Reanalysis of the Stratospheric Chemical Composition Based on Assimilation of MIPAS: methane (CH_4) and nitrous oxide (N_2O)

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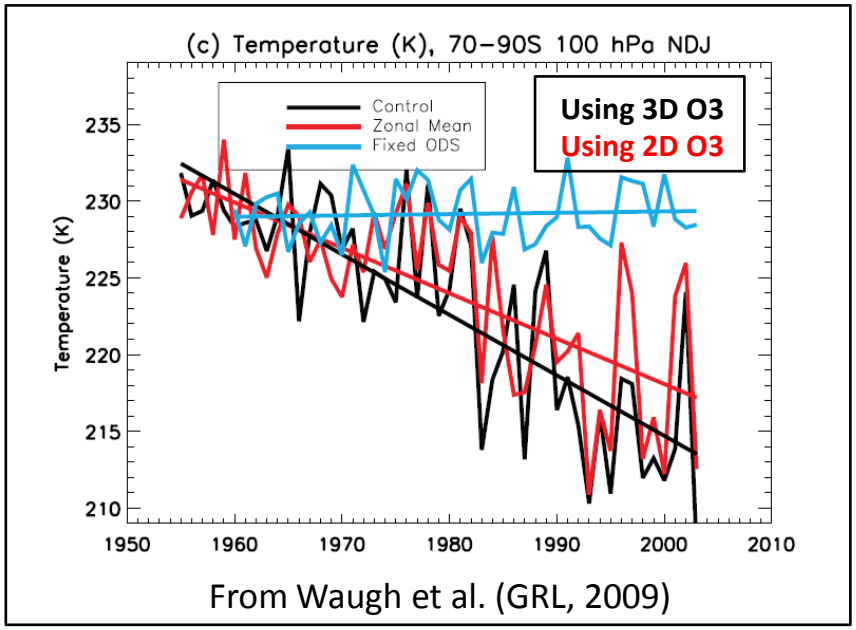
Motivations

- Climate models deal stratospheric chemistry of GHG via **linear scheme**
- Linear scheme relies on **climatology** of GHG
- Complexity of **climatology** matters
- Waugh et al. (GRL, 2009) showed that 3D or 2D O_3 in CCM radiative scheme provide different projections for T°, U and surface pressure
- Motivation: **build 3D climatology of CH_4 and N_2O** using data assimilation (DA) method



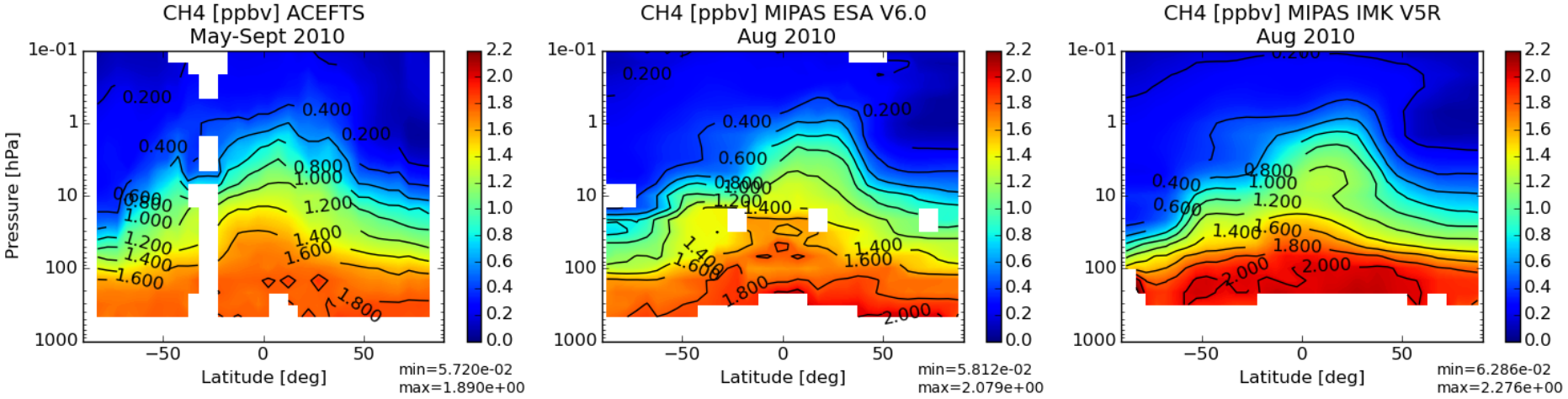
From Waugh et al. (GRL, 2009)

Choice of Assimilated Data: CH_4

MIPAS **ESA** v6.0 **or** MIPAS **IMK** V5R?

