

# Reanalysis of stratospheric chemical composition: early results

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EGU 2013



- BIRA-IASB has developed the 4D-Var Belgian Assimilation System for Chemical Observations (BASCOE) (Errera and Fonteyn, JGR, 2001; Errera et al., ACP, 2008; Errera and Ménard, ACP, 2012)  $\Rightarrow$  focus on stratospheric chemistry
- This system is relatively unique since it involves relevant stratospheric trace gases and most of the production and loss mechanisms
  - $\Rightarrow$  Assimilation of long and short lived tracers
- The original goal (2002) was to contribute to the validation of ENVISAT (see Geer et al., ACP, 2006; Vigouroux et al., ACP, 2007)
- Since then, two activities have been developed:
  1. Reanalyses within the PROMOTE project
    - 2002-2004 using MIPAS ESA v4.61 (Errera et al., ACP, 2008)
    - 1991-1997 using UARS MLS (Viscardy et al., IEEE JSTAR, 2010)
  2. NRT analysis of Aura MLS within the MACC project (see [macc.aeronomie.be](http://macc.aeronomie.be))

- Currently, BIRA-IASB is planning a reanalysis of stratospheric chemical observations (2002-2012)
- This reanalysis will be useful, e.g., to:
  - Provide initial/boundary conditions to modellers
  - Provide a fair picture of the stratospheric chemical state when interpreting, e.g., field campaigns (balloon, aircraft, ...)
  - Estimate ozone loss during:
    - Polar winters
    - Events of Energetic Particle Precipitations (EPP)
- The reanalysis will form part of the MACC catalogue and will be available to the community

# Available profile observations since 2001 (Total column not considered here)

Families		Species	MLS 2004-present	MIPAS 2002-2012	SCIA 2002-2012	GOMOS 2002-2012	SMR 2001-present	OSIRIS 2001-present
Oxygen		O3	x	x	x	x	x	x
Hydrogen	Hydrogen	H2O	x	x			x	
		CH4		x				
		OH	x					
		N2O	x	x			x	
	Nitrogen	HNO3	x	x				
		NO2		x	x	x		x
		NO		x (IMK/IAA)				
		N2O5		x				
		ClONO2		x				
	Chlorine	ClO	x	x (IMK/IAA)			x	
		HOCl	N/A	x (IMK/IAA)				
		HCl	x					
	Bromine		BrO	N/A		x		
CFCs	CFC11		x					
	CFC12		x					
	...							

