5th Atmospheric Limb Conference
Helsinki, Finland, November 16-19, 2009

On the multi-mission validation of ozone limb sounders using NDACC network data

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- *T. von Clarmann (IMK)*
- *Instrument PIs and staff of NDACC and contributing networks*
- *Satellite science and data processing teams*
- *Funding: EC GEOmon, ProDEx SECPEA, ESA Multi-TASTE*

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Outline

- 9 limb sounders vs. 2 networks (10 and 50+)
- Error budget of a data comparison/fusion
- ✓ Detection of satellite drifts
- ✓ Altitude/latitude consistency of limb sounders

Mutual consistency of limb data records on the long term and at the global scale?

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Limb viewing ozone profilers

VIS and IR solar occultation

ERBS SAGE II v6.2	1984-2005
UARS HALOE v19	1991-2005
SPOT-3 POAM II v6.0	1993-1996
SPOT-4 POAM III v4	1998-2005
SCISAT-1 ACE-FTS v2.2updated	since 2004

IR and MW limb emission

Envisat MIPAS IPF 4.61/4.62 (NR)	2002-2004
EOS Aura MLS v2.2x	since 2004

UV/VIS stellar occultation

Envisat GOMOS v6.0f / IPF 5.0	since 2002

UV/VIS limb scattering

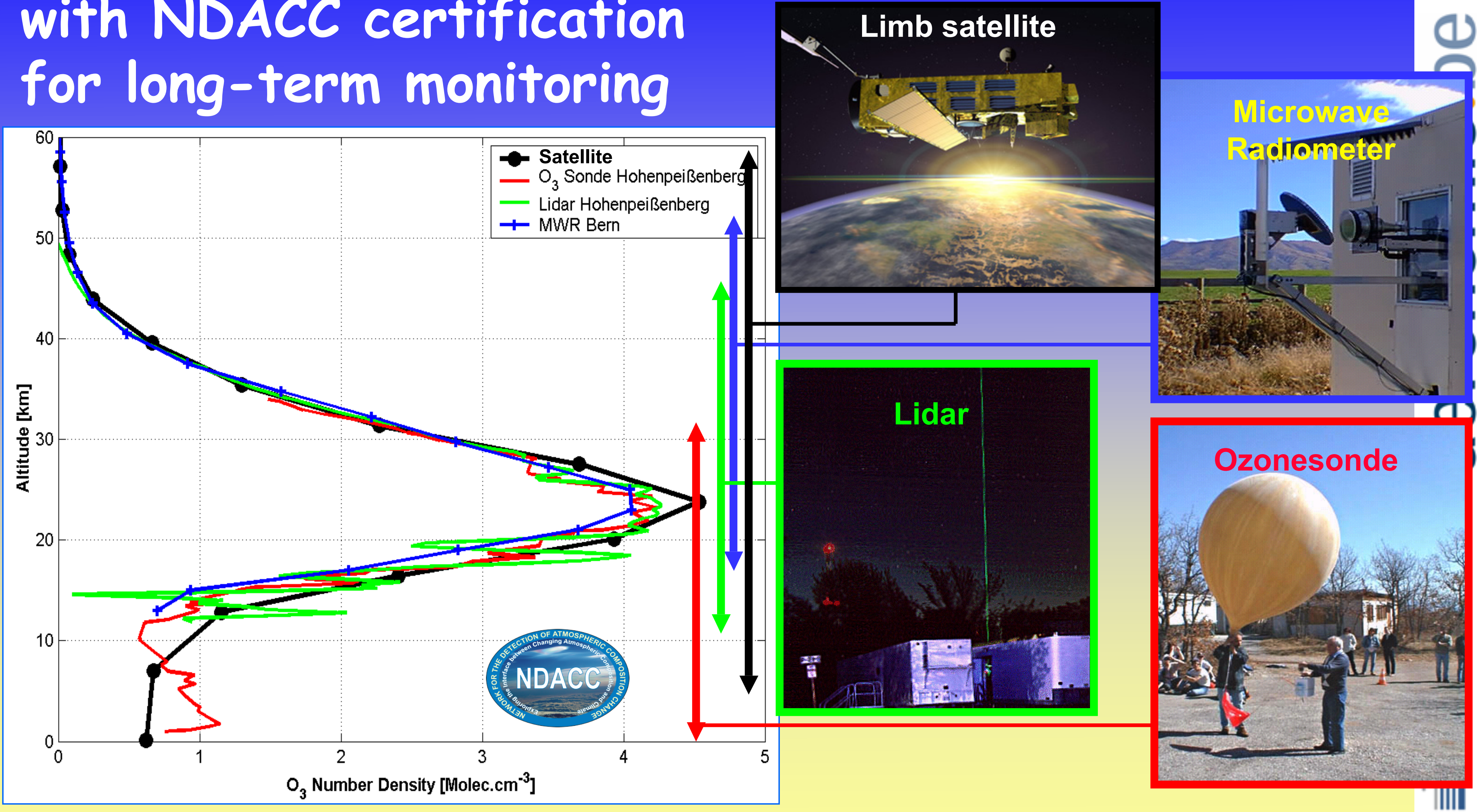
Envisat SCIAMACHY SGP 3.01	since 2002

Not studied here

LIMS, SAGE, ORA, CLAES, ISAMS, UARS MLS, ILAS, CRISTA, SAGE-III, MAESTRO, OSIRIS, SMR, HIRDLS…

Ground-based ozone profilers

with NDACC certification for long-term monitoring



Formal QA/QC protocols; network homogeneity documented

Error budget of data comparison/fusion

$$S_{2\ vs.\ 1} = S_{M2} + S_{M1}$$ } measurement

$$+ S_{B2} + S_{B1}$$ } measurement parameters

$$+ (I - A_2)\, S_{A2}\, (I - A_2)^t$$
$$+ (I - A_1)\, S_{A1}\, (I - A_1)^t$$ } retrieval parameters

$$+ (A_{V2} - A_{V1})\, S_{XV}\, (A_{V2} - A_{V1})^t$$ } vertical smoothing differences

$$+ (A_{H2} - A_{H1})\, S_{XH}\, (A_{H2} - A_{H1})^t$$ } angular smoothing differences

$$+ S(\partial_t O_3\, dt,\ \nabla_{\theta\phi} O_3\, d\theta\phi,\ \partial_z O_3\, dz)$$ } time, space and pointing differences

+ errors due to sampling differences (incl. non respect of Nyquist)

Rodgers, JAS 1976, JGR 1990
Rodgers and Connor, JGR 2003
Lambert, ULB 2006

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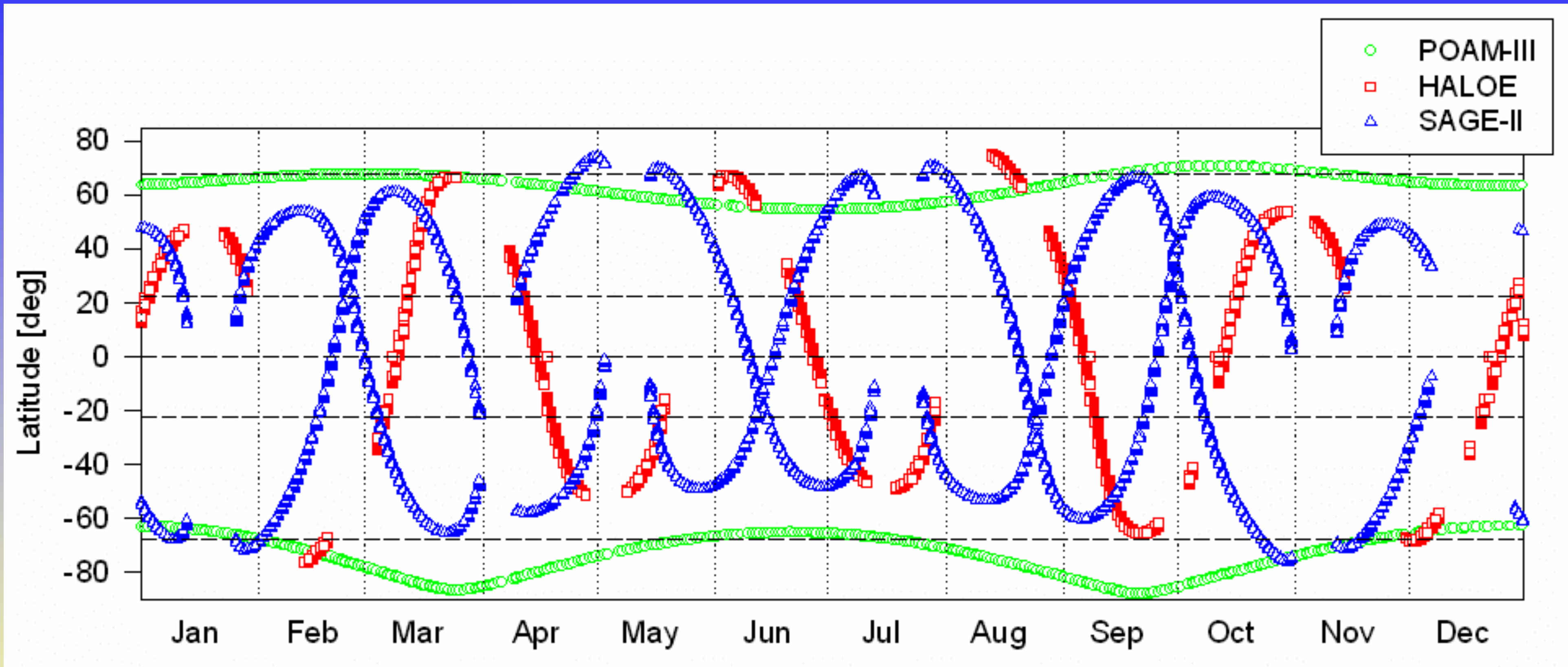
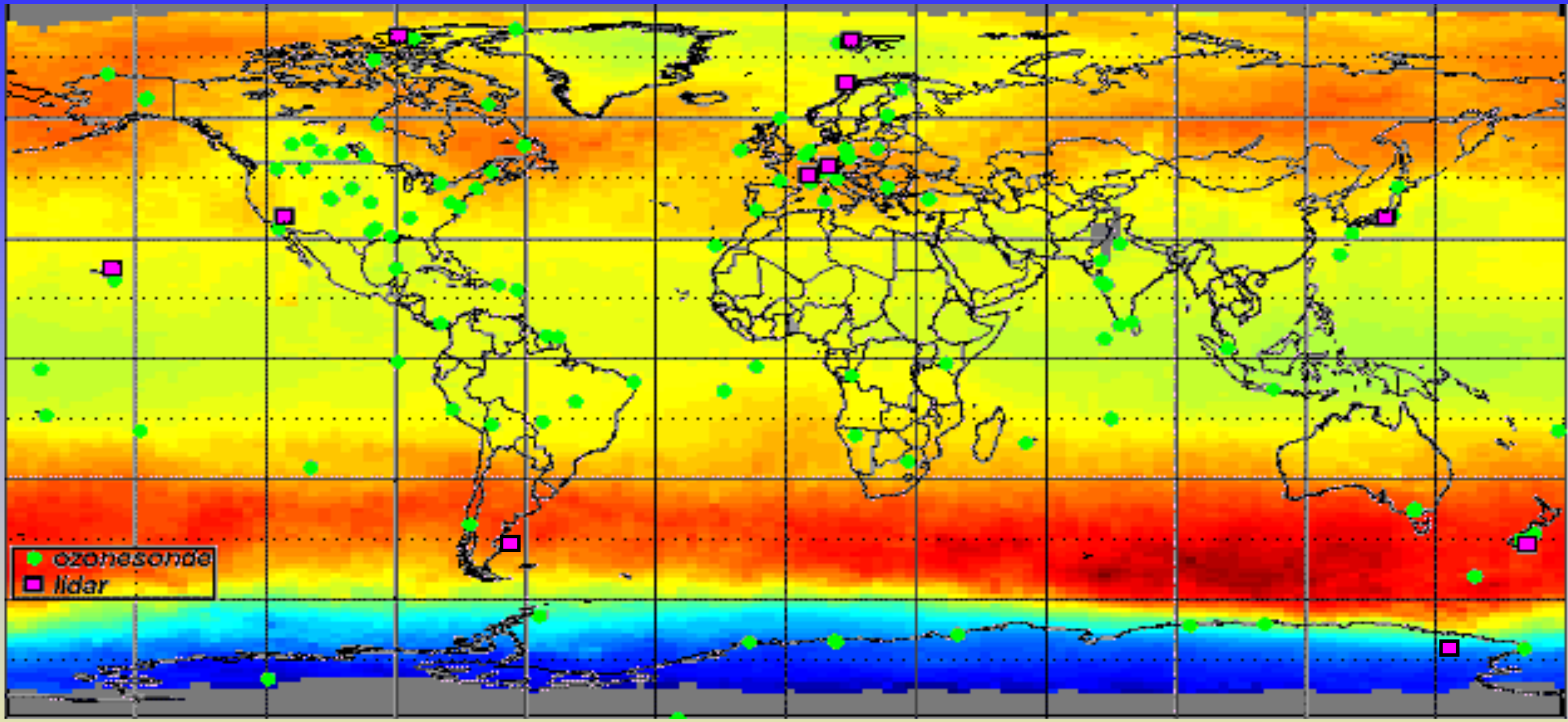
Geographical sampling by solar occultation

