The use of IASI atmospheric composition data in the MACC-II data assimilation system

or

Why noise matters!

Antje Inness (ECMWF)

Thanks to R. Engelen, M. Parrington , S. Massart

Monitoring Atmospheric Composition and Climate – Interim Implementation

MACC-II is the third in a series of FP6 & 7 EU projects (since 2005), benefiting also from earlier ESA/GSE projects. It is coordinated by ECMWF and the consortium comprises 36 partners from 13 countries. MACC-II runs until end of July 2014, when the operational Copernicus Atmosphere Service starts.

Weather services

Atmospheric environmental service

Environmental agencies

Copernicus
The European Earth Observation Programme

provide data & information on

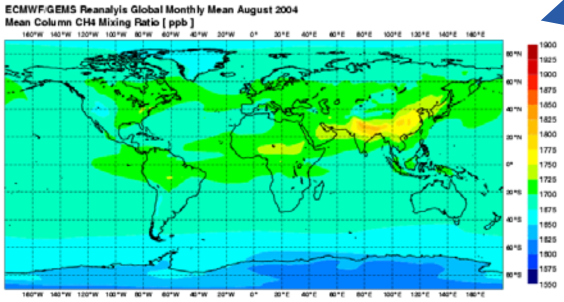
- Long-range pollutant transport
- European air quality
- Dust outbreaks
- Solar energy
- UV radiation
- Climate forcing by gases and aerosols
- …

MACC Service Provision

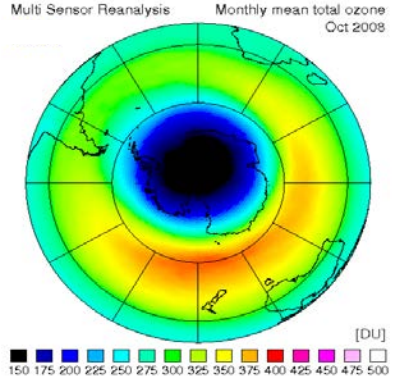
Retrospective

Reanalysis

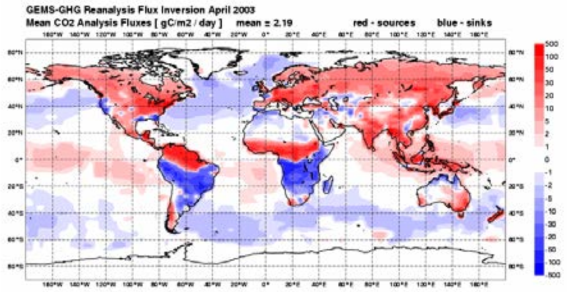
2003-2012



Ozone records



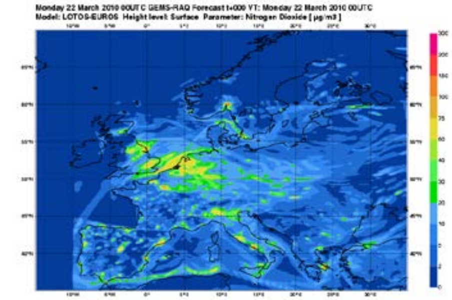
Flux Inversions



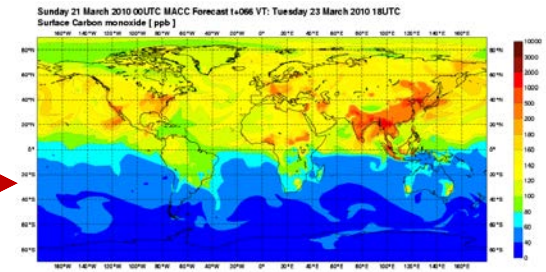
www.gmes-atmosphere.eu

Daily (NRT)

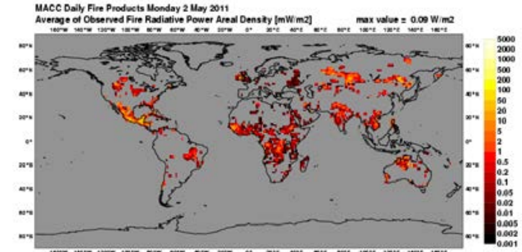
Air quality



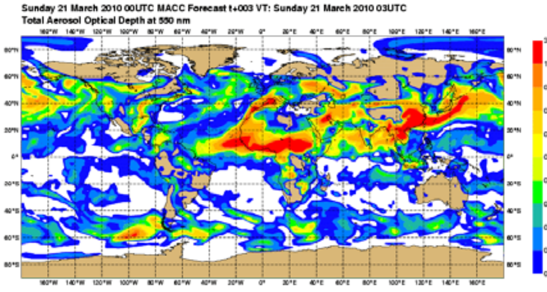
Global Pollution



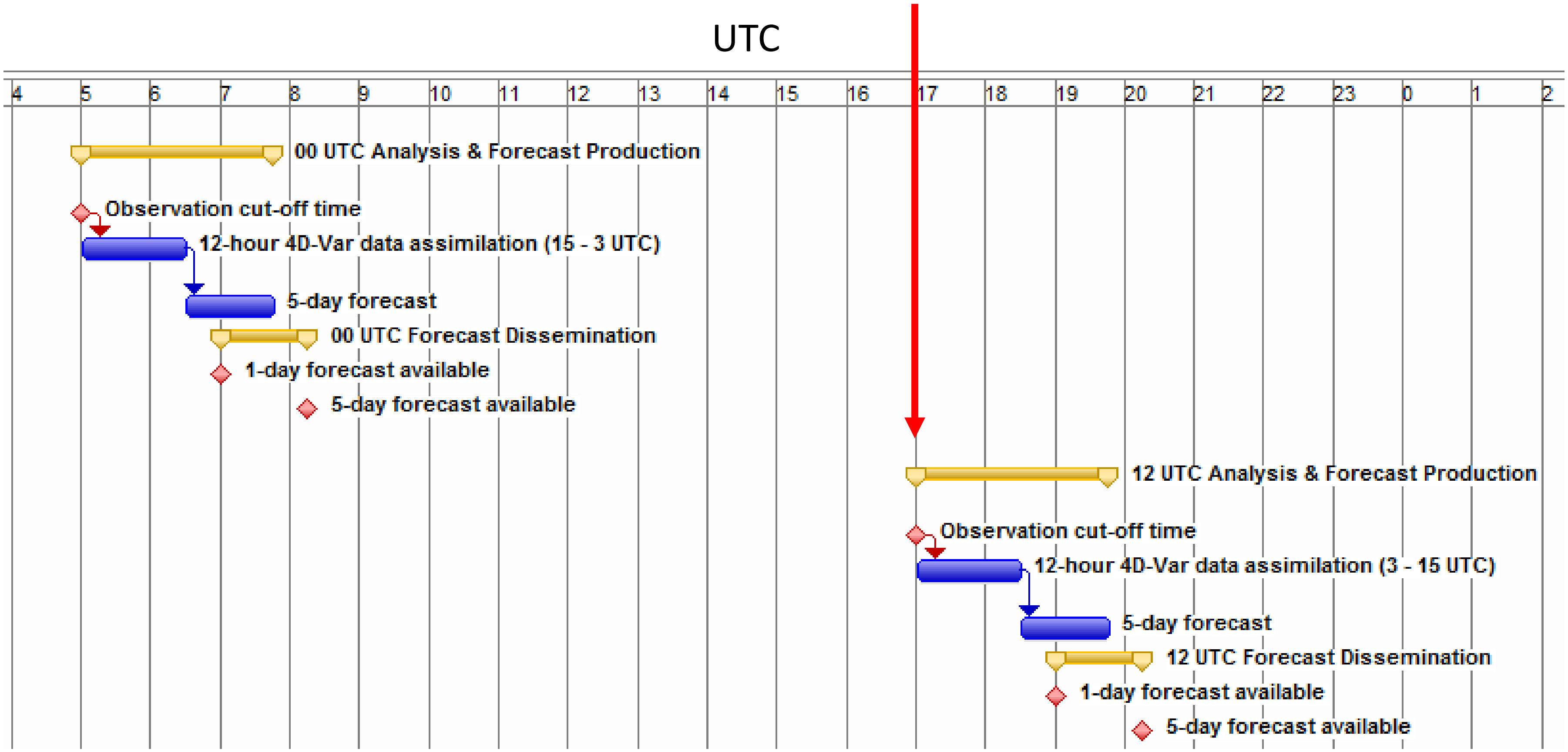
Fires



Aerosol



Envisaged operational MACC-II NRT production system (2014)

