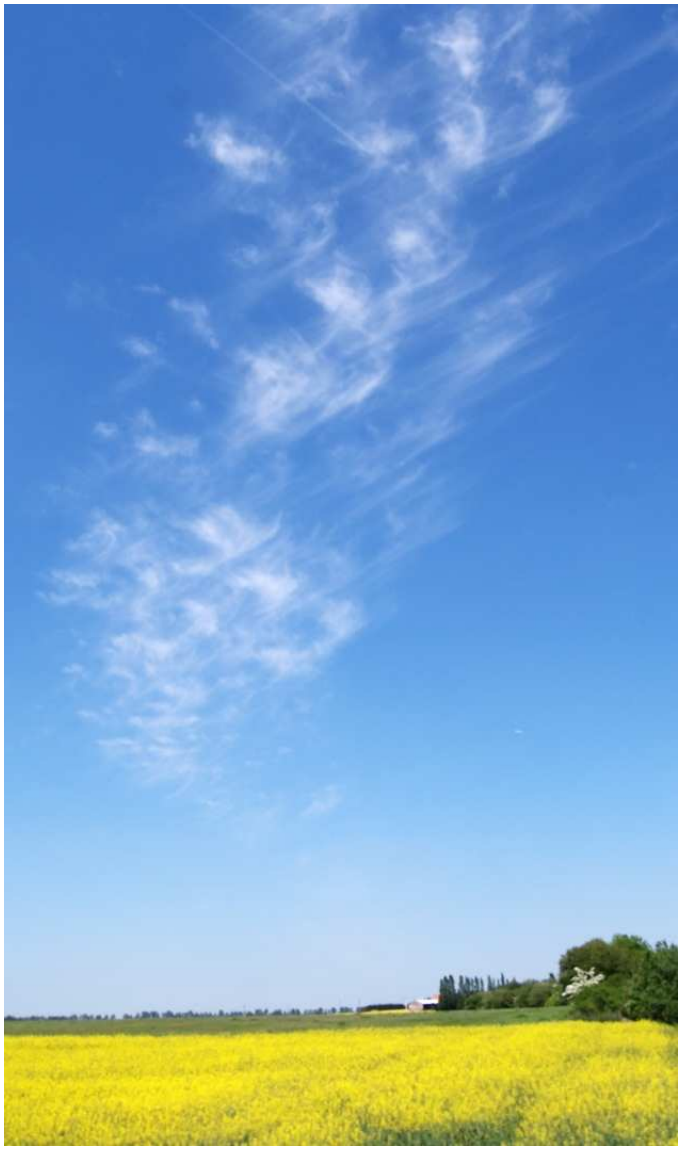
MACC

Monitoring Atmospheric Composition and Climate

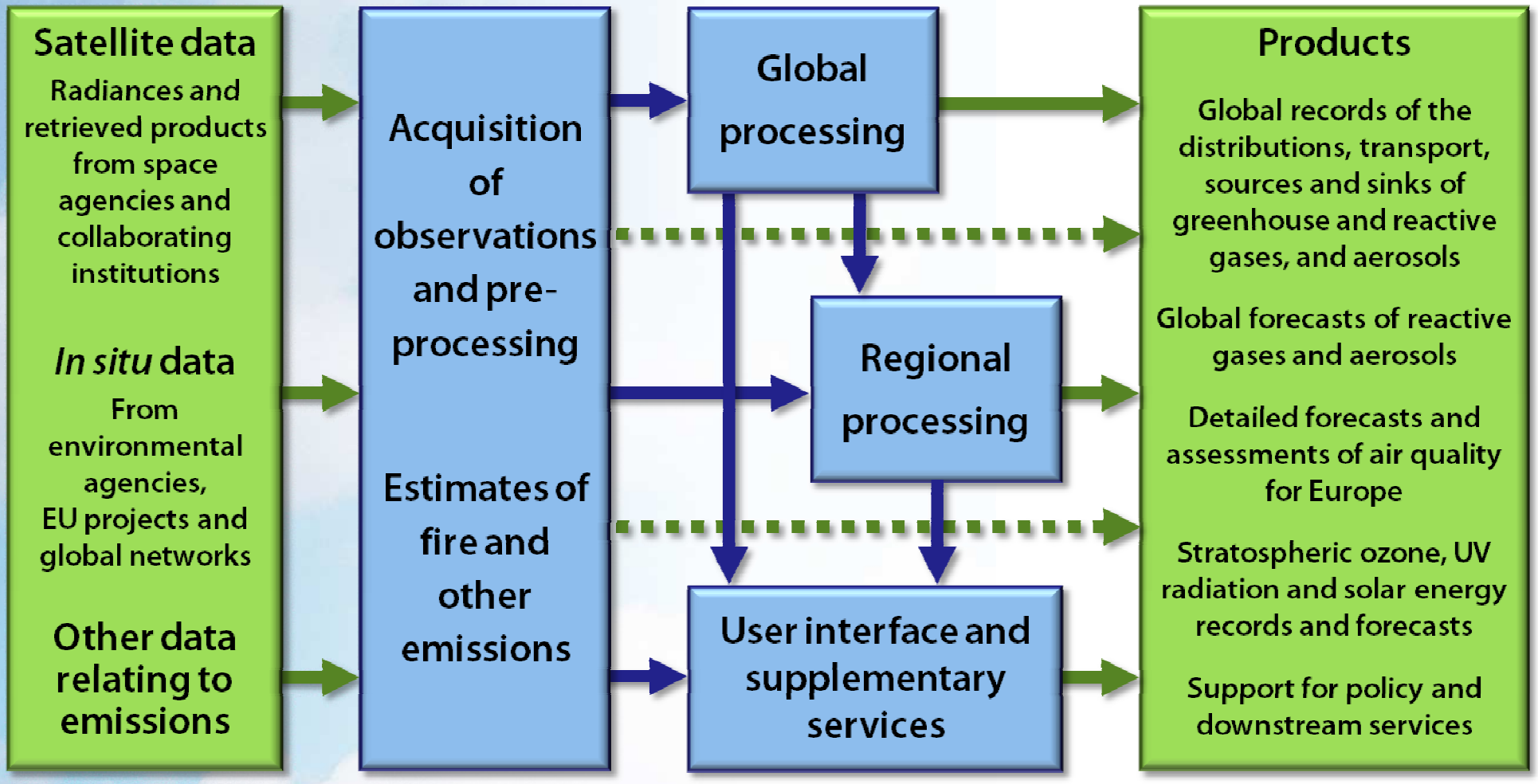
Delivering global and regional atmospheric composition services using forecasting and assimilation tools

