Assessment of the Meteo France model with satellite Ozone products in the framework of the ESA-CCI program

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Description of Météo France models

- CNRM-CCM free run

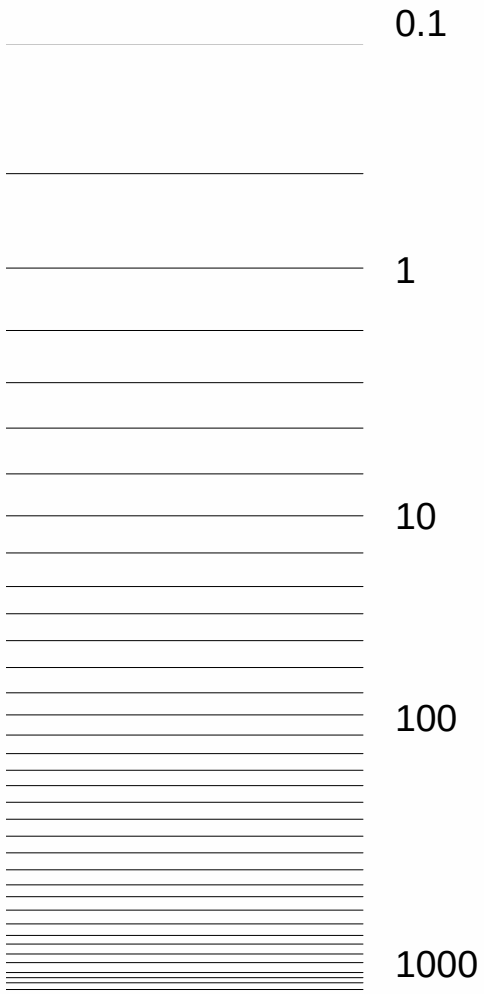
Chemistry Climate Model composed of the General Circulation Model ARPEGE-Climat, with detailed on-line stratospheric chemistry (Cariolle) tested in MOCAGE (see Michou and al. 2011 for the evaluation of this Model)

- Vertical resolution : 33 pressure levels (1000 to 0.1 hPa)
- Horizontal resolution : 2,8° x 2,8°.

- CNRM-CCM nudged

A new version of the model CNRM-CCM which is nudged towards the ERA-Interim reanalyses (temperature, wind and dynamic)

- Vertical resolution : 33 pressure levels (1000 to 0.1 hPa)
- Horizontal resolution : 2,8° x 2,8°



Tropospheric Ozone not considered

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p1

Abstract
This paper presents a new version of the M´ et ´eo-France CNRM Chemistry-Climate Model, so-called CNRM-CCM. It includes some fundamental changes from the previous version (CNRM-ACM) which was extensively evaluated in the context of the 5 CCMVal-2 validation activity. The most notable changes concern the radiative code of the GCM, and the inclusion of the detailed stratospheric chemistry of our Chemistry-Transport model MOCAGE on-line within the GCM. A 47-yr transient simulation (1960–2006) is the basis of our analysis. CNRM-CCM generates satisfactory dynamical and chemical fields in the stratosphere. Several shortcomings of CNRM-ACM simulations 10 for CCMVal-2 that resulted from an erroneous representation of the impact of volcanic aerosols as well as from transport deficiencies have been eliminated.
Remaining problems concern the upper stratosphere (5 to 1 hPa) where temperatures are too high, and where there are biases in the NO2, N2O5 and O3 mixing ratios.
In contrast, temperatures at the tropical tropopause are too cold. These issues are 15 addressed through the implementation of a more accurate radiation scheme at short wavelengths. Despite these problems we show that this new CNRM CCM is a useful tool to study chemistry-climate applications.
phulpin, 15/05/2013

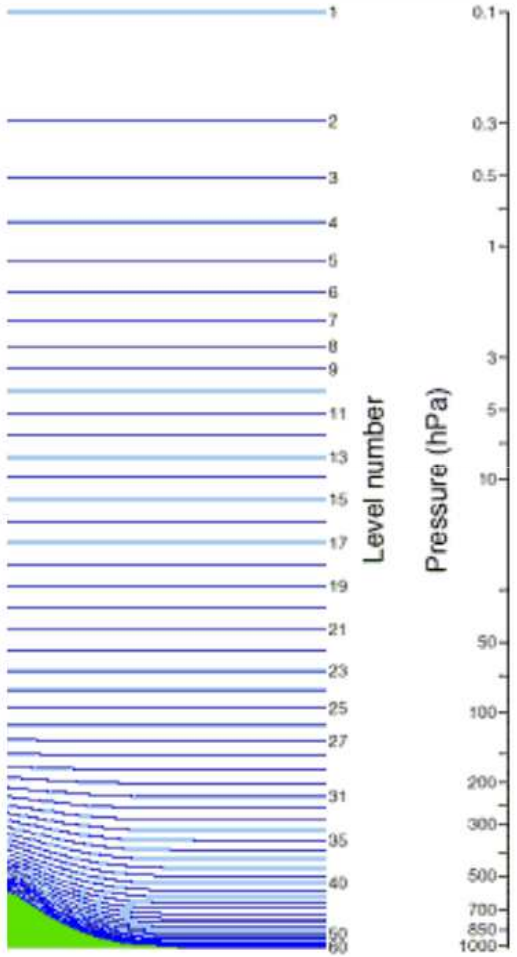
Description of Météo France models

- MOCAGE with the chemical scheme Cariolle

Chemistry transport Model developed at Meteo France and Cerfacs, also assimilated with IASI (troposphere) + MLS (stratosphere)

- Vertical resolution : 60 levels
- Horizontal resolution : 2° x 2°

Well suited for Air quality monitoring



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Description of ozone CCI products :

- The Ozone CCI data products are listed in the table below. All data sets are delivered in NetCDF-CF format and are compliant with CCI rules.

Limb profiles (LP)	
Level	**Instrument**
L2 (harmonized single instrument) and L3 (Monthly zonal mean)	SCIAMACHY
	GOMOS
	MIPAS
	OSIRIS
	SMR
	ACE
L3 (Monthly zonal mean)	MERGED
L3 (Semi-Monthly mean)	MERGED
L3 (Fine resolution merged data)	MERGED

Total columns (TC)	
Level	**Instrument**
L2	GOME
	SCIAMACHY
	GOME 2
L3	MERGED

Nadir profiles (NP)	
Level	**Instrument**
L2	GOME
	SCIAMACHY
	GOME2
L3	MERGED
L4	MERGED

Comparison of model outputs and CCI products : Limb-viewing ozone profiles

- Data used for Limb ozone profiles confrontation

  - Year 2008 (for the first stage)

  - Monthly model outputs
    - CNRM-CCM free run
    - CNRM-CCM nudged

  - CCI products
    - Monthly zonal mean limb products (L3) selected with a good coverage

      SCIAMACHY

      OSIRIS

      MIPAS

      MERGED product
    - Bi-weekly merged limb product (L3)

First comparison of model outputs and CCI products : Limb-viewing ozone profiles

- Mean error estimates compared to CMUG requirements
  - Example : profile of mean errors estimated (%) for the monthly zonal mean ozone for October 2008

Parameter	Application	Horizontal Resolution (km)	Vertical Resolution (km)	Observing Cycle (h)	Precision (%)	Accuracy (%)	Stability (%)	Types of error
Ozone profile								
Higher stratosphere & mesosphere (HS & M)	Model Development and Evaluation	500	3	48	15	15%	3.0 %/decade	SSEOB
	Reanalysis and Data Assimilation	100	1	6	5	5%	1.0 %/decade	SSEOB
Lower stratosphere (LS)	Model Development and Evaluation	100	2	72	15	15%	3.0 %/decade	SSEOB
	Reanalysis and Data Assimilation	75	1	6	5	5%	1.0 %/decade	SSEOB
Higher troposphere (HT)	Model Development and Evaluation	100	2	72	20	20%	3.0 %/decade	SSEOB
	Reanalysis and Data Assimilation	20	1	6	5	5%	1.0 %/decade	SSEOB
Lower troposphere (LT)	Model Development and Evaluation	50	2	72	20	20%	3.0 %/decade	SSEOB
	Reanalysis and Data Assimilation	10	1	3	10	10%	1.0 %/decade	SSEOB

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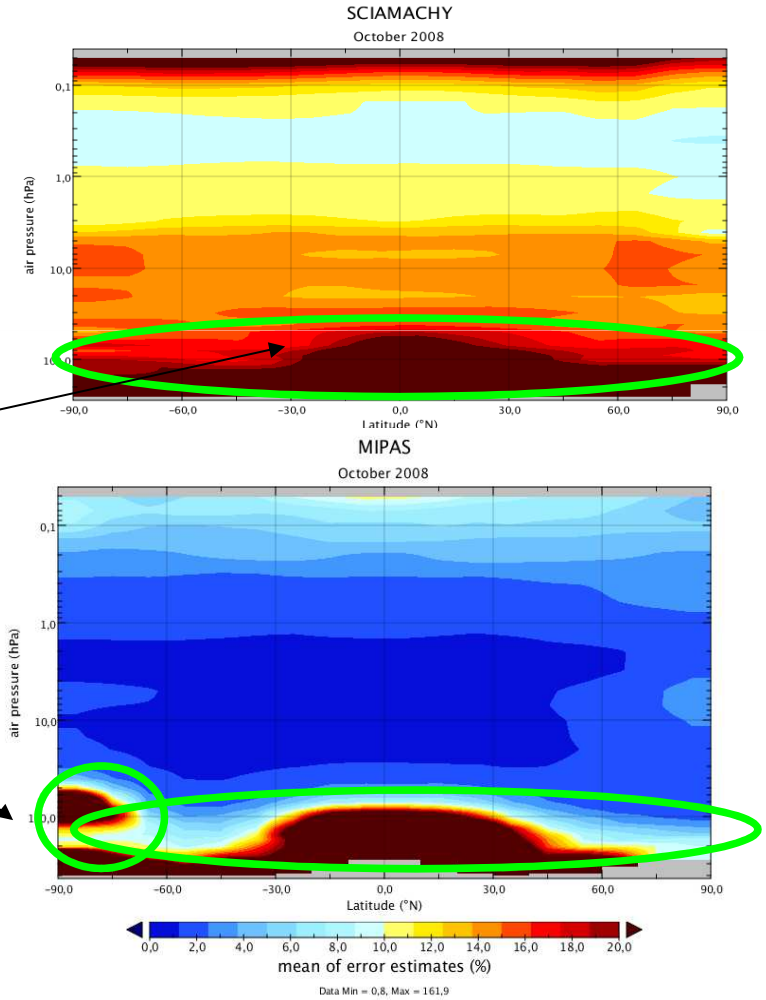
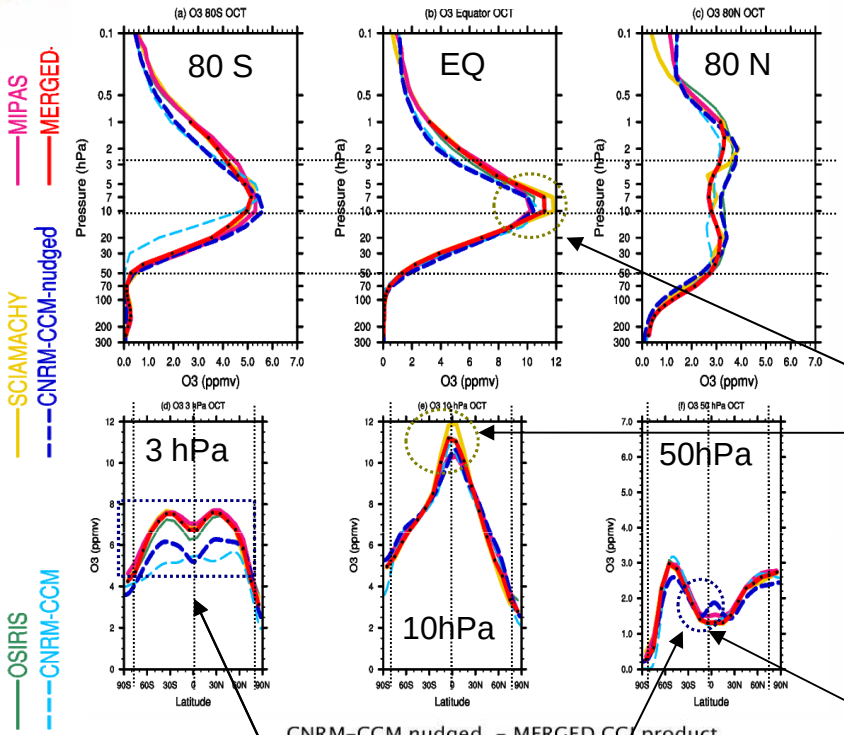


