The MIPAS ozone record since 2002

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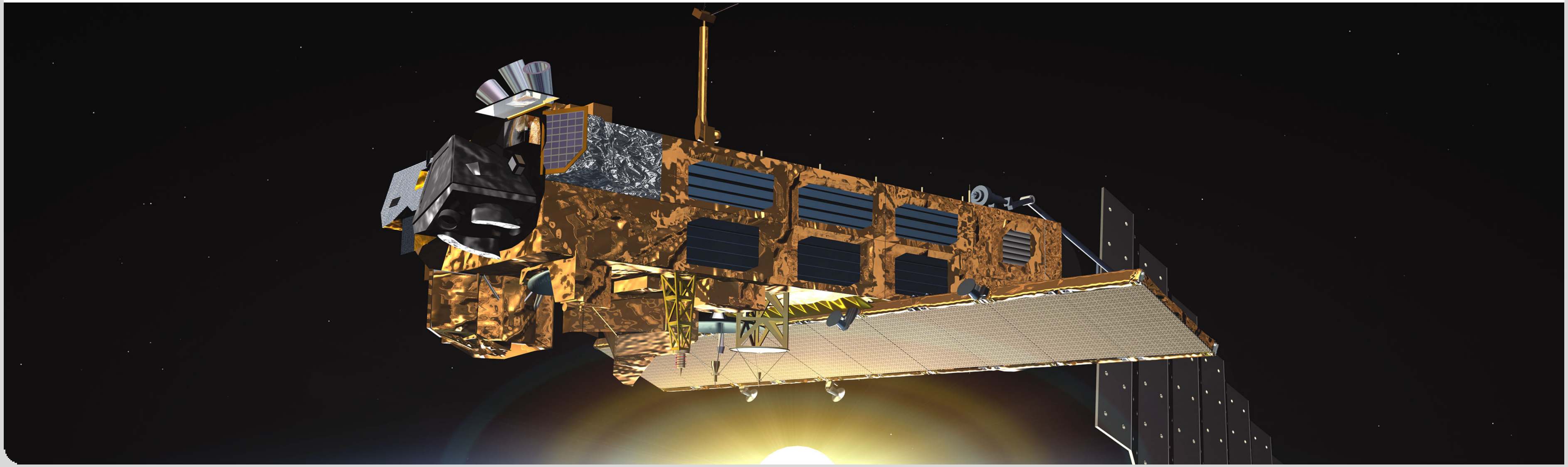
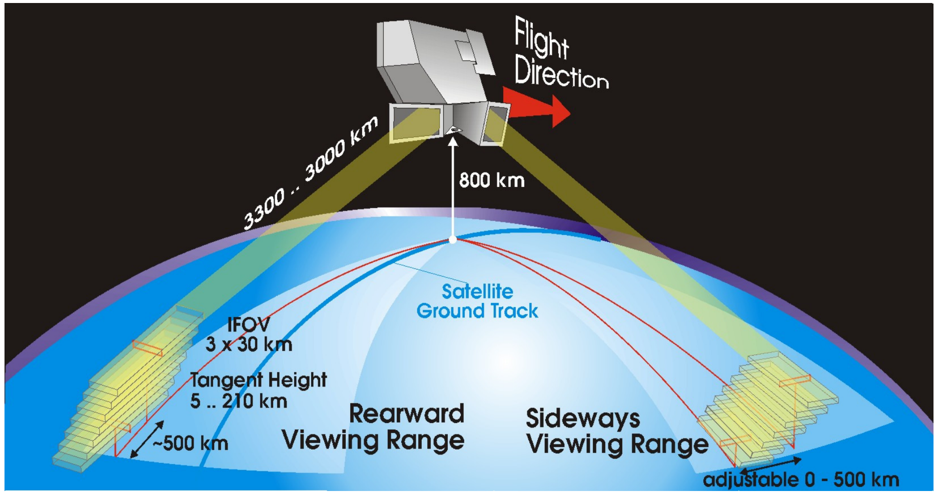
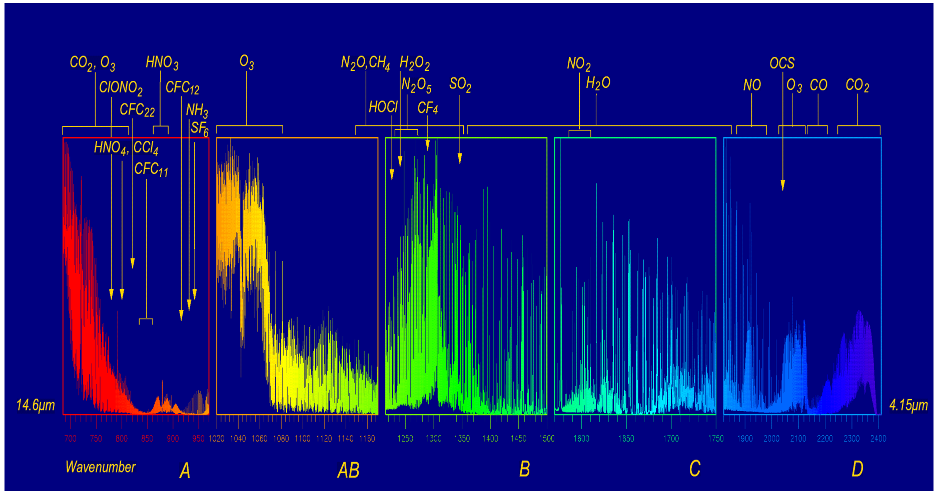