Sylvie Malardel,

V.-H. Peuch, A. Simmons and the MACC consortium

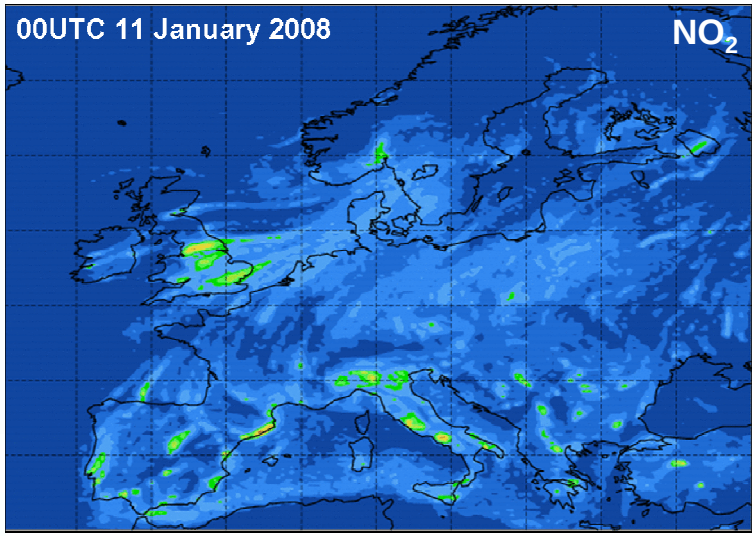


A 45-partner/18-country project developing the operational GMES Atmosphere Monitoring Service

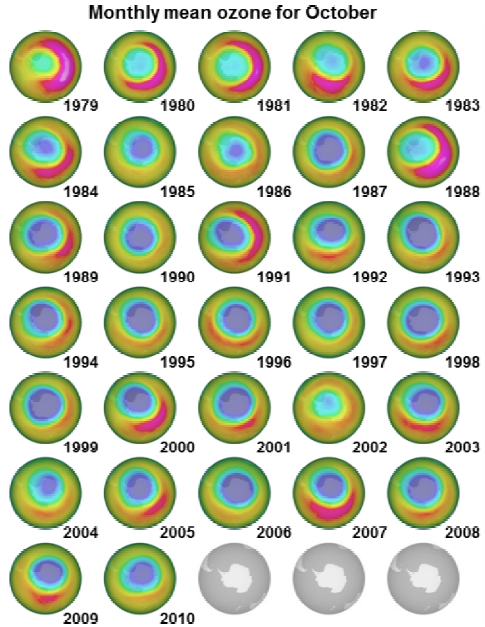


http://www.gmes-atmosphere.eu

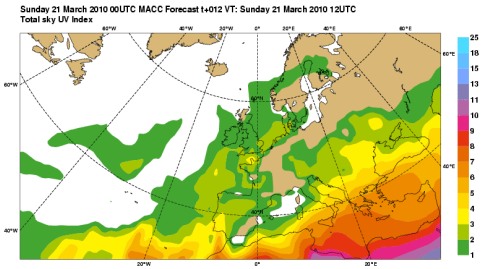
Air-quality forecast



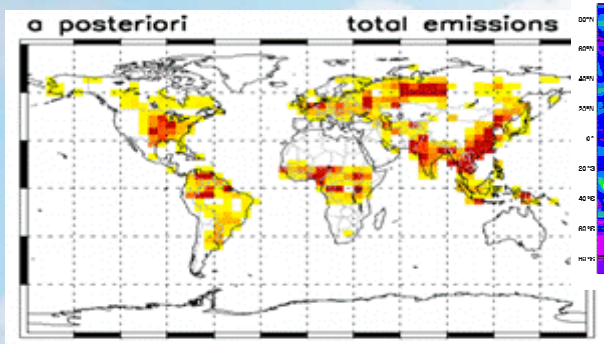
Stratospheric ozone records



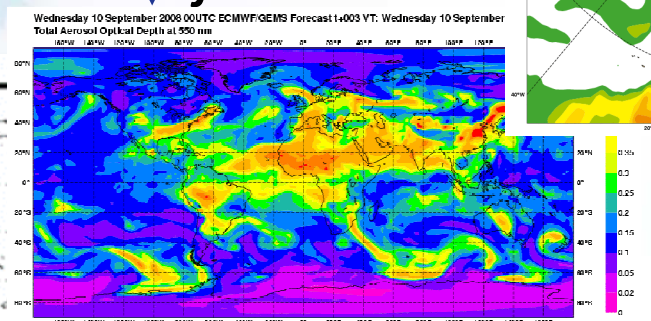
UV index



Monthly methane emissions



Aerosol forecast



ECMWF

The MACC global reactive gases system evolution

GEMS : 2005-2009
MACC : 2009-2011
MACC-II : 2011-2014

Pre-GEMS, GEMS studies : IFS and CTMs separate

IFS NWPM
ECMWF
4d-var strat. ozone assimilation (linear scheme)

MOZART CTM
Jülich, NCAR

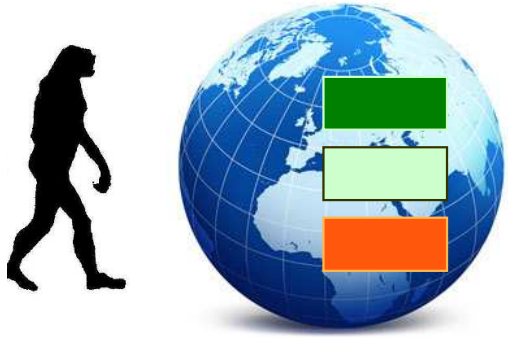
TM5 CTM
KNMI

MOCAGE CTM
Météo-France

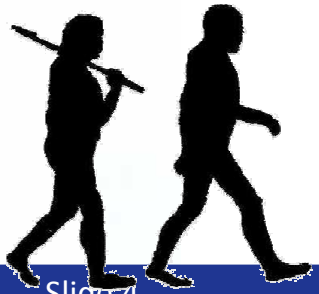
GEMS development, GEMS/MACC production : IFS and CTMs coupled

