# HALOE Retrievals:
# The Use Of Constant Lockdown Angles
# Can Lead to Data Artifacts

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HALOE was an occultation instrument that used the solar image as an energy source to measure atmospheric transmission. During an occultation, the HALOE telescope's field of view (FOV) tracked a point at a fixed angle below the top edge of the Sun. This angle is referred to as the lockdown angle. The average lockdown angle for each event in the HALOE dataset is plotted in **Plot 1**. Spacecraft motions and tracker jitter imposed small variations on the lockdown angle, and knowledge of the exact instantaneous lockdown angle is extremely important because the solar intensity is not uniform but is brightest at the center and dims substantially (depending on wavelength) towards the edge of the solar disk. The intensity as a function of distance from center is well modeled by a solar limb darkening curve (SLDC), illustrated in **Plot 1**; HALOE measured the SLDC for each channel during each event. During the retrieval process, HALOE signals are simulated by convolving the FOV over the product of the measured SLDC and the calculated atmospheric transmittance profile.

To help understand the importance of accurate knowledge of the lockdown angle, **Plot 2** shows the SLDC for all the HALOE channels. The scale is from the edge of the sun (0 arcmin) to the center (16 arcmin) and shows how the intensity varies with lockdown and from channel to channel. Assuming a lockdown position, for example, of 16 arcmin from the solar edge when in fact the lockdown angle is 4 arcmin from the solar edge would lead to large errors in the source function used to create simulated signals. Each event has a lockdown angle, and that angle is used in the retrieval process for that event. There can be substantial differences in lockdown angles from event to event. Lockdown angles were set to approximately 8 arcmin (2.3e-3 radians) for most of the HALOE mission. Occasionally, especially early in the mission, other lockdown angles were used, ranging from 4 to 15 arcmin. These various lockdown settings were chosen for testing, validation, targeted studies of the upper and lower atmosphere, and other mission-related reasons.

It was discovered in 2007 that retrieved $H_2O$ profiles for a sequence of days in November 1991, exhibit an extremely dry layer near 65 km. This seemed out of character, and as part of the HALOE close-out tasks, we investigated possible causes for any systematic retrieval artifact that would cause this. The lockdown angle was suspected as a possible cause, because at this altitude the retrieval switches from assuming a constant lockdown value to using the instantaneous measured value. This switchover in lockdown was implemented to be consistent with the way the transmission signals are smoothed—namely smoothed above ~65 km and unsmoothed below.

The average lockdown angle is calculated for each event over *approximately* 100-150km, and the retrieval assumes this lockdown for all altitudes above a specified cutoff altitude, which corresponds to the cutoff altitude for smoothing the transmission signals. For each channel there is a specified altitude at which the signal smoothing begins to be turned off. Let's take $H_2O$ as an example. Below 65 km, the signal smoothing is gradually reduced over ~10 km and finally turned off near 55 km. Similarly, at 65 km the assumed lockdown angle is switched from the constant average value to the measured values. As in the case of the transmission signals, this is transitioned over the same ~10 km altitude window.

The plots mentioned above clearly show an additional characteristic: the switch from the constant lockdown angle to the measured lockdown profile can be very abrupt, even with the 10 km smoothed transition region. In addition, the direction of the change is not random, but repeats over periods of several days for sunrise events. The change appears more random for sunset events. This systematic behavior in the sunrises could lead to systematically biased retrievals. It should be stressed that this potential problem would only impact the radiometers because the DV signals are by their nature immune to changes in the source function. Also, the V signals that go with the 4 DV channels have the lockdown switch well above where the retrievals of aerosols start.

To illustrate the nature of the lockdown angles, **plot 3** shows the FOV position as determined by the HALOE Fine Sun Sensor (FSS) for the first 5 rise events (time increasing with altitude) for Nov. 15, 1991. (The other 8 sunrise events are similar but are not shown.) These reflect where the spacecraft's FOV was locked on the solar image during the various events plotted as a function of altitude (or time). There are a few things to point out. First, the positioning of the FOV on the solar image tended to repeat for all sunrises in this day. Next, at the very top, the FSS angles suddenly change as the instrument switched from track mode to solar scan mode. This should have occurred above 150 km, but took place at the very upper limit of the normal data range because the "trip angle" was incorrectly set (see the trip angle review). The trip angle problem can lead to data errors, but the presence of the trip angle problem cannot explain these lockdown angle questions. Also, note that the very bottom of the data shows lost of track higher than normal; this is because of the heavy aerosol loading due to Mt. Pinatubo.

Of particular interest is the manner in which the lockdown changes over the useful data portion of the event. Just below where the trip angle problem takes place, the FSS angle slowly increases down to about 95 km. Below this altitude and down to near 50km, the lockdown shows an increase in magnitude of oscillation as well as a shift downward in size. Below 50 km the lockdown looks more like it did above 95 km until track is lost because of the aerosols. It is not clear exactly why the tracking behavior repeated event after event, but as will be seen shortly, this can lead to data artifacts. Note that the repeated tracking behavior appears only in sunrise events.

**Plot 4** is this same data, plotted over the altitude range of 20-100 km. (These data were re-plotted to make comparison to **plot 5** easier.) **Plot 5** shows the lockdown angles used in the $H_2O$ retrieval. These are FSS values with a constant lockdown above 65 km where the $H_2O$ signals were smoothed. The lockdown angle data at the very top of the profile, which has a sudden change due to the trip angle, does not *appear* to have been included in calculating this constant value. The plot clearly shows that at 65 km there is an abrupt change, a discontinuity, in the angles. This leads to an abrupt change in the lockdown angle where the constant value switches to the actual smoothed values near 65 km. This means that there will be an abrupt change in the source function used in simulating signals, resulting in a sharp gradient in the retrieved $H_2O$.

**Plot 6** shows the FSS profiles for the first 5 sunsets of this day. These are the unsmoothed lockdown angles (same parameter shown in **plot 3**). Note that the sunset data does not have the trip angle problem, so the $H_2O$ does not show a sudden change. Note that the lockdown data also does not change character in the same way as the sunrise data. **Plot 7** shows the smoothed lockdown angle data for the set data from 100 km to 20 km. In this case, however, there is no large discontinuity where the constant value ends.

**Plot 8** shows data for another day, April 15, 1992. This day, which also has a trip angle problem, was picked because it has sunrise events near the same latitude as the Nov. 15, 1991 data, and might show similar characteristic. Note that the scale on the angle is the same as on the previous plots, although the range has been changed since the lockdown angle was different. This data also has a trip angle problem – the angles near 150 km suddenly change. Also, note that the frequency of the lockdown movements appears different because of the beta dependent sink rate. Like the data for Nov. 15, 1991 the lockdown angles show a different character as a function of altitude. **Plot 9** shows the same data, but on a different altitude scale to make comparison to **plot 10** easier. **Plot 10**, like **plot 5**, shows the smoothed lockdown angles for the first 5 sunrise events. Once again, there is a discontinuity where the lockdown angle switched from the constant value.

**Plot 11** shows the smoothed lockdown data for the first 5 set events for the April 15, 1992 data. In this case, there appears to be a discontinuity at 65 km, but in the opposite direction as the rise data and much smaller.

**Plots 12-15** show similar plots for Feb. 16, 2003. These data also have the trip angle problem (rise data only). While there is also an abrupt change in the rise lockdown angles at 65 km, it is not as big as shown for the April 15, 1992 data. The reason for this is that while the FSS rise lockdown angles are changing with altitude, the large change in character under 95 km (as shown in **plot 3)** does not exist for these data.

The last data plotted is for Nov. 13, 2004. **Plots 16-19** can be reviewed in a manner similar to the previous days show above. (This was not a day with a trip angle problem.) From examining all the above plots, it is clear that some data have large/abrupt changes in the lockdown angle while other data do not.

Several questions arise. Does an abrupt change in smoothed lockdown angle impact the retrievals? To address this, we can check the first rise event on Nov. 15, 1991.

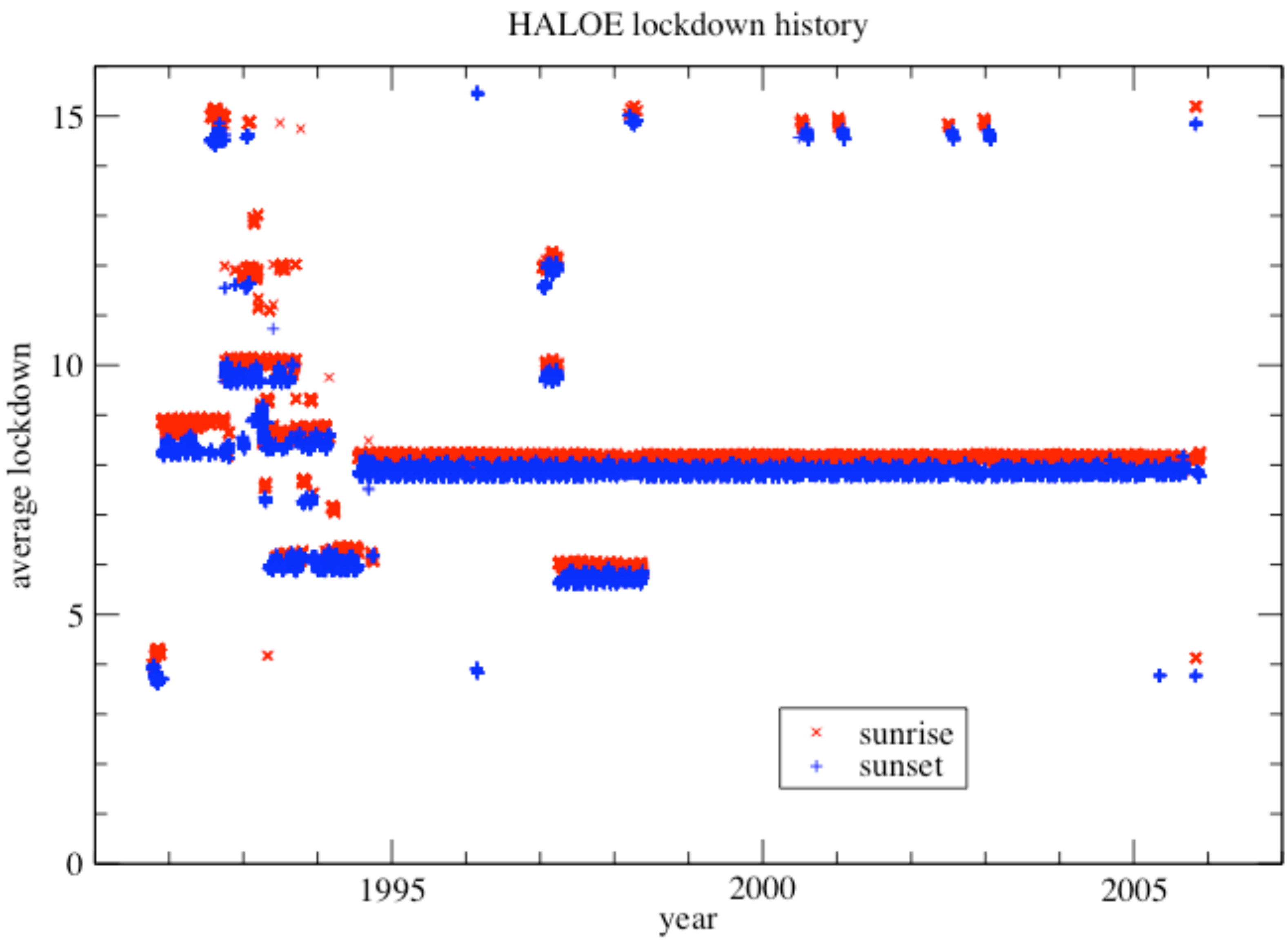
**Plot 20** shows the difference between the measured (FSS) and constant/measured (lockdown) angles for this event. To test the sensitivity of the retrievals to these angle differences, two retrieval cases were run. One was run normally with the $H_2O$ retrieval using the smoothed lock down and the other with the $H_2O$ retrieval using the non-constant lockdown. Note that the code used was an initial version of the V20 code, and the results shown here will not exactly match the V19 data. Since the only change between the two cases was the lockdown angle, the two cases only show that effect. Water was chosen as the species because it should be particularly sensitive to changes in the source function due to the signal/noise ratio at 65km and the highly curved nature of the $H_2O$ channel SLDC. **Plot 21** shows a comparison between the two retrievals. There is a substantial difference in the two retrievals where the lockdown angles differ. The differences in the $H_2O$ correlate with the differences in the angles. **Plot 22** and **plot 23** show the same type of information but for the first set event. Since the angle differences are smaller for the sunset data, the sunset retrievals show less effect.

The second question is whether or not the retrievals will exhibit a systematic bias, or if the errors will average out. To test this, all the data for Nov. 15, 1991 were run in two ways (1) $H_2O$ retrievals using the smoothed lockdown and (2) using non-constant lockdowns. This will show the impact of the abrupt lockdown change at 65 km. **Plot 24** and **plot 25** show this comparison. **Plot 24** is a plot of the mean profiles for all the sunrise data. Even when all sunrise events for the day are averaged, there is still a difference of about 30% near 65 km. Since the abrupt change in lock down at 65 km as shown in **plot 5** has the same character from event to event, one would expect the impact on the retrievals to not average out using just one day's data. For the mean sunset data (see **plot 25**), between 65-70 km there is a 3-5% change between running the two types of lockdown angles. Based on this, we conclude that for sunset events, the lock down effect appears to be random, and averages out.

Additional questions now arise. How much data have been degraded by this problem? Do data artifacts average out if you use many days' data? First, we investigate the problem by plotting a series of profiles. **Plot 26** shows about 75 $H_2O$ profiles in November 1991. There is a huge feature at 65 km in almost all the profiles. The abrupt change in the lockdown angle is repeating from event to event and is obviously not going to average out using just this data. The problem is also clearly noticeable in **plot 27** which is a latitude cross-section plot of $H_2O$ containing data from October 11, 1991 through November 4, 1991. There is a narrow strip of low $H_2O$ near 0.10 mb in most of this data. However, there are regions without the low values where the lockdown angles must not have the same large/abrupt change at 65 km.

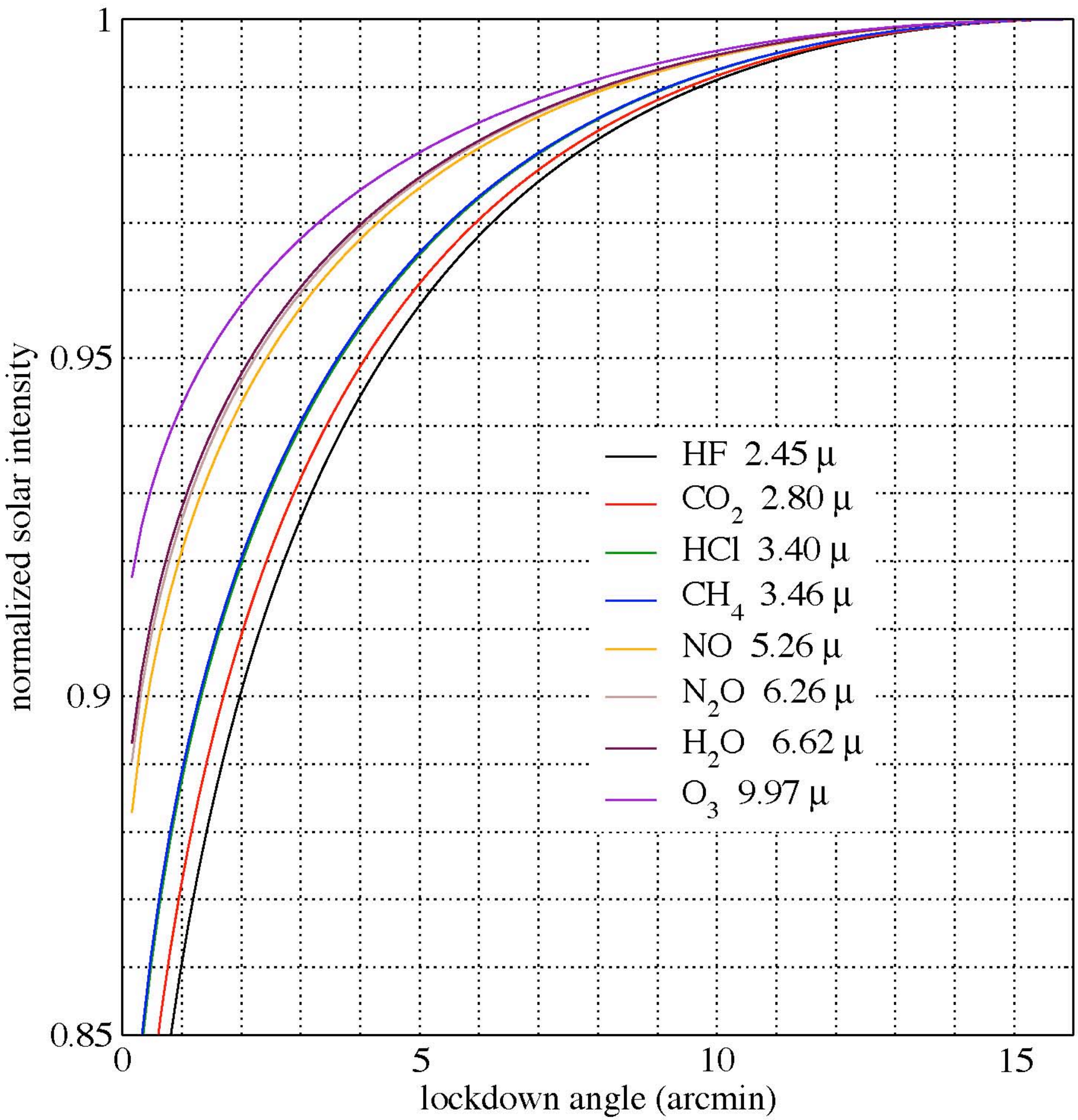
**Plot 28** shows the temperature retrievals for the same time period as in **Plot 26**. There is a lockdown angle induced feature much like the water feature, but near 80 km instead of 65 km because for the temperature retrieval, this is where the lockdown angle is switched. **Plot 29** is a similar plot for $O_3$, and there is indeed a small feature at 65 km (where the lockdown angle is switched from a constant for this channel). The last plot in this series, **Plot 30**, is for $NO_2$. $NO_2$ does not show a feature because the lockdown angle is switched at 50 km, where the $NO_2$ concentrations are too low.

To assess the effect on the $H_2O$ retrievals, we computed the $H_2O$ gradient (vmr per km) at 65 km for each profile in the HALOE dataset. We also computed the change in lockdown angle at this altitude and the change in solar intensity this would impart. **Plot 31** shows the $H_2O$ gradient as a function of change in SLDC intensity. While there is a small apparent (negative) correlation between $H_2O$ gradient and SLDC change, no significant bias is discernable on an event-by-event basis—that is, the induced error in any given event is just as likely to be too high as it is too low. However, if we compute the values as daily averages (sometimes called zonal averages) for sunrises and sunsets, we find that a small number of days that exhibit a significant bias. This is shown in **plot 32**. As indicated by the data points in circles, only the sunrises taken with lockdown < 5 arcmin in 1991 show a significant bias. When these data are removed, no apparent bias in the dataset, even for daily averages, is apparent.



