GOMOS stellar occultation measurements

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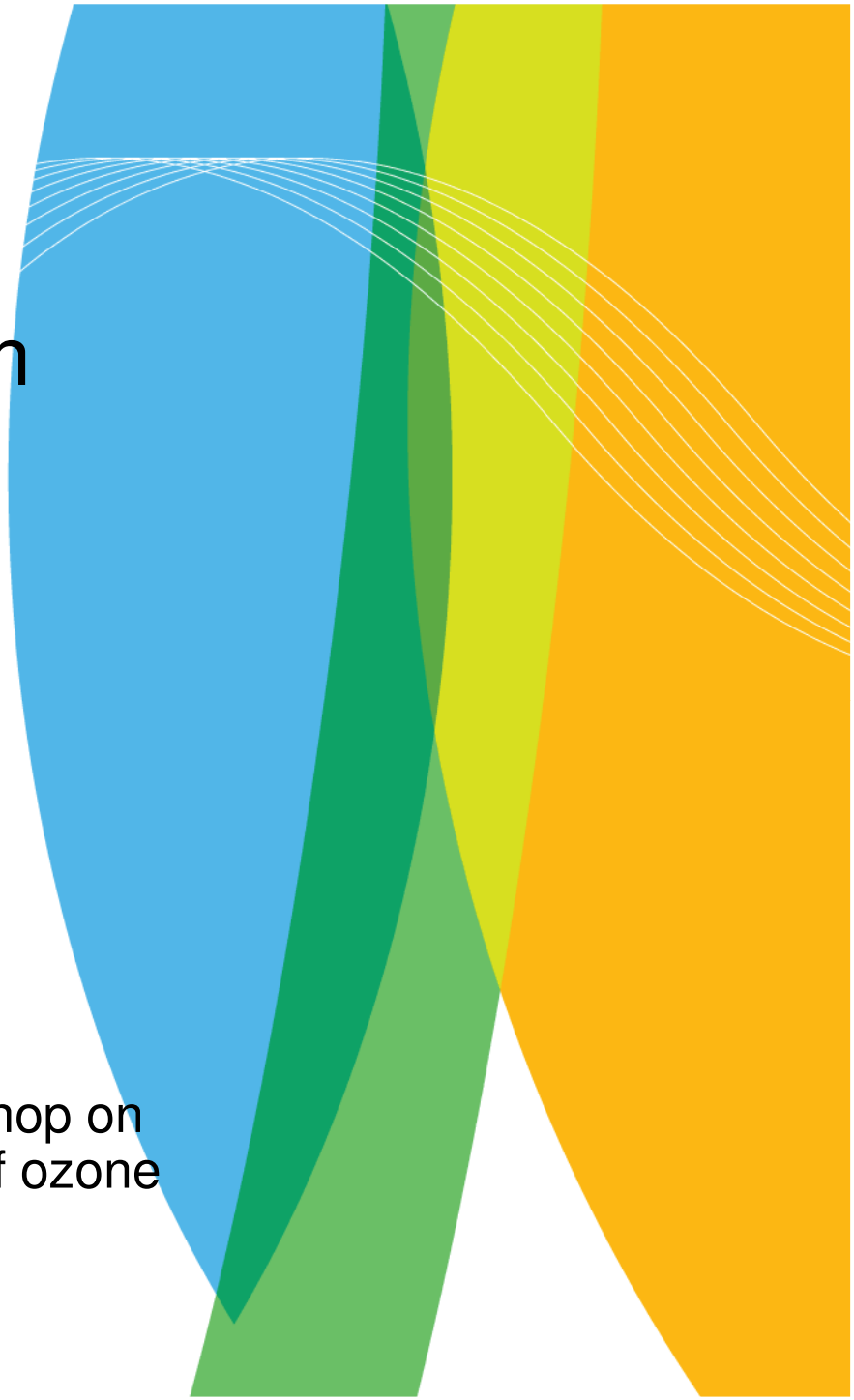
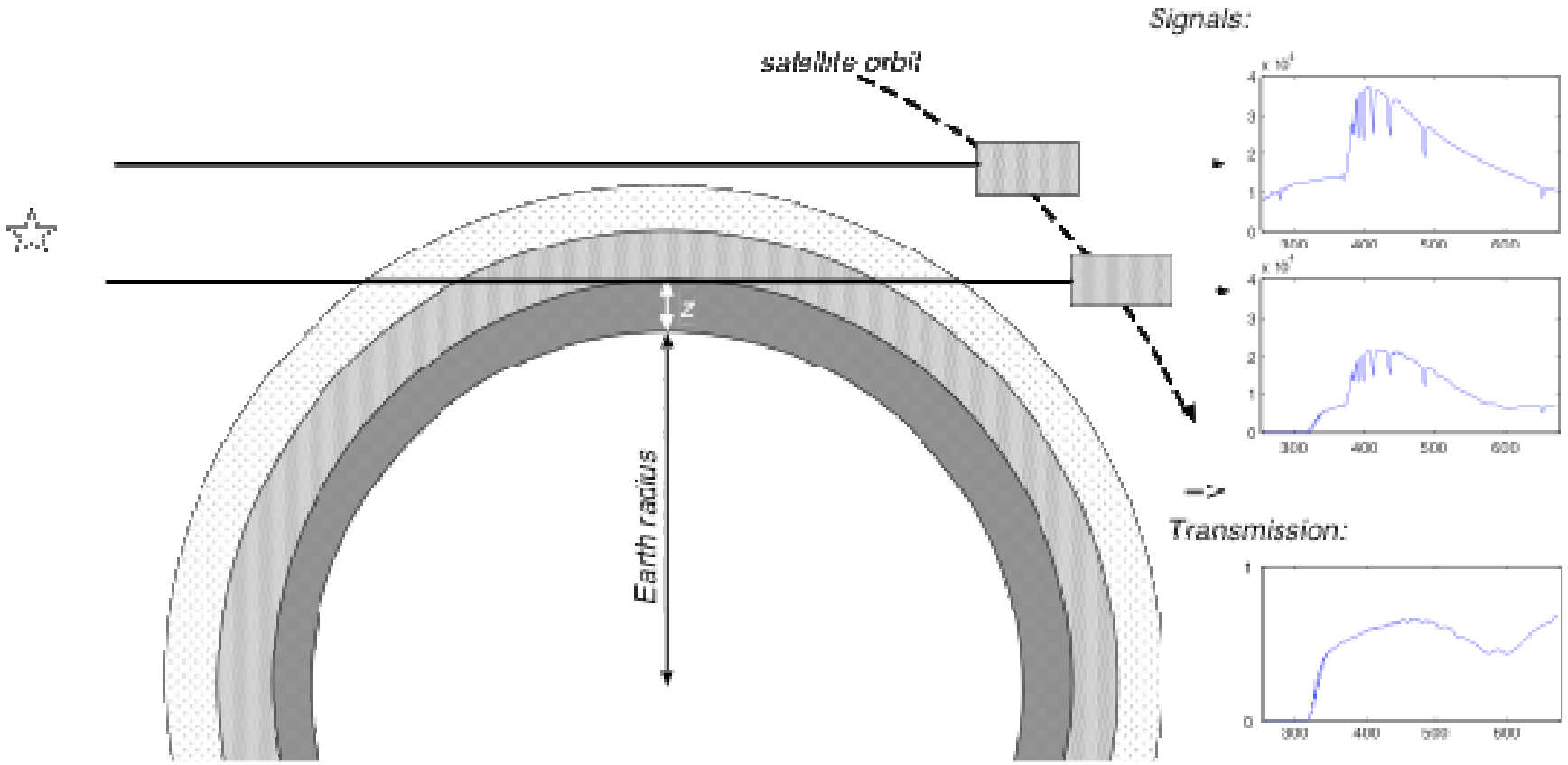
SPARC/IOC/WMO/IGACO-O3/UV workshop on
Past changes in the vertical distribution of ozone

