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

Anthony Hollingsworth

ECMWF

Credits to GEMS Management team

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Credits to ECMWF team

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

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	

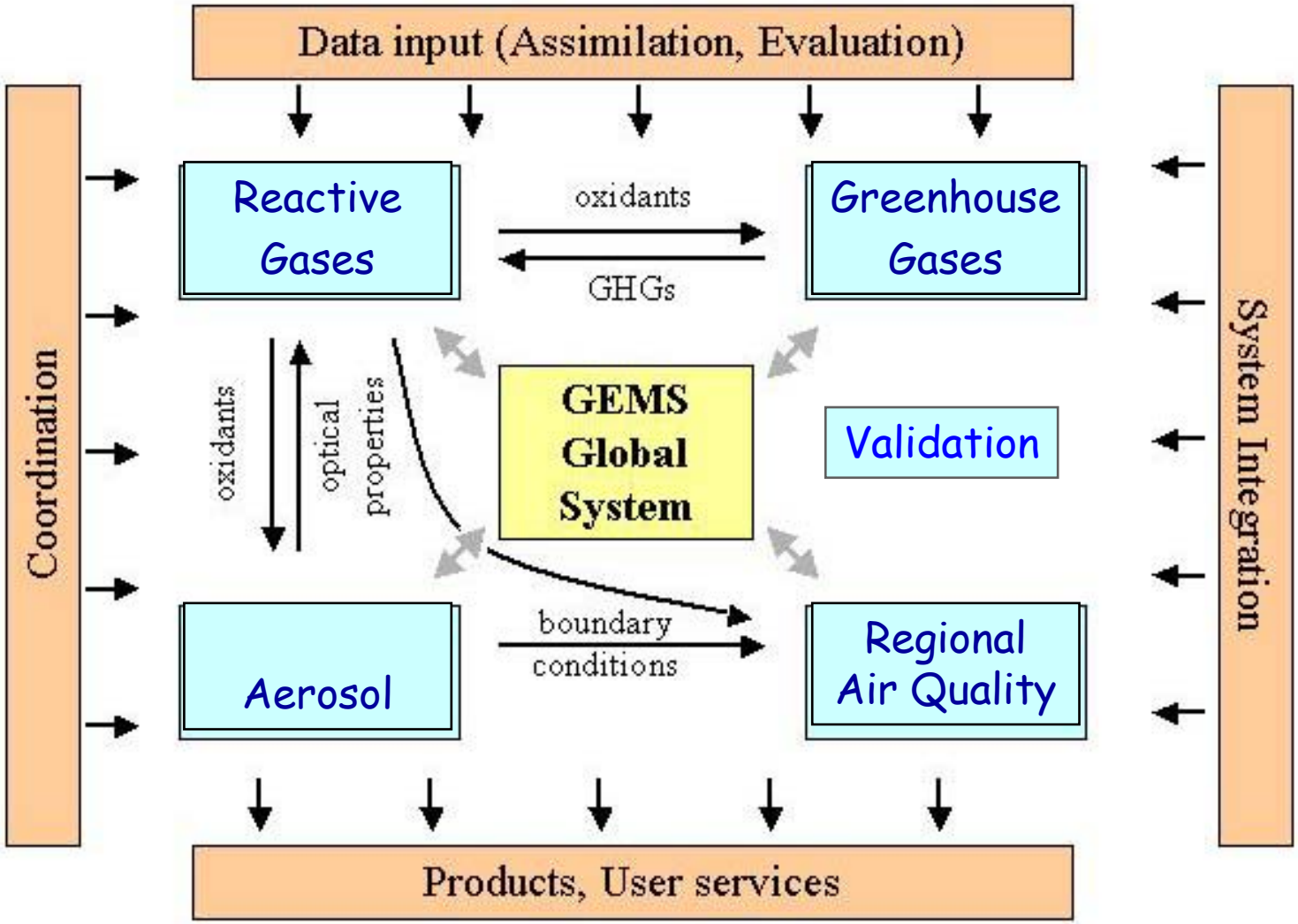
Underline: info on composition

Red: in orbit

Black: Planned

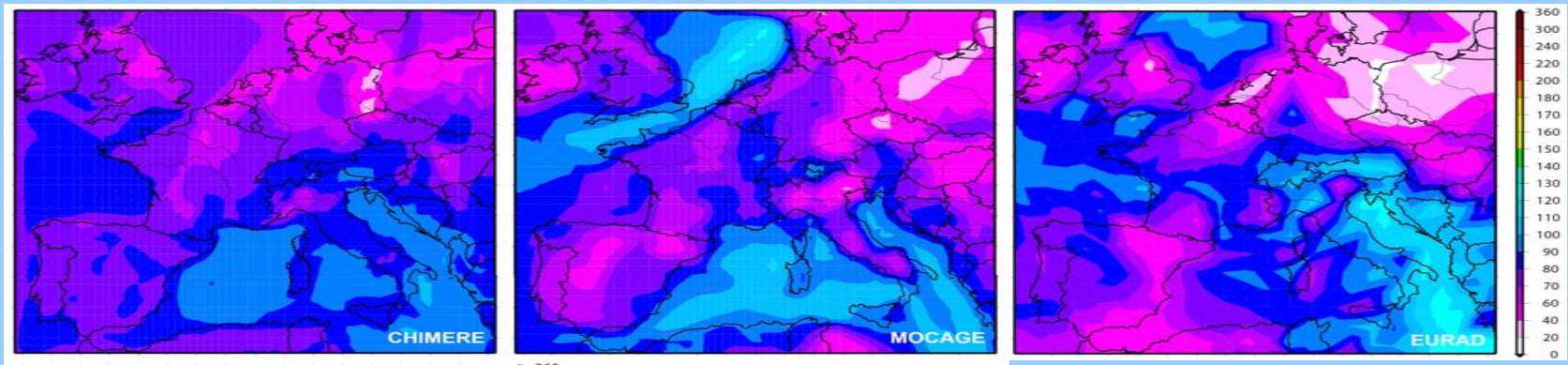
Organisation of the GEMS Project

GEMS is organised in 6 projects



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

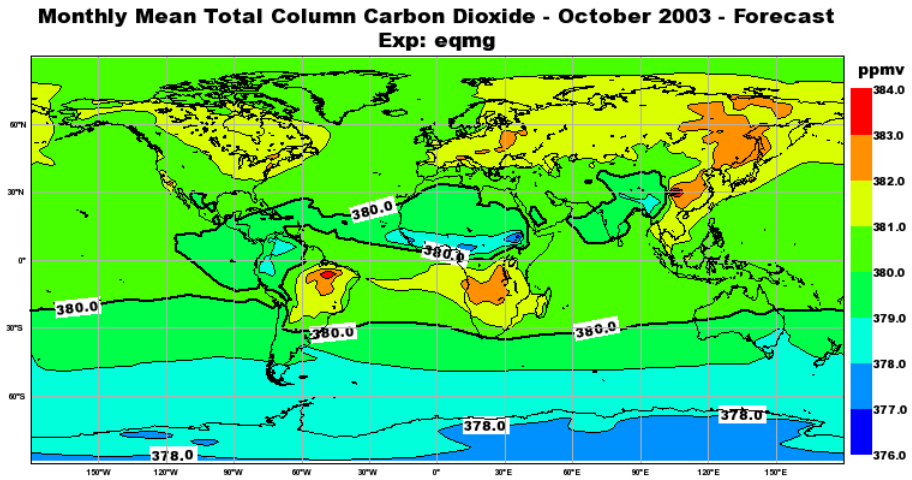
Global Operational System

- 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)