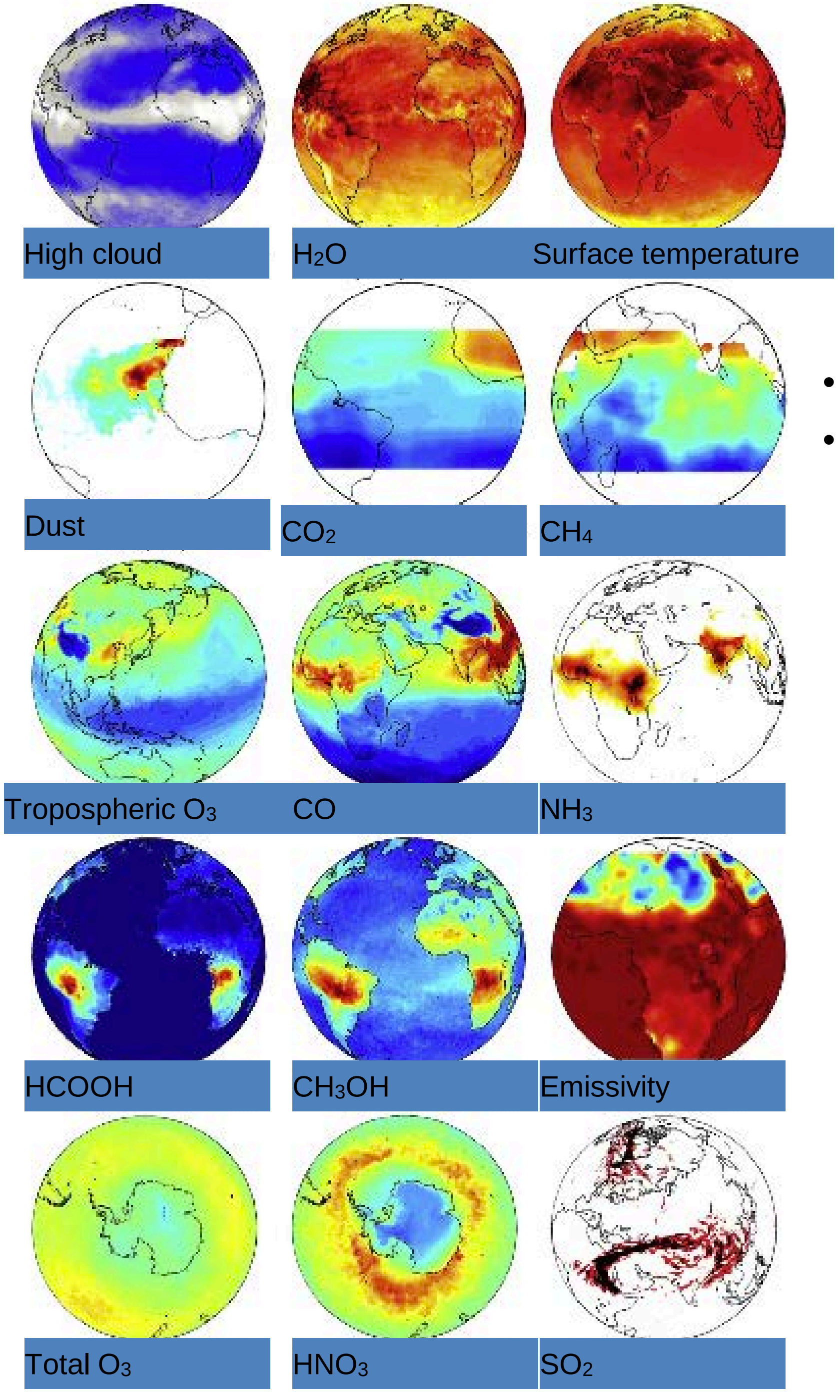


- 12UTC cycle (using observations from 3 -15 UTC) starts with an observation cut-off time of 17UTC
- Dissemination of the 5-day forecast at approximately 20:15UTC

Data used in MACC NRT system

Instrument	Satellite	Satellite operator	Data provider	Species	Status
MODIS	Terra	NASA	NASA/NOAA	Aerosol, fires	**Active**
MODIS	Aqua	NASA	NASA/NOAA	Aerosol, fires	**Active**
SEVIRI	Meteosat-9	EUMETSAT	IM	Fires	**Active**
Imager	GOES-11, 12	NOAA	NOAA	Fires	**Passive**
Imager	MTSAT-2	JMA	JMA	Fires	Planned
MLS	Aura	NASA	NASA	O_3	**Active**
OMI	Aura	NASA	NASA	O_3	**Active**
SBUV-2	NOAA-16,17,18,19	NOAA	NOAA	O_3	**Active**
SCIAMACHY	Envisat	ESA	KNMI	O_3	**Died**
GOME-2	Metop-A	EUMETSAT	DLR	O_3	**e-suite**
IASI	Metop-A	EUMETSAT	LATMOS/ULB	CO	**Active**
IASI	Metop-B	EUMETSAT	LATMOS/ULB	CO	**Passive**
MOPITT	Terra	NASA	NCAR	CO	**Active**
GOME-2	Metop-A	EUMETSAT	DLR	NO_2	**Passive/Tests**
OMI	Aura	NASA	KNMI	NO_2	**Active**
OMI	Aura	NASA	NASA	SO_2	**Active**
GOME-2	Metop-A	EUMETSAT	DLR	SO_2	**Passive/Tests**
GOME-2	Metop-A	EUMETSAT	DLR	HCHO	**Passive**
Offline tests:					
IASI	Metop-A	EUMETSAT	LATMOS/ULB	O3	**Tests**

CH4 and CO2 used in delayed-mode analysis and reanalysis

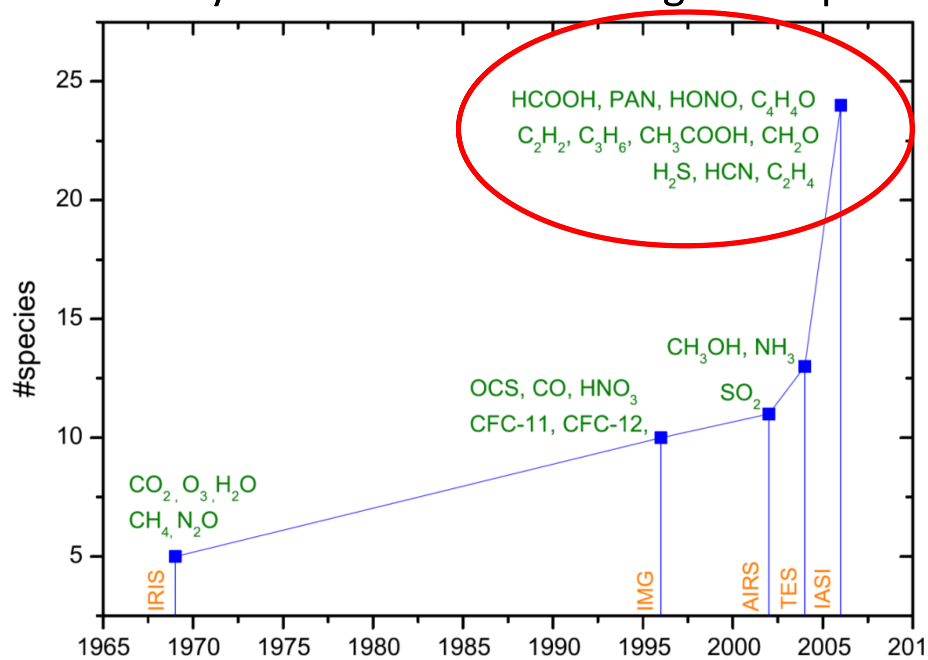


Clerbaux & Crevoisier, Atm. Env., 2013

Potential for retrieving wide range of geophysical parameters from EO measurements, e.g. IASI

- Tropospheric sensitivity to several chemical species
- Long-term measurements with multiple instruments

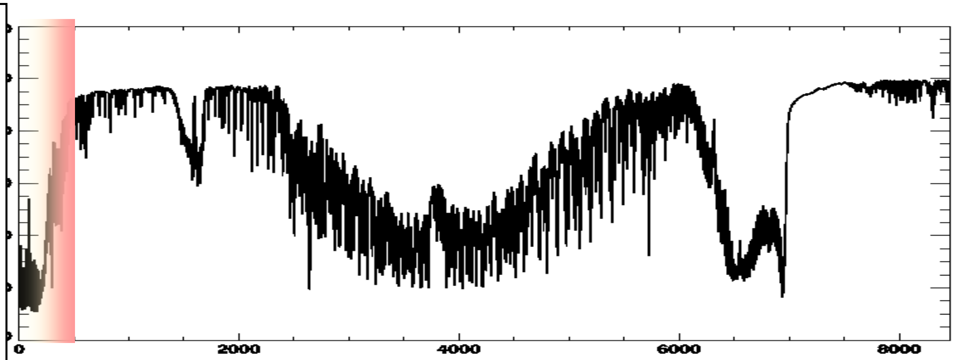
History of thermal IR sounding from space