**N/A: data available but not suited for assimilation**

# Assimilated data in used in this presentation

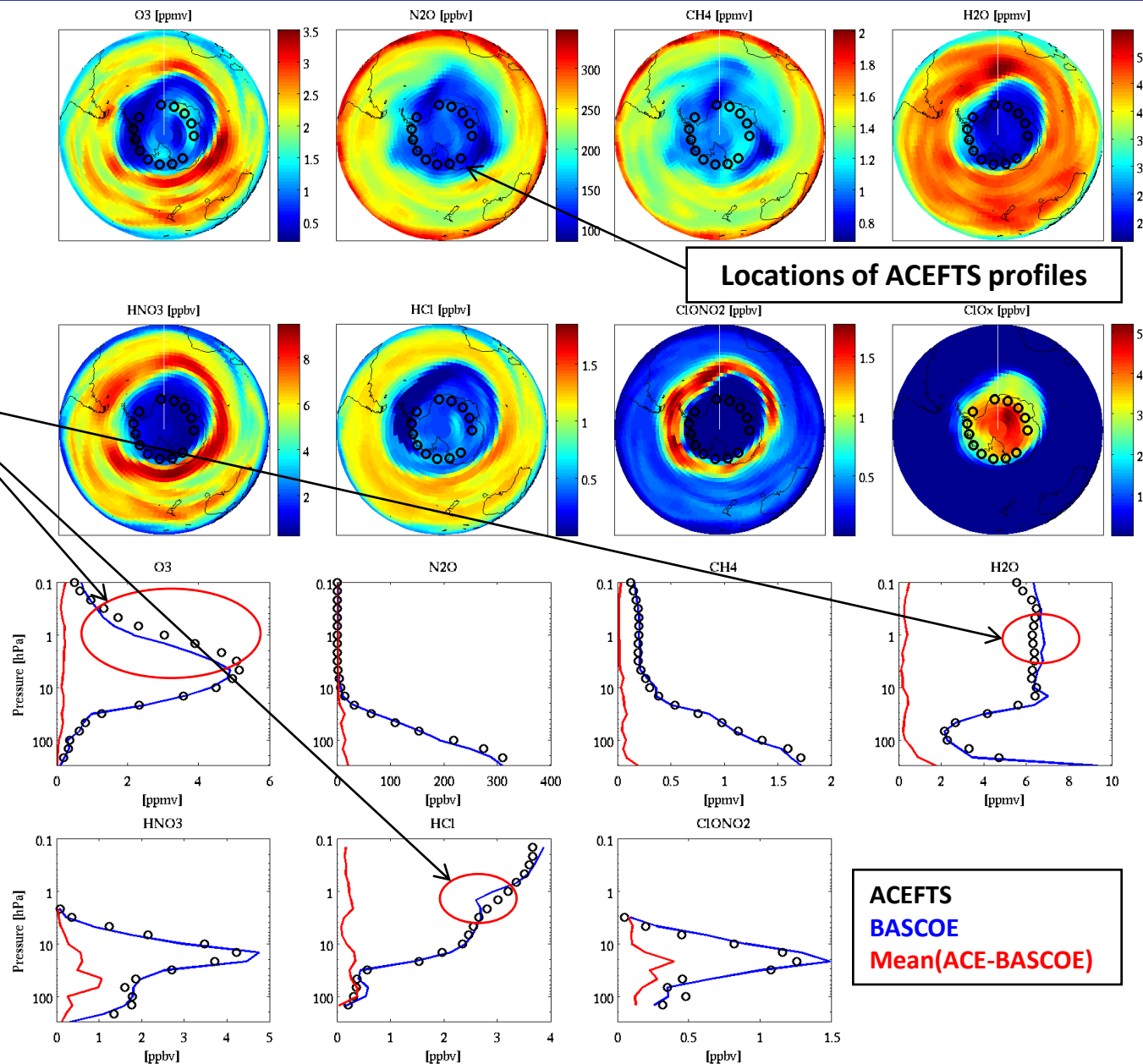
Families		Species	MLS 2004-present	MIPAS 2002-2012	SCIA 2002-2012	GOMOS 2002-2012	SMR 2001-present	OSIRIS 2001-present	
Oxygen	Hydrogen	O3	x	x	x	x	x	x	
		H2O	x	x			x		
		CH4		x					
		OH	x						
	Nitrogen	N2O	x	x			x		
		HNO3	x	x					
		NO2		x	x	x		x	
		NO		x (IMK/IAA)					
		N2O5		x					
		ClONO2		x					
	Chlorine	ClO	x	x (IMK/IAA)			x		
		HOCl	N/A	x (IMK/IAA)					
		HCl	x						
	Bromine	BrO	N/A		x				
	CFCs	CFC11		x					In Grey: Not yet implemented
		CFC12		x					
...								N/A: data available but not suited for assimilation	

- BASCOE**
  - 4D-Var system dedicated to stratospheric chemical observations
  - CTM including 57 species, 200 chemical reactions, PSC parameterization
  - **B** matrix: Homogeneous and isotropic correlations (Courtier et al., QJRMS, 1998; Errera and Ménard, ACP, 2012)
  - Source of Mesospheric NO<sub>x</sub> NOT (yet) modelled
- Dynamic**
  - ECMWF ERA-Interim
- Resolution**
  - 3.75° long x 2.5° lat x 37 levels (surf. to 0.1 hPa) x 30 minutes
- Runs**
  - Assimilation of MIPAS/ESA: May-Nov 2003
  - Assimilation of MLS & MIPAS: 2008

