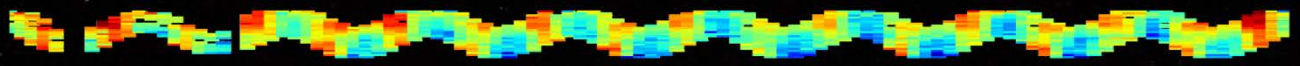
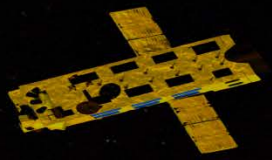
Atomic oxygen in the mesopause region as derived from SCIAMACHY O(^{1}S) green line measurements





Martin Kaufmann, Yajun Zhu, Manfred Ern, Martin Riese
Research Centre Jülich, Germany

Outline

Presentation of a new global dataset of atomic oxygen at the mesopause (80N – 50S, 2003-2012)

Comparison with other measurements (WINDII, SABER, OSIRIS)

A few other characteristics of the dataset, including solar cycle dependence

Motivation

Atomic oxygen is important, because it

- stores and redistributes solar energy (O_2-photolysis, exothermal reactions)
- is involved in chemical reactions + quenching processes
  - deactivation of (vibrationally) excited CO_2, O_3, OH, or NO

→ very important for inversion of SABER or MIPAS data

How to measure atomic oxygen?

- fine structure emissions at 63um and 147 um (Grossmann et al., 2001) (> 120 km)

- Afterglow of O+O recombination (90-130 km)

$$O(^3P) + O(^3P) + M \xrightarrow{\alpha k_1} O_2^* + M$$

$$O_2^* + O(^3P) \rightarrow O_2 + O(^1S)$$

red + green line emissions

$$O_2^* + O_2 \xrightarrow{\gamma k_3^{O_2}} O_2(b^1\Sigma_g^+) + O_2$$

atmospheric bands

- measure $OH^* \leftarrow H + O_3$ and $H + O_3 \leftrightarrow O + O_2 + M$ (80-100 km)

- Photochemical equilibrium with O_3

Photochemical model for nighttime O(^{1}S)

Barth process:

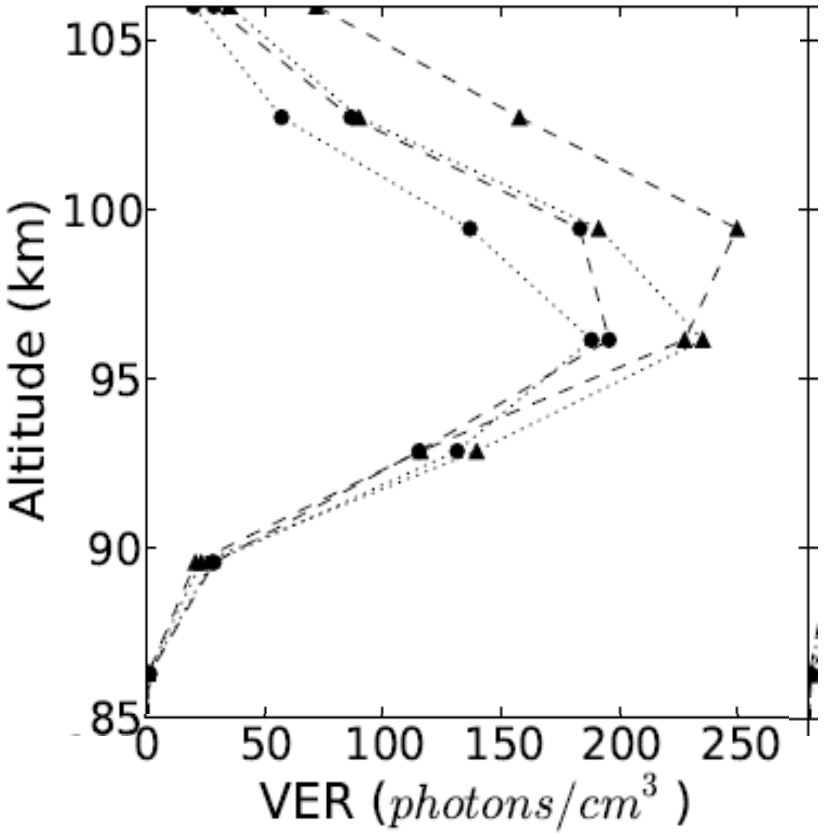
$O+O+M \rightarrow O_2^* + M$

$O_2^* + O \rightarrow O_2 + O(^1S)$

Empirical model of McDade et al [1986]

$$ER = \frac{A_{557.7} k_1 [O]^3 [M]}{[A(^1S) + k_2[O_2]][C^{(1)}[O] + C^{(2)}[O_2]]}$$