OASIS coupler
CERFACS

MACC develop., MACC-II production : IFS with online CTMs chemistry



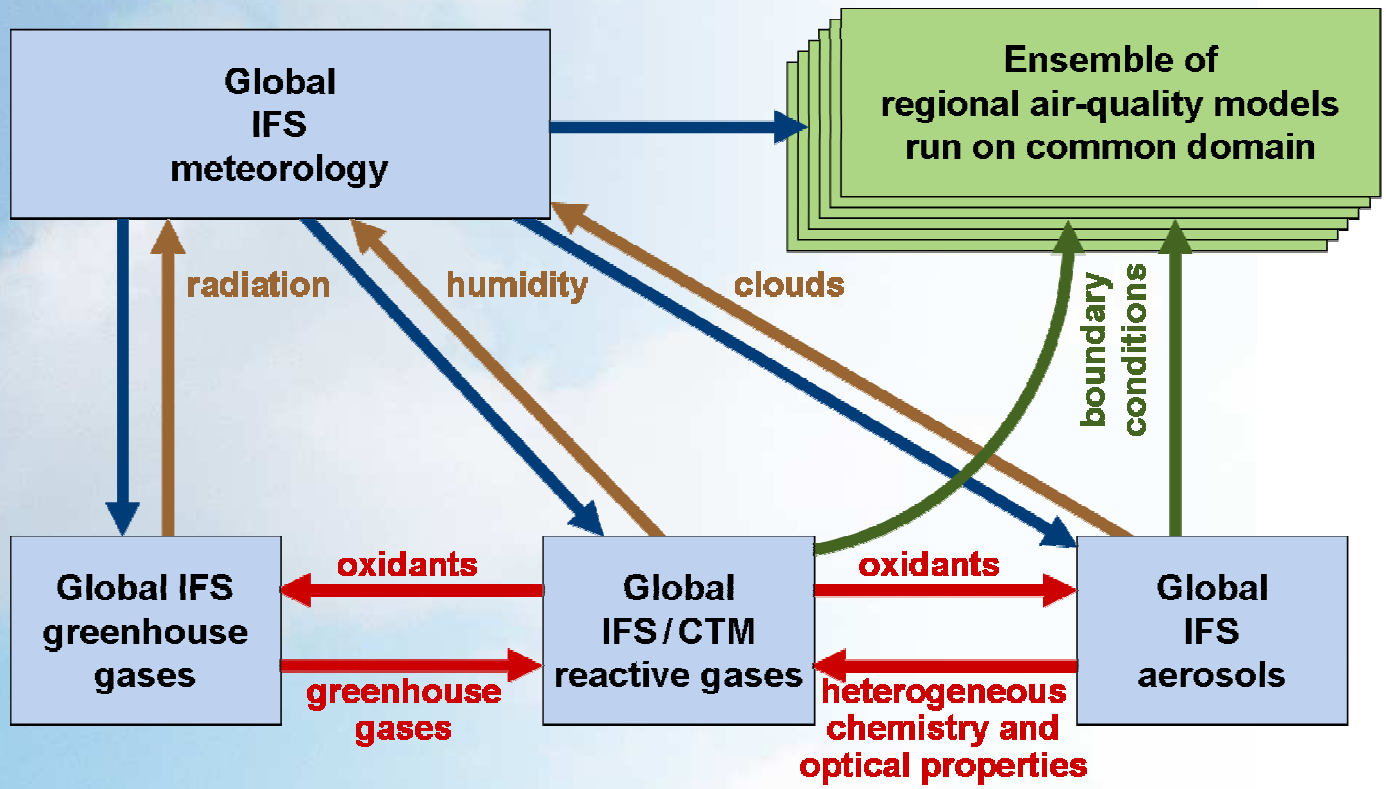
C-IFS v0
4d-var assimilation for ozone, CO, NO_2, SO_2…



C-IFS v1
integrate aerosol and greenhouse gases

ECMWF

Assimilation and forecast suites



A multi-model ensemble of regional chemistry and transport models (off-line)

3 streams :

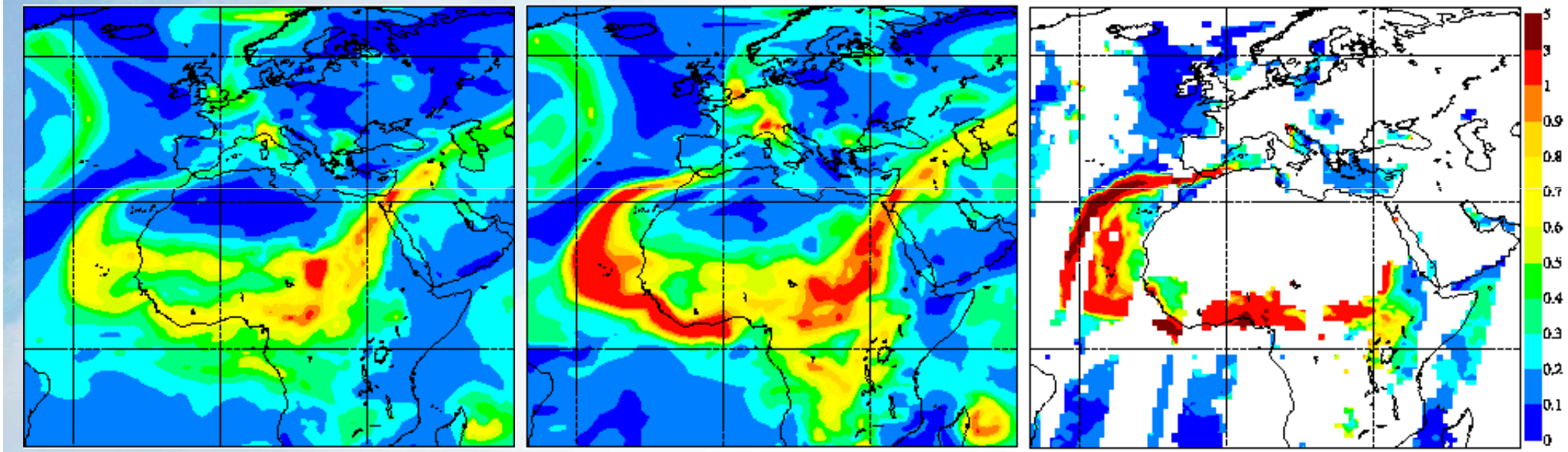
- NRT analyses and forecasts
- Delayed mode (6m-1y) analyses
- Re-analyses

A global integrated system based on the IFS and including composition ("C-IFS", on-line). Note: not all couplings are currently active.

