

**Coordinated activity for the geophysical validation
of MIPAS-ENVISAT v4.61/ v4.62 Ozone data**

Ugo Cortesi
IFAC-CNR, Firenze, Italy

MIPAS O₃ Validation – Contributing Teams

Name	Institute	Country	Contribution
C.E. Blom	IMK.FZK	Germany	AB
T. Blumenstock and S. Mikuteit	IMK-FZK	Germany	GB
A. Bracher and M. Weber	IUP-Un. Bremen	Germany	SI
I. Boyd	NIWA-ERI	New Zealand	GB
M. Iarlori	Univ. L'Aquila	Italy	GB
K. Jucks and K. Chance	SAO-CfA	USA	AB
J. Kuttipurath	CNRS-LMD	France	AB
J-C Lambert and C. DeClercq	BIRA	Belgium	GB
Y. Meijer	RIVM	The Netherlands	GB
F.Mencaraglia	IFAC-CNR	Italy	AB
H. Oelhaf	IMK-FZK	Germany	AB
S. Payan and C. Camy-Peyret	LPMA-CNRS	France	AB
C. Piccolo	Univ. Oxford	UK	SI
M. Pirre and V. Catoire	LPCE-CNRS	France	AB
F. Ravegnani and I. Kostadinov	ISAC-CNR	Italy	AB
G. Redaelli	Univ. L'Aquila	Italy	MA
H. Sembhi and J.J. Remedios	Univ. Leicester	UK	GB + SI
T. Steck	IMK-FZK	Germany	SI
K. Strong and T. Kerzenmacher	Univ. Toronto	Canada	GB
C. Varotsos and C. Tzanis	Univ. Athens	Greece	GB
C. Vigouroux	BIRA	Belgium	GB
A. Waterfall, J. Reburn, R. Siddans	RAL	UK	MA + SI

MIPAS O₃ coord. validation: OBJECTIVE AND STRATEGY

Geophysical validation of level-2 operational O₃ data obtained during MIPAS nominal spectral resolution ($\Delta\sigma = 0.025 \text{ cm}^{-1}$) mission, from July 6th, 2002 to March 26th, 2004.

Focus on off-line products from the Instrument Processing Facility versions 4.61 and 4.62 (hereafter MIPAS IPF v4.61 and v4.62 data).

Merging of individual validation results provided by the GBMCD, ESABC and MASI teams and based on re-analyses sharing common criteria and tools for the inter-comparison.

Update of the pre-launch estimates for precision and accuracy of MIPAS Ozone VMR vertical profiles.

Intercomparison Criteria

Baseline criteria for spatial and temporal coincidence: $\Delta s < 300$ km
 $\Delta t < 3$ hours

Additional requirement for max. PV differences ($(\Delta PV/PV)_{\max} \sim 15\%$) to be considered for intercomparison of polar winter measurements.

Reduction of vertical smoothing differences using averaging kernels and common a priori state.

Recommended representation of O₃ vertical profiles: volume mixing ratio versus pressure.

Standard settings for calculation/ comparison of O₃ partial columns.

Use of trajectory calculations to increase the number of coincidences (with the same baseline collocation criteria adopted for direct coincidences).

● Ground-based measurements

Pseudo-global comparison with O ₃ data from NDSC/GAW stations	(BIRA)
FT-IR measurements at high and midlatitude stations	(BIRA) (IMK-FZK)
Lidar measurements (EQUAL project)	(RIVM)
O ₃ sondes at mid-latitudes	(Un L'Aquila) (Un. Athens) (Un. Toronto)
ECMWF Ozone data	(RAL)
GOME	(RAL)

CONTINUE =>

MIPAS O₃ validation by ground-based FT-IR measurements

METHODOLOGY

Comparison of MIPAS v4.61/v4.62 O₃ data with O₃ profiles and columns from five FT-IR stations:

Kiruna	(lat. 67.8°N)
Jungfrauoch	(lat. 46.5°N)
Wollongong	(lat. 34.4°N)
Lauder	(lat. 45.0°S)
Arrival Heights	(lat. 77.5°S)

Baseline collocation criteria (slightly relaxed for Wollongong station: $\Delta s < 500$ km).

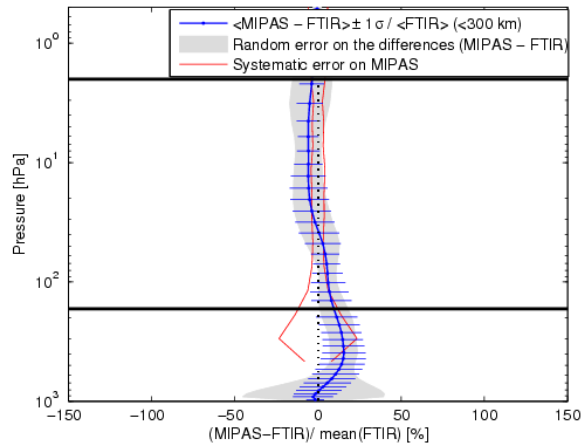
MIPAS O₃ profiles downgraded to lower vertical resolution, by applying FTIR AKM, and compared with the mean of collocated FTIR measurements recorded within the chosen temporal coincidence criterion.

O₃ partial column limits defined, taking into account MIPAS lowest altitudes (mean value ~ 12 km) and FT-IR sensitivity (reasonable up to ~ 40 km for O₃)

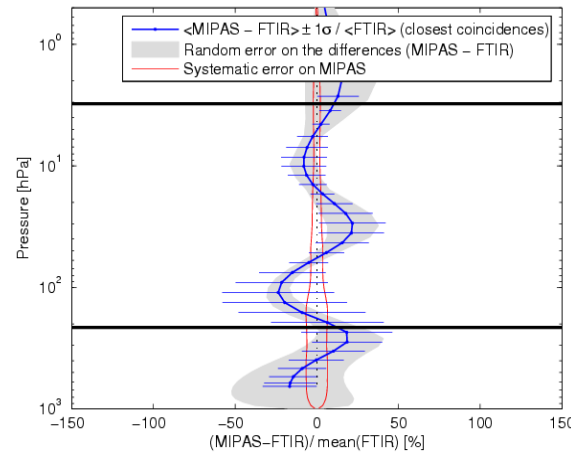
MIPAS O₃ validation by ground-based FT-IR measurements