WMO, Geneva, January 25-27, 2011

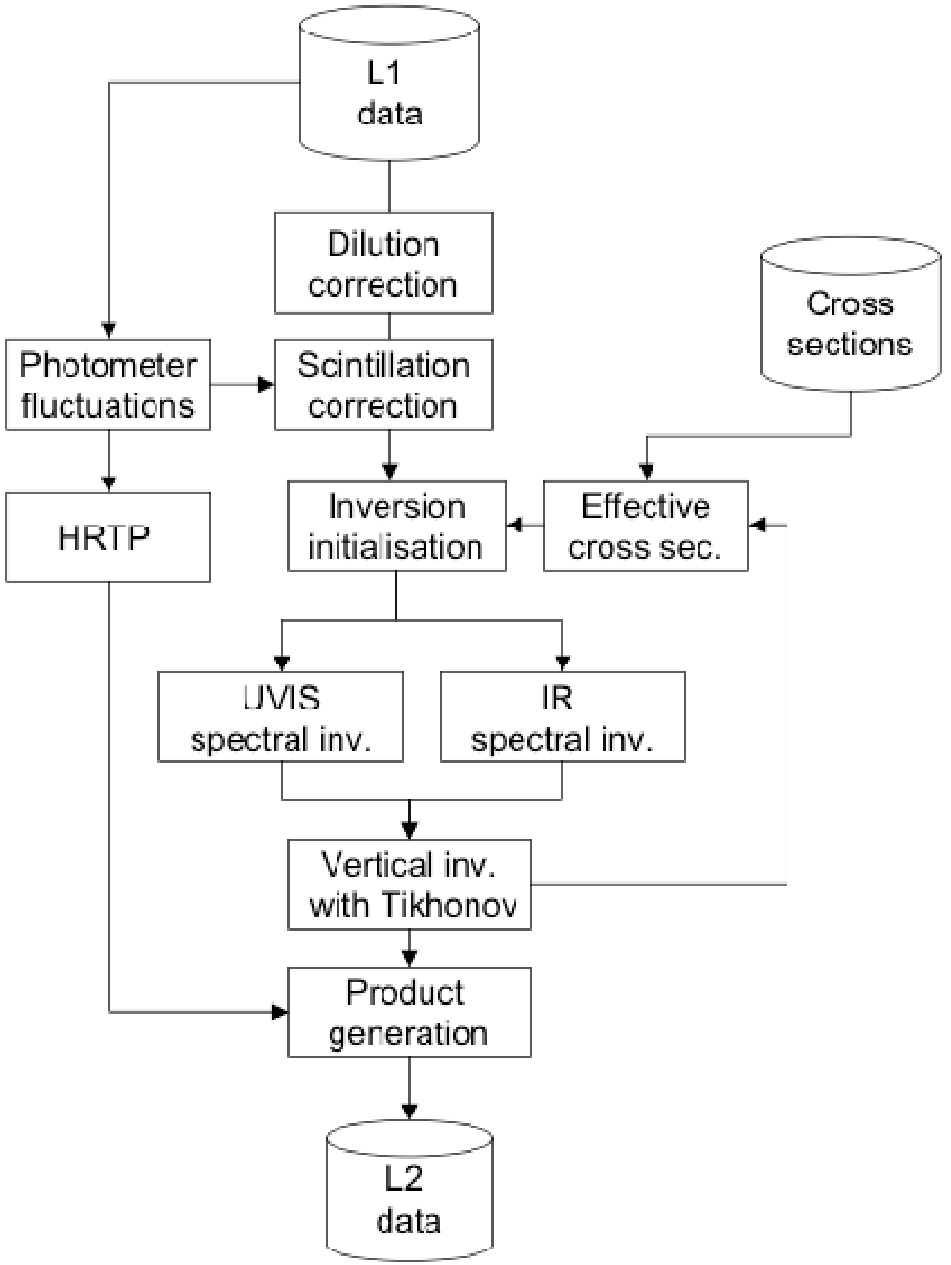


Stellar occultation of GOMOS

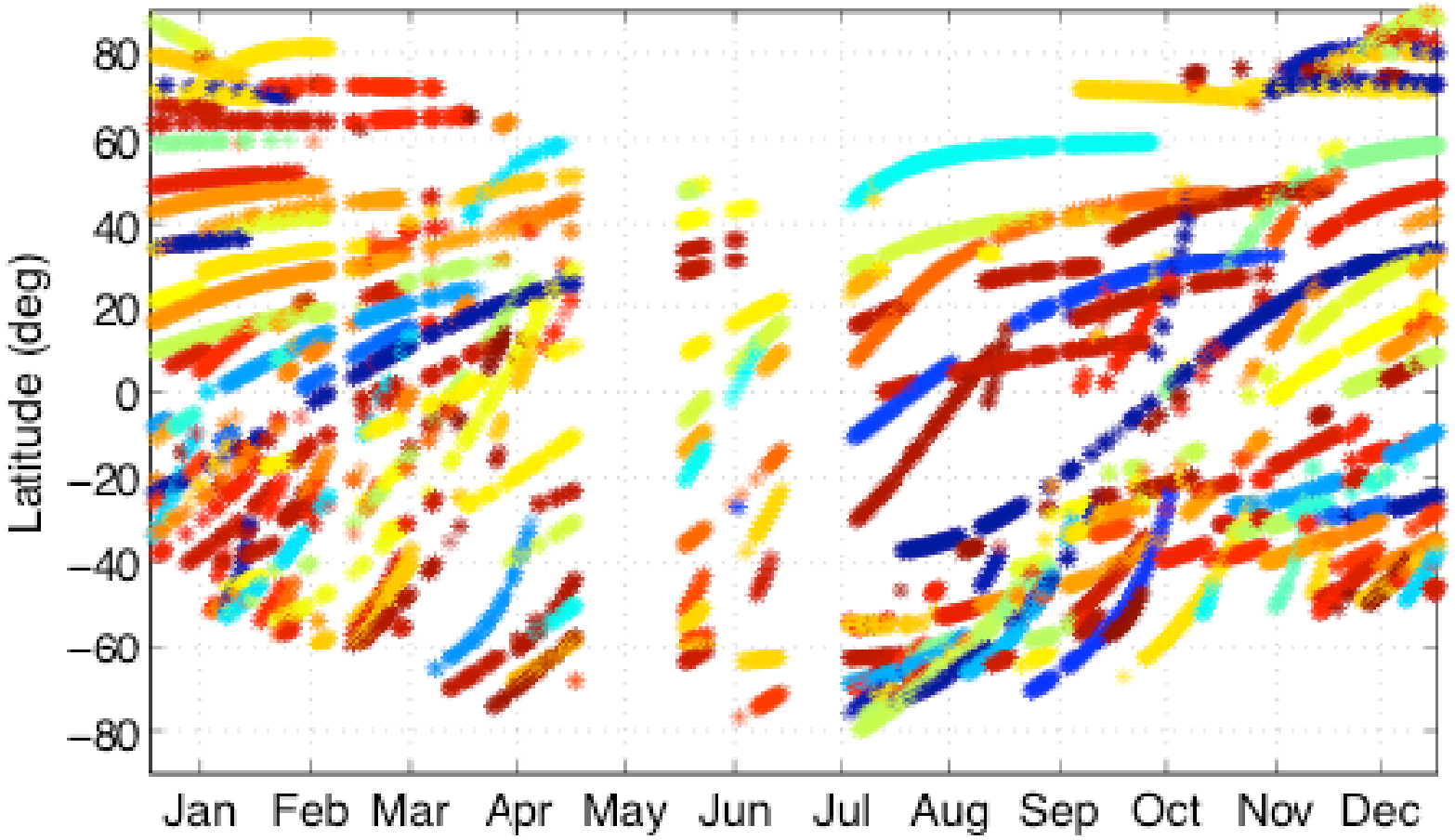


GOMOS retrieval

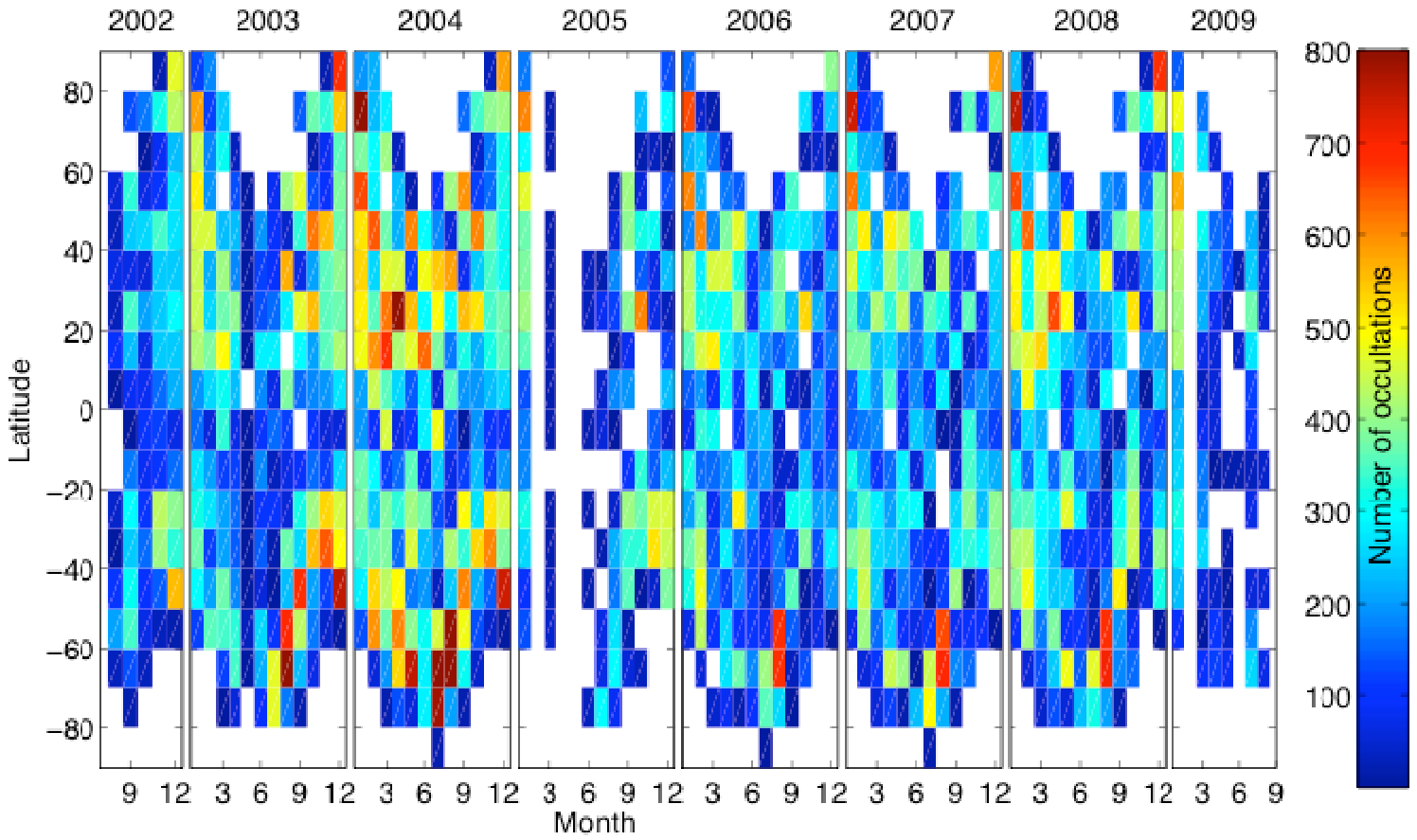
- **O3, NO2, NO3, aerosols fitted simultaneously using 250-675 nm**
- **Spectral inversion separately for each altitude ➔ horizontally integrated densities**
- **Vertical inversion: each constituent separately ➔ vertical profiles**



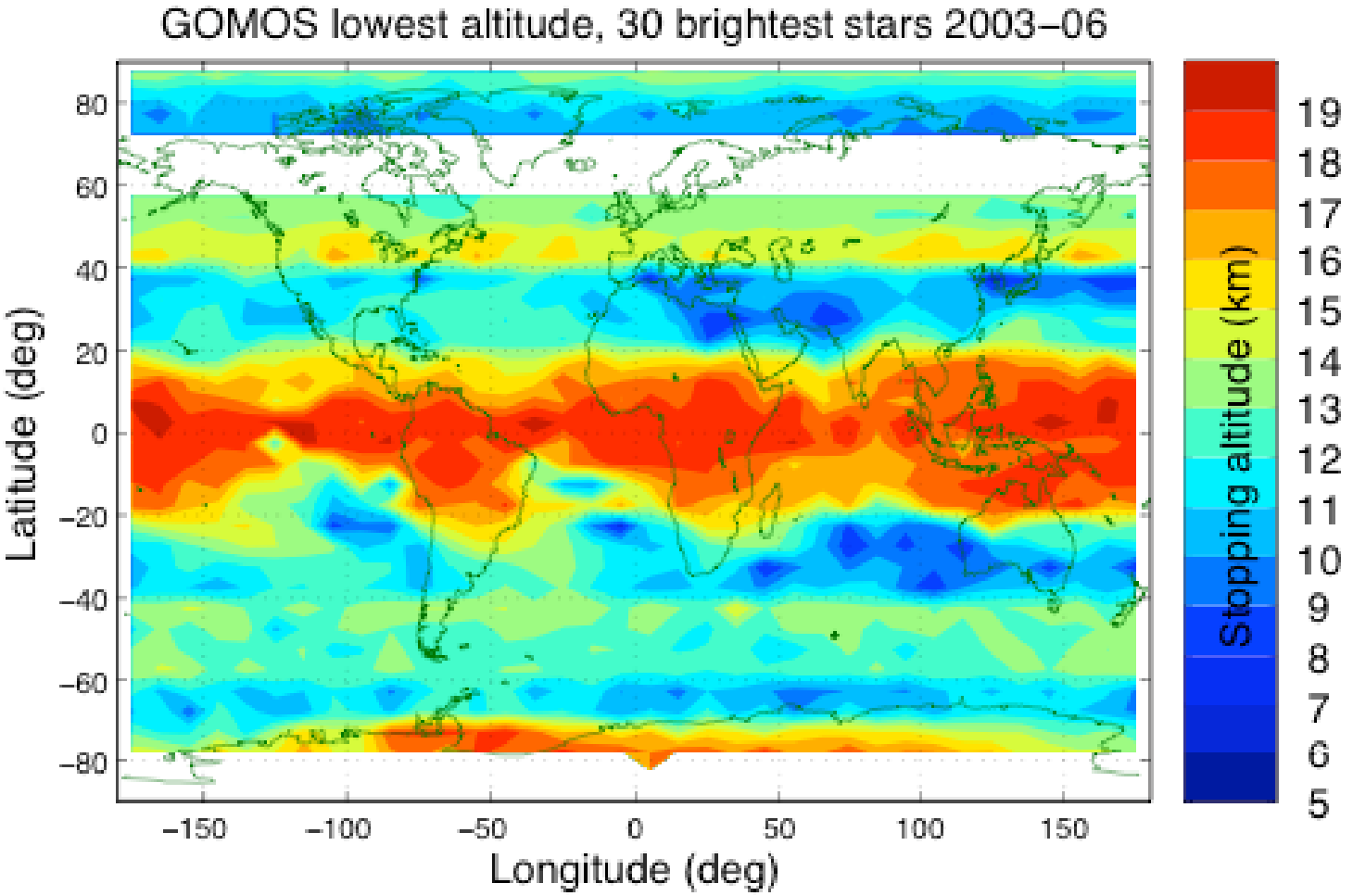
Latitude/month coverage and stars



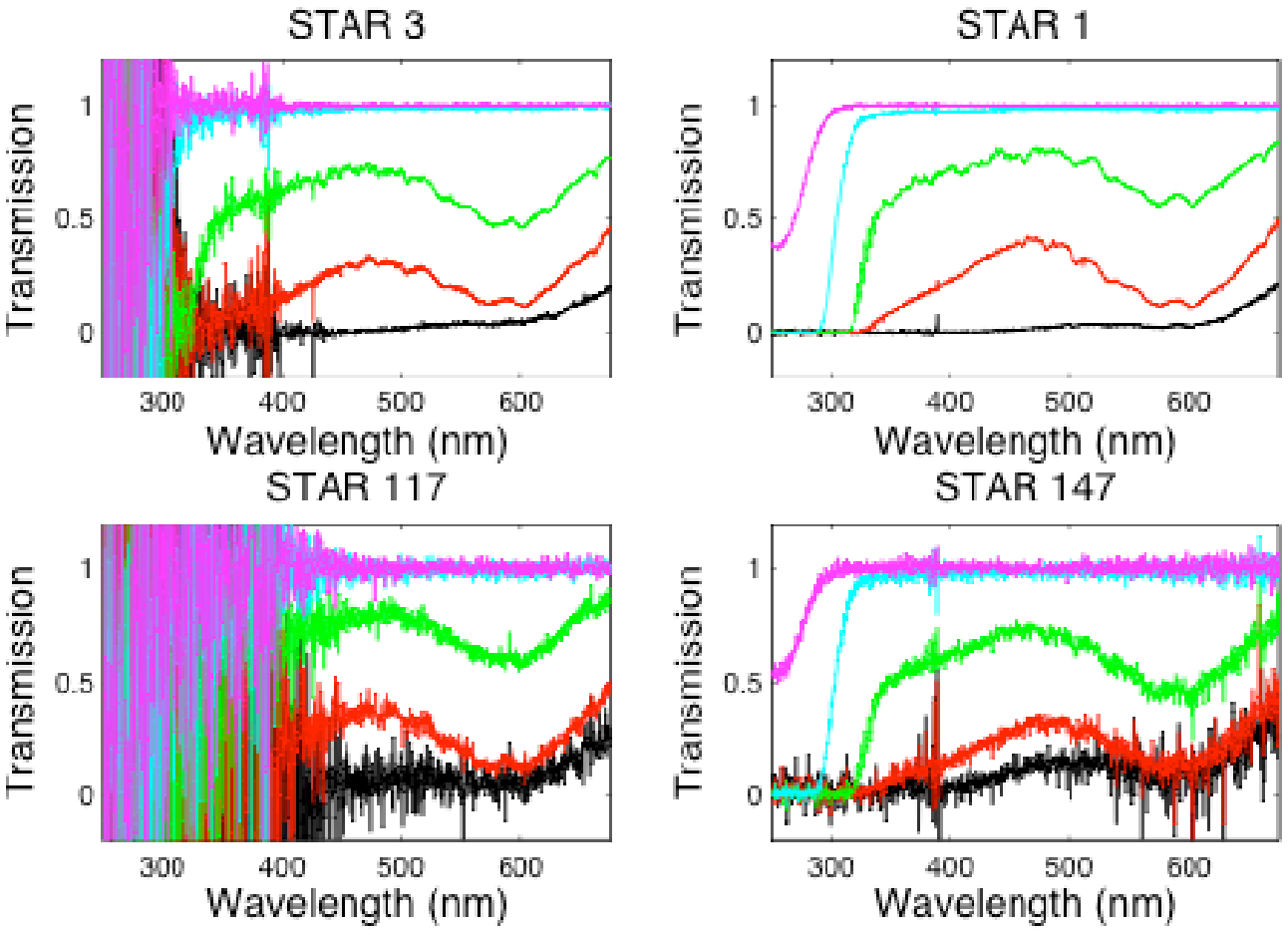
Latitude / monthly coverage from pole to pole



Altitude range of measurements

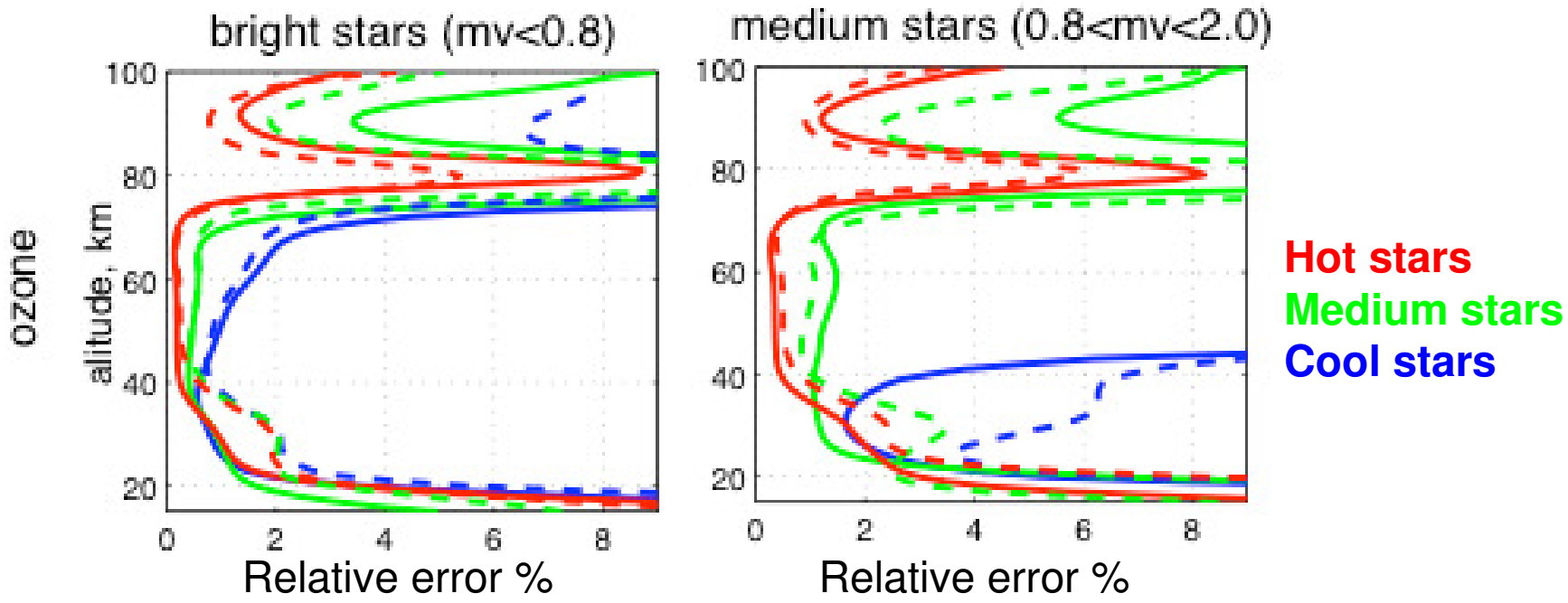


Varying signal to noise ratio



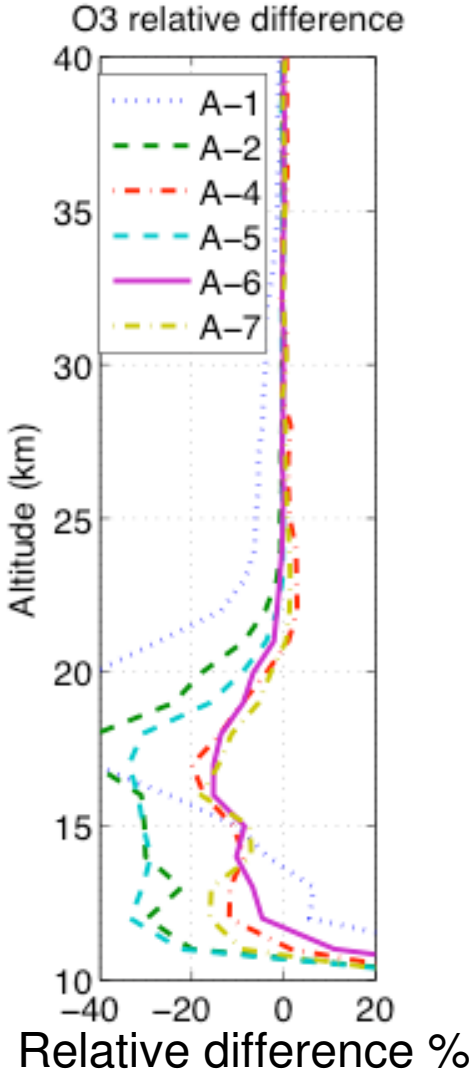
GOMOS transmissions measured using different stars at 10, 20, 30, 50, 70 km.