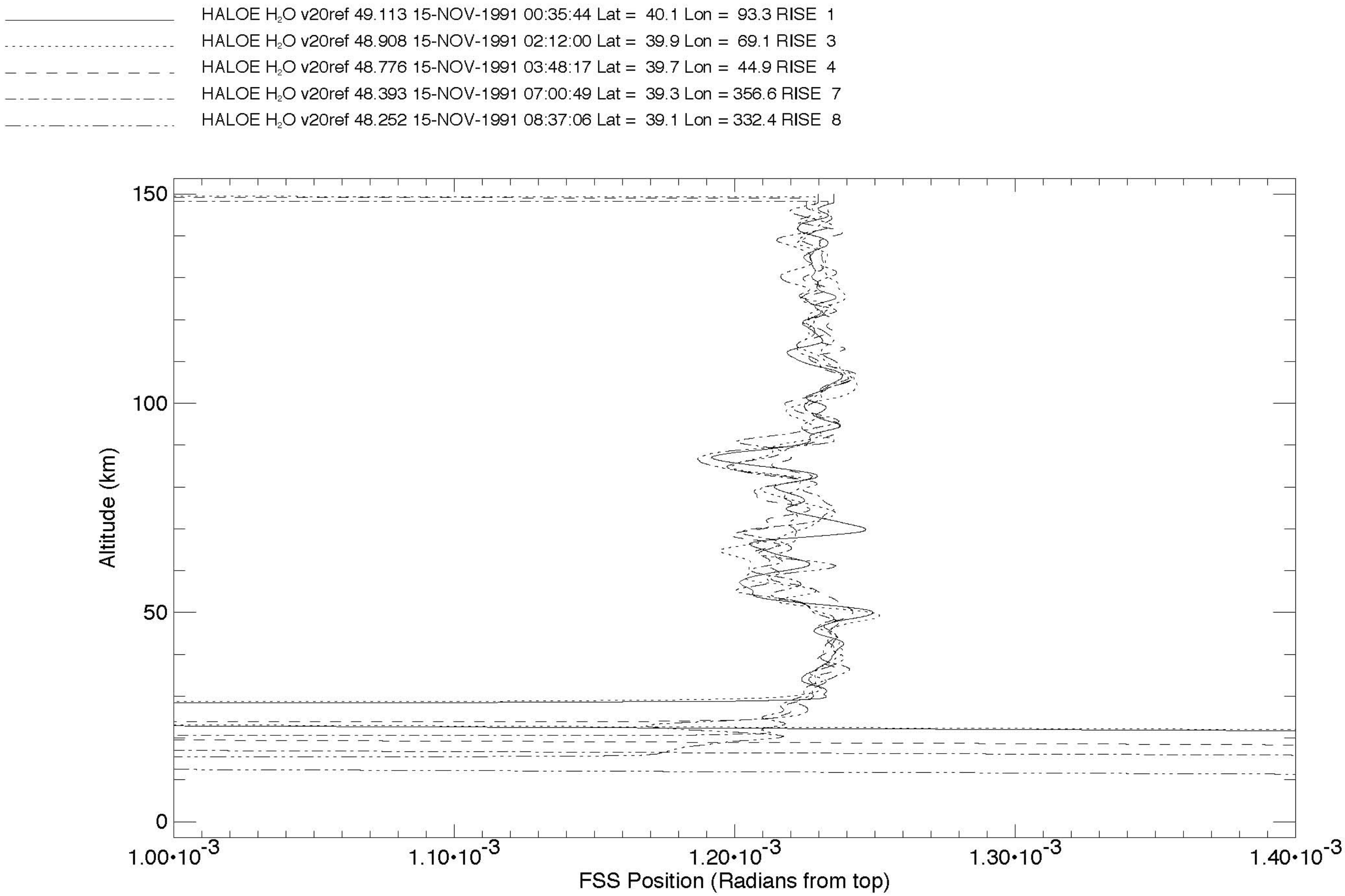
HALOE lockdown history
average lockdown
year
0
5
10
15
1995
2000
2005
sunrise
sunset


**Plot 1**



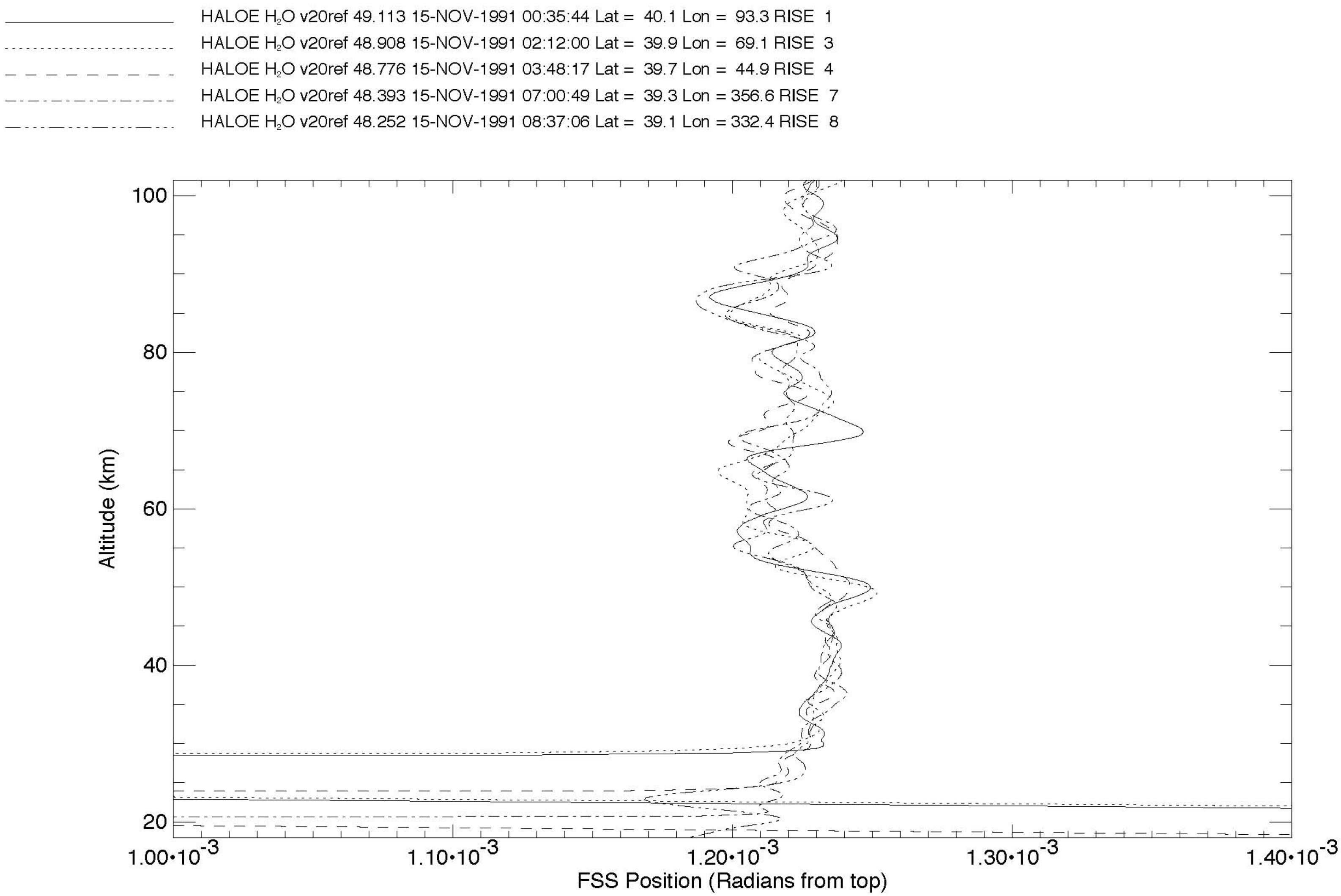
1
0.95
0.9
0.85
0
5
10
15
normalized solar intensity
lockdown angle (arcmin)
HF 2.45 μ
CO2 2.80 μ
HCl 3.40 μ
CH4 3.46 μ
NO 5.26 μ
N2O 6.26 μ
H2O 6.62 μ
O3 9.97 μ