Comparison of O₃ profiles: RESULTS

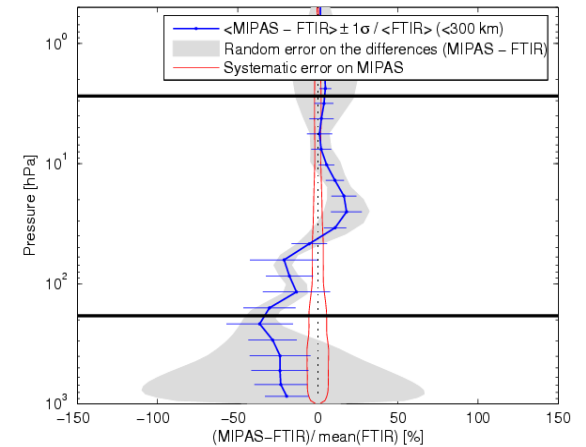
O₃ at Kiruna



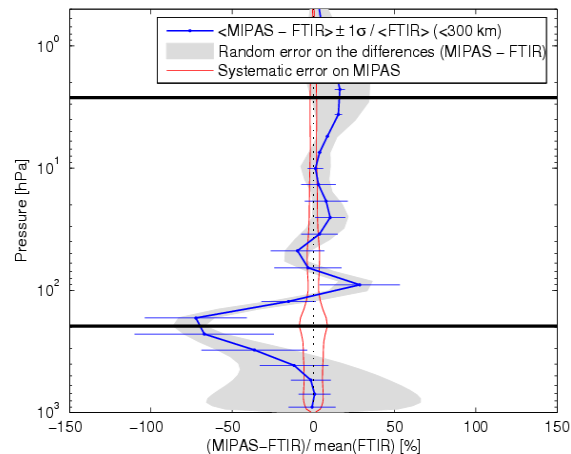
O₃ at Jungfraujoch



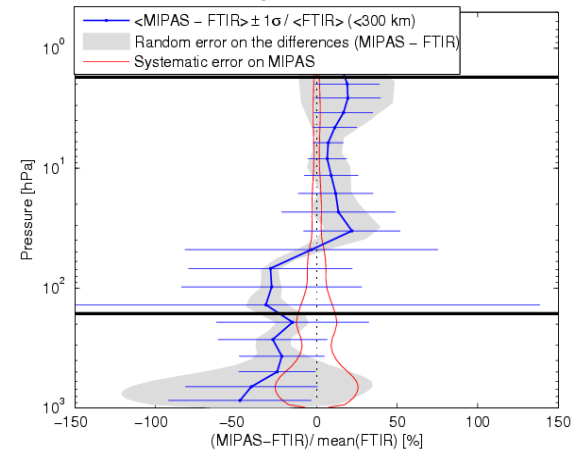
O₃ at Lauder



O₃ at Wollongong

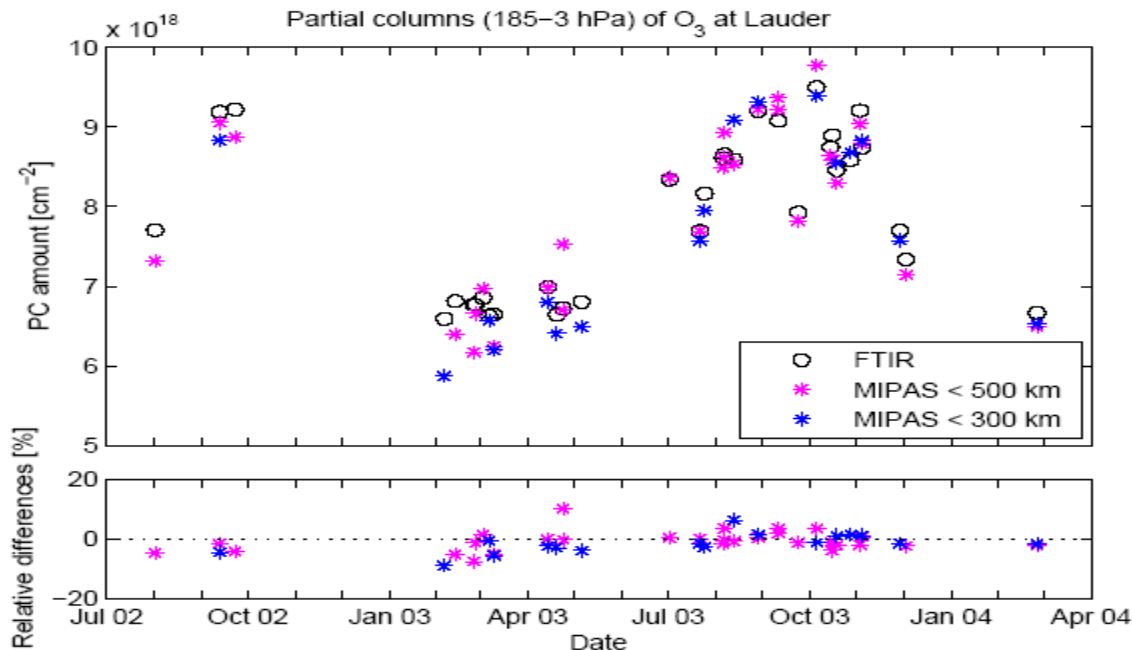


O₃ at Arrival Heights



MIPAS O₃ validation by ground-based FT-IR measurements

Comparison of O₃ partial columns: RESULTS



- Statistics1:** $\Delta s < 300 \text{ km}, \Delta t < 3 \text{ h}$
- Statistics2:** $\Delta s < 500 \text{ km}, \Delta t < 3 \text{ h}$
- Statistics3:** $\Delta s < 200 \text{ km}, \Delta t < 3 \text{ h}$

Station	Pressure Range	Statistics1	Statistics2	Statistics3
Kiruna	2 – 168 hPa	$+1.3 \pm 6.3\%$ [24]	-----	-----
Jungfraujoch	3 – 214 hPa	$+0.3 \pm 5.6\%$ [12]	$+0.8 \pm 4.7\%$ [26]	-----
Wollongong	3 – 196 hPa	$+1.9 \pm 2.3\%$ [4]	$+3.4 \pm 3.9\%$ [19]	-----
Lauder	2 – 185 hPa	$-1.6 \pm 3.5\%$ [17]	$-1.1 \pm 3.4\%$ [46]	-----
Arrival Heights	2 – 163 hPa	$-4.4 \pm 11.1\%$ [16]	$-0.8 \pm 13.5\%$ [39]	$0.5 \pm 5.6\%$ [9]

CONCLUSIONS

In the region of the O₃ maximum, around 10 hPa, MIPAS and FTIR profiles are in good agreement for all the stations

Significant bias around 90 hPa at Wollongong.

The standard deviation is within the combined random error from the upper limit of the comparison down to ~10 hPa for Arrival Heights and down to ~ 60 hPa for all other stations.

MIPAS O₃ validation by lidar measurements (EQUAL project)

Methodology

Comparison of MIPAS v4.61/v4.62 O₃ data with O₃ profiles from ground-based lidar measurements obtained by 11 stations of the EQUAL project (ENVISAT QUality Assessment by Lidar) in the period 6th July 2002 to 26th March 2004.

Spatial and temporal coincidence criteria:

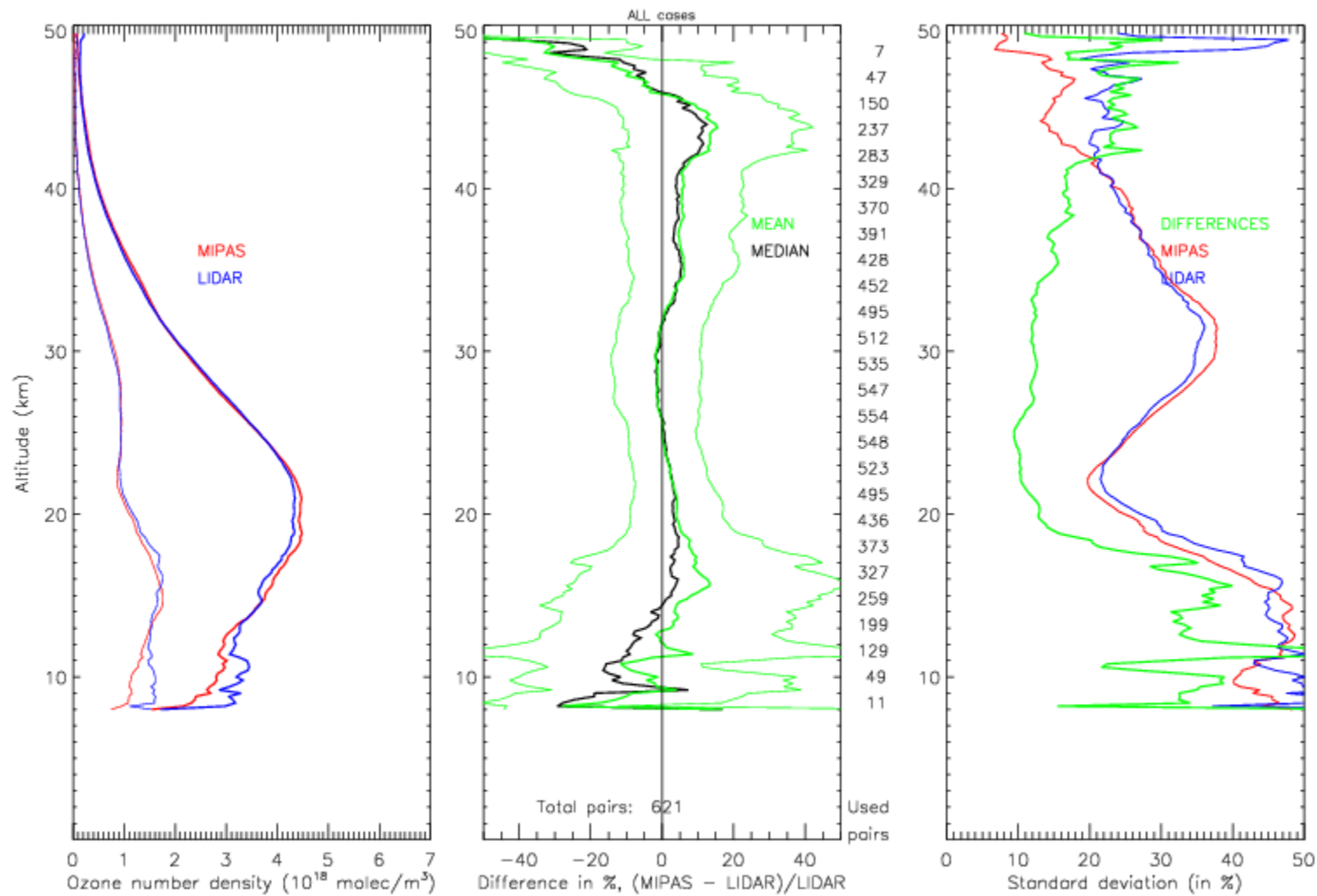
- $\Delta s < 800$ km, $\Delta t < 20$ h
- $\Delta s < 400$ km, $\Delta t < 10$ h
- $\Delta s < 200$ km, $\Delta t < 5$ h

Collocated pairs of MIPAS and lidar O₃ profiles represented using number density as a function of altitude:

MIPAS profiles → altitude grid reconstruction using ECMWF data

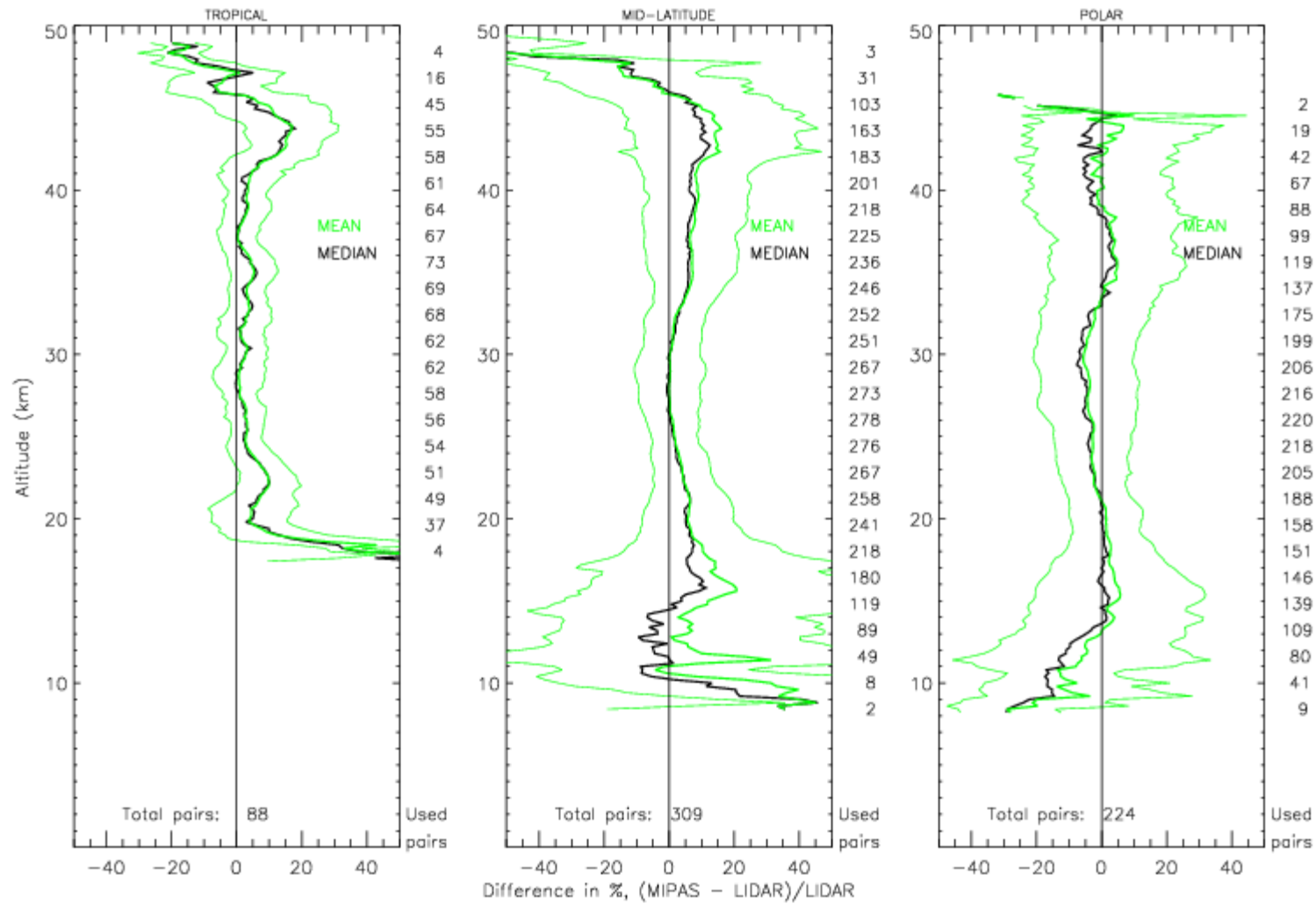
Comparison of MIPAS and lidar O₃ profiles: RESULTS

ALL CASES



Comparison of MIPAS and lidar O₃ profiles: RESULTS

LATITUDE DEPENDENCY



MIPAS O₃ validation by lidar measurements

CONCLUSIONS

Very good agreement between MIPAS and LIDAR O₃ mean profiles:

Relative diff. within $\pm 5\%$

~20 - 40 km

Relative diff. within $\pm 15\text{-}20\%$

below ~ 20 km and above ~ 40 km

Larger differences in the tropical UTLS (up to 40% and higher at ~ 15-20 km) and in the polar stratosphere ($-10\% < \Delta O_3/O_3 < -5\%$ at ~30 km)