- MIPAS IMK CH_4 (and N_2O) is **high biased** in the Eq lower stratosphere and **low biased** in polar vortex
- MIPAS ESA v6.0 is know to have **oscillated profiles** in the Eq lower stratosphere (Payan et al., ACP, 2009)

=> MIPAS ESA is choosen although oscillation in profiles (see later)



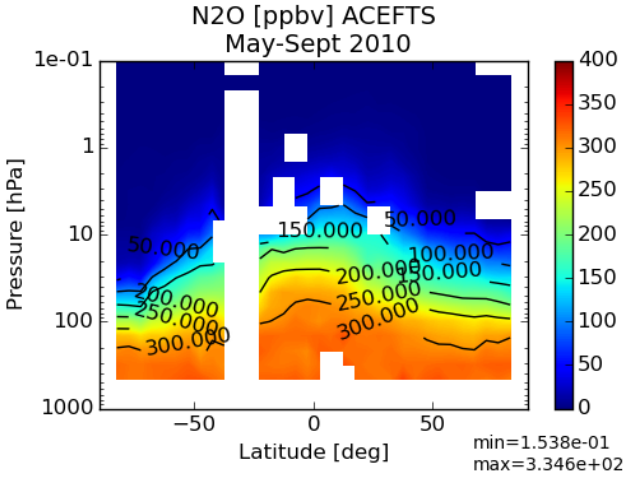
Choice of Assimilated Data: N_2O

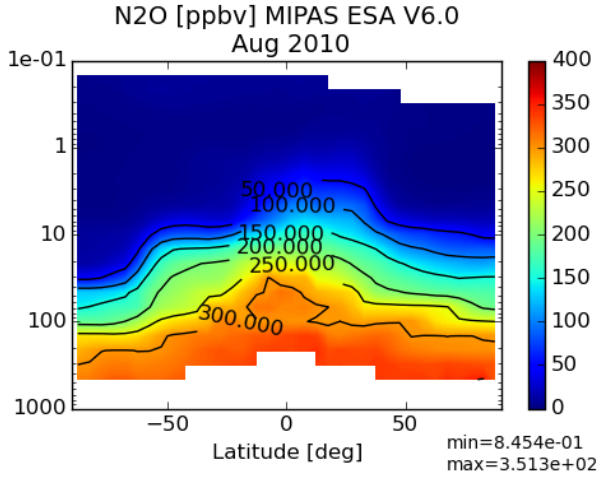
MIPAS **ESA** V6.0 **and** Aura **MLS**?

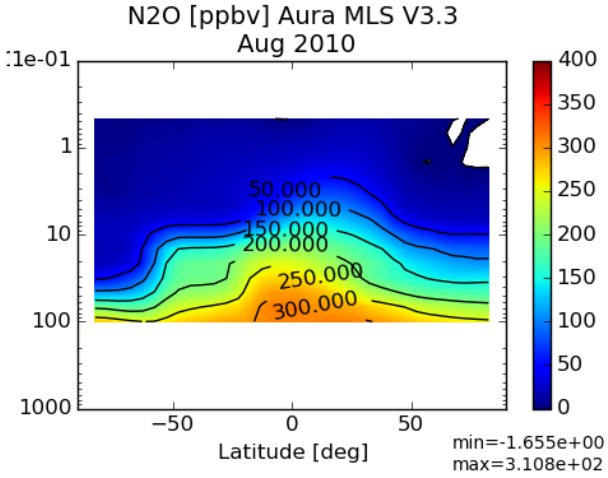
- Assimilating both datasets would have request to remove the biases between them
- Effort to harmonize MIPAS and MLS using ACEFTS as anchor failed

MIPAS ESA V6.0 **or** Aura MLS?

- Aura MLS excellent between 10-100 hPa, above 10 hPa error bars too large (>50%) to constrain the DA system

