Global Earth-system Monitoring using Space and in-situ data – GEMS

Anthony Hollingsworth

ECMWF

Credits to GEMS Management team

C.Granier (S d'A), P.Rayner (LSCE), M.Schultz (FZJ),

O.Boucher (UKMetO), V-H.Peuch (Met-Fr), H.Eskes (KNMI), A.Simmons (ECMWF)

Credits to ECMWF team

A.Benedetti, A.Dethof, R.Engelen, J-J.Morcrette,

J.Flemming, M.Razinger, S.Serrar, M.Suttie

Scope of the Presentation

- Overall GEMS Objectives:
  - Exploit huge investments in satellite data
  - Extend NWP Modelling and Data Assimilation capabilities to atmospheric composition on global and regional scales
  - Provide a new range of services for Europe, with Global & Regional Deliverables
- Progress since Spring 2005 start of GEMS
- Challenges
- Schedule for Transition to Operations in 2009

GMES: Motivations for GEMS

- **TREATY ASSESSMENT & VALIDATION**
  - Conventions (Kyoto, Montreal, LRTAP) and IPCC need best estimates of sources/ sinks/ transports of atmospheric constituents.
- **BETTER OPERATIONAL SERVICES**
  - Improved forecasts: excess deaths in summer 2003 heatwave:- 18K in France, at least 33K in western Europe.
- **SCIENCE**
  - GEMS will synthesise all available satellite & in-situ data into accurate 'status assessments', and will meet many needs of the GCOS Implementation Plan

Environmental Concerns have triggered $25B for New satellite missions in 2001-2008

N.America	Europe / Collabs.	Asia /Collabs.
	JASON-1	
TERRA	ENVISAT	ADEOS-II
AQUA	MSG	COSMIC
SSMI/S	METOP-A	GPM
AURA	GOCE	
CALIPSO	ADM	
CLOUDSAT	CRYOSAT	
OCO	SMOS	

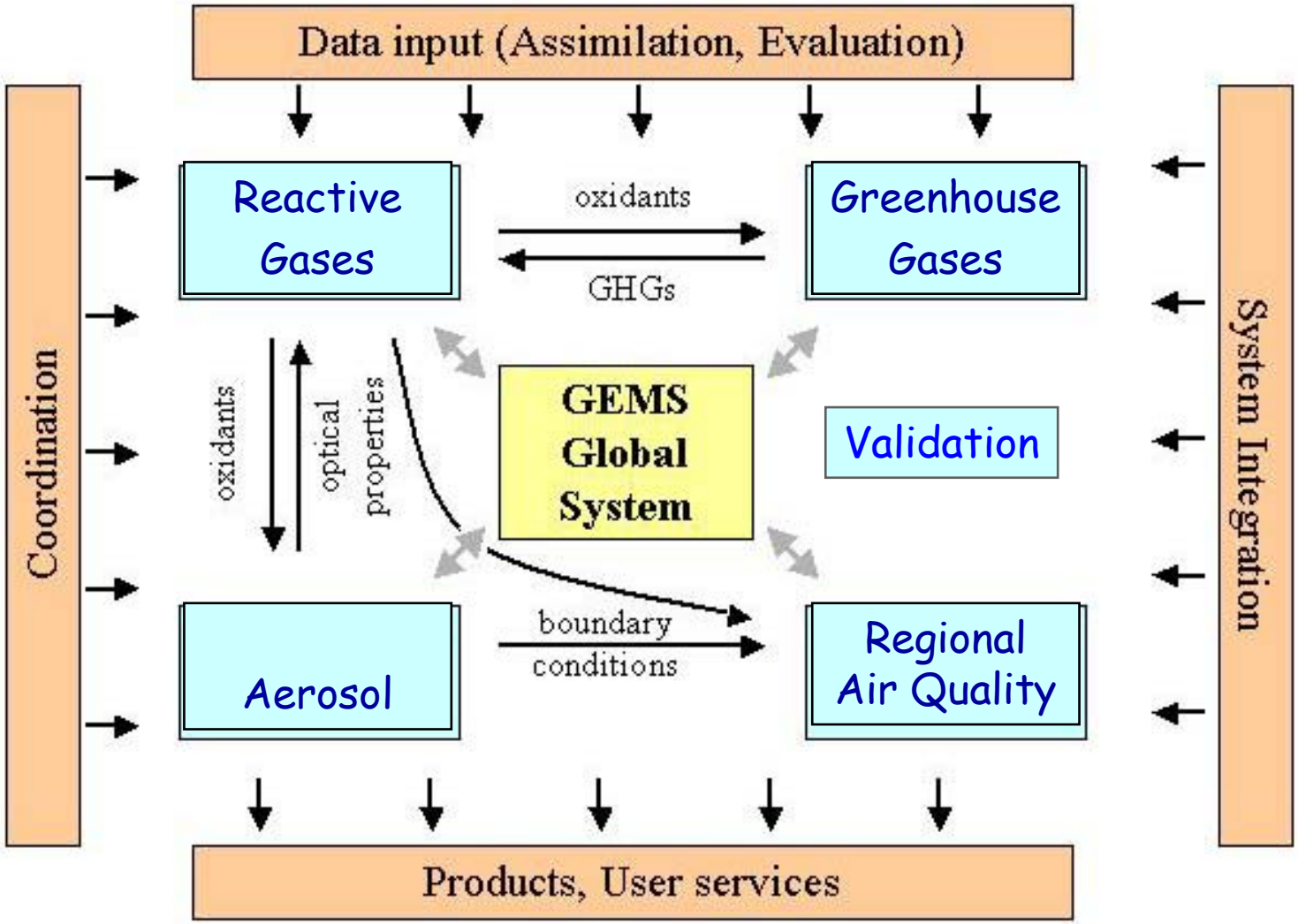
Underline: info on composition

Red: in orbit

Black: Planned

Organisation of the GEMS Project

GEMS is organised in 6 projects



GEMS Regional Deliverables: -Regional Air-Quality Forecasts
- Improved services for health sector
- Mapping of regional sources / deposition

- Regional Air Quality: initial & boundary conditions
  - Provide initial and boundary conditions for operational regional air-quality and 'chemical weather' forecast systems
- Improved monitoring and forecast services for the health sector
  - UV exposure and skin cancer
  - Heat stress and drought
  - Acute pollution events
  - Respiratory and Cardiovascular disease
  - Future
    - Vector borne and zoonotic disease (cf. malaria experience)
- Regional estimation of sources/sinks of CO2, O3, aerosol…

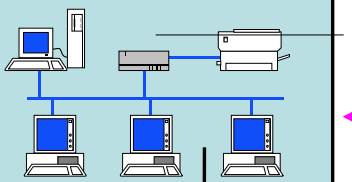
Global Core Service

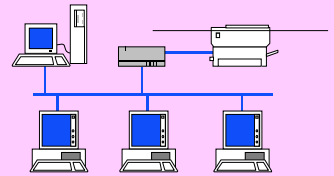
National / Regional Air Agencies

Weather Data

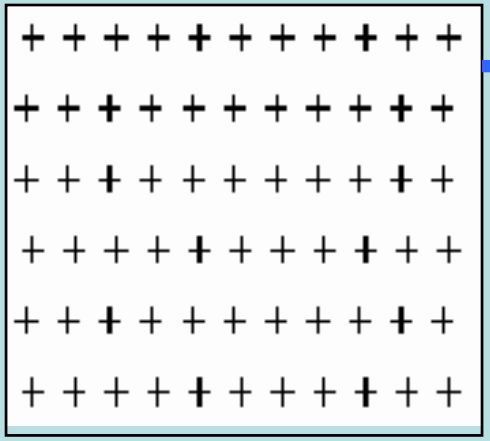
AQ Data

Emissions Inventory

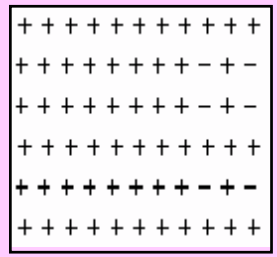




O_3 /NO_2 Data / Movies



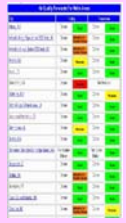
Global Forecast Pollutant Concentration Fields



