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Intercomparison of scientific tropospheric NO_2 retrievals from SCIAMACHY data

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Introduction

Retrievals of tropospheric NO_2 columns from nadir UV/vis observations are an important source of information on the global distribution of nitrogen oxides, their sources, sinks, and trends. Nitrogen dioxide data from the SCIAMACHY instrument have been used in many scientific studies as they cover a time period of nearly a decade and provide good spatial resolution of 30 x 60 km^2.

Several independent scientific NO_2 retrievals have been developed for the SCIAMACHY instrument, using different spectral windows, stratospheric correction schemes and a-priori assumptions. As a result, the products differ significantly for some situations, creating ambiguities for data users.

Here, five tropospheric NO_2 products are compared for selected scenarios on both an end-to-end basis and for individual steps of the algorithms. In particular, the effects of spectral retrieval, stratospheric correction, air mass factor calculation, and cloud treatment are investigated.

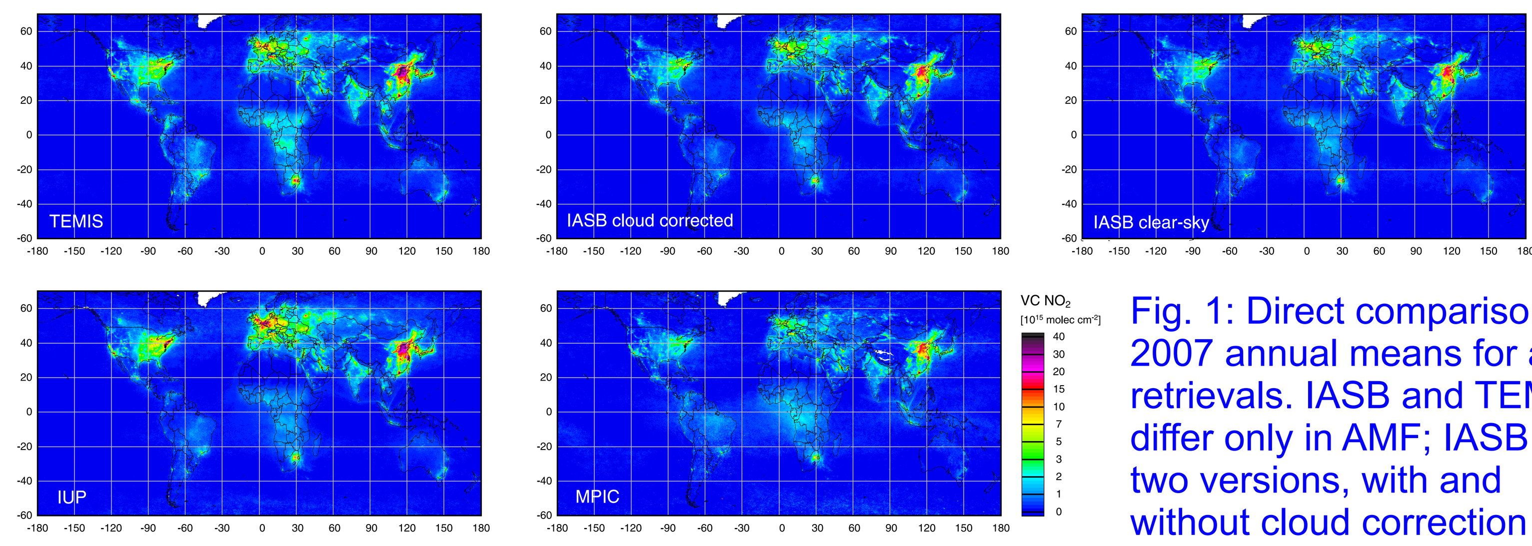

Fig. 1: Direct comparison of 2007 annual means for all 5 retrievals. IASB and TEMIS differ only in AMF; IASB has two versions, with and without cloud correction

