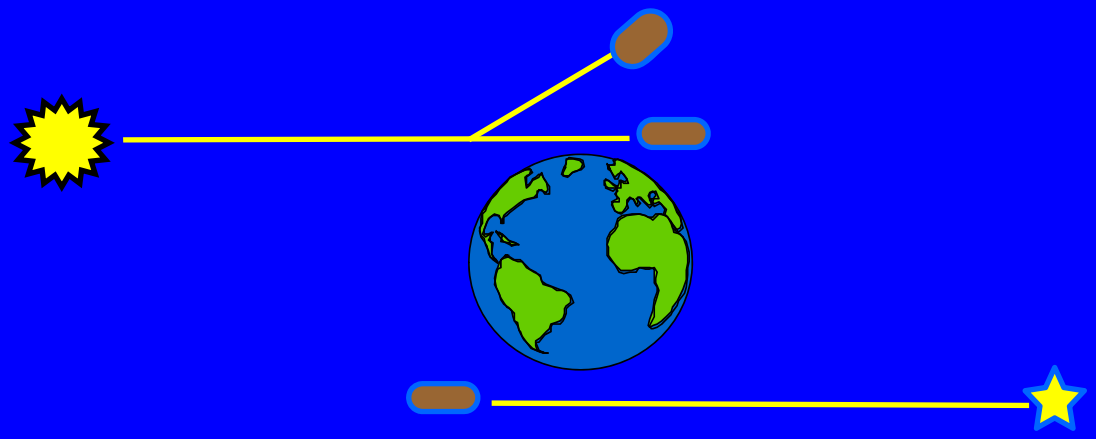


Ozone Time Series and Trend Analysis from SAGE II, OSIRIS and GOMOS Measurements

Kyrölä, E., Laine, M., Sofieva, V., Tamminen, J.

Finnish Meteorological Institute

Zawodny, J., Thomason, L.

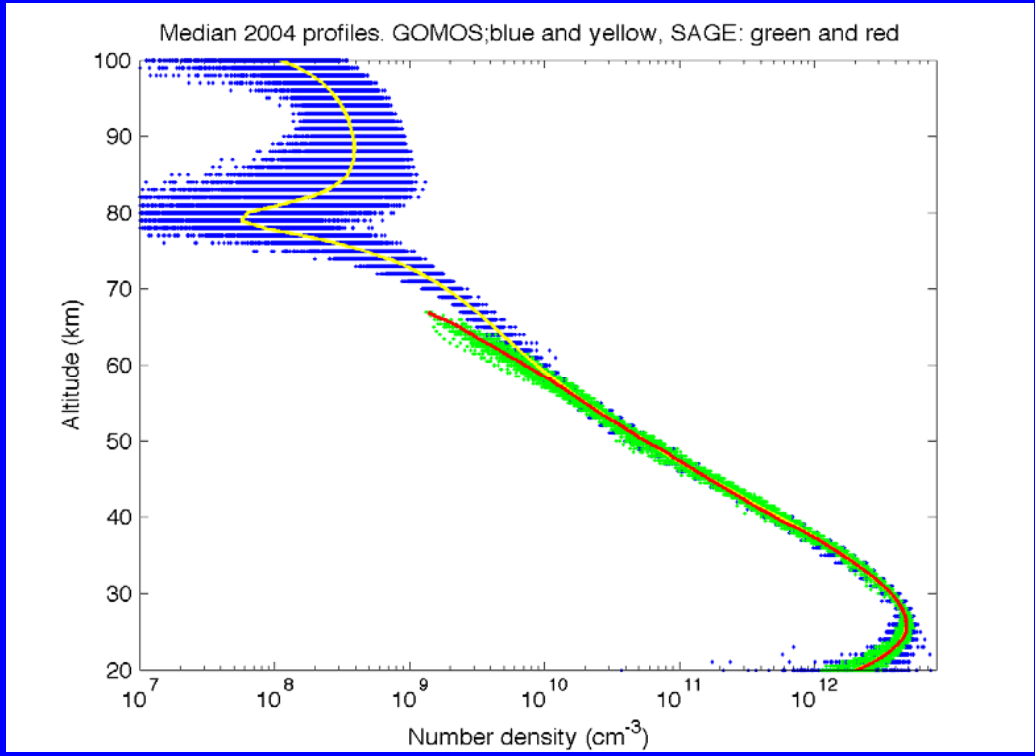
NASA Langley Research Center

Adams, C., Degenstein, D., Bourassa, A., Sioris, C.

