - 1998-2005
  - WVMS
    - 1992-present
  - AURA MLS
    - 2004-present

Water Vapor Mm-wave Spectrometer (WVMS)

22 GHz radiometers using pressure broadening information to make water vapor profile measurements from 40-80 km

WVMS measurements are made at 3 sites of the Network for the Detection of Stratospheric Change (NDSC).

Two of these sites are currently operating:

Lauder, New Zealand (45^{o}S, 169.7^{o}E):

Nov. 1992-Apr. 1993, Jan. 1994-present

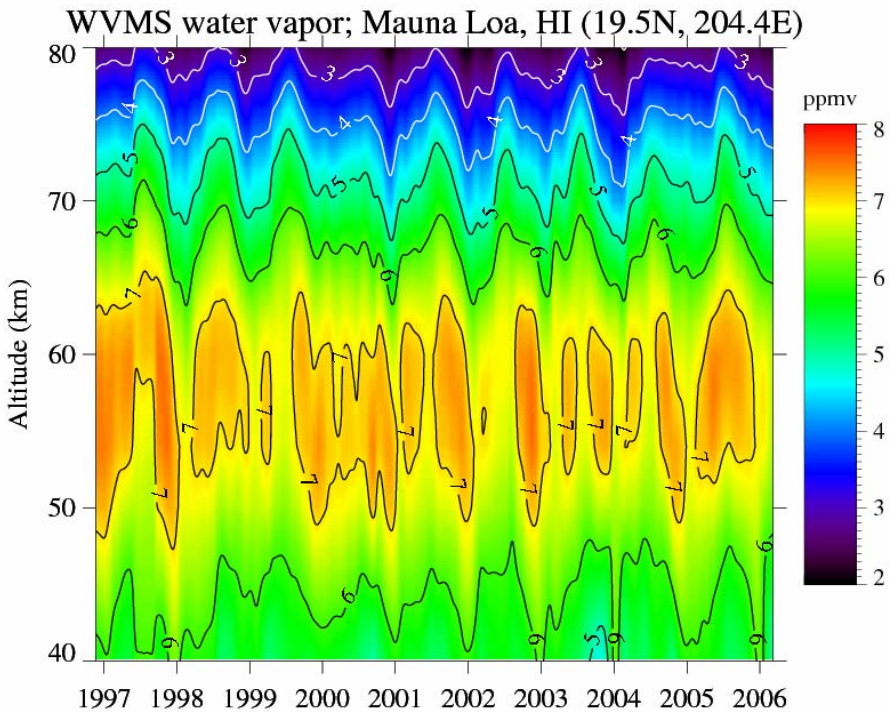
Mauna Loa, HA (19.5^{o}N, 204.4^{o}E):

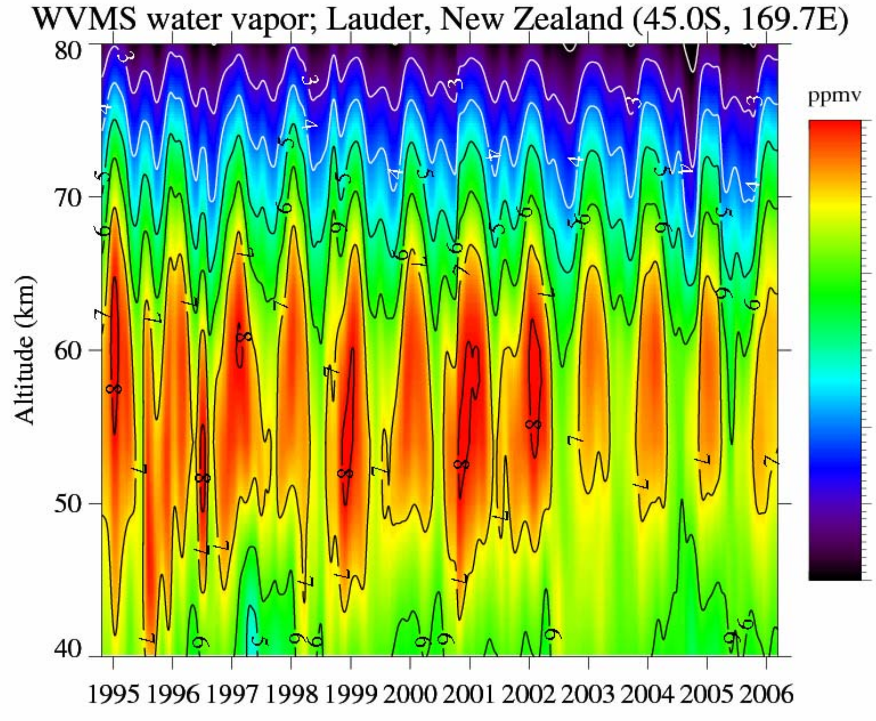
Mar. 1996-present

Water Vapor Mm-wave Spectrometer (WVMS)

Status of instrument at Table Mountain California (34.4^{o}N, 242.3^{o}E):

- Data in NDSC database for May 1993-Nov. 1997
- Data available from Nov. 2003-July 2005, but this data should not be compared to the 1993-1997 data.
- Instrument is currently not operating
  - Problems with conversion from DOS to Windows operating system
  - Hardware tests implemented to help determine cause of differences between 1993-1997 and 2003-2005 data.

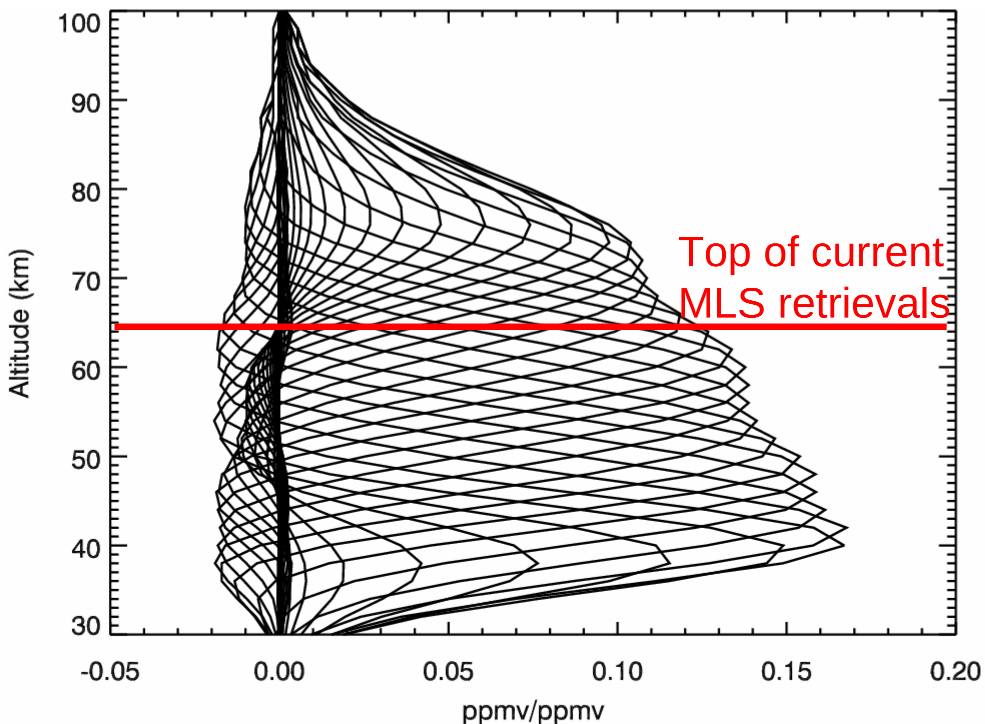

WVMS water vapor; Mauna Loa, HI (19.5N, 204.4E)
Altitude (km)
ppmv
80
70
60
50
40
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
8
7
6
5
4
3
2


WVMS water vapor; Lauder, New Zealand (45.0S, 169.7E)
Altitude (km)
ppmv
80
70
60
50
40
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
8
7
6
5
4
3
2

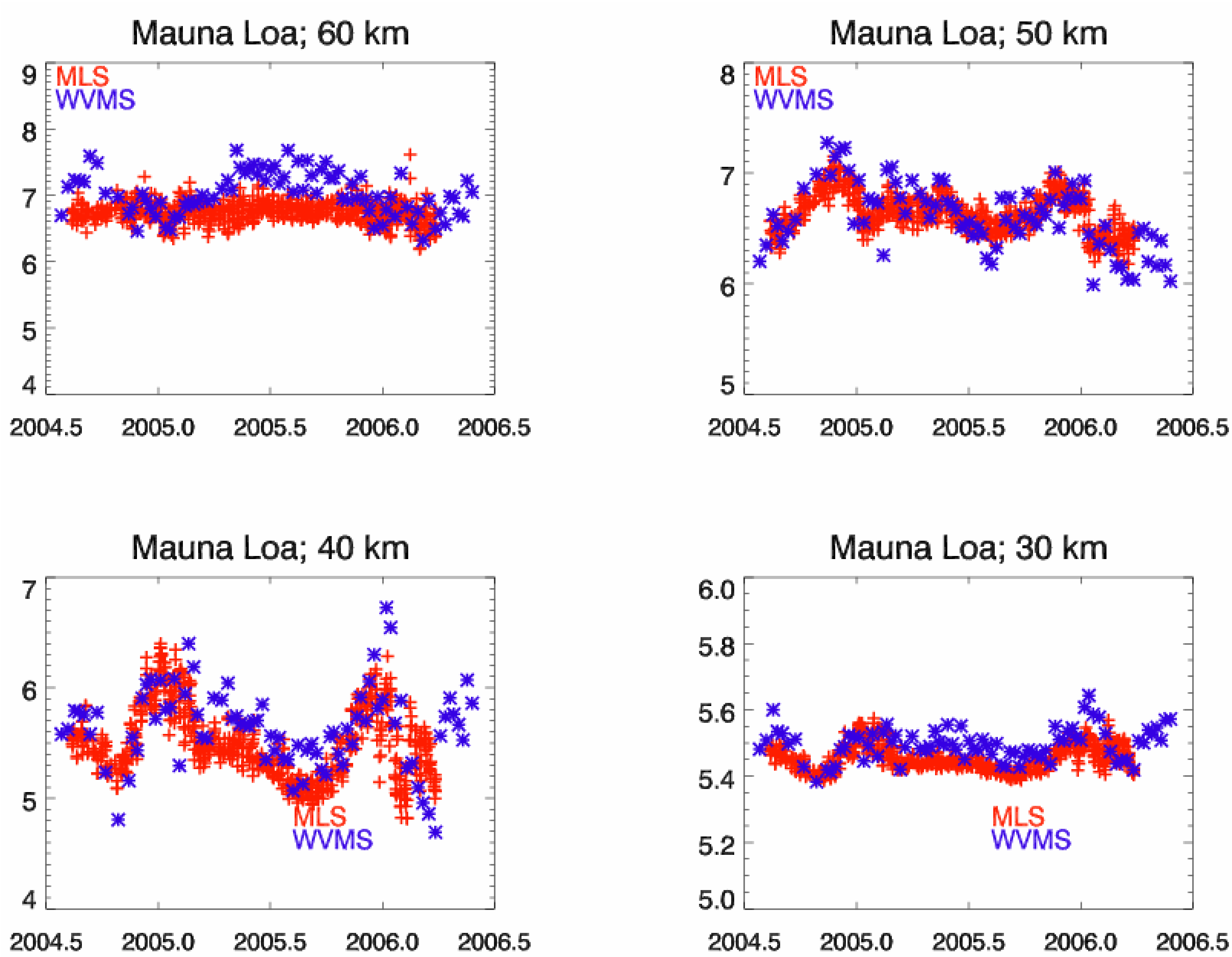
Vertical Resolution

- Vertical resolution of MLS AURA water vapor is estimated to be:
  - 3 km in the upper troposphere and lower stratosphere
  - 4 km in most of the stratosphere
  - 6 km in the lower mesosphere
- Vertical resolution of POAM water vapor is estimated to be:
  - 1 km up to ~30 km
  - Degrading with altitude from 1 to 2 km from 30-40 km
- Vertical resolution of WVMS:

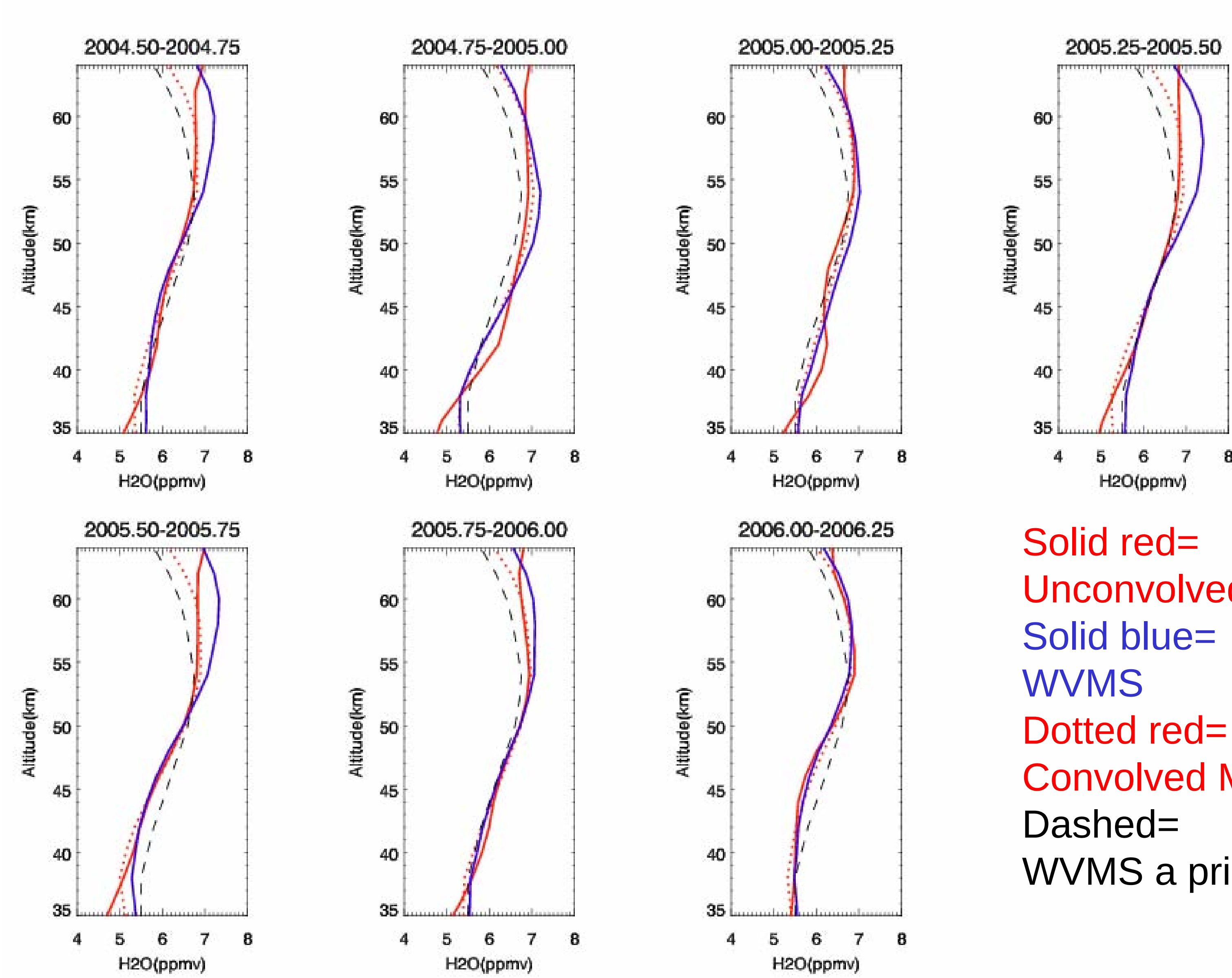
1 week integration
WVMS3, Mauna Loa



WVMS-MLS (convolved) comparisons

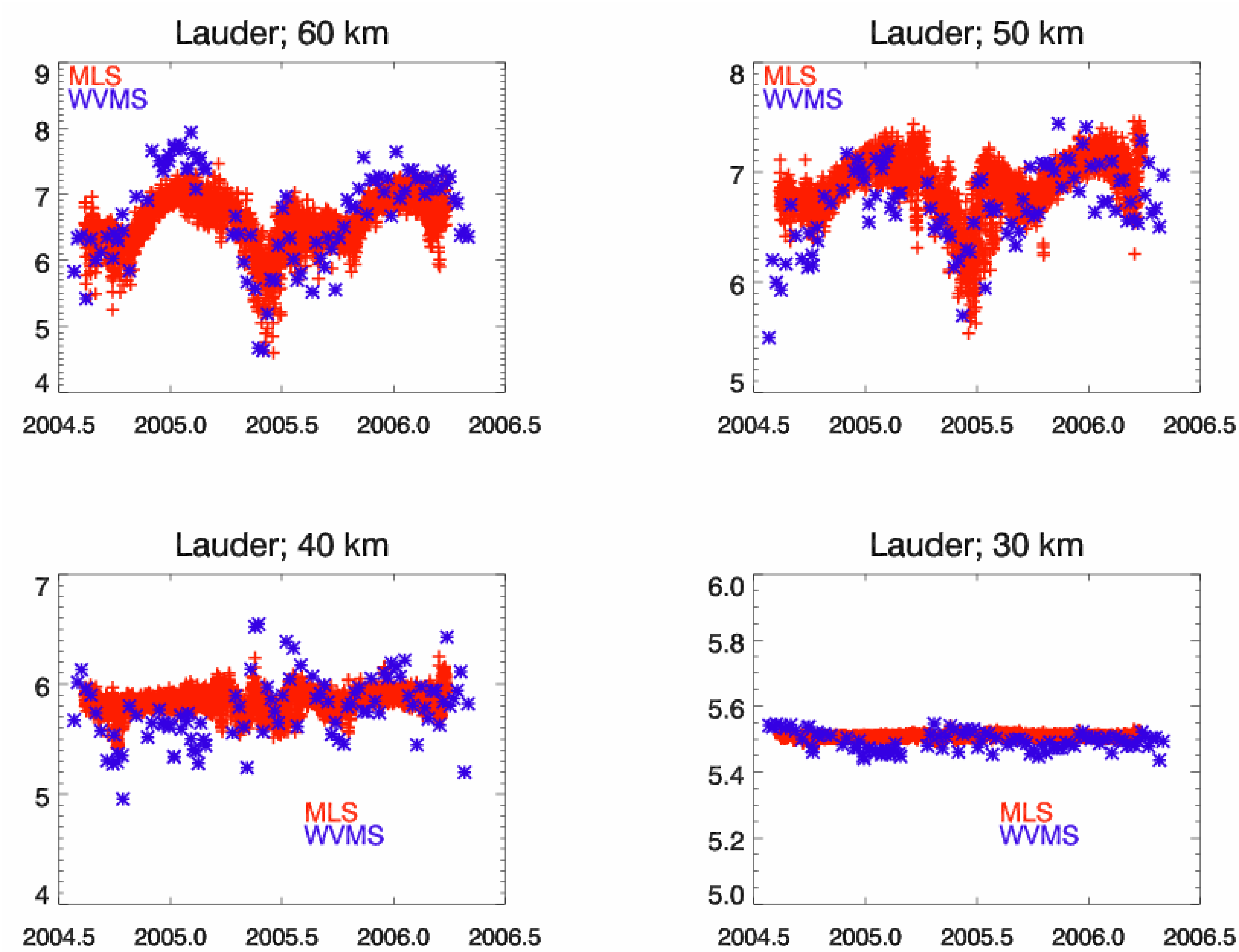


WVMS Mauna Loa (19.5N, 204.4E)
MLS +/-2 deg latitude and 30 deg longitude

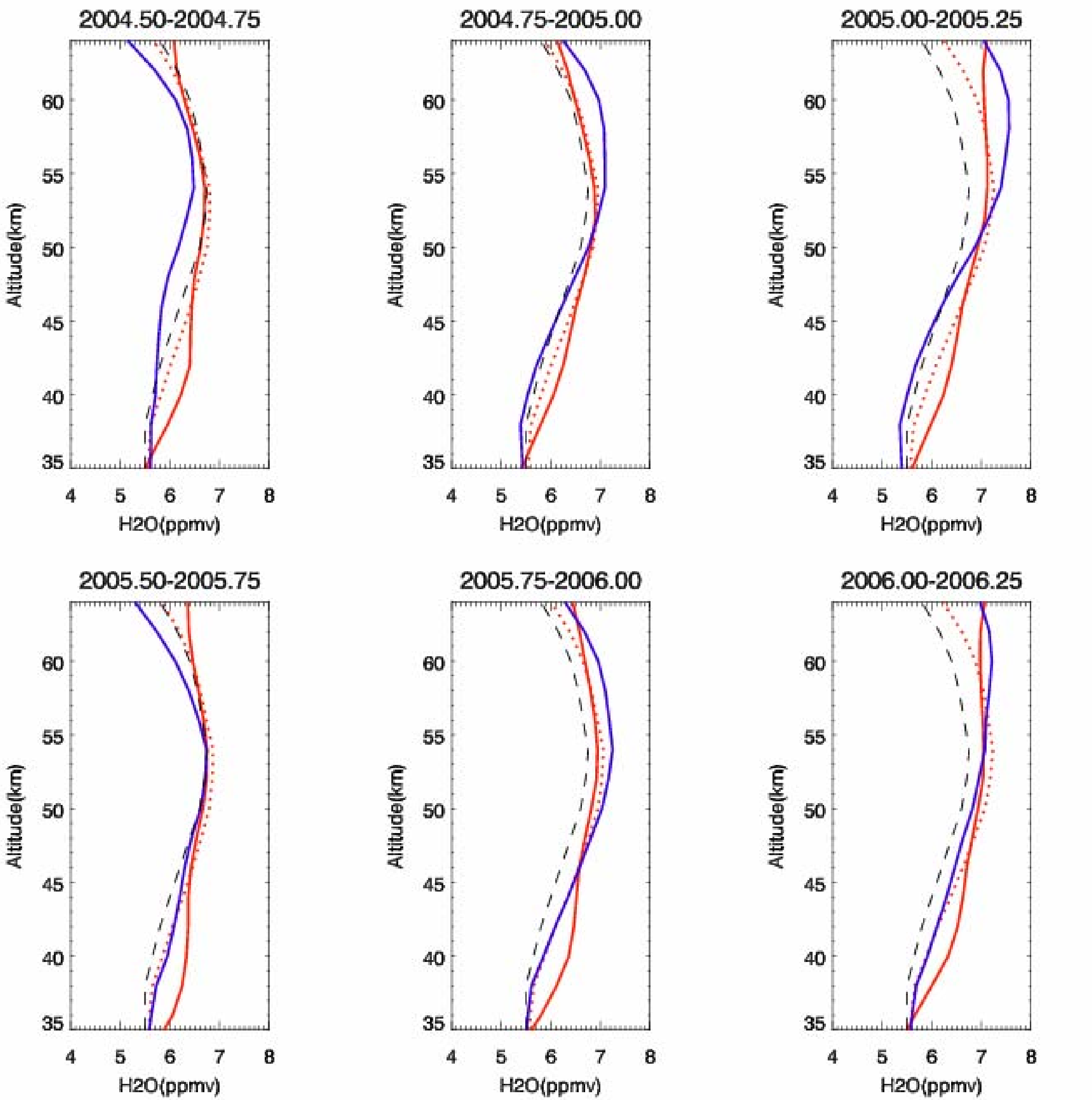


Solid red= Unconvolved MLS
Solid blue= WVMS
Dotted red= Convolved MLS
Dashed= WVMS a priori