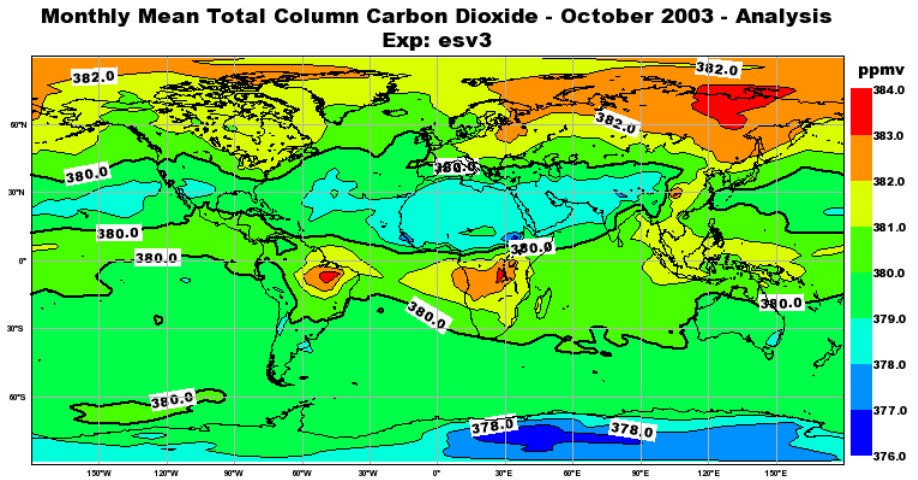
- **Retrospective Analysis**
  - Provide a retrospective analysis of all accessible in-situ and remotely sensed data on atmospheric dynamics and composition for the ENVISAT-EOS era (1999-2007)

- **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

First three-month reanalysis assimilating AIRS data



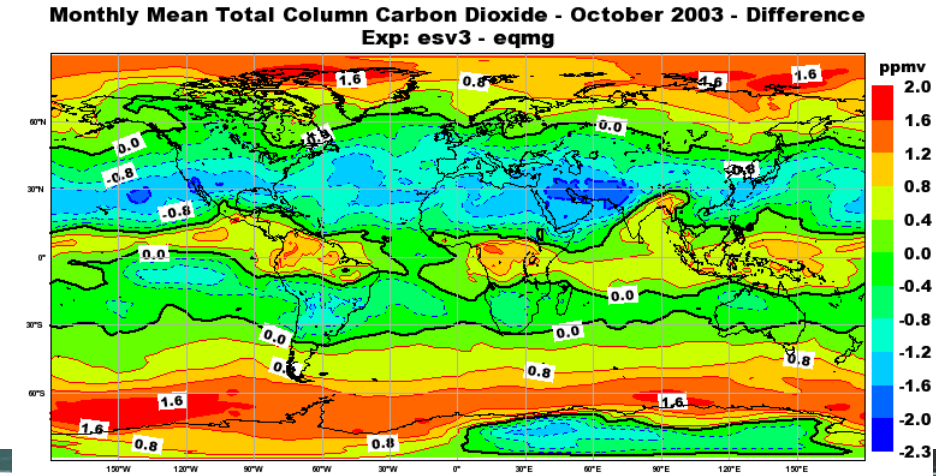
Free-running CO_2



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

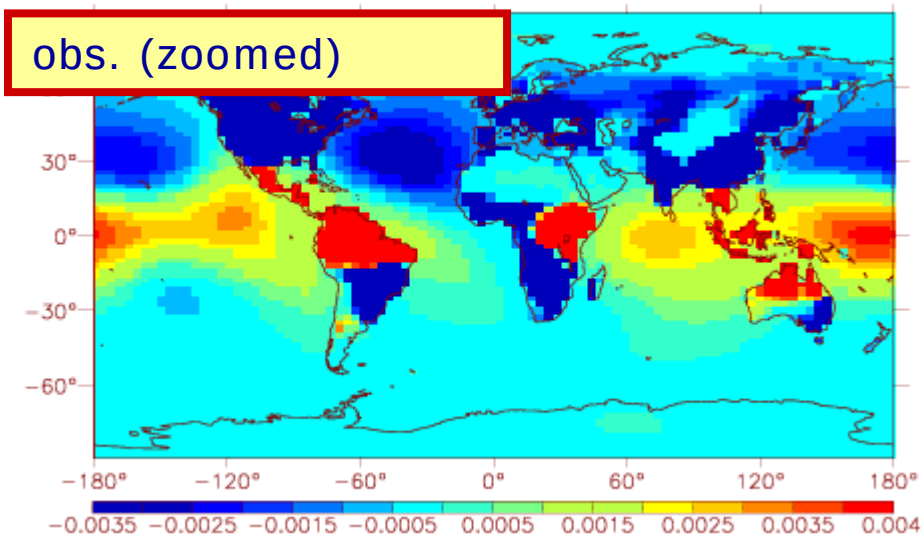


Difference

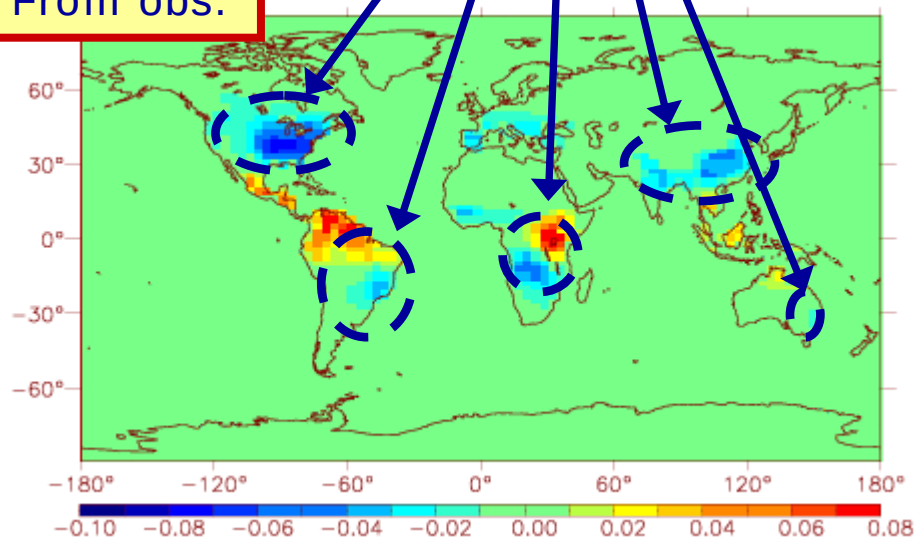
Flux increments (kgC/m² over 3 months)

First Hessian eigenvectors

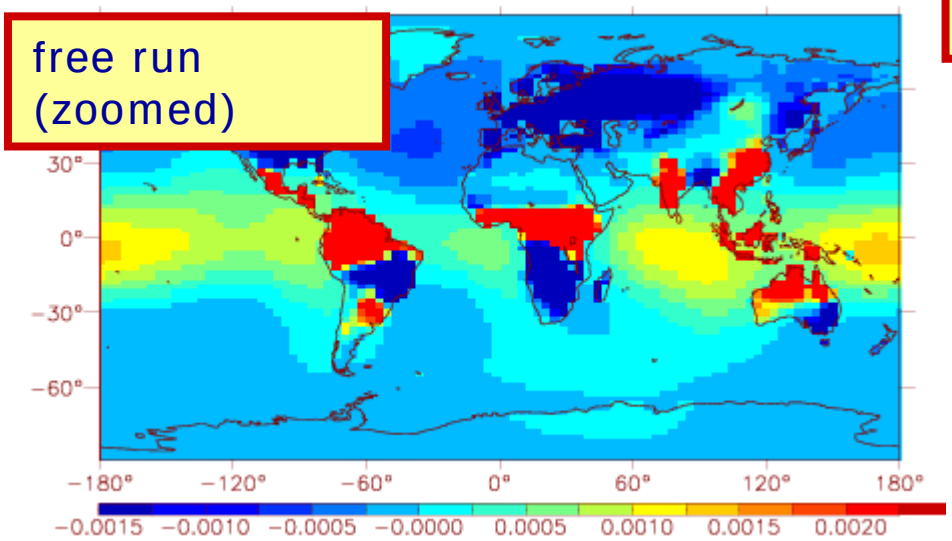
obs. (zoomed)