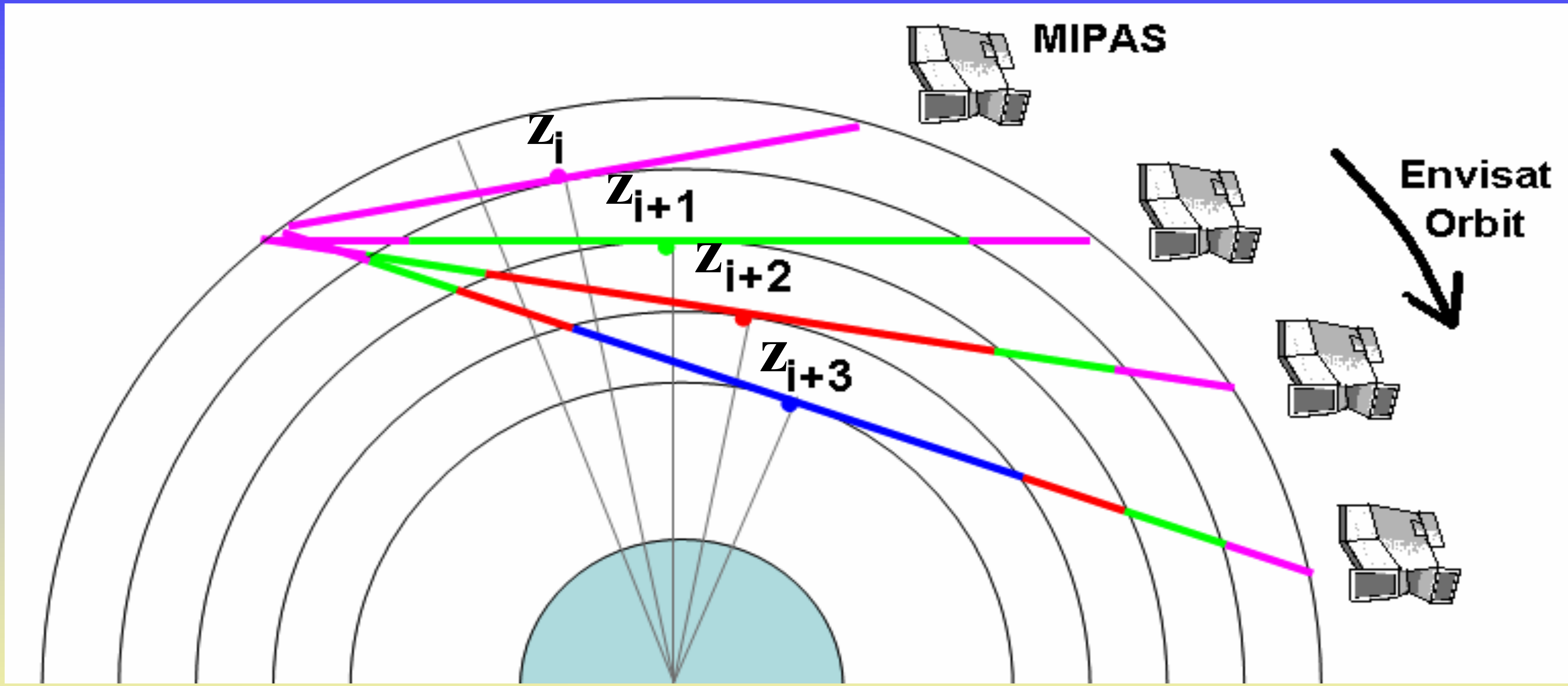


Geographical sampling by networks



Horizontal smoothing by limb sounding

MIPAS Limb IR emission



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2-D averaging kernels for a 1-D profile retrieval

$$A = GK$$

Inverse model   Direct model

Use of the KOPRA 2-D model (FZK-IMK Karlsruhe)

Bi-dimensional atmosphere

$$x_{2D} = (x_{1,1}, \ldots, x_{1,j}, x_{2,1}, \ldots, x_{2,j}, \ldots x_{k,j})$$

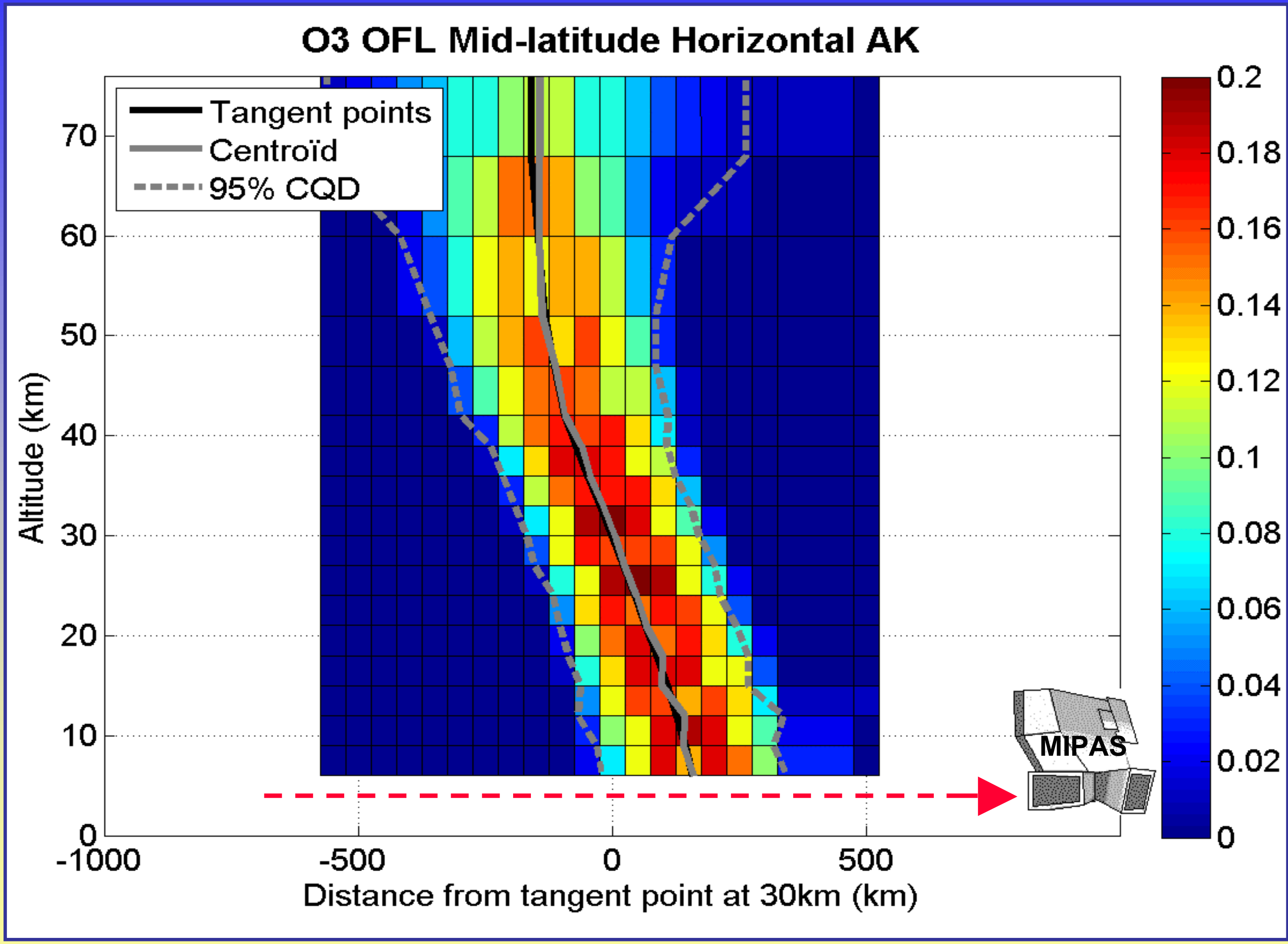
2-D inversion with a constraint to horizontal homogeneity

$$A_{2D} = (K_{2D}^T S_y^{-1} K_{2D} + R)^{-1} K_{2D}^T S_y^{-1} K_{2D}$$

For details see von Clarmann, De Clercq, Ridolfi, Höpfner, and Lambert, AMT 2009

and also De Clercq, von Clarmann and Lambert, GEOmon TN, 2009

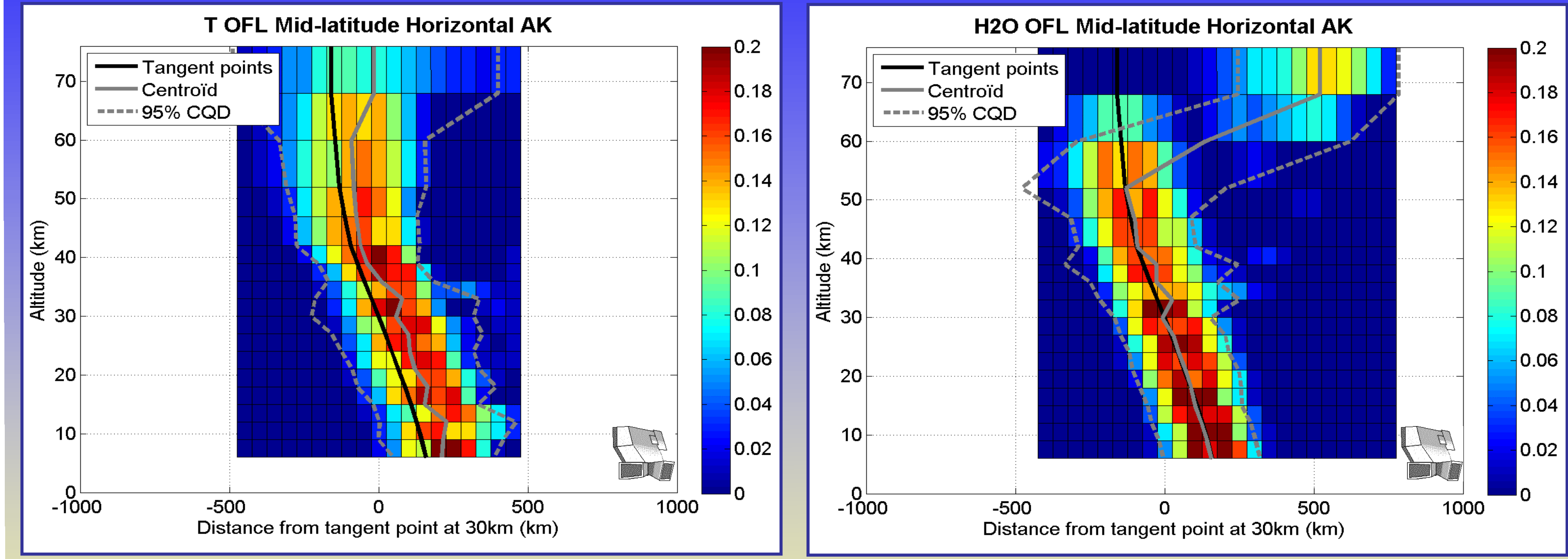
Horizontal averaging kernels for MIPAS IPF