WVMS-MLS (convolved) comparisons



WVMS Lauder (45.0S, 169.7E)
MLS +/-2 deg latitude and 30 deg longitude



Solid red= Unconvolved MLS

Solid blue= WVMS

Dotted red= Convolved MLS

Dashed= WVMS a priori

MLS-WVMS comparisons
Averages

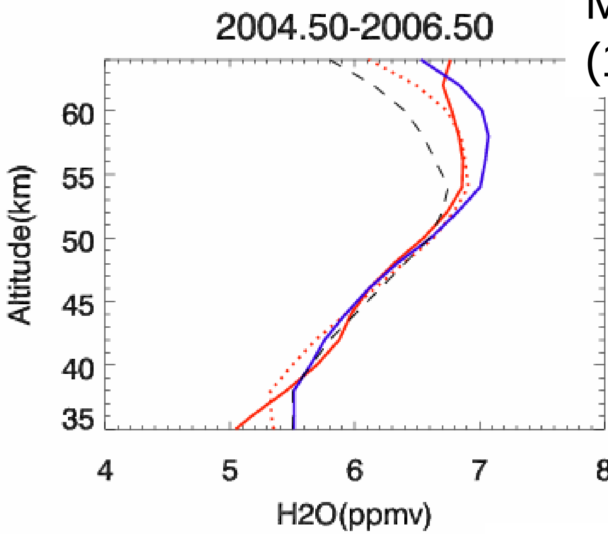
Solid red=
Unconvolved MLS

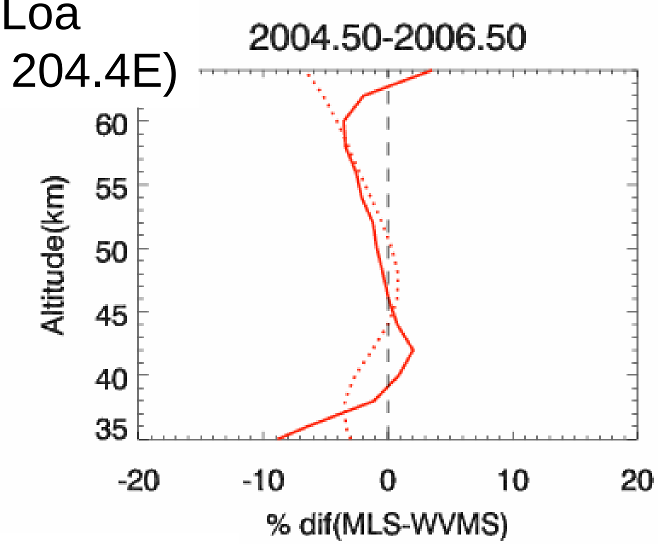
Dotted red=
Convolved MLS

Solid blue=
WVMS

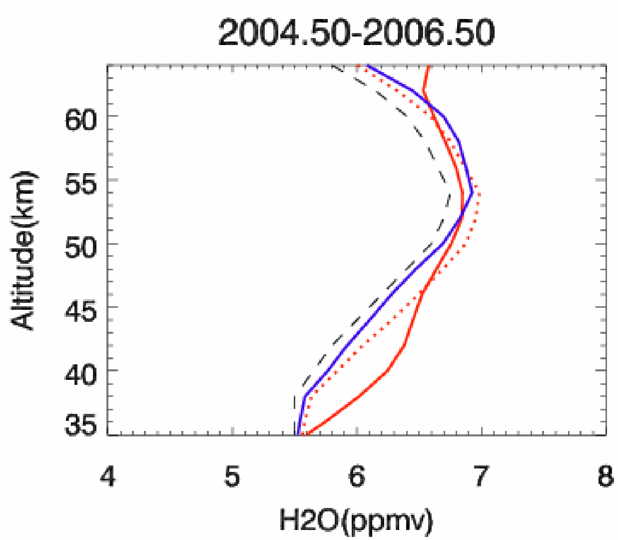
Dashed=
WVMS a priori

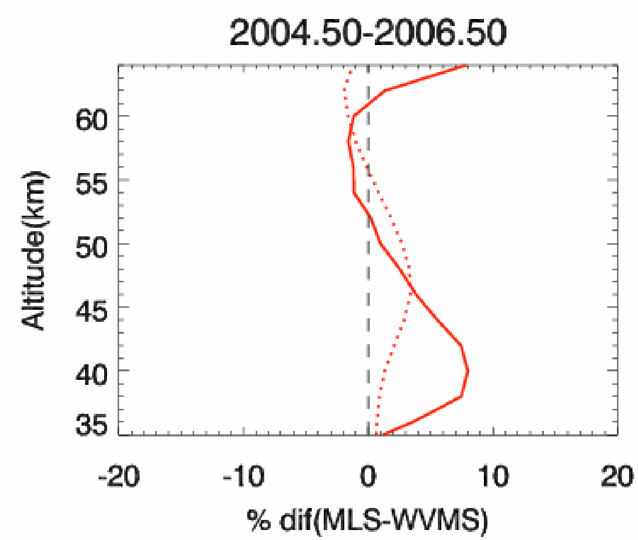
Mauna Loa
(19.5N, 204.4E)



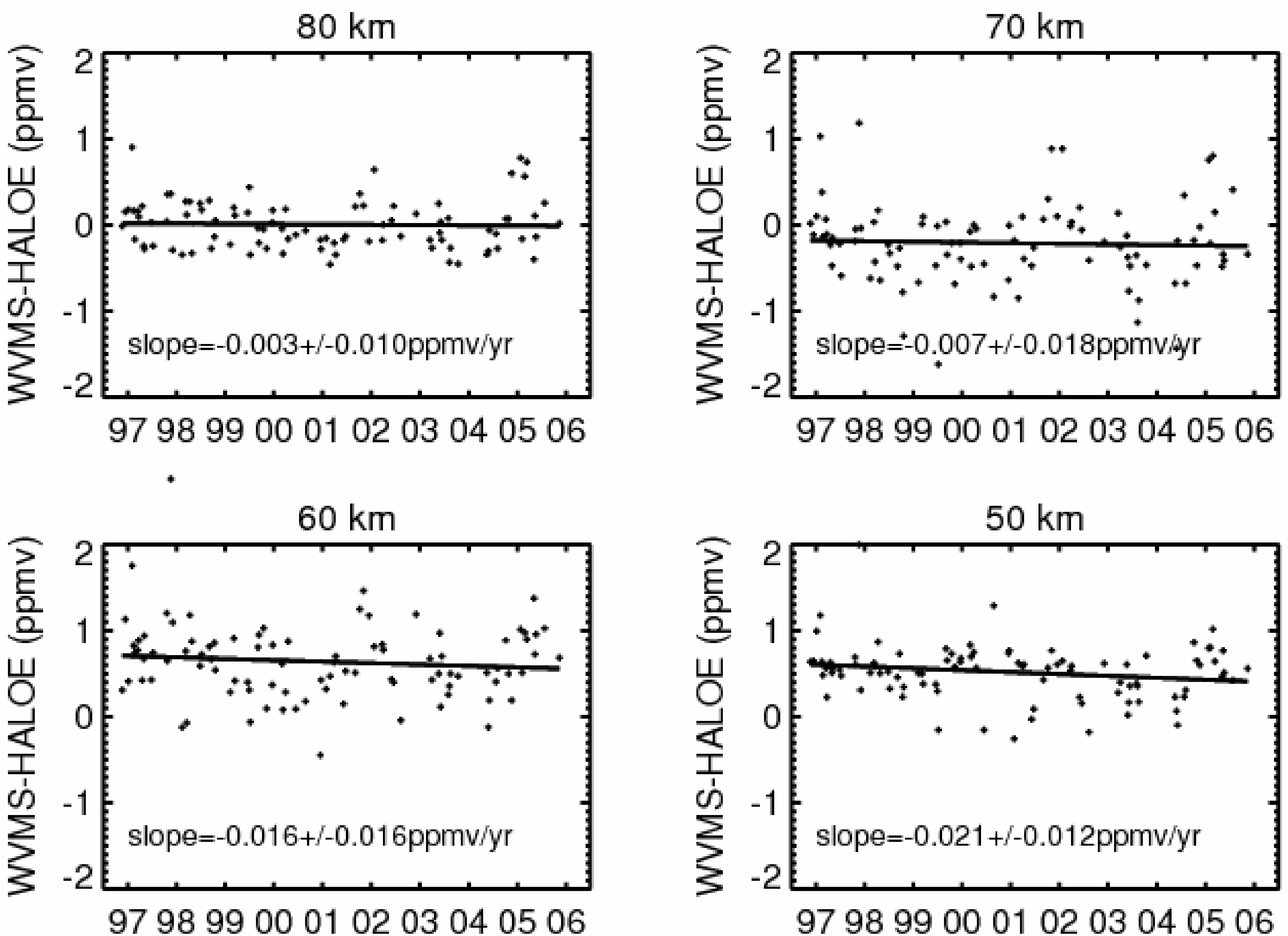


Lauder (45S, 169.7E)

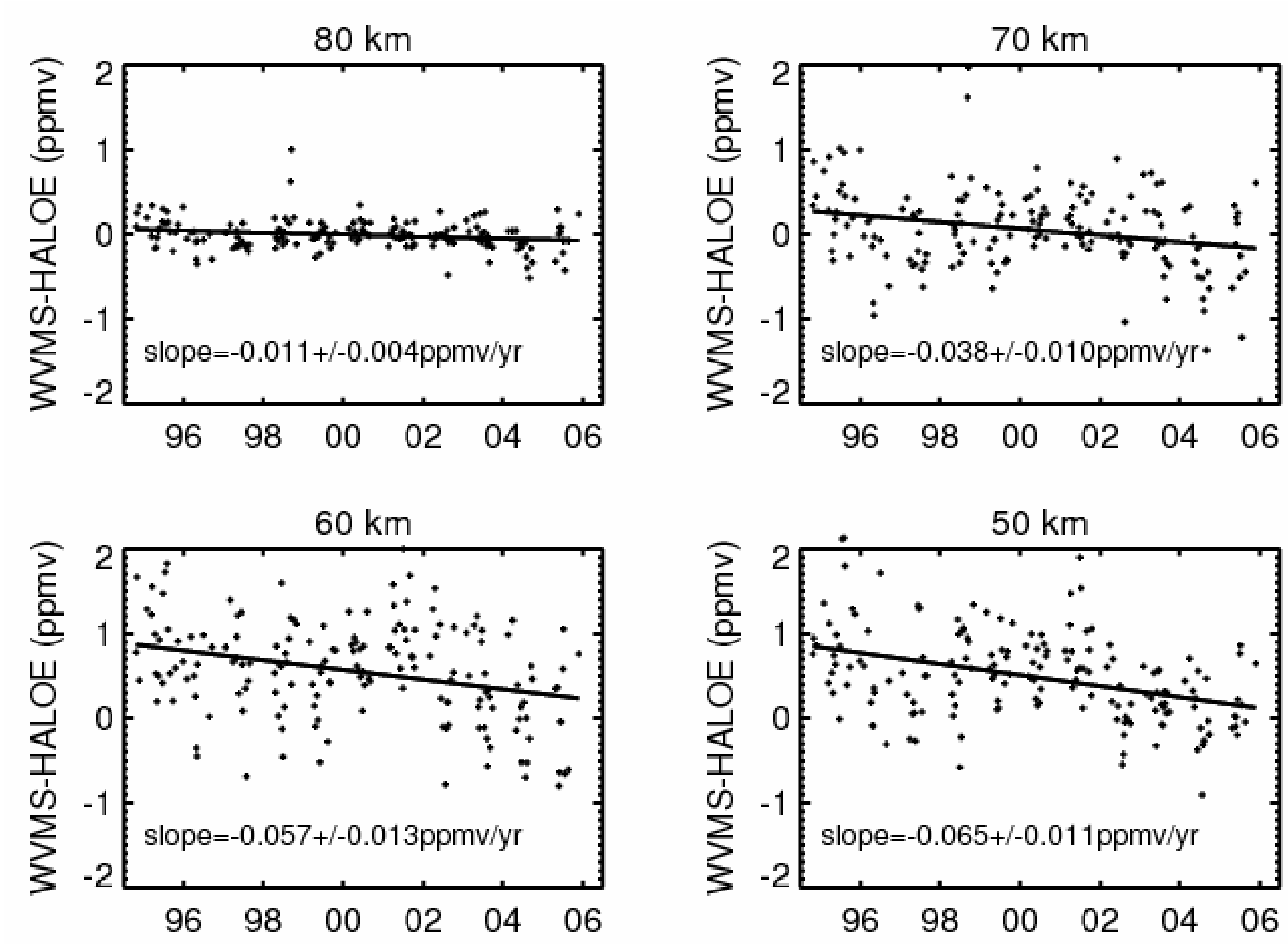




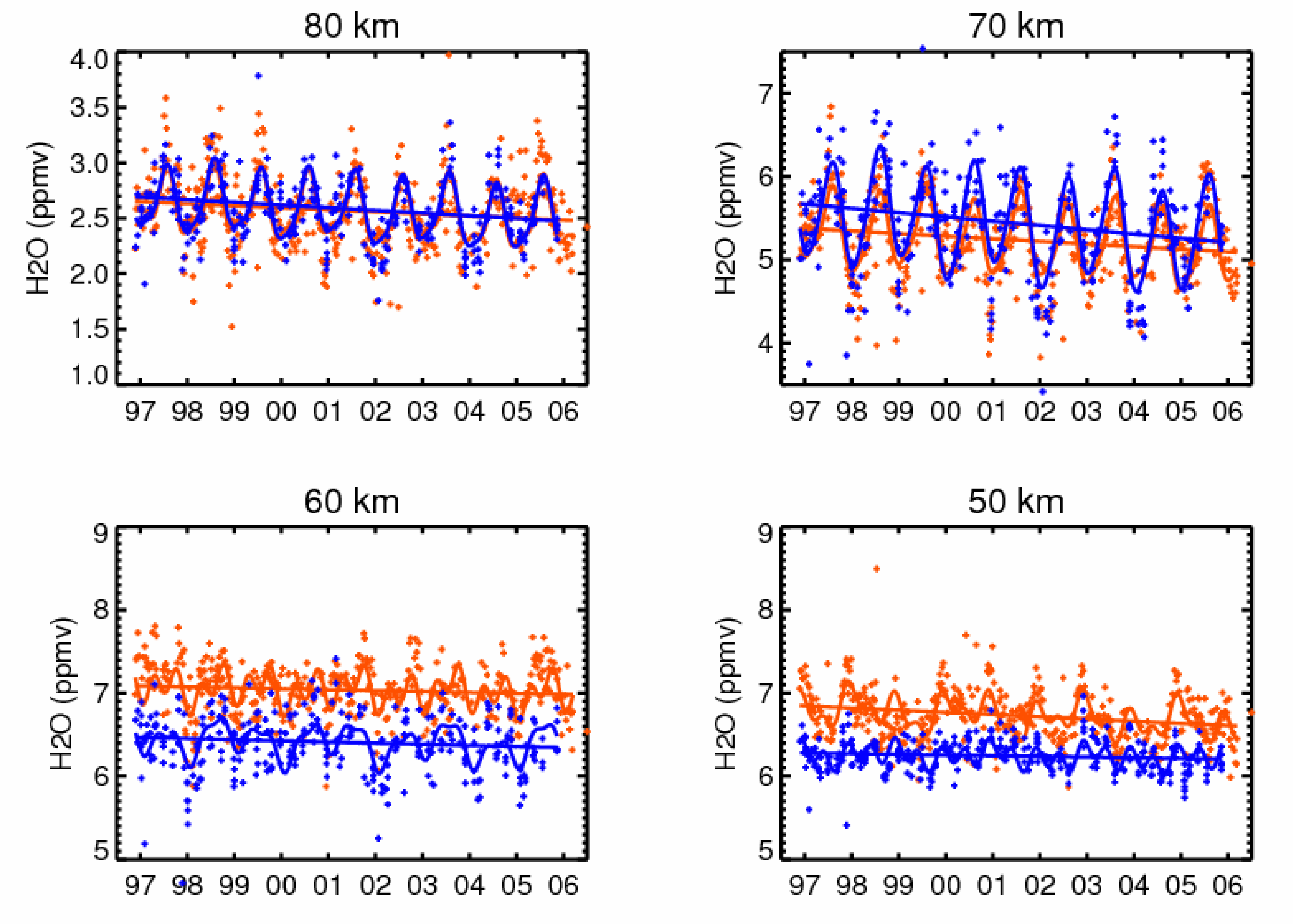
WVMS at MLO - HALOE (14.5N-24.5N)



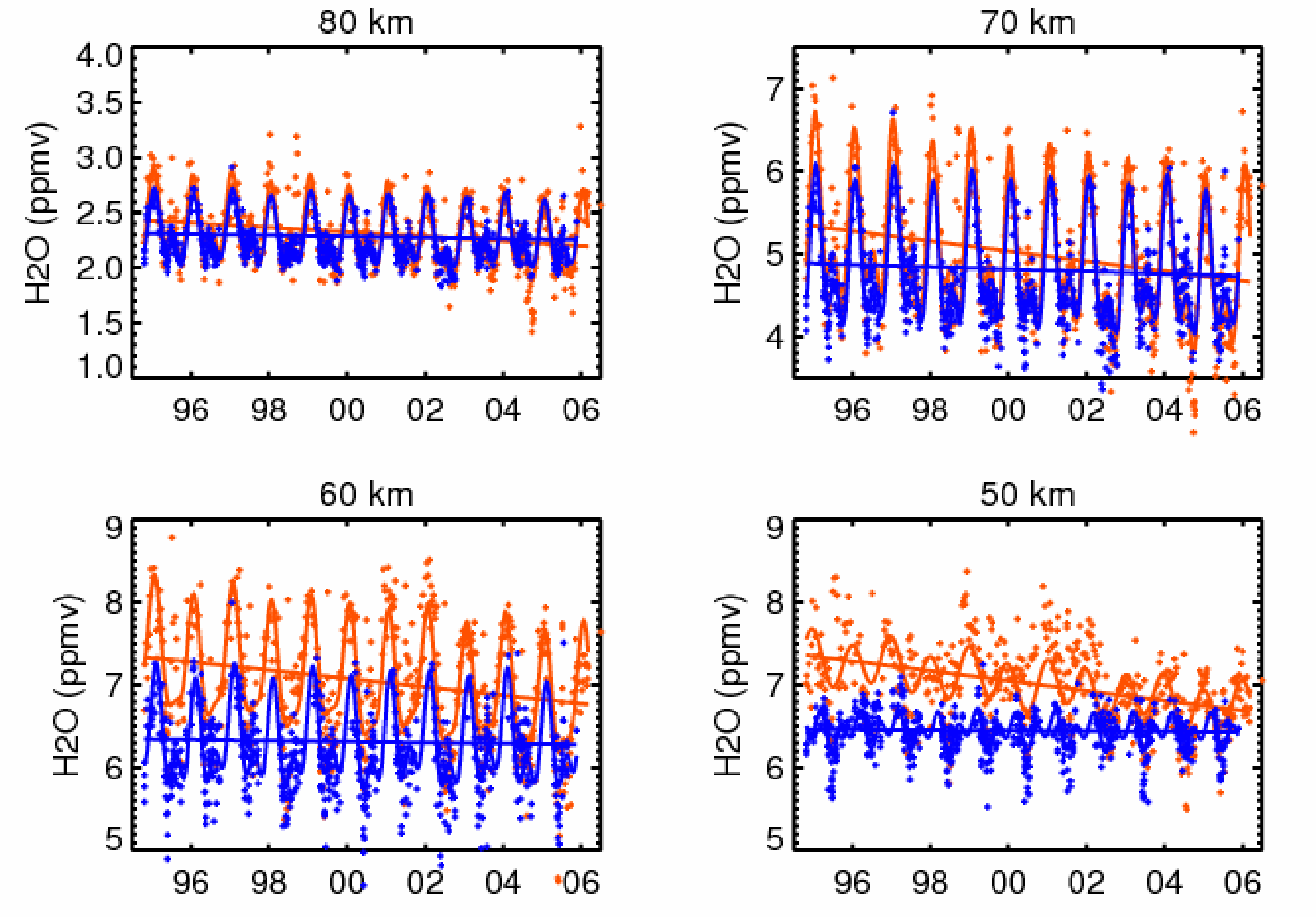
WVMS at Lauder - HALOE (40S-50S)