Pseudo-global comparison with O₃ data from NDACC stations

METHODOLOGY

Comparison of MIPAS v4.61 O₃ data with correlative measurements from:

- 39 ozonesondes stations (O3S)
- 8 lidars (LID)
- 7 microwave radiometers (MWR)

Spatial and temporal coincidence criteria: $\Delta s < 500$ km, $\Delta t < 6$ h (O3S, LID)
 $\Delta s < 500$ km, $\Delta t < 2$ h (MWR)

Comparison of O₃ profiles and partial columns limited to 2003 data

Error budget including:

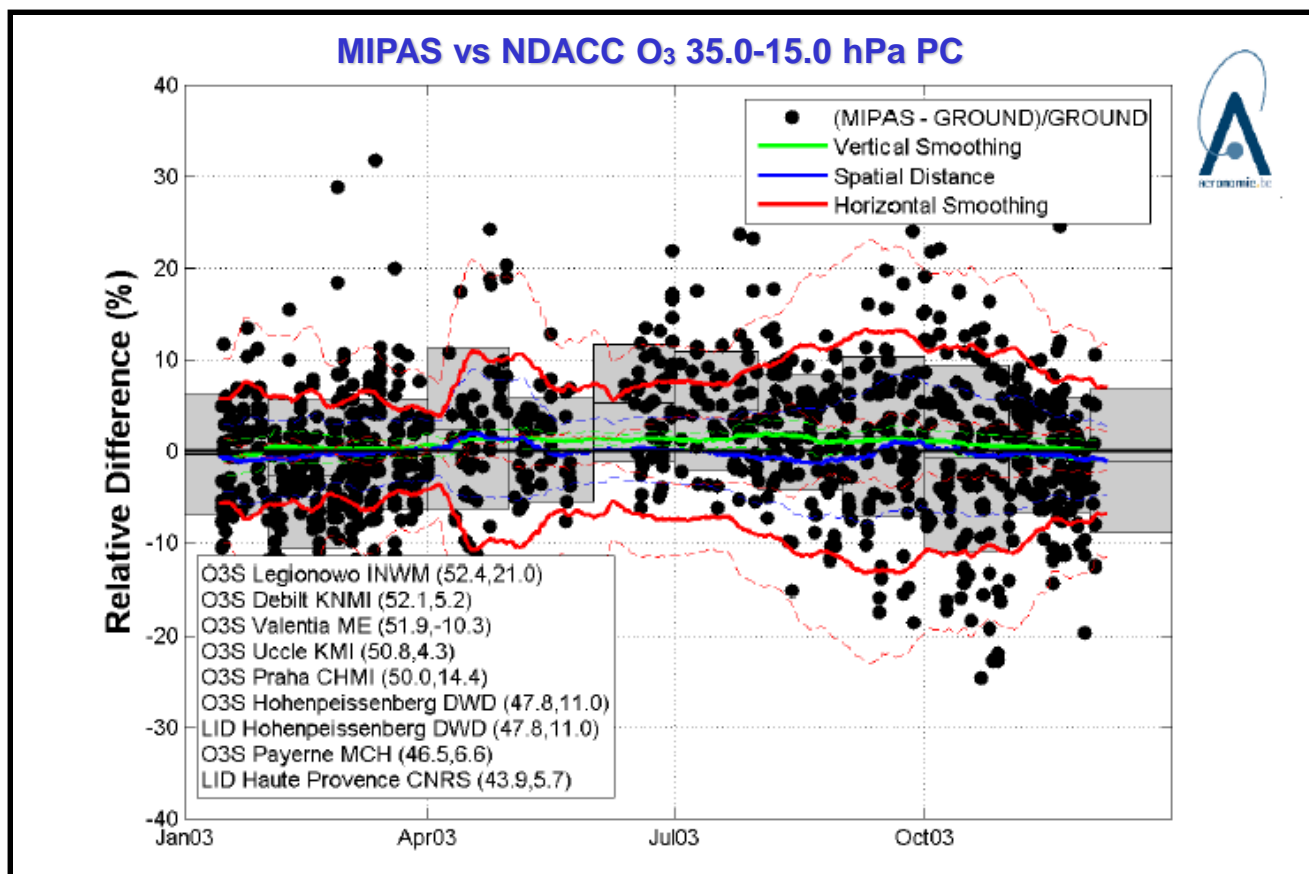
- (a) MIPAS and ground-based instrument errors
- (b) Vertical smoothing error
- (b) Horizontal smoothing error
- (c) Error due to geolocation differences

Estimates based on assimilated O₃ fields by the Belgian Assimilation System of Chemical Observations from ENVISAT (BASCOE).

Pseudo-global comparison with O₃ data from NDACC stations

RESULTS: time series of O₃ partial columns differences

O₃ partial columns defined on 5 layers ranging from 75 to 0.8 hPa (\cong 18 - 50 km)



Time series of the percentage relative difference in O₃ partial columns between MIPAS and ozone sondes data from Western and Central Europe stations

Pseudo-global comparison with O₃ data from NDACC stations

CONCLUSIONS

Observed differences:

Lower stratosphere => ~ synoptic behaviour (chemistry & dynamics)
Upper stratosphere => ~ zonal behaviour (photochemistry)

Comparison error budget:

Errors due to MIPAS > uncertainty associated to > errors due to vertical
horizontal smoothing geolocation differences smoothing differences

The different error components generally account for the observed differences in O₃ partial columns, with the following exceptions:

- (a) In the 75-35 hPa layer at mid-latitudes, equator and tropics
- (b) In the 35-15 hPa layer at equator, tropics and Antarctica during O₃ hole
- (c) In the 3-0.8 hPa layer at European stations

Validation of MIPAS O₃ profiles by aircraft/balloon-borne measurements

MIPAS-B

Balloon-borne version of the MIPAS-ENVISAT instrument, operated by IMK-FZK.

Field of view, spectral range, spectral resolution, radiometric noise similar to MIPAS-ENVISAT

