Calibration of Herschel/HIFI in the CO absorption bands of Mars

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Herschel Space Observatory Calibration Workshop#2, Madrid, 6-8 February 2008

Outline

- *Idea*
- *Short description of MAOAM*
- *Approach*
- *Results*

Idea and Approach

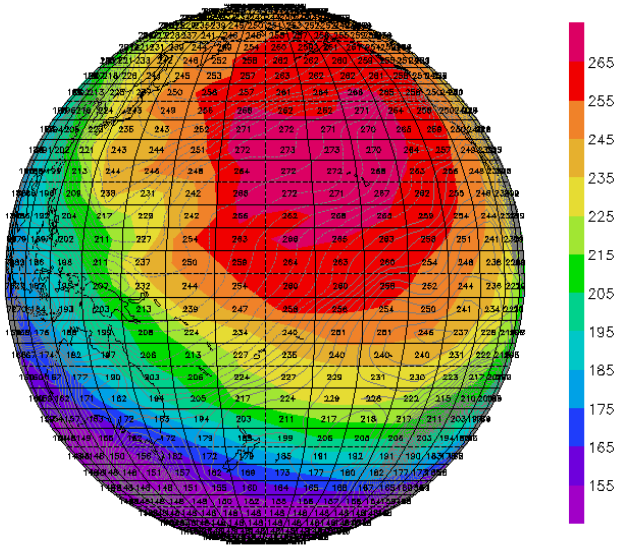
- *Use of atmosphere as calibration source*
- *Get less sensitive to dust storms*
- *Instead surface, detect optically thick lines*
- *Simulate with a GCM how strong these lines vary with time of the day and season*
- *Estimate errors (temperature, CO-profiles, pressure broadening)*

General description of the MAOAM-GCM

- Grid point model from the surface to 130 km
- Log-pressure coordinates (6 mb at z=0 km)
- Resolution: vertical (~1 km) and horizontal (32x36 or 64x36)
- Realistic topography and surface parameters: albedo and thermal inertia
- Chemistry Transport Module (CTM)

Model genesis

-**COlogne Model of the Middle Atmosphere –Institute of Atmospheric Physics (COMMA-IAP) [1982-2005]**
- MART ACC [*Berger and Ebel,* 1997]
- MAOAM *v0,* [2003]: Re-designed version of MART ACC .
- **MAOAM v1 [2005]: *(Hartogh et al, JGR, 2005; PSS 2007)***
- **MAOAM v2 [2006]: (*Medvedev and Hartogh, Icarus 2007)***
- **MAOAM CTM [2007] *(Sonnemann et al, submitted, 2008)***
- **MAOAM v3 [2007/8]: new dynamical core**



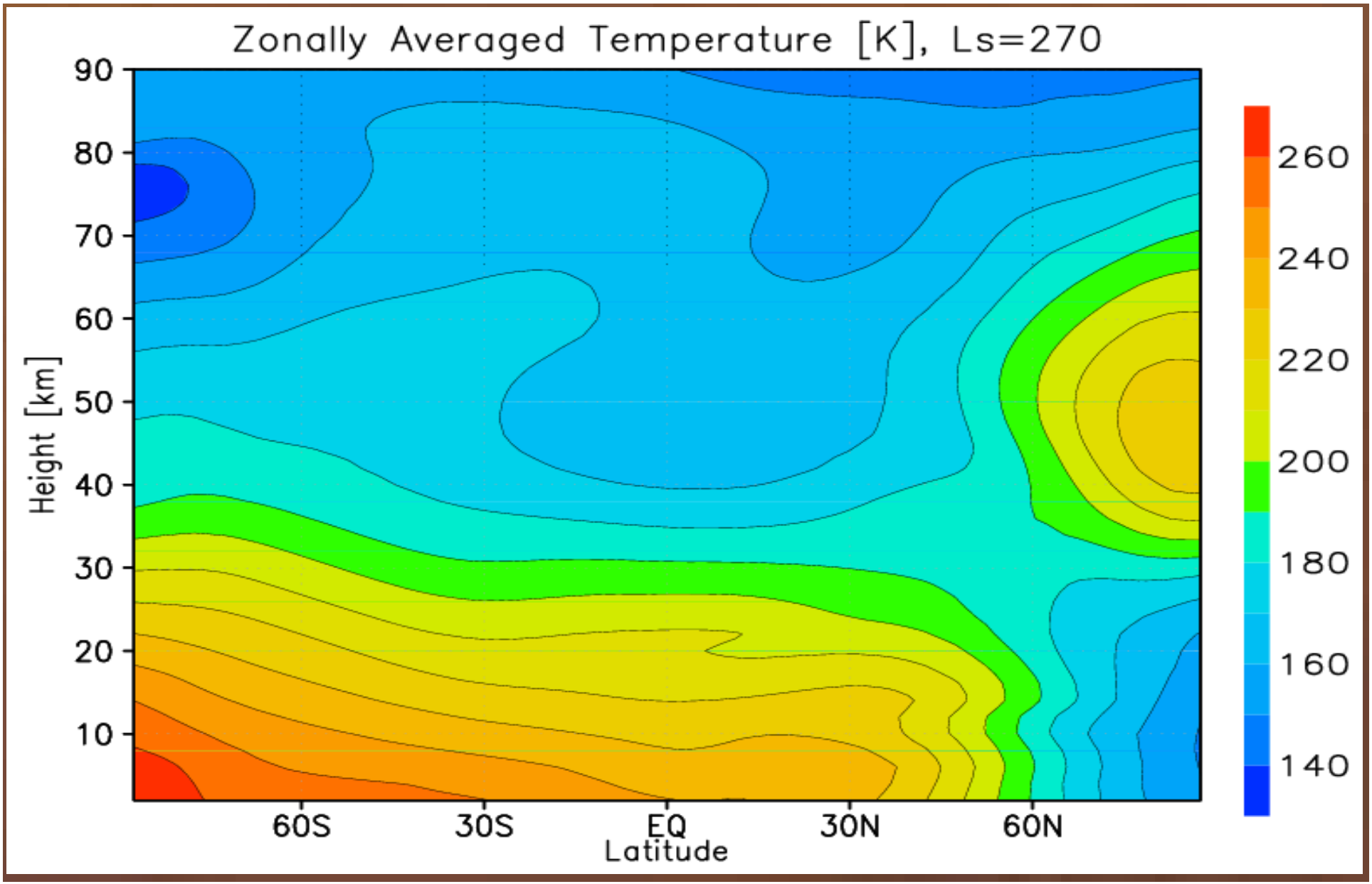
Old dynamical core

- Time integration scheme: “leapfrog” with the Asselin filter
- Small scale horizontal dissipation: Shapiro Δ^2 operator
- “Near pole” Fourier filter (higher 82.5 deg)
- Staggered vertical grid with 118 levels
- Time step *dt* = 100-120 s

To maintain the stability without resorting to an excessive numerical diffusivity for the low density and high variability

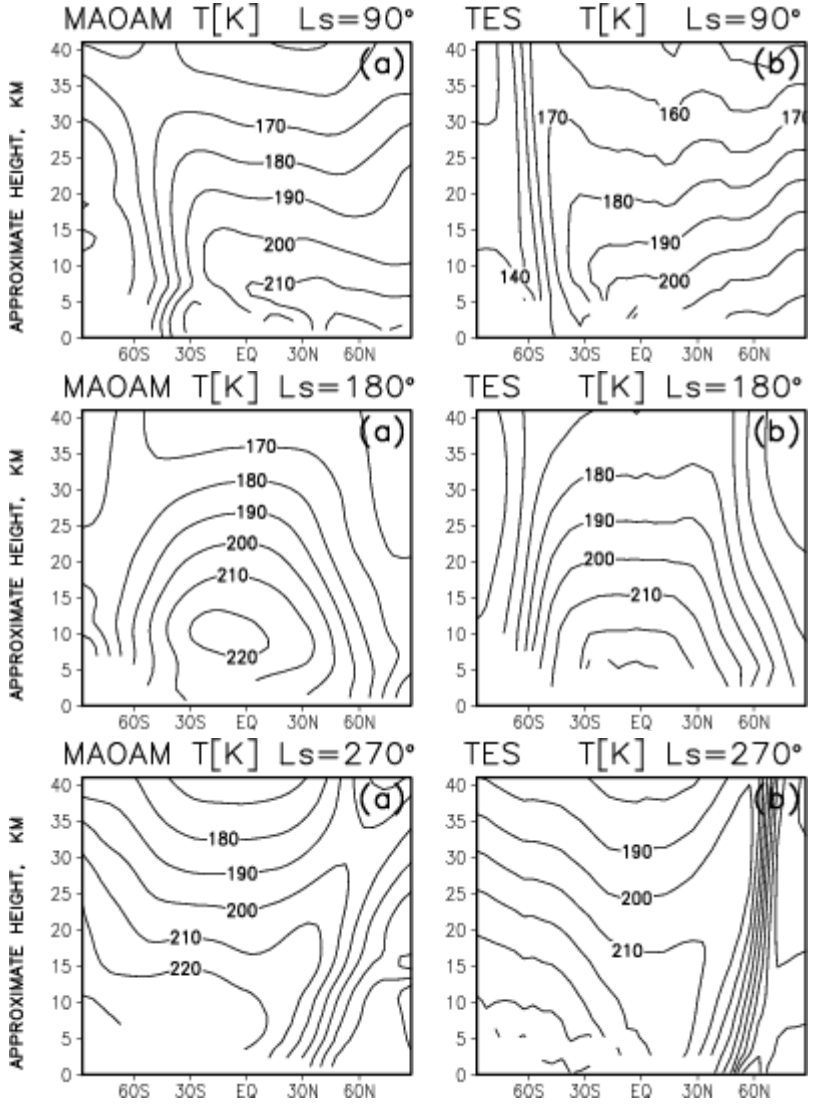
New physics packages

- Non-LTE radiation cooling/heating (CO_2 15 μm)
- Dust radiation scheme
- Surface energy budget
- Gravity wave drag parameterization
- Turbulent diffusion parameterization
- CO_2 sublimation and condensation (only thermal effects)


Zonally Averaged Temperature [K], Ls=270
Height [km]
90
80
70
60
50
40
30
20
10
60S
30S
EQ
30N
60N
Latitude
260
240
220
200
180
160
140

Zonal mean temperature

Globally averaged temperature difference < ± 2 K



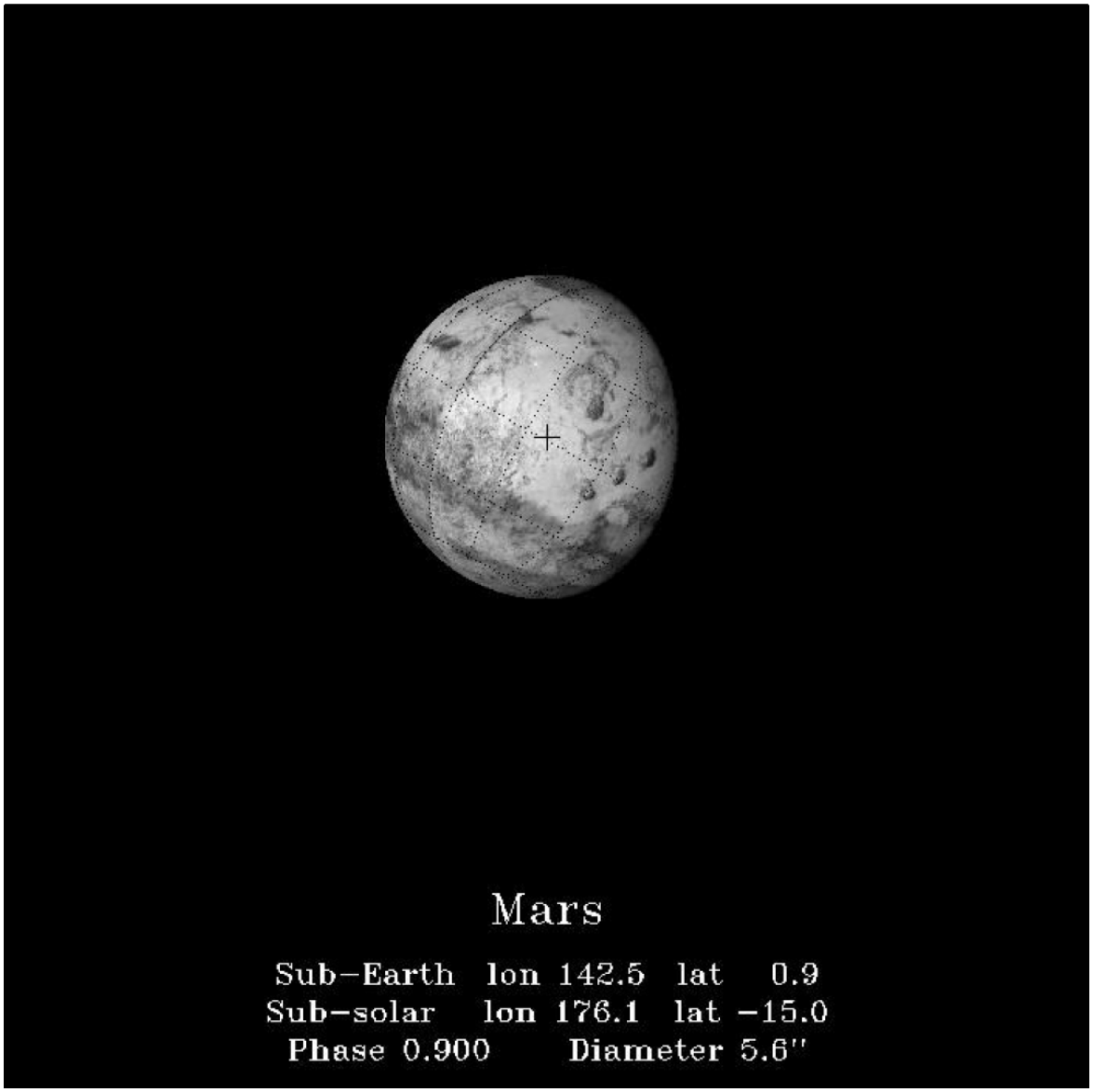
Approach

- *Use GCM temperatures as input for radiative transfer calculations of CO*
- *Calculate spectra for each gridpoint for given dates and times (UT) including limb contributions. Take care about illumination*
- *Calculate a weighted average of all lines*
- *Repeat this for selected solar longitudes*
- *Determine the scattering of line intensities*

Parameters and boundary conditions

- Herschel constraints: angle Sun-Spacecraft-Mars is 90 +/- 30 degrees. Thus HERSCHEL cannot observe Mars, when it is in opposition (in this case the angle would be approx. 180 degrees).
- First opportunity to observe Mars is around the Jan/Feb 2010 opposition
- 2 sets of 5 dates before and after the opposition have been chosen with angle S-S-M = 60, 75, 90, 105 and 120 degrees (Ls=323 – 116), corresponding to 18 August 2009 until 11 July 2010.
- Additionally Ls=180 and 270 have been considered.
- Lines: 691 and 1037 GHz with 200 MHz bandwidth. The 1 % transmission bandwidth is 107 and 149 MHz, the surface contributes less than 2 K to the brightness temperature (Rayleigh-Jeans brightness temperature).