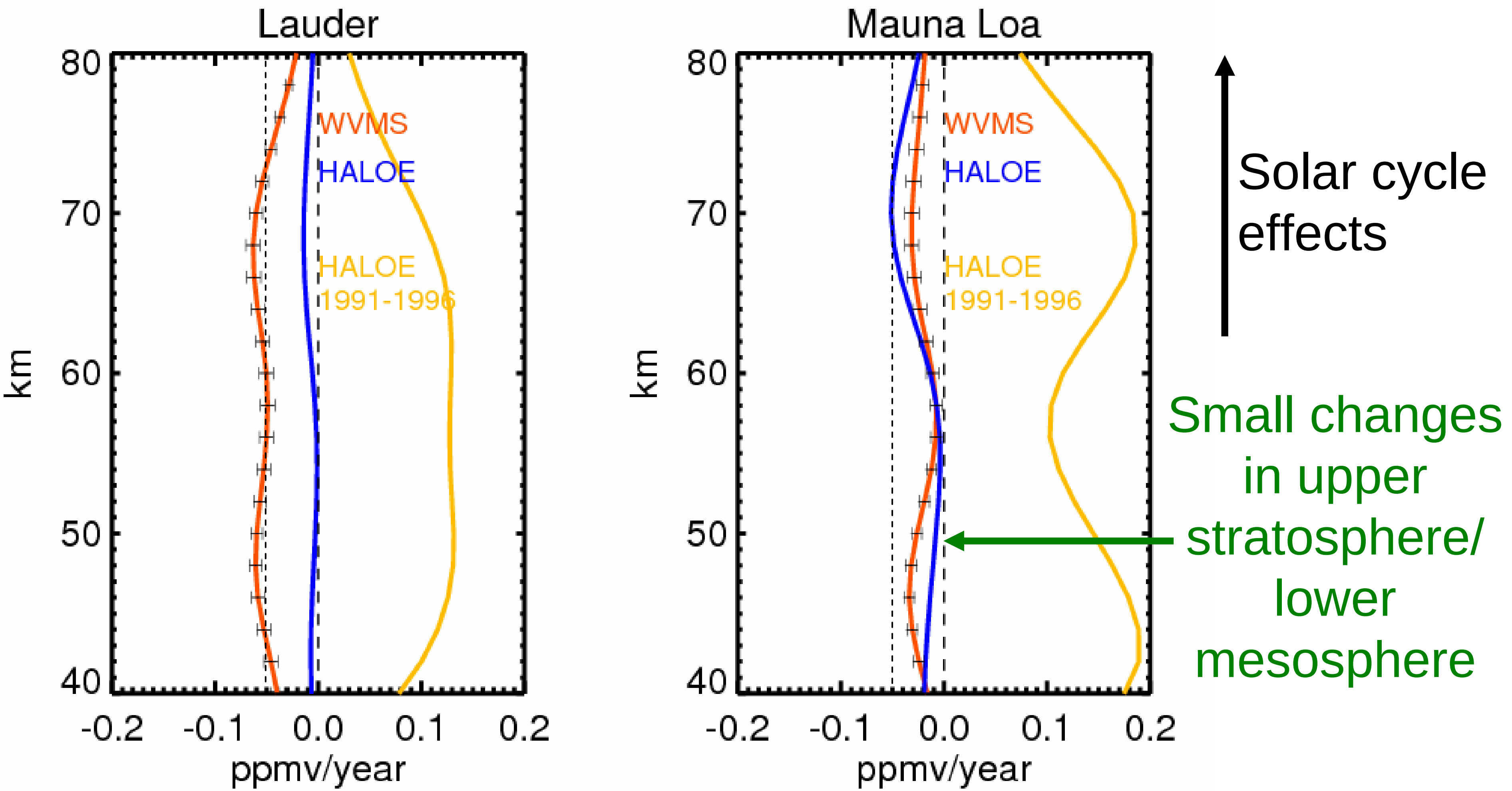
WVMS at MLO and HALOE (14.5N-24.5N)



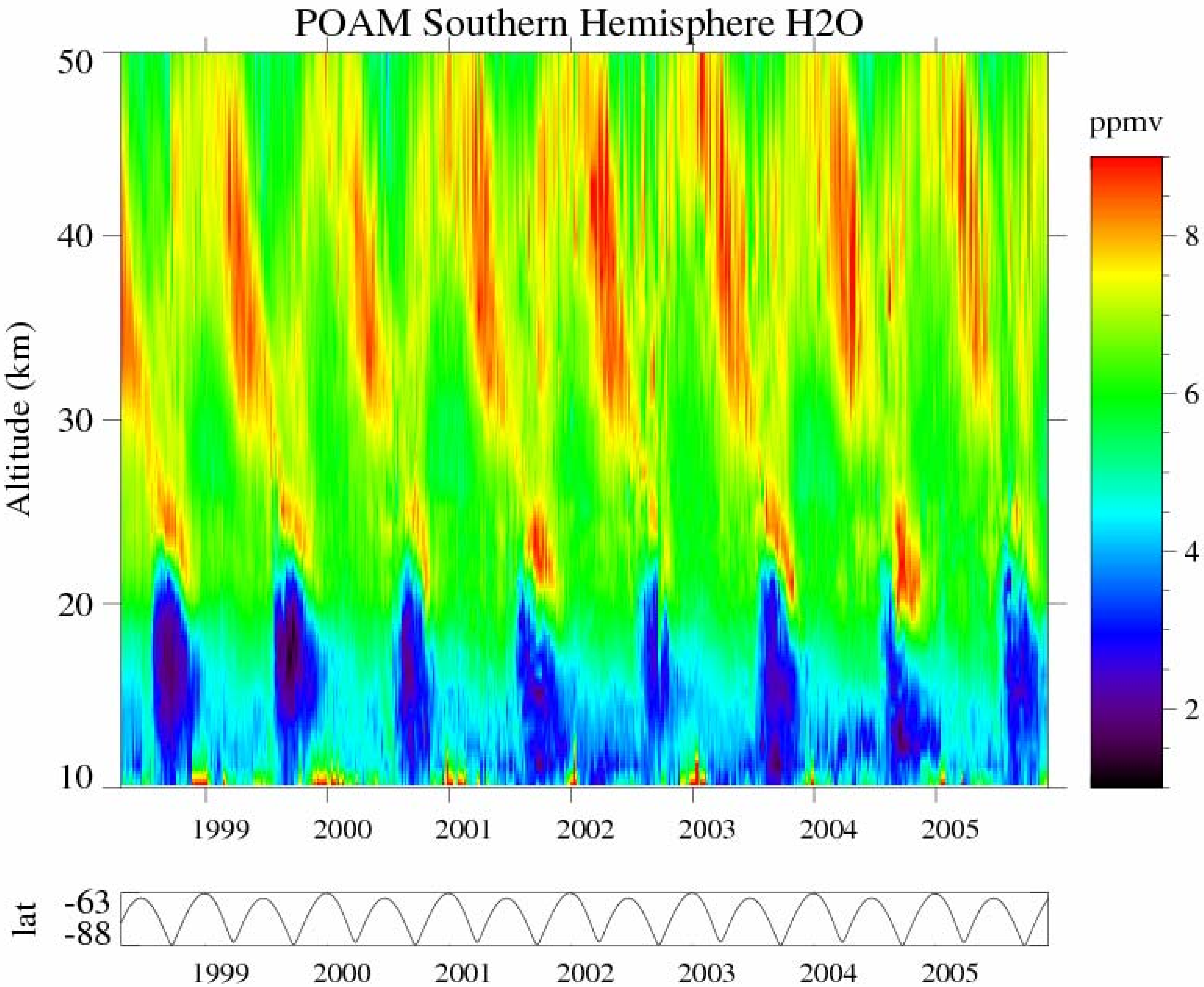
WVMS at MLO and HALOE (14.5N-24.5N)



Lauder (45S) and Mauna Loa (14.5N) trends since November 1996

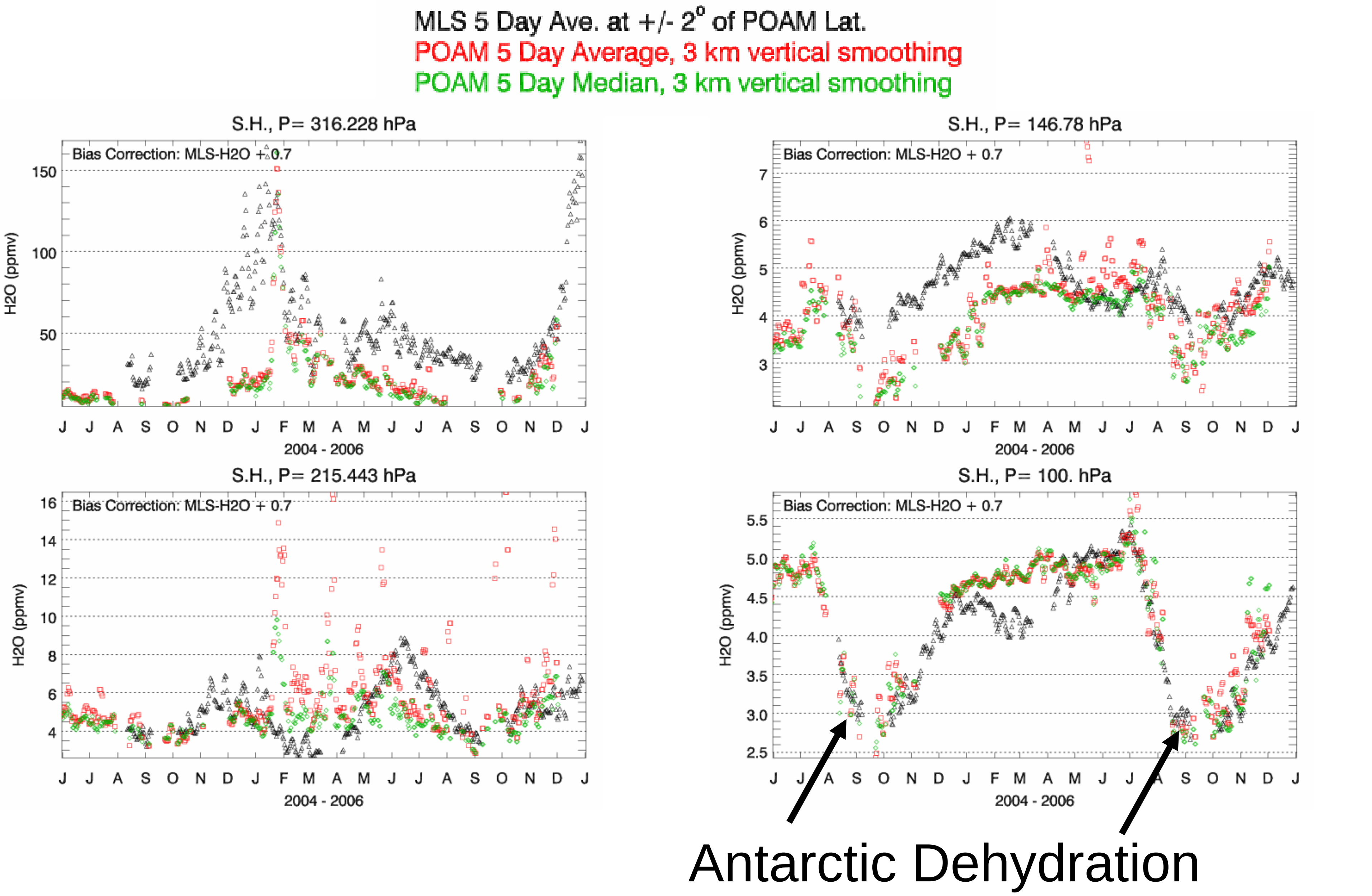


1σ errors shown

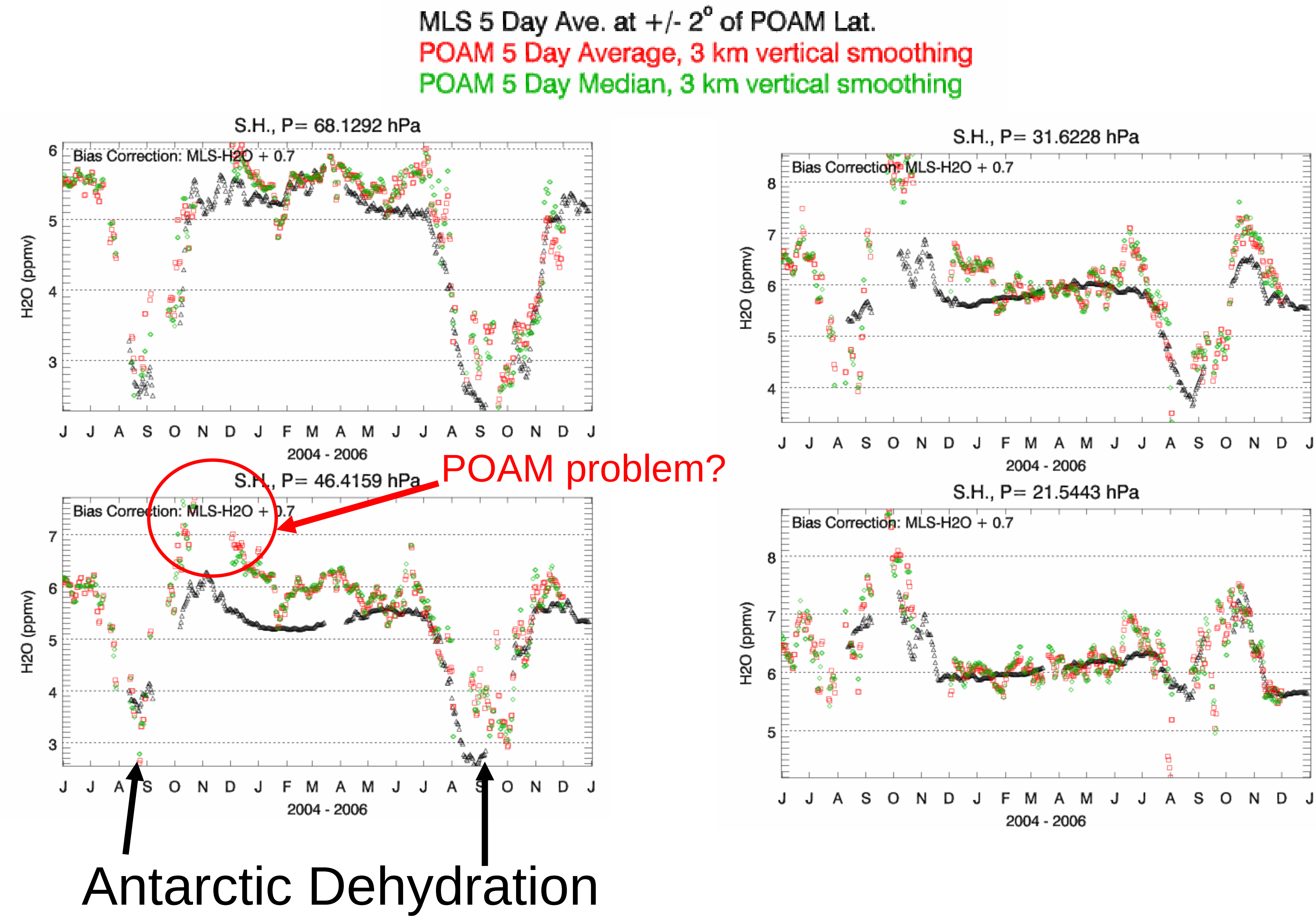


POAM Southern Hemisphere H2O
Altitude (km)
50
40
30
20
10
1999
2000
2001
2002
2003
2004
2005
ppmv
8
6
4
2
lat
-63
-88
1999
2000
2001
2002
2003
2004
2005