**Plot 2**



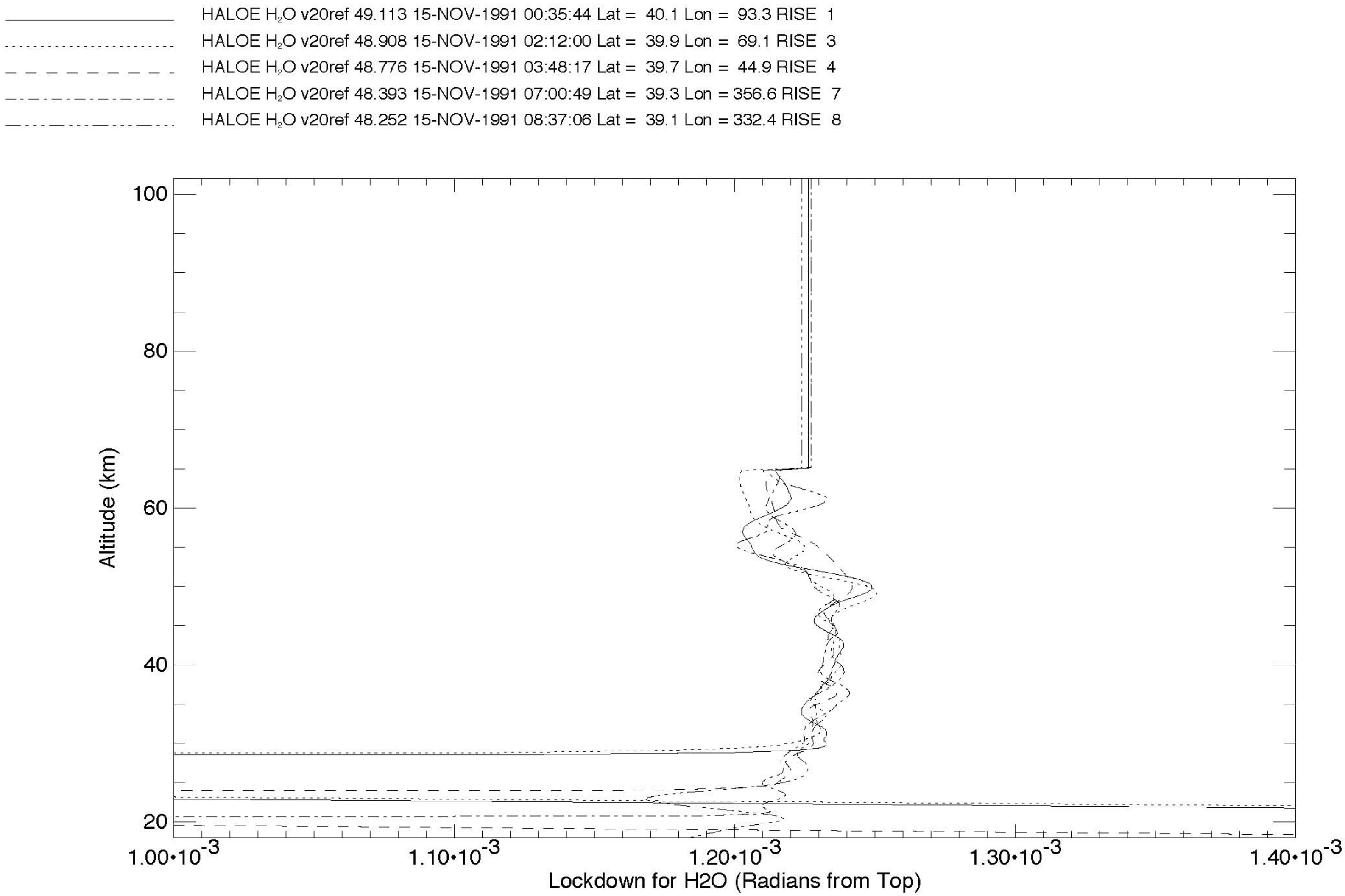

Wed Apr 25 08:00:09 EDT 2007

**Plot 3**



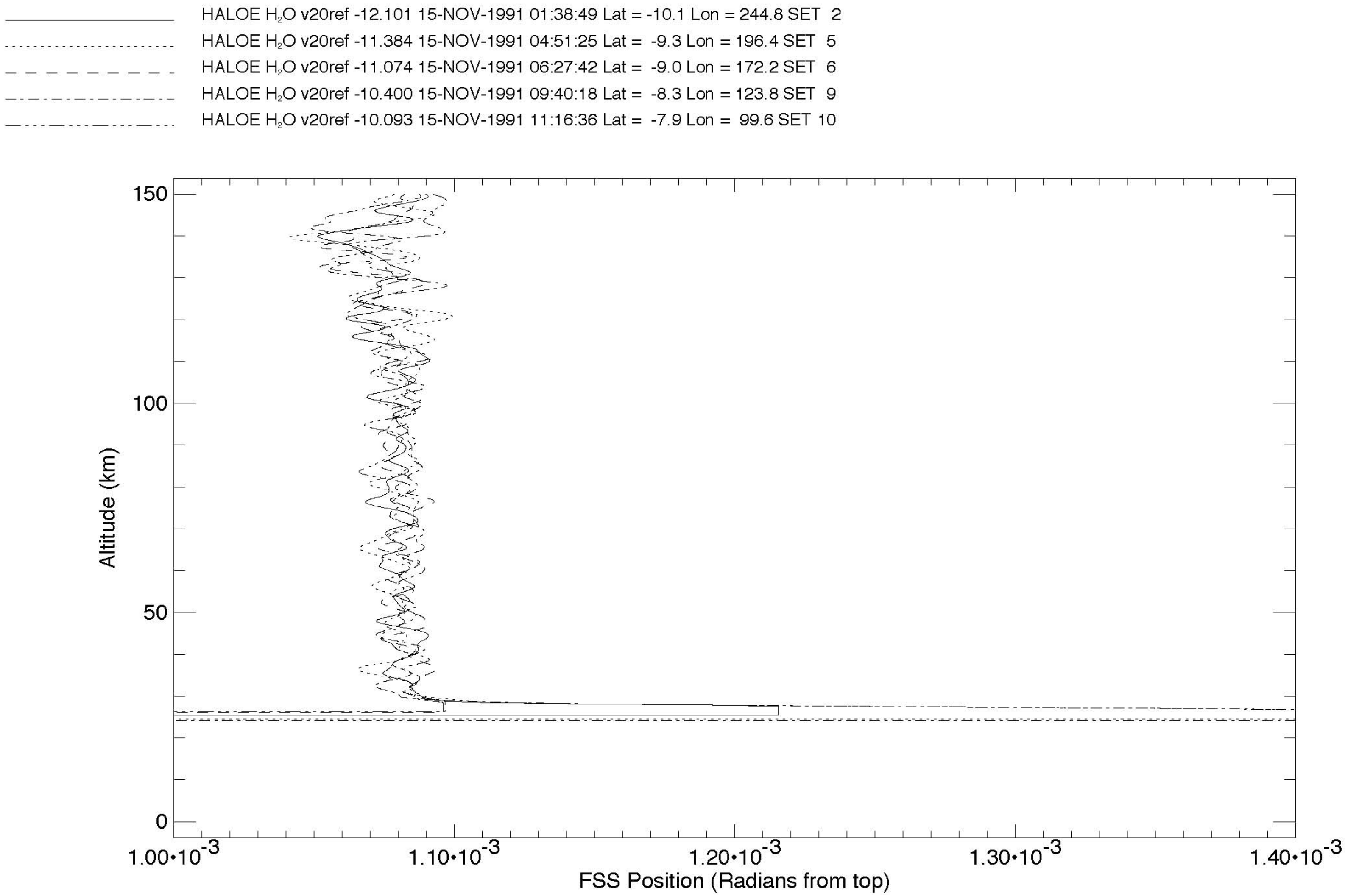

Wed Apr 25 07:59:51 EDT 2007

**Plot 4**



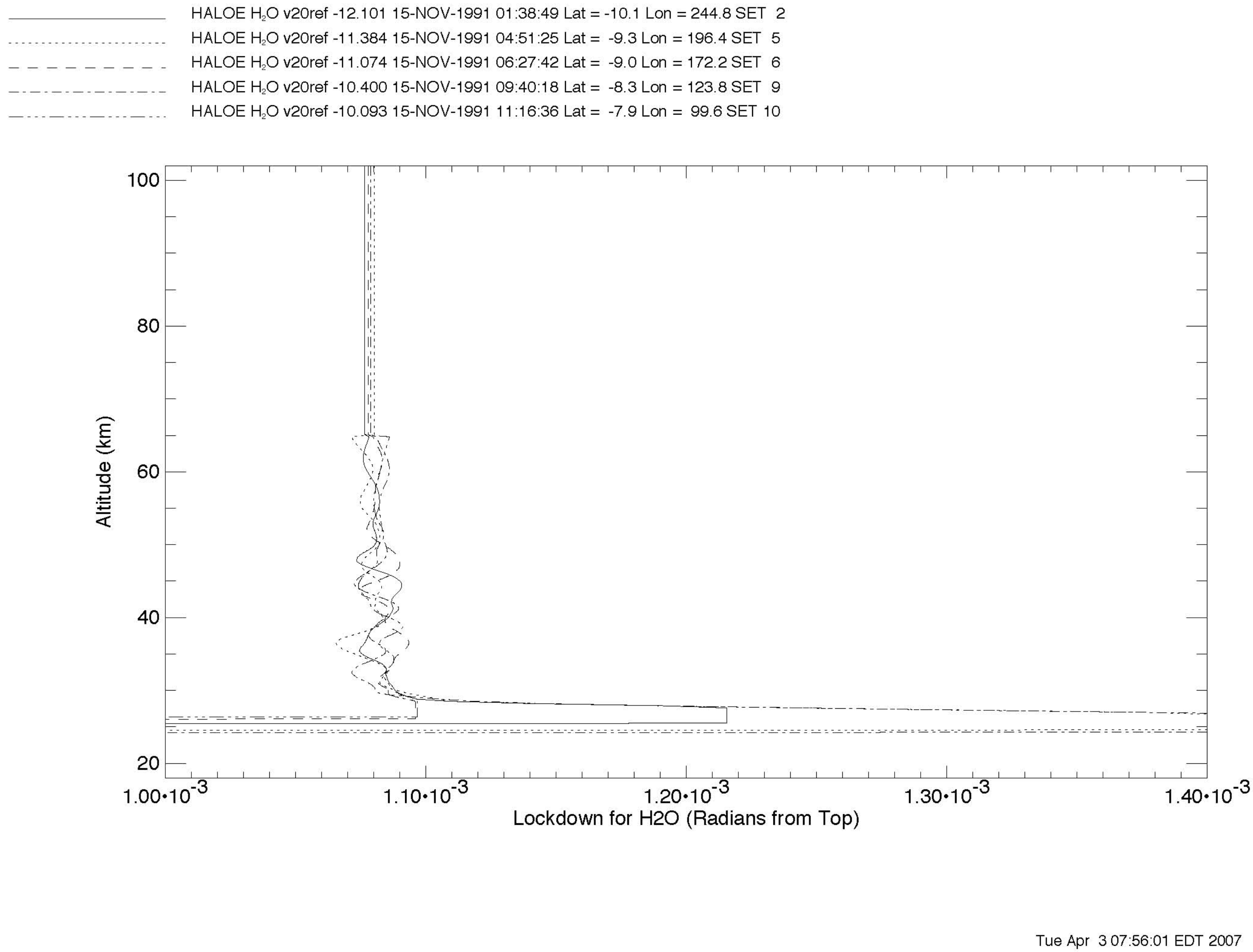

Tue Apr 3 07:54:46 EDT 2007

**Plot 5**




Tue Mar 20 07:39:33 EDT 2007

**Plot 6**



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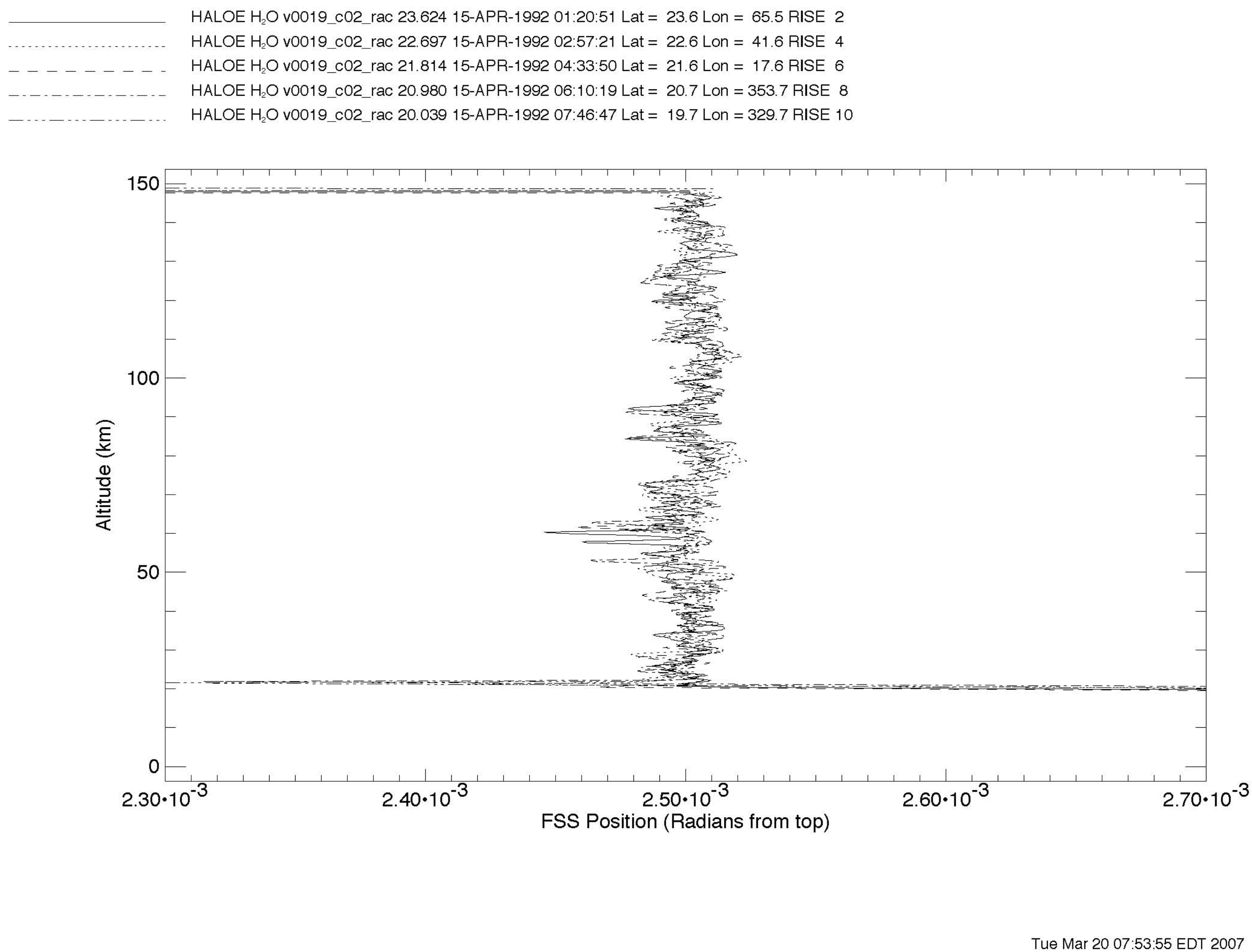
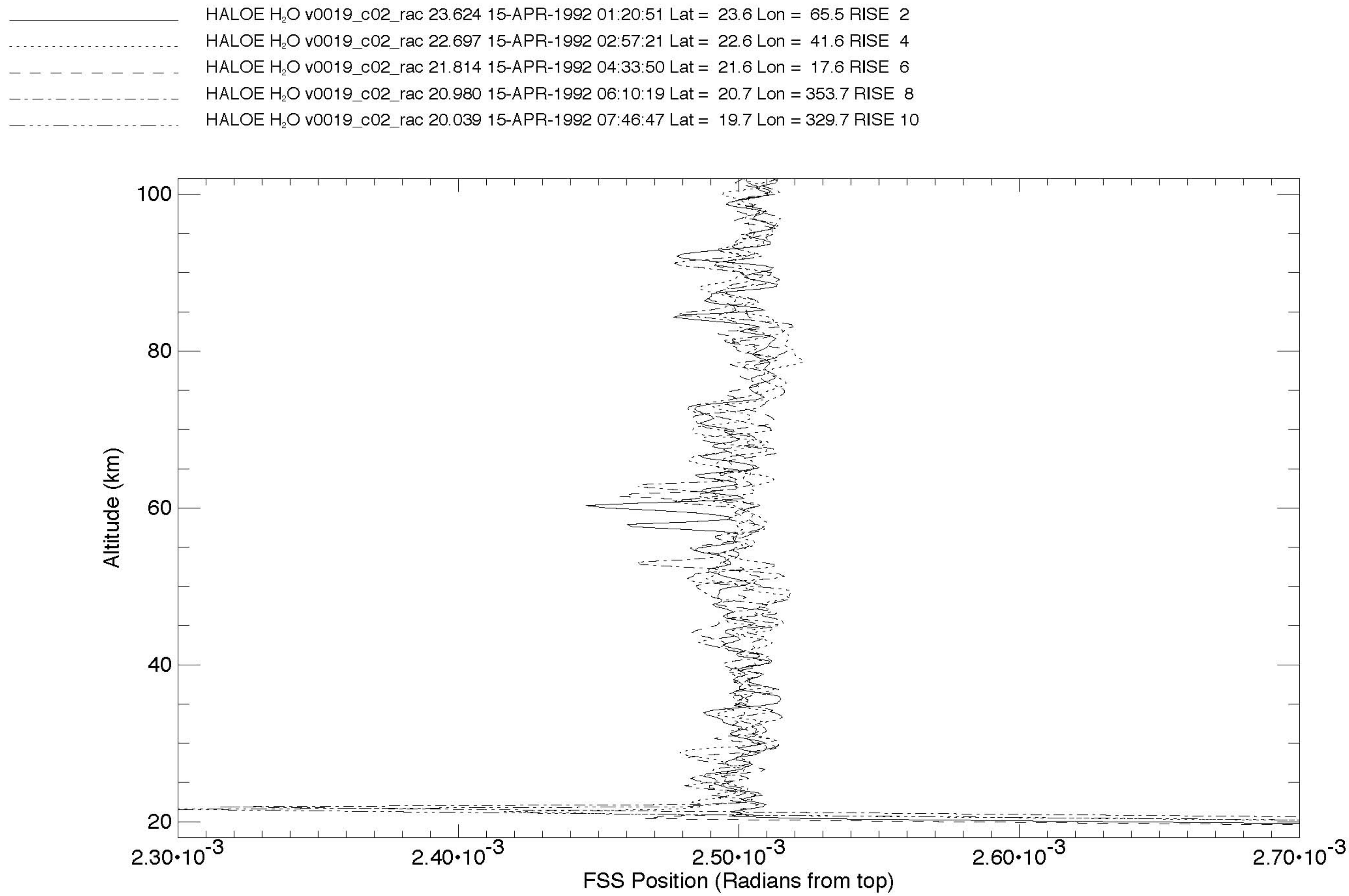
HALOE H2O v20ref -11.384 15-NOV-1991 04:51:25 Lat = -9.3 Lon = 196.4 SET 5
HALOE H2O v20ref -11.074 15-NOV-1991 06:27:42 Lat = -9.0 Lon = 172.2 SET 6
HALOE H2O v20ref -10.400 15-NOV-1991 09:40:18 Lat = -8.3 Lon = 123.8 SET 9
HALOE H2O v20ref -10.093 15-NOV-1991 11:16:36 Lat = -7.9 Lon = 99.6 SET 10
Altitude (km)
100
80
60
40
20
1.00•10-3
1.10•10-3
1.20•10-3
1.30•10-3
1.40•10-3
Lockdown for H2O (Radians from Top)
Tue Apr 3 07:56:01 EDT 2007


**Plot 7**

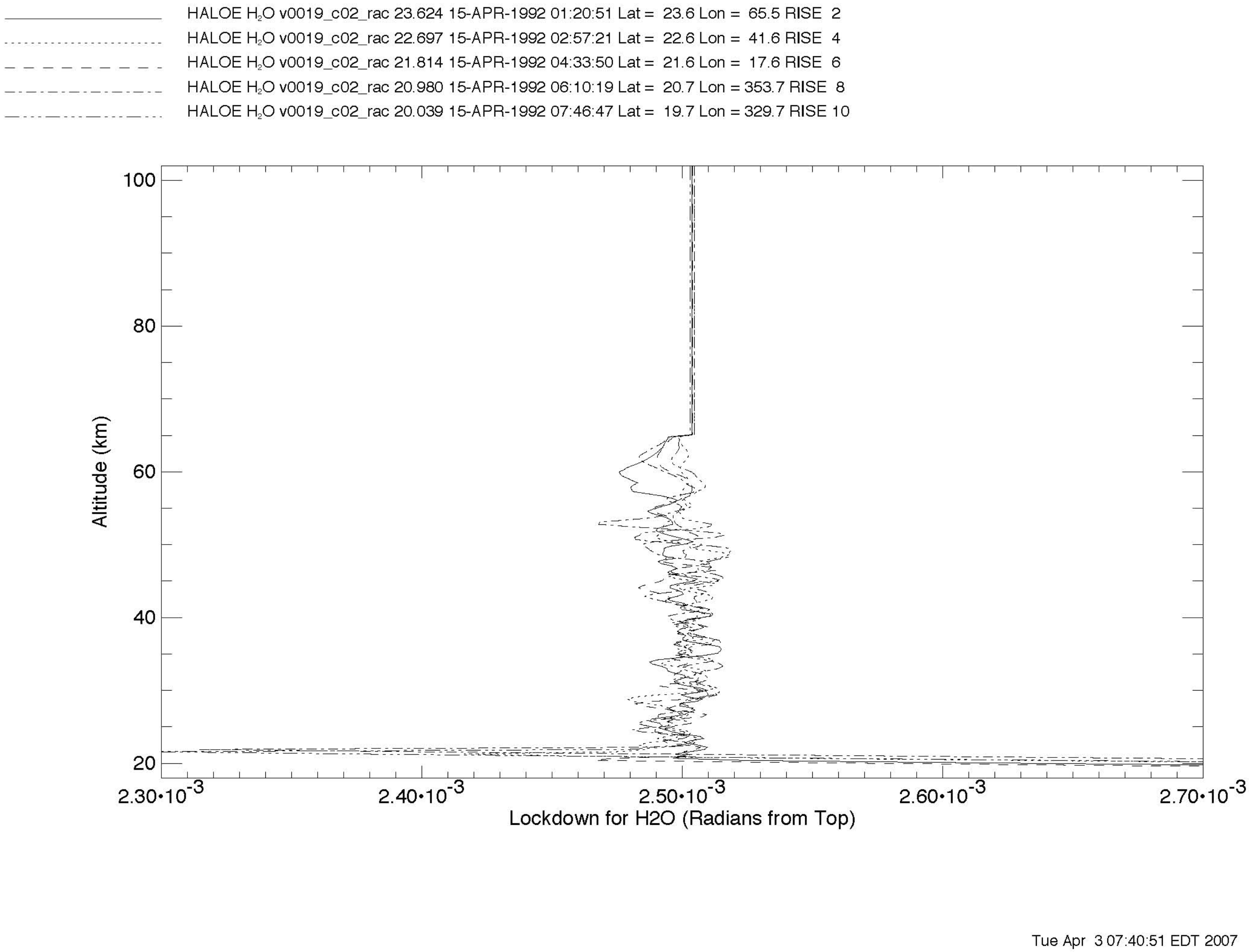

HALOE H2O v0019_c02_rac 23.624 15-APR-1992 01:20:51 Lat = 23.6 Lon = 65.5 RISE 2
HALOE H2O v0019_c02_rac 22.697 15-APR-1992 02:57:21 Lat = 22.6 Lon = 41.6 RISE 4
HALOE H2O v0019_c02_rac 21.814 15-APR-1992 04:33:50 Lat = 21.6 Lon = 17.6 RISE 6
HALOE H2O v0019_c02_rac 20.980 15-APR-1992 06:10:19 Lat = 20.7 Lon = 353.7 RISE 8
HALOE H2O v0019_c02_rac 20.039 15-APR-1992 07:46:47 Lat = 19.7 Lon = 329.7 RISE 10
150
100
50
0
Altitude (km)
2.30•10-3
2.40•10-3
2.50•10-3
2.60•10-3
2.70•10-3
FSS Position (Radians from top)
Tue Mar 20 07:53:55 EDT 2007

**Plot 8**




Tue Mar 20 07:56:22 EDT 2007

**Plot 9**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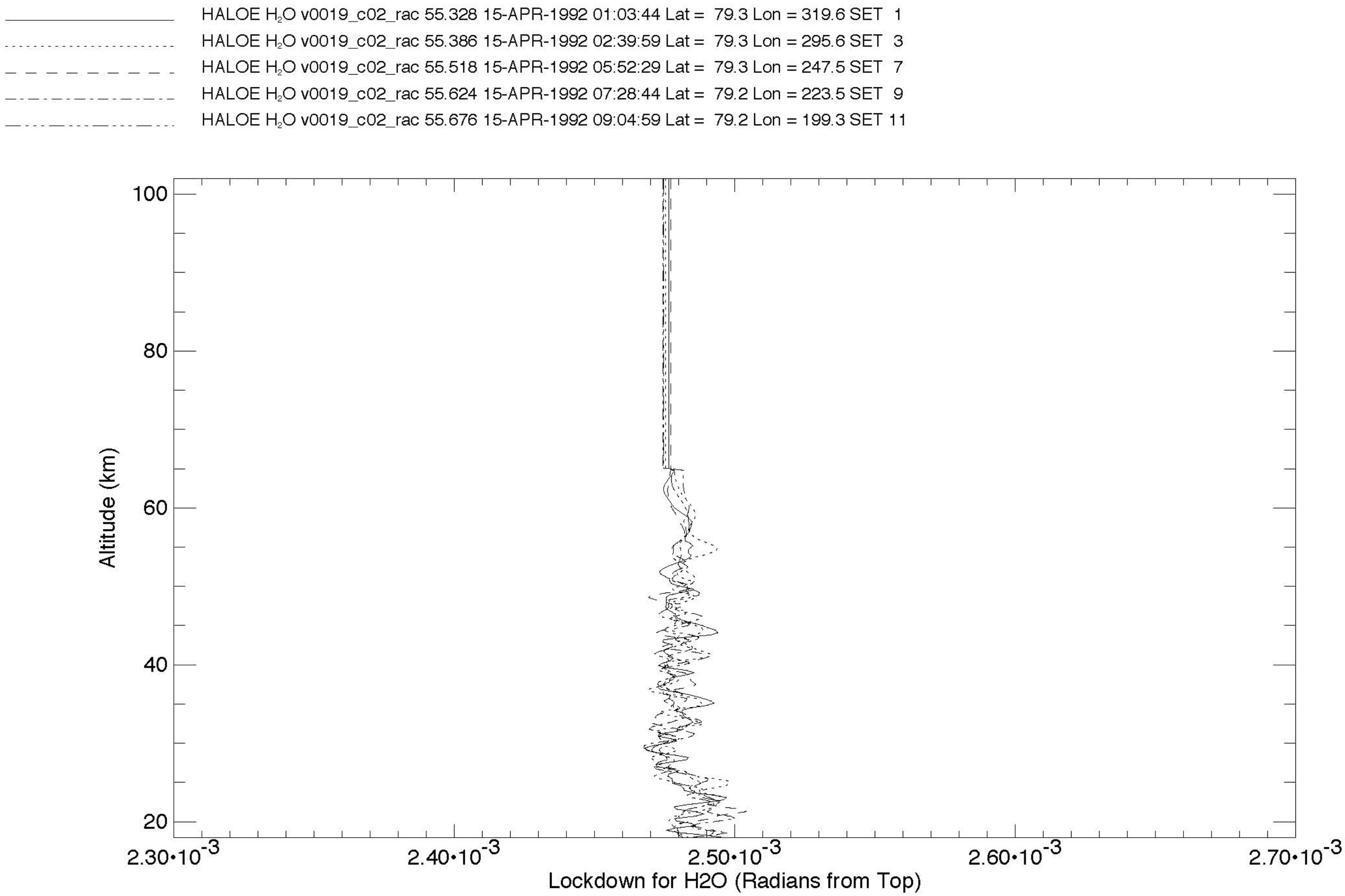
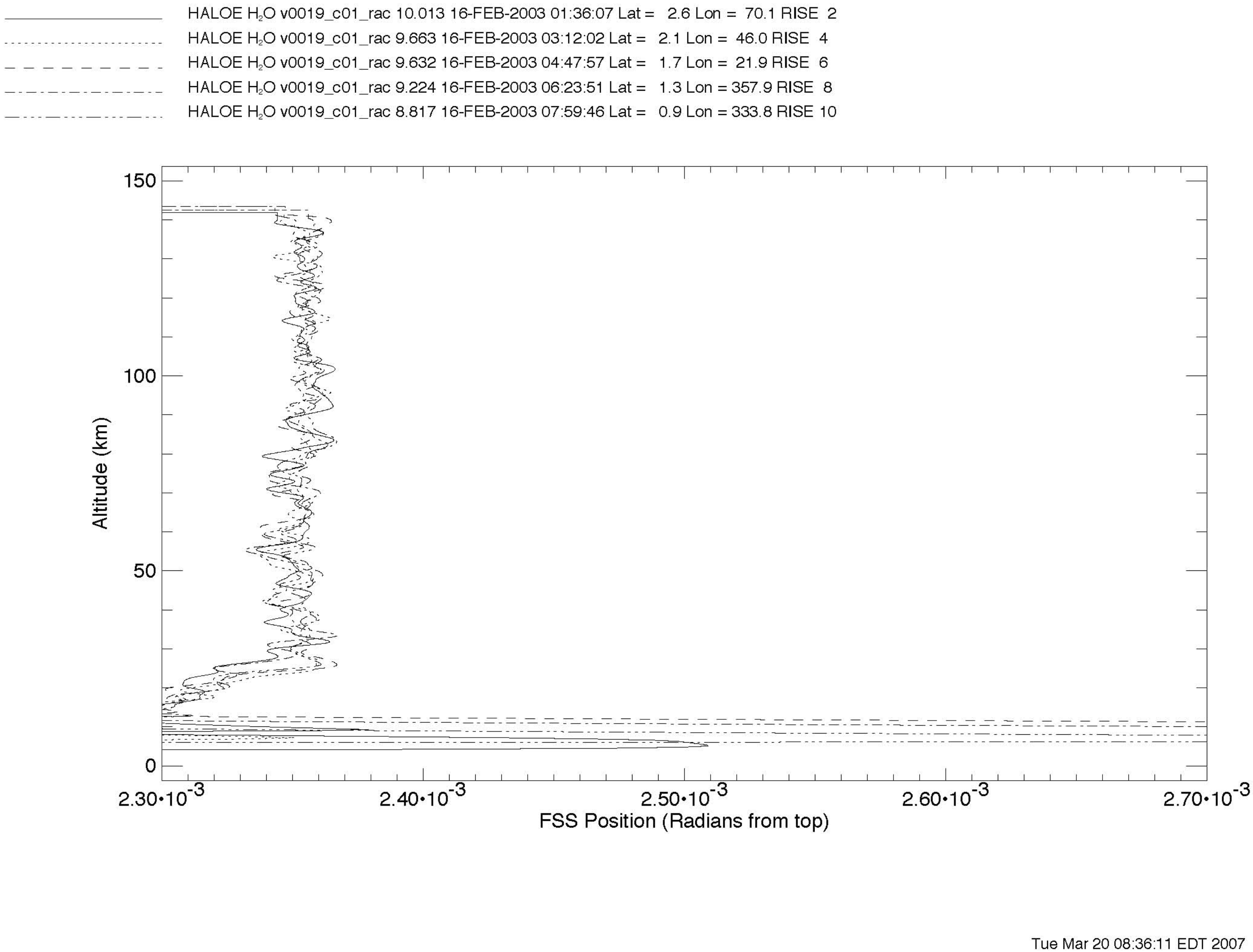
HALOE H2O v0019_c02_rac 22.697 15-APR-1992 02:57:21 Lat = 22.6 Lon = 41.6 RISE 4
HALOE H2O v0019_c02_rac 21.814 15-APR-1992 04:33:50 Lat = 21.6 Lon = 17.6 RISE 6
HALOE H2O v0019_c02_rac 20.980 15-APR-1992 06:10:19 Lat = 20.7 Lon = 353.7 RISE 8
HALOE H2O v0019_c02_rac 20.039 15-APR-1992 07:46:47 Lat = 19.7 Lon = 329.7 RISE 10
Altitude (km)
100
80
60
40
20
2.30•10^-3
2.40•10^-3
2.50•10^-3
2.60•10^-3
2.70•10^-3
Lockdown for H2O (Radians from Top)
Tue Apr 3 07:40:51 EDT 2007

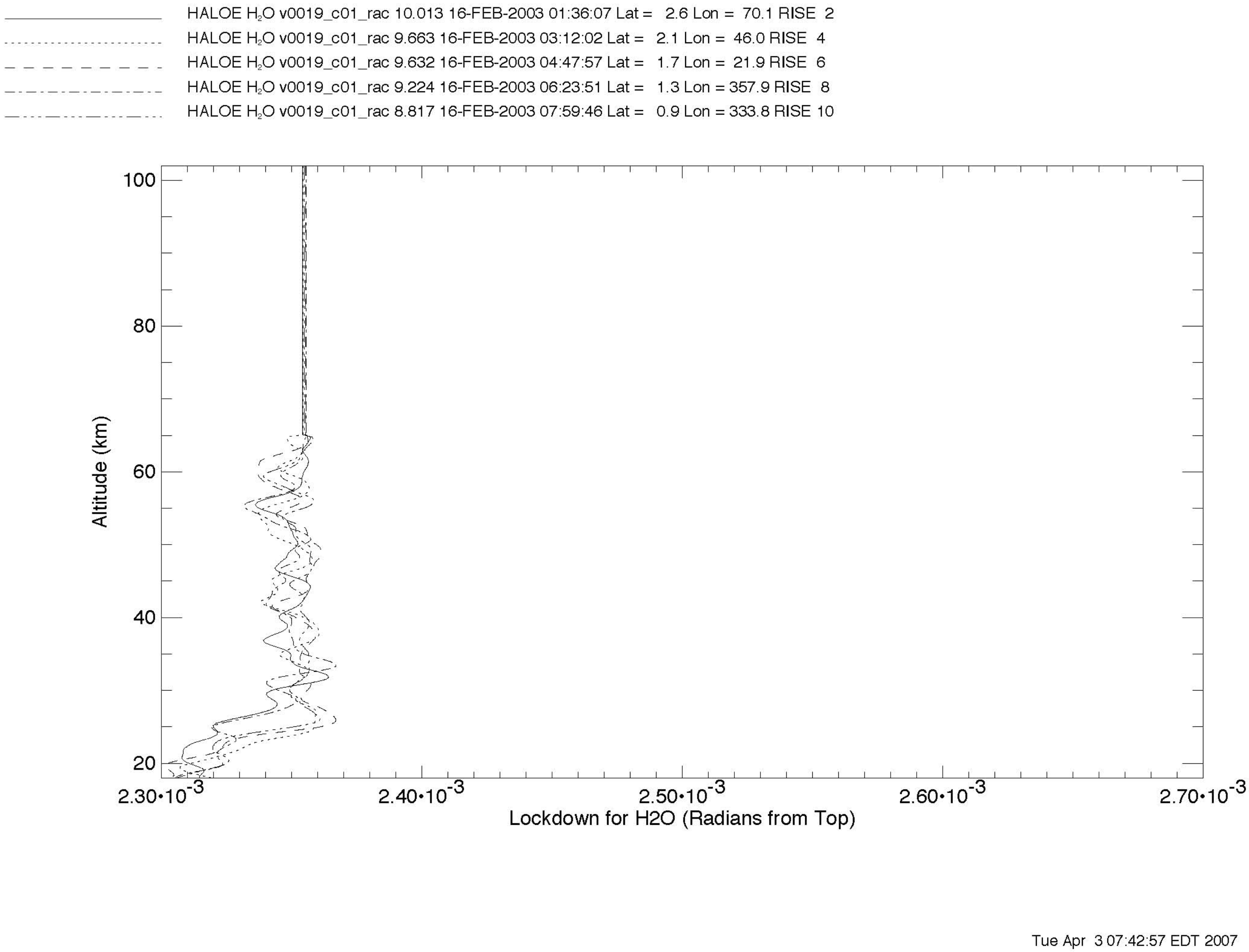
**Plot 10**


HALOE H2O v0019_c02_rac 55.328 15-APR-1992 01:03:44 Lat = 79.3 Lon = 319.6 SET 1
HALOE H2O v0019_c02_rac 55.386 15-APR-1992 02:39:59 Lat = 79.3 Lon = 295.6 SET 3
HALOE H2O v0019_c02_rac 55.518 15-APR-1992 05:52:29 Lat = 79.3 Lon = 247.5 SET 7
HALOE H2O v0019_c02_rac 55.624 15-APR-1992 07:28:44 Lat = 79.2 Lon = 223.5 SET 9
HALOE H2O v0019_c02_rac 55.676 15-APR-1992 09:04:59 Lat = 79.2 Lon = 199.3 SET 11
Altitude (km)
100
80
60
40
20
2.30•10-3
2.40•10-3
2.50•10-3
2.60•10-3
2.70•10-3
Lockdown for H2O (Radians from Top)
Tue Apr 3 07:42:02 EDT 2007