Random error: error estimates of ozone



Systematic errors

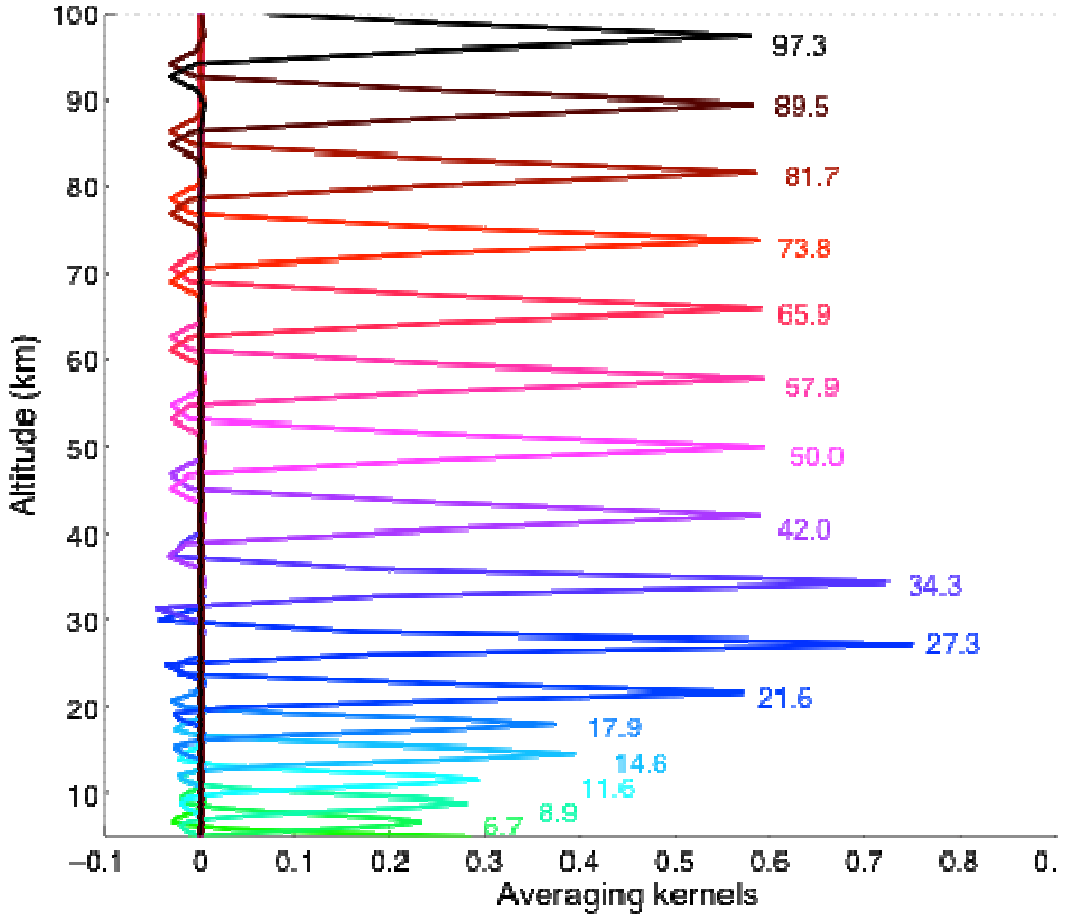
- **Aerosols are the main source of systematic errors in the UTLS**
  - **Difference in ozone 10-20 % below 20 km.**
- **Cross sections**
  - **BDM vs Bogumil have 1-1.5% impact.**



Impact of aerosol model selection

GOMOS resolution

- **Vertical sampling resolution 0.2-1.6 km**
- **Tikhonov regularization applied**
- **Vertical resolution of ozone:**
  - **2 km below 30 km**
  - **3 km above 40 km**

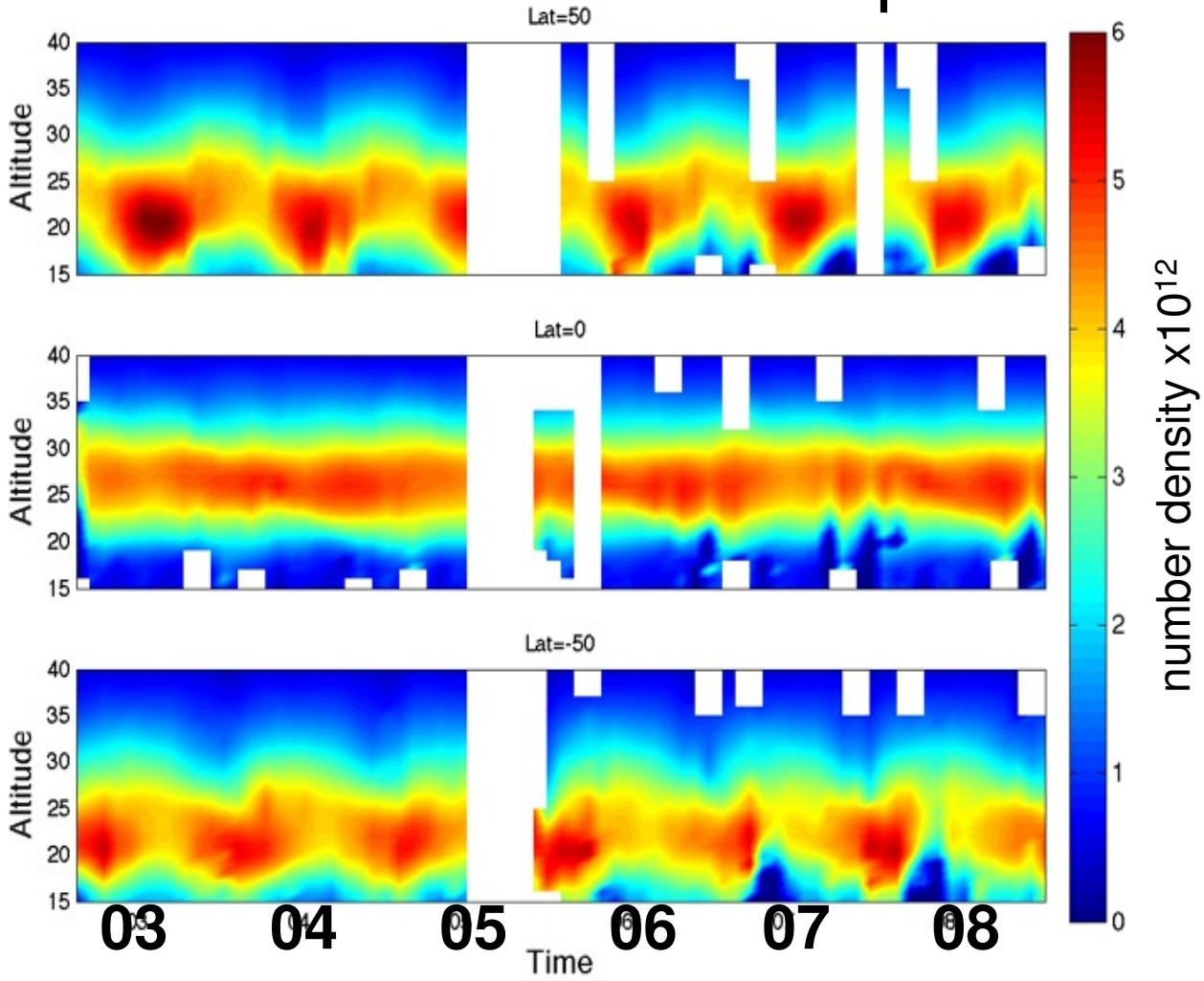


GOMOS measurements: stratosphere

Lat 50N

Equator

Lat 50S



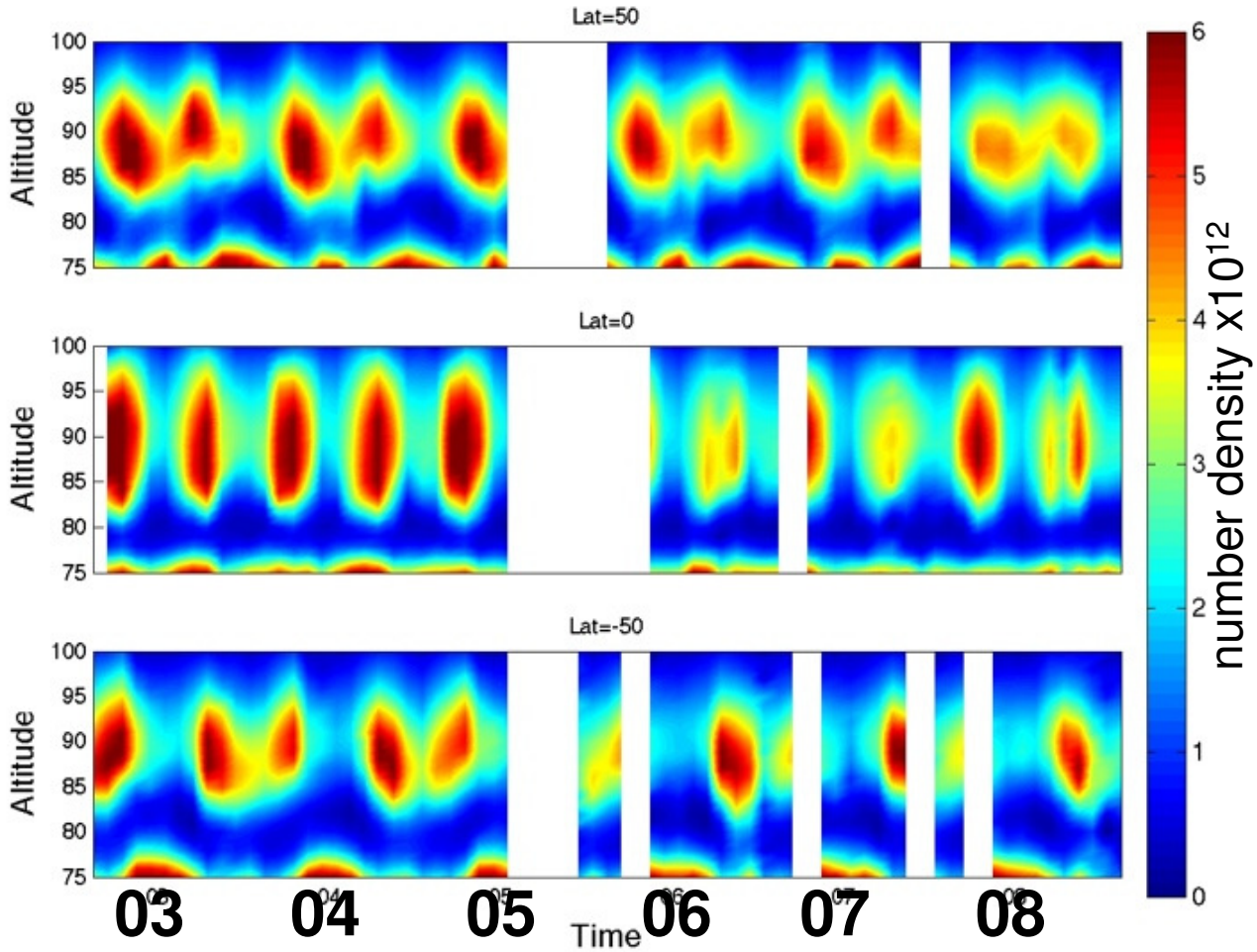
E. Kyrölä et al., GOMOS O_3, NO_2, and NO_3 observations in 2002-2008. ACP GOMOS special issue 2010

