living planet symposium | BONN 23–27 May 2022

TAKING THE PULSE OF OUR PLANET FROM SPACE

# Final MIPAS L1 and L2 V8 full mission reprocessing, lessons learnt and possible further improvements

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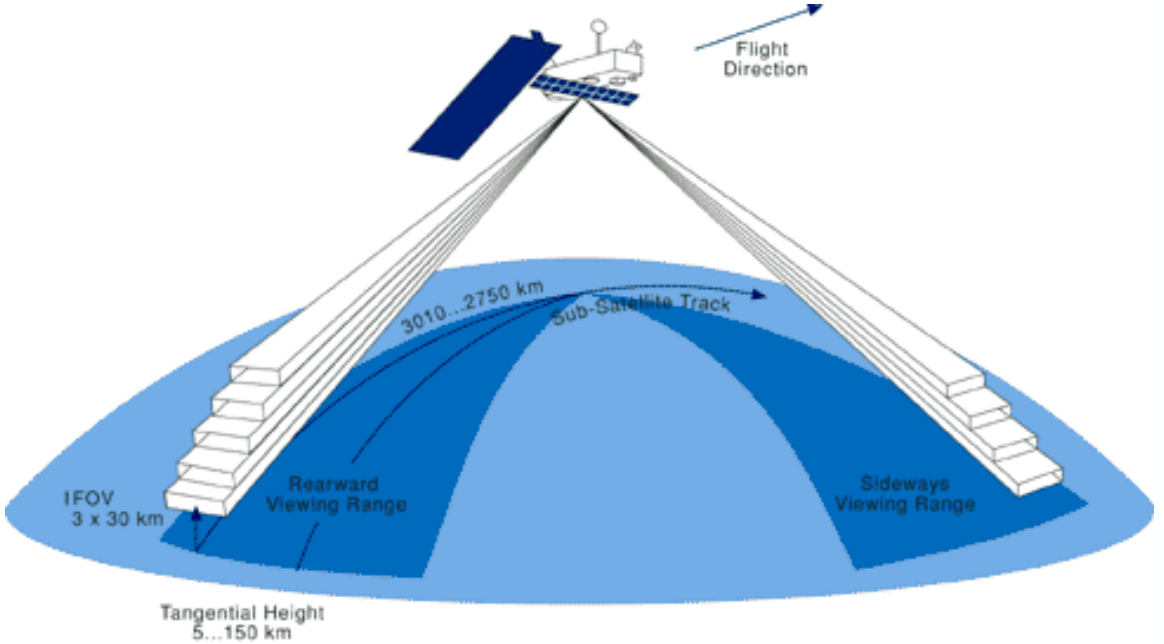
# MIPAS measurements on ENVISAT

MIPAS is a Fourier Transform spectrometer that measured the **atmospheric limb emission** spectra in the **middle infrared** on board the ENVISAT satellite. These measurements allowed the global monitoring of temperature and trace spcies concentraton during **both day and night**, for 10 years, from July 2002 to April 2012.

MIPAS measurements allowed to study the atmosphere from the upper troposphere to the thermosphere.

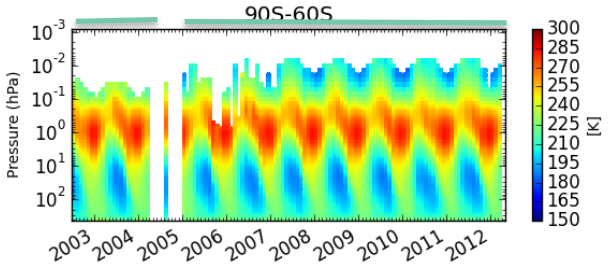



Many species:

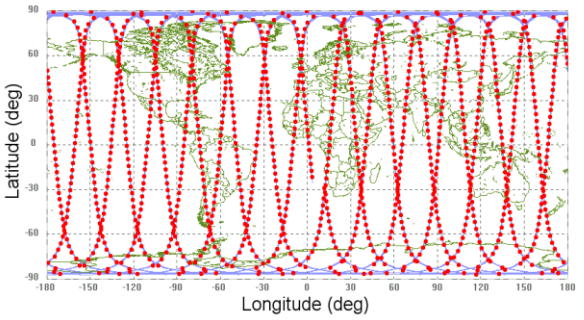
- CO2, used for temperature retrieval;
- water vapour; ozone and many other longer-lived greenhouse gases;
- species of interest for ozone chemistry;
- many nitrogen and sulfur compounds;
- gases produced by biomass burning and other pollution plumes;
- some isotopologues

Full Resolution phase (2002-2004)

Optimized Resolution phase: reduced spectral resolution, finer vertical sampling (2005-2012)

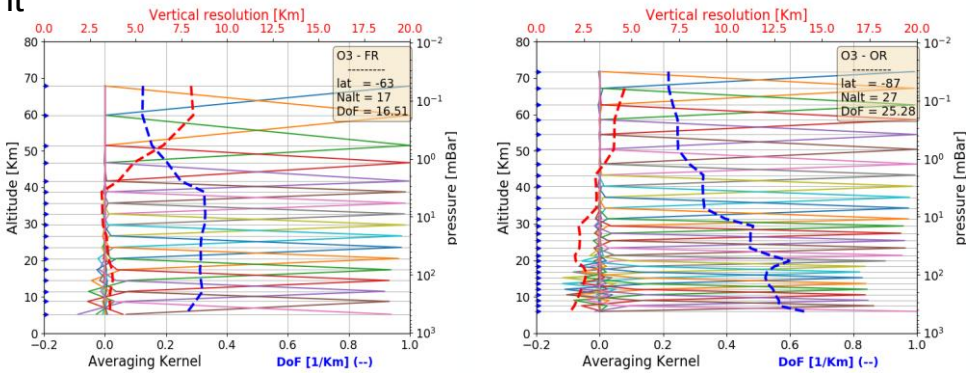



High geographical coverage, both day and night



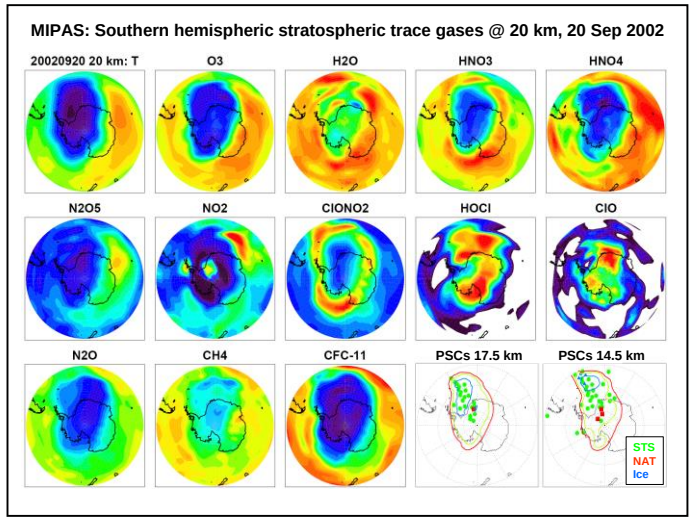

*Spatial coverage in 24 h*

High vertical resolution (different in the two phases)