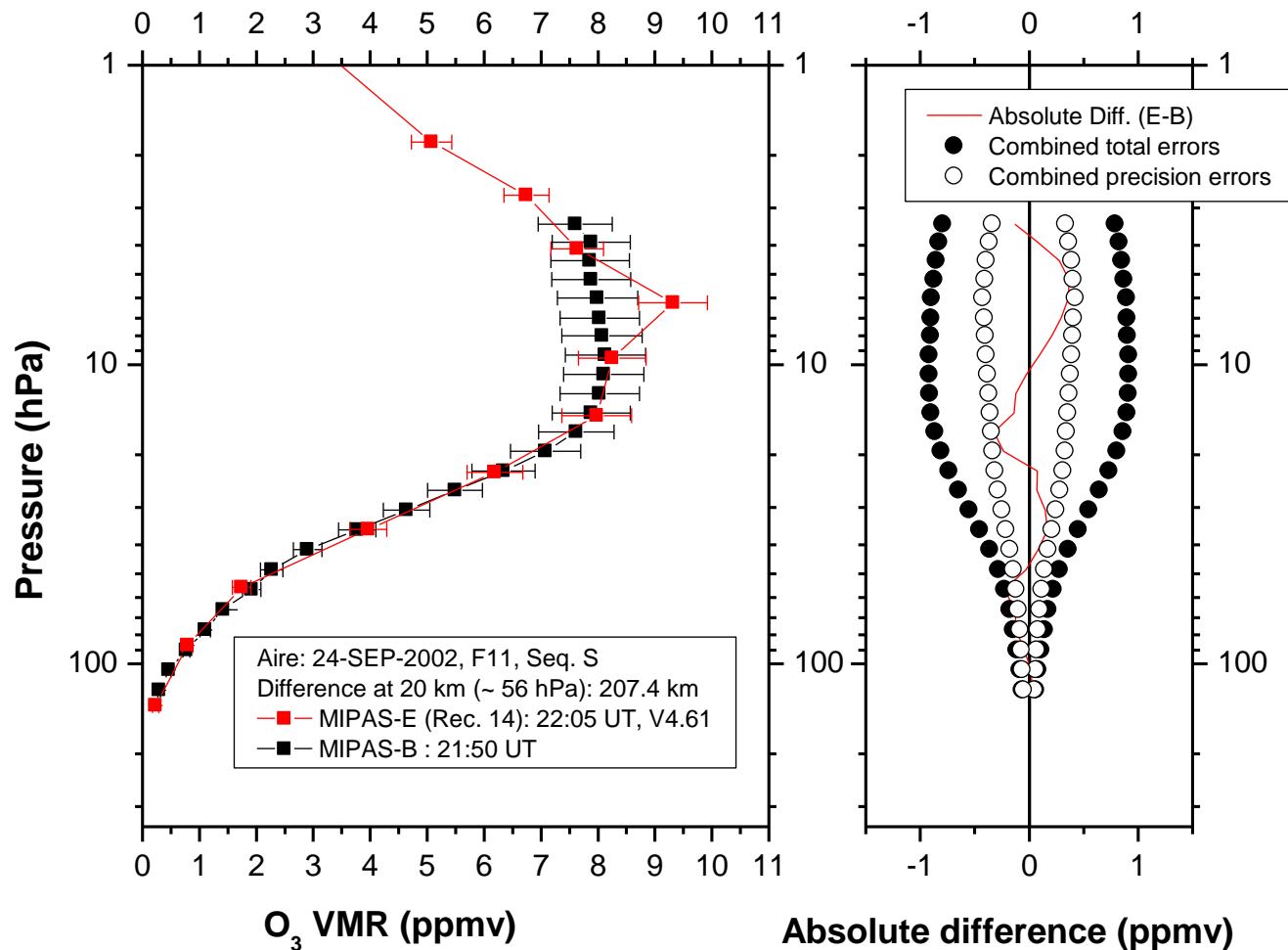
Correlative measurements:	Aire-Sur-L'Adour	43.5°N	24 Sep 2002
	Kiruna	67.8°N	20/21 Mar 2003
			03 Jul 2003

High quality matching within baseline collocation criteria:

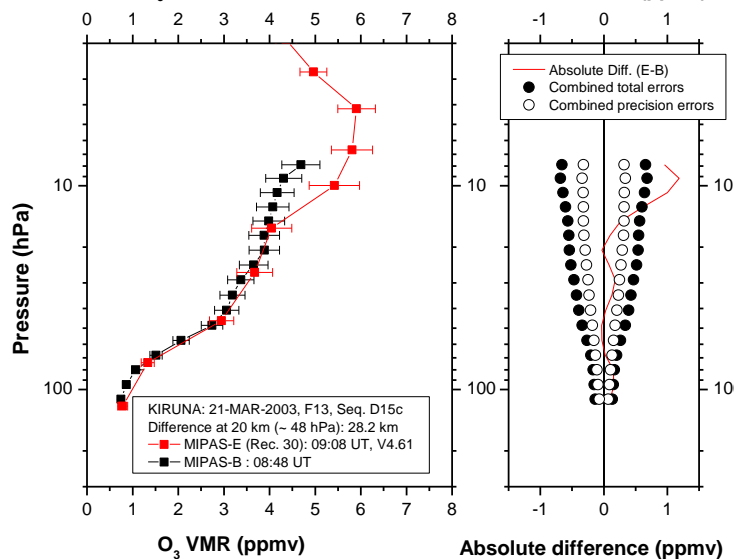
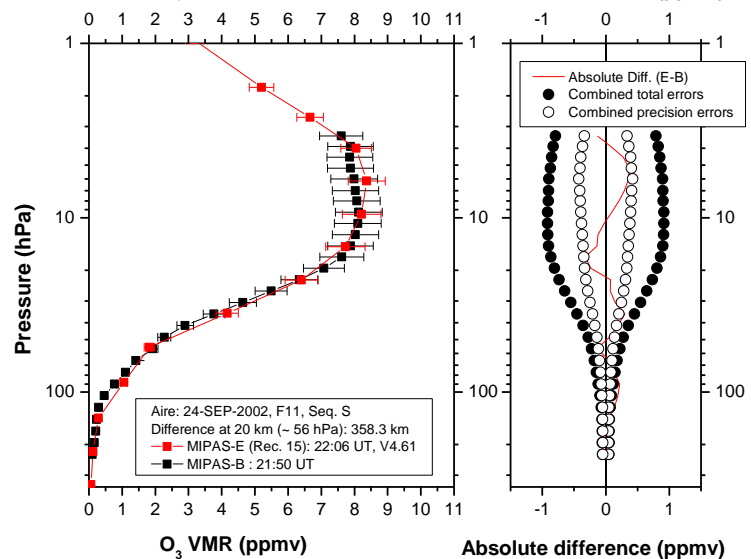
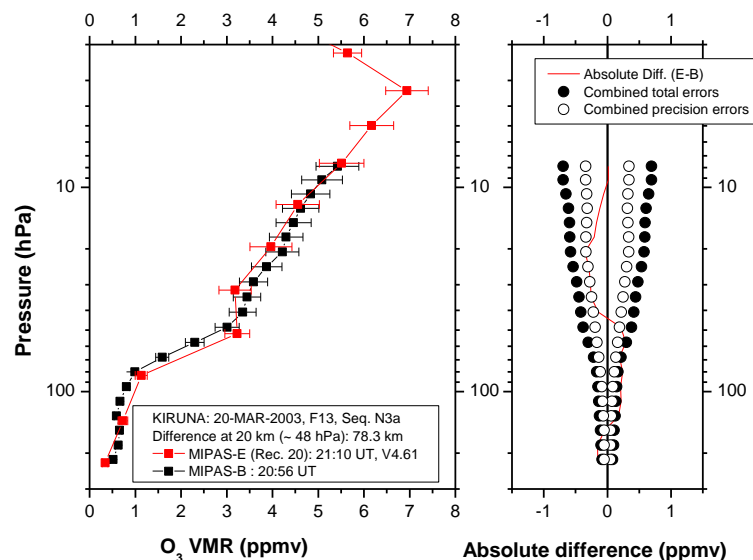
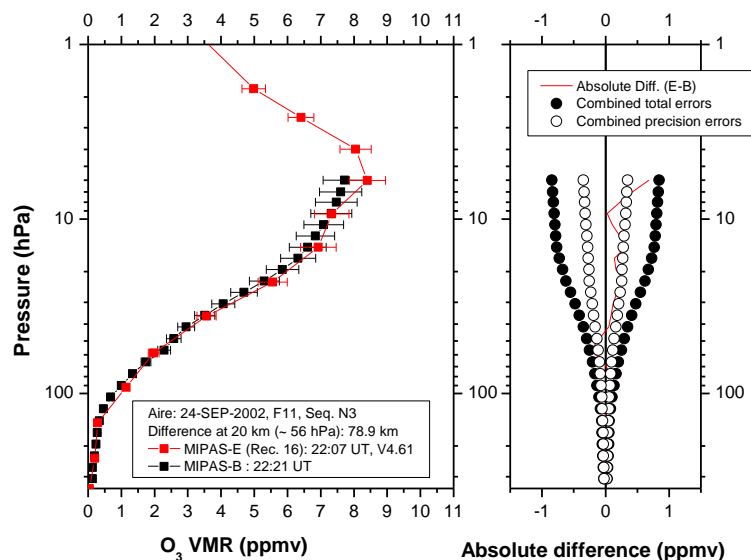
300 km, 3 h