Troposphere/lowermost stratosphere measurements



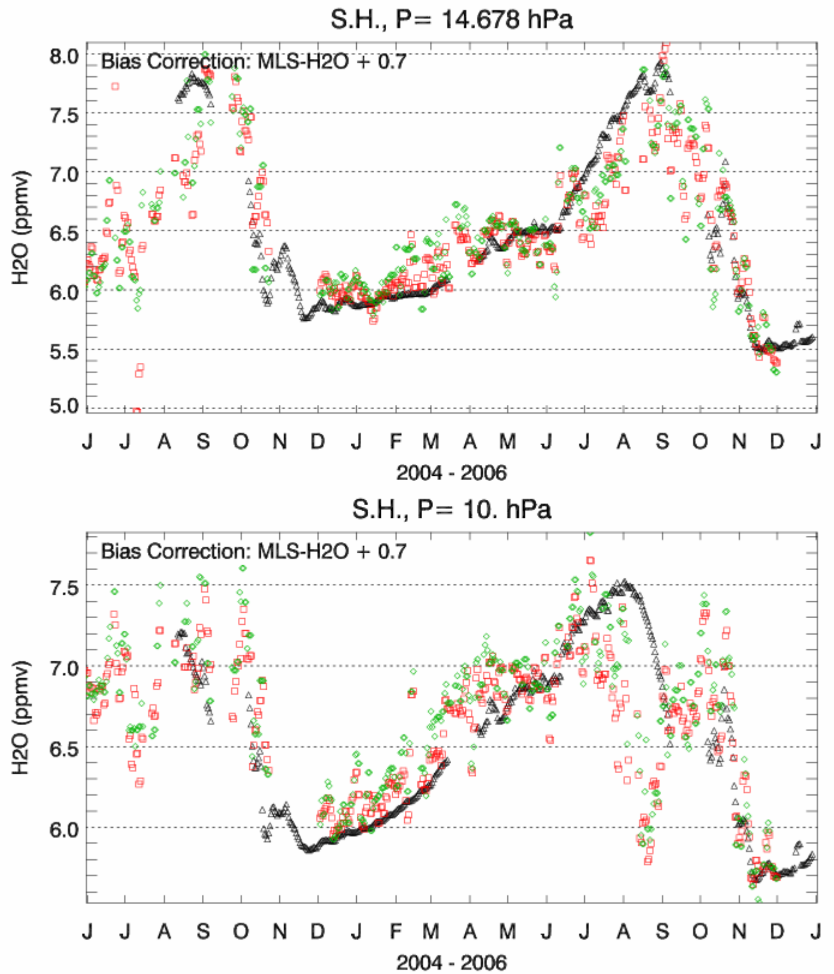
Lower stratosphere measurements

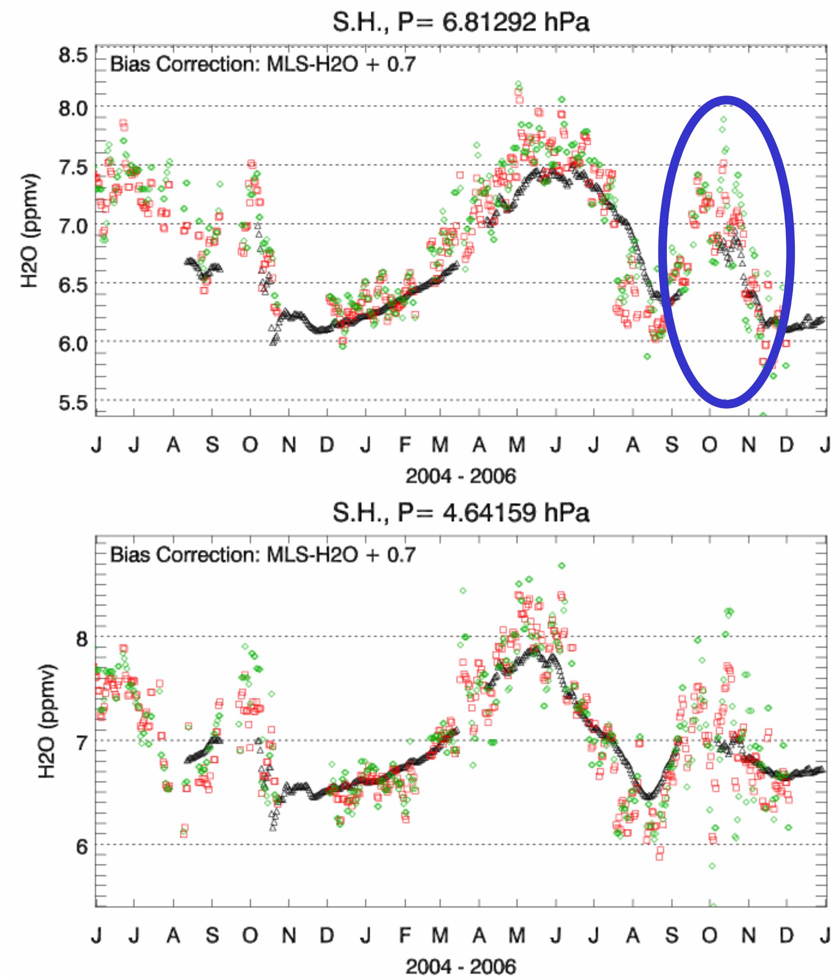


Upper stratosphere measurements

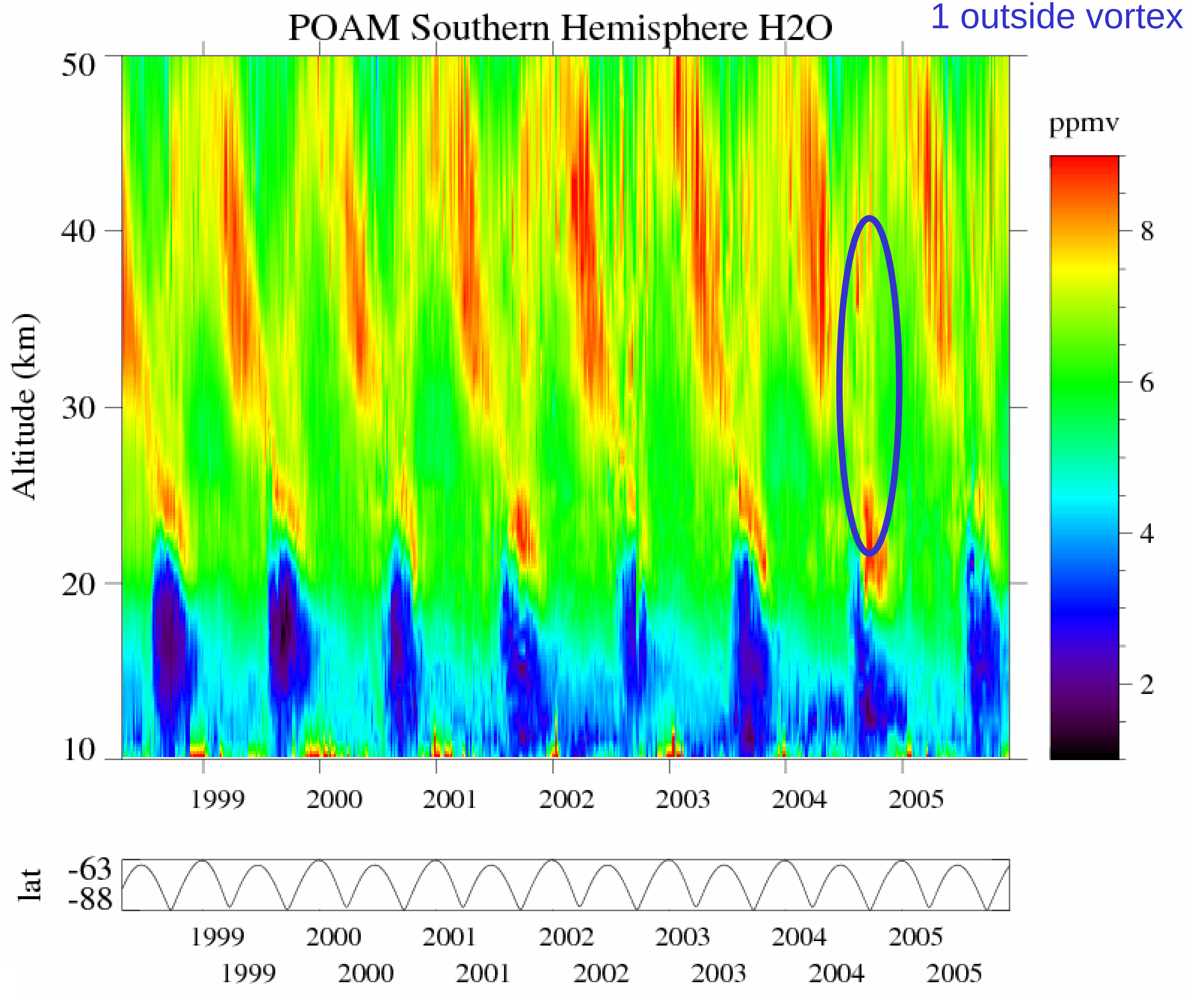
MLS 5 Day Ave. at +/- 2^{o} of POAM Lat.
POAM 5 Day Average, 3 km vertical smoothing
POAM 5 Day Median, 3 km vertical smoothing

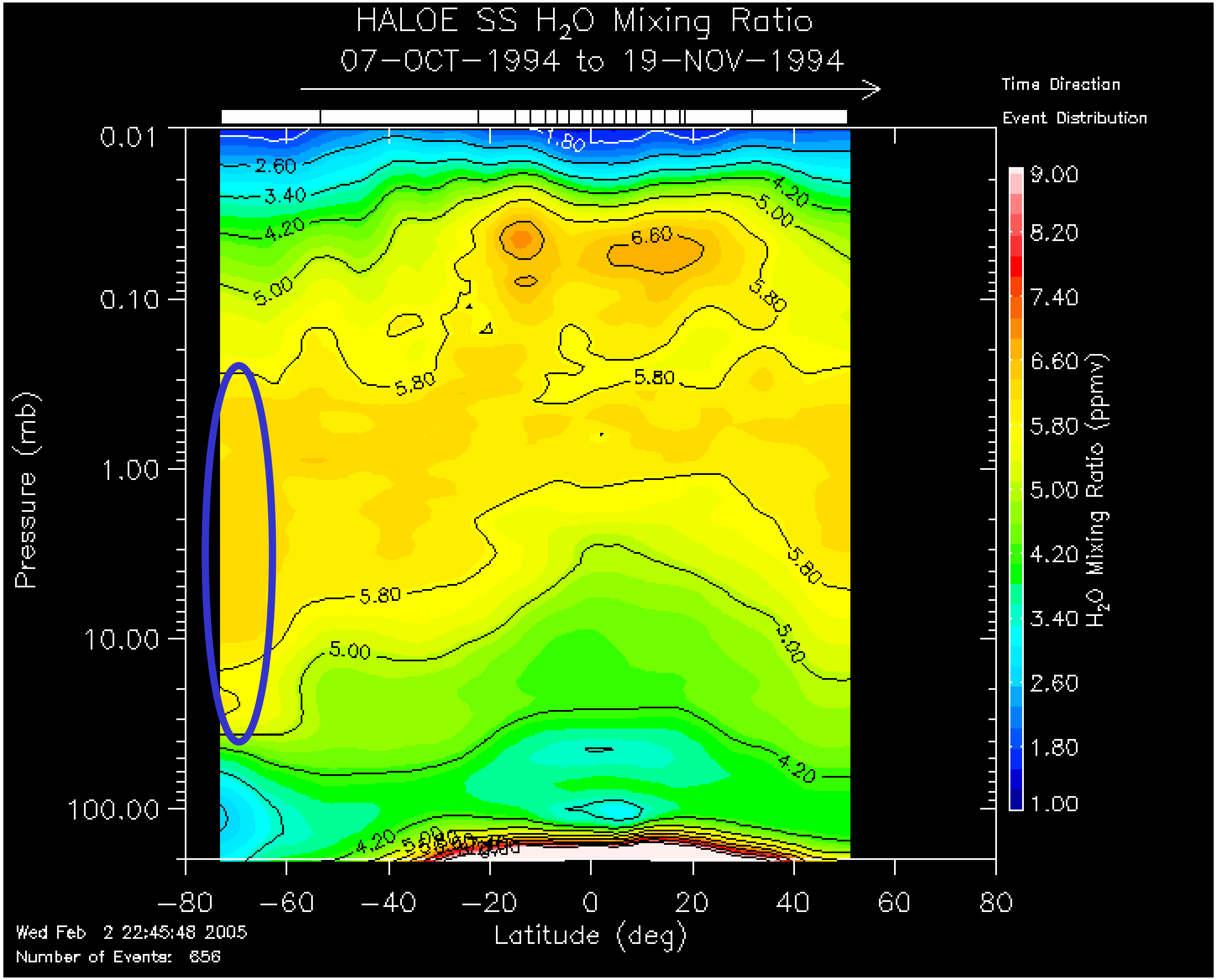
What's this?





2 peaks, 1 inside vortex and
1 outside vortex

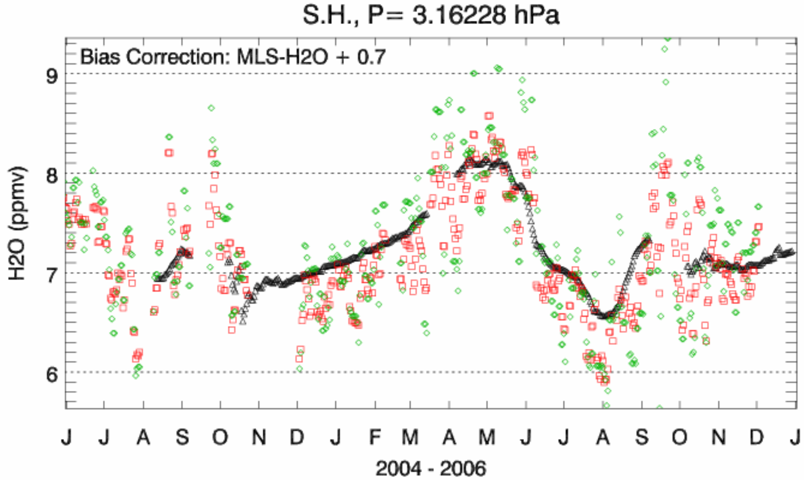


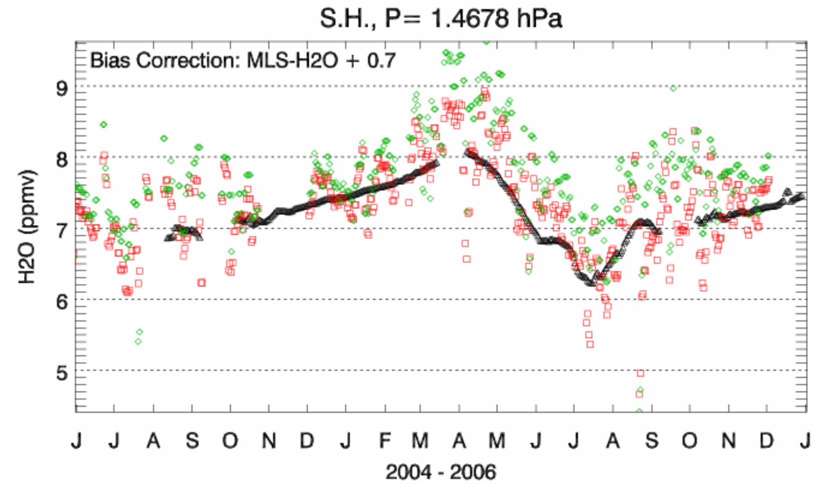


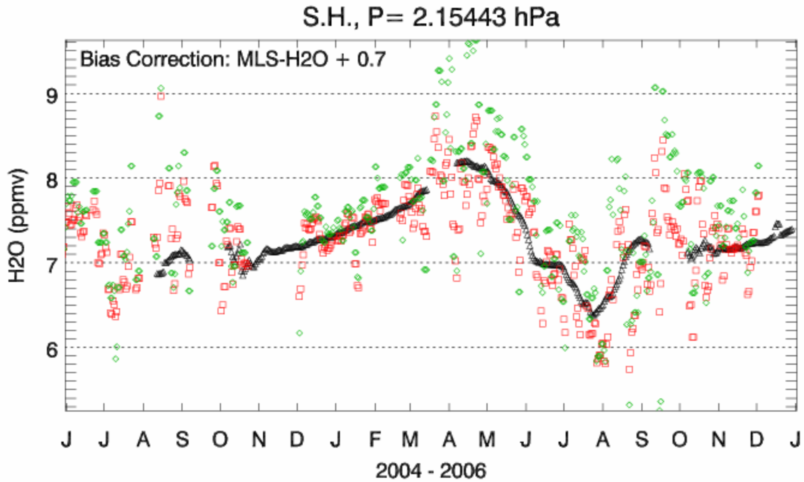
HALOE SS H_2O Mixing Ratio
07-OCT-1994 to 19-NOV-1994
Time Direction
Event Distribution
Pressure (mb)
0.01
0.10
1.00
10.00
100.00
Latitude (deg)
-80 -60 -40 -20 0 20 40 60 80
H_2O Mixing Ratio (ppmv)
9.00
8.20
7.40
6.60
5.80
5.00
4.20
3.40
2.60
1.80
1.00
Wed Feb 2 22:45:48 2005
Number of Events: 656

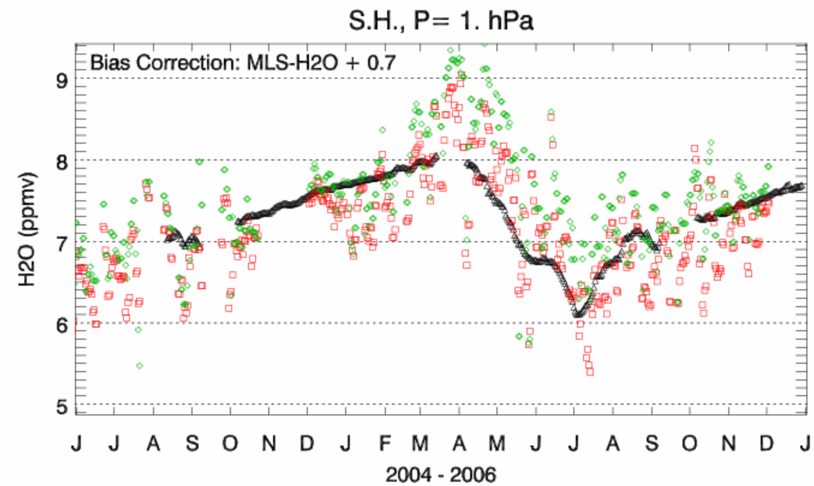
Upper stratosphere measurements

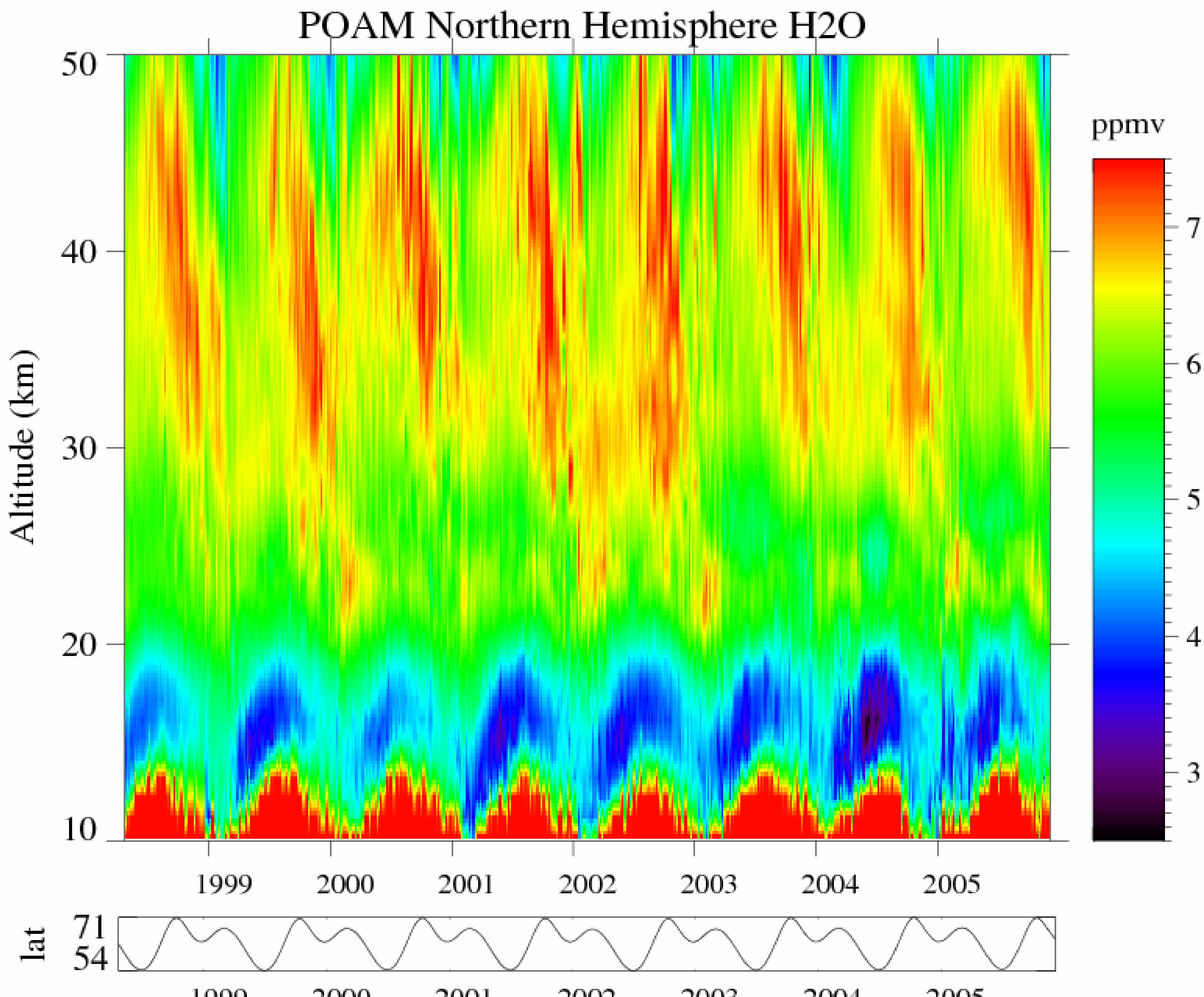
MLS 5 Day Ave. at +/- 2° of POAM Lat.
POAM 5 Day Average, 3 km vertical smoothing
POAM 5 Day Median, 3 km vertical smoothing