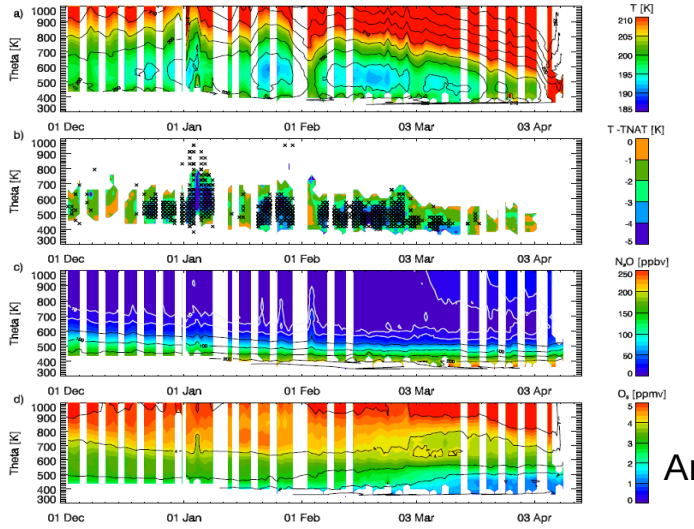


# 10 years of MIPAS measurements on ENVISAT: many L2 algorithms, many results

## Polar vortex Chemistry

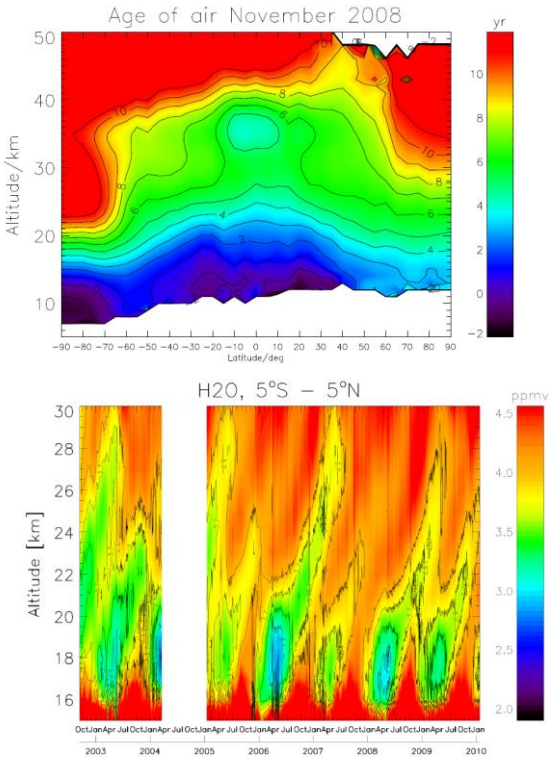



*Höpfner* et al., 2004, 2006



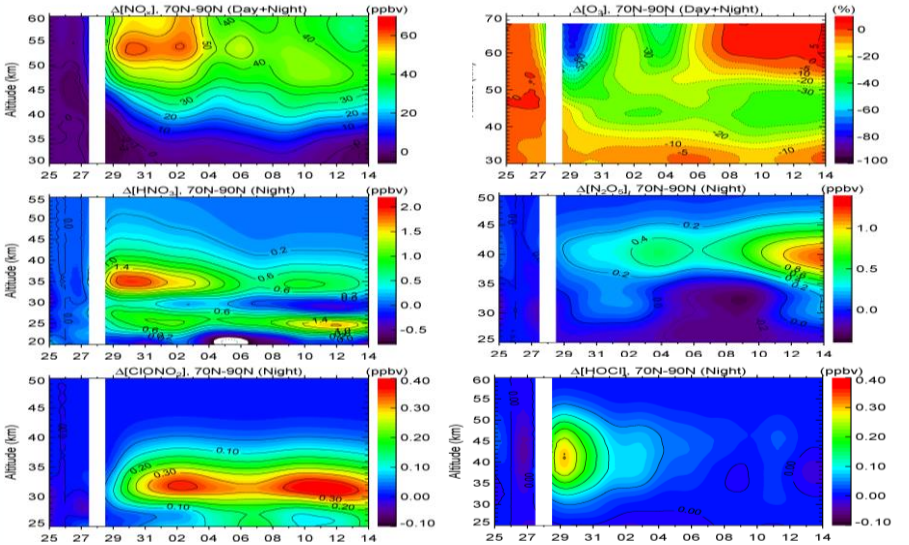

Arnone et al., 2012

## Brewer Dobson circulation




Stiller et al., 2012

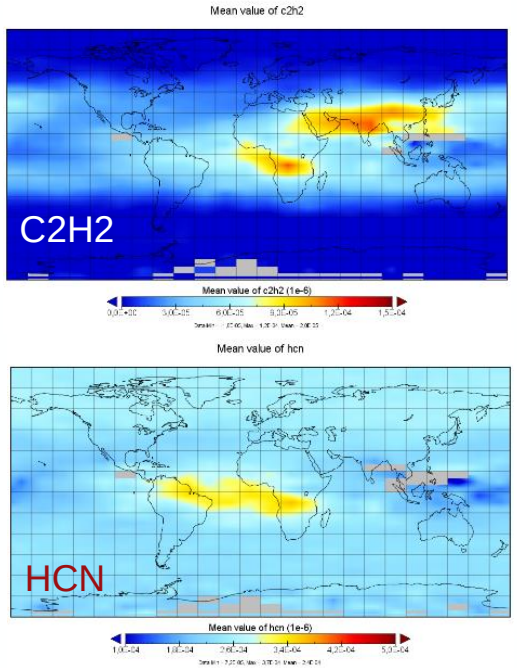
## Solar influence on atmospheric composition/ Non- LTE