MIPAS measurement principle

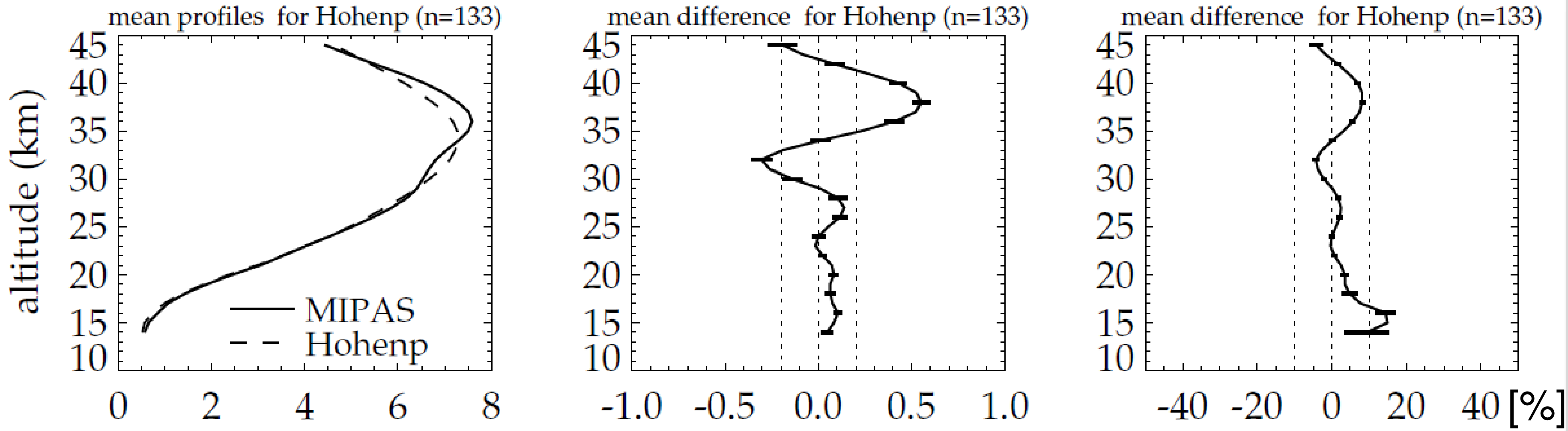




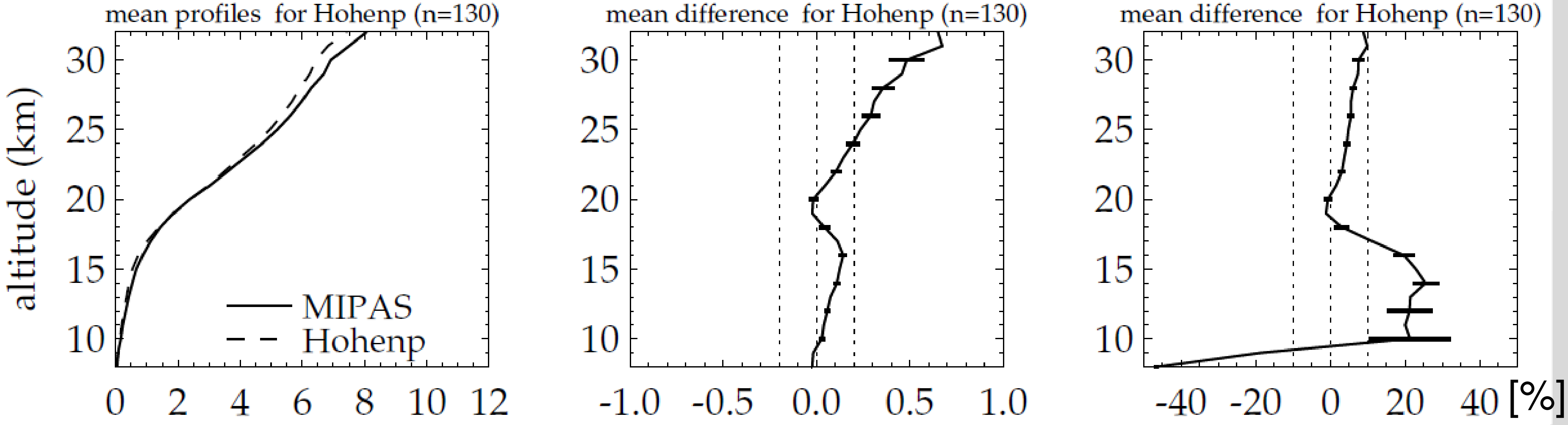
- IR limb emission spectrometer
- Measures day and night
- Altitude range 6 to 70 km (170 km)
- Pole-to-pole, > 1000 profiles/day
- So far 30 trace species, temperature and cloud composition
- 2002 – 2004: full spectral res., vertical resolution 3.5 - 6 km
- Since 2005: reduced spectral resolution, vertical resolution improved (2 - … km)
- Non-operational scientific analysis of MIPAS data at IMK/IAA

Validation of full-resolution MIPAS ozone profiles (examples)