**Plot 11**


HALOE H2O v0019_c01_rac 10.013 16-FEB-2003 01:36:07 Lat = 2.6 Lon = 70.1 RISE 2
HALOE H2O v0019_c01_rac 9.663 16-FEB-2003 03:12:02 Lat = 2.1 Lon = 46.0 RISE 4
HALOE H2O v0019_c01_rac 9.632 16-FEB-2003 04:47:57 Lat = 1.7 Lon = 21.9 RISE 6
HALOE H2O v0019_c01_rac 9.224 16-FEB-2003 06:23:51 Lat = 1.3 Lon = 357.9 RISE 8
HALOE H2O v0019_c01_rac 8.817 16-FEB-2003 07:59:46 Lat = 0.9 Lon = 333.8 RISE 10
150
100
50
0
Altitude (km)
2.30•10-3
2.40•10-3
2.50•10-3
2.60•10-3
2.70•10-3
FSS Position (Radians from top)
Tue Mar 20 08:36:11 EDT 2007

**Plot 12**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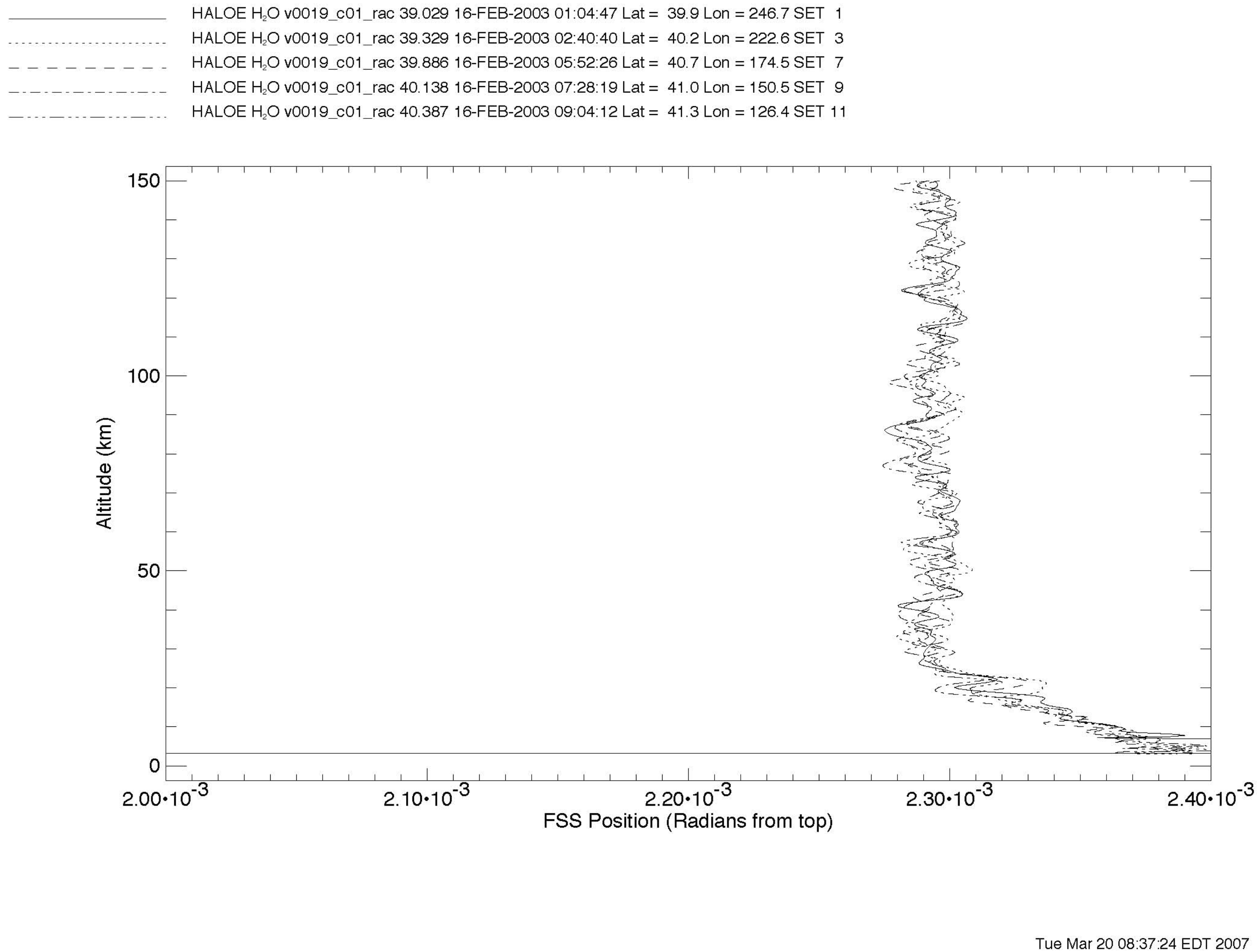
HALOE H2O v0019_c01_rac 9.663 16-FEB-2003 03:12:02 Lat = 2.1 Lon = 46.0 RISE 4
HALOE H2O v0019_c01_rac 9.632 16-FEB-2003 04:47:57 Lat = 1.7 Lon = 21.9 RISE 6
HALOE H2O v0019_c01_rac 9.224 16-FEB-2003 06:23:51 Lat = 1.3 Lon = 357.9 RISE 8
HALOE H2O v0019_c01_rac 8.817 16-FEB-2003 07:59:46 Lat = 0.9 Lon = 333.8 RISE 10
Altitude (km)
100
80
60
40
20
2.30•10-3
2.40•10-3
2.50•10-3
2.60•10-3
2.70•10-3
Lockdown for H2O (Radians from Top)
Tue Apr 3 07:42:57 EDT 2007

**Plot 13**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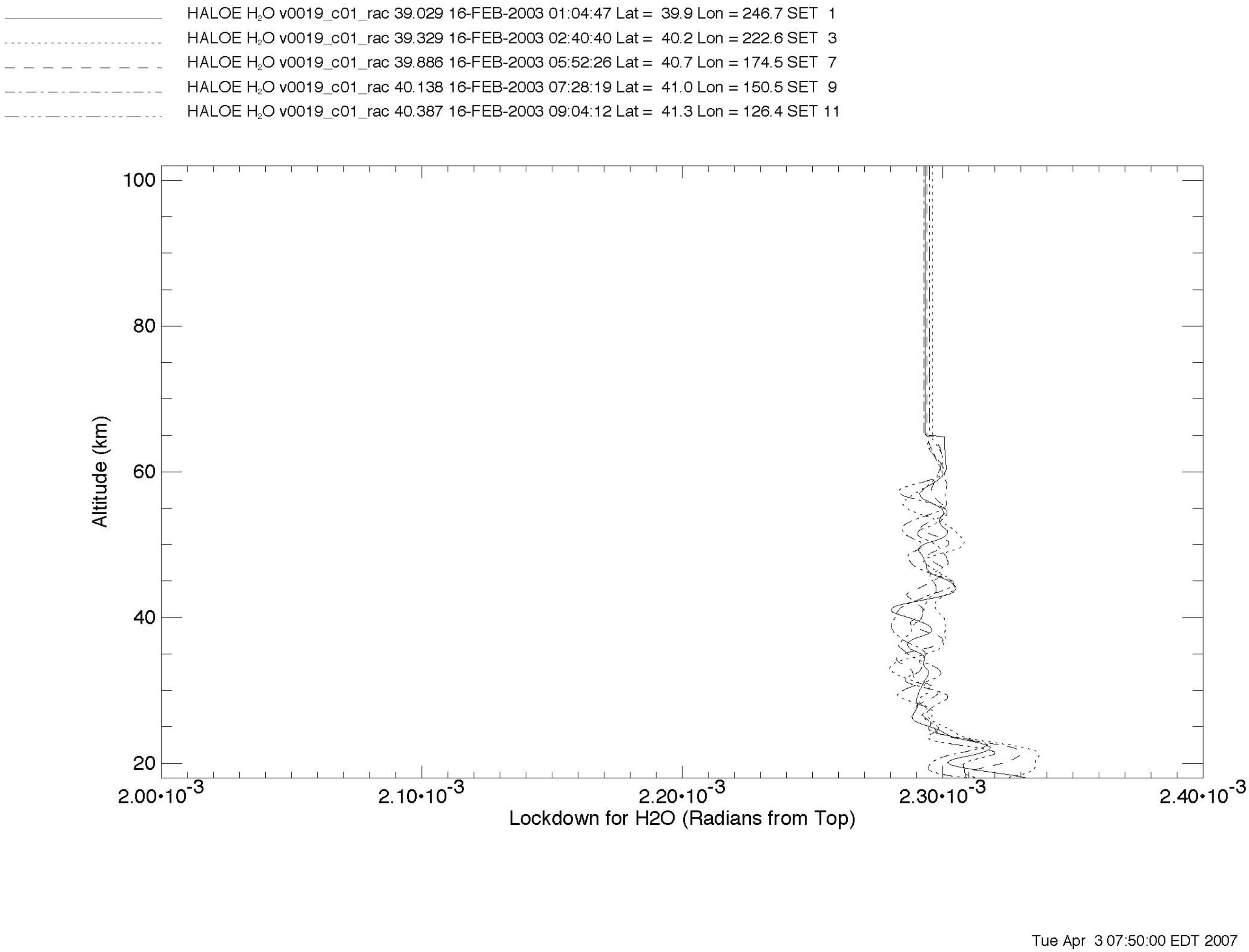
HALOE H2O v0019_c01_rac 39.886 16-FEB-2003 05:52:26 Lat = 40.7 Lon = 174.5 SET 7
HALOE H2O v0019_c01_rac 40.138 16-FEB-2003 07:28:19 Lat = 41.0 Lon = 150.5 SET 9
HALOE H2O v0019_c01_rac 40.387 16-FEB-2003 09:04:12 Lat = 41.3 Lon = 126.4 SET 11
150
100
50
0
Altitude (km)
2.00•10-3
2.10•10-3
2.20•10-3
2.30•10-3
2.40•10-3
FSS Position (Radians from top)
Tue Mar 20 08:37:24 EDT 2007

**Plot 14**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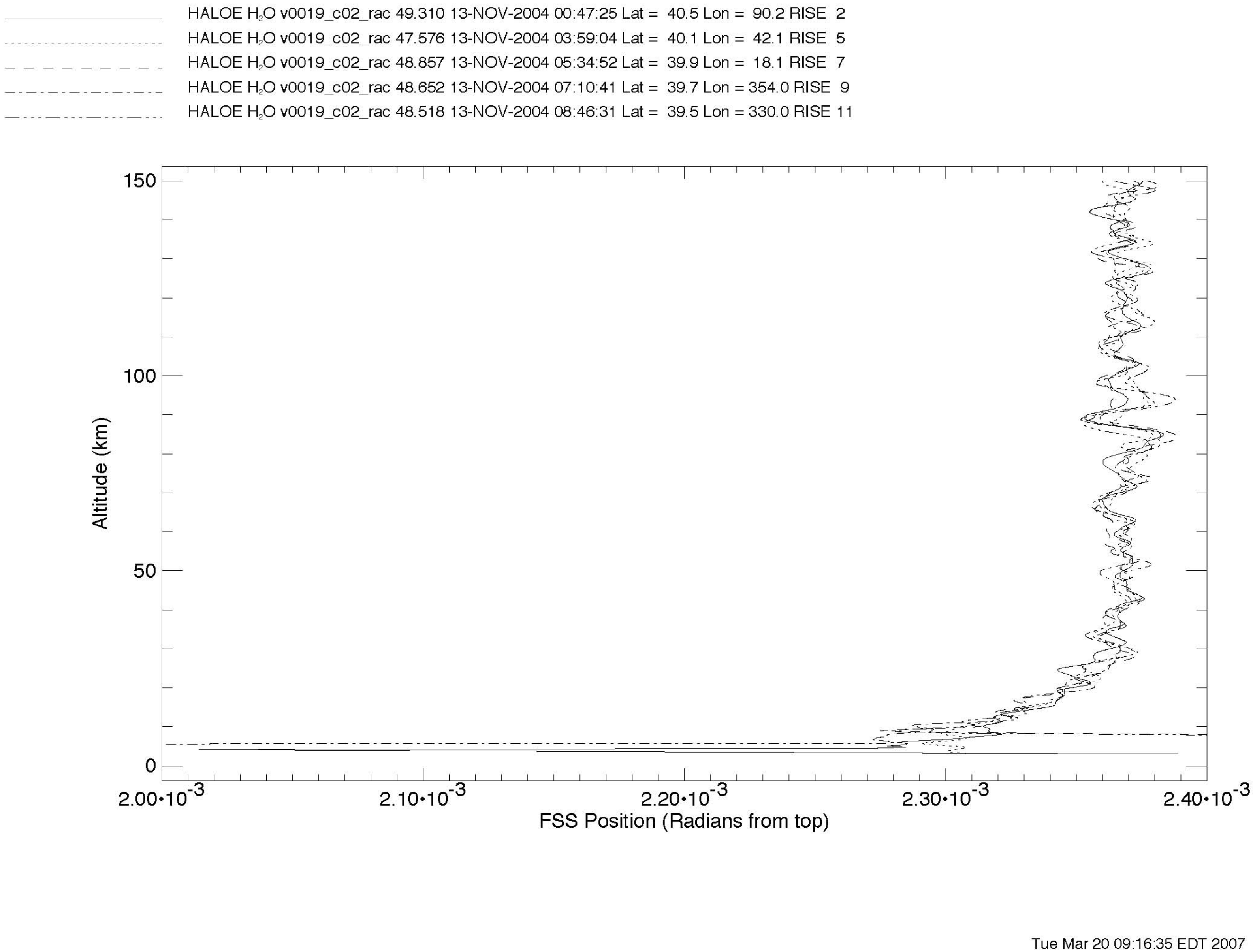
HALOE $H_2O$ v0019_c01_rac 39.329 16-FEB-2003 02:40:40 Lat = 40.2 Lon = 222.6 SET 3
HALOE $H_2O$ v0019_c01_rac 39.886 16-FEB-2003 05:52:26 Lat = 40.7 Lon = 174.5 SET 7
HALOE $H_2O$ v0019_c01_rac 40.138 16-FEB-2003 07:28:19 Lat = 41.0 Lon = 150.5 SET 9
HALOE $H_2O$ v0019_c01_rac 40.387 16-FEB-2003 09:04:12 Lat = 41.3 Lon = 126.4 SET 11
Altitude (km)
100
80
60
40
20
$2.00 \cdot 10^{-3}$
$2.10 \cdot 10^{-3}$
$2.20 \cdot 10^{-3}$
$2.30 \cdot 10^{-3}$
$2.40 \cdot 10^{-3}$
Lockdown for H2O (Radians from Top)
Tue Apr 3 07:50:00 EDT 2007

**Plot 15**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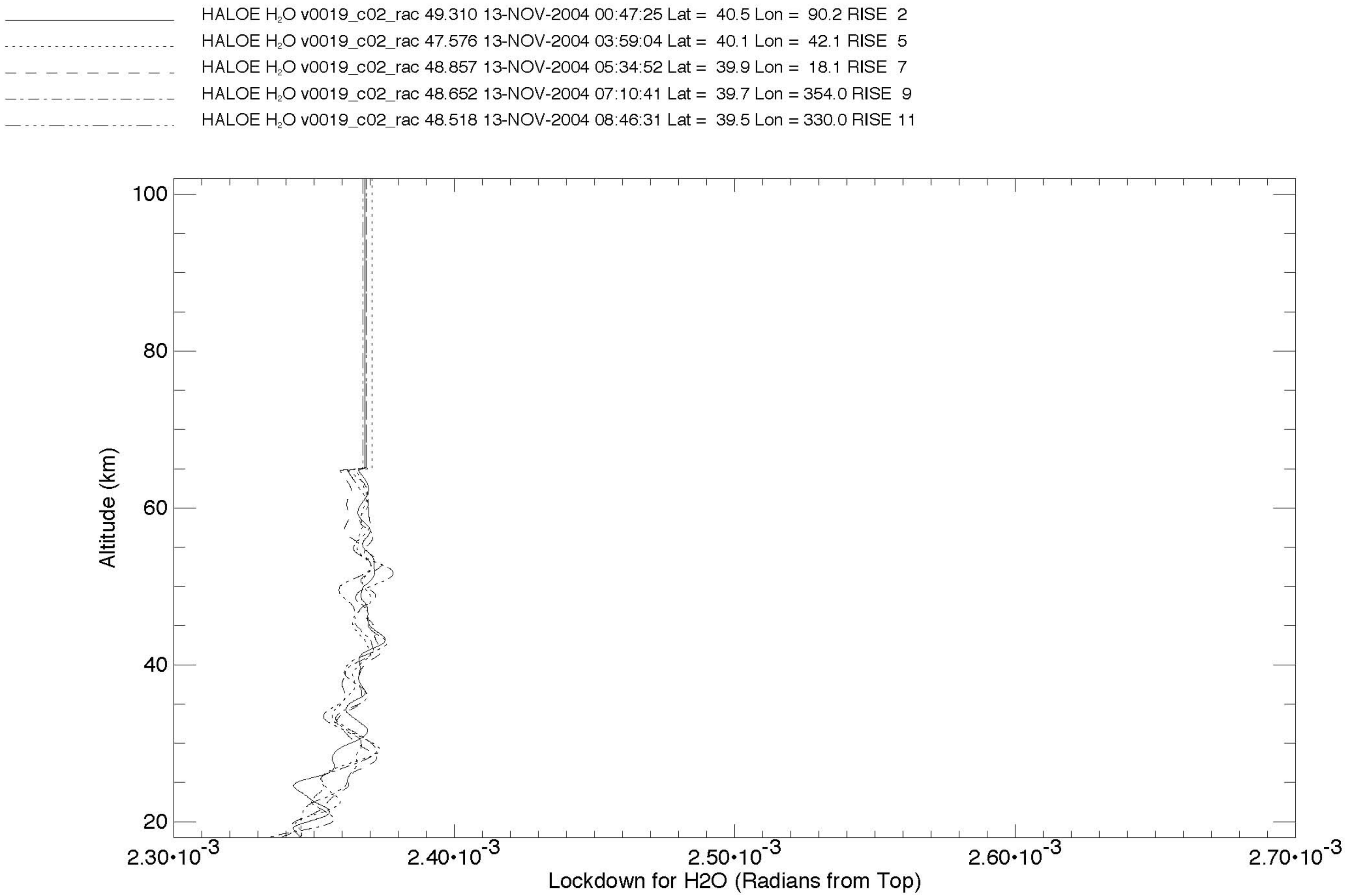
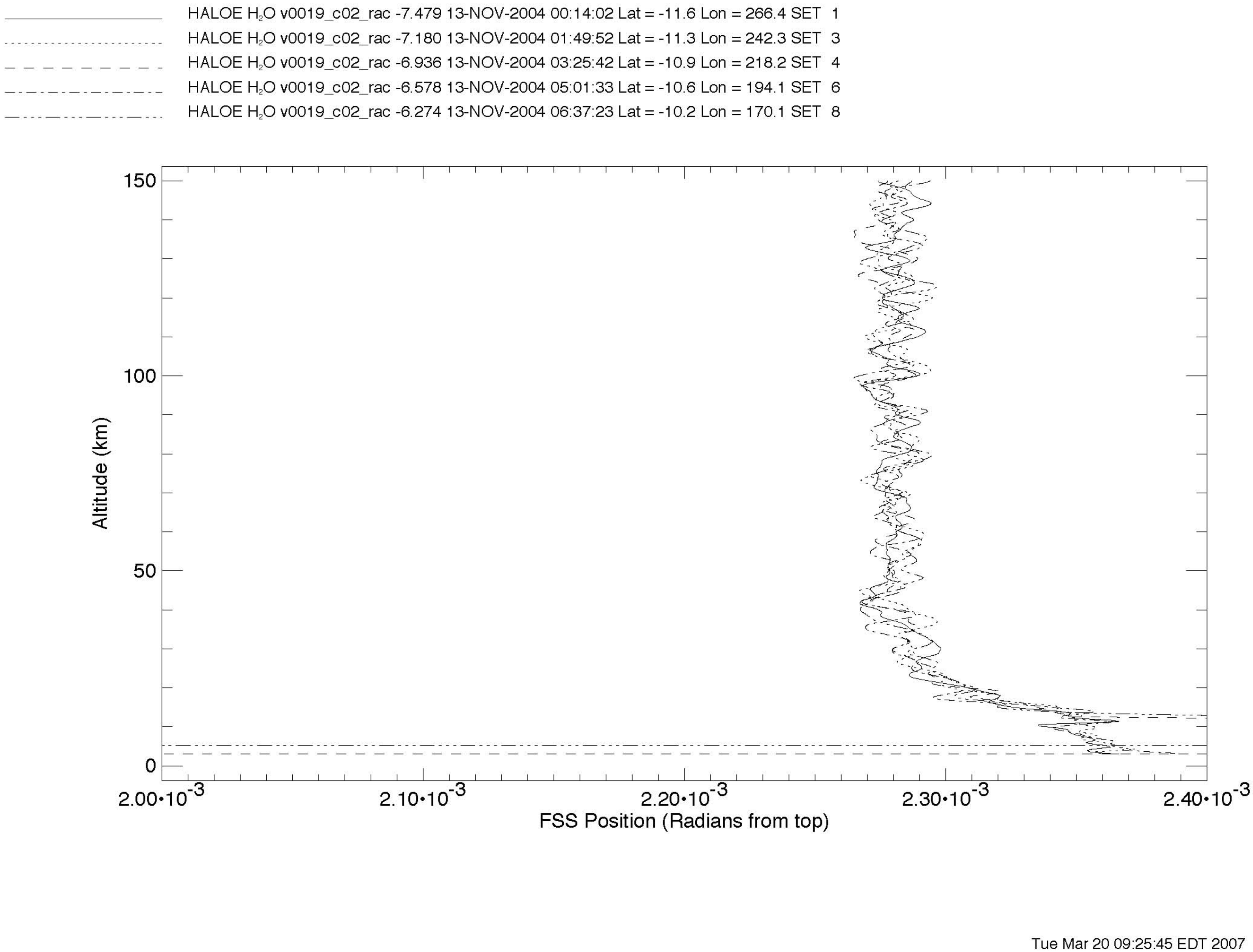
HALOE H2O v0019_c02_rac 47.576 13-NOV-2004 03:59:04 Lat = 40.1 Lon = 42.1 RISE 5
HALOE H2O v0019_c02_rac 48.857 13-NOV-2004 05:34:52 Lat = 39.9 Lon = 18.1 RISE 7
HALOE H2O v0019_c02_rac 48.652 13-NOV-2004 07:10:41 Lat = 39.7 Lon = 354.0 RISE 9
HALOE H2O v0019_c02_rac 48.518 13-NOV-2004 08:46:31 Lat = 39.5 Lon = 330.0 RISE 11
150
100
50
0
Altitude (km)
2.00•10-3
2.10•10-3
2.20•10-3
2.30•10-3
2.40•10-3
FSS Position (Radians from top)
Tue Mar 20 09:16:35 EDT 2007