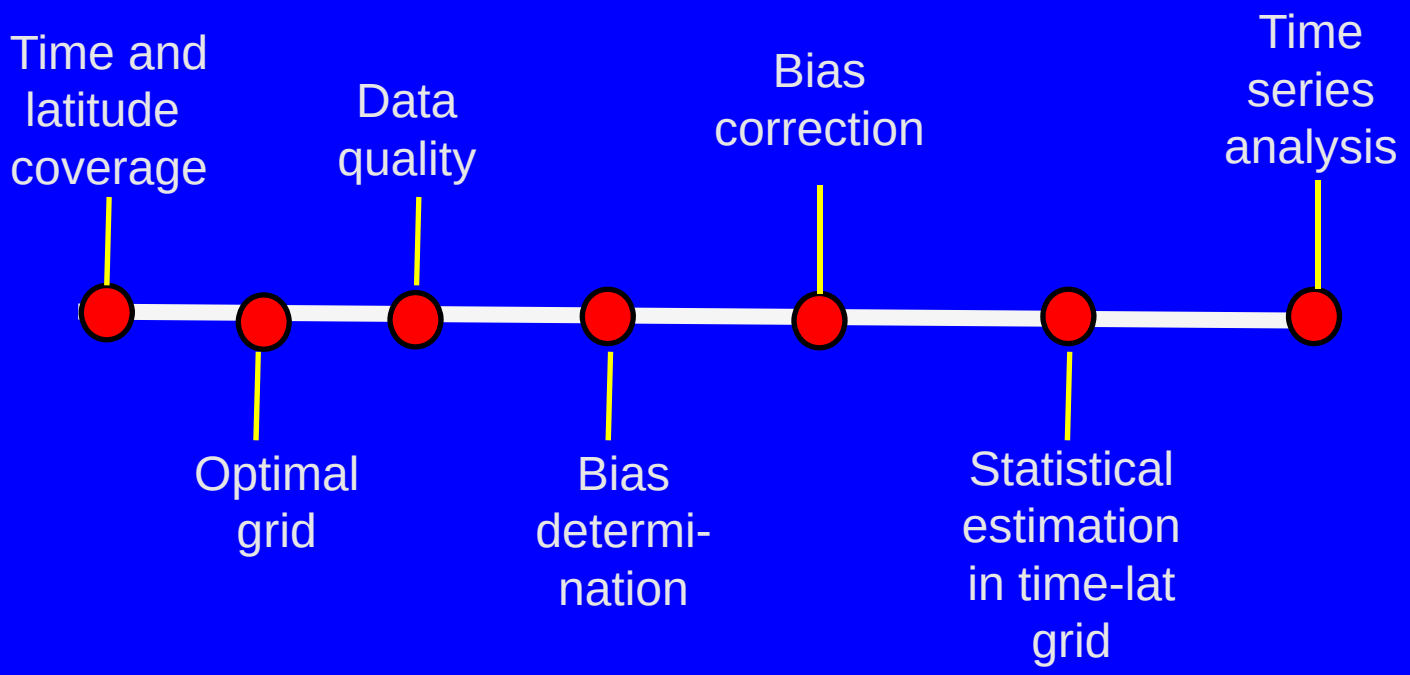
University of Saskatchewan

Contents

1. SAGE II-GOMOS time series
2. SAGE II-OSIRIS time series
3. From the hockey stick to a garden hose

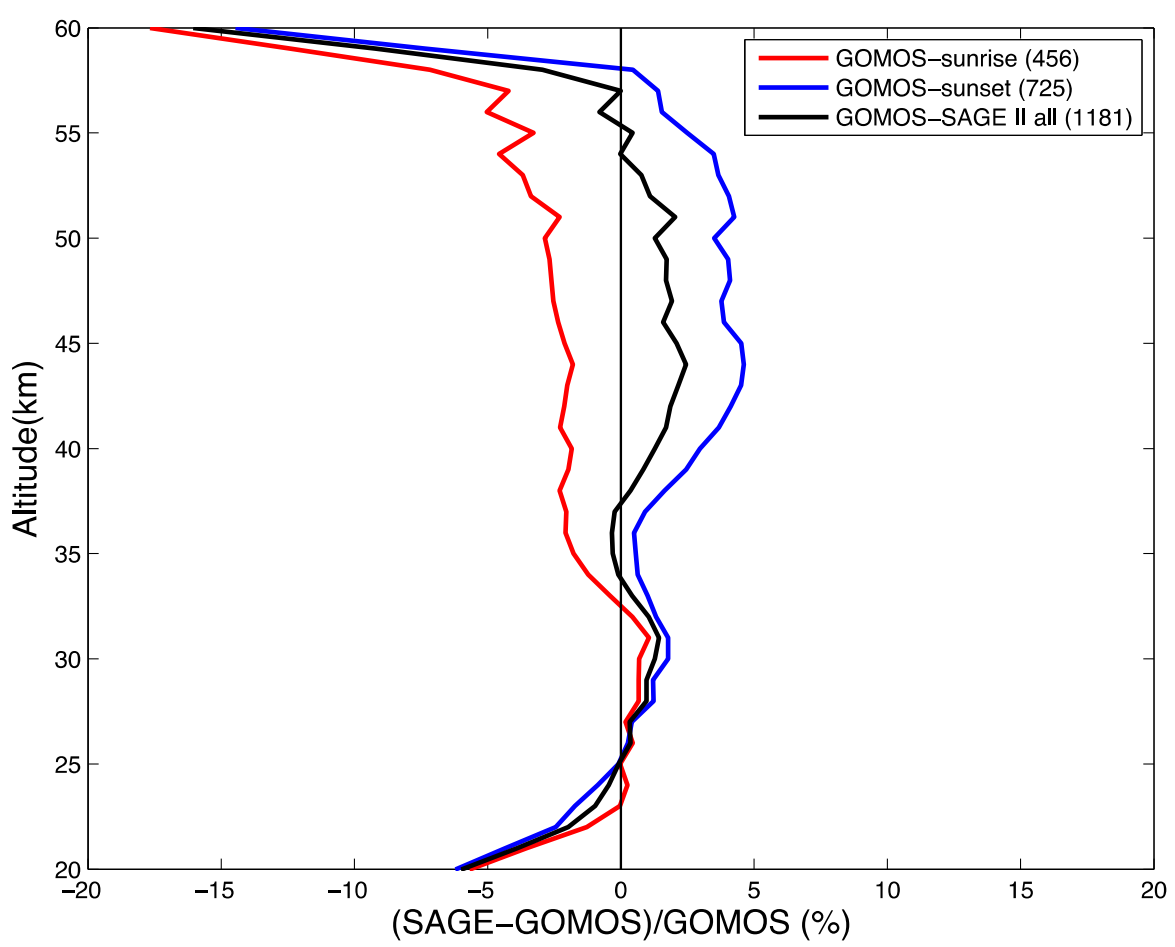


Steps for a common time series

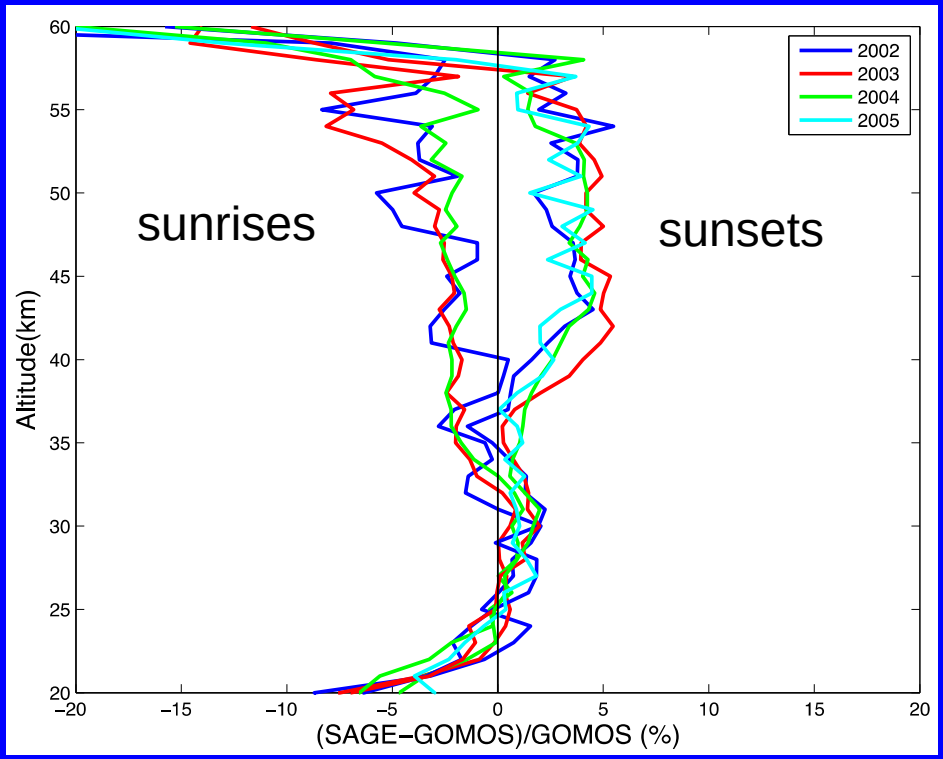


Comparison of SAGE II and GOMOS from collocated measurements during 2002-2005

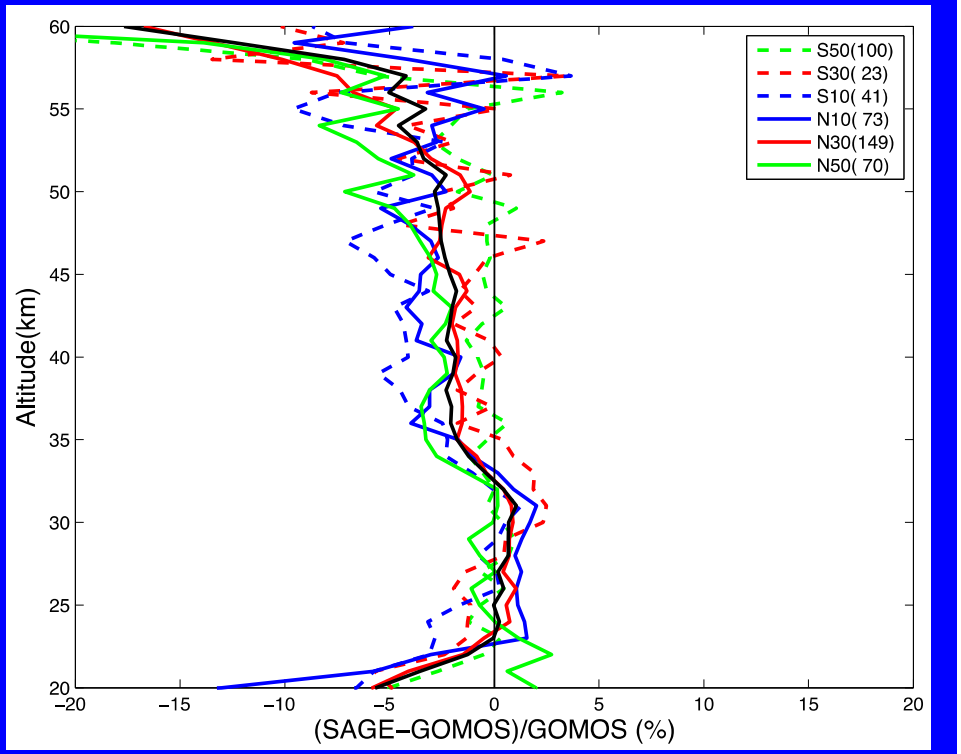
lat. diff<2 deg
lon. diff. <10 deg
time diff. < 12 h