*Funke et al., 2014*

# 10 years of MIPAS measurements on ENVISAT: many L2 algorithms, many results

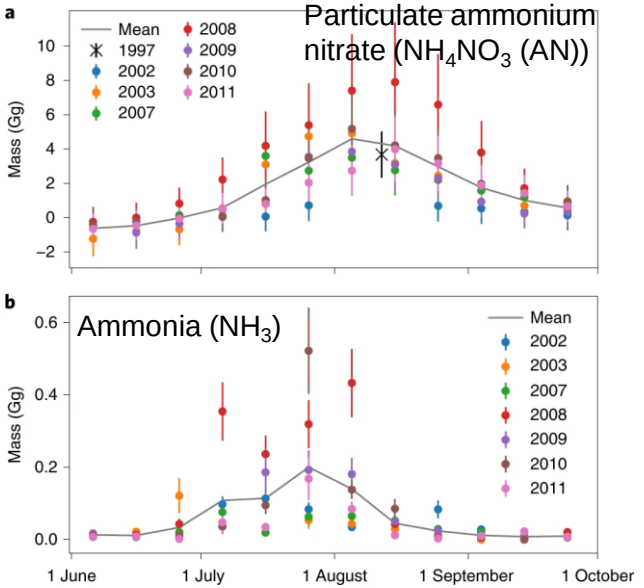
## Upper tropospheric pollution




Average of September V8 L2 data

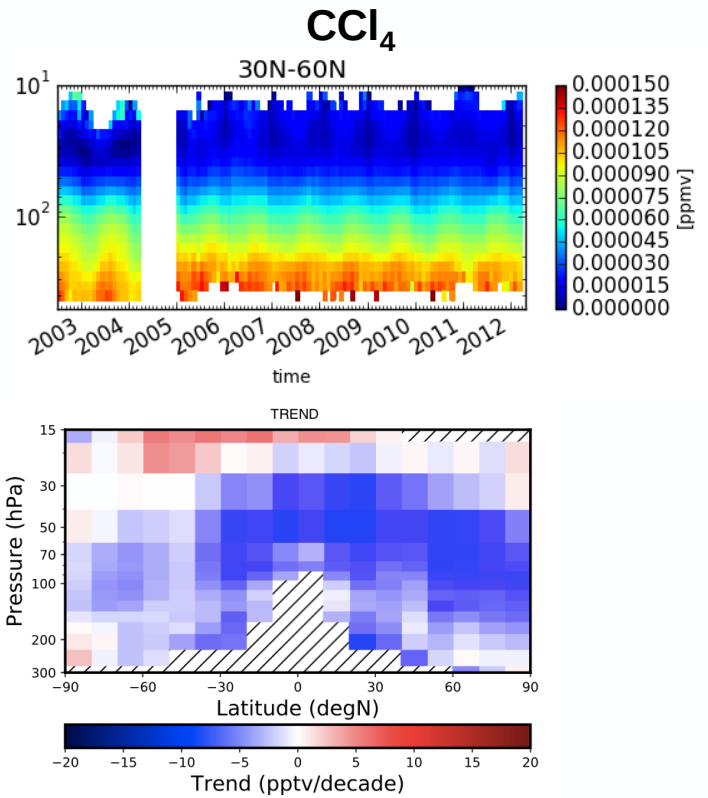
*Glatthor et al., 2007,2015*

## Aerosols in the UTLS




*Höpfner et al., 2019*

## Stratospheric trend of long-lived green house gases




Valeri et al., 2017

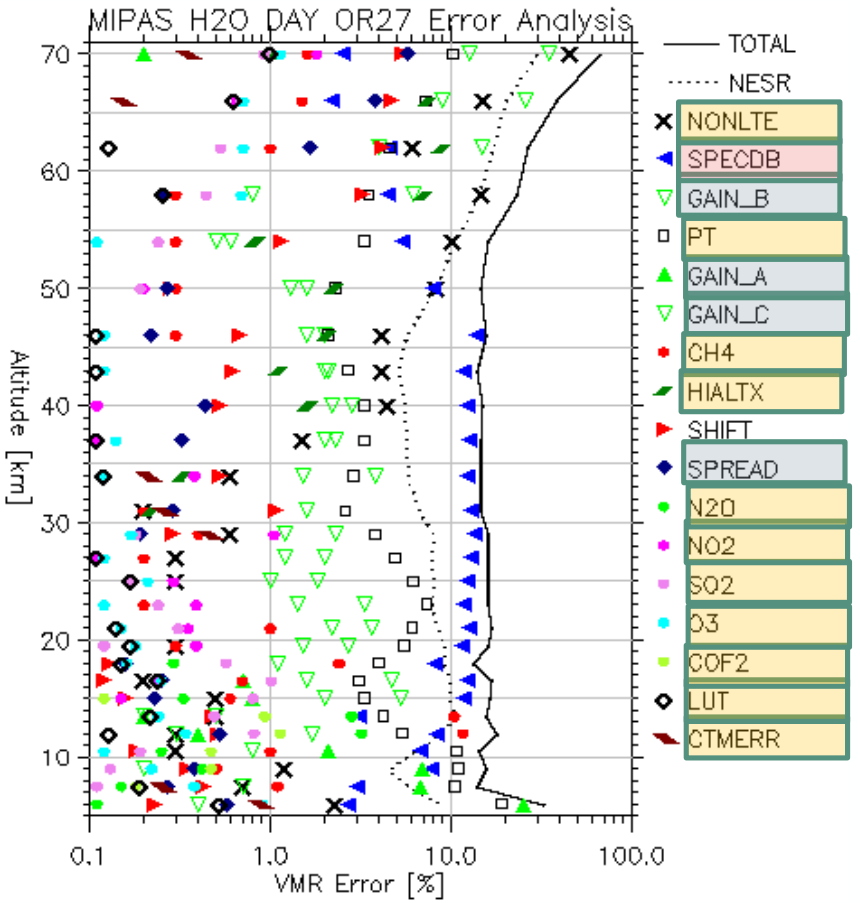
# Activities for improving MIPAS data supported by ESA: latest Level 1 and Level 2 re-processing

The quality of MIPAS L2 products depends on:

- quality of L1 products (Kleinert et al., 2018)

- L2 modelling
- Spectroscopy

} (Raspollini et al., 2022)

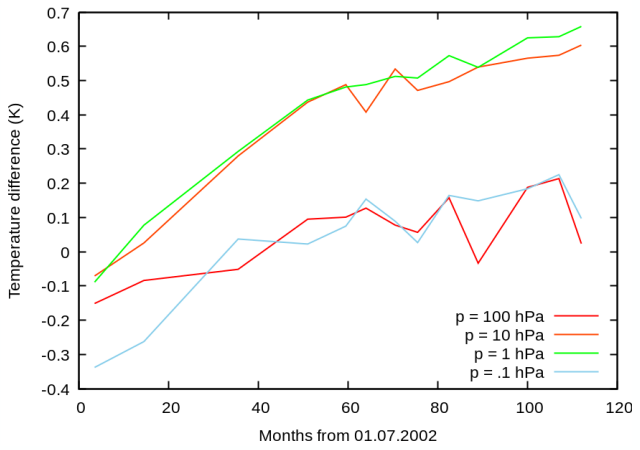


# Main improvements in L1 database

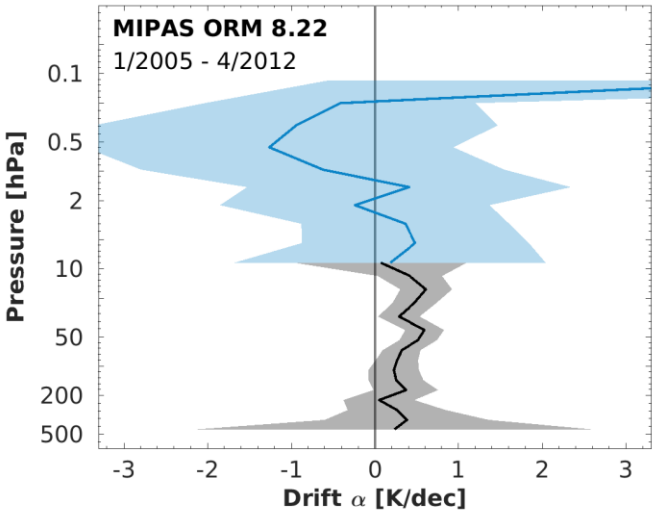
## Improvements in temporal stability of the measurements