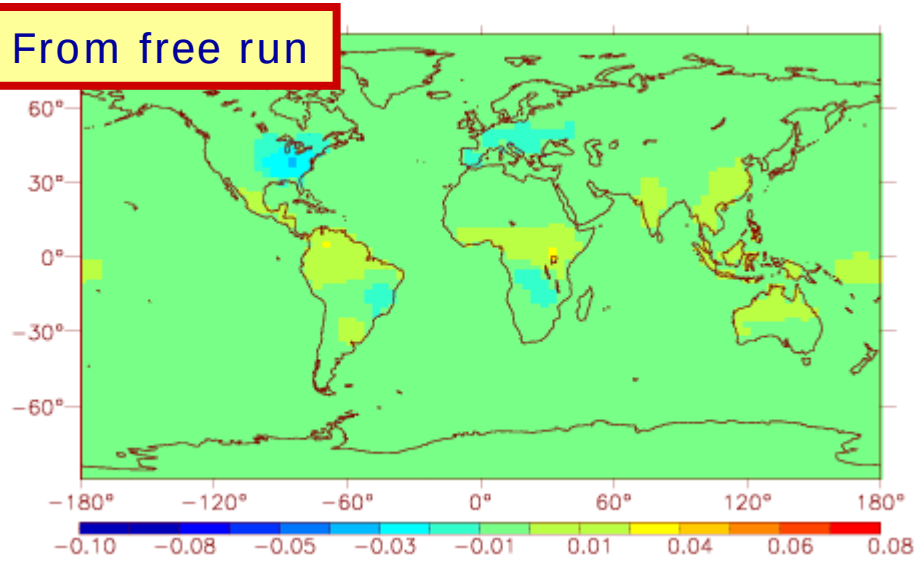
From obs.



free run (zoomed)

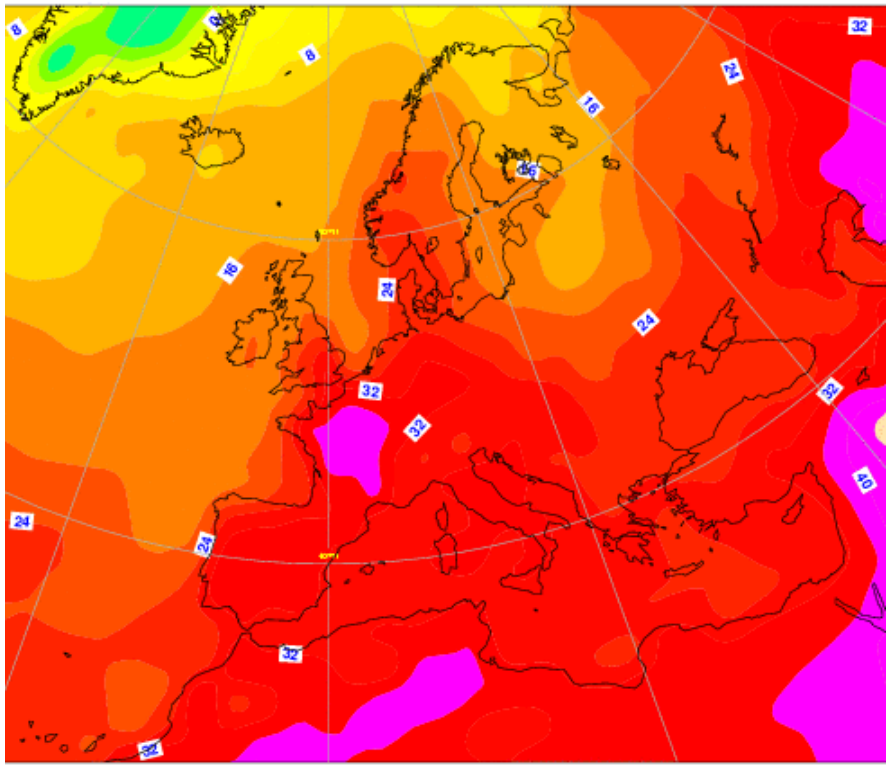


From free run

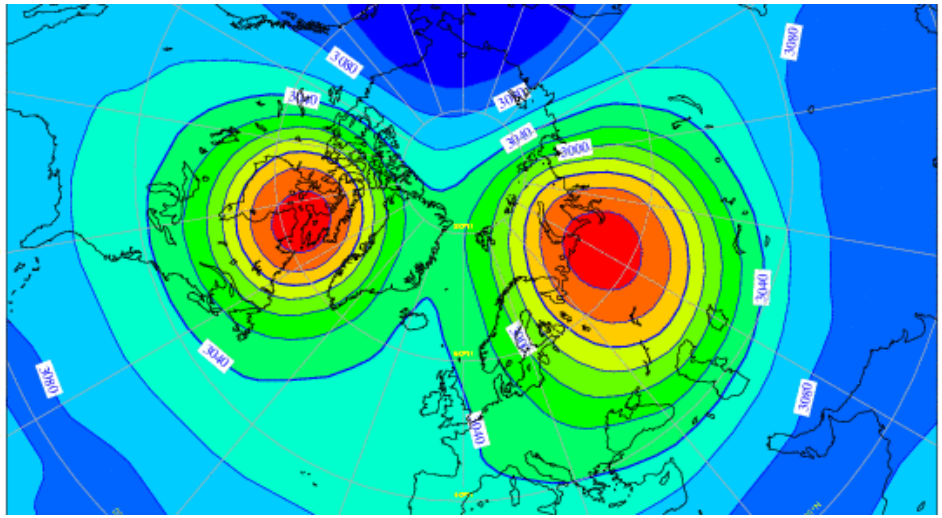


A reanalysis of 2003 for Chemical Transport Model intercomparison

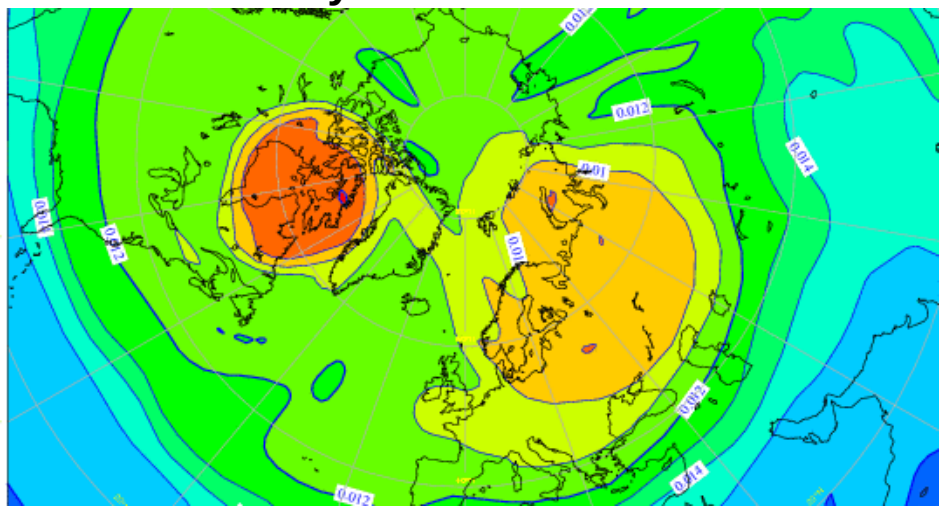
10 August 2003 12UTC Surface: 2 metre temperature