# BASCOE analyses vs. ACEFTS on Sep. 18, 2008 at 50hPa

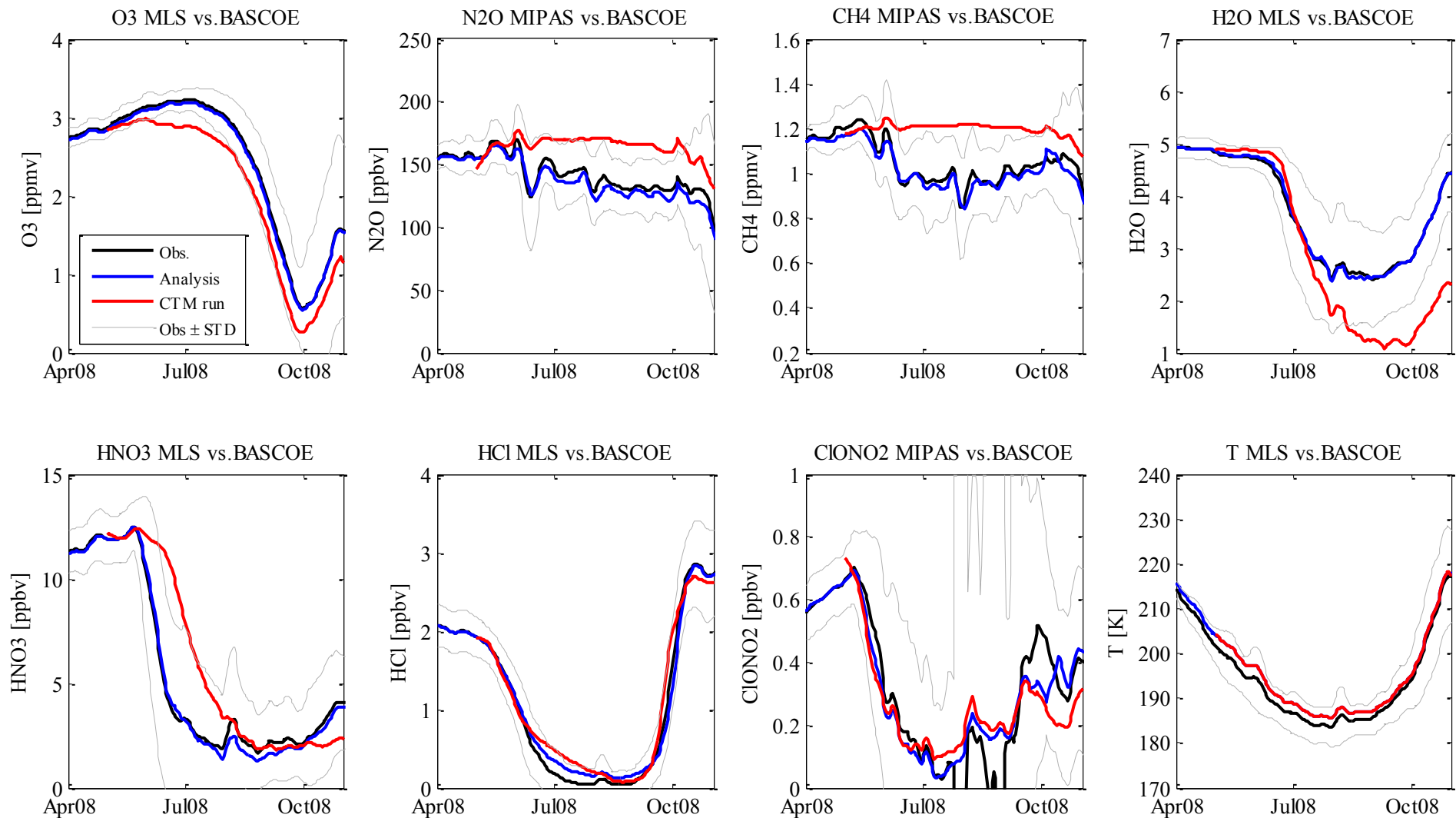
Generally good agreement between ACE and BASCOE, but:

- Bias in O3, H2O and HCl in upper stratosphere



# BASCOE vs. Assimilated Data in 2008

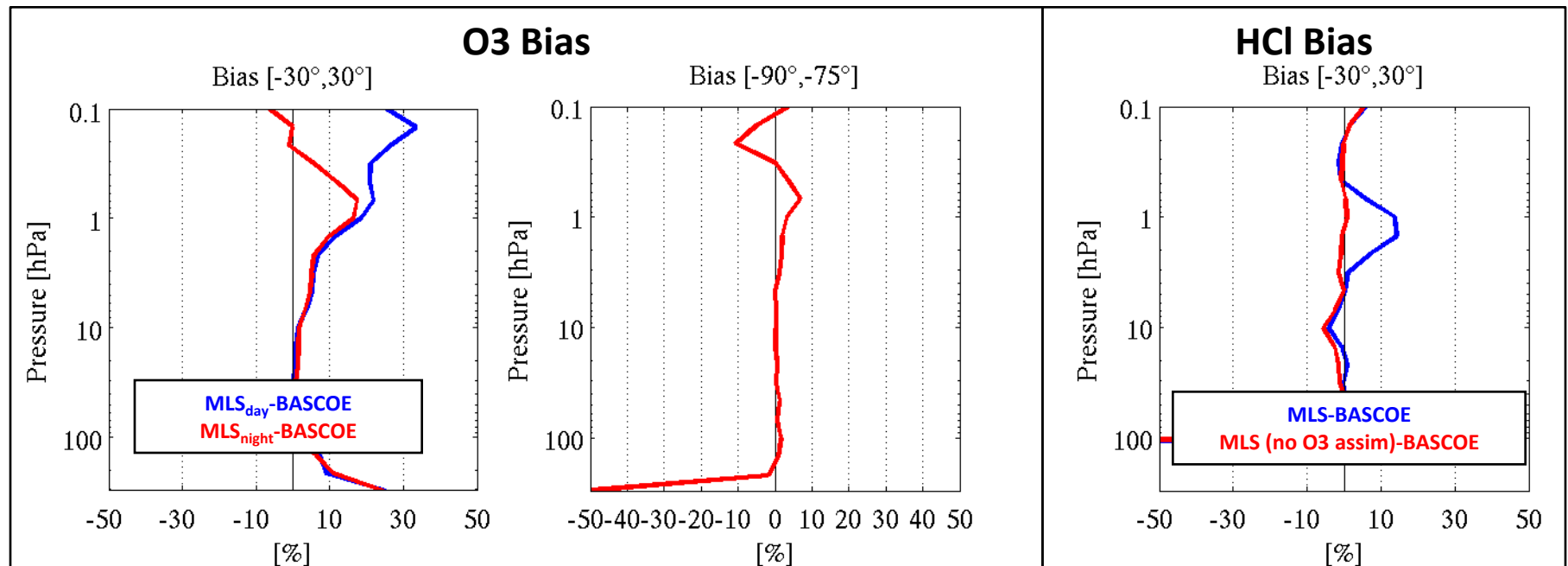
- Time series of daily moving average data around 46 hPa between 90°S and 65°S