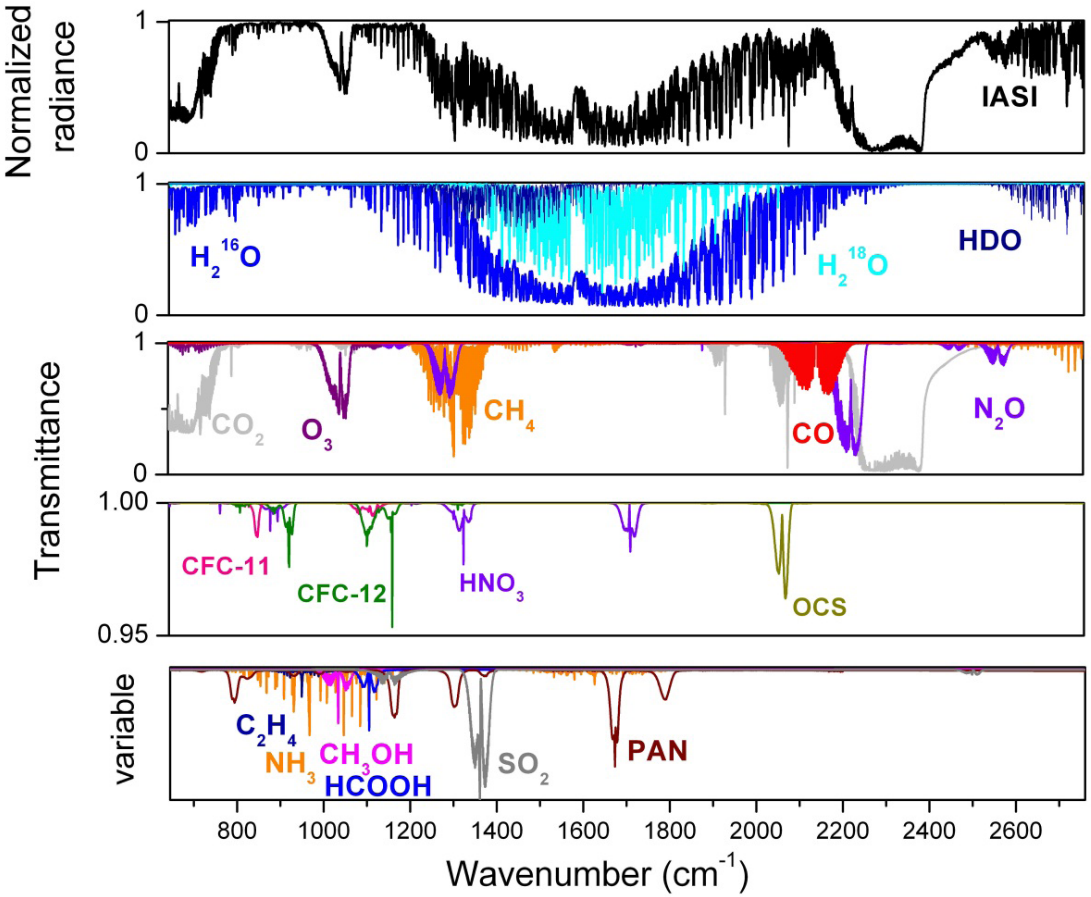
Clarisse et al., Geophys. Res. Lett., 2011

IASI spectrum

1st 500 channels cover the 15µm CO_2 band giving the bulk of temperature information in current systems.



A. Collard



M. George et al. (LATMOS/ULB)

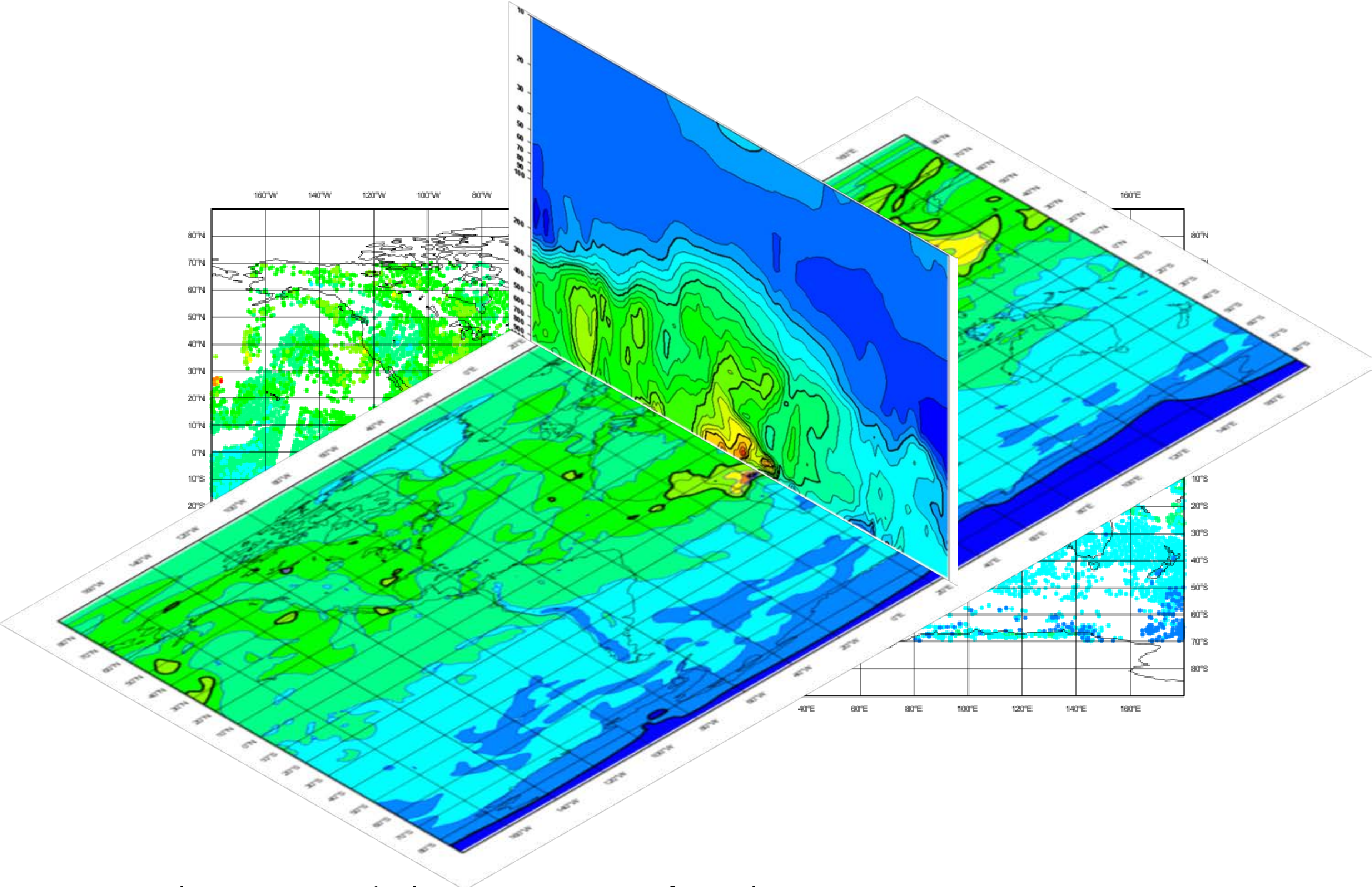
Using trace gas retrievals in MACC

- Easier
- No radiative transfer model for some of the species of interest
- Bad experiences with radiance assimilation:
  - Combination of model bias and VarBC in CO_2 data assimilation from AIRS and IASI radiances caused artificial long-term trend. New experiments with correction to fluxes are needed to assess the use of VarBC.
  - Tests with IASI/AIRS ozone radiance assimilation led to degraded tropospheric ozone