**Instrumental drift reduction** through a time dependent Non-Linearities correction

Impact on temperature

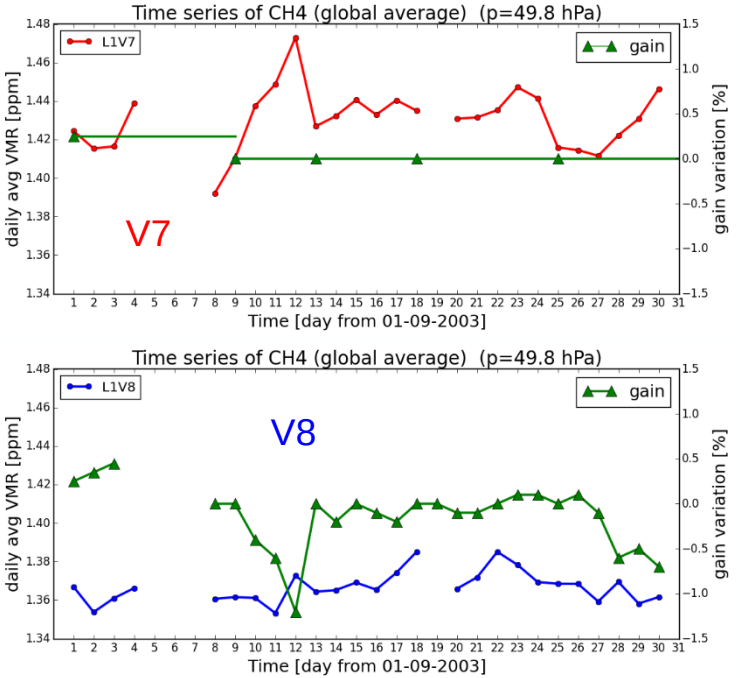



Small residual drift



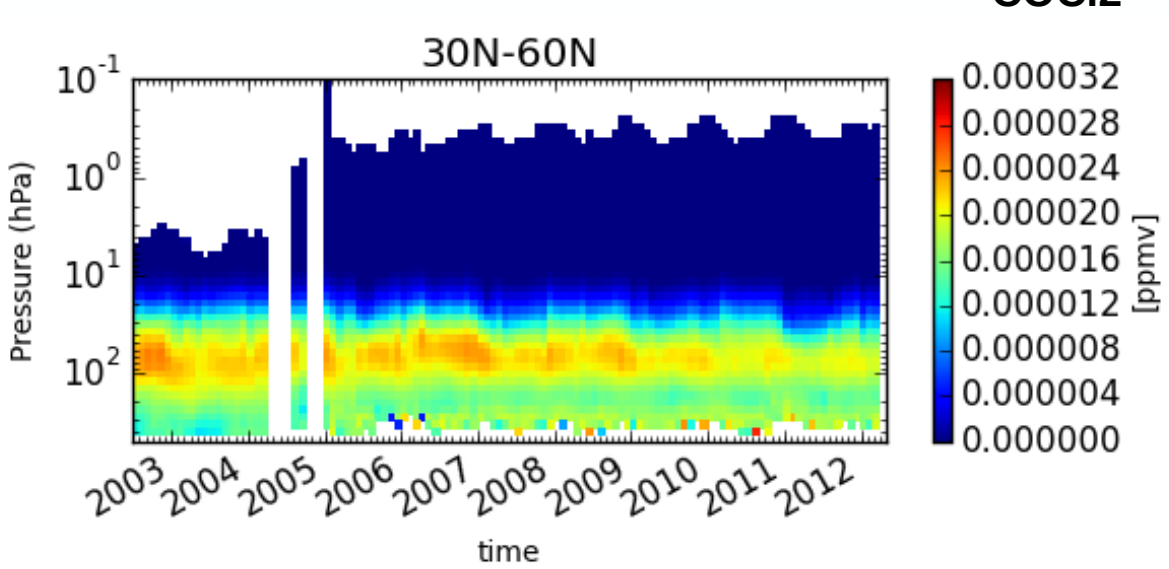

Drift of MIPAS V8.22 temperature versus sonde (lower plots) and lidar (upper plots) networks over the full phase of the mission. The shaded area represents the estimated 95% confidence interval. Positive drift values indicate that MIPAS temperature biases become progressively more positive over time wrt reference. Hubert et al., 2020

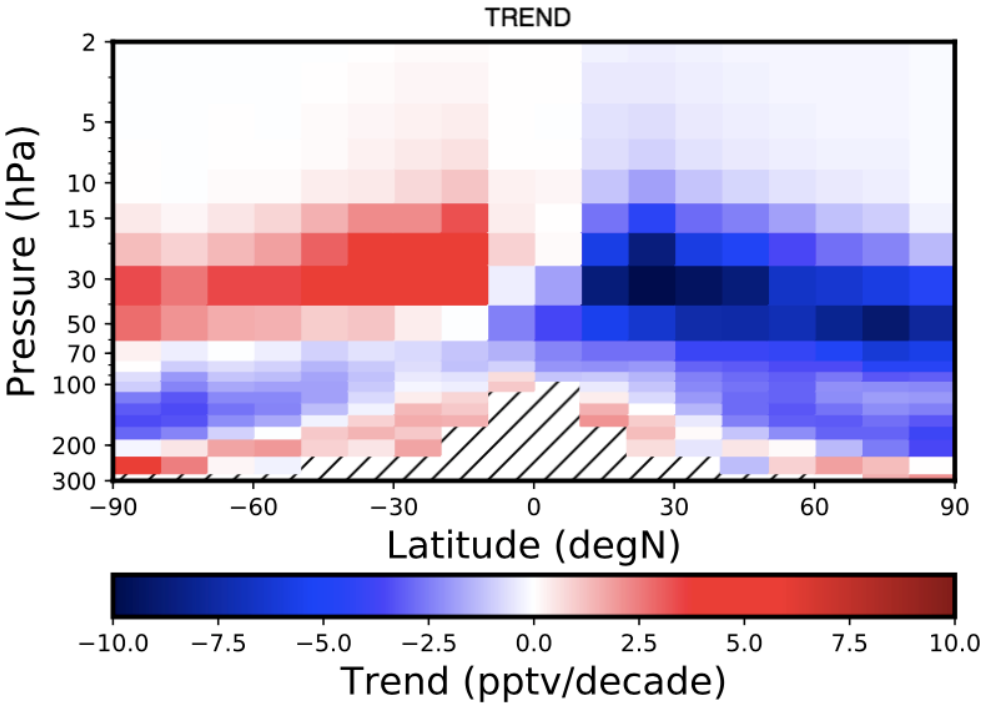
**Improved gain calibration**. Gain was measured on a daily basis, but until L1V7, it was updated only on a weekly basis. Band B gain has some jumps, especially after decontamination periods.