**Plot 16**



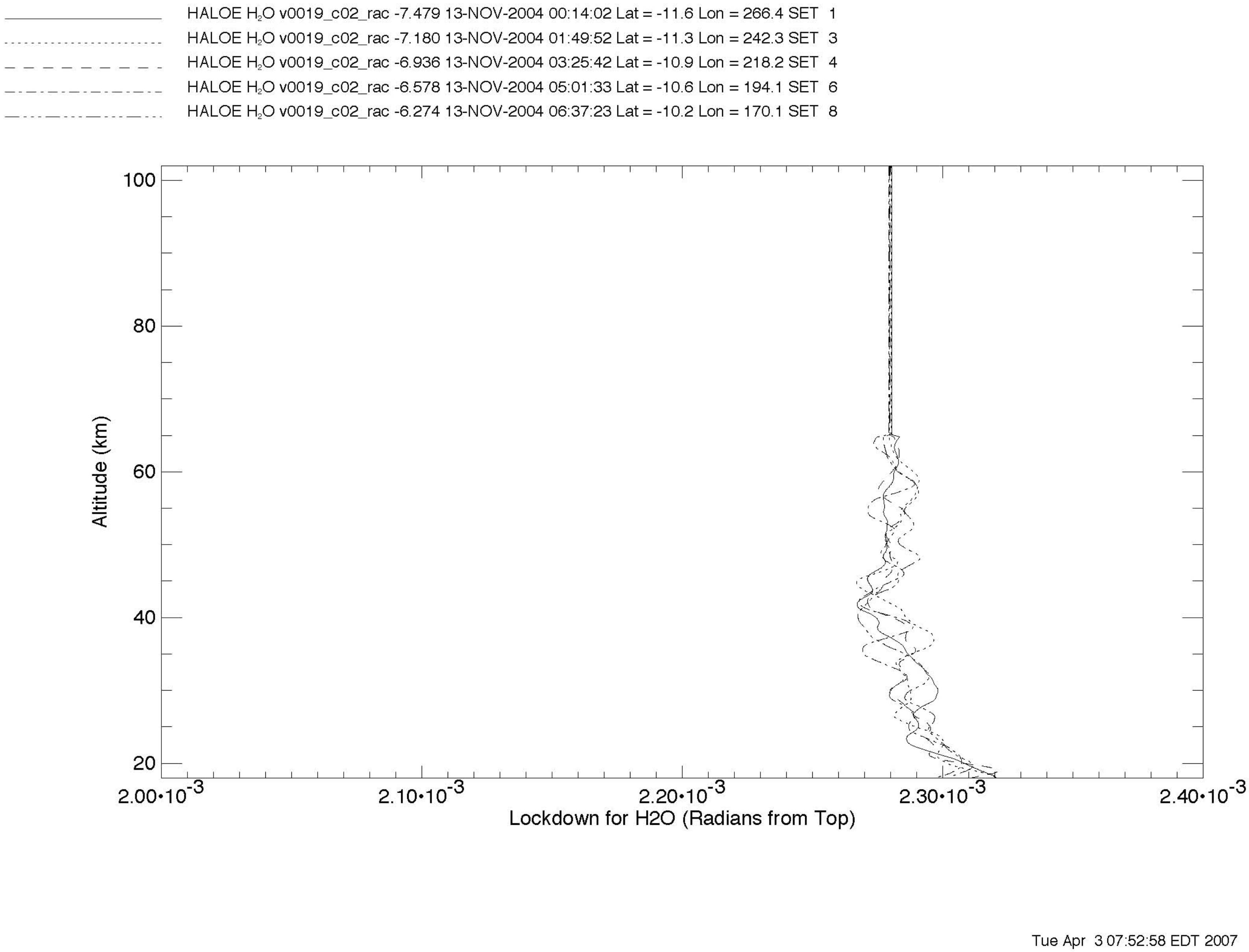

Tue Apr 3 07:51:31 EDT 2007

**Plot 17**

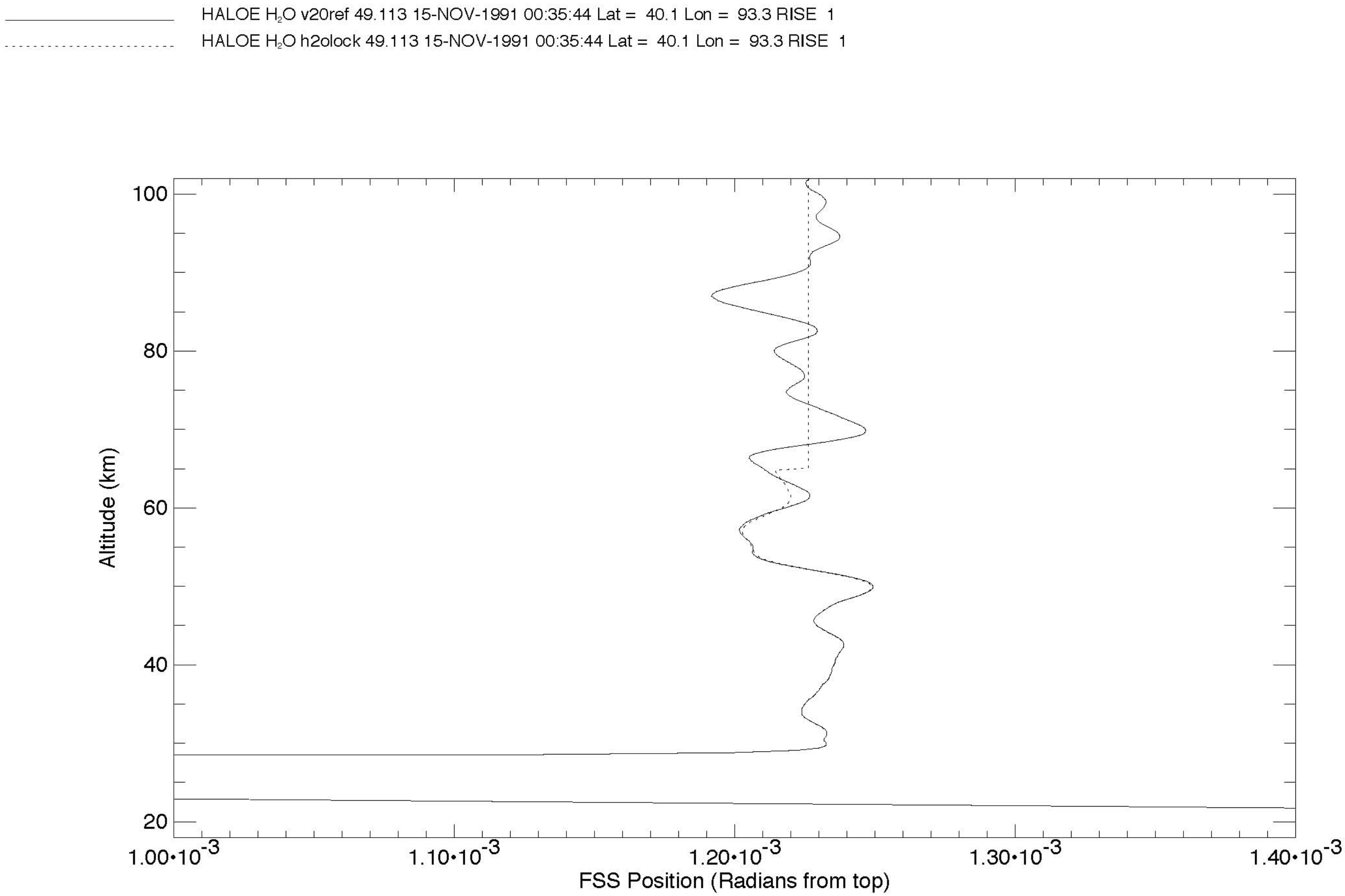


HALOE H2O v0019_c02_rac -7.479 13-NOV-2004 00:14:02 Lat = -11.6 Lon = 266.4 SET 1
HALOE H2O v0019_c02_rac -7.180 13-NOV-2004 01:49:52 Lat = -11.3 Lon = 242.3 SET 3
HALOE H2O v0019_c02_rac -6.936 13-NOV-2004 03:25:42 Lat = -10.9 Lon = 218.2 SET 4
HALOE H2O v0019_c02_rac -6.578 13-NOV-2004 05:01:33 Lat = -10.6 Lon = 194.1 SET 6
HALOE H2O v0019_c02_rac -6.274 13-NOV-2004 06:37:23 Lat = -10.2 Lon = 170.1 SET 8
150
100
50
0
Altitude (km)
2.00•10-3
2.10•10-3
2.20•10-3
2.30•10-3
2.40•10-3
FSS Position (Radians from top)
Tue Mar 20 09:25:45 EDT 2007


**Plot 18**

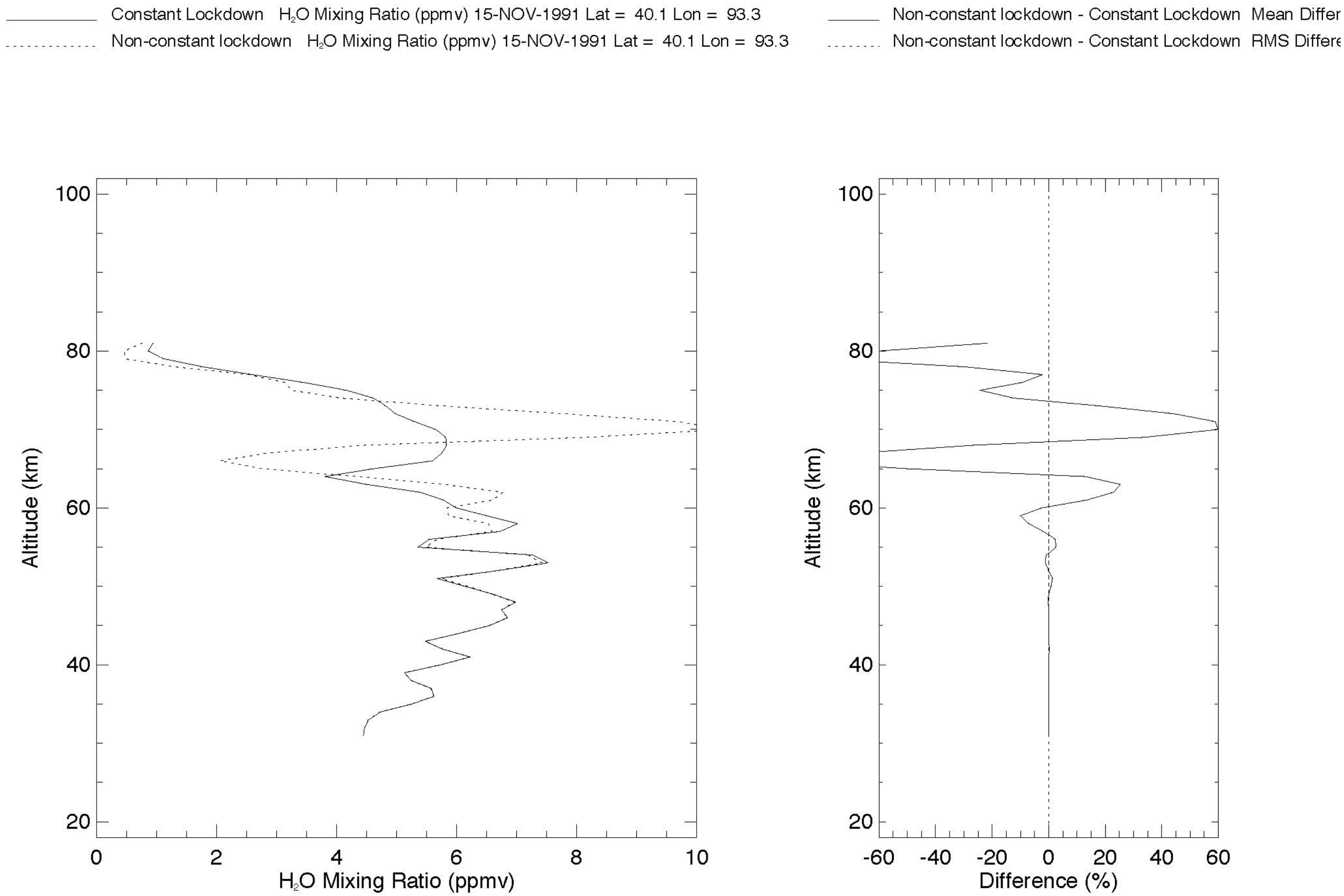

HALOE H2O v0019_c02_rac -7.479 13-NOV-2004 00:14:02 Lat = -11.6 Lon = 266.4 SET 1
HALOE H2O v0019_c02_rac -7.180 13-NOV-2004 01:49:52 Lat = -11.3 Lon = 242.3 SET 3
HALOE H2O v0019_c02_rac -6.936 13-NOV-2004 03:25:42 Lat = -10.9 Lon = 218.2 SET 4
HALOE H2O v0019_c02_rac -6.578 13-NOV-2004 05:01:33 Lat = -10.6 Lon = 194.1 SET 6
HALOE H2O v0019_c02_rac -6.274 13-NOV-2004 06:37:23 Lat = -10.2 Lon = 170.1 SET 8
100
80
60
40
20
Altitude (km)
2.00•10-3
2.10•10-3
2.20•10-3
2.30•10-3
2.40•10-3
Lockdown for H2O (Radians from Top)
Tue Apr 3 07:52:58 EDT 2007