Retrieval Settings

	TEMIS	IASB	IUP-UB V 2.0	MPI-C v1.0
Fitting window	426.5-451.5 nm	see TEMIS	425 – 450 nm	430.8-459.5 nm
NO2	Bogumil et al, 1999, 243K		Bogumil et al, 1999, 243K	Vandaele et al., 1998, 220 K
O3	Bogumil et al, 1999, 223K		Bogumil et al, 1999, 223K	Bogumil et al, 1999, 223K
O4	Greenblatt et al, 1990		Greenblatt et al, 1990	Greenblatt et al, 1990
H2O	Rothman et al., 1992		Rothman et al., 1992	Rothman et al., 1992
H2O liquid	-		-	Pope and Fry, 1997
Ring	Chance et al.		Vountas et al.	Chance et al.
CHOCHO	-		-	Volkamer et al., 2005, 296 K
VRS-Ring	-		-	Kurosu, pers. comm.
Undersampling	-		Chance et al.	-
offset / slope	offset		offset	-
Polynomial	2		2	5
Stratospheric correction	TM4 with SCIAMACHY data assimilation		B3dCTM + latitude dependent offset	SCIAMACHY limb + latitude dependent offset
NO2(T) correction	yes	yes	no	constant 1.2
Cloud correction	yes, FRESCO+	yes, FRESCO+ / no	no	yes, FRESCO+
Aerosol correction	no	no	static three types from LOWTRAN (rural, maritime, urban) based on surface type and EDGAR CO2 emissions	constant aerosol in BL (1 km high) with an extinction of 0.5/km, SSA = 0.9, and g = 0.68
Surface Albedo	MODIS Black Sky Albedo over land) + OMI LER (over ocean)	MERIS	GOME	0.05
NO2 profile	TM4 CTM daily profile at 10:00LT using POET 1997 emission database	IMAGES CTM daily profile at SCIAMACHY overpass time(10:00 Local time) using 2007 emission database, 2.5(Long.)x2(lat.)	Monthly climatology based on 1997 run of MOZART CTM	1 km BLH, 80% of tropospheric NO2 column in BL (constant concentrations), 20% in free trop (1-15km) with constant mixing ratio

Comparison over regions

China East Central	30°N	40°N	110°E	120°E
US East Coast	35°N	45°N	80°W	70°W
Europe Central	45°N	55°N	5°W	15°E
America South	15°S	5°S	60°W	45°W
Africa North	0°N	10°N	15°W	45°E
Africa South	20°S	0°S	15°E	35°E

Several regions were selected covering typical polluted and biomass burning regions. Using averages over regions has the advantage of creating easy to compare results but has the problem of averaging over areas having different pollution levels, different air mass factors and different surface reflectance. In addition, sampling effects from the SCIAMACHY measurement pattern and from clouds can give individual values an inappropriately large weight.