# Ozone bias in the upper stratosphere

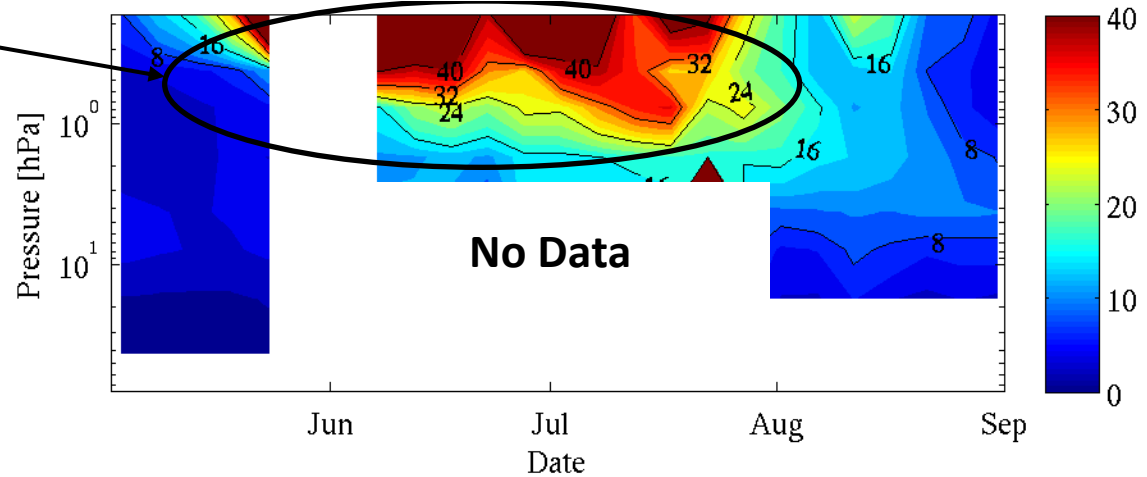
- BASCOE model suffers from an "ozone deficit" : overestimation of MLS around 1hPa by 20%
- "For ozone below 70 km, we continue to report a photochemical model deficit relative to observations... in the 10-50% range..." (Siskind et al., JGR, 2013)
- At SP during solstice, O3 deficit much lower => impact of photochemistry?
- Rejecting O3 obs. above 2 hPa in the assimilation removes the bias in HCl (and H2O)