Hohenpeissenberg LIDAR measurements

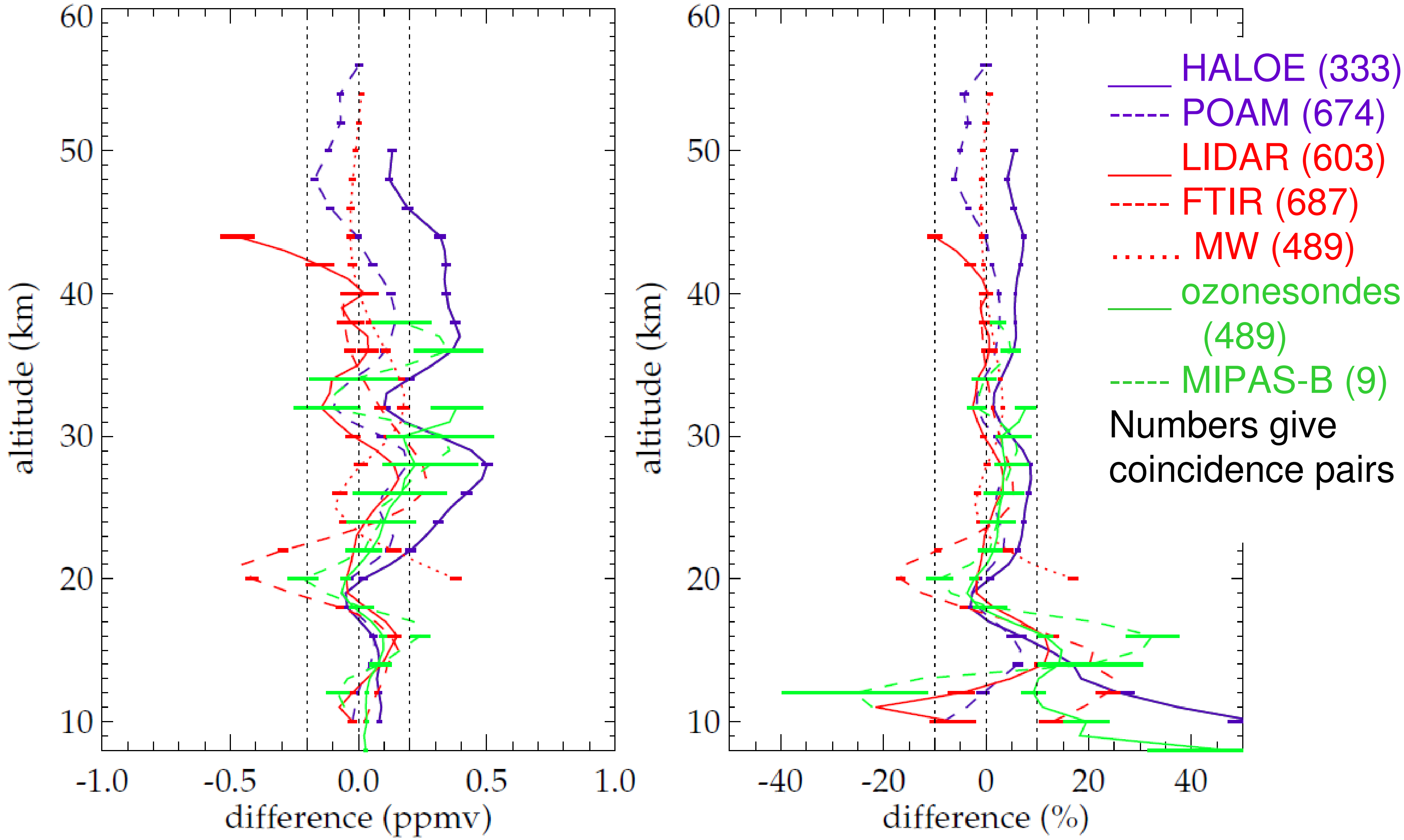


Hohenpeissenberg ozone sondes



Steck et al., ACP, 2007

Validation of full-resolution MIPAS ozone profiles cntd.



Steck et al., ACP, 2007

MIPAS optimized-resolution retrievals (2005 – …)

Spectral resolution: 0.0625 cm^{-1} unapodized

Table 7. O_3 retrieval error budget.

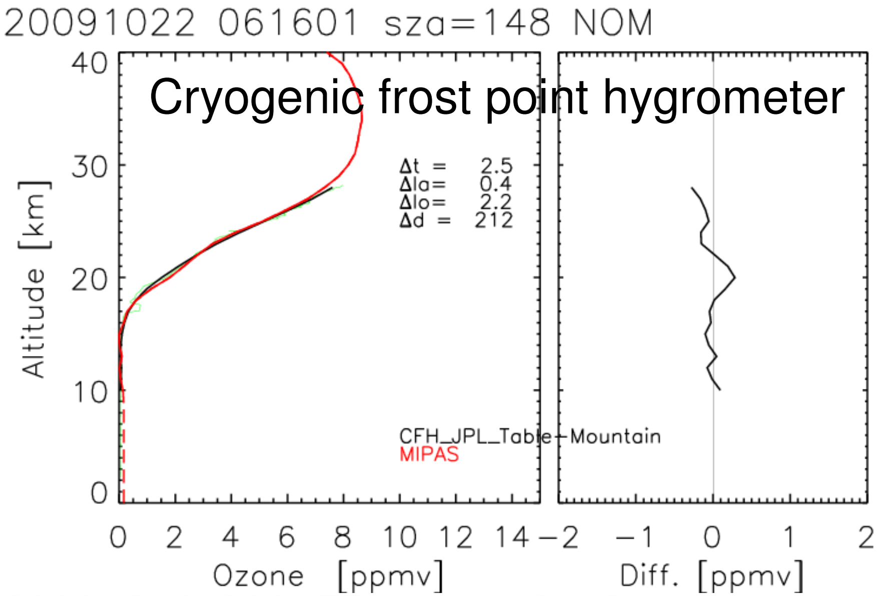
Height km	Noise ppbv (%)	Pointing ppbv (%)	Gain ppbv (%)	T ppbv (%)	Precision ppbv (%)	ILS ppbv (%)	Spectroscopy ppbv (%)	Total error ppbv (%)
50	75.0 (2.1)	180.0 (5.1)	25.0 (0.7)	76.0 (2.1)	210.8 (5.9)	2.5 (0.1)	230.0 (6.5)	312.0 (8.8)
40	50.0 (0.9)	210.0 (3.6)	120.0 (2.1)	130.0 (2.2)	279.1 (4.8)	0.3 (0.0)	650.0 (11.1)	707.4 (12.1)
35	73.0 (1.3)	170.0 (3.1)	95.0 (1.7)	78.0 (1.4)	222.1 (4.0)	85.0 (1.5)	620.0 (11.2)	664.1 (12.0)
30	67.0 (1.1)	200.0 (3.3)	130.0 (2.2)	67.0 (1.1)	256.7 (4.3)	170.0 (2.8)	720.0 (12.1)	783.1 (13.1)
25	60.0 (1.0)	220.0 (3.7)	130.0 (2.2)	85.0 (1.4)	275.9 (4.7)	130.0 (2.2)	700.0 (11.9)	763.6 (12.9)
20	46.0 (1.3)	51.0 (1.4)	120.0 (3.3)	22.0 (0.6)	140.0 (3.8)	89.0 (2.4)	410.0 (11.2)	442.3 (12.1)
15	33.0 (1.9)	1.7 (0.1)	62.0 (3.6)	9.8 (0.6)	70.9 (4.1)	28.0 (1.6)	150.0 (8.6)	168.3 (9.6)
10	28.0 (7.0)	38.0 (9.5)	13.0 (3.2)	13.0 (3.2)	50.7 (12.6)	22.0 (5.5)	40.0 (10.0)	68.2 (17.0)