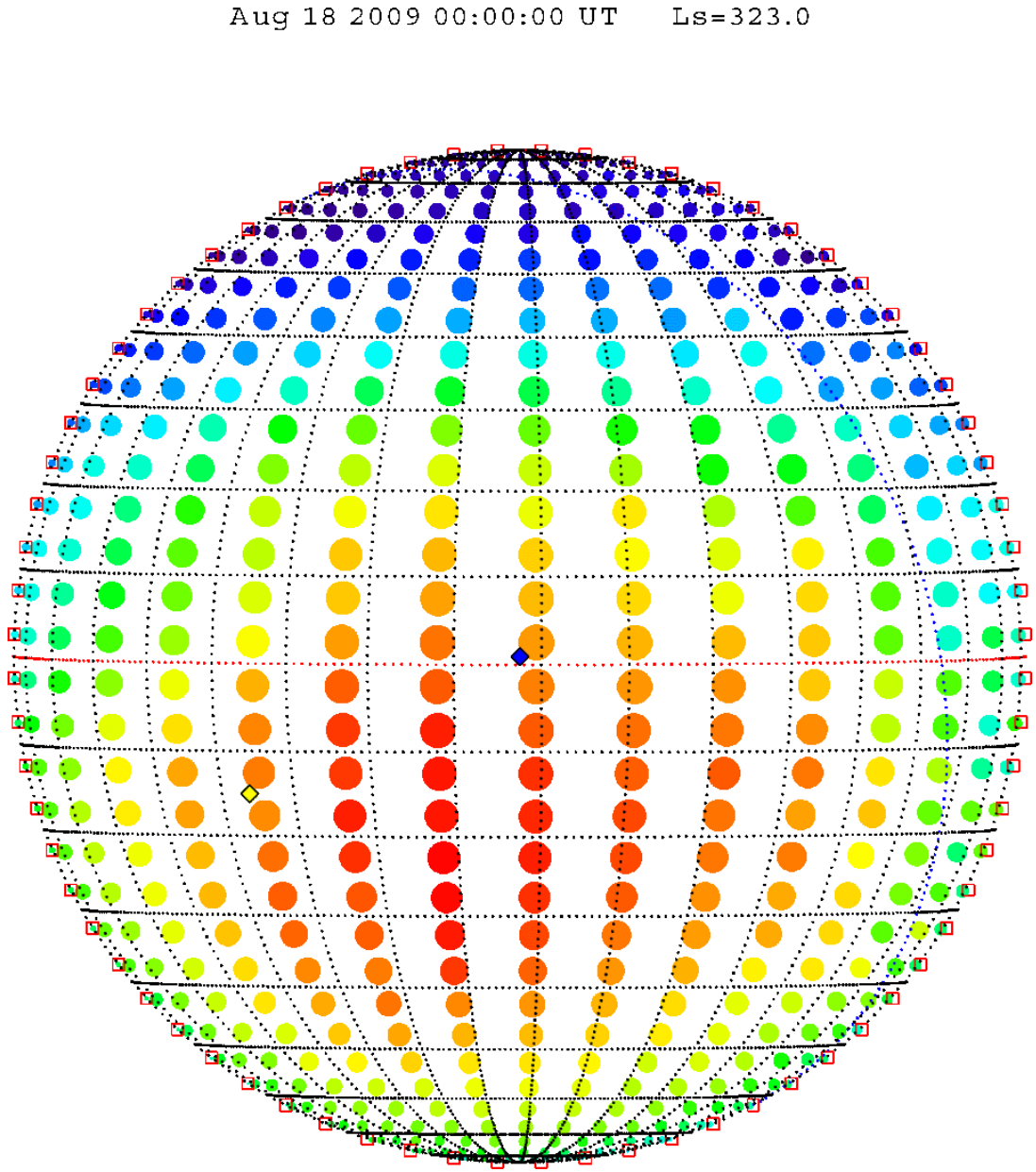
Apparent disk of Mars for 2009 Aug 18 at 00:00 UT

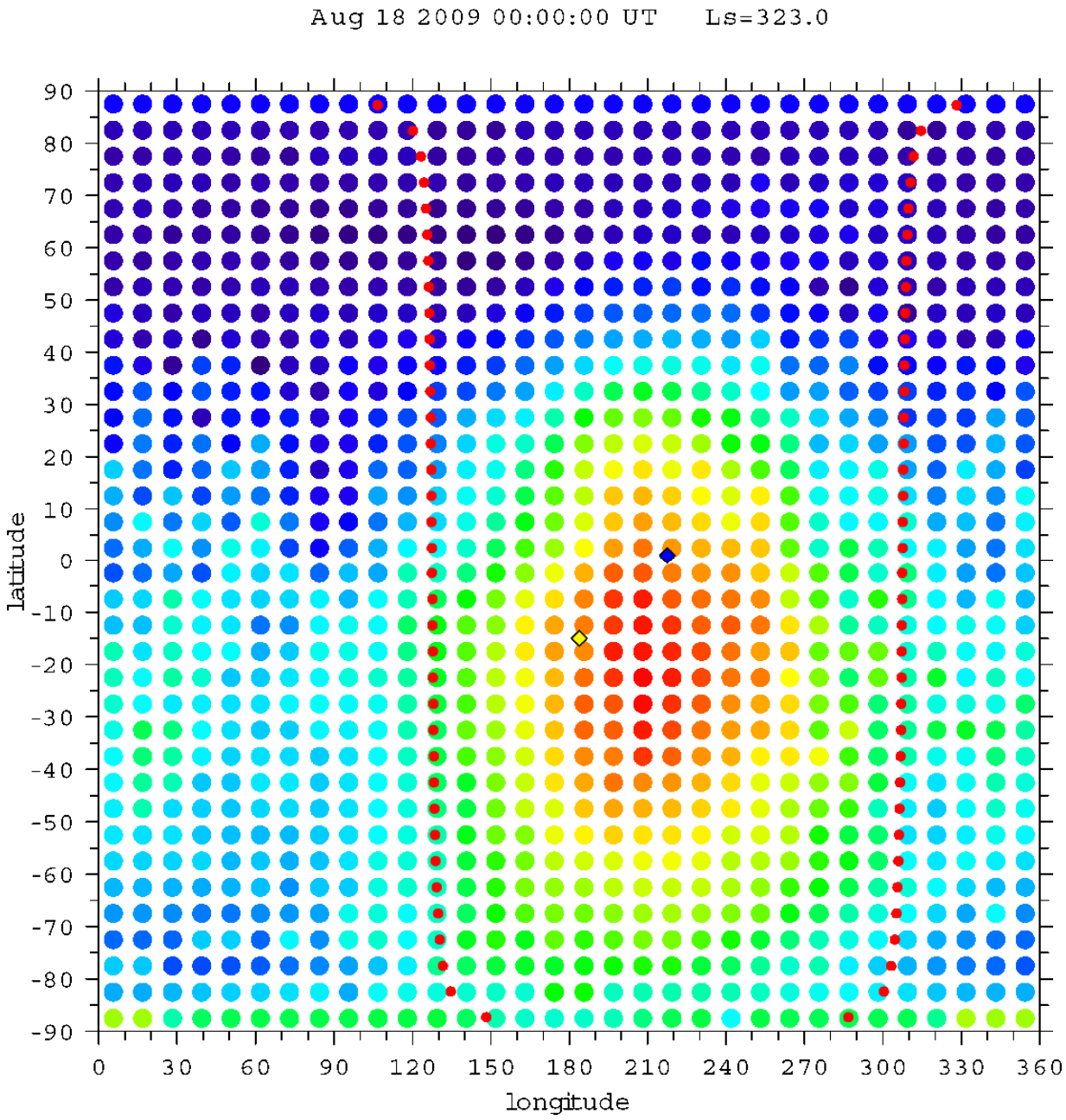


Parameters and boundary conditions

- *The temperatures of the lowest gridpoints of the GCM (0 – 1 km above surface) have been projected on the Martian disk as it appears on the selected date. Red colour corresponds to highest temperature (266 K), blue to lowest (146 K). The area of the dots represent the weight with which each gridpoint contributes to the disk average. Note that maximum temperature may be shifted by several hours from sub-solar point.*

- *Furthermore the disk has been projected as a map with fixed point size (does not correspond to the weights). The dotted red line shows the location of the limb; the limb contribution has been calculated from 72 individual profiles at the shown location.*


Aug 18 2009 00:00:00 UT Ls=323.0


Aug 18 2009 00:00:00 UT Ls=323.0
latitude
longitude
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
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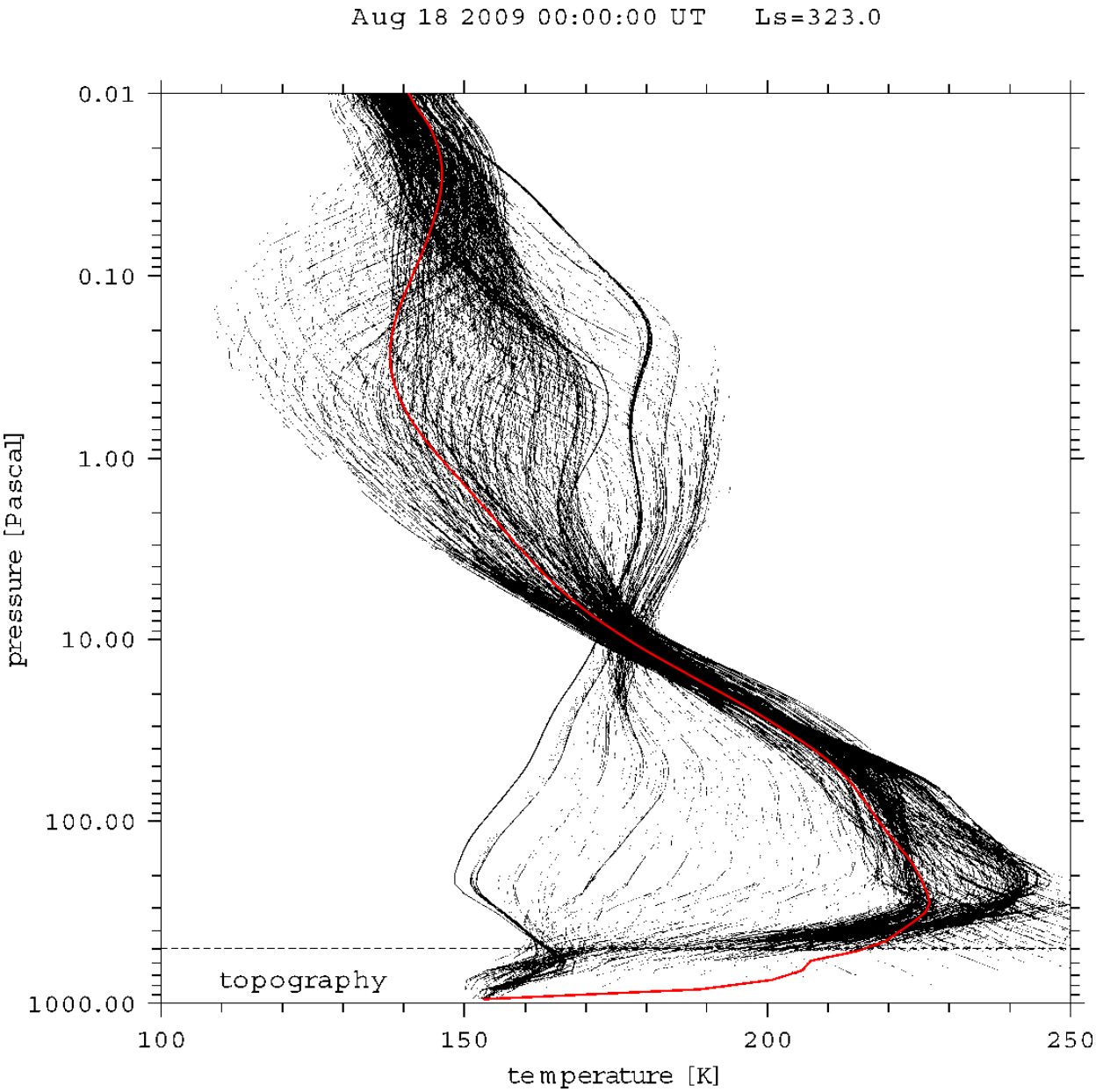
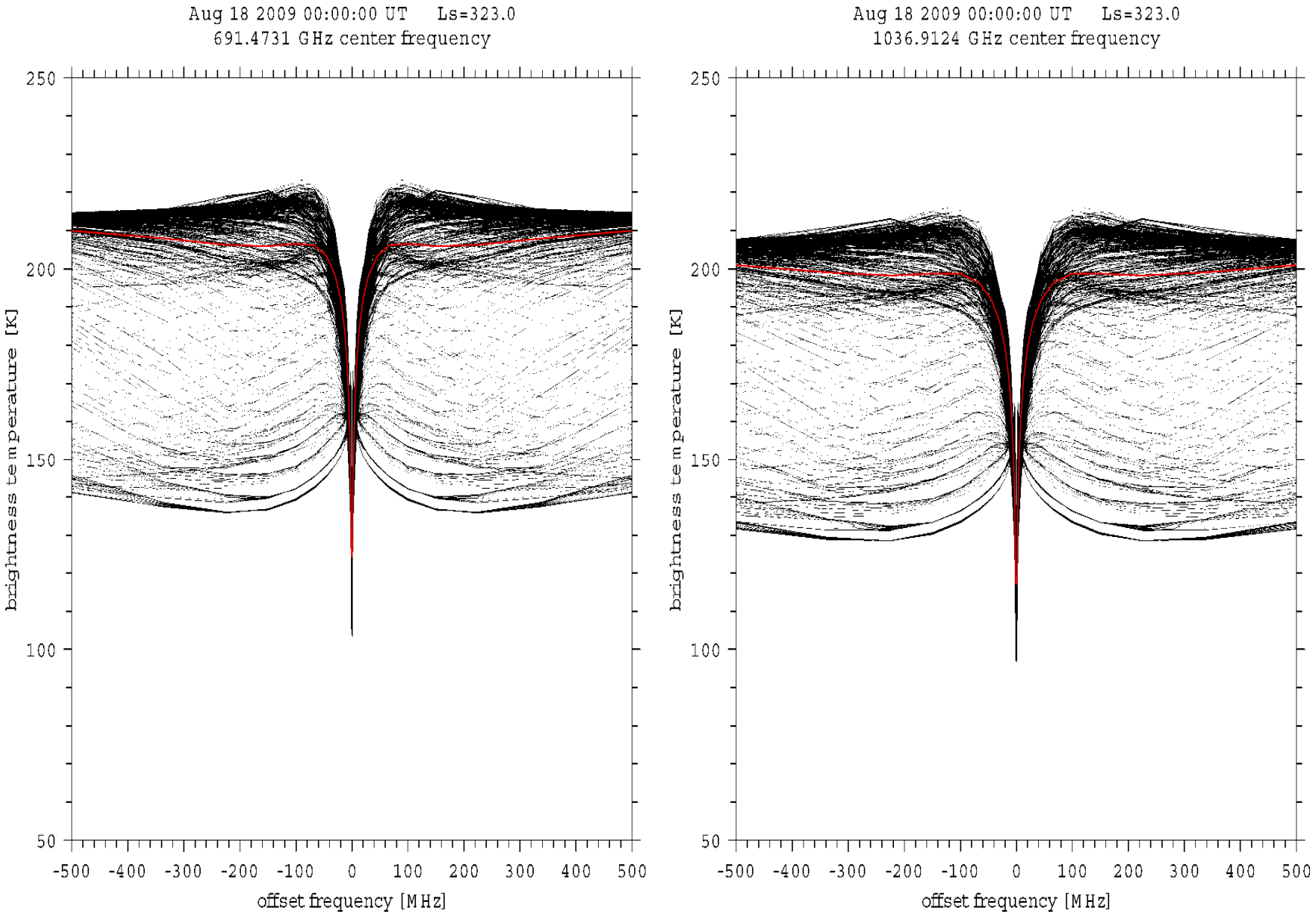
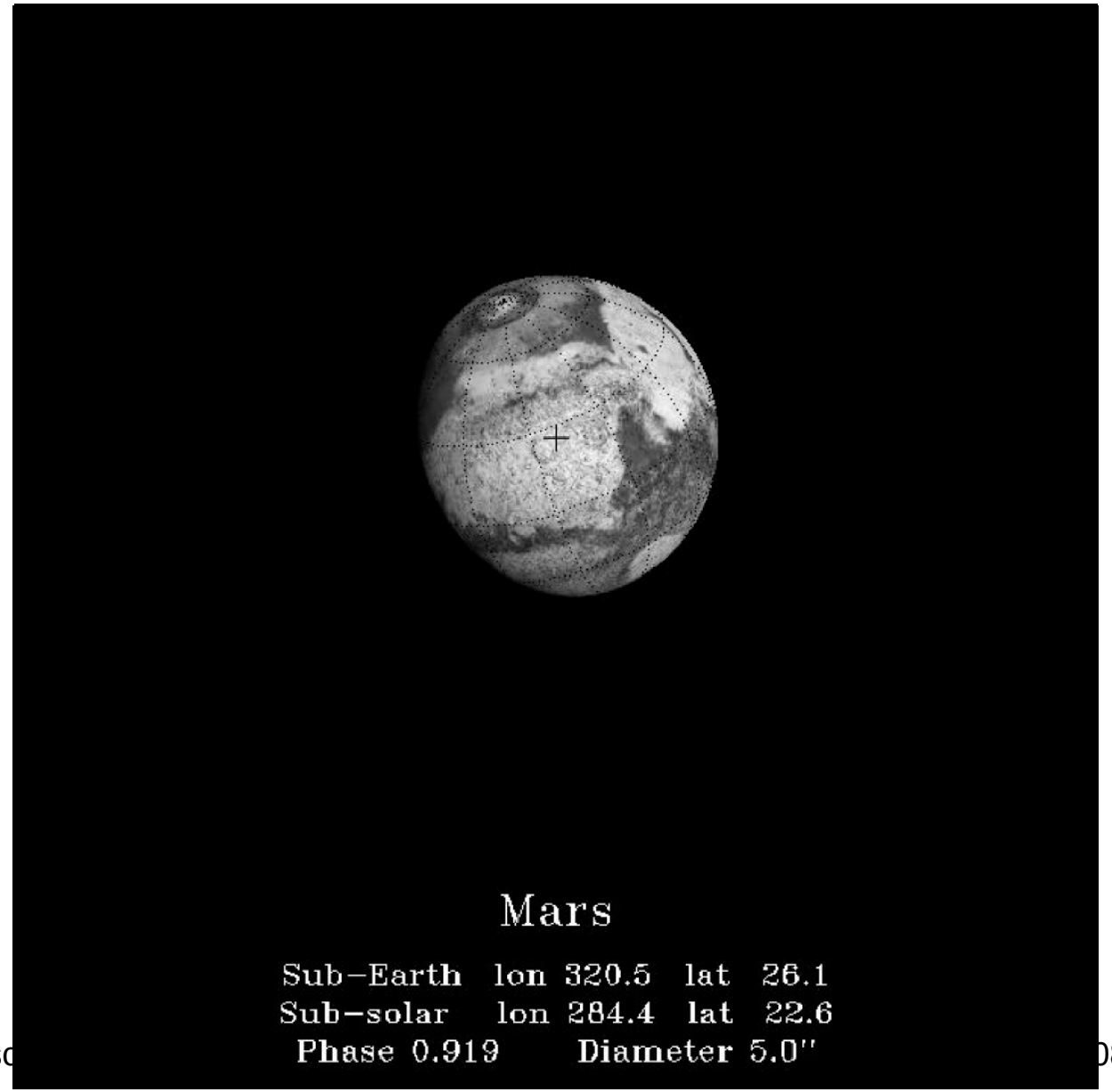
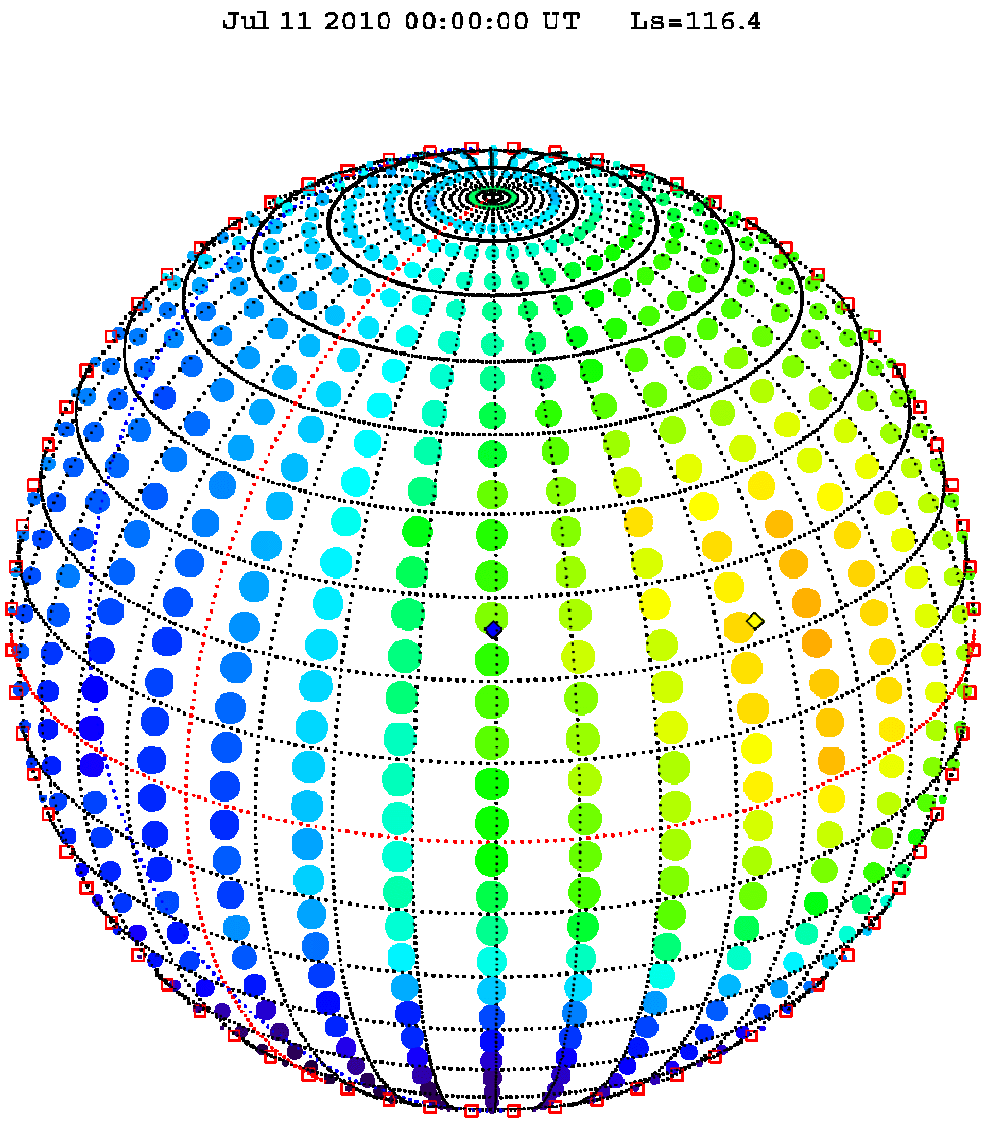
30
60
90
120
150
180
210
240
270
300
330
360

