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MIPAS Ozone retrieval

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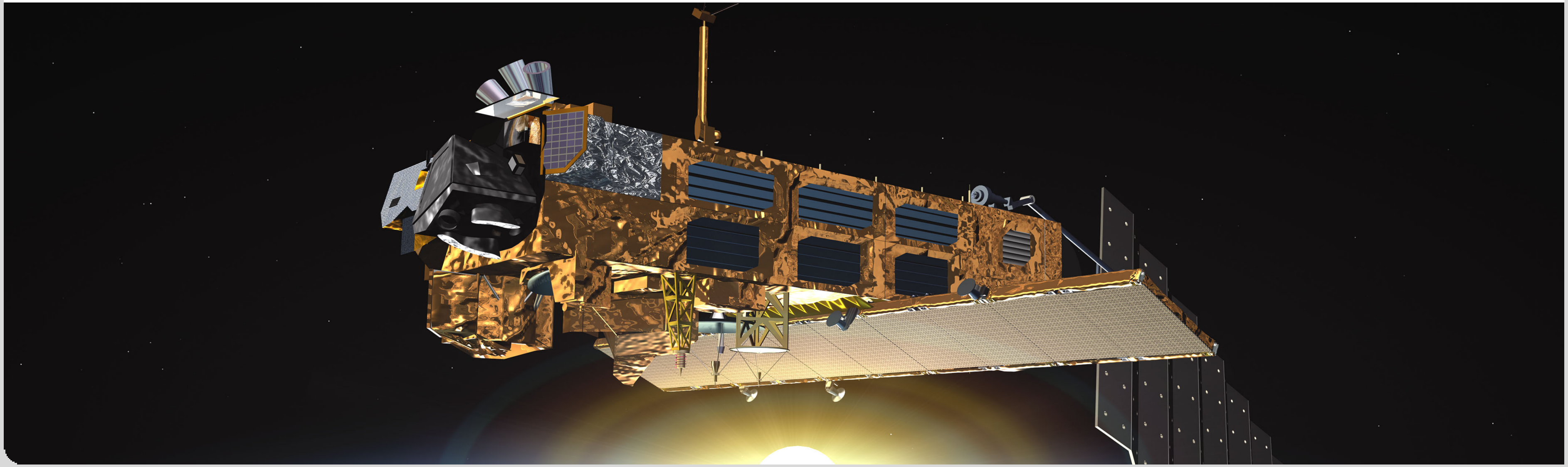
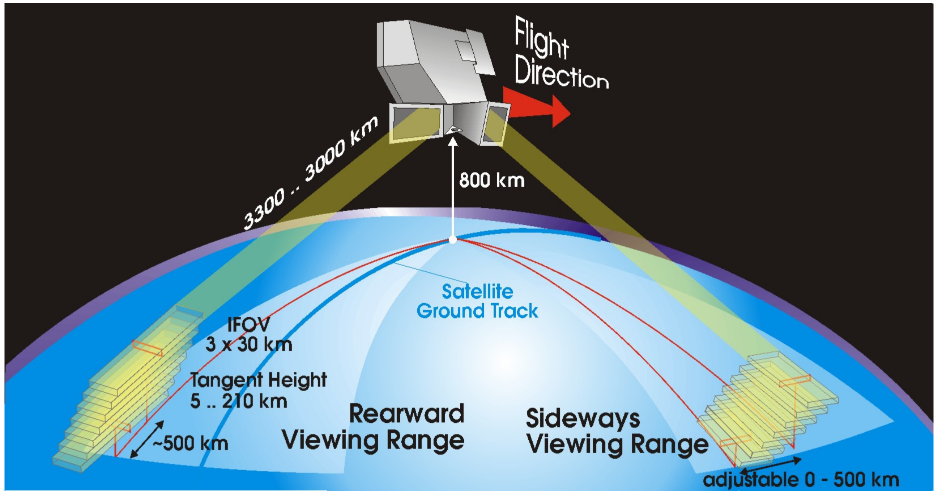
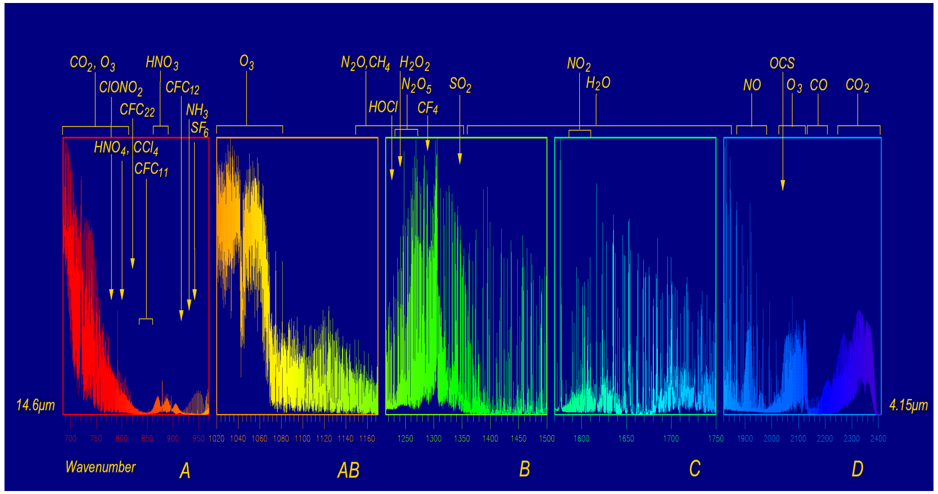
Presented by Johannes Orphal

Institute for Meteorology and Climate Research (IMK) -
Atmospheric Trace Gases and Remote Sensing (ASF)



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

MIPAS full-resolution retrievals (2002 – 2004)

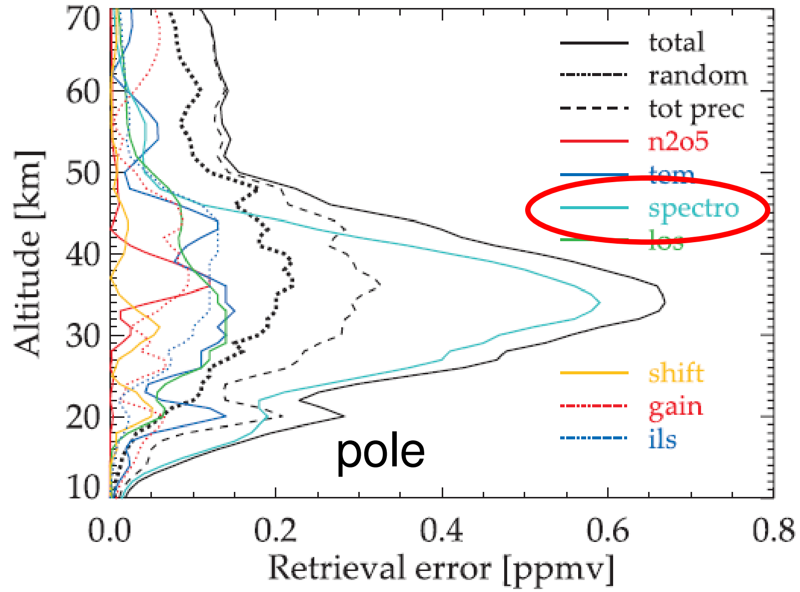
Spectral resolution: 0.035 cm^{-1} unapodized

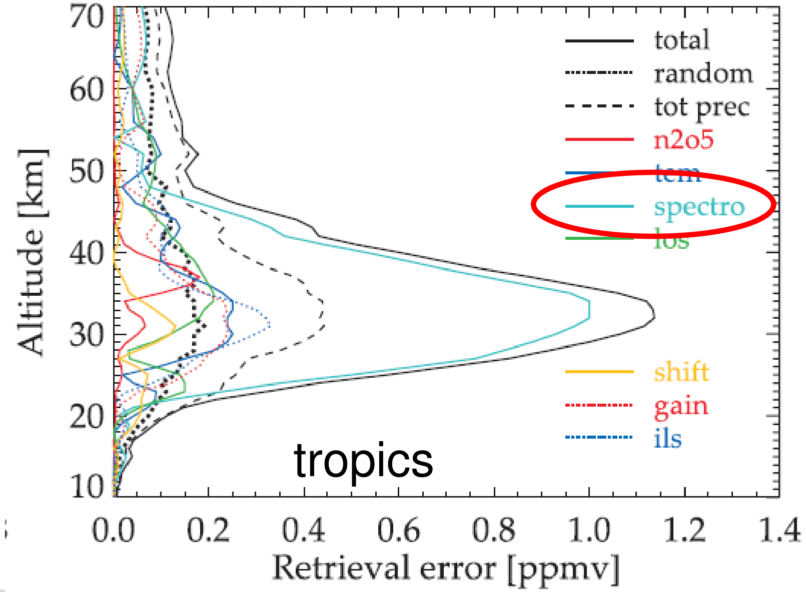
Error budget for a single polar (top) and tropical (bottom) daytime ozone profile: ⇨

Spectroscopy is the leading error source!

