

MACC

**Monitoring Atmospheric
Composition and Climate**

**GMES Atmospheric pilot Core Service on Air
quality**

Antje Inness

European Centre for Medium-Range Weather Forecasts

With acknowledgement to all MACC/GEMS colleagues

The core production lines have been developed by the GEMS and PROMOTE projects

The image displays two web browser windows. The left window shows the 'ESA project PROMOTE. PROtocol MOiTorIng for the GMES Service Element: Atmosphere' website. The right window shows the 'GEMS Project at ECMWF - GMES GCP IGOS' website.

ESA project PROMOTE. PROtocol MOiTorIng for the GMES Service Element: Atmosphere

Project supported by the European Space Agency
Stage 2 - Up-scaling the GSE Atmospheric Monitoring portfolio
July 2006 - August 2009

Mission

To deliver the Atmosphere GMES Service Element a sustainable and reliable operational service to support informed decisions on the atmospheric policy issues of stratospheric ozone depletion, surface UV exposure, air quality and climate change.

Services

Ozone Service, UV Service, Air Quality Service, Climate Study Support Service, Aviation Support Service

Services by user communities

Health, Meteorological, Environmental, Research/Modelling, Policy/Conventions, Citizens

gmes
GMES, Global Monitoring for Environment and Security, is a joint initiative of the European Commission and the European Space Agency

GEMS Project at ECMWF - GMES GCP IGOS

Project Objectives

The EU-funded GEMS project is developing comprehensive data analysis and modelling systems for monitoring the global distributions of atmospheric constituents important for climate, air quality and UV radiation, with a focus on Europe.

Products

Reanalysis, Regional Air Quality, Aerosol Forecast, UV Forecast, Reactive gas Forecast, POLARCAT Support, Greenhouse Gases, All

Themes

- Overview
- Global Greenhouse Gases
- Global Reactive Gases
- Aerosols
- Regional Air Quality
- Production
- Validation

Project Information

- About the Project
- Participants List
- Documents
- Meetings, Workshops & Seminars
- Software & Tools
- Products
- Data Access (new)
- Collaboration Tools
- Reporting Tools
- Contact Us

First versions of the systems are now being run daily to provide current analyses and forecasts, and retrospective analyses for the years 2003-2007. Prototype products are available for inspection, trial use and [user feedback](#). Products are at present openly available only in graphical form. Provision of digital data is under development.

Envisaged evolution of the GMES Atmospheric Core Service

GEMS

EC FP6 Integrated Project
March 2005 – May 2009

PROMOTE

ESA GMES Service Element
April 2004 – August 2009

MACC

EC FP7 Integrated Project
June 2009 – October 2011

Operational GMES Atmospheric Core Service

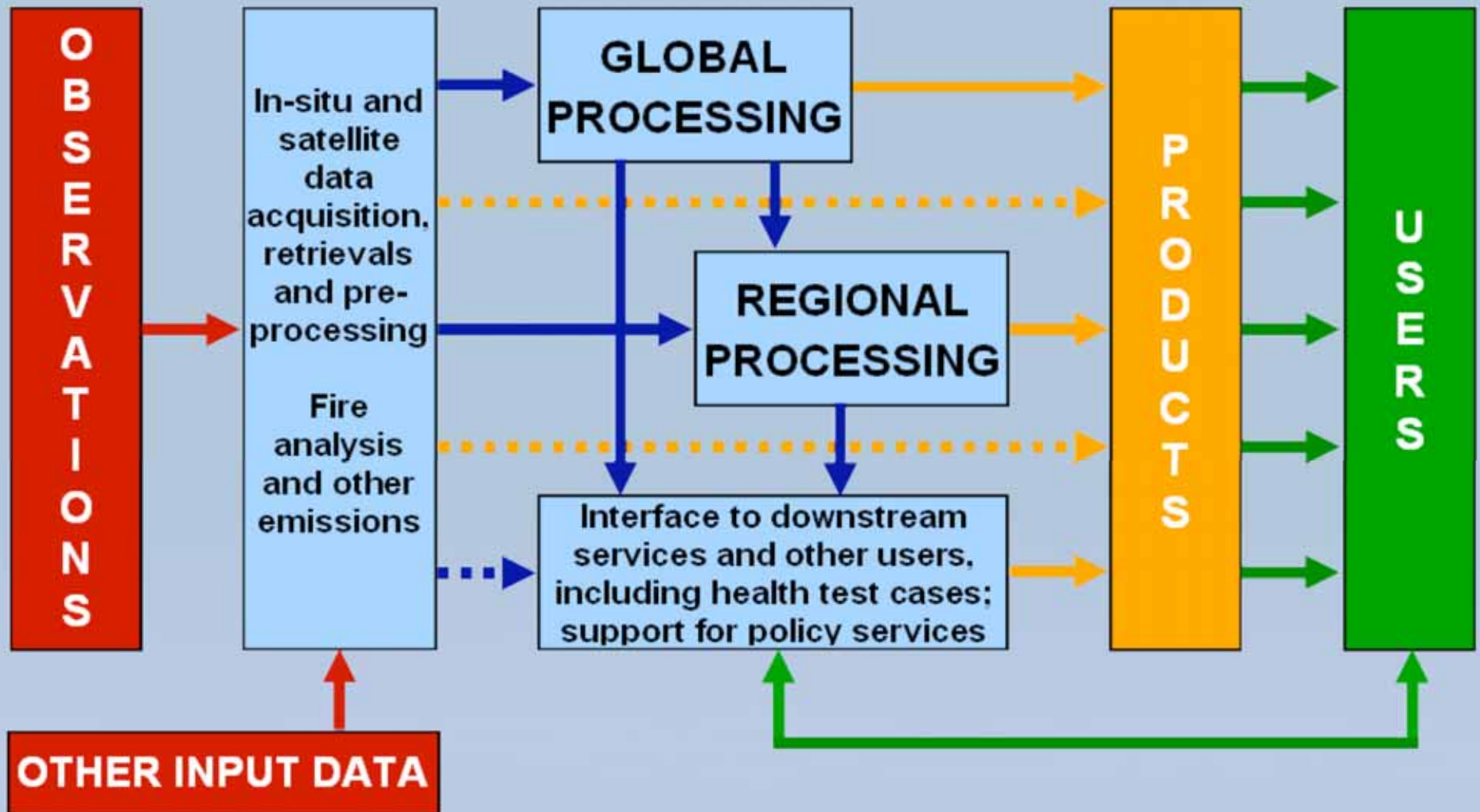
November 2011 –

ECMWF	European Centre for Medium-Range Weather Forecasts	INT
UKMET	Met Office	UK
LMD, LA, LISA, ICARE	Centre National de la Recherche Scientifique	FR
CEA	Commissariat à l'Energie Atomique	FR
DLR	Deutsches Zentrum für Luft- und Raumfahrt e.V.	DE
MPG	Max-Planck-Gesellschaft zur Förderung der Wissenschaften e. V.	DE
KNMI	Royal Netherlands Meteorological Institute	NL
BIRA-IASB	Institut d'aéronomie spatiale de Belgique	BE
FMI	Ilmatieteen Laitos - Finnish Meteorological Institute	FI
DMI	Danish Meteorological Institute	DK
DWD	Deutscher Wetterdienst	DE
IUP-UB	University of Bremen	DE
UPMC-SA	Université Pierre et Marie Curie - Paris 6	FR
NKUA	National and Kapodistrian University of Athens	GR
MF-CNRM	Météo-France - Centre National de Recherches Météorologiques	FR
NUIG	National University of Ireland, Galway	IE
SMHI	Swedish Meteorological and Hydrological Institute	SU
ARPA ER	ARPA Emilia Romagna	IT
AEMet	Agencia Estatal de Meteorología	ES
MET.NO	Meteorologisk Institutt	NO
FRIUUK	Rheinisches Insti. für Umweltforschung an der Universität zu Köln	DE
JRC	European Commission - Joint Research Centre	JRC
INERIS	Institut National de l'Environnement Industriel et des Risques	FR
CHMI	Czech Hydrometeorological Institute	CZ
NMA	National Meteorological Administration, Romania	RO
PIEP	Institute of Environmental Protection	PL
IMPERIAL	Imperial College of Science, Technology and Medicine	UK
FZJ	Forschungszentrum Jülich GmbH	DE
ARSO	Environmental Agency of the Republic of Slovenia	SV
ARMINES	Association pour la recherche et le développement des méthodes et processus industriels	FR
SRON	Netherlands Institute for Space Research	NL
UNIVLEEDS	University of Leeds	UK
KCL	King's College London	UK
VUA	Vrije Universiteit, Amsterdam	NL
UBA_AT	Umweltbundesamt GmbH	AT
TNO	Nederlandse Organisatie voor toegepast-natuurwetenschappelijk onderzoek	NL
CERC	Cambridge Environmental Research Consultants Ltd	UK
CGS	Carlo Gavazzi Space S.p.A.	IT
Flyby	Flyby s.r.l.	IT
CERFACS	Centre Européen de Recherche et Formation avancée en Calcul Scientifique	FR
CNES	Centre National d'Etudes Spatiales	FR
NILU	Norsk Institutt for Luftforskning	NO
CNR	National Research Council	IT
NEPA	National Environmental Protection Agency	RO
UWS	University of the West of Scotland	UK

The MACC Partnership

- 46 national entities (universities, national labs, environment agencies, ...) from 18 European States, plus ECMWF and JRC
- Partners include 11 National Met Services
- Supporting organizations comprise several other national institutes, EUMETSAT and WMO
- ECMWF is project coordinator

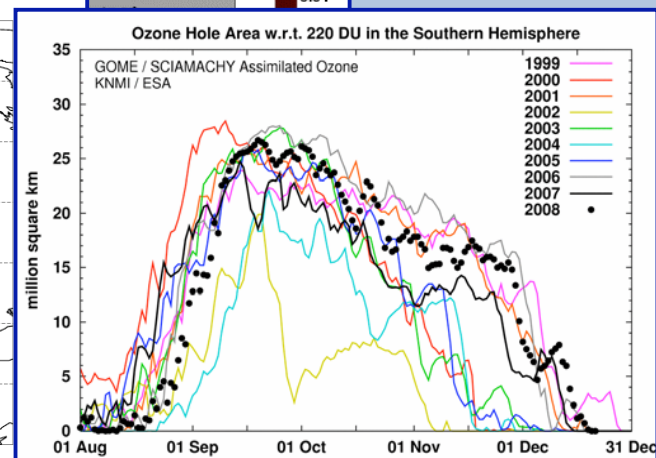
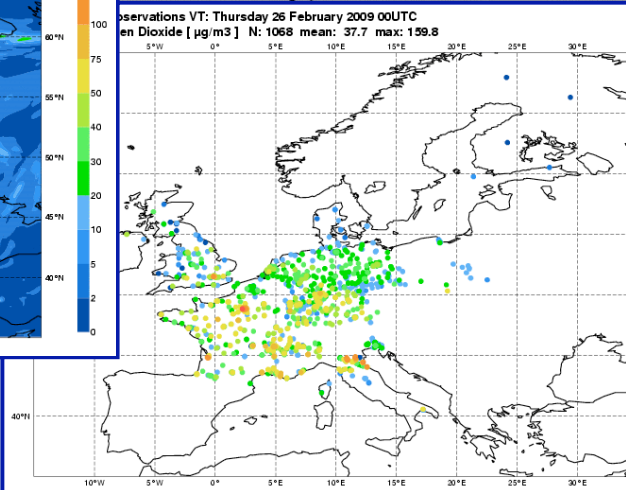
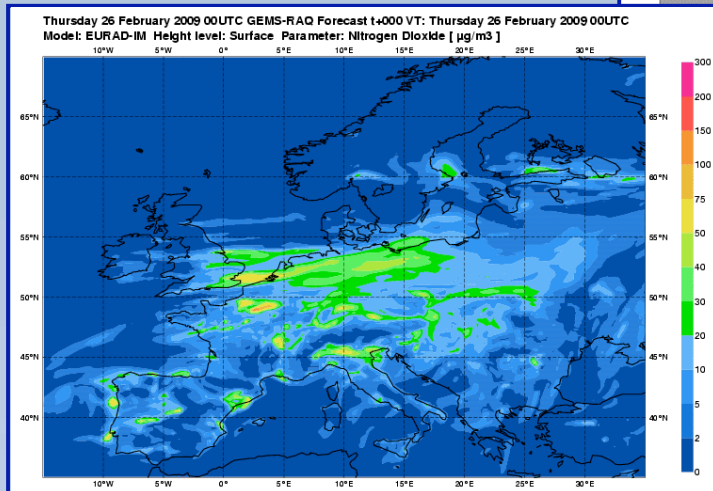
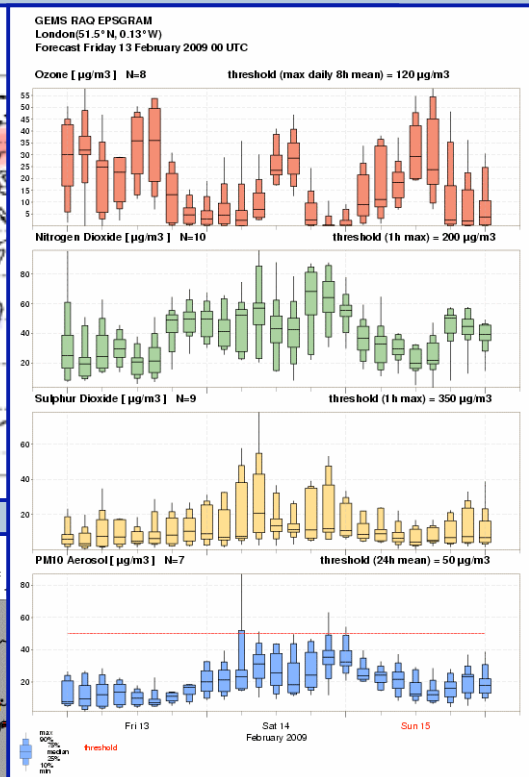
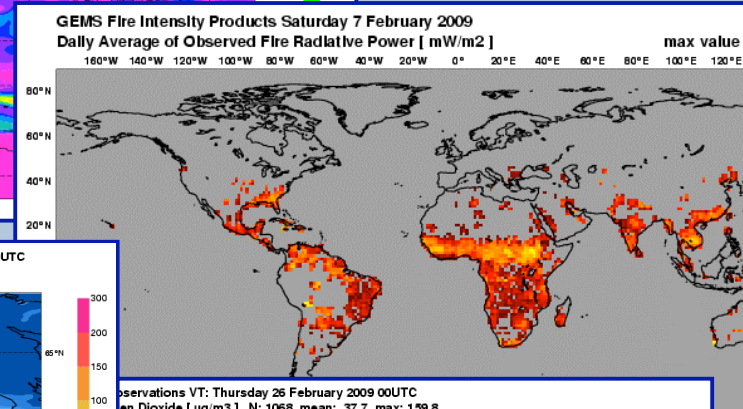
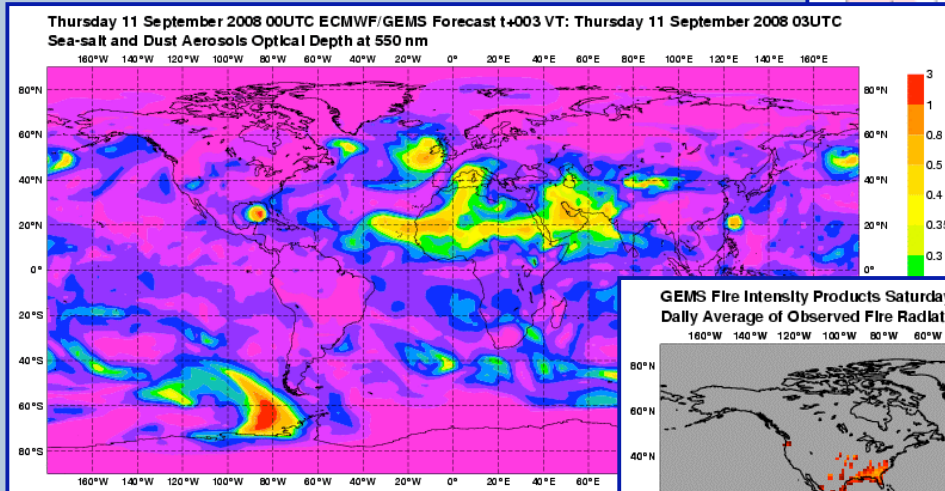
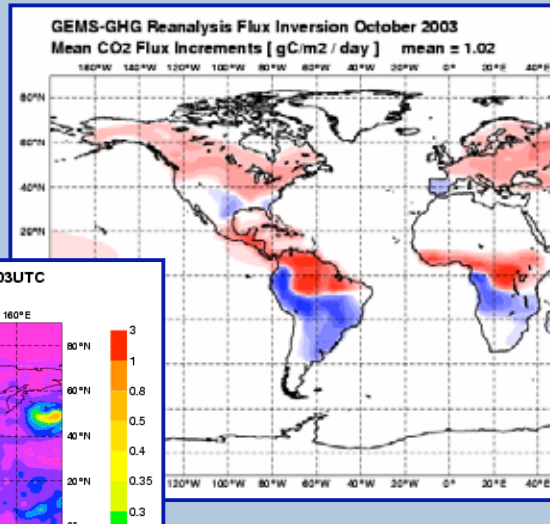
The MACC Project Architecture