Yearly development



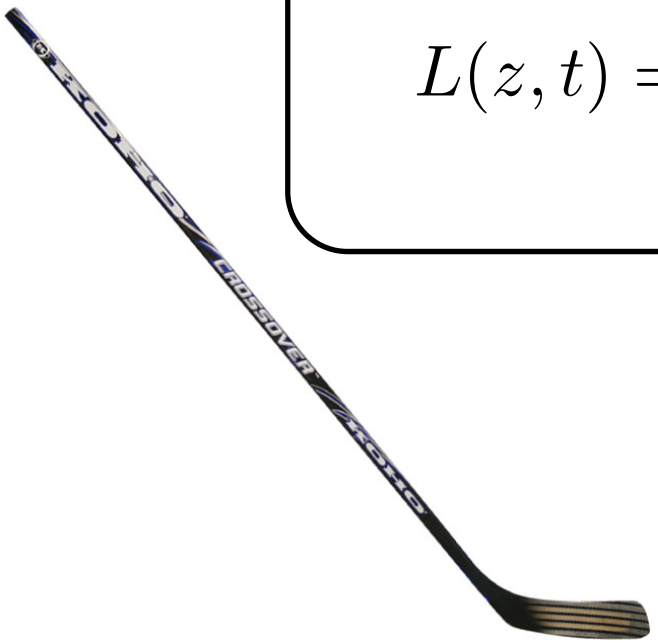
Latitudinal dependence of sunrises



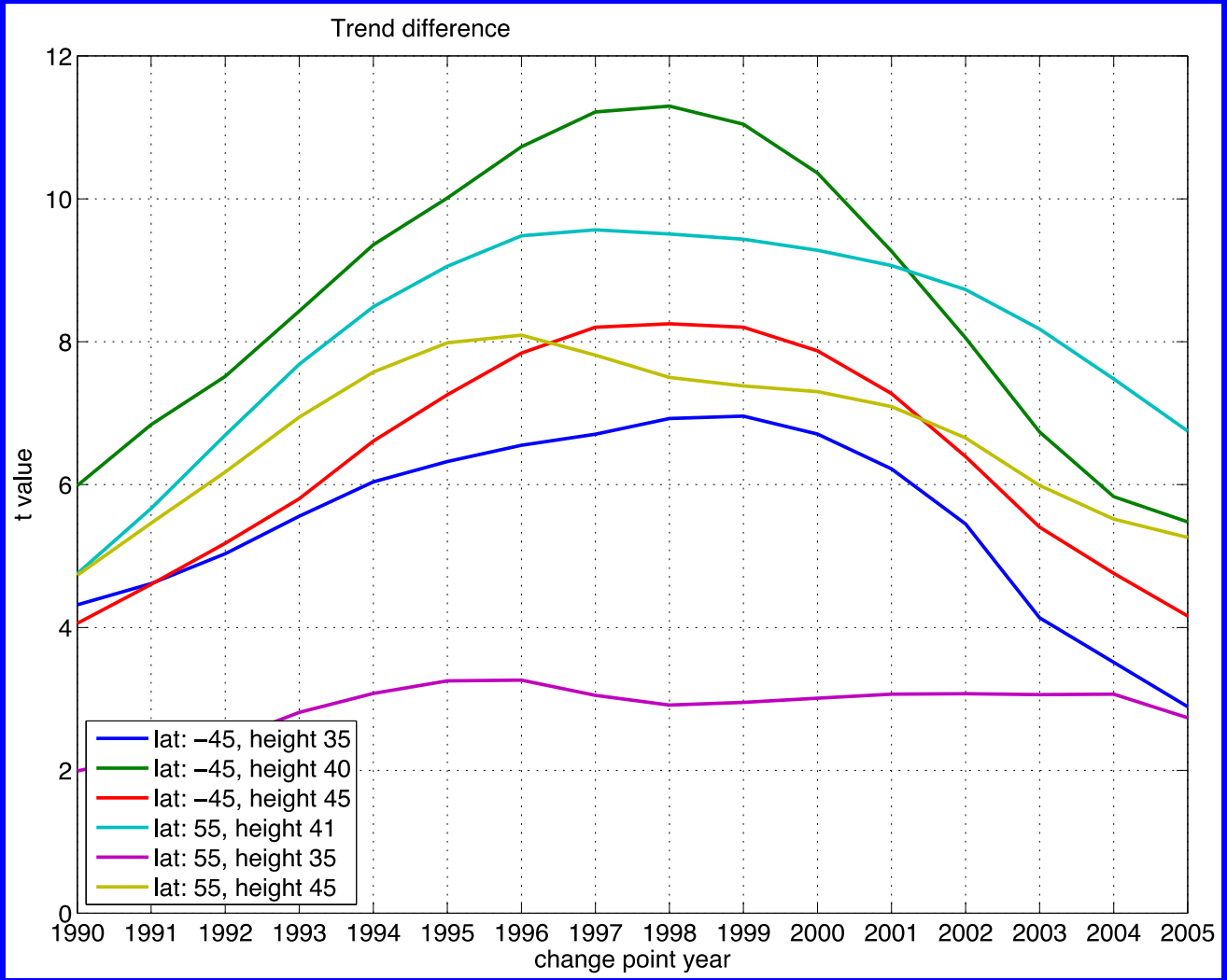
Time series analysis

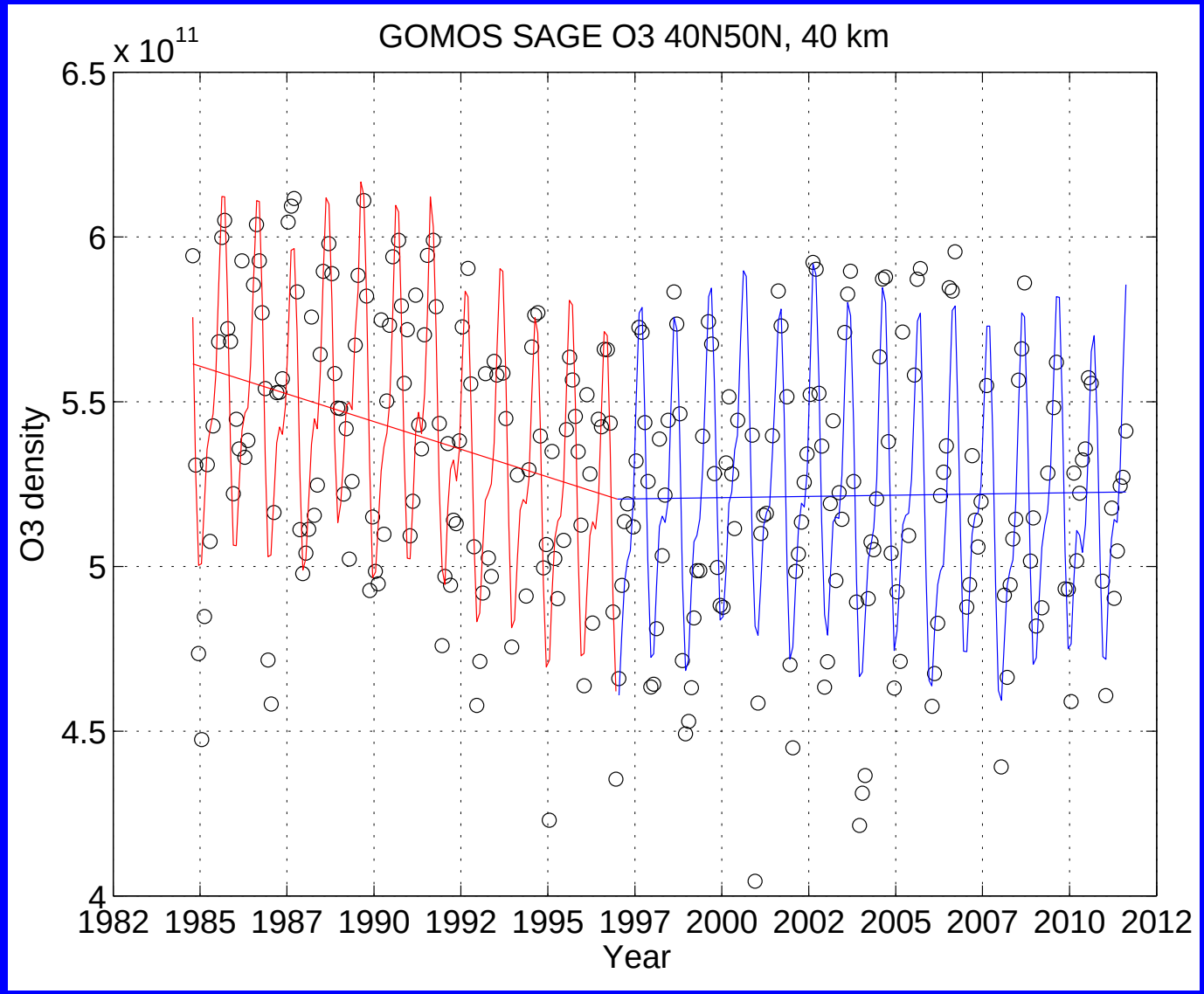
$$\rho^{\mathrm{fit}}(z,t) = c(z) + L(z,t) + s(z)F_{10.7}(t) + q_1(z)F^{10}_{qbo}(t) + q_2(z)F^{30}_{qbo}(t) + \sum_{n=1}^{2}(a_n(z)\cos(nwt) + b_n(z)\sin(nwt))$$