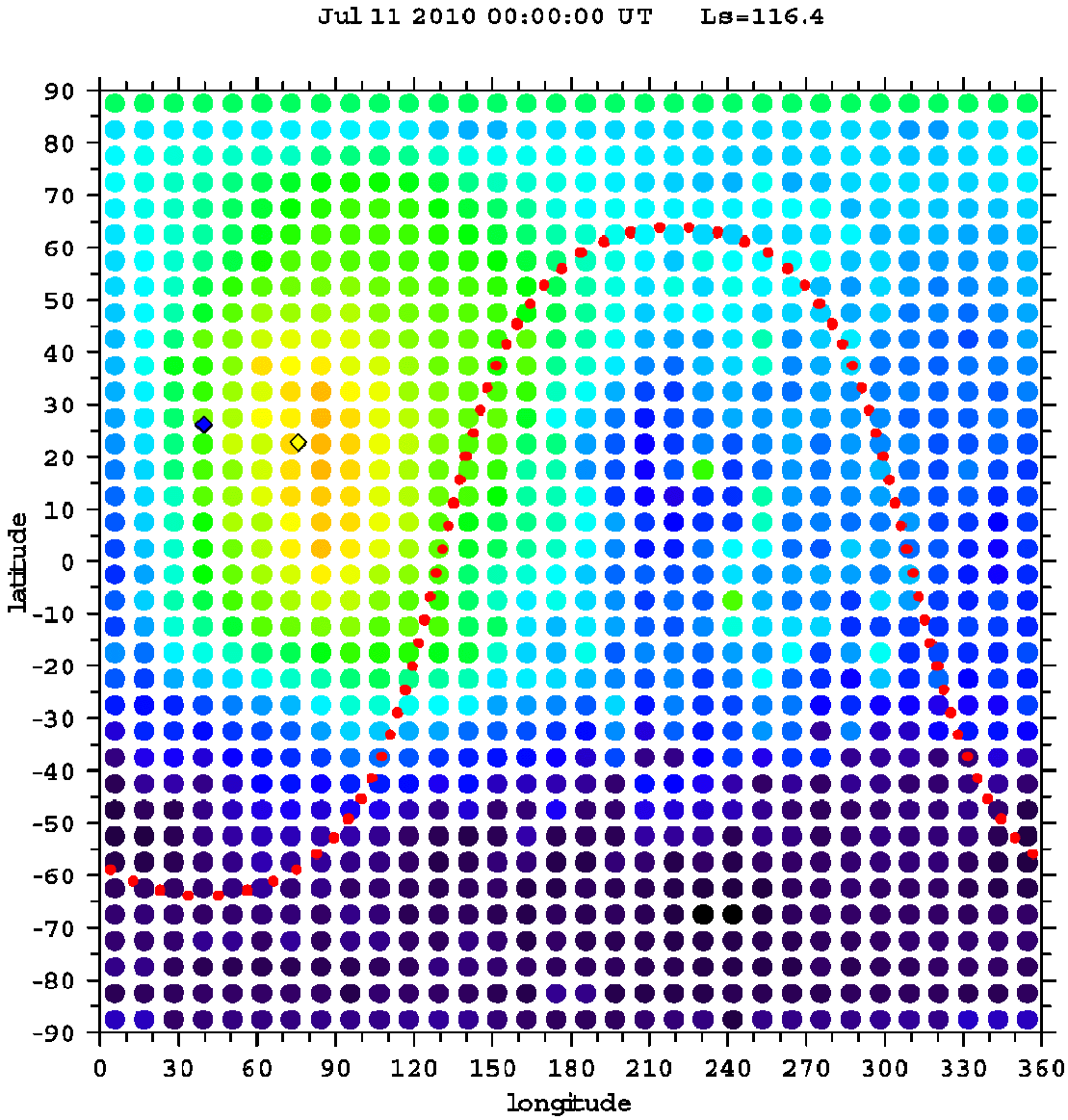

Aug 18 2009 00:00:00 UT Ls=323.0
0.01
0.10
1.00
10.00
100.00
1000.00
pressure [Pascal]
topography
100
150
200
250
temperature [K]


Aug 18 2009 00:00:00 UT Ls=323.0
691.4731 GHz center frequency
brightness temperature [K]
offset frequency [MHz]
Aug 18 2009 00:00:00 UT Ls=323.0
1036.9124 GHz center frequency
brightness temperature [K]
offset frequency [MHz]

Apparent disk of Mars for 2010 Jul 11 at 00:00 UT




Jul 11 2010 00:00:00 UT Ls=116.4


Jul 11 2010 00:00:00 UT Ls=116.4
latitude
longitude
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
0
30
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90
120
150
180
210
240
270
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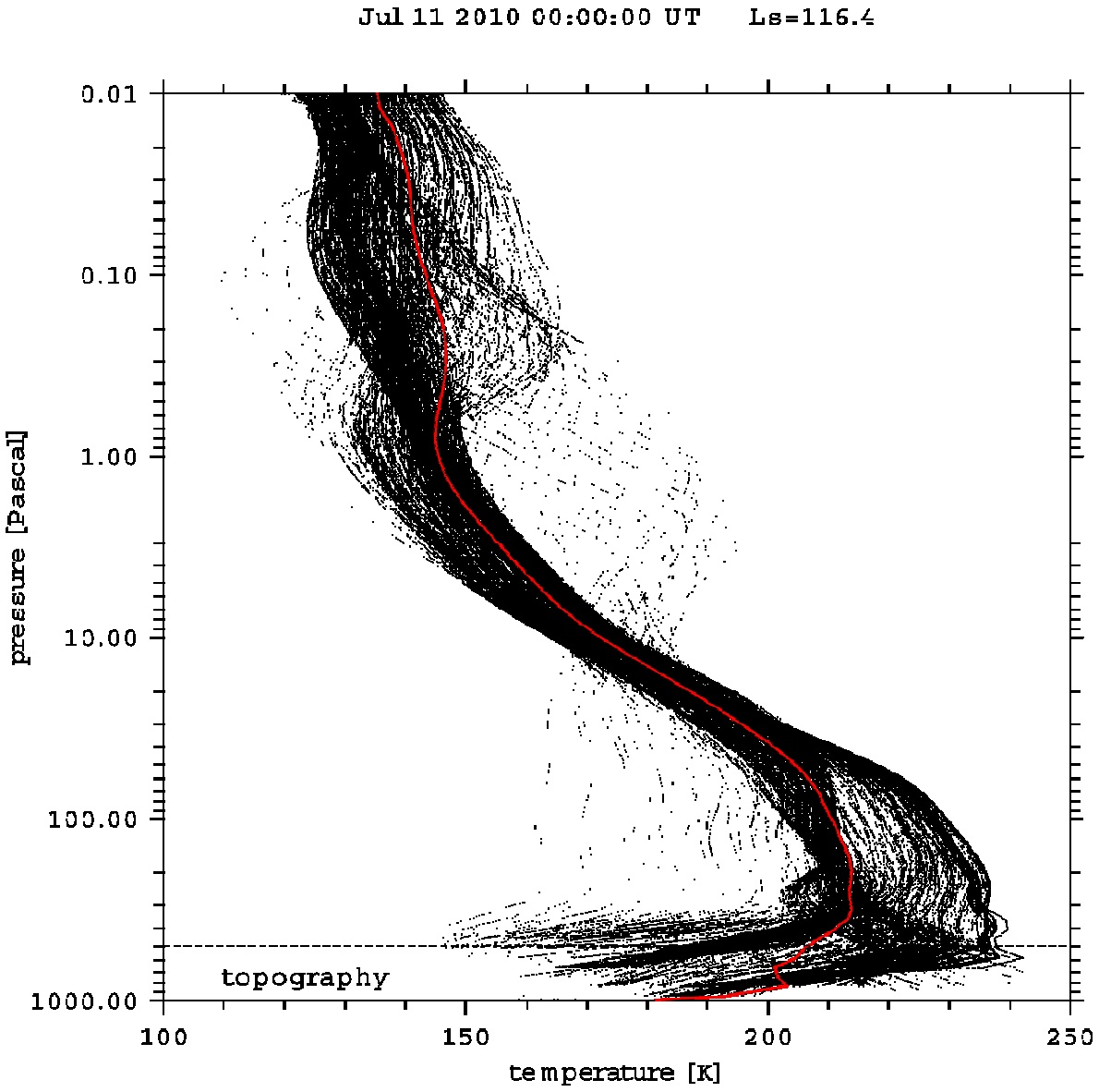
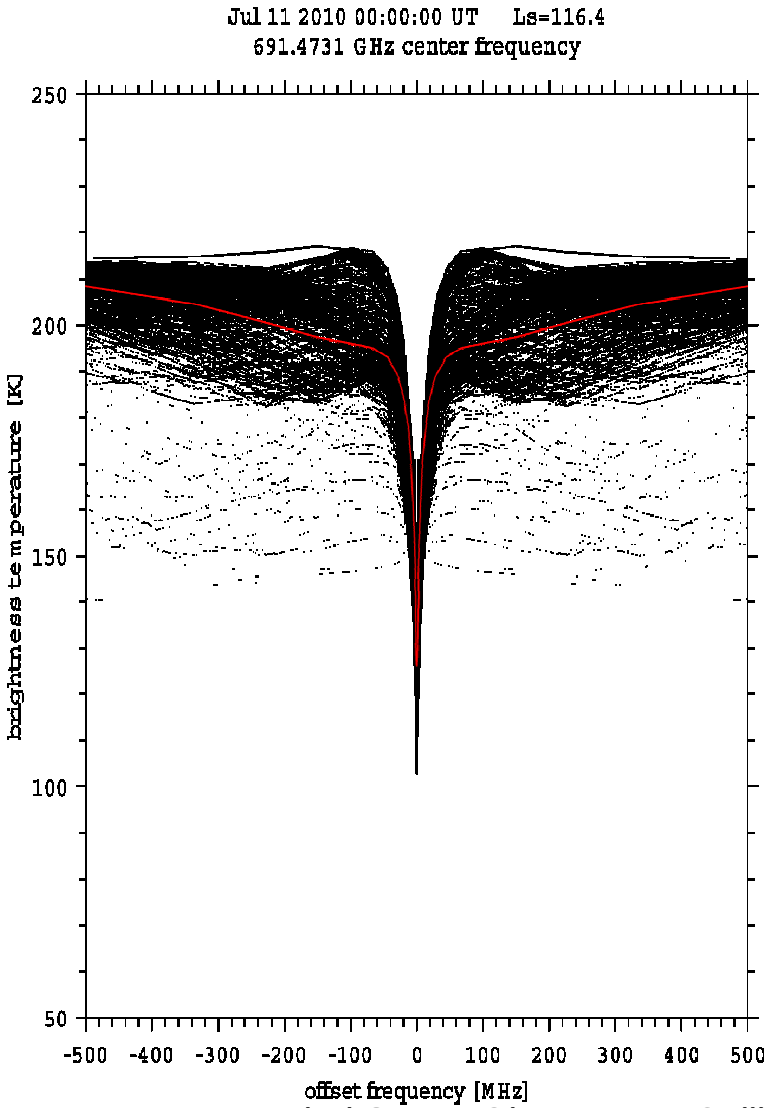
330
360