Spectral ranges used for retrieval

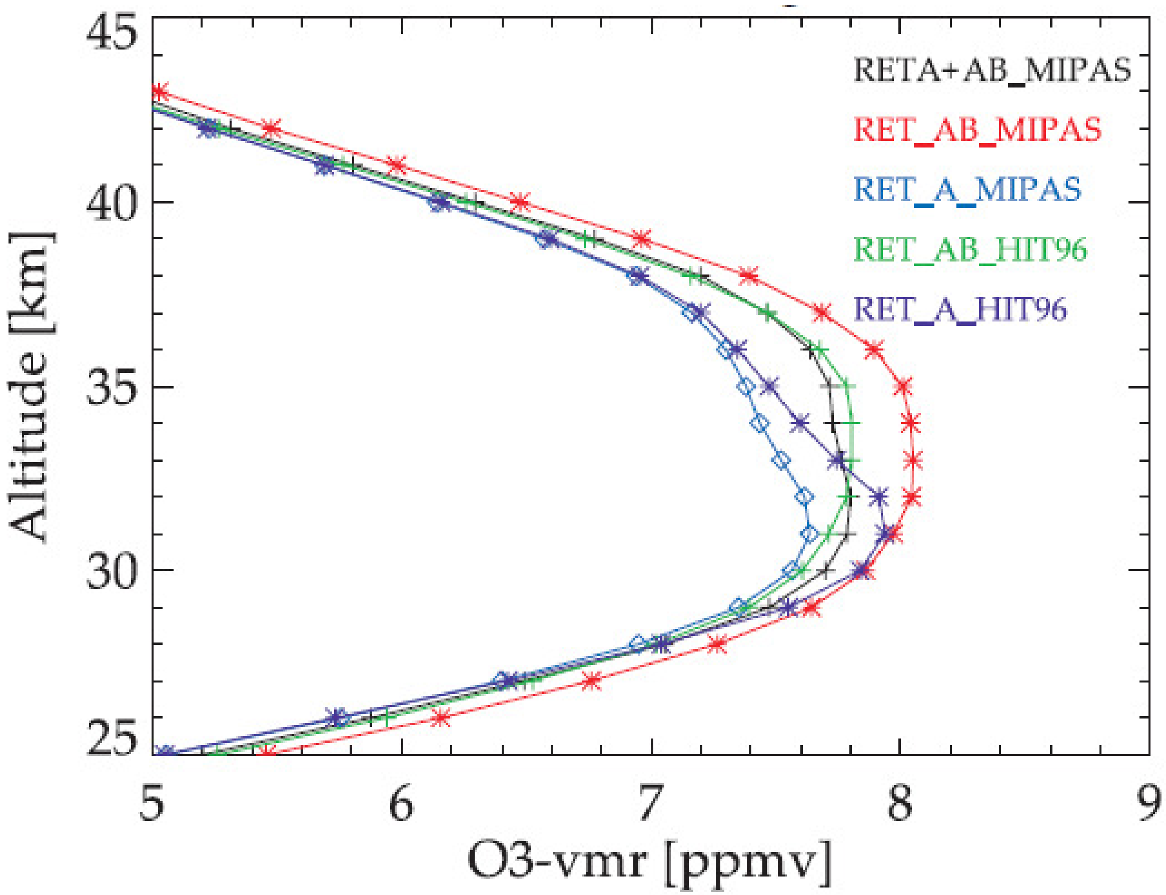
	Microwindow cm^{-1}	Altitude coverage 6–68 km
		00111222333344566 69258147036927208 ↓
Band A	741.675–741.825	====T====TTTTTTT=
Band A	744.950–745.125	=TTTTTTTTTTTTTTTT
Band A	757.900–758.000	==TTTTTTTTTT===T
Band A	759.225–761.650	TTTT==TTTTTTTTTTT
Band A	764.800–764.950	T==TTTTTT==TT=TTT
Band A	798.450–798.650	===TTTTTTTTTTTTTT
Band AB	1062.325–1062.475	====T=========TTT
Band AB	1081.500–1081.600	TTTTT=TTTTTTTTTTT
Band AB	1090.350–1090.475	TTTTT=TTTTTTTTTTT
Band AB	1108.000–1108.350	TTT=T===TT=T=====





Glatthor et al., ACP, 2006

Sensitivity to spectroscopic data base



Reference (MIPAS spectroscopic data base, Band A + Band AB

MIPAS spectroscopic data base, only Band AB

MIPAS spectroscopic data base, only Band A

HITRAN96, only Band AB

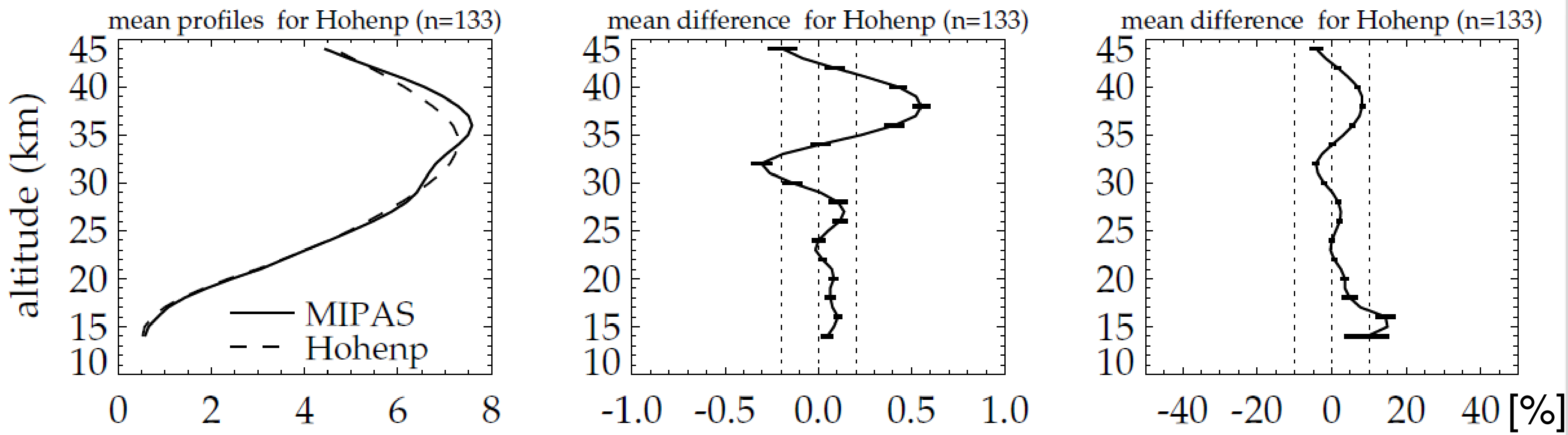
HITRAN96, only Band A

- MIPAS spectroscopic data base: Flaud et al., 2003; later included in HITRAN2004
- Gain calibration inconsistencies between Band A and AB have been excluded as reason for retrieval inconsistencies

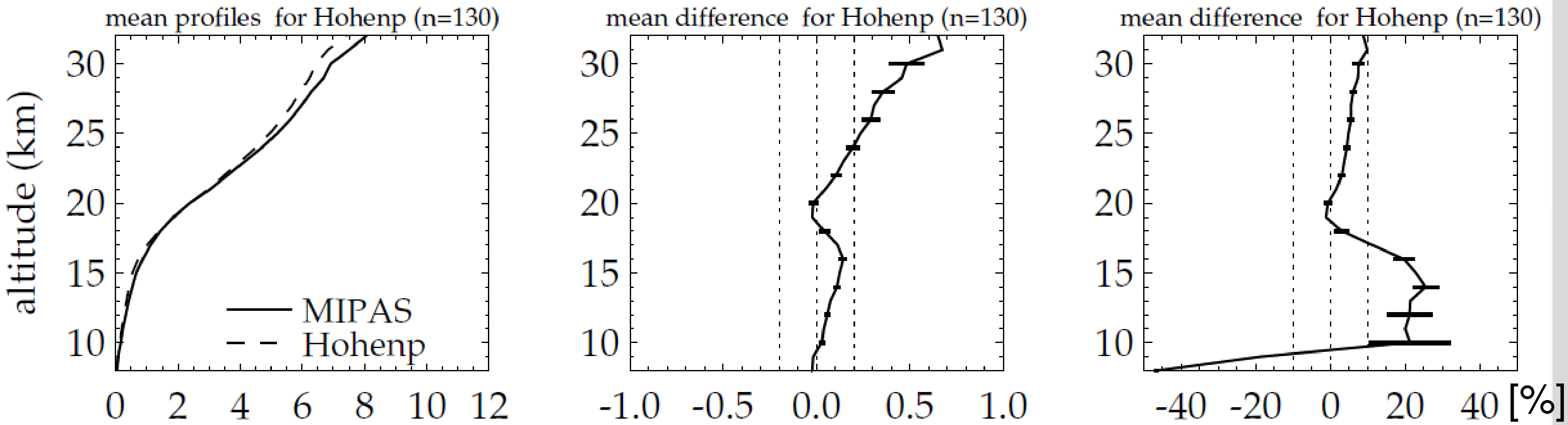
Glatthor et al., ACP, 2006

Validation of full-resolution MIPAS ozone profiles (examples)