ER ≈ O^2 - O^3, depending on altitude

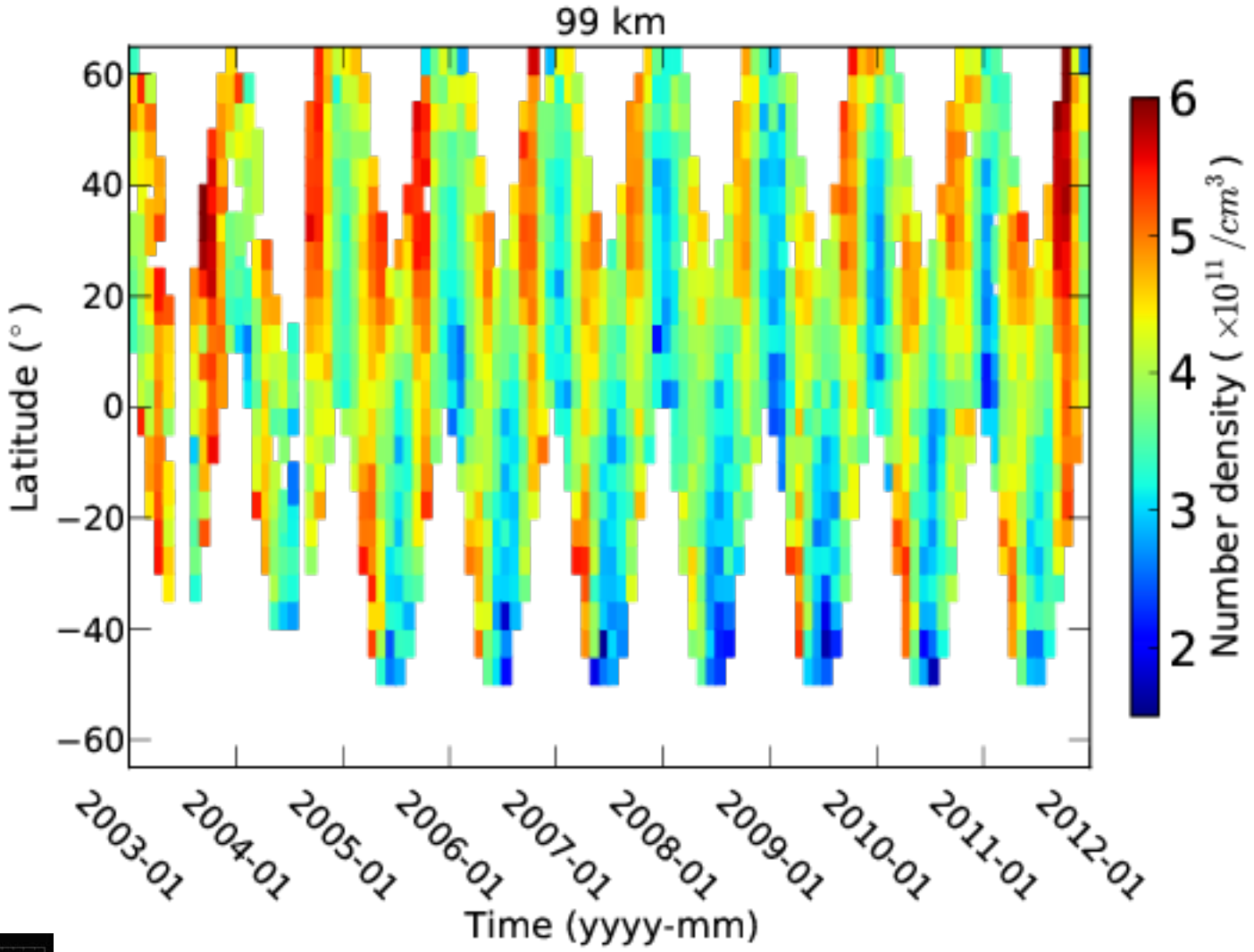


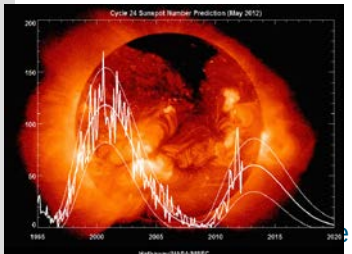
$C^{(1)}$ and $C^{(2)}$ are fit parameters to rocket borne measurements
The O_2 - term considers collisions with N_2 and O_2

SCIAMACHY on Envisat

2002-2012
polar orbit 10am/pm
limb-nadir sounder
emission/scatter/occultation measurements
240-2400 nm