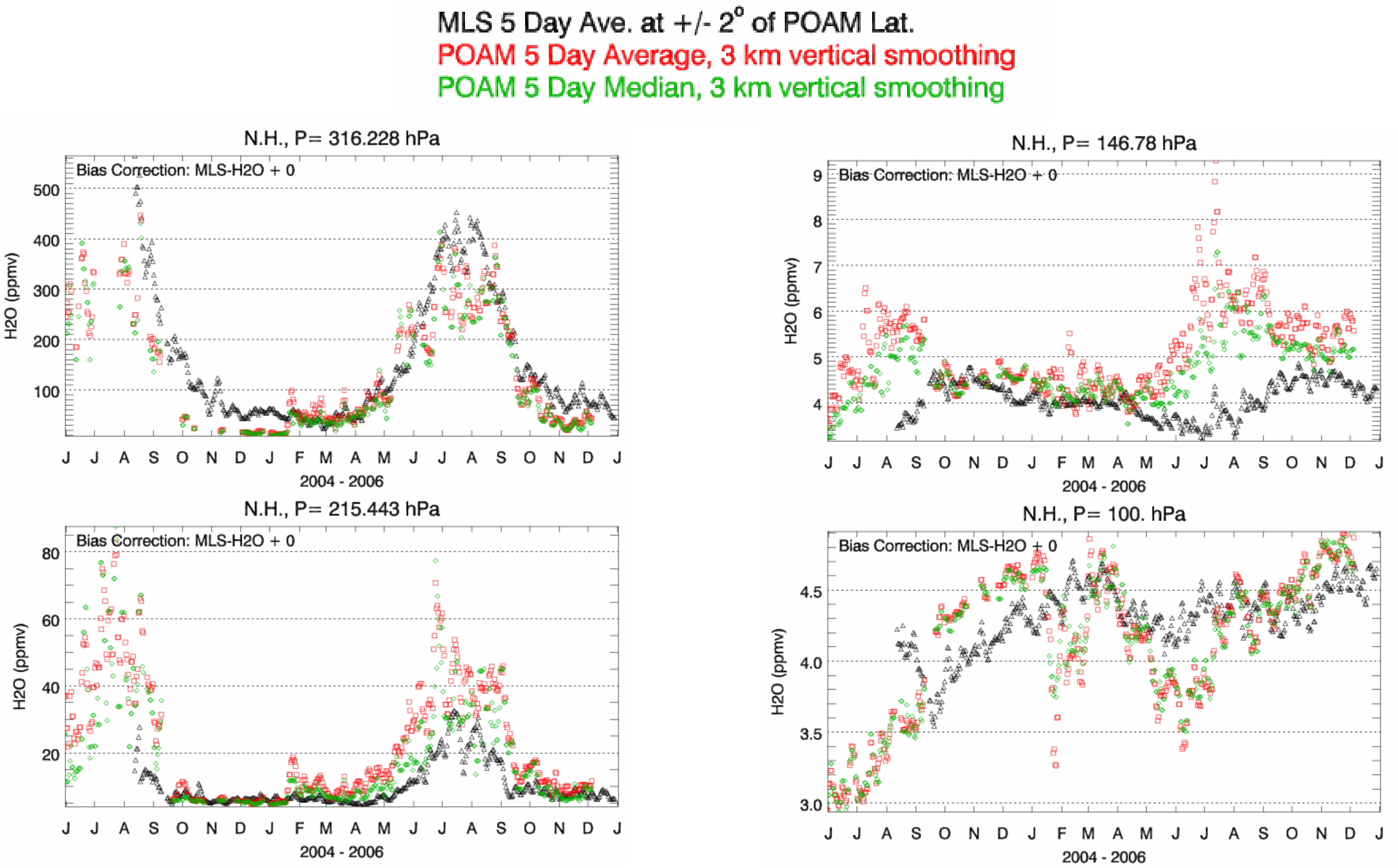




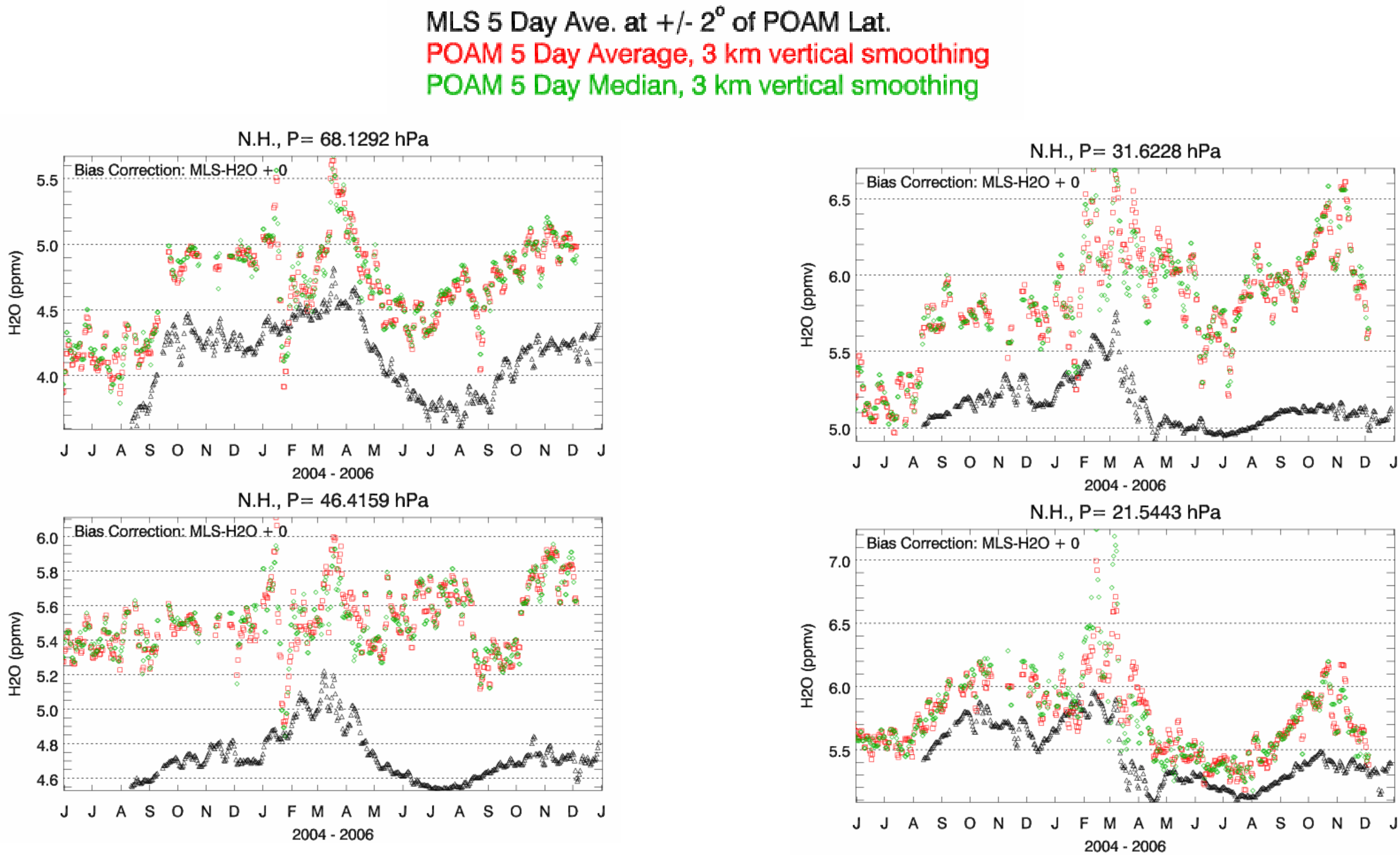


POAM Northern Hemisphere H2O
Altitude (km)
50
40
30
20
10
1999
2000
2001
2002
2003
2004
2005
ppmv
7
6
5
4
3
lat
71
54
1999
2000
2001
2002
2003
2004
2005

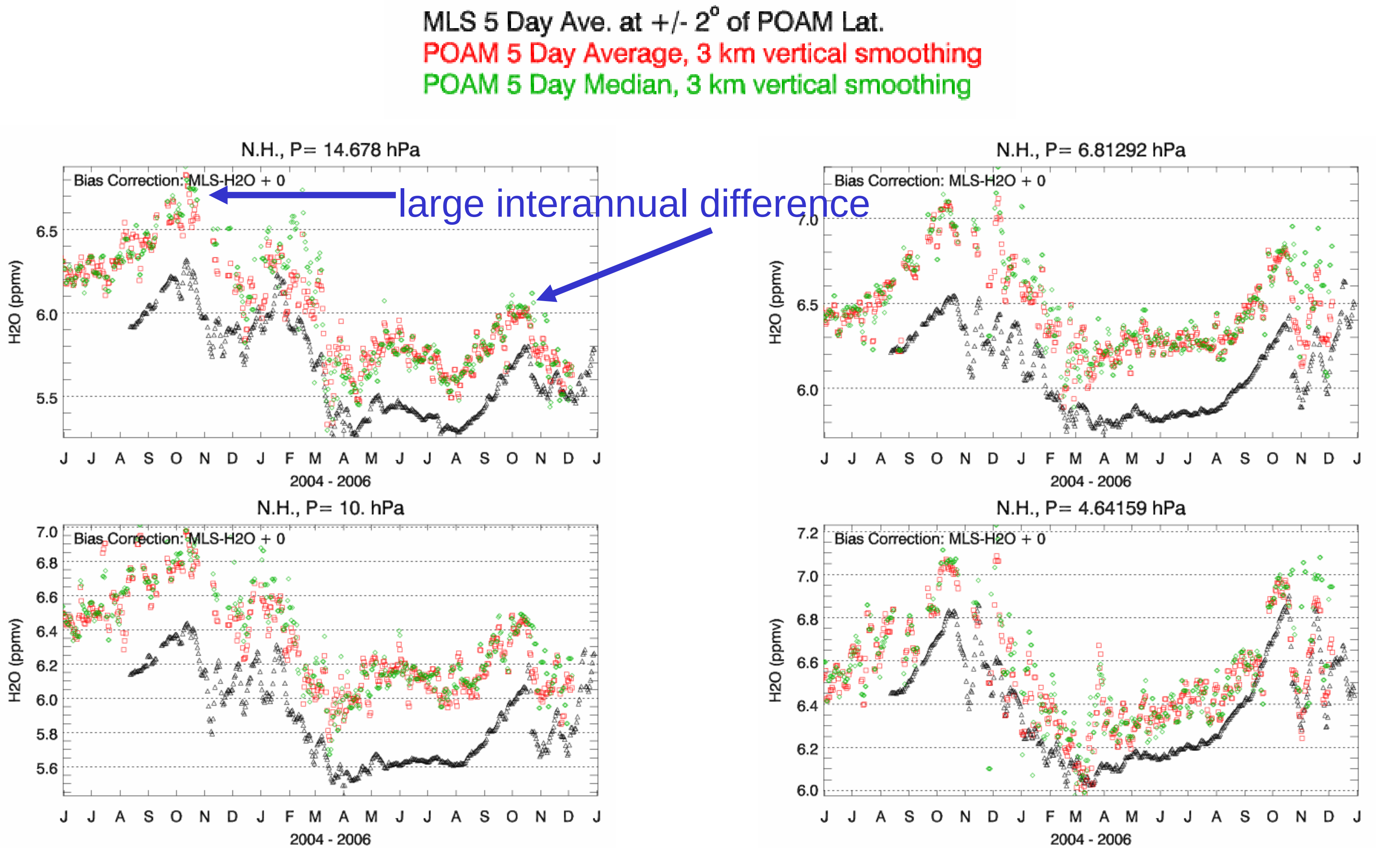
Troposphere/lowermost stratosphere measurements



Lower stratosphere measurements

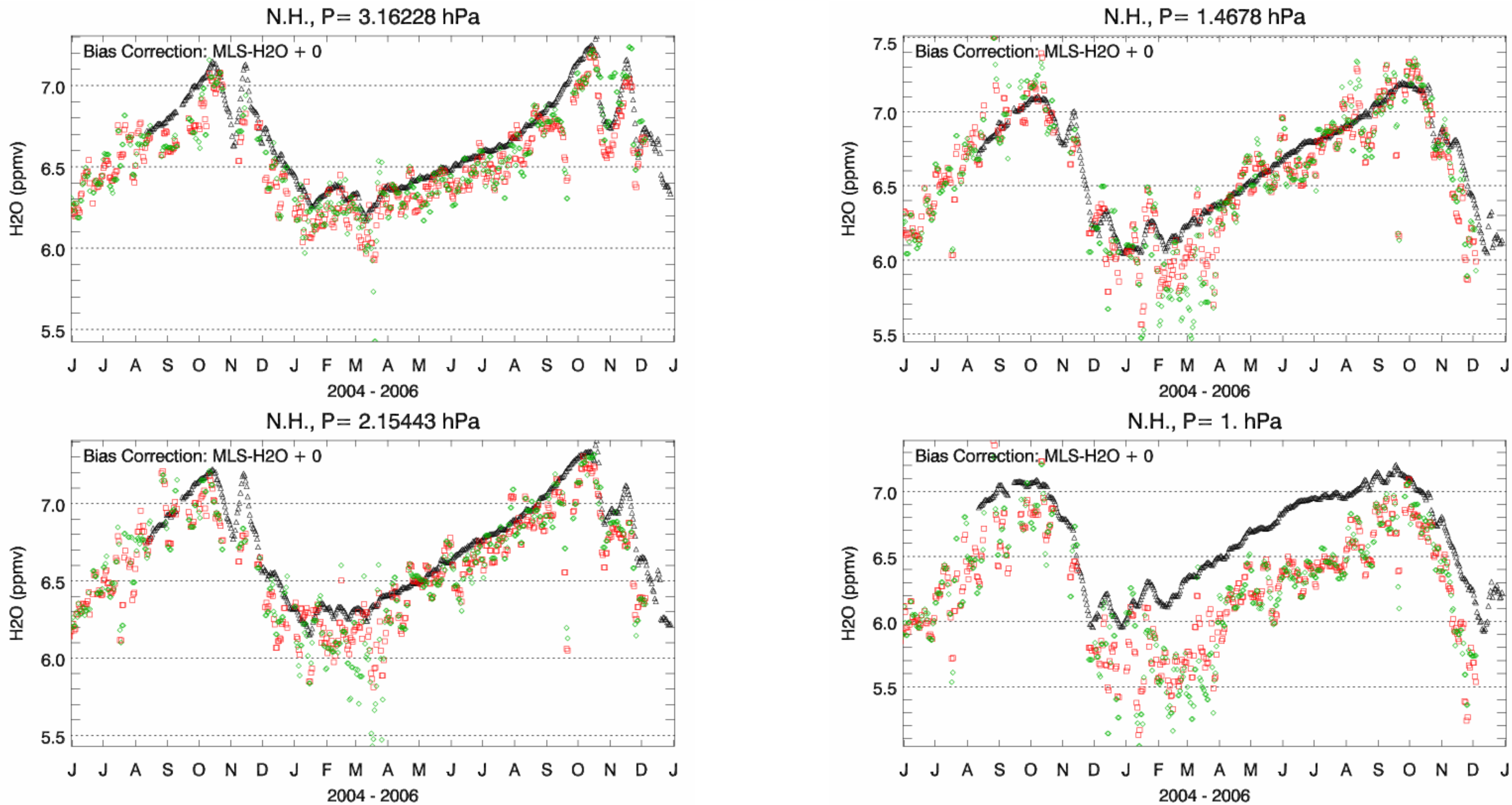


Upper stratosphere measurements

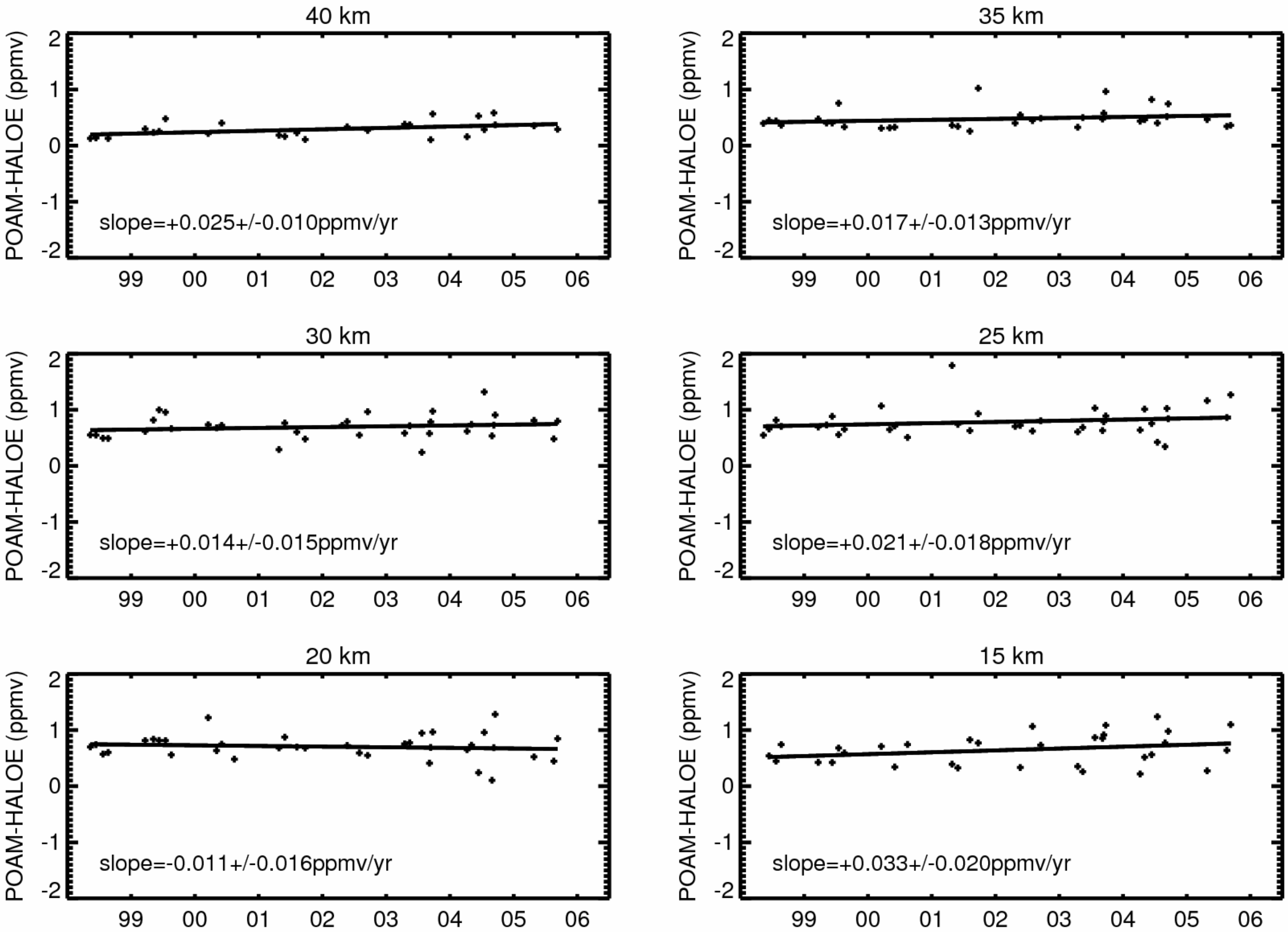


Upper stratosphere measurements

MLS 5 Day Ave. at +/- 2° of POAM Lat.
POAM 5 Day Average, 3 km vertical smoothing
POAM 5 Day Median, 3 km vertical smoothing