# BASCOE analyses during descent of mesospheric NO<sub>x</sub>: assimilation of MIPAS NO<sub>2</sub> (May-Nov 2003)

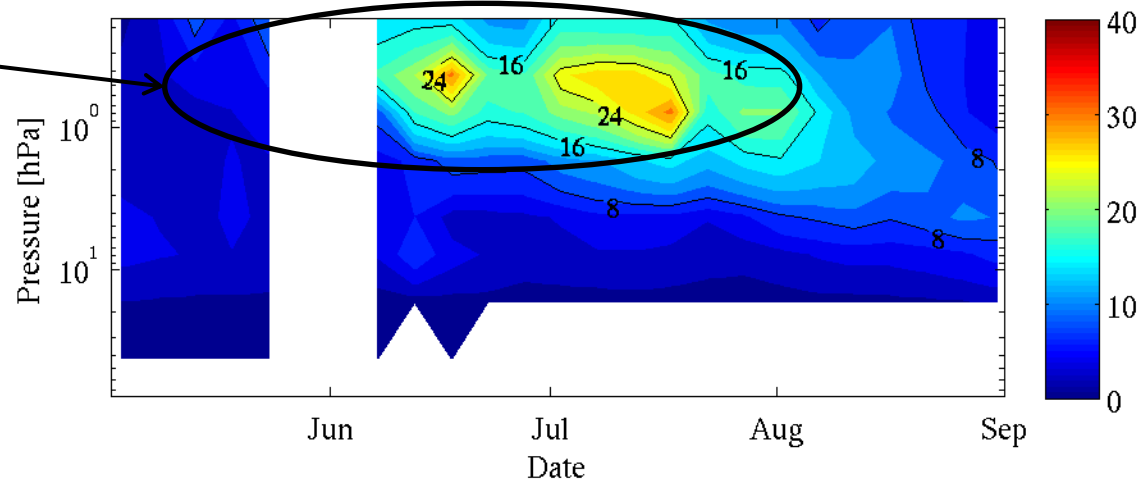
Downward transport of mesospheric NO<sub>x</sub> produced by EPP (Funke et al., JGR, 2005)

Time Series of MIPAS/ESA NO<sub>2</sub> averaged over [-90,-60] Latitude



- Underestimations of NO<sub>x</sub> by BASCOE
- Modelling source of meso. NO<sub>x</sub> might help (underway)

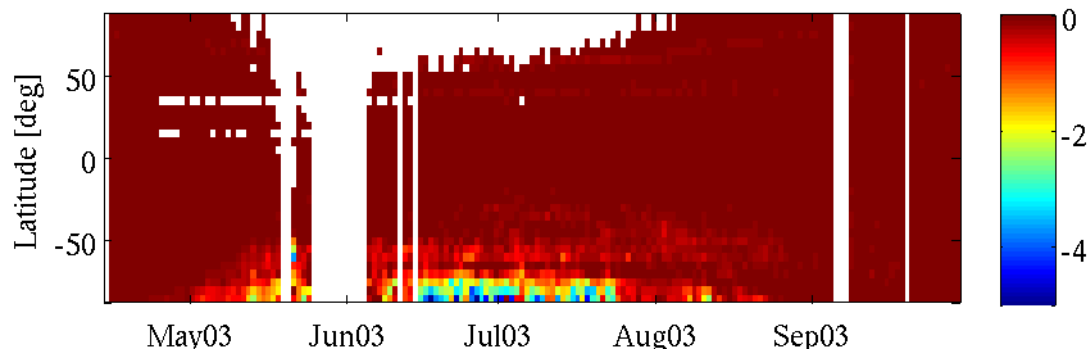
Time Series of BASCOE NO<sub>2</sub> averaged over [-90,-60] Latitude



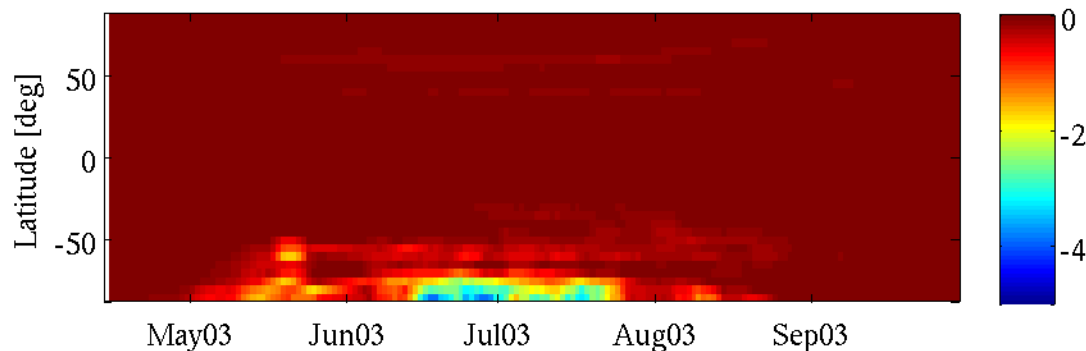
# NO<sub>2</sub> Flux at model lid using MIPAS data

- Flux of NO<sub>2</sub> at model upper boundary (UB) estimated using:
  - $d[\text{NO}_2]/dz$  from MIPAS data: This is possible because MIPAS NO<sub>2</sub> data are available above and below 0.1 hPa
  - Profile of turbulent diffusion ( $K_{zz}$ ) from SOCRATES 2D model \* 30