Max PV rel. diff. at the tangent points ~ 15%

Comparison of MIPAS-ENVISAT and MIPAS-B O₃ profiles: RESULTS



Comparison of MIPAS-ENVISAT and MIPAS-B O₃ profiles: RESULTS



Comparison of MIPAS O₃ profiles with balloon-borne FT-FIR data

FIRS-2 and IBEX

Comparison of MIPAS v4.61 O₃ profiles with correlative measurements performed by high resolution FT-FIR spectrometers during balloon flights at mid-latitudes:

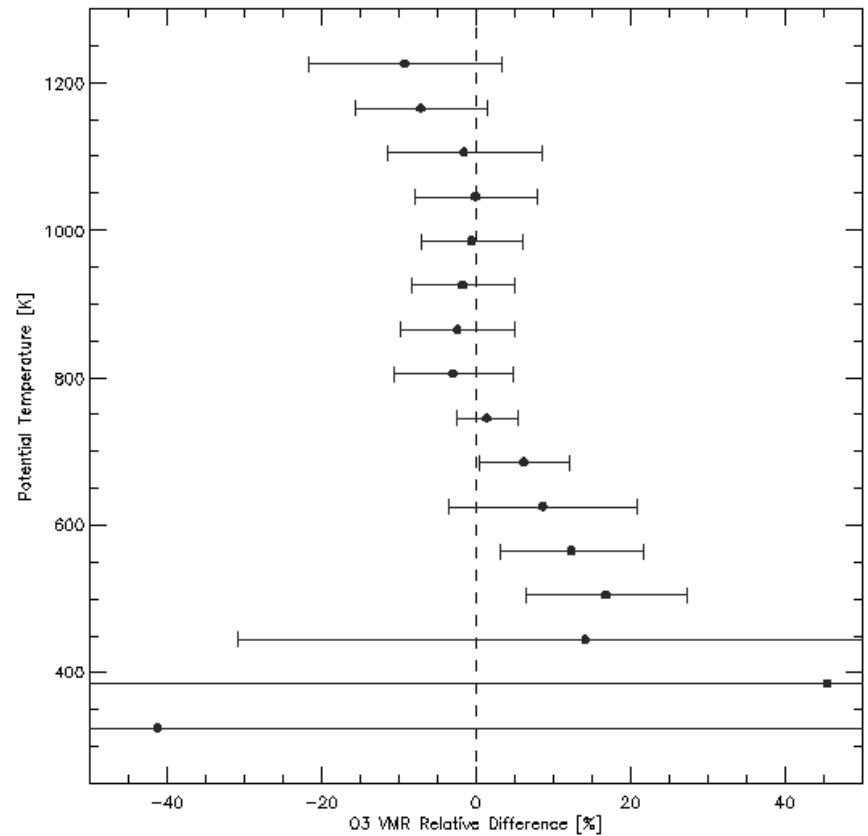
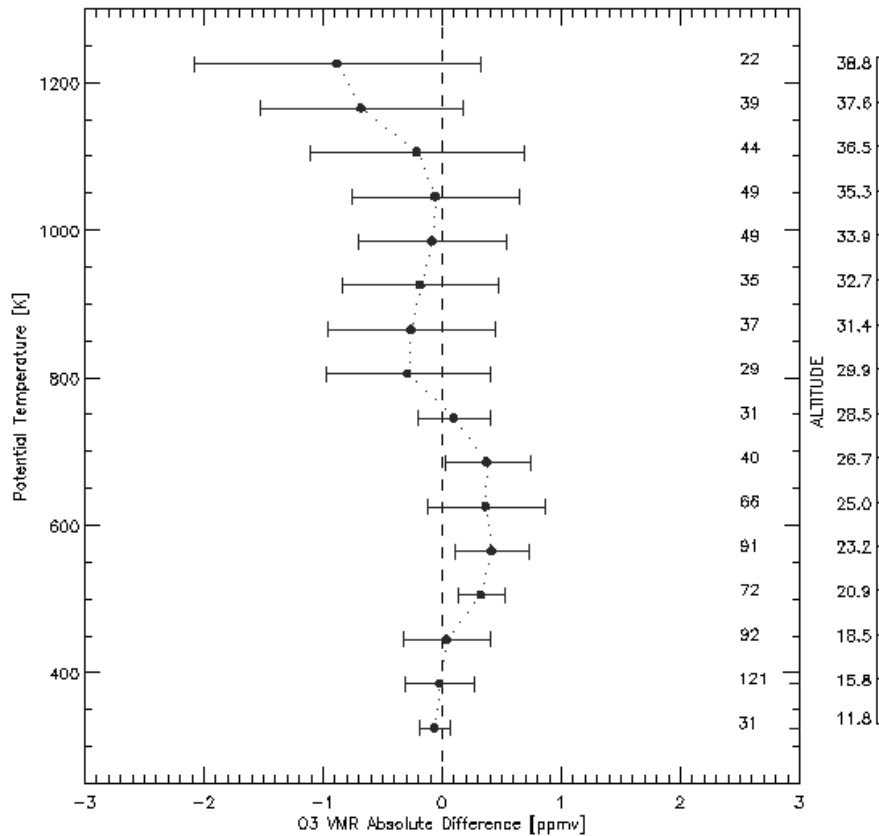
FIRS-2 (Far InfraRed Spectromeer, CfA-SAO, USA): Fort Sumner (34°N), Sep 19-20, 2003

IBEX (Infrared Balloon EXperiment, IFAC-CNR, Italy), Trapani (38°N), Sep 29-30, 2002

Methodology:

- (1) Matching pairs of O₃ values identified by means of trajectory calculations (Global Trajectory Model, Univ. of L'Aquila, Italy) with coincidence criteria:
 $\Delta\text{lat} < 2\text{deg}$, $\Delta\text{lat} < 2\text{deg}$, $\Delta t < 2\text{ hours}$
- (2) Binning in Potential Temperature in steps of $\Delta\Theta = 60\text{K}$
- (3) Calculation of mean absolute and relative differences between MIPAS and FIRS-2 (or IBEX) O₃ values.

Comparison of MIPAS and FIRS-2 O₃ profiles: RESULTS



Mean absolute and relative difference between MIPAS and FIRS-2 O₃ VMR binned by Potential Temperature values ($\Delta\Theta = 60\text{K}$)



Validation of MIPAS O₃ profiles by satellite intercomparison: SAGE II

SAGE II (Stratospheric Aerosol and Gas Experiment)

Comparison of MIPAS O₃ data v4.61/v4.62 with SAGE II v6.2 collocated data for the period 6th Jul 2002 to 26th Mar 2004.