The MACC product set

- Global analyses of greenhouse gases, reactive gases and aerosols, provided in near-real-time and retrospectively
- Some of the required satellite data retrievals
- Estimates of global climate forcing, and of emissions and sinks
- Global forecasts of reactive gases and aerosols
- Multi-model forecasts and assessments of air quality for Europe using regional systems
- Services for stratospheric ozone, UV radiation and solar energy
- Products to support downstream services, including those providing downscaling and health warnings for dust-related meningitis and pulmonary disorder
- Estimates of long-range pollutant transport and source attribution; data in support of related international studies; tools for evaluating control strategies

Graphical products

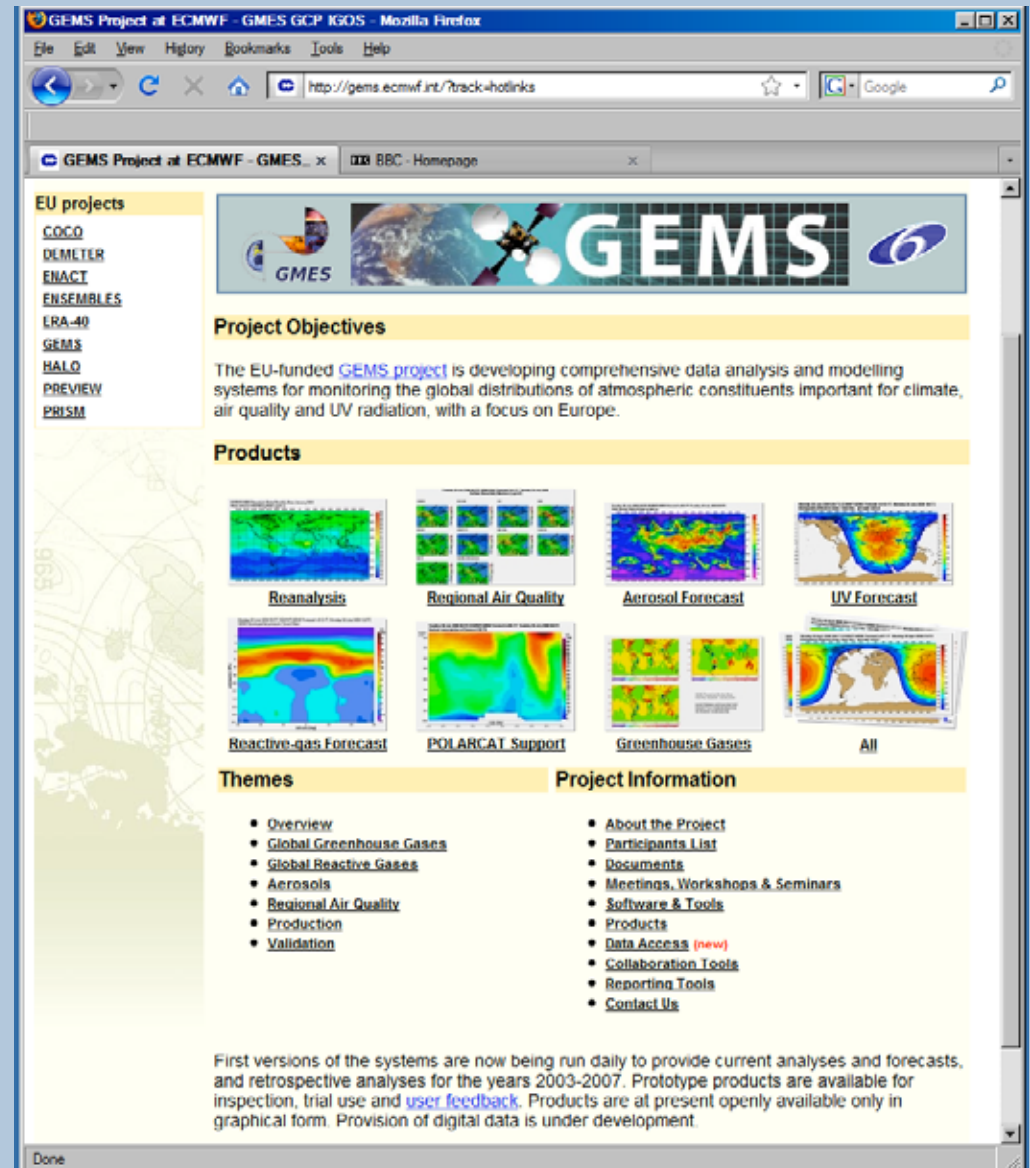


<http://gems.ecmwf.int>

GEMS results

Daily GEMS products at ECMWF

- Near-real-time global analysis and 3-day forecasts for reactive gases (O₃, CO, NO_x, HCHO, SO₂), aerosols and UV radiation
- A global reanalysis for 2003-2007 for reactive gases, aerosols and greenhouse gases
- Web-hosting, archiving and verification of coordinated regional air-quality forecasts from ten models



<http://gems.ecmwf.int>

Downloadable data

GEMS Re-analysis 2003-2007 - Mozilla Firefox

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http://data-portal.ecmwf.int/data/t/gems_reanalysis/levtype=pl/

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GEMS Re-analysis 2003-2007

Note: In order to retrieve data from this server, you first have to accept the [conditions of use](#).

Type of level
Model levels
Pressure levels
Surface

GEMS fields
Near real-time
Re-analysis

Personal
Your Requests

Data usage
Conditions

Select date

☒ Select a date range between 2003-01-01 and 2007-05-23:

Start date: 2003-01-01 End date: 2007-05-23

☐ Select a list of month:

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2003	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2004	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2005	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2006	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2007	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Select Time

☐ 00:00:00 ☐ 06:00:00 ☐ 12:00:00 ☐ 18:00:00

Select Level

☐ 1 ☐ 2 ☐ 3 ☐ 5 ☐ 7 ☐ 10 ☐ 20 ☐ 30 ☐ 50 ☐ 70 ☐ 100 ☐ 150 ☐ 200 ☐ 250

☐ 300 ☐ 400 ☐ 500 ☐ 600 ☐ 700 ☐ 800 ☐ 850 ☐ 900 ☐ 925 ☐ 950 ☐ 1000

Select Parameter

☐ Carbon Dioxide ☐ Carbon monoxide ☐ Divergence ☐ Formaldehyde

☐ GEMS Ozone ☐ Geopotential ☐ Methane ☐ Nitrogen Oxides

☐ Ozone mass mixing ratio ☐ Potential vorticity ☐ Relative humidity ☐ Specific humidity

☐ Sulphur dioxide ☐ Temperature ☐ Vertical velocity ☐ Vorticity (relative)

Done

GEMS Integrated Near Real-time Analysis/Forecast - Mozilla Firefox

File Edit View History Bookmarks Tools Help

http://data-portal.ecmwf.int/data/t/gems_nrealtime/levtype=pl/

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GEMS Integrated Near Real-time Analysis/Forecast

Note: In order to retrieve data from this server, you first have to accept the [conditions of use](#).

Type of level
Model levels
Pressure levels
Surface

GEMS fields
Near real-time
Re-analysis

Personal
Your Requests

Data usage
Conditions

Select date

☒ Select a date range between 2008-08-30 and 2009-03-01:

Start date: 2008-08-30 End date: 2009-03-01

☐ Select a list of month:

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2008	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2009	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Select Time

☐ 00:00:00 ☐ 12:00:00

Select Level

☐ 1 ☐ 2 ☐ 3 ☐ 5 ☐ 7 ☐ 10 ☐ 20 ☐ 30 ☐ 50 ☐ 70 ☐ 100 ☐ 150 ☐ 200 ☐ 250

☐ 300 ☐ 400 ☐ 500 ☐ 700 ☐ 850 ☐ 925 ☐ 1000

Select Parameter

☐ Carbon monoxide ☐ Formaldehyde ☐ GEMS Ozone ☐ Nitrogen Oxides ☐ Sulphur dioxide