GOMOS measurements: mesosphere

Lat 50N

Equator

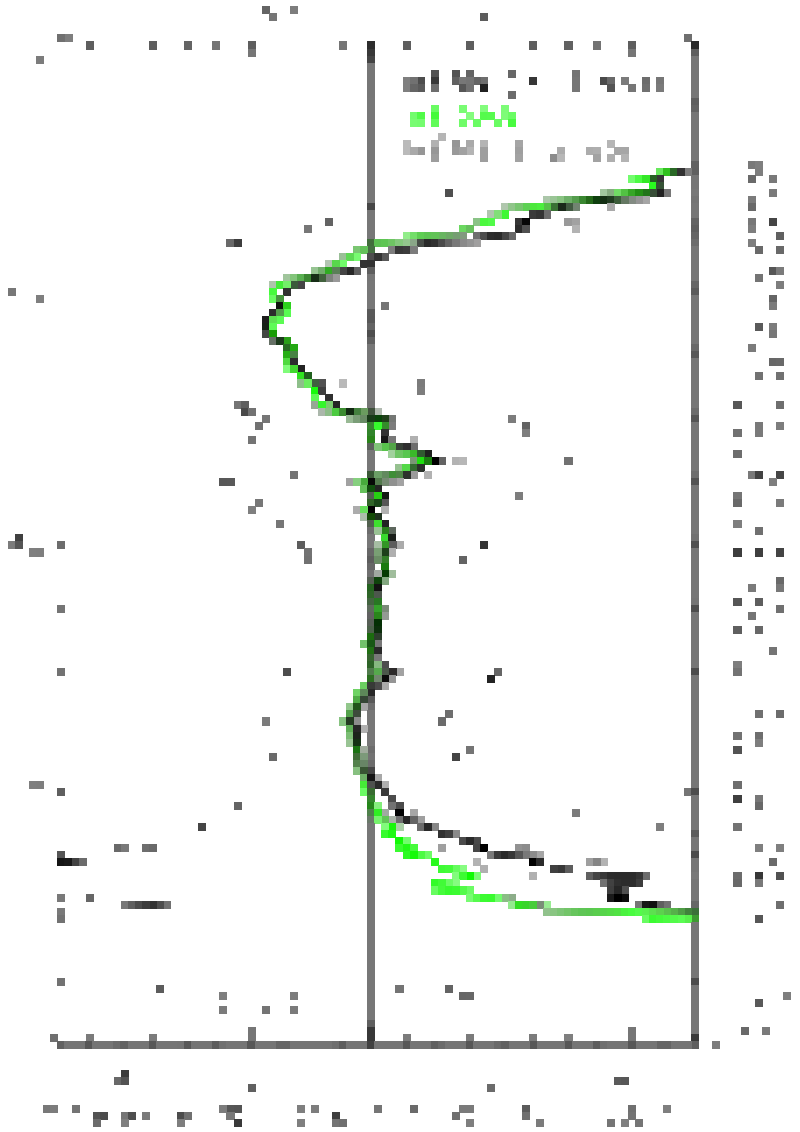
Lat 50S



E. Kyrölä et al., GOMOS O_3, NO_2, and NO_3 observations in 2002-2008. ACP GOMOS special issue 2010

Validation

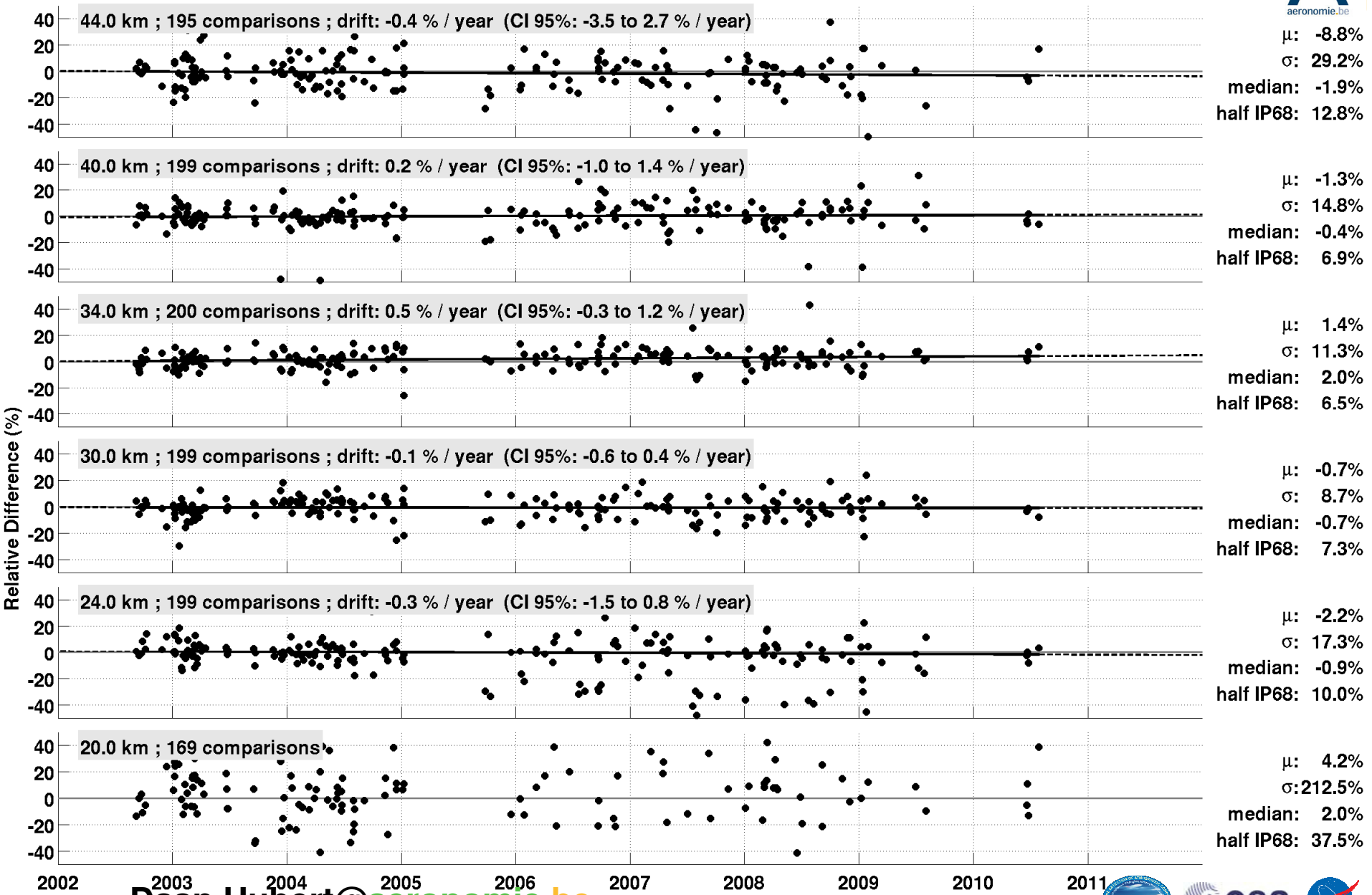
- **A. van Gijsel et al compared GOMOS ozone profiles with lidars, soundings and microwave profiles**
- **Good agreement btw 20-40 km: ±2%**
- **At 15-20 km GOMOS larger by 5-20%**



A.Van Gijsel et al. ACP GOMOS special issue 2010

206 coincidences

GOMOS IPF 5 00 GOPR 6 0 cf O3 vs JPL Lidar at Mauna Loa, United States (19.5°, -155.6°)



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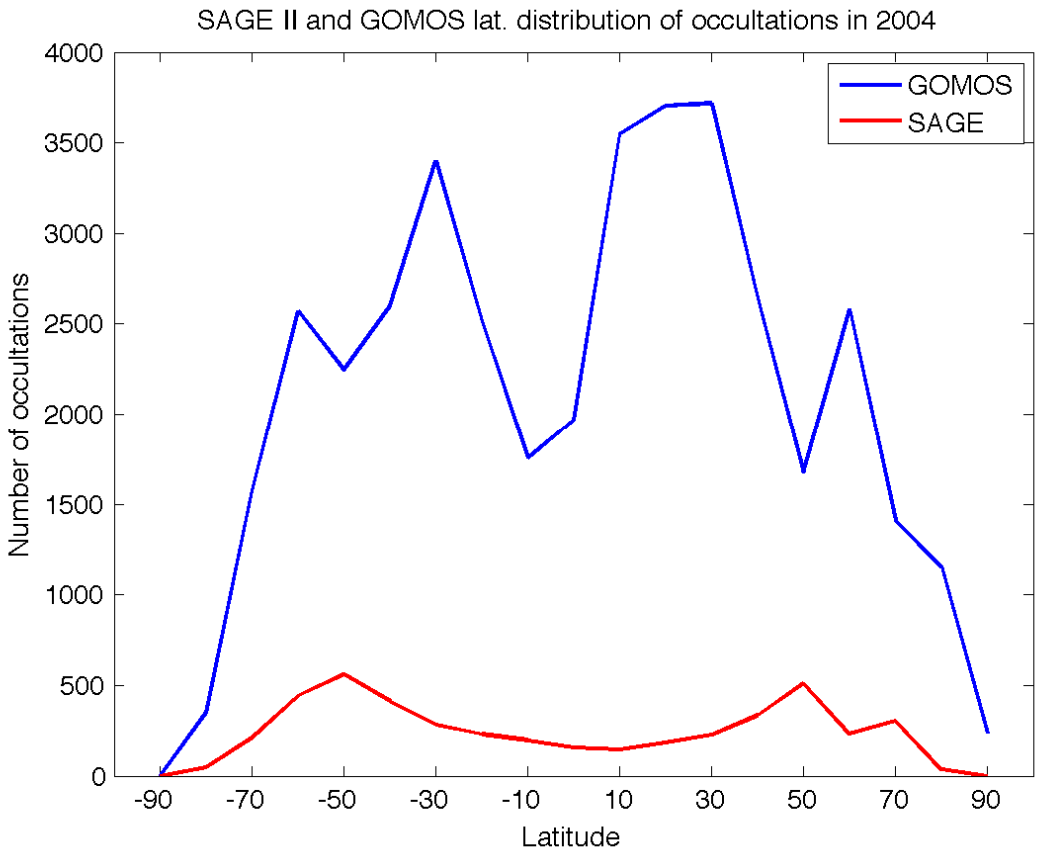
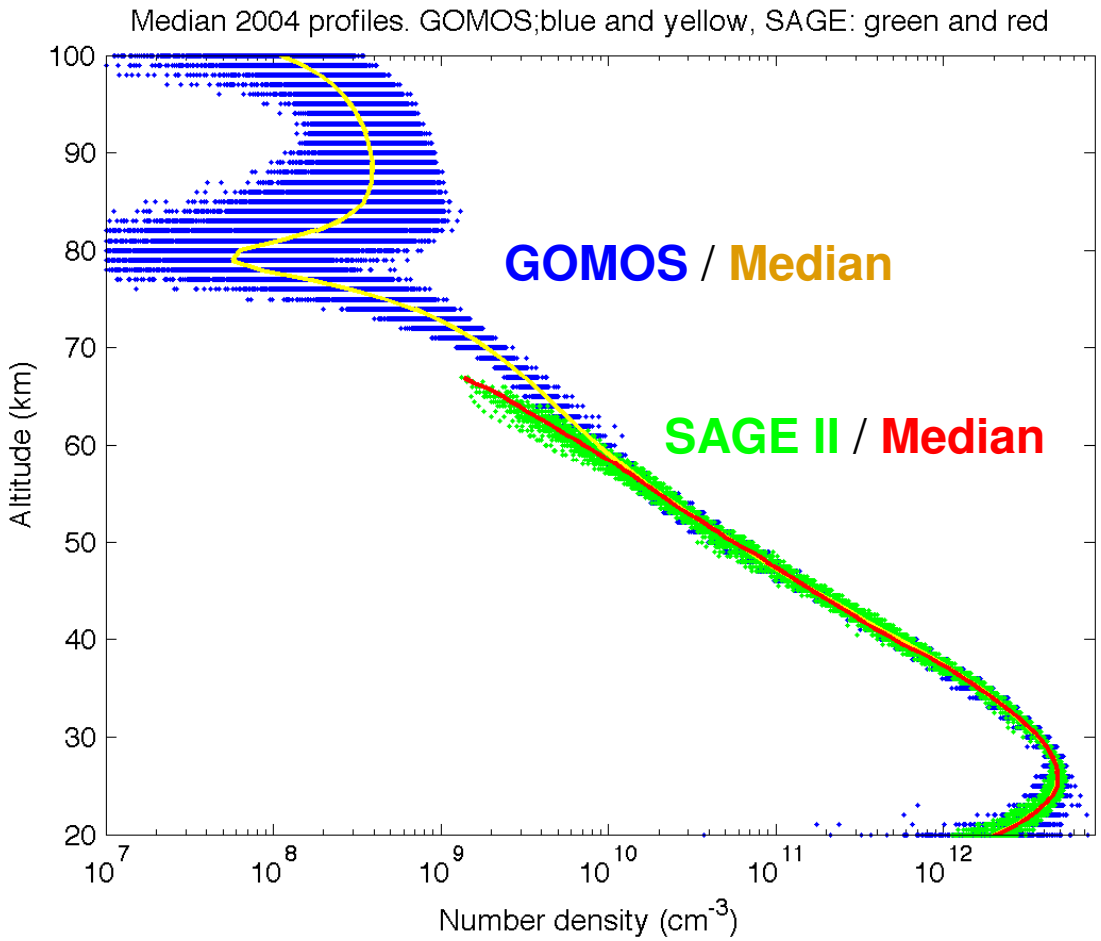
GOMOS data to continue SAGE series

- **Self calibrating instruments**
- **Minimal use of a priori data**
- **Overlap 2002-05**
- **Global latitude coverage**



GOMOS profiles vs SAGE II profiles at equator



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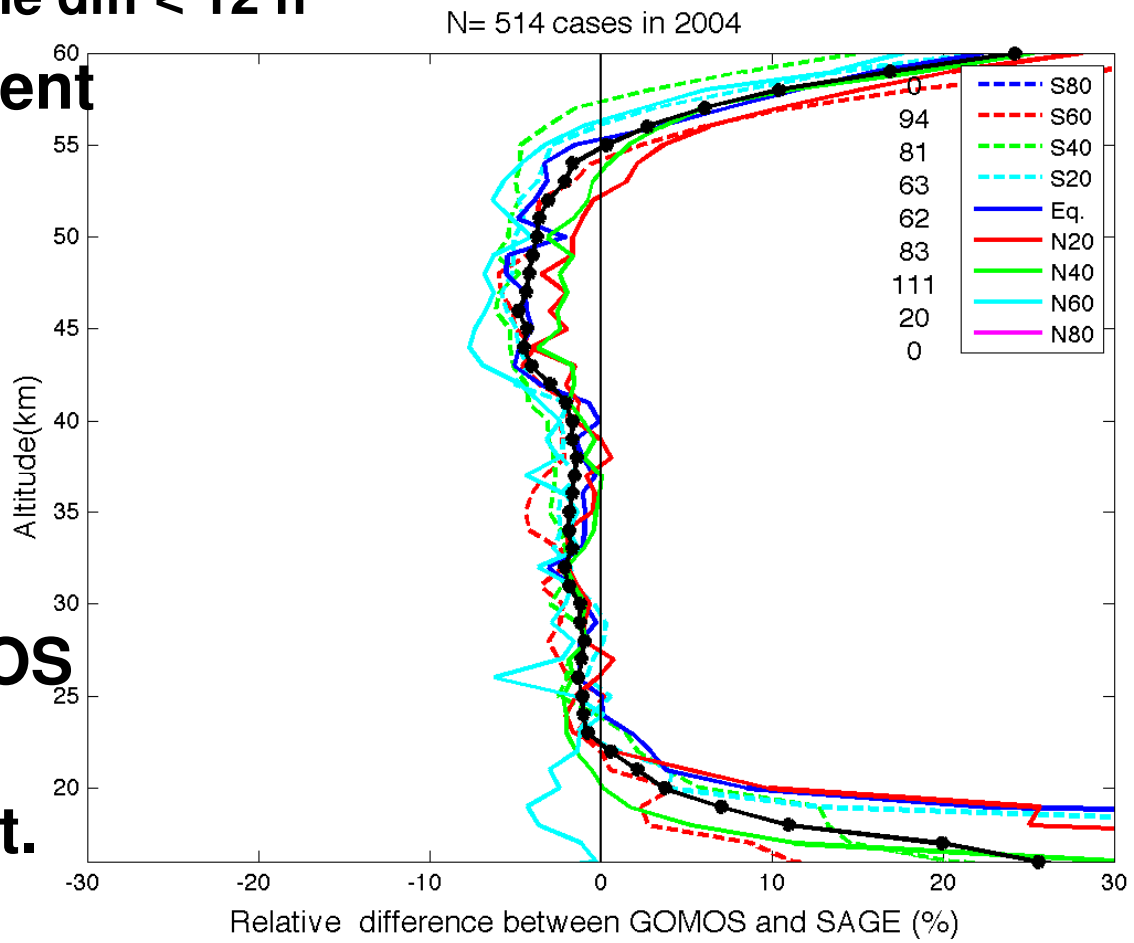
GOMOS-SAGE II 2004 co-located differences

- **Co-location criteria: Δlat < 2 deg, Δlon < 5 deg, Δtime diff < 12 h**
- **Consistent agreement at all latitudes**
- **Difference at 20-40 km 1-3% SAGE > GOMOS**
- **Difference at 40-55 km ~5%**
- **Below 20 km GOMOS higher 10-20%**
- **X-sections different.**