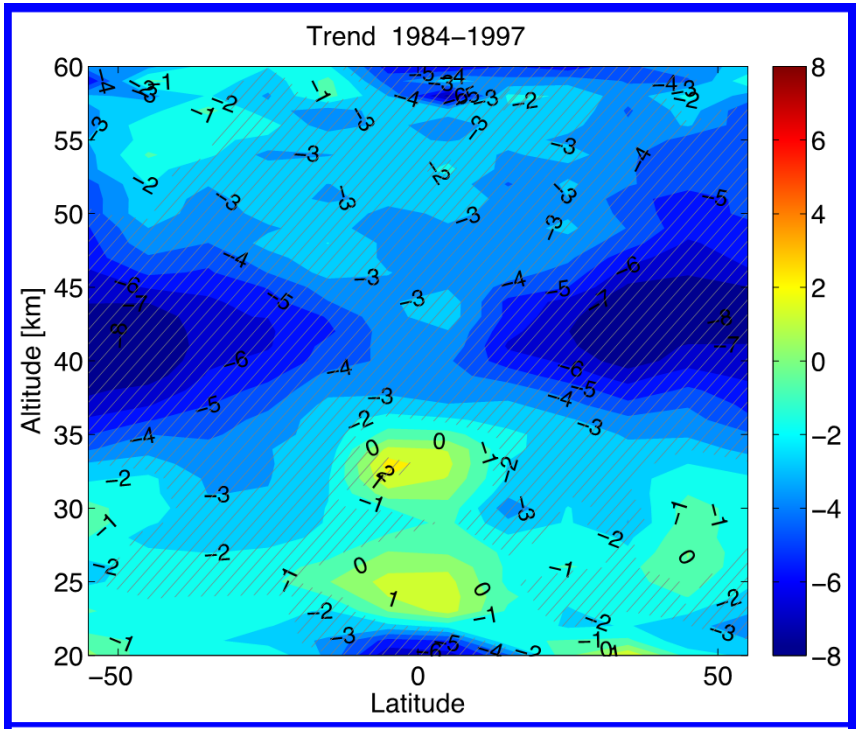
$$L(z,t) = \begin{cases} d_1(z)(t-t_c) & \text{if } t < t_c \\ d_2(z)(t-t_c) & \text{if } t \geq t_c \end{cases}$$

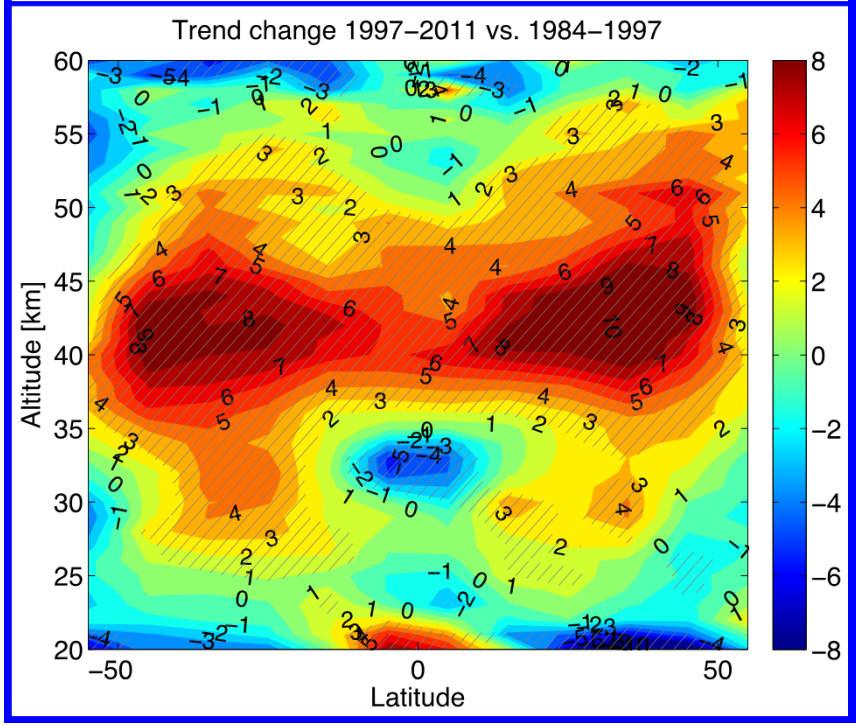


Determine turning point from data



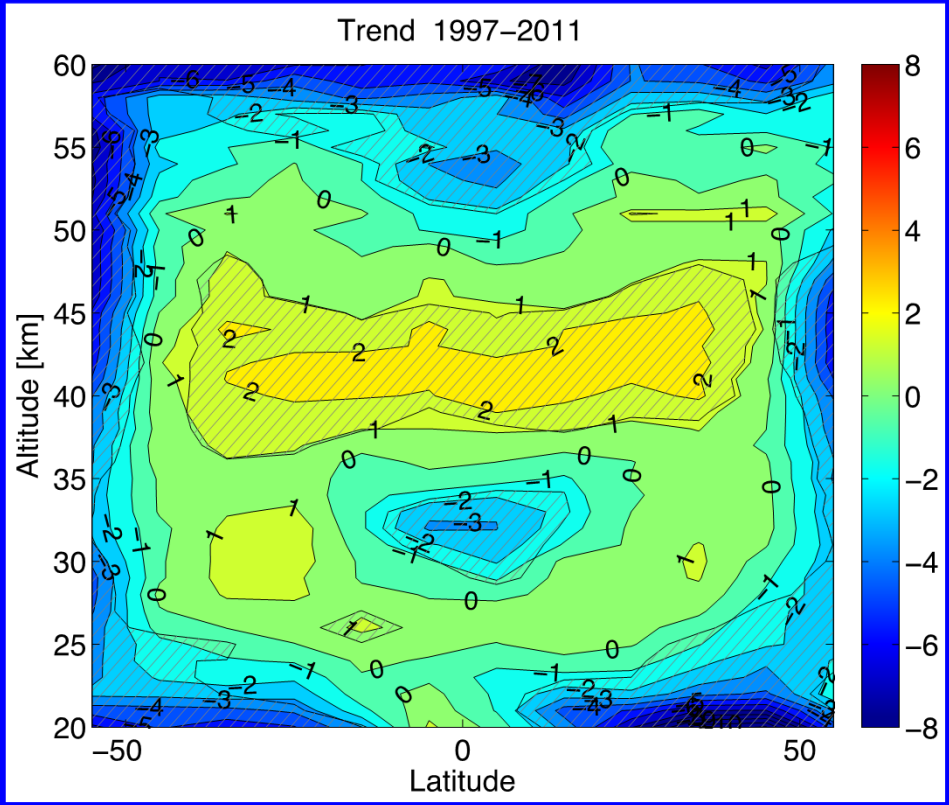

GOMOS SAGE O3 40N50N, 40 km
x 10^11
6.5
6
5.5
5
4.5
4
O3 density
1982 1985 1987 1990 1992 1995 1997 2000 2002 2005 2007 2010 2012
Year