- ECMWF uses IASI/AIRS/HIRS-9 radiances in ozone analysis

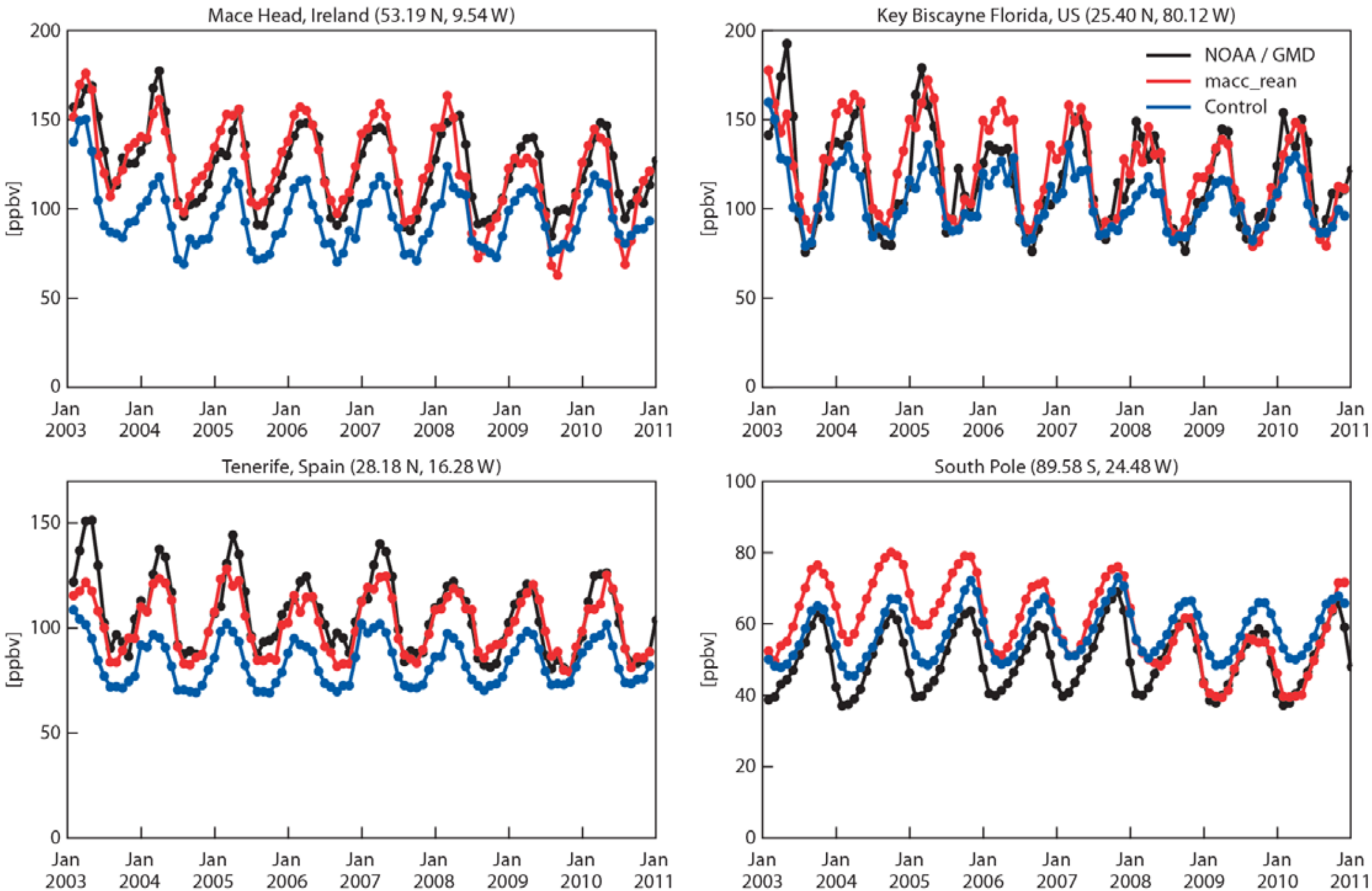
AIRS O3 channels	950 to 1178	1088 as anchor
IASI O3 channnels	1479, 1509, 1513, 1521, 1536, 1574, 1578, 1579, 1585, 1587, 1626, 1639, 1643, 1652, 1658, 1671	varbc
HIRS channel 9	active	varbc

Assimilation of CO observations in a global model



Carbon Monoxide (CO) is a tracer of combustion sources

MACC reanalysis: Validation against monthly mean CO concentrations from ground-based NOAA/GMD stations



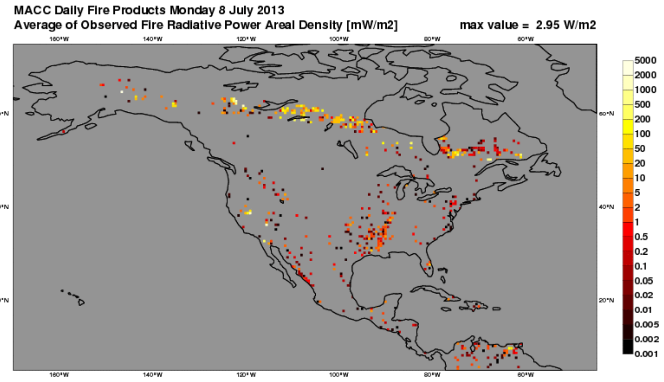
[ppbv]

Reanalysis (red), control run (blue) observations (black)

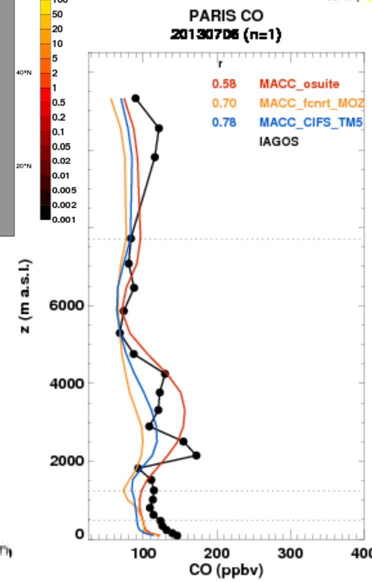
I. Bouarar (LATMOS)

MOPITT TCCO (from NCAR) assimilated from January 2003 onwards.
IASI TCCO (from LATMOS/ULB) assimilated from April 2008 onwards.
More validation in Inness et al. (2013) and from www.gmes-atmosphere.eu

