The SPARC Data Initiative -

A multi-instrument comparison of stratospheric limb measurements

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Motivation

Knowledge of quality of different satellite data sets needs to be improved for different applications:

- Tracer scenario validation (Montreal Protocol, Cl_y)
- Model validation projects (CCMI, IPCC)
- Trend analyses (e.g., stratospheric water vapour)
- Empirical studies of stratospheric climate and variability

Objectives

Inter-comparison of vertically resolved climatologies of 25 chemical tracers and aerosol from 18 multi-national satellite instruments

- Will be published as **a peer-reviewed SPARC report**, as well as in journal publications
- Will summarize useful information and highlight differences between data sets
- Will provide guidance to space agencies about required improvements in existing data sets and future observations

Team

- ✓ HALOE (UARS): **John Anderson**
- ✓ MLS (Aura/UARS): **Lucien Froidevaux, Ryan Fuller**
- ✓ TES (Aura): **Jessica Neu**
- ✓ ACE-FTS (SCISAT-1): **Kaley Walker, Ashley Jones**
- ✓ MAESTRO: **Kaley Walker**
- ✓ OSIRIS (Odin): **Doug Degenstein, Adam Bourassa**
- ✓ SMR (Odin): **Joachim Urban**
- ✓ MIPAS (ENVISAT): **Thomas von Clarmann, Bernd Funke**
- ✓ SCIAMACHY (ENVISAT): **Alexei Rozanov**
- ✓ GOMOS (ENVISAT): **Erkki Kyröla**
- ✓ SAGE I / II / III: **Ray Wang**
- ✓ HIRDLS (AURA): **John Gille, Lesley Smith**
- ✓ SMILES (ISS): **Yasuko Kasai**
- ✓ LIMS (NIMBUS-7): **Ellis Remsberg, Gretchen Lingenfelser**
- ✓ POAM II / III: **Jerry Lumpe**
- ✓ **Matthew Toohey**

Done

Nearly done

In progress

	O_3	H_2O	CH_4	N_2O	CCl_3F	CCl_2F_2	CO	HF	SF_6	NO	NO_2	NO_x	HNO_3	HNO_4	N_2O_5	$ClONO_2$	NO_y	HCl	ClO	HOCl	BrO	OH	HO_2	CH_2O	aerosol
ACE-FTS	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x						x	
Aura-MLS	x	x		x			x						x					x	x	x		x	x		
GOMOS	x										x														x
HALOE	x	x	x					x		x	x	x						x							
HIRDLS	x				x	x					x		x												
LIMS	x	x									x		x												
MAESTRO	x																								
MIPAS	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x		x	x				x	
OSIRIS	x										x	x_d					x_d				x				x
POAM II	x										x														x
POAM III	x	x									x														x
SAGE I	x																								
SAGE II	x	x									x														x
SAGE III	x	x									x														x
SCIAMACHY	x	x									x	x_d									x				x
SMILES	x												x					x	x	x	x				x
SMR	x	x		x			x			x			x				x_d		x				x_{lc}		
TES	x_t						x_t																		
UARS-MLS	x	x											x						x						

'Climatologies'

- Monthly mean zonal mean time series
  - **VMR or aerosol extinction coefficients**,
  - 1σ standard deviation,
  - number of measurements per grid box,
  - mean, min, and max local solar time,
  - average day of month and latitude.
- Range: upper troposphere to the lower mesosphere
- Time period covered: 1978 - 2010
- Grid: 5° latitude bins on the CCMVal-2 pressure grid (28 levels)
- Data sets are provided in a common format (netcdf) easily useable by the atmospheric science community

'Climatological' validation approach based on binned/interpolated datasets

- Possibly some differences can arise as a result of the methodology
- Additional analyses applied to further examine these differences:
  - Sampling bias (Toohey et al., submitted to JGR)
  - Vertical resolution (Neu et al., to be submitted to JGR)
- Other features can arise from problems in retrievals or forward model

Basic diagnostics of monthly /annual zonal mean cross-sections

- Average over maximum number of years
- Derive mean differences between the data sets
- Uncertainty in our knowledge of the atmospheric mean state

Evaluation of variability and other physical features

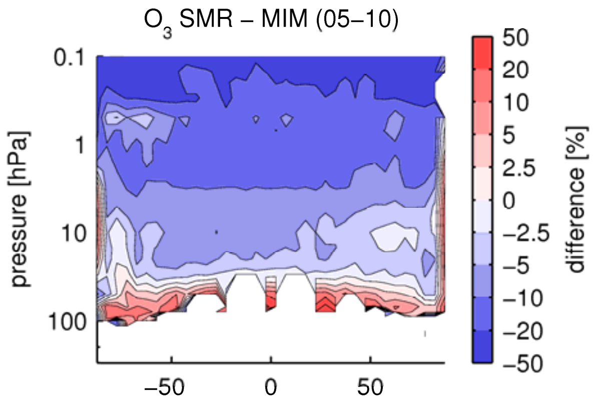
- Seasonal cycle
- Interannual variability
- QBO, Tropical tape recorder
- Antarctic ozone
- Polar vortex dehydration
- EPP NOx enhancement

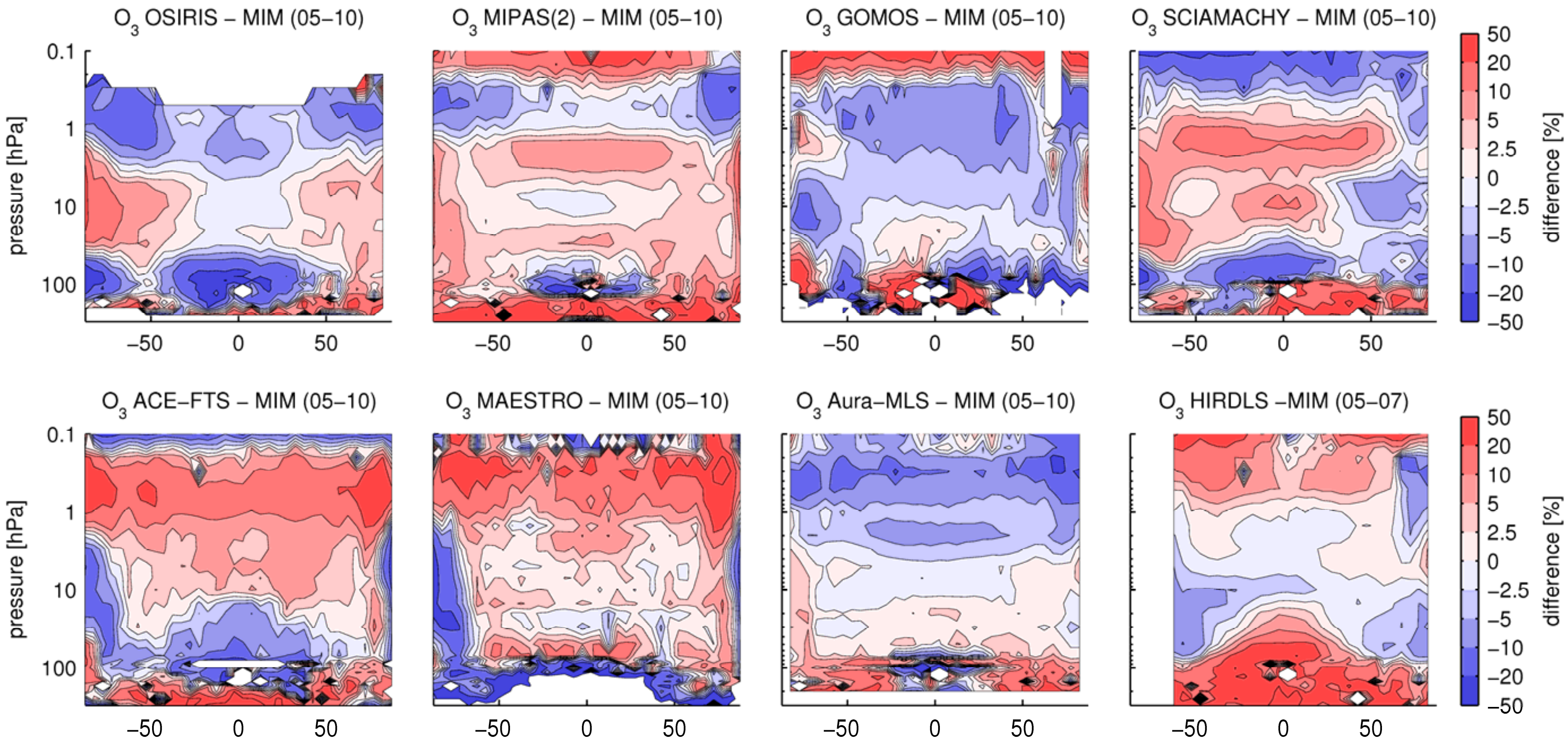
Basic diagnostics

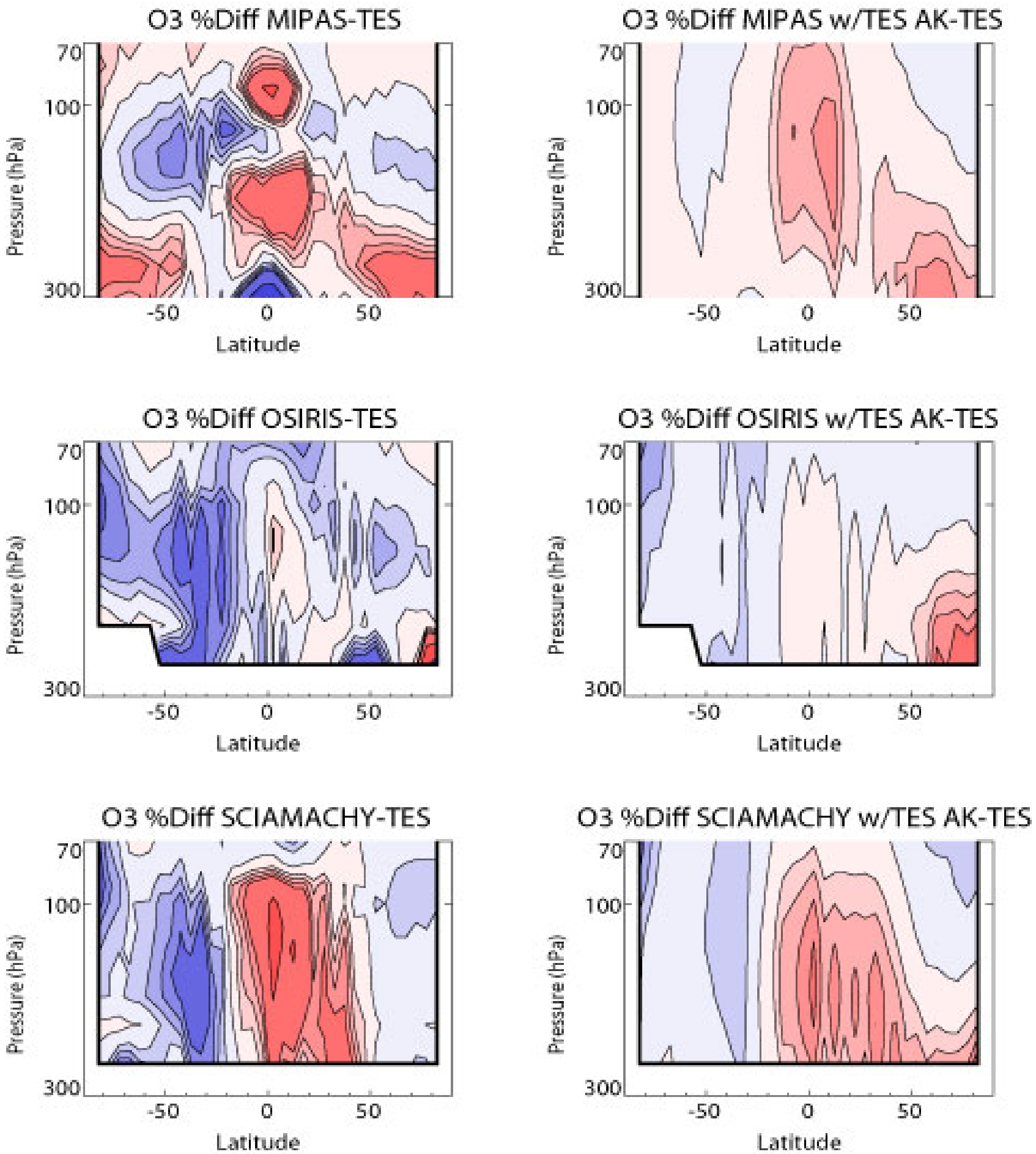
- ➢ **Monthly/annual zonal mean cross-sections**
- ➢ **Mean differences over a given latitude and altitude region**
- ➢ **Climatological spread**
    - O_3