Hohenpeissenberg LIDAR measurements

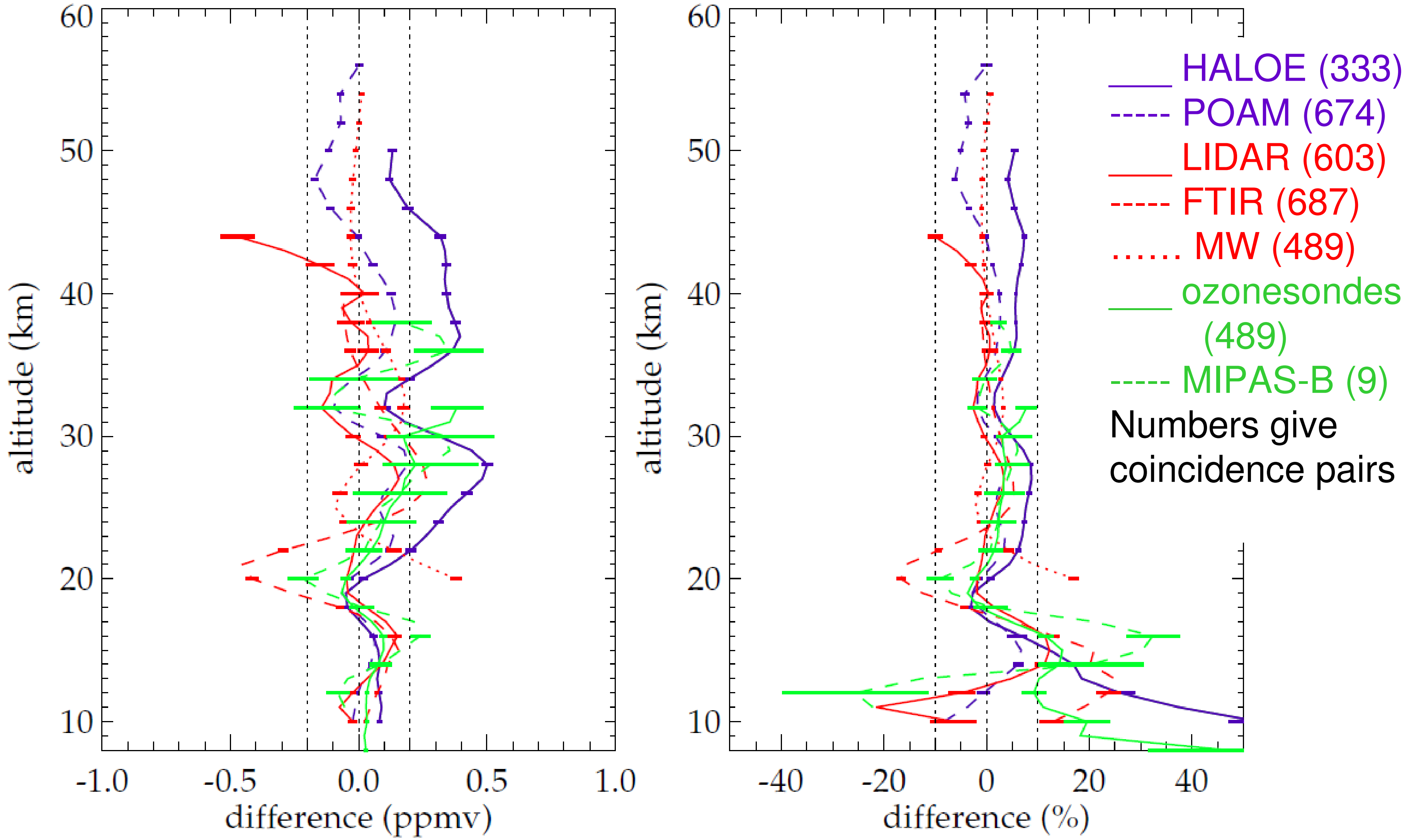


Hohenpeissenberg ozone sondes



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

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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)

Reduces by √n with averaging

Still leading systematic error source!

Adjusted set of spectral ranges for retrieval from lower reduced spectra

O_3
760.6875–761.06250
763.5625–764.3125
766.8750–767.1875
776.1875–776.5000
777.6875–777.9375
781.0000–781.7500
782.5000–782.8750
787.0000–788.0000
1029.0000–1031.0000
1038.0000–1039.0000

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

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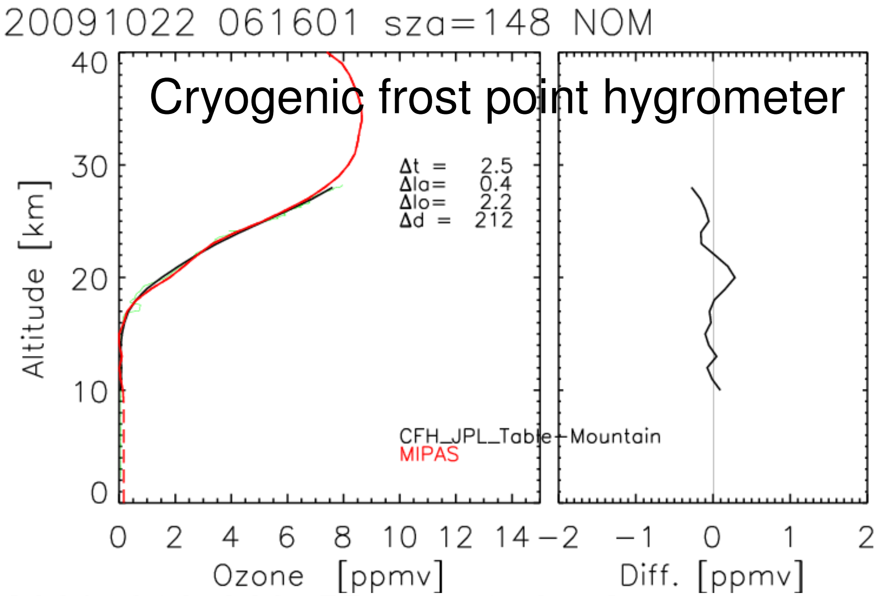
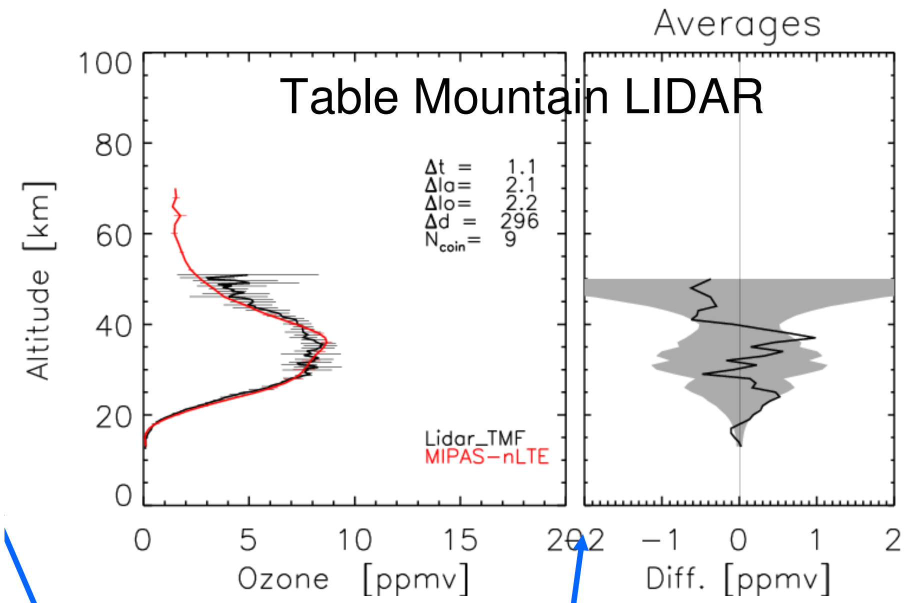
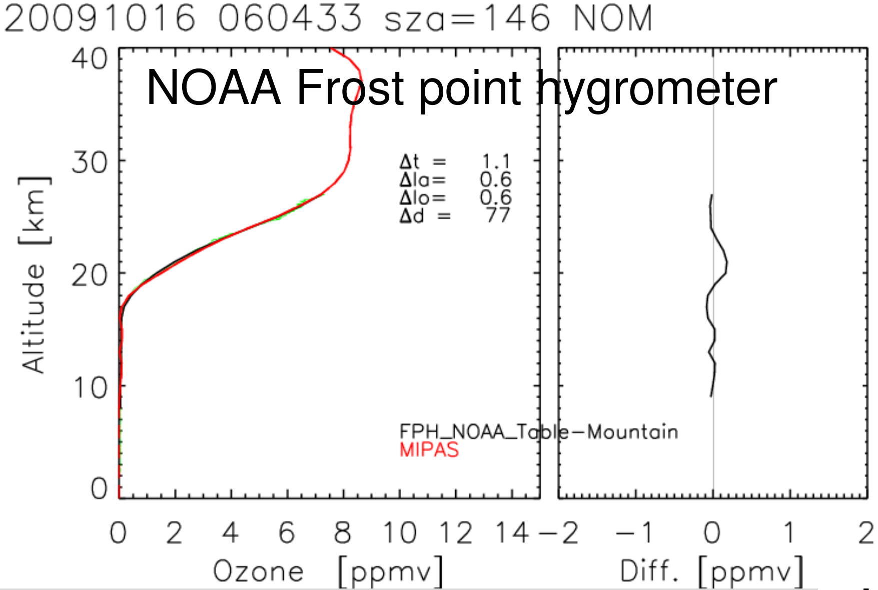






Averages of TMF and MIPAS: within combined error (precision)