Regional Forecast Pollutant Concentration Fields

Commercial Air Quality Providers

Media



Public

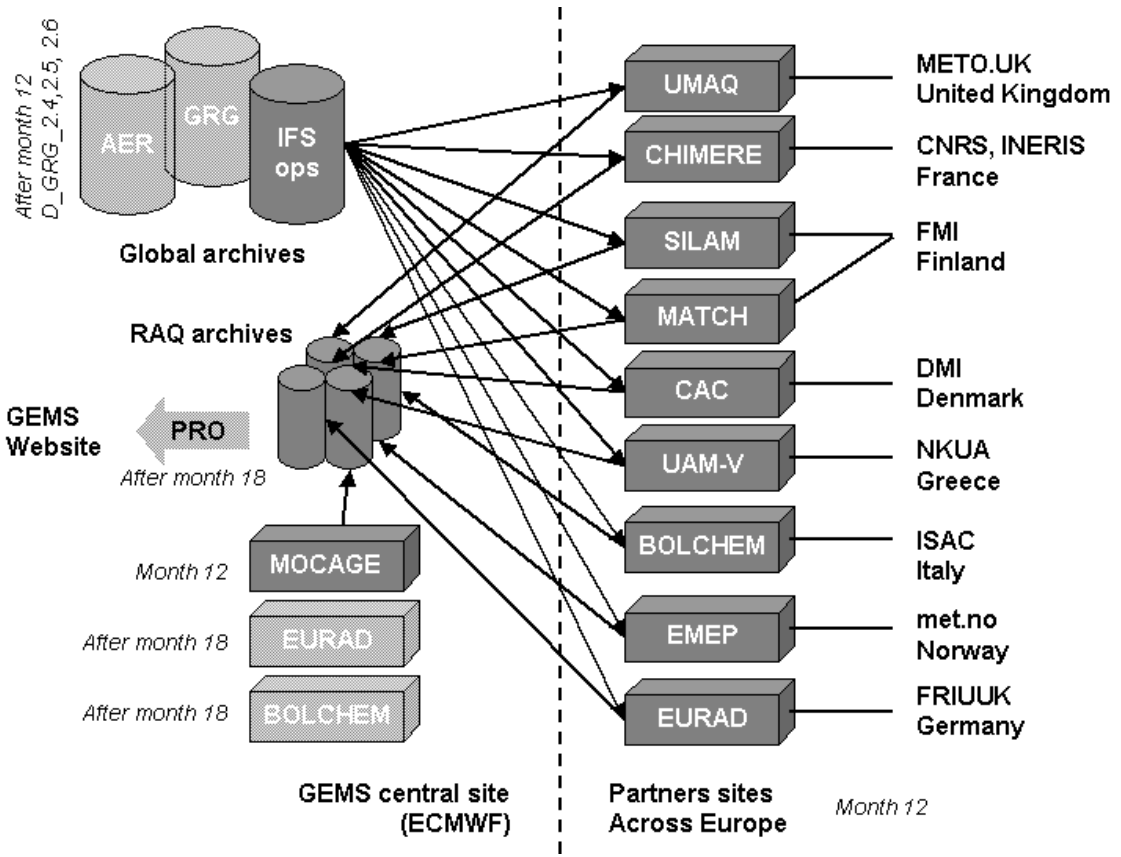
City-specific AQI forecasts

Functional Sketch of the GMES Air Quality Service

(iii) GEMS: a distributed system for operations and research

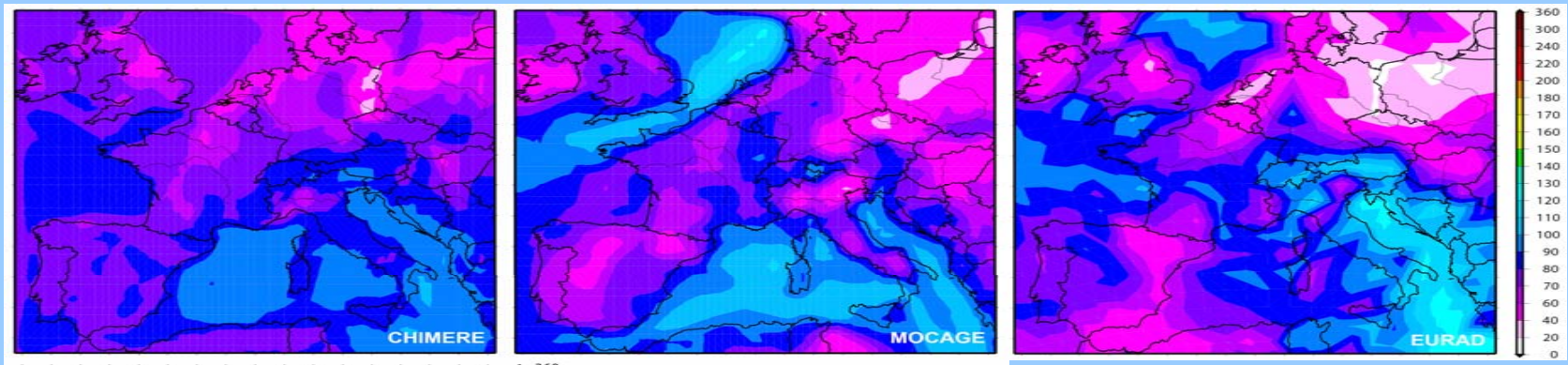
The GEMS system

- Distributed system for Research and Operations.
- Many Regional Systems
- Many Global CTMs
- A Global Weather system



Ensemble Regional Air Quality Forecasts

Production of regional forecasts of chemical species and air quality indices based on an ensemble of air-quality models on the European scale



Example: Surface ozone daily maxima (in 10-6 g.m-3): forecast for 20/10/2006 from the models CHIMERE (CNRS-INSU and INERIS), MOCAGE (Météo-France), and EURAD (Rhenish Institute for Environmental Research, Univ. Köln).

GEMS Global Deliverables: -Operational System for Atmospheric Composition
-Retrospective Analyses
-Operational mapping of CO2 sources/sinks

Global Operational System

- By 2009, at ECMWF, an operational global monitoring/ forecast system for atmospheric composition, combining all remotely sensed and in-situ data to create 3 dimensional global distributions [50km (H), 1km (V), 6 hours] of key atmospheric trace constituents:
  - greenhouse gases (initially including CO_2, and progressively adding CH_4, N_2O, plus SF_6 and Radon to check advection accuracy),
  - reactive gases (initially including O_3, NO_2, SO_2, CO, HCHO, and gradually widening the suite of species),
  - aerosols (initially a 15-parameter representation, later ~ 30)

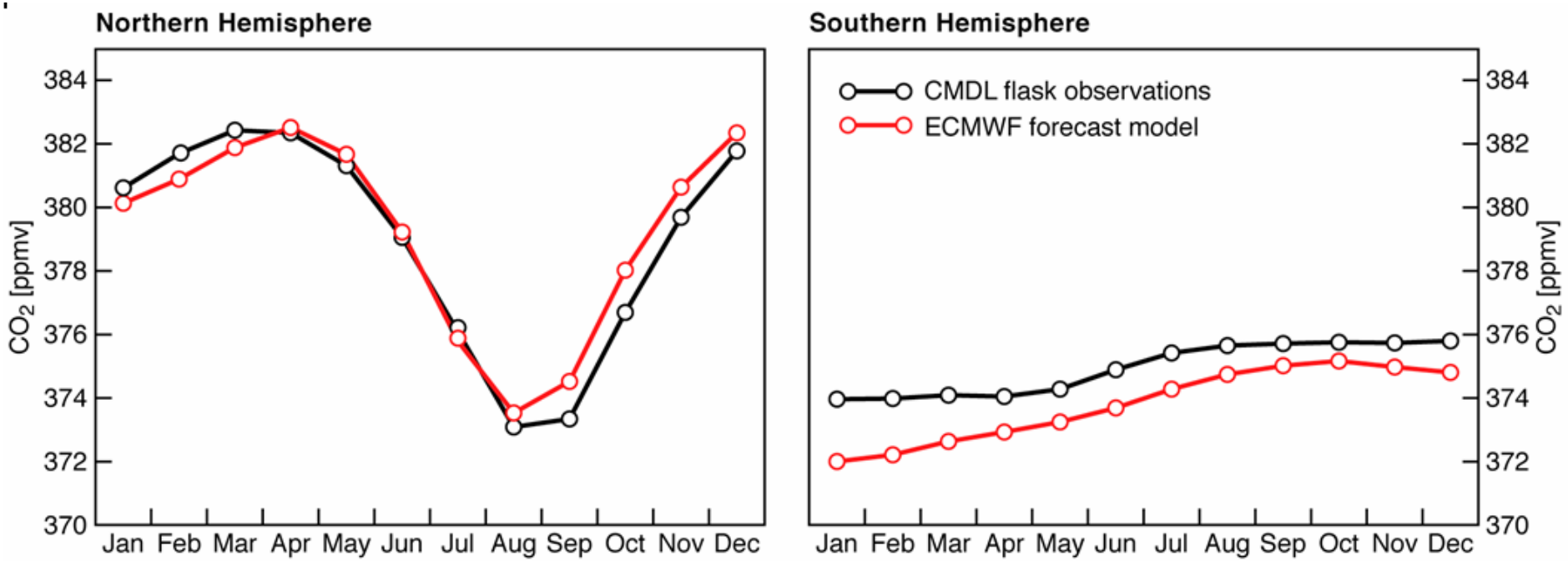
- **Retrospective Analysis**
  - Provide a retrospective analysis of all accessible in-situ and remotely sensed data on atmospheric dynamics and composition for the ENVISAT-EOS era (1999-2007)

- **Sources, Sinks and Transports**
  - Monthly/ seasonal maps of the sources, sinks and inter-continental transports, of CO2, O3 and many other trace gases and aerosols, based on in-situ & satellite data

GEMS tasks at ECMWF

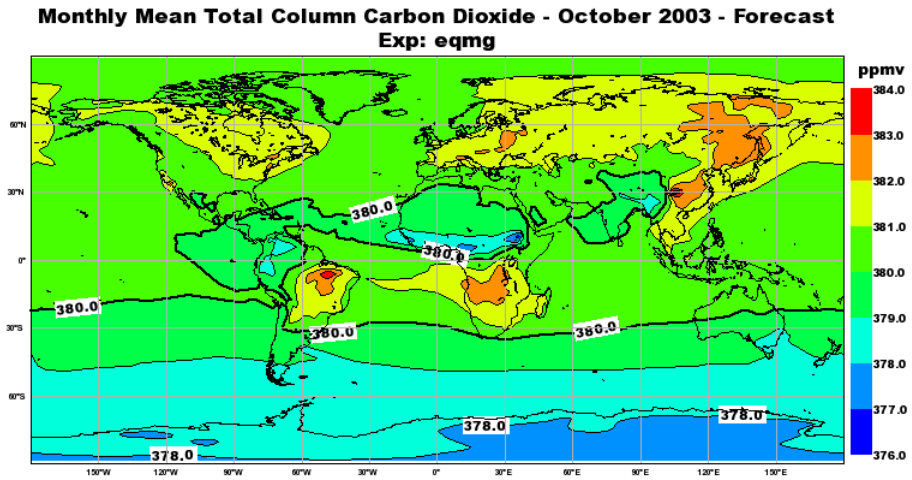
- Greenhouse gases
  - Start on CO_2, then CH_4, CO and N_2O
  - Develop modelling and data assimilation, and use analyses to infer sources and sinks for CO_2 and CH_4
- Reactive gases
  - Couple main forecast model with global CTMs
  - Carry O_3, CO, NO_2, SO_2 and $HCHO$ in main model and develop data assimilation
- Aerosols
  - Add to model, based on externally-produced parameterizations
  - Develop assimilation of retrievals, then radiances
- Integrate above components, and run past periods
- Provide boundary conditions and technical support for regional air-quality prediction