Jul 11 2010 00:00:00 UT Ls=116.4
0.01
0.10
1.00
10.00
100.00
1000.00
pressure [Pascal]
topography
100
150
200
250
temperature [K]


Jul 11 2010 00:00:00 UT Ls=116.4
691.4731 GHz center frequency
brightness temperature [K]
offset frequency [MHz]
250
200
150
100
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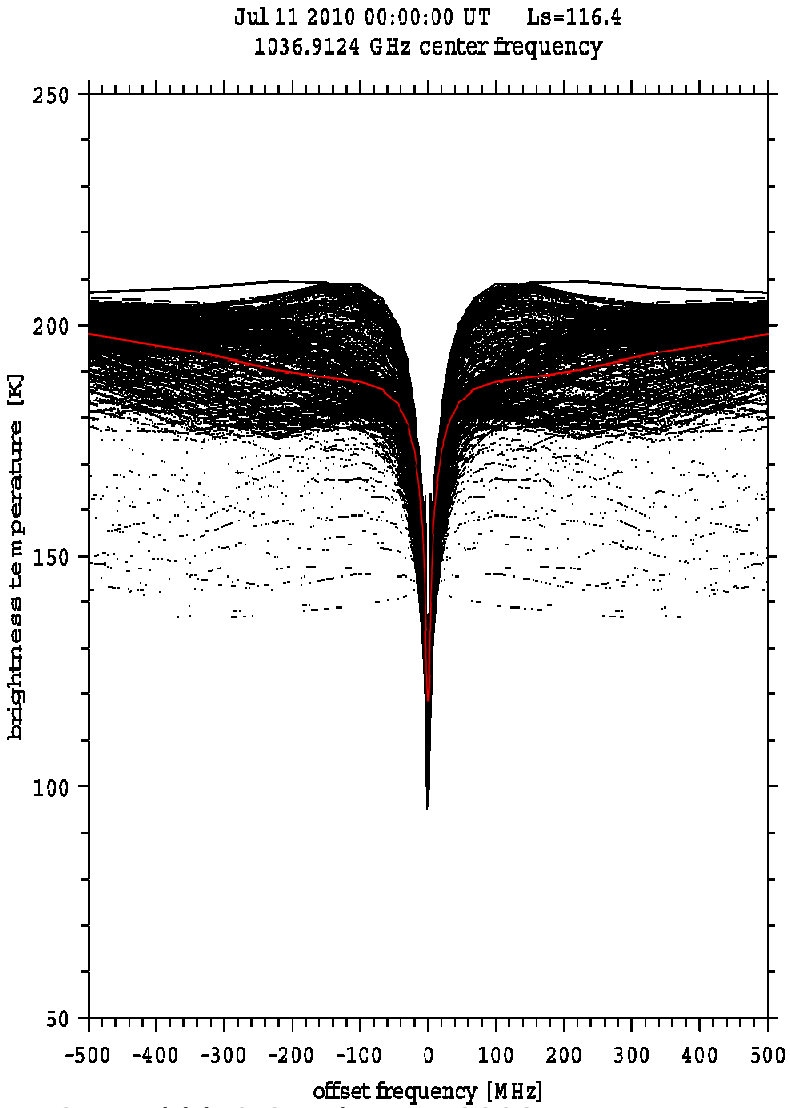
-500 -400 -300 -200 -100 0 100 200 300 400 500


Jul 11 2010 00:00:00 UT Ls=116.4
1036.9124 GHz center frequency
brightness temperature [K]
offset frequency [MHz]
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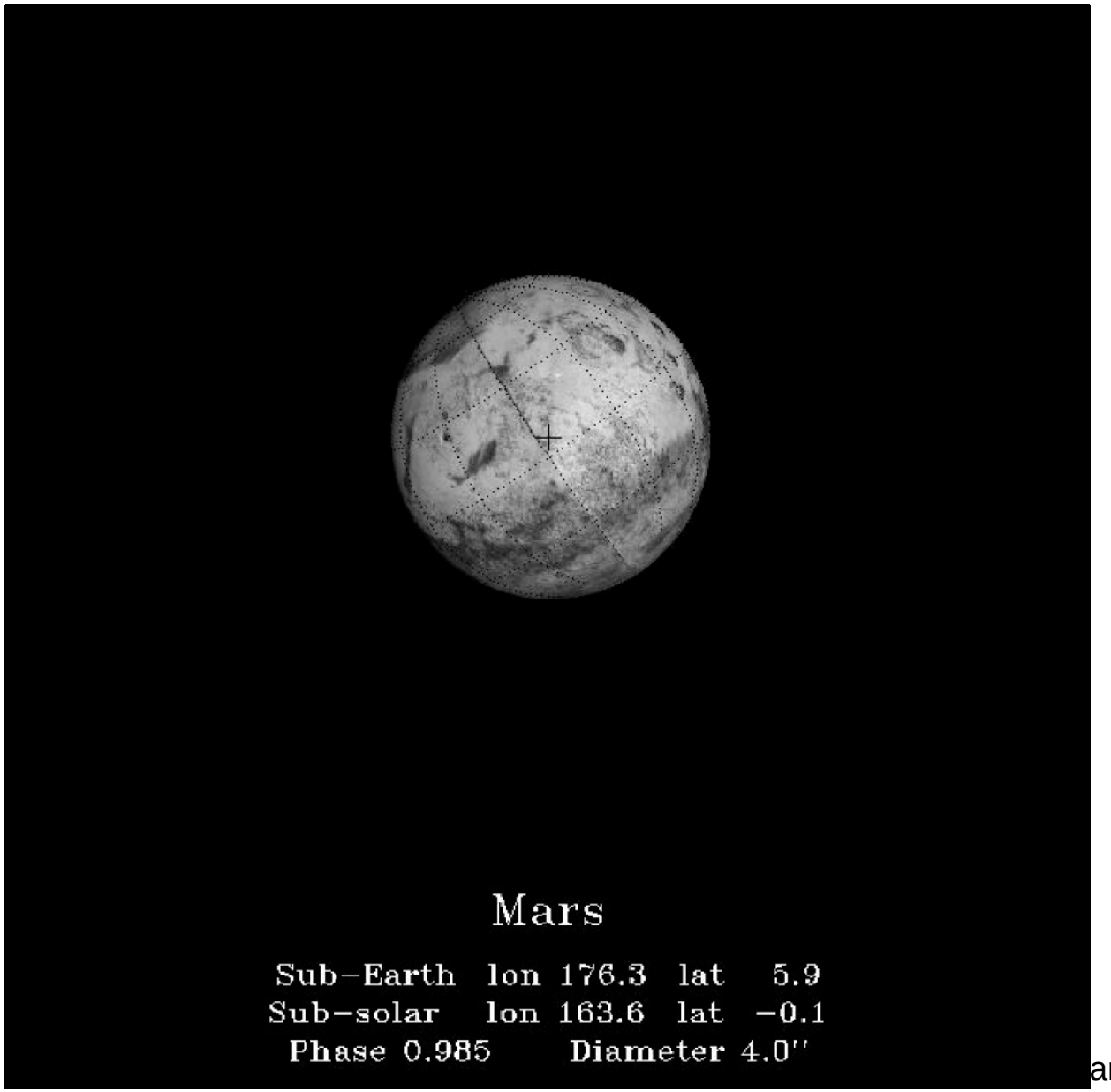
-500 -400 -300 -200 -100 0 100 200 300 400 500

Apparent disk of Mars for 2010 Nov 13 at 00:00 UT



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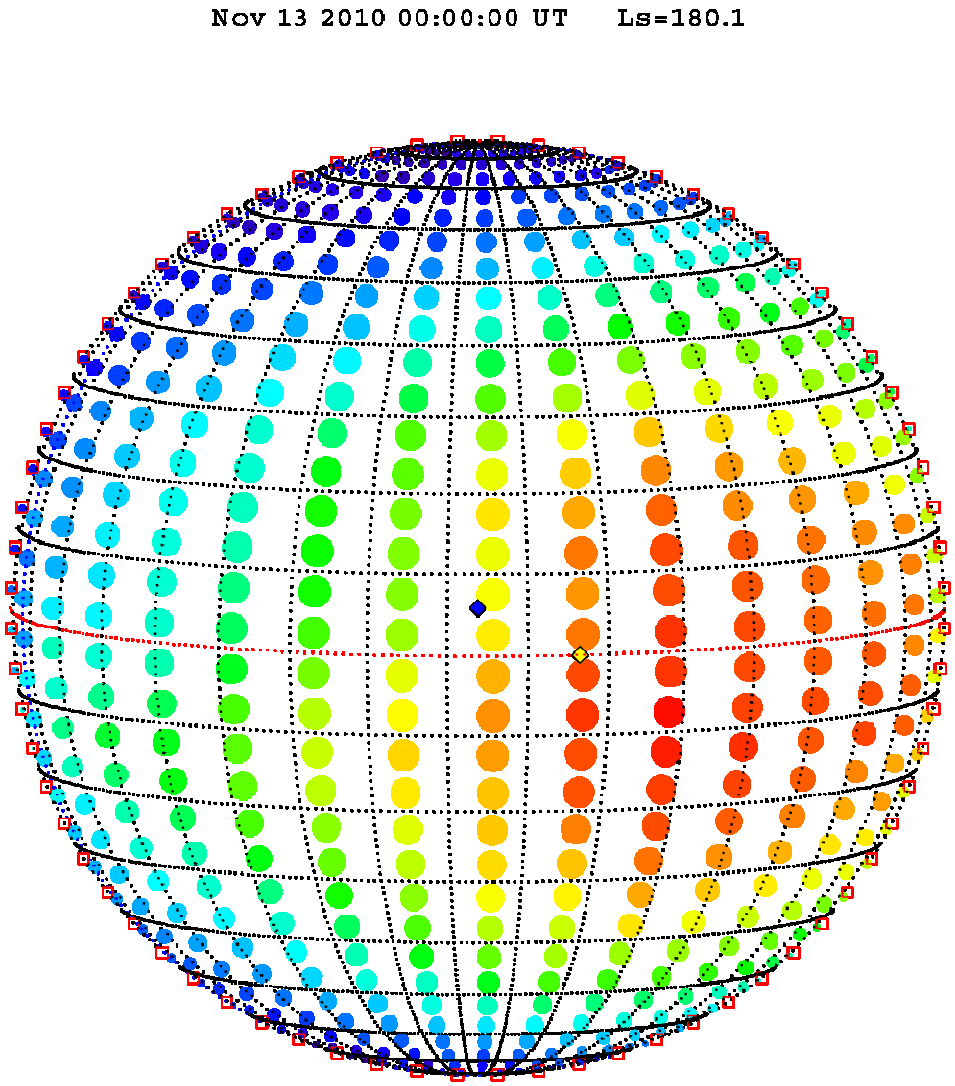
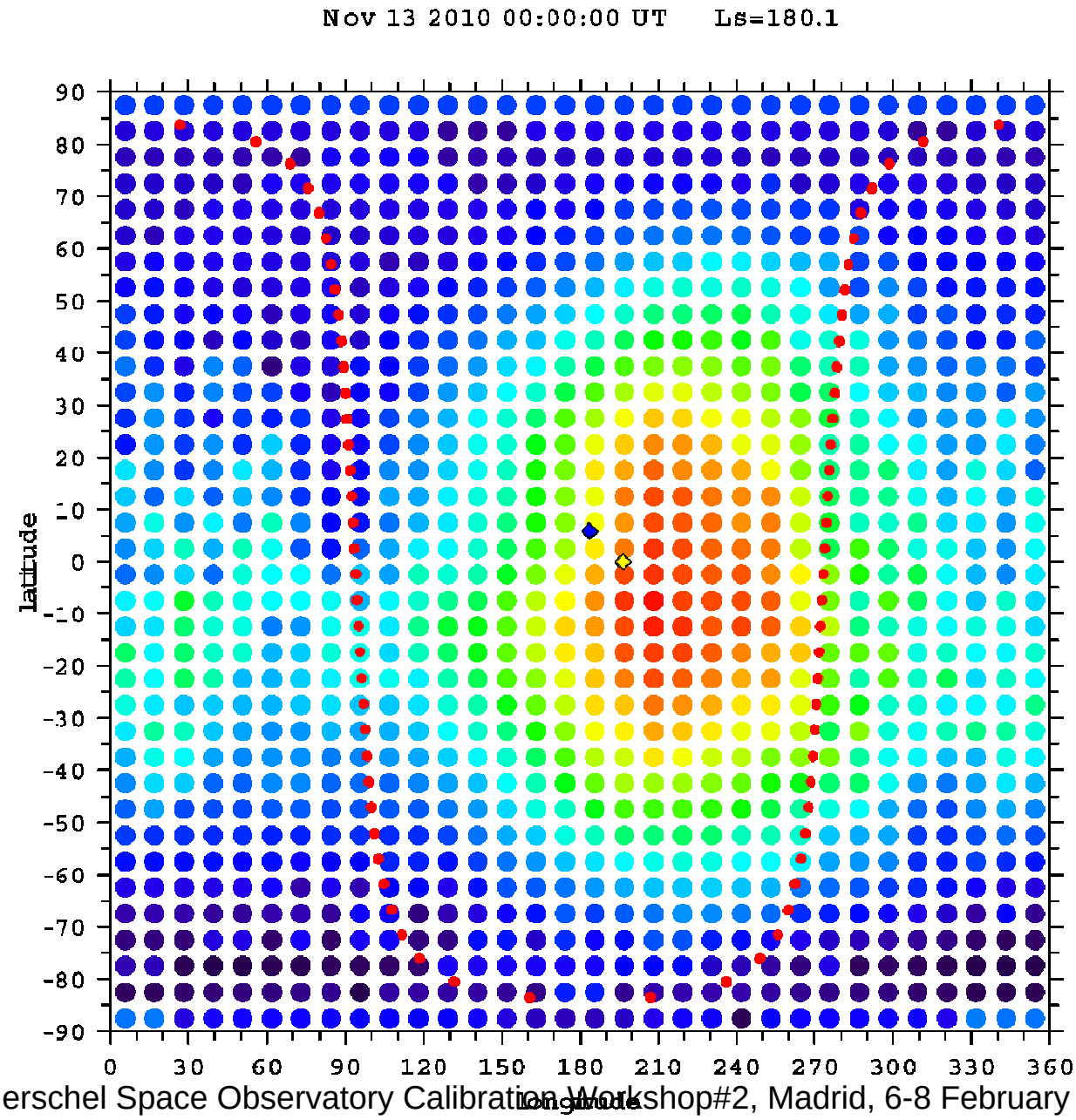