# Drift correction and study of trends

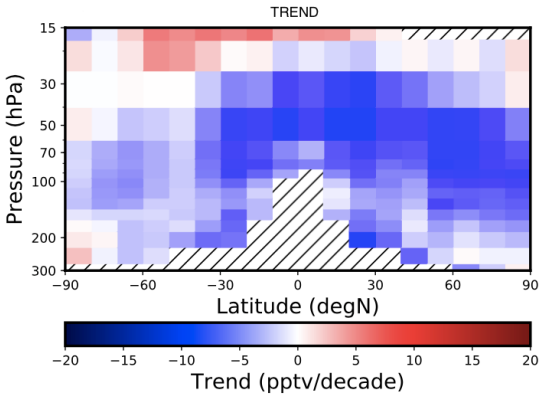
**COCl2**



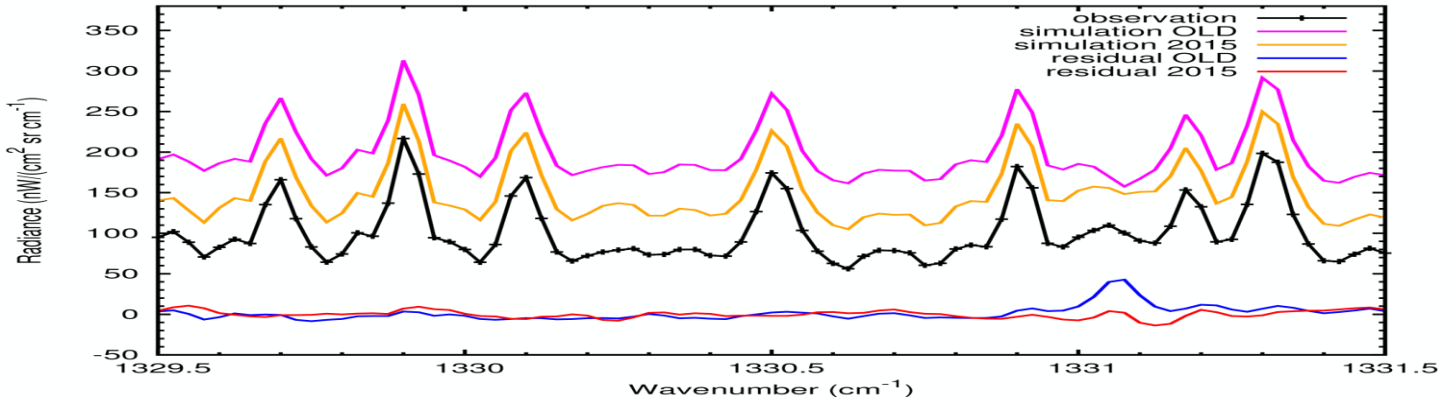




Pettinari et al., 2021

**CCl4**



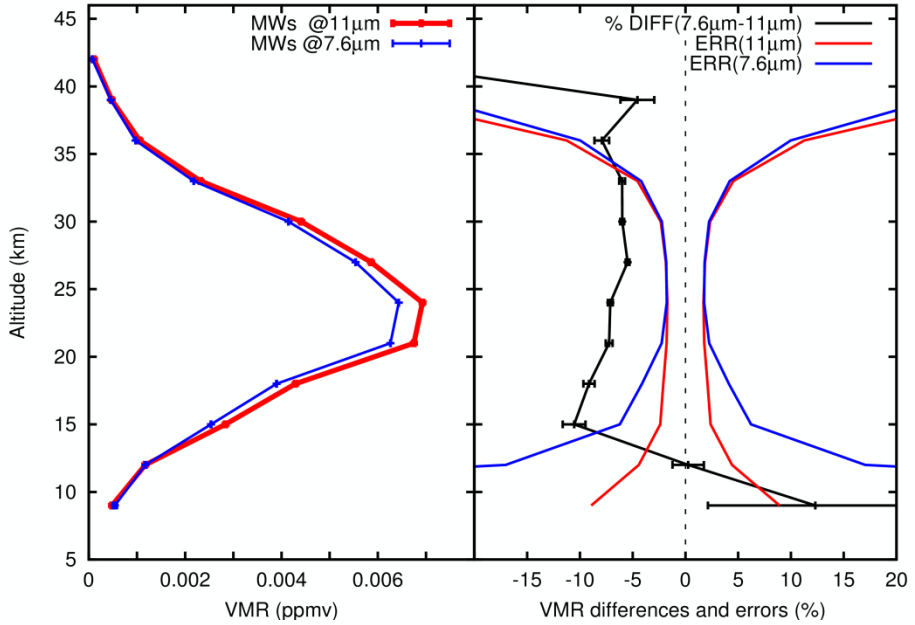
# Improvements in spectroscopy



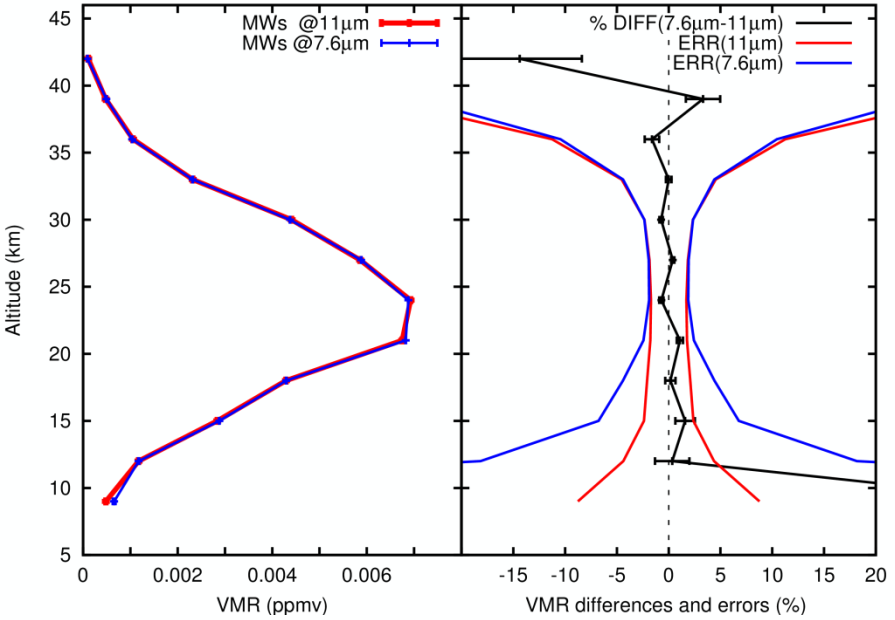

Improved HNO3 spectroscopy at 7.6 μm leads to smaller residuals and better consistency between the 11 and 7.6 μm regions

Perrin et al., 2016

**BEFORE THE CURE**




**AFTER THE CURE**



# Improvements in L2 processor

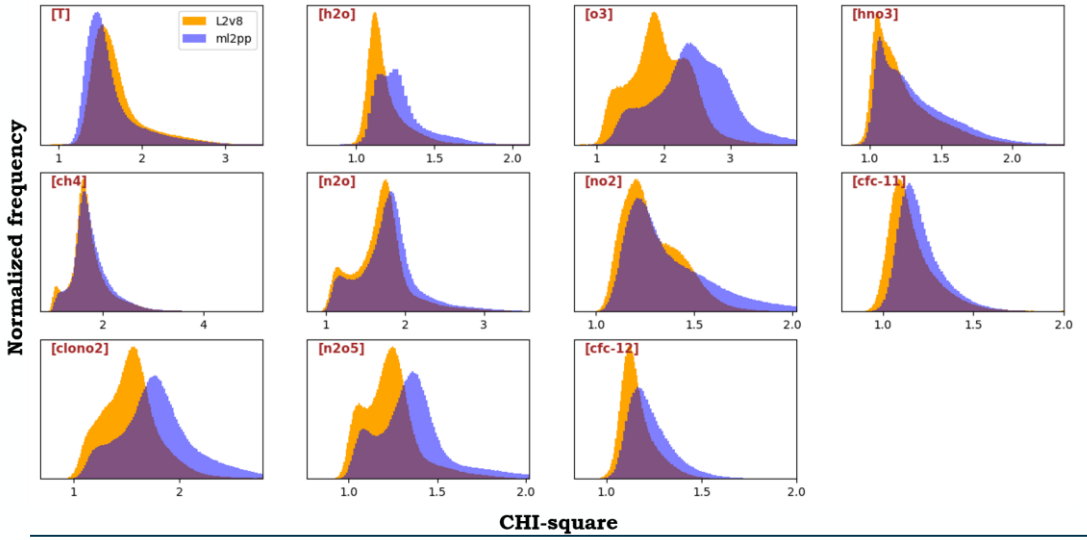
Improved modelling of the measurements using:

- State of the art of the atmosphere (new Initial Guess database) for handling interfering species,

https://earth.esa.int/eogateway/instruments/mipas/products-information?text=mipas