Max. Time Diff. = 4h

Max. Distance Diff. = 500km

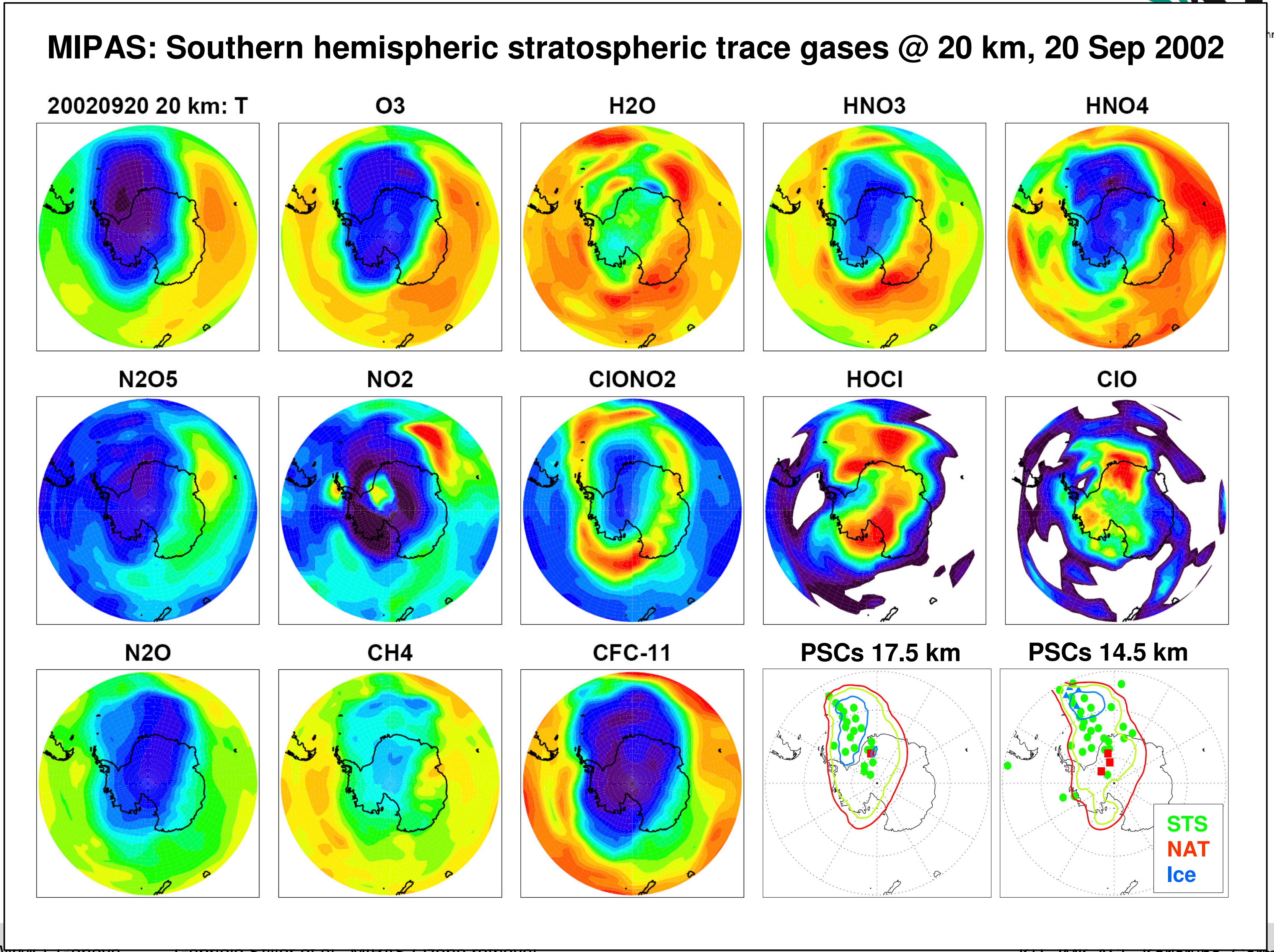
Individual profiles (best coincidences)

Δt (mean) time lag (h)

Δd (average) distance (km)

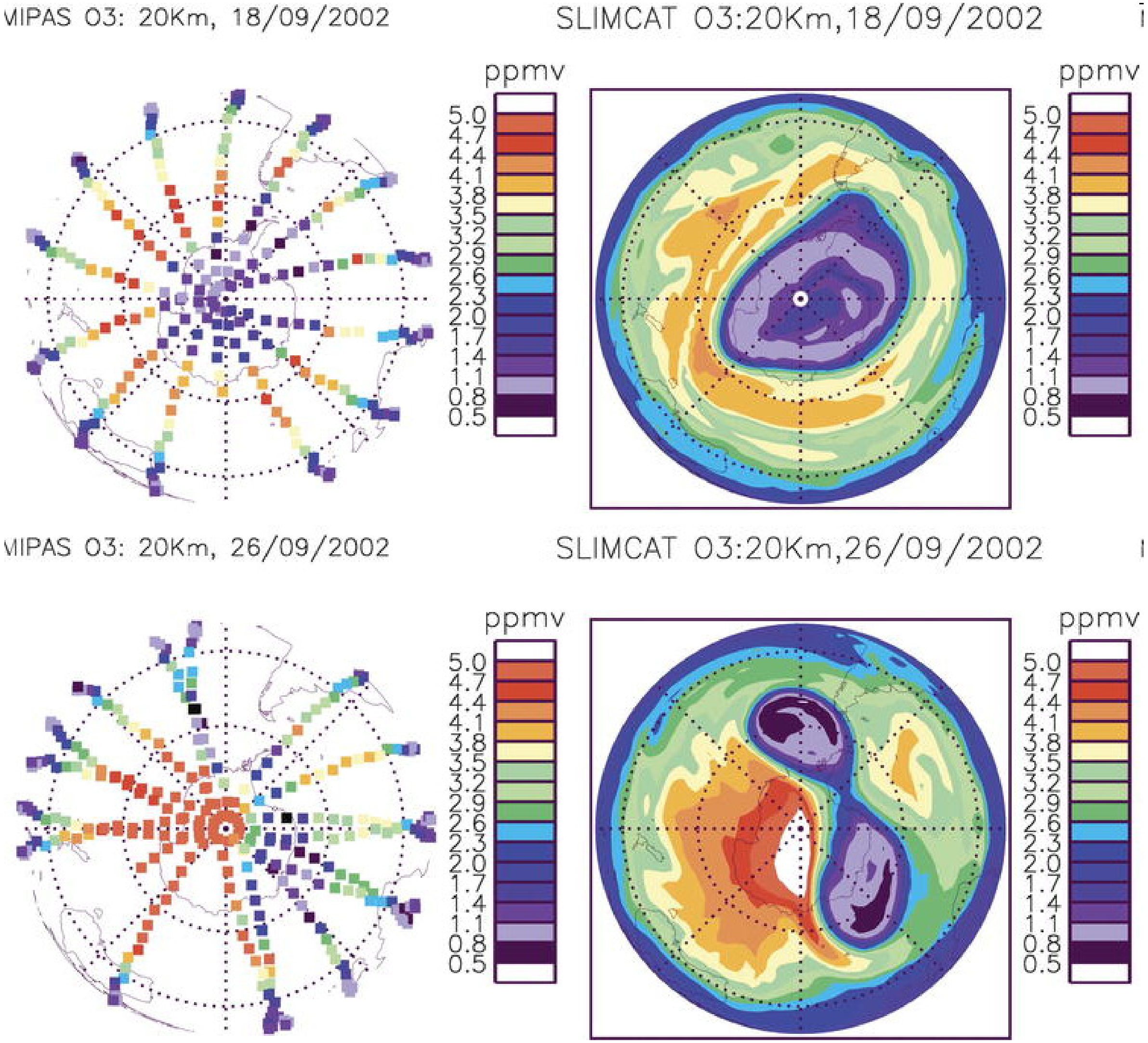
http://tmf-lidar.jpl.nasa.gov/campaigns/mohave2009.htm

Applications: Ia. Polar ozone chemistry



Applications: Ib. The SH major warming 2002

Vertically resolved information on ozone loss for comparison of MIPAS and SLIMCAT



Feng et al., J. Atm. Sciences, 2005

Applications: II. Validation of vertical distribution in CTMs – ECHAM5 / MESSy1 (now EMAC)