Select Step

☐ 0 ☐ 3 ☐ 6 ☐ 9 ☐ 12 ☐ 15 ☐ 18 ☐ 21 ☐ 24 ☐ 27 ☐ 30 ☐ 33 ☐ 36 ☐ 39 ☐ 42 ☐ 45 ☐ 48

☐ 51 ☐ 54 ☐ 57 ☐ 60 ☐ 63 ☐ 66 ☐ 69 ☐ 72

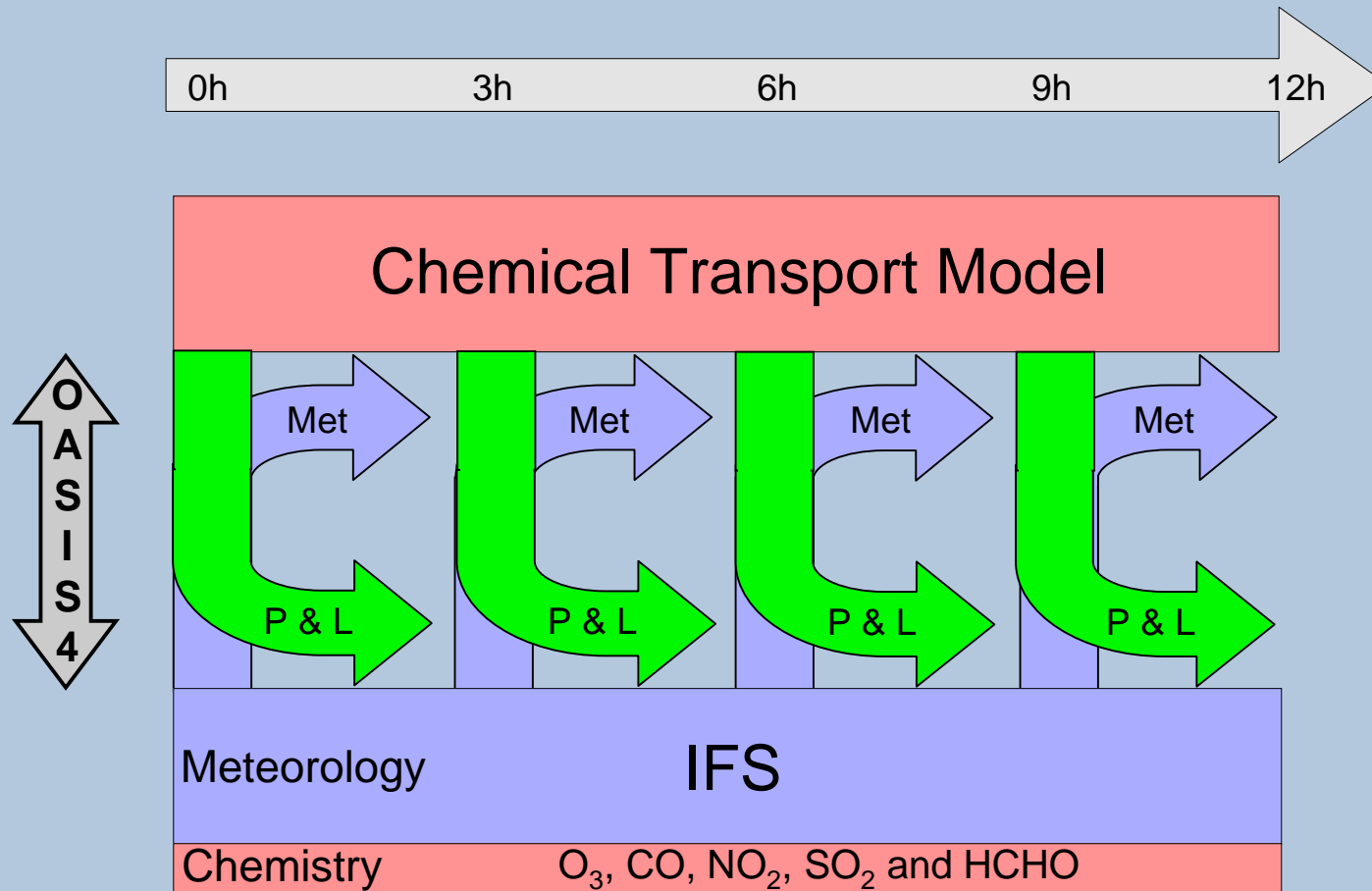
Done

http://gems.ecmwf.int



GEMS global system

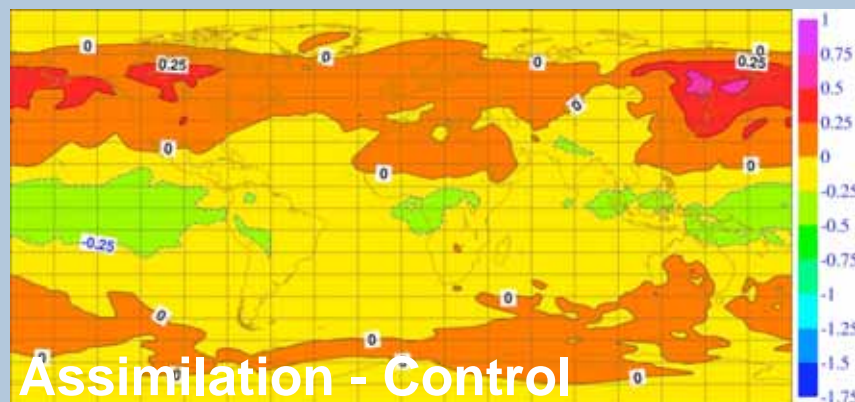
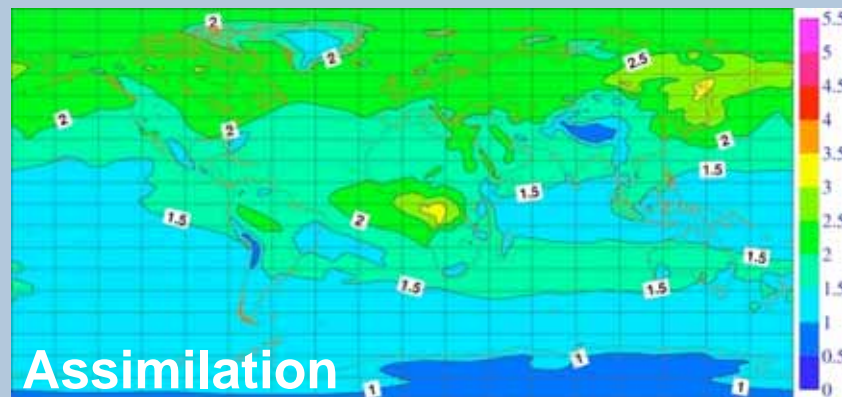
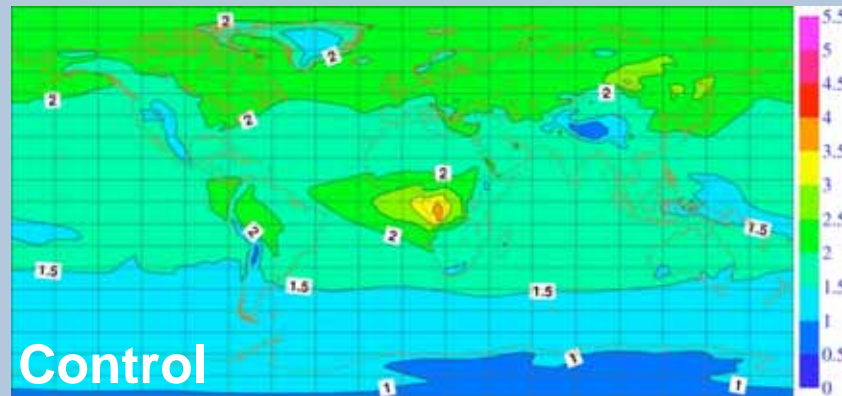
Coupled IFS-CTM reactive-gas forecasting system



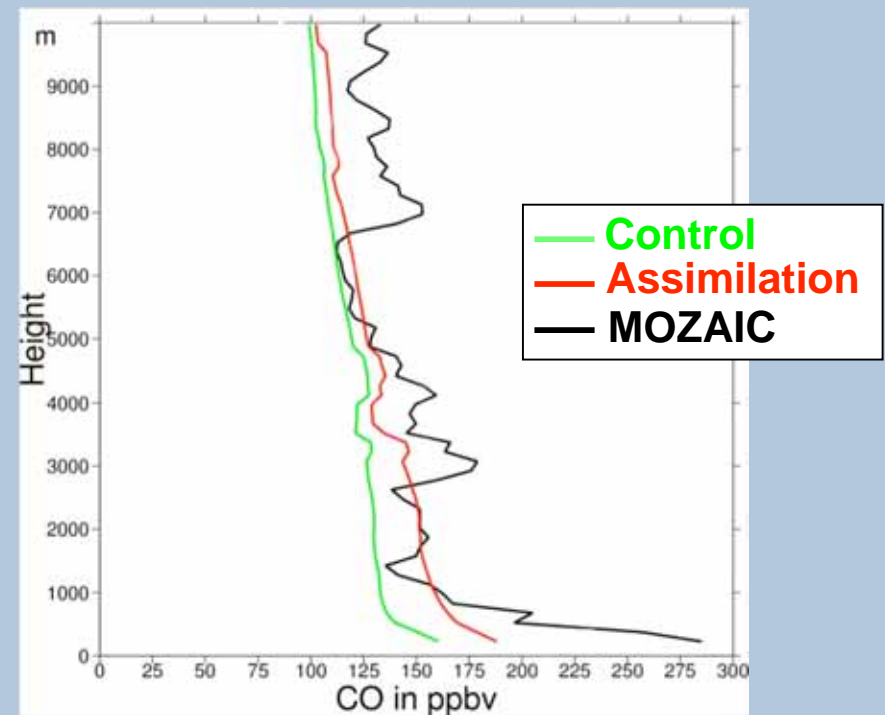
3 CTMs: MOCAGE, MOZART and TM5

MOZART chosen for main production runs

Mean CO from 15 to 30 July 2003 from assimilation of MOPITT total-column data



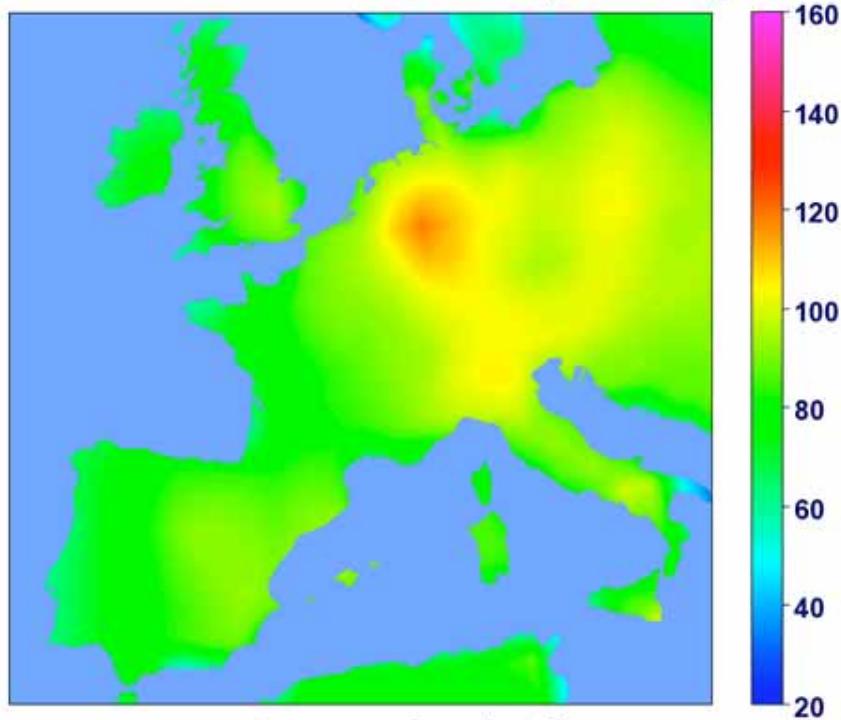
Comparison with MOZAIC aircraft data over Osaka



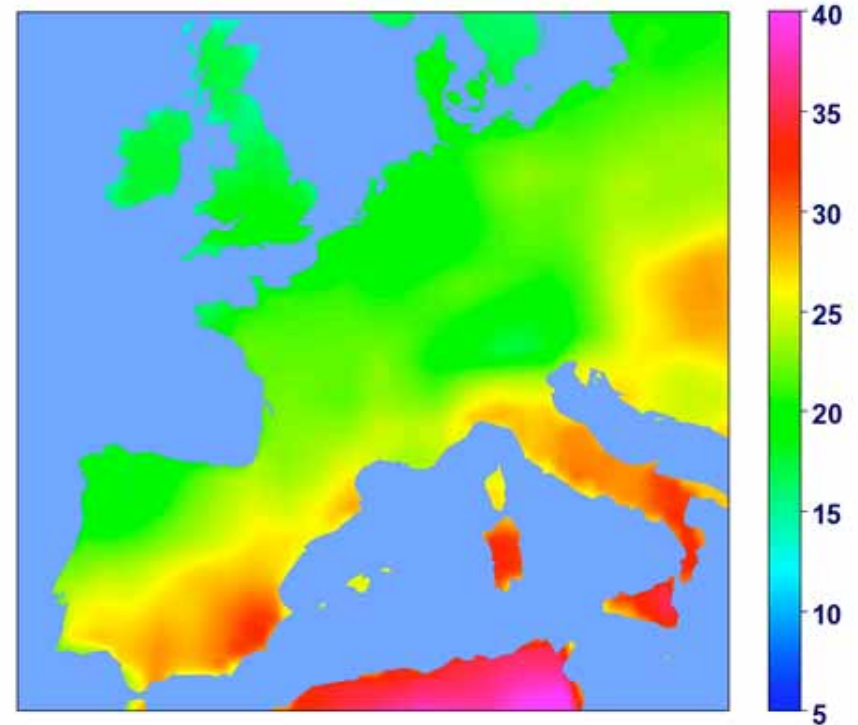
Unit: 10^{18} molec/cm²

August 2003 heat-wave (from 2003-2007 reanalysis)

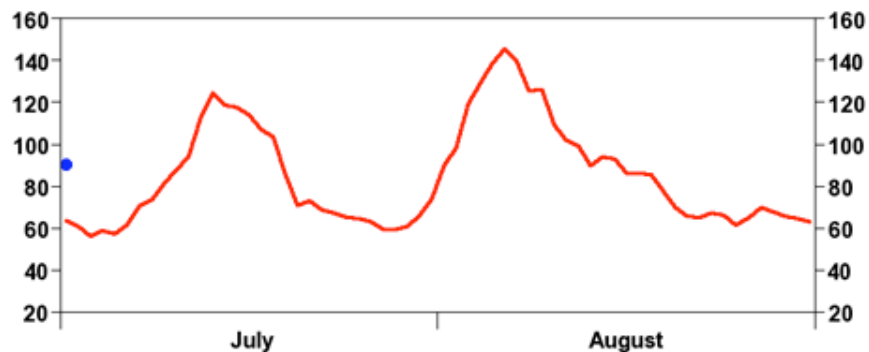
7-day averages for 15UTC centred on 2003/07/01



Ozone ($\mu\text{g}/\text{m}^3$)



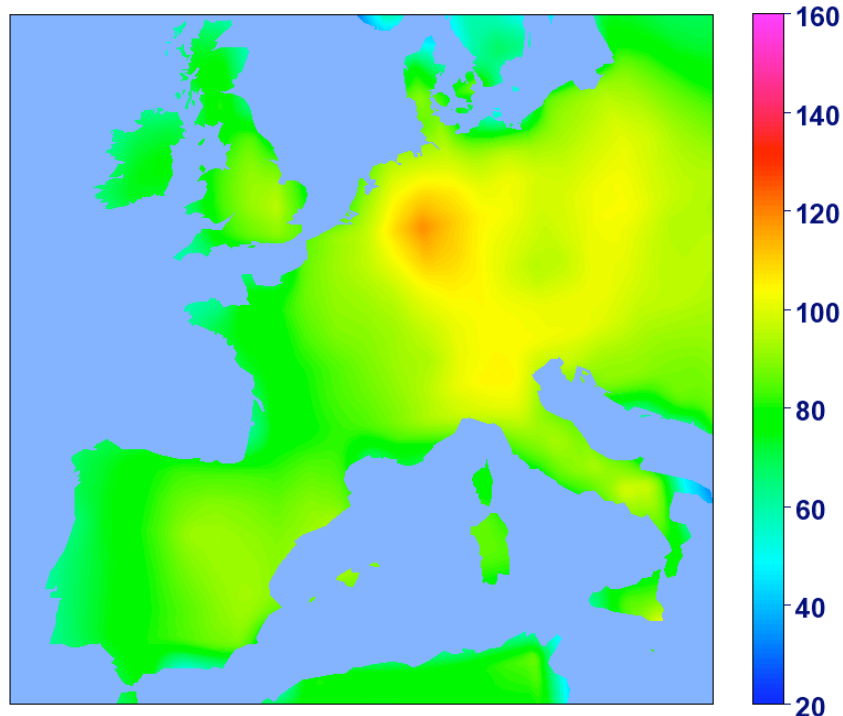
Temperature ($^{\circ}\text{C}$)



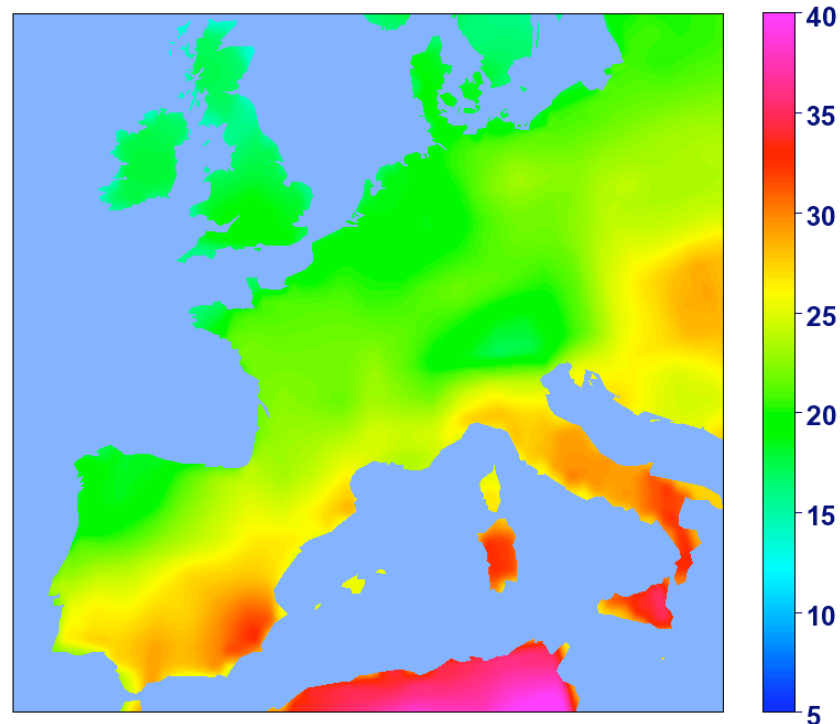
7d-mean measured ozone ($\mu\text{g}/\text{m}^3$) 14-16UTC
Bottesford, Leicestershire
www.airquality.co.uk