Nov 13 2010 00:00:00 UT Ls=180.1


Nov 13 2010 00:00:00 UT Ls=180.1
Latitude
Longitude
90
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-10
-20
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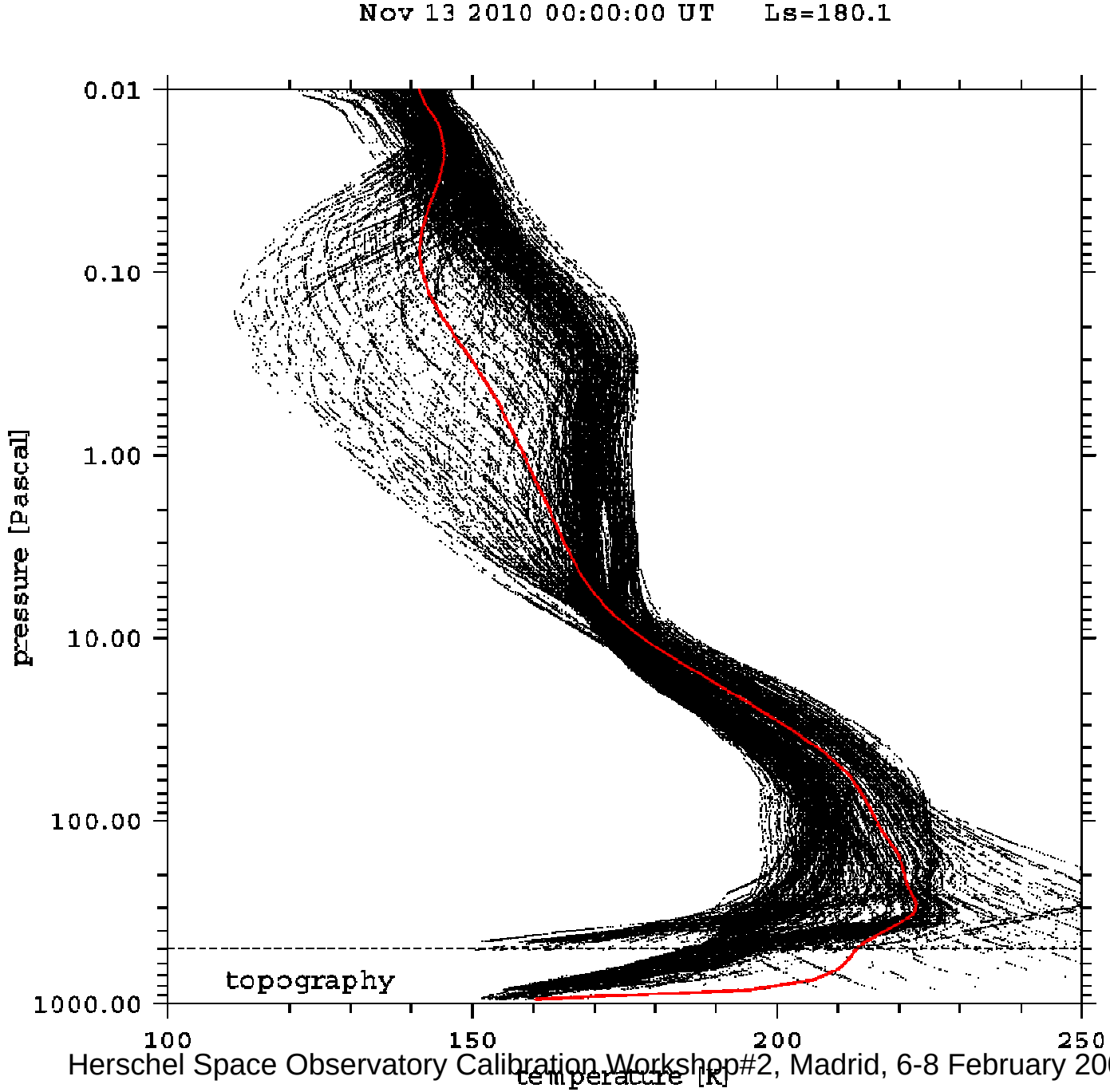
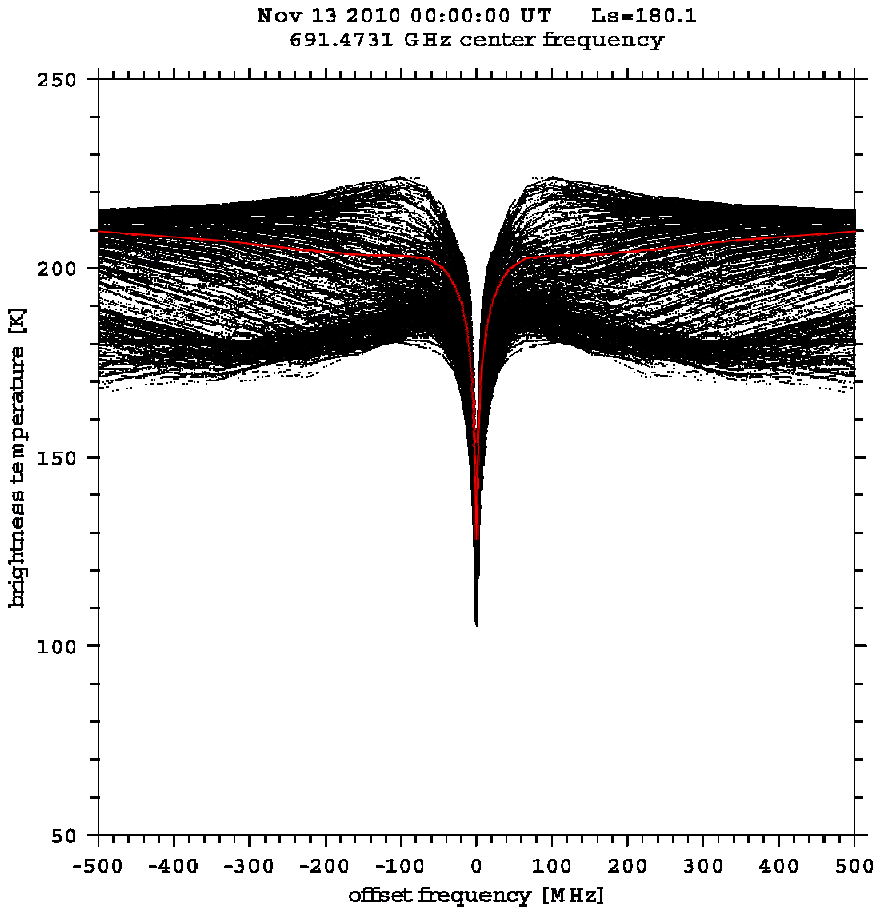
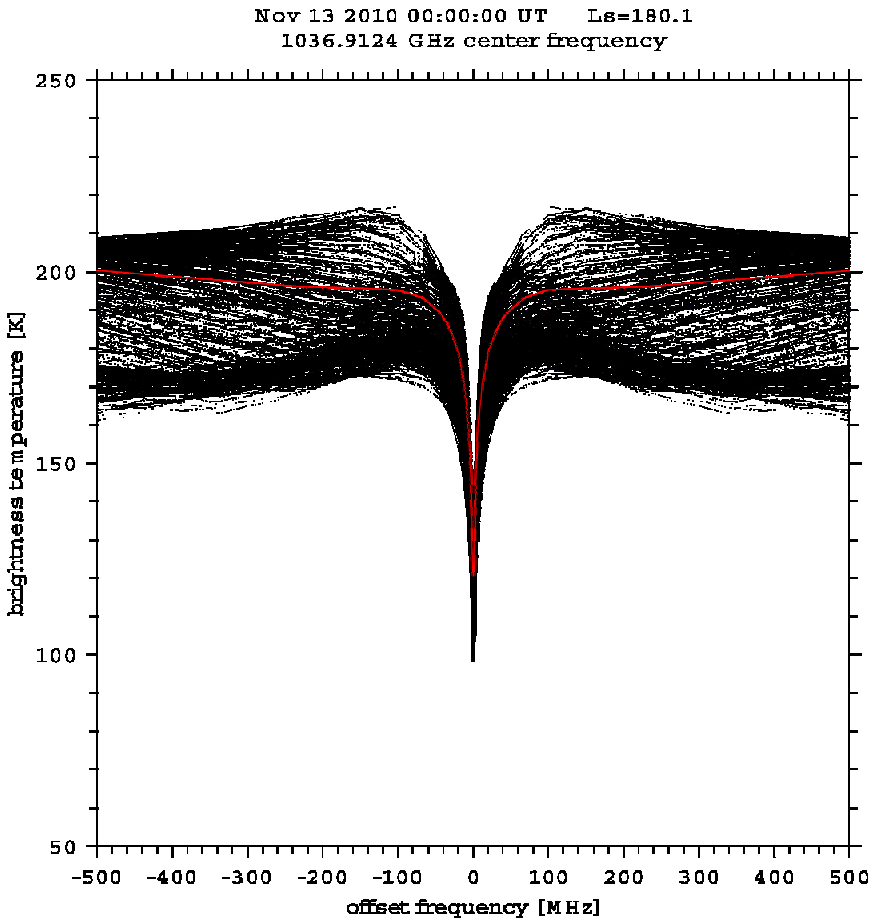

Nov 13 2010 00:00:00 UT Ls=180.1
0.01
0.10
1.00
10.00
100.00
1000.00
pressure [Pascal]
topography
100
150
200
250
temperature [K]


Nov 13 2010 00:00:00 UT Ls=180.1
691.4731 GHz center frequency
brightness temperature [K]
offset frequency [MHz]
250
200
150
100
50
-500 -400 -300 -200 -100 0 100 200 300 400 500