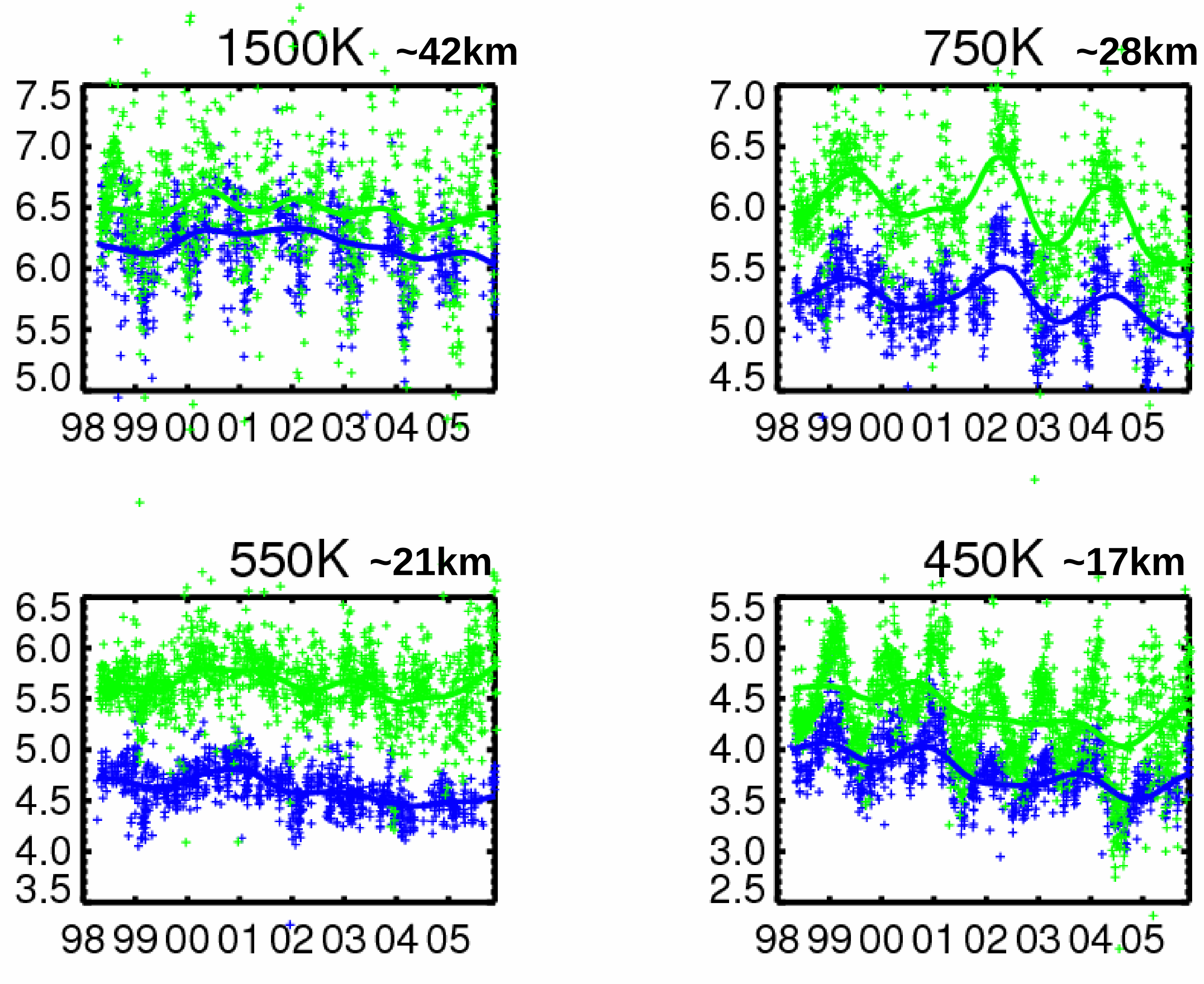


POAM sunrise - HALOE H_2O comparisons 15-40km

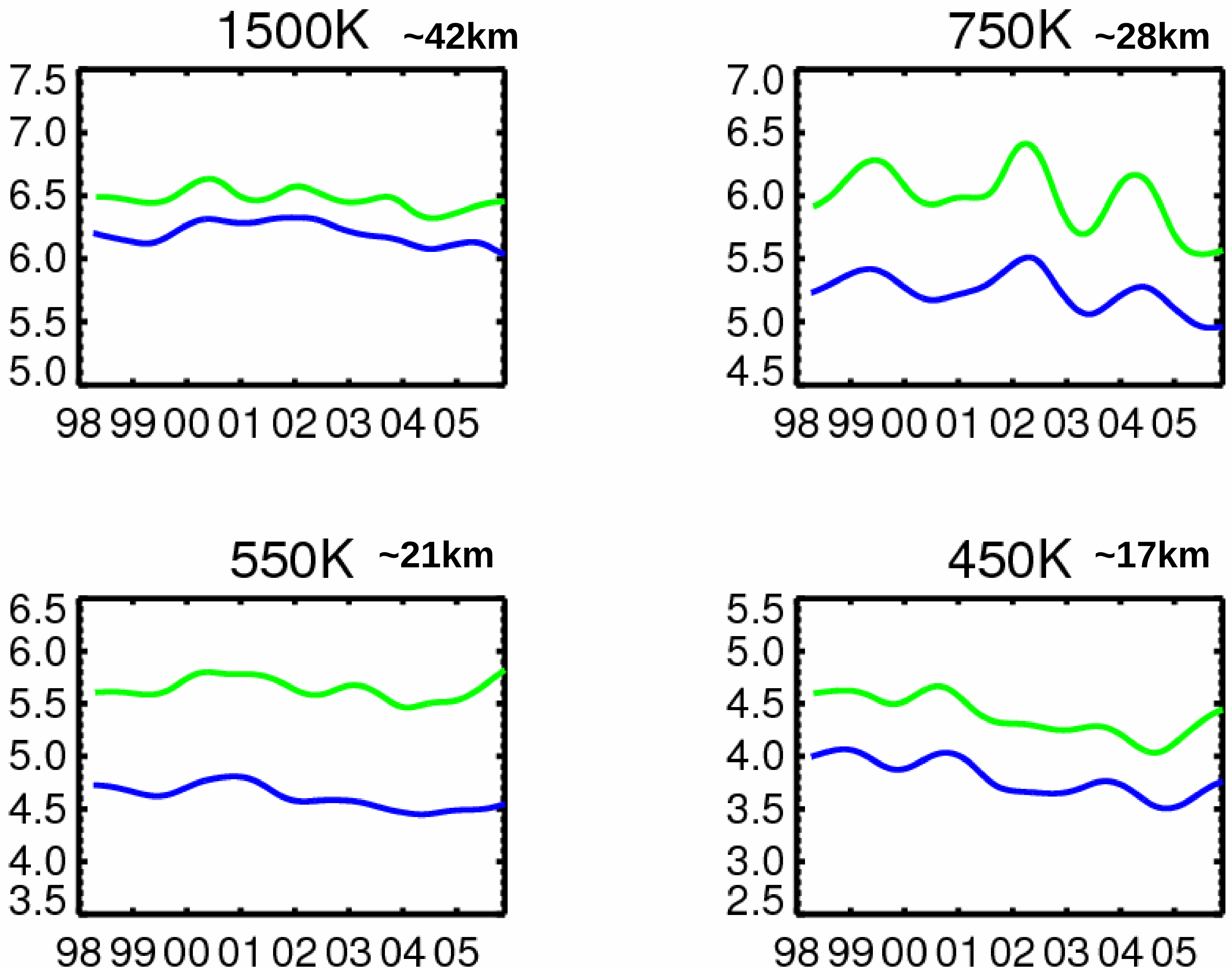


Errors are 1σ

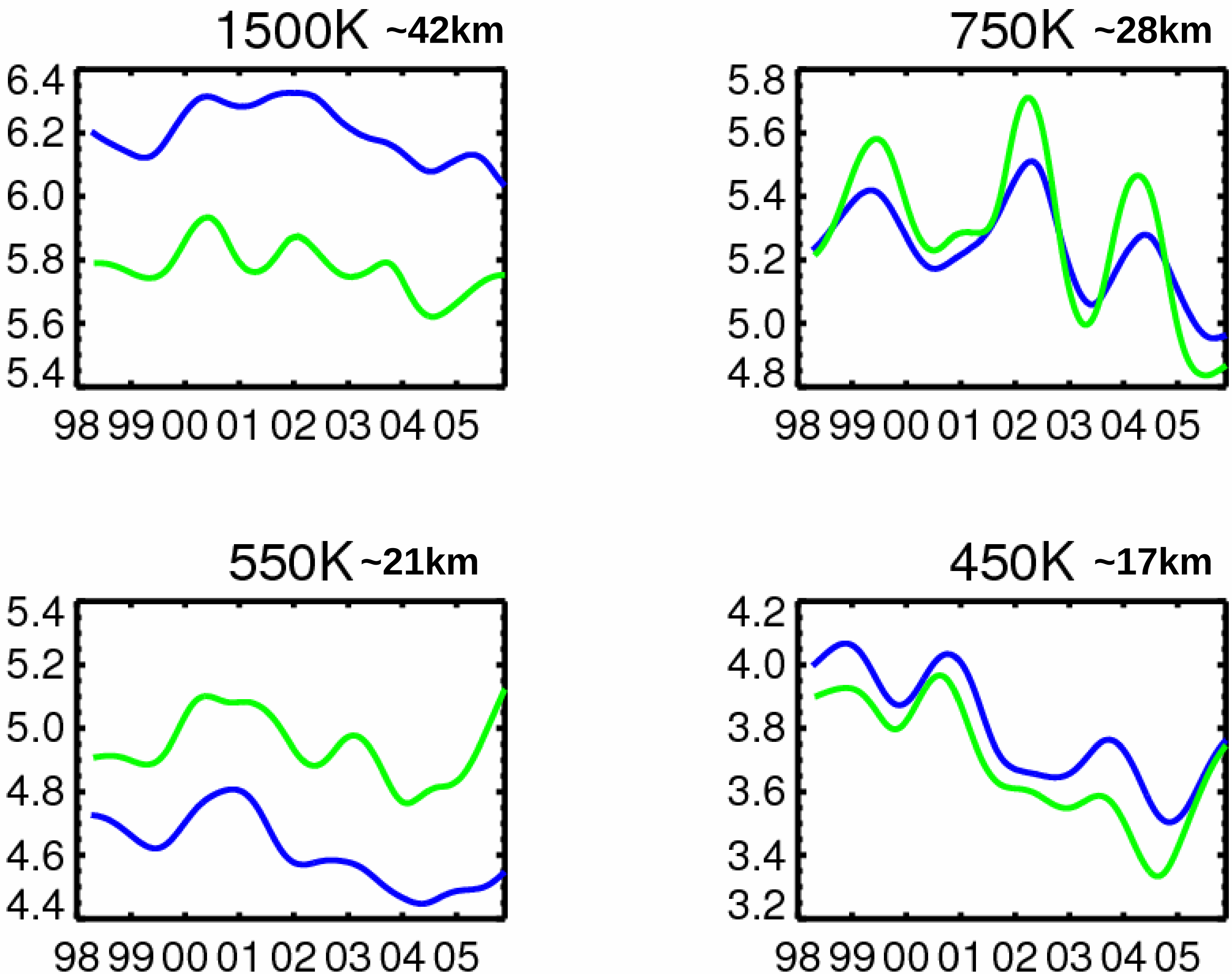
HALOE and POAM; 45N-55N Equivalent Latitude

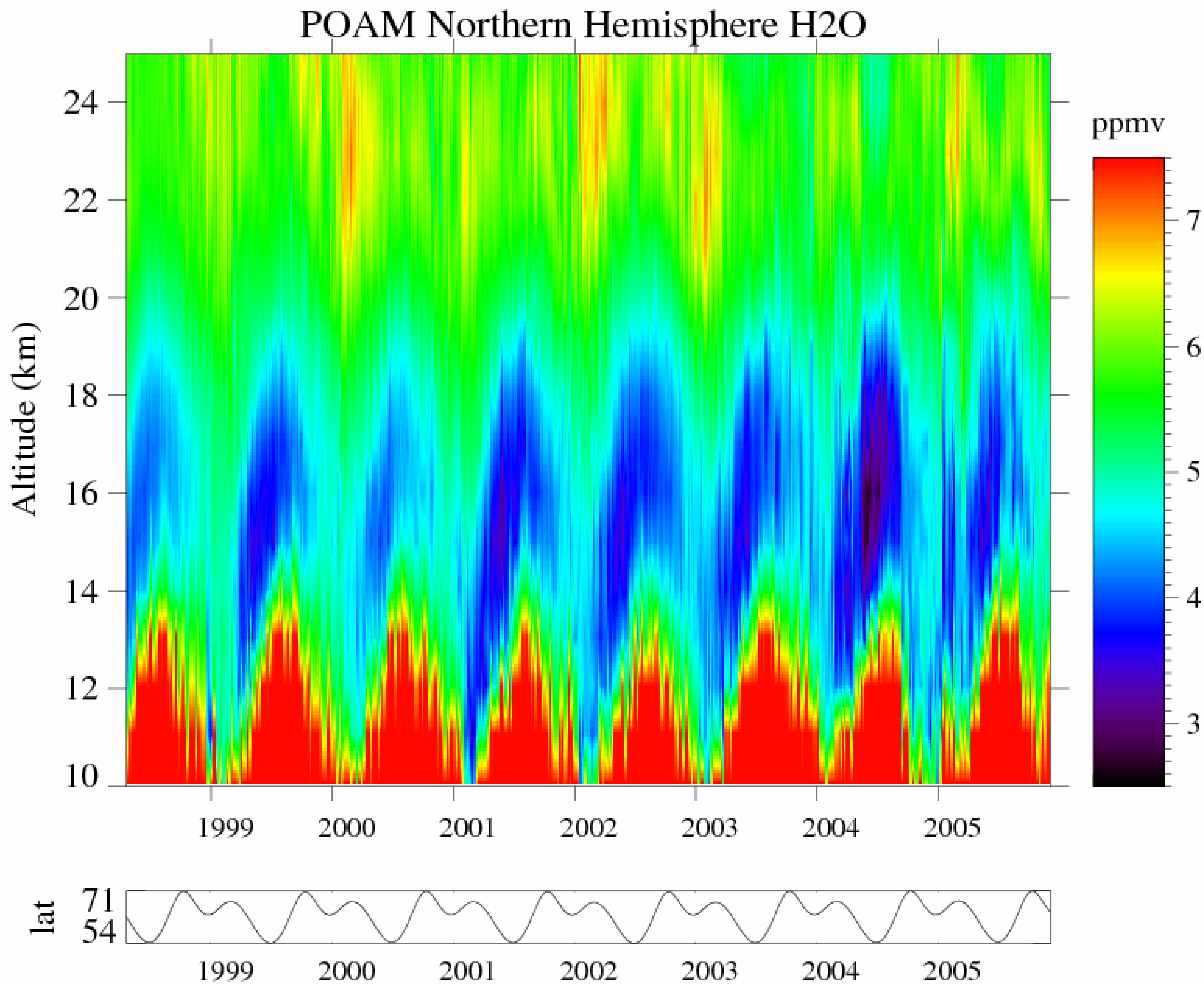


HALOE and POAM; 45N-55N Equivalent Latitude



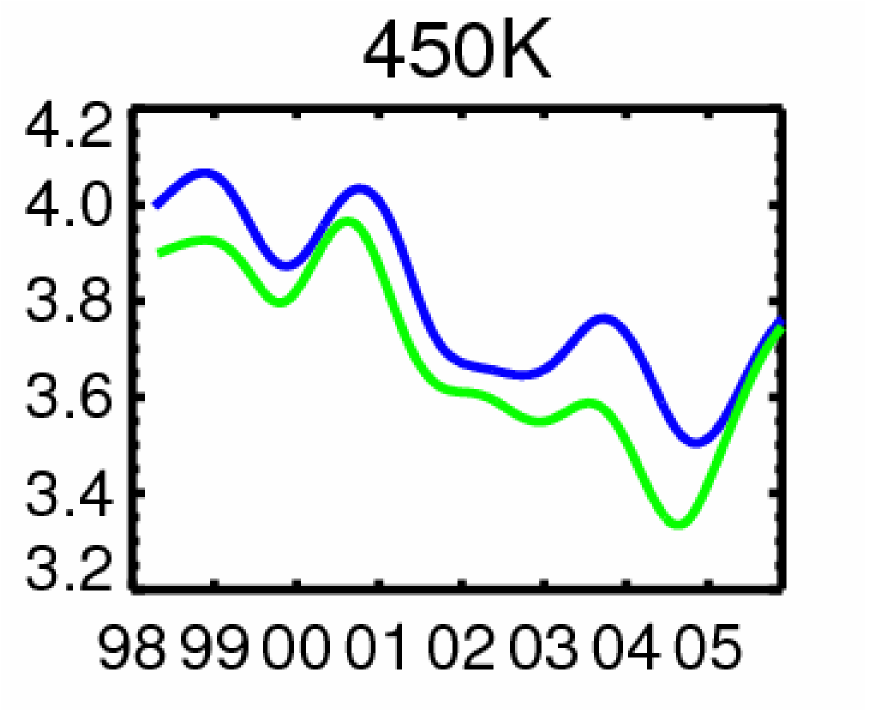
HALOE and POAM-.7ppmv; 45N-55N Equivalent Latitude

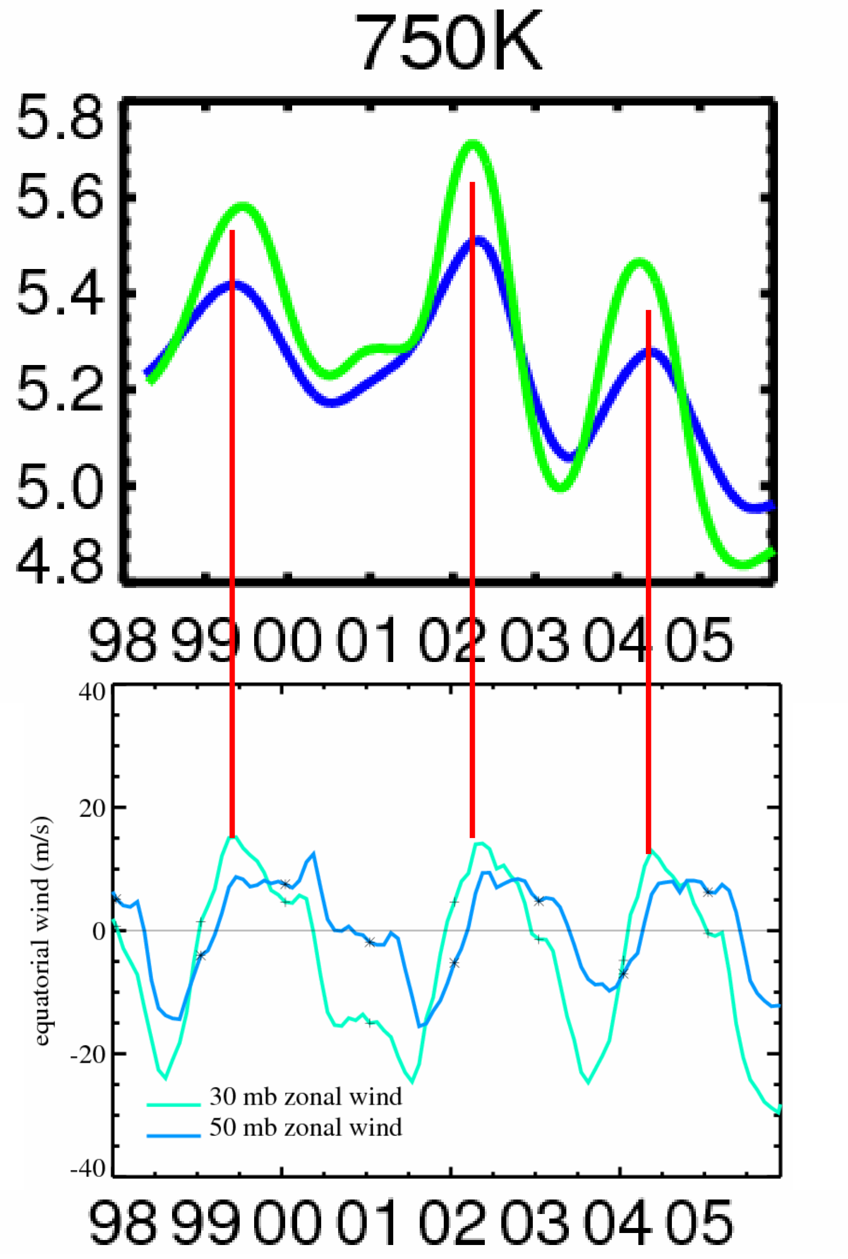



POAM Northern Hemisphere H2O
Altitude (km)
24
22
20
18
16
14
12
10
ppmv
7
6
5
4
3
1999
2000
2001
2002
2003
2004
2005
lat
71
54
1999
2000
2001
2002
2003
2004
2005

HALOE and POAM-.7ppmv; 45N-55N Equivalent Latitude

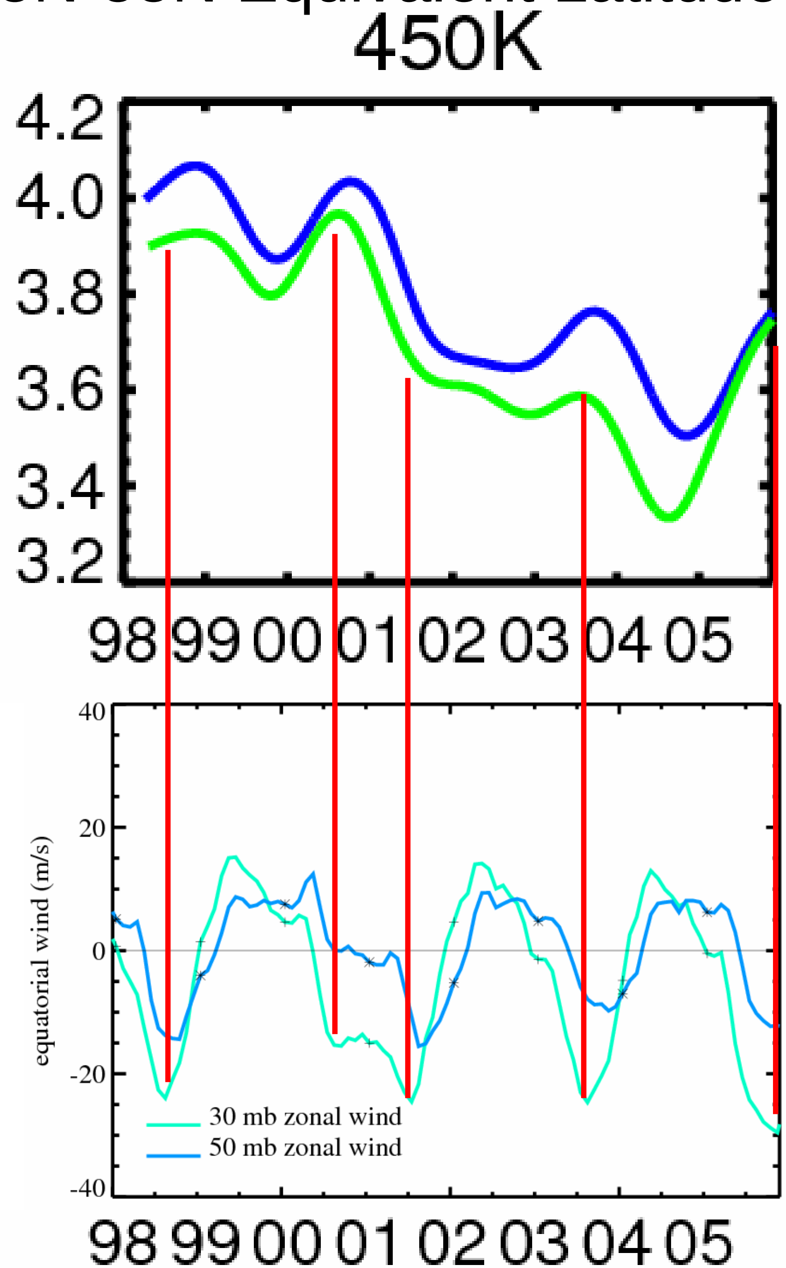
- Good correlation between 30 and 50 mb zonal winds and 750K H_2O variations at 45-55N equivalent latitude.