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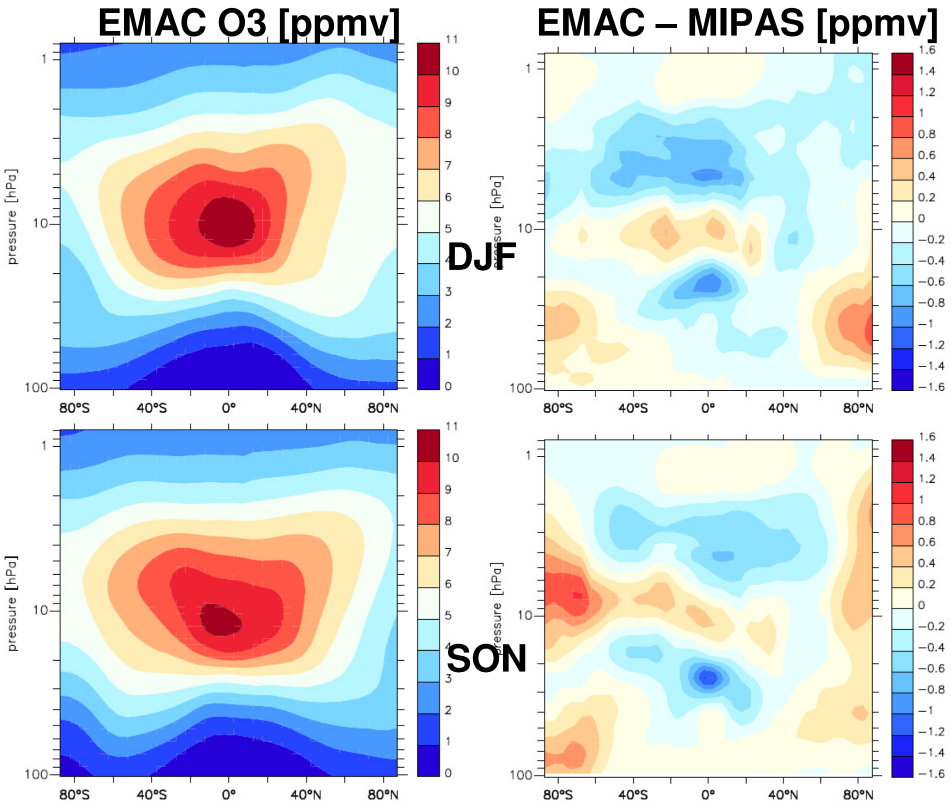
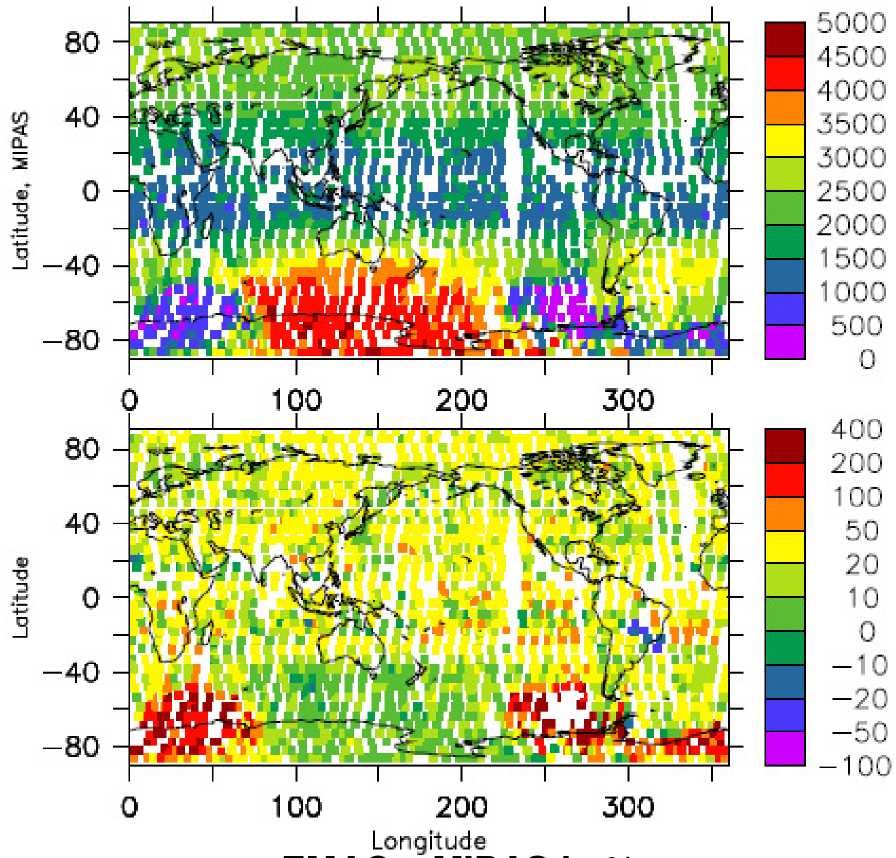
Zonal mean intercomparisons

Point-to-point intercomparison



Jöckel et al., ACP, 2006

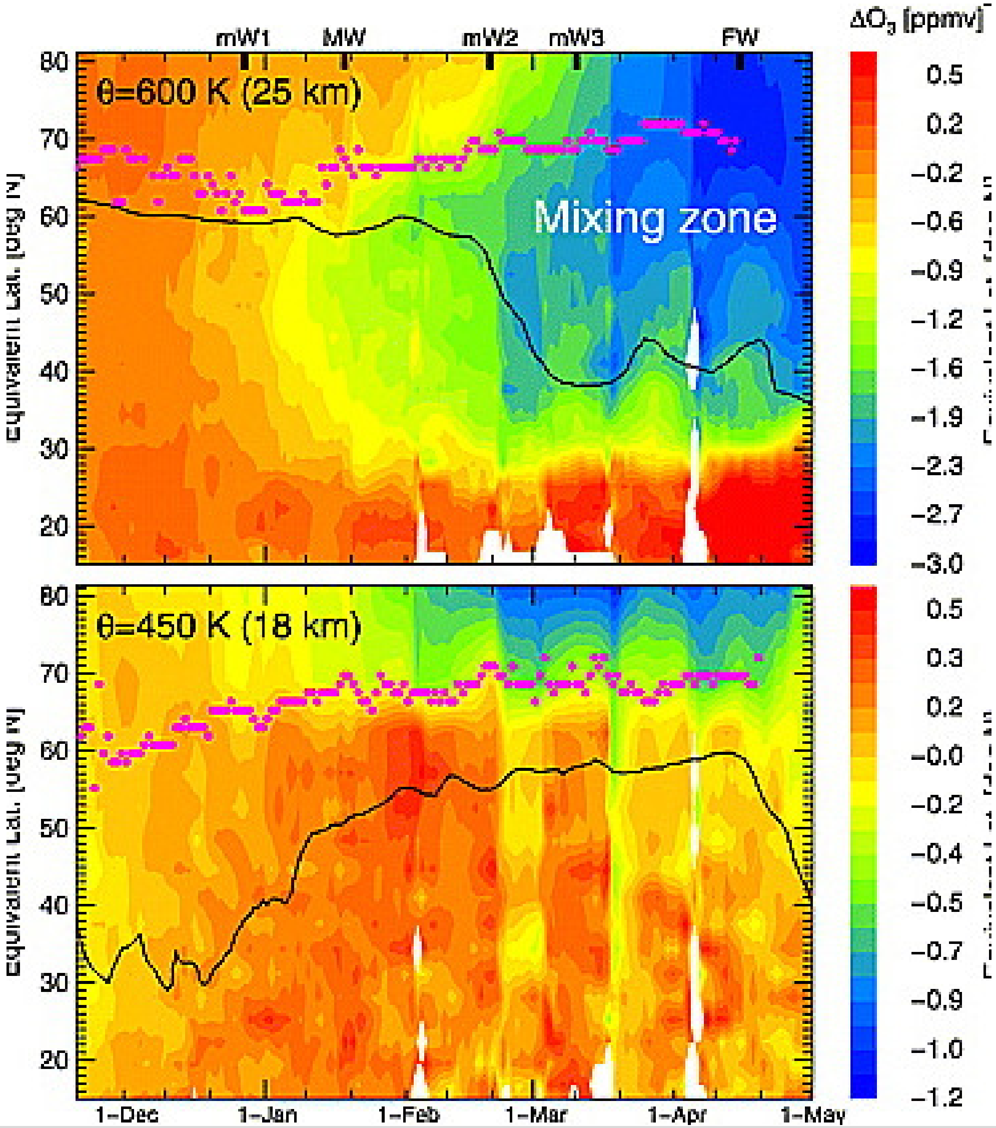
MIPAS O3, 23-25 Sep 2002, 50 hPa, in ppbv



EMAC – MIPAS in %

Brühl et al., ACP, 2007

Applications: III. Relative role of halogen chemistry, NOx chemistry and dynamics in polar ozone loss



Cumulative ozone loss vs. equivalent latitude at 600 K potential temperature level due to NOx import from lower latitudes during/after a major warming (MW) (differences between passively transported ozone in CLaMS and MIPAS observations)

Cumulative ozone loss vs. equivalent latitude at 450 K potential temperature level due to halogen chemistry

- vortex edge

Konopka et al., JGR, 2007

Applications: IVa. Stratospheric ozone loss during and after solar proton events: SACADA 4D-var data assimilation