Relative differences to the MIM 2005-2010

- Describe instrument performance on zonal mean annual mean basis
- Are used to derive climatological spread







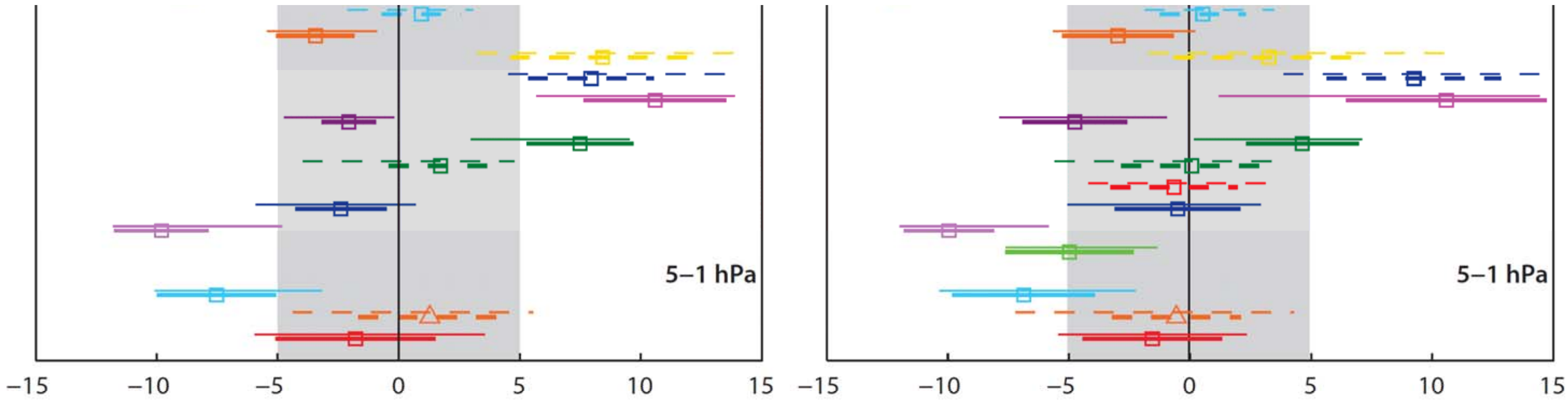
Apply TES observational operator to the limb-viewing instruments

- Smoothes small-scale structures
- Reduces and vertically smoothes differences between the limb measurements and TES and greatly improve the consistency
- Most of the limb-viewing instruments are positively biased with respect to TES with the largest relative biases in the tropics (5-75%)

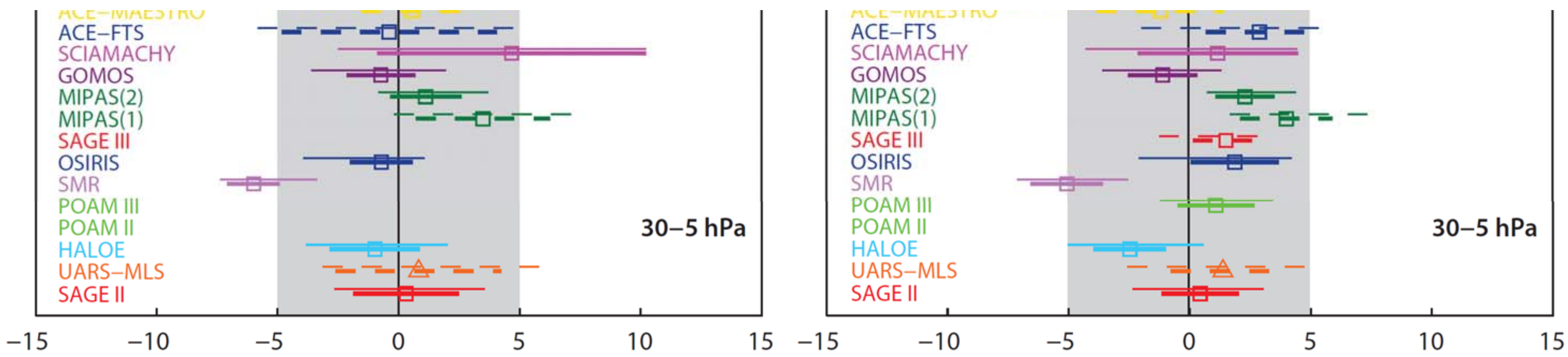
Neu et al., to be submitted to JGR

Evaluation of 18 ozone profile data sets [relative differences %]

Upper stratosphere (5-1 hPa) - Good agreement: ±5% to **±10%.**

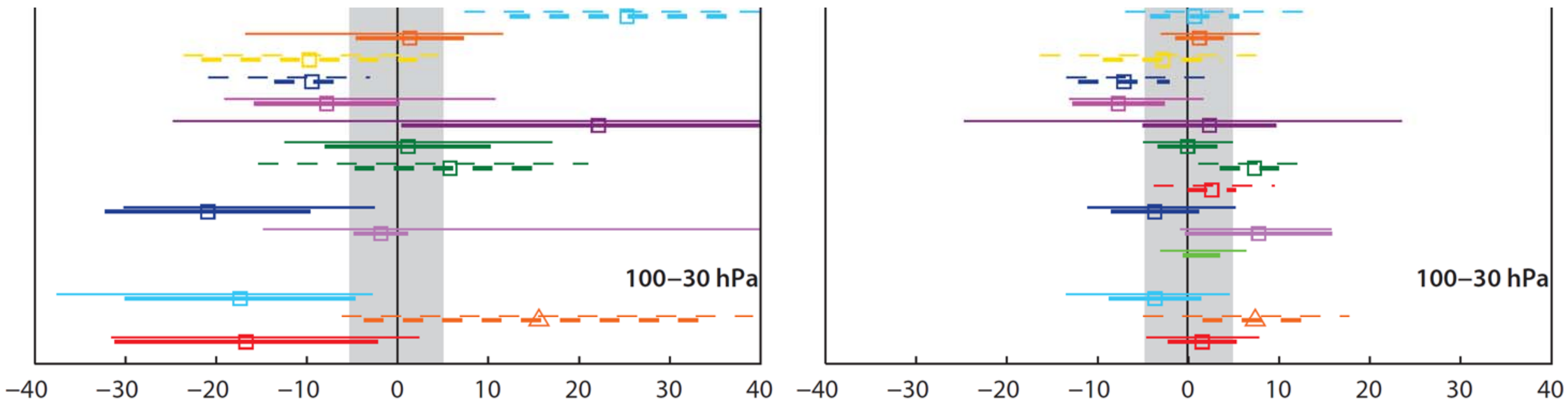


Middle stratosphere (30-5 hPa) - Lowest spread between the instrument data sets: **±5%**