**Plot 19**




Fri Aug 24 11:37:13 EDT 2007

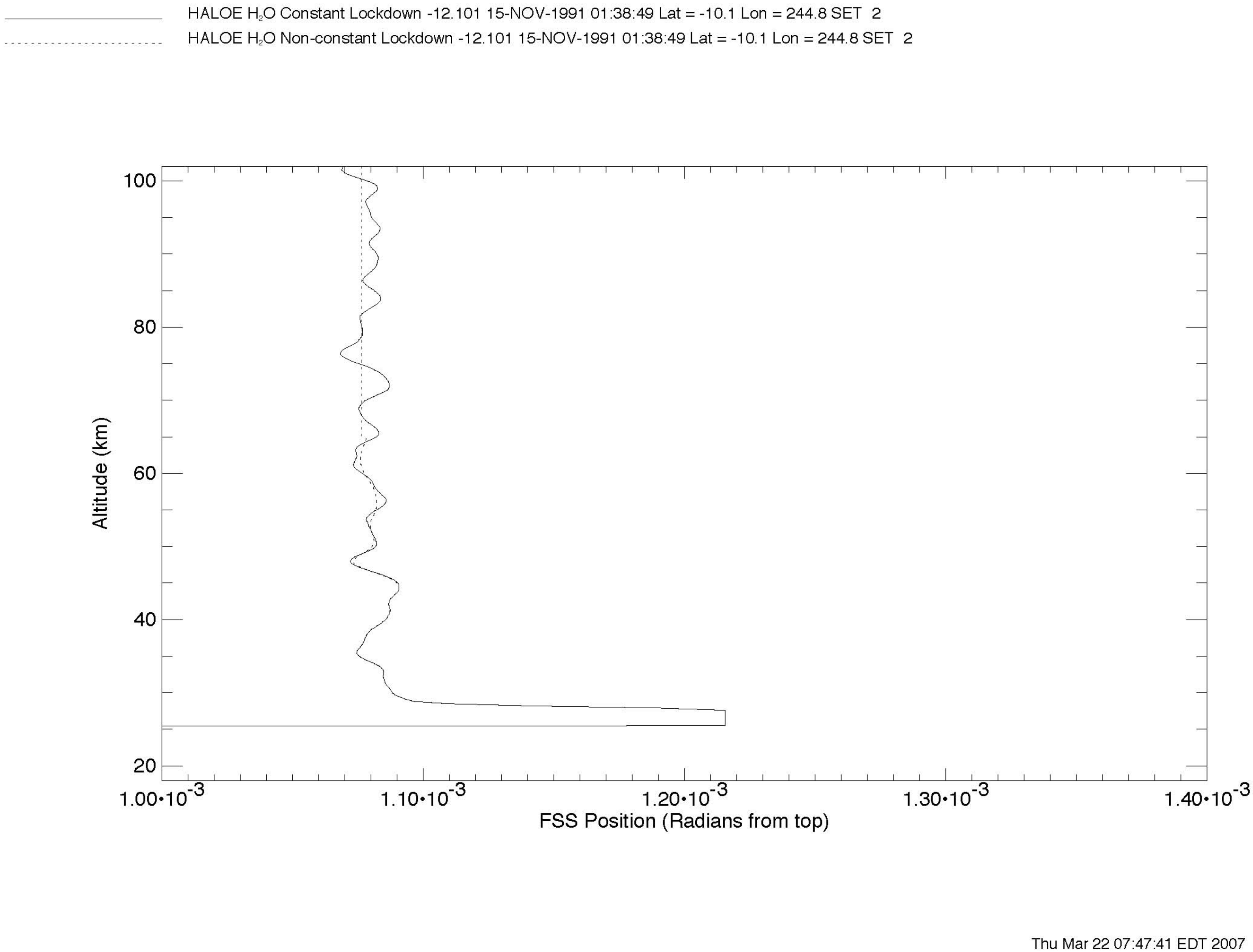
**Plot 20**




Altitude (km) vs $H_2O$ Mixing Ratio (ppmv), on
15-NOV-1991 at 40 N, 93 E

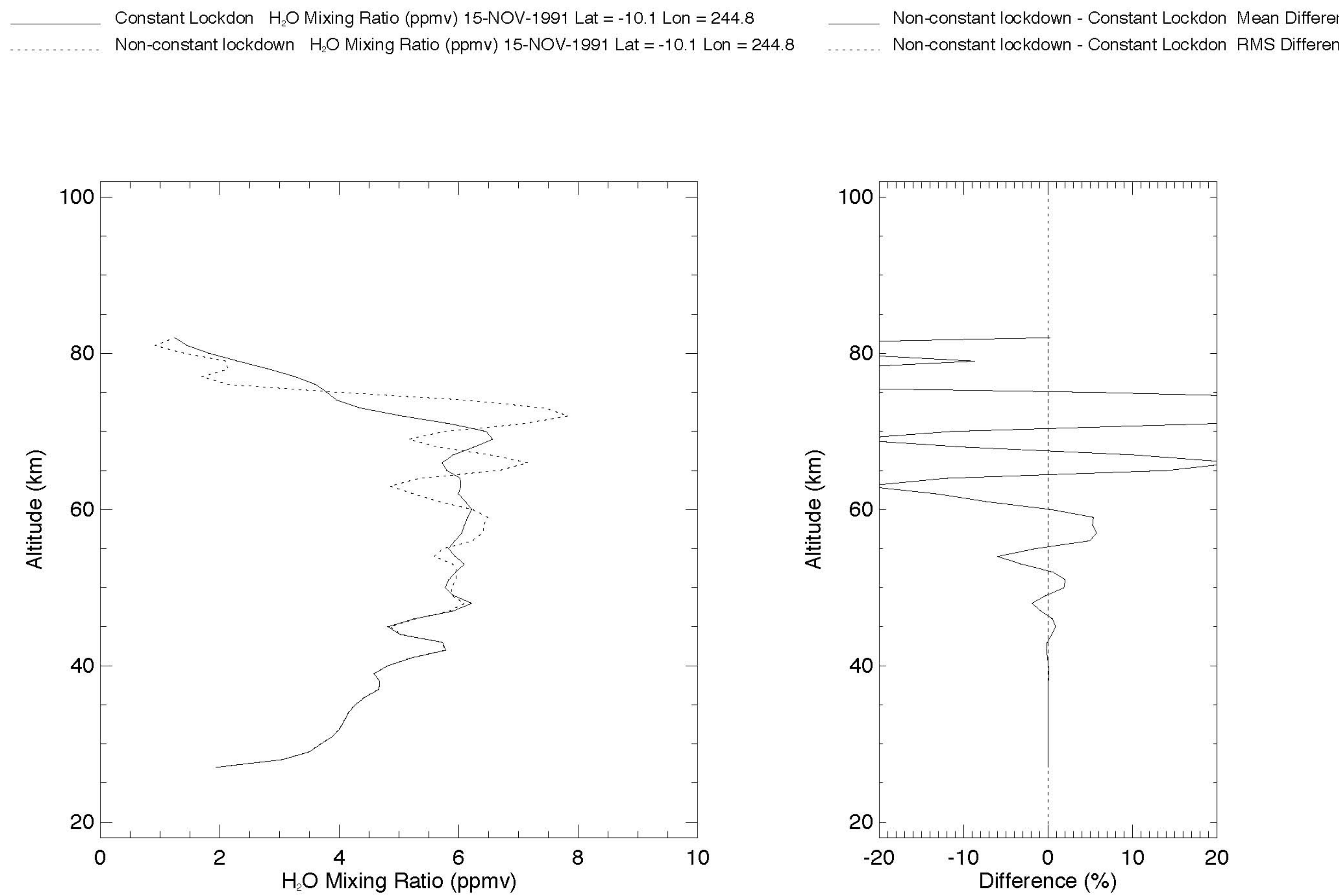
Fri Aug 24 10:39:28 EDT 2007

**Plot 21**



HALOE $H_2O$ Constant Lockdown -12.101 15-NOV-1991 01:38:49 Lat = -10.1 Lon = 244.8 SET 2
HALOE $H_2O$ Non-constant Lockdown -12.101 15-NOV-1991 01:38:49 Lat = -10.1 Lon = 244.8 SET 2
Altitude (km)
100
80
60
40
20
1.00•10^-3
1.10•10^-3
1.20•10^-3
1.30•10^-3
1.40•10^-3
FSS Position (Radians from top)
Thu Mar 22 07:47:41 EDT 2007