Details in von Clarmann, De Clercq, Ridolfi, Höpfner, and Lambert, AMT 2009

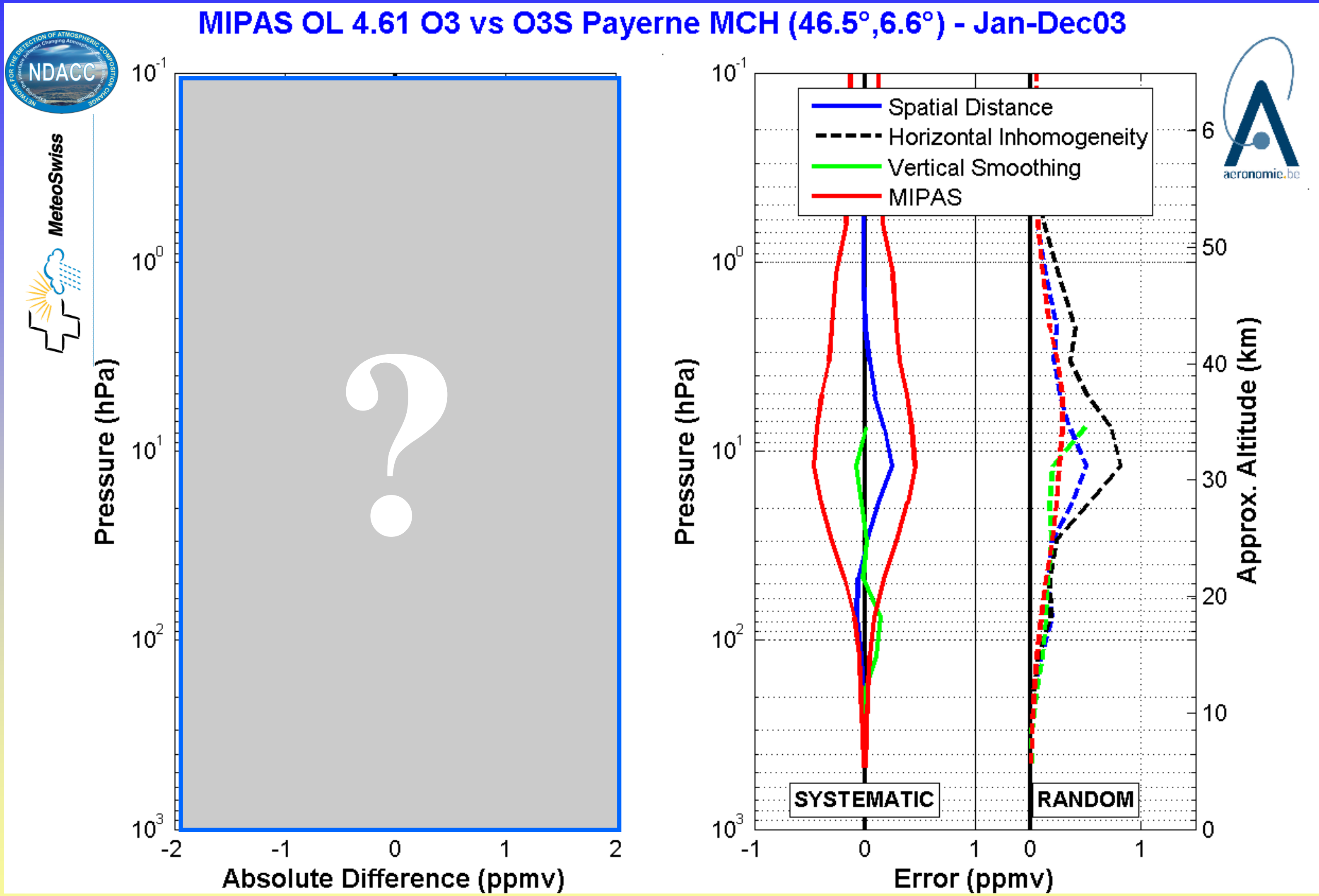
Horizontal averaging kernels for MIPAS IPF

temperature — water vapour



Details in *von Clarmann, De Clercq, Ridolfi, Höpfner, and Lambert, AMT 2009*

Error budget of MIPAS O_3 validation



See Cortesi, Lambert, De Clercq et al., ACP 2007

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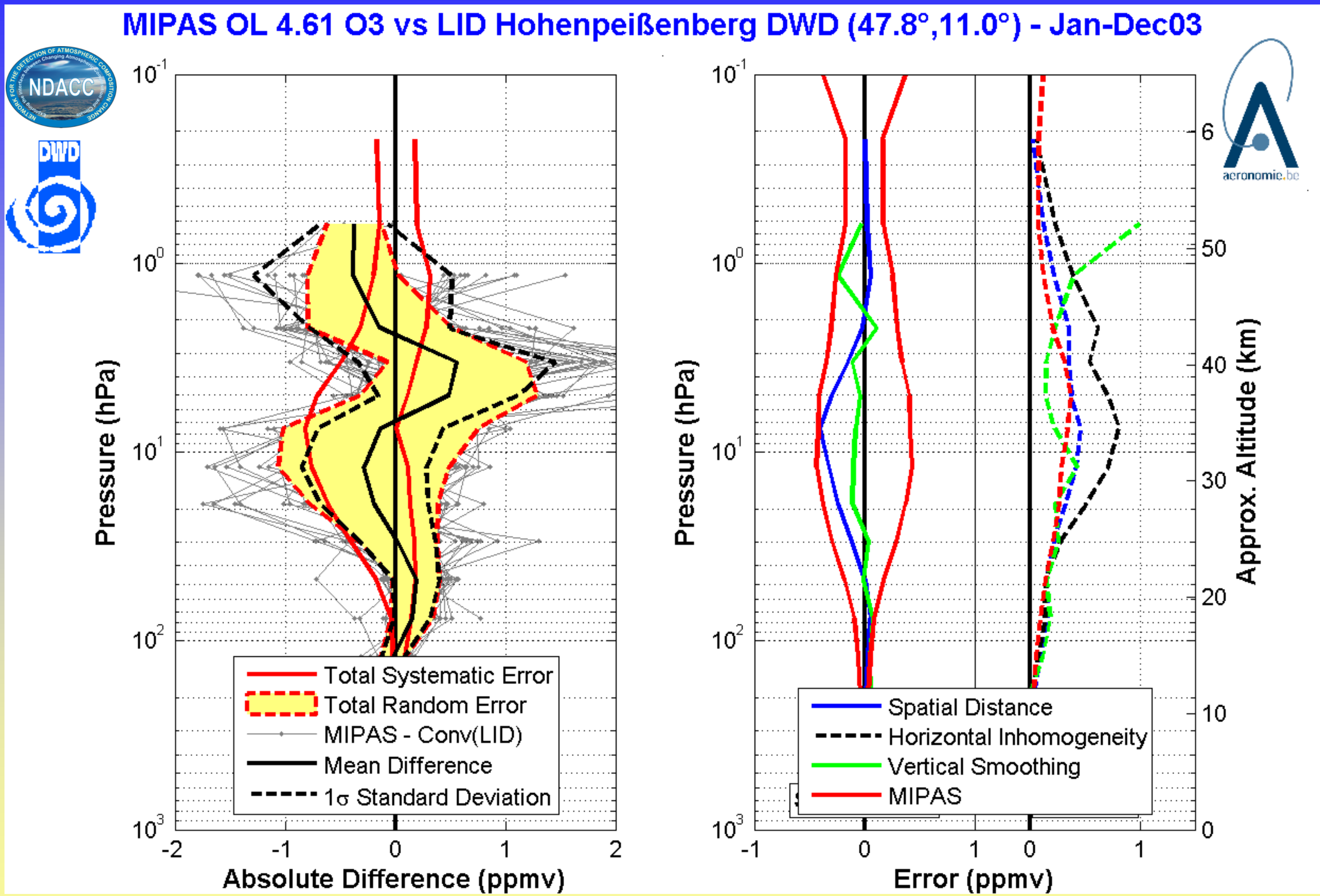

See Cortesi, Lambert, De Clercq et al., ACP 2007

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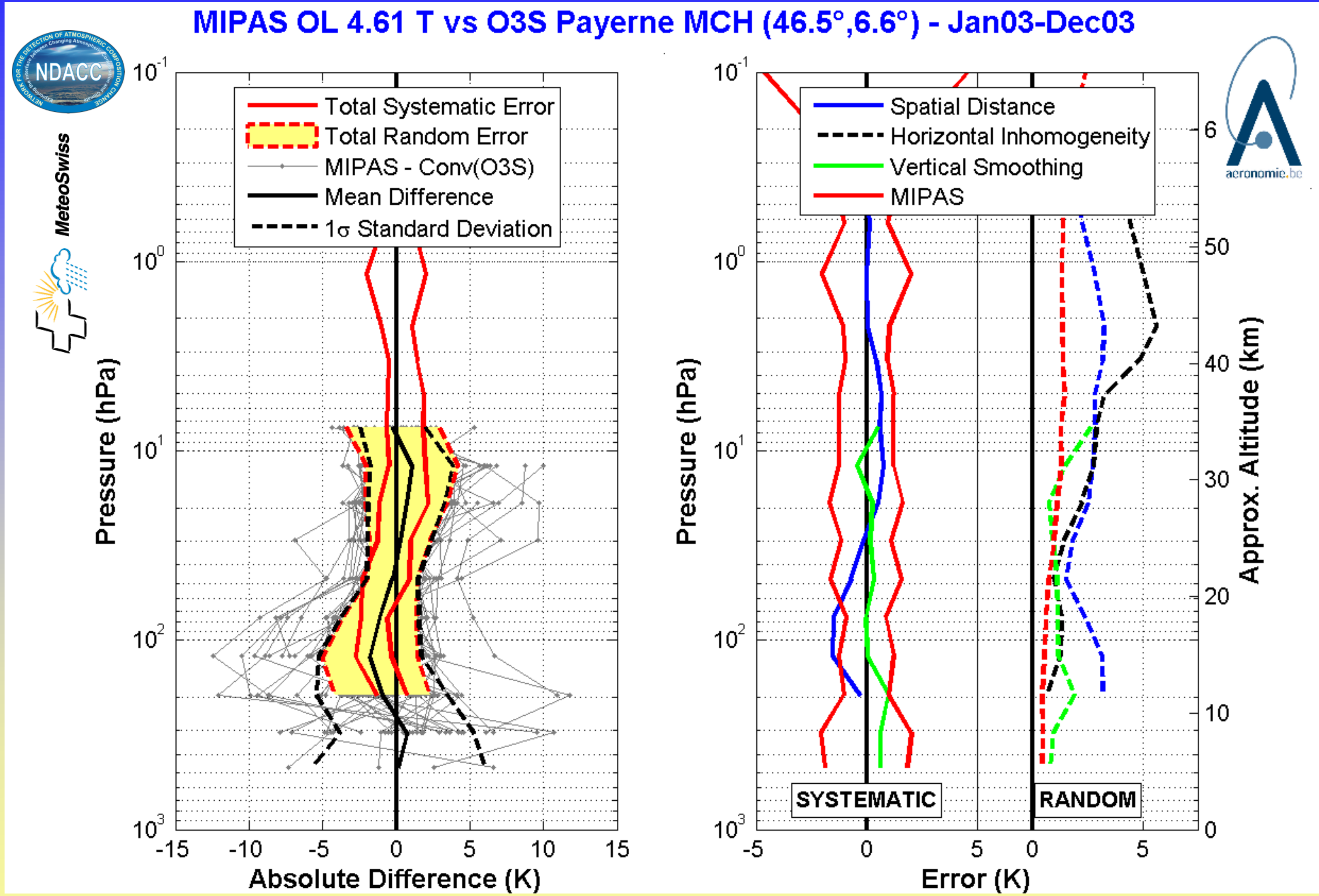
Error budget of MIPAS T validation



See Ridolfi et al., ACP 2007

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Detection of satellite drifts

- Robust linear regression (Tukey's biweight method) on the timeseries of relative differences between satellite and GB data

- σ on the trend

$$\sigma_B = \frac{\sigma_N}{\sigma_X * \sqrt{N-1}}$$

Std dev on the residuals (σ_N)

Std dev on the dates (σ_X)

Nb of data entries (N)