17 February 2003 12UTC 10hPa height

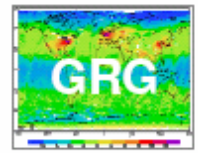


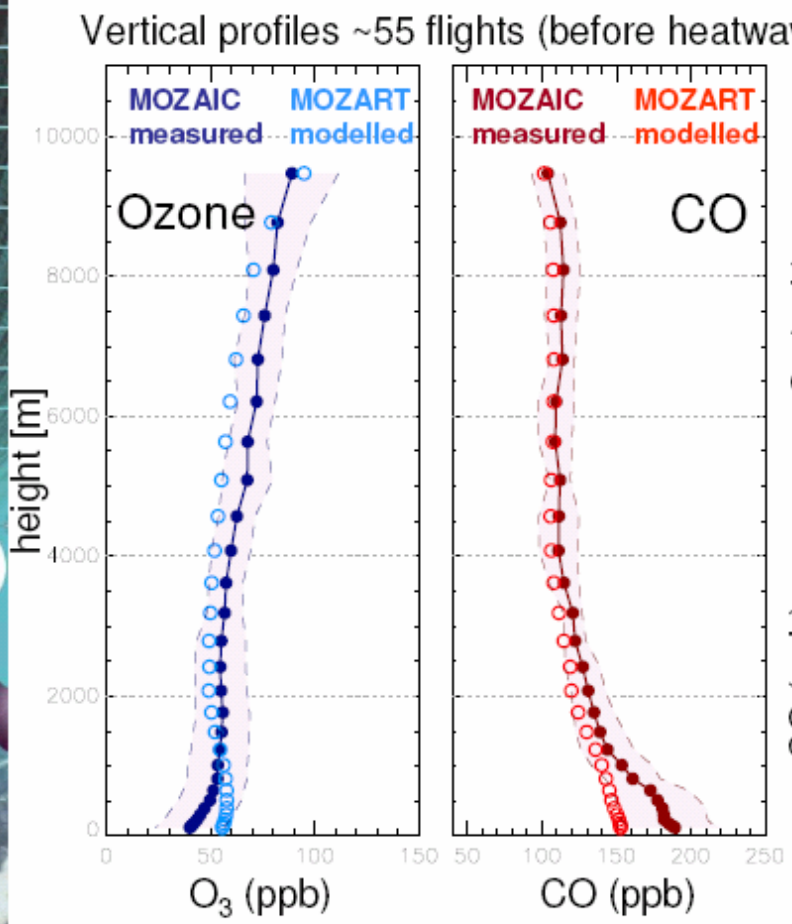
17 February 2003 12UTC 850K ozone



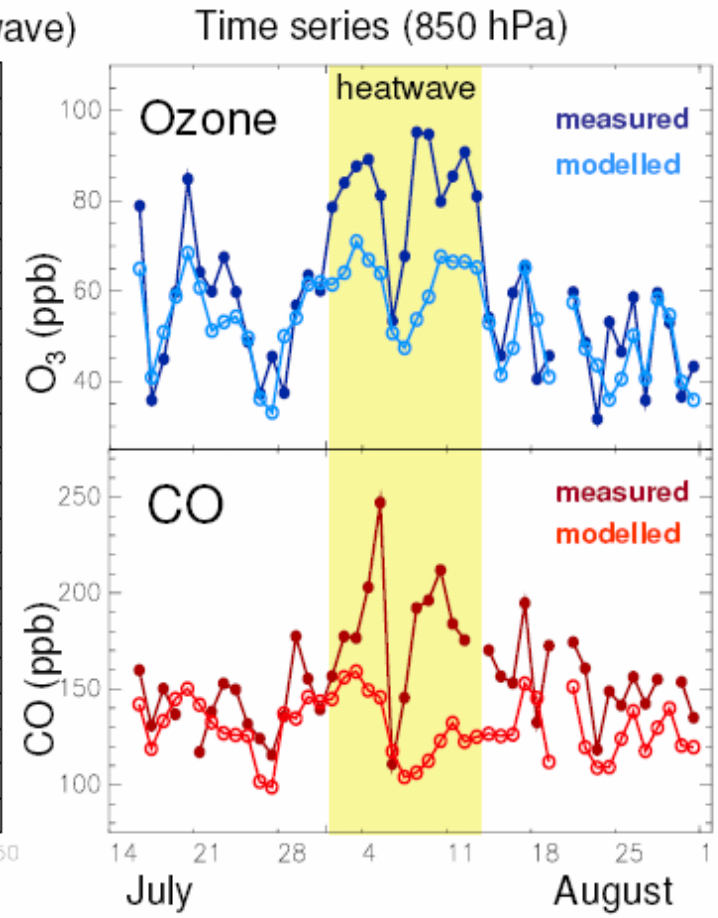
Ozone profile retrievals from both GOME and MIPAS assimilated