Comparisons with surface CO_2 measurements from NOAA/CMDL network – Seasonal cycle

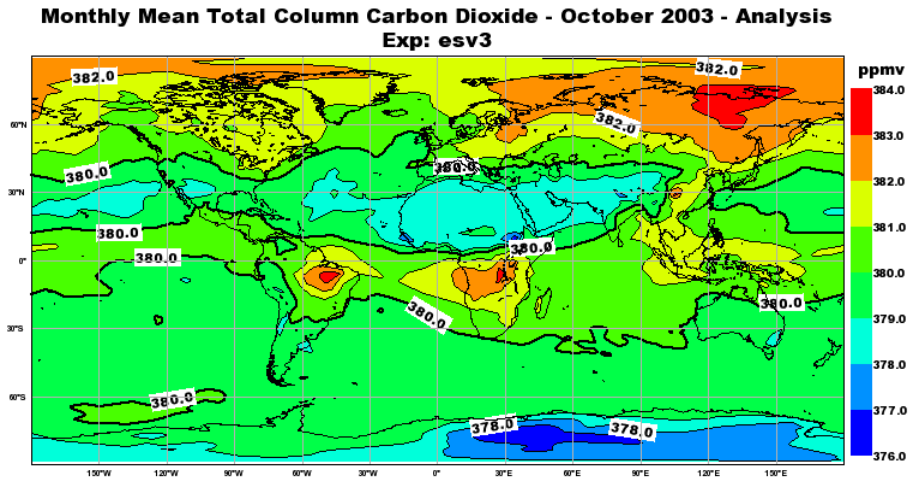


From model run with meteorological fields corrected every 12 hours and specified climatological surface fluxes of CO_2

First three-month reanalysis assimilating AIRS data



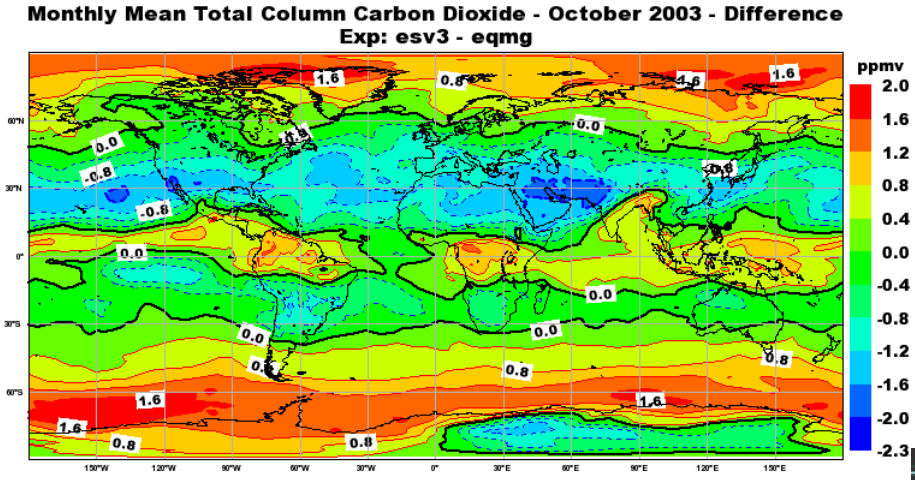
Free-running CO_2



Analysed CO_2

Monthly mean total column CO_2 after 3 month assimilation shows small but significant changes to a simulation with free-running CO_2

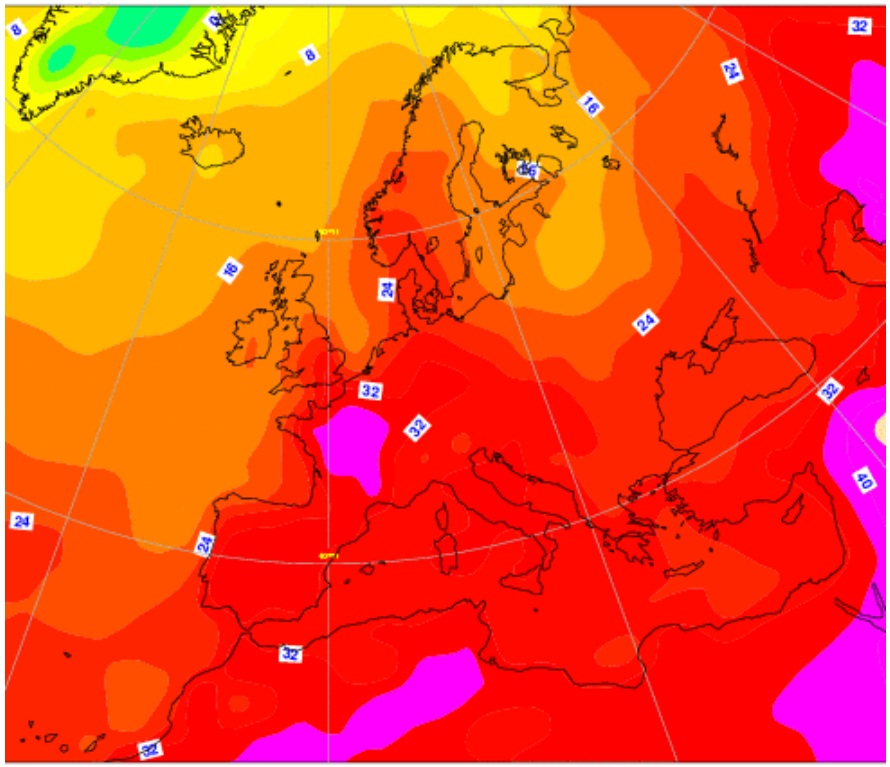
Too early to draw conclusions



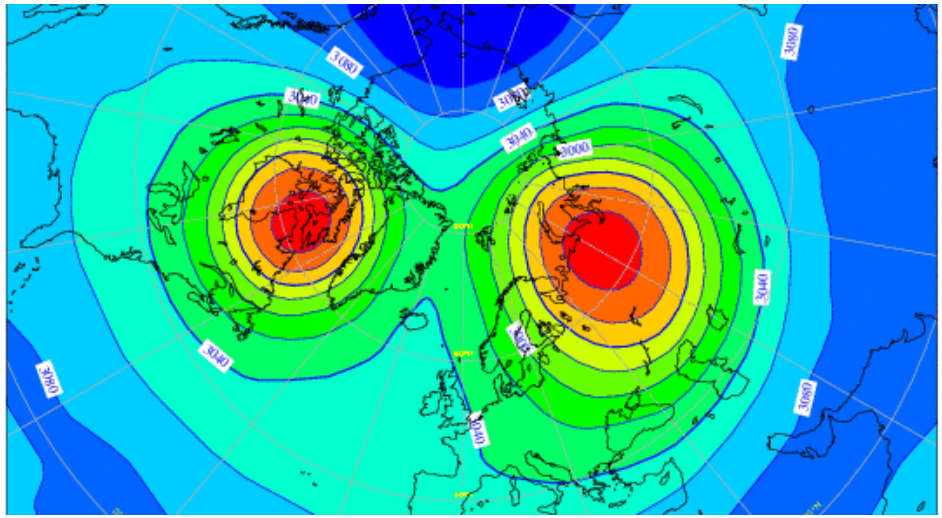
Difference

A reanalysis of 2003 for Chemical Transport Model intercomparison

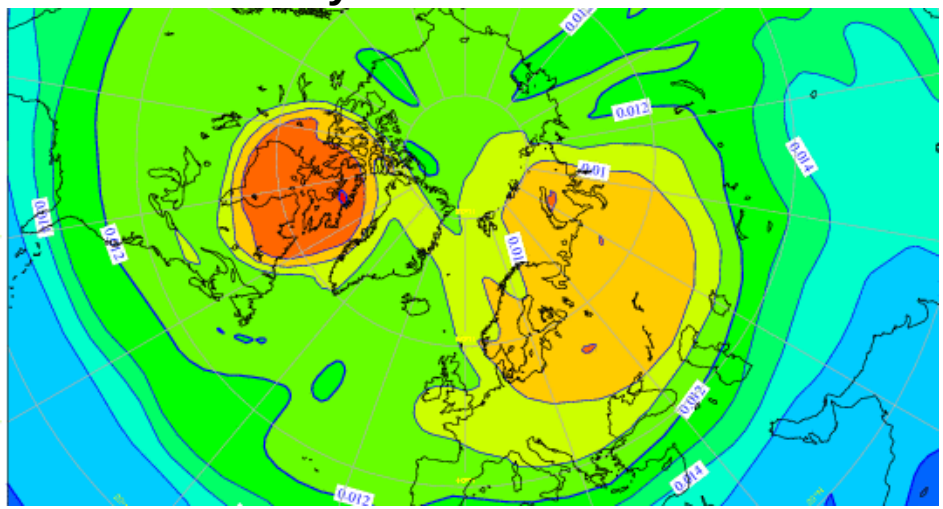
10 August 2003 12UTC Surface: 2 metre temperature