Nov 13 2010 00:00:00 UT Ls=180.1
1036.9124 GHz center frequency
brightness temperature [K]
offset frequency [MHz]
250
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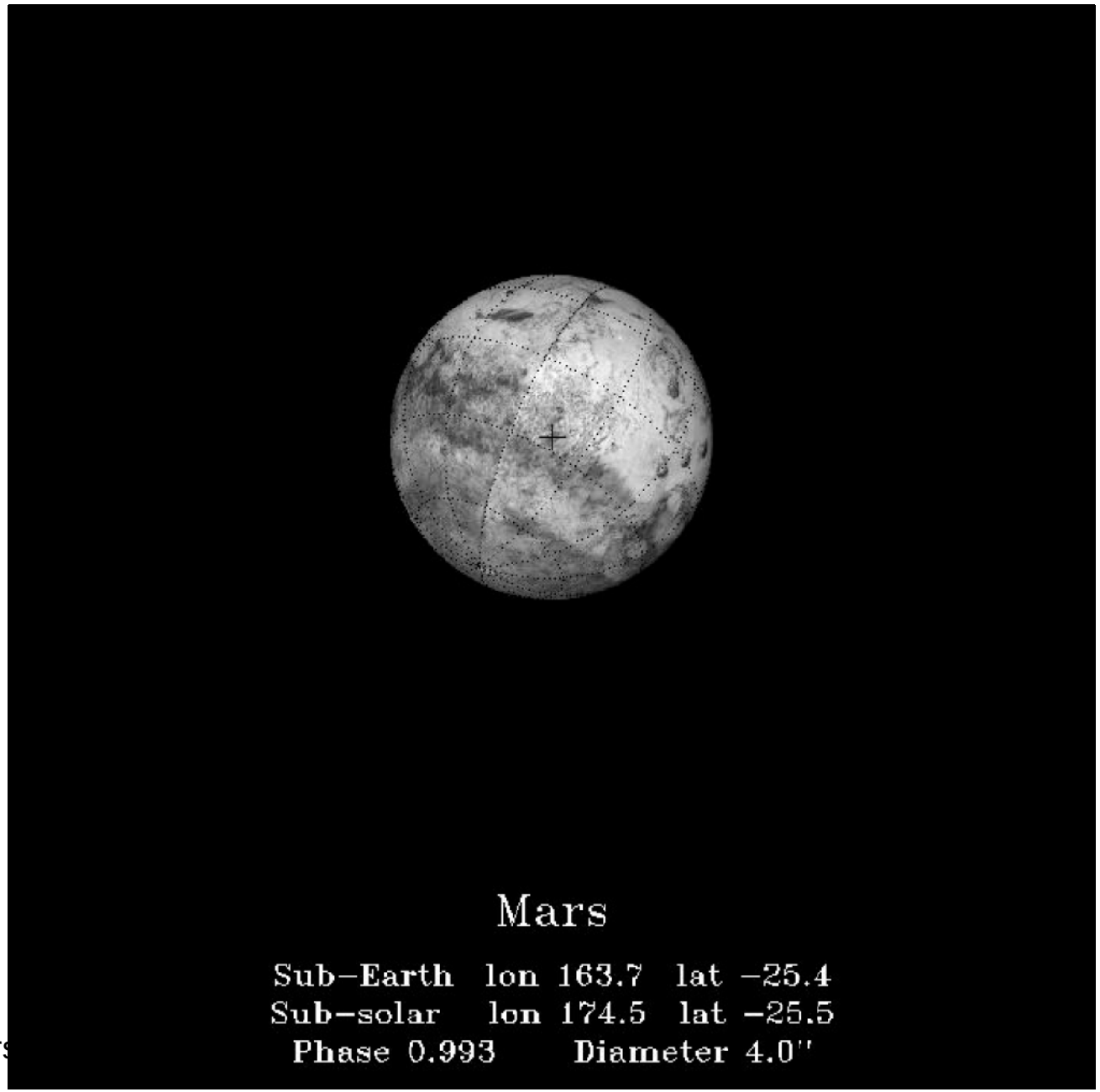
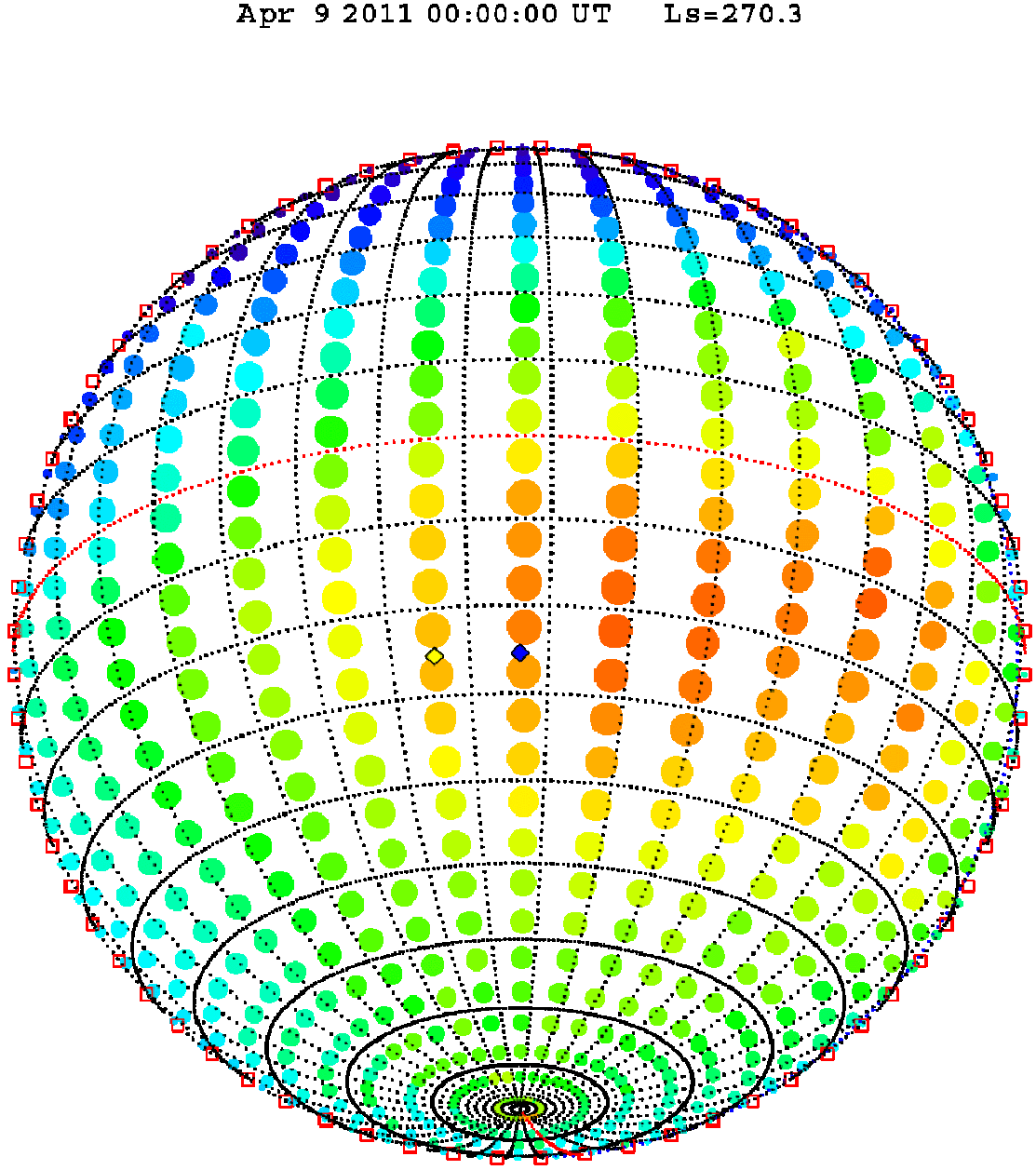
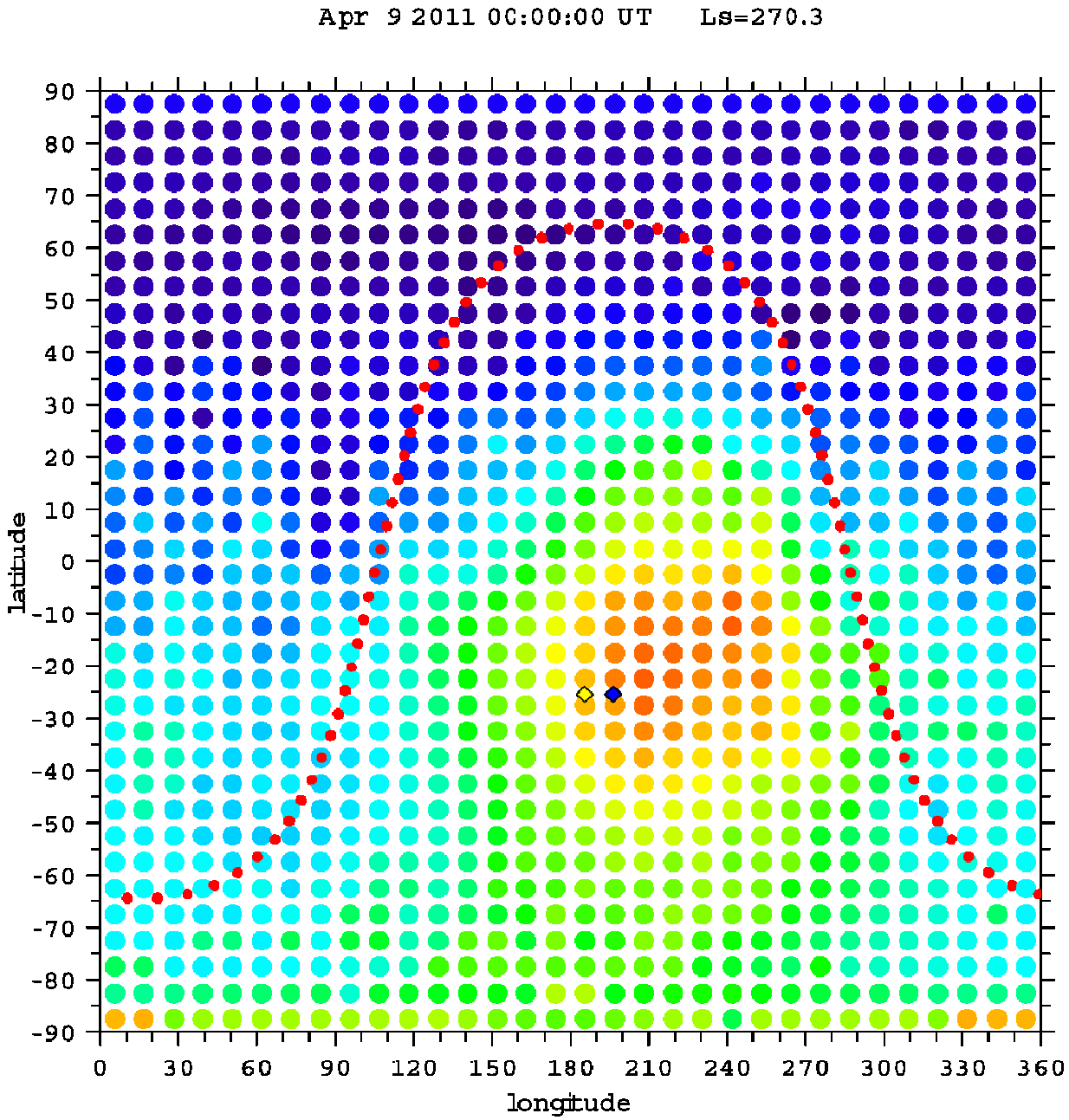
100
50
-500 -400 -300 -200 -100 0 100 200 300 400 500

Apparent disk of Mars for 2011 Apr 09 at 00:00 UT



Hers


Apr 9 2011 00:00:00 UT Ls=270.3


Apr 9 2011 00:00:00 UT Ls=270.3
latitude
longitude
90
80
70
60
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40
30
20
10
0
-10
-20
-30
-40
-50
-60
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-80
-90
0
30
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270
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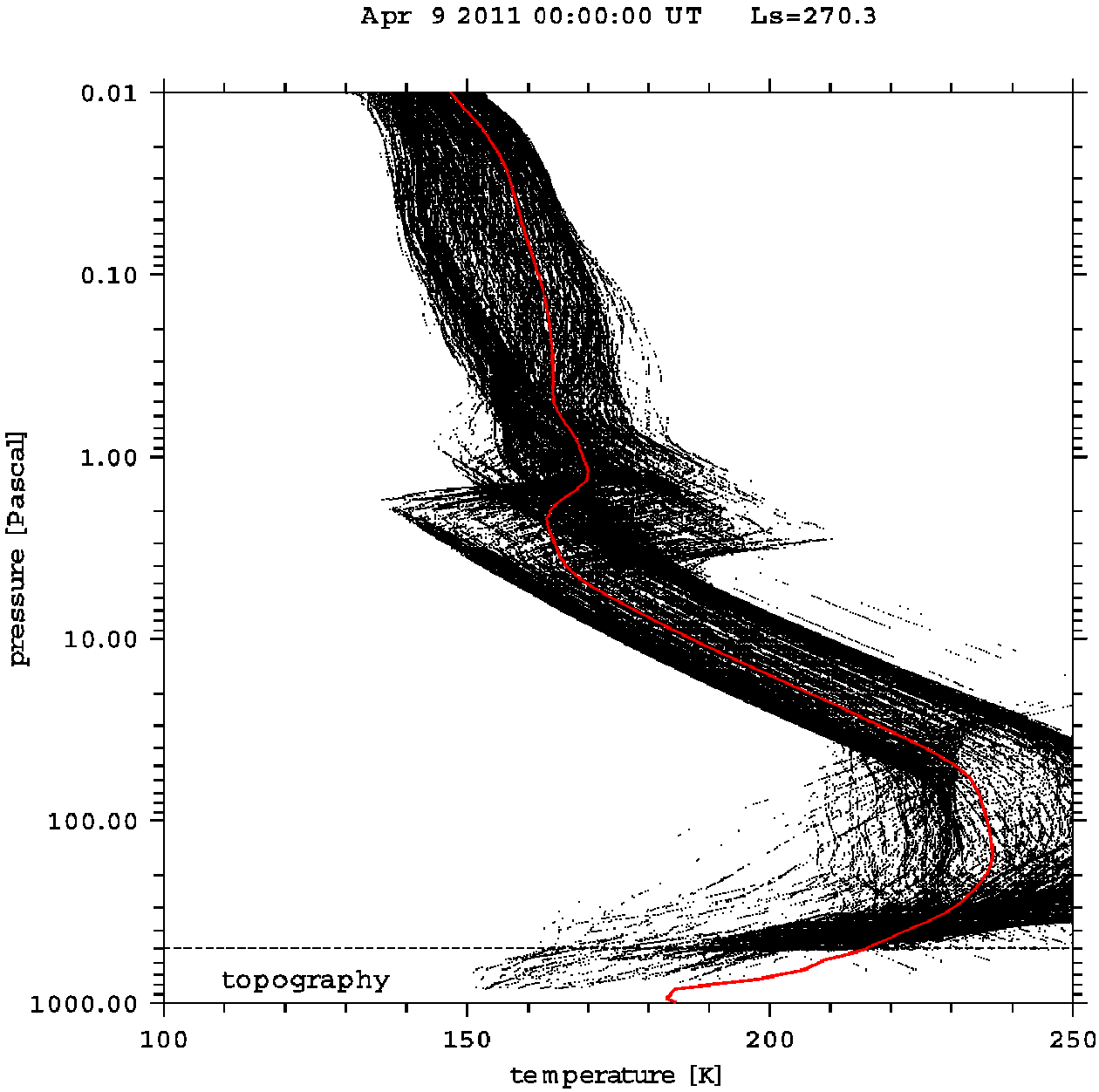
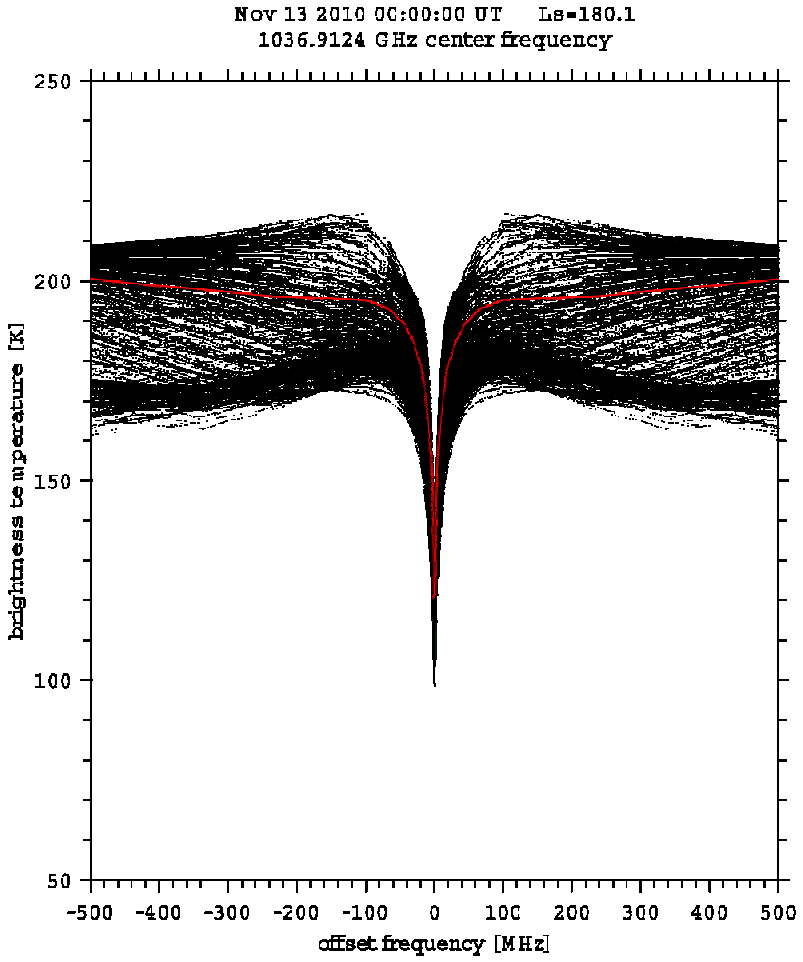
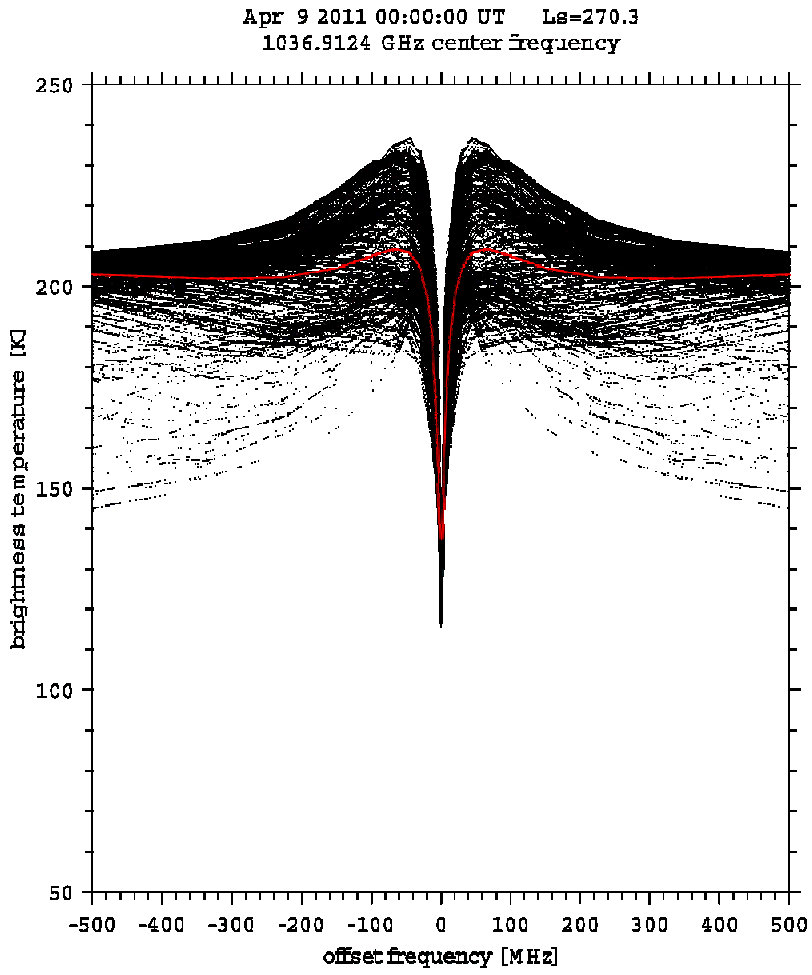

Apr 9 2011 00:00:00 UT Ls=270.3
0.01
0.10
1.00
10.00
100.00
1000.00
pressure [Pascal]
topography
100
150
200
250
temperature [K]


Nov 13 2010 00:00:00 UT Ls=180.1
1036.9124 GHz center frequency
brightness temperature [K]
offset frequency [MHz]
250
200
150
100
50
-500 -400 -300 -200 -100 0 100 200 300 400 500