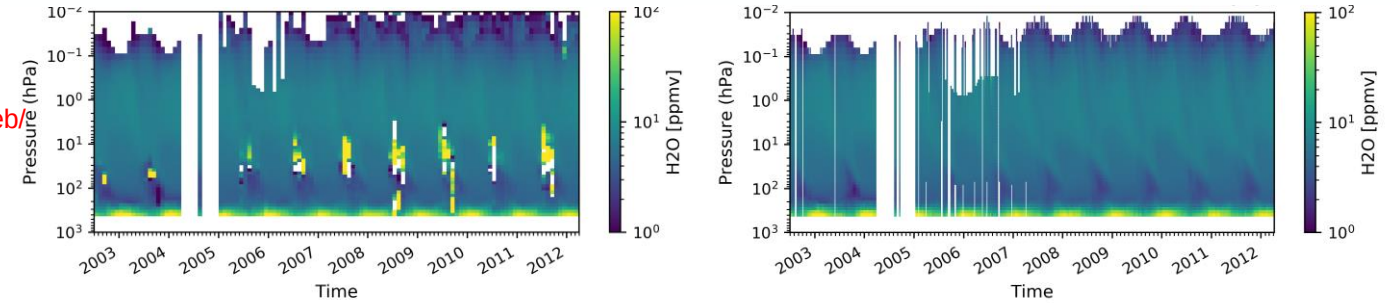
- improved spectroscopic database, https://earth.esa.int/eogateway/web/guest/instrument/mipas/mipas-spectroscopic-databas
- handling of the horizontal inhomogeneities along the line of sight in the forward model

is proven by a reduction of chi-square

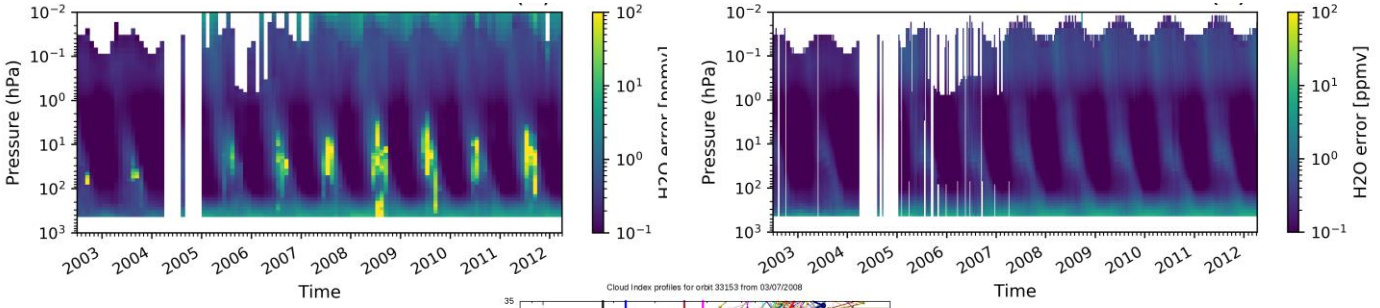


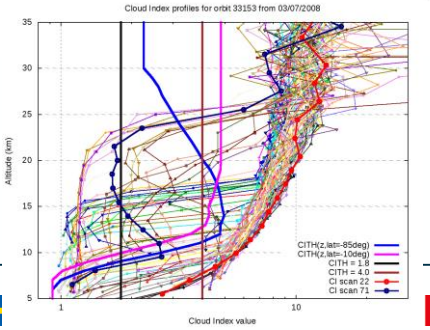

Reduction of the outliers through the use of altitude and latitude dependent cloud filtering

Time series of monthly mean V8 H2O profiles in the latitude belt from 60S to 90S before and after the cure



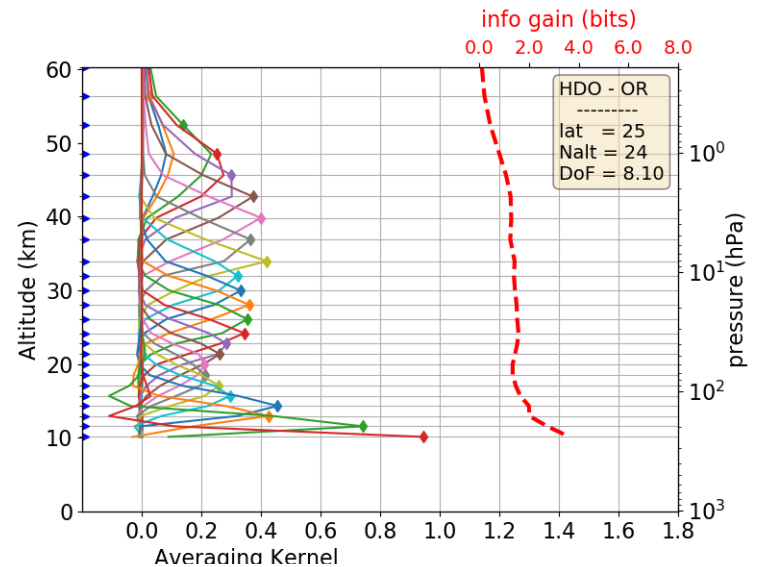

Time series of monthly mean V8 H2O error profiles in the latitude belt from 60S to 90S before and after the cu