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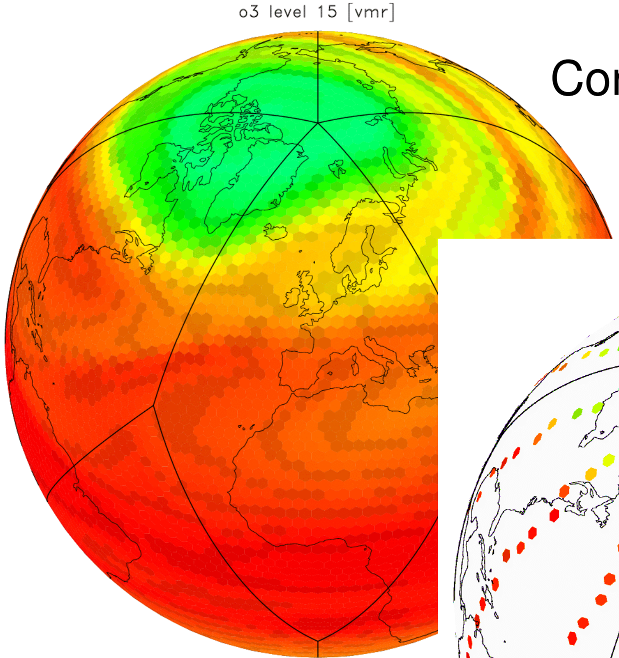
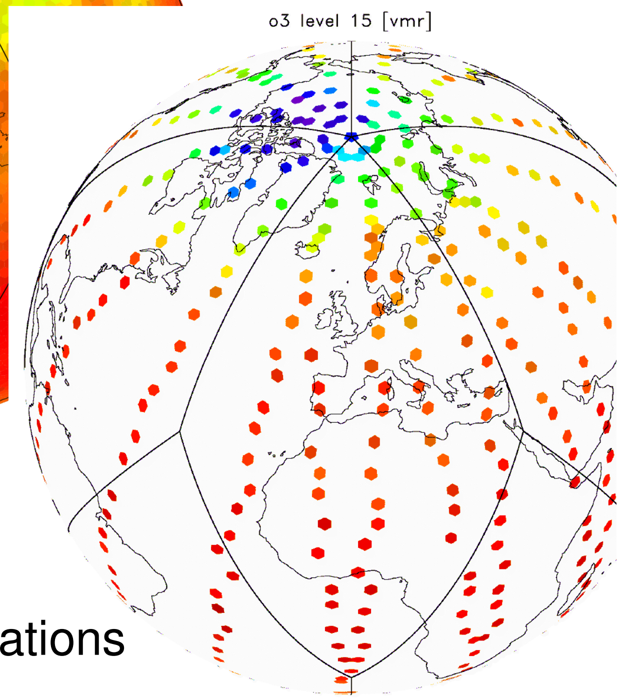
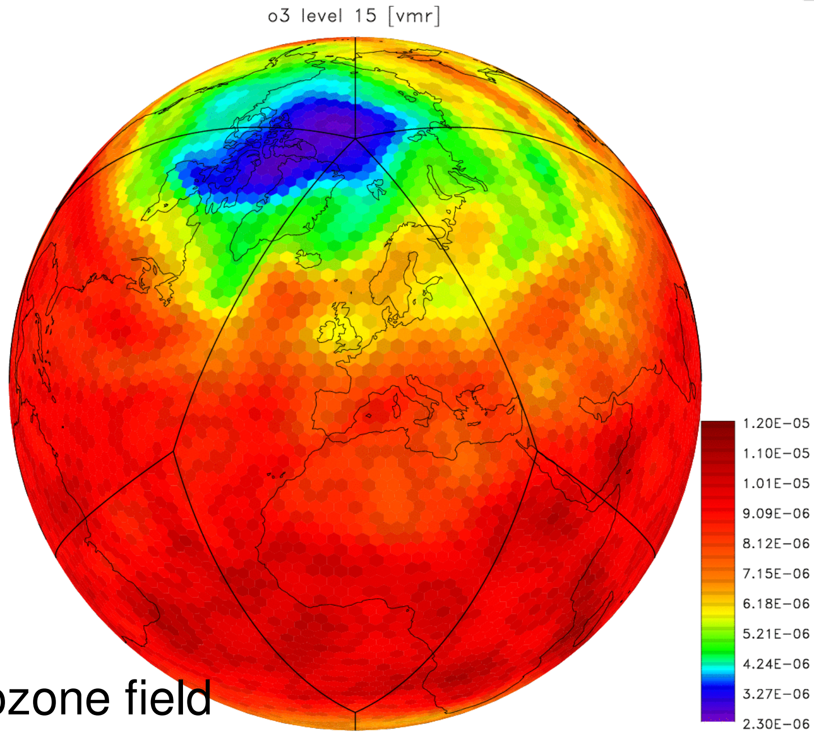


Control run without observational data



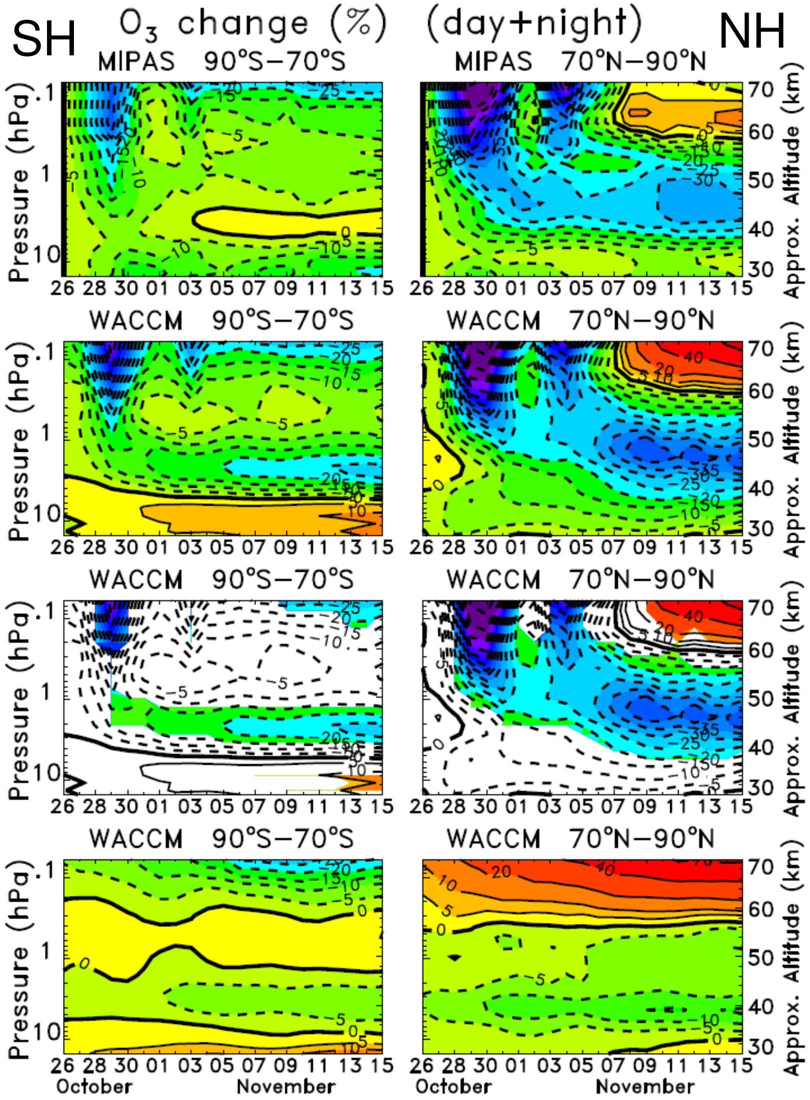
MIPAS ozone observations



SACADA assimilated ozone field

H. Elbern, J. Schwinger et al., in preparation

Applications: IVb. Atmospheric impact of high energetic particles (solar variability): Observations and modeling



Relative O3 change [%] after solar proton event in Oct/Nov 2003 as observed by MIPAS