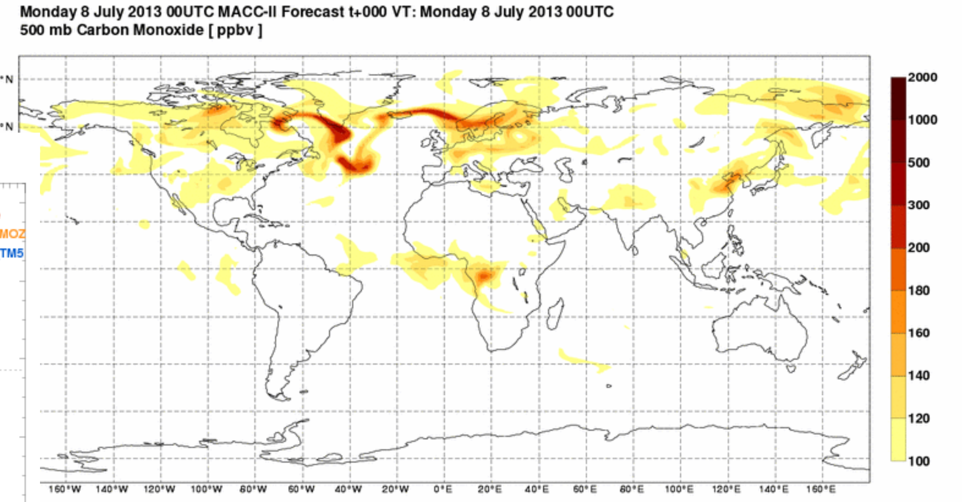
July 2013



GFAS

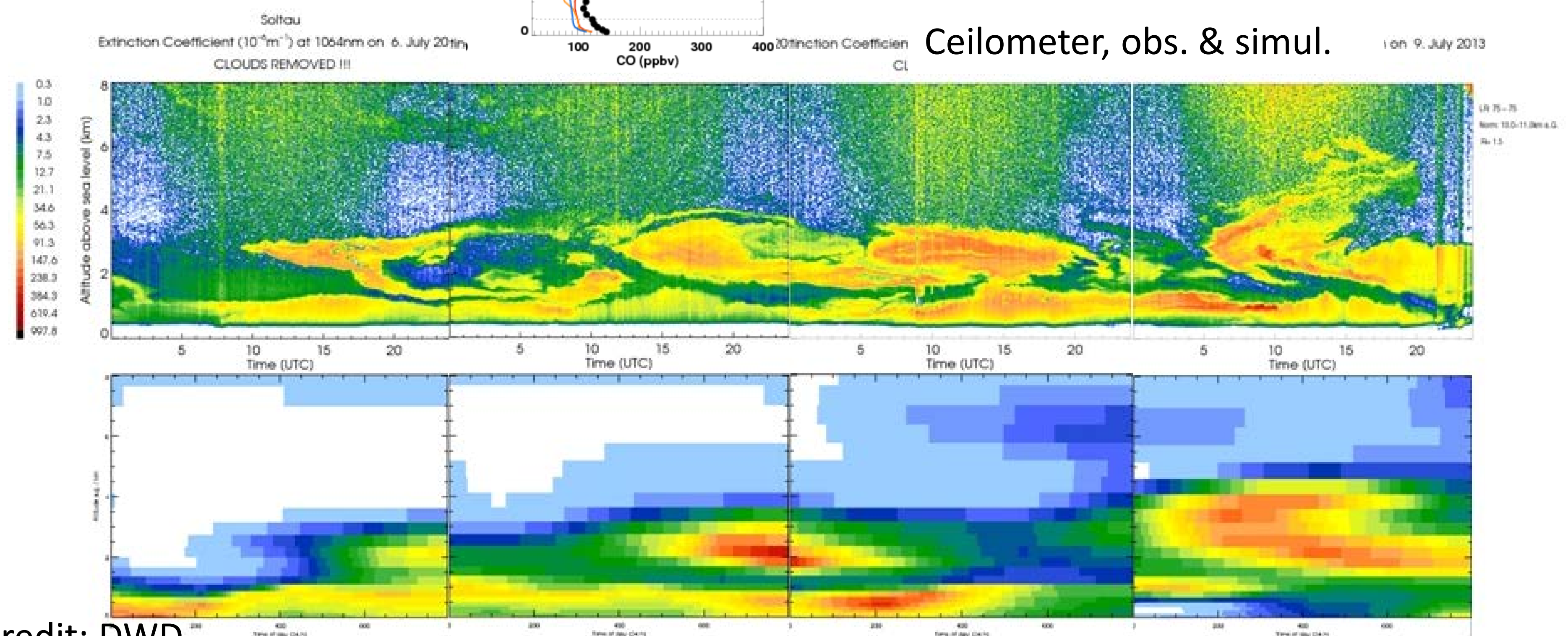


CO profiles →



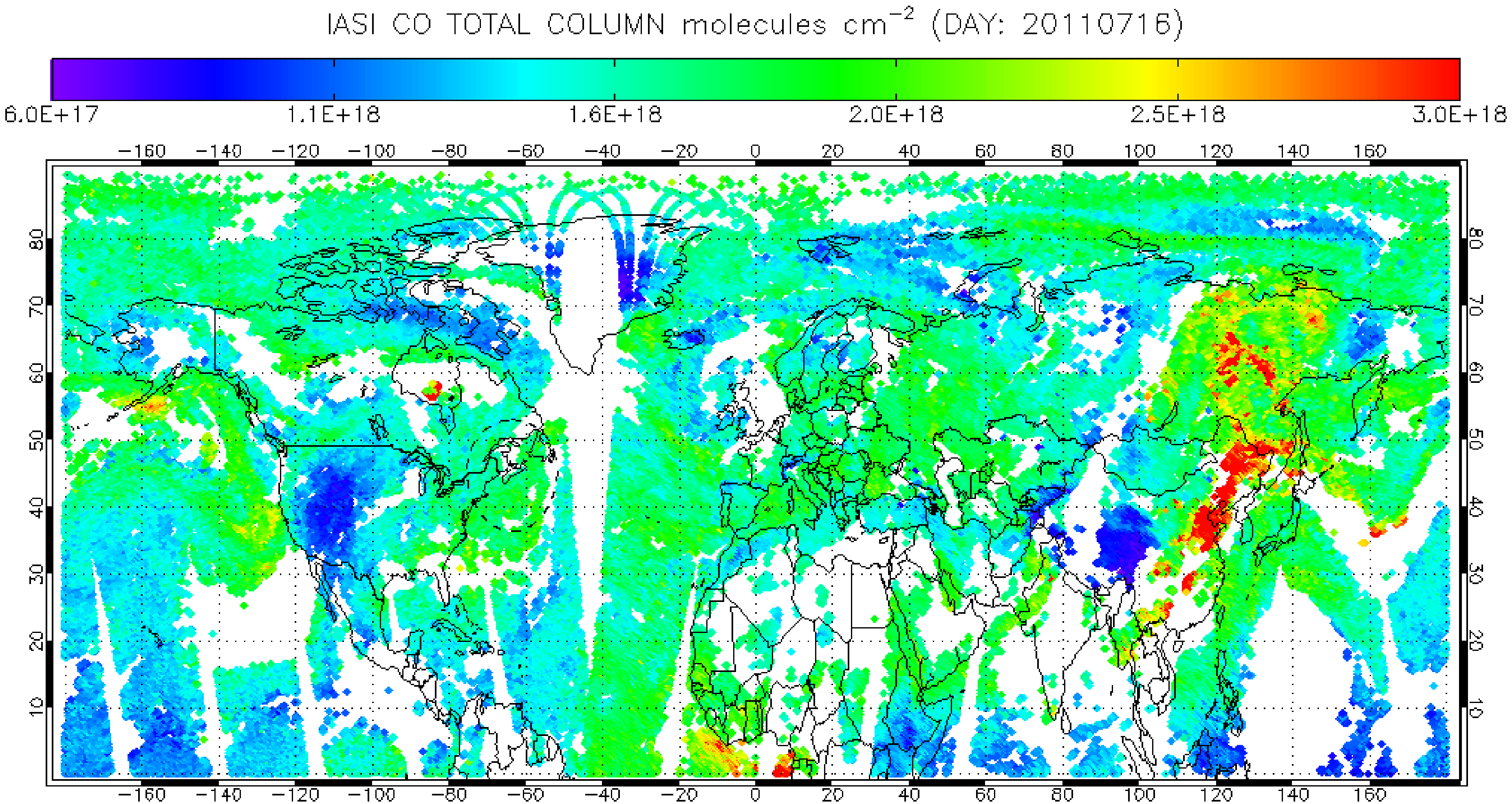
CO @ 500 hPa

Ceilometer, obs. & simul.



Credit: DWD

Forest fires in NW Ontario in July 2011

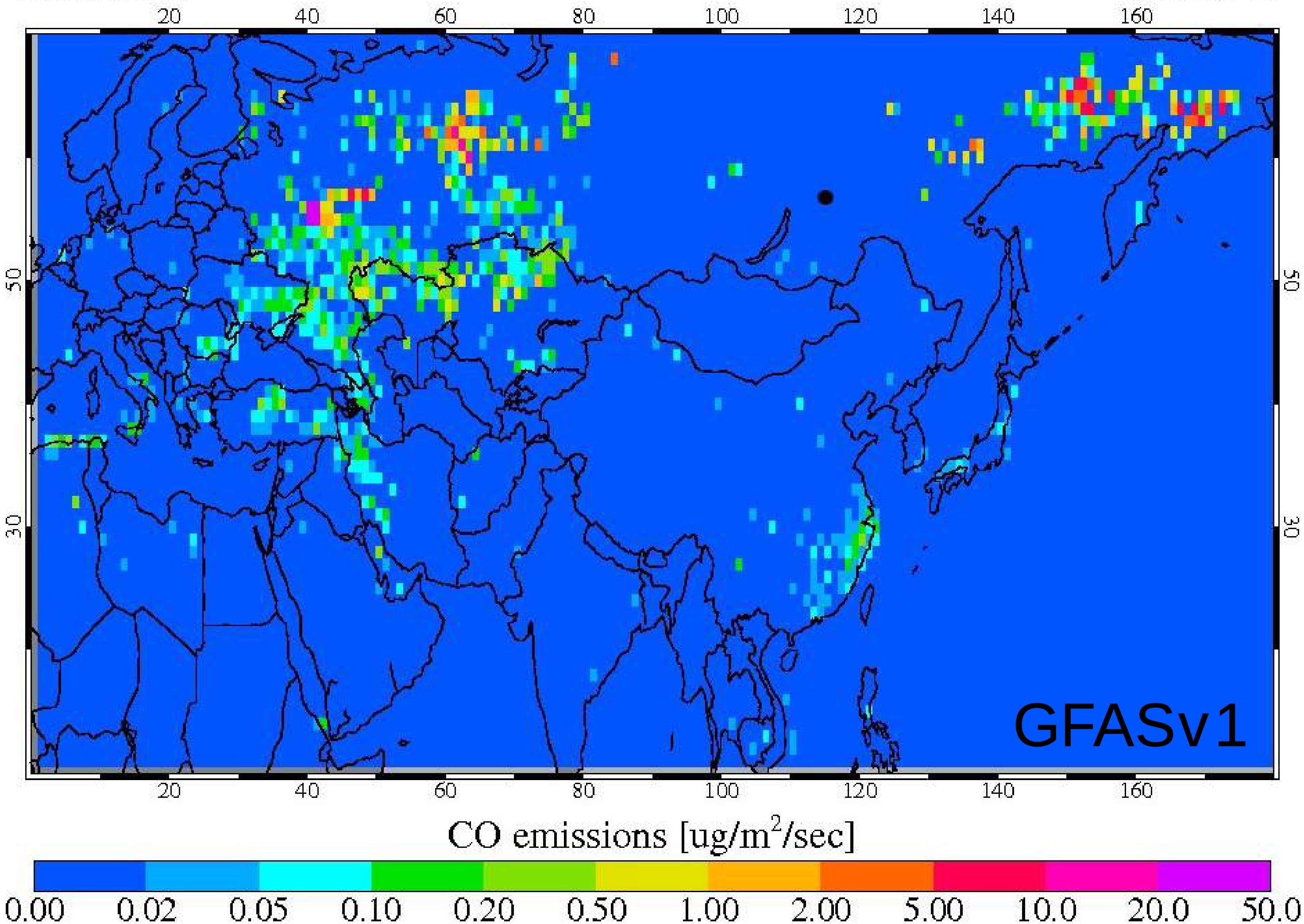


Importance of biomass burning for atmospheric composition in that it is episodic but really stands out from the background and other potential CO sources