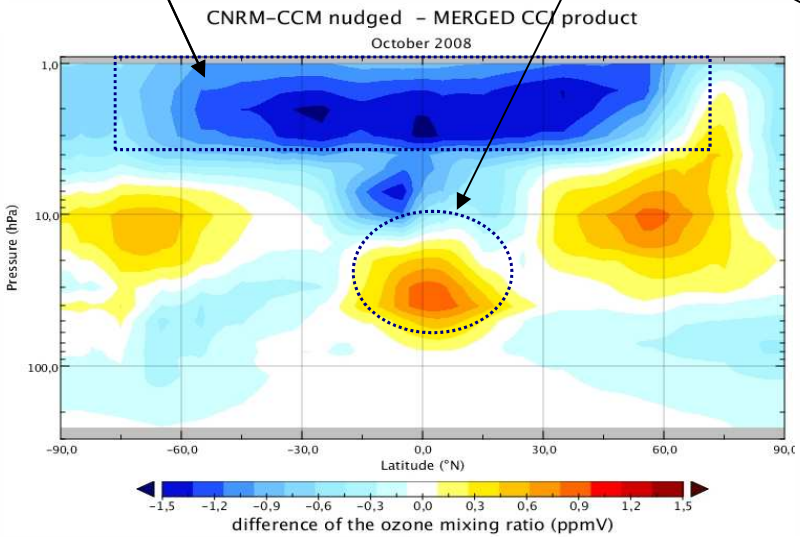
First comparison of model outputs and CCI products : Limb-viewing ozone profiles

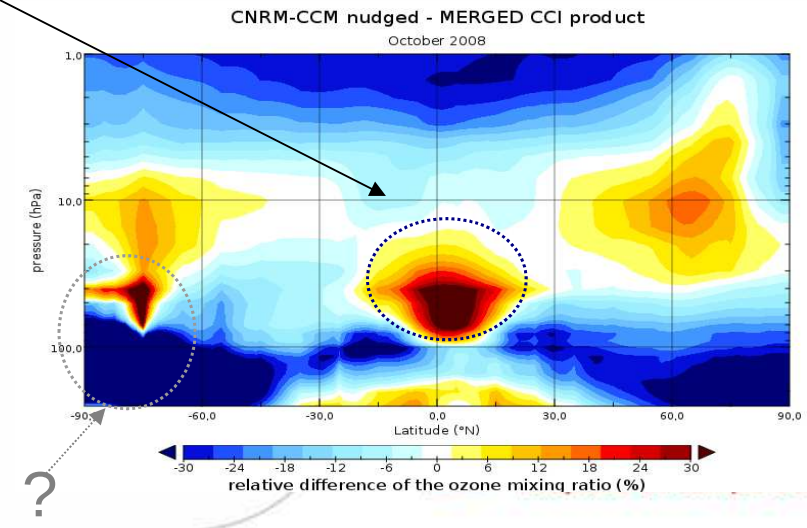
October 2008



- Spatial comparison of zonal mean ozone mixing ratios in October 2008
  - Significant bias
    - 1-5 hPa
    - Around 50 hPa at Equator
  - Dispersion of CCI products
    - 2 ppmv between MIPAS and SCIA at 10 hPa around Equator

In most cases the causes of discrepancies between model and observations are not explained. More detailed uncertainties of observations are needed.





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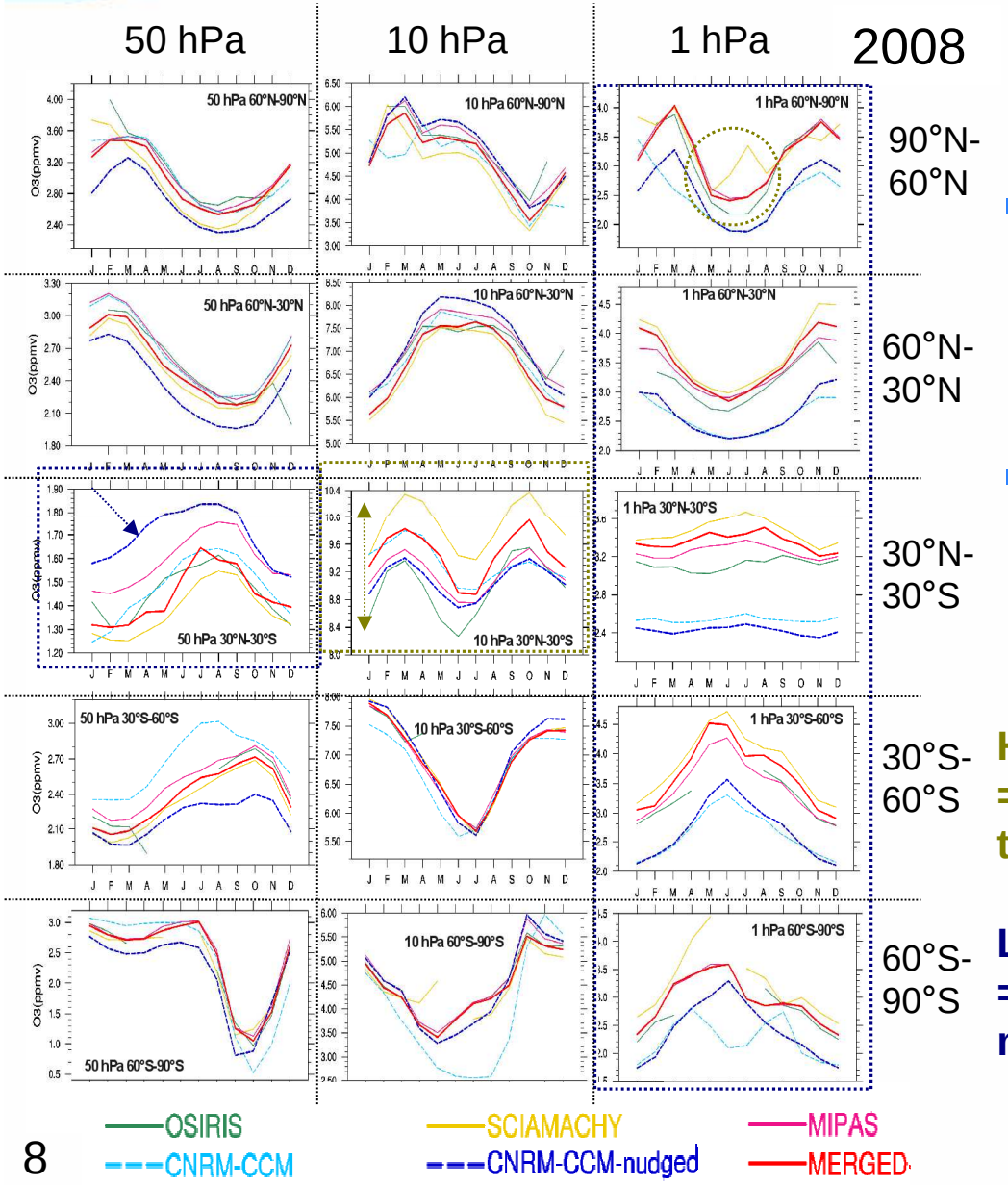
First comparison of model outputs and CCI products : Limb-viewing ozone profiles



Temporal comparison :

- Only LS & HS (50, 10 and 1 hPa) because of large errors estimated in HT for limb products
- Annual cycle of the monthly zonal mean ozone mixing ratios (ppmv)
  - Annual variations reproduced
  - Bias observed

High dispersion of values for CCI products => Comparison with model should be taken carefully

Low dispersion of values for CCI products => Analysis with model are probably more meaningful

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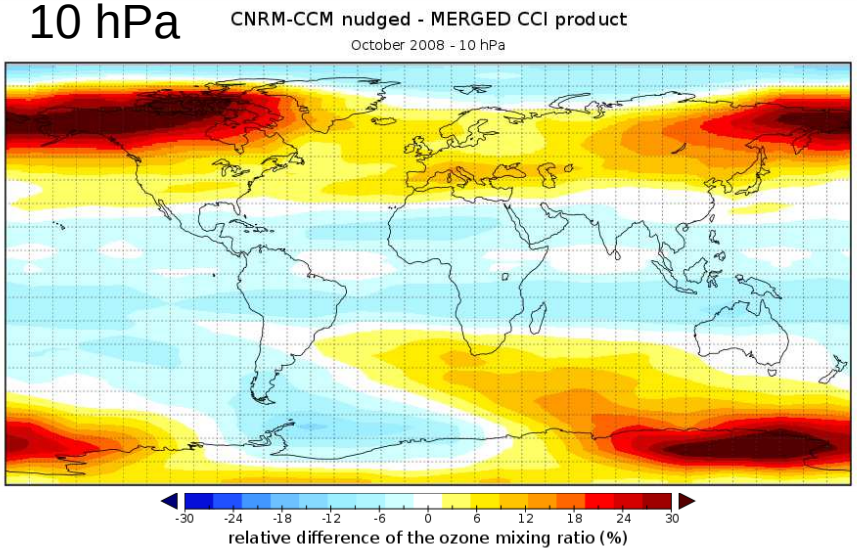
First comparison of model outputs and CCI products : Limb-viewing ozone profiles