Model evaluation with airborne observations from MOZAIC



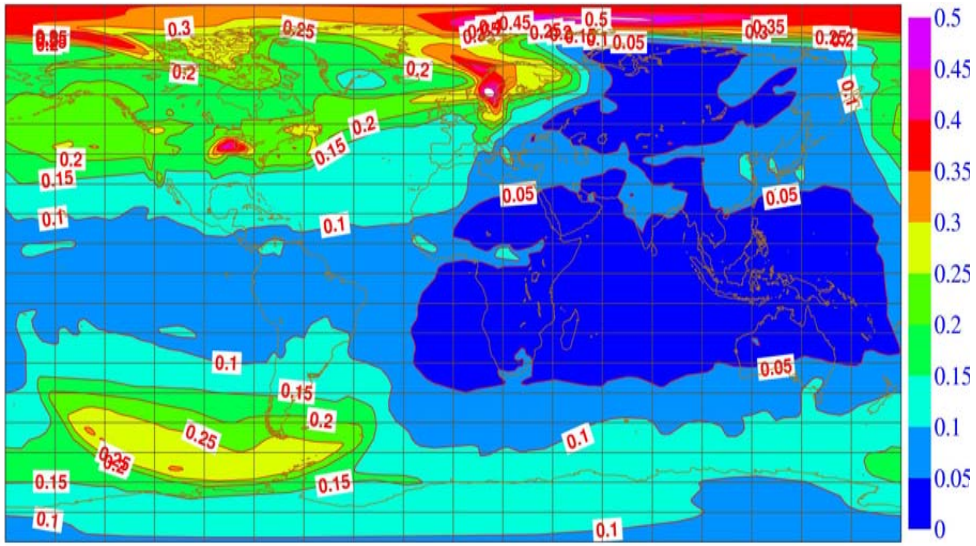


over Frankfurt, summer 2003



MOZART biased low in ground-level O3 & CO at peak of heat-wave

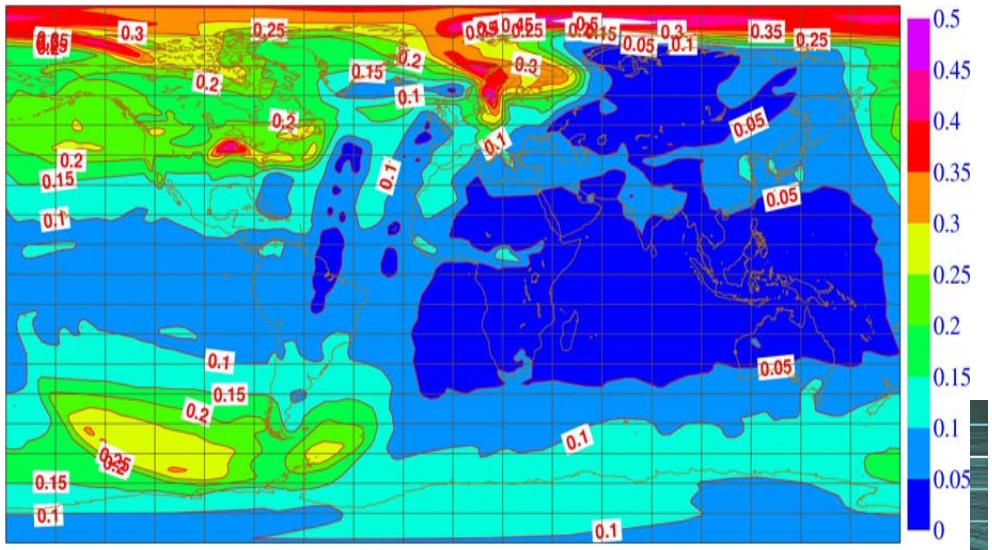
Assimilation of total column NO_2 from SCIAMACHY



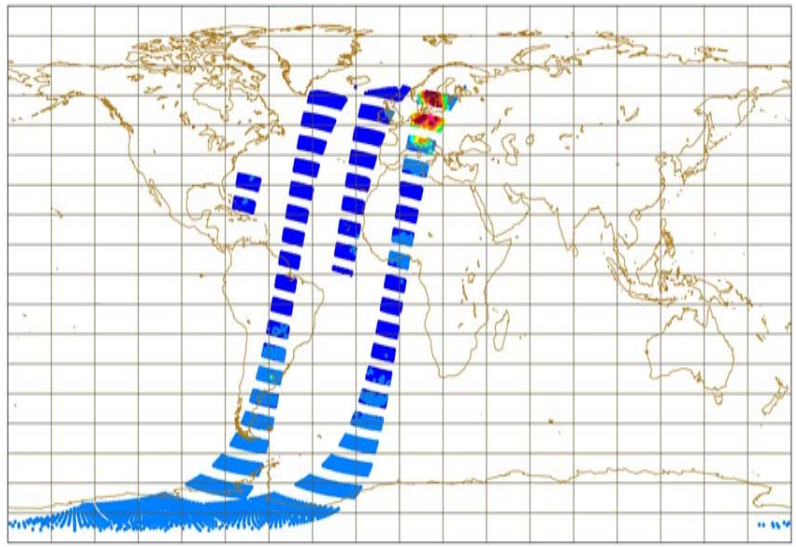
Background field (with no tendencies applied in IFS, and initial data from CTM)

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

Analysis



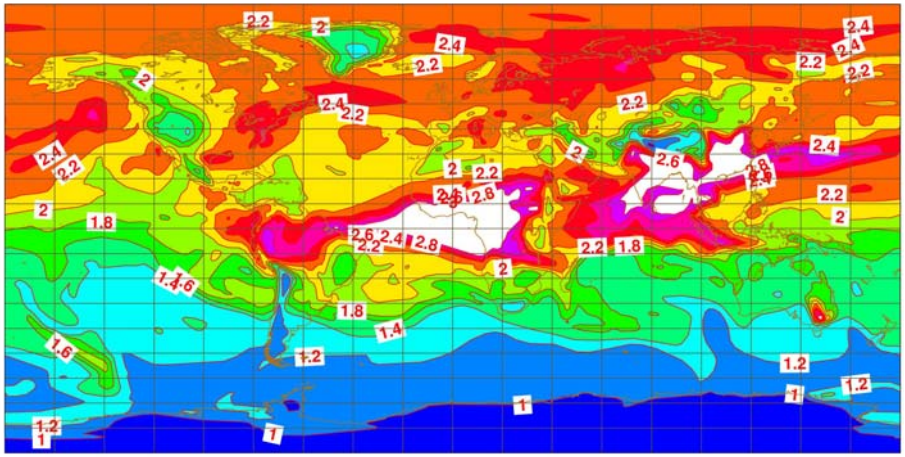
Active observations



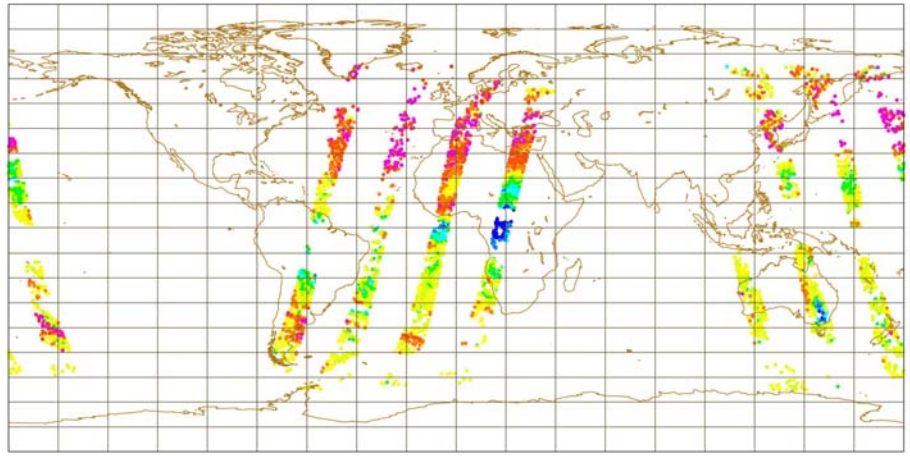
Assimilation of total column CO from MOPITT

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

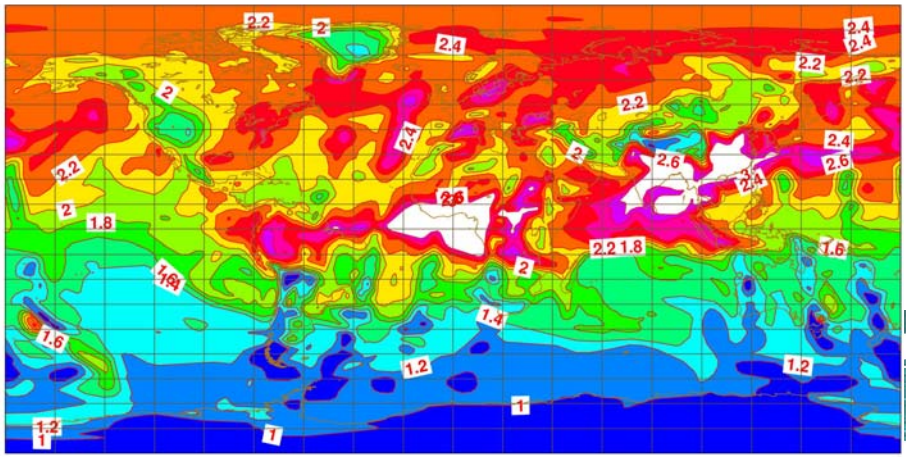
Background (no tendencies)