1984-1997: Severe ozone losses

1997-2011: Ozone has started to recover

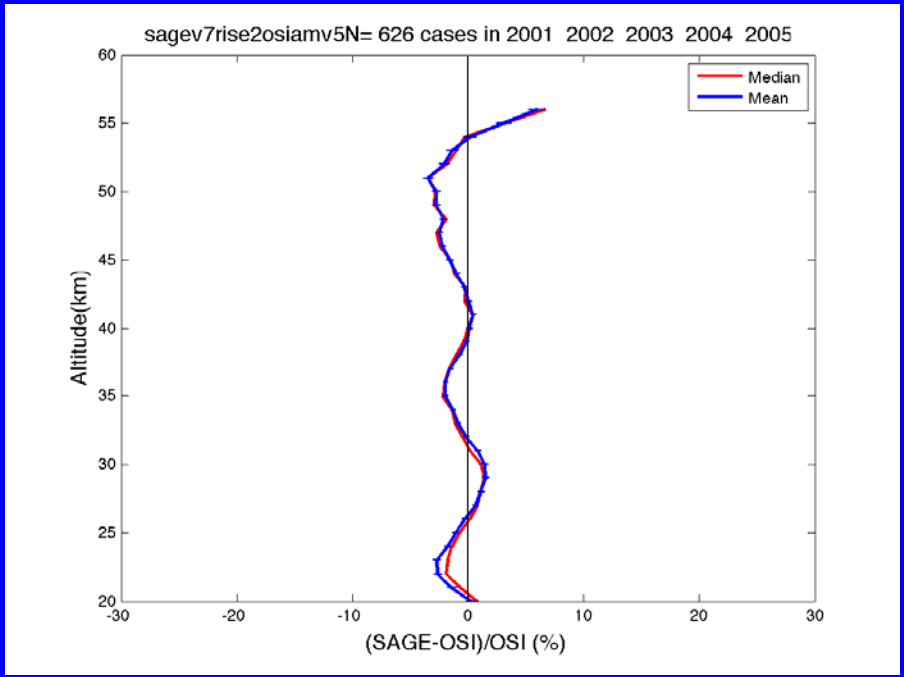


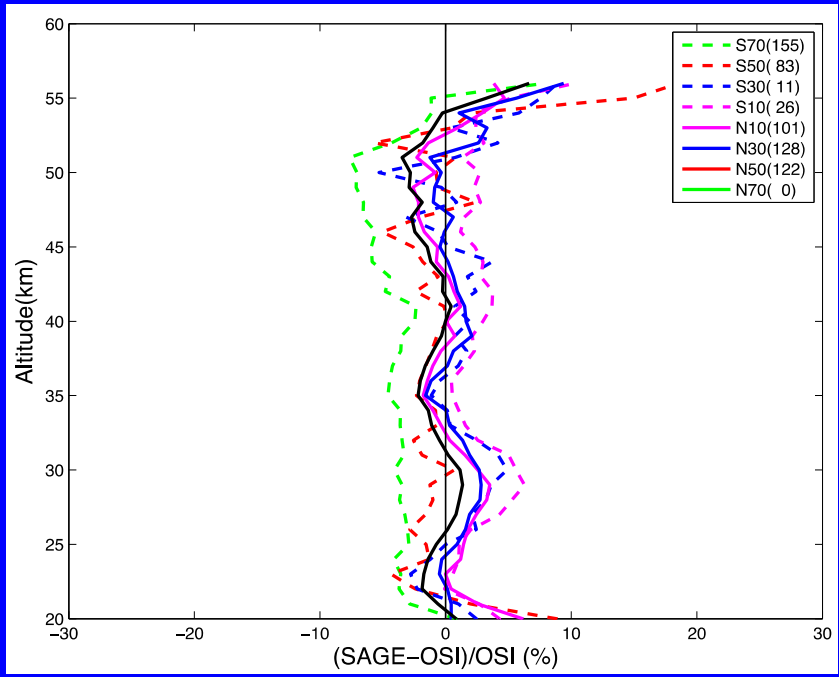
Change of trends

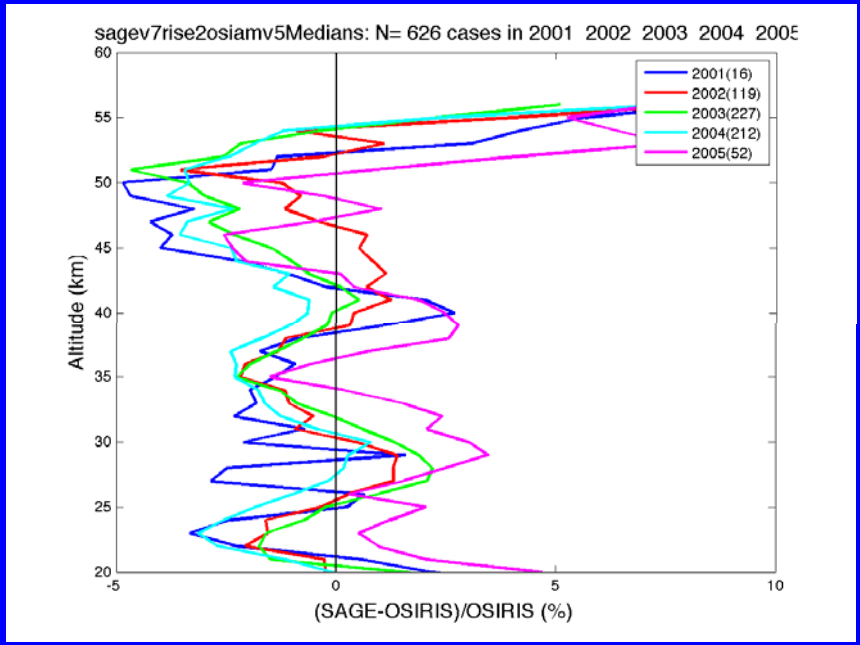
SAGE II and OSIRIS

Only OSIRIS AM has a good coverage

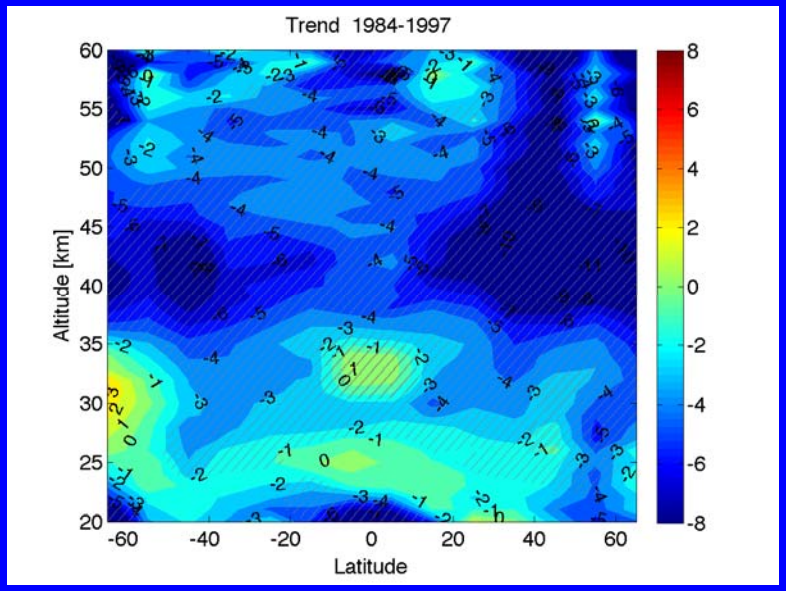
SAGE II sunrises vs OSIRIS AM