- Trend is significant if slope > $2*\sigma_B$

- Further (case by case) consolidation of the trends

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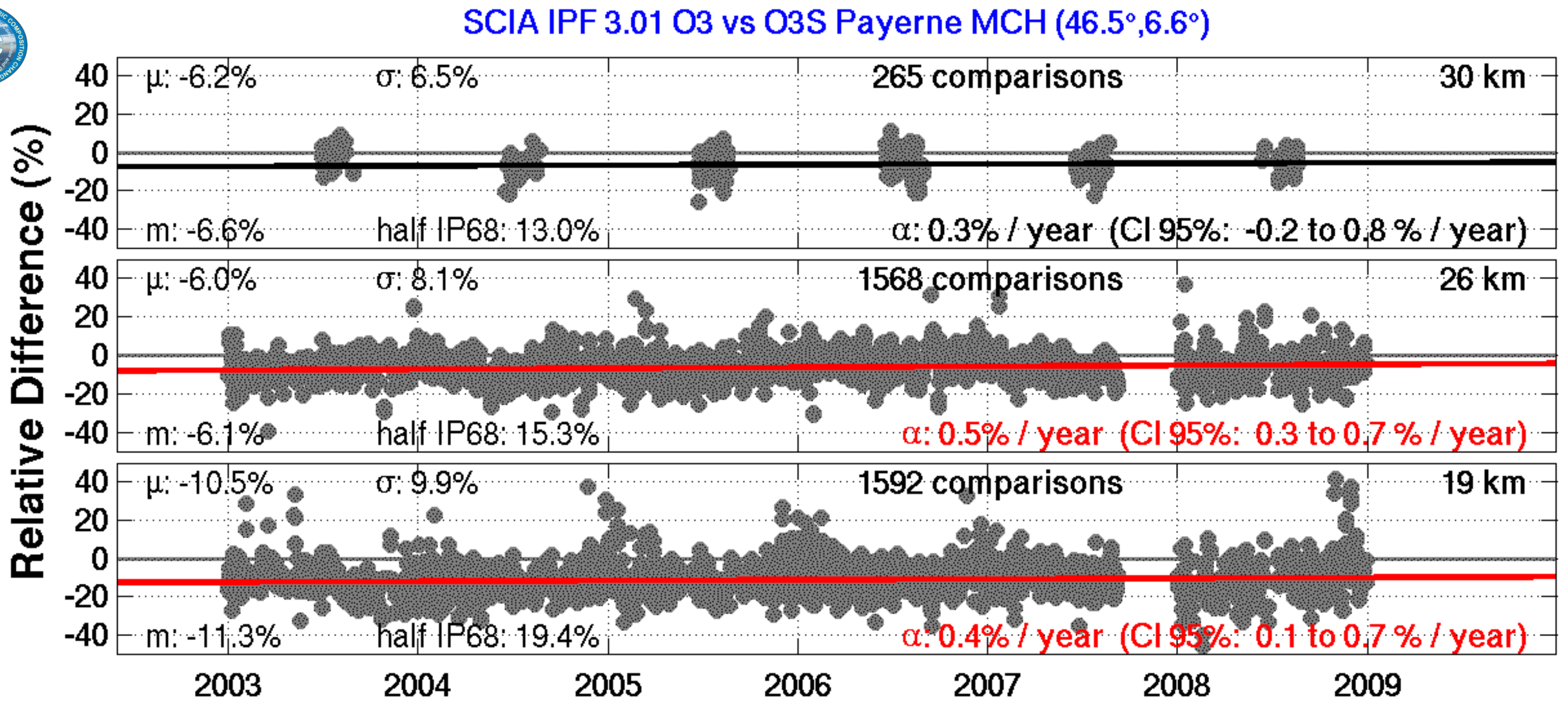
Detection of satellite drifts



SCIAMACHY

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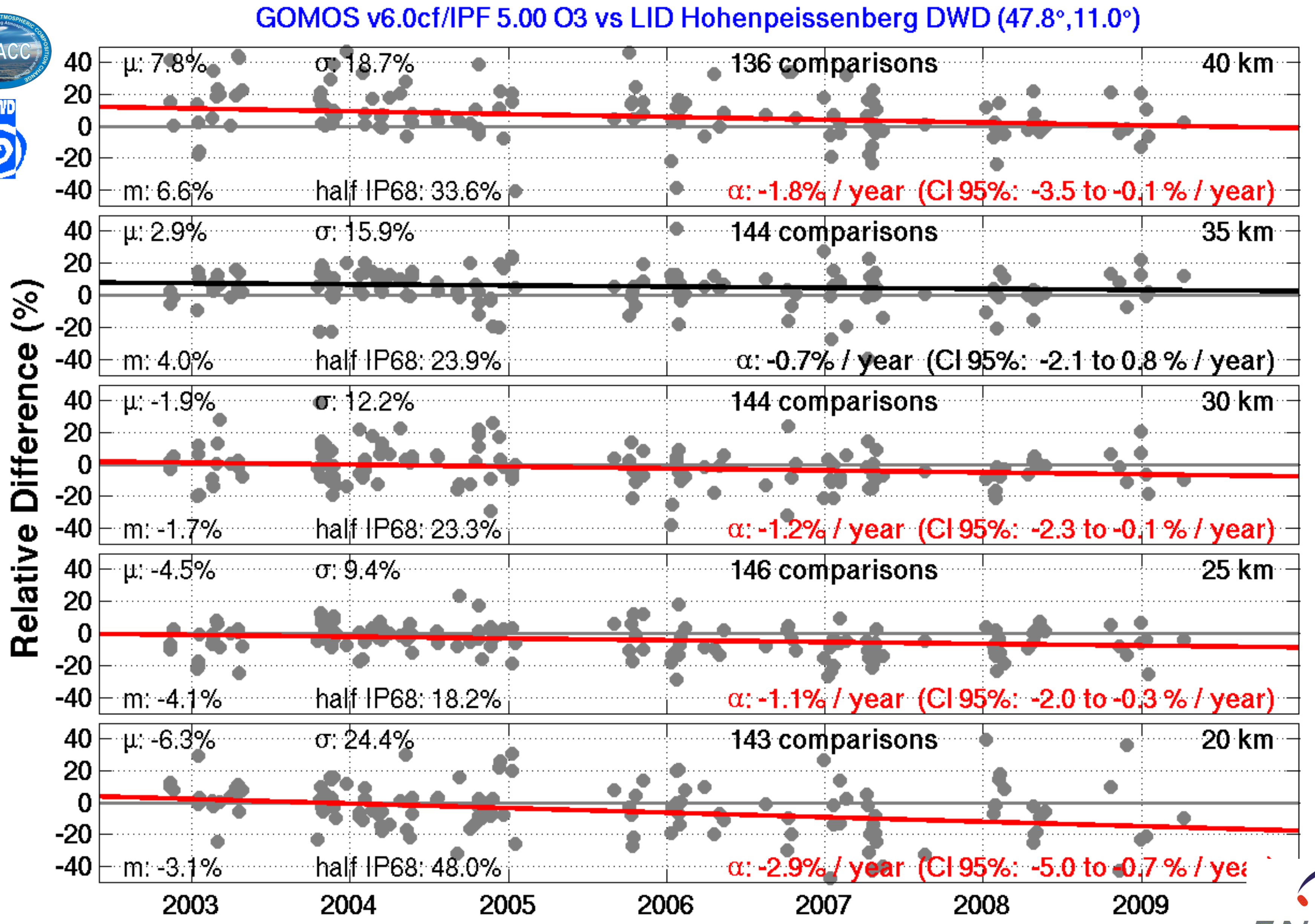
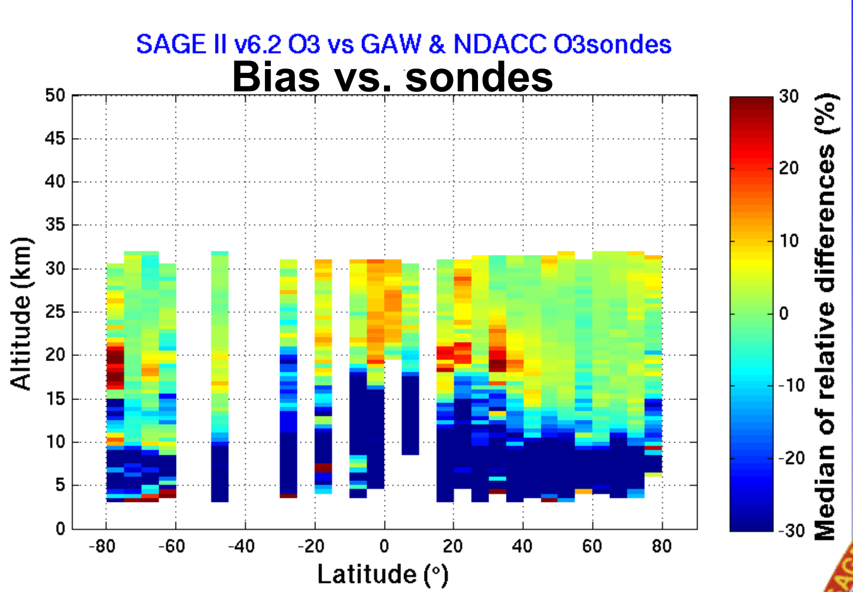
Detection of satellite drifts

