Ozone retrieval from SPICAM UV and near IR measurements :

a first global view of ozone on Mars

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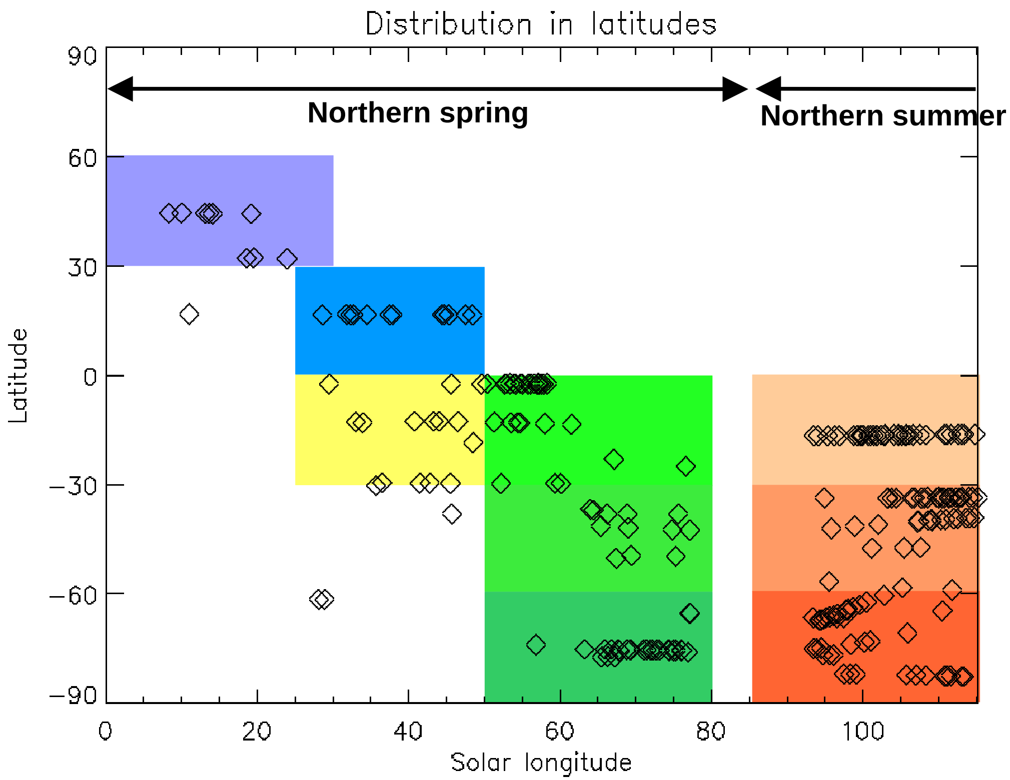
Ozone detection with SPICAM spectrometers

- 4 ways of detection
  - UV stellar occultations
  - UV solar occultations

  Ozone vertical distribution
  - UV nadir viewing : ozone total column density
  - $O_2(1\Delta)$ emission at 1.27 μm : contribution of ozone at high altitudes. Access to ozone column density above 20 km.

- Ozone column densities and vertical profiles are now retrieved for different latitudes, longitudes, local time and seasons (L_S=330 to 140°)
  - Around 240 profiles determined by stellar occultations
  - Around 260 nadirs already analysed

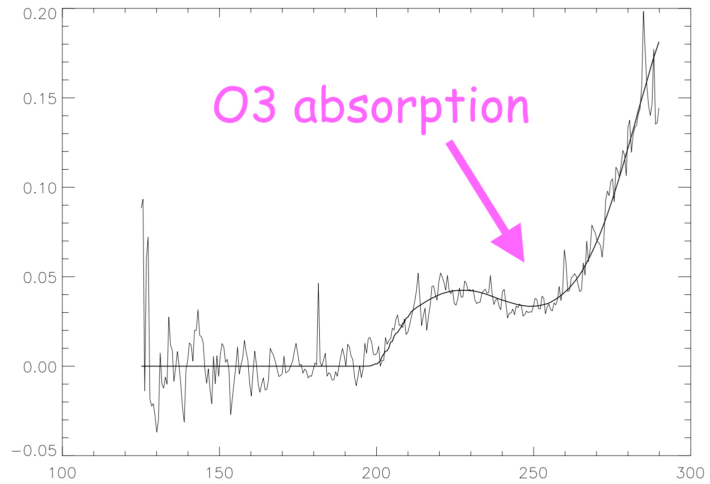
1st method : ozone by stellar occultations



So far, analysed data cover 9 « regions » in the Season-Latitude plan

The longitude dimension is fairly sampled

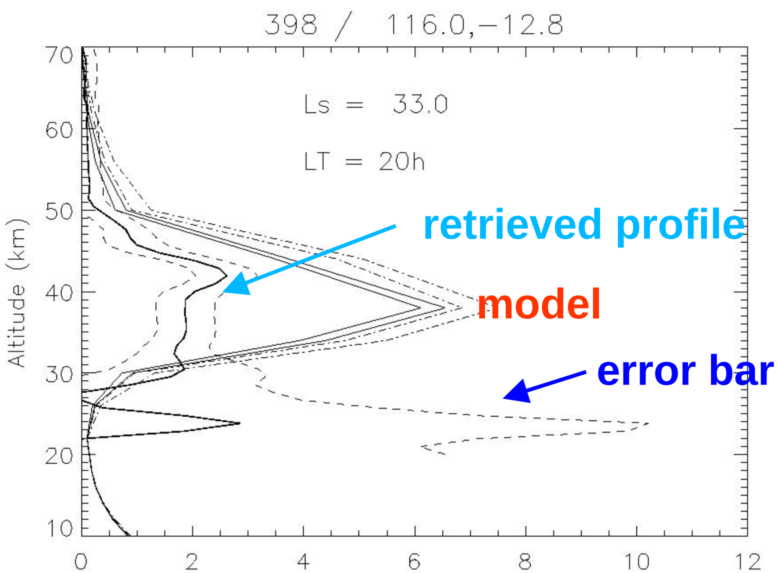
Orbit 174, at 14.5 of altitude



1st method : ozone by stellar occultations

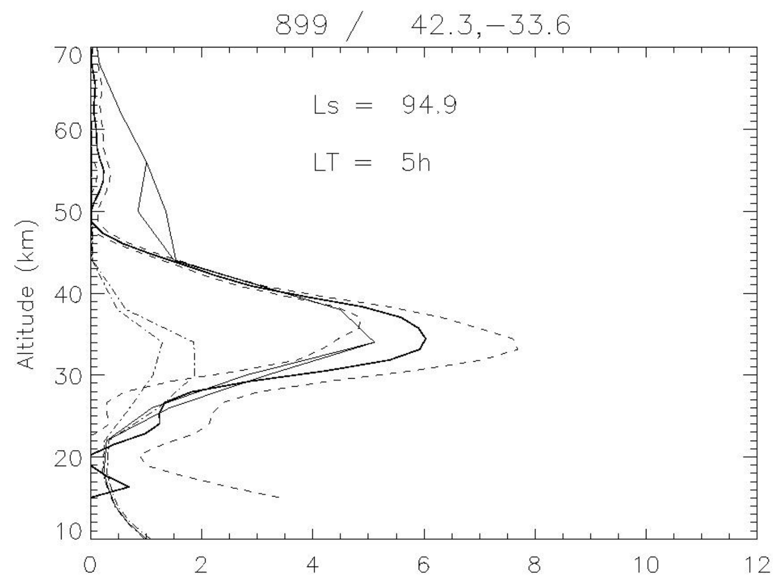
Comparison to LMD MGCM (S. Lebonnois, F.Lefèvre)

orbit 398, Ls=330°, 13°S



O_3 density (10^9 cm^{-3})