August 2003 heat-wave (from 2003-2007 reanalysis)

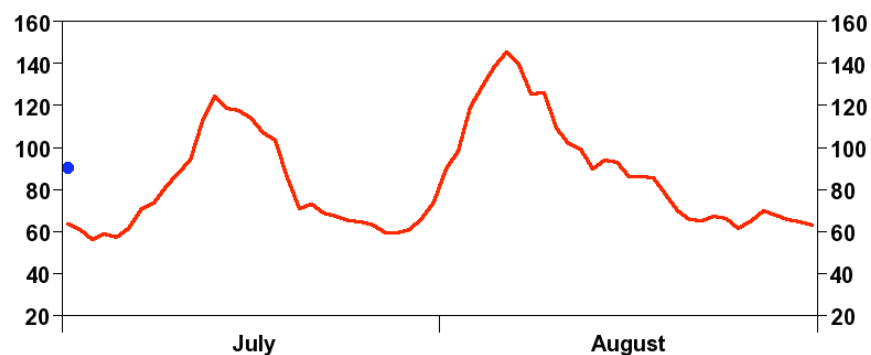
7-day averages for 15UTC centred on 2003/07/01



Ozone ($\mu\text{g}/\text{m}^3$)

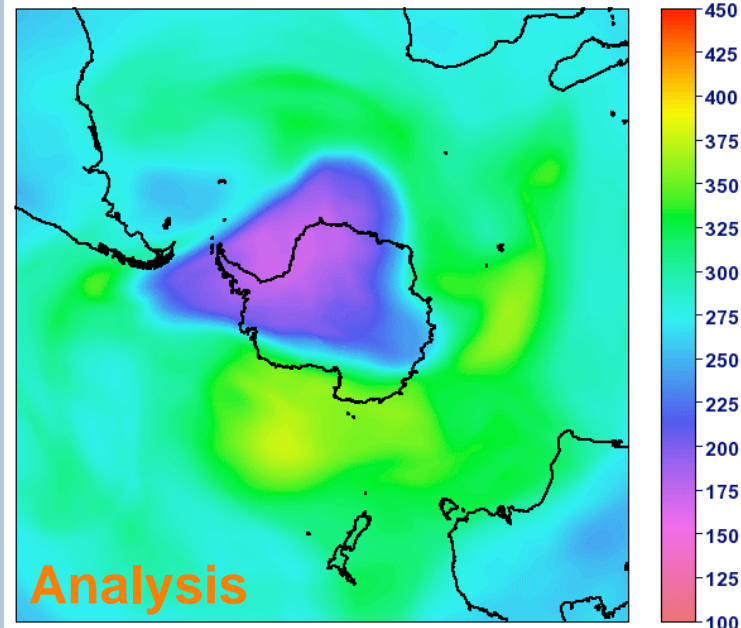
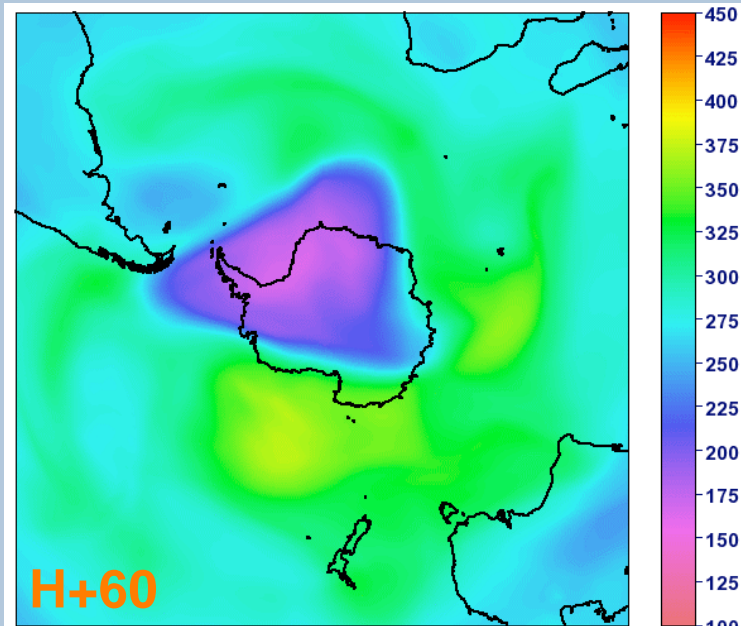


Temperature ($^{\circ}\text{C}$)

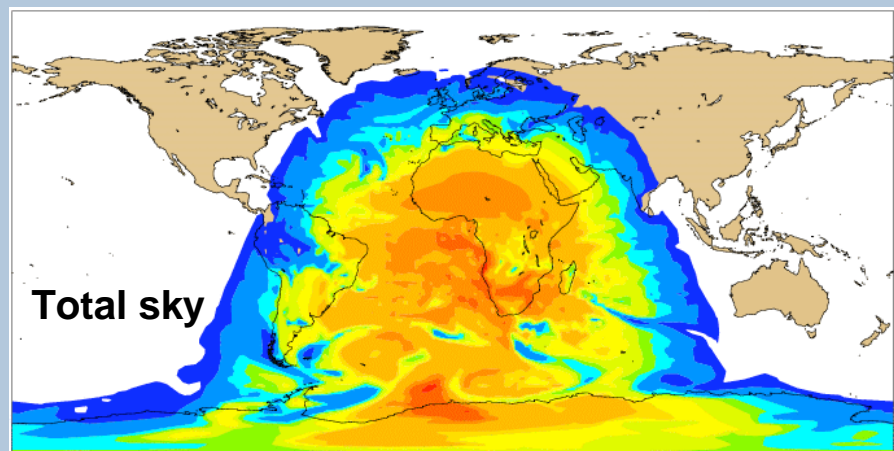
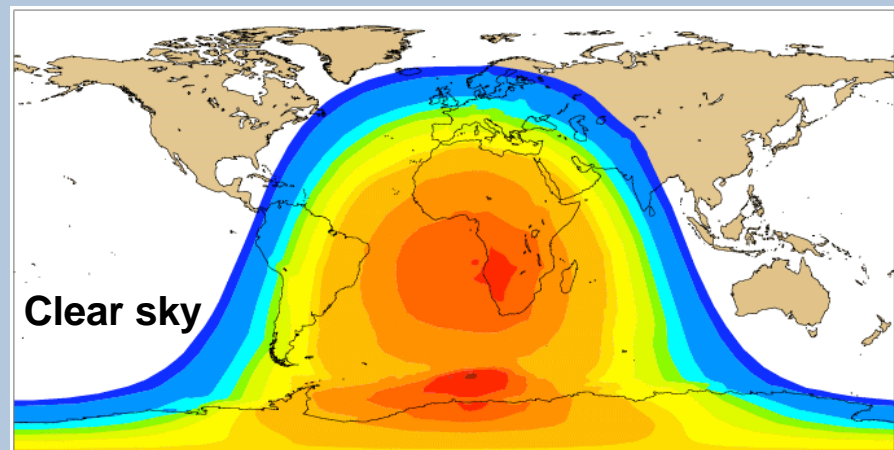


7d-mean measured ozone ($\mu\text{g}/\text{m}^3$) 14-16UTC
Bottesford, Leicestershire
www.airquality.co.uk