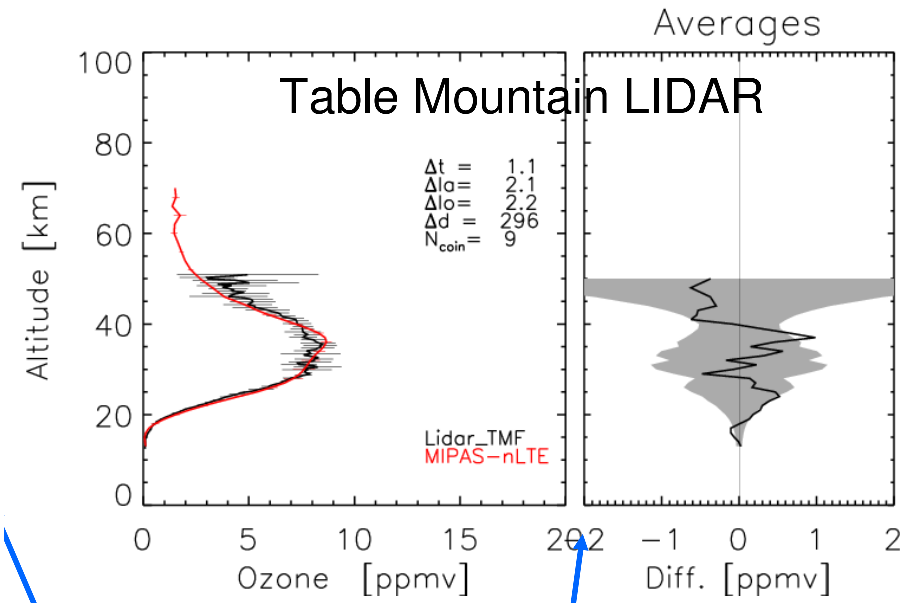
Vertical resolution: 2.4km @ 20km to
3.5km @ 50km

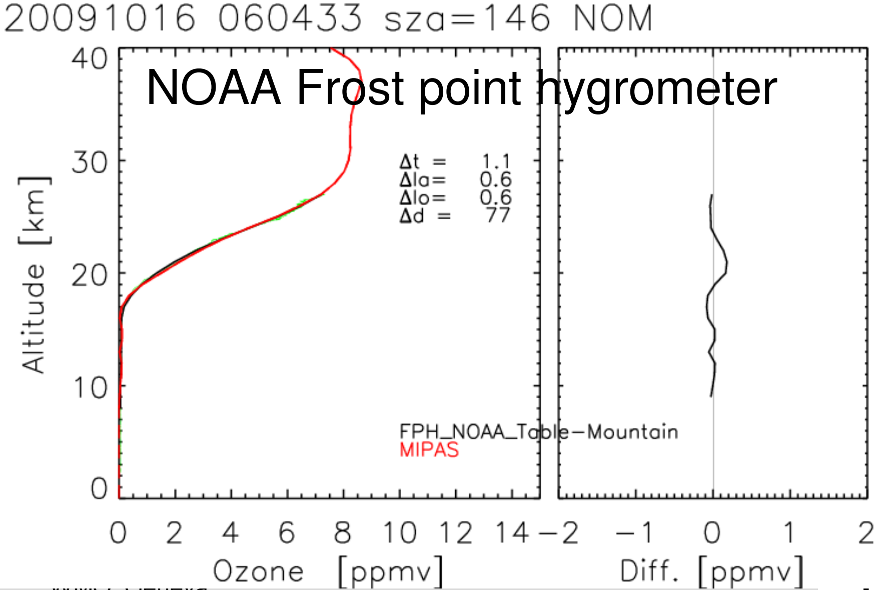
Horizontal resolution: 250km @ 10km to
400km @ 40 km

Validation of optimized-resolution MIPAS ozone data: MOHAVE campaign

KIT Karlsruhe Institute of Technology







Averages of TMF and MIPAS: within combined error (precision)

Max. Time Diff. = 4h

Max. Distance Diff. = 500km

Individual profiles (best coincidences)