Baseline coincidence criteria (300 km, 3h) → 331 matching pairs of O₃ profiles

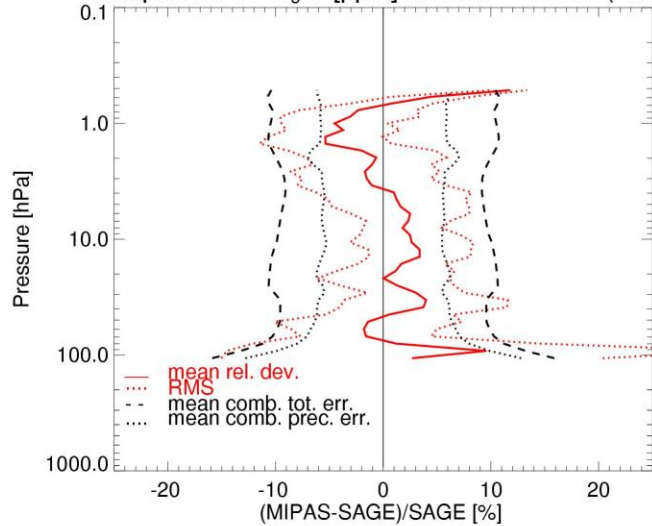
No AKs applied because of similar vertical resolution (SAGE 2 to 3 km)

Investigation of zonal and seasonal averages of the relative differences MIPAS to SAGE II.

Comparison of MIPAS O₃ v4.61/v4.62 and SAGE II v6.2 O₃ data: RESULTS

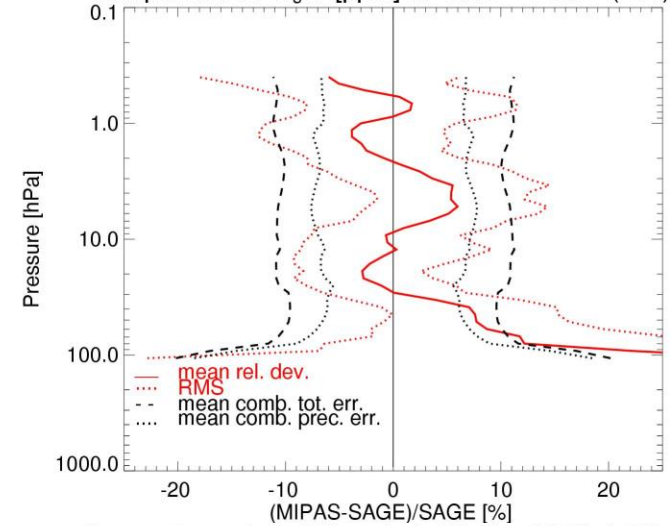
Northern Hemisphere

Comparison of O₃-P [ppm] at 30.0° - 60.0° (29)



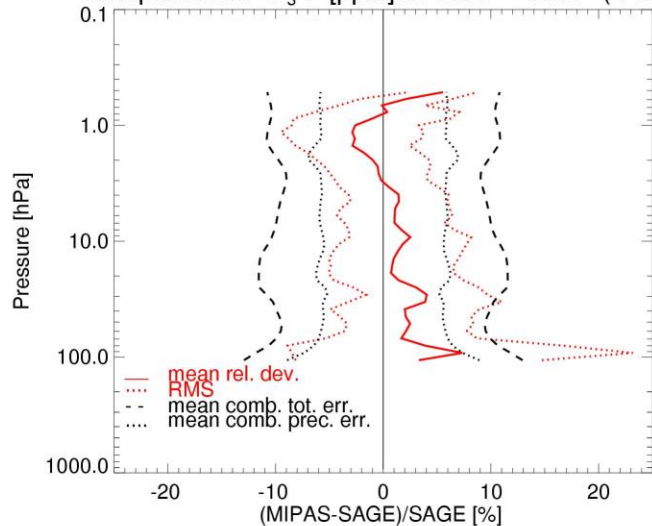
Southern Hemisphere

Comparison of O₃-P [ppm] at -60.0° - -28.0° (64)



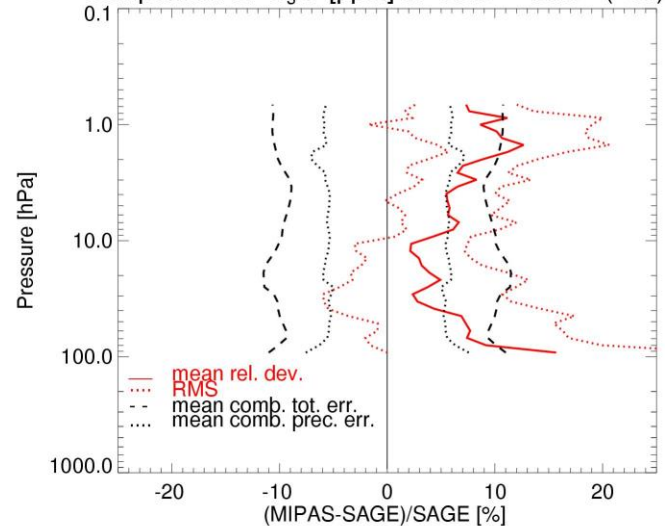
Mid
latitudes

Comparison of O₃-P [ppm] at 60.0° - 90.0° (169)



High
latitudes

Comparison of O₃-P [ppm] at -90.0° - -60.0° (69)



IUP – Univ. Bremen

Comparison of MIPAS O₃ v4.61/v4.62 and SAGE II v6.2 O₃ data: RESULTS

Statistics over all comparisons of MIPAS to SAGE II

Zone	Mean Relative Deviation	RMS	N.; month of year
80°S-63°S	at 70 – 0.7 hPa +2 – +12%	4 - 10%	69; Dec 03, Feb 04
28°S-55°S	at 60 – 0.5 hPa -4 – +8%	5 - 10%	64; Jan 03/04, Apr-May 03, Jul 03
45°N-60°N	at 70 – 0.6 hPa -5 – +4%	4 - 9%	29; Jan+Mar 03, Apr 03, Jul 02/03
60°N-76°N	at 70 – 0.6 hPa -3 – +4%	4 - 7%	169; Apr+Jun 03, Jul 02/03, Sep 03

Season

	Spring	at 60 – 0.7 hPa +2 ↔ +9%	3 ↔ 10%	37
SH	Summer	at 65 – 1.5 hPa +1 ↔ +10%	4 ↔ 10%	45
	Fall	at 60 – 0.4 hPa -6 ↔ +8%	4 ↔ 10%	25
	Winter	at 65 – 1.0 hPa -4 ↔ +8%	5 ↔ 10%	26
	Spring	at 80 – 0.5 hPa -4 ↔ +4%	3 ↔ 10%	101
NH	Summer	at 60 – 0.7 hPa -4 ↔ +4%	4 ↔ 10%	95
ALL		at 70 – 0.7 hPa -1 ↔ +4%	6 ↔ 10%	331

Conclusions

MIPAS and SAGE II O₃ profiles agree within 5% (RMS <10%) at 70 to 0.6 hPa

Positive bias of MIPAS to SAGE in high southern latitudes spring and summer (up to 12%, RMS <10%), not in SH fall/ winter and in NH spring/summer

GOME (Global Ozone Monitoring Instrument)

Validation of MIPAS v4.61 data against GOME O₃ profiles (retrieved by using the retrieval scheme developed at RAL) for four selected months (Sep 2002, Dec 2002, March 2003, May 2003) covering the time range with global coverage from both instruments.