orbit 899, Ls=95°, 34°S

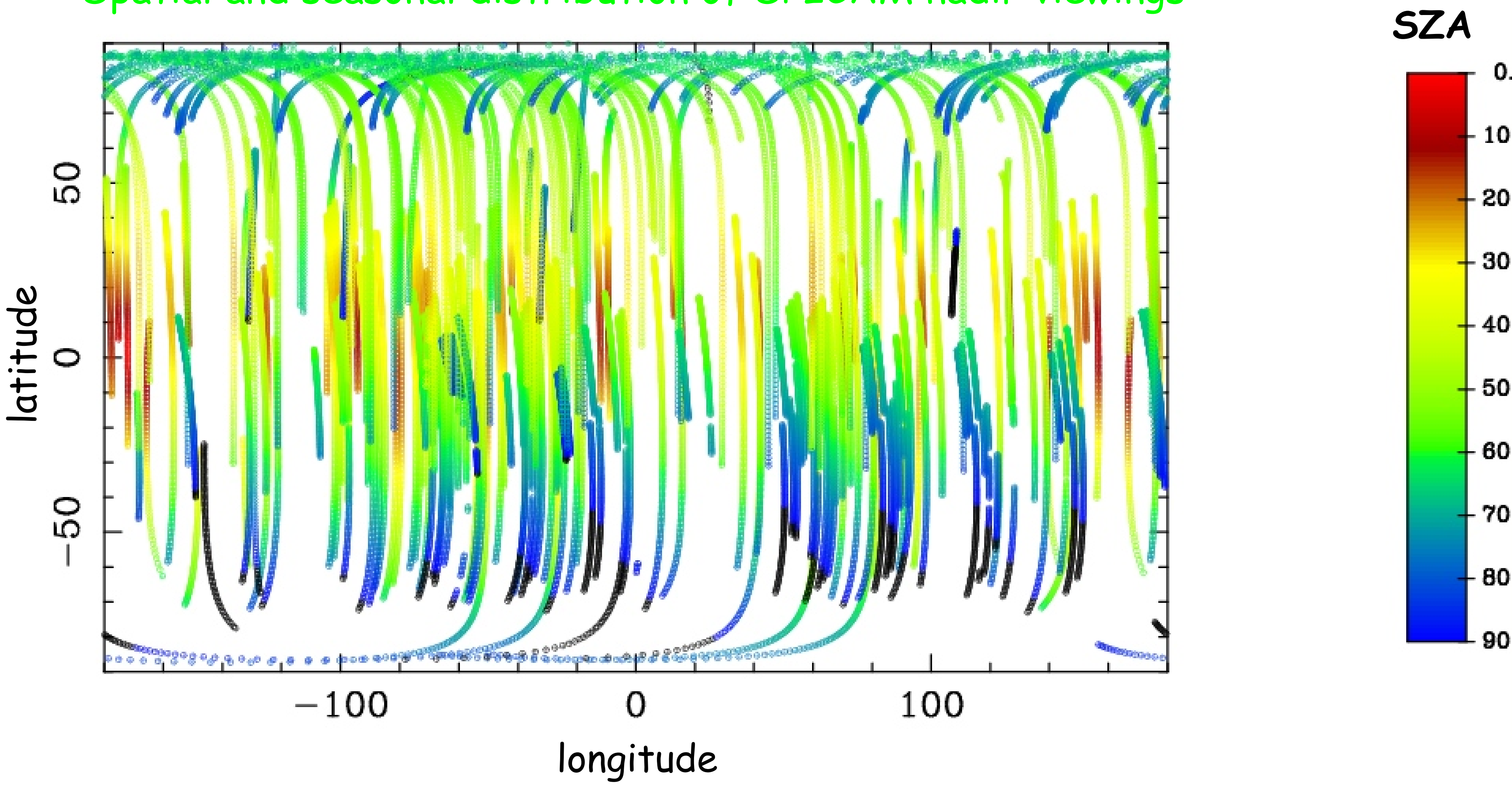


O_3 density (10^9 cm^{-3})

Cf. poster of Sébastien Lebonnois for detailed results

Ozone by nadirs viewings

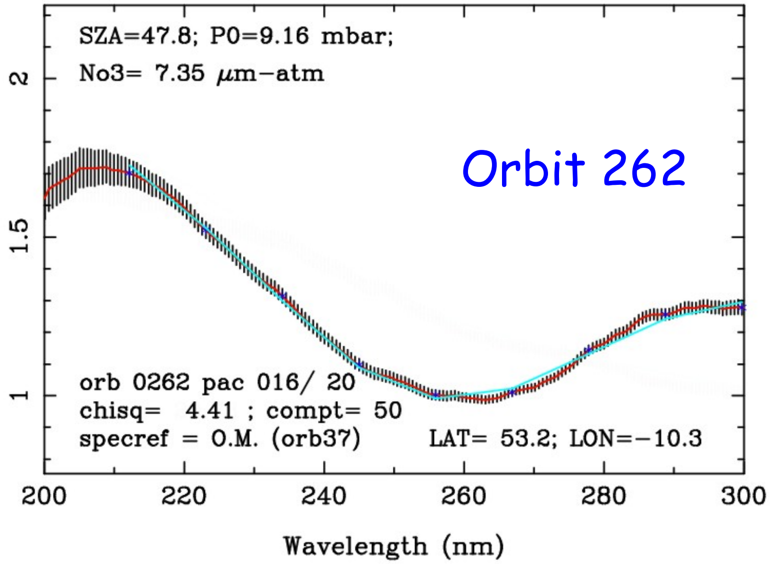
Spatial and seasonal distribution of SPICAM nadir viewings



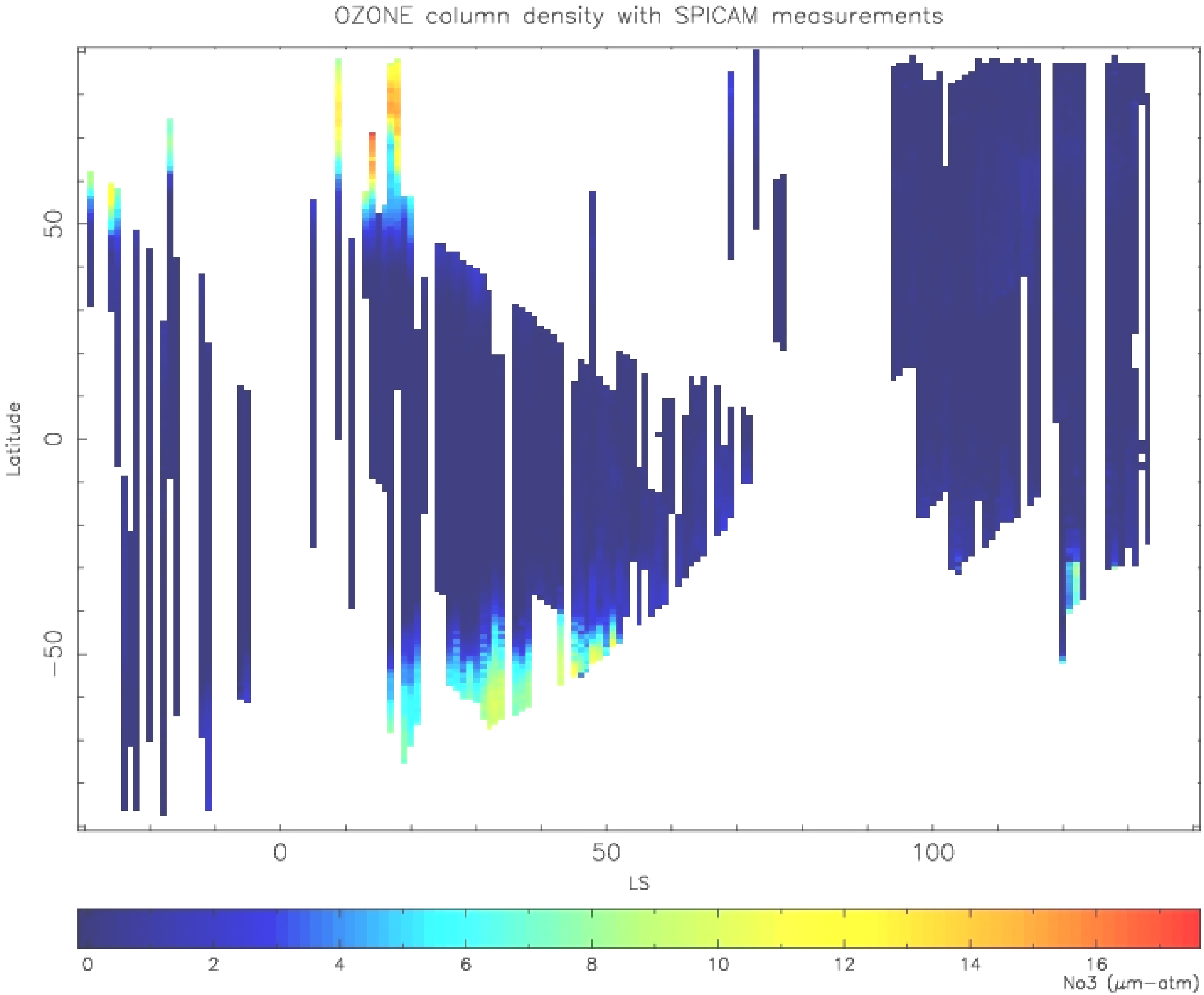
2d method : ozone by UV absorption

Computation of ozone column density

- Relatives data (no need of the detector efficient area)
- Reference spectrum : orbit 37, above Olympus Mons, where no ozone is detected (confirmed by GCM modele)
- About 50 spectra averaged
- Retrieval of total ozone column density from the broad band at 250 nm



Use of SHDOM radiative transfer code


OZONE column density with SPICAM measurements
Latitude
50
0
−50
0
50
100
LS
0
2
4
6
8
10
12
14
16
No3 (μm−atm)