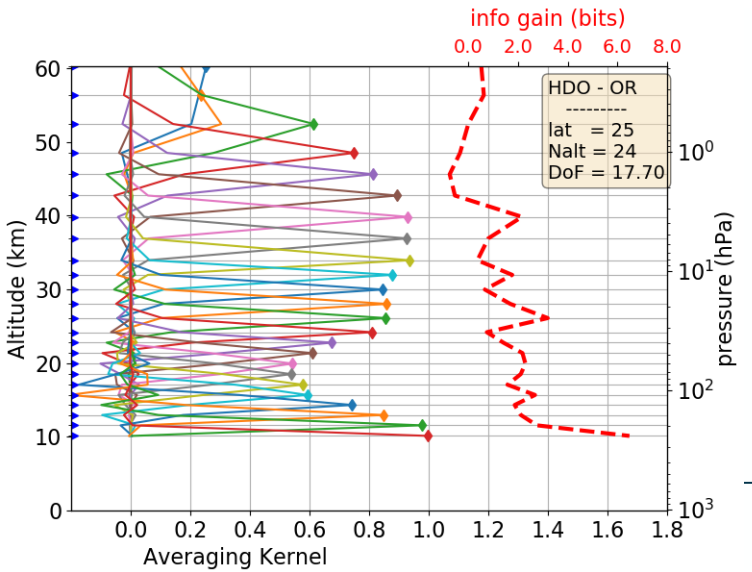


# L2 processor: retrieval of weak species

HDO retrieval

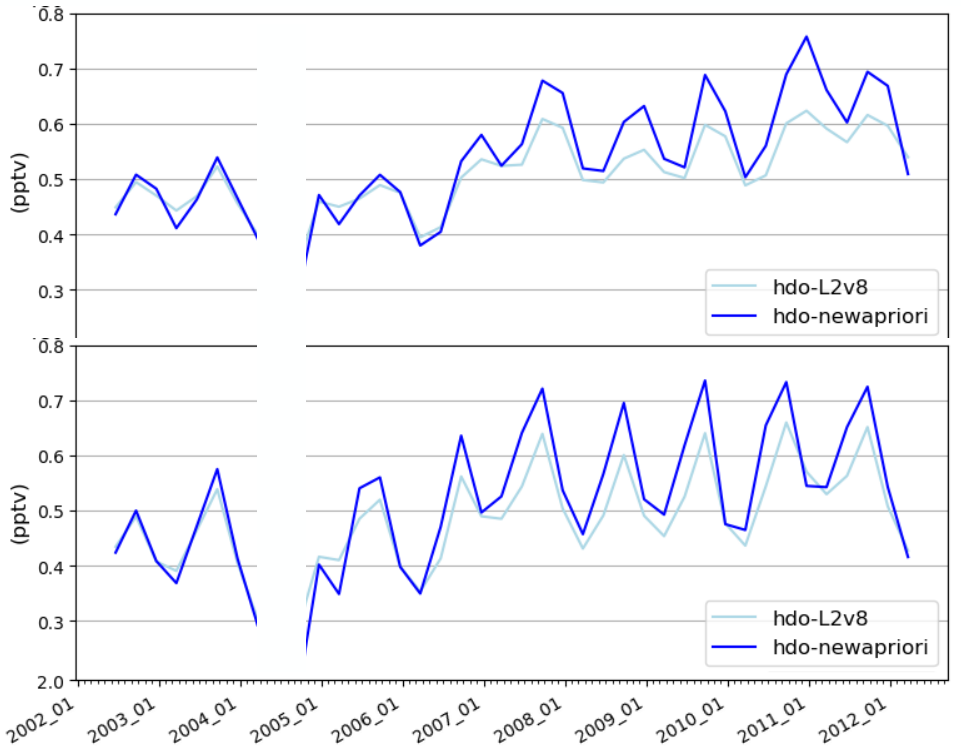



Time series of HDO with and without correction

59 hPa

69 hPa

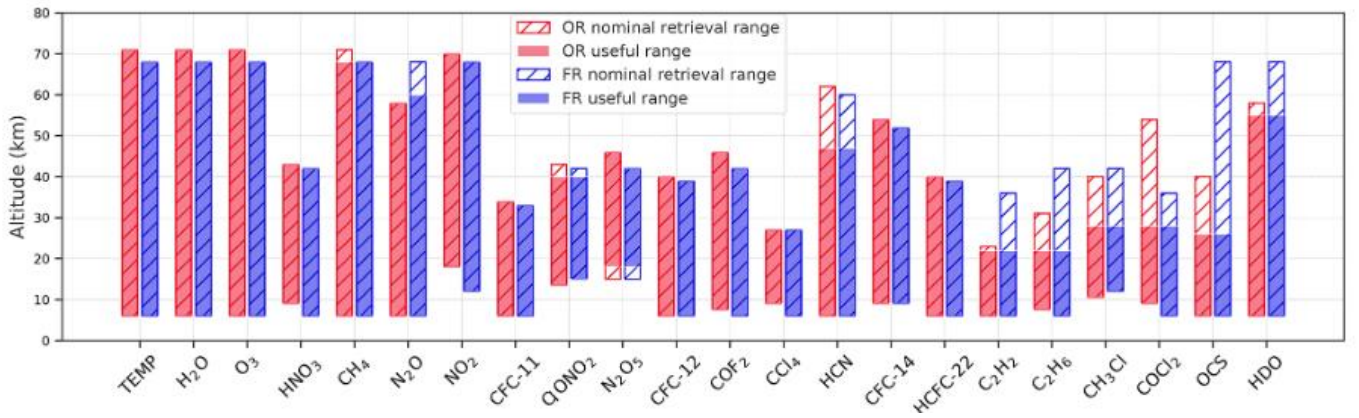



*For the species retrieved with OE, an a posteriori method for managing the a priori information contribution can be applied (Ceccherini et al., 2014). and complete data fusion (CDF) procedure can be used to combine different measurements*

# The ESA Level 1 and Level 2 v.8 datasets

Both L1 and L2 Data can be obtained from
https://earth.esa.int/eogateway/missions/envisat/data
after registration
(see ESA, 2021).

L2 data in NetCDF




*Dinelli et al., 2021*

Include the profiles at tangent pressures of:

atmospheric temperature;

VMRs of the following species:

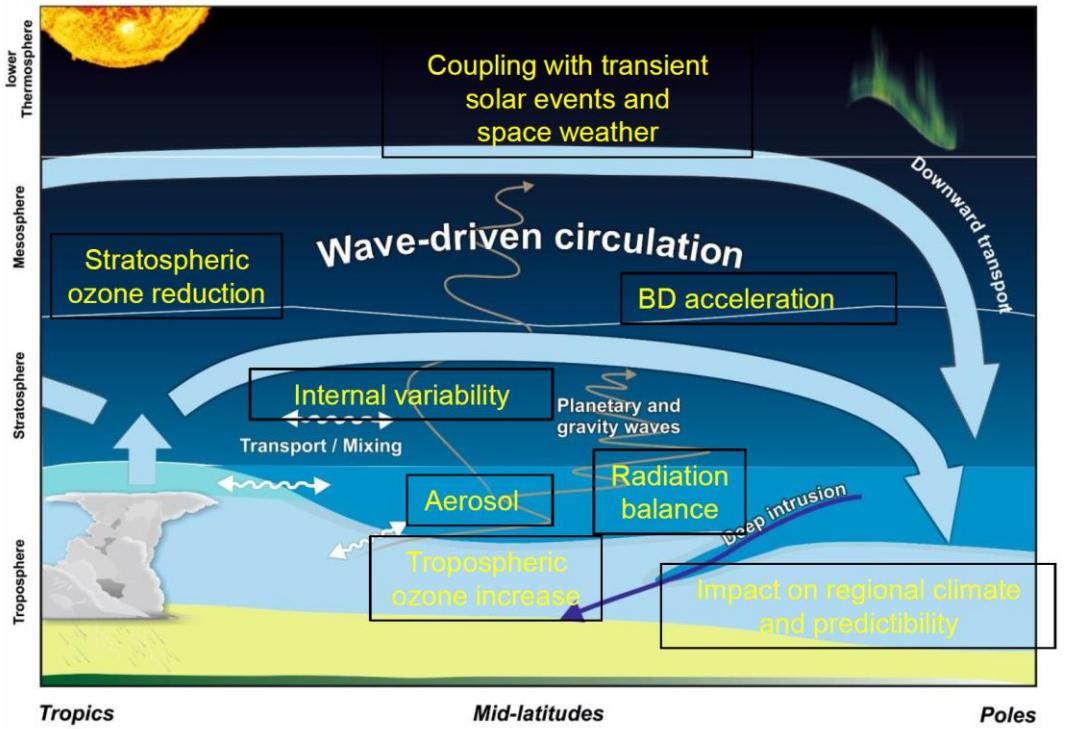
$H_2O$, $O_3$, $HNO_3$, $CH_4$, $N_2O$, $NO_2$, CFC-11, $ClONO_2$, $N_2O_5$, CFC-12, COF2, $CCl_4$, $CF_4$, HCFC-22,
*retrieved using the regularising Levenberg–Marquardt method*

HCN, CFC-14, $COCl_2$, $CH_3Cl$, $C_2H_2$, $C_2H_6$, OCS, HDO
*retrieved using the Optimal Estimation Marquardt method*

# MIPAS measurements as a benchmark for future missions (e.g. CAIRT)

**The Changing-Atmosphere InfraRed Tomography explorer CAIRT** is one of the four candidates selected for phase 0 of ESA Earth Explorer 11. It aims to provide a holistic view of the entire atmosphere from the troposphere to the lower thermosphere and, by measuring temperature and atmospheric composition with unprecedented spatial and vertical resolutions, to understand the processes that couple atmospheric circulation, chemistry, composition and regional climate change.

| Objectives | Measurement |
|---|---|
| Middle-atmosphere circulation | age-of-air from SF6, and other long-lived trace gases time series. |
| Waves driving the Middle Atmosphere Circulation | temperature observations at unprecedented scales |
| Changes in stratospheric ozone due to circulation and chemistry | O3, CFC-11, CFC-12, ClONO2, HNO3, N2O, H2O, and CH4 |
| Impact of transient solar events and space weather on stratospheric ozone and natural climate variability | NOy, CO and CH4 |
| Budget and origin of UTLS aerosol composition and impact on regional climate | OCS, SO2, H2SO4 and extinction |
| UTLS variability, STE and impact on tropospheric composition and air quality | temperature, H2O, O3, CH4, CO, HNO3, CFC-11, HCN, NO2 and PAN |