From http://aolab.phys.dal.ca/data/archive/halifax_2011/iasi/Archive/July21PM/world.gif

Russian fires 2010

3-week average fire CO emissions (1-20 August)



Huijnen et al. 2012

Hindcast experiments

- *TM5-chem-v3.0 coupled to ECMWF-IFS*
- *'daily' 4 day hindcasts were produced*
- *From 15 July – 31 August 2010*

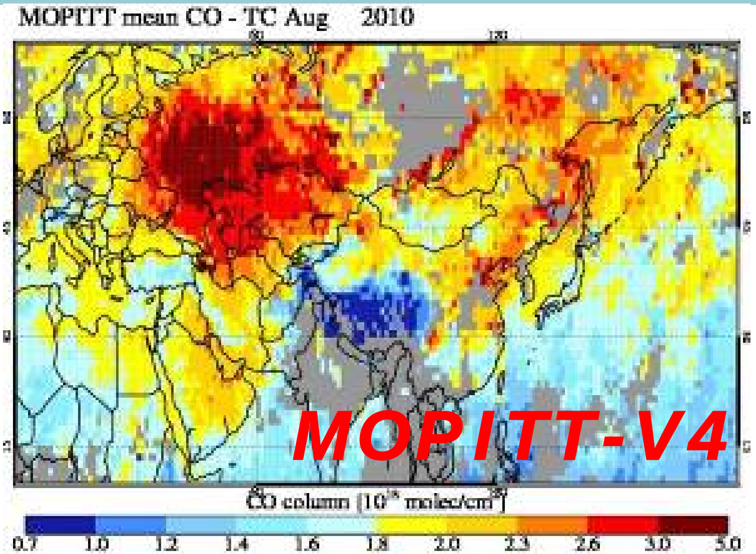
Version	Assimilation	Emissions
Ref	no	GFEDv2 climatology
Assim	CO (IASI), O3 (OMI, MLS), NO2 (OMI)	GFEDv2 climatology
GFAS	no	GFASv1
Assim-GFAS	CO (IASI), O3 (OMI, MLS), NO2 (OMI)	GFASv1

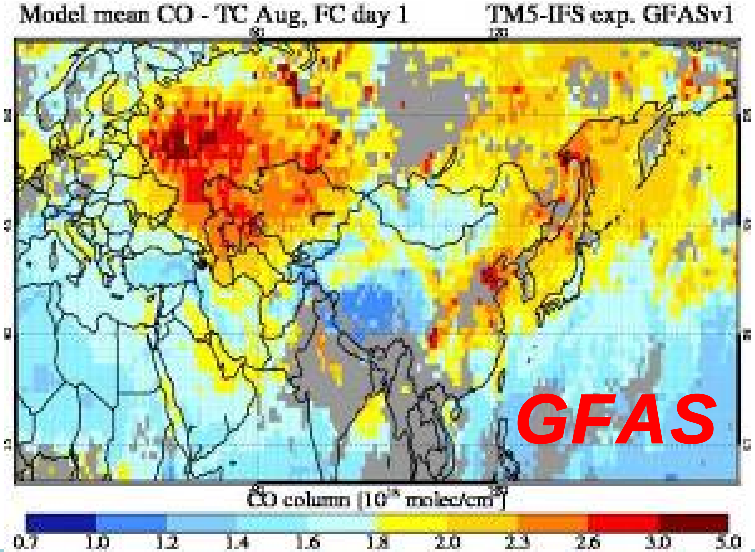
Notes:

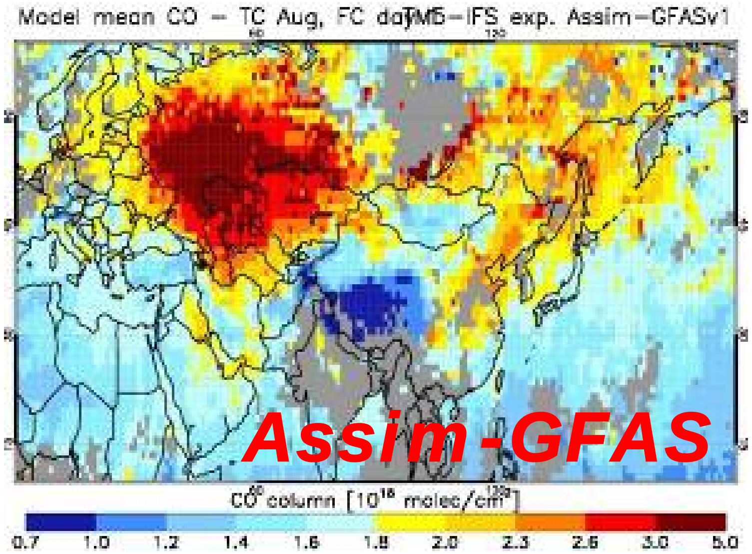
- *One year spin-up (free model run)*
- *RETRO/REAS anthropogenic emissions*
- *In forecasts: persistency of fire emissions*