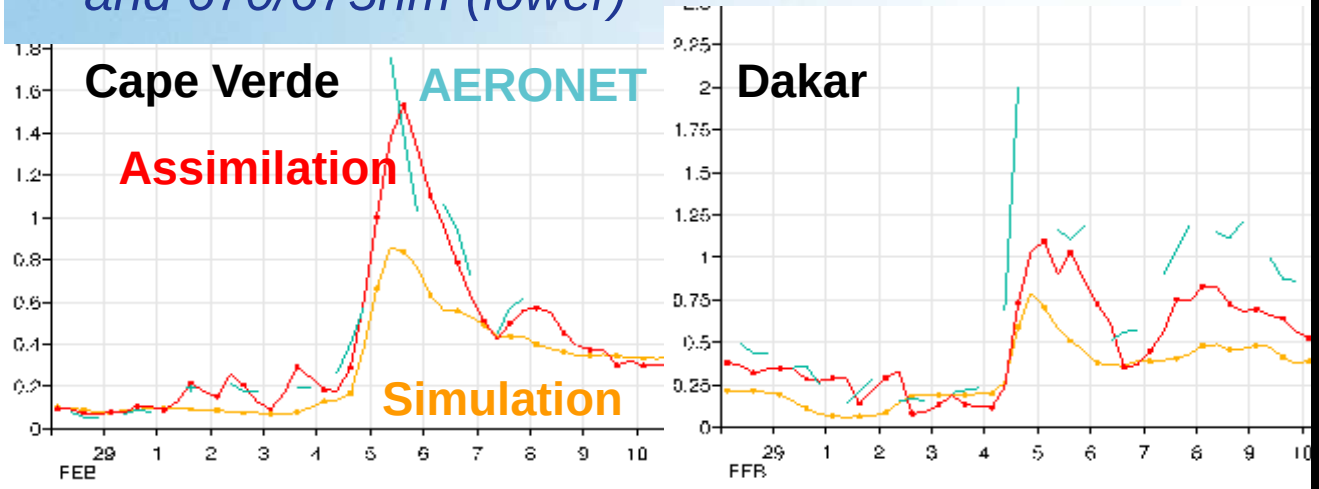
Global Aerosol: on-line approach in IFS

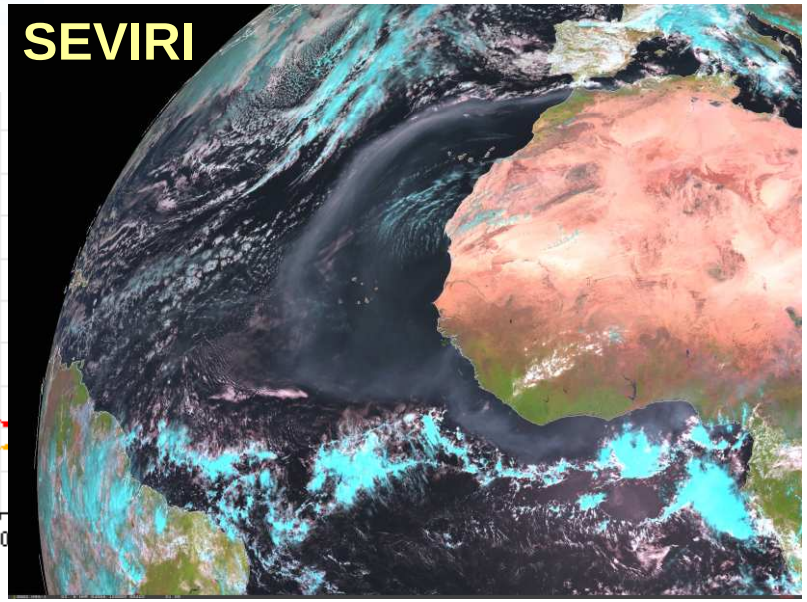
Example : Assimilation of MODIS AOD at 550 nm, Saharan dust outbreak, 06-03-2004

Model simulation *Assimilation* *MODIS*



Aerosol optical depth at 550nm (upper) and 670/675nm (lower)

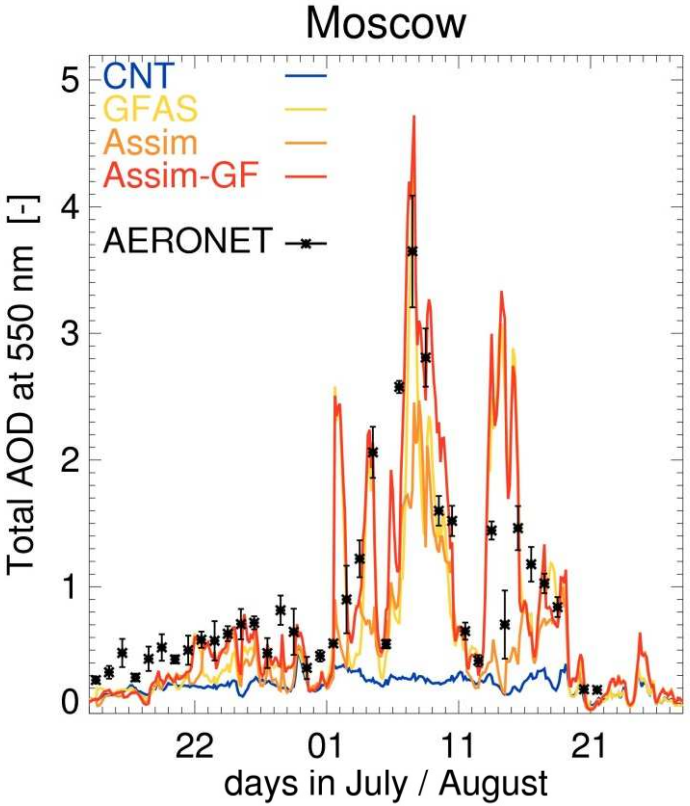




Morcrette et al., 2009, *JGR*; Benedetti et al., 2009, *JGR*

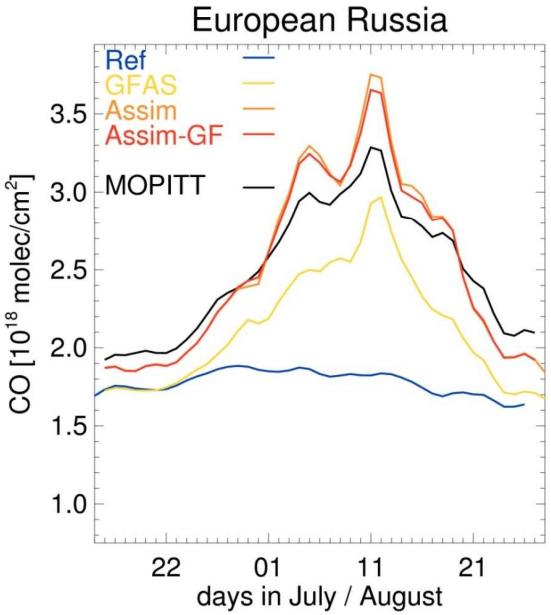
2010 fires over western Russia : AOD and CO

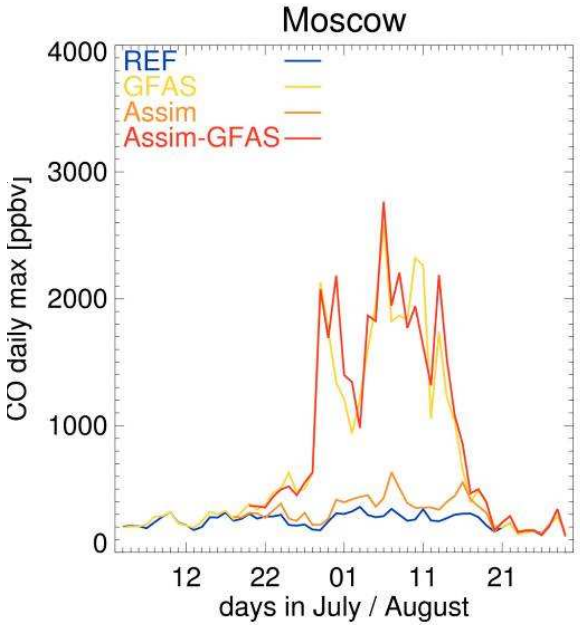
Aerosol (online)



MODIS aerosol optical depth and IASI CO data are assimilated

Reactive Gases (offline approach)





Much of signal in CO column is captured by assimilation, regardless of fire emissions

But: emissions needed for forecasts!