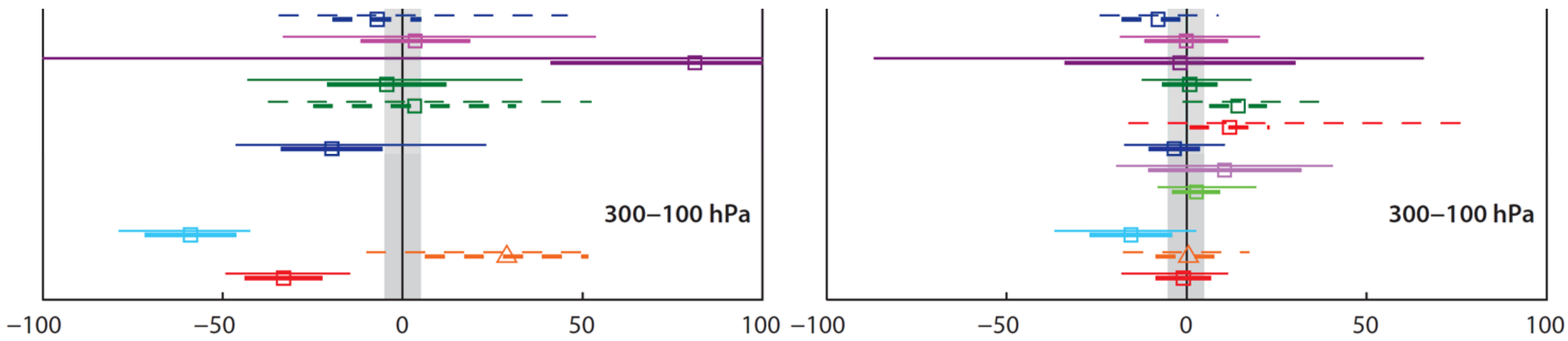


Evaluation of 18 ozone profile data sets

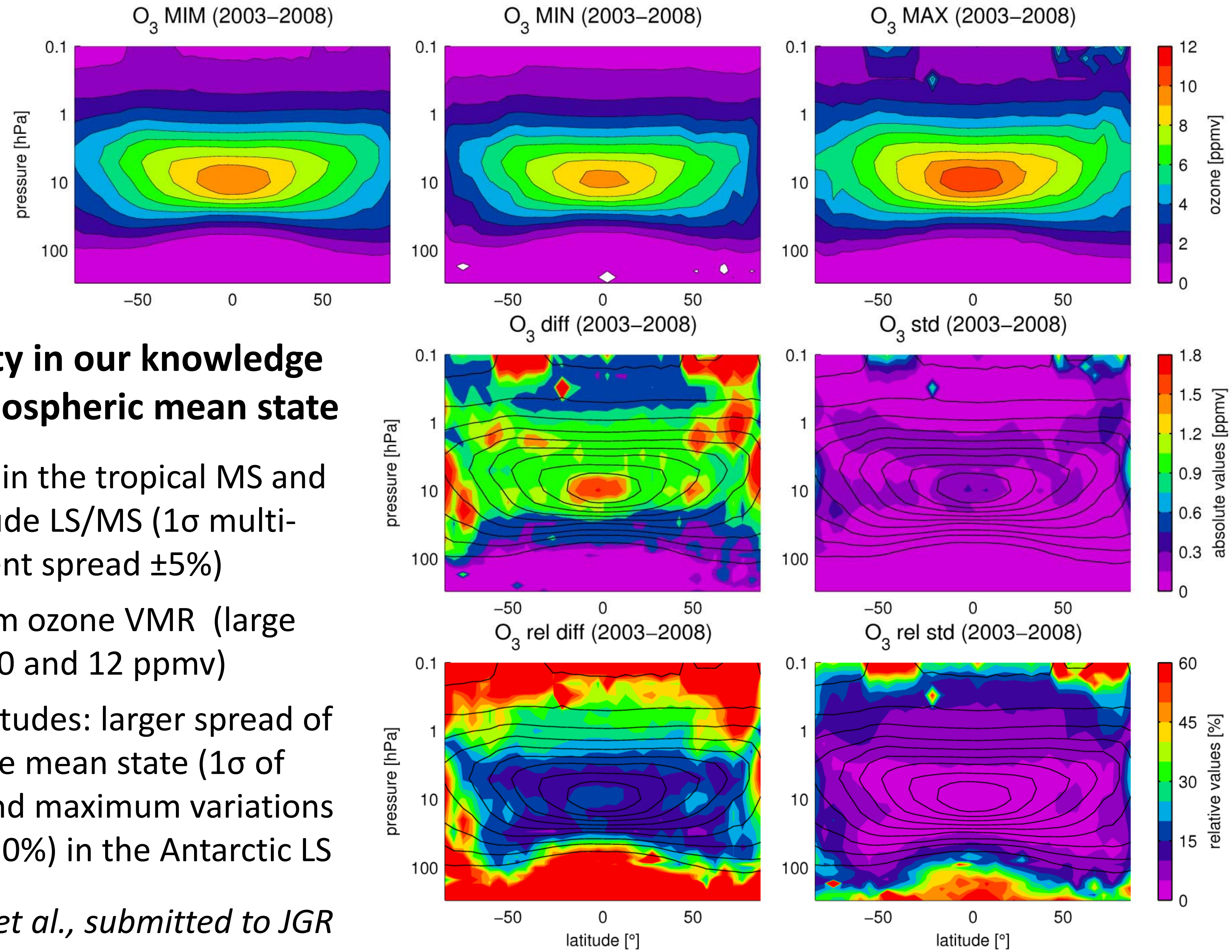
Lower stratosphere (100-30 hPa) - Tropics: **±20%** and Mid-latitudes: **±10%**



Upper troposphere (300-100 hPa) - Tropics: ±20% to **±50%** and Mid-latitudes: mostly **±10%**



O_3 atmospheric mean state



Uncertainty in our knowledge of the atmospheric mean state

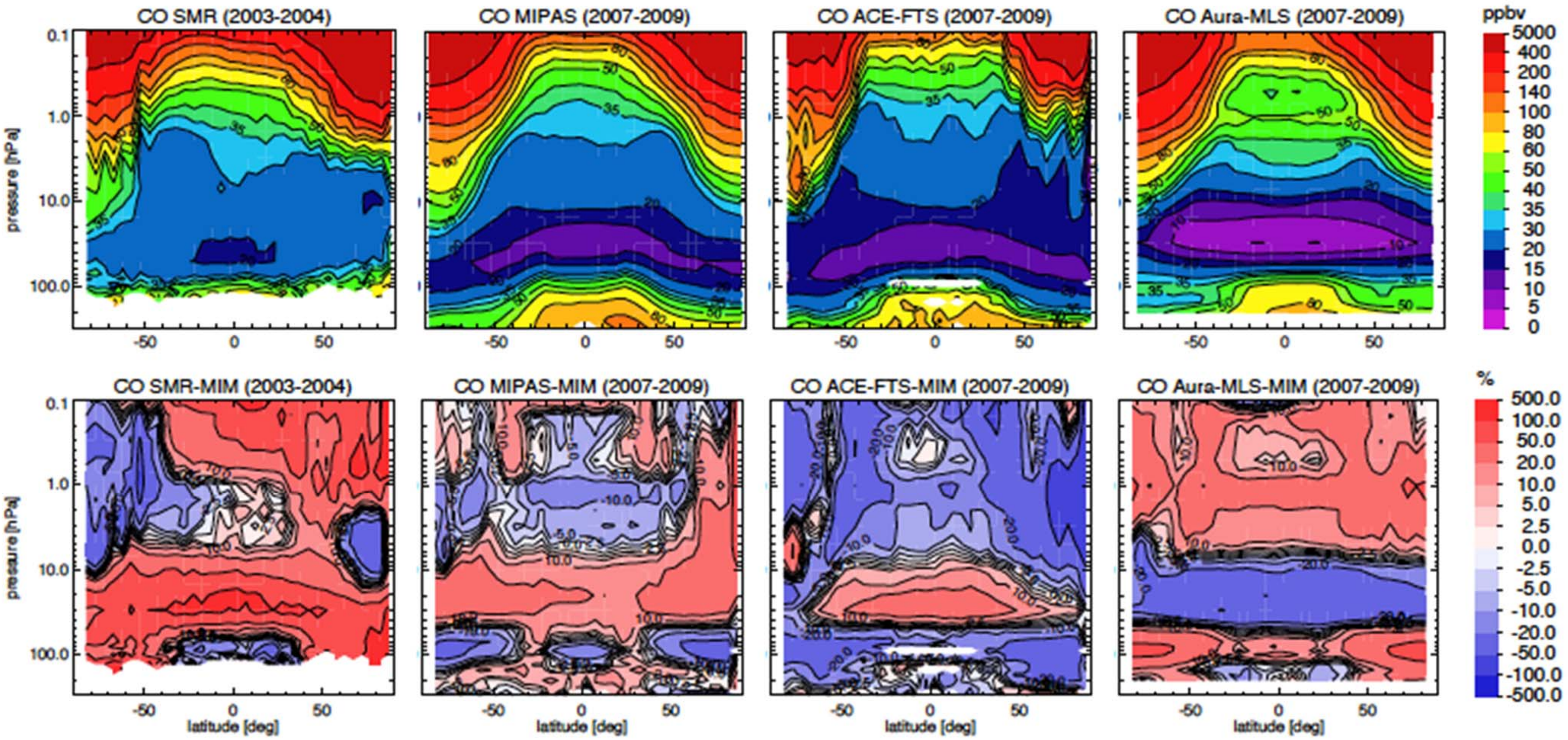
- Smallest in the tropical MS and midlatitude LS/MS (1σ multi-instrument spread ±5%)
- Maximum ozone VMR (large spread 10 and 12 ppmv)
- Polar latitudes: larger spread of the ozone mean state (1σ of ±15%) and maximum variations (1σ of ±30%) in the Antarctic LS

Tegtmeier et al., submitted to JGR

Basic diagnostics

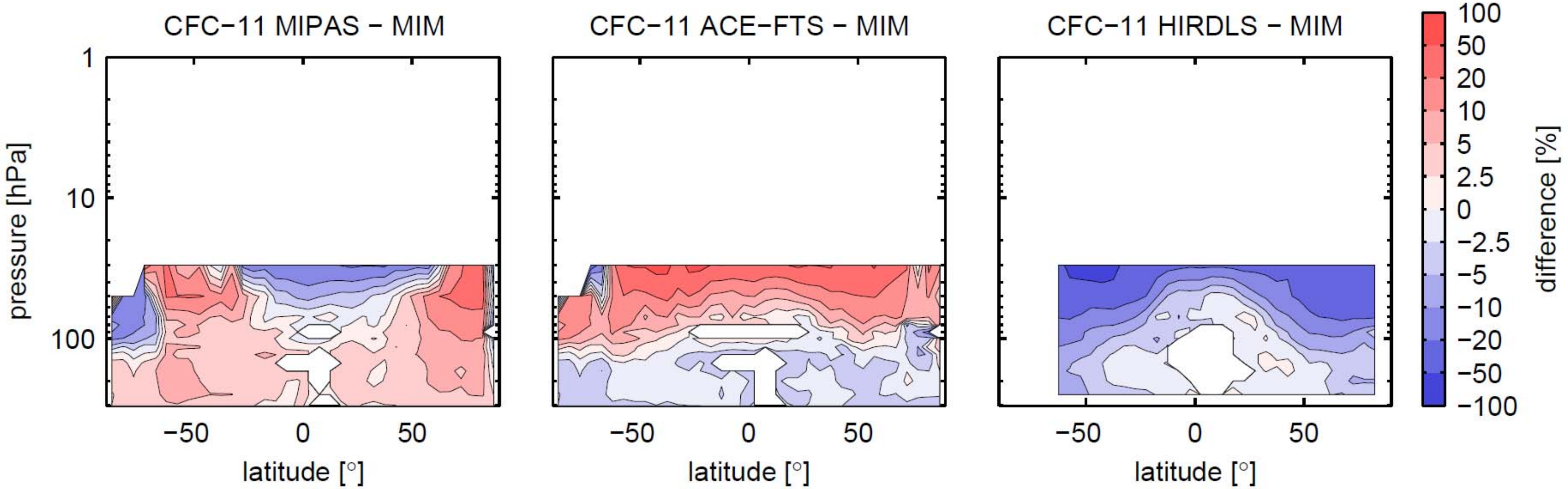
- **Annual zonal mean cross-sections**
  - CO
  - CFC-11
- **Monthly mean profiles**
  - CFC-12

CO annual zonal mean cross sections



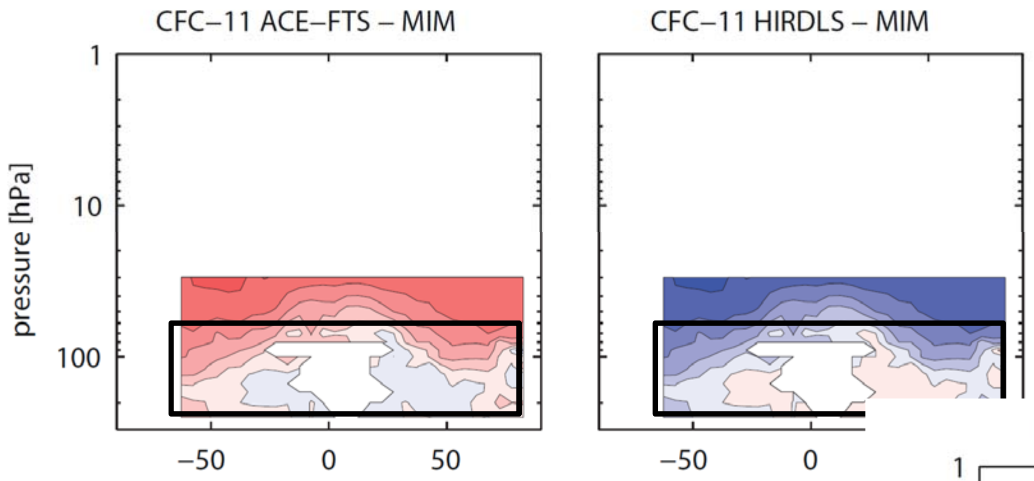
- **Large differences** exist in some of the species in the annual zonal means. Further retrieval studies are suggested to get at the cause of this discrepancy.