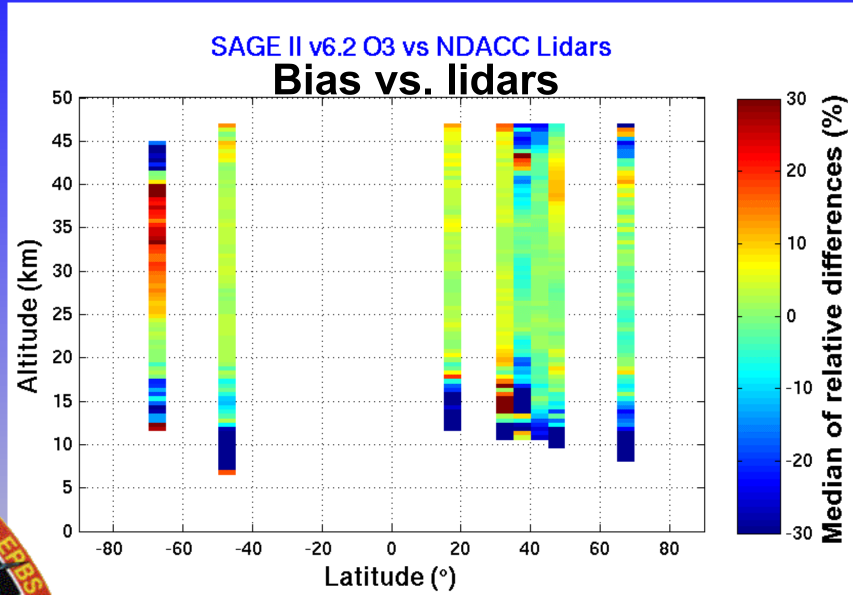


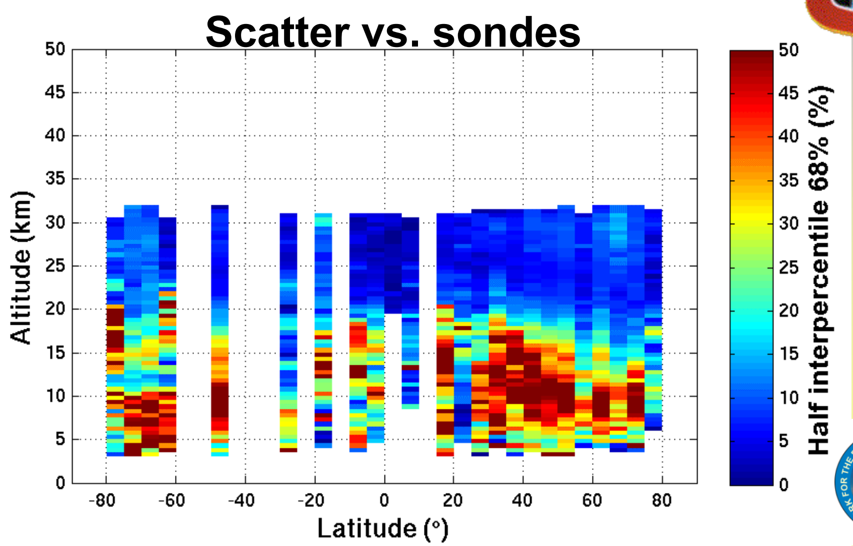
Overview of satellite drifts

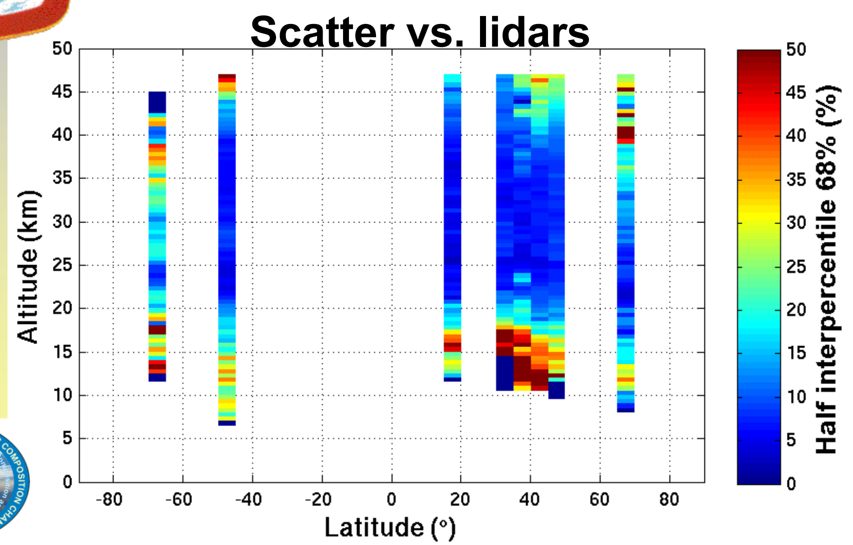
Instrument	Drift	Latitude	Altitude	Comment
SAGE-II (v6.2)	none detected			
HALOE (v19)	about -1% /y.	Mid + high N	25 - 30km	consolidated
POAM2 (v6)	none detected (short time series)			
POAM3 (v4)	about +1% /y.	Mid N	25 - 30km	quite consolidated though short timeseries
MIPAS (IPF4.61)	short time series => very "noisy" (waiting for RR data 2005-now)			
SCIAMACHY (SGP3.01)	about +1% /y.	All N (+S)	(22 -) 26km	quite consolidated though "noisy"
GOMOS (IPF5/6.0cf)	-1 -2% /y.	Mid N	(20 -) 25km	quite consolidated though "noisy"
ACE (v2.2u)	none detected (but only few comparison pairs)			
MLS (v2.2x)	about -1% /y. about +1% /y.	Mid N	~ 20 km ~ 24 km	short time series => "noisy" results

ERBS SAGE II

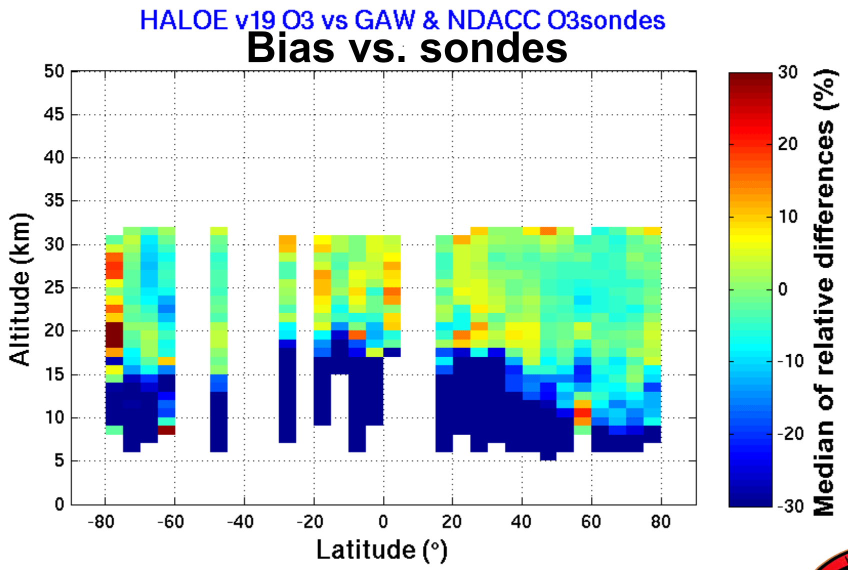

SAGE II v6.2 O3 vs GAW & NDACC O3sondes
Bias vs. sondes
Altitude (km)
Latitude (°)
Median of relative differences (%)

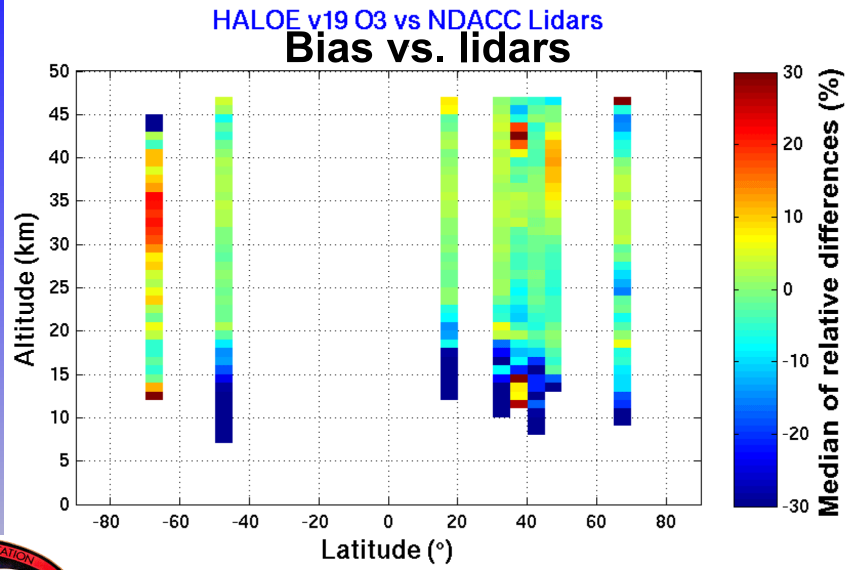

SAGE II v6.2 O3 vs NDACC Lidars
Bias vs. lidars
Altitude (km)
Latitude (°)
Median of relative differences (%)

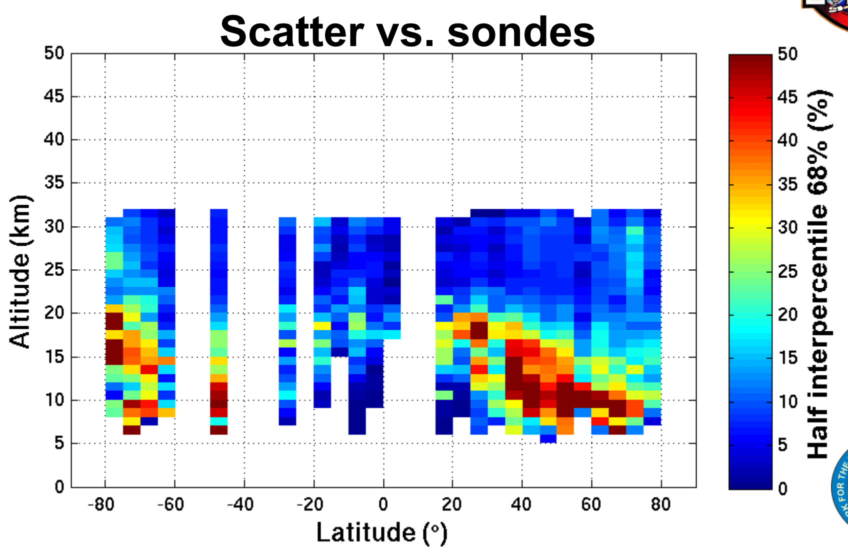

Scatter vs. sondes
Altitude (km)
Latitude (°)
Half interpercentile 68% (%)


Scatter vs. lidars
Altitude (km)
Latitude (°)
Half interpercentile 68% (%)

UARS HALOE


HALOE v19 O3 vs GAW & NDACC O3sondes
Bias vs. sondes
Altitude (km)
Latitude (°)
Median of relative differences (%)


HALOE v19 O3 vs NDACC Lidars
Bias vs. lidars
Altitude (km)
Latitude (°)
Median of relative differences (%)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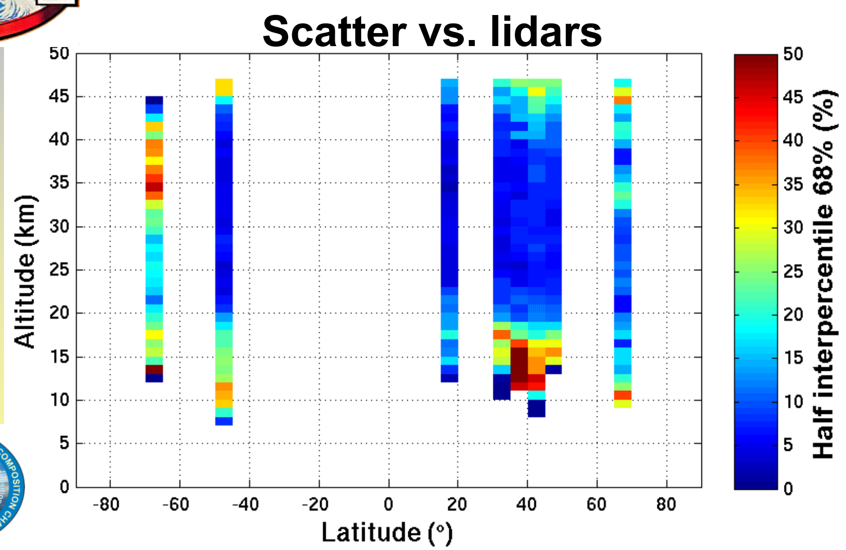
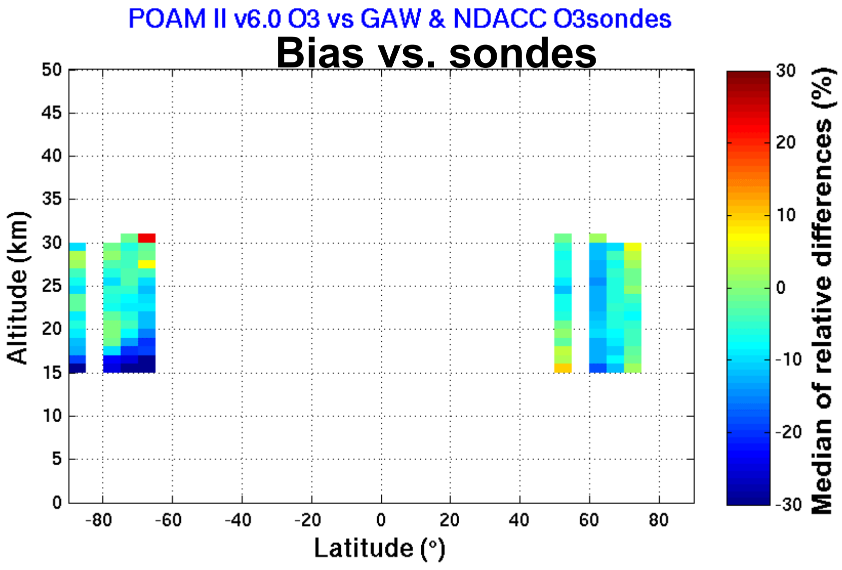
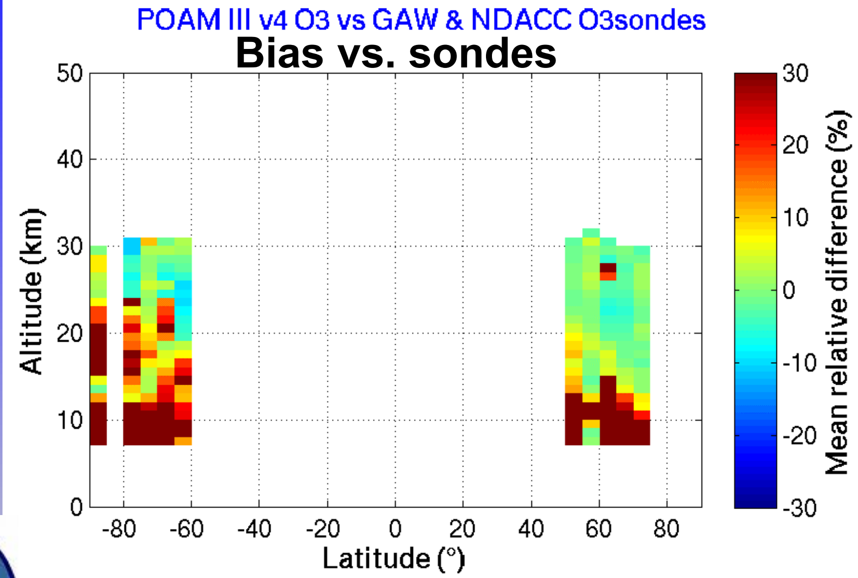
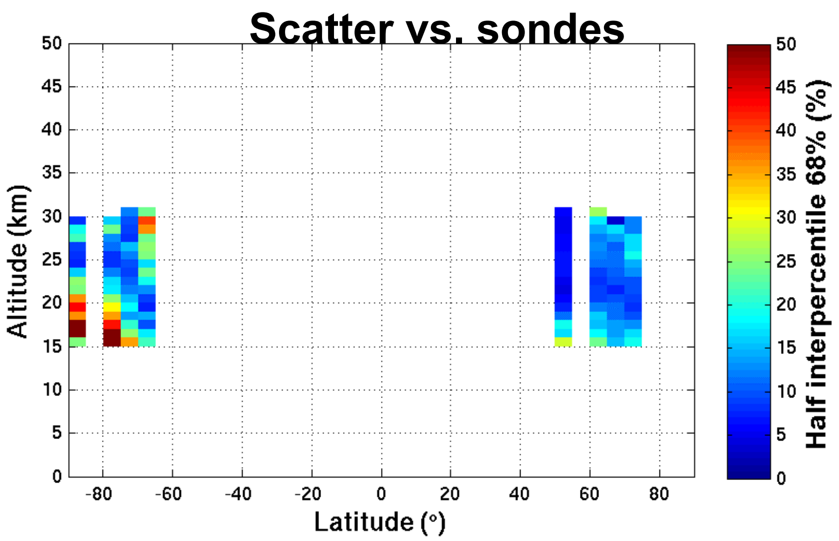
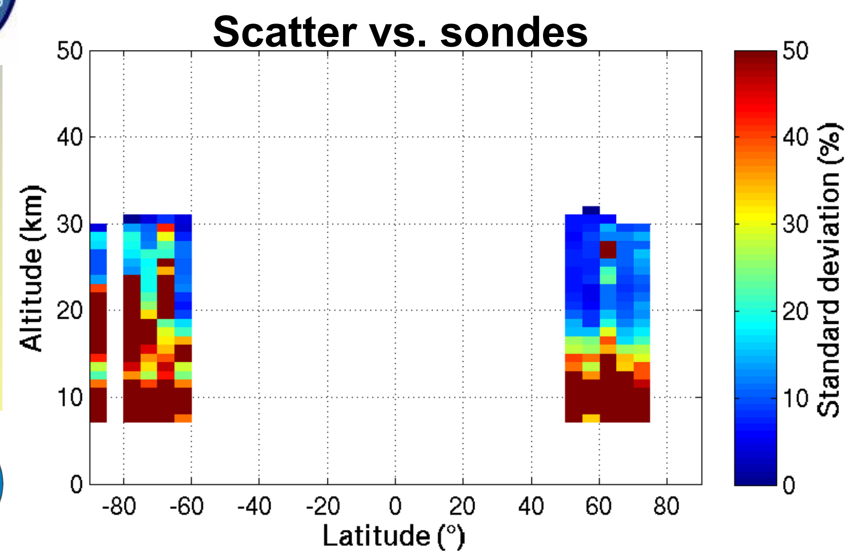