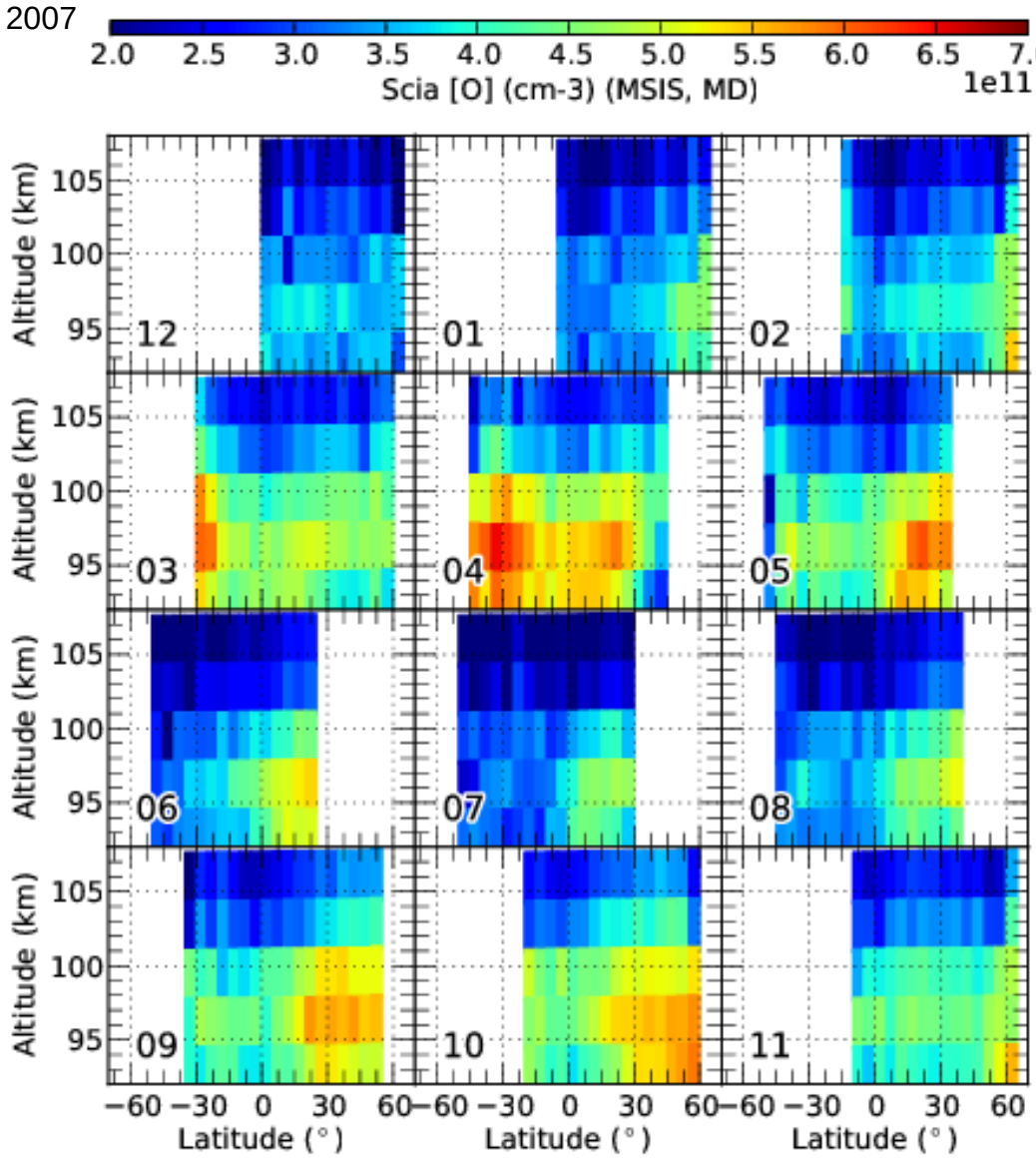
Spatio-temporal distribution of SCIAMACHY data





This pattern is caused by solar illumination and various calibration measurements on the night side of the satellite orbit

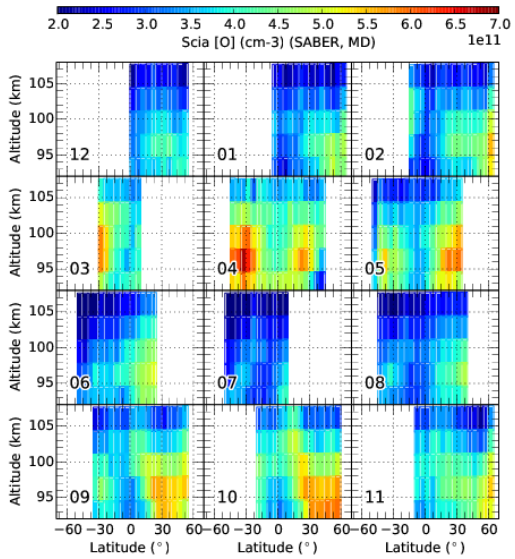
Latitudinal distribution of atomic oxygen densities



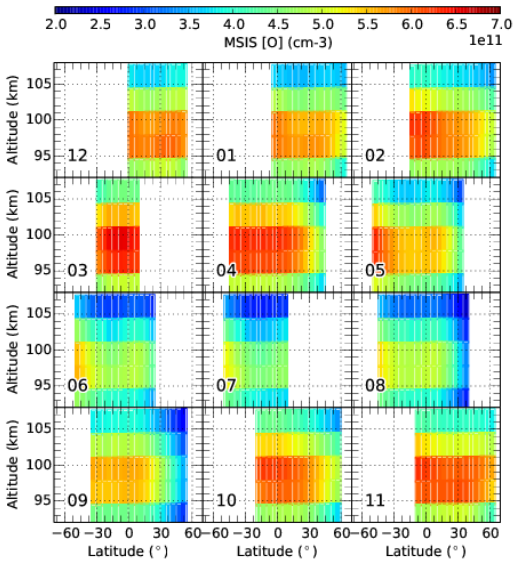
- Max @ 95 km
- [O](equinox) > [O](solstice)
- Max @ mid latitudes
- tides