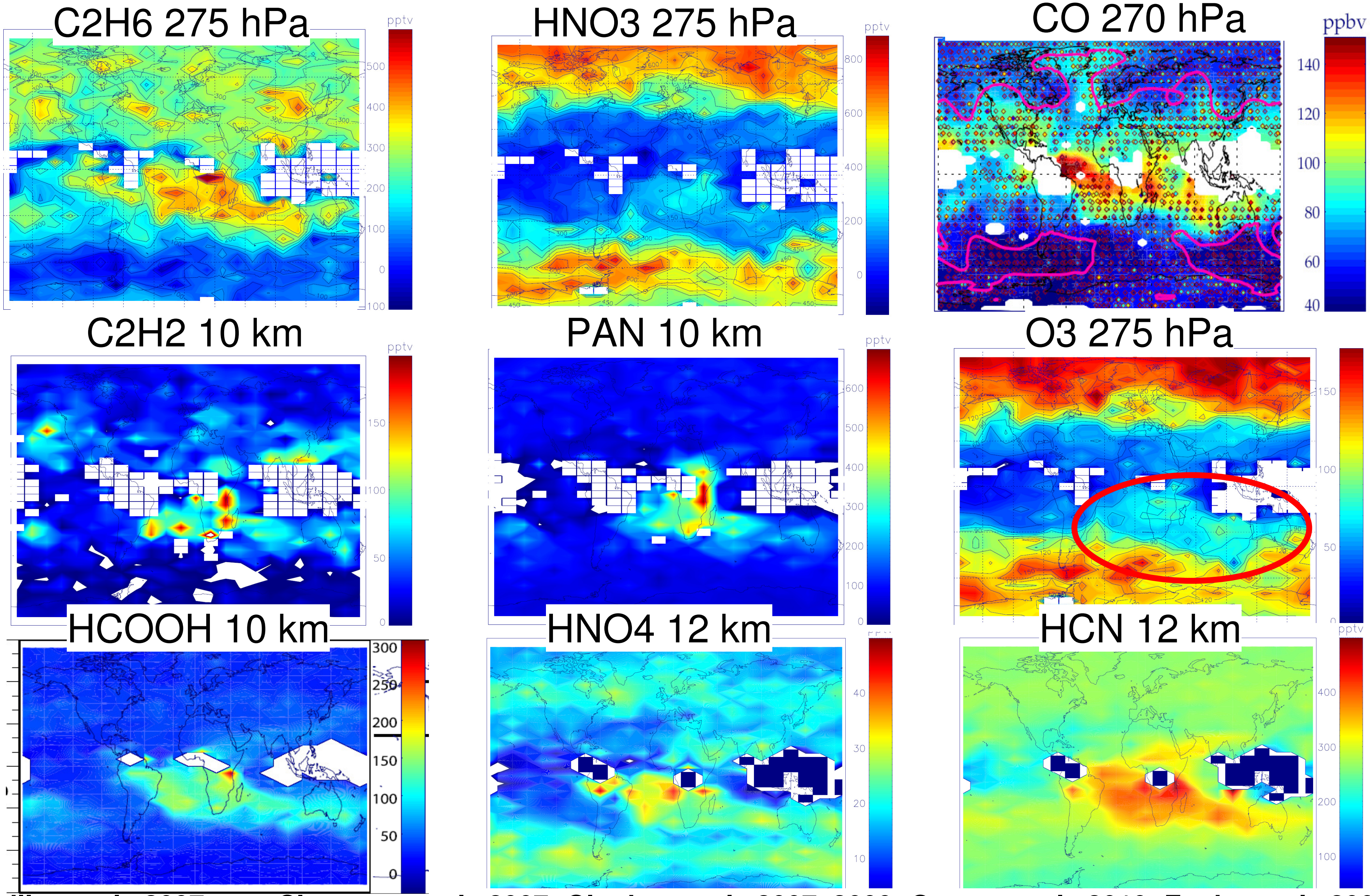
… as modeled by WACCM

… with 2σ statistically significant regions colored only

Control run of WACCM without SPE modeling

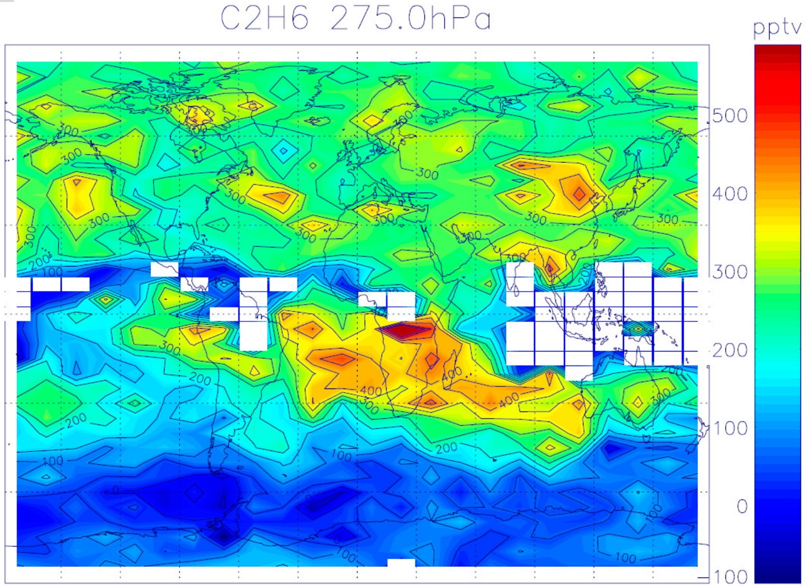
Jackman et al., ACP, 2008

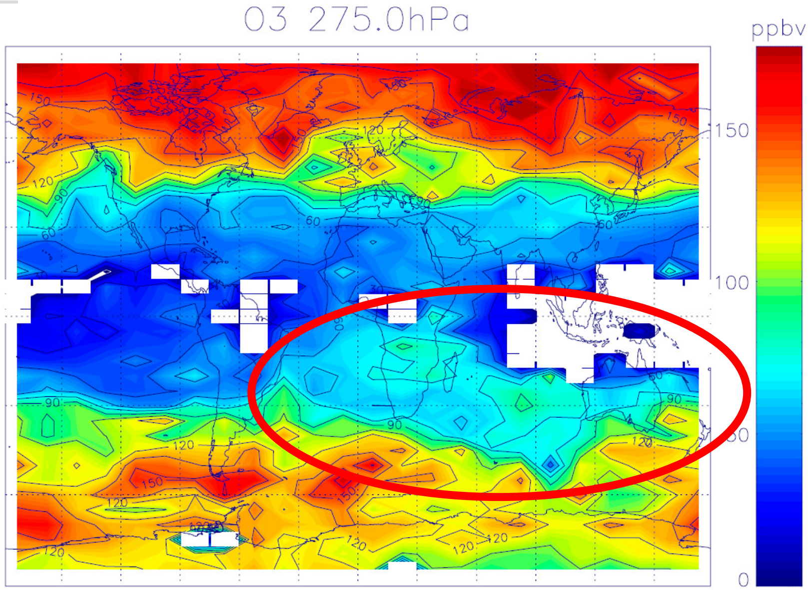
Applications: V. Chemical pollution of the upper troposphere and ozone production: SH biomass burning season fall 2003

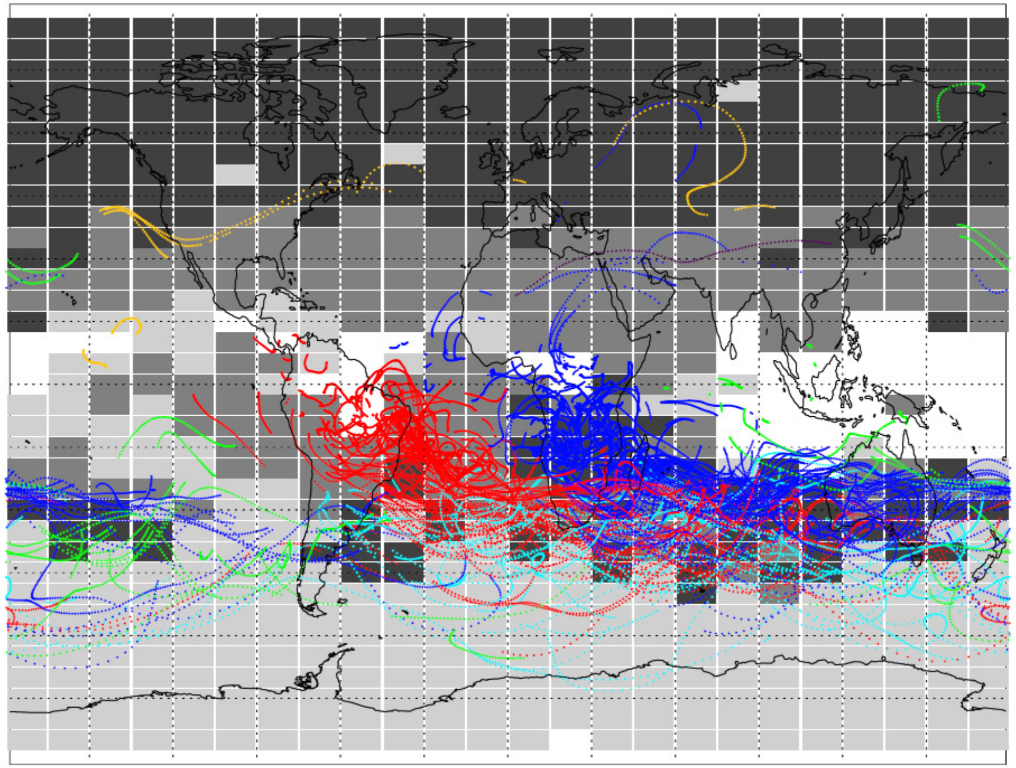


Stiller et al., 2007; von Clarmann et al., 2007; Glatthor et al., 2007, 2009; Grutter et al., 2010; Funke et al., 2009

Applications: V. Ozone production in a biomass burning plume: 21 Oct – 12 Nov 2003