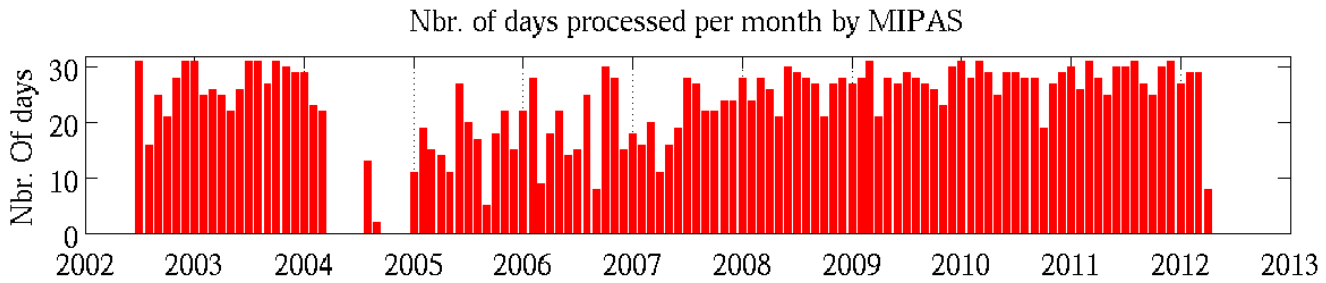






Assimilated Data: MIPAS ESA v6.0 Nominal mode

- Focus on opt. resolution period: Jan 2005 – April 2012



- Background quality check (BgQC) to reject outliers (Anderson and Jarvïnen, 2000, QJRMS):
  - Obs is rejected if: $(obs - mod)^2 > 5(\sigma_{obs}^2 + \sigma_{mod}^2)$

Use of Averaging Kernels (AK) with MIPAS ESA

- Usuall use of AK: $x_m = y_0 + \tilde{A}(\tilde{x}_m + \tilde{y}_0)$

where: x_m is the modelled profile

y_0 is the obs a priori profile

A is the AK matrix

"~" denote interpolation on model levels

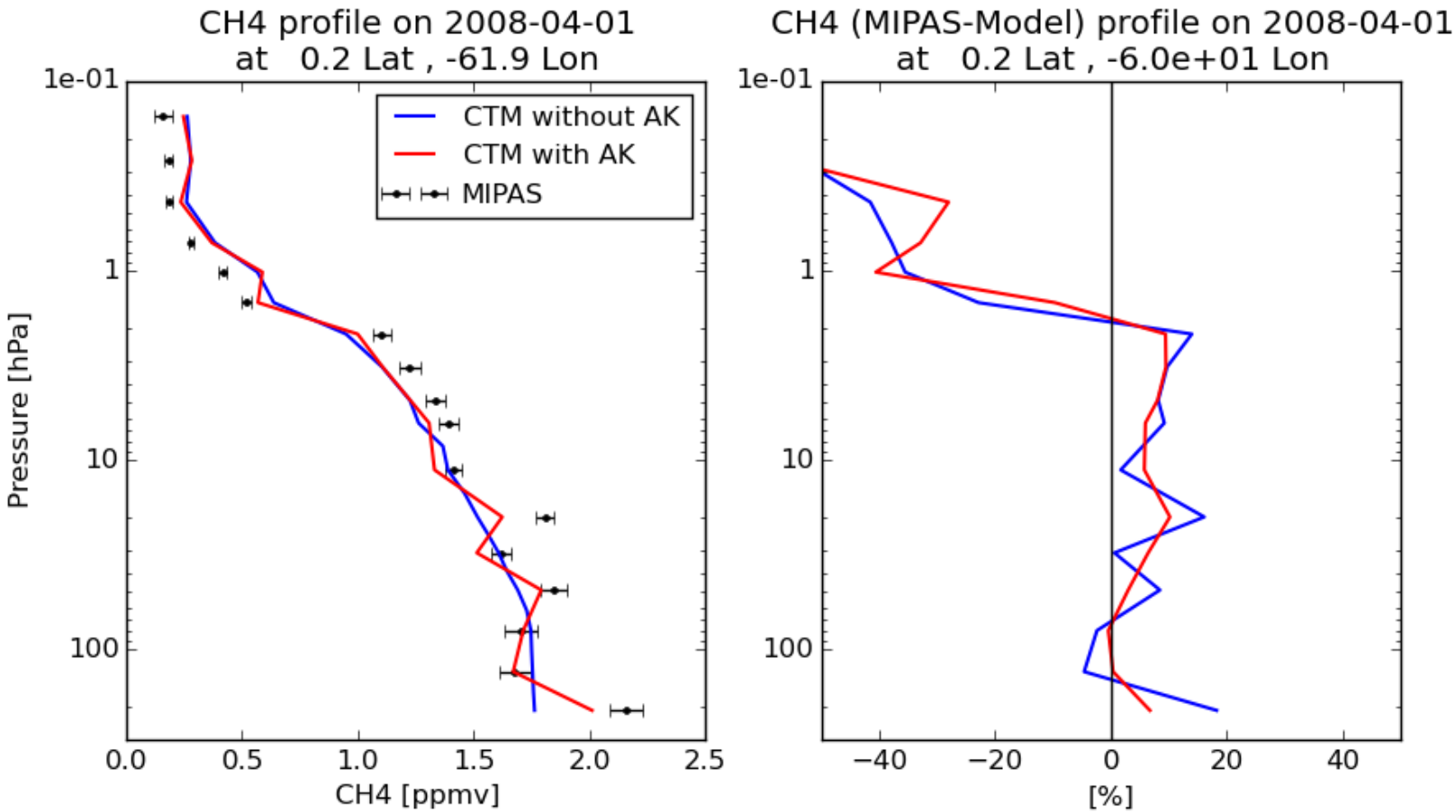
- With MIPAS ESA v6.0 (Ridolfi et al., 2011):