CFC-11 annual zonal mean comparisons



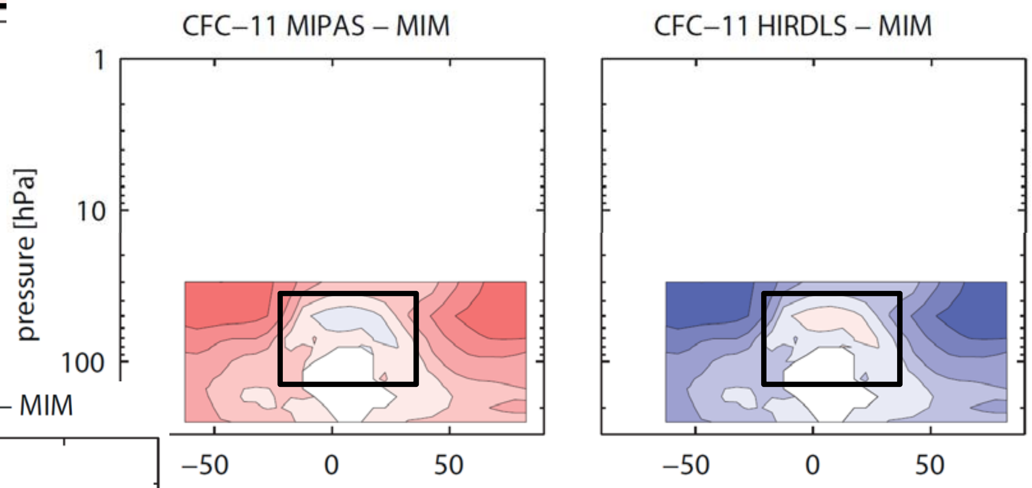
- One important question for all tracer evaluations is to determine in which area **which instruments are closest to each other**.

CFC-11 comparisons

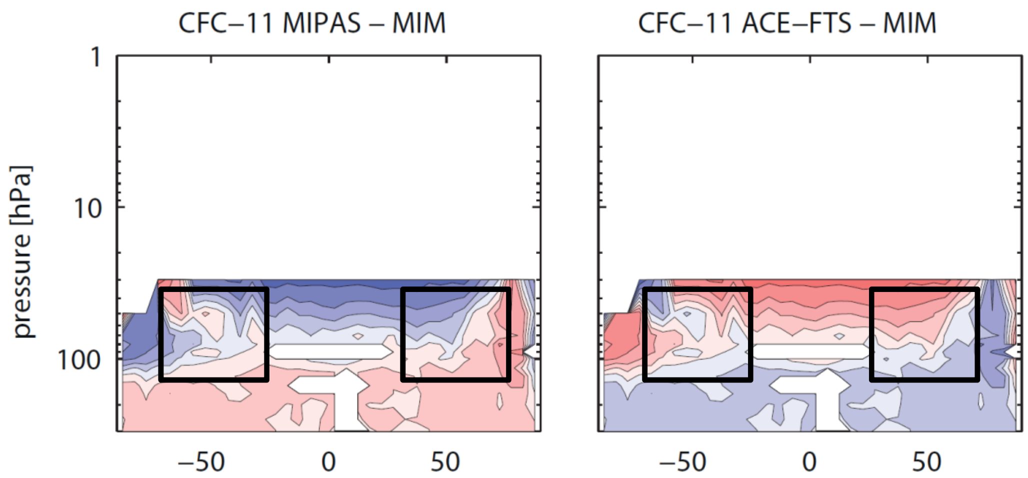


CFC-11

- ACE-FTS and HIRDLS show excellent agreement (±2.5%) below 50 - 100 hPa.

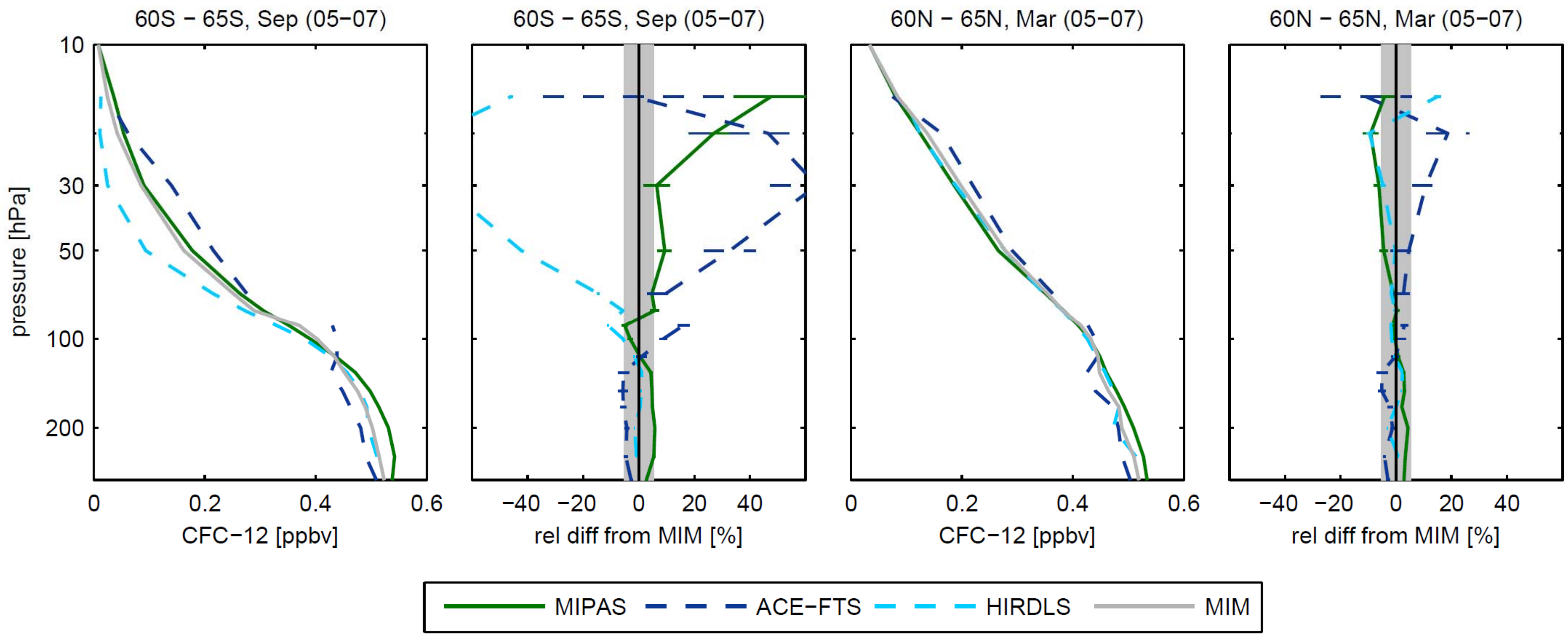


- MIPAS and HIRDLS agree very well in the tropics (±5%).



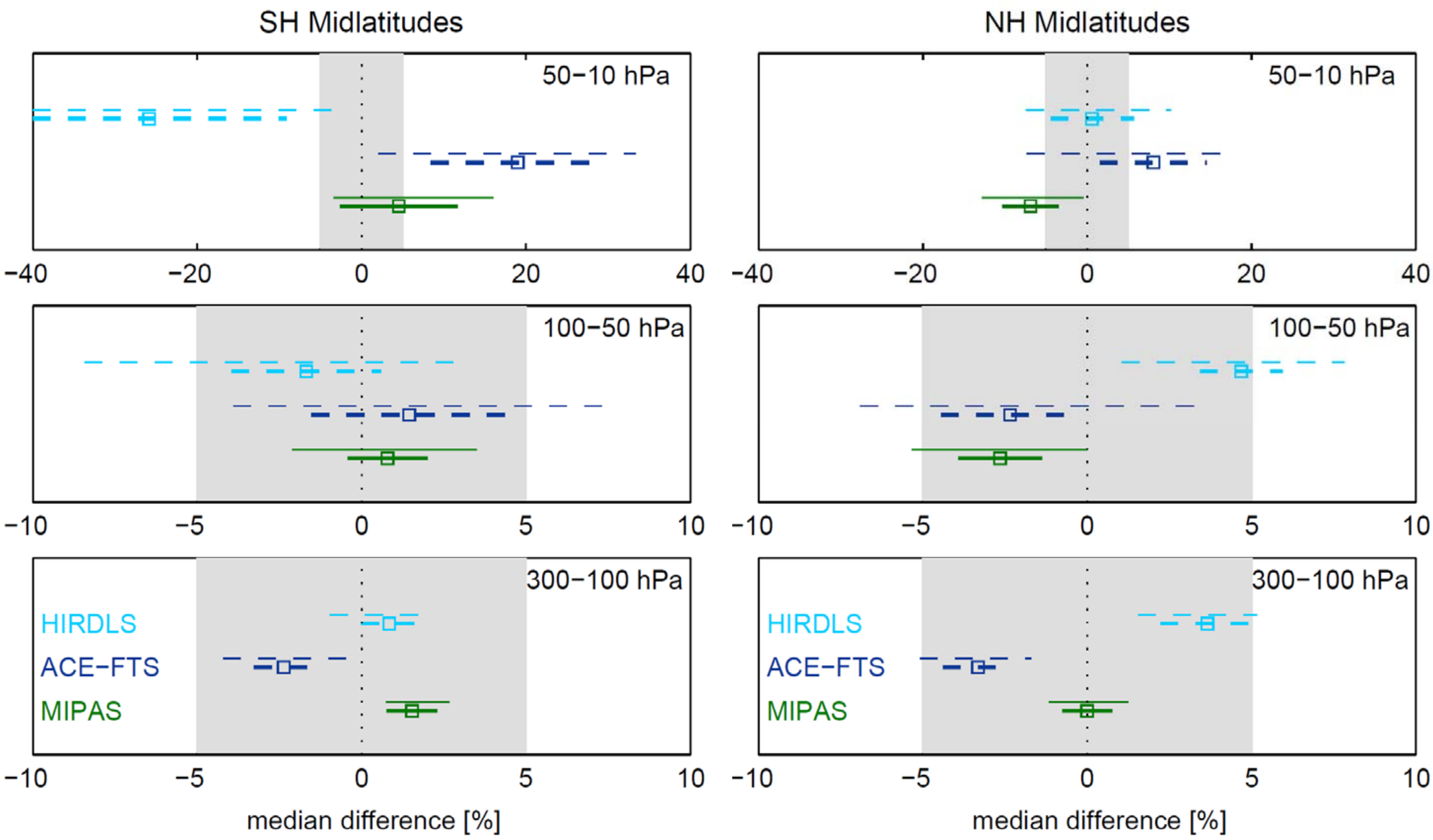
- MIPAS and ACE-FTS agree very well in the extratropics (±5%).

CFC-12 profiles at high latitudes



- Hemispheric differences with larger spread in the SH (±50%) than in the NH (±10%).