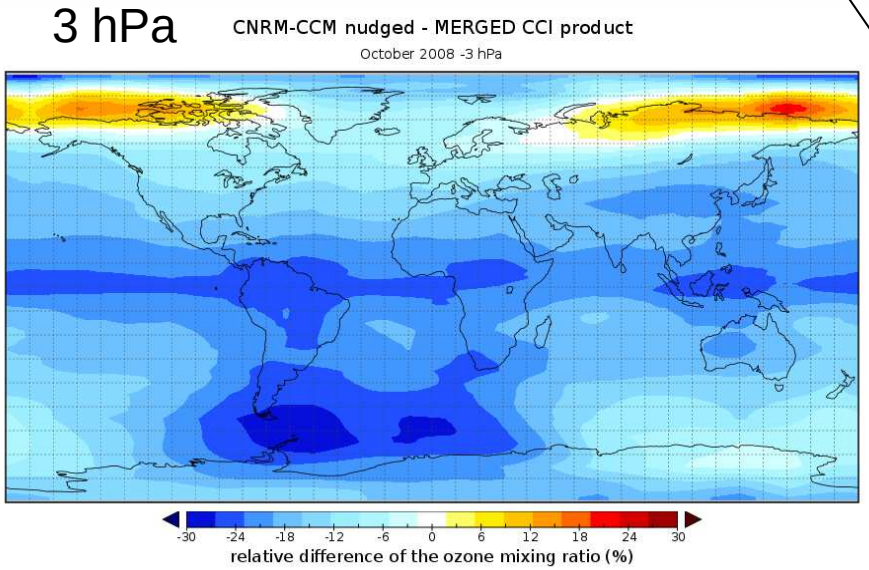
- Spatial comparison of monthly ozone mixing ratios in October 2008 at level pressure 50, 10 and 3 hPa using the semi-monthly product

- Spatial resolution limited => Use nadir profiles (later)
- Zonal mean can raise interrogation !

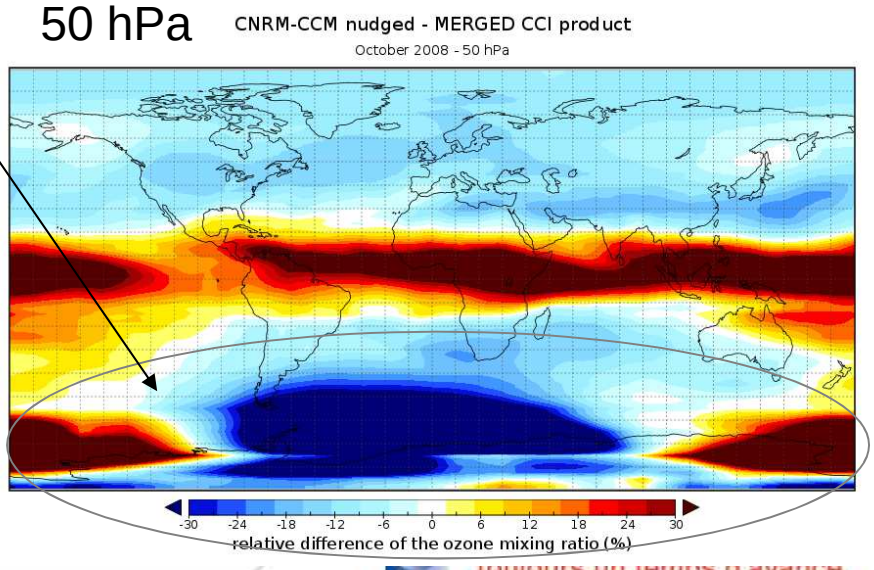
10 hPa



3 hPa



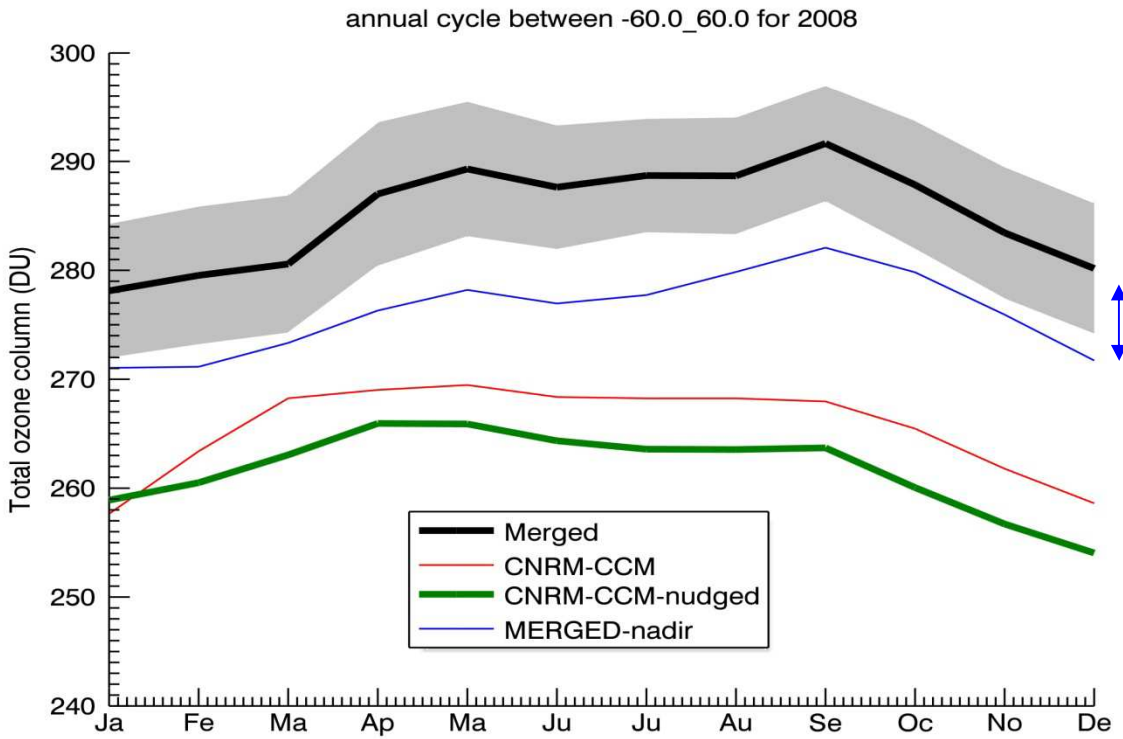
50 hPa



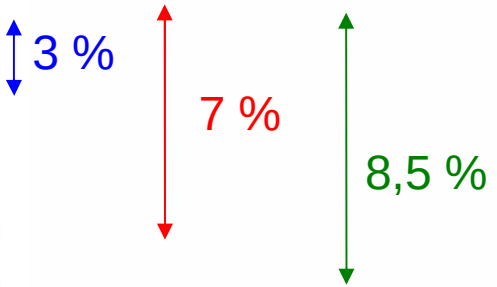
Comparison of model outputs and CCI products : Total columns ozone

Annual cycle comparison of total columns (DU) for 2008 at 60°S and 60°N

- Monthly total column of the nadir product and monthly total column product have a bias (3%)
- CNRM-CCM model outputs have a more important bias and decreases for J J A S



Relative difference for 2008 between 60°S and 60°N



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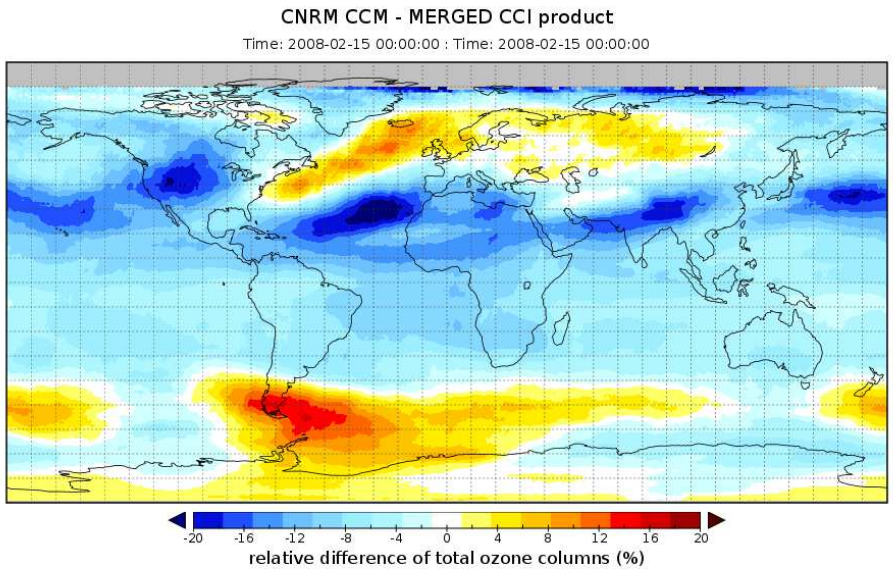
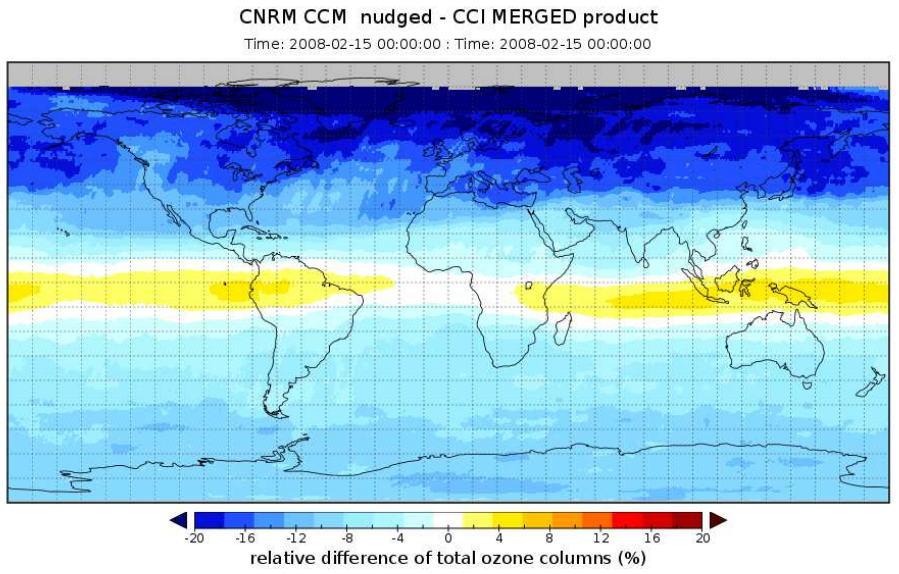
Comparison of model outputs and CCI products : Total columns ozone

- Spatial comparison of monthly total columns for the year 2008
  - CNRM-CCM free run vs MERGED CCI product
  - CNRM-CCM nudged vs MERGED CCI product
    - Model is overestimating around the Equator
    - Model is underestimating following season in the high latitude