Model, with climatological emissions

Model, with analysed emissions

Assimilation, with climatological emissions

Assimilation, with analysed emissions

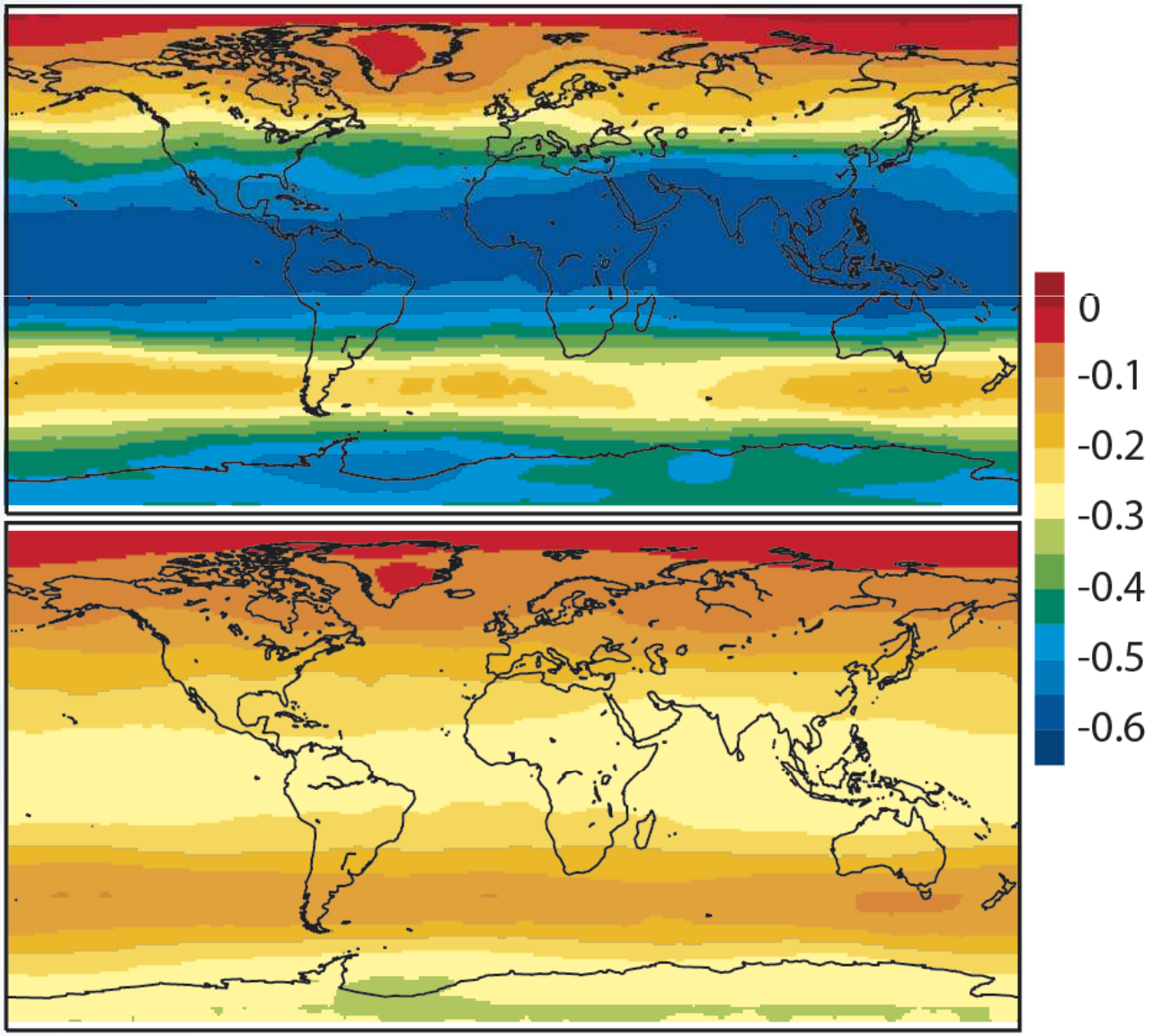
Emissions dominate surface values

Beyond composition, benefits to expect on NWP

Bias correction using fixed CO_2 of 377 ppm, the value prescribed in RTTOV

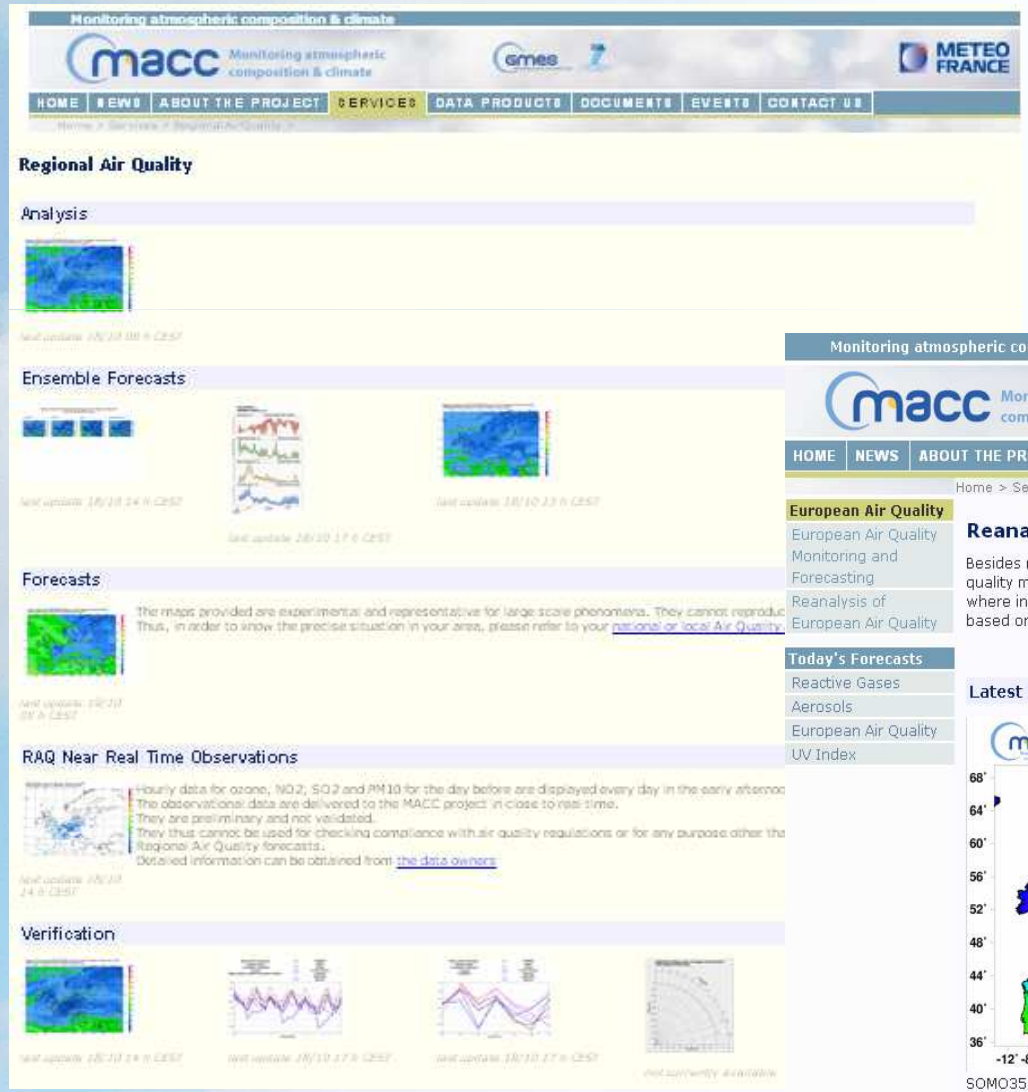
See Engelen and Bauer, QJRMS, 2011: CO_2 modelling allows a drastic reduction of the bias correction for assimilation