Scatter vs. lidars
Altitude (km)
Latitude (°)
Half interpercentile 68% (%)

SPOT-3 POAM II & SPOT-4 POAM III









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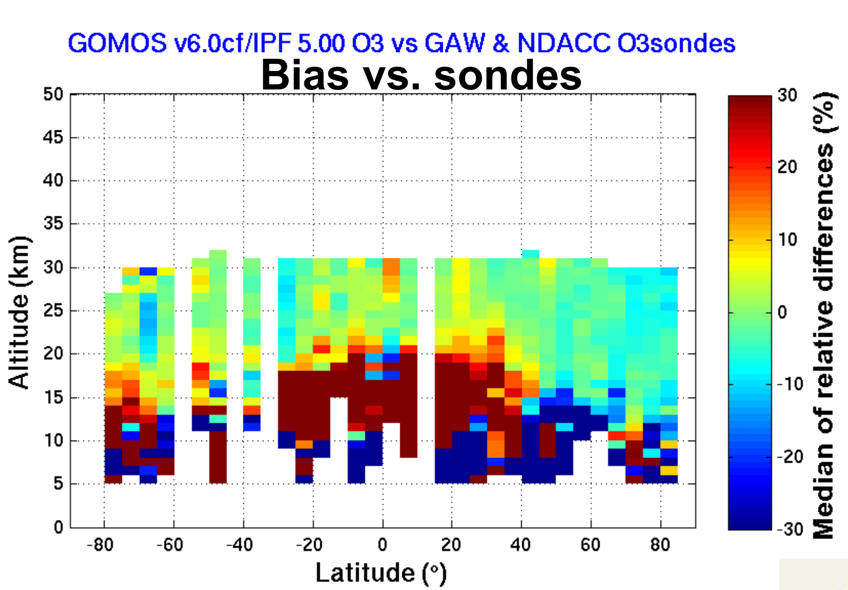

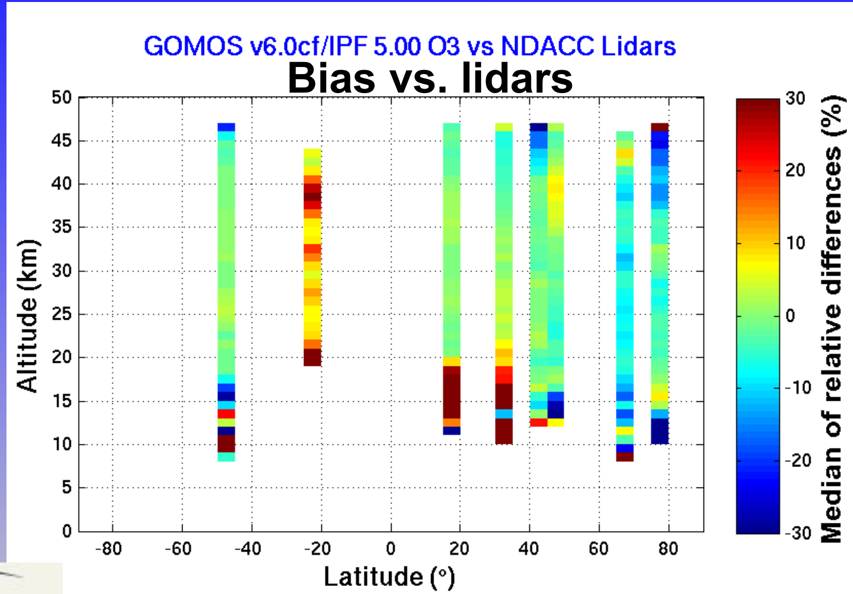

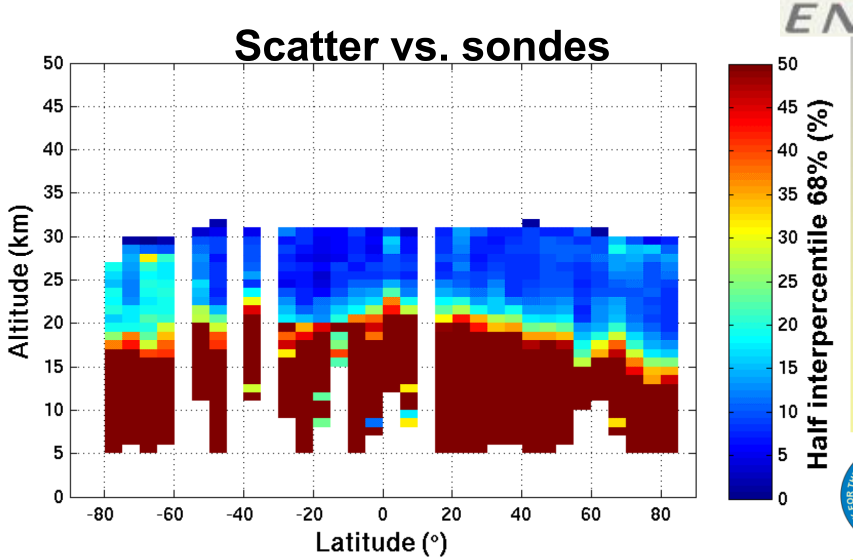

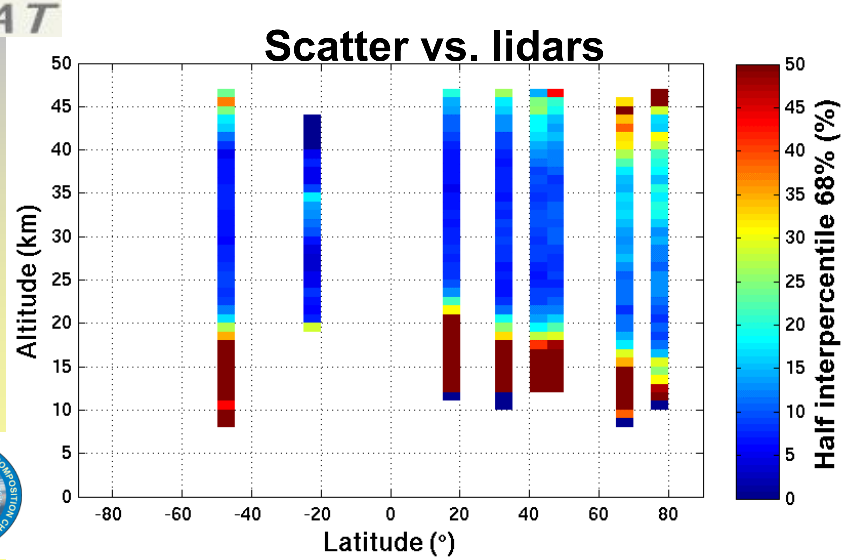

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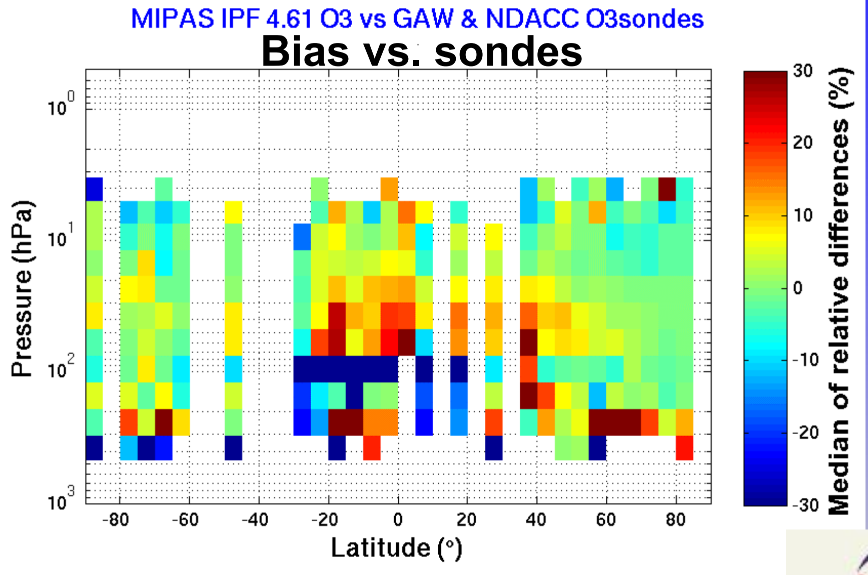