$$x_m = y_k + \tilde{A}(\tilde{x}_m + \tilde{y}_k)$$

where: y_k denote retrieved obs profile

=> Net effect: oscillations in MIPAS profiles is introduced in model profiles

Impact of Averaging Kernels (AK)



Setup of BASCOE (Belgian Assimilation System for Chemical ObsErvations)

Errera et al., ACP, 2008, 2012

- 4D-Var system based on CTM (chemistry is off)
- Winds from ERA-Interim
- Resolution: 2.5° lat x 3.75° lon x 37 levels (surf to 0.1 hPa)
- Time step: 30'

$$J(\mathbf{x}) = \underbrace{\frac{1}{2}[\mathbf{x}-\mathbf{x}^{\mathrm{b}}]^T\mathbf{B}^{-1}[\mathbf{x}-\mathbf{x}^{\mathrm{b}}]}_{J^{\mathrm{b}}\equiv\text{background term}} + \underbrace{\frac{1}{2}[\mathbf{y}-H(\mathbf{x})]^T\mathbf{R}^{-1}[\mathbf{y}-H(\mathbf{x})]}_{J^{\mathrm{o}}\equiv\text{observation term}}$$

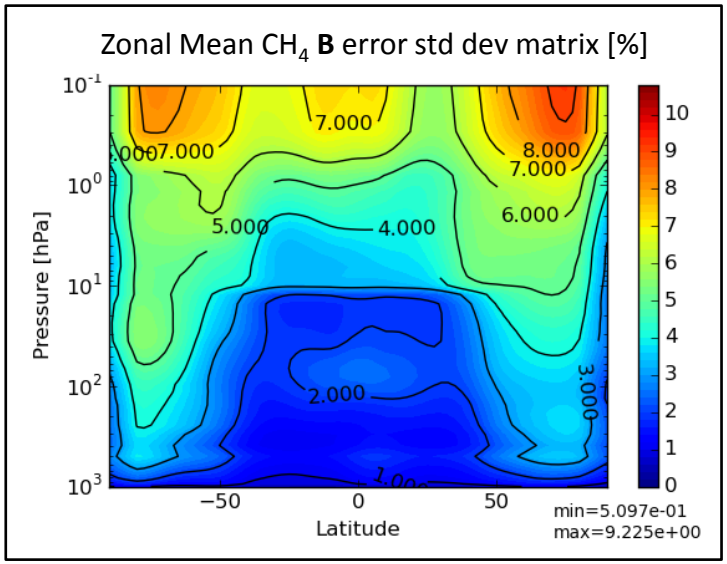
- **B** matrix is given on a spherical harmonic basis assuming homogeneous and isotropic spatial correlations
- **B** is calibrated with an ensemble method (Fisher, 2003, ECMWF sem.)

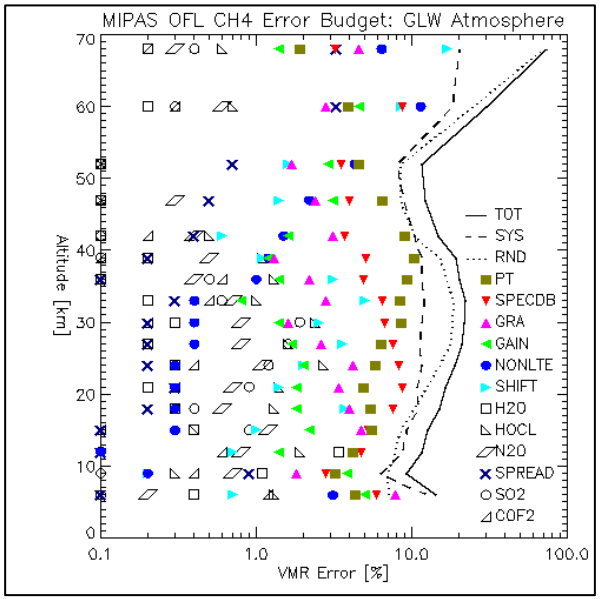
Calibration of **B**

- **B** is calibrated instead of using a priori values (5% std dev, Gaussian spatial correlations, L_h 800 km, L_v 1 lev)
- **B** error std dev matrix is much lower than observational error