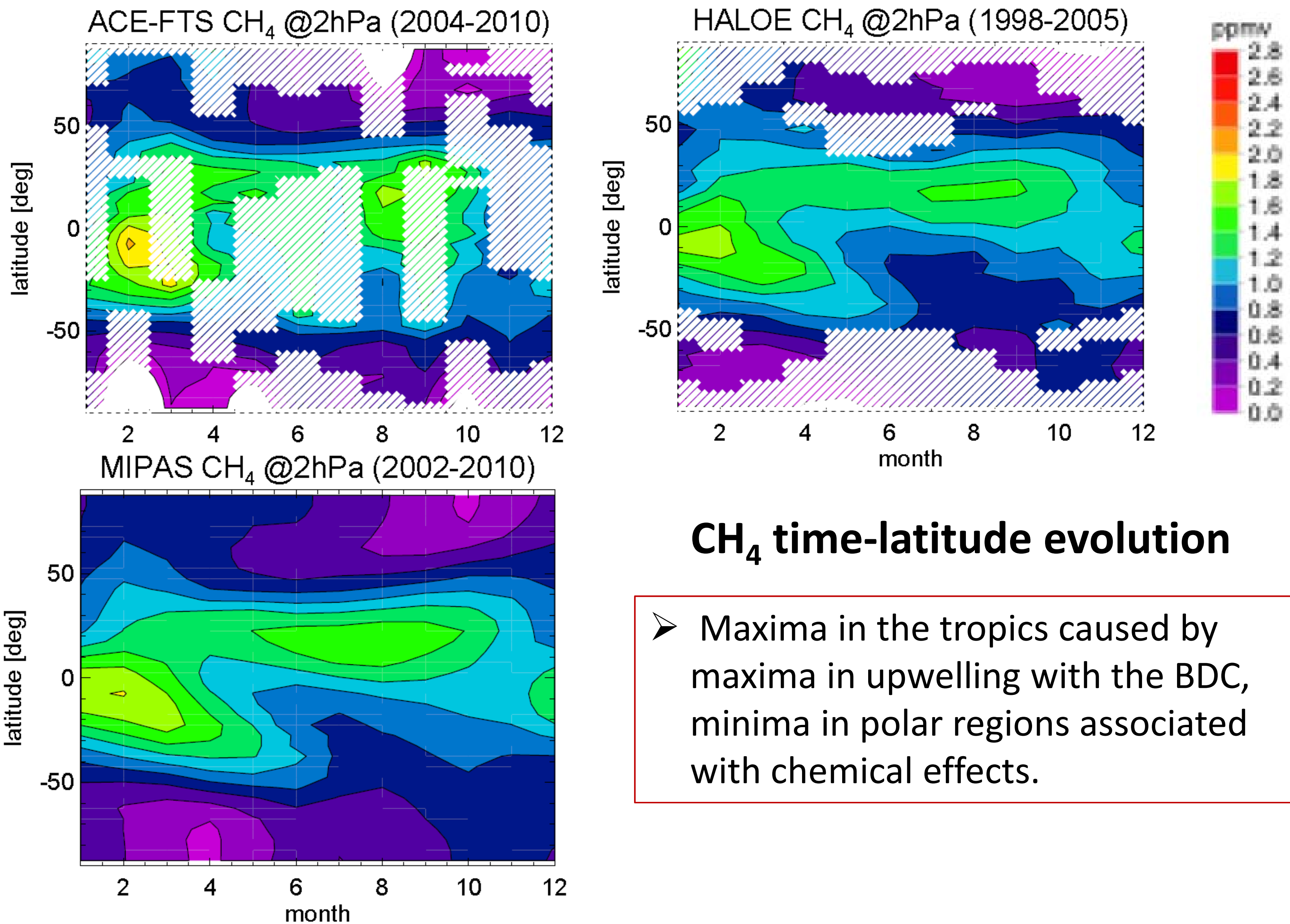
CFC-12 summary split into NH and SH mid-latitudes



Further diagnostics

- **Seasonal cycle**
  - H_2O, CH_4
- **Interannual variability**
  - O_3, HF
- **Polar vortex**
  - O_3

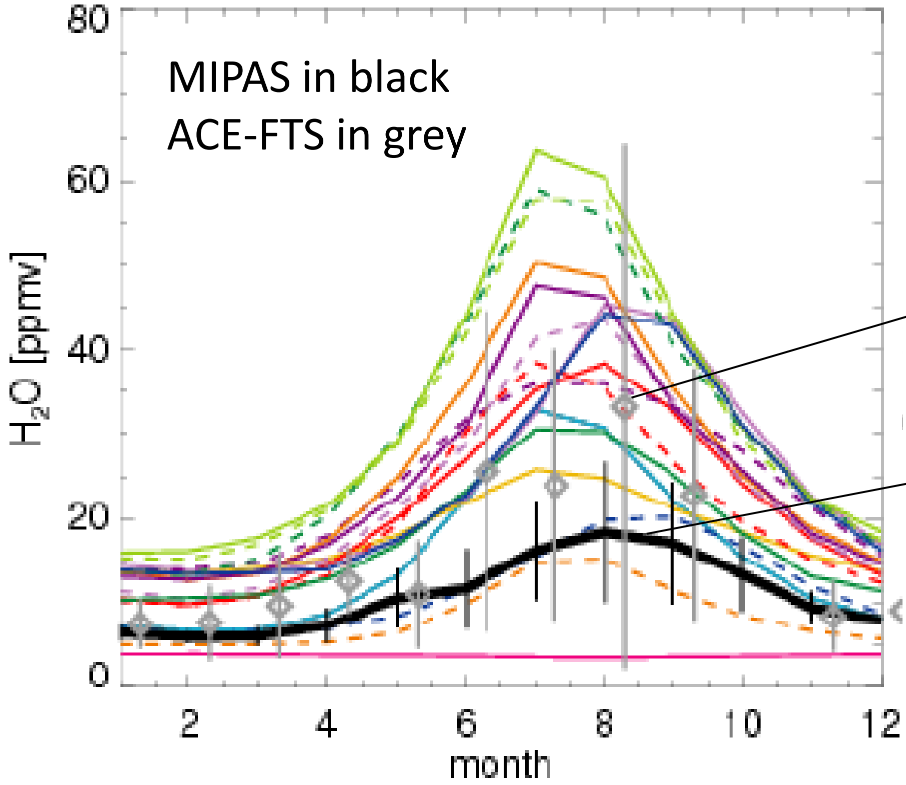
CH_4 comparisons

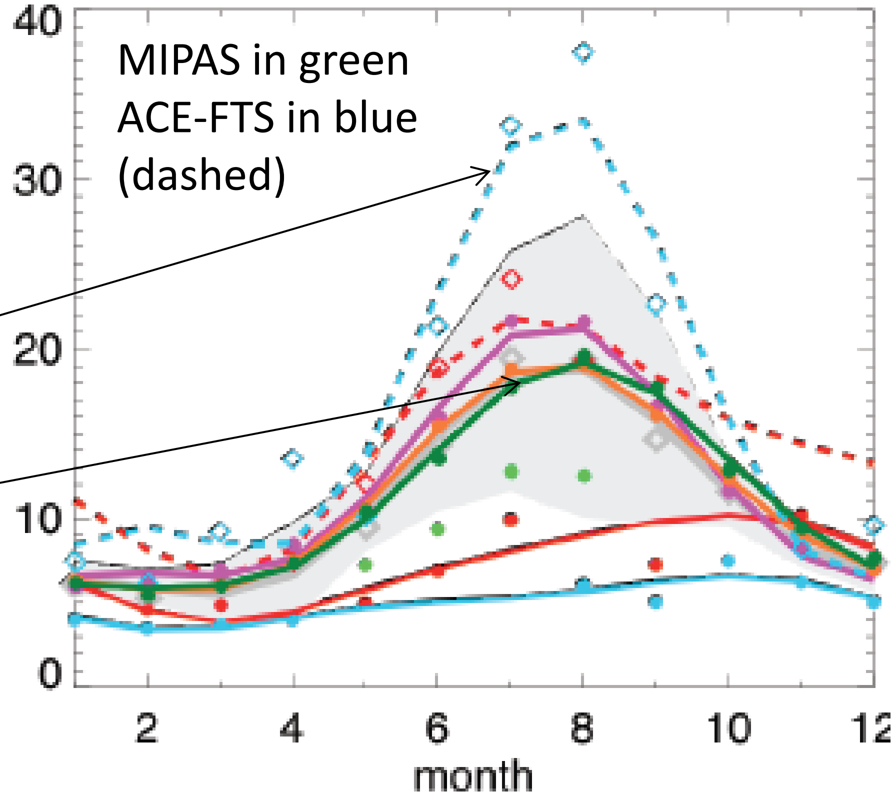


CH_4 time-latitude evolution

- Maxima in the tropics caused by maxima in upwelling with the BDC, minima in polar regions associated with chemical effects.

H2O seasonal cycle 40°N – 60°N, 200 hPa





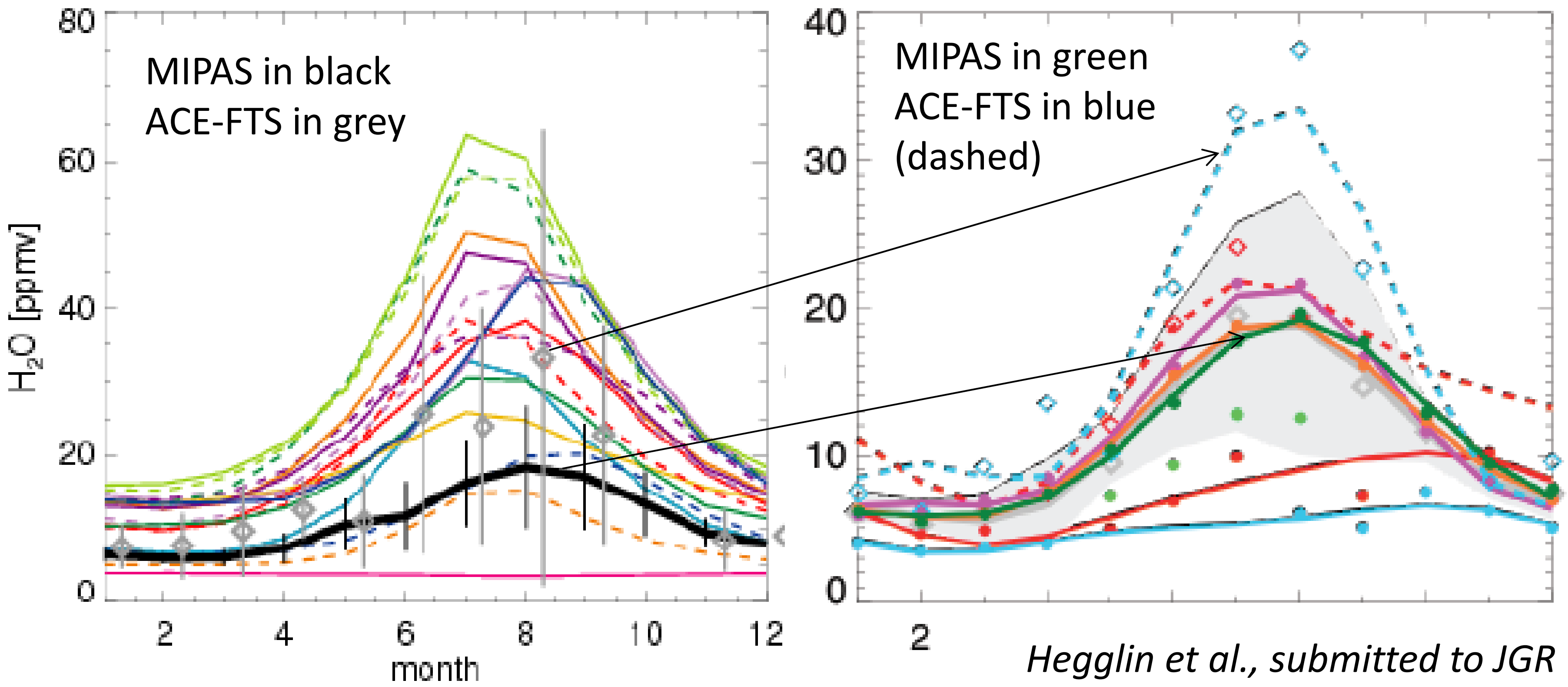
Model-measurement comparison

✓ MIPAS averaging kernels are expected to smear out maxima which can lower the amplitude of the seasonal cycle