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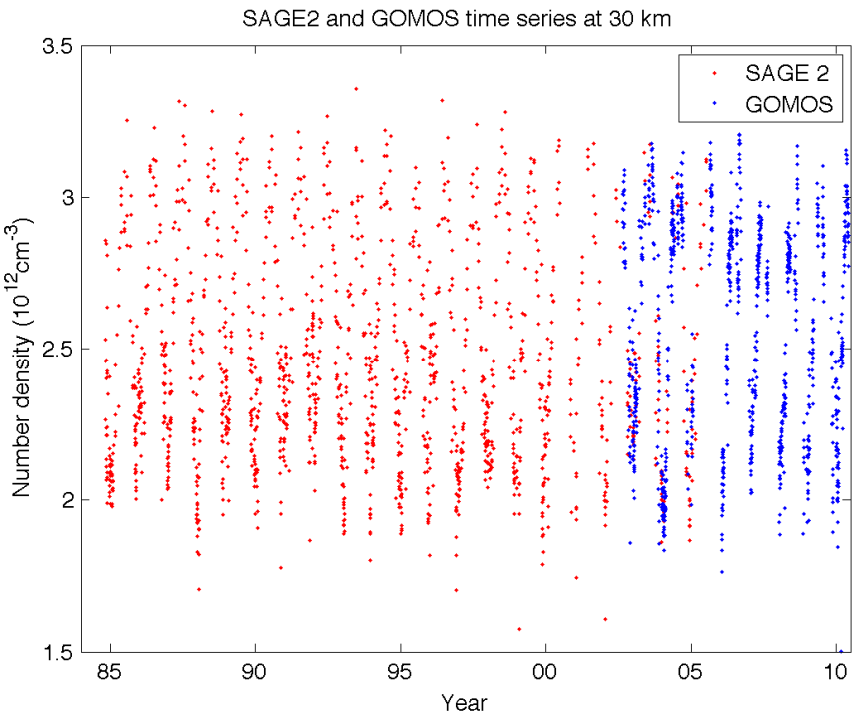
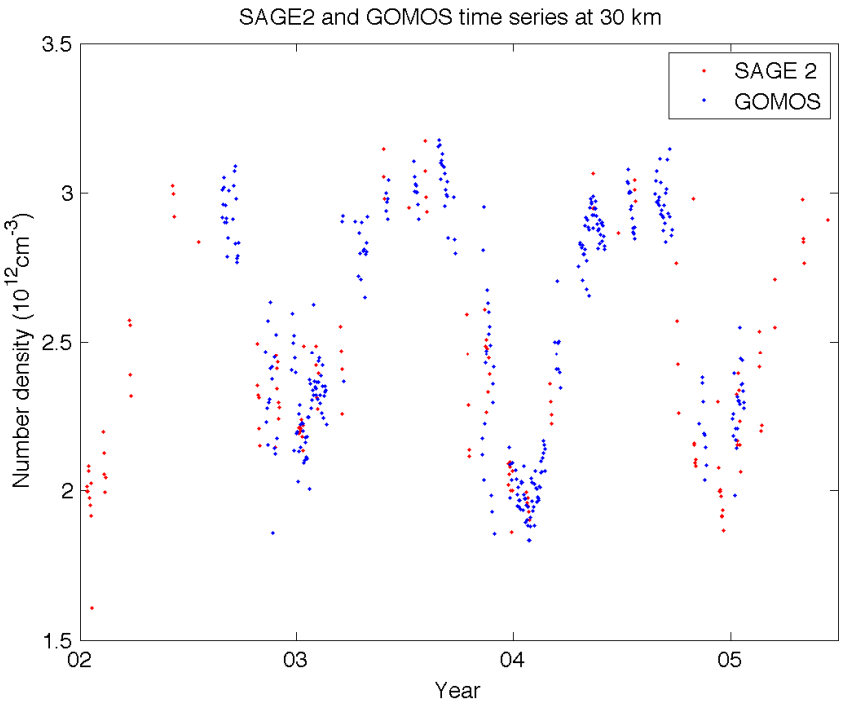
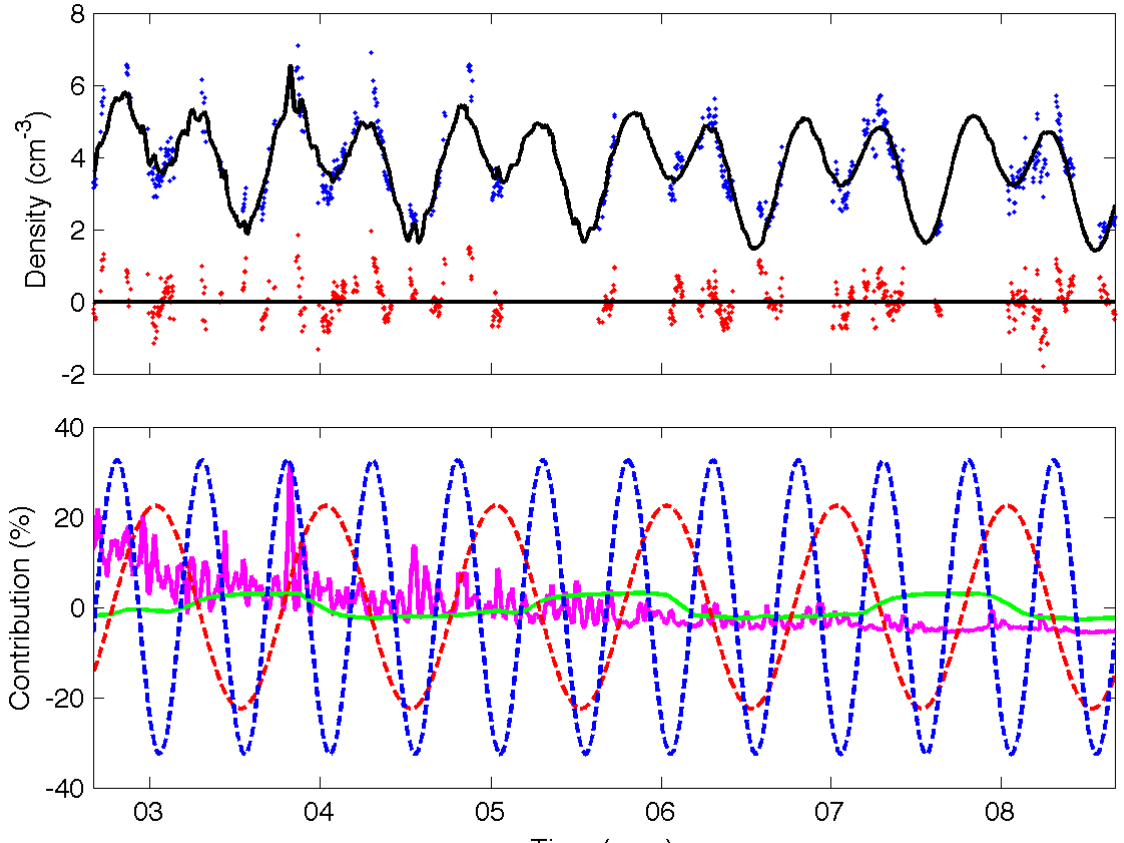
Time series comparisons: SAGE II & GOMOS 40-50 N daily





Fitting GOMOS measurements: 90 km in 40-50 N



GOMOS
FIT
Residual

Semi-annual
Annual
Solar

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

Conclusions

- **Global GOMOS high resolution ozone profiles 15-100 km available since 2002**
- **Random errors dominating in stratosphere**
- **In UTLS aerosols main cause for systematic errors**
- **Almost a decade long excellent stability**
- **Very good agreement with SAGE II data (profiles within 1-3 % in 20-40 km).**
- **GOMOS data is suitable for continuing SAGE II ozone profile records.**
- **On-going work: time series analysis, climatologies, within ESA CCI/ECV project create merged datasets.**

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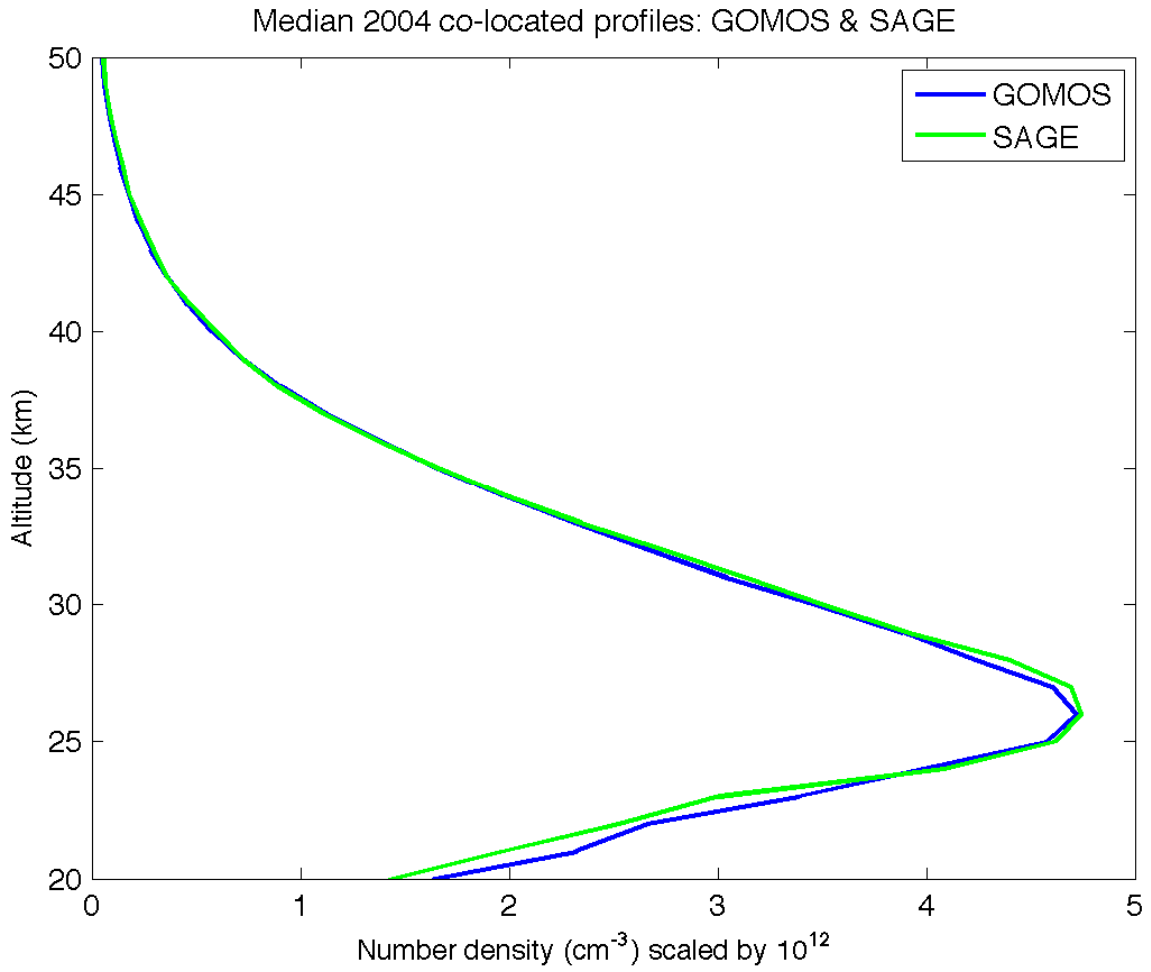
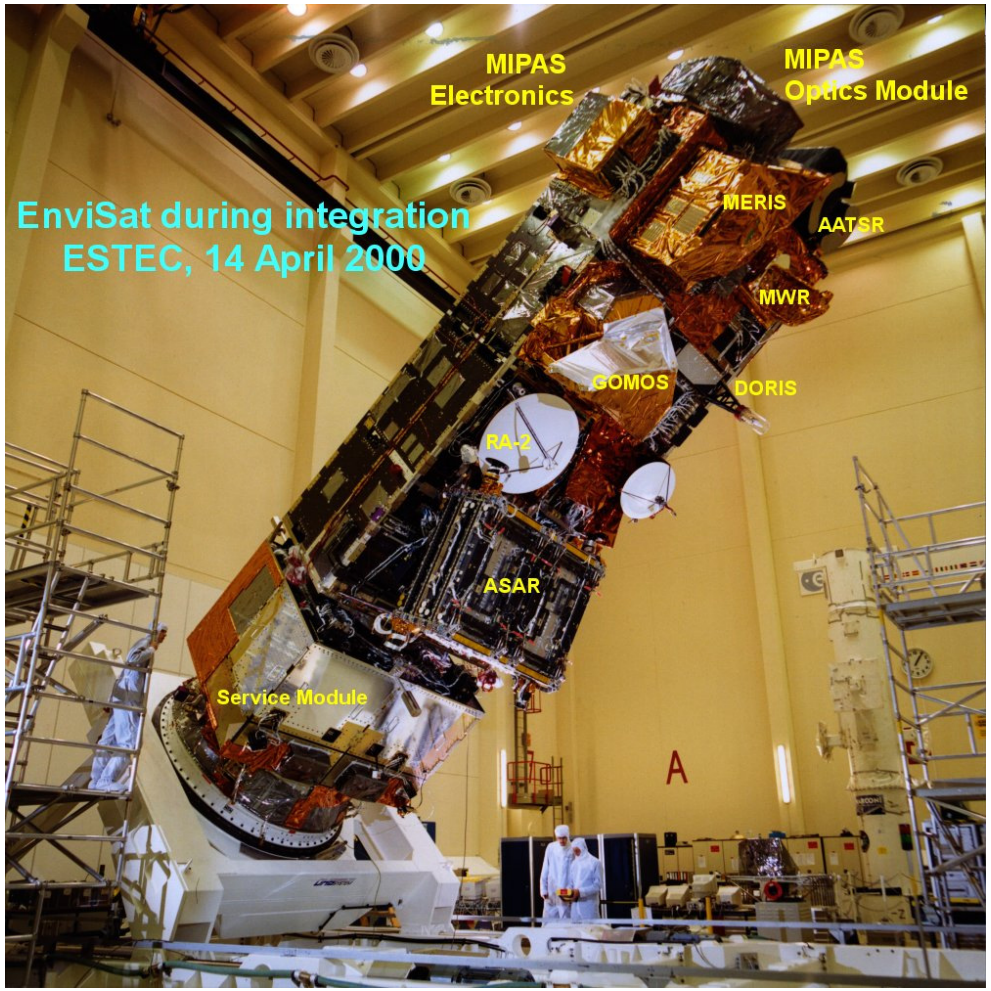
GOMOS error estimates - summary

Data characteristics	O_3	NO_2	NO_3	Aerosol extinction
Altitude range	15–100km	20–50 (65) km	25–50 km	20–40km:
Resolution	2 km stratosphere 3 km mesosphere	4 km	4 km	4km:
Random errors:	10% around 15km			30% around 10km:
Measurement noise and scintillations	0.5–4% stratosphere 2–10% mesosphere	20–30%	20–30%	2–10% at 15–25km: 10–50% 25–40km:
	Slightly increasing with time			
Systematic errors:				
Aerosol model selection	2% below 20km 1–5% at 20–25km >5% above 25km	10% at 15–20 km 5–5% at 20–25 km negligible elsewhere	negligible above 25 km	10% below 35km: 10–30% at 35–40km:
Temperature uncertainty	<0.5% at 60–90km negligible elsewhere	negligible	negligible	
Uncertainty in cross sections	1%	less per cent (?)	few per cents (?)	
Uncertainty in neutral density	1% below 20km negligible elsewhere	negligible	negligible	5% below 22km: 5–15% at 22–40km:

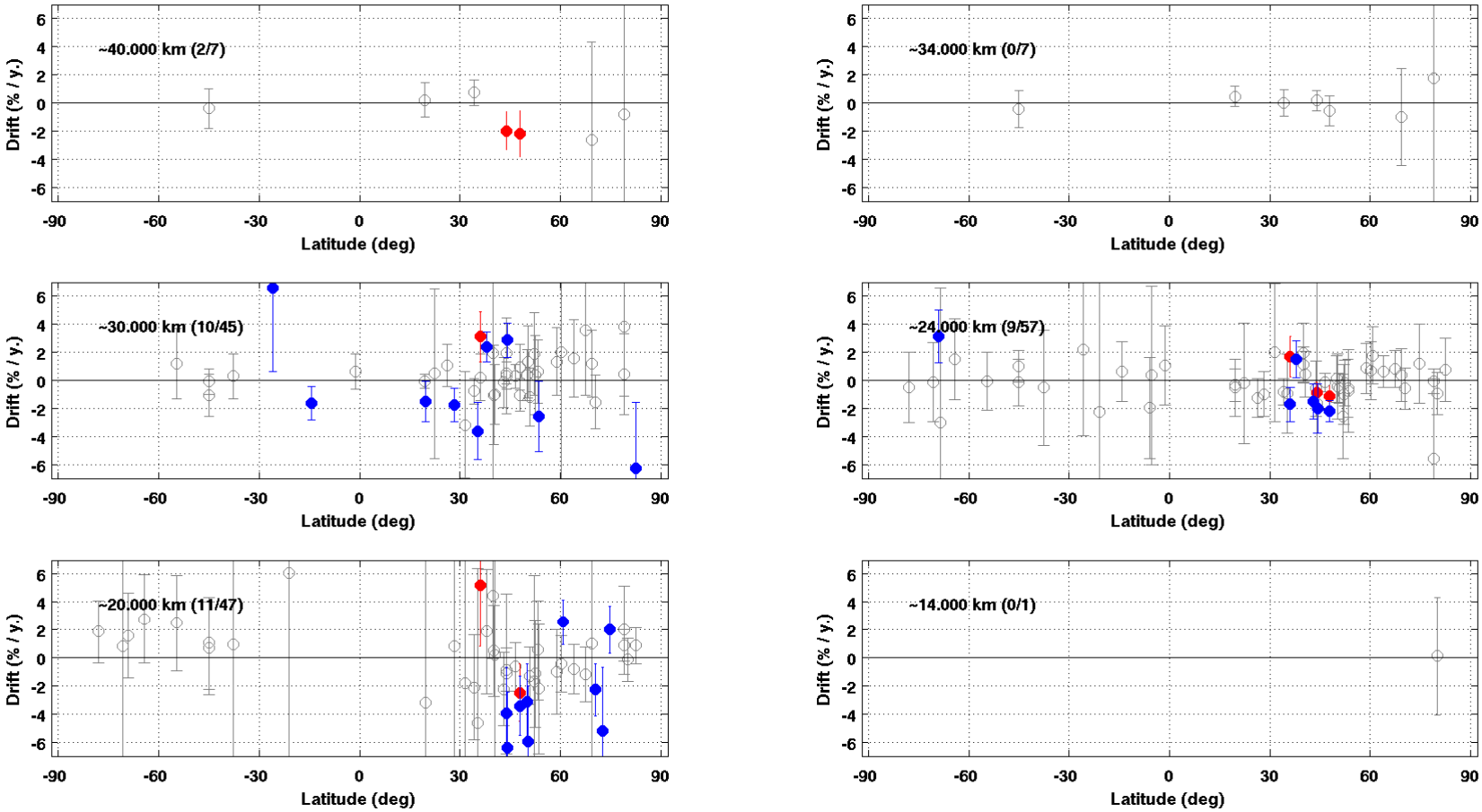
From Tamminen et al ACP 2010


Median 2004 co-located profiles: GOMOS & SAGE
GOMOS
SAGE
Altitude (km)
50
45
40
35
30
25
20
0
1
2
3
4
5
Number density (cm-3) scaled by 1012

GOMOS ja Envisat



GOMOS IPF 5 00 GOPR 6 0 cf O3 vs GAW & NDACC O3sondes and Lidars



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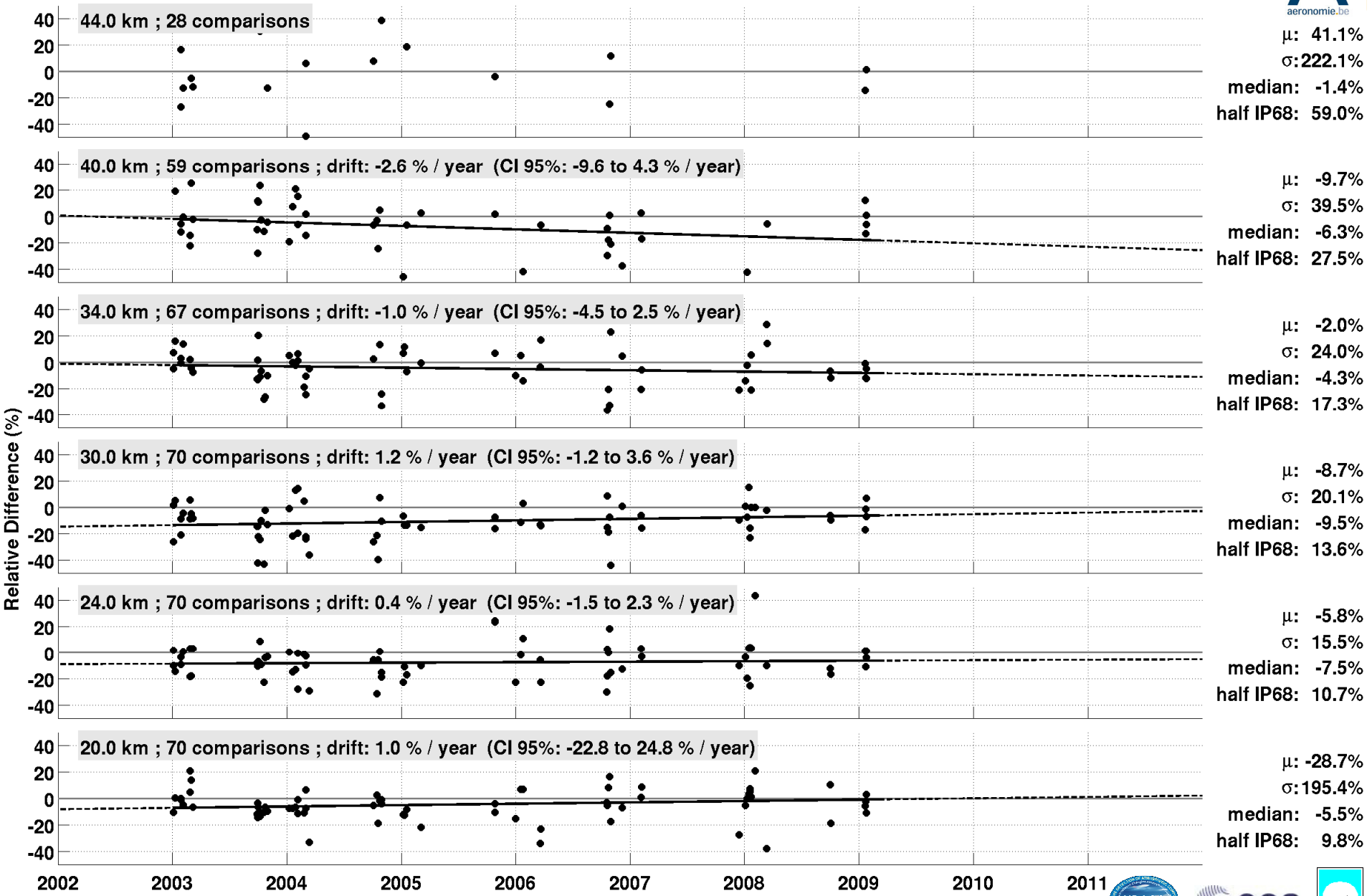
74 coincidences

GOMOS IPF 5 00 GOPR 6 0 cf O3 vs NILU Lidar at Andoya, Norway (69.3°, 16.0°)



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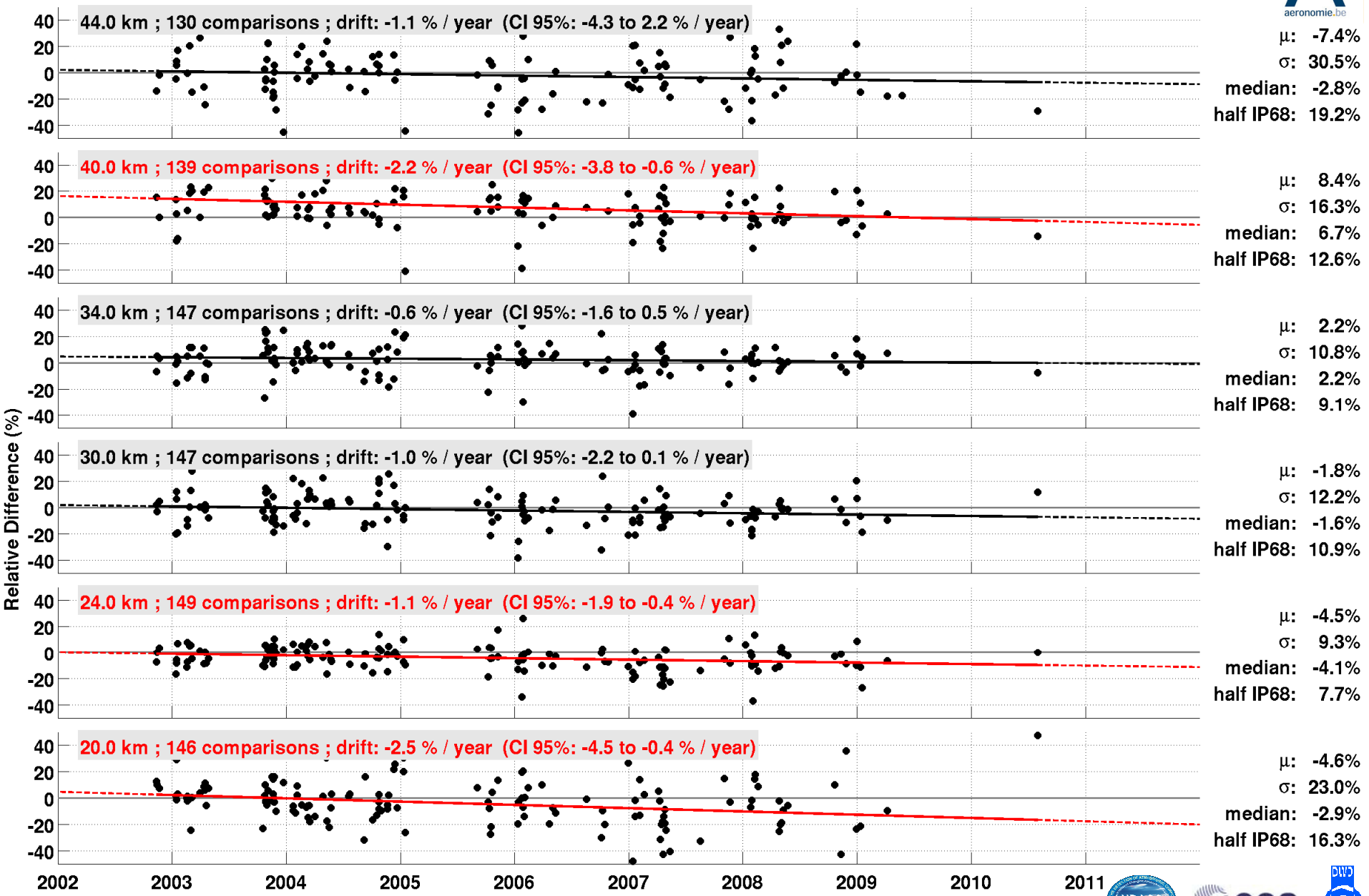
153 coincidences

GOMOS IPF 5 00 GOPR 6 0 cf O3 vs DWD Lidar at Hohenpeißenberg, Germany (47.8°, 11.0°)



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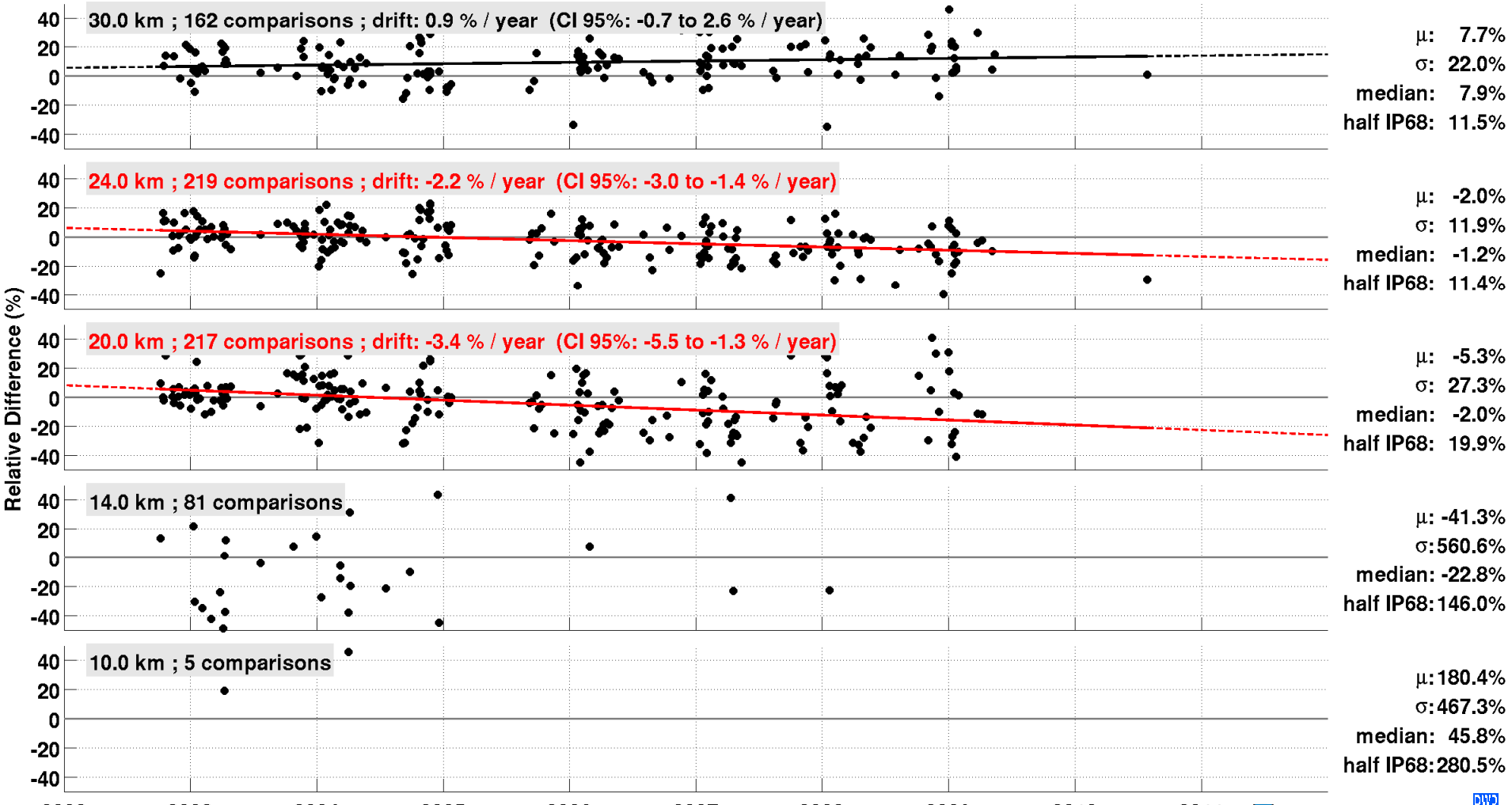
236 coincidences