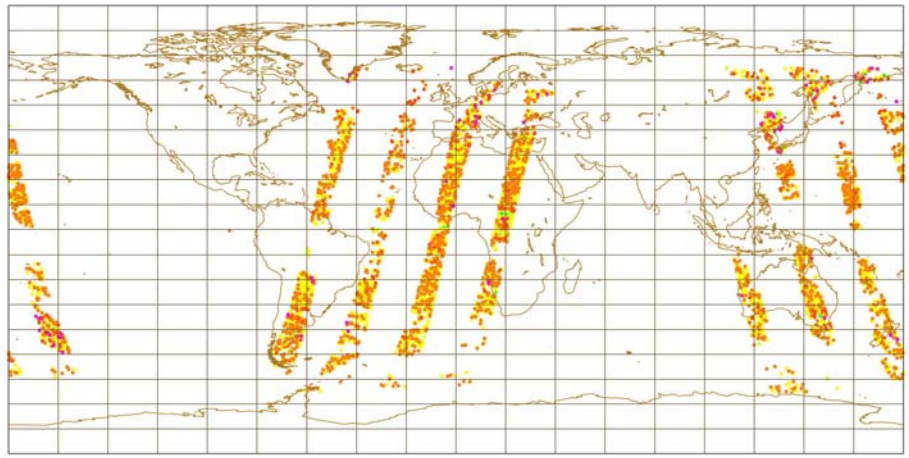
Background departures (active data)



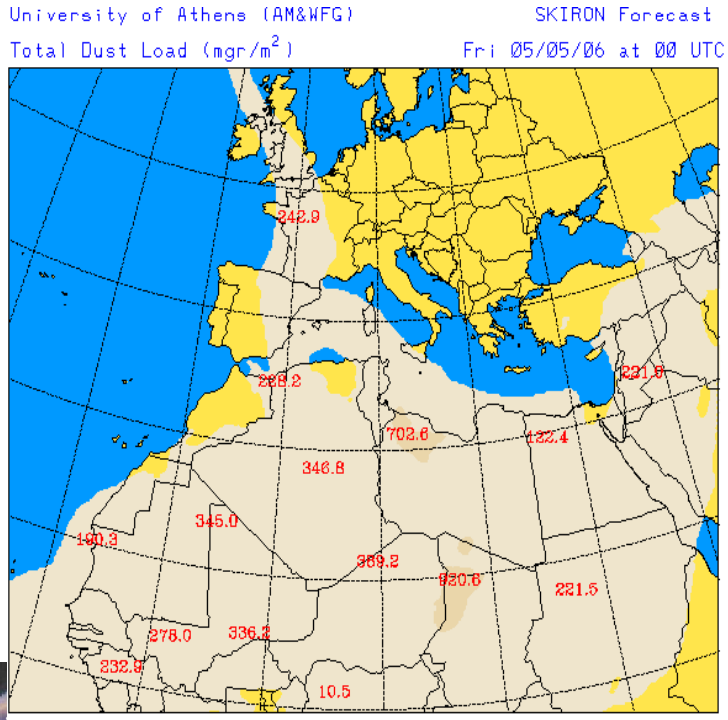
Analysis

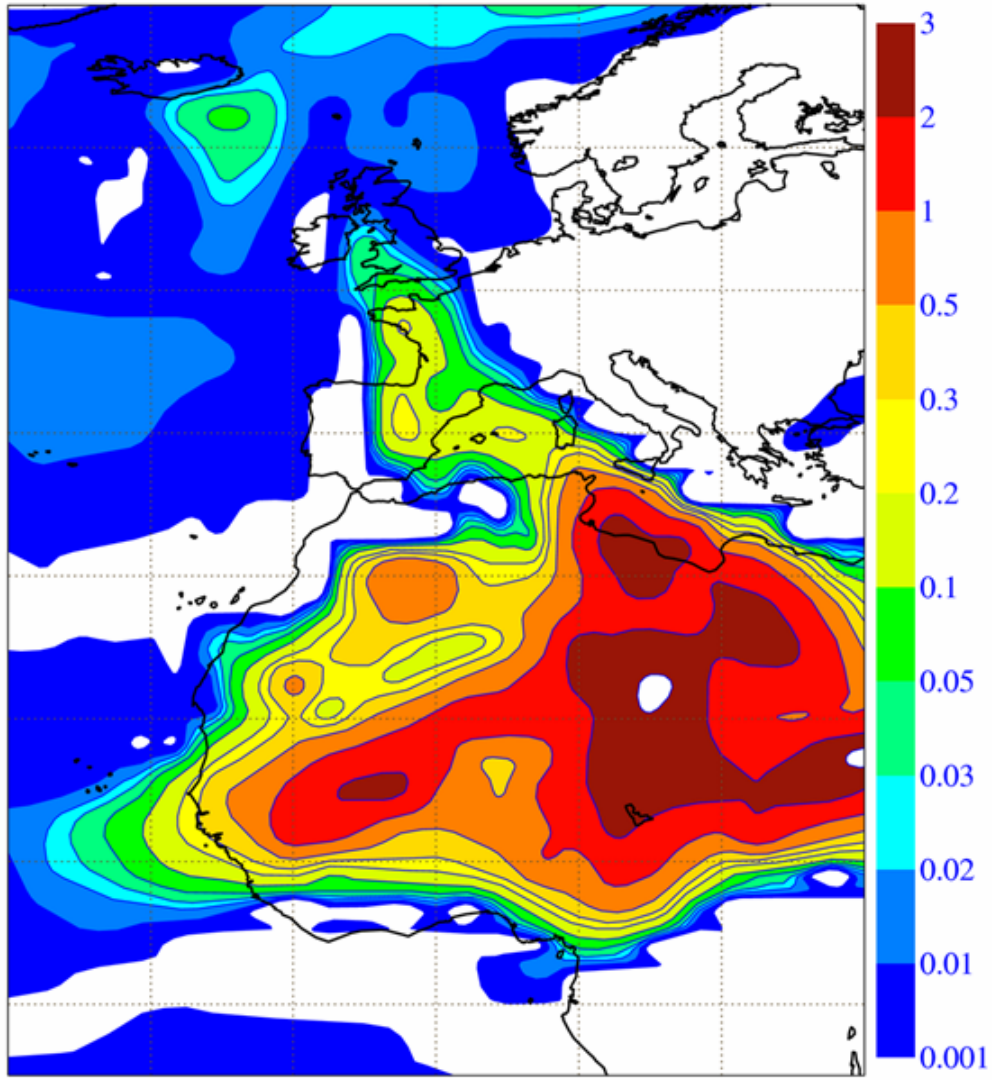


Analysis departures (active data)