3d method : ozone by IR emission

$$O_3 + h\nu \longrightarrow O(^1D) + O_2(a^1\Delta_g) \qquad J$$

220 nm < λ < 320 nm — excited state

Photon emission

$$O_2(a^1\Delta_g) \longrightarrow O_2(X^3\Sigma_g) + h\nu$$

$\tau \sim 3850$ s

Quenching by collisions with CO2

$$O_2(a^1\Delta_g) + CO_2 \longrightarrow O_2(X^3\Sigma_g) + CO_2$$

$k \sim 10^{-20}$ cm^3 s^{-1}
Quenching factor

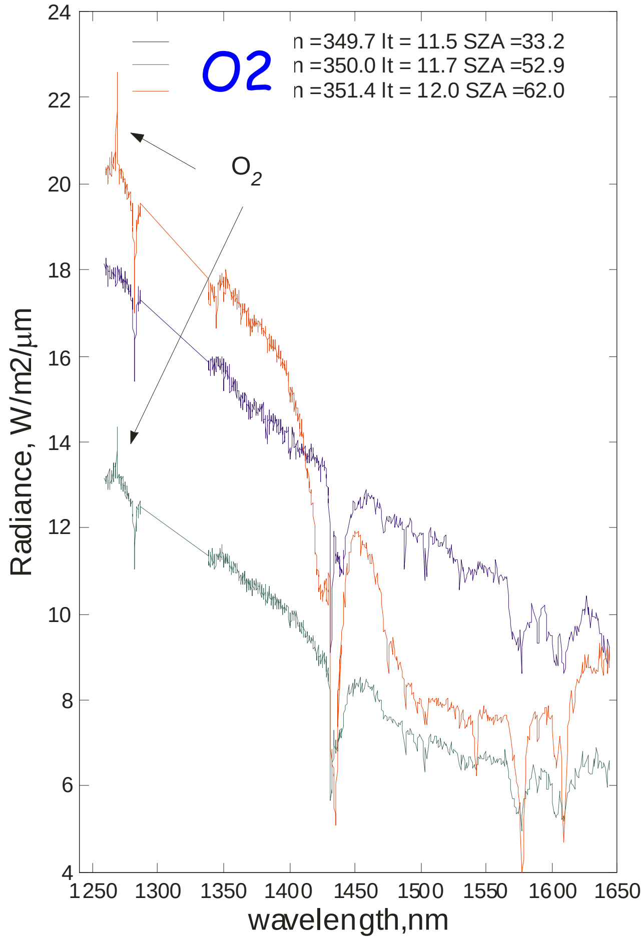
O_2 emission at 1,27 μm

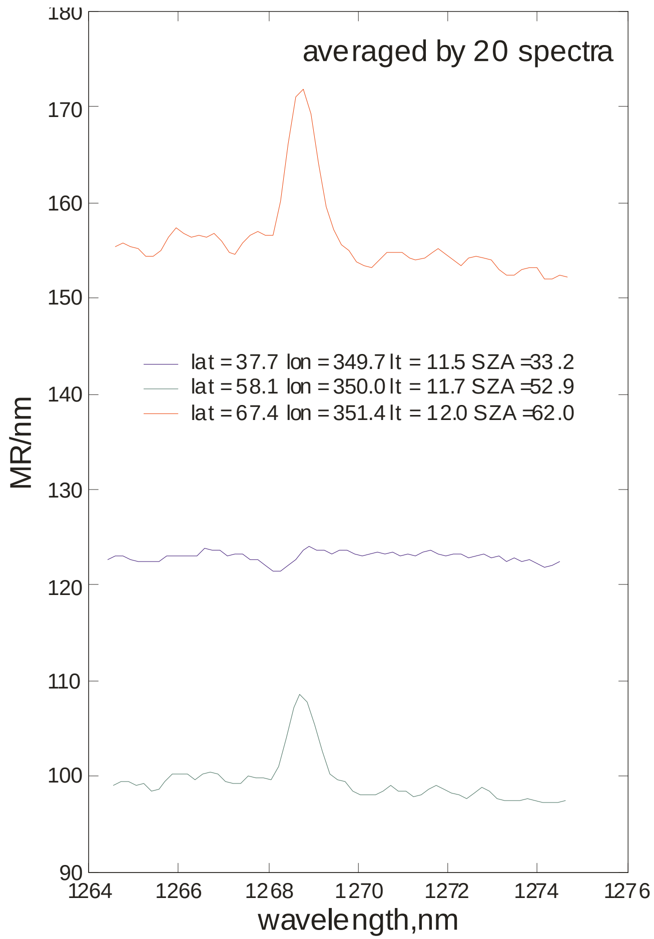
O2 emission = good tracor for ozone at high latitudes (above 20 km)