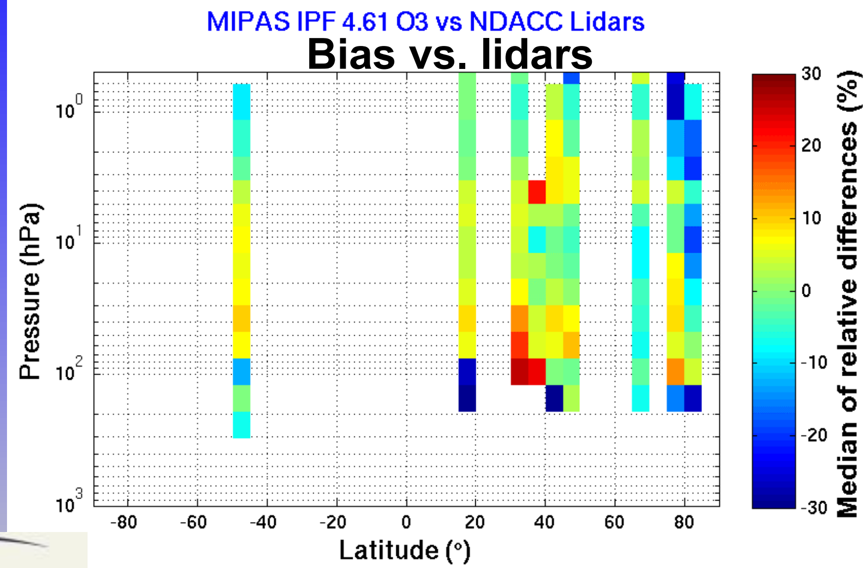

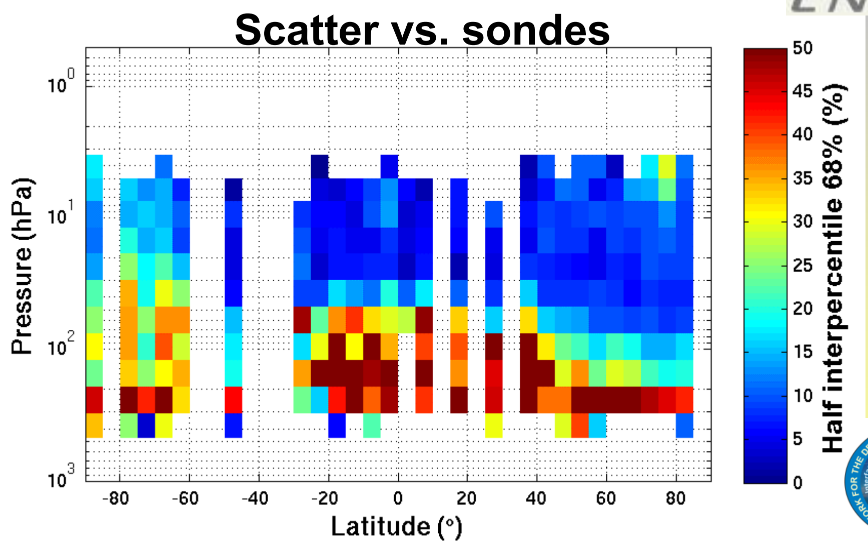

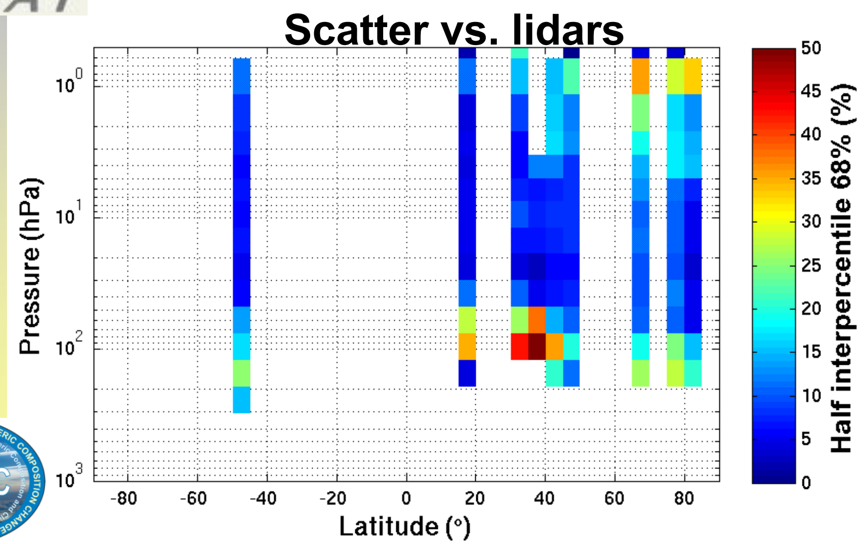

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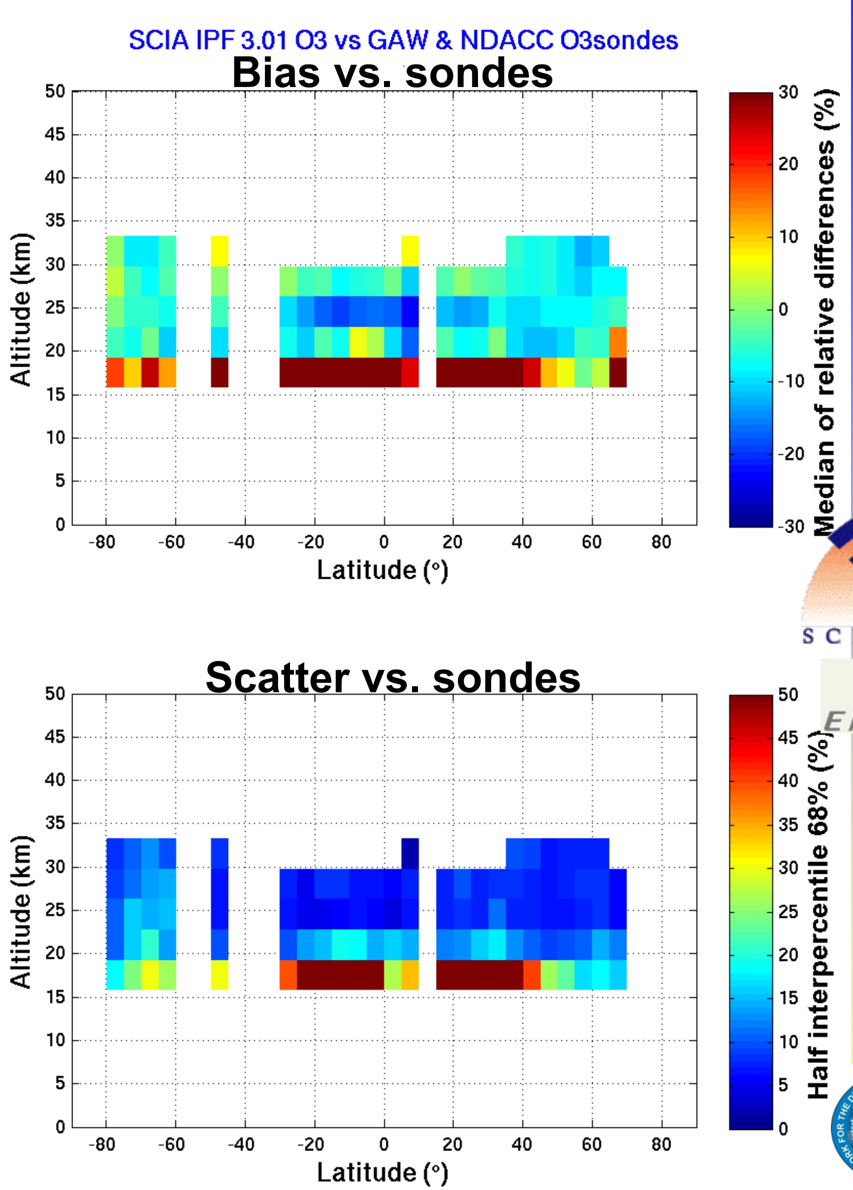
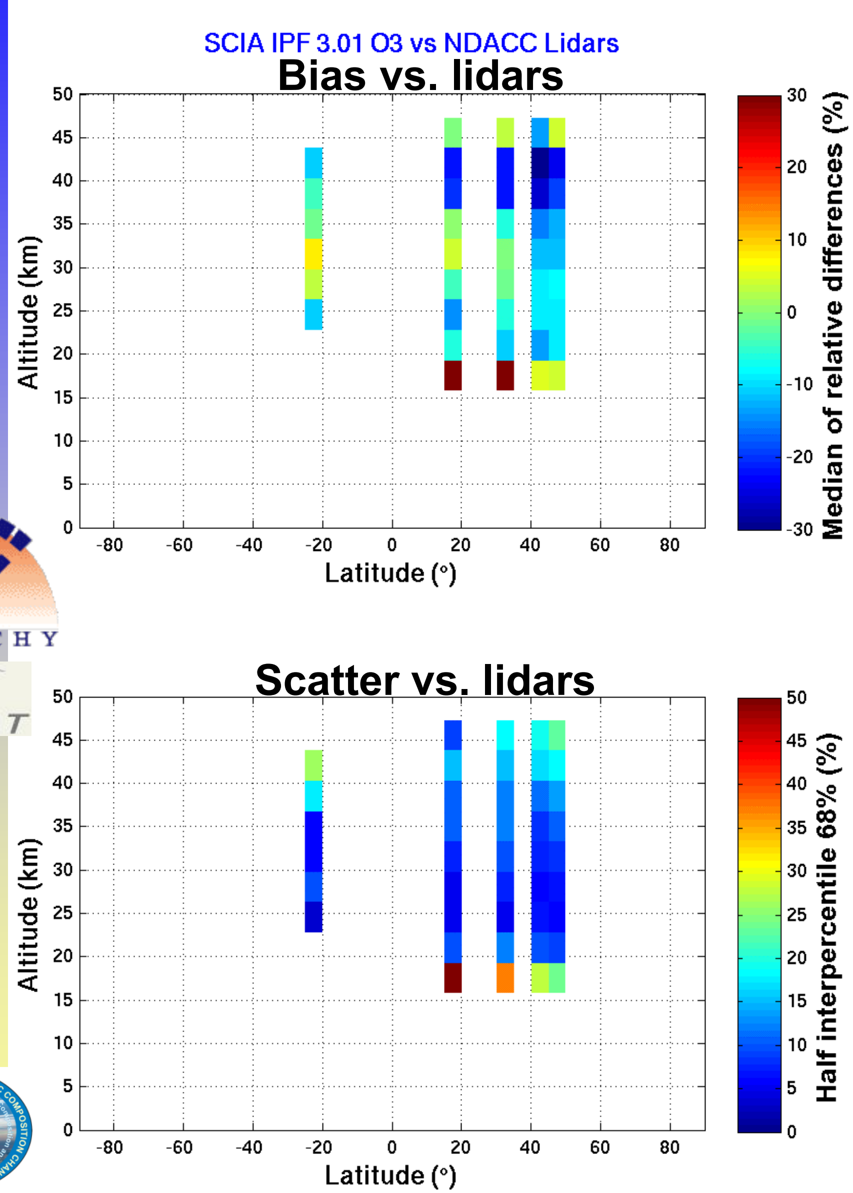
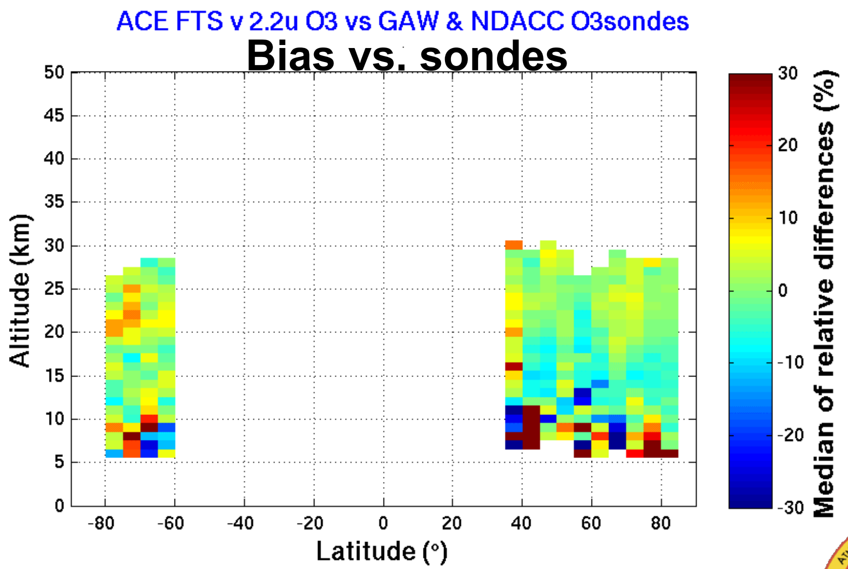
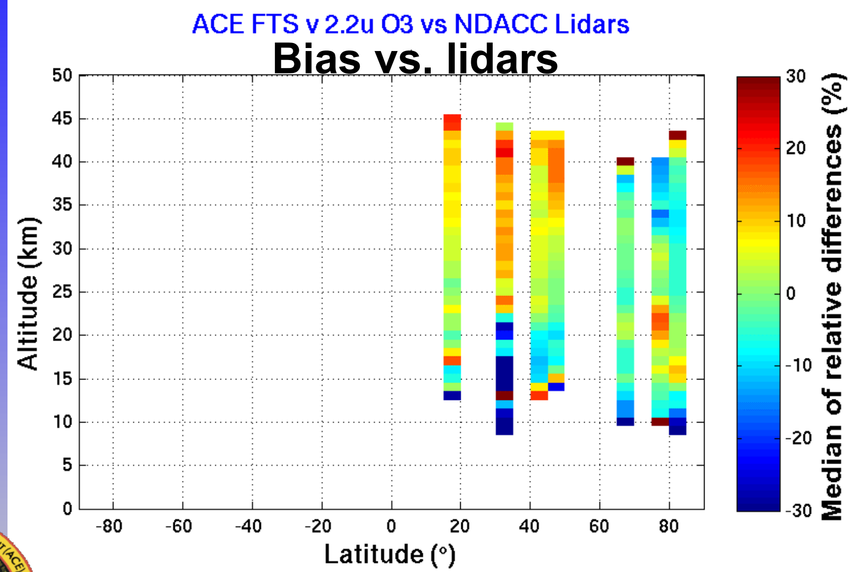