SCIAMACHY, MSIS, and SABER [O] latitudinal x-sections

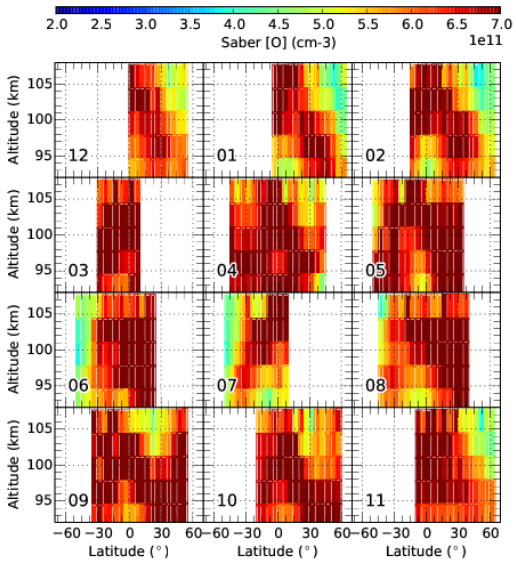
SCIAMACHY



MSIS

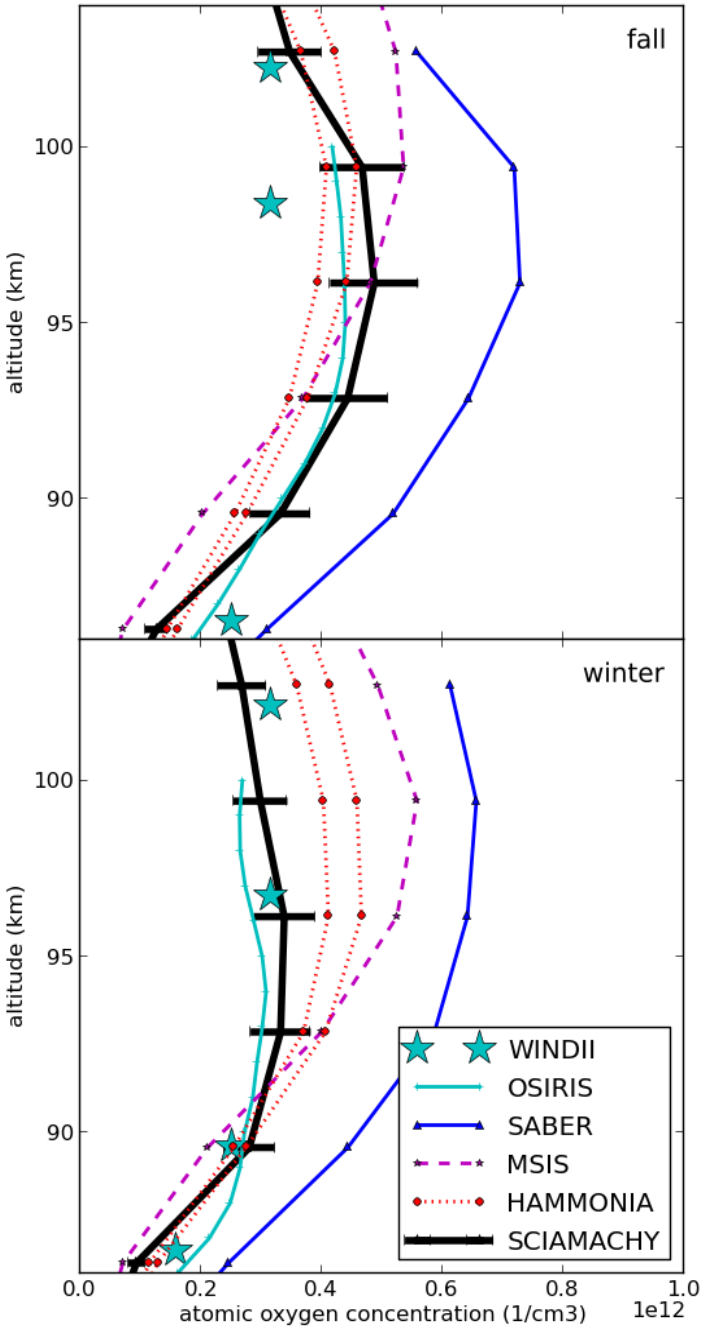


SABER

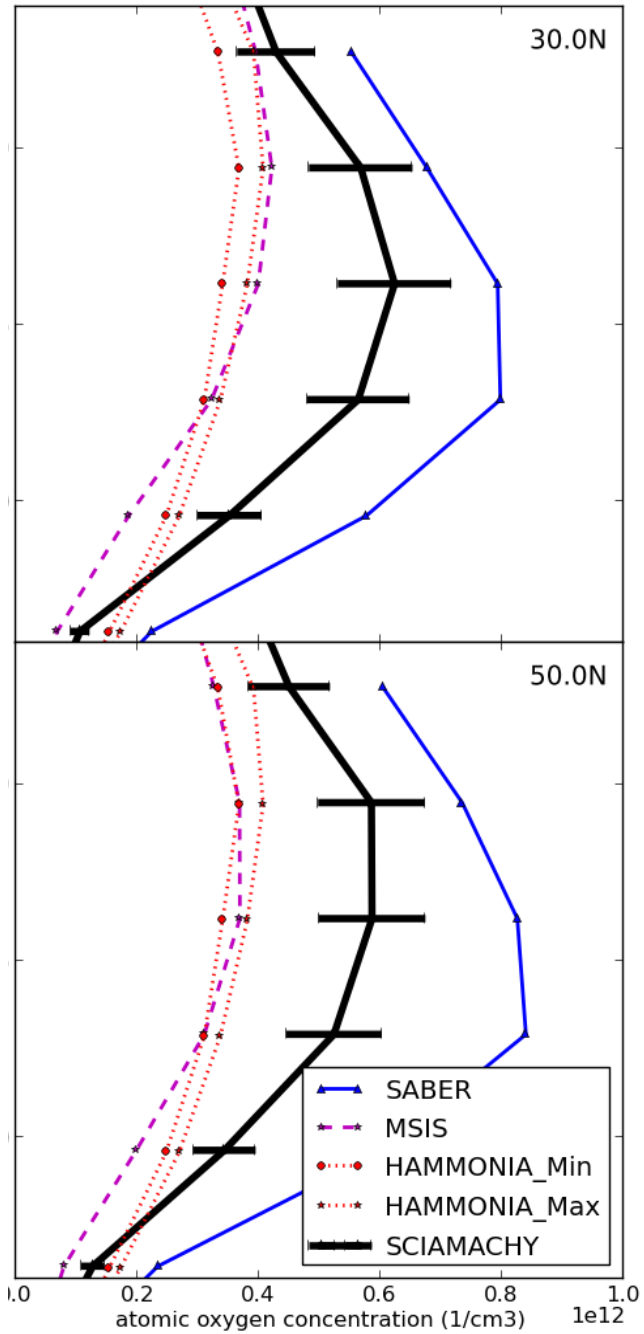


- 2007
- monthly and zonal means at 10 pm
- latitudinal structure caused by atmospheric tides

Equator, fall and winter



30N and 50N, fall



Times:

SCIAMACHY:
2005 or 2005/2006

SABER:
2005 or 2005/2006

OSIRIS:
2005

WINDII:
1993 or 1993/1994

References:

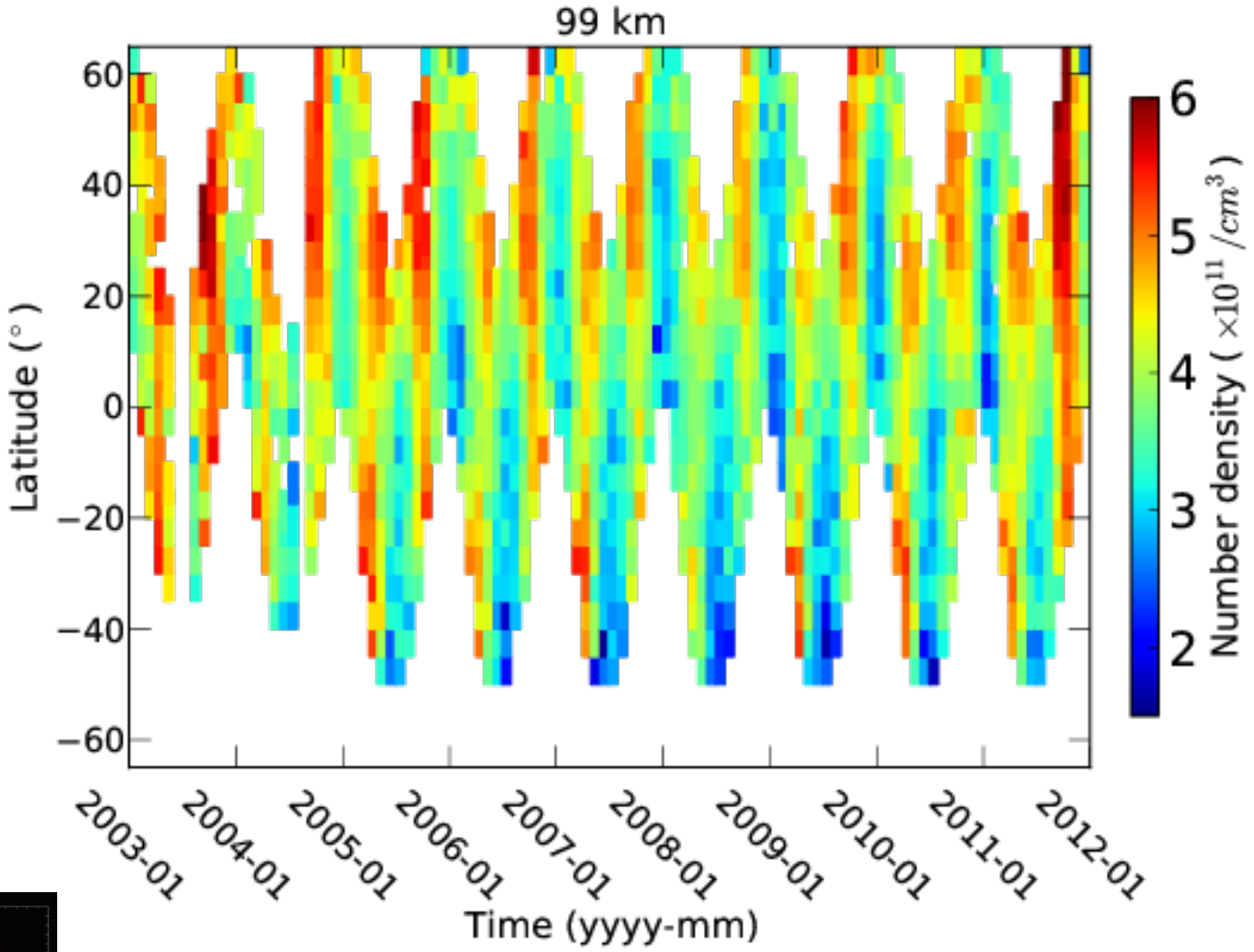
SABER:
Mlynczak et al., 2013

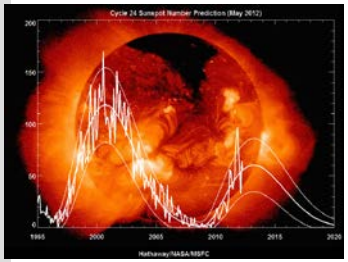
OSIRIS:
Sheese et al. 2011

WINDII:
Russel et al., 2005