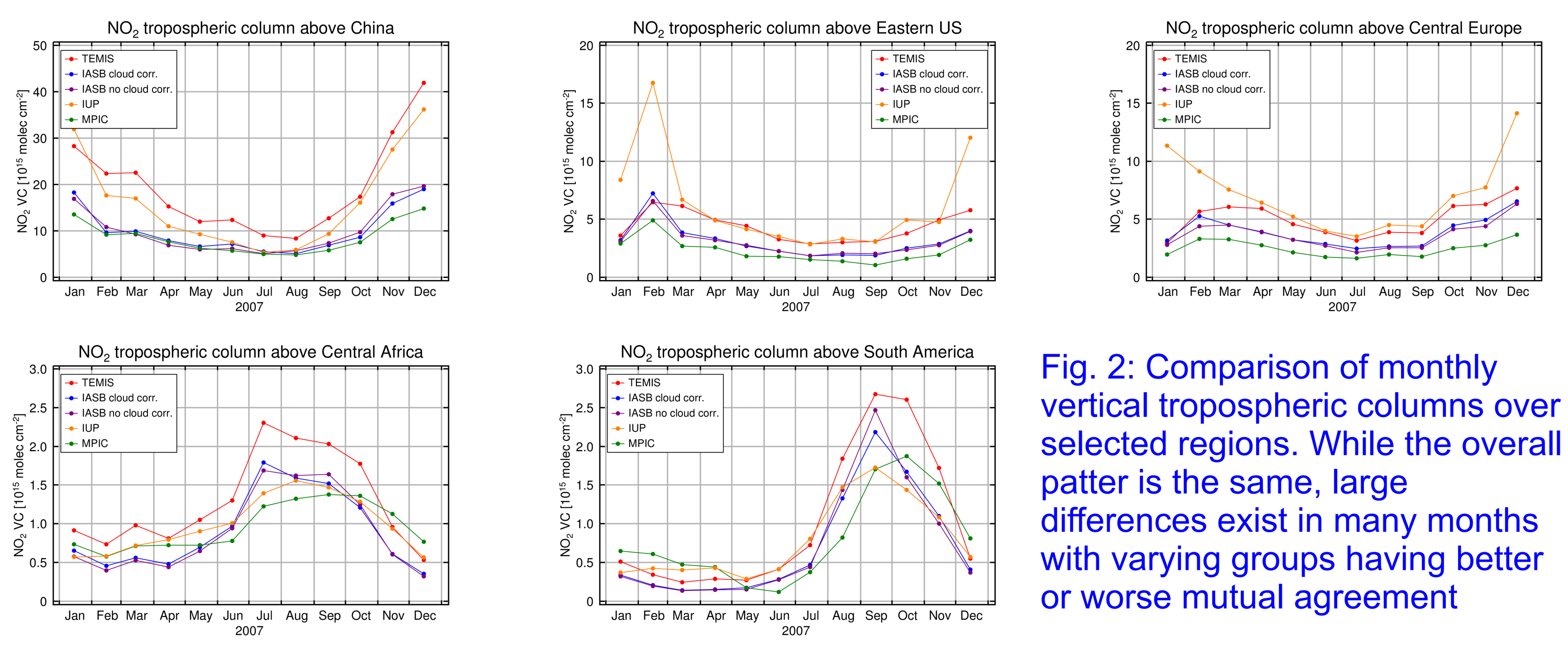

Fig. 2: Comparison of monthly vertical tropospheric columns over selected regions. While the overall patter is the same, large differences exist in many months with varying groups having better or worse mutual agreement

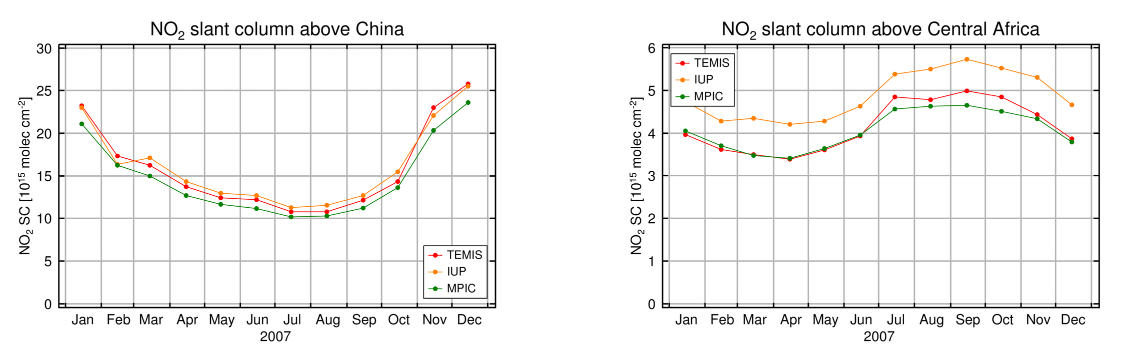

Fig. 3: The initial quantity (Slant Columns) is very similar between retrievals with an overall high bias in the IUP product linked to use of a different solar spectrum and some differences over polluted regions