Huijnen et al. 2012

CO without/with assim vs MOPITT-V4

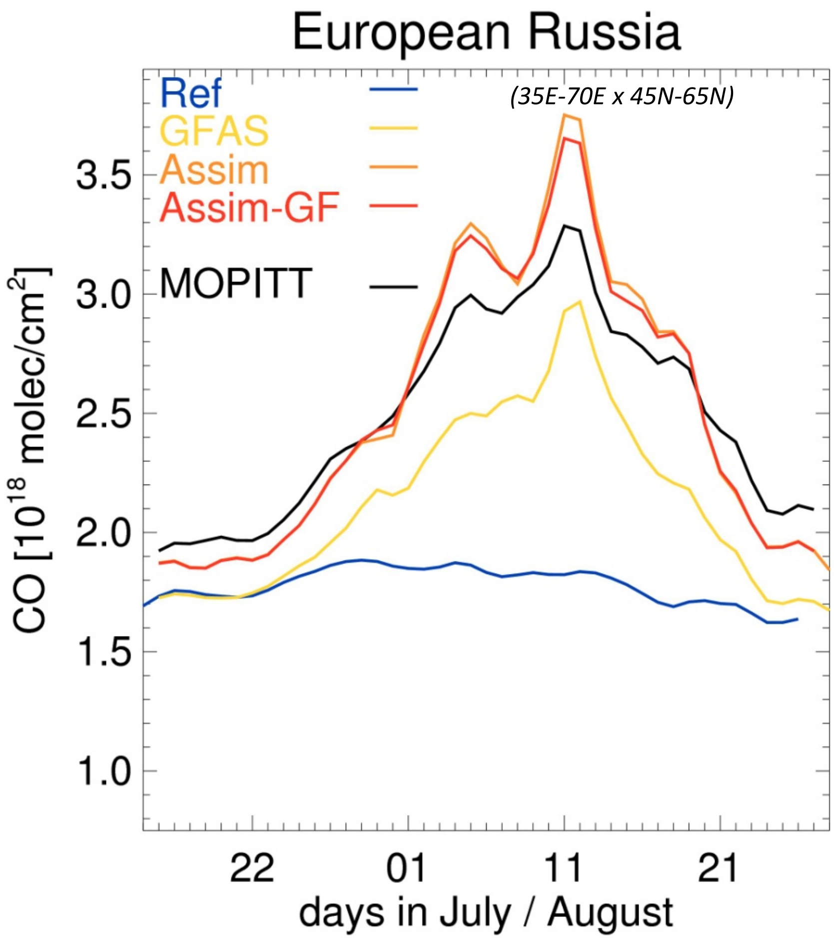






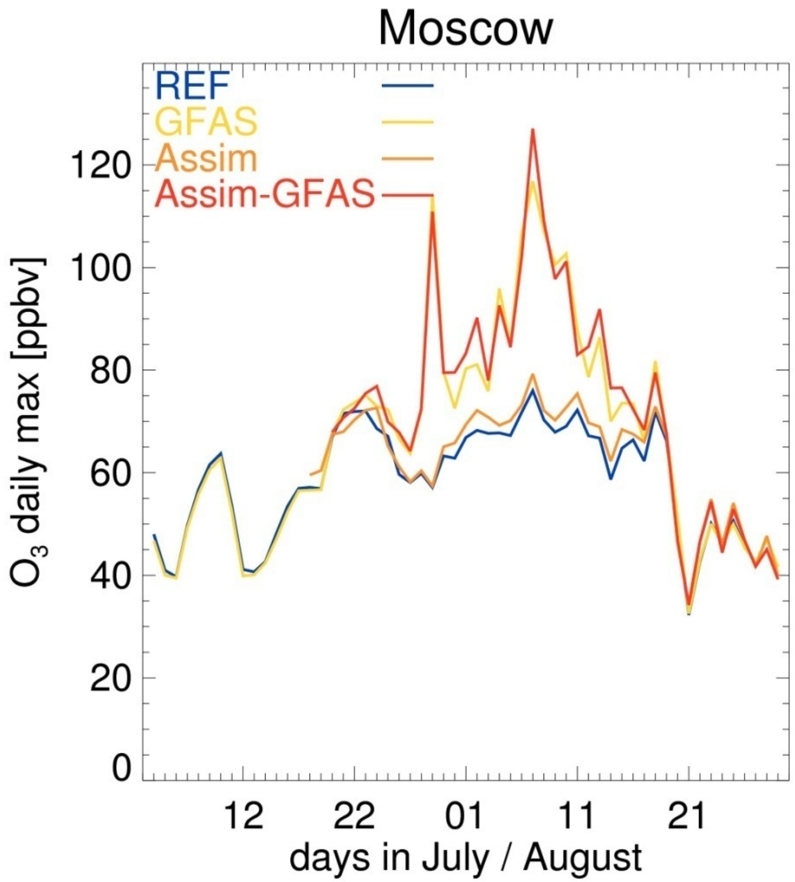
Huijnen et al. 2012

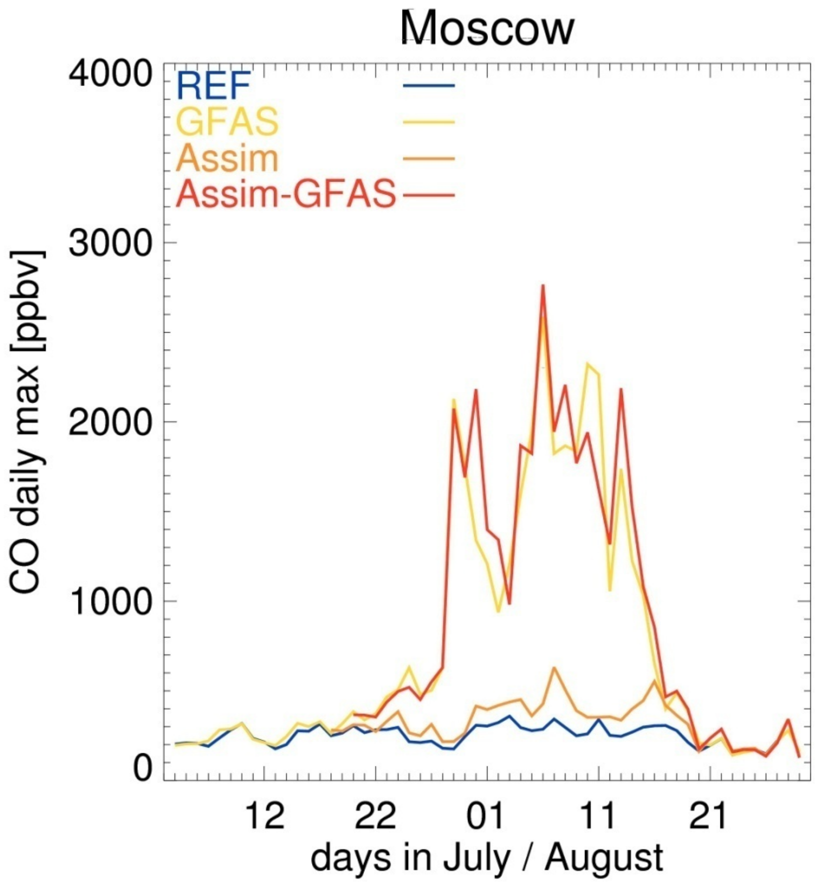
Evolution of CO columns vs MOPITT-V4



Huijnen et al. 2012

Daily maximum surface O_3 and CO concentrations





Huijnen et al. 2012

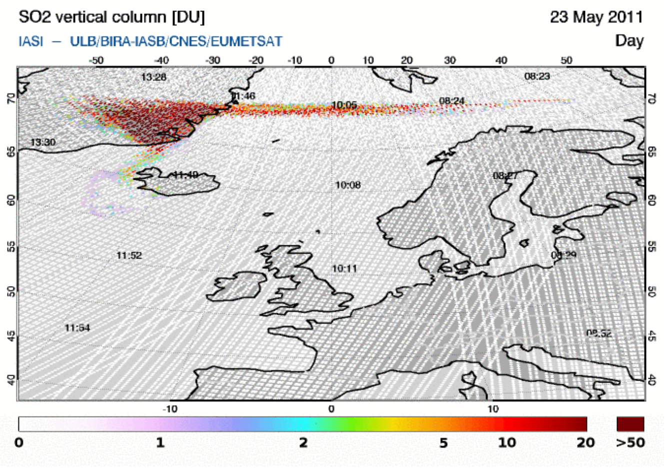
Assimilation of OMI SO2 in the MACC system. Detecting volcanic SO2 signal with IASI L1 data

• Method used to produce SO2 alerts by the Support to Aviation Control service (SACS), see http://sacs.aeronomie.be/nrt/

• From the IASI L1C BUFR file calculate (Clerbaux pers. comm.):

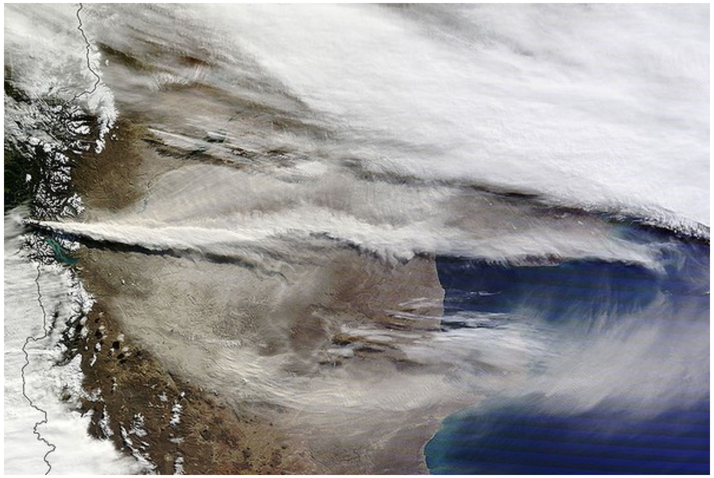
dBT=(BT(b1)+BT(b2)-BT(s1)-BT(s2))/2

b1 = channel 3050, 1407.25 cm-1 (baseline 1)
b2 = channel 3056, 1408.75 cm-1 (baseline 2)
s1 = channel 2907, 1371.50 cm-1 (SO2 channel 1)
s2 = channel 2908, 1371.75 cm-1 (SO2 channel 2)



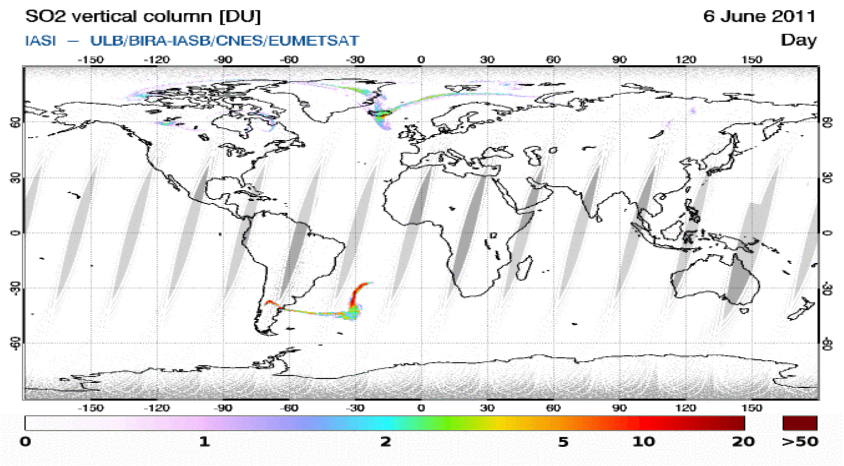
• Clarisse et al. (2008) and Karagulian et al. (2010) found linear correlation between dBT and SO2 concentrations for SO2< 35DU:
Maps of dBT can show volcanic SO2. Also Clarisse et al. (2012)