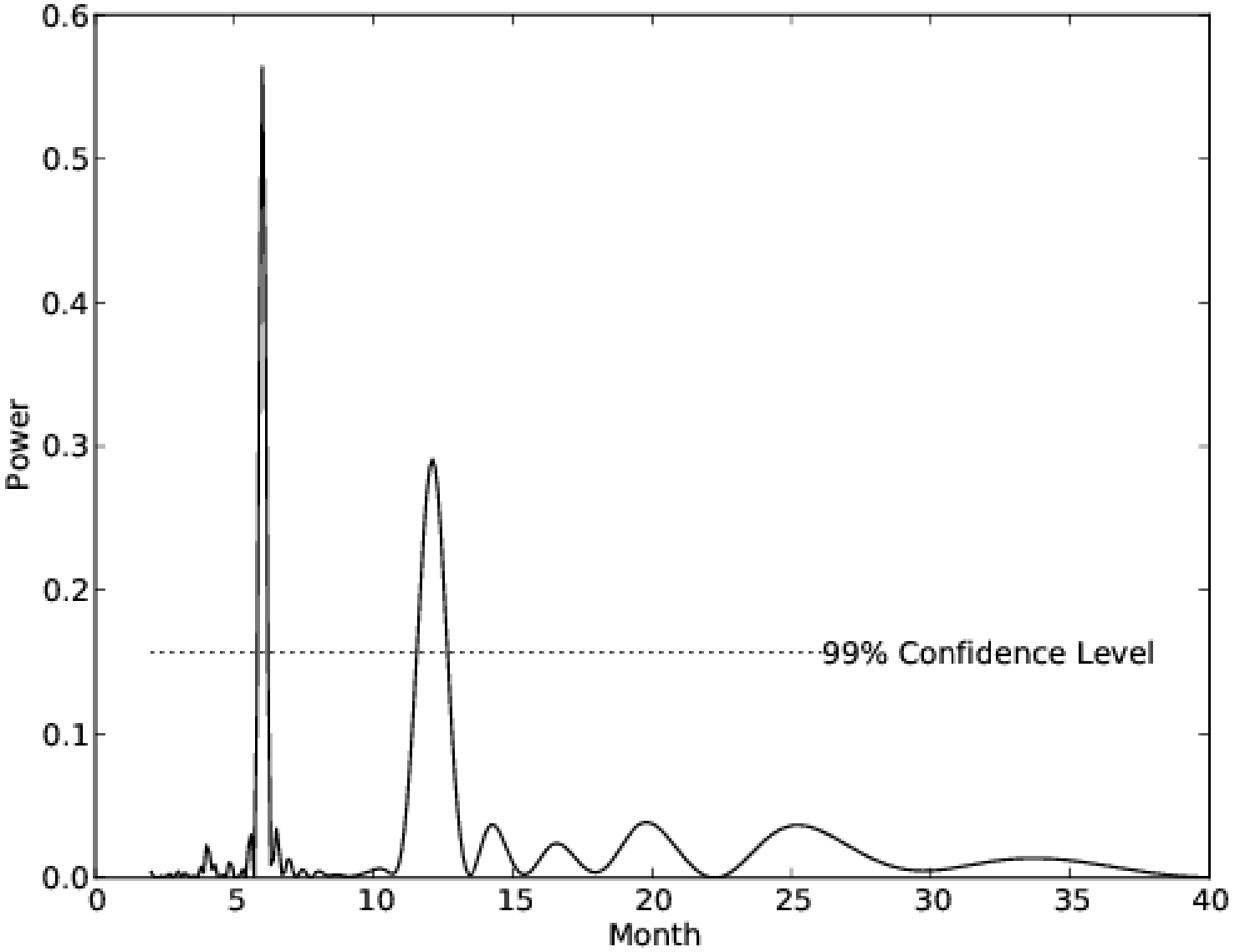
HAMMONIA:
Schmidt, 2006

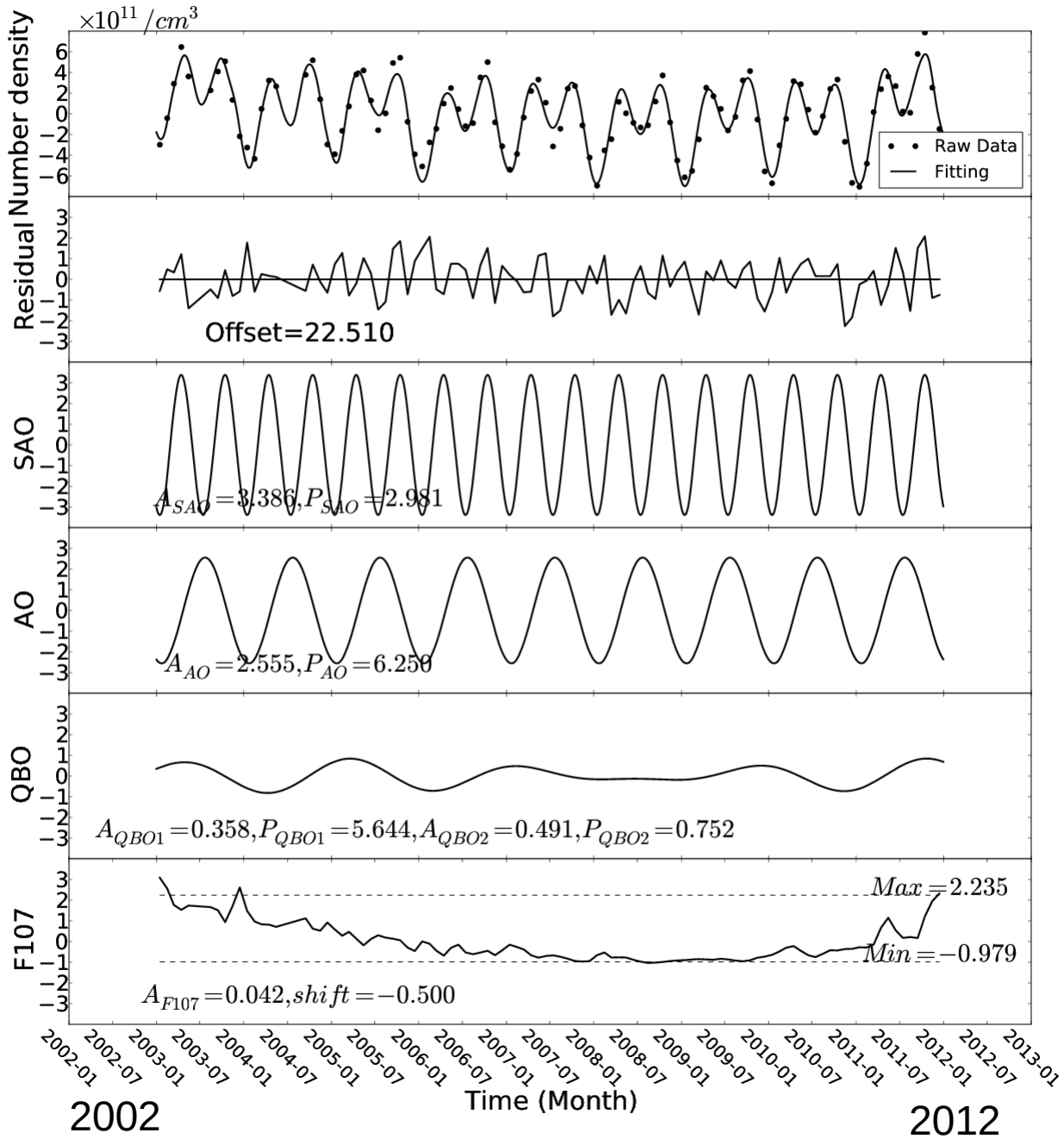
Spatio-temporal distribution of SCIAMACHY data