Time Series of MIPAS NO<sub>2</sub> flux at 0.1 hPa [ $10^5 \cdot \text{molec}/\text{m}^2/\text{s}$ ]

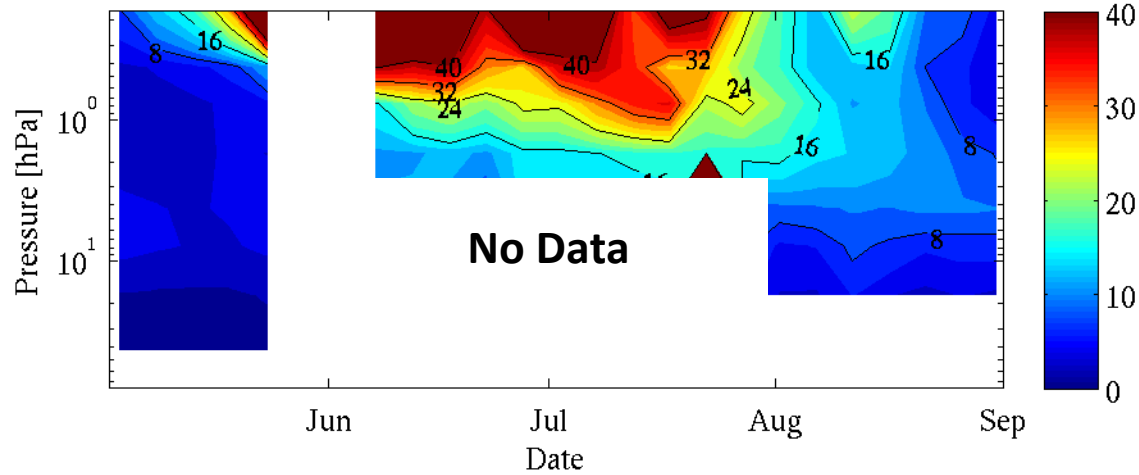


Time Series of Smoothed/Interpolated NO<sub>2</sub> flux at 0.1 hPa [ $10^5 \cdot \text{molec}/\text{m}^2/\text{s}$ ]