Bias correction using variable CO_2 modelled with MACC system



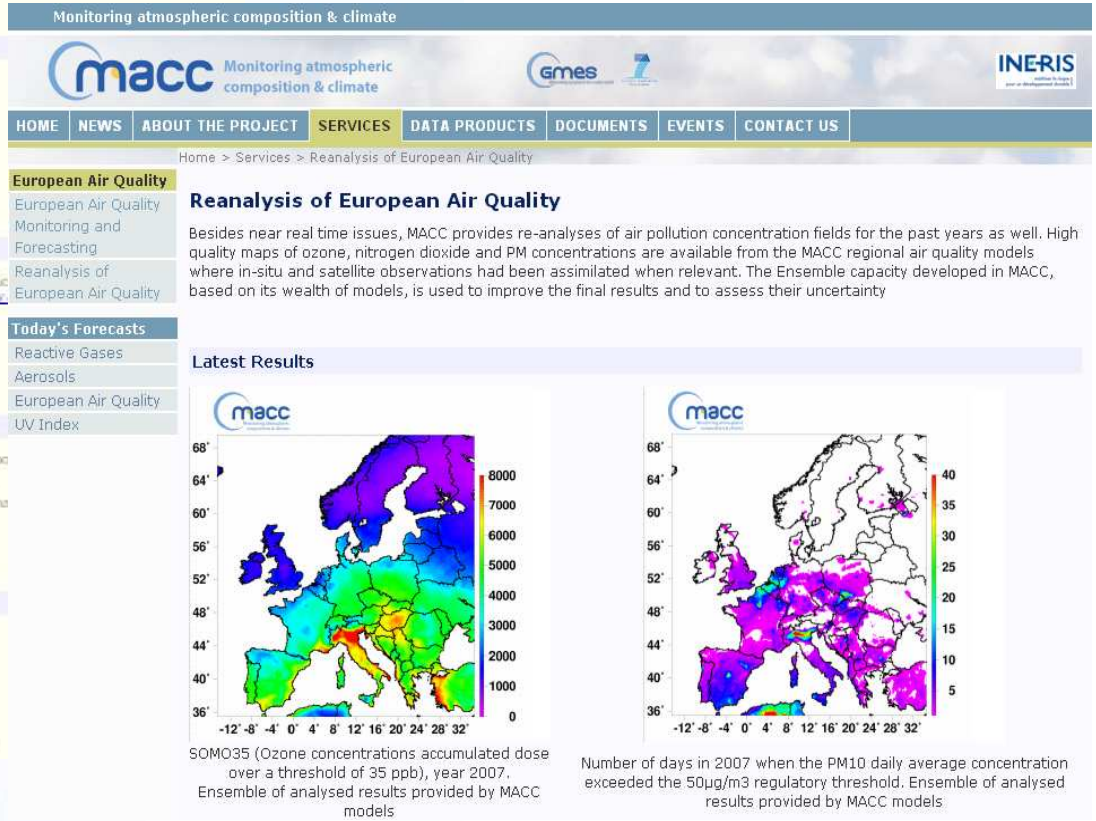
Mean bias correction (K) for August 2009 for AIRS channel 175 (699.7 cm^{-1}; maximum temperature sensitivity at ~ 200 hPa)

Regional Air Quality products (Europe)



72h forecasts and hourly analyses (NRT)

Re-analyses for assessments in support of European AQ policies (delayed mode)



SOMO35 (Ozone concentrations accumulated dose over a threshold of 35 ppb), year 2007. Ensemble of analysed results provided by MACC models

Number of days in 2007 when the PM10 daily average concentration exceeded the 50µg/m3 regulatory threshold. Ensemble of analysed results provided by MACC models