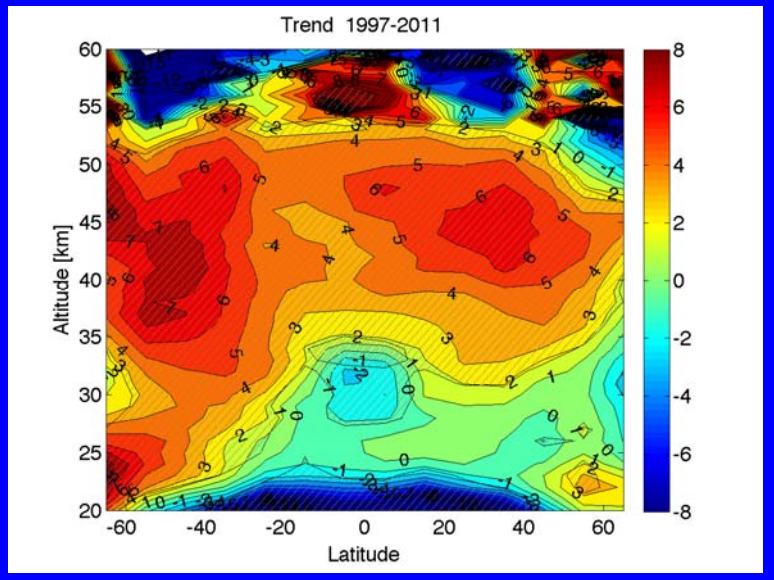




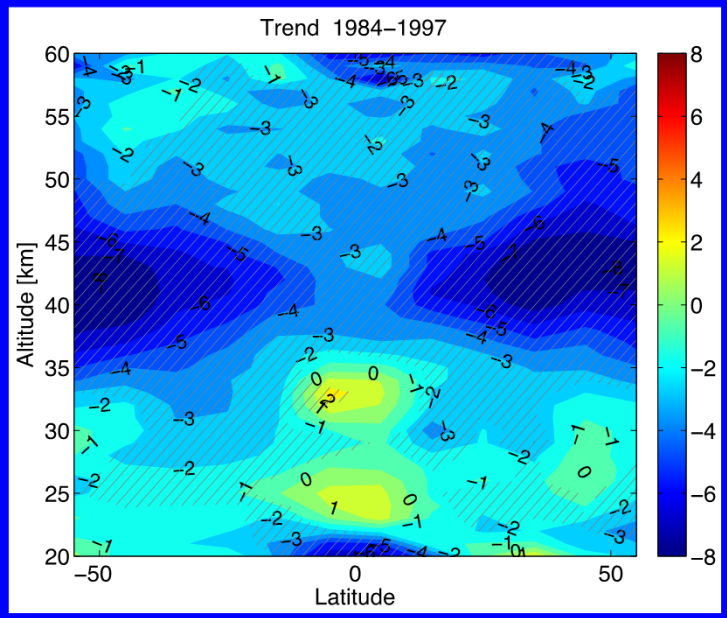


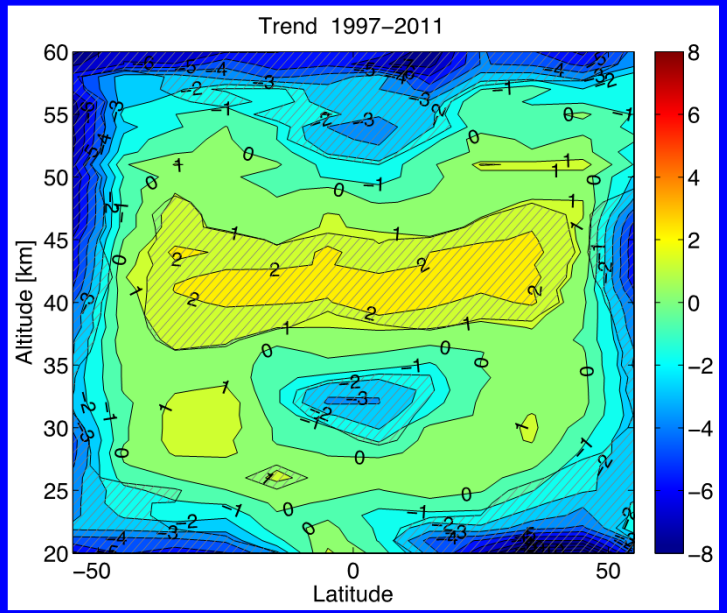
Results for SAGE II 1984-2005 and OSIRIS 2001-2011





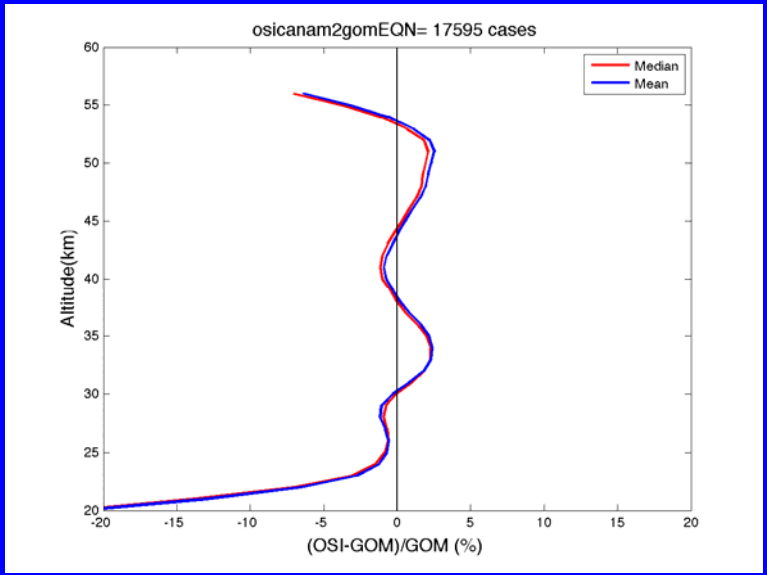
SAGE II and GOMOS

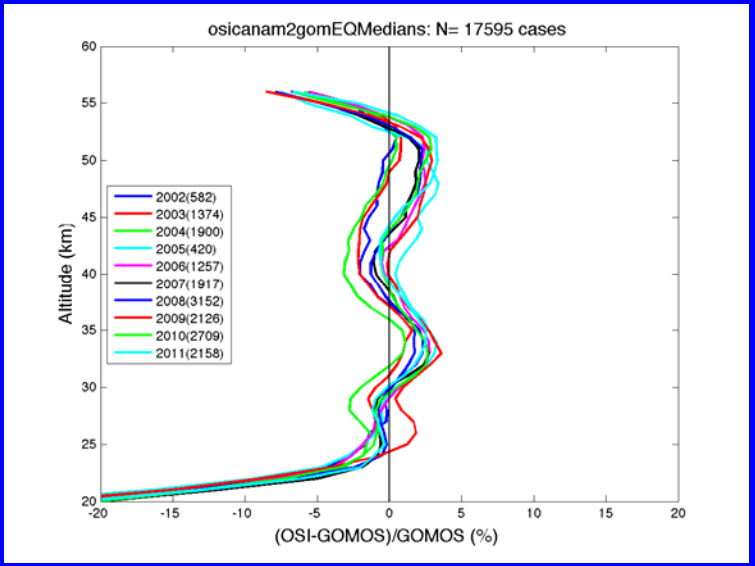




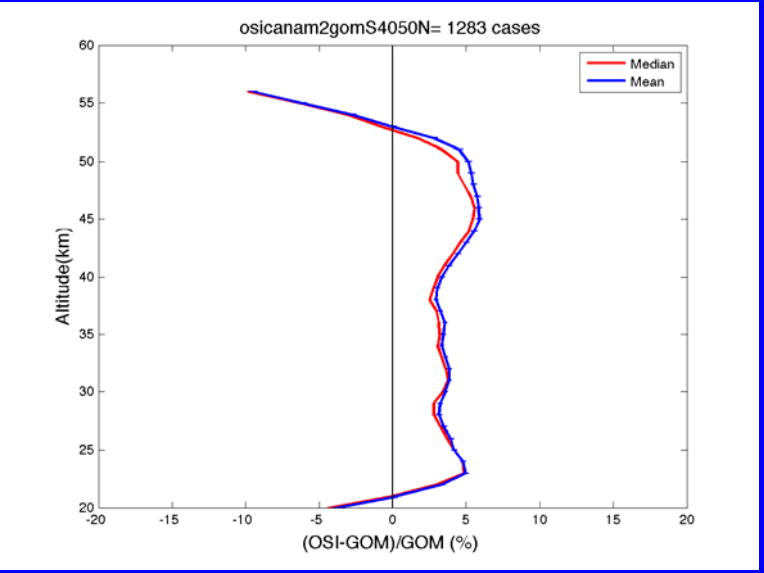
How about OSIRIS vs GOMOS in collocations?