Eruption of Puyehue, Chile, 5 June 2011, 12z

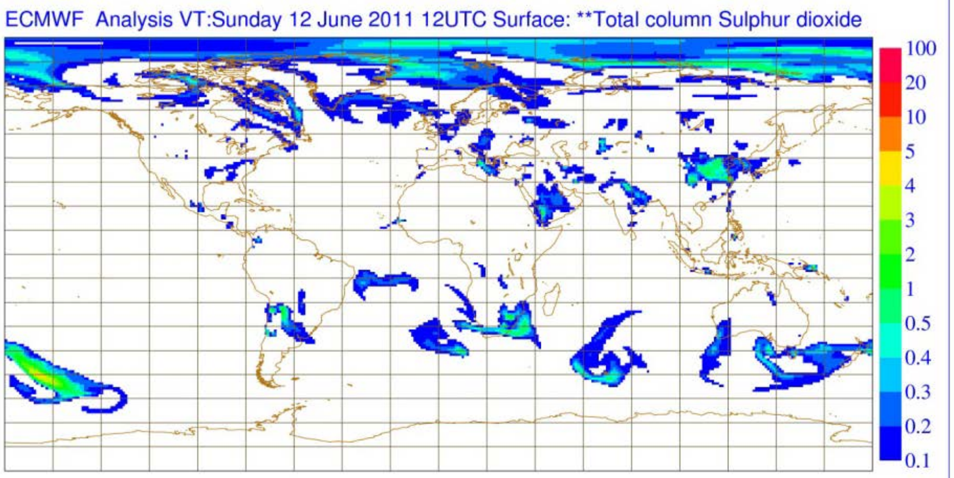


OMI SO2 are assimilated if

- SO2 > 5DU
- 60S < Latitude < 70N
- SCANPOS < 24
- SOE > 15deg



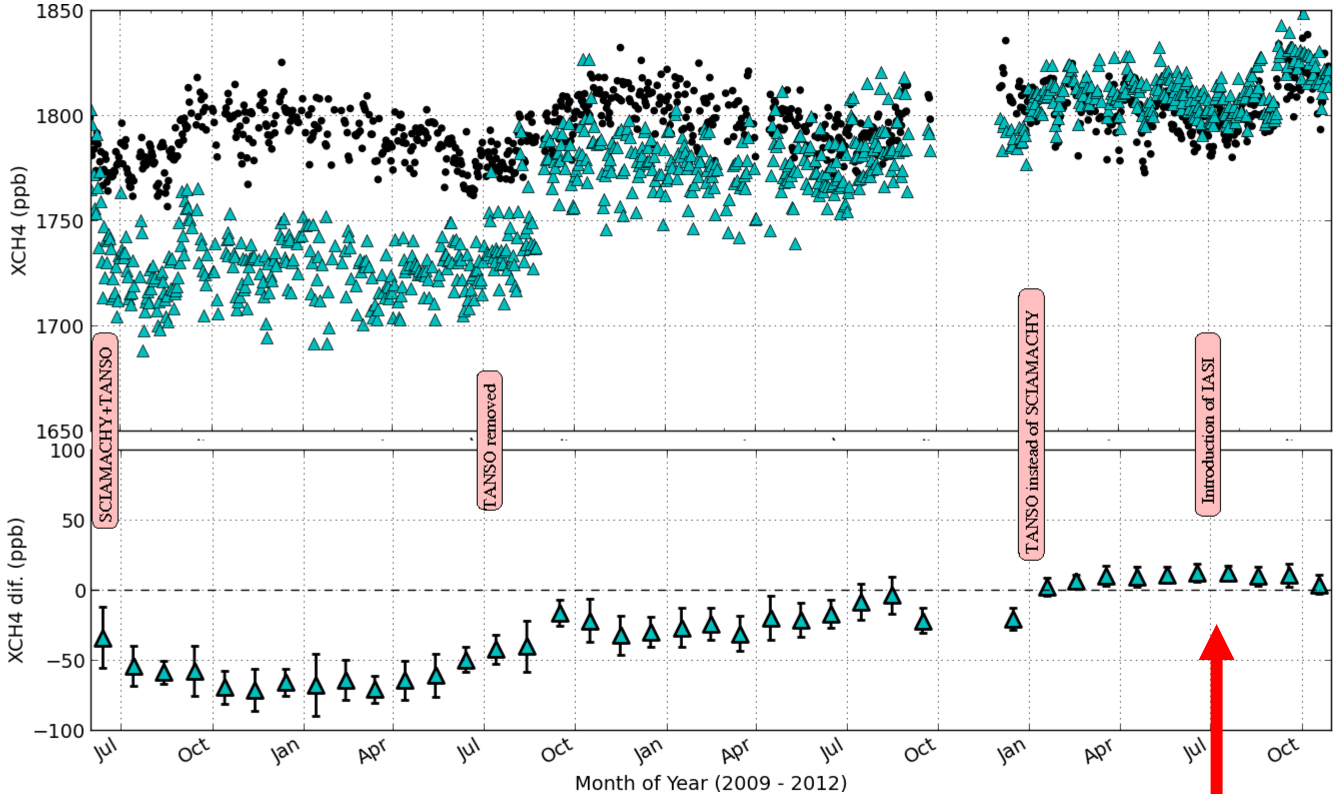
SO2 analysis and IASI SO2 dBT signal



- Black dots: dBT values > 1K
- Grey dots: dBT values > 3K

Now also IASI SO2 images, from http://sacs.aeronomie.be/nrt/

Use of IASI CH4 retrievals in MACC delayed-mode analysis



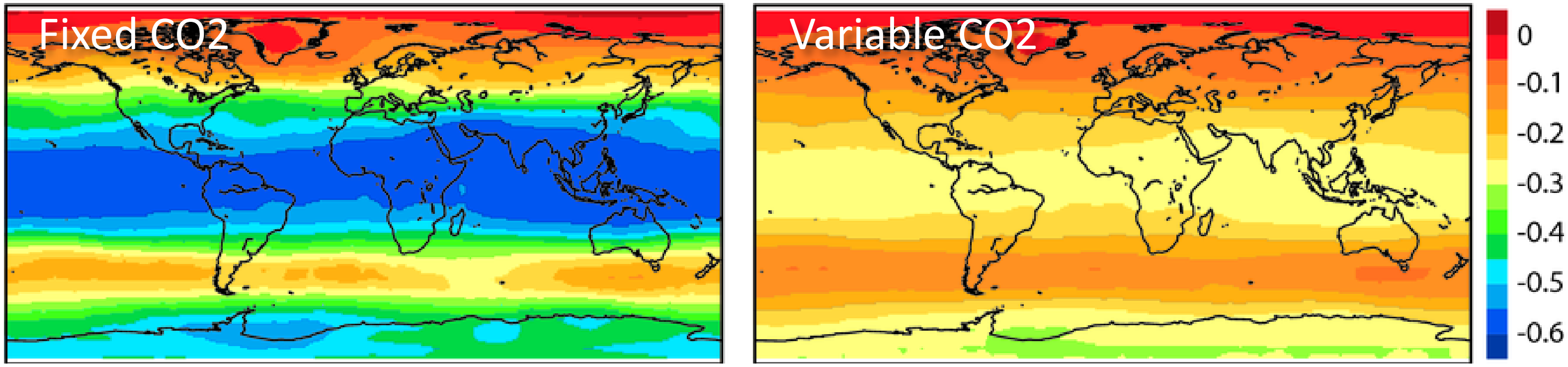
July 2009

Dec 2012

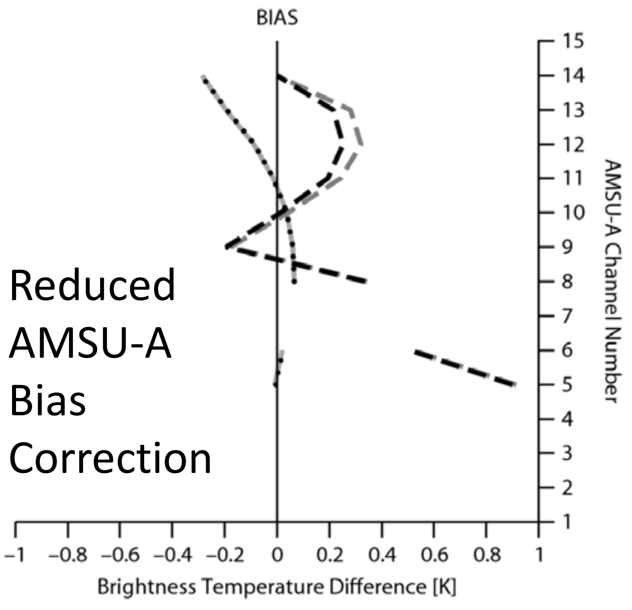
Use of IASI begins

Benefit of trace gases for NWP: $VarCO_2$ in radiance assimilation

Reduced AIRS and IASI Bias Correction



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



Reduced AMSU-A Bias Correction

Using modelled CO_2 in AIRS/IASI radiance assimilation leads to significant reduction in needed bias correction.

Small positive effect on T analysis and neutral scores.

Use of different approximations instead of fully modelled CO_2 is subject of further study.

Engelen and Bauer, QJRMS, 2011

One person's noise is another person's signal