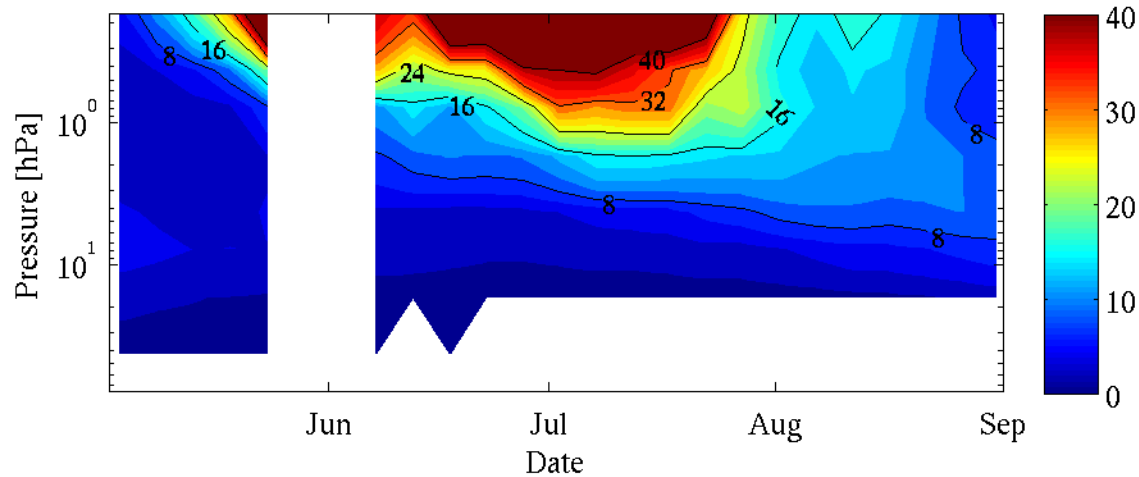


# BASCOE CTM (no assimilation) during descent of mesospheric NO<sub>x</sub> including NO<sub>x</sub> UB conditions

Time Series of MIPAS/ESA NO<sub>2</sub> averaged over [-90,-60] Latitude



Time Series of CTM NO<sub>2</sub> with UB averaged over [-90,-60] Latitude



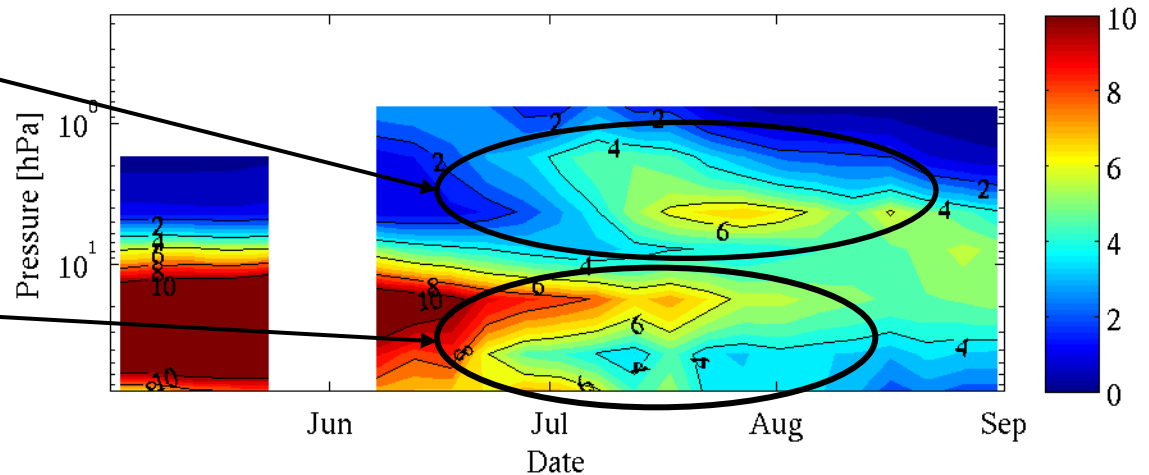
# BASCOE analyses during descent of mesospheric NO<sub>x</sub>: assimilation of MIPAS HNO<sub>3</sub> (May-Nov 2003)

Local production of HNO<sub>3</sub> due to NO<sub>x</sub> enhancement

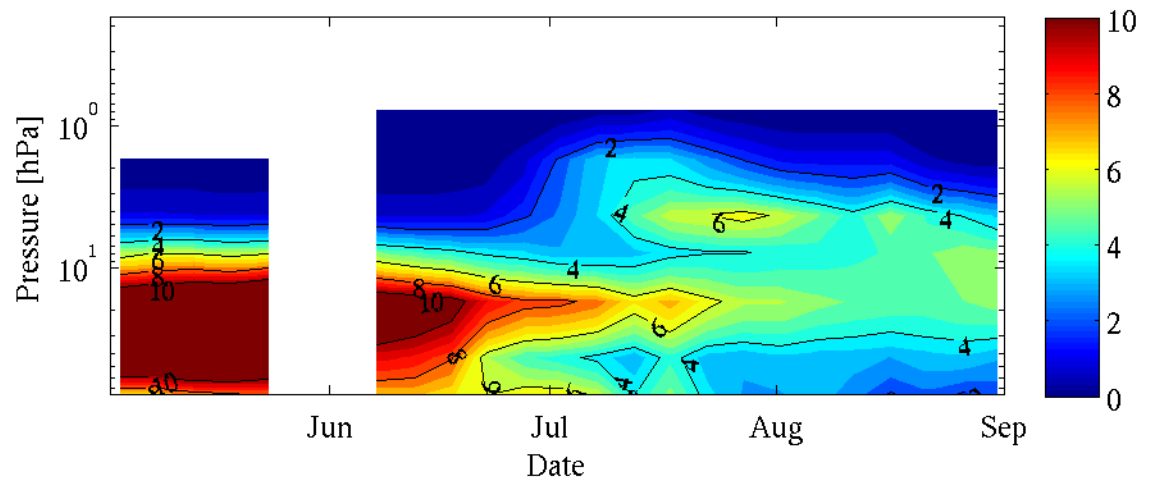
Denitrification

HNO<sub>3</sub> relatively well reproduced by BASCOE in both local production by meso NO<sub>x</sub> and during denitrification