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



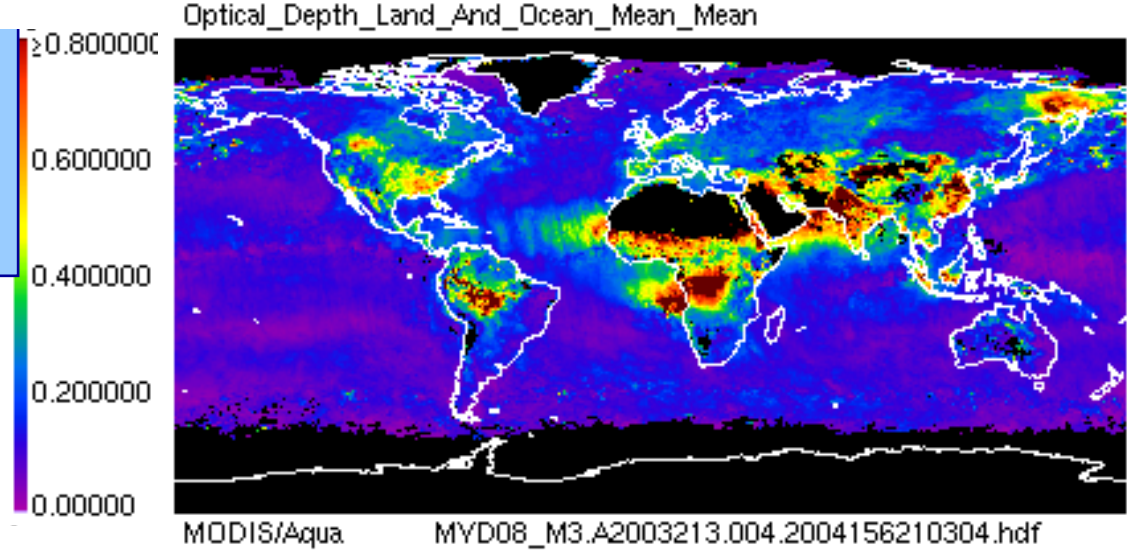


Aerosol optical depth at 0.55 micron

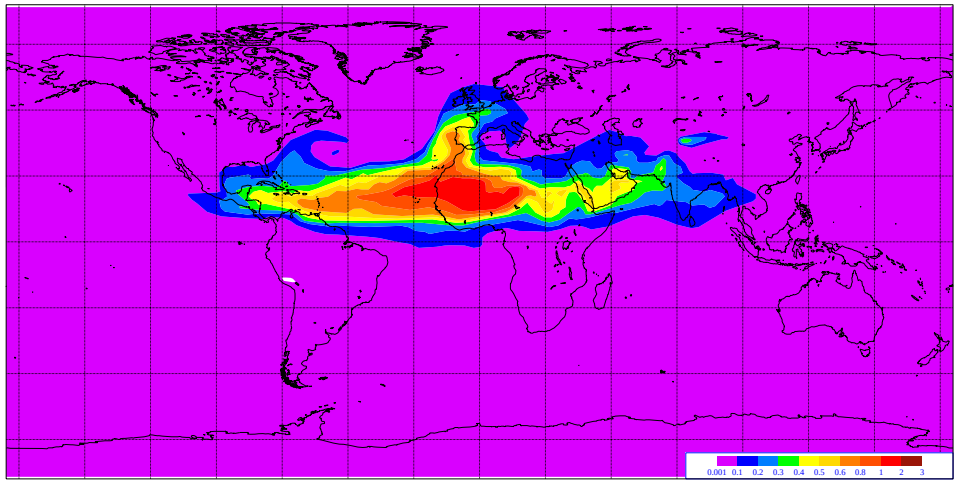
00UTC 5 May 2006

GEMS

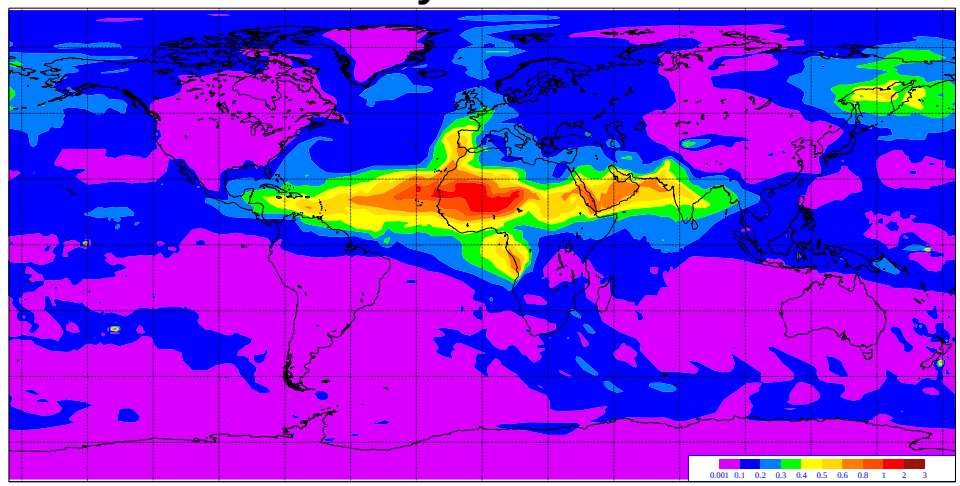
Comparison of aerosol optical depth with MODIS observations