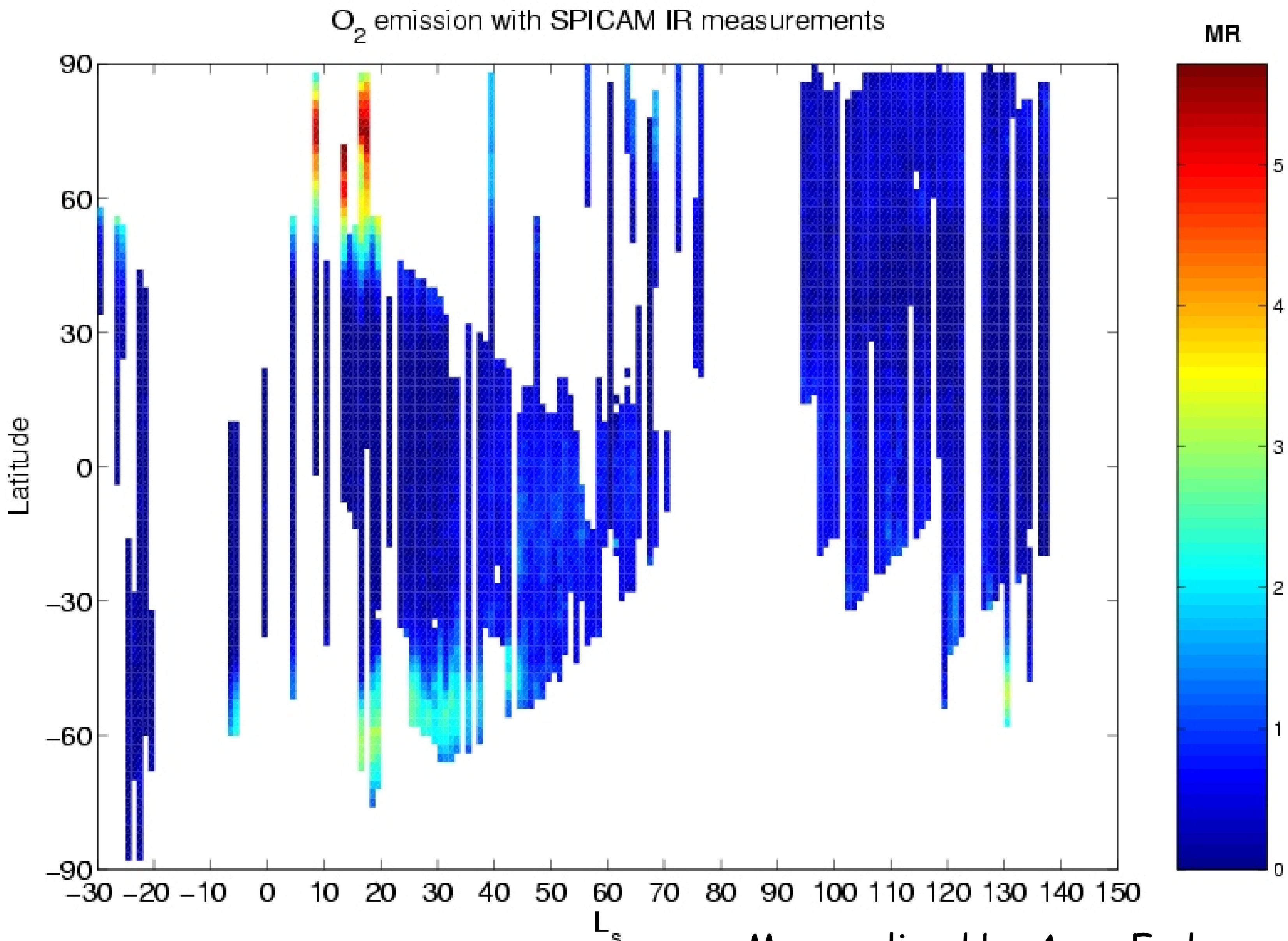
3d method : ozone by IR emission

1 MR=$10^{12}/(4\pi)$ photons.$cm^{-2}s^{-1}sr^{-1}$

Orbit 262, Ls=13.3°



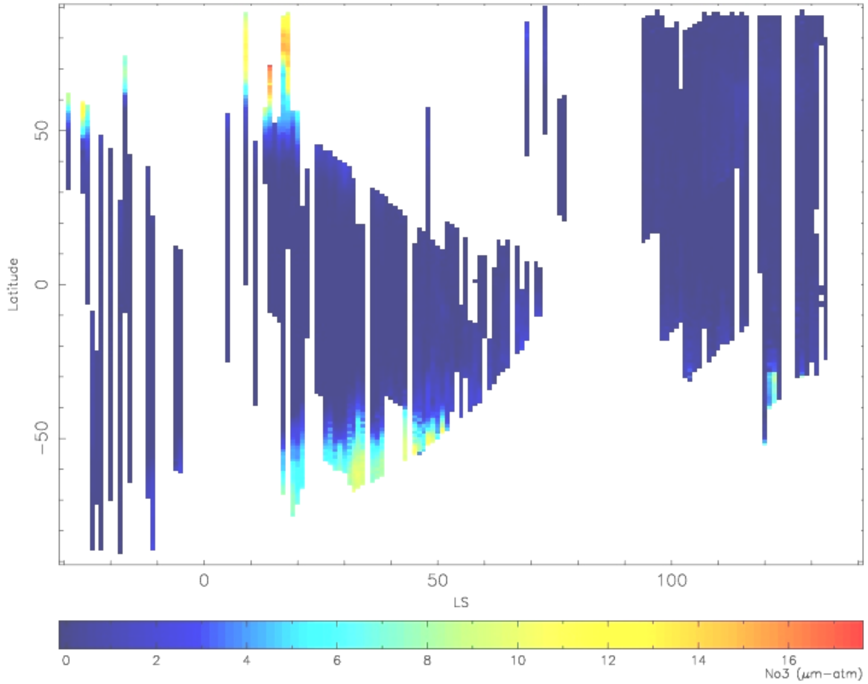




Map realized by Anna Fedorova

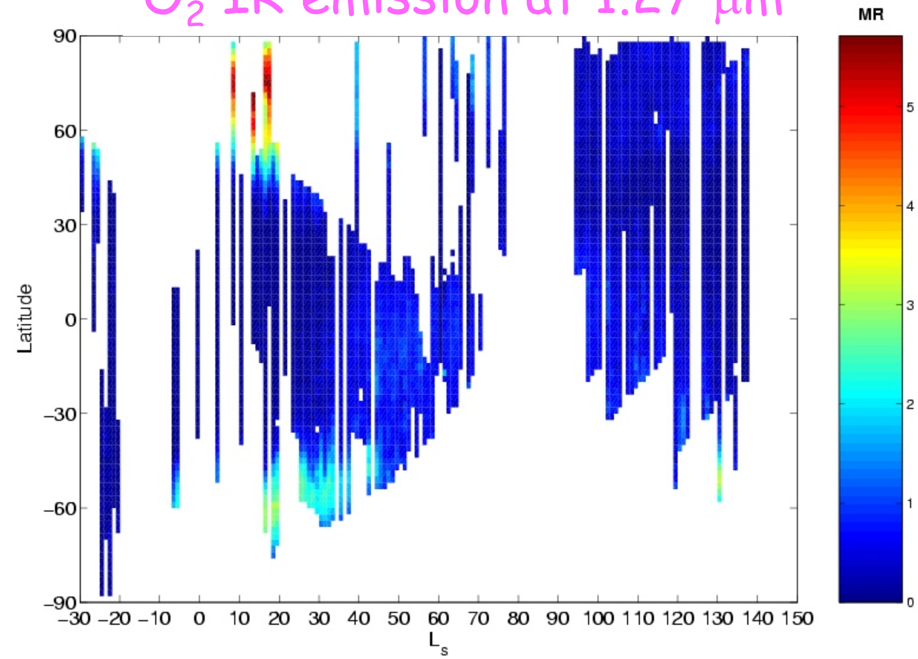
Comparison O_3 absorption vs O_2 emission

O_3 UV absorption at 250 nm



Total column density

O_2 IR emission at 1.27 μm



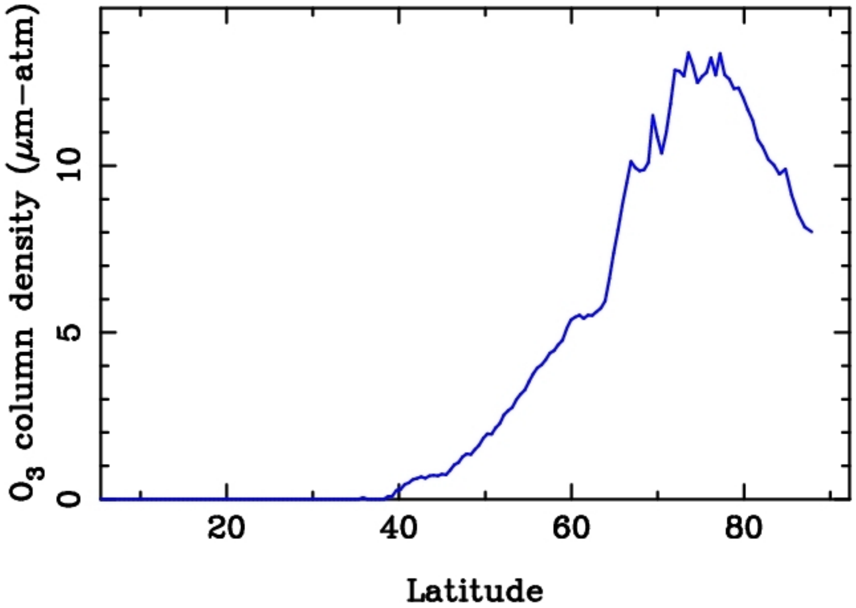
Ozone above 20 km

- Agreement is globally good between the two ways of detection
- Differences give information about the ozone vertical distribution : at the surface or at high altitude