Some artifacts are visible in CCI products





Slide 11

PJ1 Movies :
CNRMCCM-MERGED_2008.mov
CNRMCCMNUDGED-MERGED_2008.mov

PRIOUL Jean-Charles, 30/05/2013

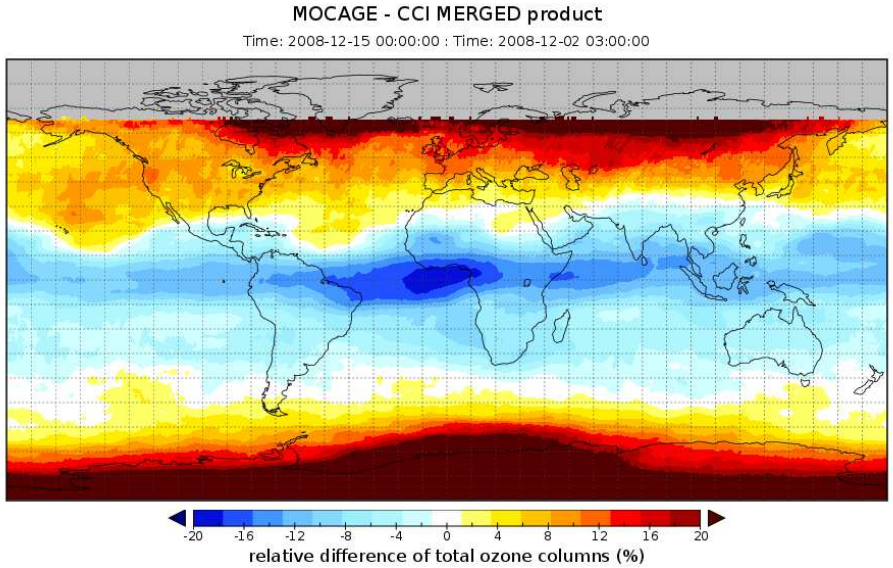
Comparison of model outputs and CCI products : Total columns ozone

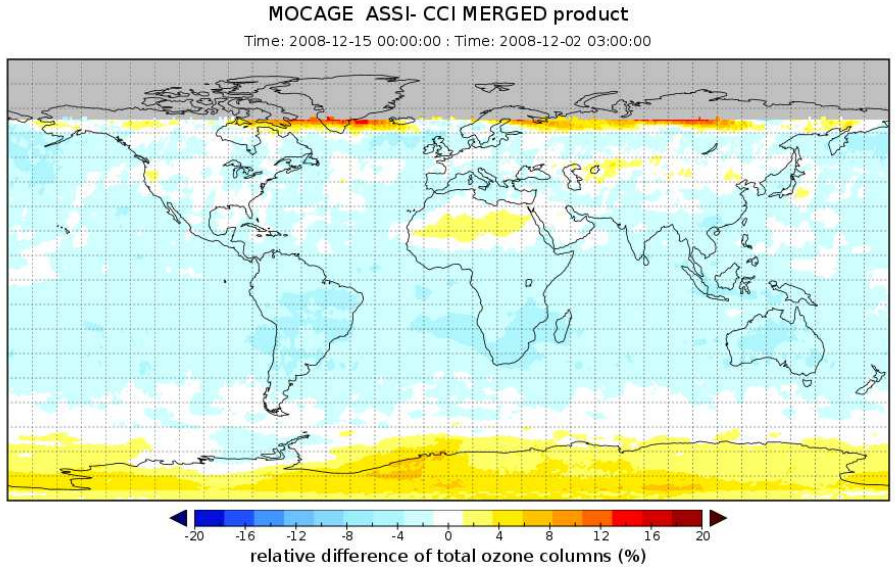
Spatial comparison of monthly total columns for the year 2008

(only J J A S O N D)

- MOCAGE free run vs CCI MERGED product
- MOCAGE assimilated with MLS + IASI vs CCI MERGED product
  - Assimilation in the model decreases the bias (only 3% of difference)

Some artifacts are visible in CCI products





Slide 12

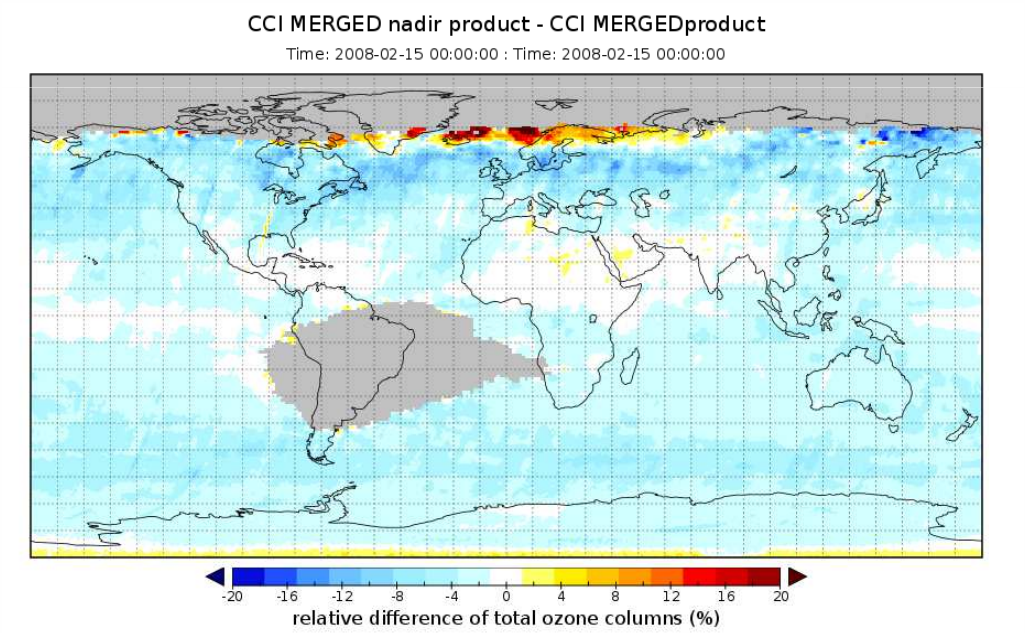
PJ1

Movies :
MOCAGEASSI-MERGED_JJASOND2008.mov
MOCAGE-MERGED_JJASOND2008.mov

PRIOUL Jean-Charles, 30/05/2013

Comparison of model outputs and CCI products : Total columns ozone

- Difference between the monthly total column of the nadir product and monthly total columns product for the year 2008
  - Approximately 6 % of difference



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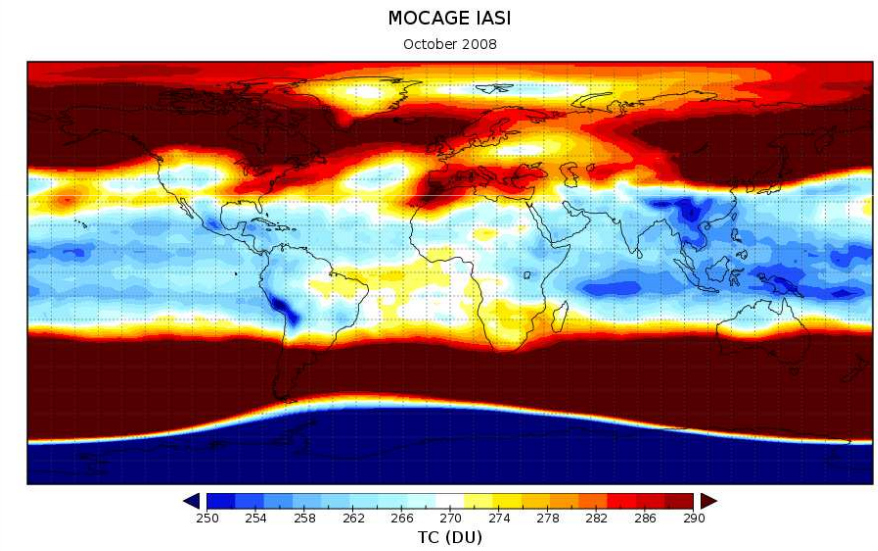
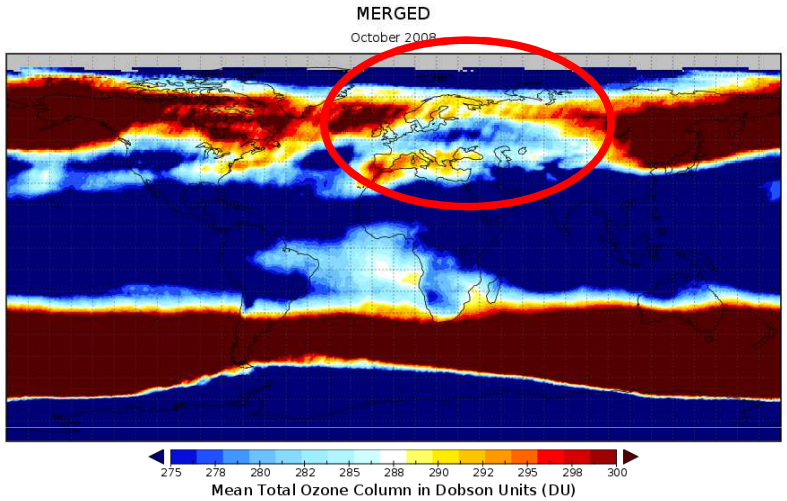
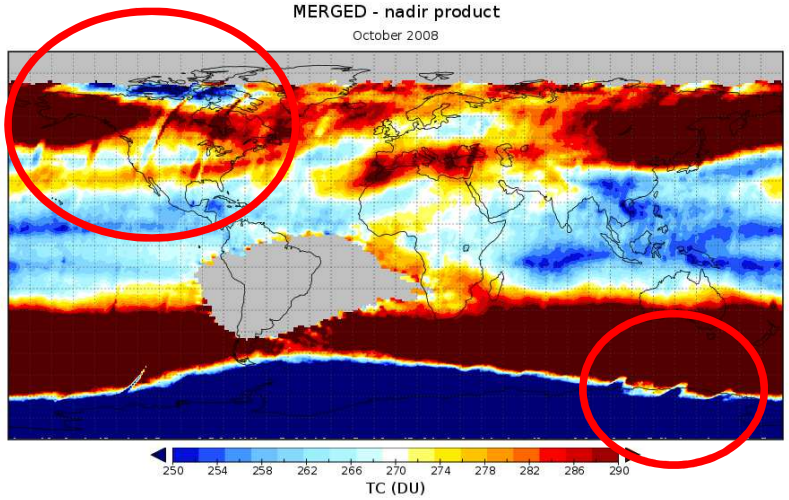
Comparison of model outputs and CCI products : Total columns ozone

- Artefacts apparent for the CCI products on map (zoom on the total columns)