Total column ozone, and biologically-effective dose of surface UV radiation



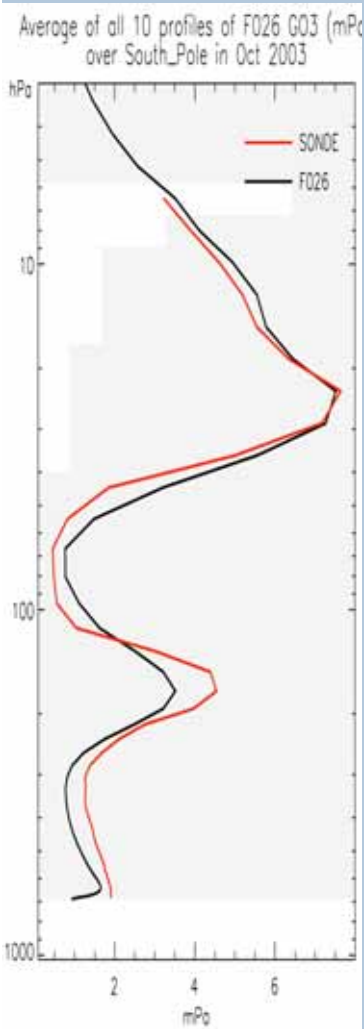
H+60 valid 12UTC 27 November 2008



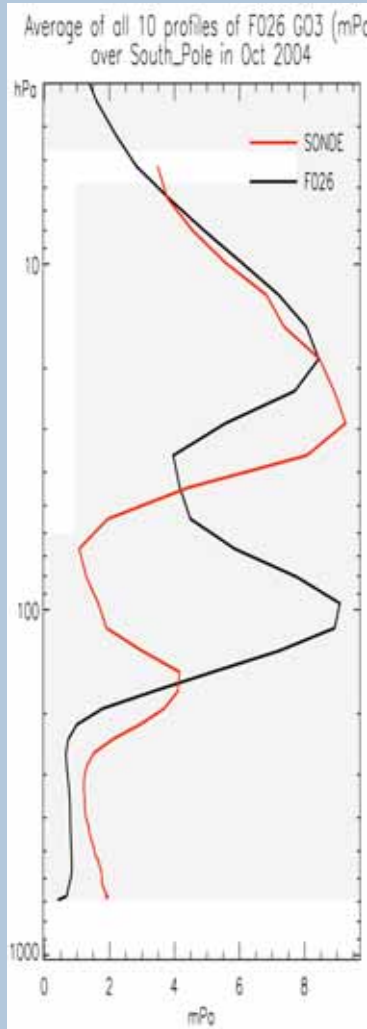
With A. Arola, FMI

South Pole ozone profiles from GEMS reanalysis

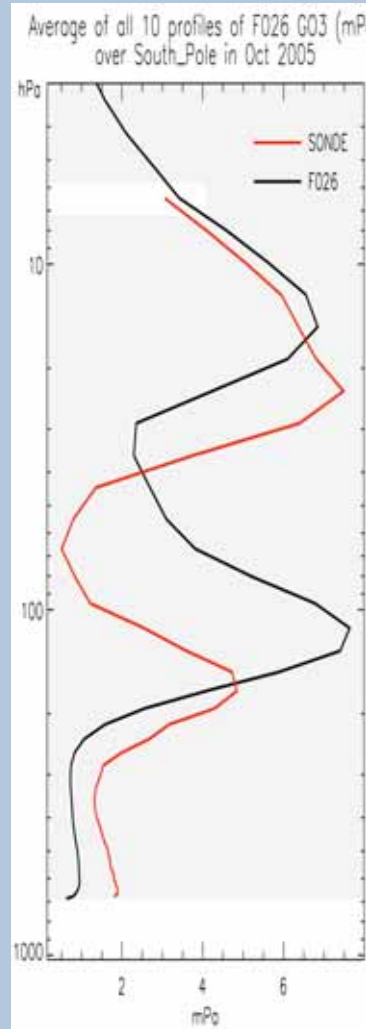
Oct 2003



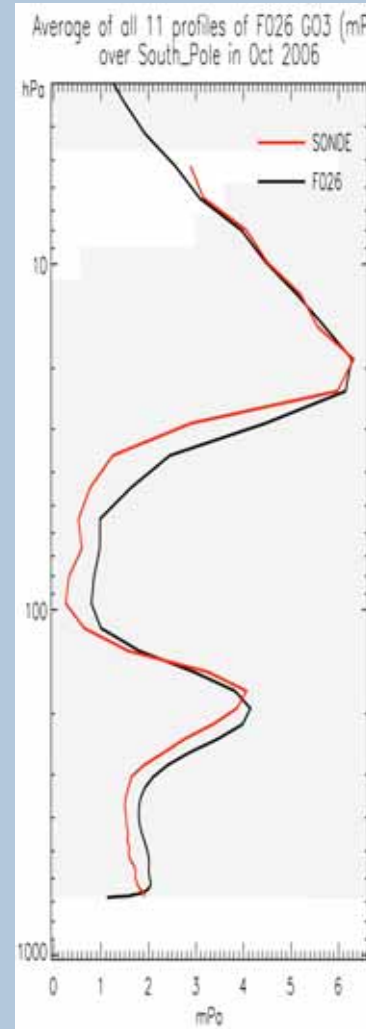
Oct 2004



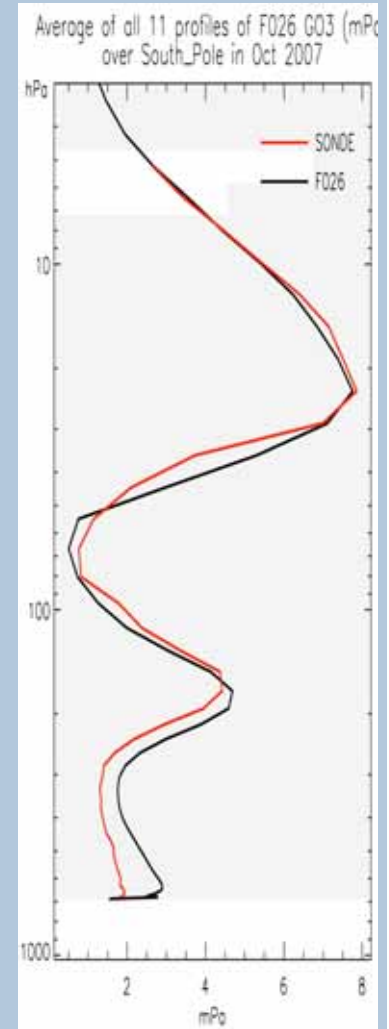
Oct 2005



Oct 2006



Oct 2007



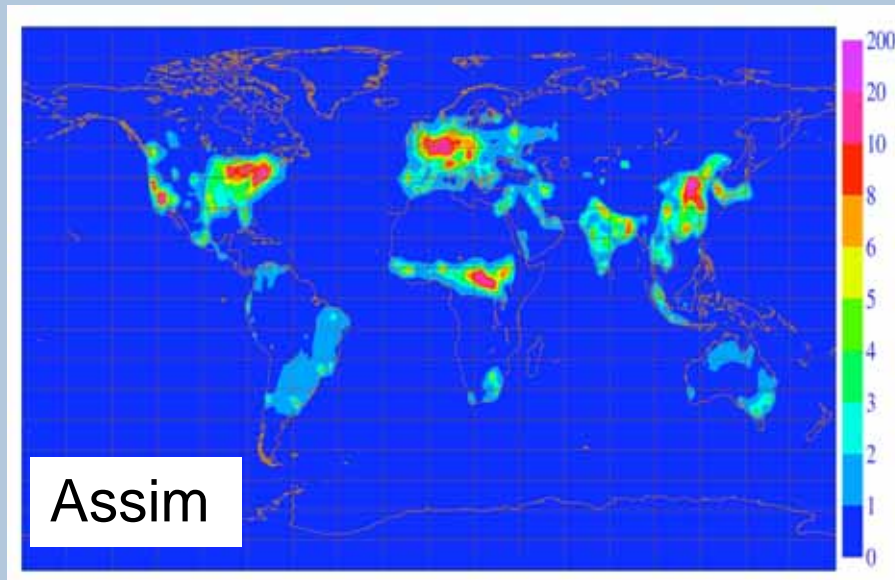
MIPAS

MLS

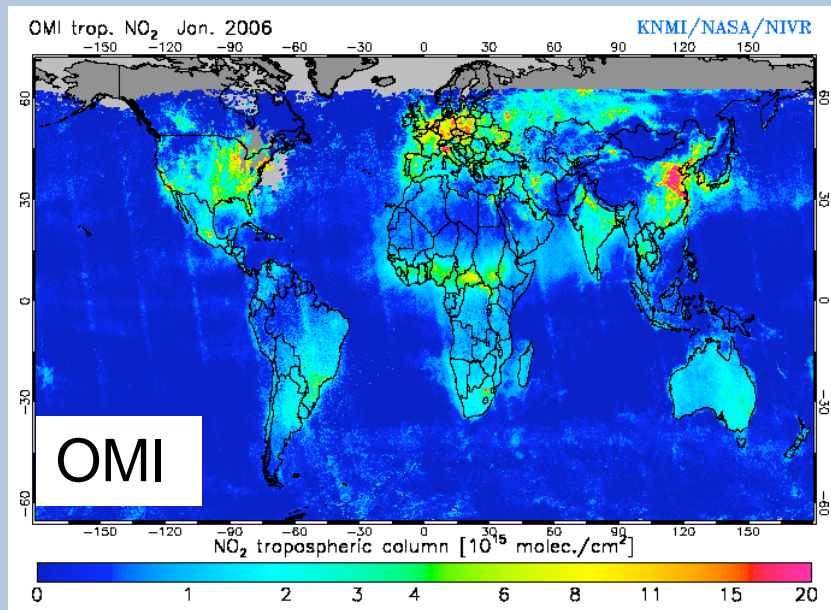
MLS

Ozone profile data important for assimilation

SCIAMACHY NO₂ assimilation – January 2006



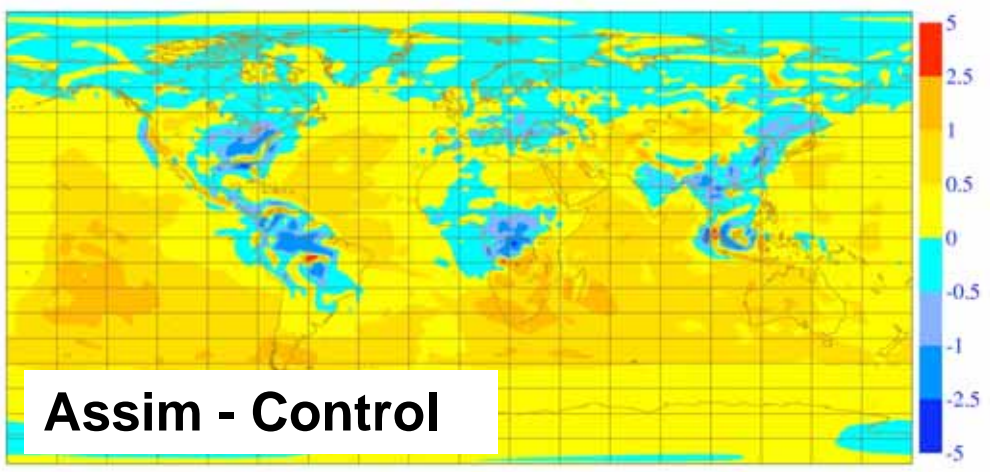
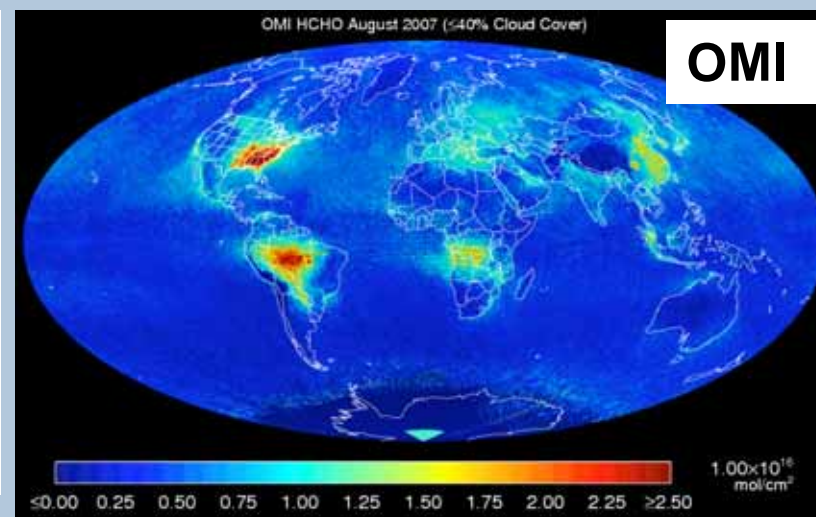
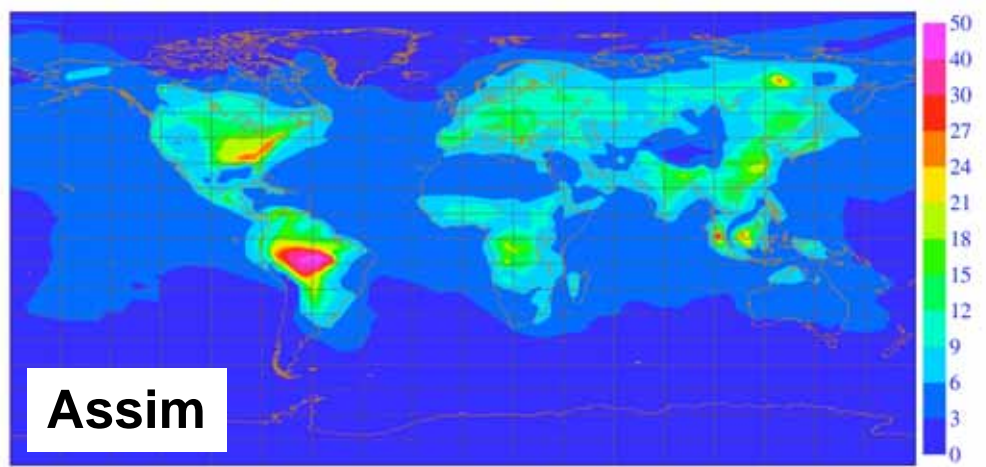
Monthly mean tropospheric
NO_x columns



OMI NO₂ from
<http://www.gse-promote.org/>

Unit: 10^{15} mol/cm²

SCIAMACHY HCHO assimilation – August 2007



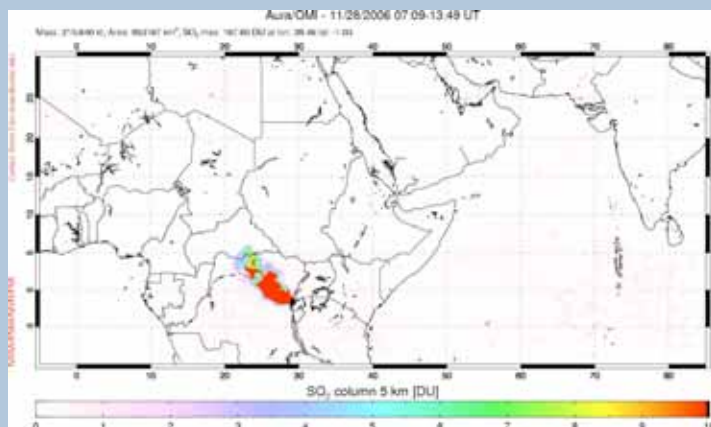
OMI plot from:
<http://www.cfa.harvard.edu/~tkurosu/SatelliteInstruments/OMI/SampleImages/HCHO/index.html>

Unit: 10^{15} mol/cm²

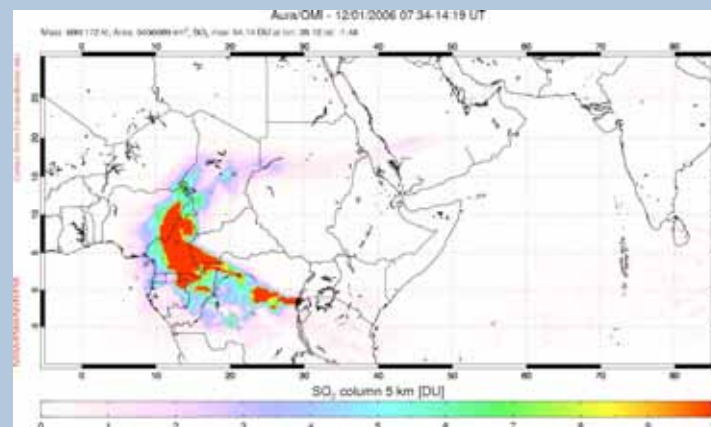
SO₂ assimilation

- Case study of Nyamuragira eruption (Democratic Republic of Congo): 27 Nov – 4 Dec 2006
- SCIAMACHY SO₂ total column retrievals produced by BIRA (<http://www.gse-promote.org>), assumed plume height of 6km

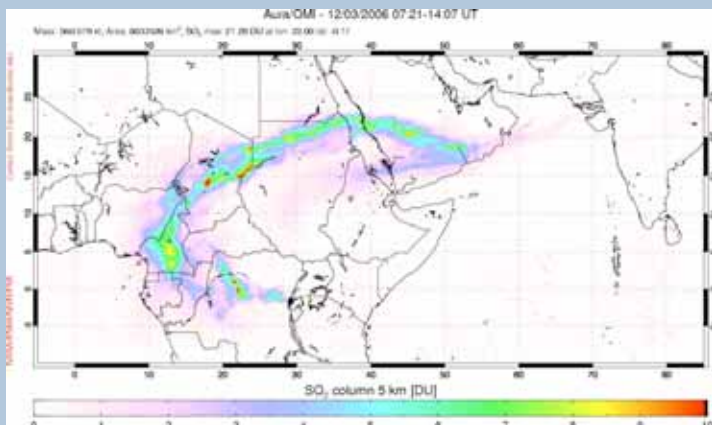
28 Nov



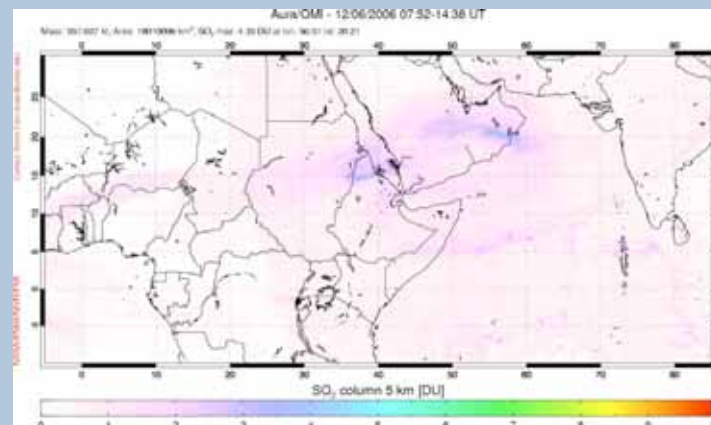
1 Dec



3 Dec



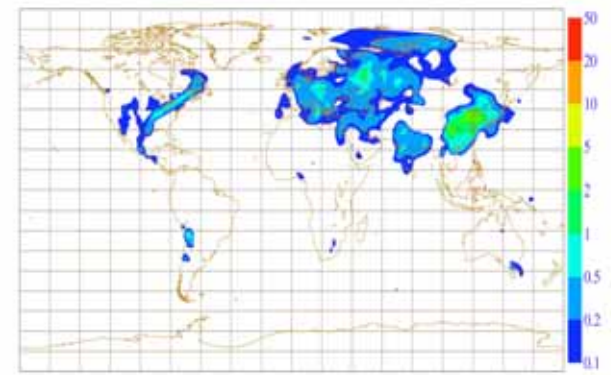
6 Dec



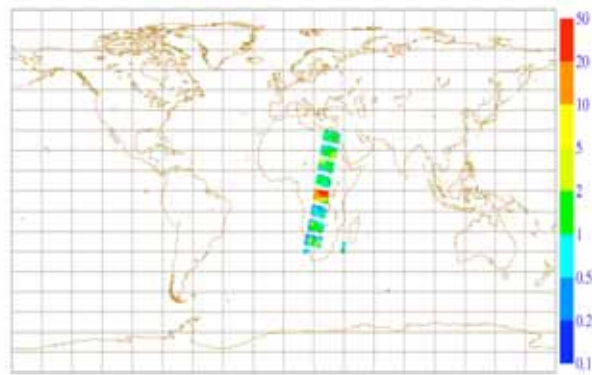
OMI SO₂ columns [DU] from <http://so2.umbc.edu/omi/>