Measurement comparison

✓ However, MIPAS agrees well with most other instruments whereas ACE-FTS has a larger amplitude

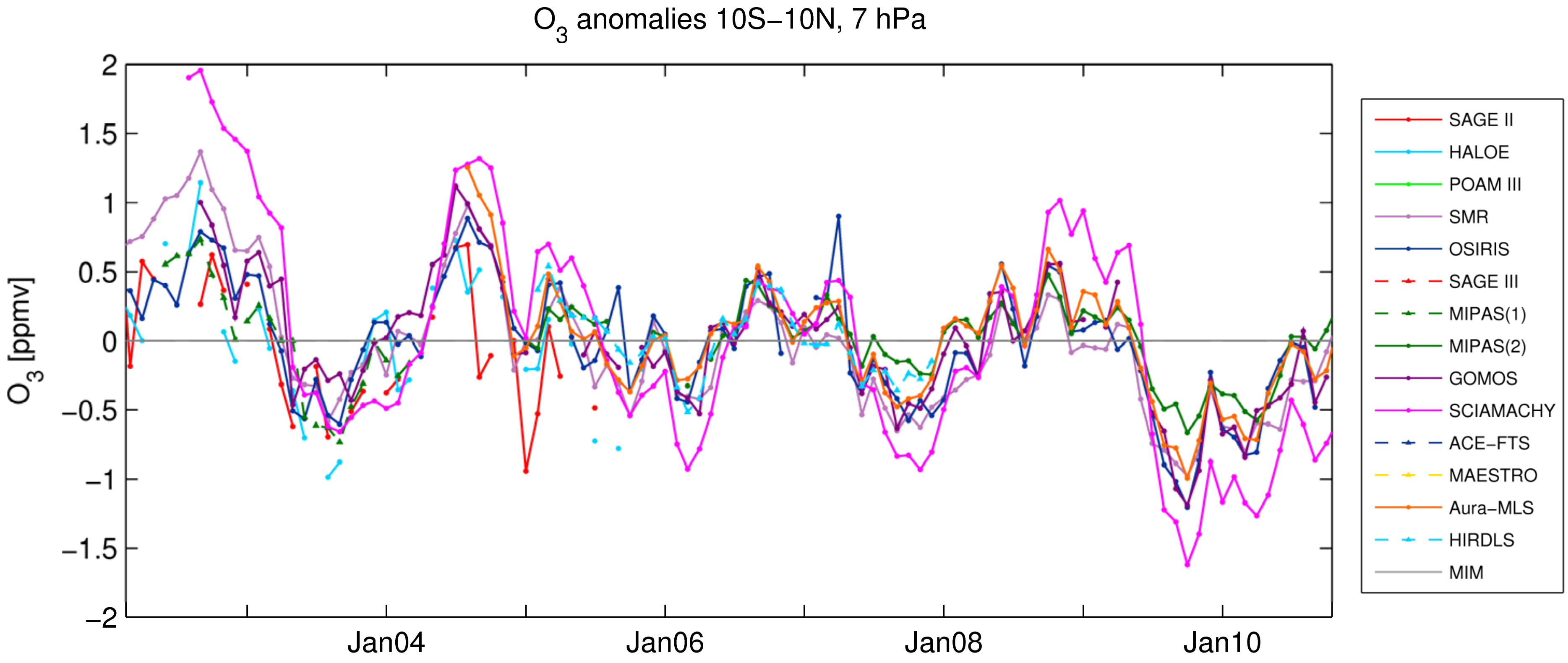
H2O seasonal cycle 40°N – 60°N, 200 hPa



Hegglin et al., submitted to JGR

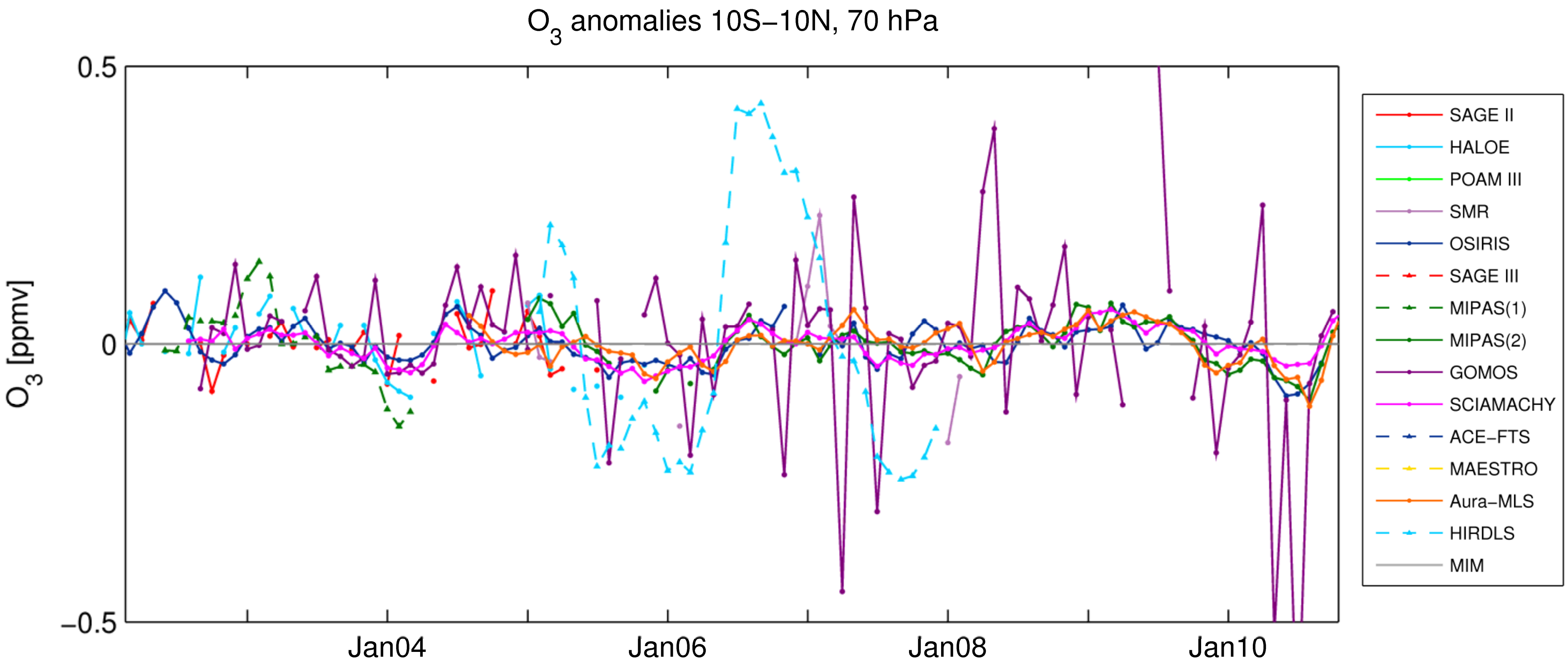
- ✓ Further studies are required to explain the differences (e.g., apply MIPAS averaging kernels to model output, take into account ACE sampling pattern)
- ✓ SDI should coordinate a **follow-on activity** with specific focus on the **UTLS** (take into account geophysical variability, available in-situ measurements, nadir sounders)

Ozone - Evaluation of interannual variability



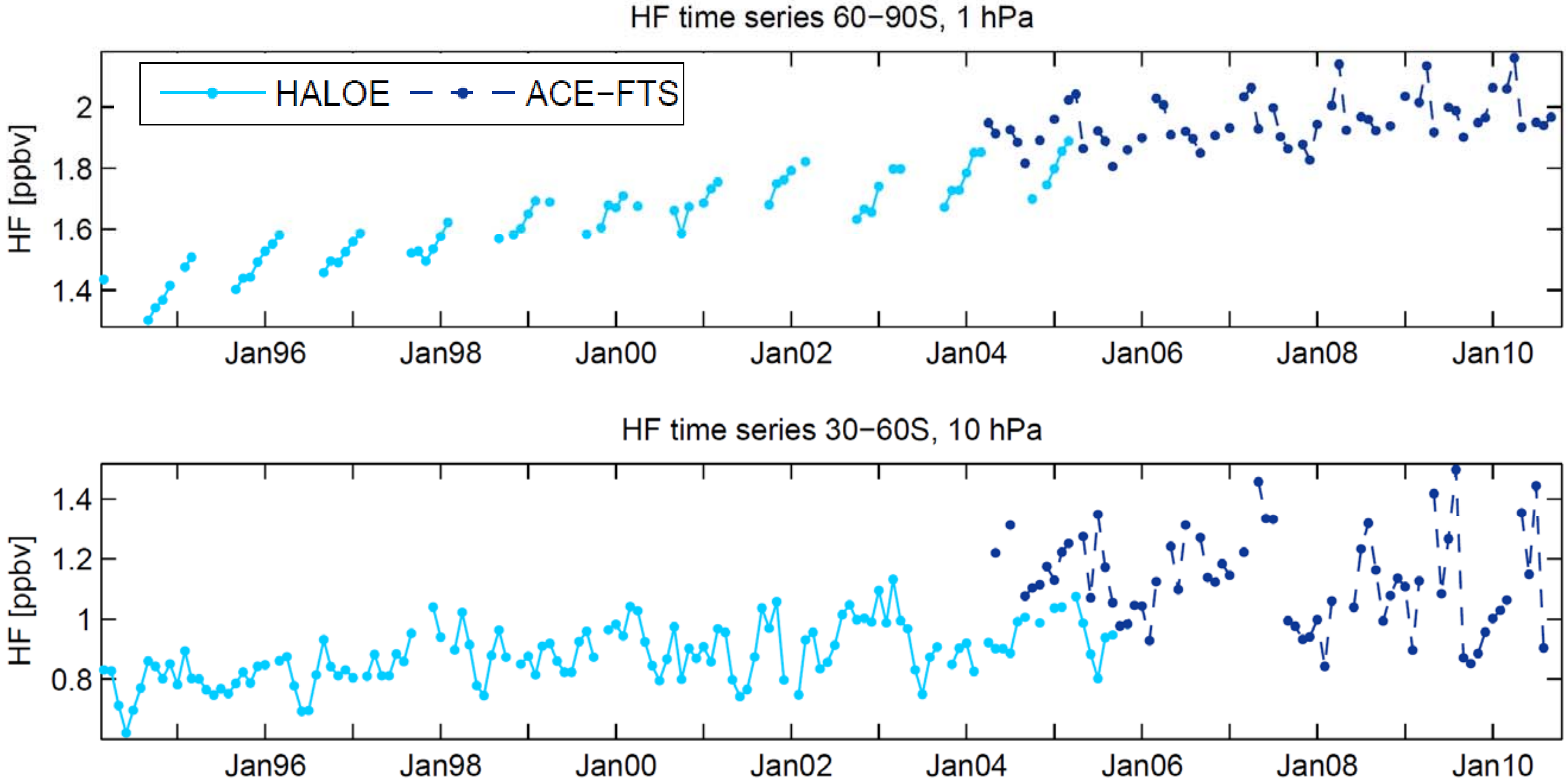
- Tropical **QBO signal in the middle stratosphere is captured well** by all instruments
- Slight deviations in displayed amplitude