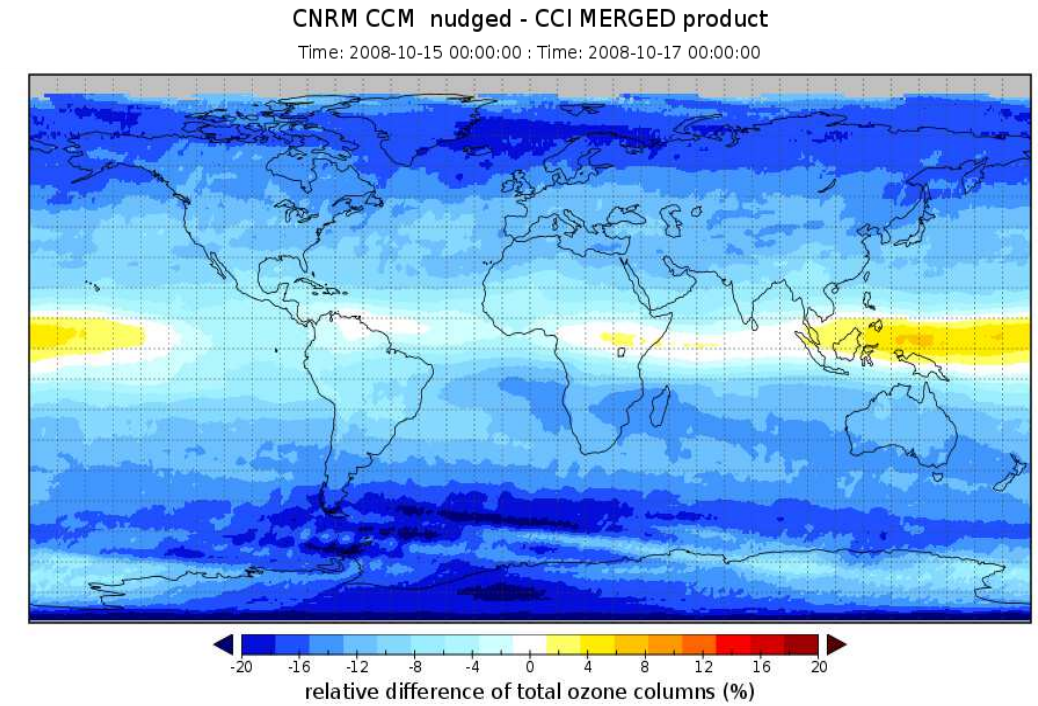


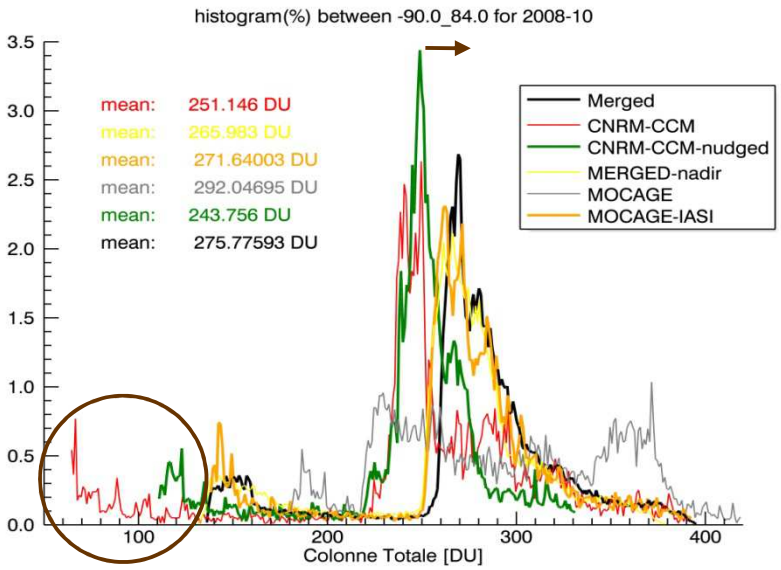




Comparison of model outputs and CCI products : Total columns ozone

- Histogram of total columns for October 2008
  - MOCAGE free run doesn't reproduce shape of histogram and mean is overestimated
  - CNRM-CMM mean is underestimated 30 DU the TC





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Statements

- Statements of the first comparison with Limb Profiles

  - Good agreement at certain conditions (levels, locations, time) although some scattering.
  - Large errors estimates of CCI limb products below 100 hPa
  - Important difference between model and products around 3 hPa and around 50 hPa at the Equator certainly due to model.
  - Sciamachy is less reliable (more important errors)
  - Improvement of models at Météo France

Statement of the comparison with Total Columns

- Bias between the total columns product and the total columns of nadir product
- Better agreement with MOCAGE when assimilated with IASI+ MLS
- Artefacts are visible on map of CCI products

- Perspectives
  - Analyze causes of differences between products and models
    - Through expansion of the period to other years (phase II) and IASI (phase II)
    - Through analysis of spatio temporal characteristics derived from Fourier Analysis
    - Through the use of *fine resolution* merged limb product
  - Add on plot the errors estimated on products
  - Use GOMOS, ACE and SMR for the limb comparison
  - Use IASI observations (precursor) and ERA-interim reanalyses on figures
  - Use nadir ozone profiles for further analysis with limb products and check the consistency
  - Use MOCAGE for profiles in the comparison with products
  - Compare with results of MOCAGE assimilating IASI+MLS

Final objective is to use observations to control upgrade of the model (higher resolution, include tropospheric chemistry, etc.)

At longer term, the objective in phase 2 will be to contribute to CCM-I in the framework of CMIP AR6s

Atmosphere:
L3 Ozone and Aerosols

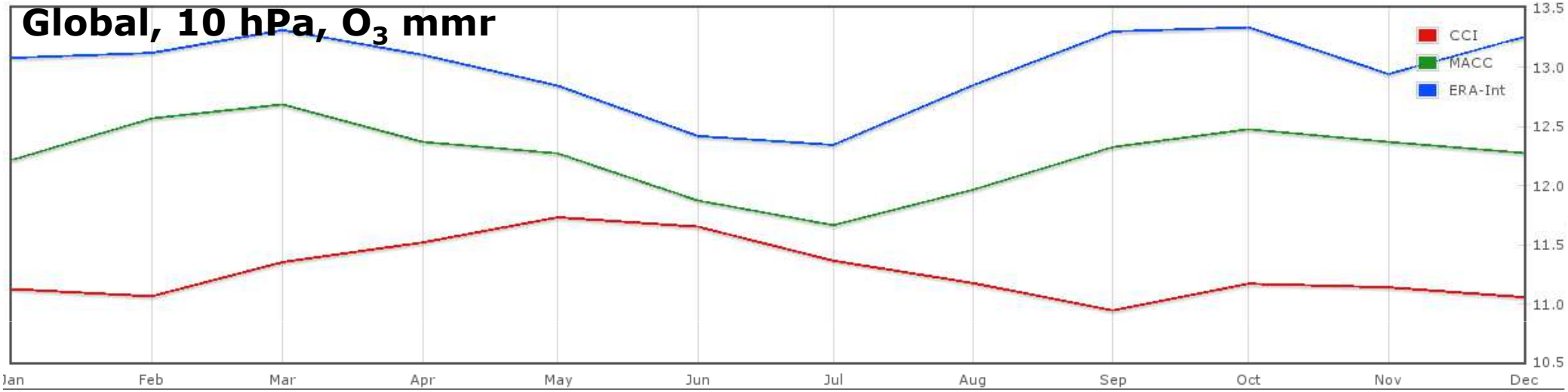
Rossana Dragani

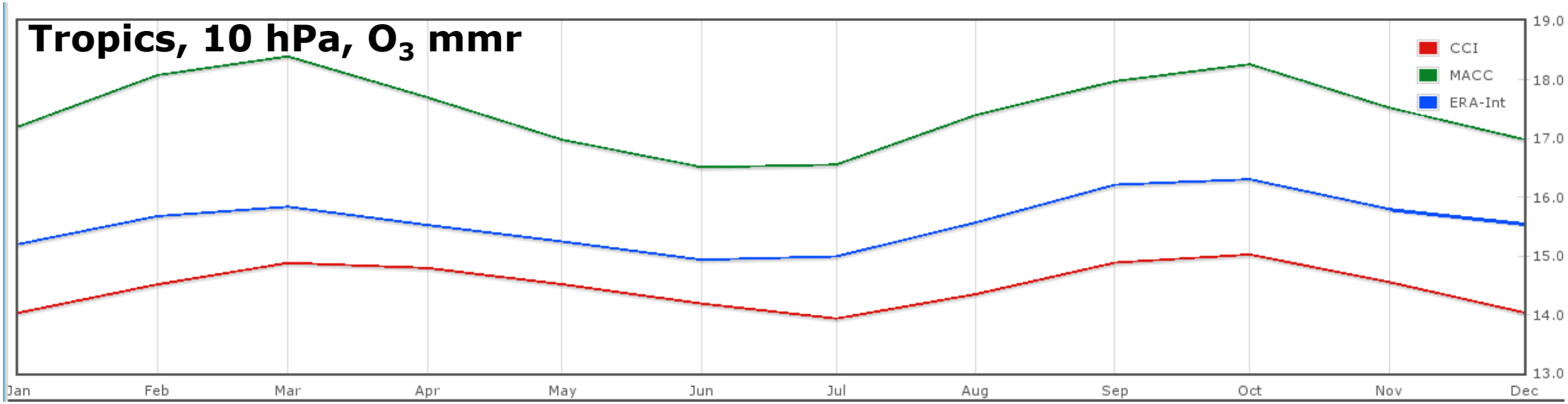
ECMWF

Ozone

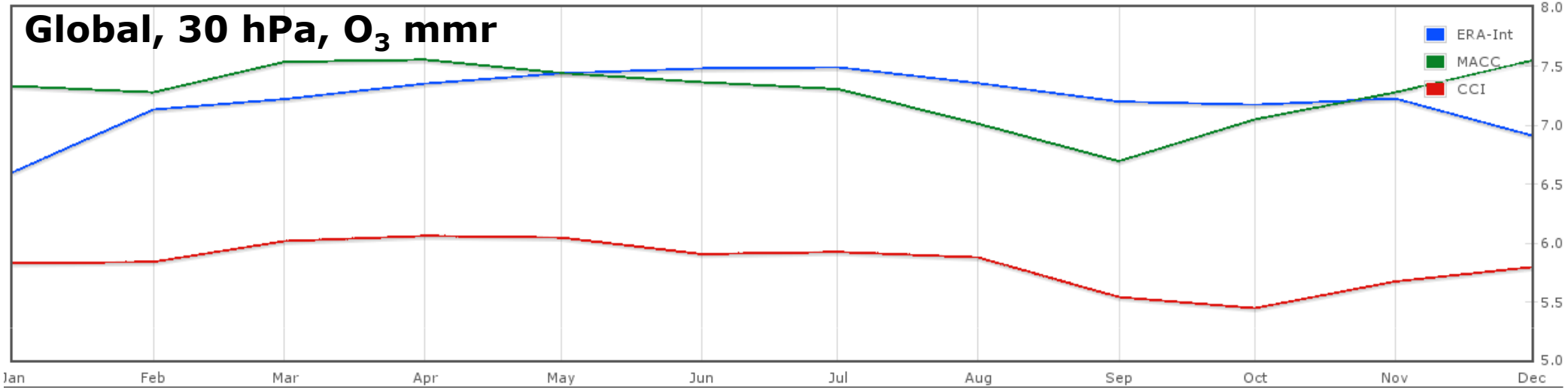
Merged L3 dataset	Availability	Period assessed	Reanalysis streams
NP O_3	Jan-Dec 1997 Jan-Dec 2008	Jan-Dec 2008	ERA-Interim MACC
TCO_3	Apr 1996 – Jun 2011	Apr 1996 – Jun 2011	ERA-Interim MACC JRA-25