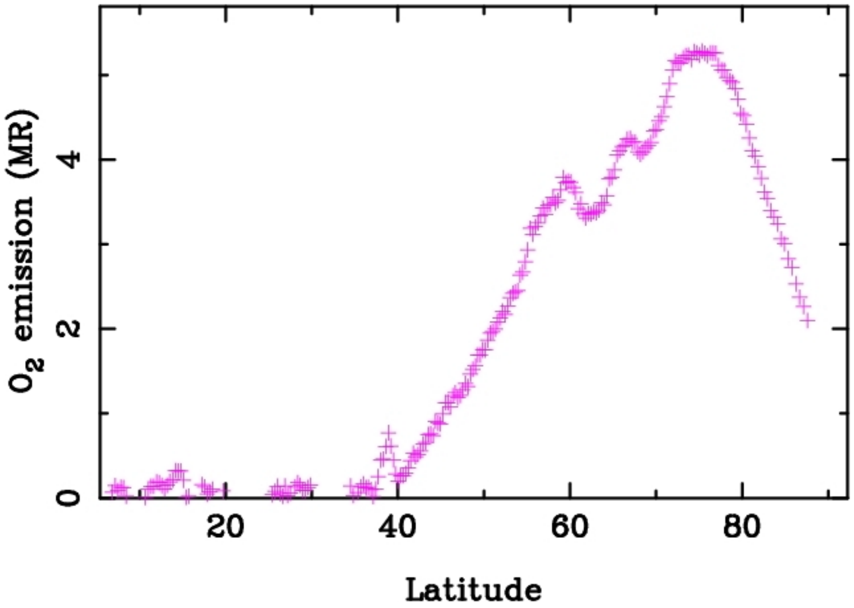
Comparison O3 absorption – O2 emission

Orbit 231, Ls = 8.7

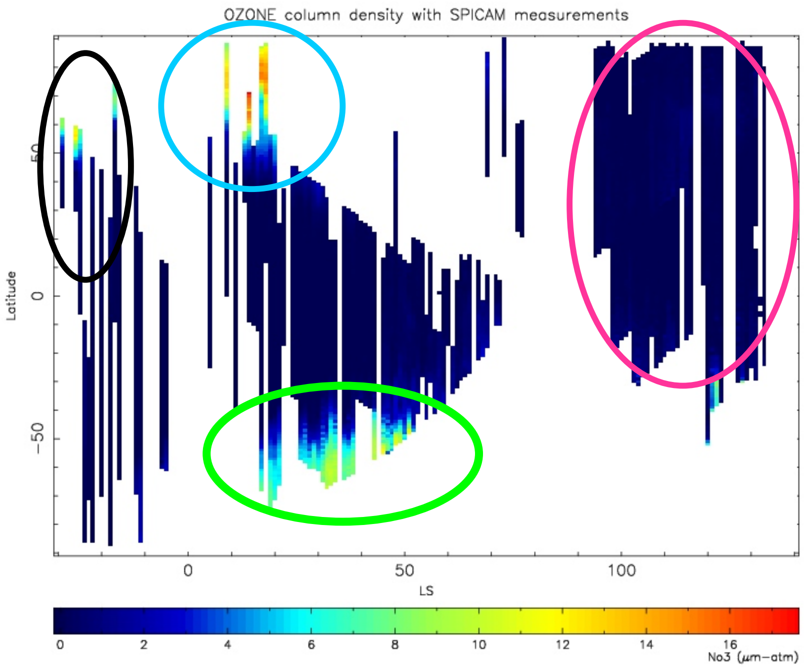
O_3 UV absorption at 250 nm



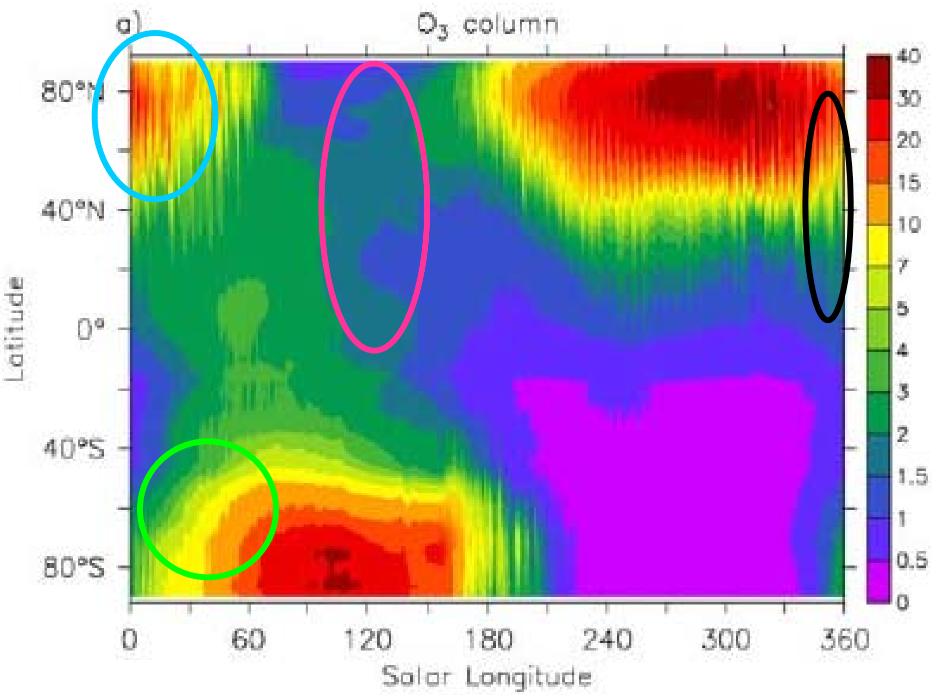
O_2 IR emission at 1.27 μm



Comparison
SPICAM O3 data - GCM model predictions



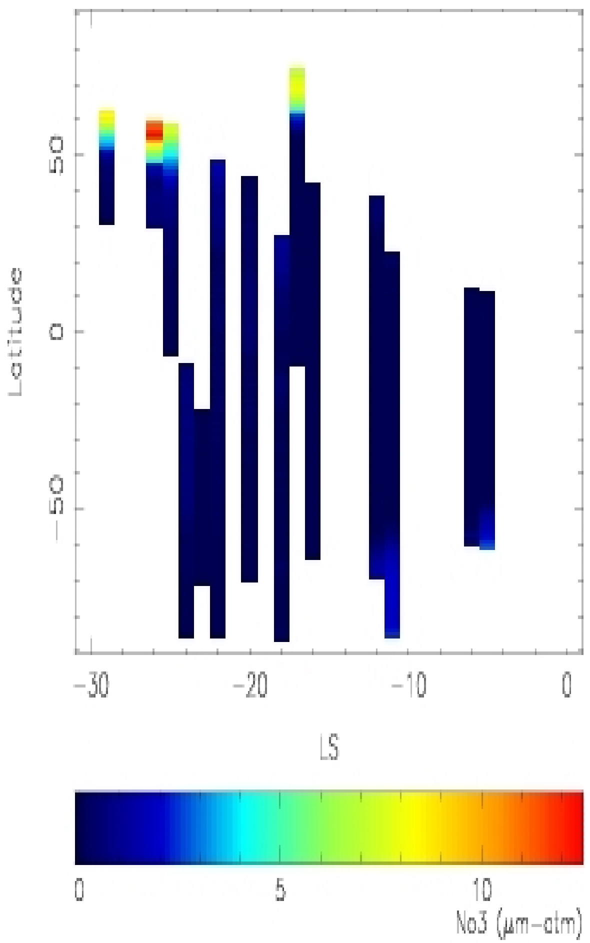
Ozone column map (diurnal average)
from GCM model
(F.Lefevre et al, JGR 109, 2004)

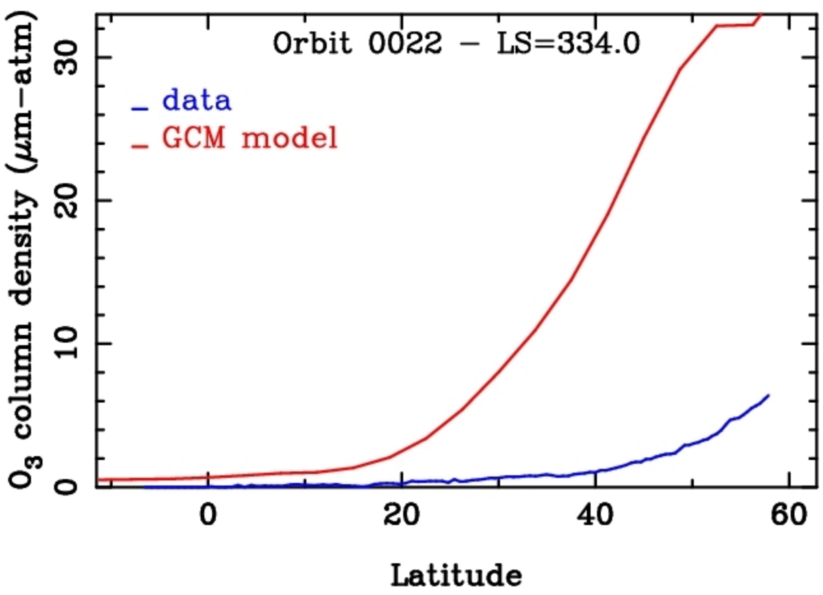


- Good general agreement between Spicam data and GCM model

- differences exist

LS = 330-360° (NH late winter)





- High variability from one orbit to another

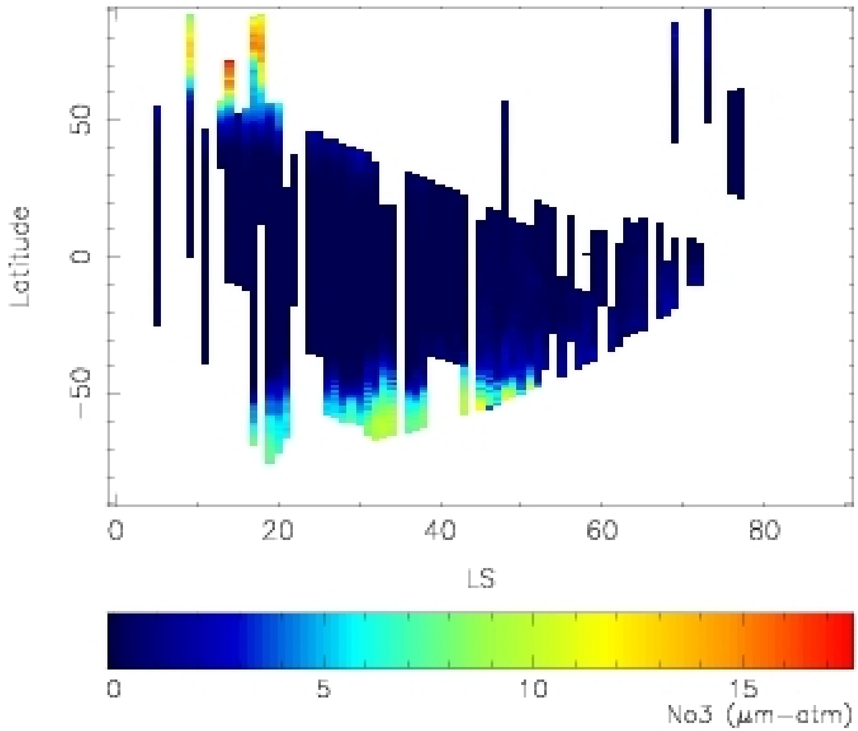
- Less ozone in the data than predicted by the GCM at high latitudes during NH late winter

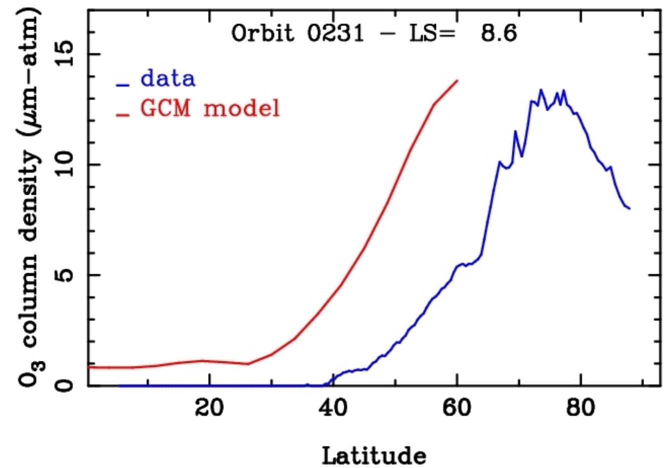
LS = 330-360° (NH late winter/SH late summer)

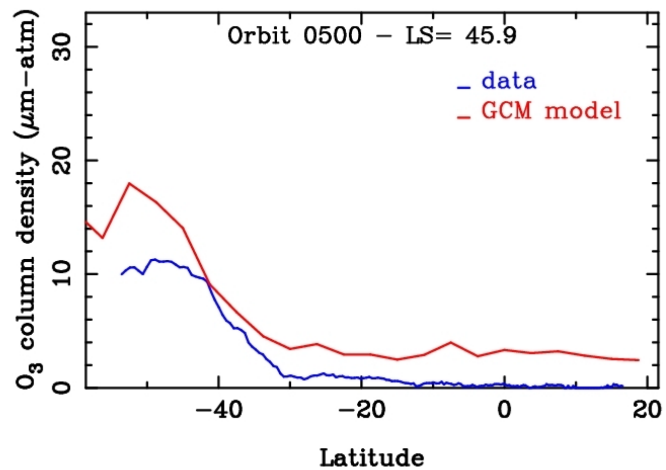
	Spicam measurements	GCM prediction	Previous measurements
50N-75N	8-12 μm-atm	10-35 μm-atm	5-40 μm-atm (Traub et al, 1979)
Equator	no O3	no O3	no O3 (Barth et al, 1973) (Novak et al, 2003)
50S-75S	0 at Ls=340 2.5μm at LS=350	0 at Ls=330 3μm at Ls=360	3μm at Ls=330 10μm at Ls=360 (Barth et al, 1973)

- At equator and high latitudes of SH : good agreement with GCM model
- Possible interannual variability in the onset of the late summer O3 increase in the SH

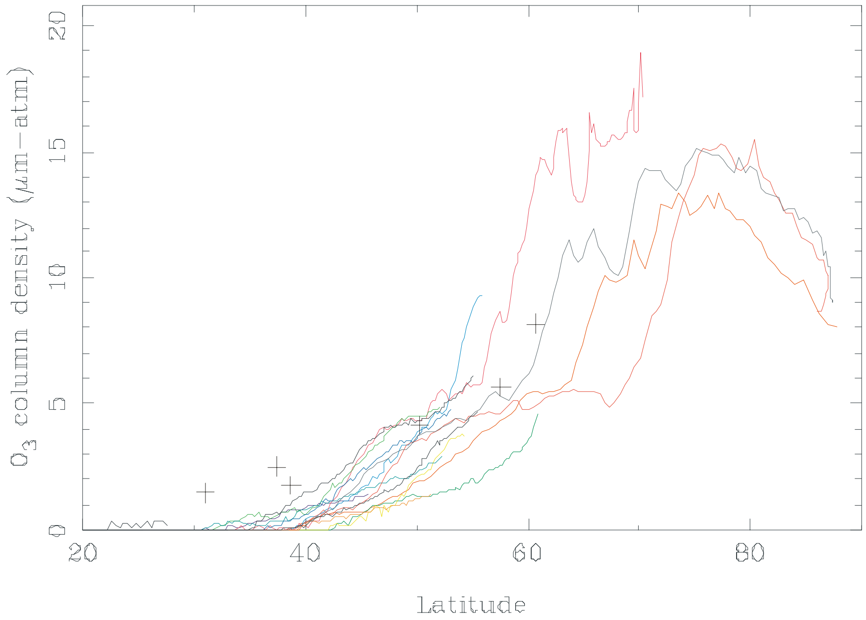
LS = 0-90° (NH spring / SH fall)