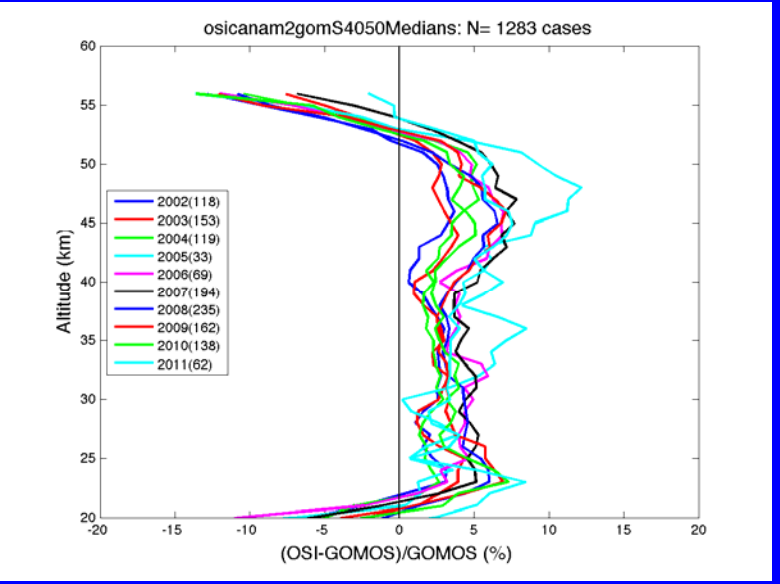
EQ





40S-50S

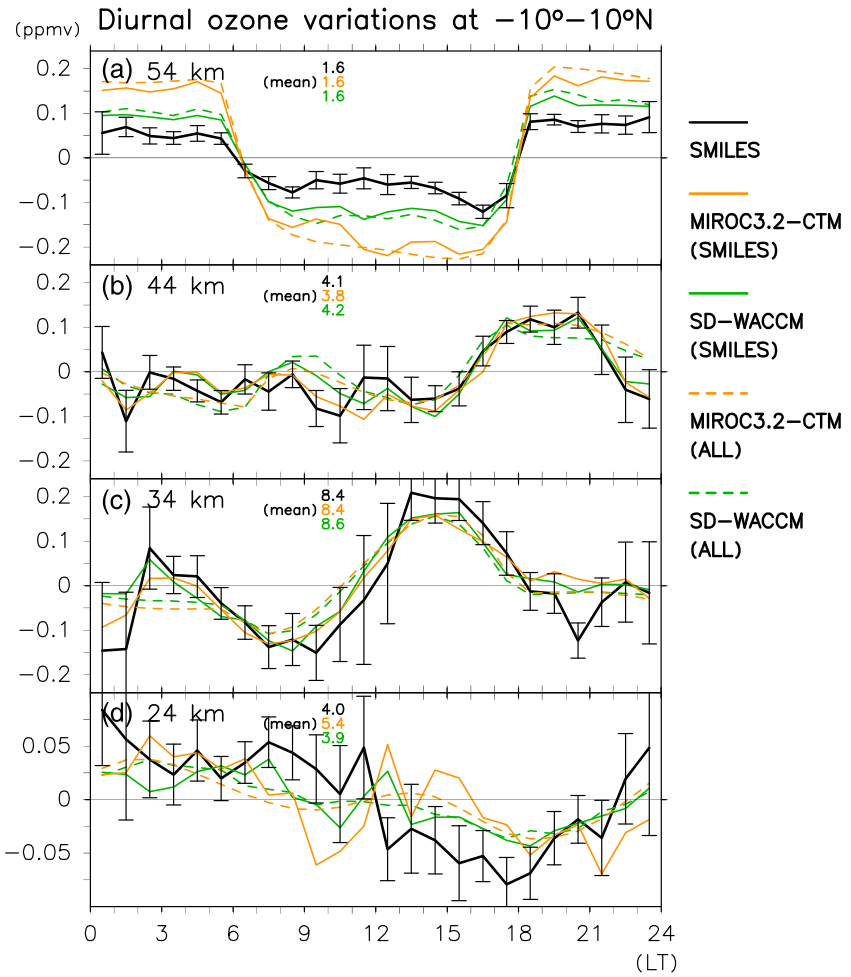




Why collocated measurements differ?

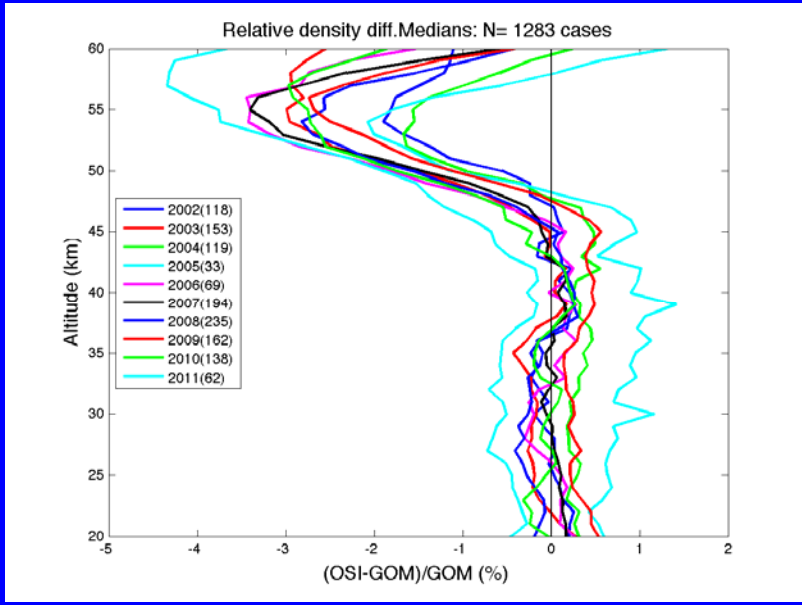
- Instrument does not measure correctly (ageing, calibration)
- Data handling is not accurate enough (Interfering species
- Local hour of the measurement
- Cross sections
- A priori data: temperature (cross sections), neutral density (Rayleigh)
- Local averaging differences

OSIRIS local time has changed by 1 h during the mission
Diurnal variation of ozone



Sakazaki et al., JGR, 2013

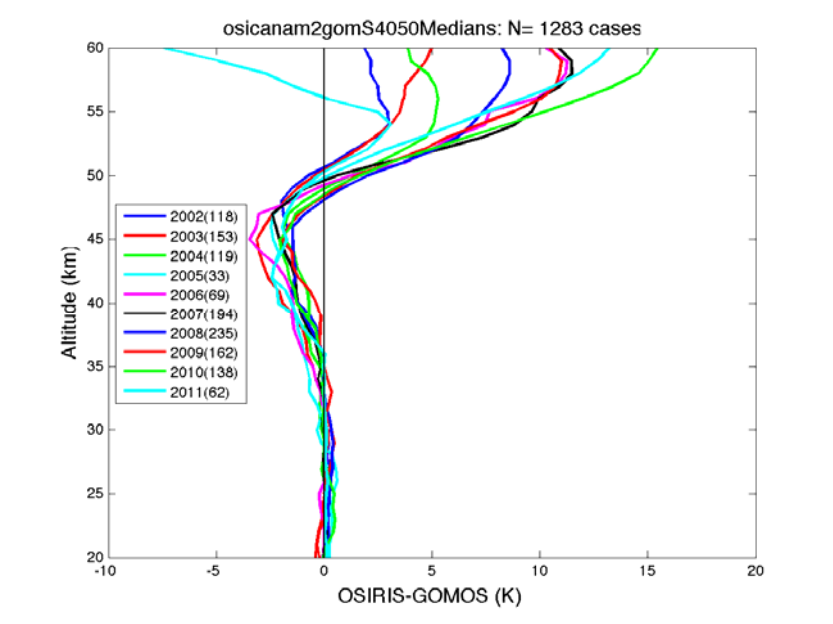
Density



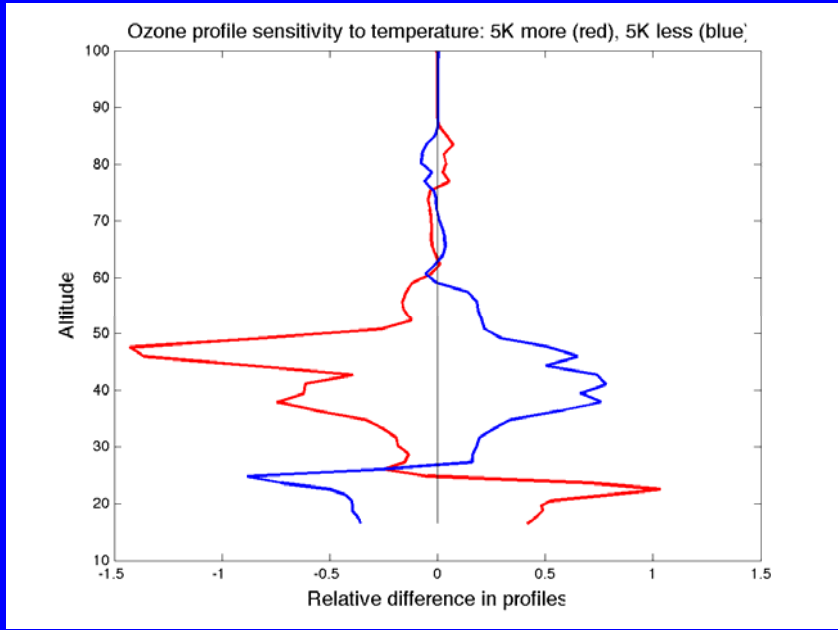
OSIRIS VS GOMOS: A priori density and temperature