SO₂ assimilation

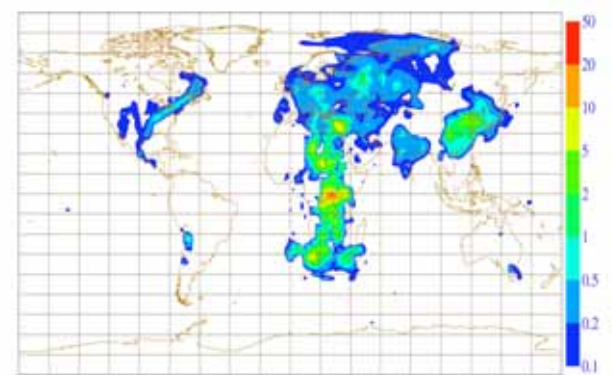
Forecast for 1 Dec, 0z



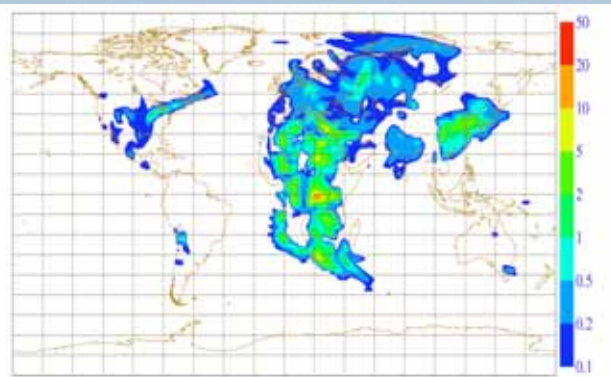
Obs for 1 Dec, 0z



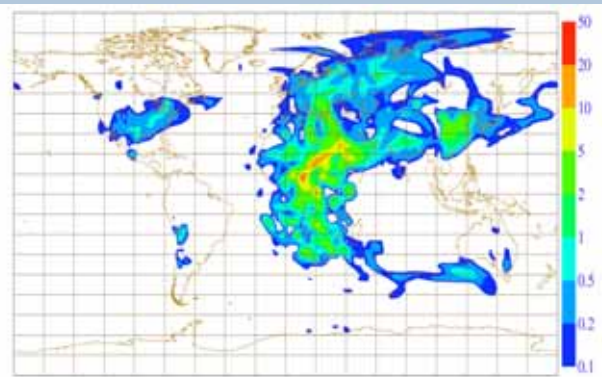
Analysis 1 Dec, 0z



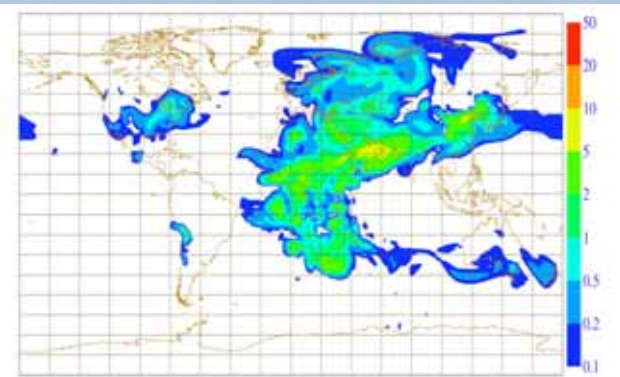
Analysis 1 Dec, 12z



Analysis 3 Dec, 12z



Analysis 6 Dec, 12z



Dobson Units

SO₂ assimilation started on 1 Dec 2006, because no SCIAMACHY data available over Africa on 28-30 Nov 2006

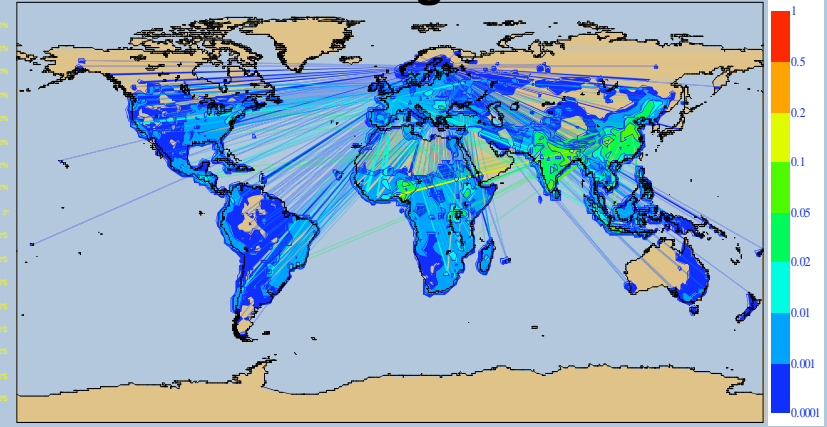
Aerosol model development

Model includes:

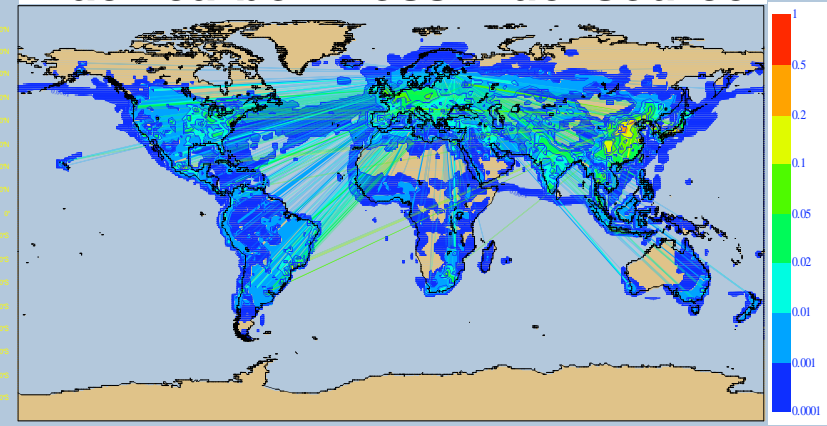
- Sea salt (3 bins, with parametrized source)
- Desert dust (3 bins, with parametrized source)
- Black carbon and organic matter (hydrophilic and hydrophobic, with specified sources)
- Sulphate aerosol (with specified precursor emissions)
- Separate scheme for stratospheric aerosols

Development (validation, improved modelling and emissions) is ongoing

Black carbon: biogenic source

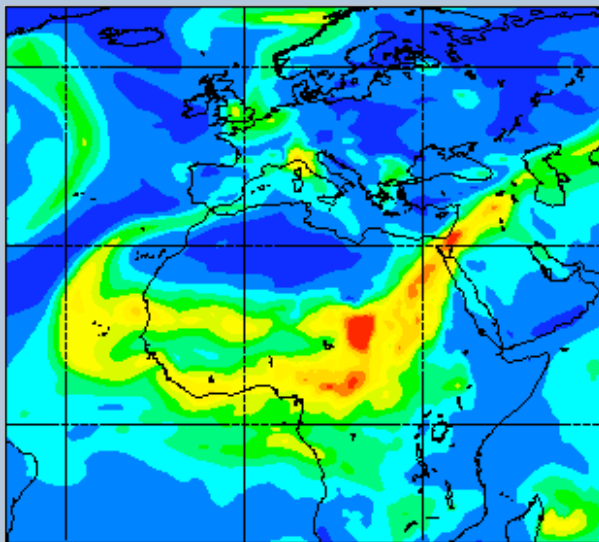


Black carbon: fossil-fuel source

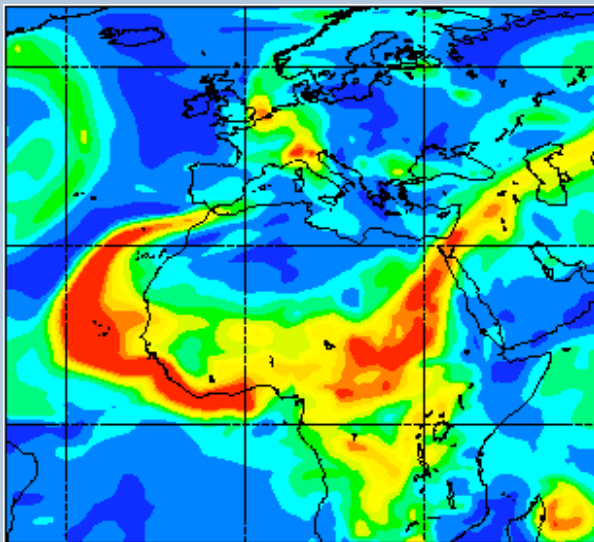


Saharan dust outbreak: 6 March 2004

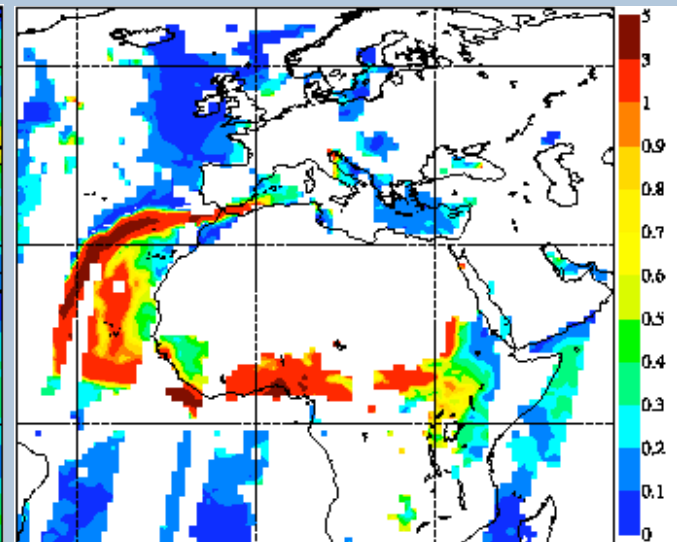
Model simulation



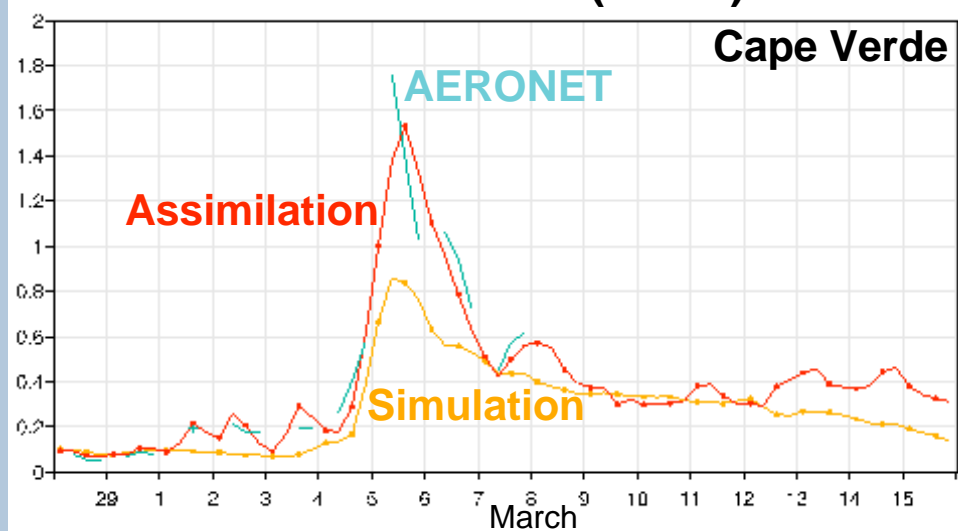
Assimilation



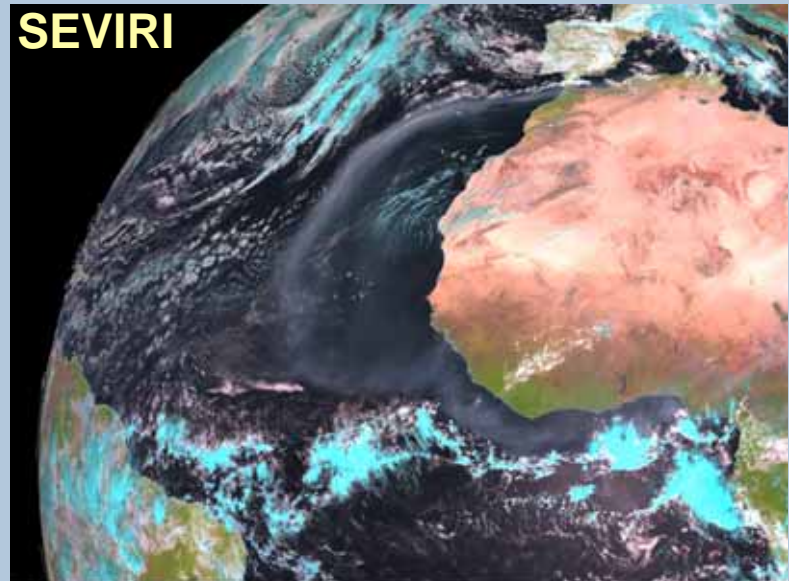
MODIS



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



SEVIRI

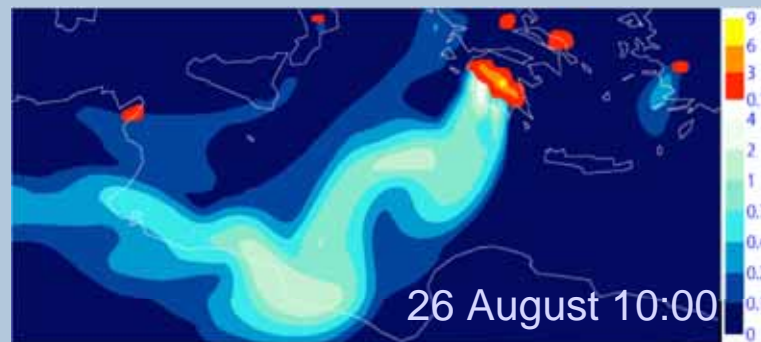


Emissions from Mediterranean fires in Summer 2007

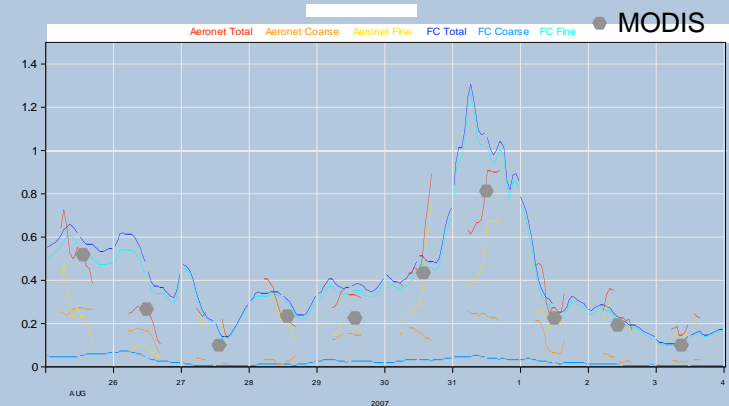


Observed Fire Radiative Power (from SEVIRI on Meteosat) is converted to emitted aerosol.

Run at 25km global resolution rather than 125km standard GEMS global resolution.



Joint work with Eumetsat-funded FREEVAL project (M. Wooster, G. van der Werf, ...).