$\Rightarrow$ DAS provides more weight to background than to observations

- At Poles and above 10hPa, **B** error std dev is multiplied by 2 => to increase the weight of the obs. where there are known to be good

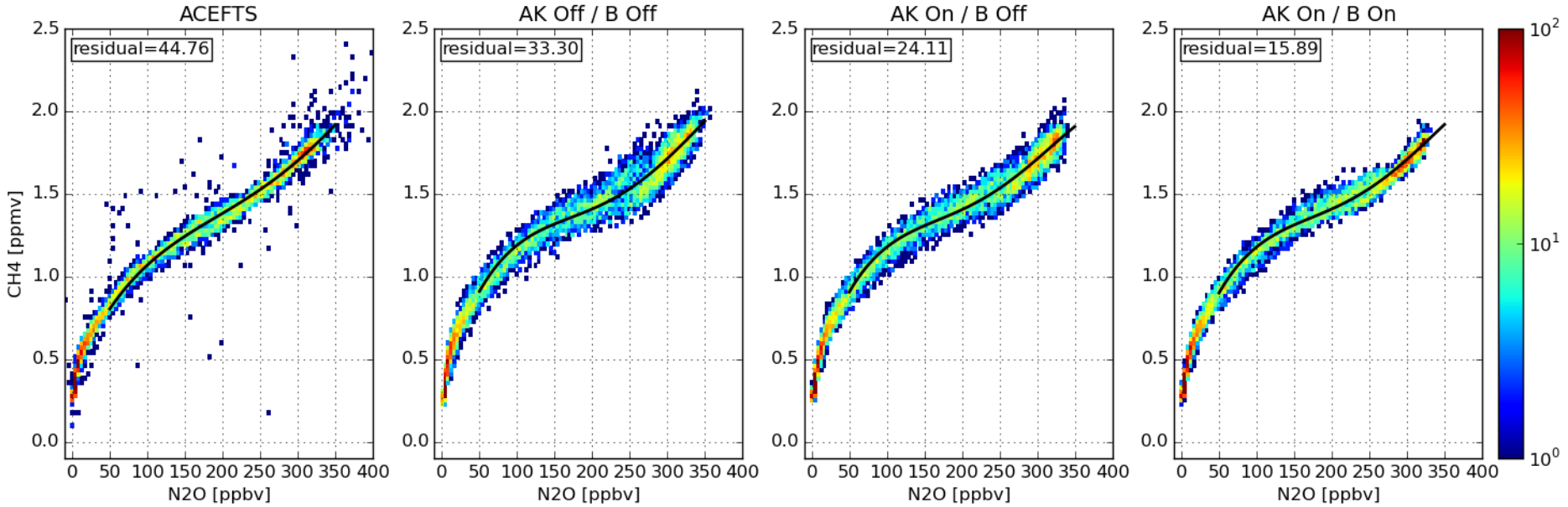




Impact of AK and calibration of **B**

N_2O-CH_4 correlations in 2010 between 30°S-30°N

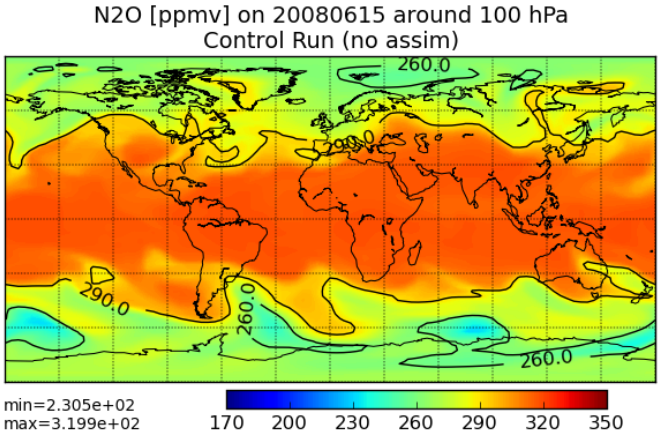
- Using AK and calibrated **B**, correlations are much compact, in particular in the lower stratosphere
- Better agreement with ACEFTS