Apr 9 2011 00:00:00 UT Ls=270.3
1036.9124 GHz center frequency
brightness temperature [K]
offset frequency [MHz]
250
200
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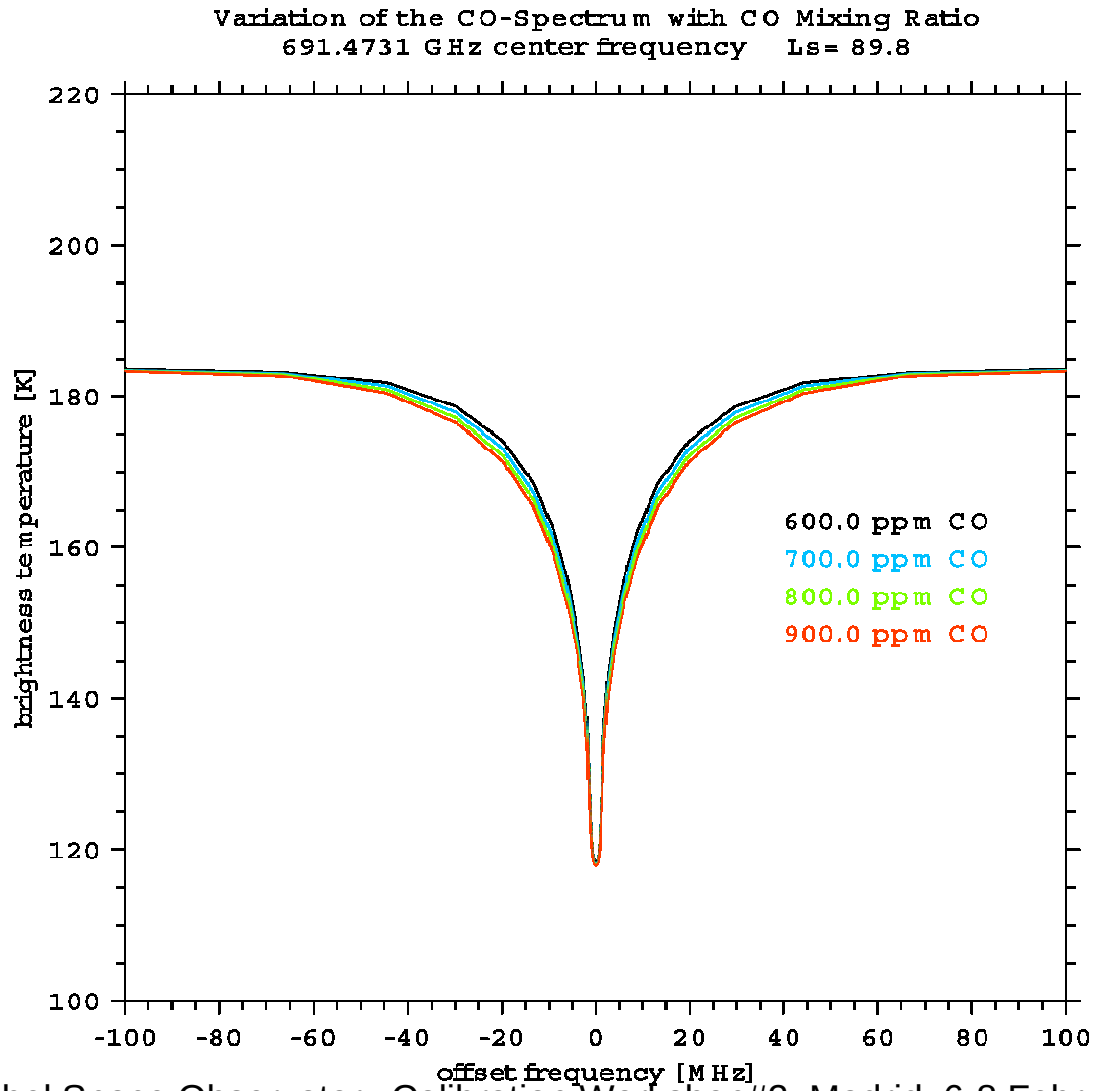
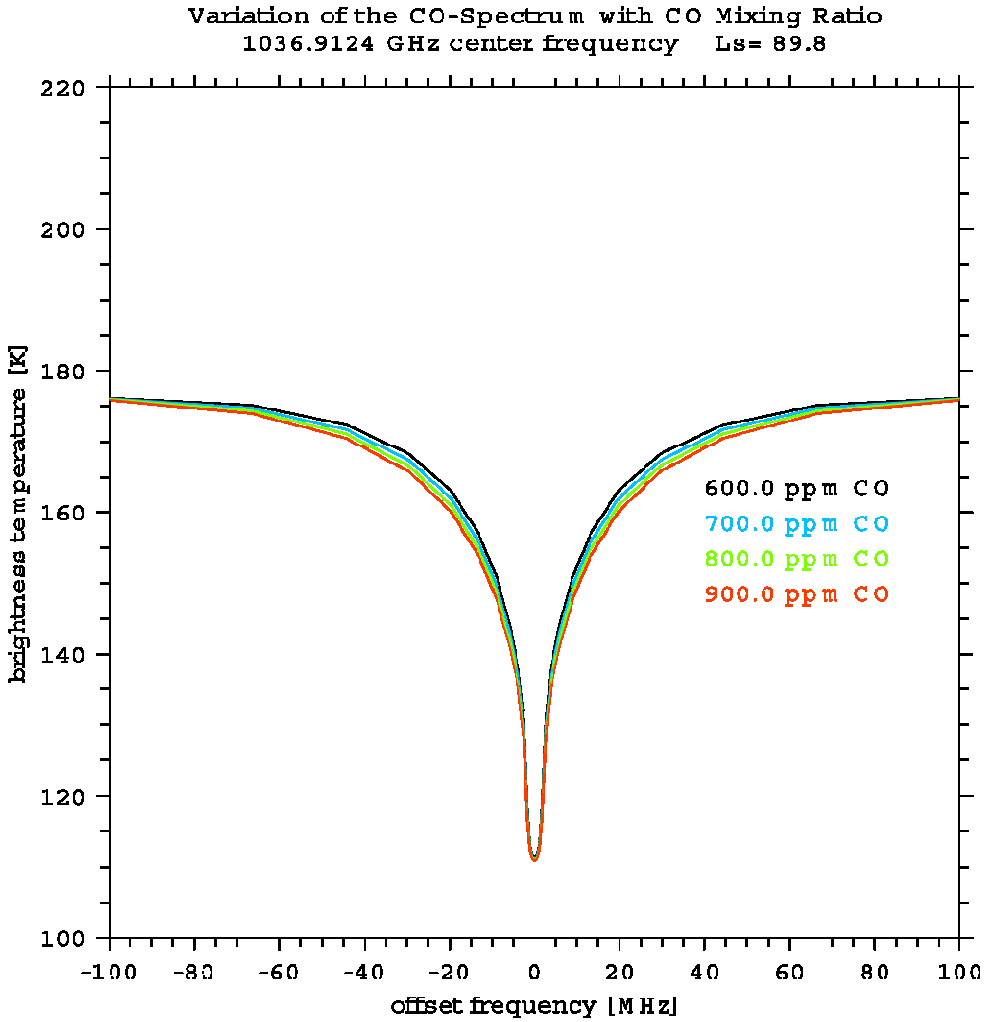
-500 -400 -300 -200 -100 0 100 200 300 400 500

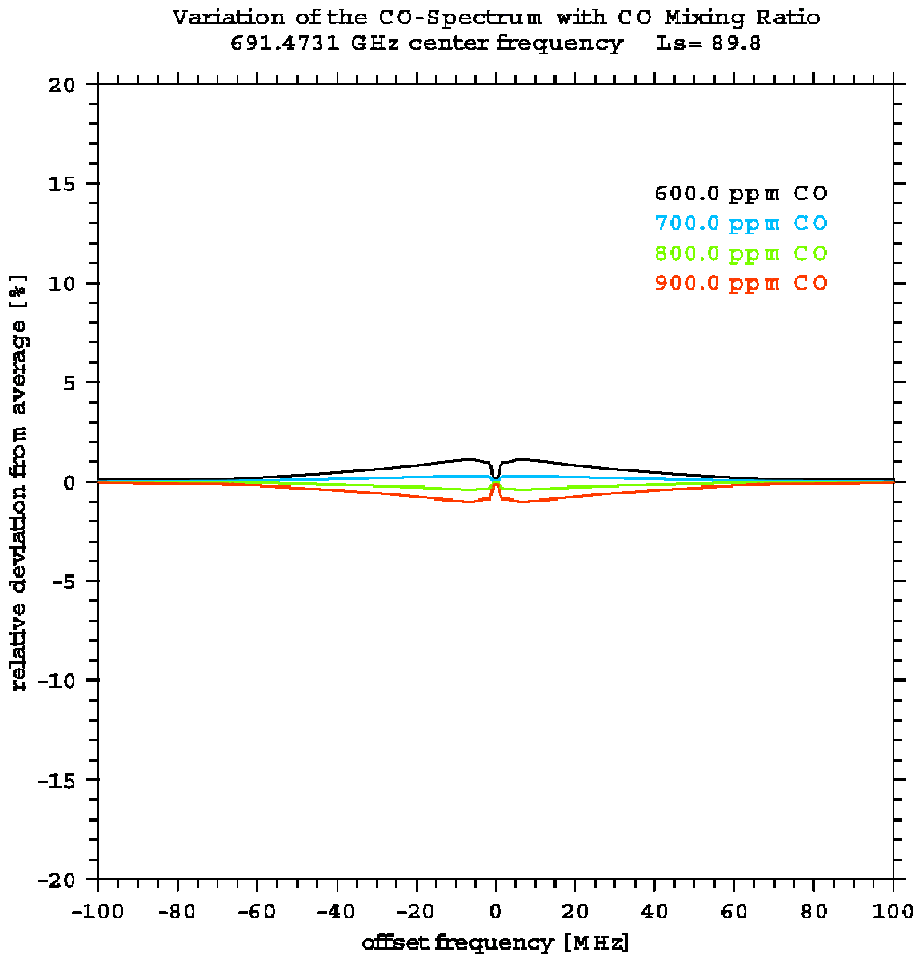
Variation of CO profile (691 GHz)



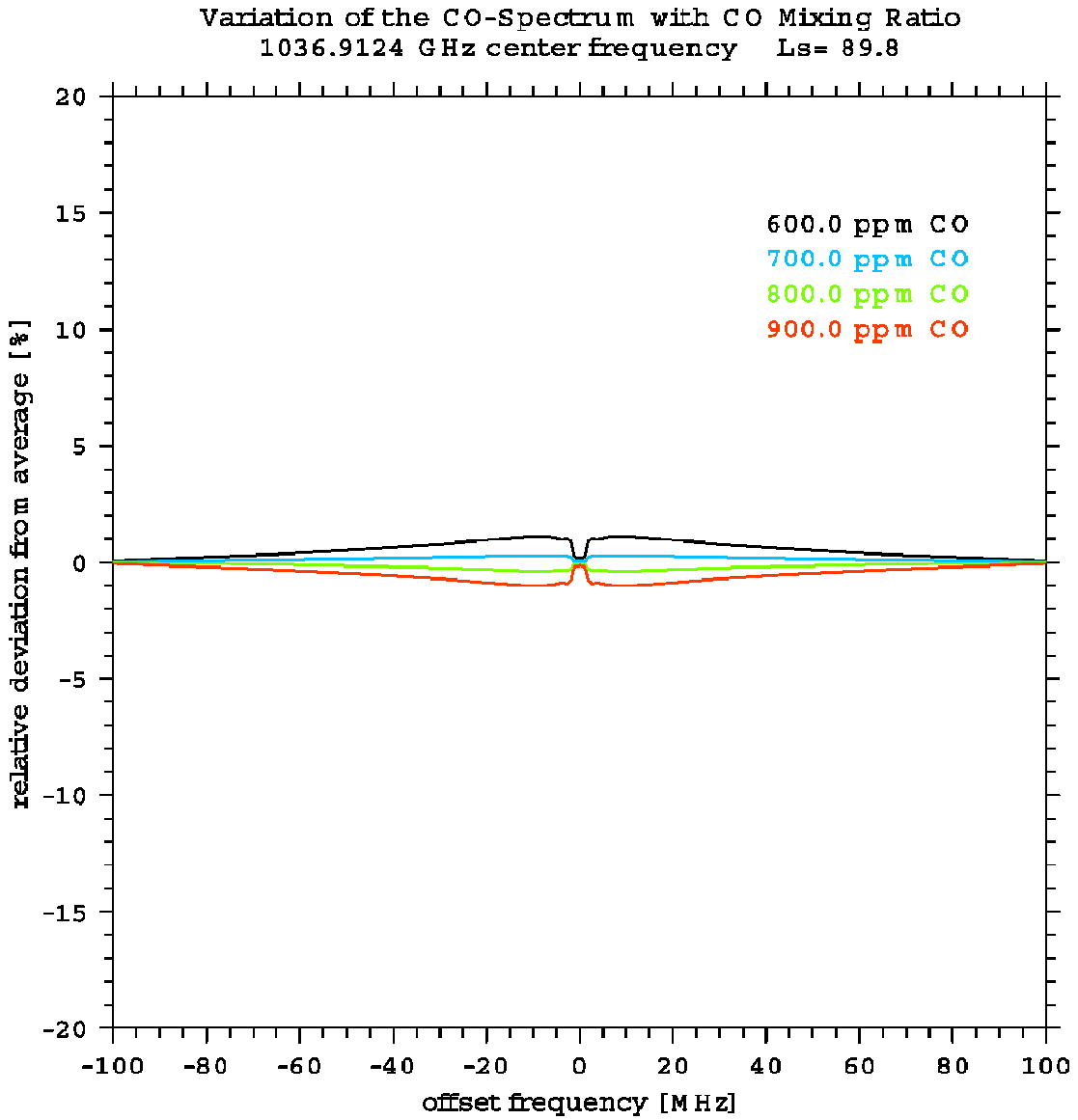
Variation of CO profile (1037 GHz)