Ozone - Evaluation of interannual variability



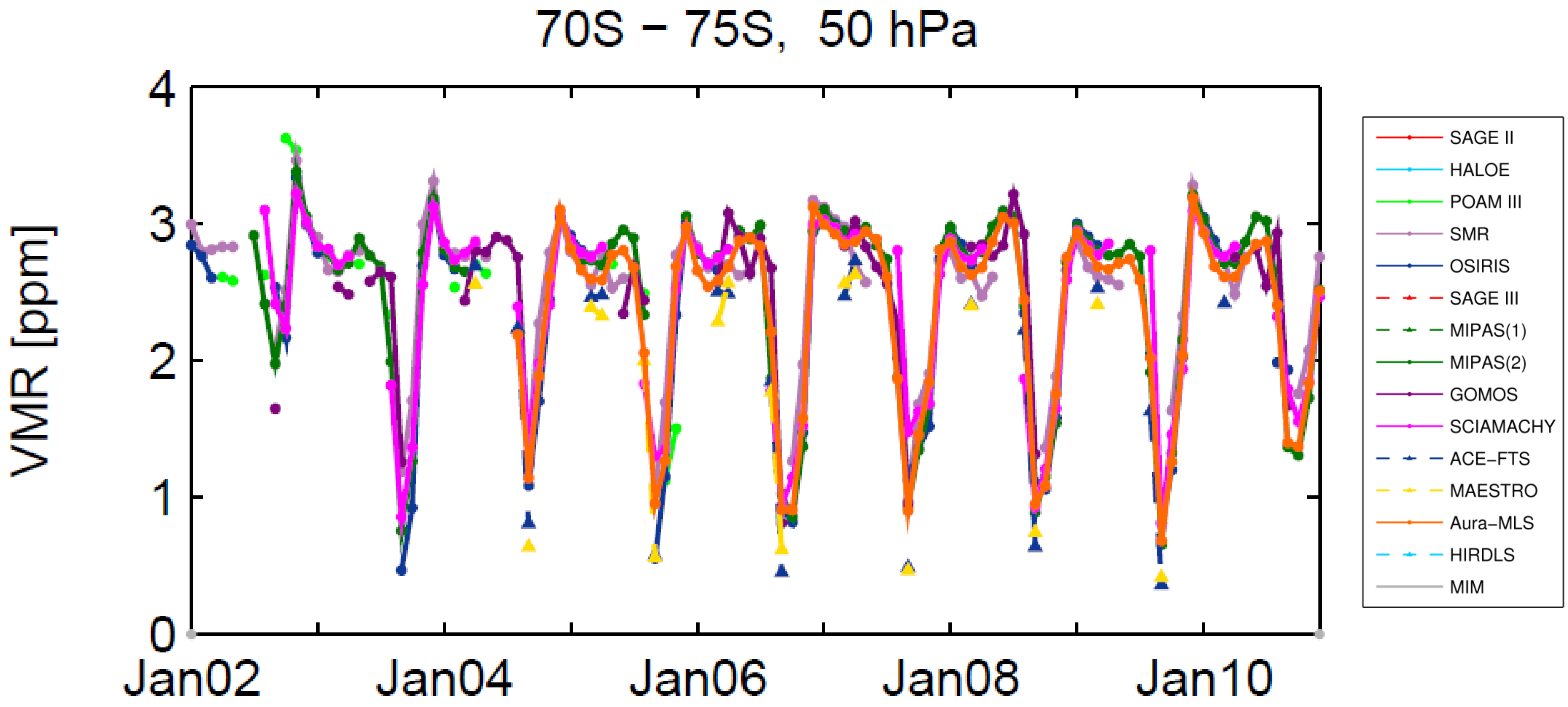
- **Larger difficulties in the lower stratosphere** where ozone abundances and inter-annual variations are small

HF - Evaluation of interannual variability



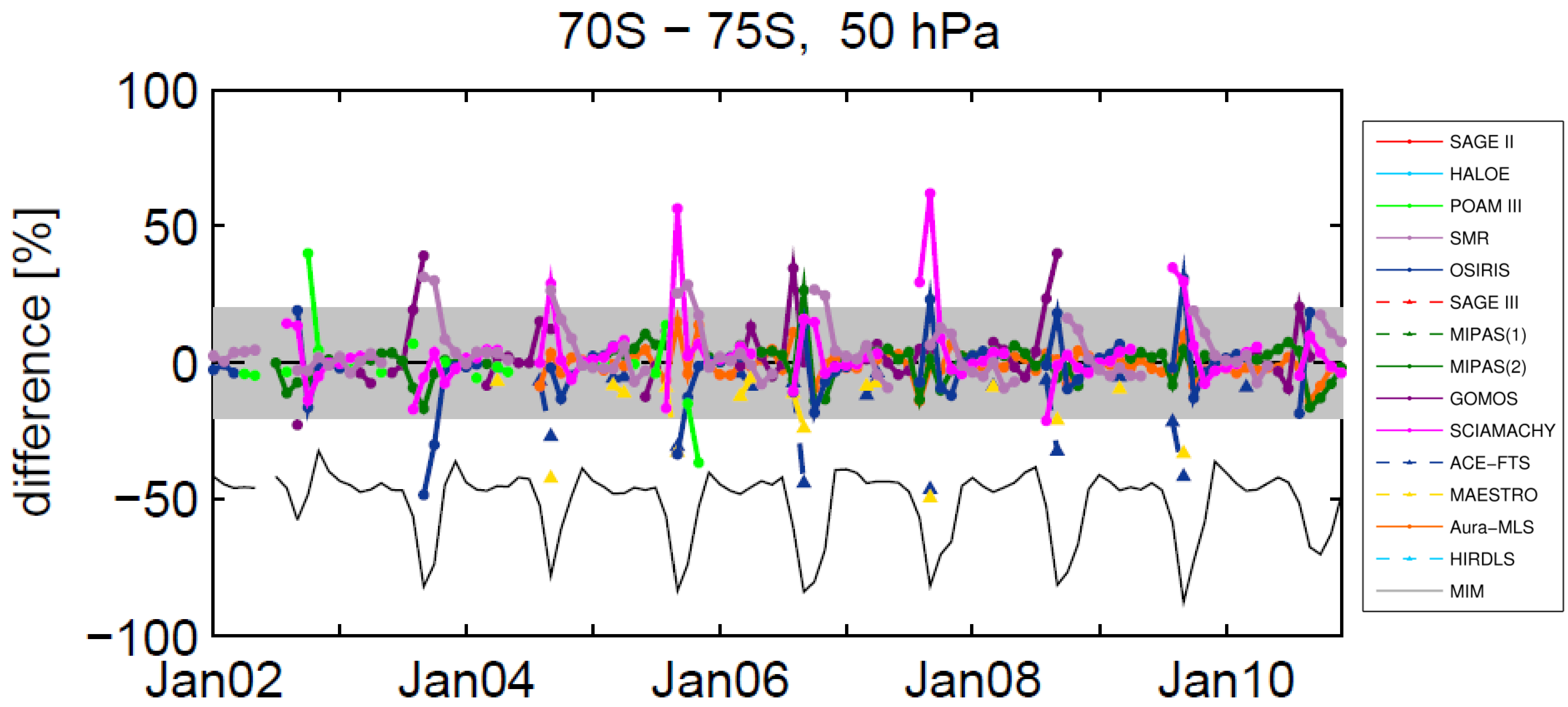
- For some gases (e.g., HF) there is not enough overlap to quantify the seasonal cycle and the interannual variability

Evaluation of Antarctic ozone



- **Large relative differences (to the MIM) in the Antarctic polar cap region** during the time of the ozone hole
- Spread between the monthly zonal mean fields of ±50%

Evaluation of Antarctic ozone



- **Large relative differences (to the MIM) in the Antarctic polar cap region** during the time of the ozone hole
- Spread between the monthly zonal mean fields of ±50%

How to deal with short-lived species?

- Measurements correspond to different LST and direct comparisons won't be meaningful → Dependence on the LST needs to be accounted for

Approach

- Solar occultation measurements can be compared amongst each other if separated into local sunrise and sunset
- Measurements are separated into am and pm
- Some instruments have a fixed local solar time (e.g., MIPAS 10 am)
- Other measurements have been scaled to a fixed LST (e.g., 10 am) with the help of a chemical box model

Diurnal cycle in NO_2 at 10°N derived with a chemical box model

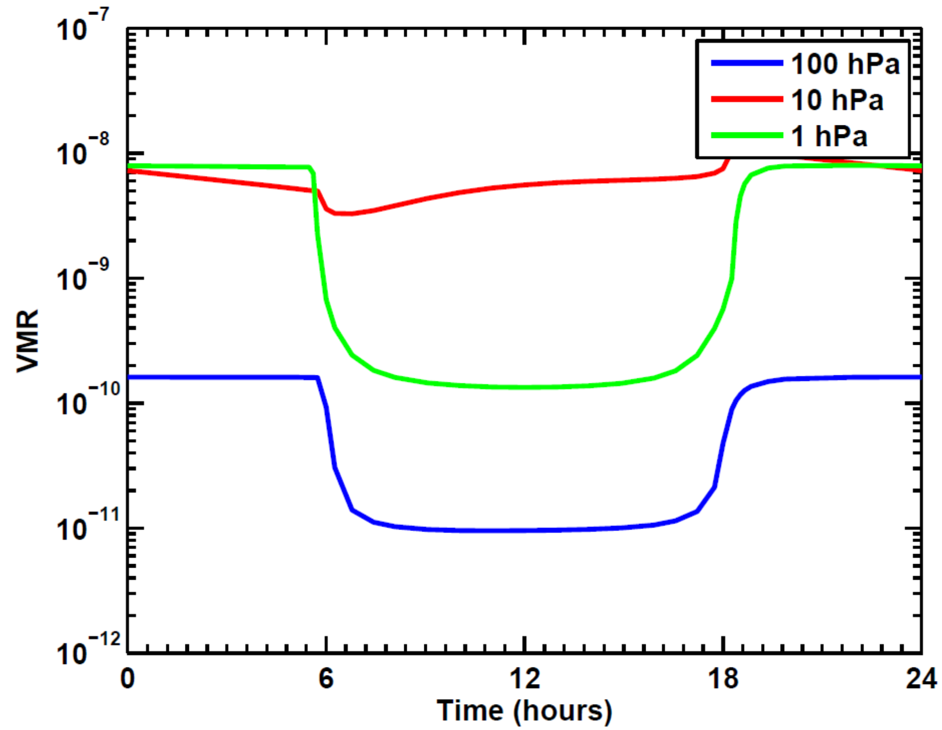
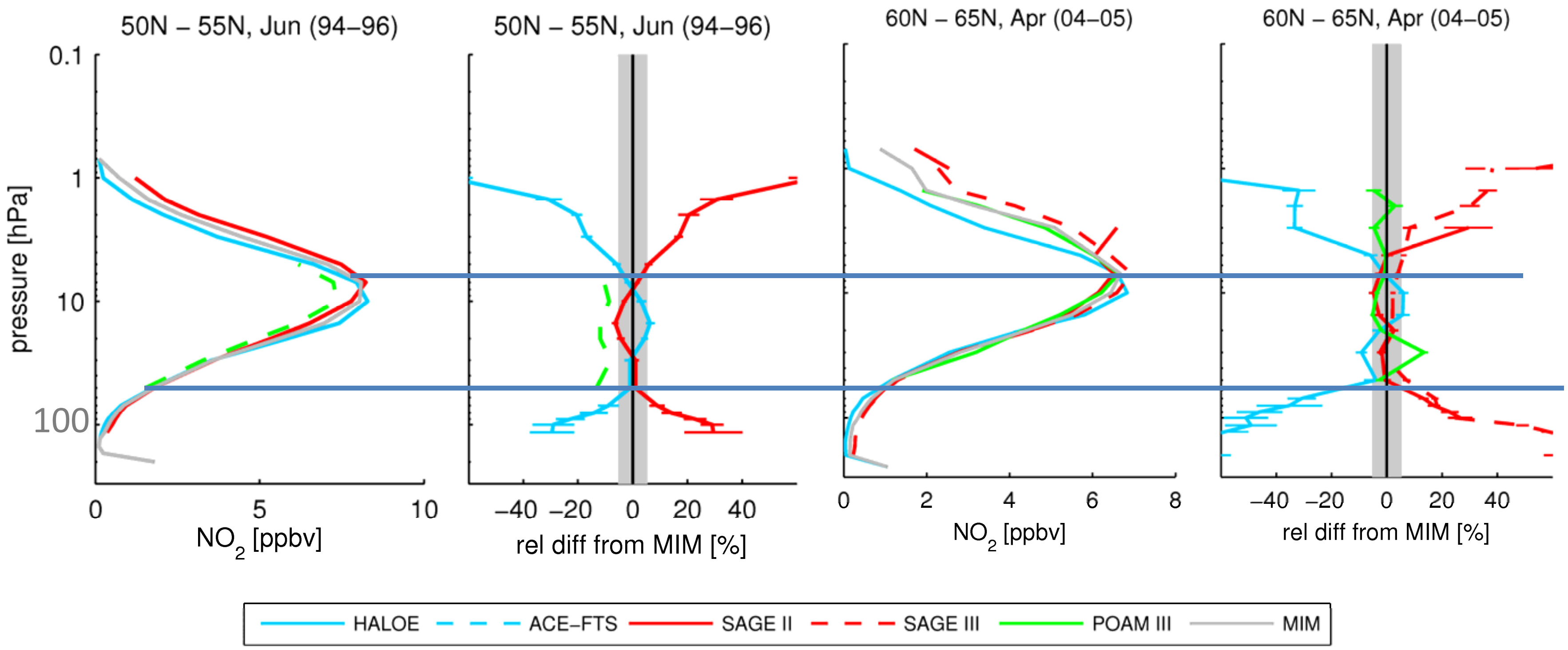