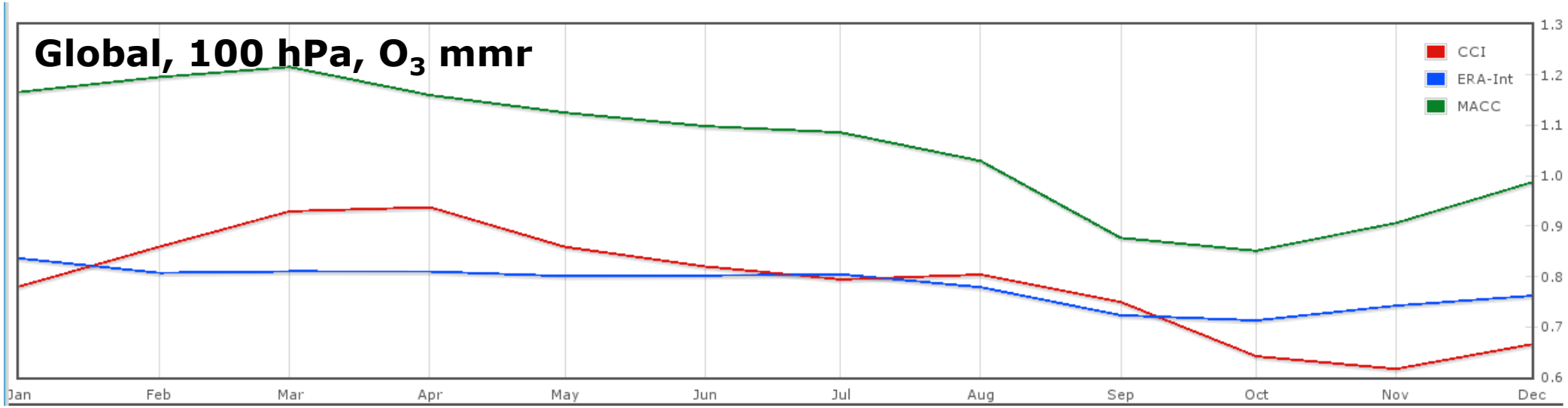
Nadir O_3 profiles (2008)



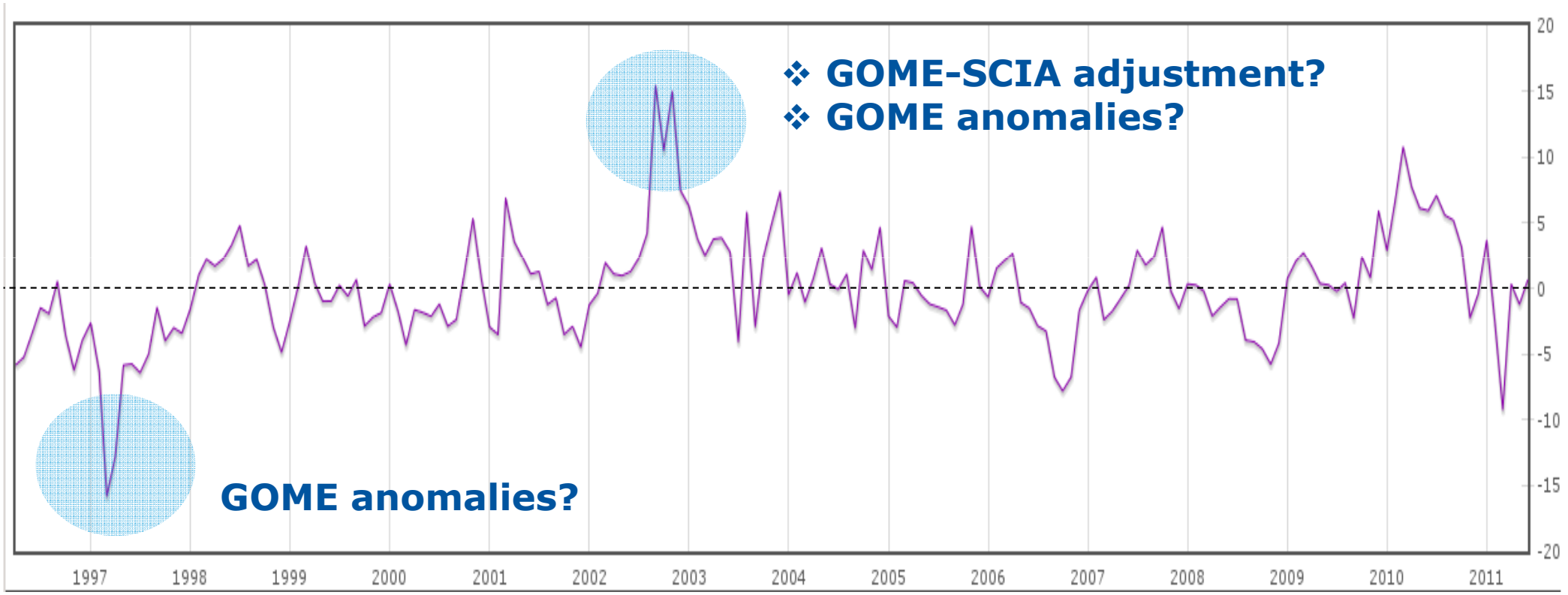


Nadir O_3 profiles (2008)

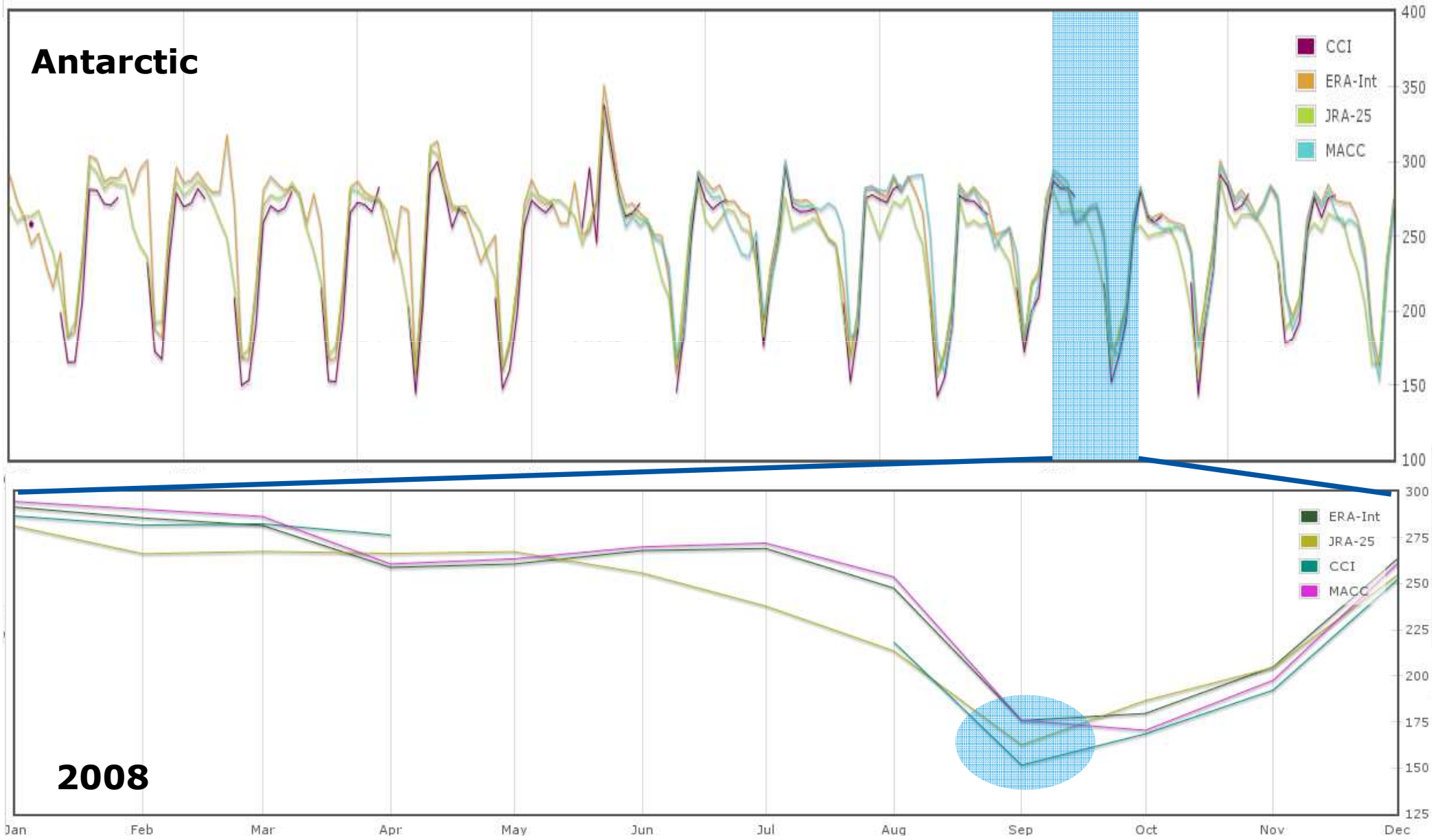




Merged TCO_3 (Glob mean anomaly)