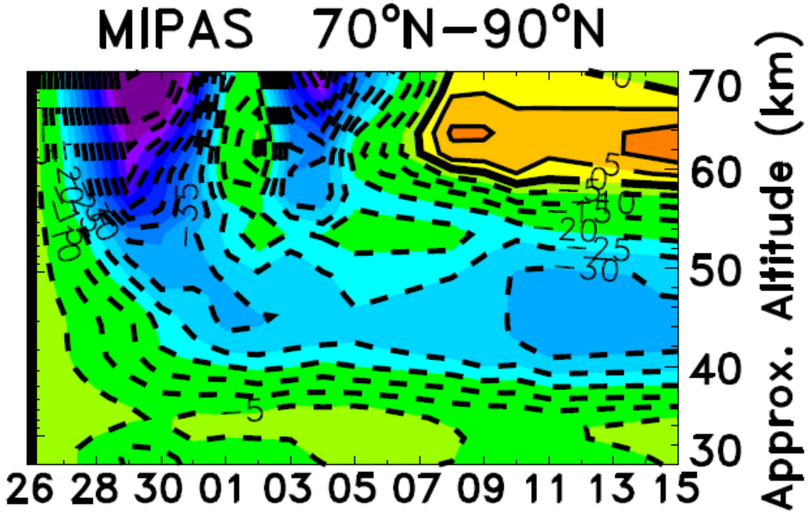
Δt (mean) time lag (h)

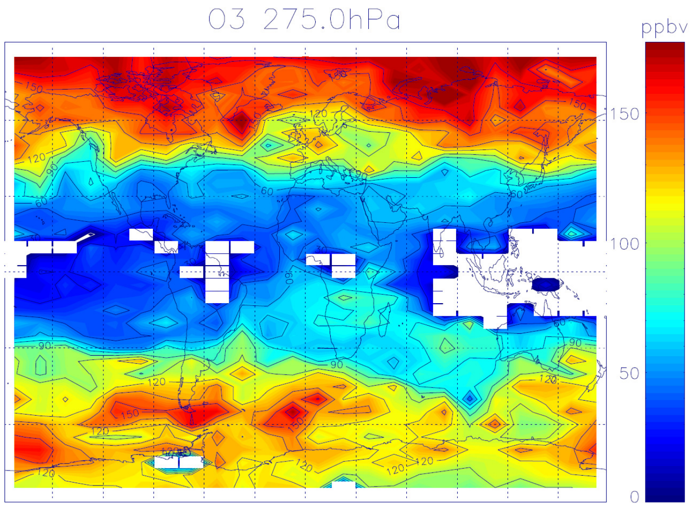
Δd (average) distance (km)

http://tmf-lidar.jpl.nasa.gov/campaigns/mohave2009.htm

We see episodes …:

Ozone reduction after SPE (Lopez-Puertas et al, 2005; Jackman et al., 2008

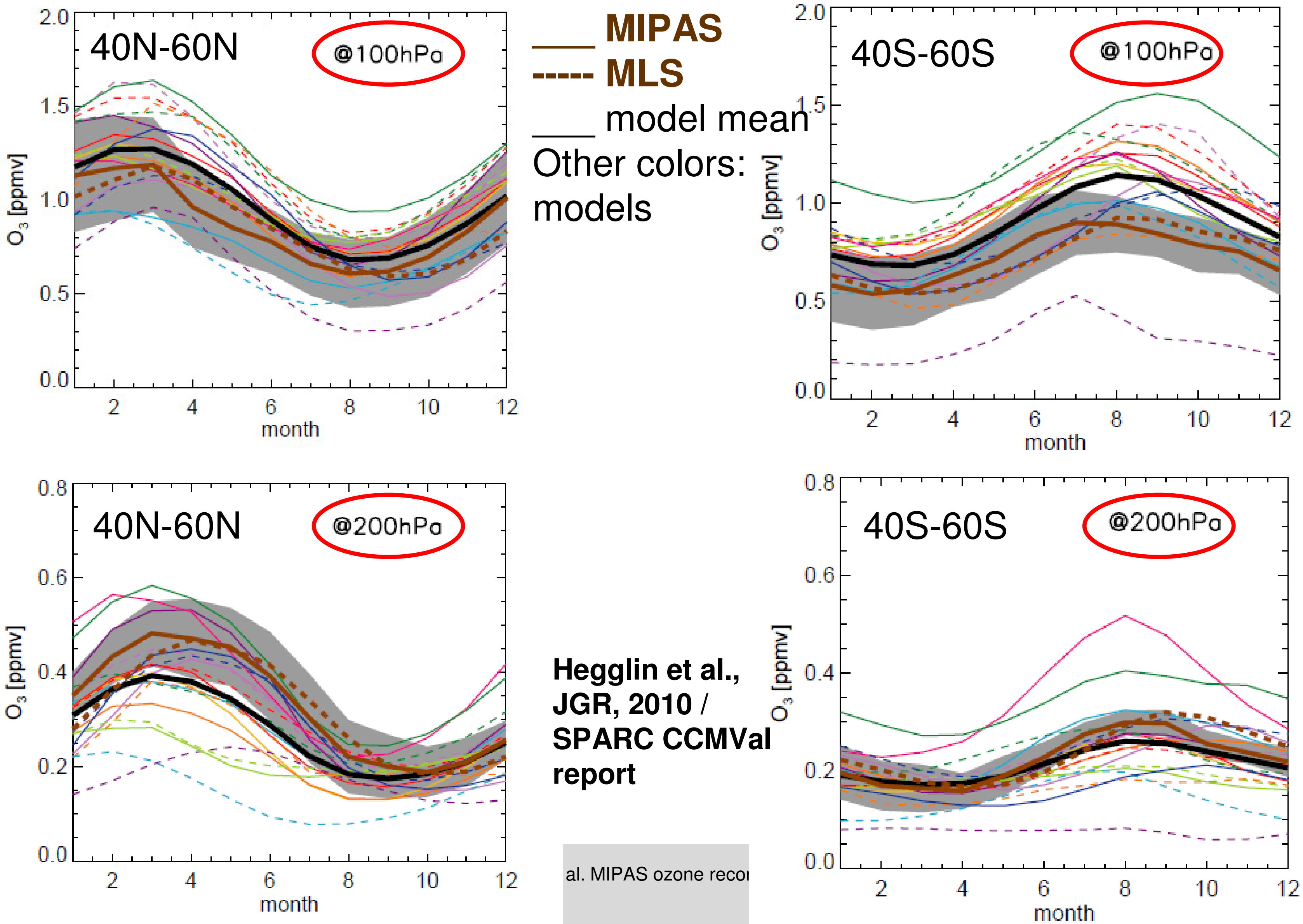




Biomass burning, v. Clarmann et al. 2007,

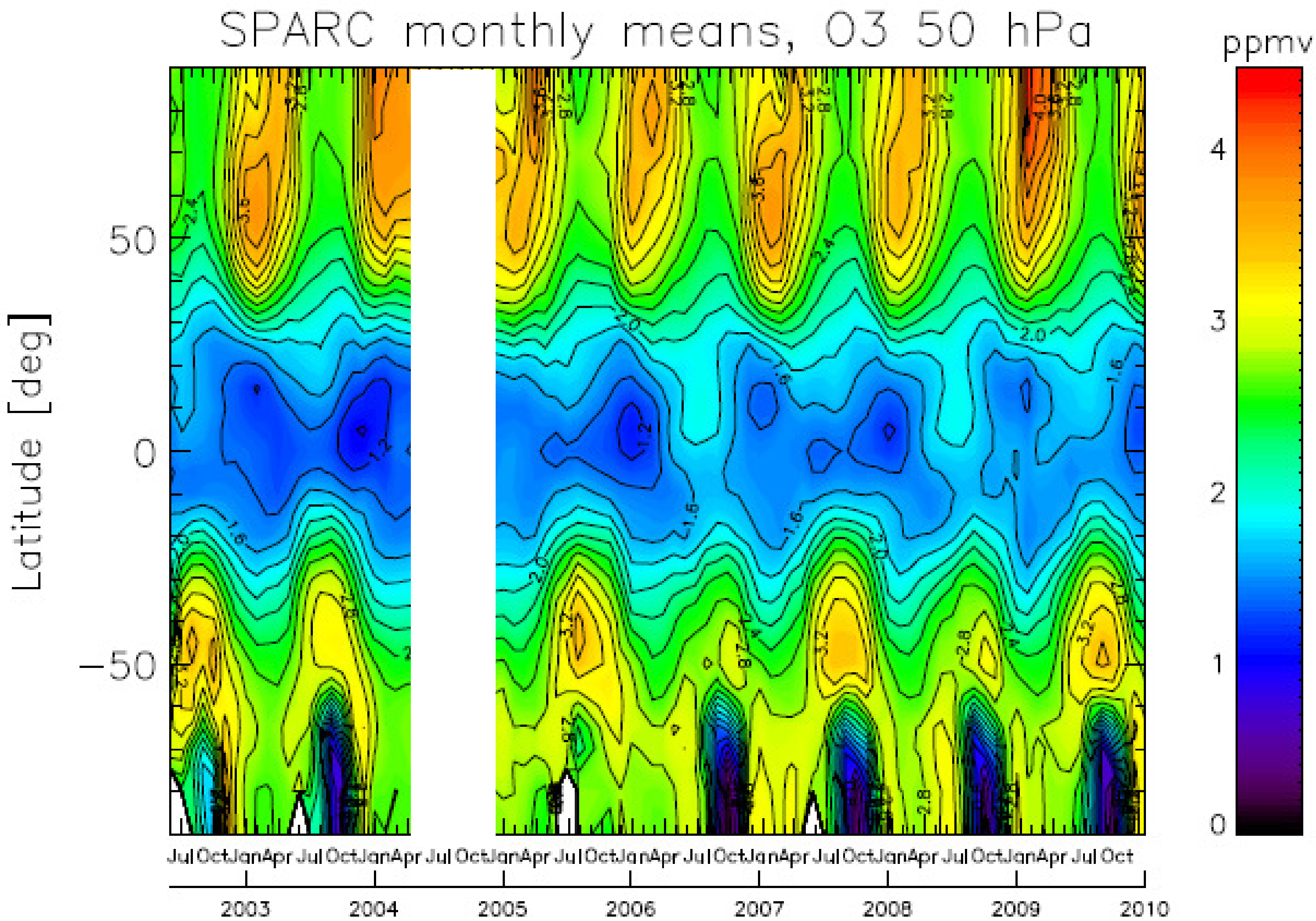
Use of MIPAS O3 in SPARC-CCMVal activities

Validation of phase and amplitude of the seasonal cycle of ozone in the extra-tropical UTLS



Hegglin et al., JGR, 2010 / SPARC CCMVal report

The MIPAS data record since 2002



How to cope with different characteristics?