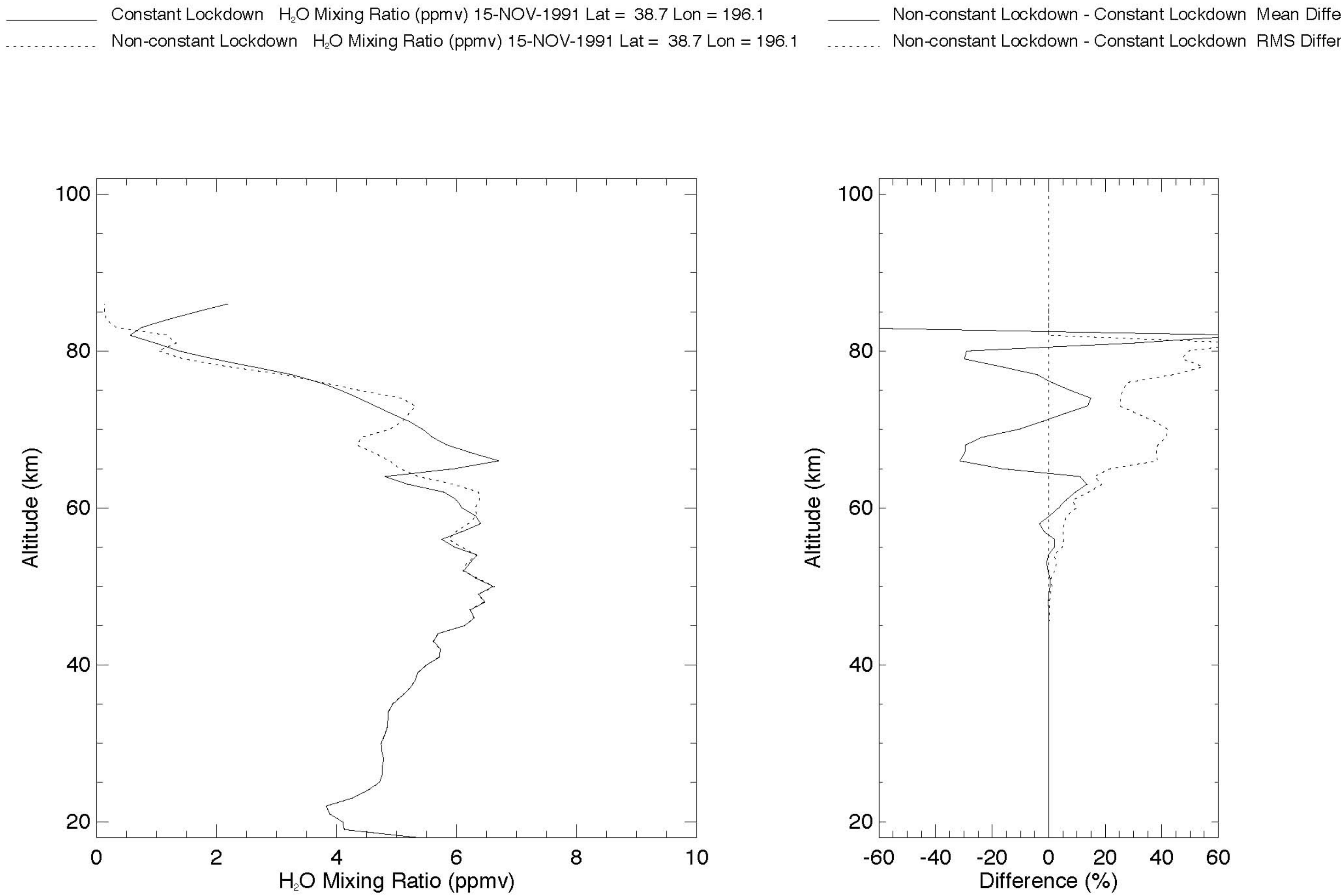

**Plot 22**




Altitude (km) vs $H_2O$ Mixing Ratio (ppmv), on 15-NOV-1991 at 10 S, 244 E

Tue Apr 3 07:09:19 EDT 2007

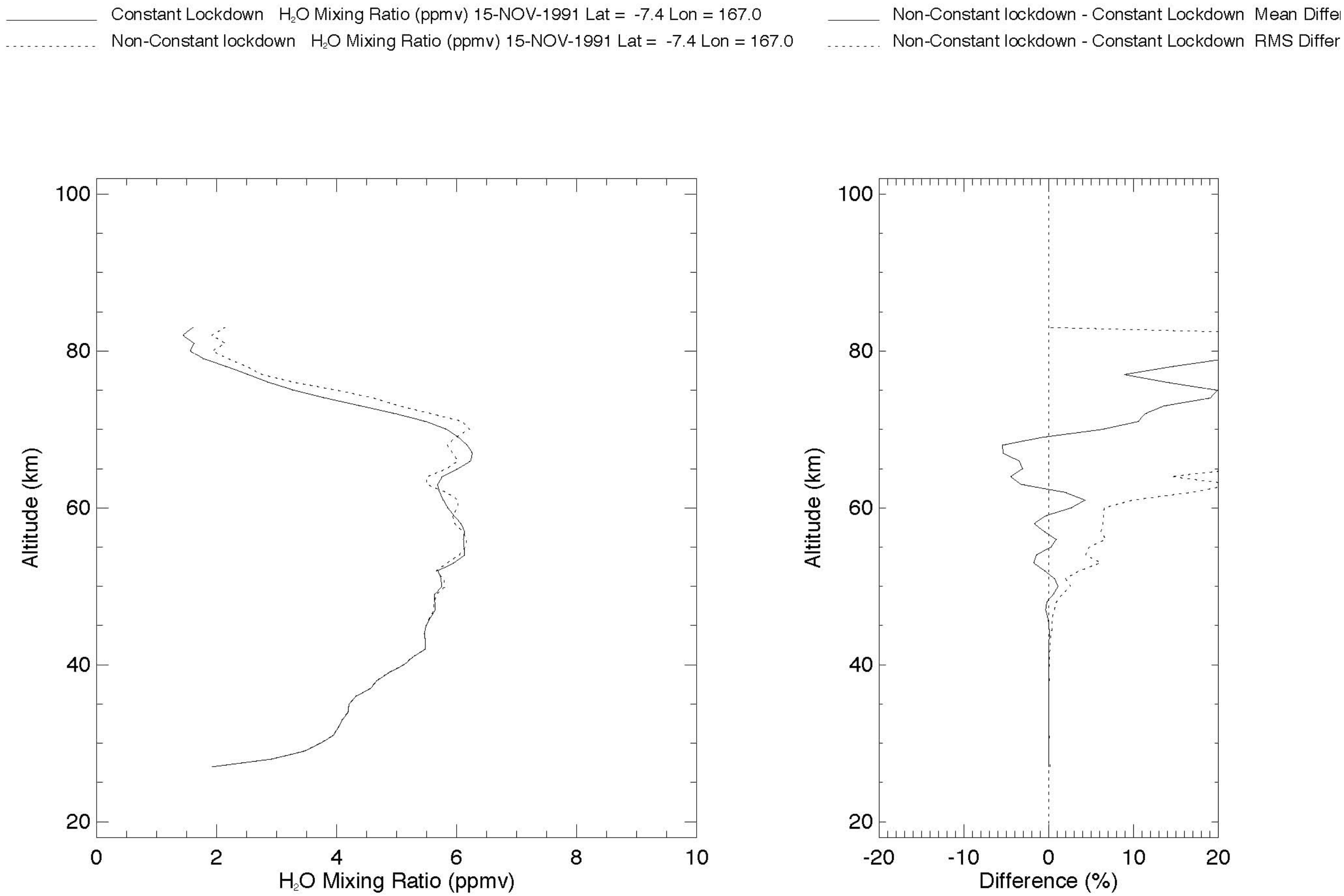
**Plot 23**




# Altitude (km) vs $H_2O$ Mixing Ratio (ppmv), on 15-NOV-1991 at 38 N, 196 E

Fri Sep 28 11:22:34 EDT 2007

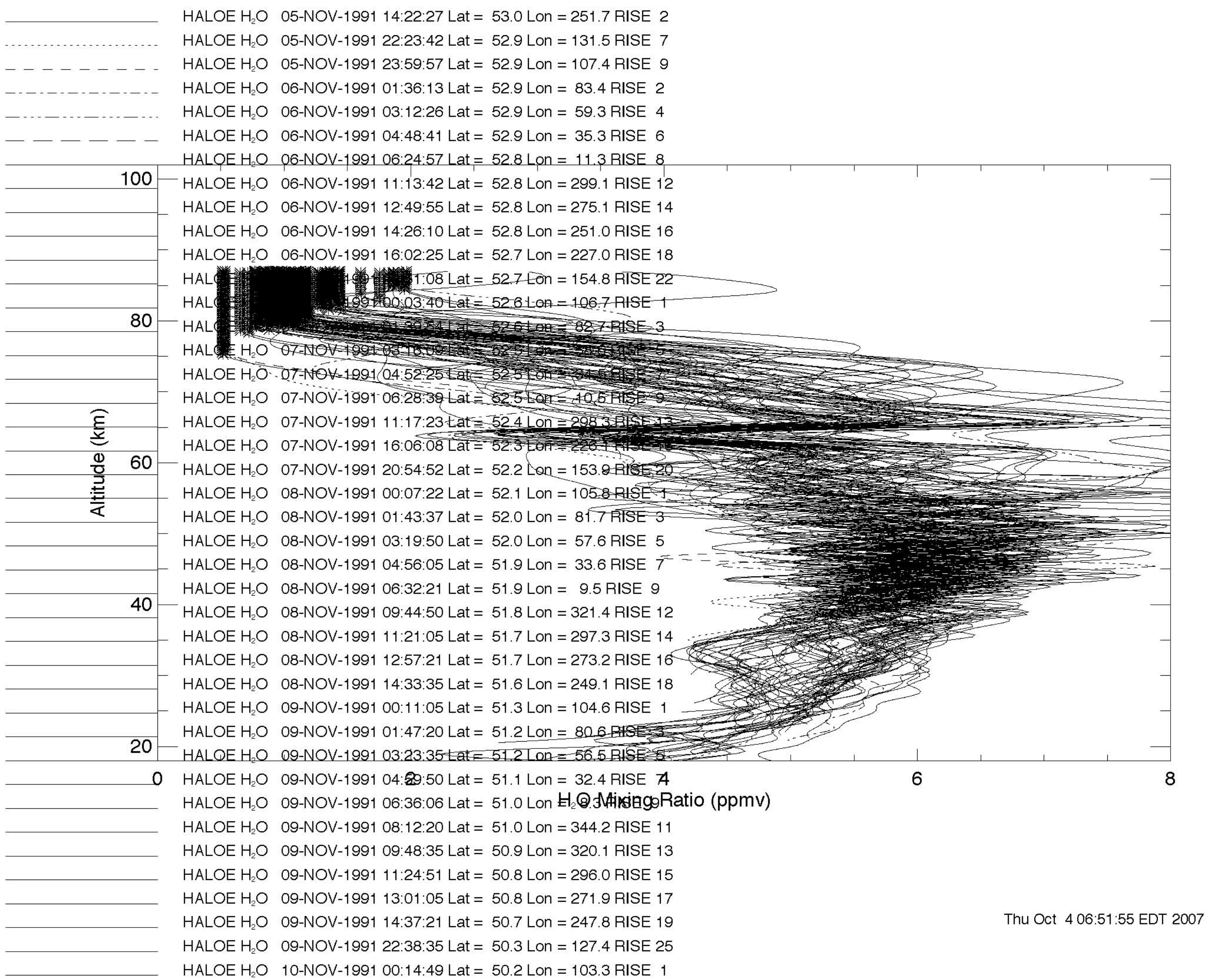
**Plot 24**



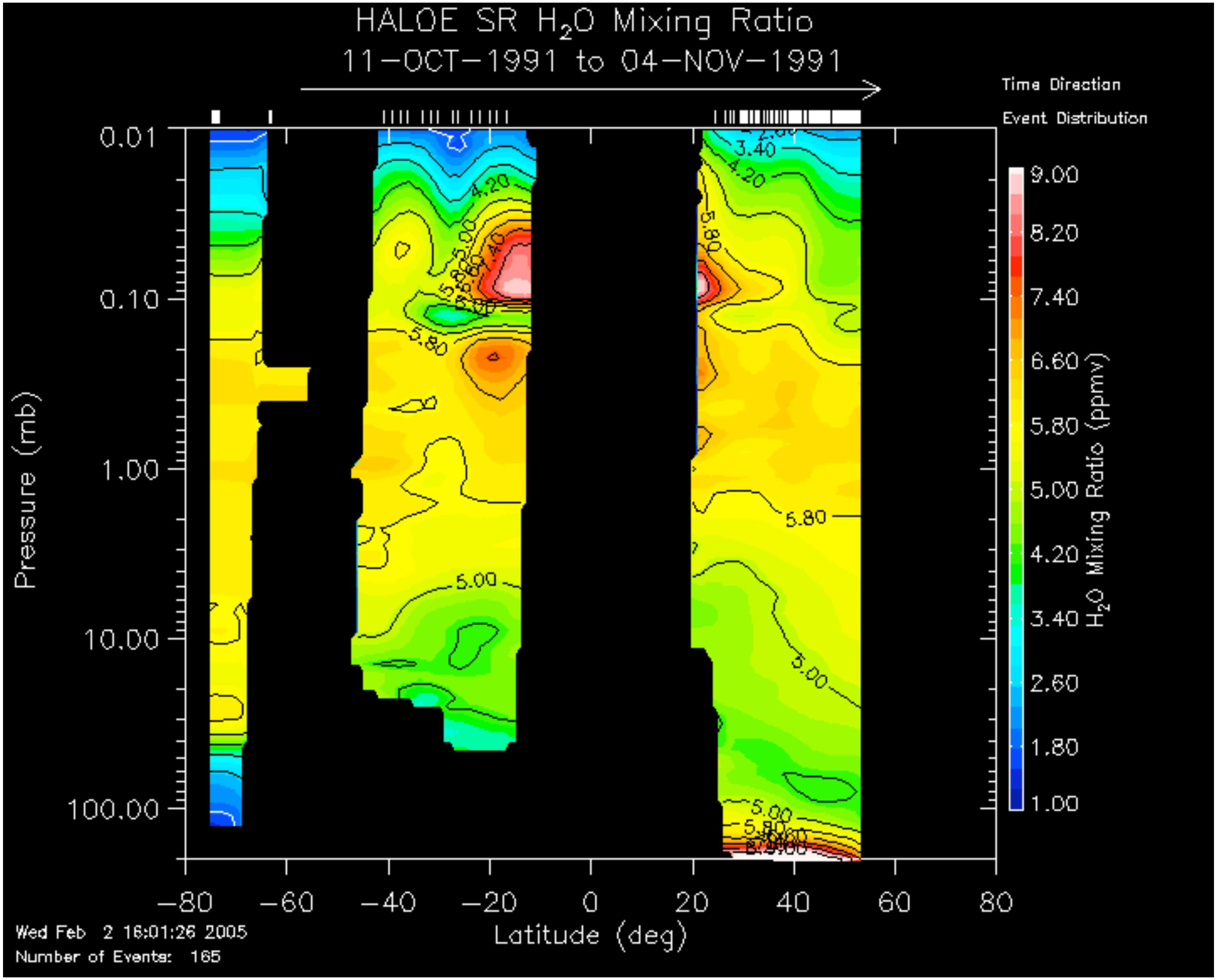

# Altitude (km) vs $H_2O$ Mixing Ratio (ppmv), on 15-NOV-1991 at 7 S, 167 E

Fri Sep 28 11:23:35 EDT 2007

**Plot 25**

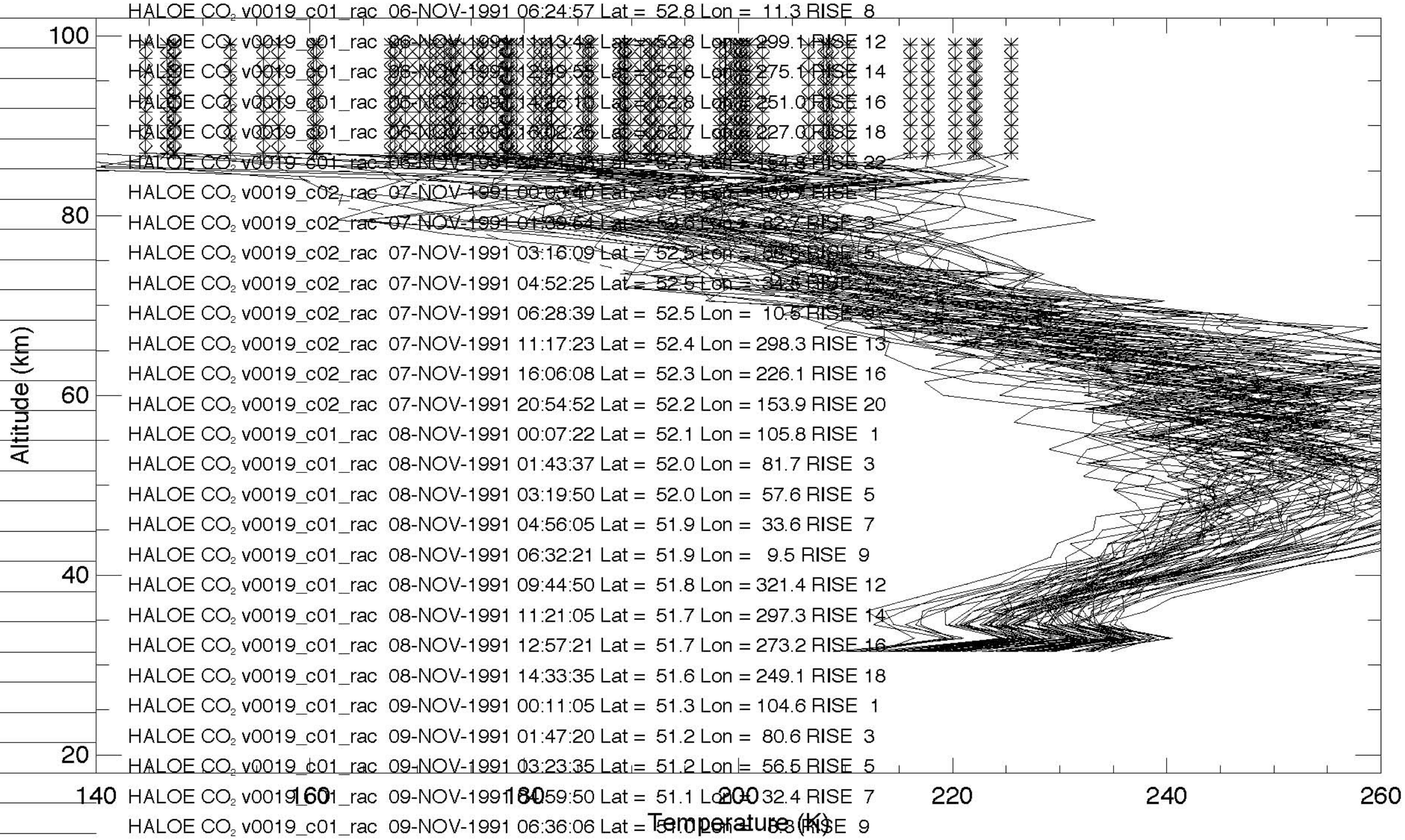

HALOE H2O 05-NOV-1991 14:22:27 Lat = 53.0 Lon = 251.7 RISE 2
HALOE H2O 05-NOV-1991 22:23:42 Lat = 52.9 Lon = 131.5 RISE 7
HALOE H2O 05-NOV-1991 23:59:57 Lat = 52.9 Lon = 107.4 RISE 9
HALOE H2O 06-NOV-1991 01:36:13 Lat = 52.9 Lon = 83.4 RISE 2
HALOE H2O 06-NOV-1991 03:12:26 Lat = 52.9 Lon = 59.3 RISE 4
HALOE H2O 06-NOV-1991 04:48:41 Lat = 52.9 Lon = 35.3 RISE 6
HALOE H2O 06-NOV-1991 06:24:57 Lat = 52.8 Lon = 11.3 RISE 8
HALOE H2O 06-NOV-1991 11:13:42 Lat = 52.8 Lon = 299.1 RISE 12
HALOE H2O 06-NOV-1991 12:49:55 Lat = 52.8 Lon = 275.1 RISE 14
HALOE H2O 06-NOV-1991 14:26:10 Lat = 52.8 Lon = 251.0 RISE 16
HALOE H2O 06-NOV-1991 16:02:25 Lat = 52.7 Lon = 227.0 RISE 18
1:08 Lat = 52.7 Lon = 154.8 RISE 22
00:03:40 Lat = 52.6 Lon = 106.7 RISE 1
Lat = 52.6 Lon = 82.7 RISE 3
HALOE H2O 07-NOV-1991
HALOE H2O 07-NOV-1991 04:52:25 Lat = 52.5 Lon = 34.6 RISE 7
HALOE H2O 07-NOV-1991 06:28:39 Lat = 52.5 Lon = 10.5 RISE 9
HALOE H2O 07-NOV-1991 11:17:23 Lat = 52.4 Lon = 298.3 RISE 13
HALOE H2O 07-NOV-1991 16:06:08 Lat = 52.3
HALOE H2O 07-NOV-1991 20:54:52 Lat = 52.2 Lon = 153.9 RISE 20
HALOE H2O 08-NOV-1991 00:07:22 Lat = 52.1 Lon = 105.8 RISE 1
HALOE H2O 08-NOV-1991 01:43:37 Lat = 52.0 Lon = 81.7 RISE 3
HALOE H2O 08-NOV-1991 03:19:50 Lat = 52.0 Lon = 57.6 RISE 5
HALOE H2O 08-NOV-1991 04:56:05 Lat = 51.9 Lon = 33.6 RISE 7
HALOE H2O 08-NOV-1991 06:32:21 Lat = 51.9 Lon = 9.5 RISE 9
HALOE H2O 08-NOV-1991 09:44:50 Lat = 51.8 Lon = 321.4 RISE 12
HALOE H2O 08-NOV-1991 11:21:05 Lat = 51.7 Lon = 297.3 RISE 14
HALOE H2O 08-NOV-1991 12:57:21 Lat = 51.7 Lon = 273.2 RISE 16
HALOE H2O 08-NOV-1991 14:33:35 Lat = 51.6 Lon = 249.1 RISE 18
HALOE H2O 09-NOV-1991 00:11:05 Lat = 51.3 Lon = 104.6 RISE 1
HALOE H2O 09-NOV-1991 01:47:20 Lat = 51.2 Lon = 80.6 RISE 3
HALOE H2O 09-NOV-1991 03:23:35 Lat = 51.2 Lon = 56.5 RISE 5
HALOE H2O 09-NOV-1991 Lat = 51.1 Lon = 32.4 RISE 7
HALOE H2O 09-NOV-1991 06:36:06 Lat = 51.0
HALOE H2O 09-NOV-1991 08:12:20 Lat = 51.0 Lon = 344.2 RISE 11
HALOE H2O 09-NOV-1991 09:48:35 Lat = 50.9 Lon = 320.1 RISE 13
HALOE H2O 09-NOV-1991 11:24:51 Lat = 50.8 Lon = 296.0 RISE 15
HALOE H2O 09-NOV-1991 13:01:05 Lat = 50.8 Lon = 271.9 RISE 17
HALOE H2O 09-NOV-1991 14:37:21 Lat = 50.7 Lon = 247.8 RISE 19
HALOE H2O 09-NOV-1991 22:38:35 Lat = 50.3 Lon = 127.4 RISE 25
HALOE H2O 10-NOV-1991 00:14:49 Lat = 50.2 Lon = 103.3 RISE 1
Altitude (km)
100
80
60
40
20
0
2
4
6
8
H2O Mixing Ratio (ppmv)
Thu Oct 4 06:51:55 EDT 2007

**Plot 26**


HALOE SR H2O Mixing Ratio
11-OCT-1991 to 04-NOV-1991
Time Direction
Event Distribution
Pressure (mb)
Latitude (deg)
H2O Mixing Ratio (ppmv)
Wed Feb 2 16:01:26 2005
Number of Events: 165

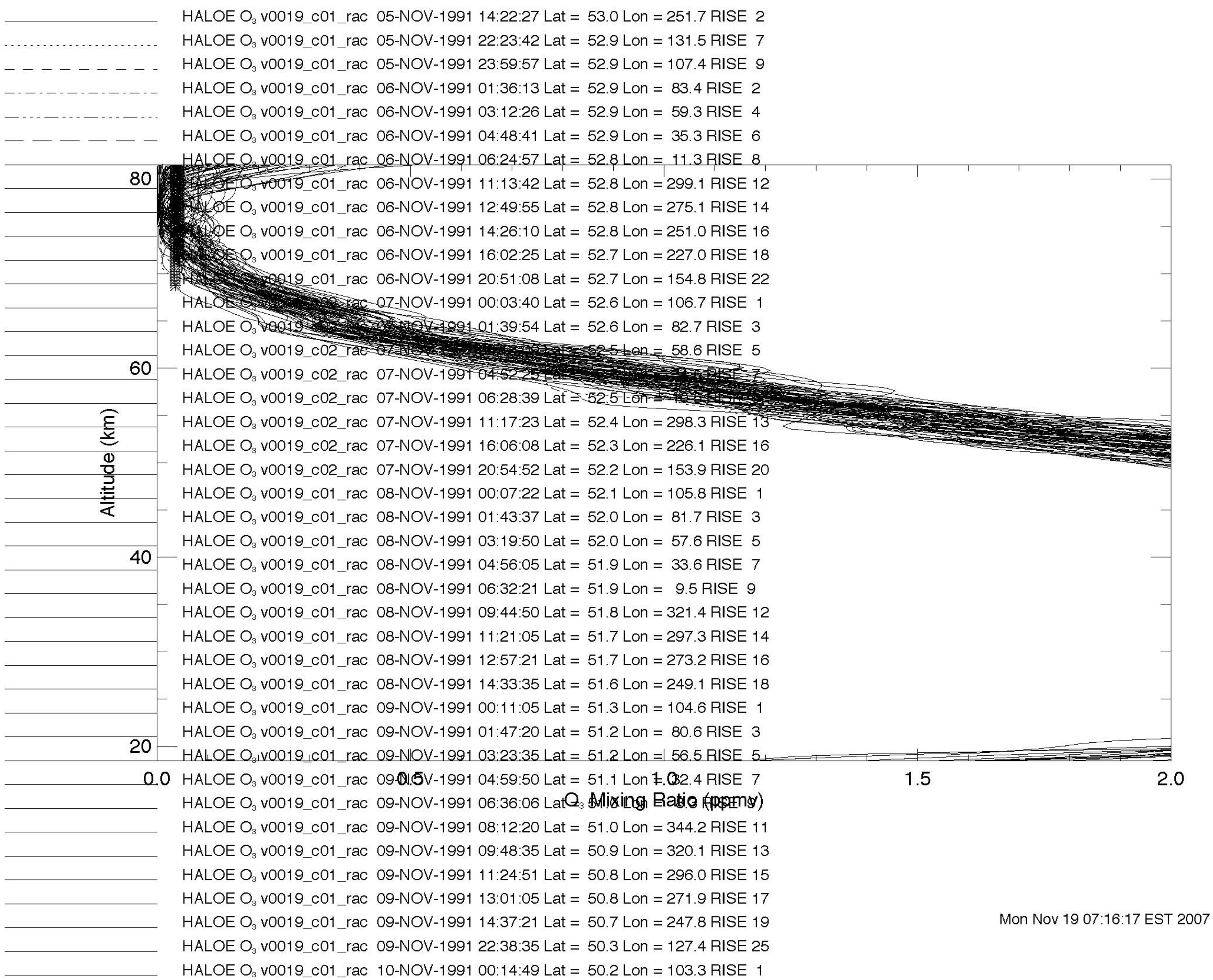
**Plot 27**

HALOE $CO_2$ v0019_c01_rac 05-NOV-1991 14:22:27 Lat = 53.0 Lon = 251.7 RISE 2
HALOE $CO_2$ v0019_c01_rac 05-NOV-1991 22:23:42 Lat = 52.9 Lon = 131.5 RISE 7
HALOE $CO_2$ v0019_c01_rac 05-NOV-1991 23:59:57 Lat = 52.9 Lon = 107.4 RISE 9
HALOE $CO_2$ v0019_c01_rac 06-NOV-1991 01:36:13 Lat = 52.9 Lon = 83.4 RISE 2
HALOE $CO_2$ v0019_c01_rac 06-NOV-1991 03:12:26 Lat = 52.9 Lon = 59.3 RISE 4
HALOE $CO_2$ v0019_c01_rac 06-NOV-1991 04:48:41 Lat = 52.9 Lon = 35.3 RISE 6
HALOE $CO_2$ v0019_c01_rac 06-NOV-1991 06:24:57 Lat = 52.8 Lon = 11.3 RISE 8
HALOE $CO_2$ v0019_c01_rac 06-NOV-1991 11:13:42 Lat = 52.8 Lon = 299.1 RISE 12
HALOE $CO_2$ v0019_c01_rac 06-NOV-1991 12:49:55 Lat = 52.8 Lon = 275.1 RISE 14
HALOE $CO_2$ v0019_c01_rac 06-NOV-1991 14:26:10 Lat = 52.8 Lon = 251.0 RISE 16
HALOE $CO_2$ v0019_c01_rac 06-NOV-1991 16:02:25 Lat = 52.7 Lon = 227.0 RISE 18
HALOE $CO_2$ v0019_c01_rac 06-NOV-1991 [illegible] Lat = 52.7 Lon = 154.8 RISE 22
HALOE $CO_2$ v0019_c02_rac 07-NOV-1991 00:03:40 Lat = 52.6 Lon = [illegible] RISE 1
HALOE $CO_2$ v0019_c02_rac 07-NOV-1991 01:39:54 Lat = 52.6 Lon = 82.7 RISE 3
HALOE $CO_2$ v0019_c02_rac 07-NOV-1991 03:16:09 Lat = 52.5 Lon = [illegible] RISE 5
HALOE $CO_2$ v0019_c02_rac 07-NOV-1991 04:52:25 Lat = 52.5 Lon = 34.6 RISE 7
HALOE $CO_2$ v0019_c02_rac 07-NOV-1991 06:28:39 Lat = 52.5 Lon = 10.5 RISE 9
HALOE $CO_2$ v0019_c02_rac 07-NOV-1991 11:17:23 Lat = 52.4 Lon = 298.3 RISE 13
HALOE $CO_2$ v0019_c02_rac 07-NOV-1991 16:06:08 Lat = 52.3 Lon = 226.1 RISE 16
HALOE $CO_2$ v0019_c02_rac 07-NOV-1991 20:54:52 Lat = 52.2 Lon = 153.9 RISE 20
HALOE $CO_2$ v0019_c01_rac 08-NOV-1991 00:07:22 Lat = 52.1 Lon = 105.8 RISE 1
HALOE $CO_2$ v0019_c01_rac 08-NOV-1991 01:43:37 Lat = 52.0 Lon = 81.7 RISE 3
HALOE $CO_2$ v0019_c01_rac 08-NOV-1991 03:19:50 Lat = 52.0 Lon = 57.6 RISE 5
HALOE $CO_2$ v0019_c01_rac 08-NOV-1991 04:56:05 Lat = 51.9 Lon = 33.6 RISE 7
HALOE $CO_2$ v0019_c01_rac 08-NOV-1991 06:32:21 Lat = 51.9 Lon = 9.5 RISE 9
HALOE $CO_2$ v0019_c01_rac 08-NOV-1991 09:44:50 Lat = 51.8 Lon = 321.4 RISE 12
HALOE $CO_2$ v0019_c01_rac 08-NOV-1991 11:21:05 Lat = 51.7 Lon = 297.3 RISE 14
HALOE $CO_2$ v0019_c01_rac 08-NOV-1991 12:57:21 Lat = 51.7 Lon = 273.2 RISE 16
HALOE $CO_2$ v0019_c01_rac 08-NOV-1991 14:33:35 Lat = 51.6 Lon = 249.1 RISE 18
HALOE $CO_2$ v0019_c01_rac 09-NOV-1991 00:11:05 Lat = 51.3 Lon = 104.6 RISE 1
HALOE $CO_2$ v0019_c01_rac 09-NOV-1991 01:47:20 Lat = 51.2 Lon = 80.6 RISE 3
HALOE $CO_2$ v0019_c01_rac 09-NOV-1991 03:23:35 Lat = 51.2 Lon = 56.5 RISE 5
HALOE $CO_2$ v0019_c01_rac 09-NOV-1991 04:59:50 Lat = 51.1 Lon = 32.4 RISE 7
HALOE $CO_2$ v0019_c01_rac 09-NOV-1991 06:36:06 Lat = 51.0 Lon = 8.3 RISE 9
HALOE $CO_2$ v0019_c01_rac 09-NOV-1991 08:12:20 Lat = 51.0 Lon = 344.2 RISE 11
HALOE $CO_2$ v0019_c01_rac 09-NOV-1991 09:48:35 Lat = 50.9 Lon = 320.1 RISE 13
HALOE $CO_2$ v0019_c01_rac 09-NOV-1991 11:24:51 Lat = 50.8 Lon = 296.0 RISE 15
HALOE $CO_2$ v0019_c01_rac 09-NOV-1991 13:01:05 Lat = 50.8 Lon = 271.9 RISE 17
HALOE $CO_2$ v0019_c01_rac 09-NOV-1991 14:37:21 Lat = 50.7 Lon = 247.8 RISE 19
HALOE $CO_2$ v0019_c01_rac 09-NOV-1991 22:38:35 Lat = 50.3 Lon = 127.4 RISE 25
HALOE $CO_2$ v0019_c01_rac 10-NOV-1991 00:14:49 Lat = 50.2 Lon = 103.3 RISE 1