17 February 2003 12UTC 10hPa height

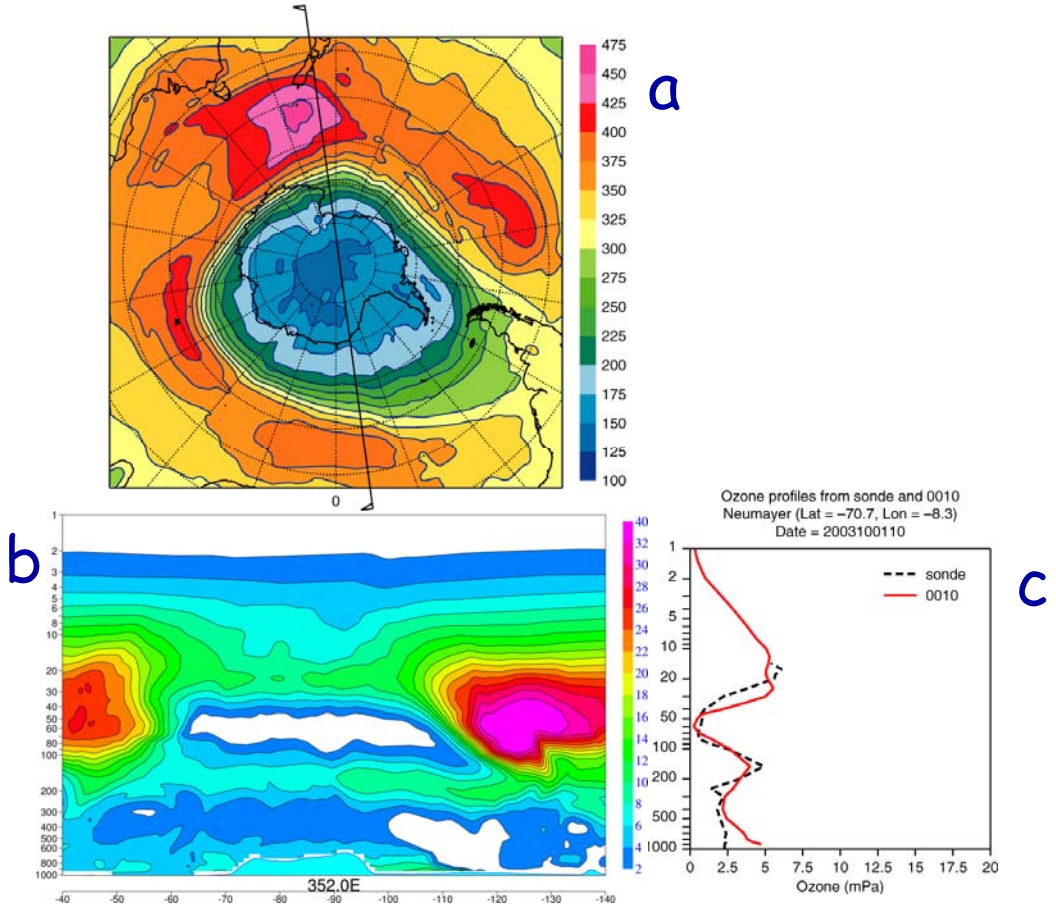


17 February 2003 12UTC 850K ozone



Ozone profile retrievals from both GOME and MIPAS assimilated

Ozone Hole 1 Oct 2003 in ECMWF assimilation



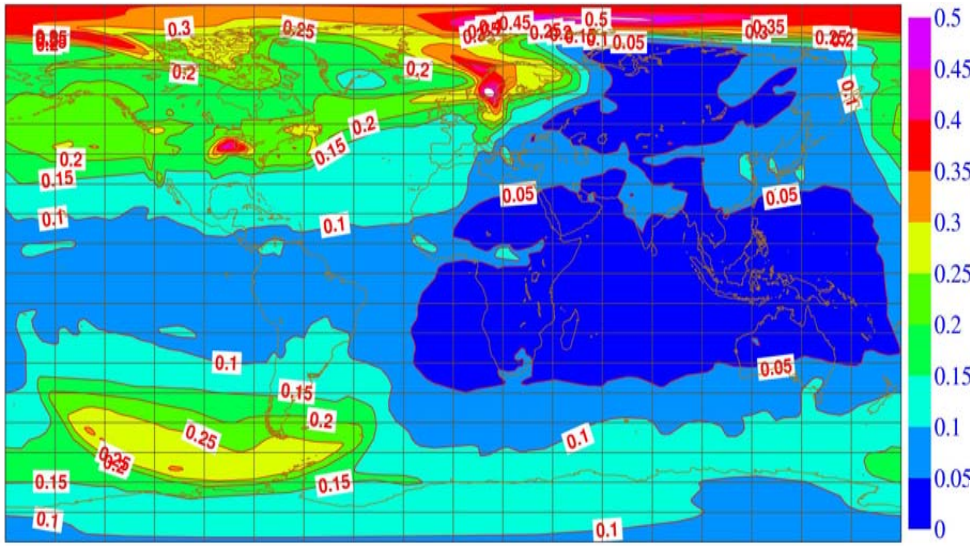
a) Ozone hole in Southern Hemisphere assimilation on 1 October 2003;

b) Vertical cross section of ozone partial pressure along 8W in a); the partial pressure of ozone is almost zero at 15km, over a wide area. Sharpness due to MIPAS

c) Comparison of (independent) ozonesonde profile data at Neumayer (70.7S 8.3W) with the assimilated field; the agreement is remarkable.

Courtesy: A.Dethof

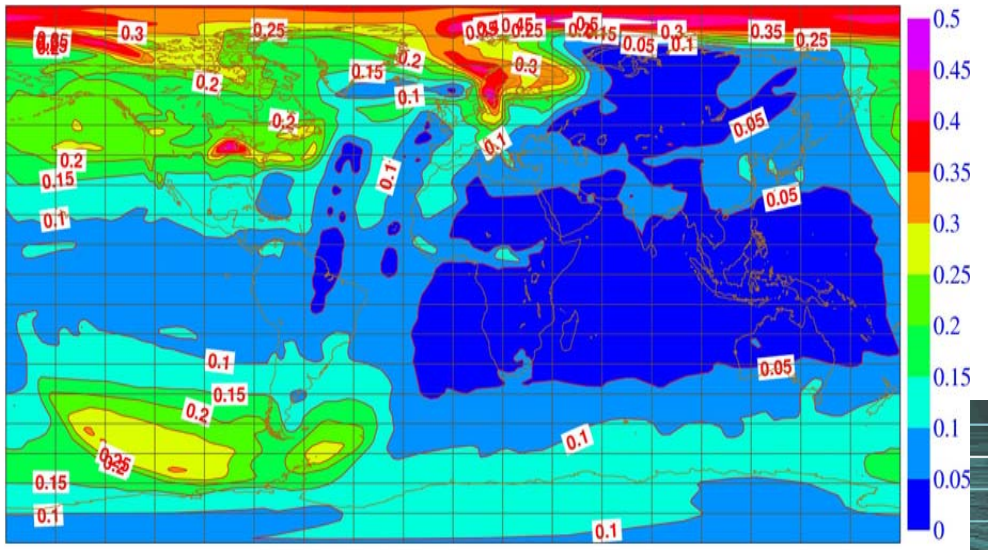
Assimilation of total column NO_2 from SCIAMACHY



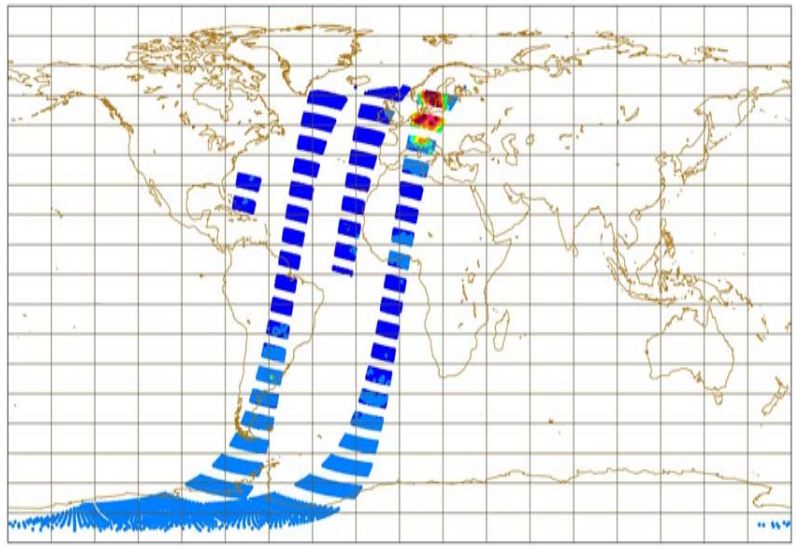
Background field (with no tendencies applied in IFS, and initial data from CTM)