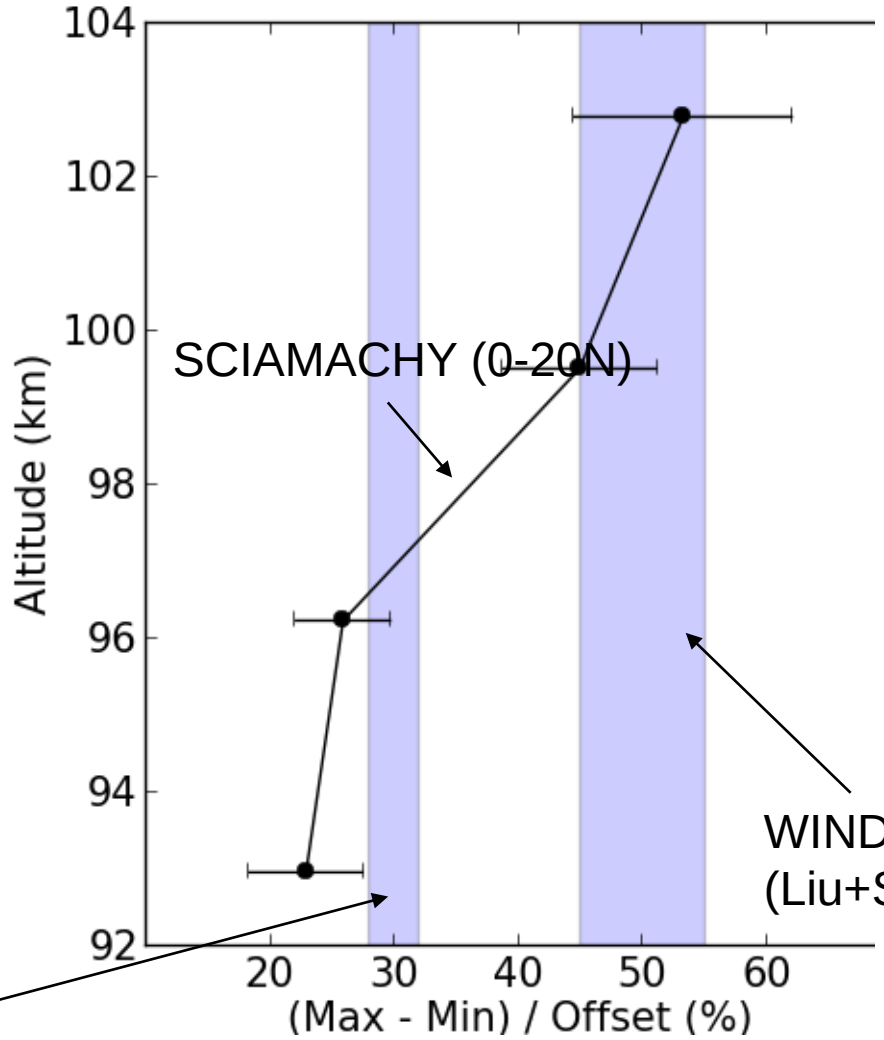


This pattern is caused by solar illumination and various calibration measurements on the night side of the satellite orbit