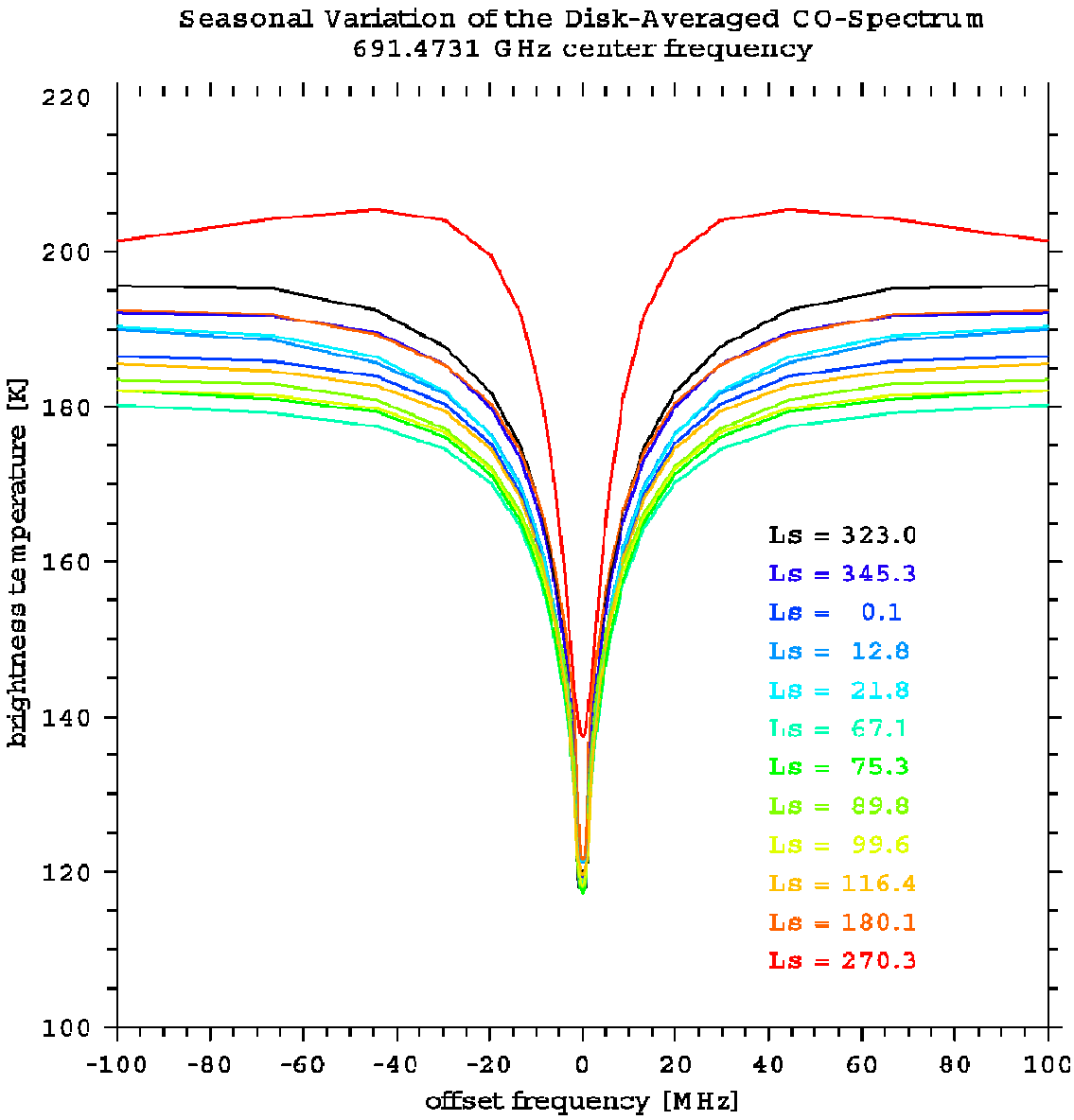


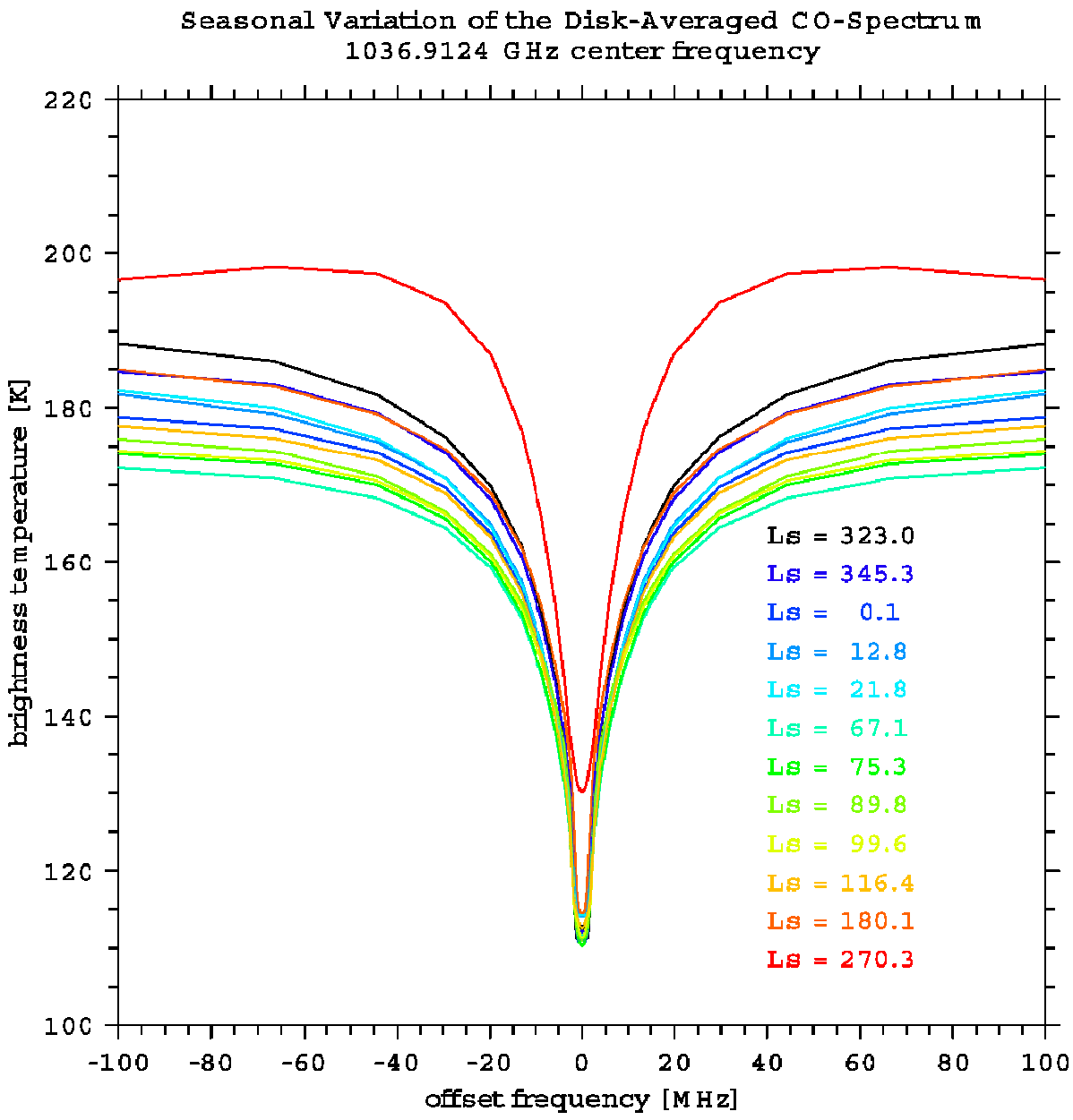
Variation of CO profile (691 GHz): relative differences

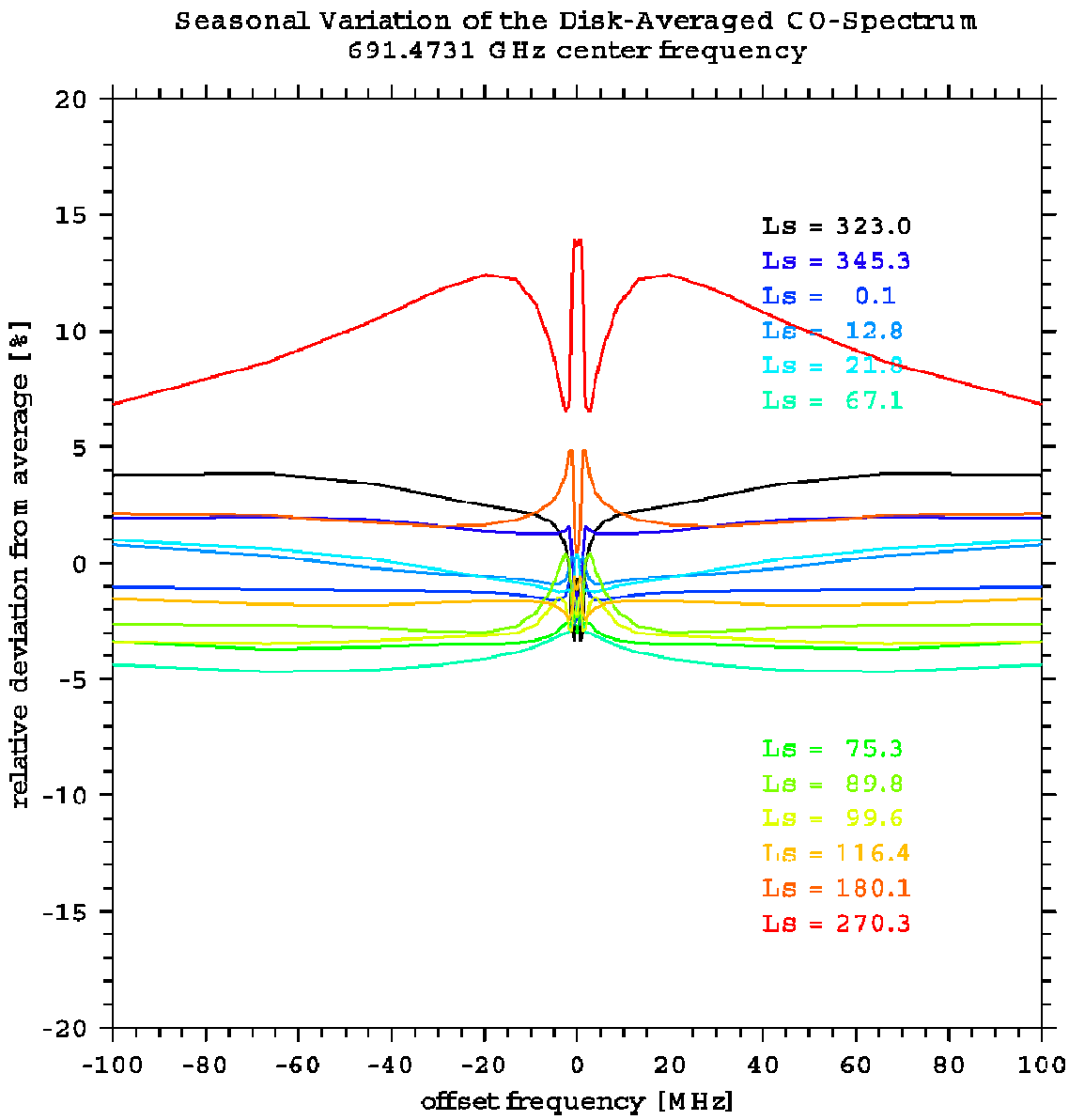


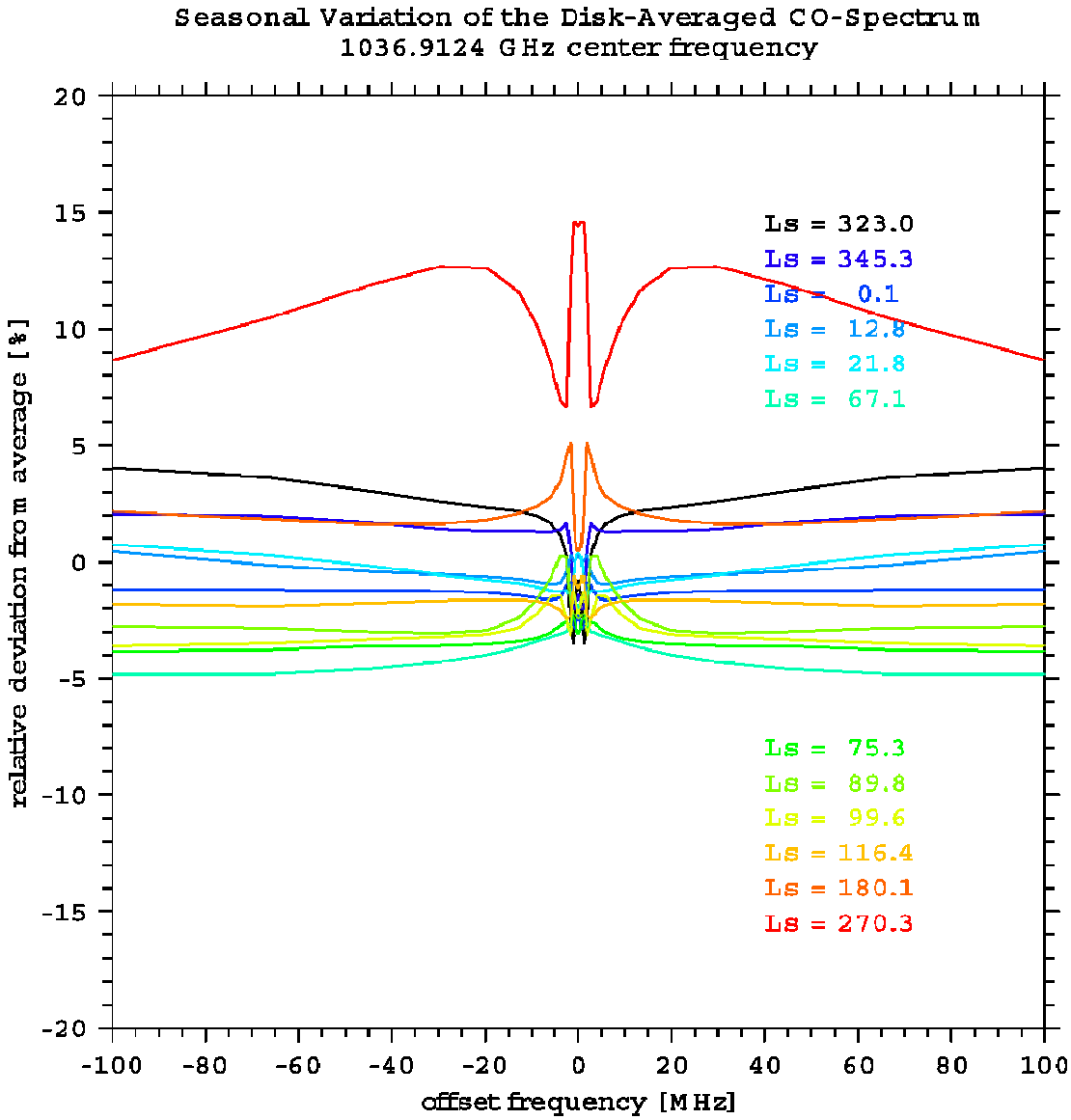
Variation of CO profile (1037 GHz): relative differences




Seasonal Variation of the Disk-Averaged CO-Spectrum
691.4731 GHz center frequency
brightness temperature [K]
offset frequency [MHz]
220
200
180
160
140
120
100
-100
-80
-60
-40
-20
0
20
40
60
80
100
Ls = 323.0
Ls = 345.3
Ls = 0.1
Ls = 12.8
Ls = 21.8
Ls = 67.1
Ls = 75.3
Ls = 89.8
Ls = 99.6
Ls = 116.4
Ls = 180.1
Ls = 270.3


Seasonal Variation of the Disk-Averaged CO-Spectrum
1036.9124 GHz center frequency
brightness temperature [K]
offset frequency [MHz]
220
200
180
160
140
120
100
-100
-80
-60
-40
-20
0
20
40
60
80
100
Ls = 323.0
Ls = 345.3
Ls = 0.1
Ls = 12.8
Ls = 21.8
Ls = 67.1
Ls = 75.3
Ls = 89.8
Ls = 99.6
Ls = 116.4
Ls = 180.1
Ls = 270.3


Seasonal Variation of the Disk-Averaged CO-Spectrum
691.4731 GHz center frequency
relative deviation from average [%]
offset frequency [MHz]
Ls = 323.0
Ls = 345.3
Ls = 0.1
Ls = 12.8
Ls = 21.8
Ls = 67.1
Ls = 75.3
Ls = 89.8
Ls = 99.6
Ls = 116.4
Ls = 180.1
Ls = 270.3


Seasonal Variation of the Disk-Averaged CO-Spectrum
1036.9124 GHz center frequency
relative deviation from average [%]
offset frequency [MHz]
Ls = 323.0
Ls = 345.3
Ls = 0.1
Ls = 12.8
Ls = 21.8
Ls = 67.1
Ls = 75.3
Ls = 89.8
Ls = 99.6
Ls = 116.4
Ls = 180.1
Ls = 270.3

Summary and open issues

- *CO variation from 600 to 900 ppm cause < ± 2% TB differences*
- *Seasonal variations cause in general < ± 4 %, except towards southern summer (+ 12 %)*

- *Simulate relative deviation of spectra for temperature error of ± 2 K. First results: error 1-2 %.*
- *Determine altitude dependence (data up to 40 km available from TES measurements, models agree. Above no data, models disagree. Near future data of MCS on MRO will help, since they go up to at least 80 km*
- *Repeat simulation for different pressure broadening coefficients and find out sensitivity.*
- *Calculations with new dynamical core and CCSR MGCM are ongoing for comparison*