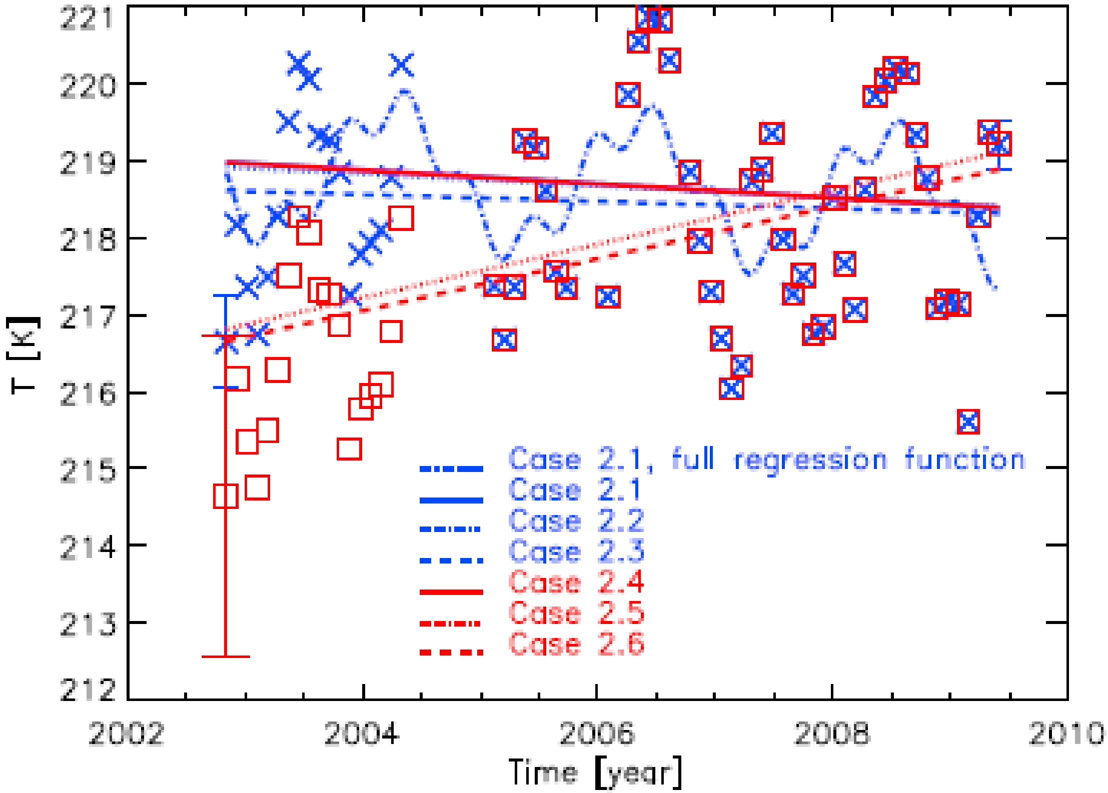
- Rough estimate of the bias (not even the sign must be known, only the order of size of the bias)
- Build covariance matrix of data errors, where a fully correlated error block is added to one subset of the data to describe the bias uncertainty.
- Calculate linear regression under consideration of the full covariance matrix

$$b = \frac{\boldsymbol{x}^T \mathbf{S}_y^{-1} \boldsymbol{y} - \frac{\boldsymbol{x}^T \mathbf{S}_y^{-1} \boldsymbol{e}\boldsymbol{e}^T \mathbf{S}_y^{-1} \boldsymbol{y}}{\boldsymbol{e}^T \mathbf{S}_y^{-1} \boldsymbol{e}}}{\boldsymbol{x}^T \mathbf{S}_y^{-1} \boldsymbol{x} - \frac{\boldsymbol{x}^T \mathbf{S}_y^{-1} \boldsymbol{e}\boldsymbol{e}^T \mathbf{S}_y^{-1} \boldsymbol{x}}{\boldsymbol{e}^T \mathbf{S}_y^{-1} \boldsymbol{e}}} = \frac{\boldsymbol{x}^T \mathbf{S}_y^{-1} \boldsymbol{y}\boldsymbol{e}^T \mathbf{S}_y^{-1} \boldsymbol{e} - \boldsymbol{x}^T \mathbf{S}_y^{-1} \boldsymbol{e}\boldsymbol{e}^T \mathbf{S}_y^{-1} \boldsymbol{y}}{\boldsymbol{x}^T \mathbf{S}_y^{-1} \boldsymbol{x}\boldsymbol{e}^T \mathbf{S}_y^{-1} \boldsymbol{e} - \boldsymbol{x}^T \mathbf{S}_y^{-1} \boldsymbol{e}\boldsymbol{e}^T \mathbf{S}_y^{-1} \boldsymbol{x}}.$$