Ozone SPICAM data at LS = 10-20°



Orbits 231 to 305
Ls = 10 – 20°

+ Clancy data (Sept 1996) Ls=10°

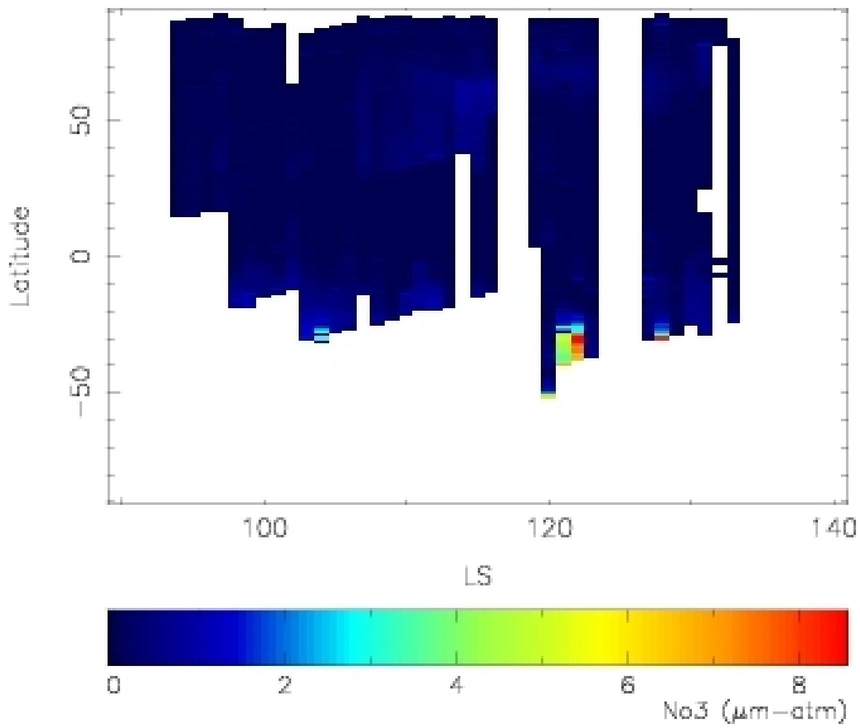
- Strong latitudinal gradient of high latitude O3, quite constant in geographic position (above 40°N)

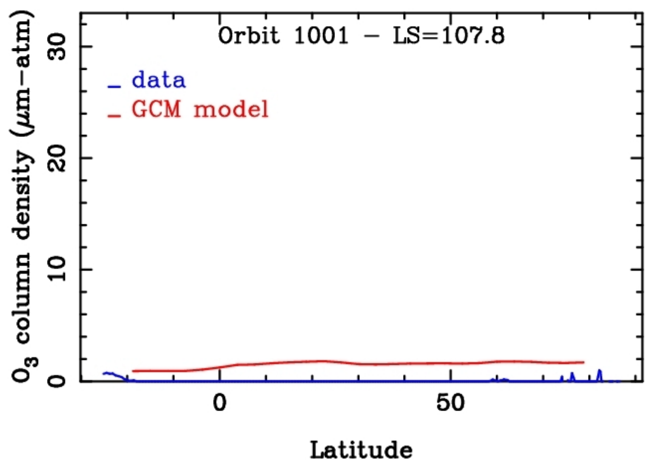
- Sharp variability in intensity (different surface elevation and/or dynamical effects)

LS = 0-90° (NH spring/SH fall)

	Spicam measurements	GCM prediction	Previous measurements
50N-75N	5-15 μm-atm	10-35 μm-atm	8 μm-atm at Ls=10 4 μm-atm at Ls=61 (Clancy at al., 1999)
Equator	less than 1 μm-atm	1-2 μm-atm	2 μm-atm at Ls=10 4 μm-atm at Ls=61 (Clancy at al., 1999)
50S-75S	6-10 μm at 60°N, increases with Ls	5-20 μm-atm	

LS = 90-180° (NH summer/SH winter)





No ozone detection around Ls=110°

The model predicts less than 2 μm-atm from 40S to 60N...

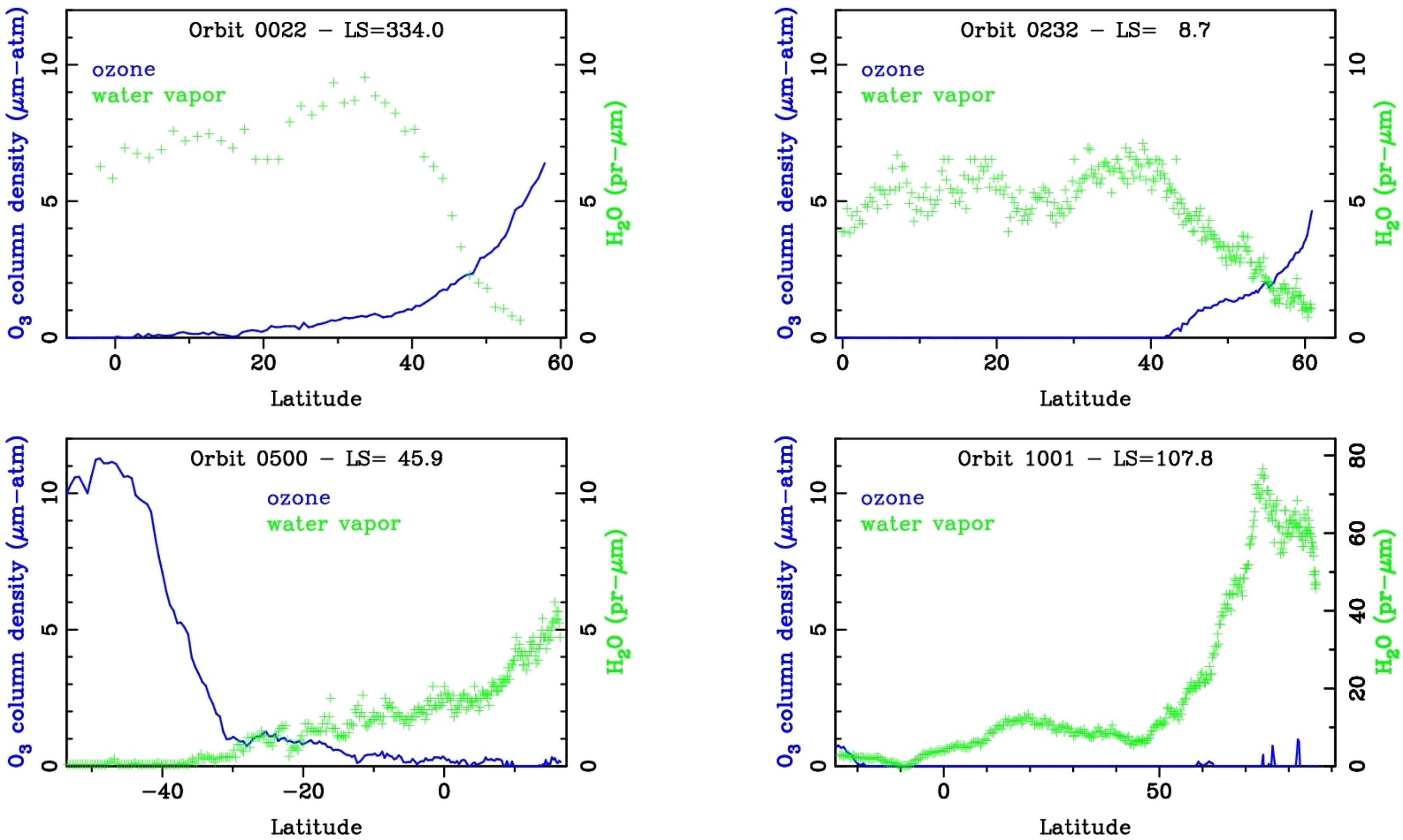
Correlation ozone – water vapor

- Ozone is destroyed by odd hydrogen species (HOx)
- HOx are produced by the photolysis of wator vapor

⇒ Expected anti-correlation between ozone and water vapor

- Water vapour is measured with IR AOTF spectrometer (see Anna Fedorova poster and presentation).
- H_2O column density deduced from the water band at 1.38 μm.

Comparison O_3 / H_2O for different LS



Anticorrelation well measured by SPICAM from Ls=330 to 90.