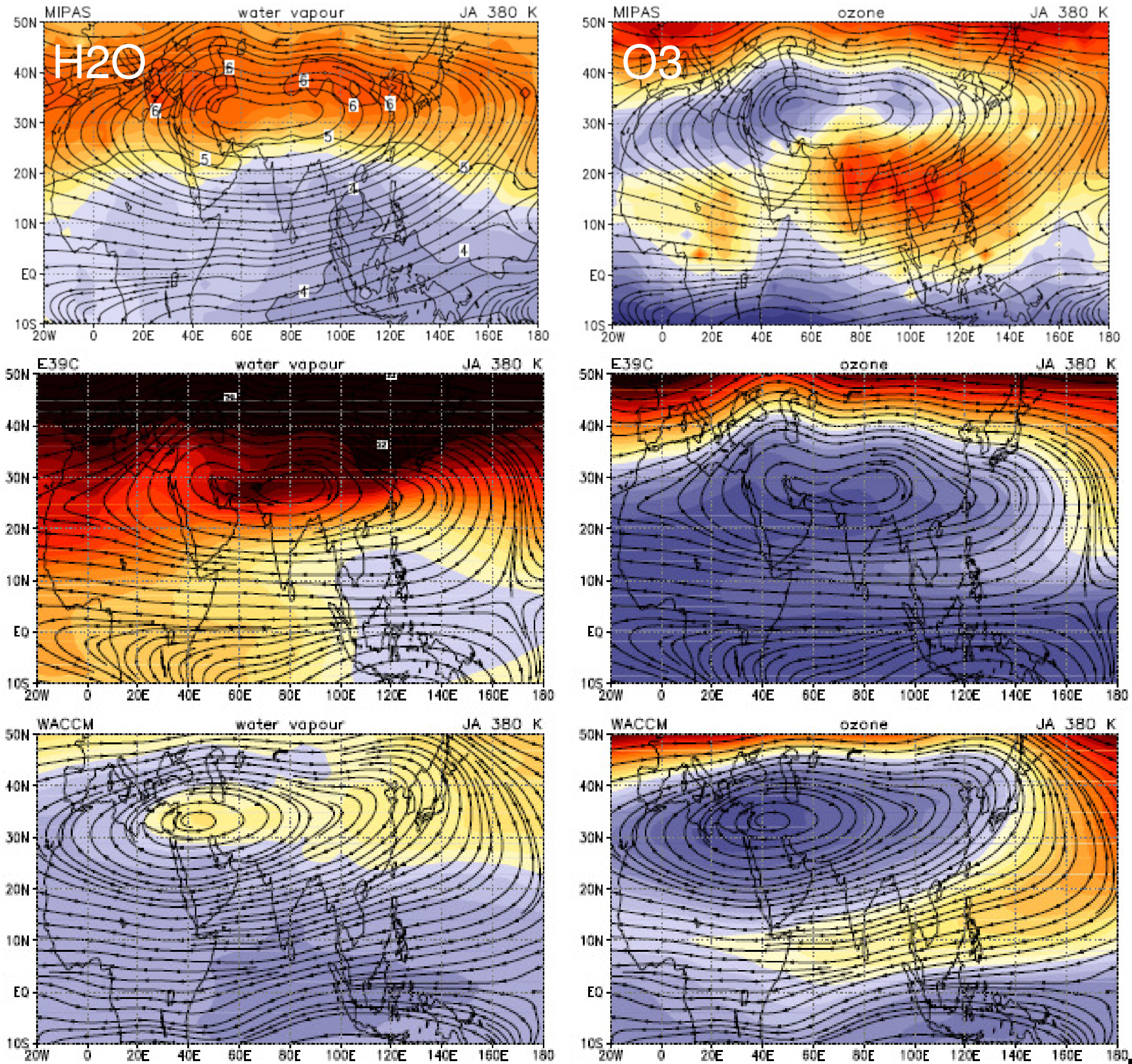




Forward trajectories starting from fire clusters; black: high O3 and high C2H6; middle grey: high C2H6 but low O3; light grey: both C2H6 and O3 low
Emission inventories regarding C2H6/O3 ratios confirmed

Von Clarmann et al., ACP 2007

Applications: VI. Upward transport near/across the tropopause in the Asian Monsoon Anticyclone



MIPAS H_2O and O_3 @ 380K

E39C

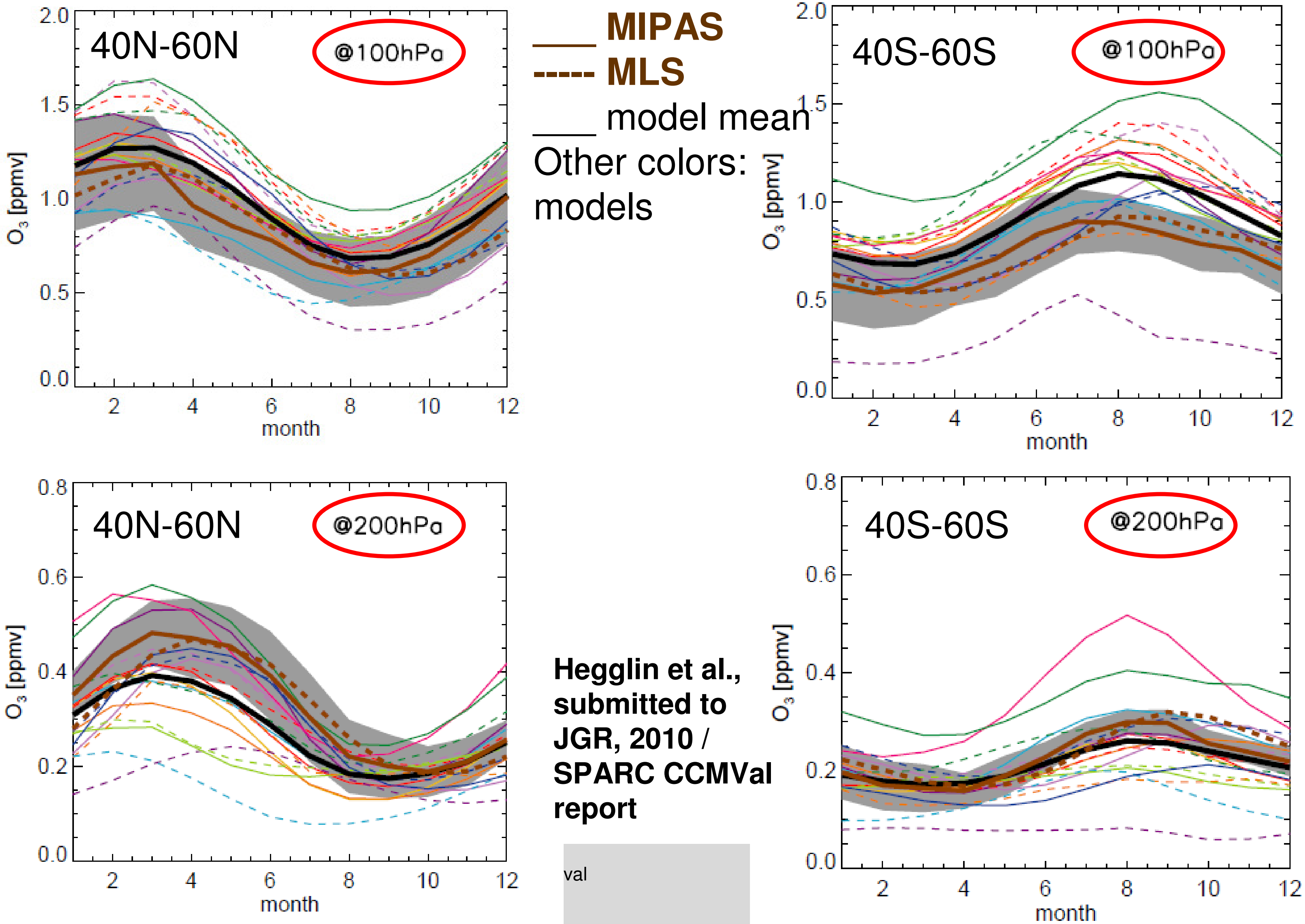
WACCM

O_3 is used as a dynamical tracer: low O_3 = tropospheric air

Kunze et al., J. Climate, in press, 2010

Applications: VII. 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., submitted to JGR, 2010 / SPARC CCMVal report

Future Application: Contribution to the ECV ozone limb profile product

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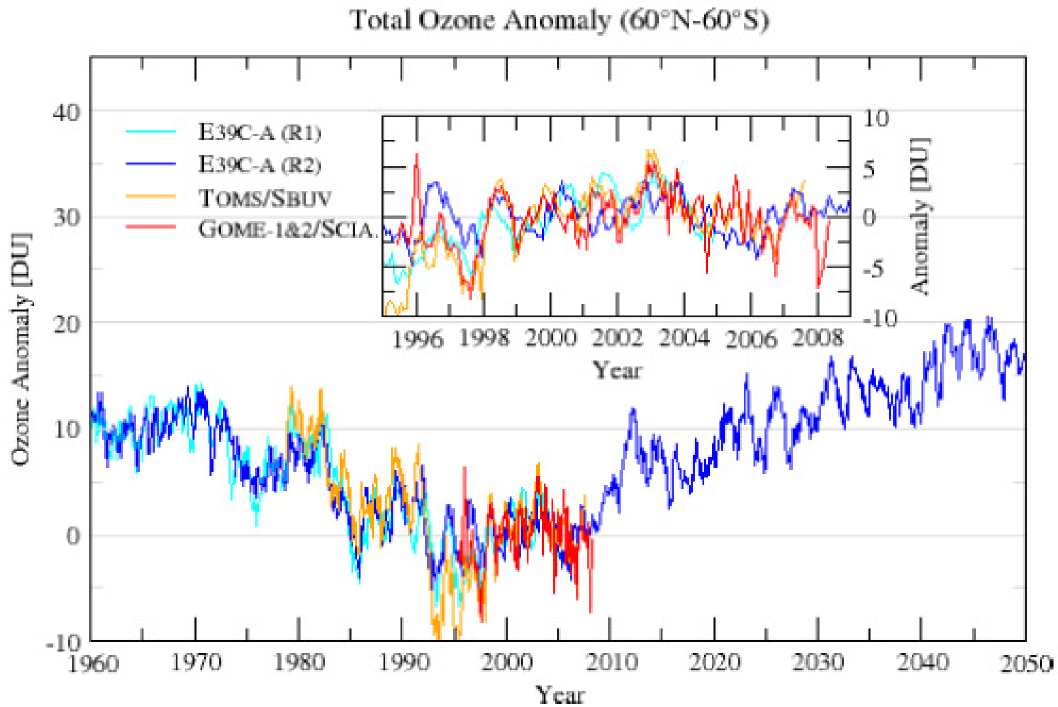
Ozone-cci Project

Building consolidated climate-relevant ozone data sets
in the framework of the ESA's Climate Change Initiative (CCI)



ESSENTIAL CLIMATE VARIABLE: OZONE

Conclusions

- MIPAS provides ozone globally during day and night with >1000 profiles a day, covering the upper troposphere up to the mesosphere (thermosphere)
- MIPAS ozone precision is about 5%
- MIPAS ozone accuracy is about 12%, with spectroscopy as the driving error source
- Spectroscopic data among bands are not consistent
- Validation confirms precision and accuracy estimations
- Vertical resolution around 3 km, horizontal resolution 250 to 400 km
- Main applications are: Polar ozone chemistry, impact of solar particles on the stratospheric composition, upper tropospheric pollution and ozone formation, troposphere-stratosphere transport, validation of CTMs and CCMs, and, in future, generation of a consolidated climate-relevant ozone data set