Both use ECMWF
GOMOS up to 1 hPa, then MSIS90
OSIRIS up to 0.1 hPa

Temperature



5 K change in T: GOMOS O3



From the hockey stick to a garden hose: Dynamic linear model

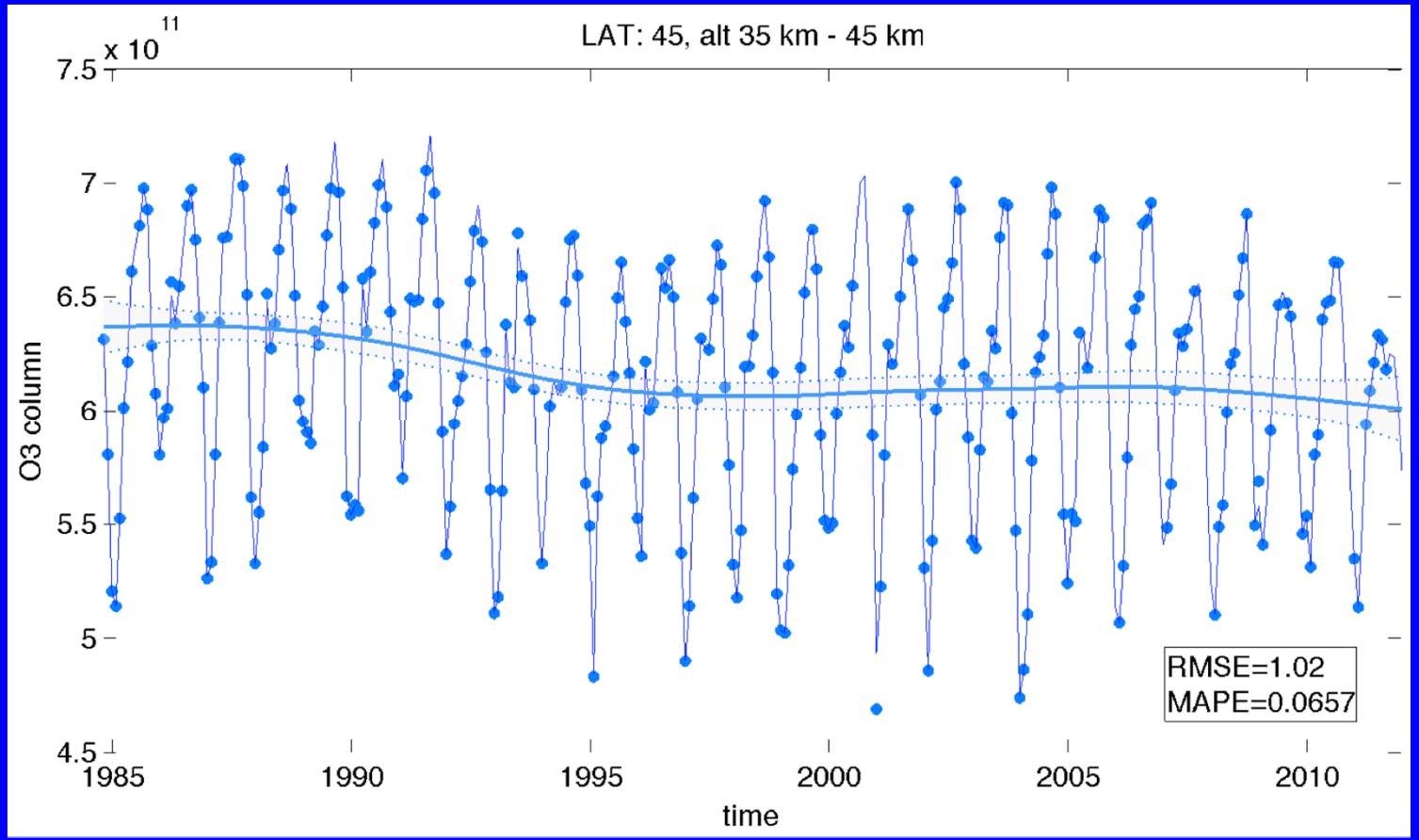
$$\rho^{\text{fit}}(z,t) = c(z) + L(z,t) + s(z)F_{10.7}(t) + q_1(z)F^{10}_{qbo}(t) + q_2(z)F^{30}_{qbo}(t) + \sum_{n=1}^{2}(a_n(z)\cos(nwt) + b_n(z)\sin(nwt))$$

$$L(z,t) = \begin{cases} d_1(z)(t-t_c) & \text{if } t < t_c \\ d_2(z)(t-t_c) & \text{if } t \geq t_c \end{cases}$$

$$\boldsymbol{y}_t = \mathbf{F}_t\boldsymbol{\theta}_t + \boldsymbol{v}_t,$$
$$\boldsymbol{\theta}_t = \mathbf{G}_t\boldsymbol{\theta}_{t-1} + \boldsymbol{w}_t,$$

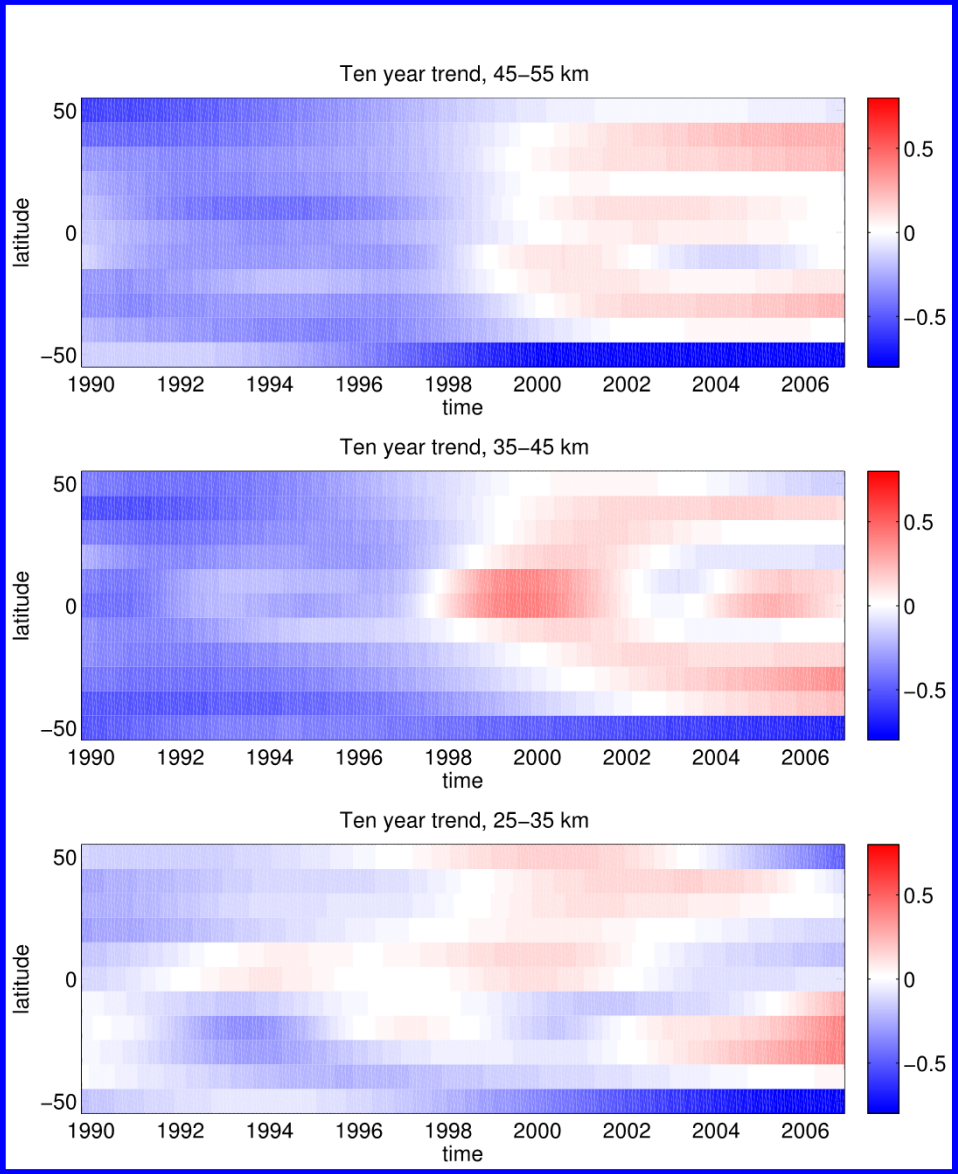
$$\boldsymbol{v}_t \sim \mathcal{N}_p(\mathbf{0}, \mathbf{V}_t),$$
$$\boldsymbol{w}_t \sim \mathcal{N}_q(\mathbf{0}, \mathbf{W}_t),$$

Results for SAGE II - GOMOS



This fit is even too accurate. Remember sampling inhomogeneities.

Turning point analysis for SAGE II - GOMOS



Summary

1. GOMOS-SAGE II bias corrected ozone data shows ozone recovering slowly after 1997 in 38-45 km.

   E. Kyrölä, M. Laine,V. Sofieva, J. Tamminen, S. Päivärinne, S. Tukiainen, J. Zawodny, L. Thomason:
   Combined SAGE II-GOMOS ozone profile data set 1984-2011 and trend analysis of the vertical distribution of ozone, ACPD discussion paper, 2013

2. If we take OSIRIS instead of GOMOS and carry out the analysis in the same way as presented, ozone is recovering more strongly. Reasons under investigation.

3. The time series model relaxed using a dynamic linear model. Work in progress.

Must ozone climatologies or time series agree?

To create a climatology we need a spatial and time grid.

As an example, take a latitude time cell in the grid.

Ozone at 40 km in 40N-50N

Density

Latitude asymmetry