A few conclusions about ozone on Mars

- Most complete ozone climatology on Mars, using complementary measurements
  - first ozone altitude profiles during the night
  - Ozone column density (total and above 20 km)

- High variability of ozone
  - with season, latitude and local time

- Comparison with GCM model
  - Good agreement for global ozone variations
  - Discrepancies in the quantities : less ozone detected than predicted by the model at some seasons and latitudes

- Comparison with water vapor
  - Anticorrelation confirmed by observations

O2 emission at 1,27 mm

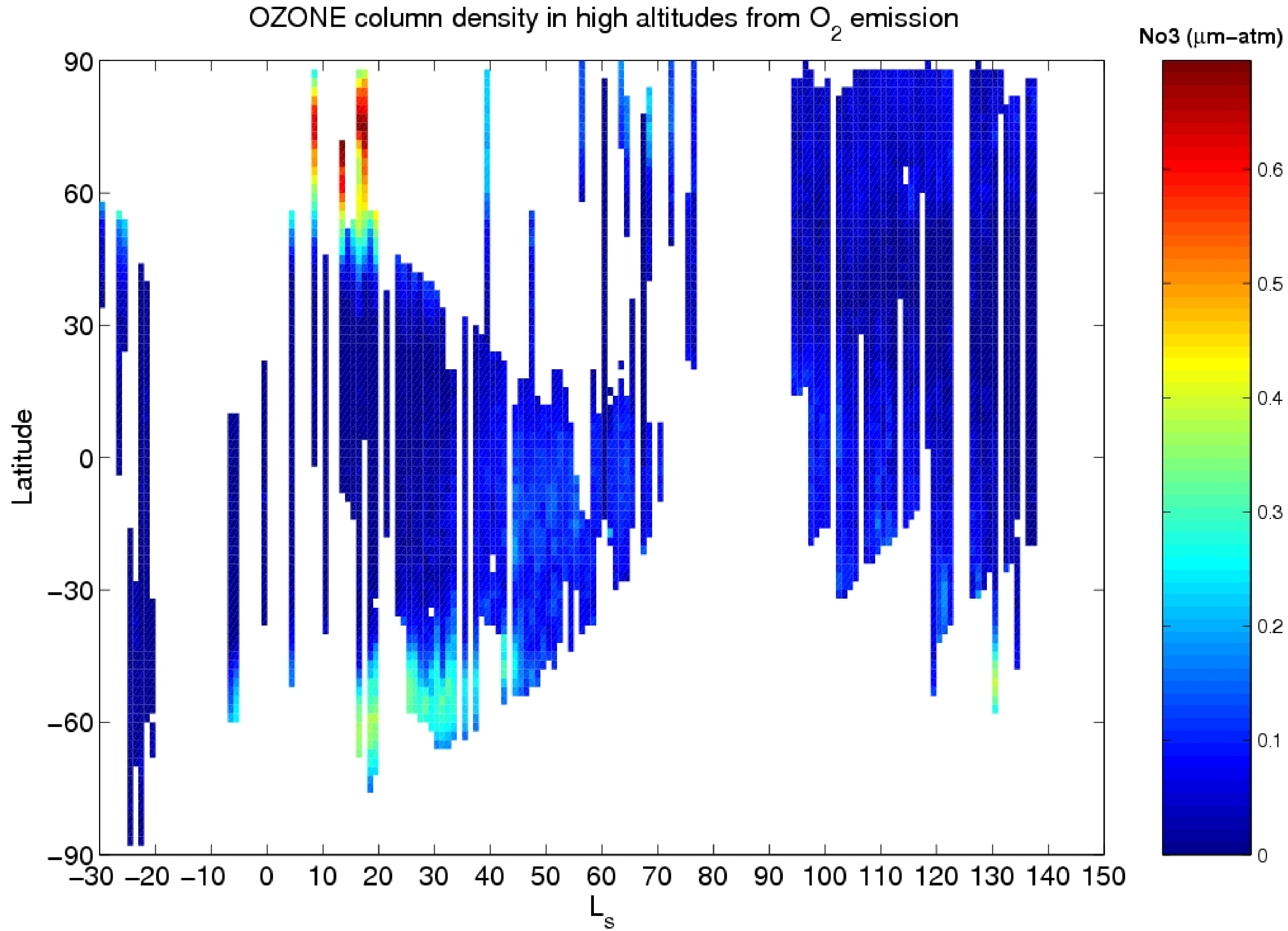
$$I(MR) = \frac{1}{r^2}\,\frac{10^{-12}}{4\,\pi}\int \frac{J\,[O_3]}{1+\tau\,k\,[CO_2]}\,dz$$

If k=0, $$I(MR) = \frac{1}{r^2}\,\frac{10^{-12}}{4\,\pi}\,J.\,N_{o3}$$

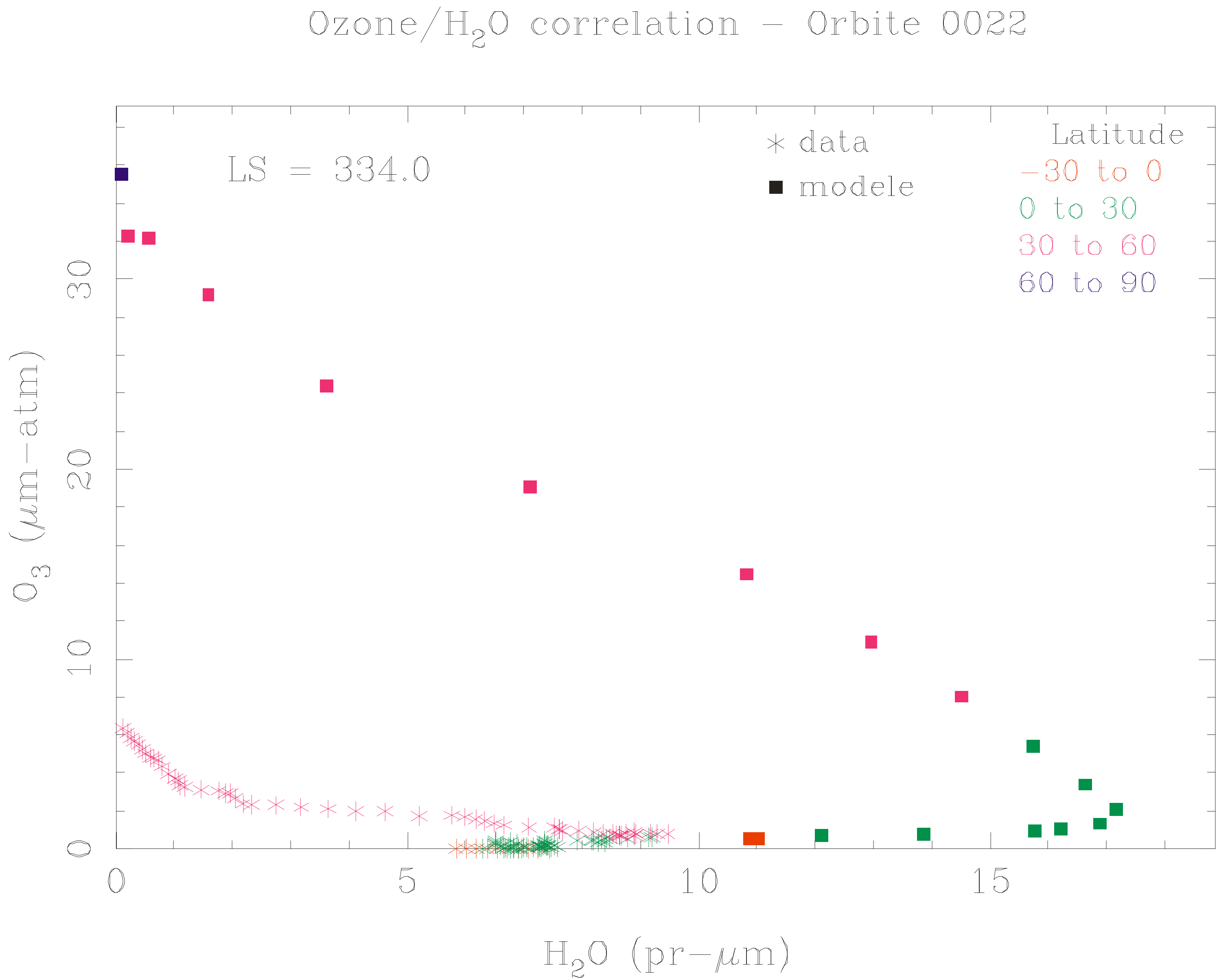
With J~0.0079 at 1 UA (Krasnopolsky 2004),

computation of ozone column density at high latitudes

From O2 emission at 1.27 μm



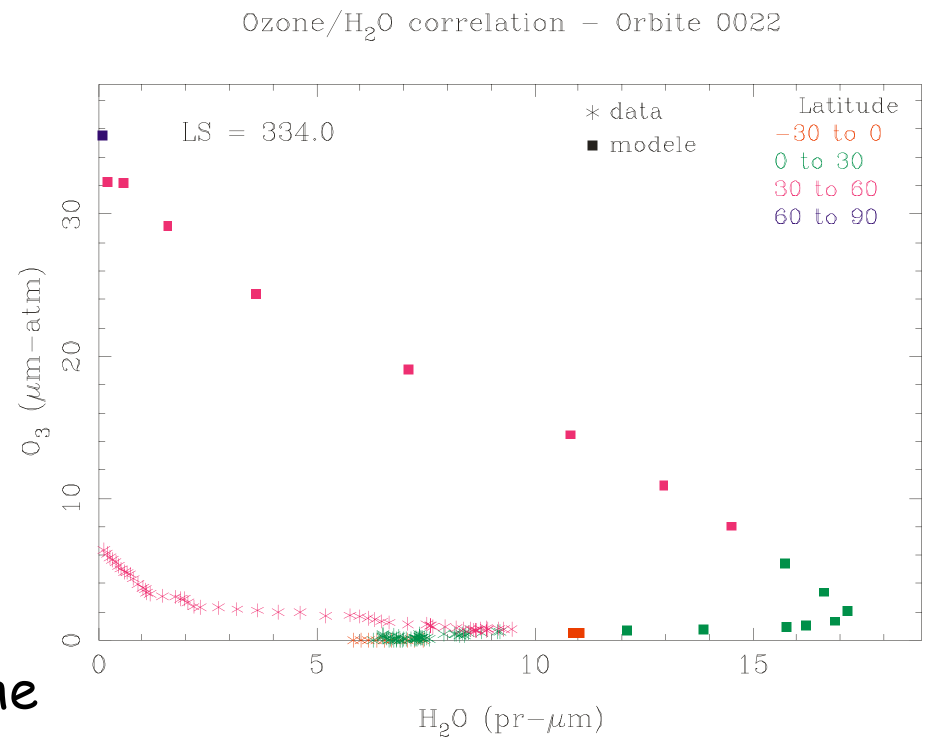
OZONE column density in high altitudes from O_2 emission
No3 (µm−atm)
0
0.1
0.2
0.3
0.4
0.5
0.6
Latitude
90
60
30
0
−30
−60
−90
−30 −20 −10 0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150
L_s