Near-real-time fire emissions

[ECMWF graphical product catalogue](#) > [Research](#) > [Gems](#) > [Global Reactive Gases](#) > [GEMS Products supporting the POLARCAT Campaigns](#) > Lat-lon plots of GEMS products for POLARCAT>

Lat-lon plots of GEMS products for POLARCAT

Step (-> valid time)



Forecast base time

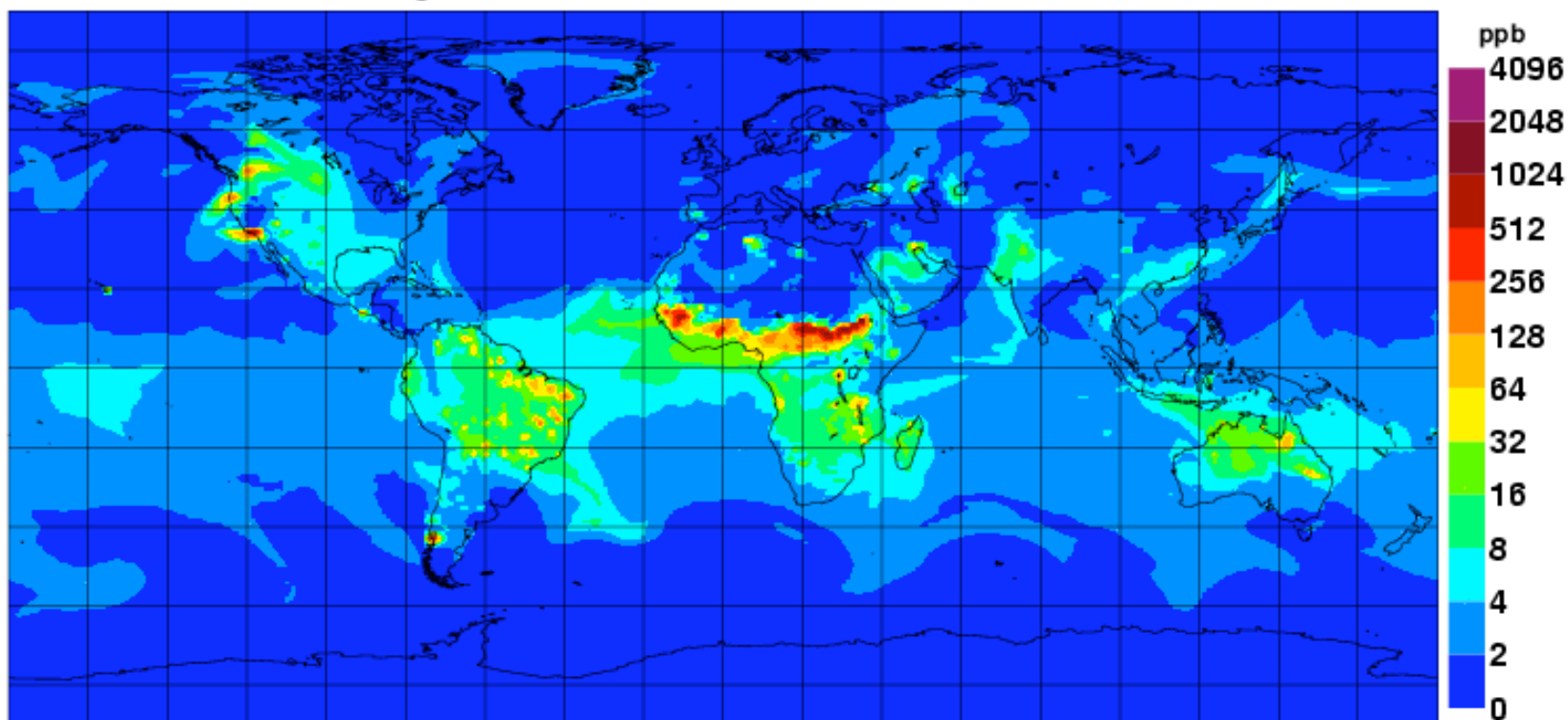


06 (Sun 16 Nov 2008 06UTC)

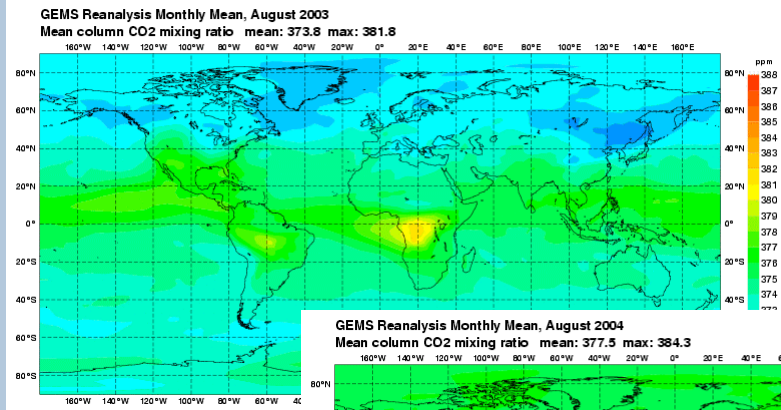
Sun 16 Nov 2008 00UTC

From SEVIRI and
MODIS FRP

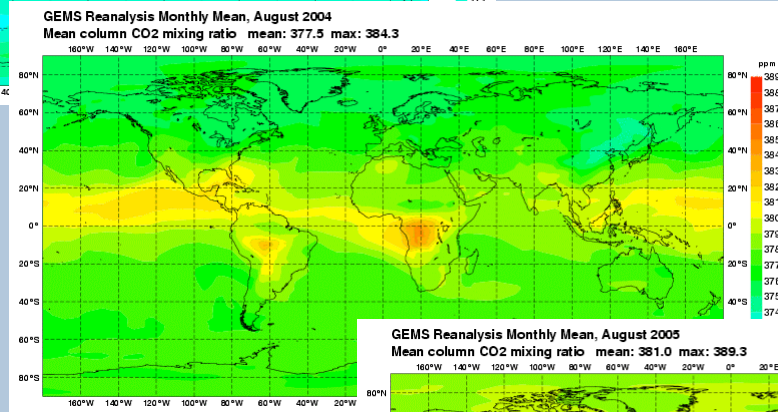
Sunday 16 November 2008 00UTC ECMWF/GEMS Forecast t+006 VT: Sunday 16 November 2008 06UTC
Surface NRT Biomass-Burning Carbon Monoxide Tracer



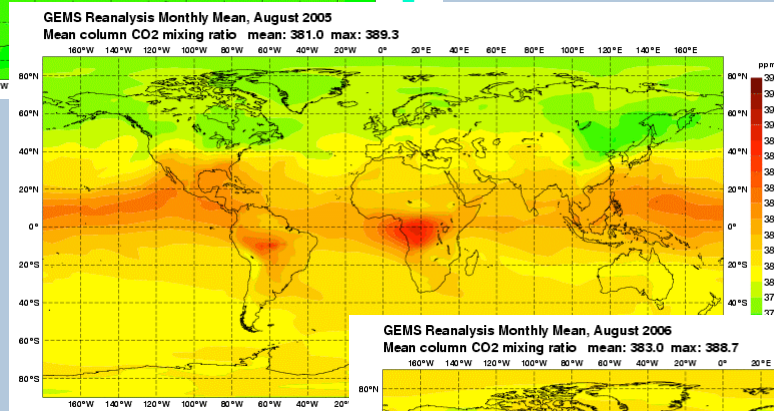
CO₂ from 2003-2007 GEMS reanalysis



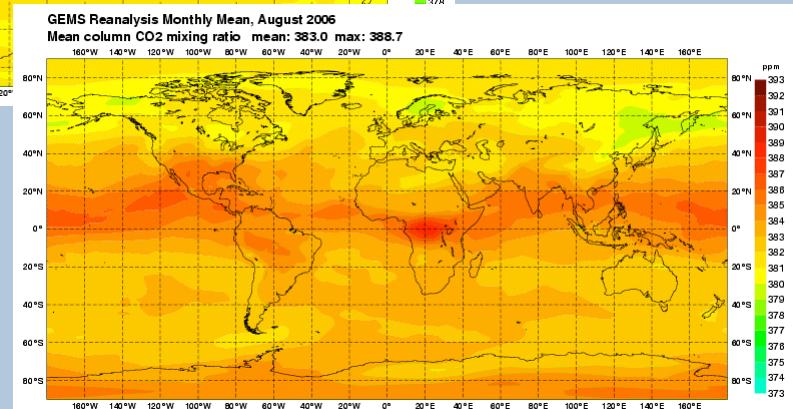
2003



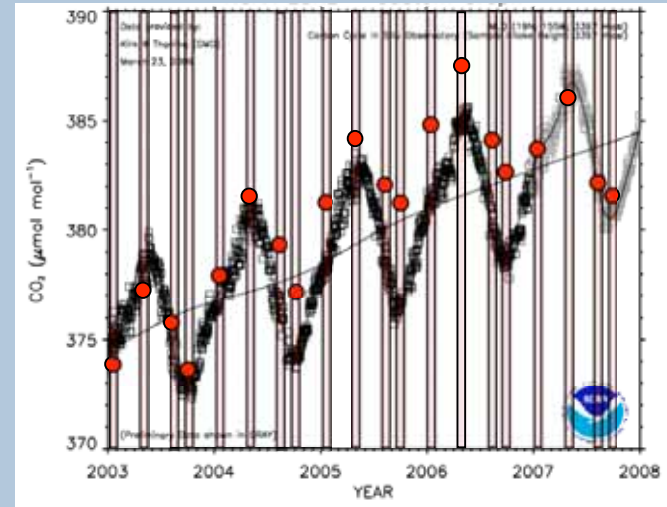
2004




2005



2006















GEMS

regional system

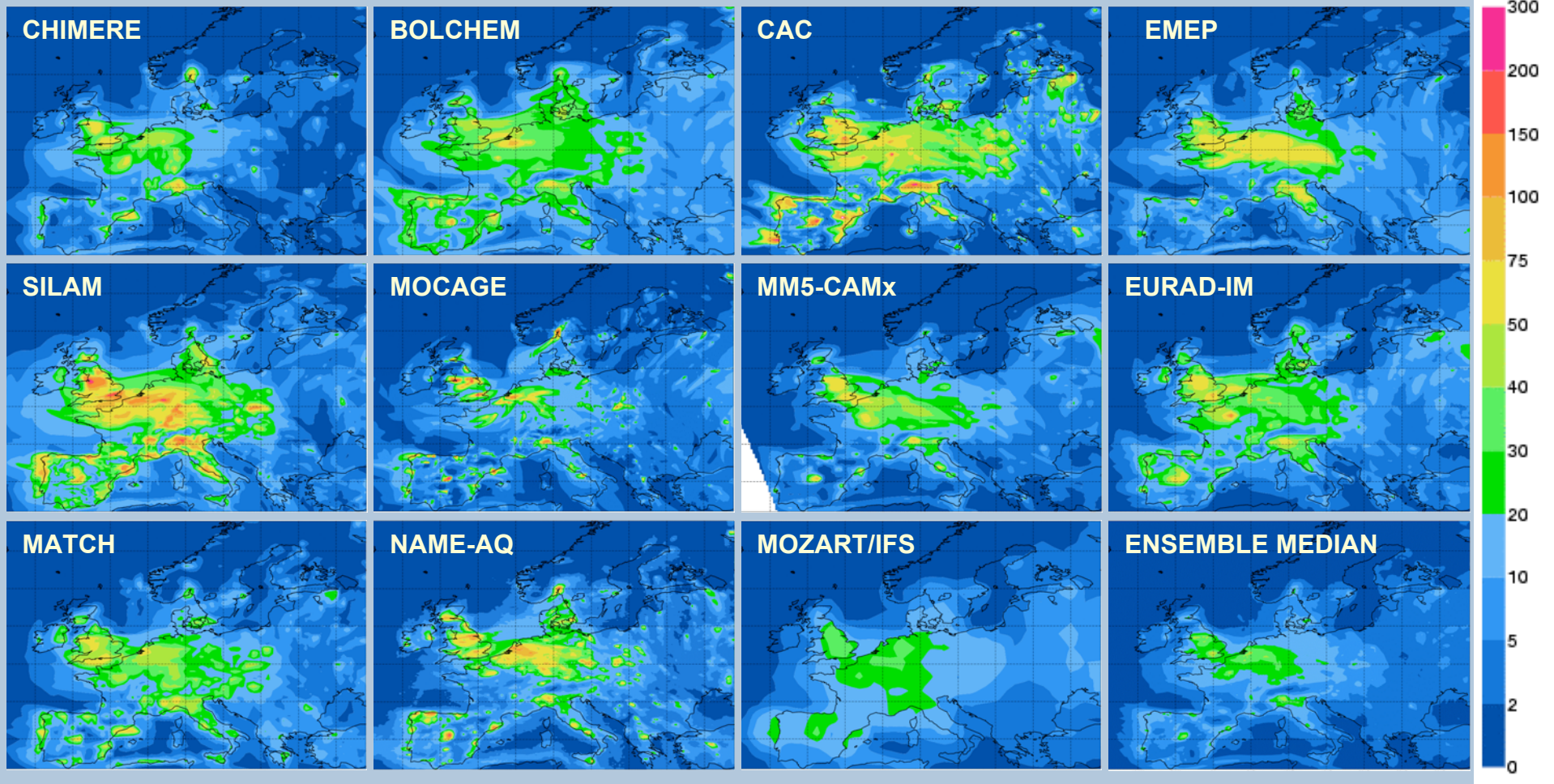
Distributed system for regional air quality forecasts

- **10 regional air-quality models run daily**
 - on common European domain
 - with common ECMWF meteorological forcing and boundary values from global GEMS system
 - with common emissions
 - with common GRIB2 output format
- **Output sent to ECMWF for**
 - archiving
 - derivation of ensemble forecast products
 - web display
 - validation
- **Near-real-time provision of national air-quality data (under MoUs) for validation of forecasts**
 - to ECMWF in common BUFR format