Unit: 10^{15} mol/cm^2

Analysis



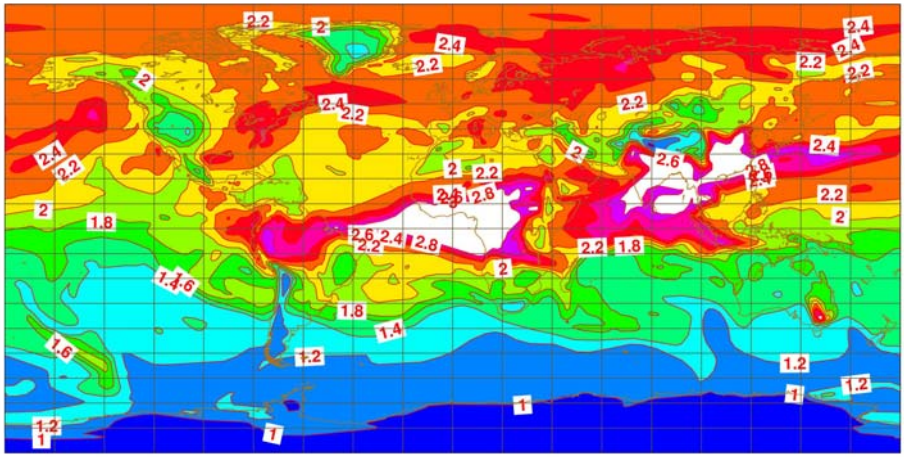
Active observations



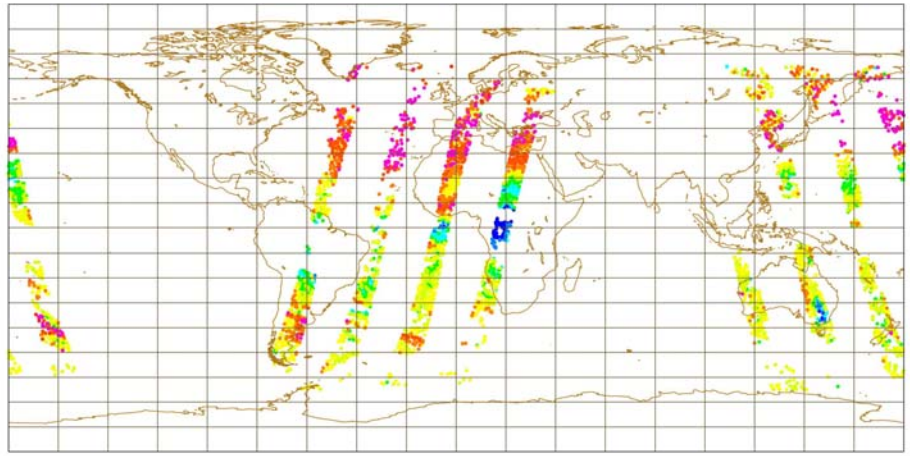
Assimilation of total column CO from MOPITT

Unit: 10^{18} mol/cm^2

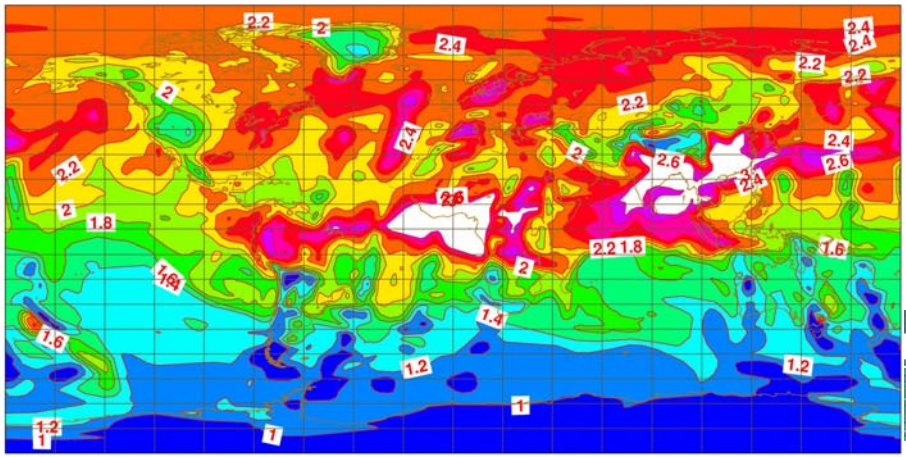
Background (no tendencies)



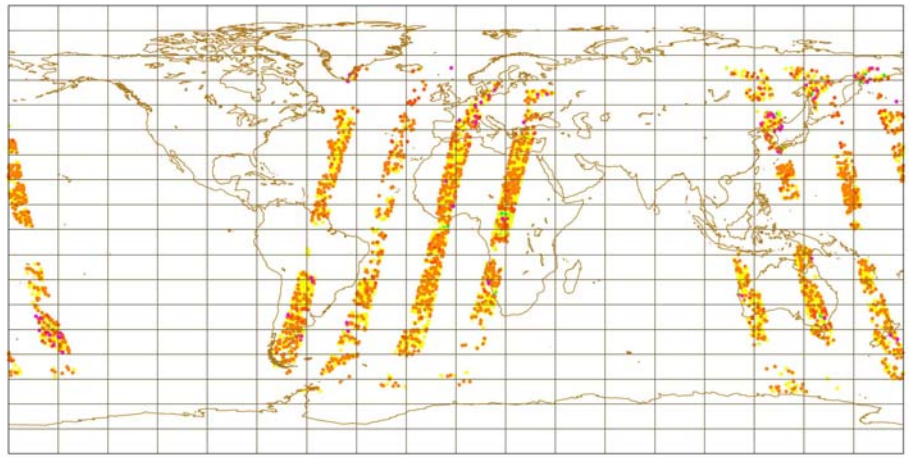
Background departures (active data)



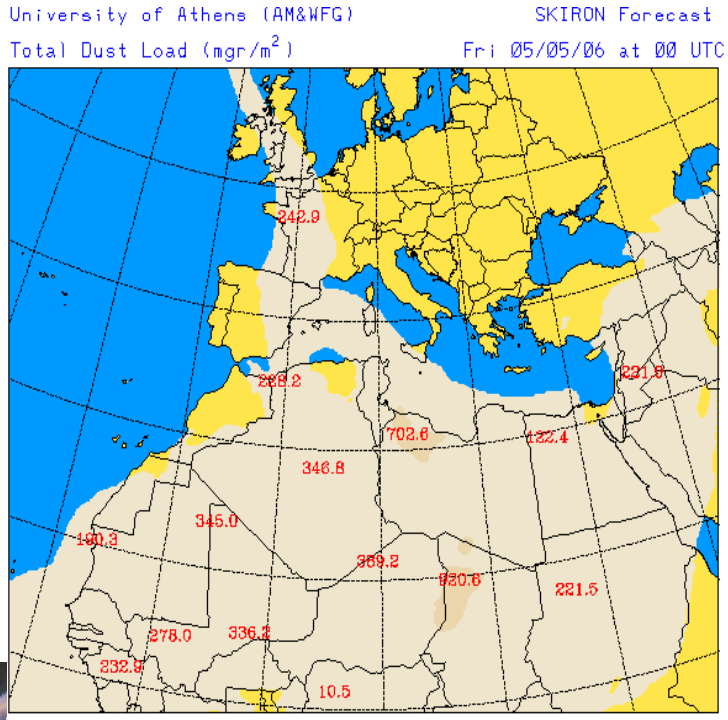
Analysis

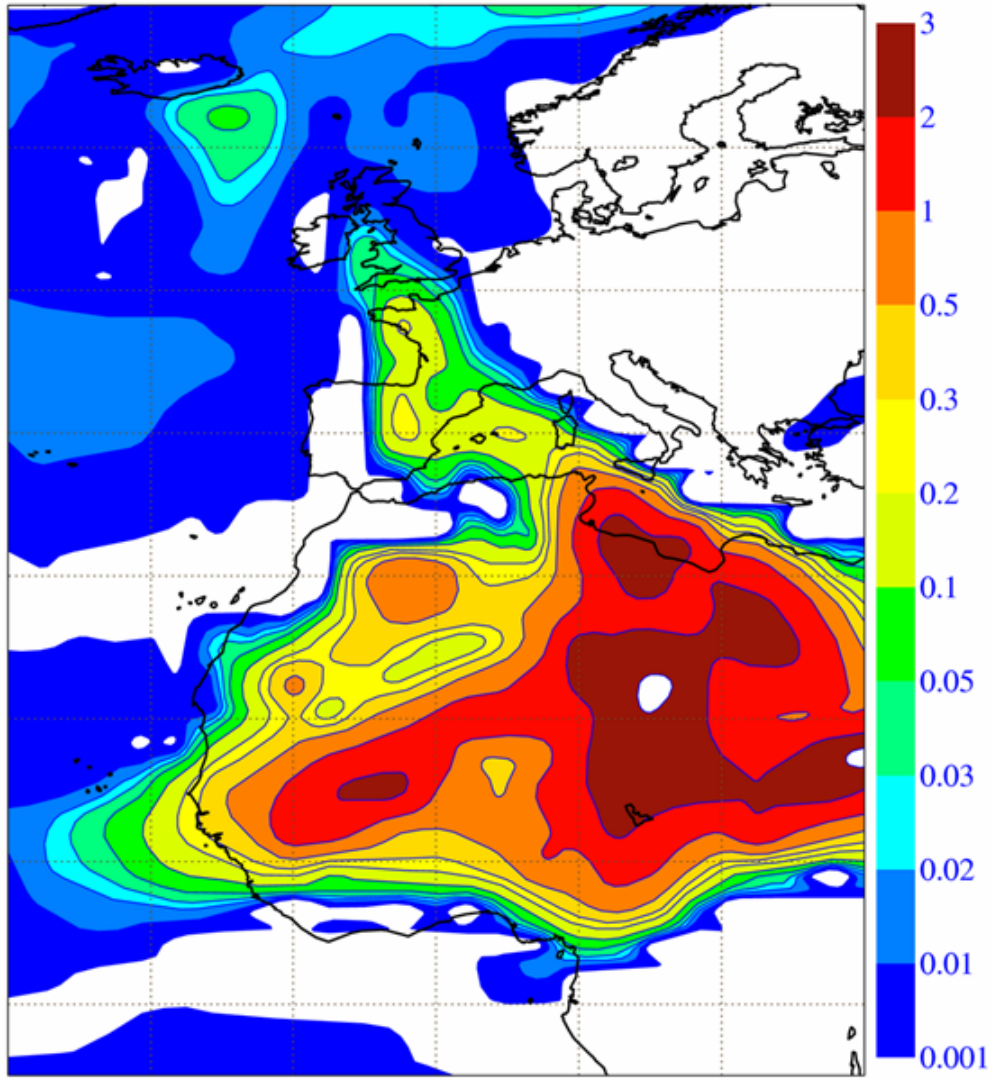


Analysis departures (active data)