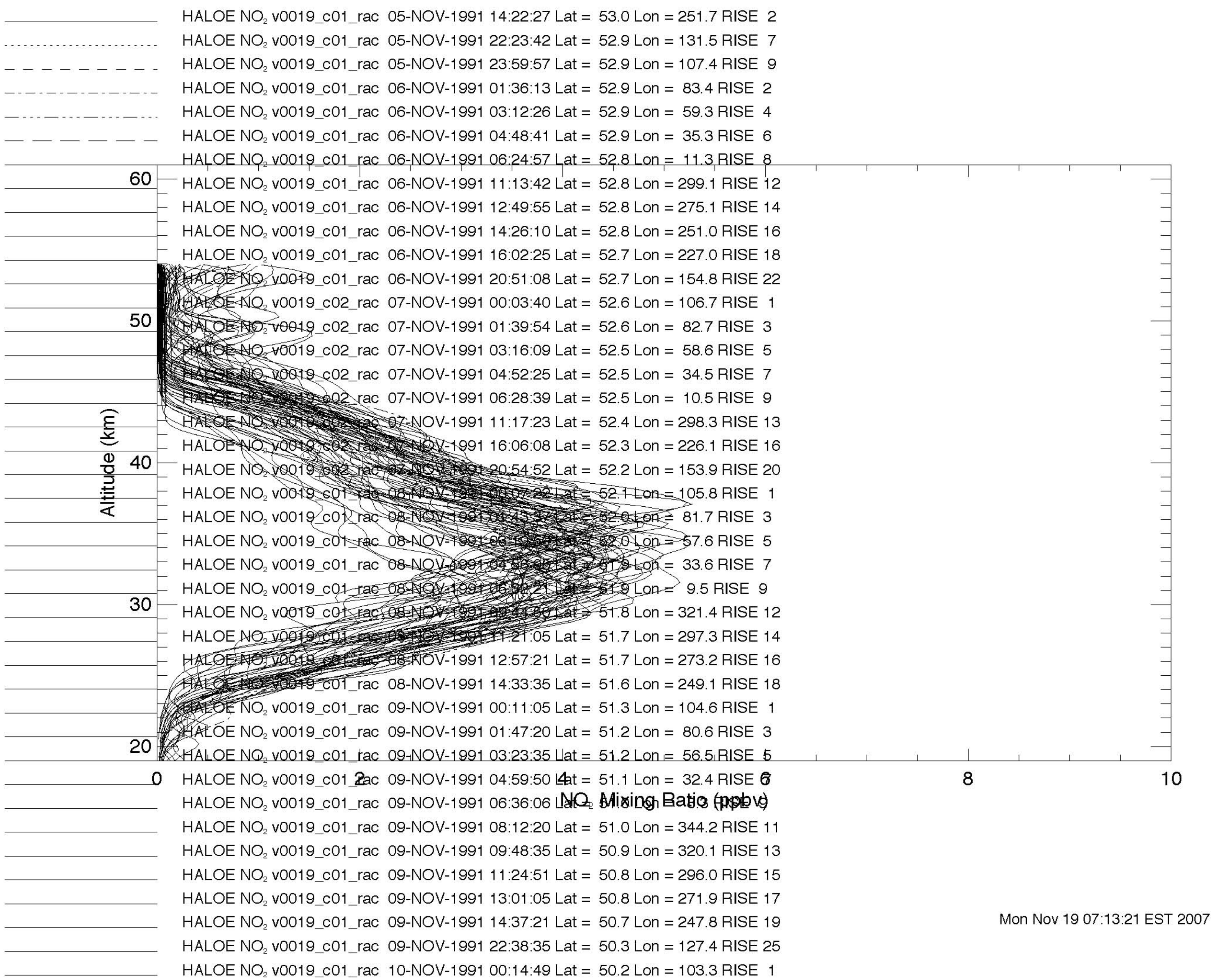

Mon Nov 19 10:39:19 EST 2007

**Plot 28**

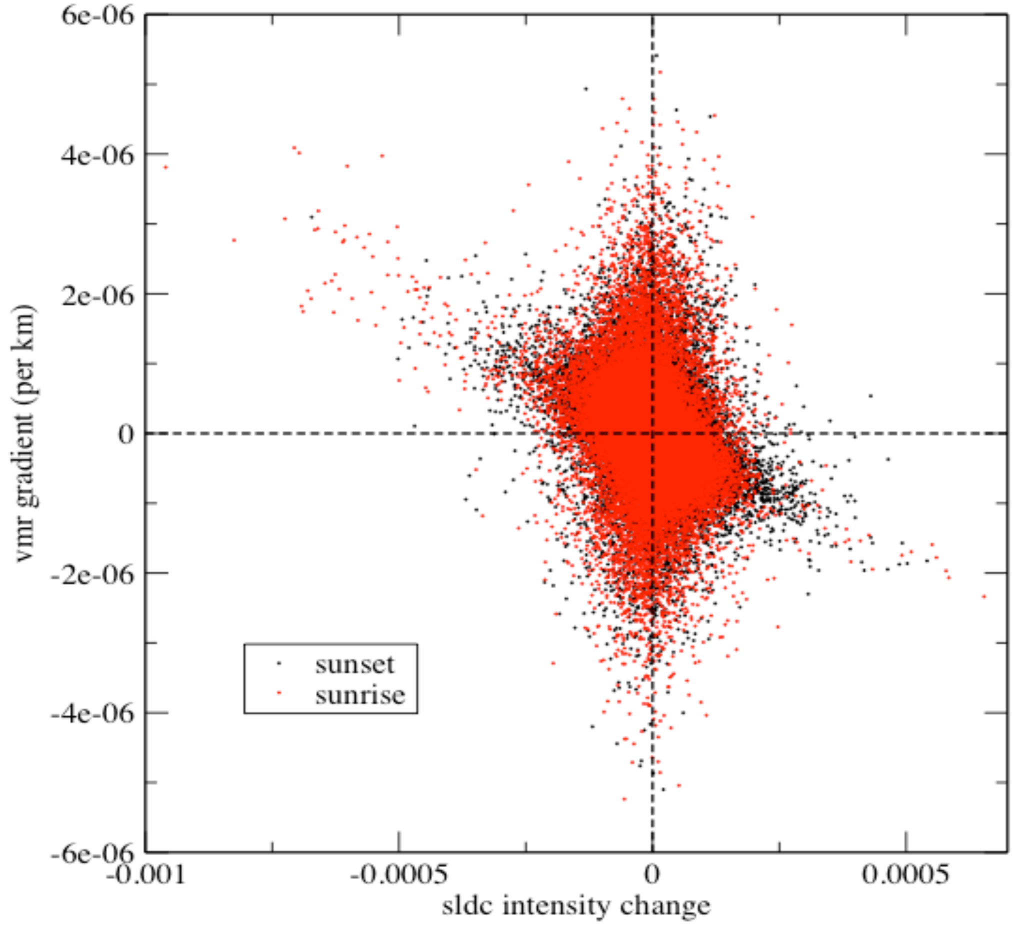


HALOE $O_3$ v0019_c01_rac 05-NOV-1991 14:22:27 Lat = 53.0 Lon = 251.7 RISE 2
HALOE $O_3$ v0019_c01_rac 05-NOV-1991 22:23:42 Lat = 52.9 Lon = 131.5 RISE 7
HALOE $O_3$ v0019_c01_rac 05-NOV-1991 23:59:57 Lat = 52.9 Lon = 107.4 RISE 9
HALOE $O_3$ v0019_c01_rac 06-NOV-1991 01:36:13 Lat = 52.9 Lon = 83.4 RISE 2
HALOE $O_3$ v0019_c01_rac 06-NOV-1991 03:12:26 Lat = 52.9 Lon = 59.3 RISE 4
HALOE $O_3$ v0019_c01_rac 06-NOV-1991 04:48:41 Lat = 52.9 Lon = 35.3 RISE 6
HALOE $O_3$ v0019_c01_rac 06-NOV-1991 06:24:57 Lat = 52.8 Lon = 11.3 RISE 8
HALOE $O_3$ v0019_c01_rac 06-NOV-1991 11:13:42 Lat = 52.8 Lon = 299.1 RISE 12
HALOE $O_3$ v0019_c01_rac 06-NOV-1991 12:49:55 Lat = 52.8 Lon = 275.1 RISE 14
HALOE $O_3$ v0019_c01_rac 06-NOV-1991 14:26:10 Lat = 52.8 Lon = 251.0 RISE 16
HALOE $O_3$ v0019_c01_rac 06-NOV-1991 16:02:25 Lat = 52.7 Lon = 227.0 RISE 18
HALOE $O_3$ v0019_c01_rac 06-NOV-1991 20:51:08 Lat = 52.7 Lon = 154.8 RISE 22
HALOE rac 07-NOV-1991 00:03:40 Lat = 52.6 Lon = 106.7 RISE 1
HALOE $O_3$ v0019 01:39:54 Lat = 52.6 Lon = 82.7 RISE 3
HALOE $O_3$ v0019_c02_rac Lon = 58.6 RISE 5
HALOE $O_3$ v0019_c02_rac 07-NOV-1991 RISE 7
HALOE $O_3$ v0019_c02_rac 07-NOV-1991 06:28:39 Lat = 52.5 Lon =
HALOE $O_3$ v0019_c02_rac 07-NOV-1991 11:17:23 Lat = 52.4 Lon = 298.3 RISE 13
HALOE $O_3$ v0019_c02_rac 07-NOV-1991 16:06:08 Lat = 52.3 Lon = 226.1 RISE 16
HALOE $O_3$ v0019_c02_rac 07-NOV-1991 20:54:52 Lat = 52.2 Lon = 153.9 RISE 20
HALOE $O_3$ v0019_c01_rac 08-NOV-1991 00:07:22 Lat = 52.1 Lon = 105.8 RISE 1
HALOE $O_3$ v0019_c01_rac 08-NOV-1991 01:43:37 Lat = 52.0 Lon = 81.7 RISE 3
HALOE $O_3$ v0019_c01_rac 08-NOV-1991 03:19:50 Lat = 52.0 Lon = 57.6 RISE 5
HALOE $O_3$ v0019_c01_rac 08-NOV-1991 04:56:05 Lat = 51.9 Lon = 33.6 RISE 7
HALOE $O_3$ v0019_c01_rac 08-NOV-1991 06:32:21 Lat = 51.9 Lon = 9.5 RISE 9
HALOE $O_3$ v0019_c01_rac 08-NOV-1991 09:44:50 Lat = 51.8 Lon = 321.4 RISE 12
HALOE $O_3$ v0019_c01_rac 08-NOV-1991 11:21:05 Lat = 51.7 Lon = 297.3 RISE 14
HALOE $O_3$ v0019_c01_rac 08-NOV-1991 12:57:21 Lat = 51.7 Lon = 273.2 RISE 16
HALOE $O_3$ v0019_c01_rac 08-NOV-1991 14:33:35 Lat = 51.6 Lon = 249.1 RISE 18
HALOE $O_3$ v0019_c01_rac 09-NOV-1991 00:11:05 Lat = 51.3 Lon = 104.6 RISE 1
HALOE $O_3$ v0019_c01_rac 09-NOV-1991 01:47:20 Lat = 51.2 Lon = 80.6 RISE 3
HALOE $O_3$ v0019_c01_rac 09-NOV-1991 03:23:35 Lat = 51.2 Lon = 56.5 RISE 5
HALOE $O_3$ v0019_c01_rac 04:59:50 Lat = 51.1 RISE 7
HALOE $O_3$ v0019_c01_rac 09-NOV-1991 06:36:06
HALOE $O_3$ v0019_c01_rac 09-NOV-1991 08:12:20 Lat = 51.0 Lon = 344.2 RISE 11
HALOE $O_3$ v0019_c01_rac 09-NOV-1991 09:48:35 Lat = 50.9 Lon = 320.1 RISE 13
HALOE $O_3$ v0019_c01_rac 09-NOV-1991 11:24:51 Lat = 50.8 Lon = 296.0 RISE 15
HALOE $O_3$ v0019_c01_rac 09-NOV-1991 13:01:05 Lat = 50.8 Lon = 271.9 RISE 17
HALOE $O_3$ v0019_c01_rac 09-NOV-1991 14:37:21 Lat = 50.7 Lon = 247.8 RISE 19
HALOE $O_3$ v0019_c01_rac 09-NOV-1991 22:38:35 Lat = 50.3 Lon = 127.4 RISE 25
HALOE $O_3$ v0019_c01_rac 10-NOV-1991 00:14:49 Lat = 50.2 Lon = 103.3 RISE 1
Altitude (km)
80
60
40
20
0.0
0.5
1.0
1.5
2.0
$O_3$ Mixing Ratio (ppmv)
Mon Nov 19 07:16:17 EST 2007

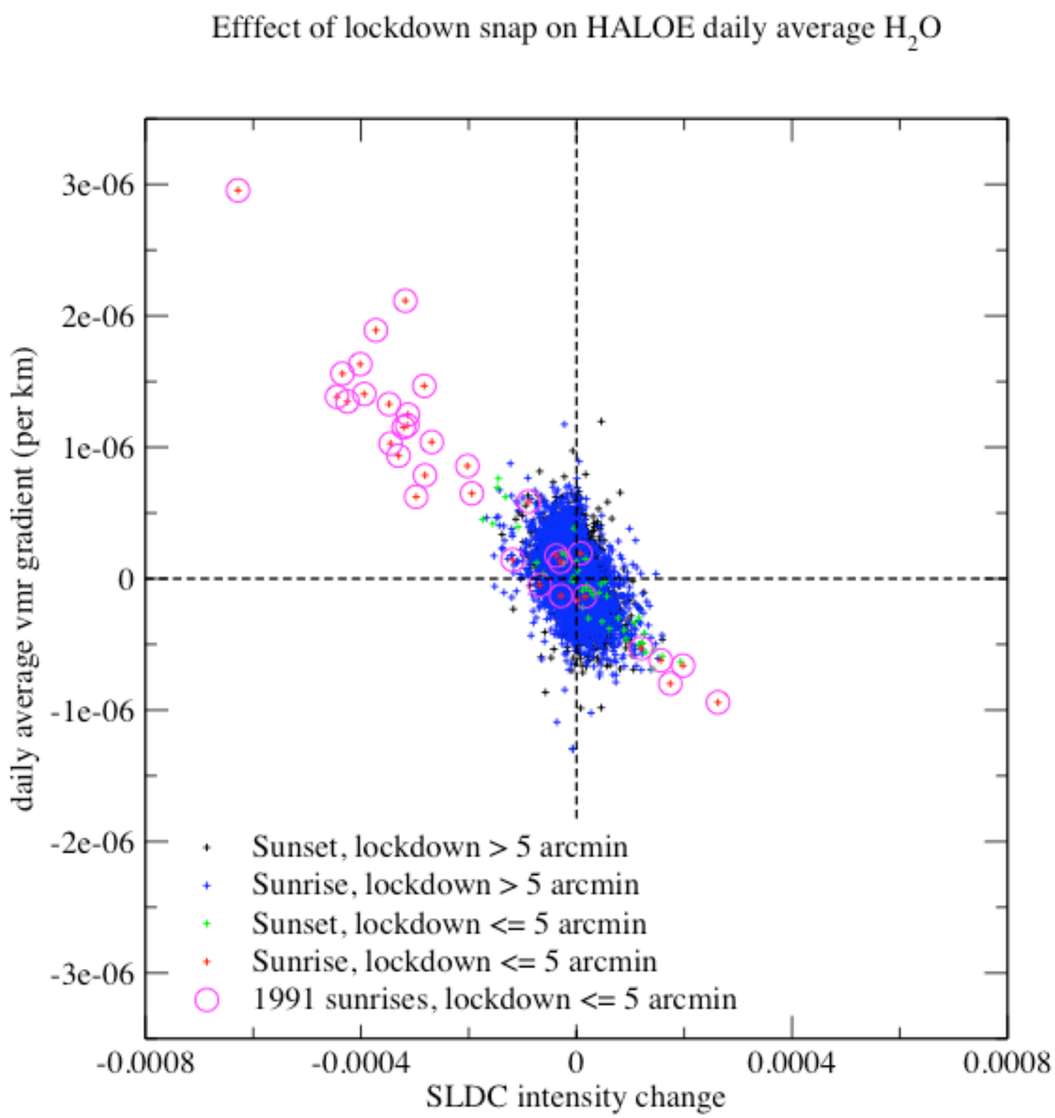

**Plot 29**


HALOE NO2 v0019_c01_rac 05-NOV-1991 14:22:27 Lat = 53.0 Lon = 251.7 RISE 2
HALOE NO2 v0019_c01_rac 05-NOV-1991 22:23:42 Lat = 52.9 Lon = 131.5 RISE 7
HALOE NO2 v0019_c01_rac 05-NOV-1991 23:59:57 Lat = 52.9 Lon = 107.4 RISE 9
HALOE NO2 v0019_c01_rac 06-NOV-1991 01:36:13 Lat = 52.9 Lon = 83.4 RISE 2
HALOE NO2 v0019_c01_rac 06-NOV-1991 03:12:26 Lat = 52.9 Lon = 59.3 RISE 4
HALOE NO2 v0019_c01_rac 06-NOV-1991 04:48:41 Lat = 52.9 Lon = 35.3 RISE 6
HALOE NO2 v0019_c01_rac 06-NOV-1991 06:24:57 Lat = 52.8 Lon = 11.3 RISE 8
HALOE NO2 v0019_c01_rac 06-NOV-1991 11:13:42 Lat = 52.8 Lon = 299.1 RISE 12
HALOE NO2 v0019_c01_rac 06-NOV-1991 12:49:55 Lat = 52.8 Lon = 275.1 RISE 14
HALOE NO2 v0019_c01_rac 06-NOV-1991 14:26:10 Lat = 52.8 Lon = 251.0 RISE 16
HALOE NO2 v0019_c01_rac 06-NOV-1991 16:02:25 Lat = 52.7 Lon = 227.0 RISE 18
HALOE NO2 v0019_c01_rac 06-NOV-1991 20:51:08 Lat = 52.7 Lon = 154.8 RISE 22
HALOE NO2 v0019_c02_rac 07-NOV-1991 00:03:40 Lat = 52.6 Lon = 106.7 RISE 1
HALOE NO2 v0019_c02_rac 07-NOV-1991 01:39:54 Lat = 52.6 Lon = 82.7 RISE 3
HALOE NO2 v0019_c02_rac 07-NOV-1991 03:16:09 Lat = 52.5 Lon = 58.6 RISE 5
HALOE NO2 v0019_c02_rac 07-NOV-1991 04:52:25 Lat = 52.5 Lon = 34.5 RISE 7
HALOE NO2 v0019_c02_rac 07-NOV-1991 06:28:39 Lat = 52.5 Lon = 10.5 RISE 9
HALOE NO2 v0019_c02_rac 07-NOV-1991 11:17:23 Lat = 52.4 Lon = 298.3 RISE 13
HALOE NO2 v0019_c02_rac 07-NOV-1991 16:06:08 Lat = 52.3 Lon = 226.1 RISE 16
HALOE NO2 v0019_c02_rac 07-NOV-1991 20:54:52 Lat = 52.2 Lon = 153.9 RISE 20
HALOE NO2 v0019_c01_rac 08-NOV-1991 Lat = 52.1 Lon = 105.8 RISE 1
HALOE NO2 v0019_c01_rac 08-NOV-1991 Lat = 52.0 Lon = 81.7 RISE 3
HALOE NO2 v0019_c01_rac 08-NOV-1991 Lat = 52.0 Lon = 57.6 RISE 5
HALOE NO2 v0019_c01_rac 08-NOV-1991 Lon = 33.6 RISE 7
HALOE NO2 v0019_c01_rac 08-NOV-1991 Lat = 51.9 Lon = 9.5 RISE 9
HALOE NO2 v0019_c01_rac 08-NOV-1991 Lat = 51.8 Lon = 321.4 RISE 12
HALOE NO2 v0019_c01_rac 08-NOV-1991 11:21:05 Lat = 51.7 Lon = 297.3 RISE 14
HALOE NO2 v0019_c01_rac 08-NOV-1991 12:57:21 Lat = 51.7 Lon = 273.2 RISE 16
HALOE NO2 v0019_c01_rac 08-NOV-1991 14:33:35 Lat = 51.6 Lon = 249.1 RISE 18
HALOE NO2 v0019_c01_rac 09-NOV-1991 00:11:05 Lat = 51.3 Lon = 104.6 RISE 1
HALOE NO2 v0019_c01_rac 09-NOV-1991 01:47:20 Lat = 51.2 Lon = 80.6 RISE 3
HALOE NO2 v0019_c01_rac 09-NOV-1991 03:23:35 Lat = 51.2 Lon = 56.5 RISE 5
HALOE NO2 v0019_c01_rac 09-NOV-1991 04:59:50 Lat = 51.1 Lon = 32.4 RISE 7
HALOE NO2 v0019_c01_rac 09-NOV-1991 06:36:06
HALOE NO2 v0019_c01_rac 09-NOV-1991 08:12:20 Lat = 51.0 Lon = 344.2 RISE 11
HALOE NO2 v0019_c01_rac 09-NOV-1991 09:48:35 Lat = 50.9 Lon = 320.1 RISE 13
HALOE NO2 v0019_c01_rac 09-NOV-1991 11:24:51 Lat = 50.8 Lon = 296.0 RISE 15
HALOE NO2 v0019_c01_rac 09-NOV-1991 13:01:05 Lat = 50.8 Lon = 271.9 RISE 17
HALOE NO2 v0019_c01_rac 09-NOV-1991 14:37:21 Lat = 50.7 Lon = 247.8 RISE 19
HALOE NO2 v0019_c01_rac 09-NOV-1991 22:38:35 Lat = 50.3 Lon = 127.4 RISE 25
HALOE NO2 v0019_c01_rac 10-NOV-1991 00:14:49 Lat = 50.2 Lon = 103.3 RISE 1
Altitude (km)
60
50
40
30
20
0
2
4
6
8
10
NO2 Mixing Ratio (ppbv)
Mon Nov 19 07:13:21 EST 2007

**Plot 30**


6e-06
4e-06
2e-06
0
-2e-06
-4e-06
-6e-06
vmr gradient (per km)
-0.001
-0.0005
0
0.0005
sldc intensity change
sunset
sunrise

**Plot 31**



Efffect of lockdown snap on HALOE daily average $H_2O$
daily average vmr gradient (per km)
3e-06
2e-06
1e-06
0
-1e-06
-2e-06
-3e-06
-0.0008
-0.0004
0
0.0004
0.0008
SLDC intensity change
Sunset, lockdown > 5 arcmin
Sunrise, lockdown > 5 arcmin
Sunset, lockdown <= 5 arcmin
Sunrise, lockdown <= 5 arcmin
1991 sunrises, lockdown <= 5 arcmin


**Plot 32**

| # sunrise events in 1991 with avg lockdown <= 5 arcmin | | |
|---|---|---|
| **yyddd** | **uarsday** | **latitude** |
| 91285 | 31 | -75.7370300292969 |
| 91286 | 32 | -75.6365127563477 |
| 91288 | 34 | -68.1732177734375 |
| 91290 | 36 | -45.8392601013184 |
| 91291 | 37 | -32.6402168273926 |
| 91296 | 42 | 23.5914745330811 |
| 91297 | 43 | 28.7465286254883 |
| 91298 | 44 | 33.7225036621094 |
| 91299 | 45 | 37.8358612060547 |
| 91300 | 46 | 41.2392425537109 |
| 91301 | 47 | 44.0458106994629 |
| 91302 | 48 | 46.3548698425293 |
| 91303 | 49 | 48.237865447998 |
| 91304 | 50 | 49.839183807373 |
| 91305 | 51 | 50.9352569580078 |
| 91306 | 52 | 51.8286666870117 |
| 91307 | 53 | 52.4548759460449 |
| 91308 | 54 | 52.8325119018555 |
| 91309 | 55 | 52.9594306945801 |
| 91310 | 56 | 52.8926124572754 |
| 91311 | 57 | 52.6054992675781 |
| 91312 | 58 | 52.0715789794922 |
| 91313 | 59 | 51.2900009155273 |
| 91314 | 60 | 50.2431411743164 |
| 91315 | 61 | 48.9118995666504 |
| 91317 | 63 | 45.2785339355469 |
| 91318 | 64 | 42.9082832336426 |
| 91319 | 65 | 40.1233406066895 |
| 91320 | 66 | 36.8897171020508 |
| 91321 | 67 | 33.1998329162598 |
| 91322 | 68 | 29.0466957092285 |
| 91323 | 69 | 23.8130683898926 |
| 91325 | 71 | 13.8736181259155 |