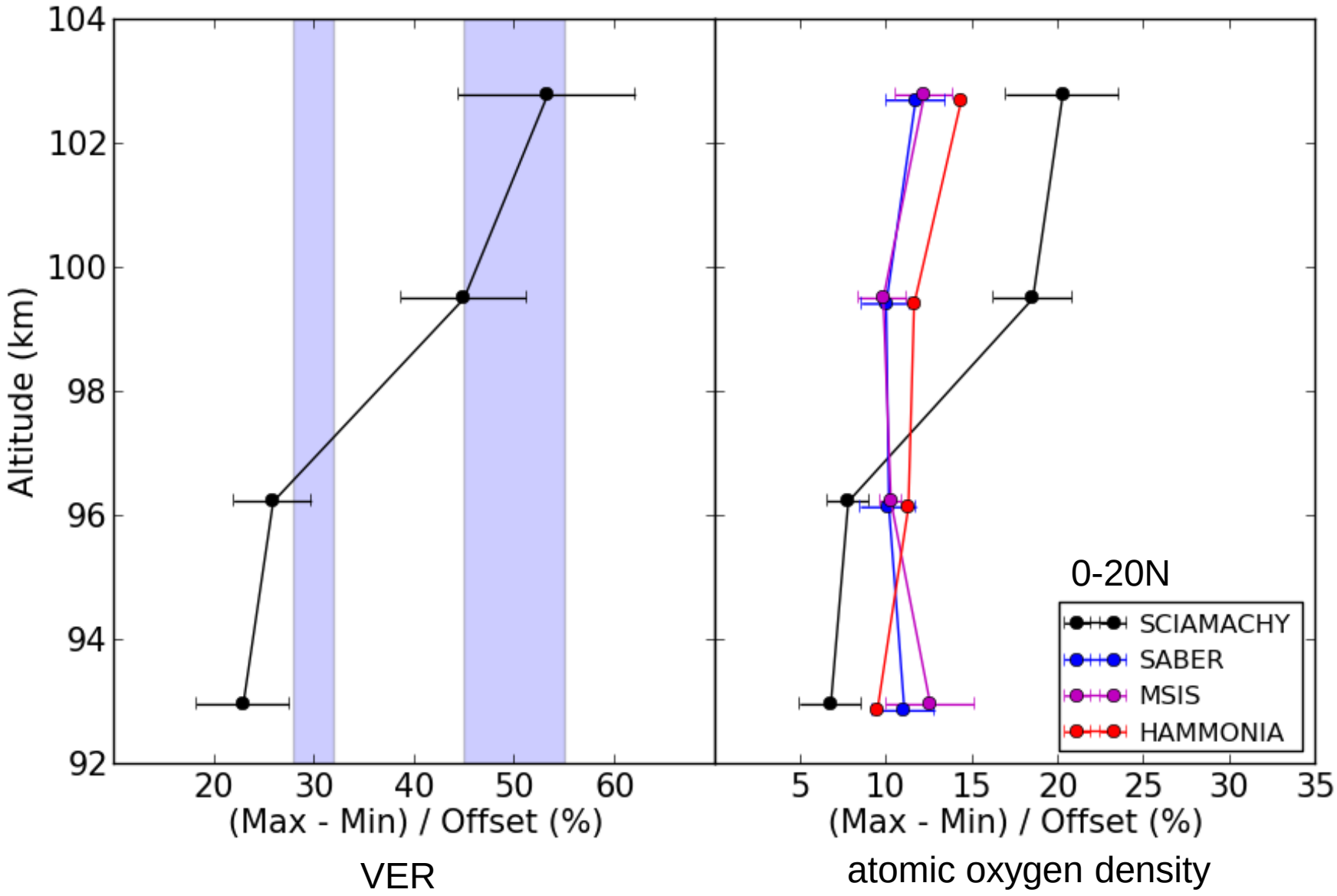

0.6
0.5
0.4
0.3
0.2
0.1
0.0
Power
99% Confidence Level
0
5
10
15
20
25
30
35
40
Month


Residual Number density
$\times 10^{11}\ /cm^3$
Raw Data
Fitting
Offset=22.510
SAO
$A_{SAO}=3.386, P_{SAO}=2.981$
AO
$A_{AO}=2.555, P_{AO}=6.259$
QBO
$A_{QBO1}=0.358, P_{QBO1}=5.644, A_{QBO2}=0.491, P_{QBO2}=0.752$
F107
$Max=2.235$
$Min=-0.979$
$A_{F107}=0.042, shift=-0.500$
2002-01
2002-07
2003-01
2003-07
2004-01
2004-07
2005-01
2005-07
2006-01
2006-07
2007-01
2007-07
2008-01
2008-07
2009-01
2009-07
2010-01
2010-07
2011-01
2011-07
2012-01
2012-07
2013-01
2002
Time (Month)
2012

11 yr solar max-min difference, VER



11 yr solar max-min difference, atomic oxygen density



Summary

New global dataset of atomic oxygen at 90-105 km, 50S-60N

Absolute values:

- similar to WINDII and OSIRIS measurements
- SABER data is significantly larger (up to 50%)
- models differ up to 40% (smaller or larger)

11 yr solar cycle dependence:

- 7-20%, altitude dependent