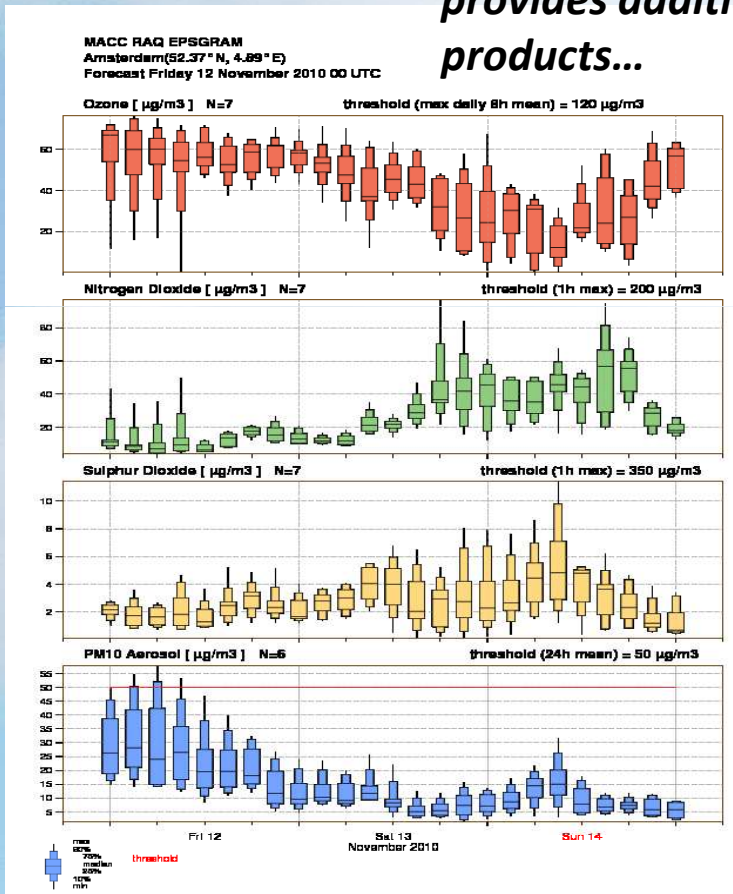
MACC european regional AQ ensemble

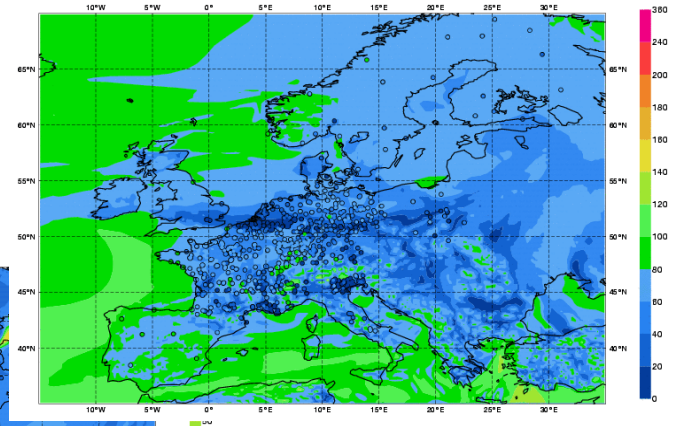
	Current geometry	*Assimilation method*	*Operations*
CHIMERE INERIS, CNRS	25km, L8, top : 500hpa	Optimal Interpolation	run @ INERIS
EMEP met.no	0.2°, L20, top : 100hpa	*3d-var in development*	run @ met.no
EURAD FRIUUK	15km, L23, top : 100hpa	Variational, 3d-var	run @ ECMWF
L-EUROS TNO, KNMI	15km, L4, top : 3.5km	Ensemble Kalman Filter	run @ KNMI
MATCH SMHI	0.2°, L40, top : 100hpa	Variational, 3d-var	run @ SMHI
MOCAGE MF, CERFACS	0.2°, L47, top : 5hpa	Variational, 3d-var	run @ MF
SILAM FMI	0.2°, L46/5, top : 100hpa	Variational, 4d-var	run @ FMI

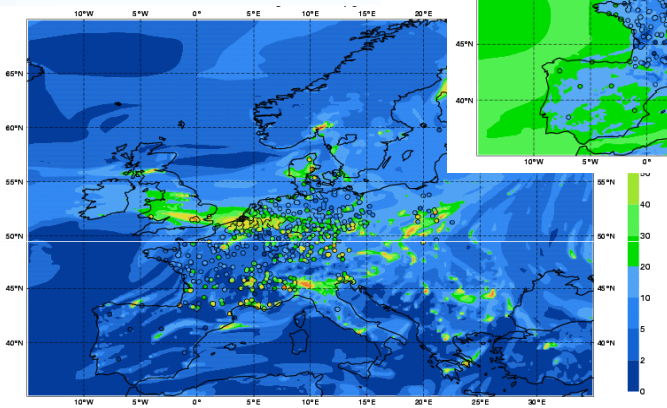
+ same emissions, same met forecasts (IFS), same chemical boundary conditions (MACC global) : spread comes from differences in CTM formulation

Why an ensemble approach?

An ensemble of models provides additional useful products…

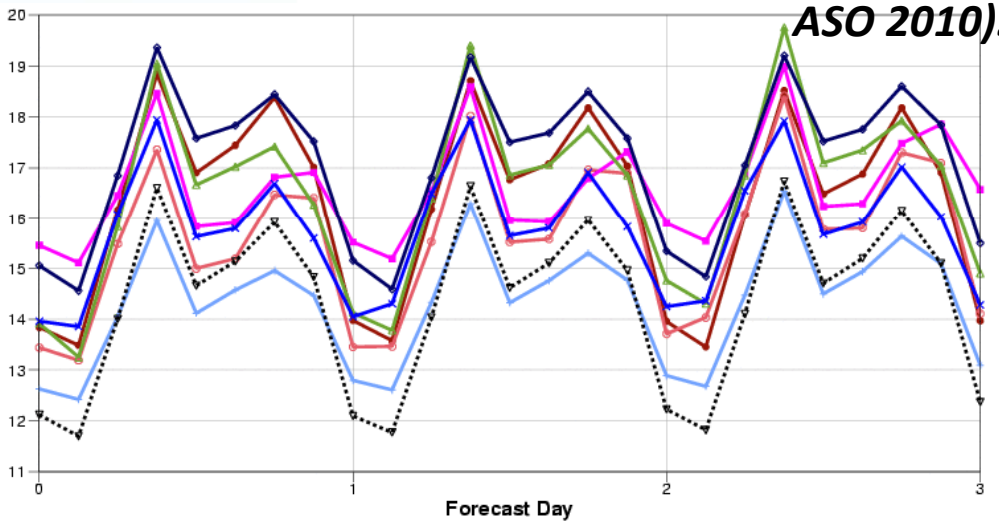




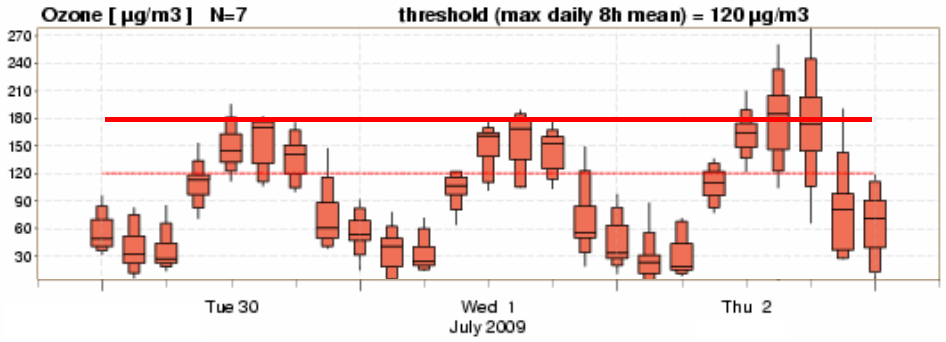


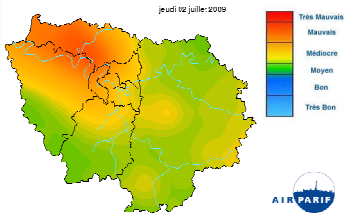
All the individual models have their golden days…

… but the median of the ensemble has always among the best skill scores (here PM10 RMSE for ASO 2010).