GOMOS IPF 5 00 GOPR 6 0 cf O3 vs DWD Ozonesonde at Hohenpeißenberg, Germany (47.8°, 11.0°)



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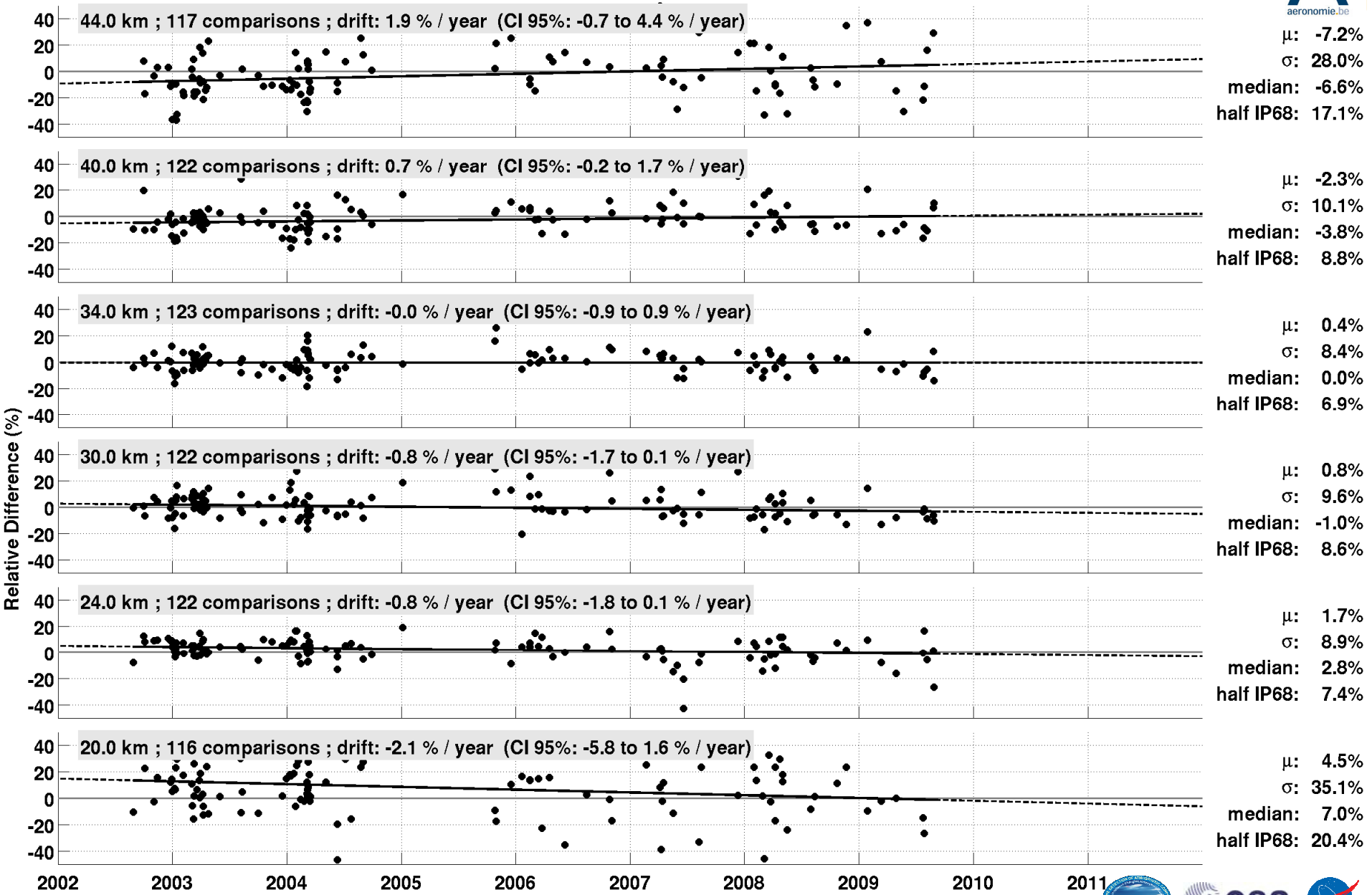
125 coincidences

GOMOS IPF 5 00 GOPR 6 0 cf O3 vs JPL Lidar at Table Mountain, United States (34.2°, -117.4°)



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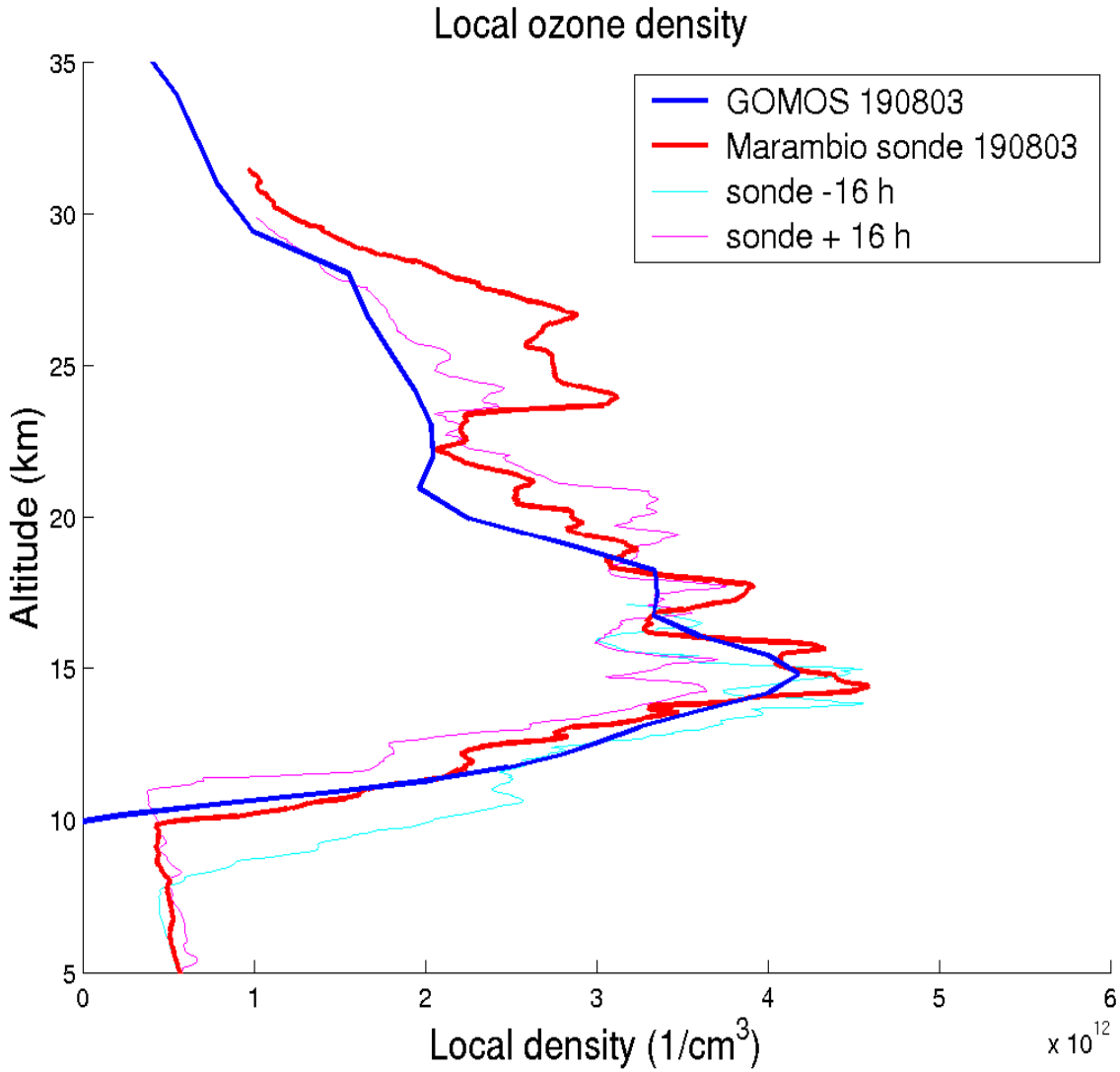
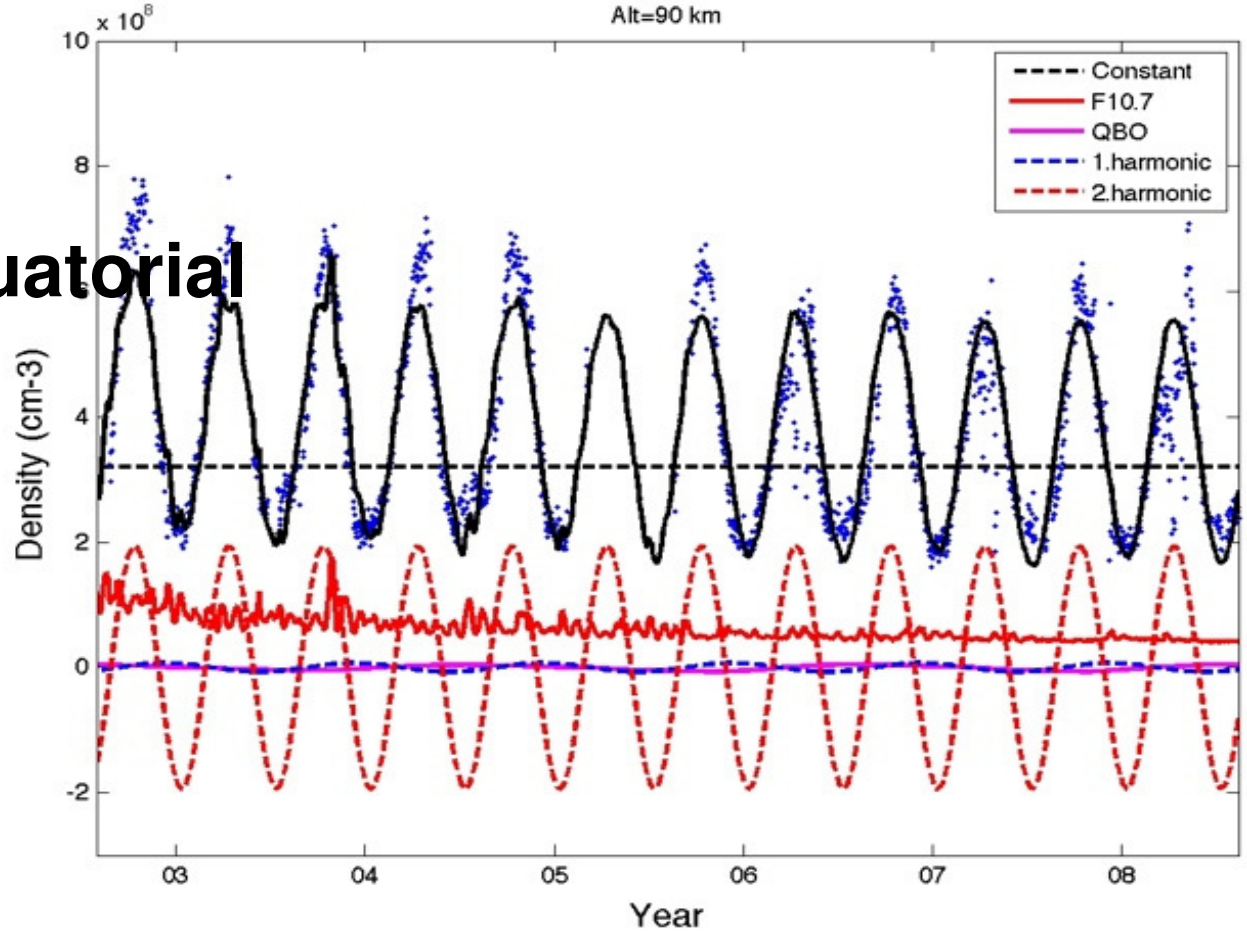