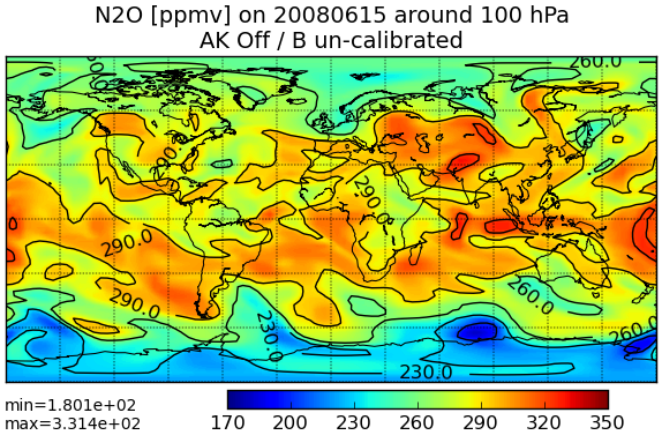


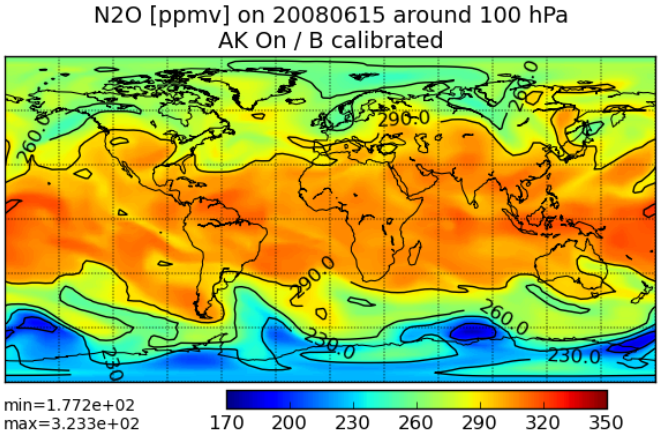
Impact of AK and calibration of **B**

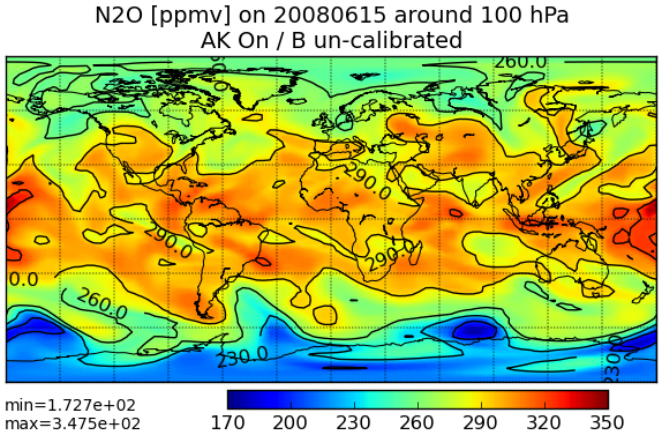
- N_2O analysis at 100 hPa for different config of BASCOE