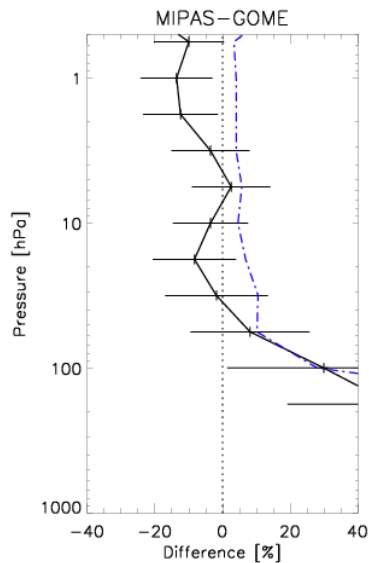
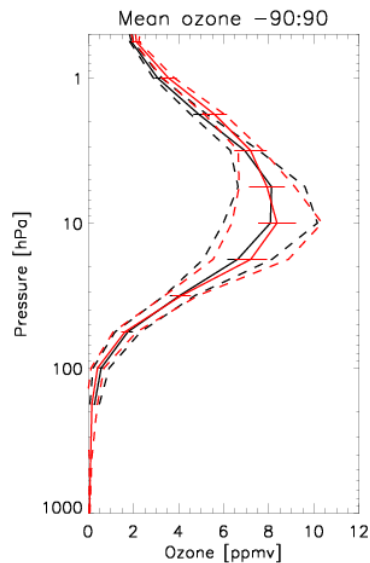
Baseline coincidence criteria (300 km, 3h).

Interpolation of MIPAS O₃ profiles to GOME pressure grid and application of GOME AKs to MIPAS data to match the lower vertical resolution of GOME profiles.

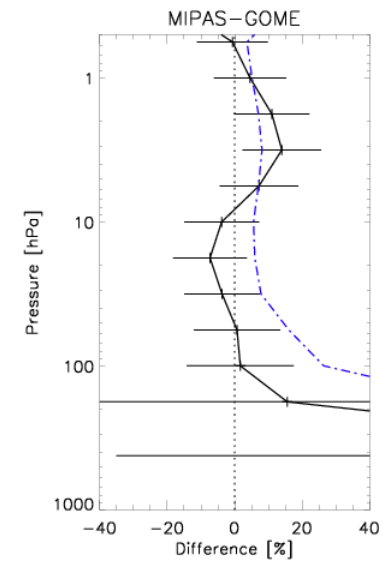
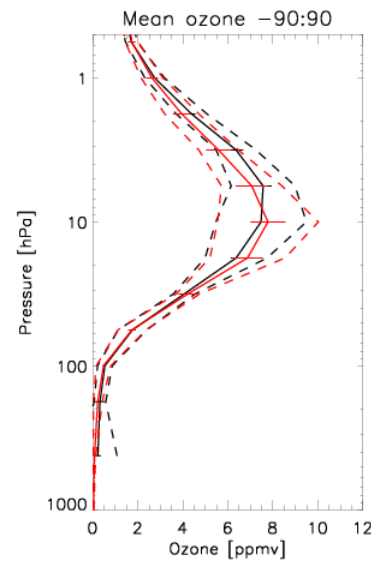
Validation of MIPAS O₃ v4.61 data with RAL GOME data: RESULTS



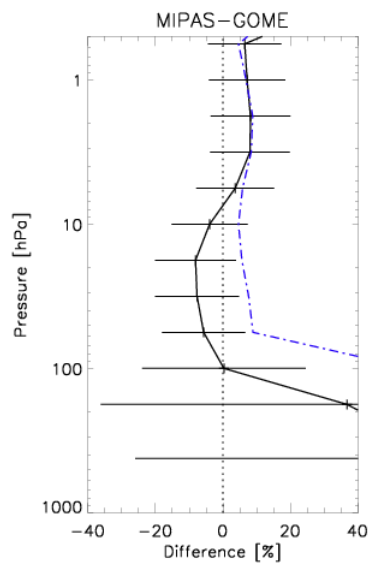
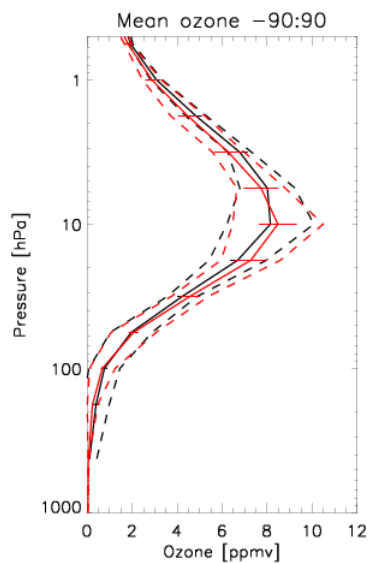
**SEP
2002**



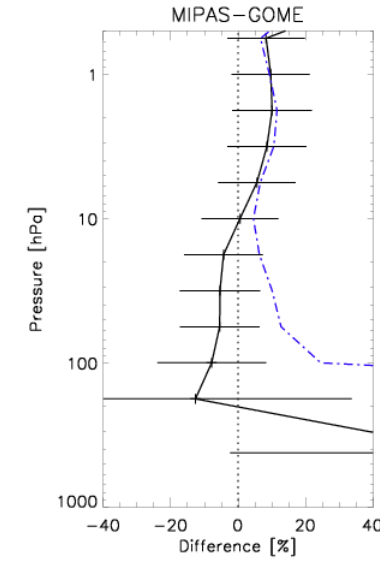
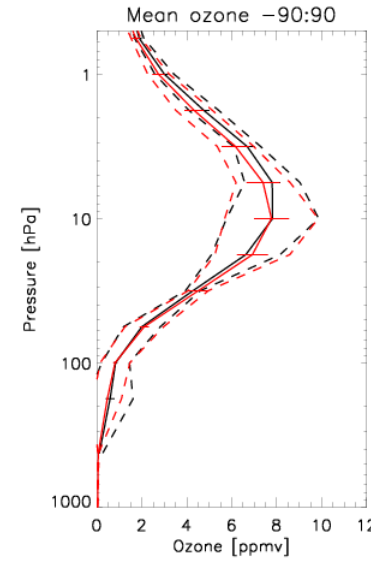
**DEC
2002**



**MAR
2003**



**MAY
2003**



Validation of MIPAS O₃ v4.61 data with RAL GOME data: CONCLUSIONS

MIPAS and GOME are in generally good agreement within the error bars of the two instruments

Between 10 and 1 hPa MIPAS is higher than GOME by 10-20% for 3 of the 4 months (generally within the combined total error).

In September 2002 MIPAS is lower than GOME that is known to be affected by additional errors in this period and might be responsible for the differences in comparison with the remaining months.

MIPAS O₃ coordinated validation: SUMMARY

A coordinated effort was carried out to combine and to better exploit the information from different activities for the validation of MIPAS ozone data.

Consolidated results are presently available from intercomparison of MIPAS v4.61/v4.62 data with O₃ measurements from a comprehensive database of individual validation experiments.

Final merging of these results is currently in progress, to produce an overall assessment of MIPAS O₃ data quality and to provide an up-to-date estimate of their accuracy and precision.

Final outcomes of the coordinated activity will be published in a dedicated paper (in preparation) to be submitted to *Atmospheric Chemistry and Physics*, as part of a Special Issue about MIPAS-ENVISAT validation.