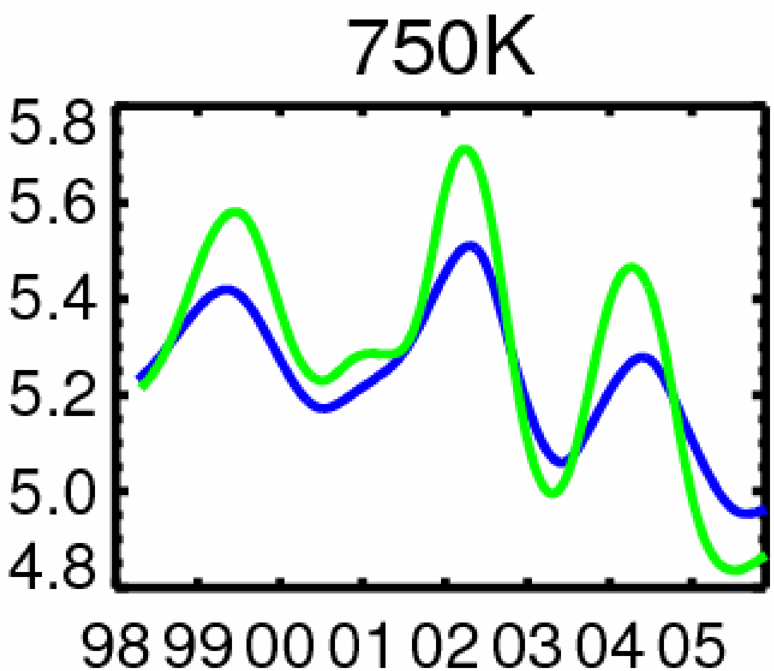




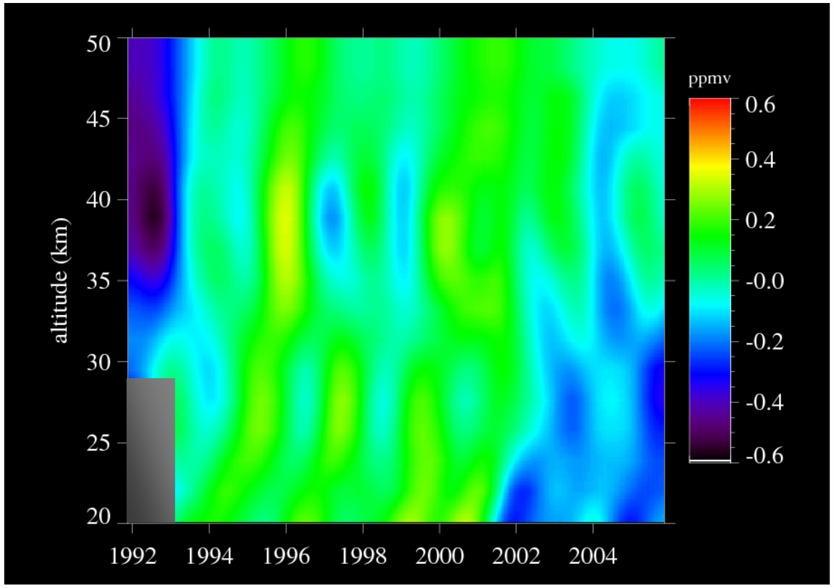
HALOE and POAM-.7ppmv; 45N-55N Equivalent Latitude

- Good correlation between 30 and 50 mb zonal winds and 750K H_2O variations at 45-55N equivalent latitude.
- Can the increased H2O at 450K in 2005 be completely attributed to the QBO?

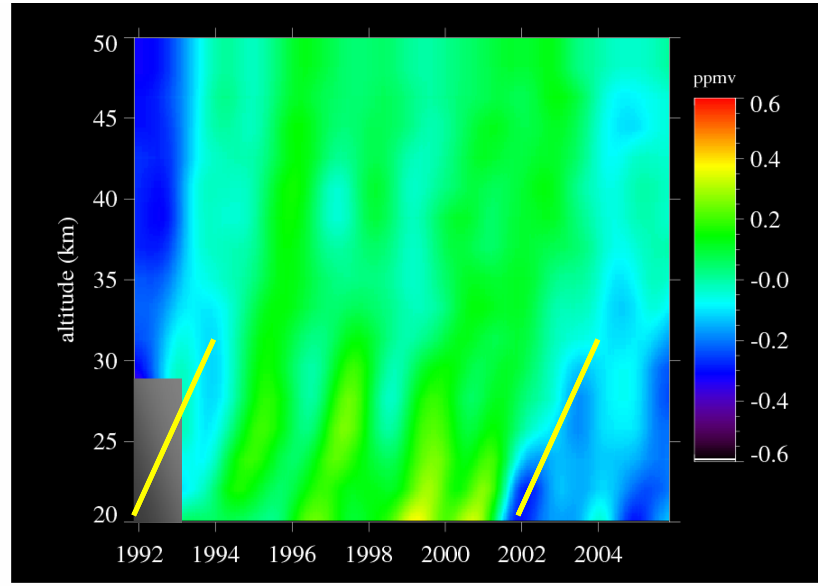




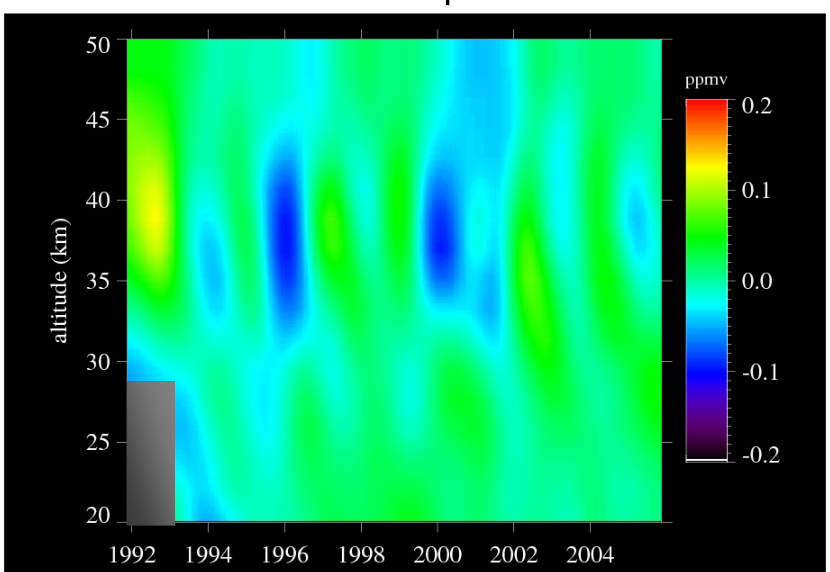
H_2O



H_2O+2CH_4

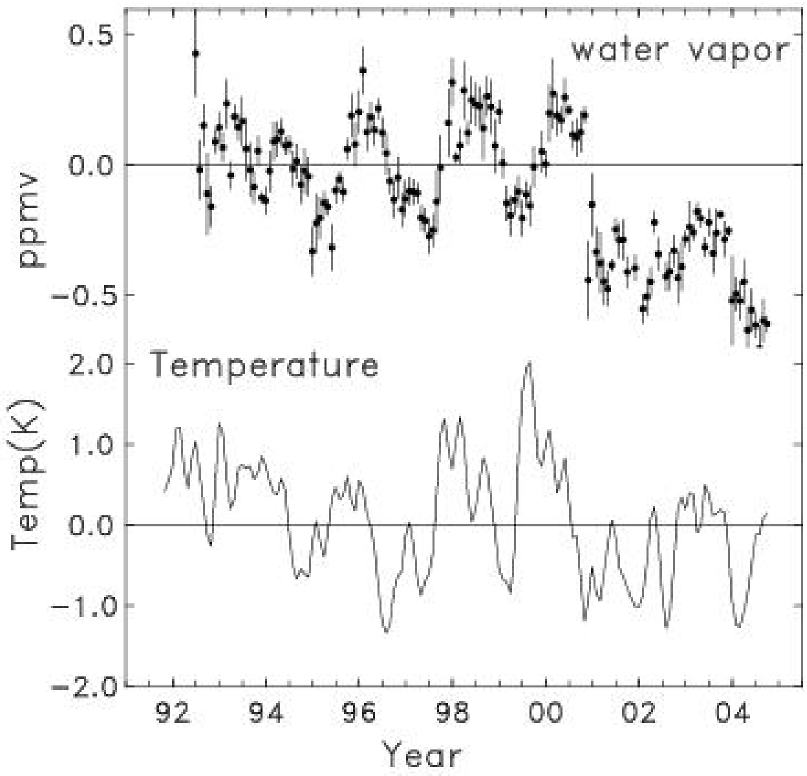


CH_4



Deseasonalized HALOE data;
20S-20N

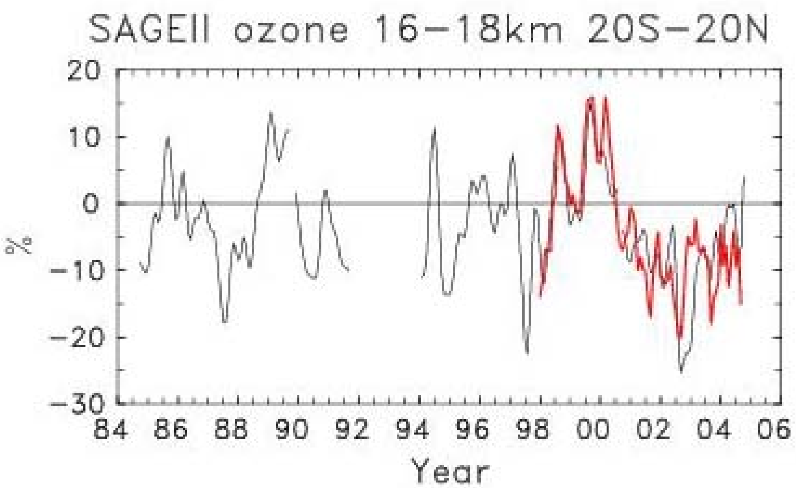
Yellow=> Fast ascent
Blue => Slow ascent

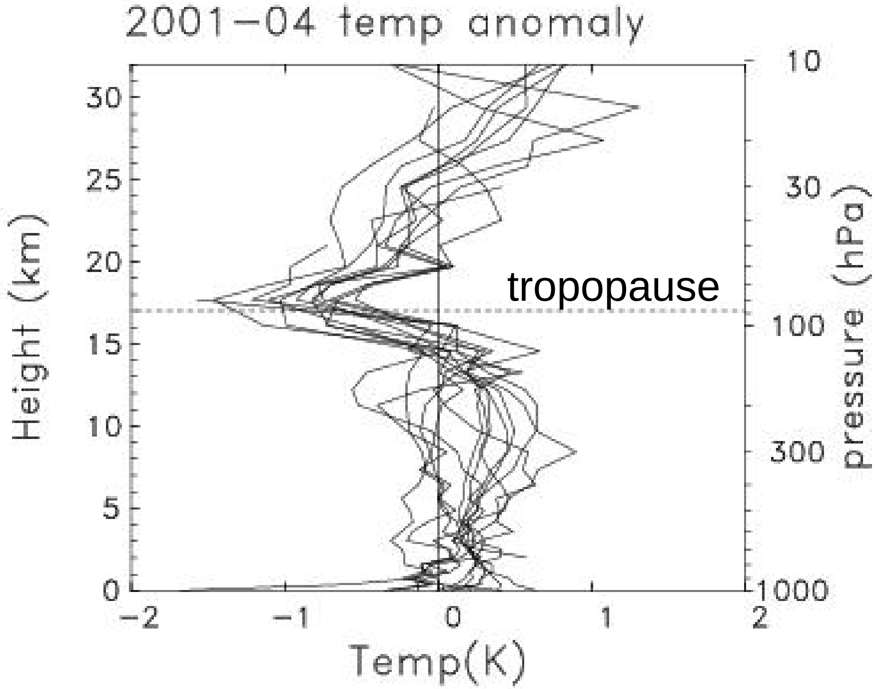


HALOE H_2O (10S-10N) and deseasonalized cold point temperature anomalies from 14 radiosonde stations

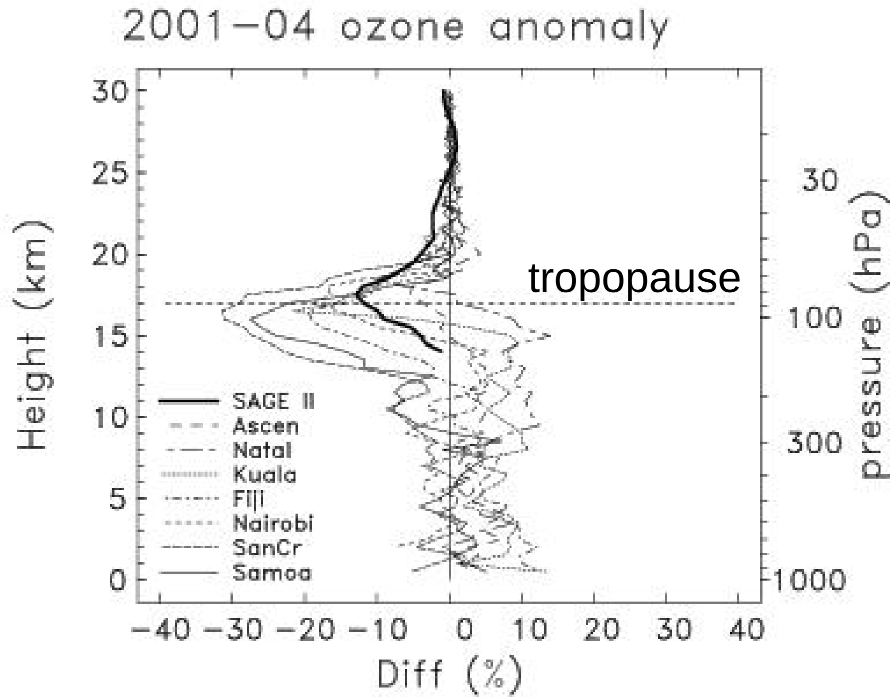
(Randel et al., in press)

Zonal mean ozone anomalies 16-18km, 20S-20N.
SAGE II and 7 tropical ozonesonde stations from SHADOZ





2001-2004 temperature anomaly (as compared to 1994-2000) for tropical radiosonde stations from 10S-10N



2001-2004 ozone anomaly (as compared to 1998-2000) for SAGE II and 7 tropical stations

- Decreased ozone may be the result of increased upwelling
- Decreased ozone will reduce local heating

(Randel et al., in press)

What's next for water vapor?

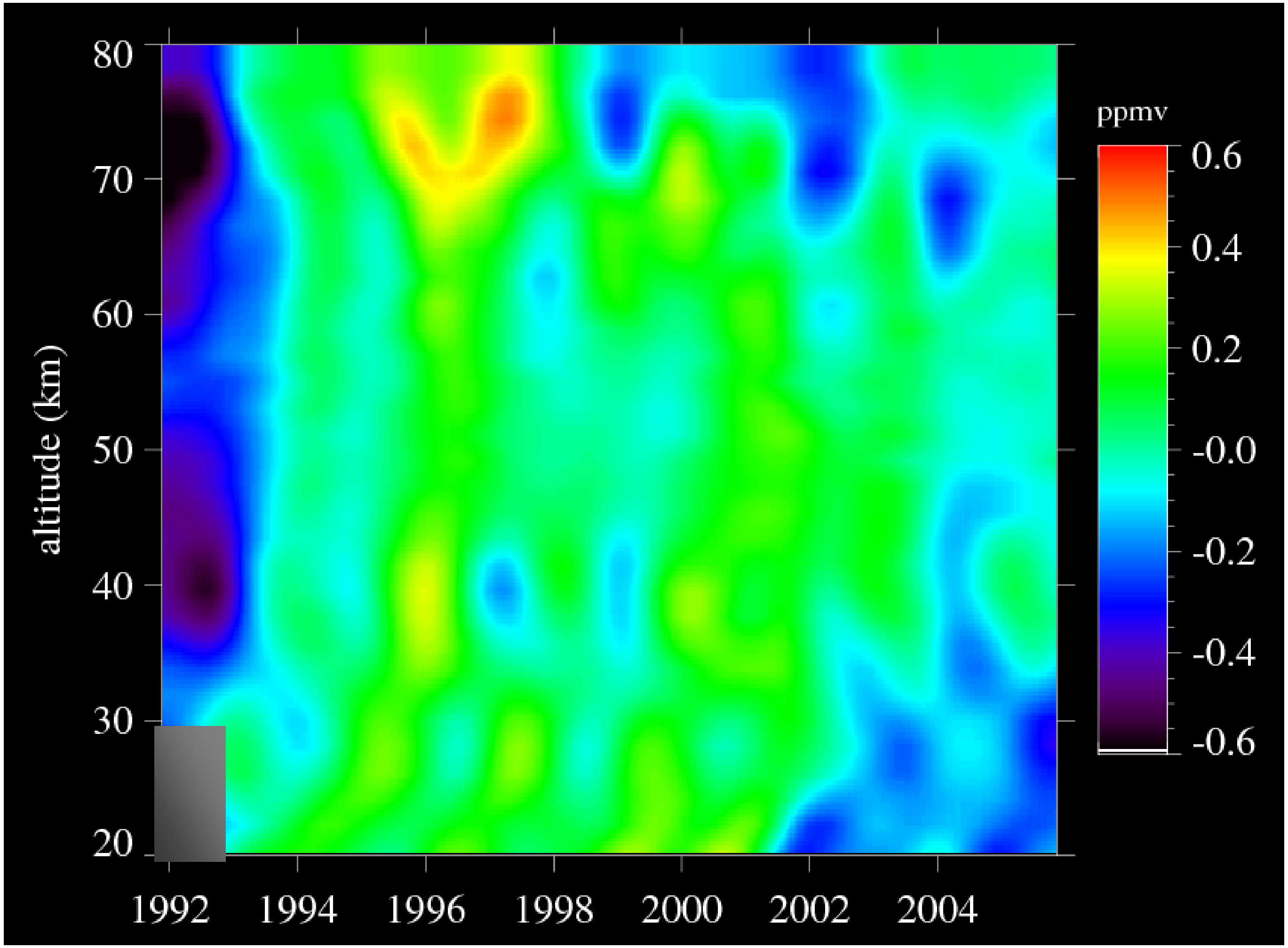
- Upper stratosphere/lower mesospheric H_2O constant since 1996.
- Lower stratospheric H_2O down since 2001.
- Even the long-term H_2O trend from CH_4 forcing trend is no longer clear. Will CH_4 continue to increase?

What we do and don’t know about the 2001 lower stratospheric H_2O decrease and its causes

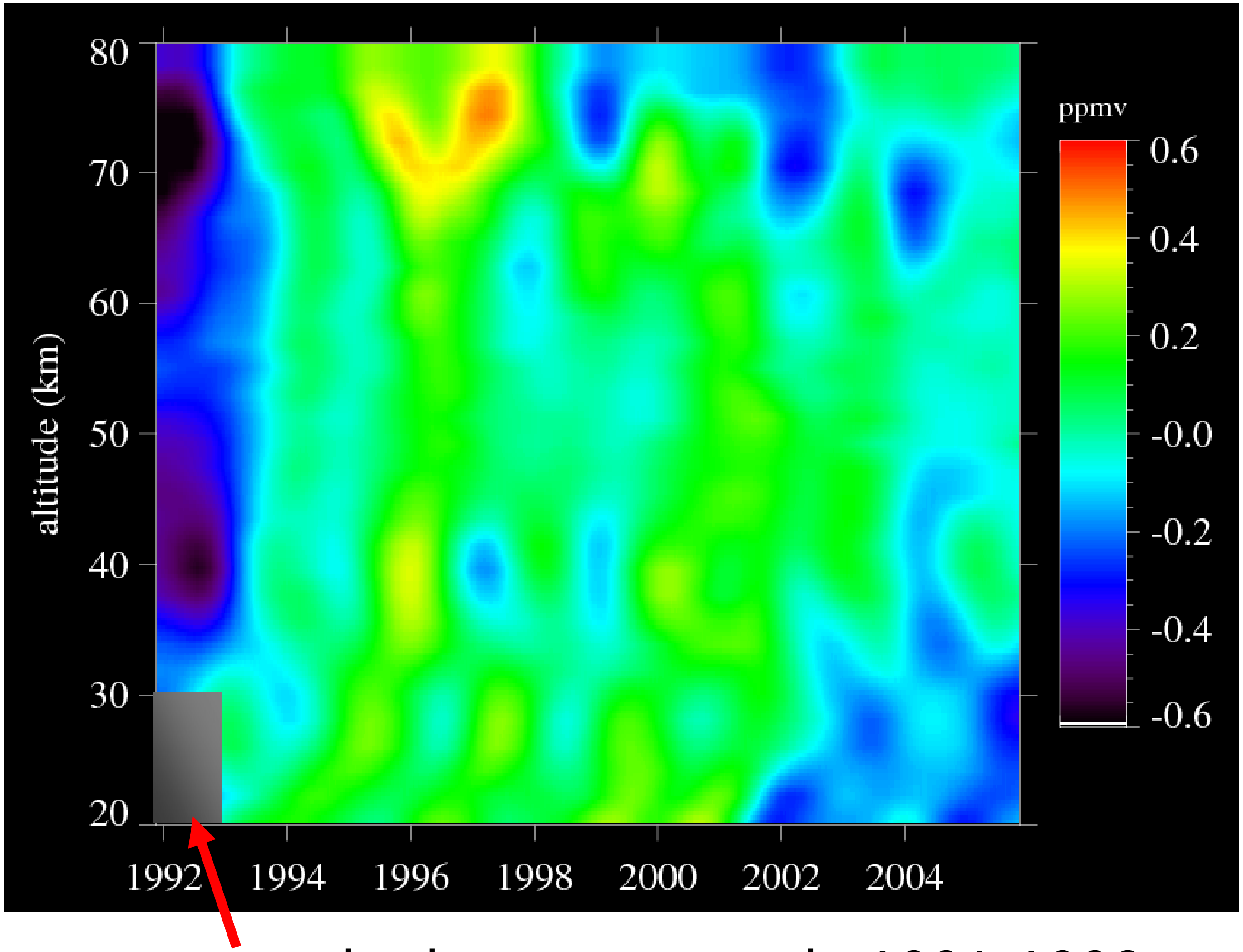
- Several instruments (HALOE, POAM III, Balloons) show decrease in water vapor.
- Decrease is correlated with decreasing tropopause temperatures.
- Ozone at the tropopause decreases at the same time as the temperature.
- Decreased ozone could be caused by increasing tropical upwelling, but there is no other evidence of changes in circulation.