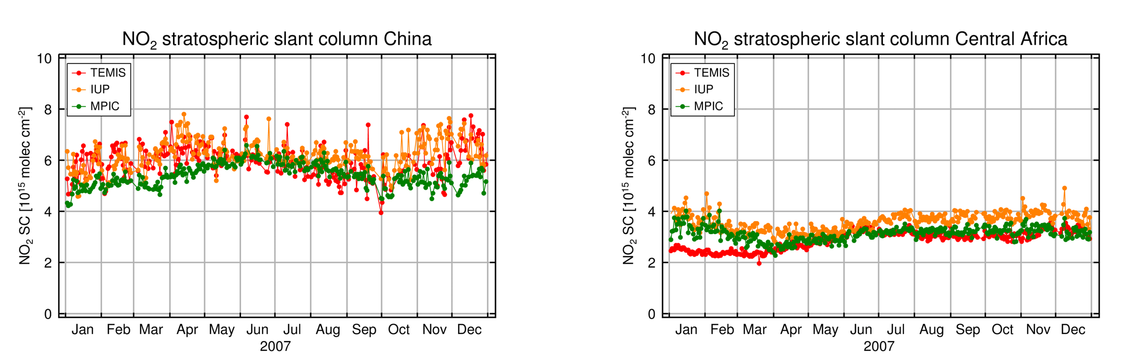

Fig. 4: The stratospheric correction agrees well between retrievals with higher values in the IUP product (to account for the higher slant columns) and some differences in the daily and seasonal variability, the MPIC limb data showing the smallest short term variation

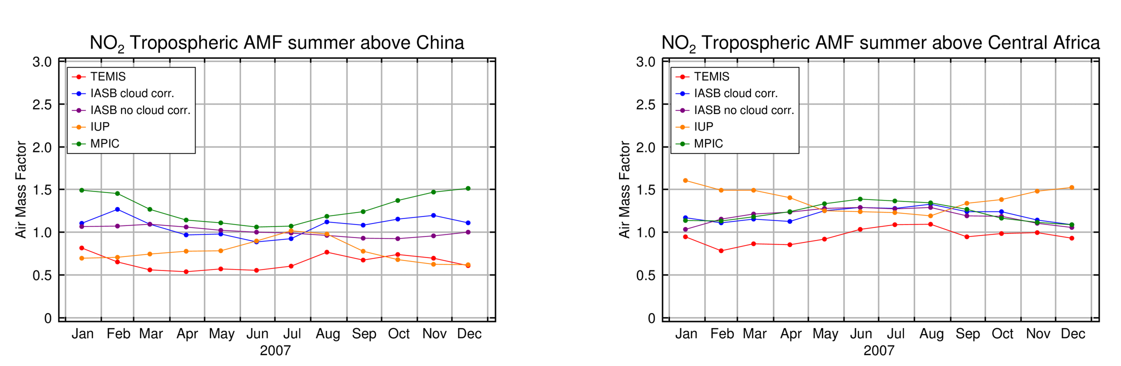

Fig. 5: Air mass factors disagree in their seasonality, variability, and absolute values by up to a factor of 2 and more. The main reason are the NO_2 profile shapes used (low NO_2 has a smaller AMF) in combination with clouds (low NO_2 is covered by clouds, higher NO_2 enhanced) and surface albedo