$$a = \frac{\boldsymbol{x}^T \mathbf{S}_y^{-1} \boldsymbol{y} - \boldsymbol{e}^T \mathbf{S}_y^{-1} \boldsymbol{x} b}{\boldsymbol{e}^T \mathbf{S}_y^{-1} \boldsymbol{e}} = \frac{\boldsymbol{e}^T \mathbf{S}_y^{-1} \boldsymbol{y} - \boldsymbol{e}^T \mathbf{S}_y^{-1} \boldsymbol{x} \frac{\boldsymbol{x}^T \mathbf{S}_y^{-1} \boldsymbol{y}\boldsymbol{e}^T \mathbf{S}_y^{-1} \boldsymbol{e} - \boldsymbol{x}^T \mathbf{S}_y^{-1} \boldsymbol{e}\boldsymbol{e}^T \mathbf{S}_y^{-1} \boldsymbol{y}}{\boldsymbol{x}^T \mathbf{S}_y^{-1} \boldsymbol{x}\boldsymbol{e}^T \mathbf{S}_y^{-1} \boldsymbol{e} - \boldsymbol{x}^T \mathbf{S}_y^{-1} \boldsymbol{e}\boldsymbol{e}^T \mathbf{S}_y^{-1} \boldsymbol{x}}}{\boldsymbol{e}^T \mathbf{S}_y^{-1} \boldsymbol{e}} = \frac{\boldsymbol{e}^T \mathbf{S}_y^{-1} \boldsymbol{y}\boldsymbol{x}^T \mathbf{S}_y^{-1} \boldsymbol{x} - \boldsymbol{e}^T \mathbf{S}_y^{-1} \boldsymbol{x}\boldsymbol{x}^T \mathbf{S}_y^{-1} \boldsymbol{y}}{\boldsymbol{e}^T \mathbf{S}_y^{-1} \boldsymbol{e}\boldsymbol{x}^T \mathbf{S}_y^{-1} \boldsymbol{x} - \boldsymbol{e}^T \mathbf{S}_y^{-1} \boldsymbol{x}\boldsymbol{x}^T \mathbf{S}_y^{-1} \boldsymbol{e}}.$$

T. von Clarmann et al., ACP, 2010

It works!

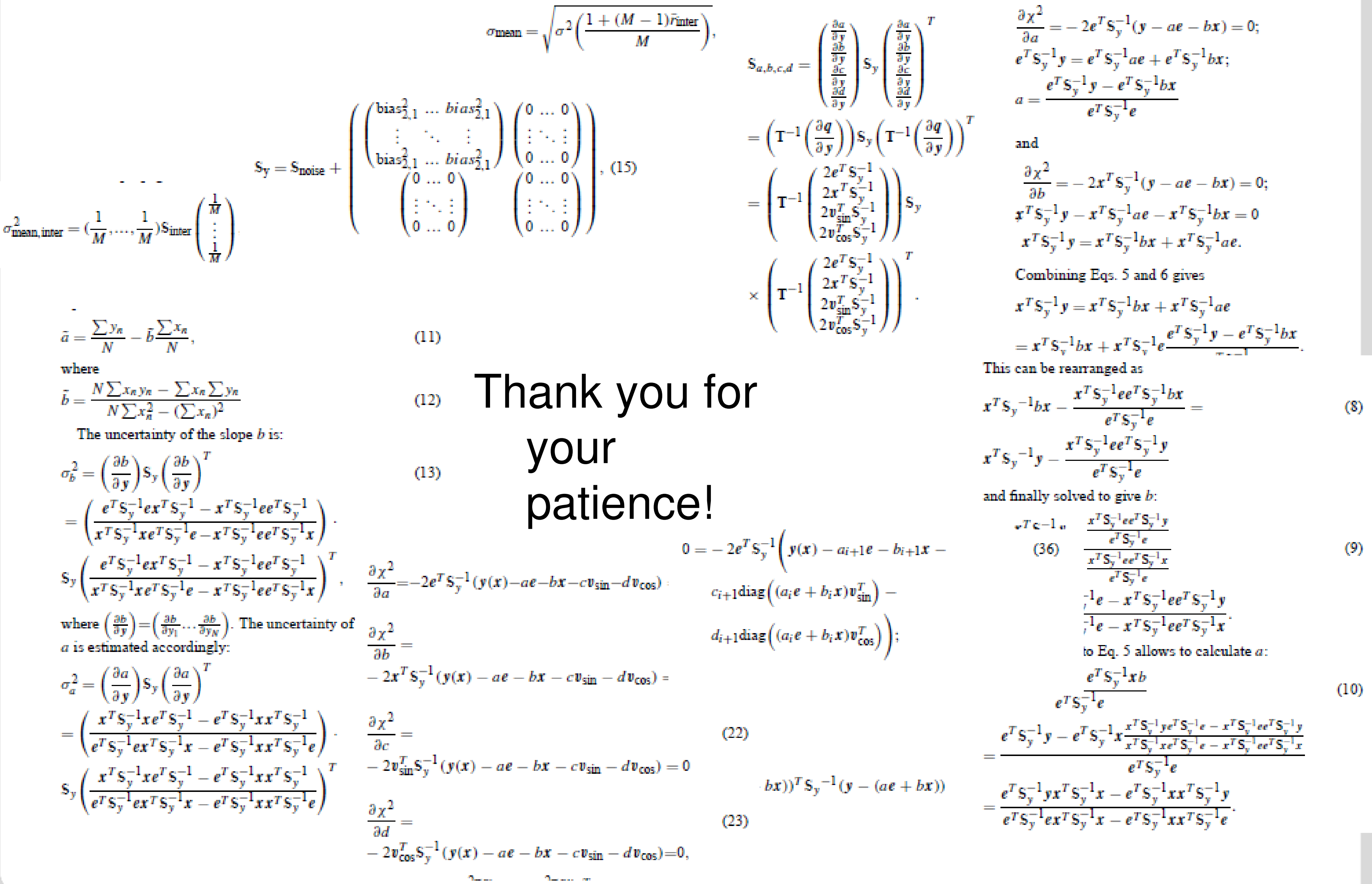


… but treatment of a superimposed periodic function requires additional sophistication

Conclusions:

- MIPAS ozone records (global, altitude resolved) are available since 2002.
- These data sets have been validated against various independent measurements.
- Accurate data characterization (error covariance matrices, horizontal and vertical averaging kernels) are available.
- The measurement mode and thus data characteristics have changed in 2004.
- A method has been developed to cope with such data inconsistencies, data inhomogeneities, clustered data etc…

- This tool may also be useful to infer trends from multiple data sources.



Thank you for your patience!