Time Series of MIPAS/ESA HNO<sub>3</sub> averaged over [-90,-60] Latitude

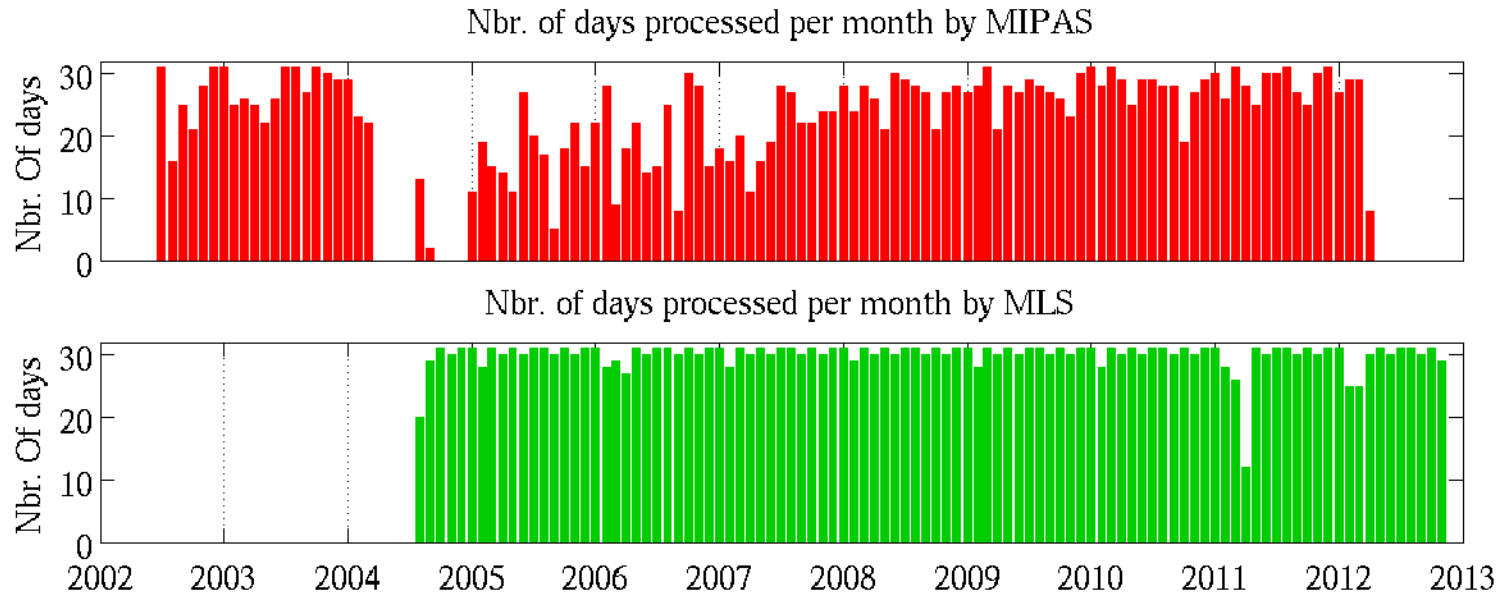


Time Series of BASCOE HNO<sub>3</sub> averaged over [-90,-60] Latitude



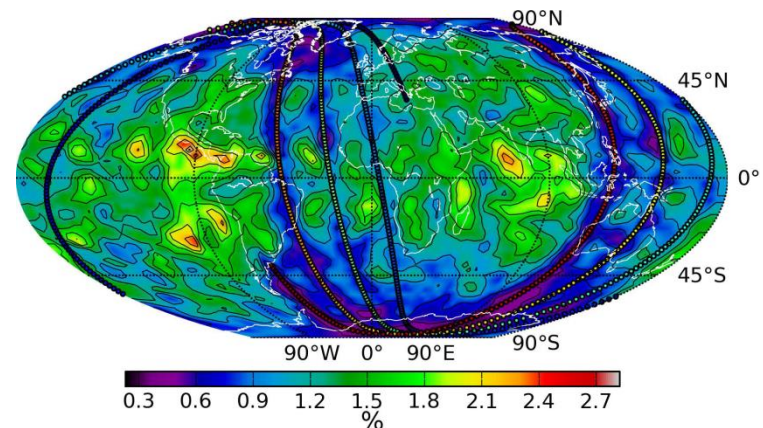
# Observation issues

- Bias between observations
- Potential issue: day-to-day consistency regarding instrument status



- BASCOE EnKF in preparation: Analysis uncertainties will be available

O3 uncertainties at 10 hPa by BASCOE EnKF assimilation of Aura MLS. Dots are the previously 6h data locations. See Skachko et al., tomorrow in NP5.1



A reanalysis of the stratospheric chemical composition of the stratosphere is planned by BIRA-IASB using the BASCOE system and observations from Aura MLS, ENVISAT (MIPAS, SCIAMACHY and GOMOS) and Odin (OSIRIS and SMR)

- Generally good agreement between analyses and observations for the two early runs but some issues persist: "ozone deficit", descent of mesospheric NO<sub>x</sub>
- To do list
  - Convert all data to BASCOE format
  - Bias correction scheme ?
  - Analysis production and evaluation
- Analysis will be part of the MACC catalogue