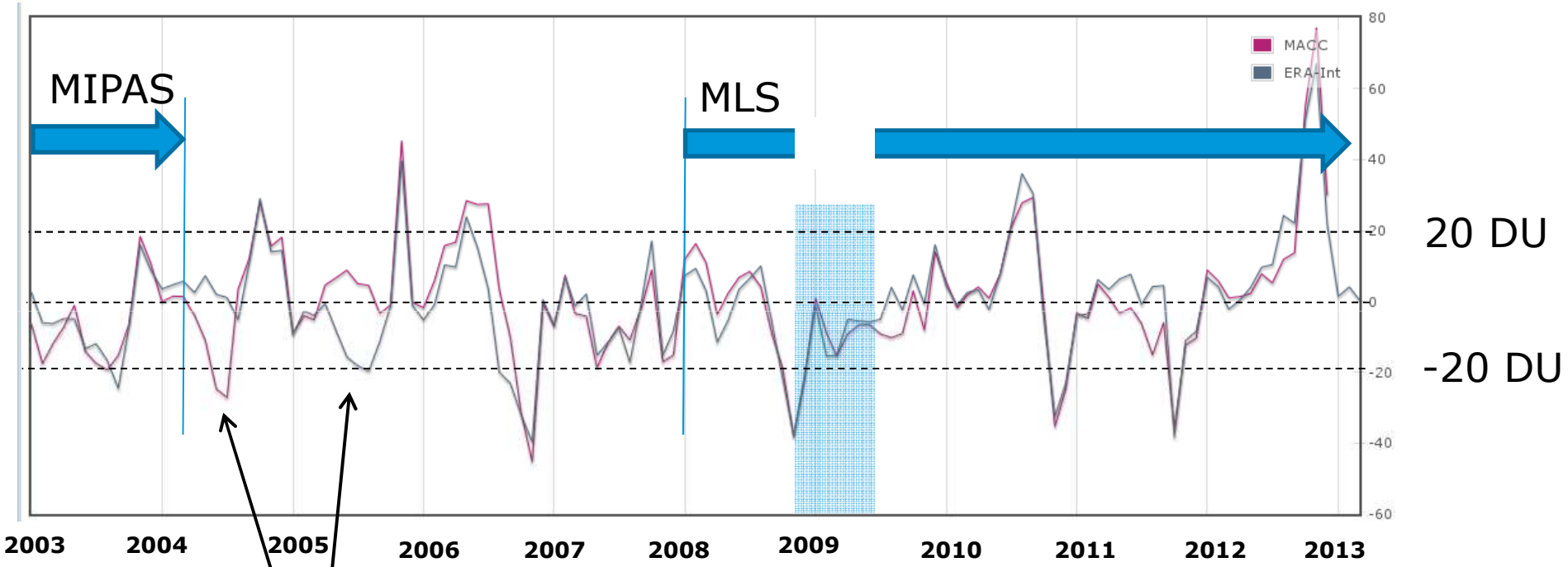


Merged TCO_3 (Mean)



Total Column O_3: ERA-I vs MACC

Mean anomalies over Antarctica:



20 DU

-20 DU

Polar winter: discrepancy could be reduced in ERA-SAT with the assimilation of the IR/O3 radiances (HIRS, AIRS, IASI, CrIS)

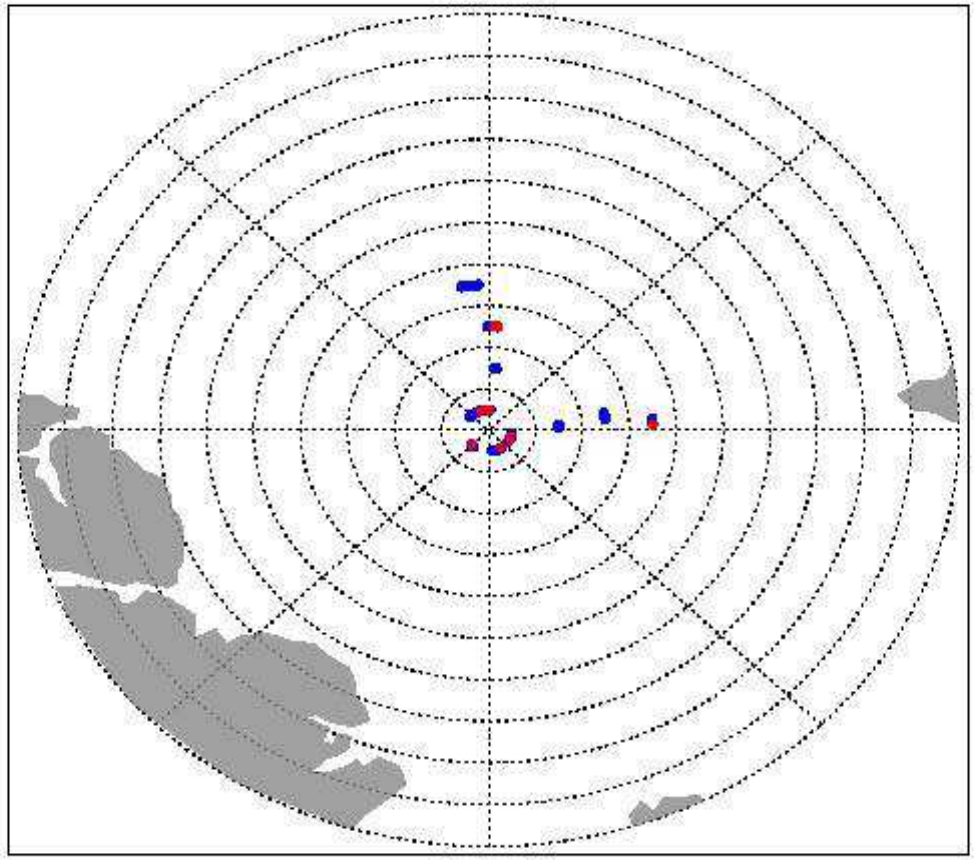
MACC benefitted from O_3 VarBC

Coupling with a CTM

(recent IFS cycle – CY36R4)

Merged TCO_3 (Stand. Dev.)

TCO_3 STD DEV, March 2005



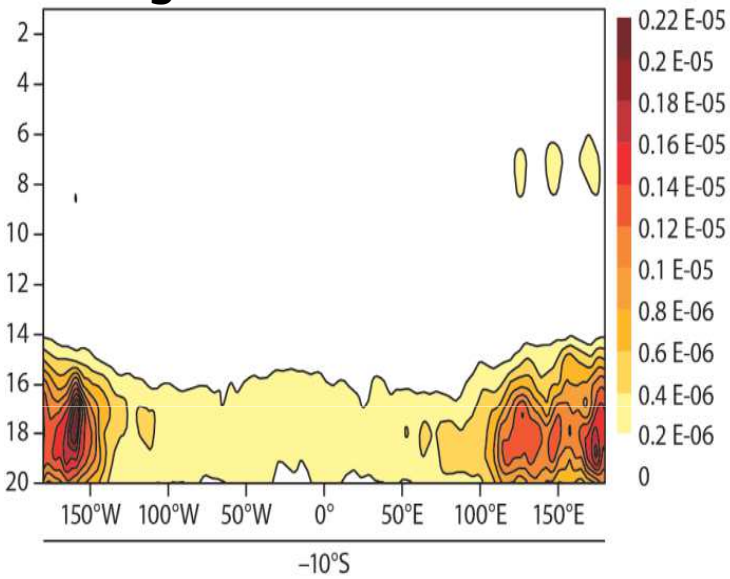
Total grid points: 64800
Points with $\sigma=0$: 114
Points with $0<\sigma\leq10^{-2}$: 13

Area	Unfiltered (DU)	Filtered (DU)	Δ (DU)
Global	23.36535	23.38880	0.02345
Oceans	22.42491	22.45844	0.03353
Arctic	40.53228	40.91231	0.38003
60-90N	39.76440	40.00783	0.24343

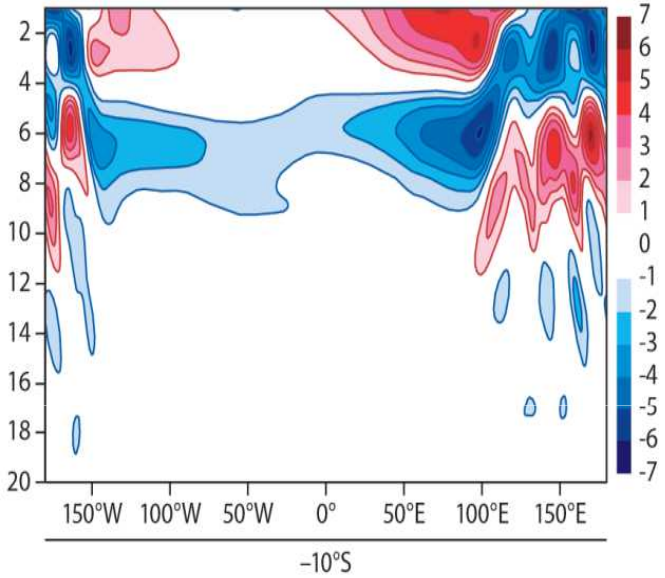
- **No Quality Information included (e.g. flags).**

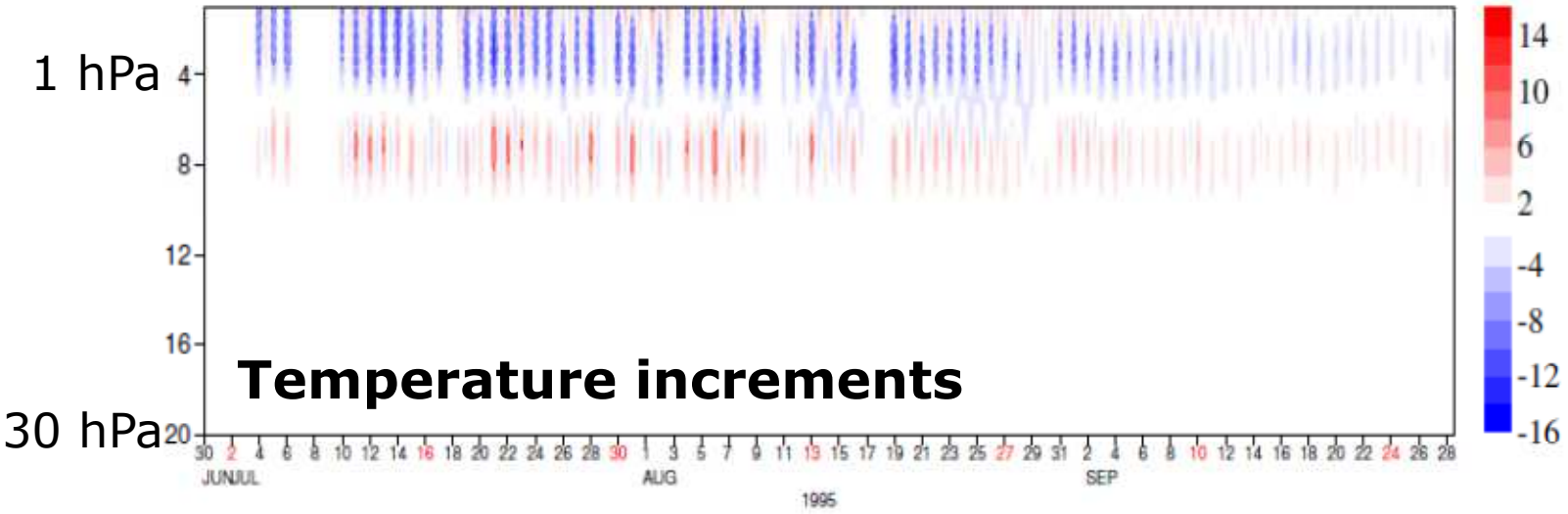
Assimilation of GOME O_3 profiles in ERA-Interim