Cloud Effects

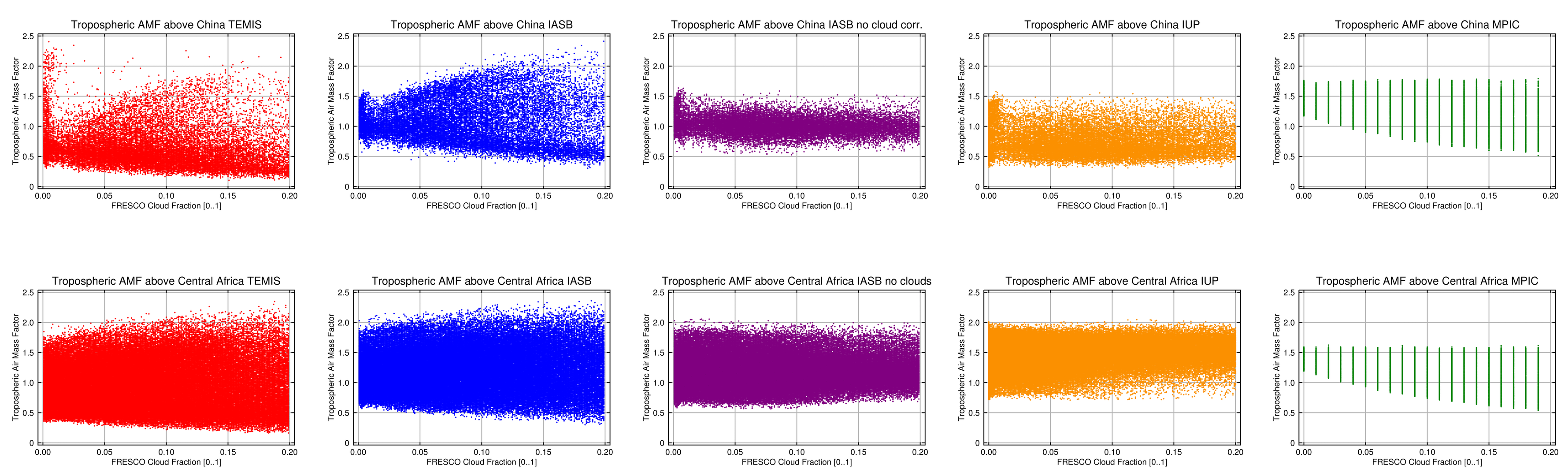

Fig. 6: Air mass factors over China in summer as function of FRESCO+ cloud fraction (all values)

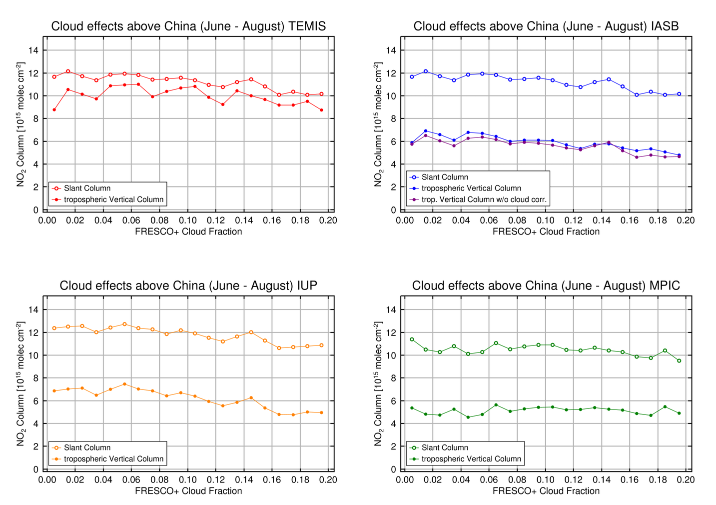

Fig. 7: Total Slant Columns and Tropospheric Vertical Columns over China in summer as function of cloud fraction (binned in 0.01 cf steps)

- Clouds are expected to shield low NO_2 and enhance visibility of NO_2 above the clouds
- Most retrievals take this into account in the AMFs, IUP and TEMIS_no_cloud being the exceptions
- Details of the cloud dependence of the AMF depend on surface reflectance and vertical NO_2 profile
- Dependence of NO_2 slant columns on clouds is small but systematic (Fig. 7)
- Dependence is well corrected in MPIC but only partly in TEMIS and IASB (no correction in IUP)

Conclusions and Outlook

- Good qualitative agreement was found between 5 independent scientific retrievals of tropospheric NO_2 from SCIAMACHY measurements but differences up to a factor of 2 exist, in particular over polluted regions
- The initial retrieval quantity NO_2 Slant Columns agrees well between groups
- The stratospheric correction is in good agreement with differences < 1E15 molec cm^{-2}, in part compensating differences in the slant columns
- The air mass factors can disagree by up to a factor of 2 which is the main reason for the observed differences
- Cloud effects are relatively small for averaged data if a common threshold of FRESCO+ cf < 0.2 is used. However, differences between retrievals can be large for individual observations

The logical continuation of this study is to investigate the impact of different a-priori data on the air mass factors step by step including surface albedo, NO_2 profile, aerosol assumptions and topography. In addition, individual observations instead of daily or monthly regional averages will be compared.

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