First version of aerosol model (sea salt and desert dust)



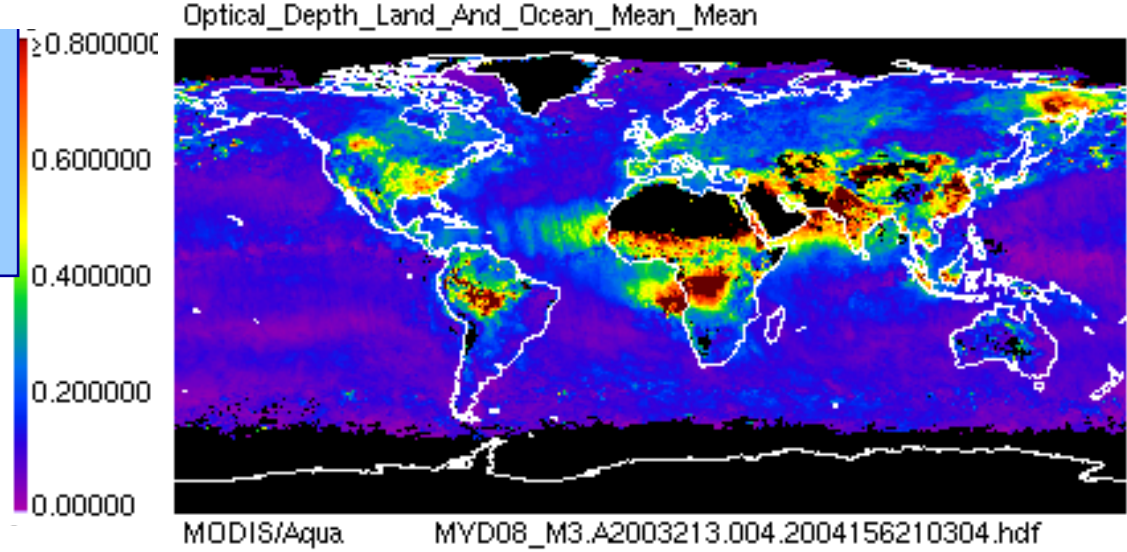


Aerosol optical depth at 0.55 micron

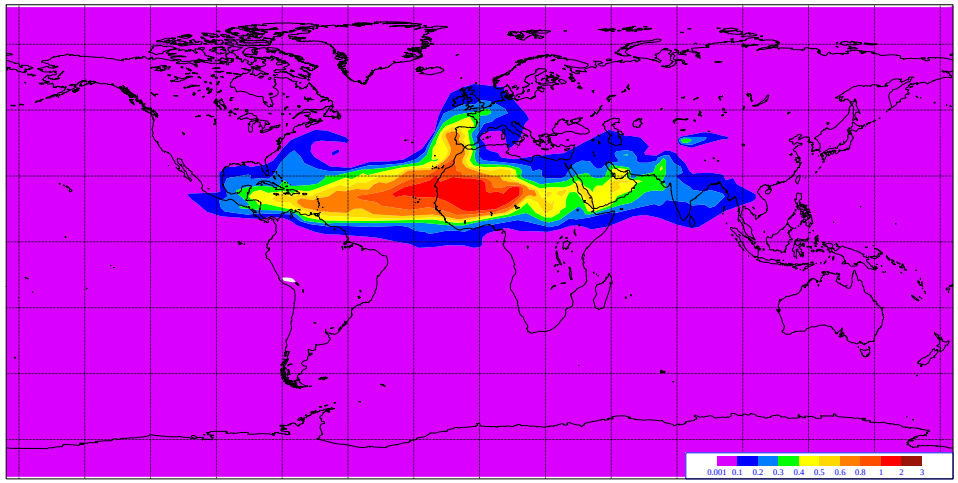
00UTC 5 May 2006

GEMS

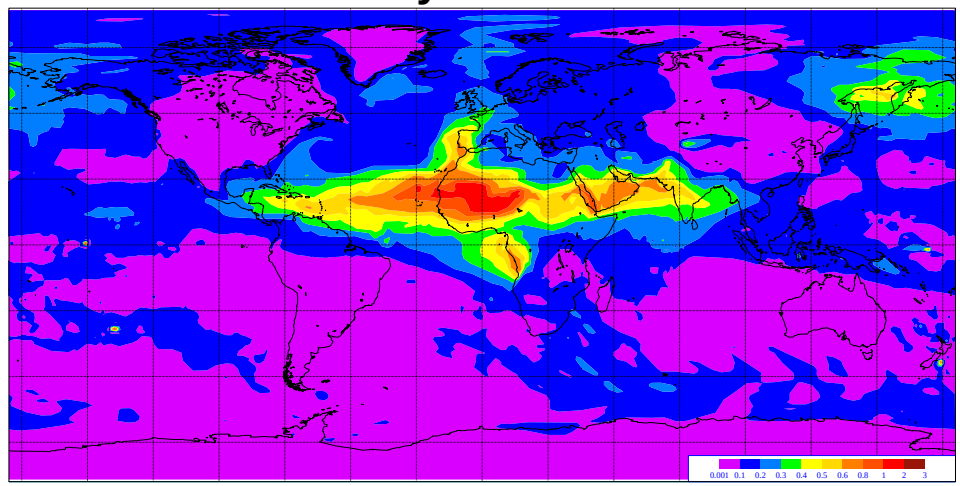
Comparison of aerosol optical depth with MODIS observations

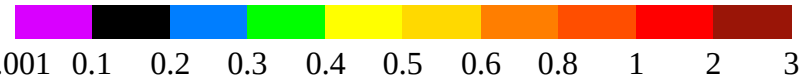


Forecast run



Analysis run

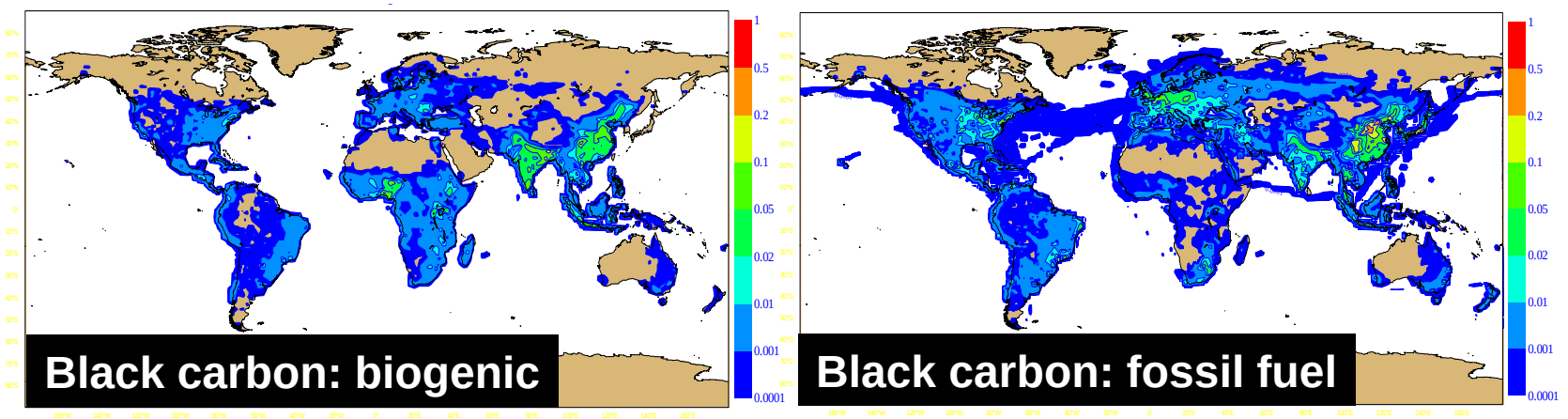




Mean fields 1-15 August 2003

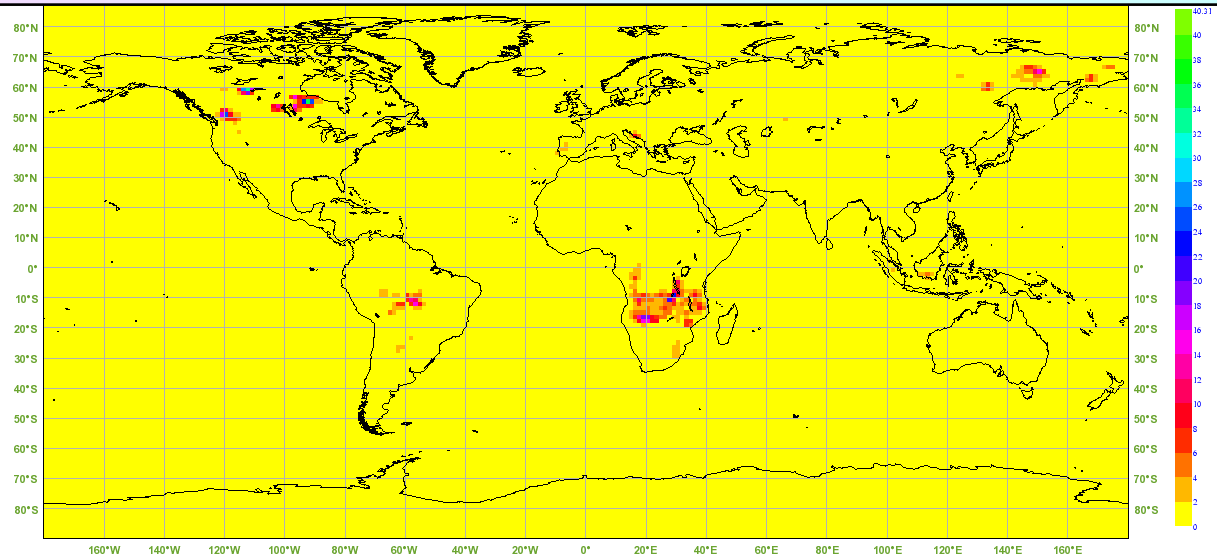
New aerosol model

- Implementing aerosol model of Huneeus and Boucher
- Model has four prognostic variables representing:
  - Coarse dust (0.5 – 10 mm)
  - Coarse sea-salt (0.5 – 10 mm)
  - Aerosols with fine emission: dust, sea-salt, black carbon, organic matter
  - Sulphate aerosols from precursor emissions
- Many source fields