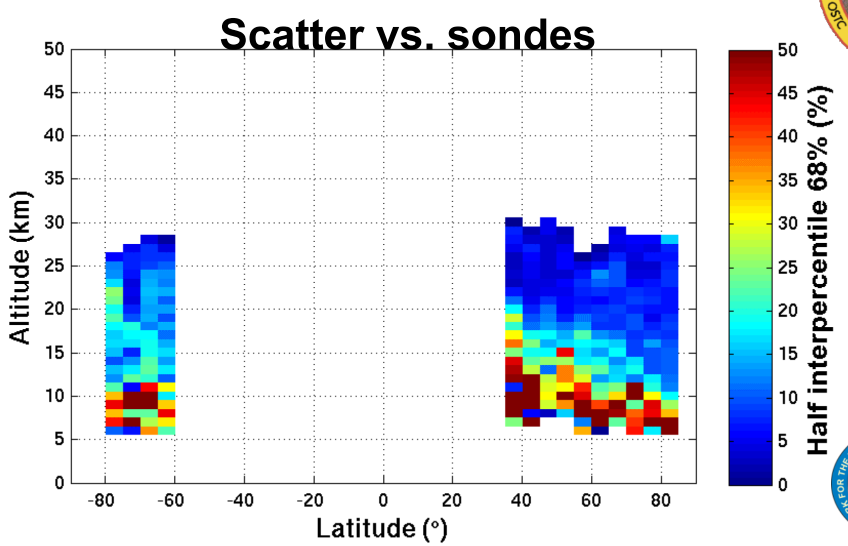
SCISAT-1 ACE-FTS

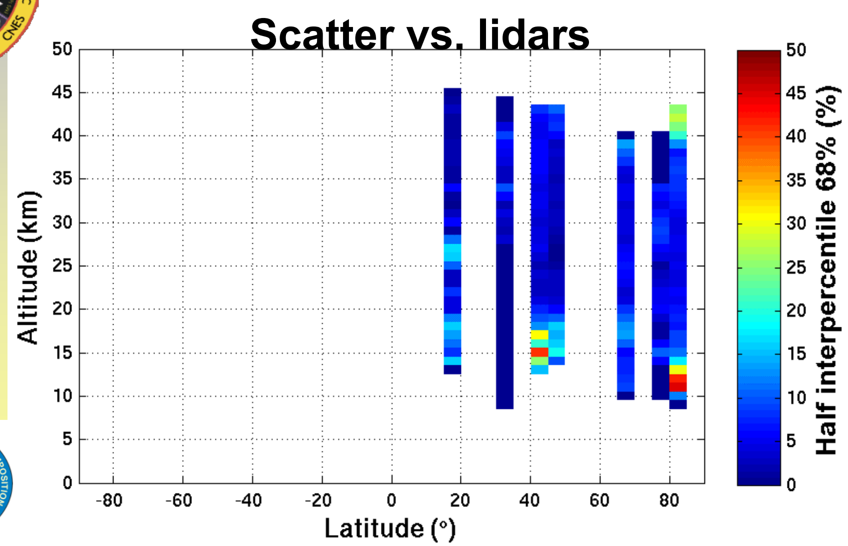




SCISAT-1

NDACC





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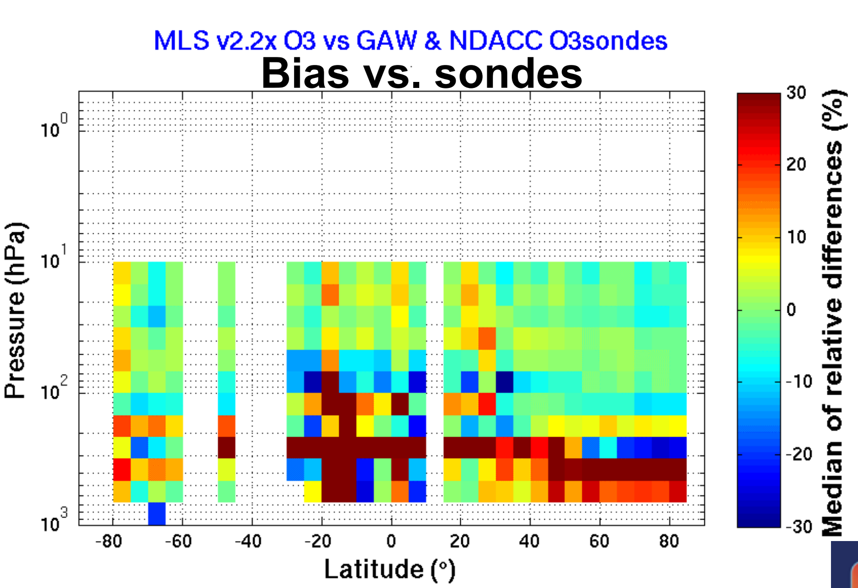
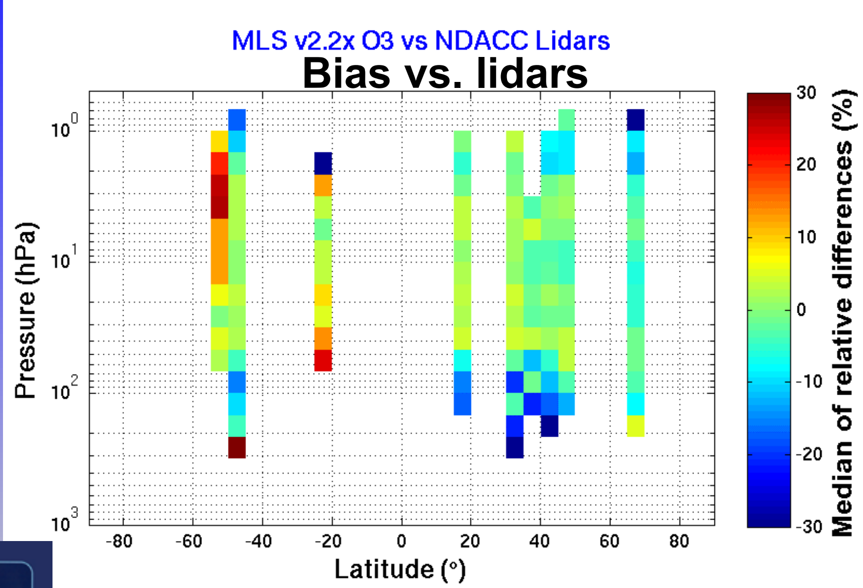
EOS Aura MLS


MLS v2.2x O3 vs GAW & NDACC O3sondes
Bias vs. sondes
Pressure (hPa)
Latitude (°)
Median of relative differences (%)
-80 -60 -40 -20 0 20 40 60 80
30 20 10 0 -10 -20 -30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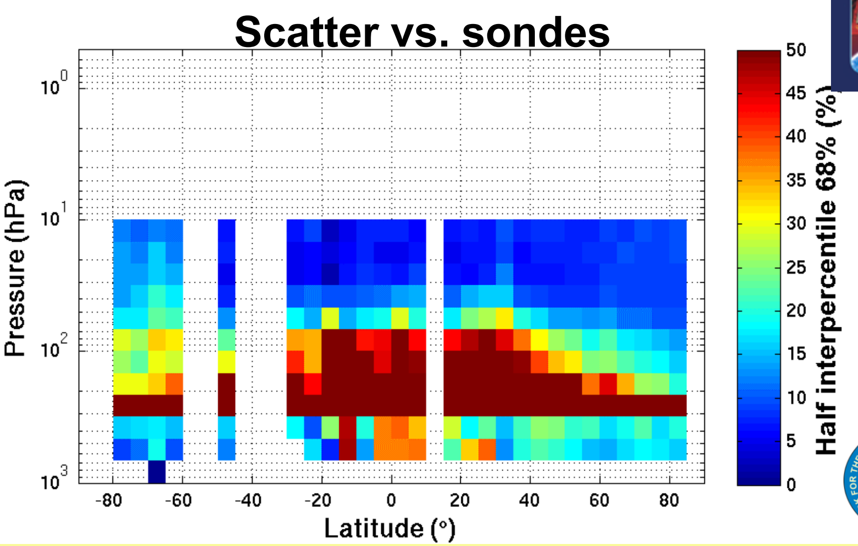
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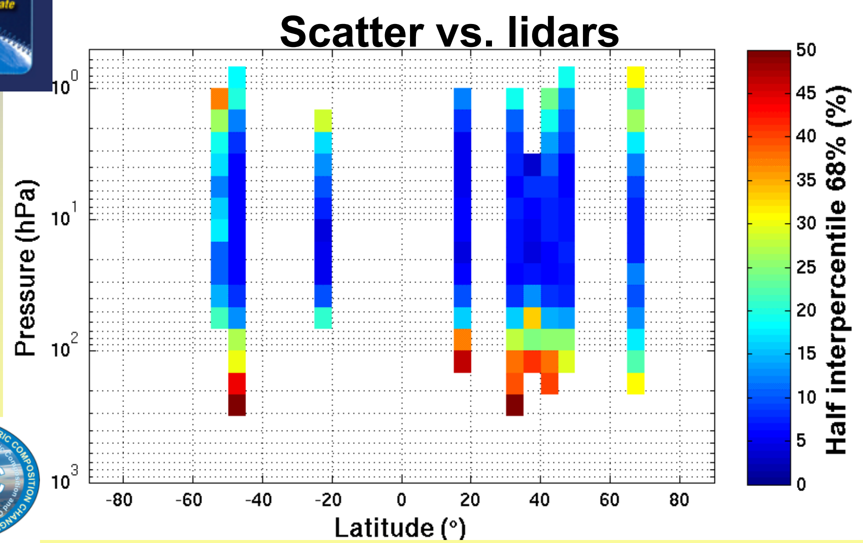
50 45 40 35 30 25 20 15 10 5 0


Scatter vs. lidars
Pressure (hPa)
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-80 -60 -40 -20 0 20 40 60 80
50 45 40 35 30 25 20 15 10 5 0

Conclusion

Mutual consistency of 9 limb ozone profilers explored using NDACC network as a standard transfer. Features:

- Long-term drifts, cyclic errors
- Altitude and latitude dependent errors

Prerequisite: network homogeneity; characterisation of measurement/retrieval errors and of comparison errors; understanding that we compare remote sensing data about a structured and changing atmosphere.

Methods for accurate drift detection not straightforward

Except a few features, we conclude to a good overall consistency. But each satellite sounder (and each station) shows its own character…

⇒ Traceability of data sources, of their QA, and of the integration process, is crucial for proper interpretation !

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