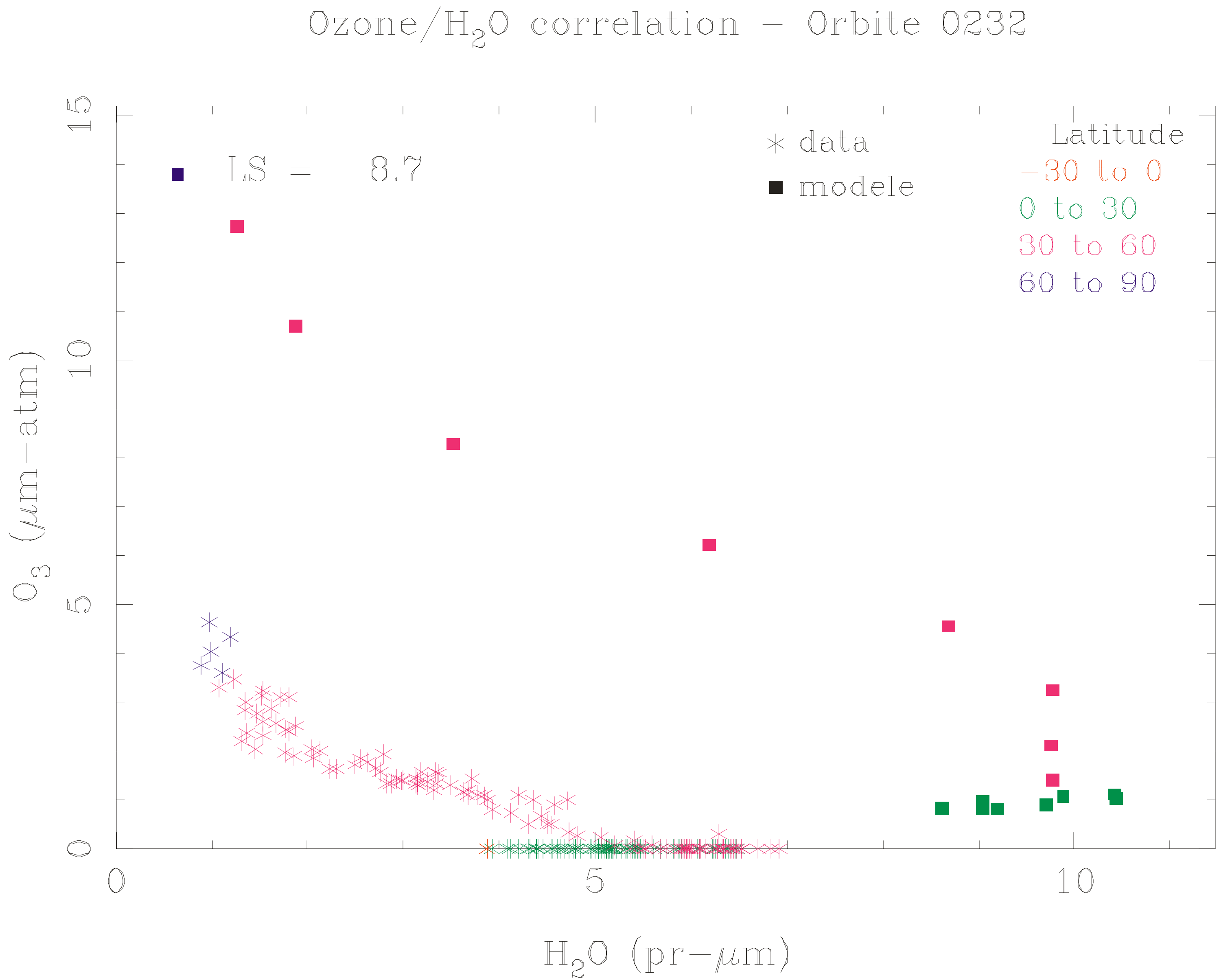


Ozone/H_2O correlation – Orbite 0022
LS = 334.0
data
modele
Latitude
–30 to 0
0 to 30
30 to 60
60 to 90
O_3 (μm–atm)
0
10
20
30
0
5
10
15
H_2O (pr–μm)

LS = 330-360° (NH late winter)

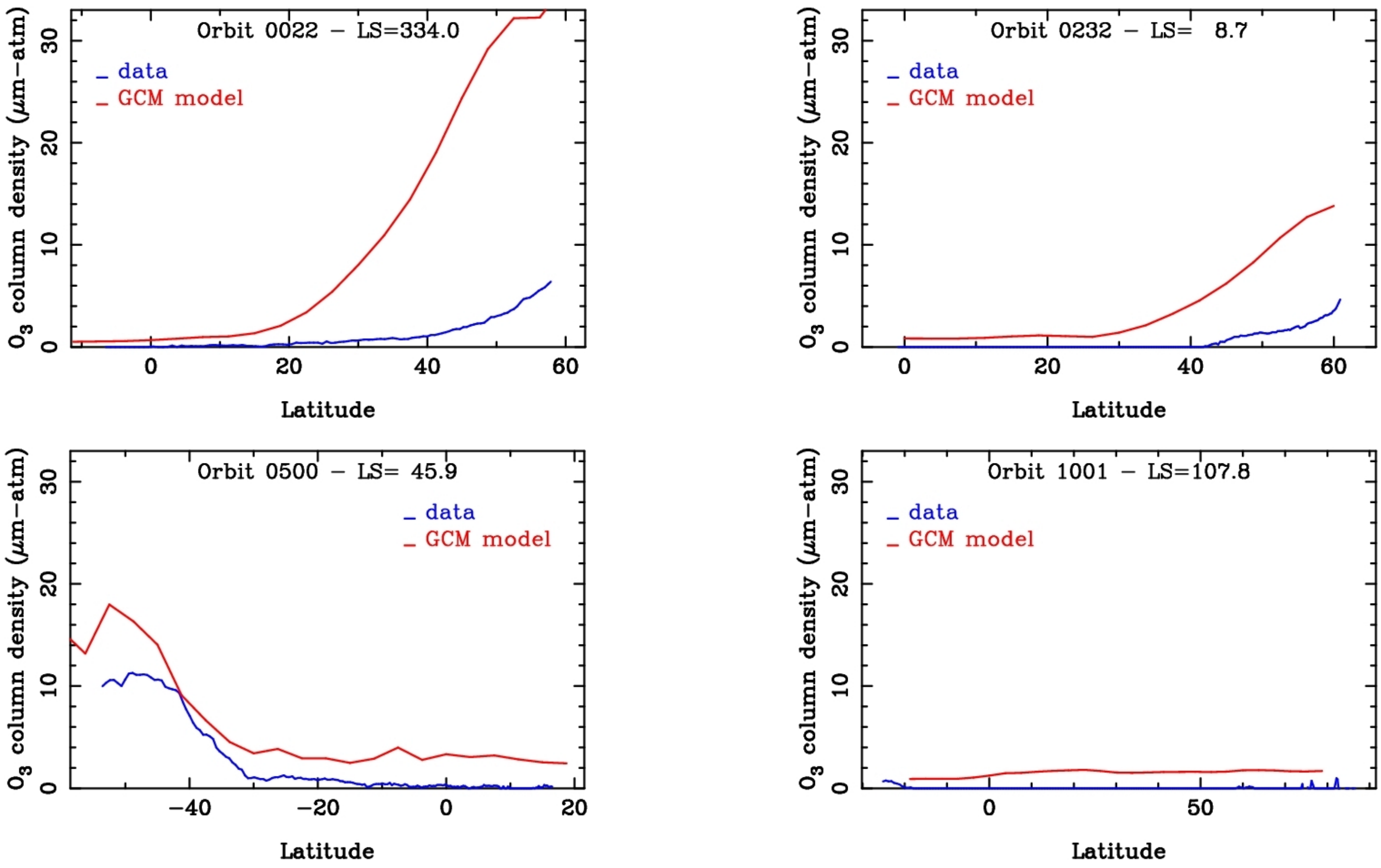
- High discrepency with the model at high latitudes of NH
- Good agreement at equator and southern hemisphere
- Possible interannual variability in the onset of the late summer O3 increase in the SH.





Ozone/H_2O correlation - Orbite 0232
LS = 8.7
⁎ data
■ modele
Latitude
-30 to 0
0 to 30
30 to 60
60 to 90
O_3 (μm-atm)
H_2O (pr-μm)
0
5
10
15
0
5
10

Comparison SPICAM data vs GCM model



Comparison O3 absorption – O2 emission for different LS