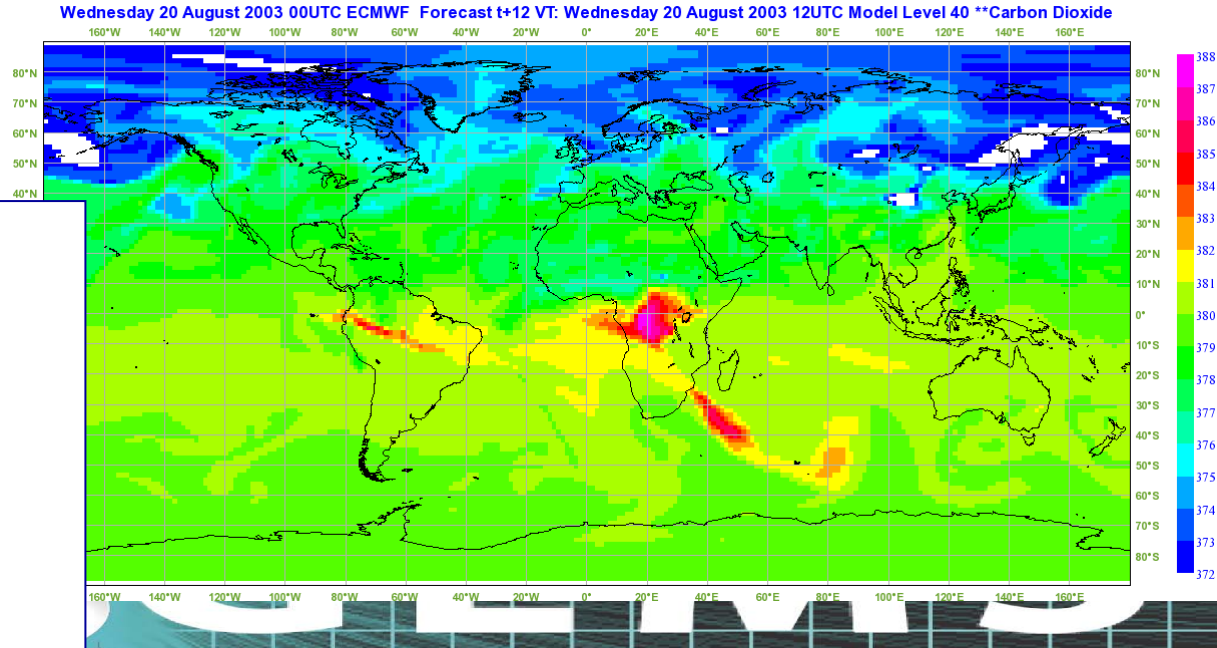


Inclusion of fire emissions

CO_2 emission from fires
[kg/m2/s]
12UTC 20 August 2003
(GFEDv3-8d)



Model CO_2
12UTC 20 August 2003
500hPa



Data acquisition and coding

- Current acquisitions
  - MODIS Aerosol (Terra & Aqua) from NASA for 2003 and 2004
  - GOME O_3 profile from RAL for 1995-2003
  - SCIAMACHY NO_2 from KNMI for 2003 and 2004
  - MOPITT CO from NASA for 2003 and 2004
  - AURA TES CH_4 and CO from NASA for July 2005
  - GOME HCHO from KNMI for December 2001
- To come:
  - CO_2, SO_2 and HCHO from SCIAMACHY, NO_2 from OMI, SAGE aerosol, …
- Datasets are being converted to BUFR code
- BUFR to ODB conversion is under test
- Data from AERONET are being acquired in near-real-time
- Ongoing work on BUFR definitions and netCDF/GRIB issues

Challenges/issues

- Greenhouse gases
  - Modelling: mass conservation, inter-hemispheric transport, methane sinks, …
  - Data assimilation: bias correction, QC, Jb statistics, …
  - Suitability for source estimation?
- Reactive gases
  - Computational efficiency of CTMs and coupling
  - Scientific aspects of coupling: use of NO_x and O_x , …
  - Delay to development of data assimilation and extended analyses
  - Jb development yet to be undertaken, …
- Aerosols
  - Establishment of new model
  - Partition of optical-depth information among species in data assimilation, use of aerosol physics in data assimilation, …
  - Some delay to extended analyses

Plans: 2007-2009

- Further development of the global assimilation systems, esp. IFS/CTM coupling & new aerosol model (4Q 2006 – 1Q 2007)
- Separate analyses of (i) CO_2, (ii) some reactive gases & (iii) aerosols for 2003/4 (4Q 2006 - 3Q 2007)
- Refinement and integration of the global assimilation system (4Q 2006 - 3Q 2007)
- Extended reanalysis with integrated global system (4Q 2007 - 3Q 2008)
- Support daily running of regional air quality forecast models & multi-model ensemble forecasts (3Q 2007 - 1Q 2009)
- Preparation of global system for operations (4Q 2008 - 1Q 2009)

END

thank you for your attention!