	CAC
	EURAD
	CHIMERE
	MOCAGE
	MM5-CAMx
	BOLCHEM
	EMEP
	SILAM
	MATCH
	NAME-AQ

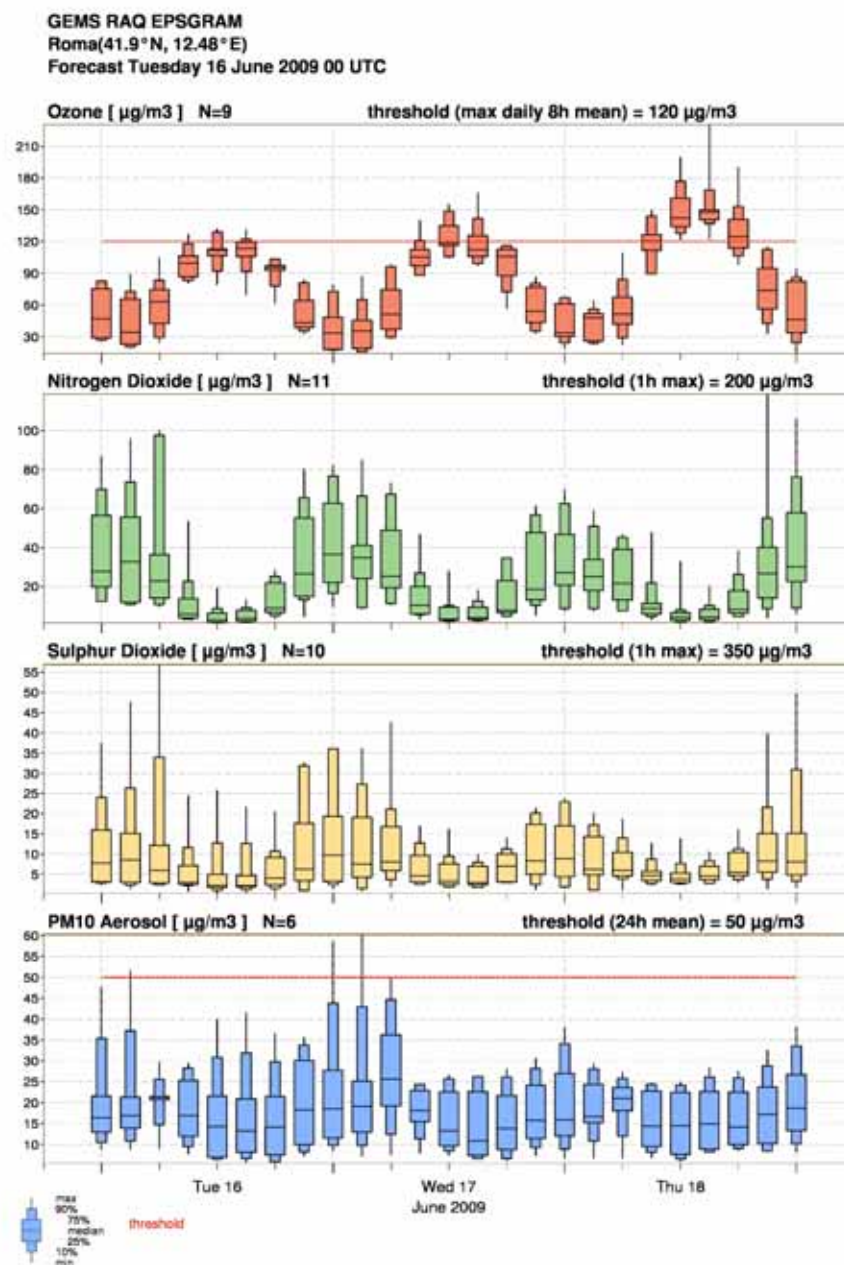
Daily maximum NO₂ (μg/m³)

24 December 2008 from 00UTC 22 December



The spread of the ensemble of regional air quality models provides an indication of the uncertainty of the forecasts.

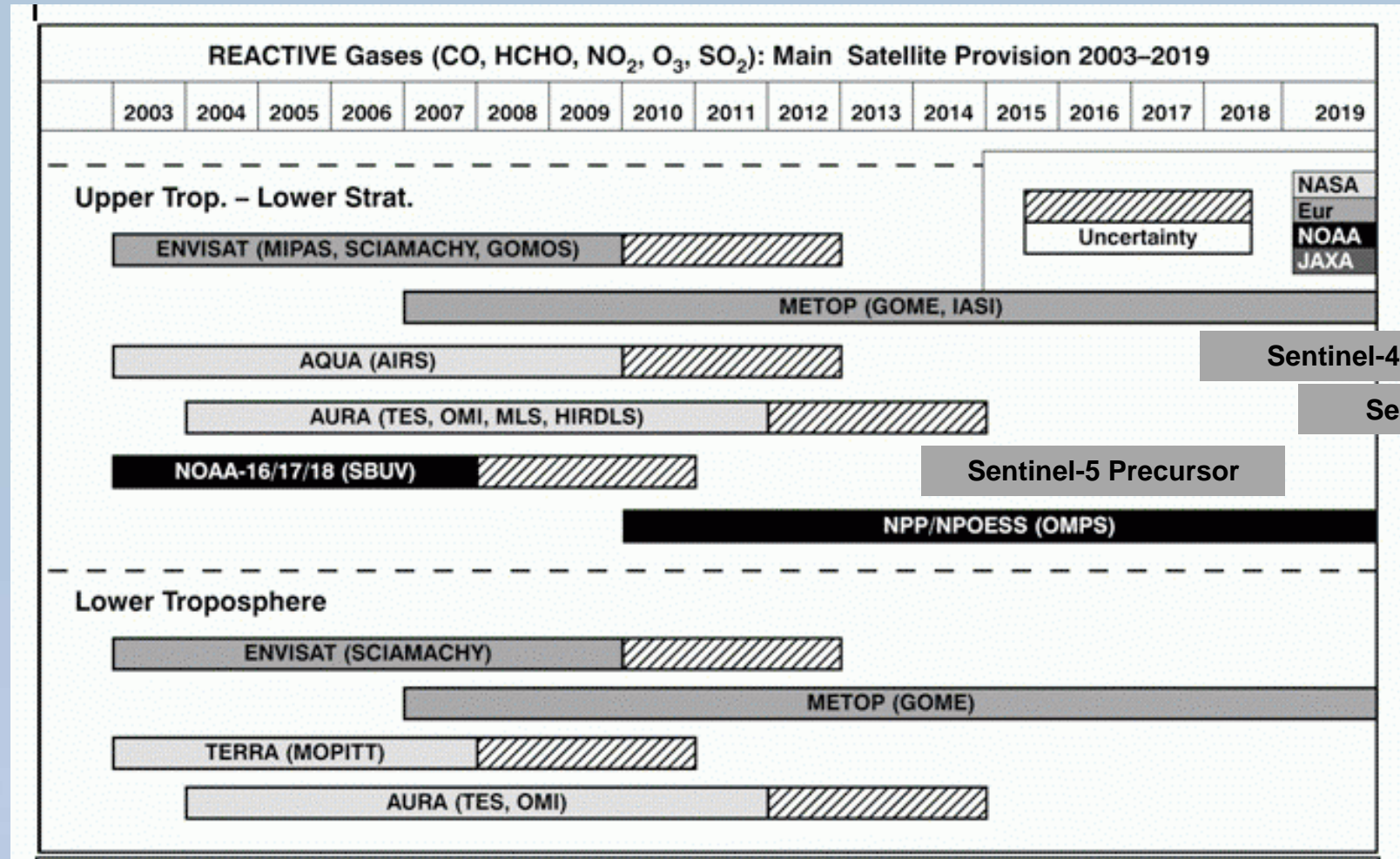
At the same time we can also show how the forecasted concentrations of the various constituents relate to their warning thresholds.



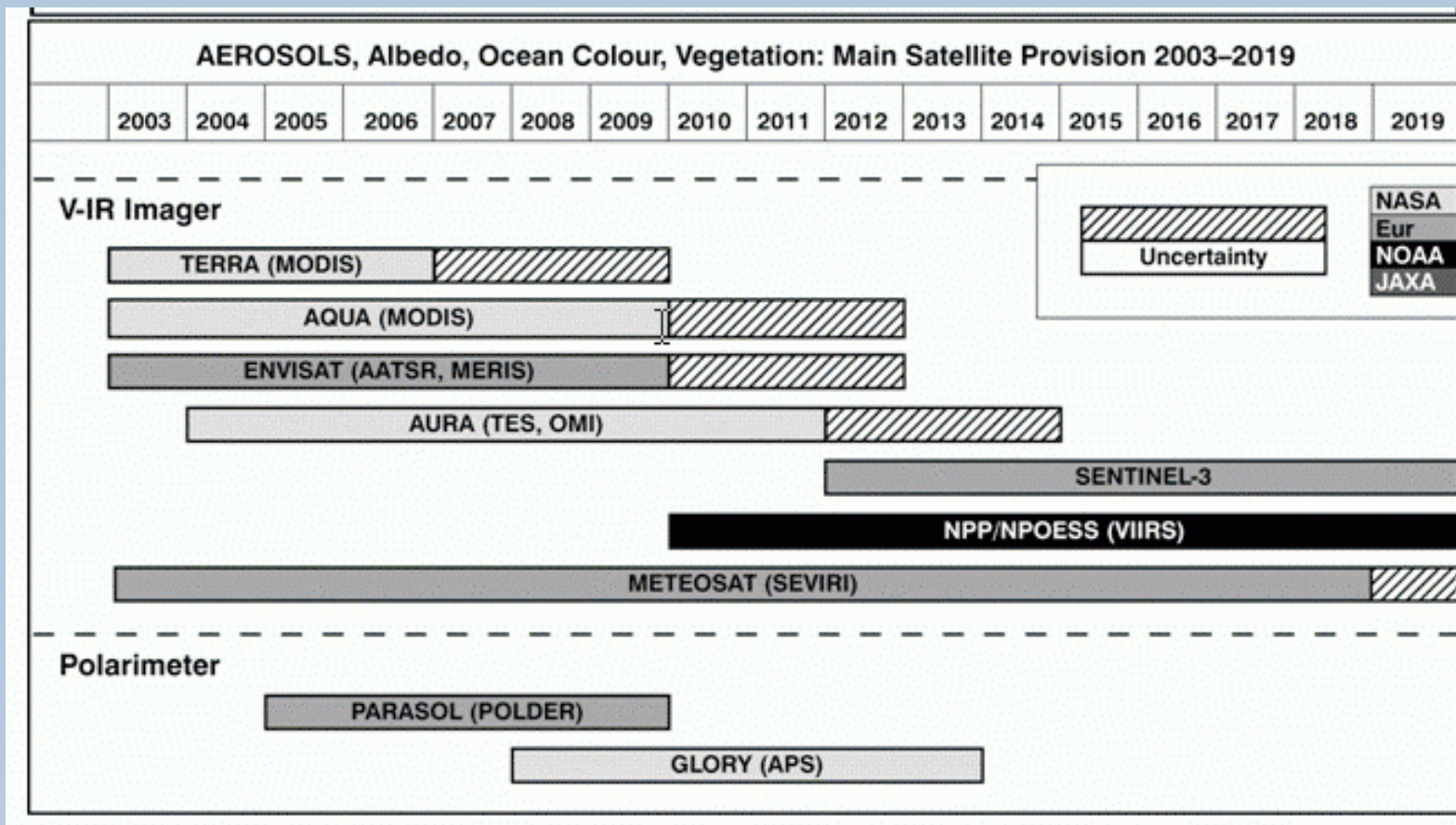


Satellite Data Provision

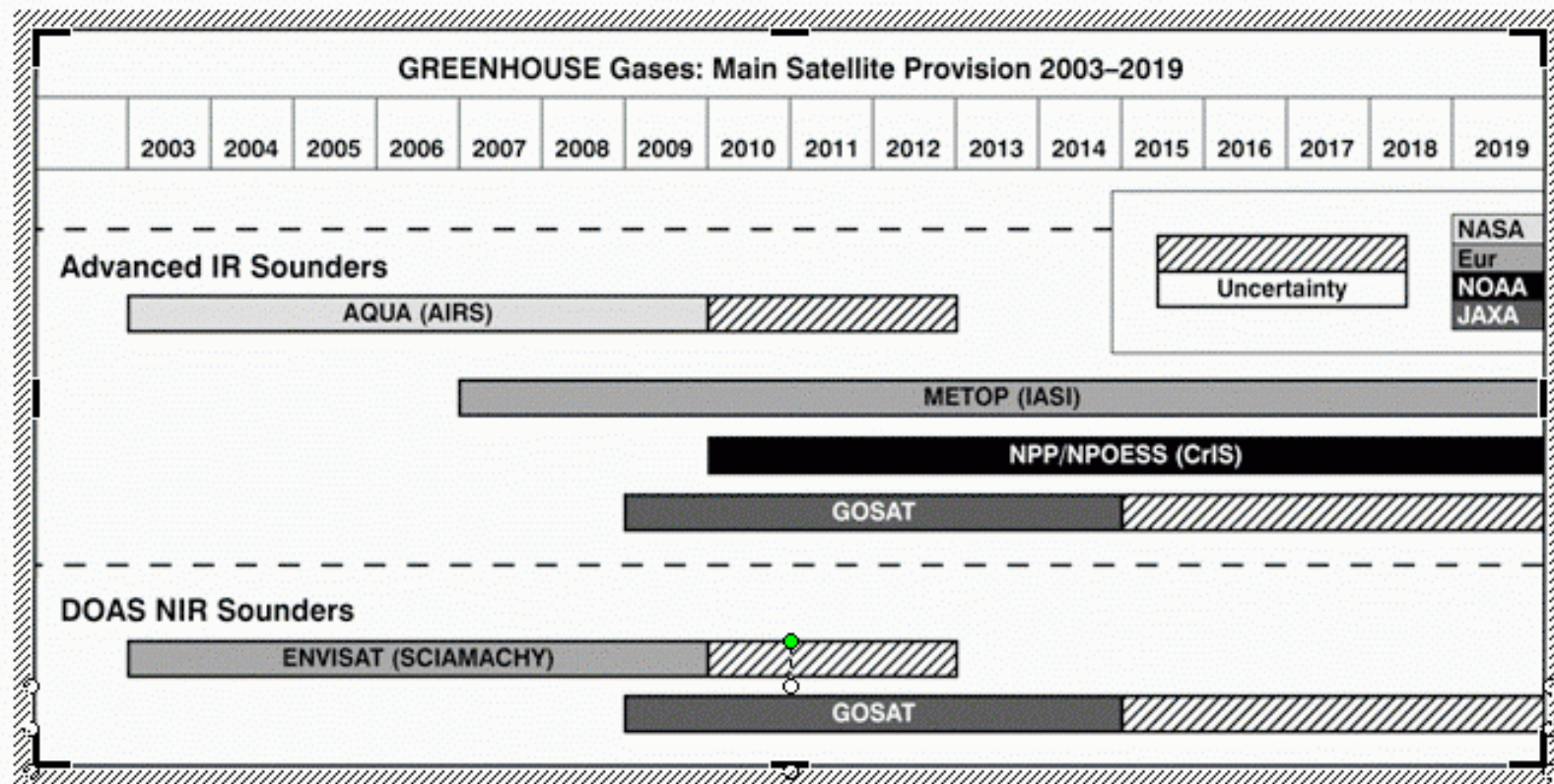
Expected primary satellite provision for measuring atmospheric composition – Reactive gases



Expected primary satellite provision for measuring atmospheric composition – Aerosols



Expected primary satellite provision for measuring atmospheric composition – Greenhouse gases



Summary

- MACC, the GMES Atmospheric pilot Core Service on Air quality, started on 1 June 2009
- Results and data from GEMS/MACC can be found on <http://gems.ecmwf.int>
 - 5 year reanalysis of GHG, GRG and AER
 - NRT analysis and forecasts for GRG and AER
 - Output from ensemble of regional air quality models
- Availability of satellite data crucial for MACC (NRT and reprocessed offline data)
- Importance of profile data