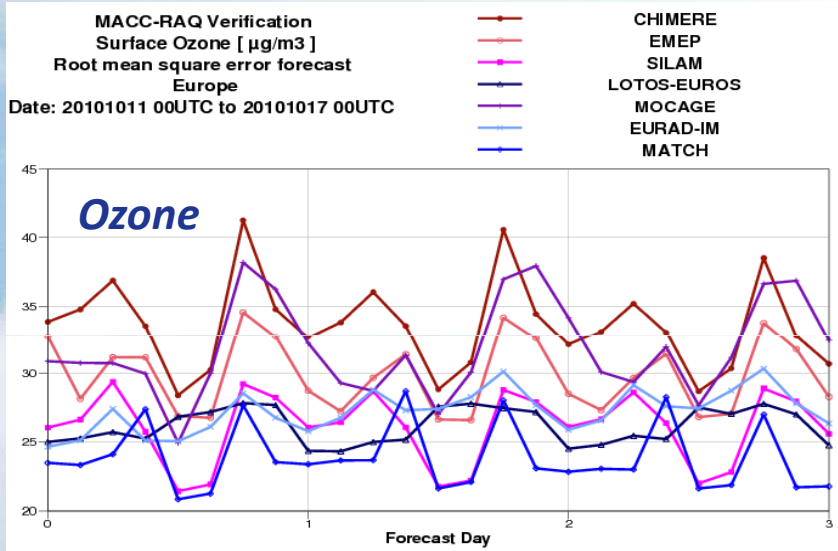
…specially when situation is complex

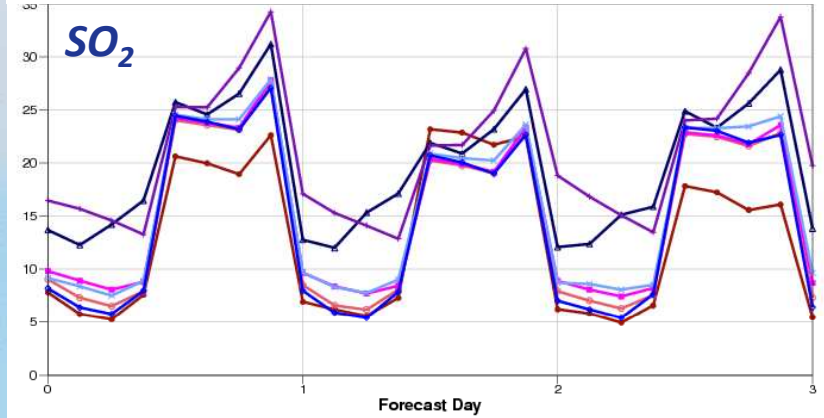


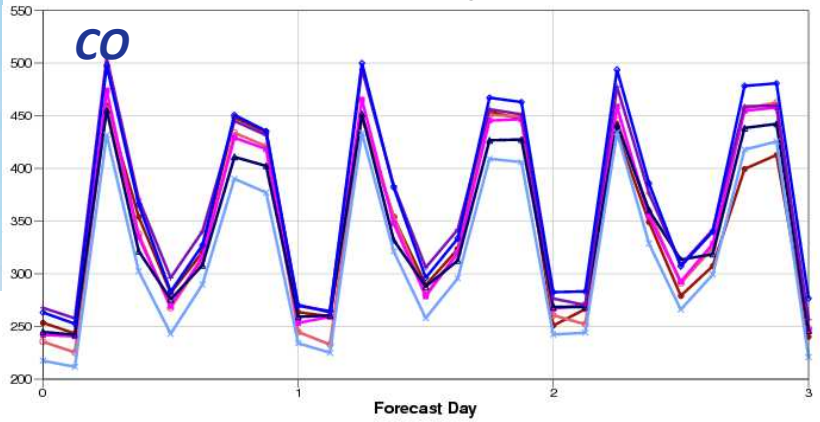


ECMWF

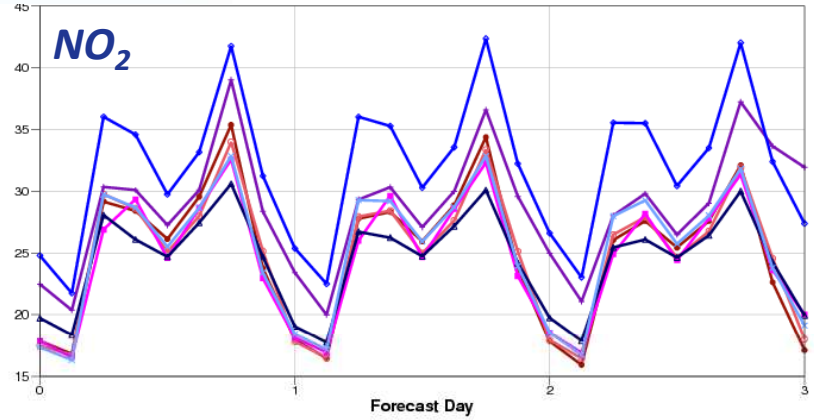
Inter-model skill score dispersion and AQ variables

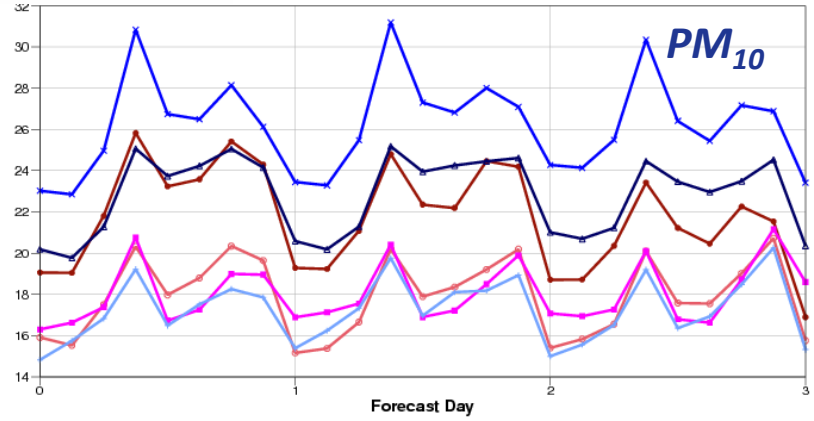






« Erroneous » model dispersion (due to bugs in the implementation of the specific MACC versions…) has been most likely ironed out, but it took more than a year. Dispersion is probably representative now of raw uncertainty in current regional Air Quality models.





Outlook

MACC (and its successor project MACC-II, 01/11/2011 to 31/07/2014) relies on a range of numerical tools to deliver products pre-figuring future operational GMES atmospheric services :

- on the regional scale, a multi-model (off-line) approach is used and effectively produces analyses and forecasts of highest quality, merging efforts from several of the leading AQ operational forecasting teams in Europe.
- on the global scale, the effort is now on integrating composition (aerosol, reactive gases, greenhouse gases) directly into the IFS. Feedbacks on NWP, that in turn further benefits to the quality of atmospheric composition products, are indeed expected.

MACC is the effort of an entire consortium. Only a limited number of partners actually run pre-operational systems, but we rely on wider research activities (developments, algorithms, validation…) that are essential to maintain at the best international level, very much like it is the case for operational NWP.