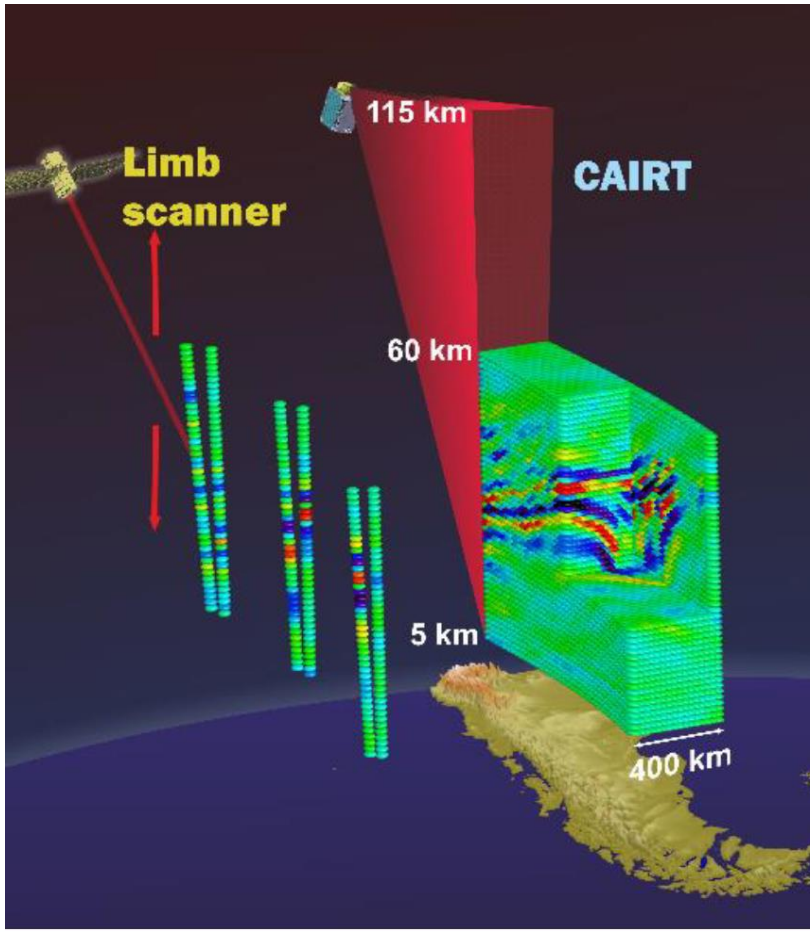



Sinnhuber et al., CAIRT Presentation Wednesday at 4:10 pm

# CAIRT vs MIPAS

CAIRT will be the first limb-sounder with imaging Fourier-transform infrared technology in space

| | MIPAS | | CAIRT |
|---|---|---|---|
| | 2002-2004 | 2005-2012 | |
| Spectral resolution | 0.025 $cm^{-1}$ | 0.0625 $cm^{-1}$ | 0.1 (0.2) $cm^{-1}$ |
| Altitude range | 6-70 for nominal modes, 40-172 km for UA modes | | 5-115 km |
| Spectral range | 685-2410 $cm^{-1}$ (14.6 -4.15 µm) | | 720-2200 $cm^{-1}$ |
| time / full altitude measurement | 75 s. | 48 s. | 7 s. |
| Vertical sampling (nominal mode) | 3 km | 1.5 km | 1 km |
| Horizontal (along track) sampling | 500 km | 410 km | 50 km |
| FOV width / swath | 30 km | | 300 (500) km |
| NESR<br>Band A 685-970 $cm^{-1}$<br>….<br>Band C 1570-1750 $cm^{-1}$<br>..... | <br>30 -40 nW/($cm^2$ sr $cm^{-1}$)<br><br>3-5 | <br>20-25<br><br>2-2.5 | Similar to MIPAS for the goal spatial sampling values (1 km x 50 km x 50 km) |



# Synergy between limb and nadir measurements

## CAIRT will fly in loose-formation with MetOp-SG, for exploiting the synergy with IASI-NG and Sentinel-5 measurements

Limb and nadir measurements can be combined in a synergistic way for improving information in the troposphere (example with IASI and MIPAS)

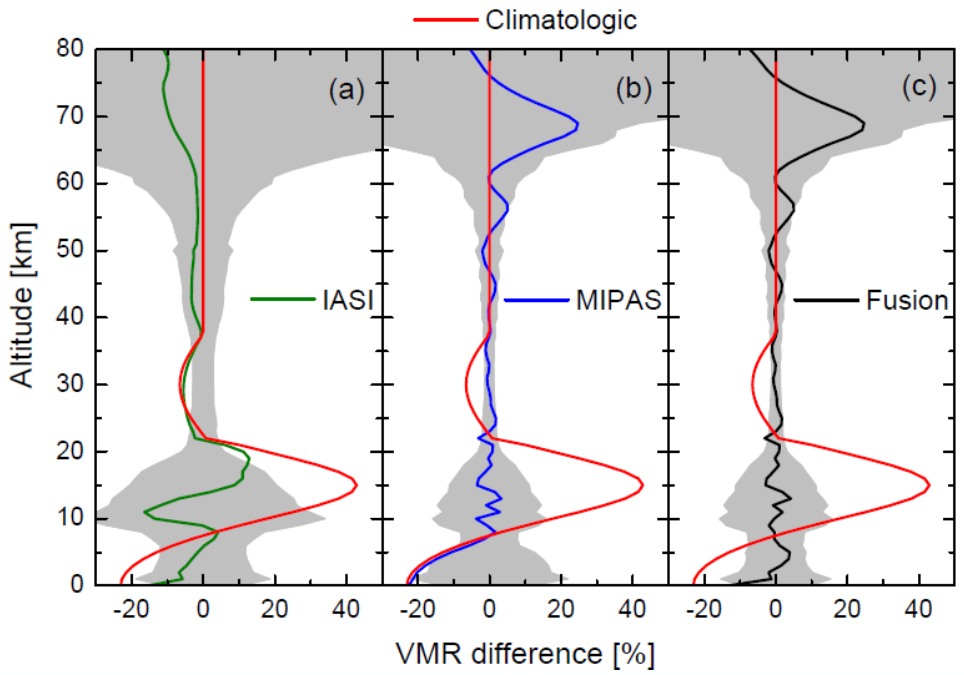



**Table 1.** Information gain and number of degrees of freedom for the profiles retrieved from simulated measurements using only the IASI measurement, only the MIPAS measurement and the IASI-MIPAS data fusion.

| | Information gain [bit] | n. of degrees of freedom |
|---|---|---|
| IASI | 11.0 | 3.7 |
| MIPAS | 59.2 | 21.7 |
| Fusion | 62.1 | 22.6 |

S. Ceccherini et al., ACP, 2010

See poster today: Raspollini et al., Session A1.03

# Possible further improvements of MIPAS data

A problem was found, after full mission reprocessing, in the L1 V8 data, consisting in the fact that about 4% of the scans of MA, 4,7% of the scans in NLC e 1.4% of the scans in UA have one tangent altitude set to 0, generally the one with nominal tangent altitude equal to 85 km. The problem is linked to a bug in the Envisat CFI software which has been now identified and corrected.

Given the significant percentage of L1b spectra (mainly in middle atmosphere MA/UA/NLC modes) and considering that missing these data would result in a serious limitation of the scientific value of the MIPAS special mode datasets, particularly due to the disturbed am/pm regular sampling, the QWG strongly recommended ESA to reprocess the affected orbits.

Just before this Conference ESA informed us about a reprocessing opportunity next year

# THANKS!!!!