O_3 increments



Temperature increments

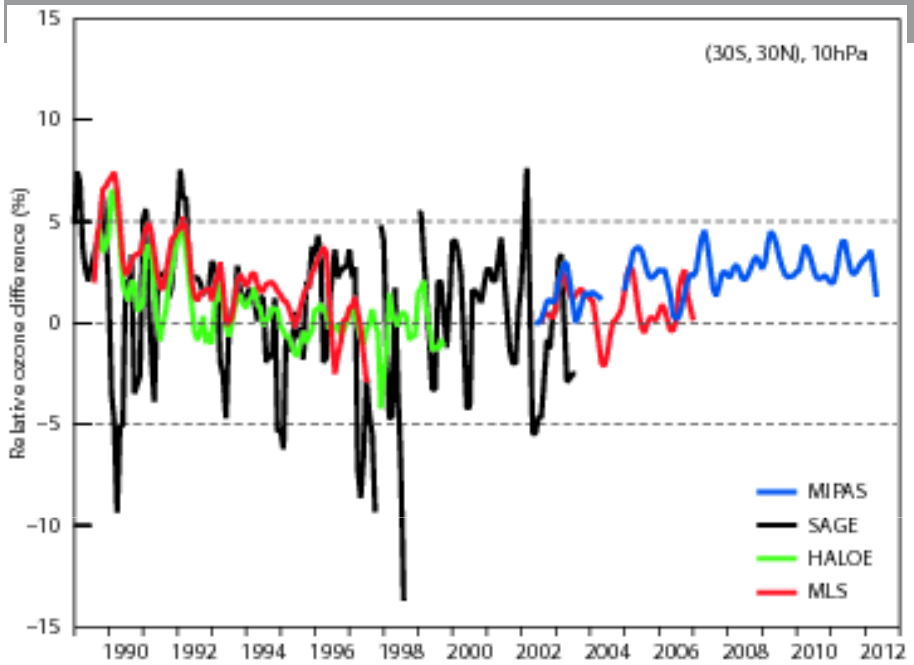




Temperature increments

Source: E.g. **CMUG D3.3/D3.4**

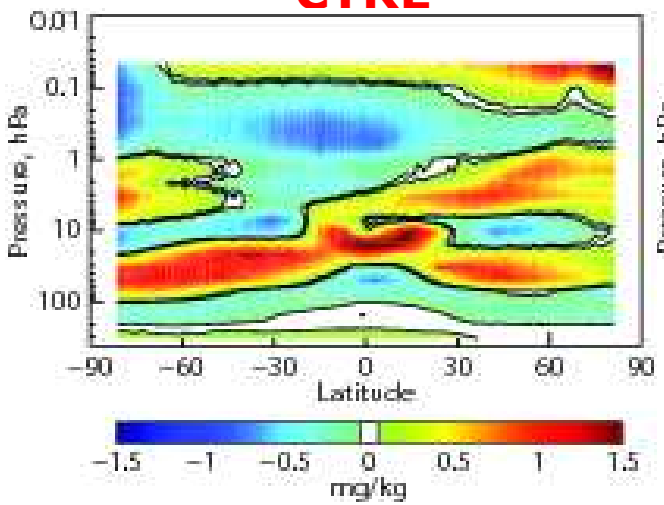
MIPAS L2 ozone (ESA reproc)



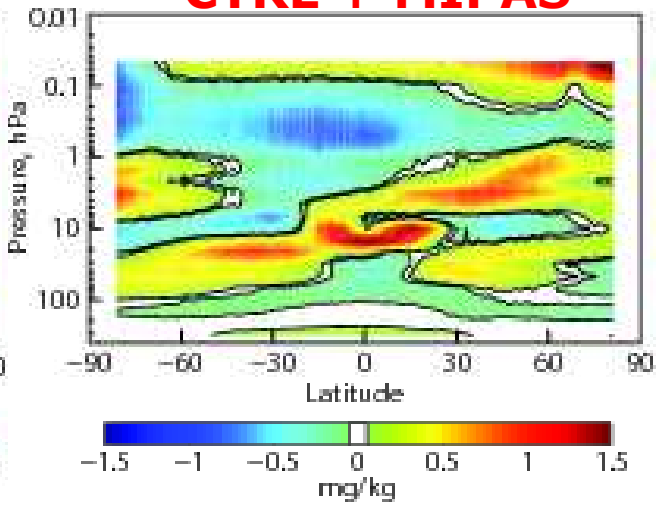
$$\frac{\text{Obs} - \text{ERA-Int}}{\text{ERA-Int}}$$

Source: **CMUG D3.3**

MLS-An: CTRL



MLS-An: CTRL + MIPAS



Source: **Dragani et al, "Ten years of ENVISAT observations at ECMWF", QJ, submitted.**

Summary on (nadir) O_3 products:

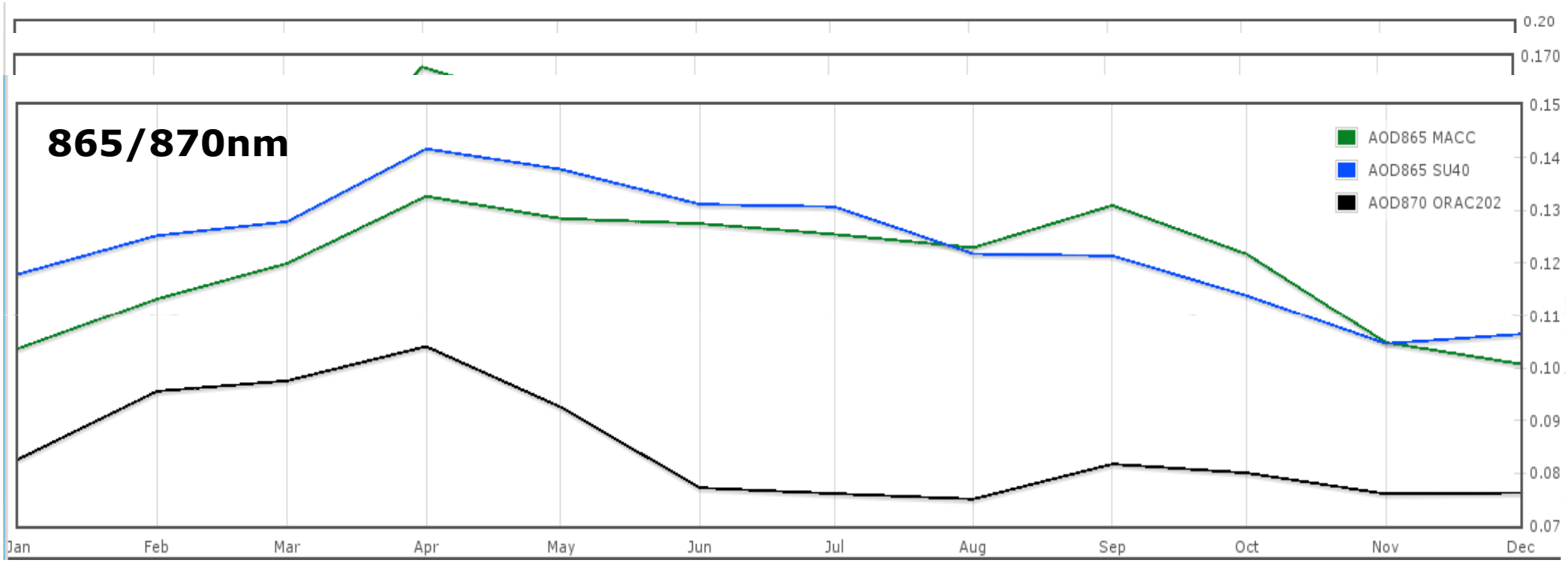
- Merged Nadir Profiles:
  - Annual variability and values seem reasonable, though one year is not enough to check long term consistency and homogeneity.
  - The ozone mmr values seem to be underestimated at 10 hPa (ozone max) in the tropics, and globally below the maximum (30 hPa) compared with reanalyses.
  - Near the tropopause, values are similar to ERA-Interim, but (~20%) lower than MACC.
- Merged Total column ozone:
  - Generally good annual variability, but not in phase with MACC ➔ maybe lagged in time (~ 1 month in the global mean);
  - Good homogeneity: there are two situations where the time series might show some problems (1997, 2002 ➔ GOME anomalies? SCIA+GOME adjustment?)
  - The ozone hole seems deeper than showed by reanalyses (~25DU in 2008, ~15%)
    - **Note: There might be little room to improve future reanalyses**
  - The standard deviations seem to have a few unreasonable values (~10^{-15} and Os)
  - **Quality flags may be useful also on L3.**

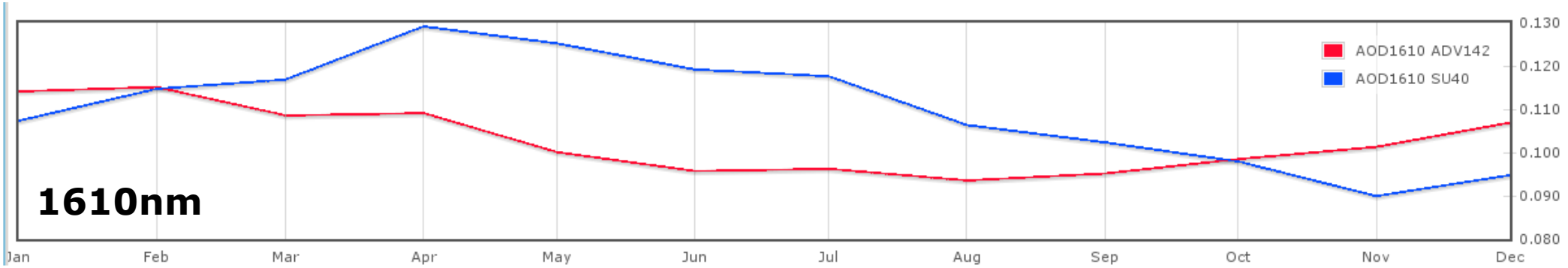
Aerosols:

Name / version	Parameter	Period	Provider	Acronym
AATSR_ADV / 1.42	AOD	2008	FMI	ADV
AATSR_ORAC / 2.02	AOD	2008	Uni. Oxford / RAL	ORAC
AATSR_SU / 4.0	AOD	2008	Uni. Swansea	SU

	550nm	659nm	670nm	865nm	870nm	1610nm	1640nm
ADV	Y	Y				Y	
ORAC	Y				Y		
SU	Y	Y		Y		Y	
MACC	Y		Y	Y			Y

Global Mean Total AOD:





Summary on Aerosols

- The three AATSR datasets are very close during winter months (Jan-Mar, and Oct-Dec). The largest differences are during Apr-Sep.

	Absolute difference at 550nm	Relative difference at 550nm
SU	0.01	5.5%
ADV	0.02	11%
ORAC	0.08	44%

$$\left(\frac{\text{MACC-AATSR}}{\text{MACC}}\right)$$

- The SU4.0 dataset seems to be the closest to the MACC reanalyses both in terms of global mean values and temporal evolution.