  => *AK and calibrated B are important*



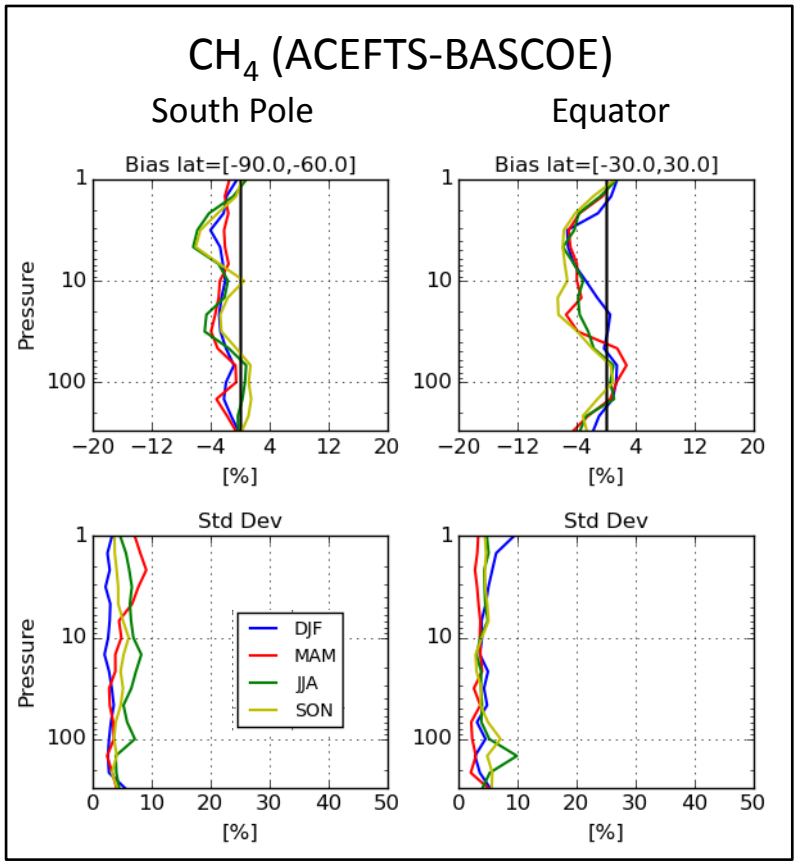


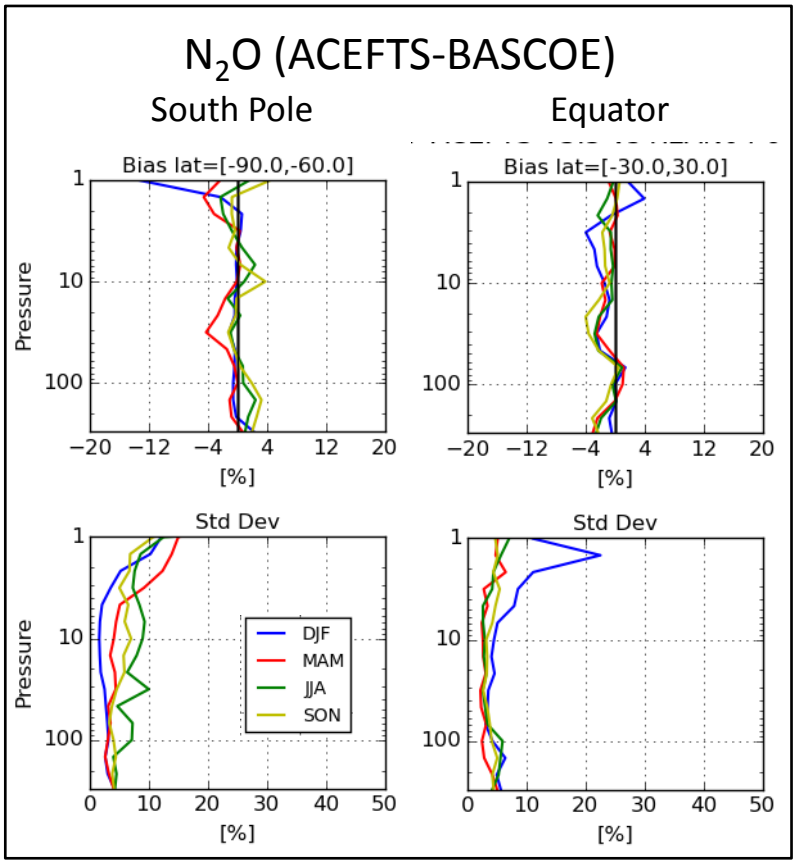




Validation against ACEFTS V3.5 in 2010

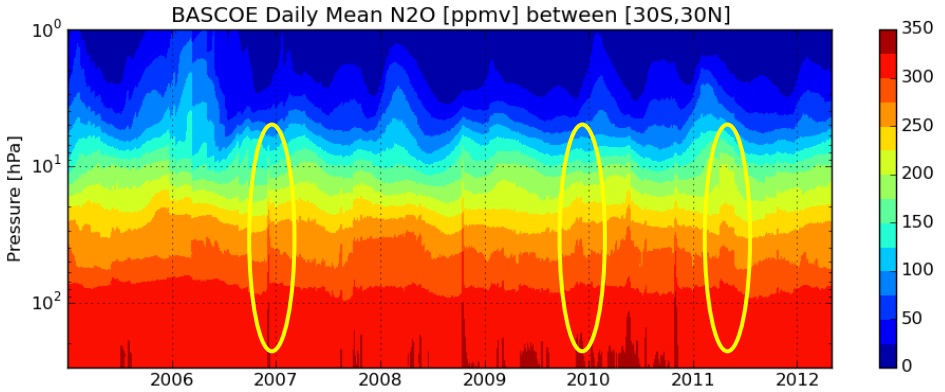
- Excellent agreement between reanalysis and ACEFTS