www.ecmwf.int/research/EU_projects/GEMS

Time lines of committed and likely missions 2009-2019

Time Lines in 2009-2019 for

committed operational missions

& likely research missions

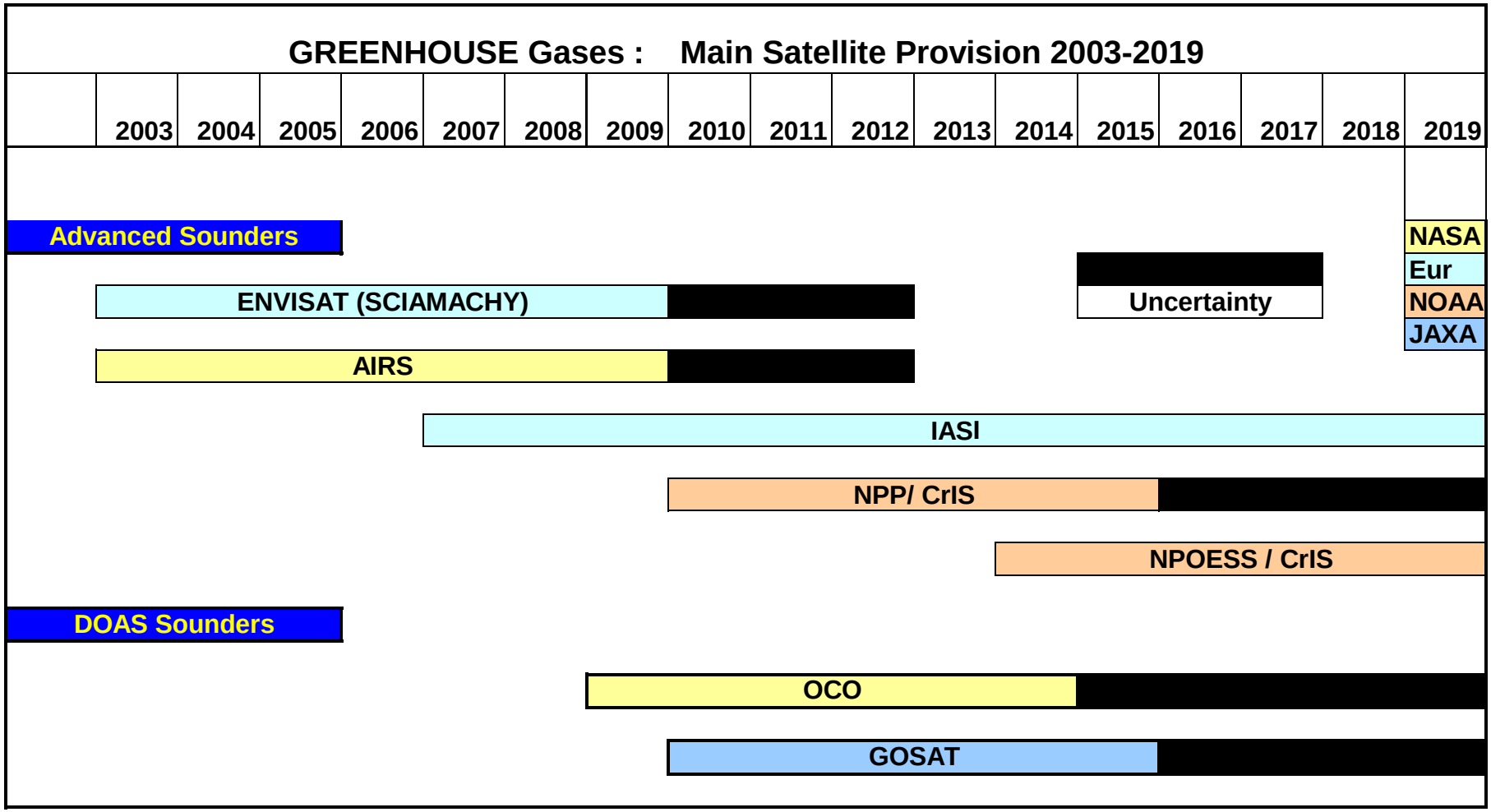
of importance to GEMS activities

Greenhouse Gases

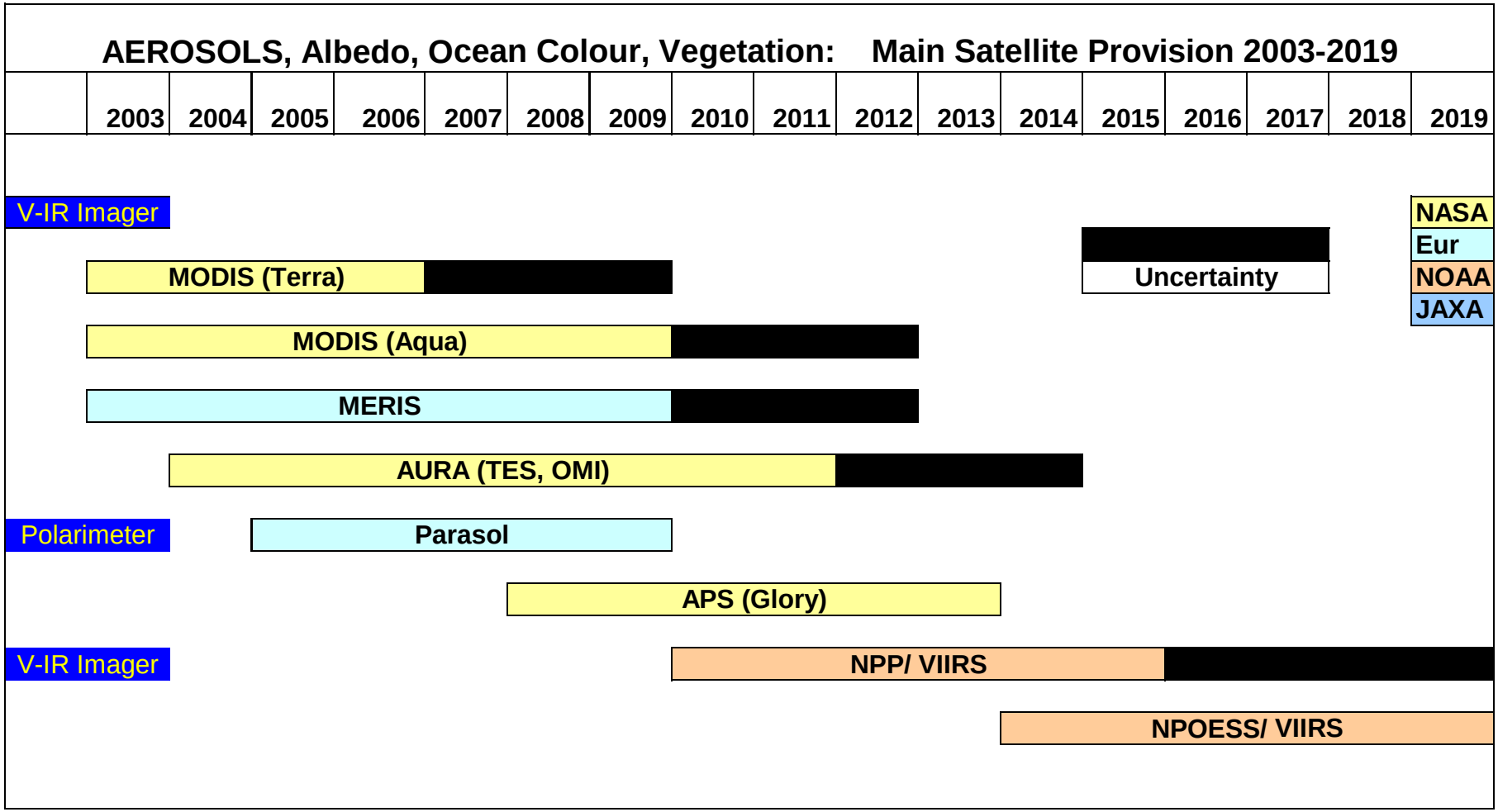
Reactive Gases

Aerosol

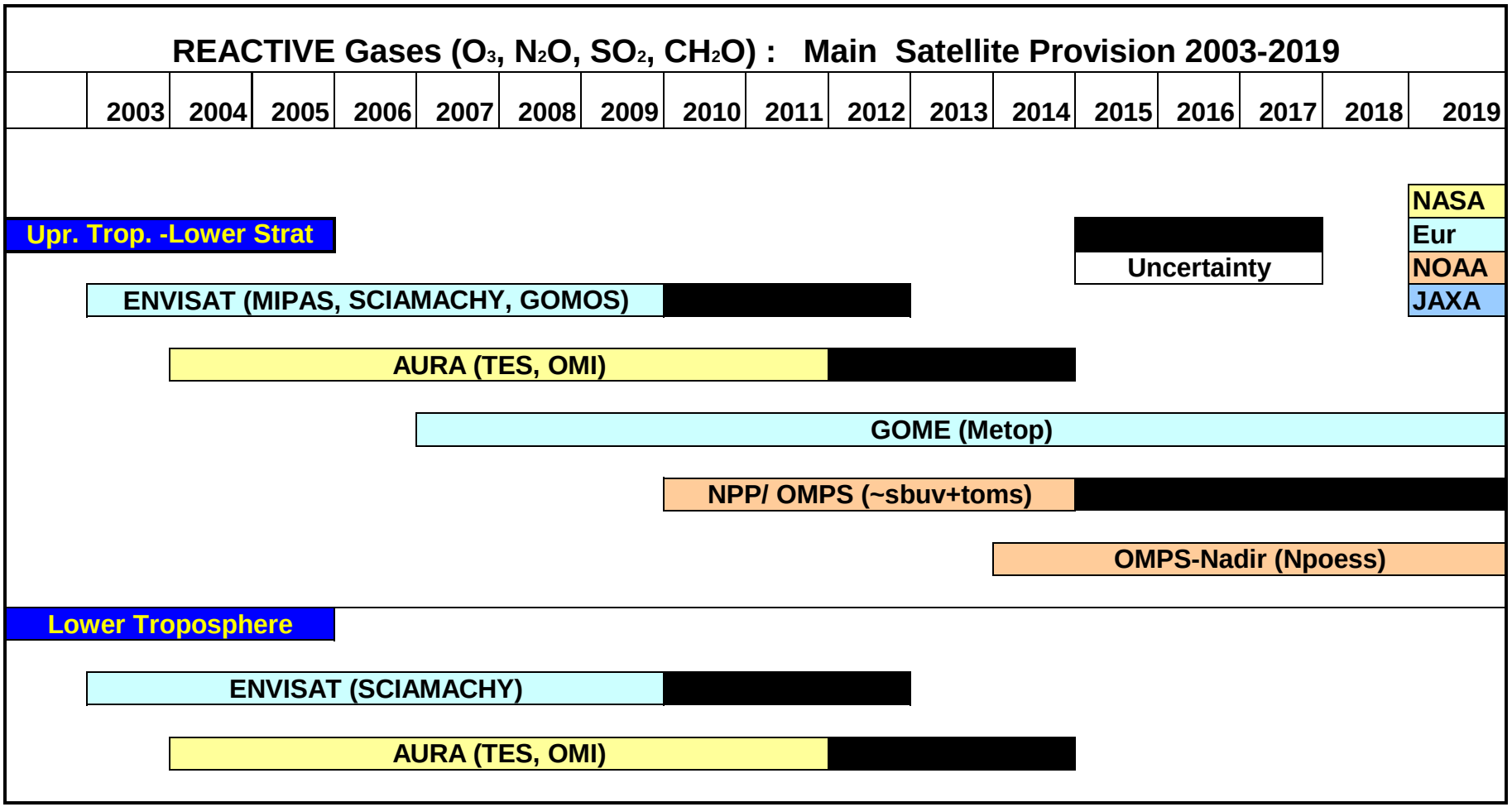
Greenhouse Gas Provision



Aerosol Provision



Reactive Gas (UTLS & Air-Quality) Provision



Perspectives on GEMS satellite provision 2009-2019

- Sustainability of GEMS products, based on satellite provision 2009-2019
  - Greenhouse gases (GHG): Assuming 2008/9 OCO launch, GHG products should be sustainable throughout the period
  - Aerosol (AER): Assuming 2009/10 launch of VIIRS on NOAA's NPP, GHG products will be sustainable throughout the period
  - Global Reactive Gases (GRG)
    - Assuming launches of METOP (2006) and NPP (2009/10) , GRG Stratospheric Ozone products will be sustainable throughout the period.
    - No committed Air-Quality mission beyond ENVISAT & AURA
- Actions for European scientists
  - Press for European Air-Quality missions: ESA by 2015, EUMETSAT by 2025
  - Urge NASA to extend the lifetime of EOS (TERRA, AQUA, AURA) as far as possible – each was launched with 15 years consumables.
  - Urge NASA to extend the lifetime of other A-train missions, + GLORY +OCO
  - Help US scientists persuade current and future US administrations to fund further NASA and NOAA missions.