(Randel et al., in press)

Deseasonalized HALOE water vapor; 20S-20N



Deseasonalized HALOE water vapor; 20S-20N



Lower stratospheric water vapor in 1991-1992 probably affected by Pinatubo aerosols. Unusually dry compared to MLS (SPARC report).

Water vapor fits

Fit using (t in years):

$$f = a_0 +$$

(annual) $a_1\sin(2\pi t) + a_2\cos(2\pi t) +$

(semi-annual) $a_3\sin(4\pi t) + a_4\cos(4\pi t) +$

(QBO) $a_5\sin((12/27)2\pi t) + a_6\sin((12/27)2\pi t$

(linear trend) $+ a_7 t$

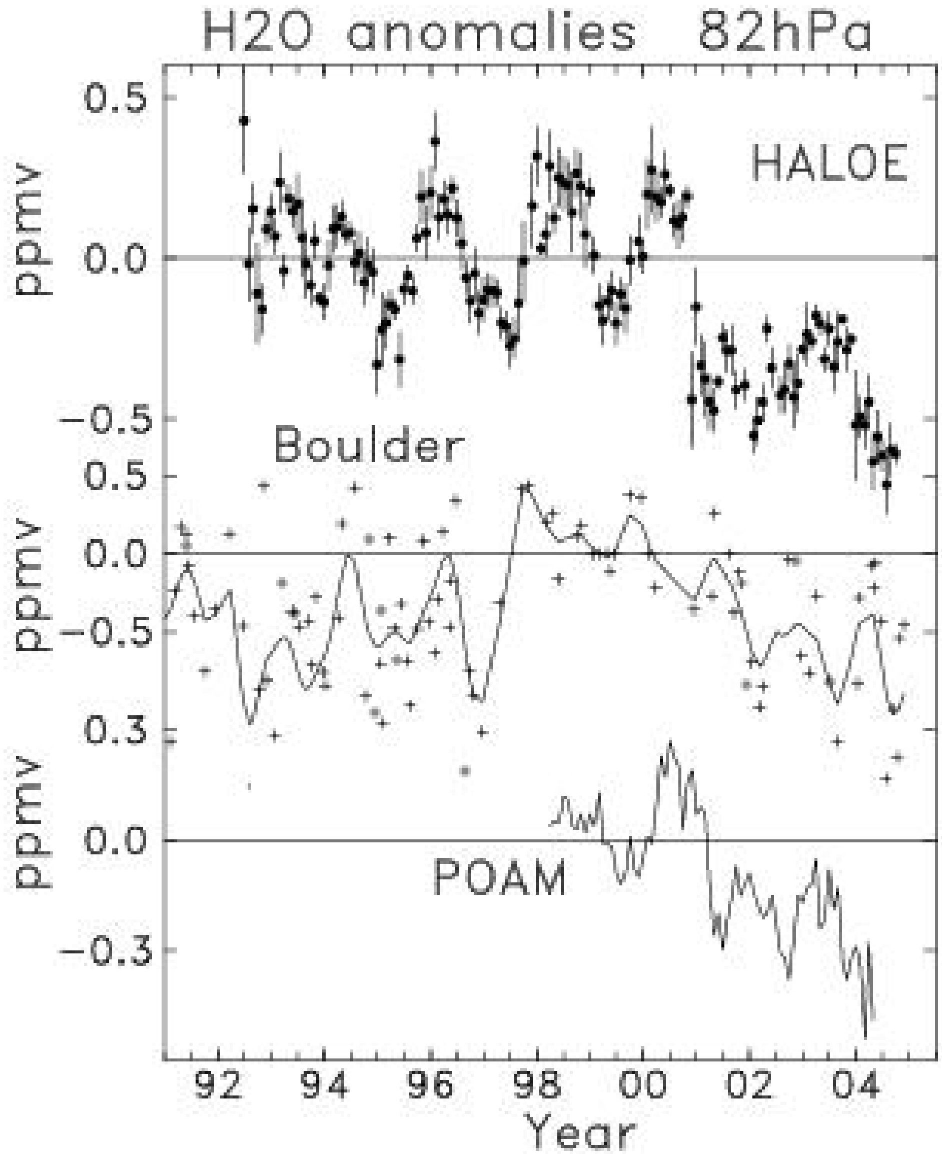
or

(solar cycle term) $+a_7 F(\text{Mg II})$

Comparing the early 1990’s increase with the 2001 decrease

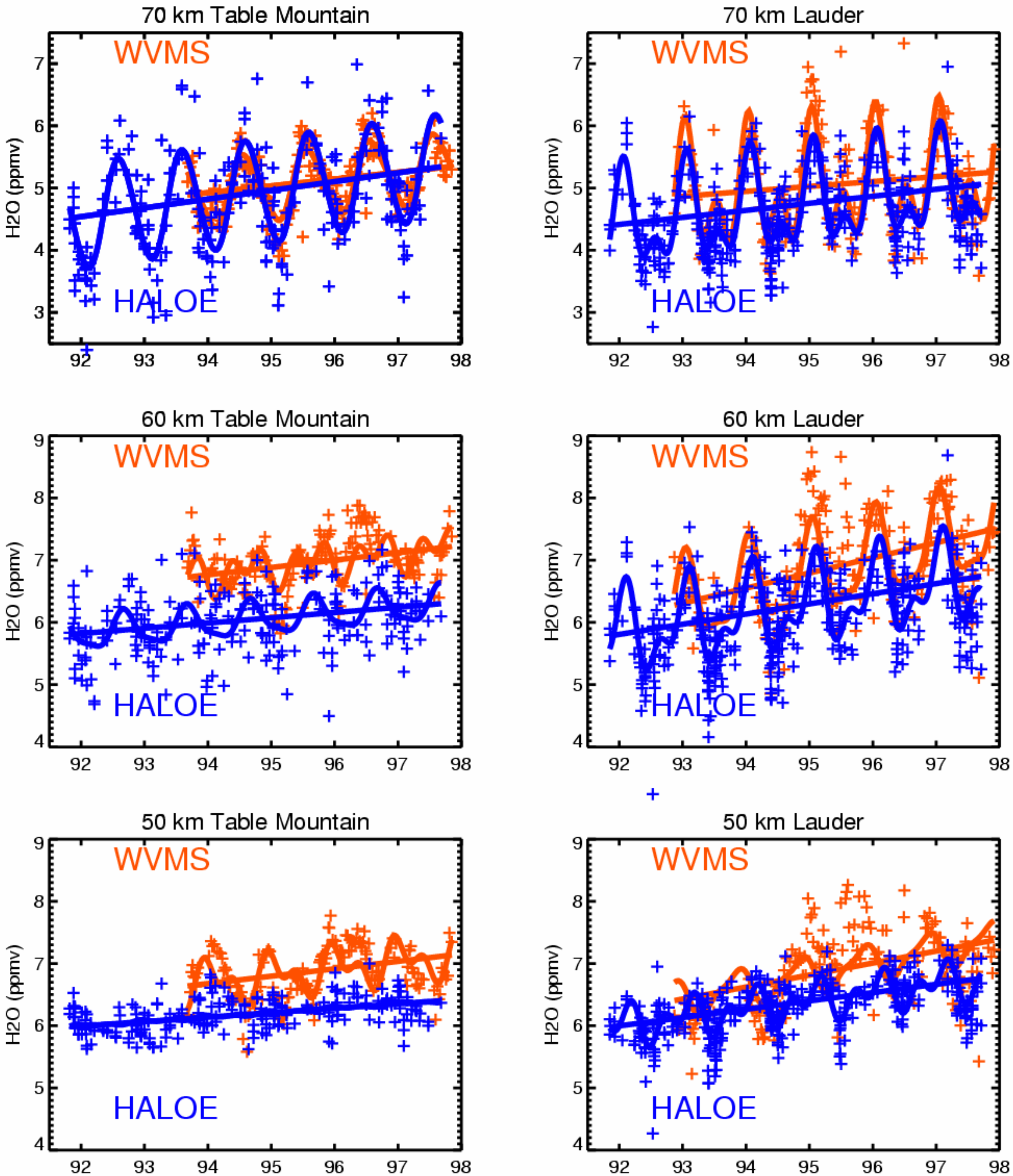
- Early 1990’s increase
  - Water in lower mesosphere increased by ~0.5 ppmv over 5 years
  - No reliable measurements in the lower stratosphere available
  - Measured tropopause temperatures not correlated with increase
  - Water vapor remained at new level until 2001

- 2001 decrease
  - Slow ascent of signal: from ~20km to ~30km in 2 years
  - Water vapor in the lower stratosphere shows a decrease of ~0.4 ppmv
  - Measured tropopause temperatures well correlated with decrease
  - Occurred after a long QBO cycle
  - Water vapor remains at new level in 2005 (2006?)



Balloon data shows a similar decline to HALOE and POAM

(Randel et al., in preparation)



Early 1990’s trend and seasonal cycle fit

WVMS H_2O trends for 40-60km (1992-1997) ~0.15 ppmv/year

Global HALOE H_2O trend for 40km-60km (1991-1997) ~0.13 ppmv/year

Of this, ~0.04 ppmv/year is attributable to changes in CH_4 conversion to H_2O

Some final thoughts

- While there where good reasons for expecting an increase in H_2O following the eruption of Pinatubo because of aerosol loading and the resultant warming of the tropopause, we don’t understand why the H_2O mixing ratio remained high.
- The H_2O decrease in 2001 is consistent with tropopause temperature changes, but we don’t understand why this temperature changed and then remained low.
- CH_4 is likely to increase over time, so this will contribute to a long-term increase in stratospheric H_2O, but this trend is likely to be very slow and will, especially in the lower stratosphere where only a fraction of the CH_4 has been oxidized. On decadal timescales this trend will probably be overwhelmed by other changes.

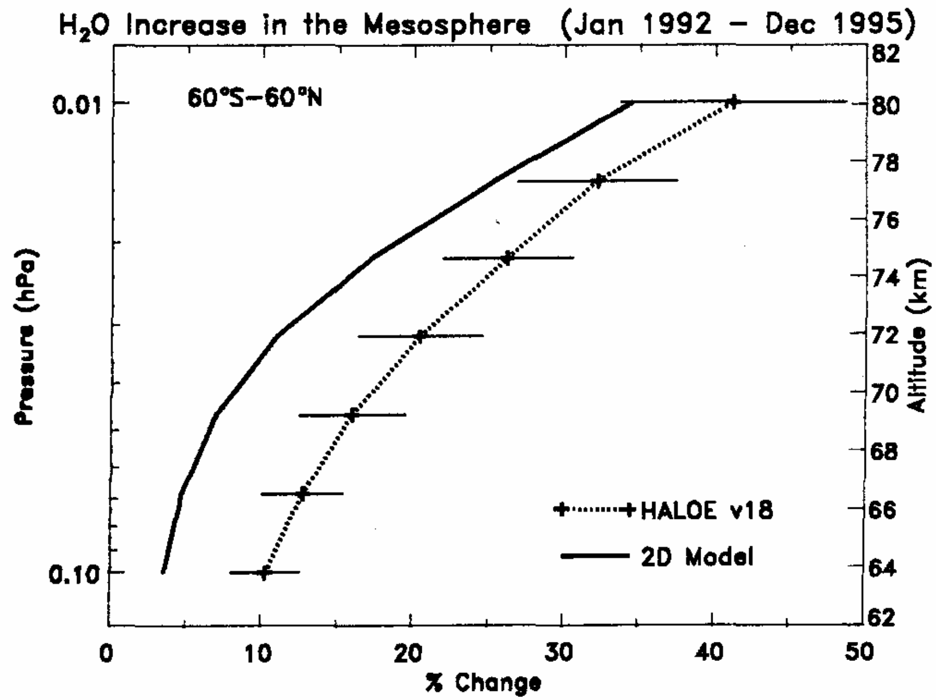
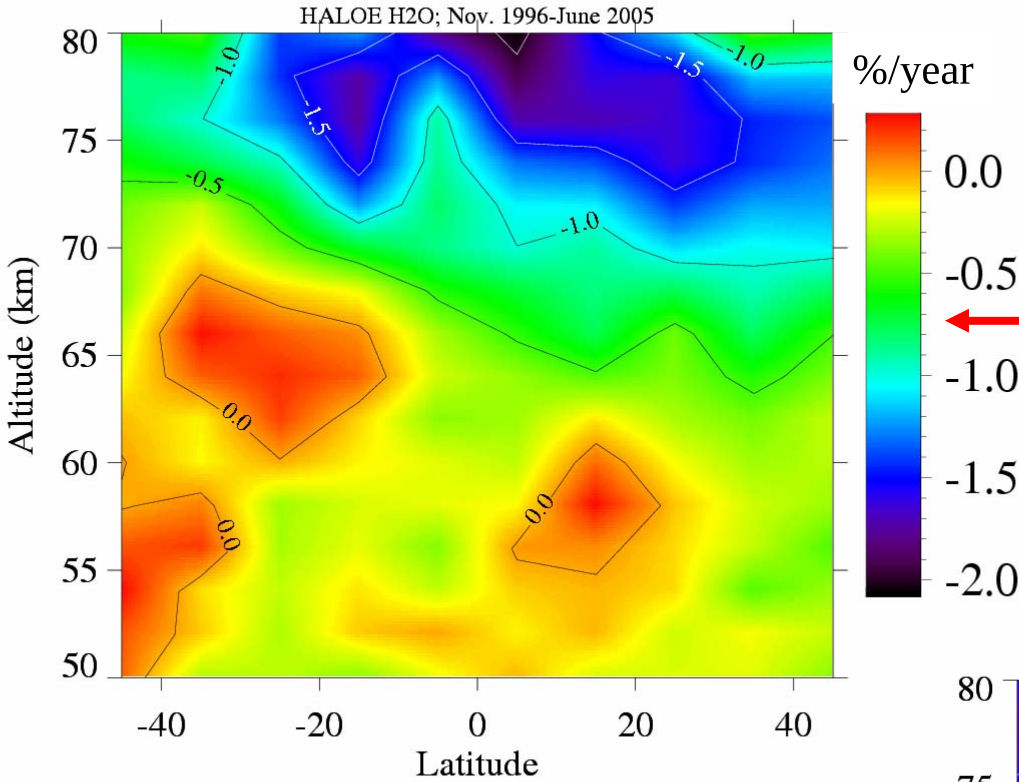


Figure 4. Height profiles of the 4 year trend estimated from both the model and the HALOE data averaged over 60°S to 60°N.

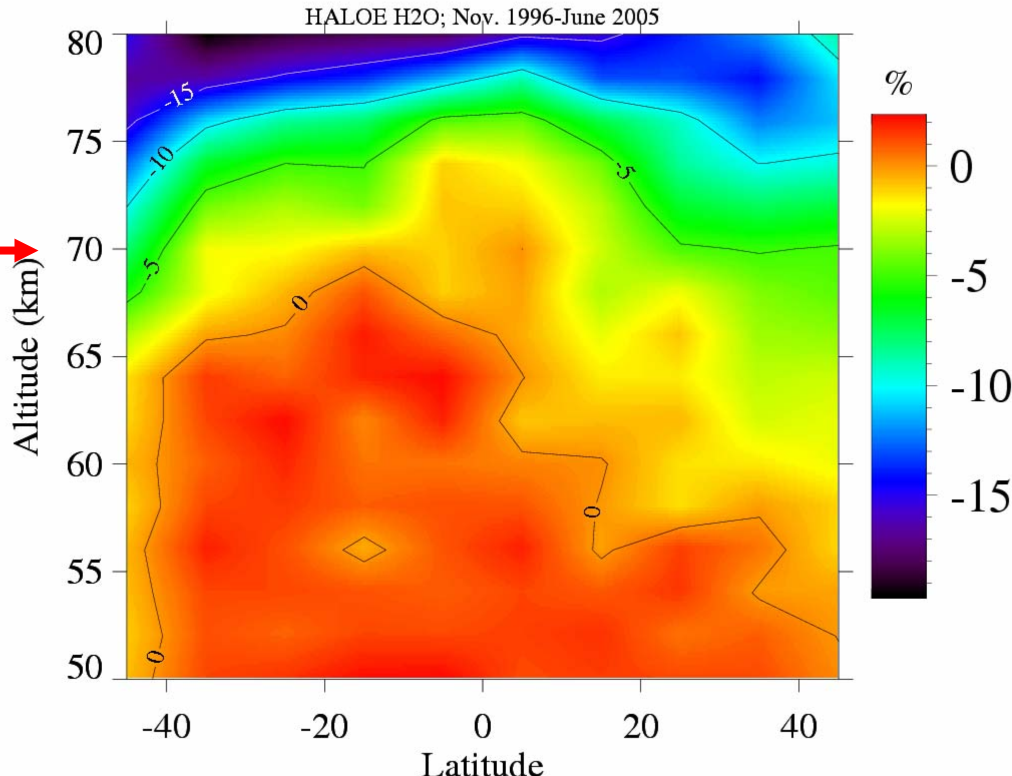
From Chandra et al., 1997



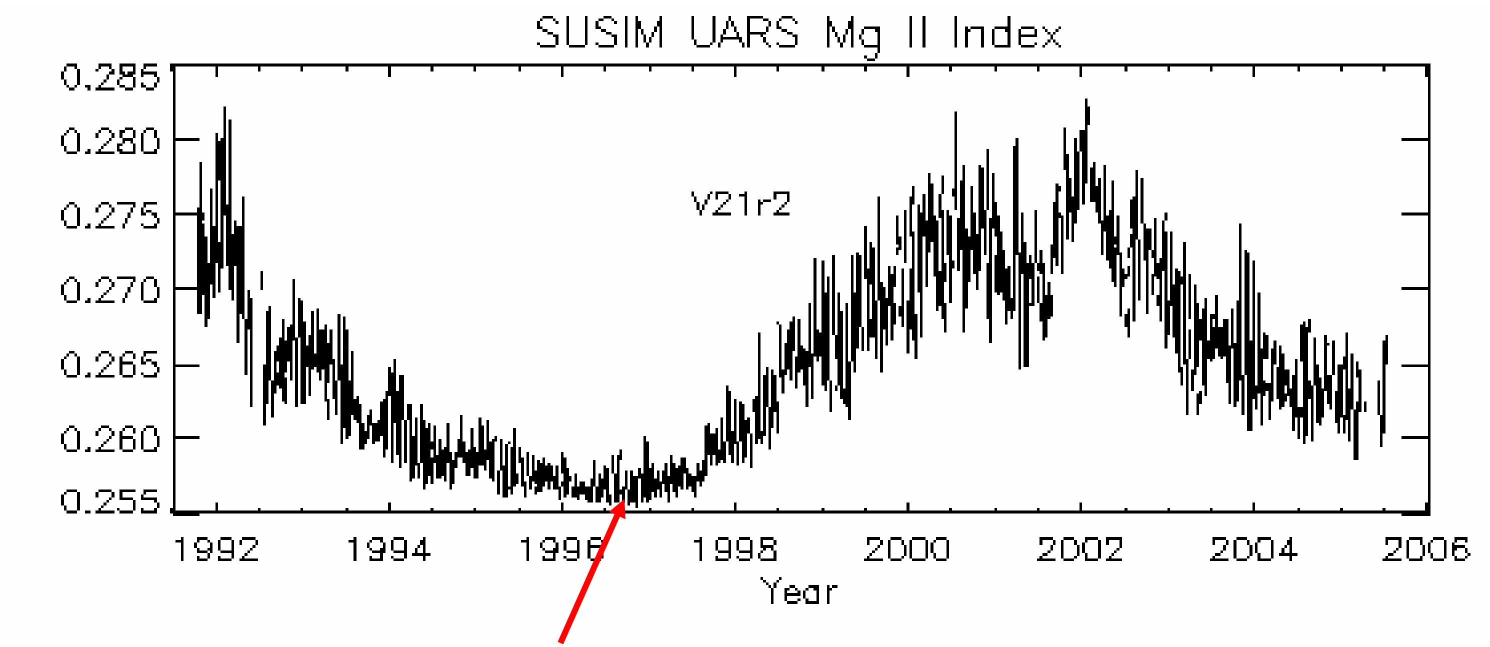
HALOE H_2O fits binned by latitude
Nov. 1996-June 2005

%/year trend calculated without a Mg II index term included in fit

Now replace the trend fit term with a fit to a normalized Mg II index.
-15% => ~30% peak-to-peak change in H_2O from solar min to solar max.



11 year Solar Cycle



minimum Mg II in 1996

=> minimum Lyman-α photodissociation

=> water vapor maximum in mesosphere

http://wwwsolar.nrl.navy.mil/susim_uars_mgii_index.html

Deseasonalized HALOE H_2O and Mg II fit