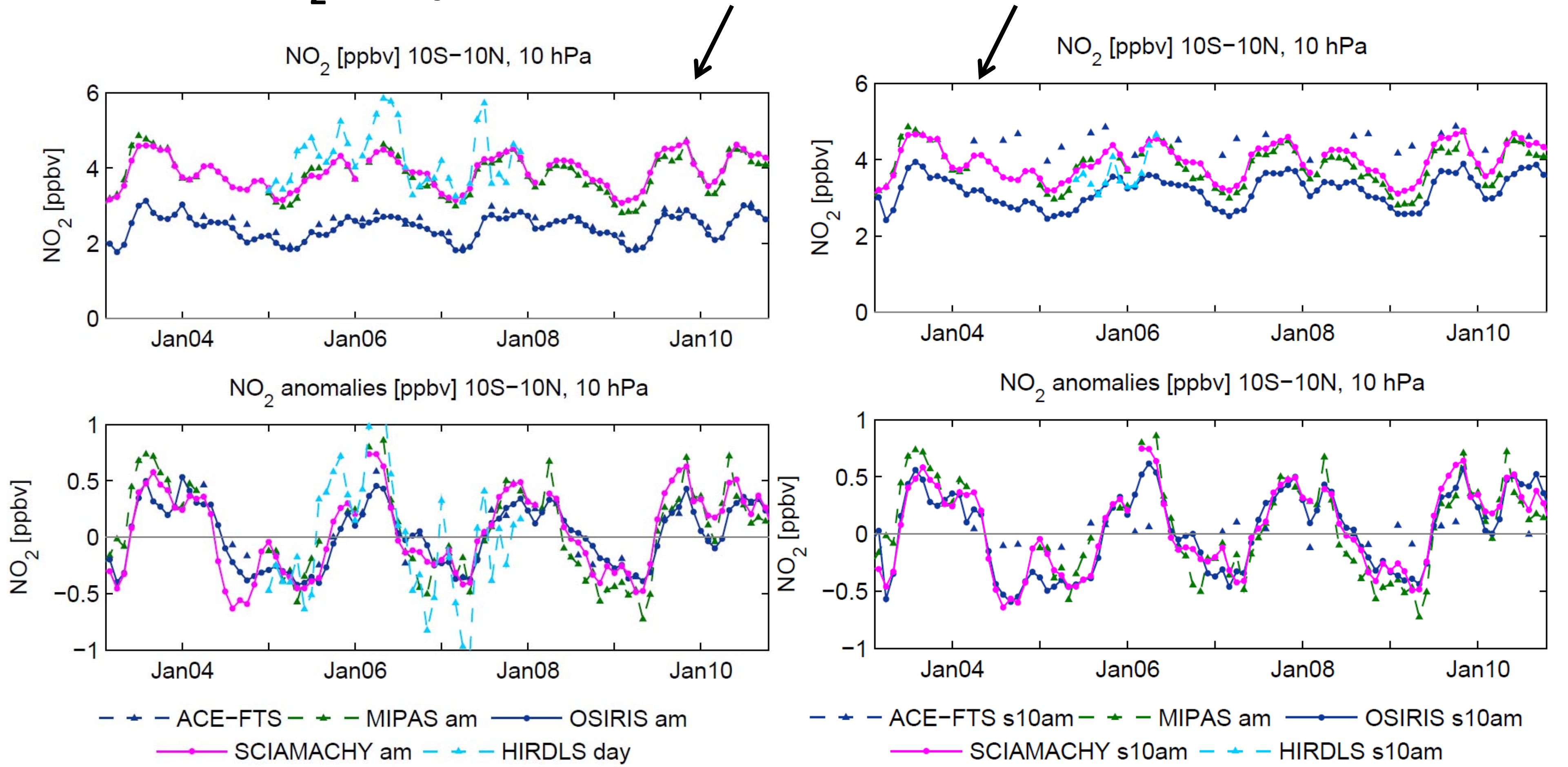
Figure by C. McLinden

NO_2 profile comparisons for solar occultation instruments



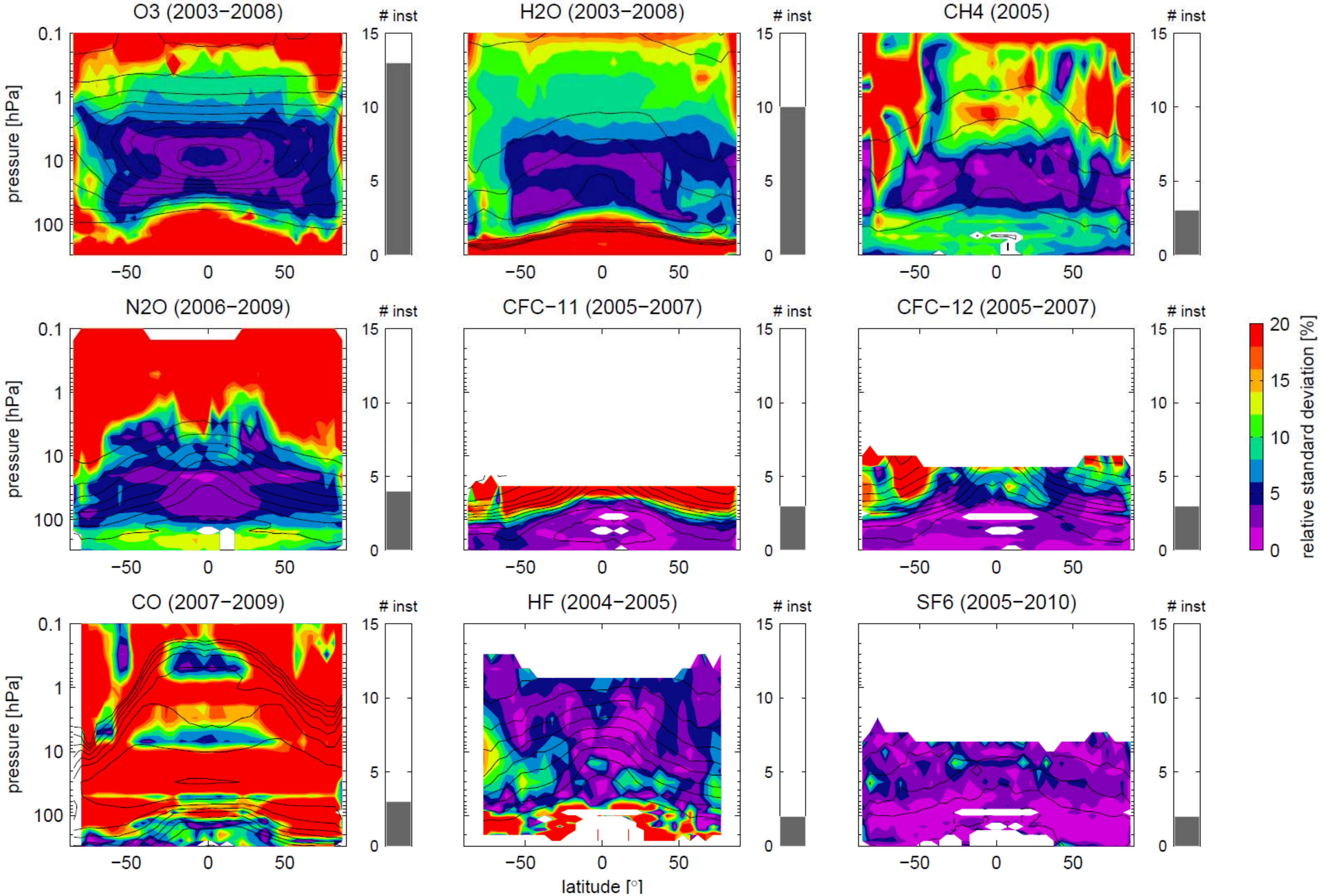
- Good agreement between 5 and 50 hPa (below NO_2 peak)
- Large differences above NO_2 peak
- Consistent results for different instruments sets and time periods

NO_2 comparisons of unscaled and scaled data sets



- Profile show good agreement between 5 and 50 hPa (below NO_2 peak)
- Large differences above NO_2 peak

Summary



O3 (2003−2008)
H2O (2003−2008)
CH4 (2005)
N2O (2006−2009)
CFC−11 (2005−2007)
CFC−12 (2005−2007)
CO (2007−2009)
HF (2004−2005)
SF6 (2005−2010)
inst
pressure [hPa]
latitude [°]
relative standard deviation [%]
0.1
1
10
100
−50
0
50
0
5
10
15
20

Comprehensive comparison of satellite instrument observations

- Better knowledge of the quality of available data products including information on where they are consistent and where they exhibit unphysical features or strong deviations
- Assessment of the range of measurements as an estimate of the systematic uncertainty in the measured field
- Need for further evaluation activities (e.g., in the UTLS and at high latitudes) identified
- Motivation for improvement of data products

Provide monthly zonal mean time series in a common format

- Will be published on the SPARC data archive website
- Will be updated in the future as soon as new time series are available)

Improve future model-measurement comparison activities

- Depending on the evaluation and trace gas, individual instruments may need to be excluded from the comparison (e.g., seasonal cycle in LS)