Ozone profiles in Marambio

GOMOS measurements

- **Equatorial**



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

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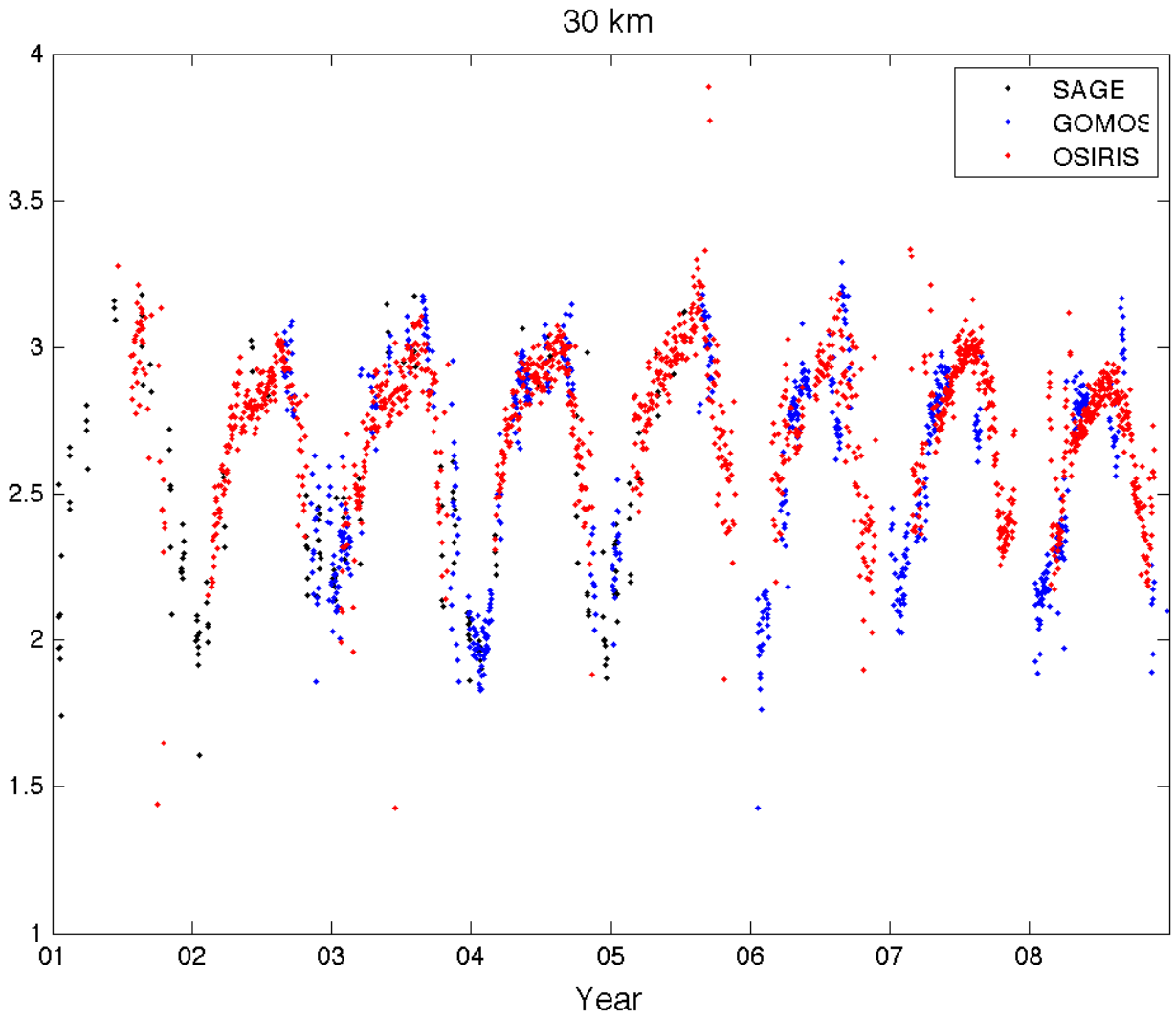
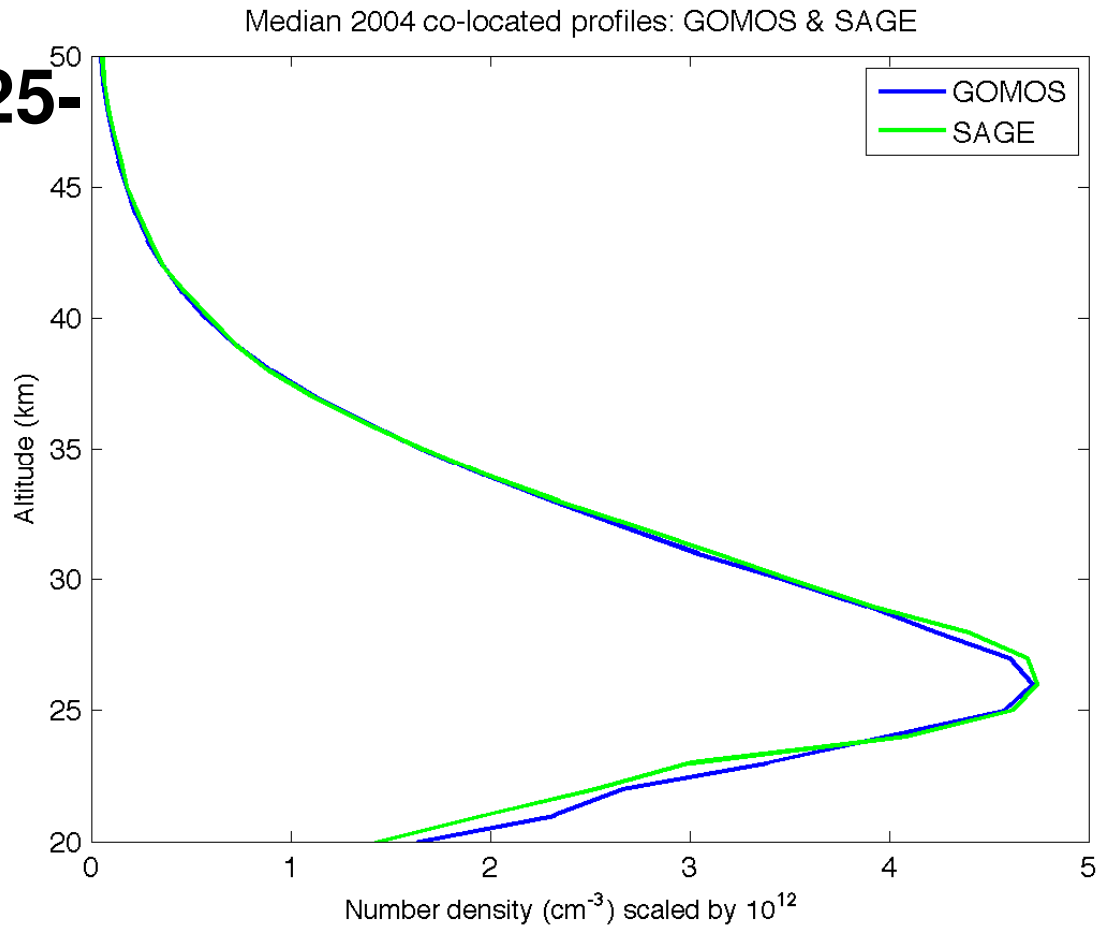
Time series comparisons: SAGE & GOMOS & OSIRIS

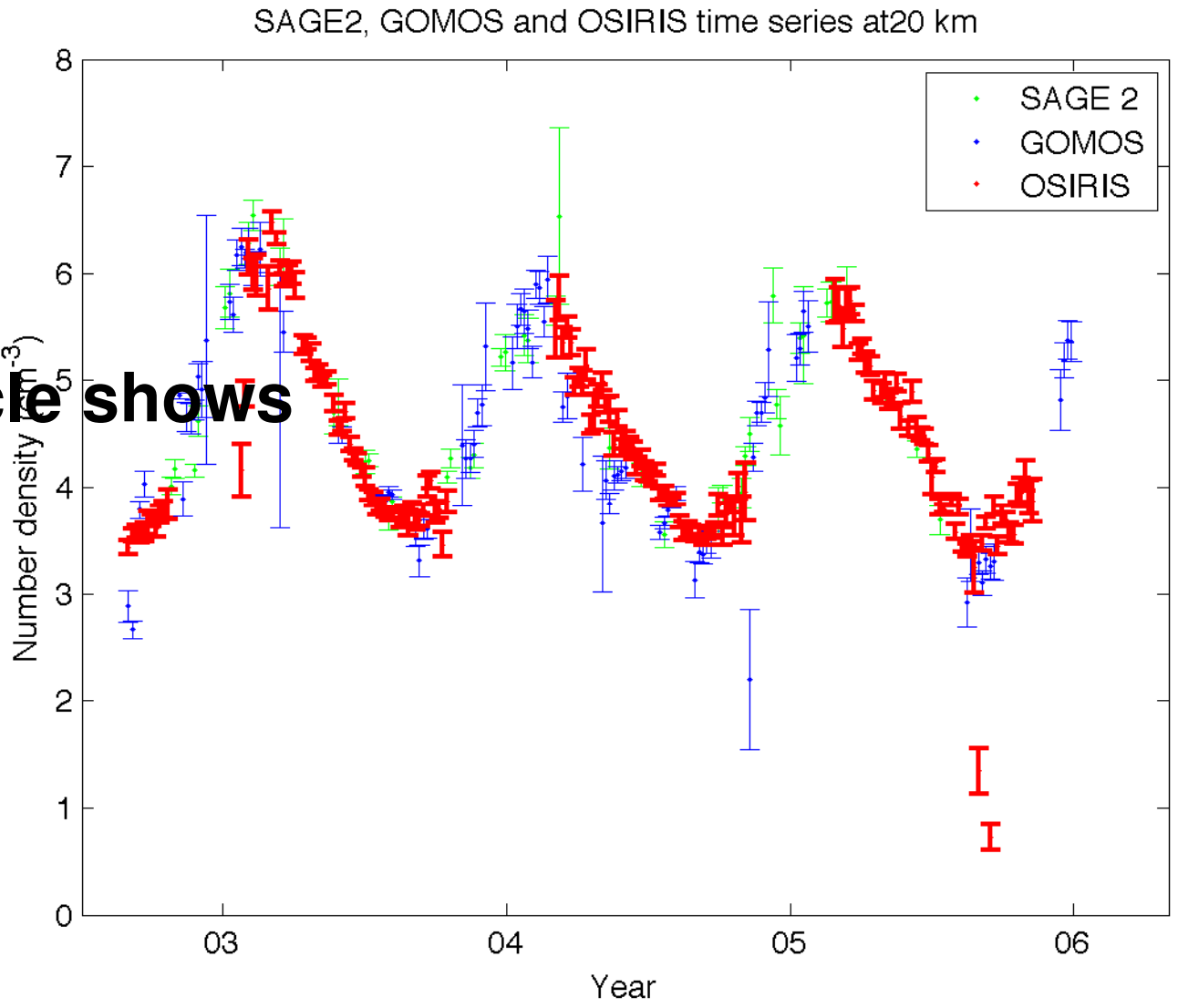


GOMOS vs SAGE II / Mid-latitude 50N

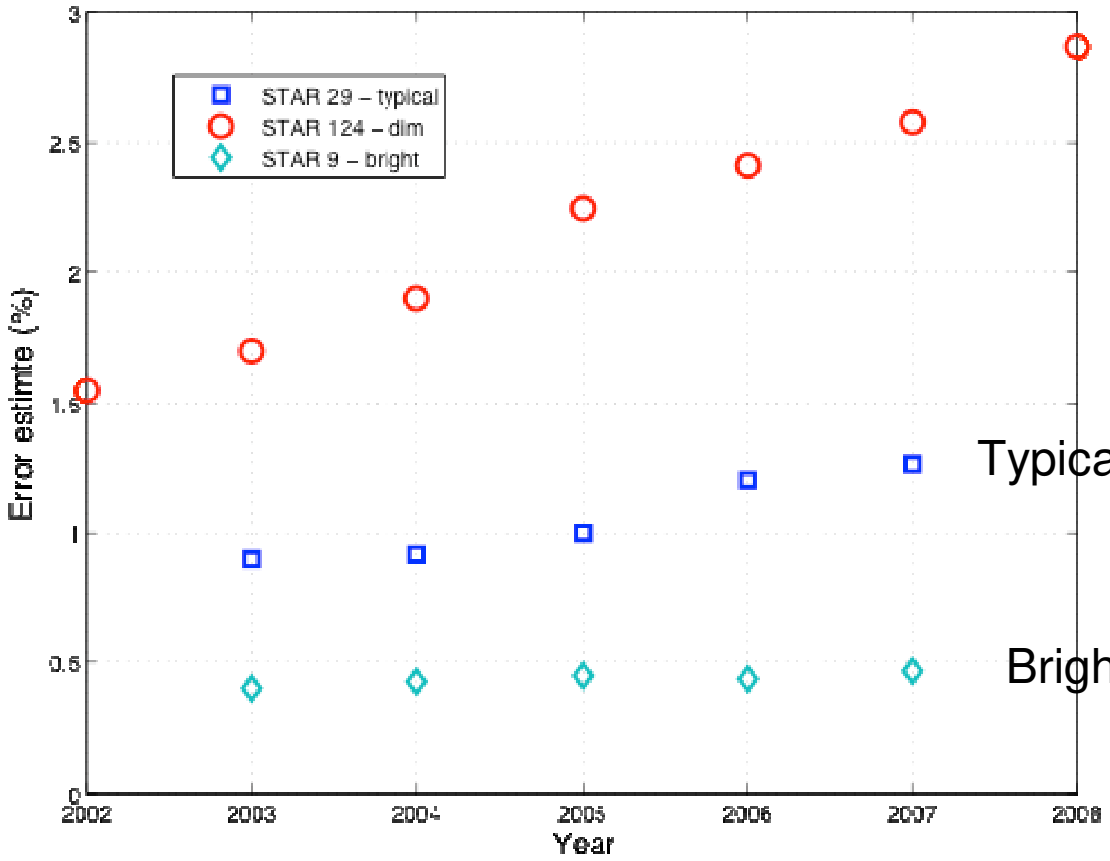
- **Excellent agreement btw 25-50 km.**
- **GOMOS slightly larger below 25 km.**



- **At 20 km**
- **Annular cycle shows up nicely**



Aging of the instrument



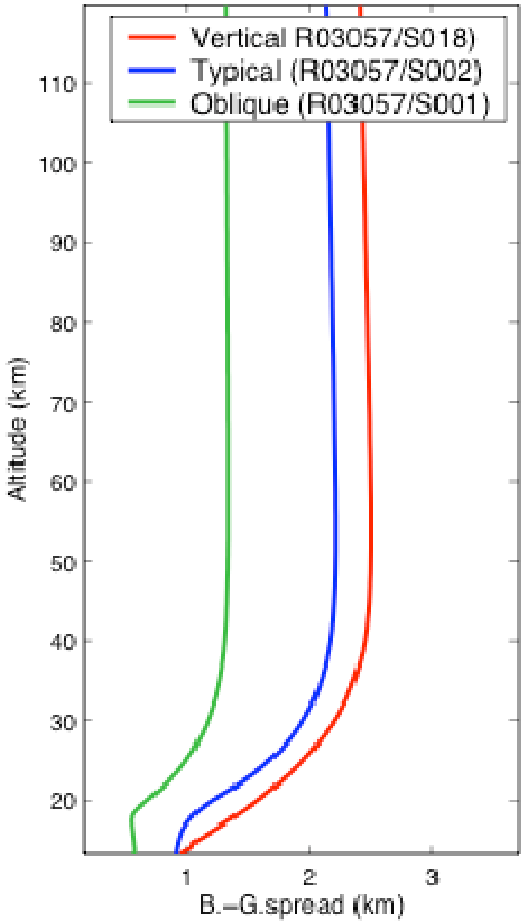
Dim star

Typical star

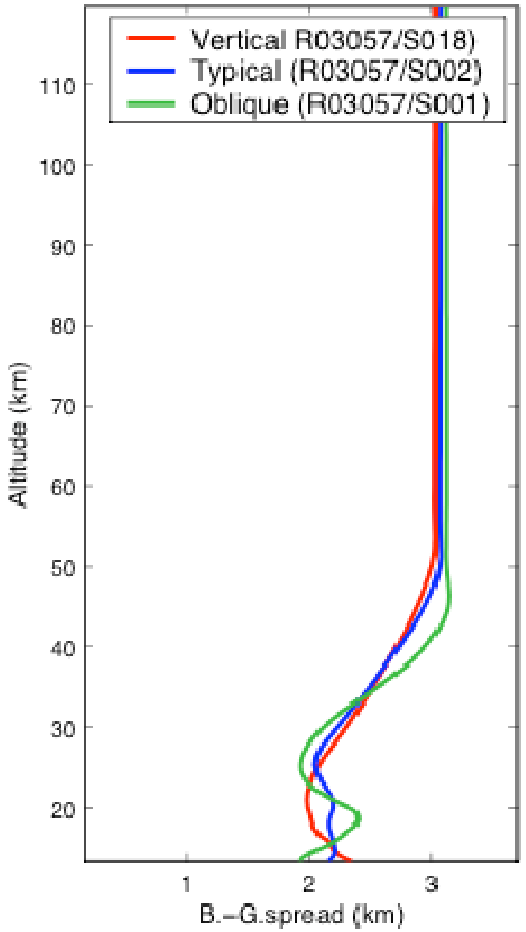
Bright star

Time evolution of the GOMOS error estimates for 3 different stars.
Corresponds to random error estimates at 40 km.

Vertical sampling and resolution



Vertical sampling resolution



Resolution of ozone profiles