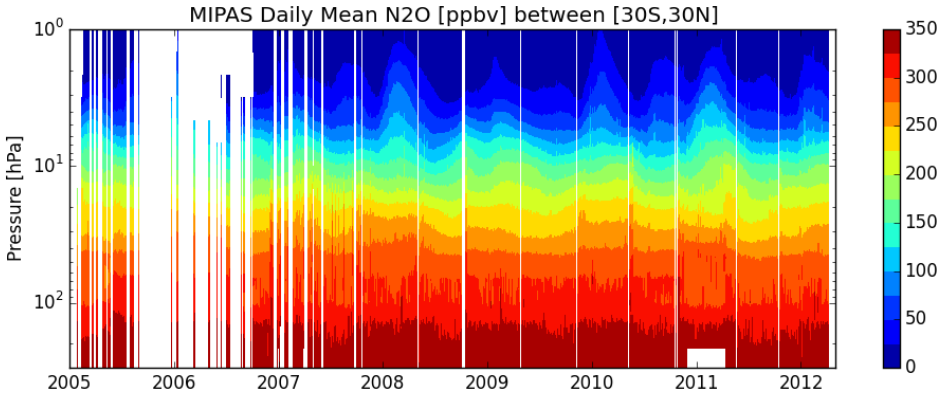


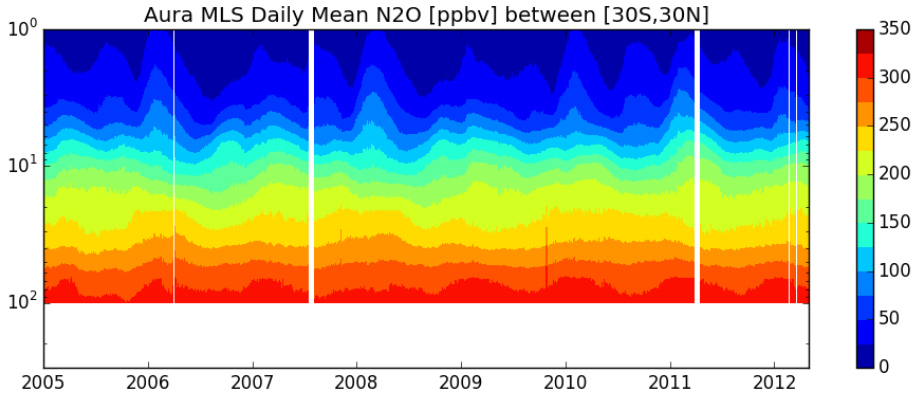


Time stability of reanalysis: N_2O

- Time series of reanalysis is “noisy” at some dates
- This noise is due to noisy MIPAS data
- Some filtering/averaging will be necessary
- Is MIPAS v7 will improve BASCOE analyses?

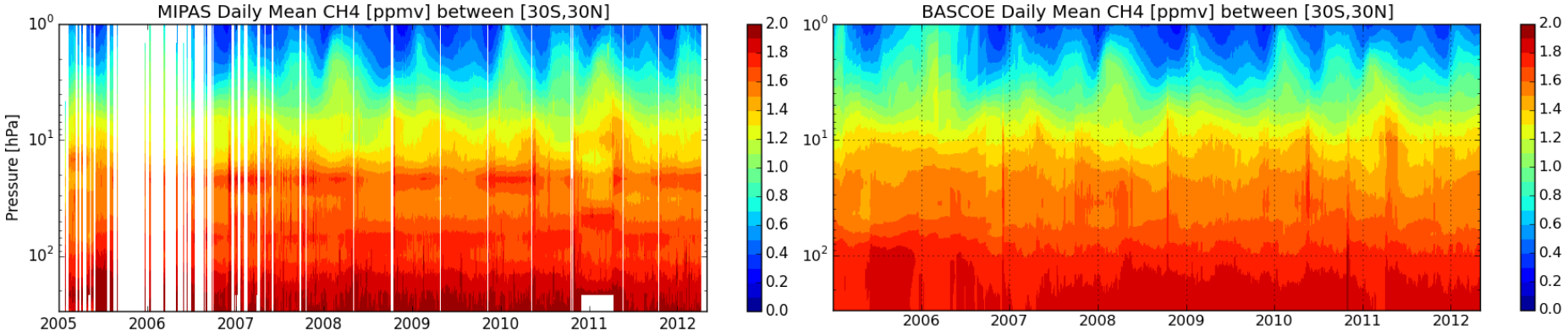






Time stability of reanalysis: CH_4

- Peaks in MIPAS CH_4 around 20 hPa are removed in reanalysis
- Time series of reanalysis is even more noisy than for N_2O
- Again, some filtering/averaging will be necessary



Conclusions

- A reanalysis of MIPAS ESA CH_4 and N_2O has been produced for 2005-2012
- General good agrement vs. ACEFTS in all regions/seasons …
- … but reanalysis is still noisy (time series):
  - filtering/averaging is necessaray
  - what could we expect from MIPAS v7?
- DA add value to MIPAS: the use of AK and **B** largely reduce the oscillations in CH_4 and N_2O Eq. lower stratospheric profiles
- Additional work is necessary to assess quantitatively the quality of the reanalysis and its period of validity
- Perscpective: reanalysis of stratospheric CFC-11 and CFC-12

Calibration of **B**