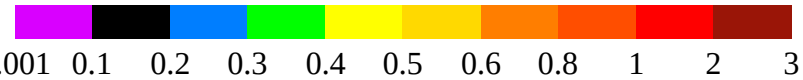


Forecast run



Analysis run

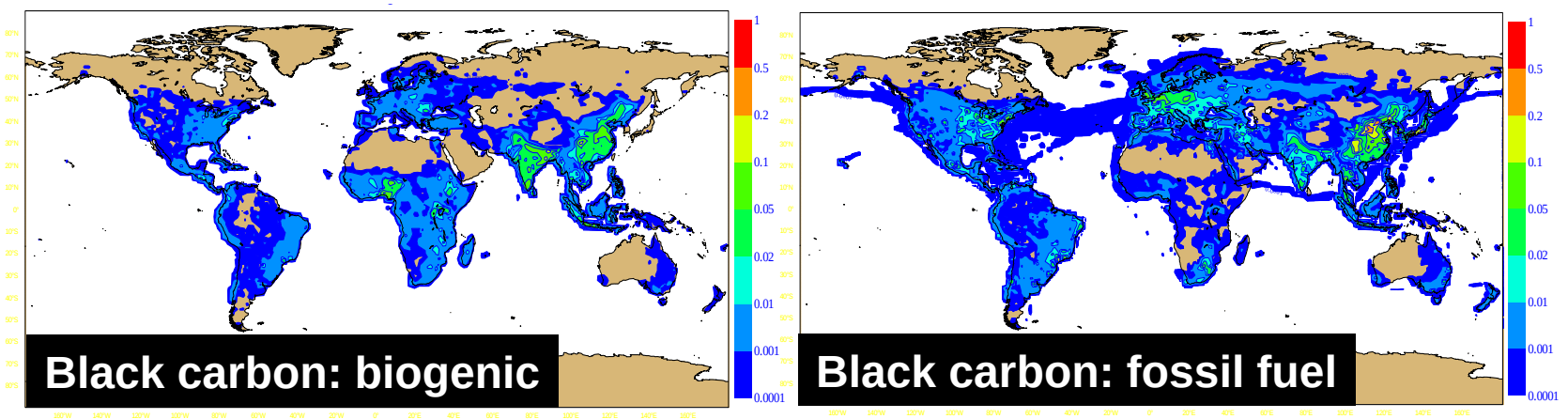




Mean fields 1-15 August 2003

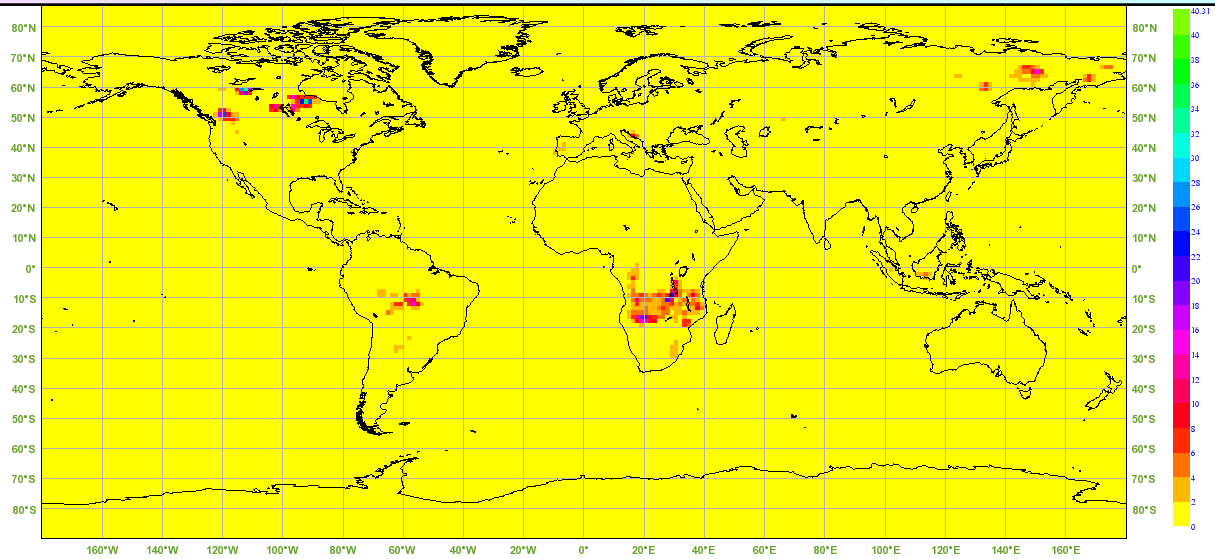
New aerosol model

- 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

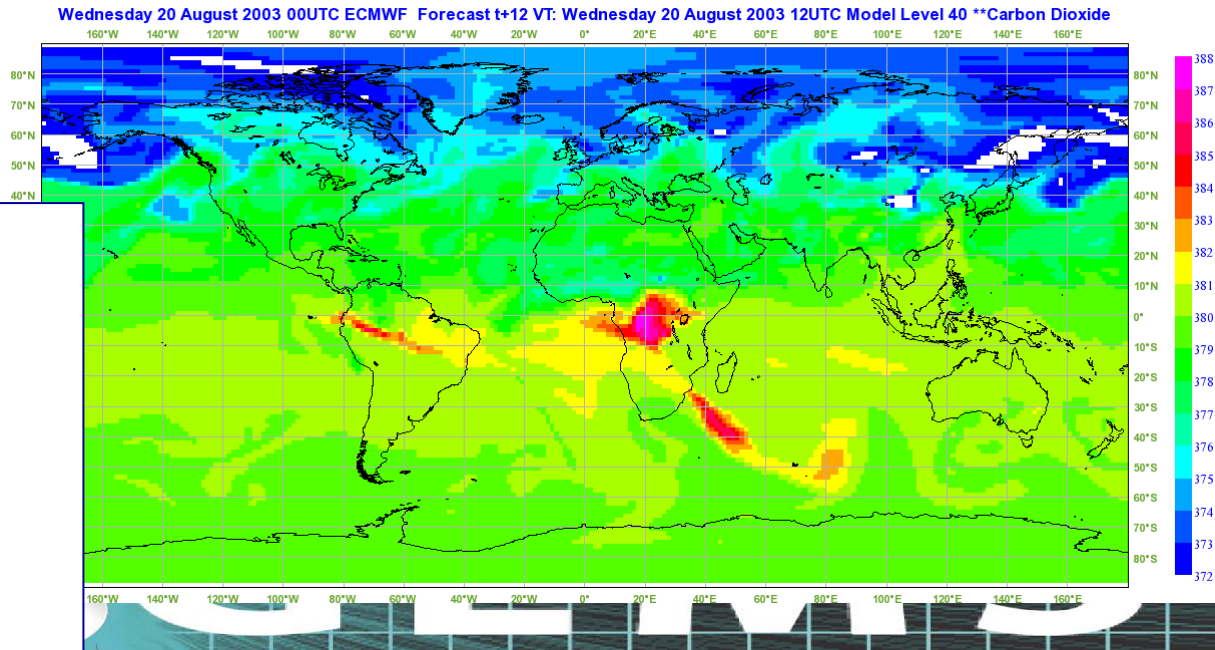


HALO Modelling of fire emissions

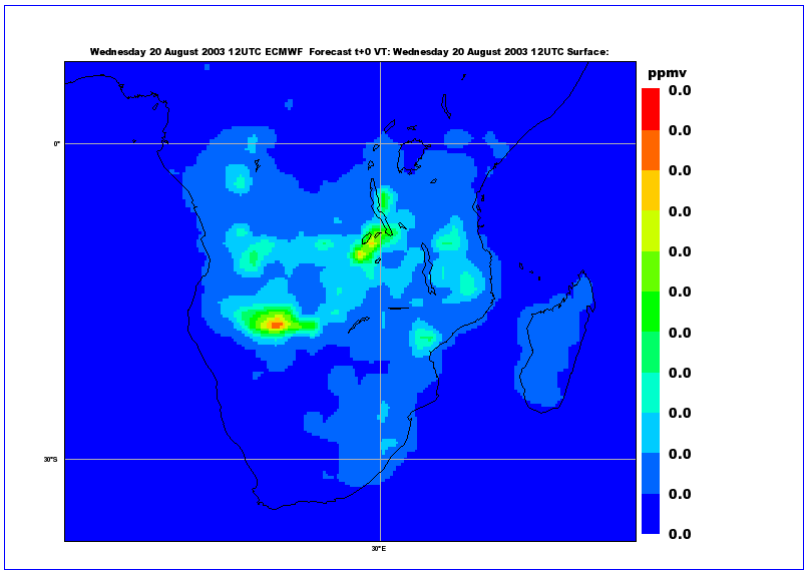
CO_2 emission from fires
[kg/m2/s]
12UTC 20 August 2003
(GFEDv3-8d)



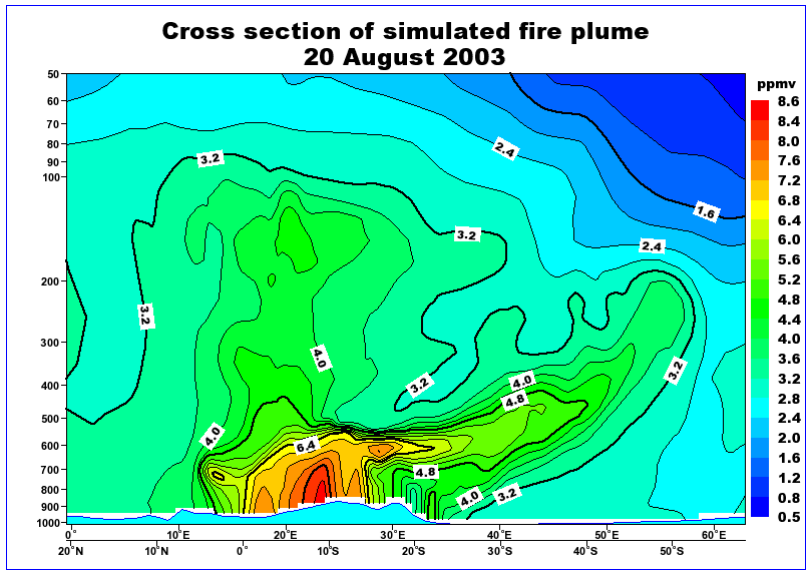
Model CO_2
12UTC 20 August 2003
500hPa

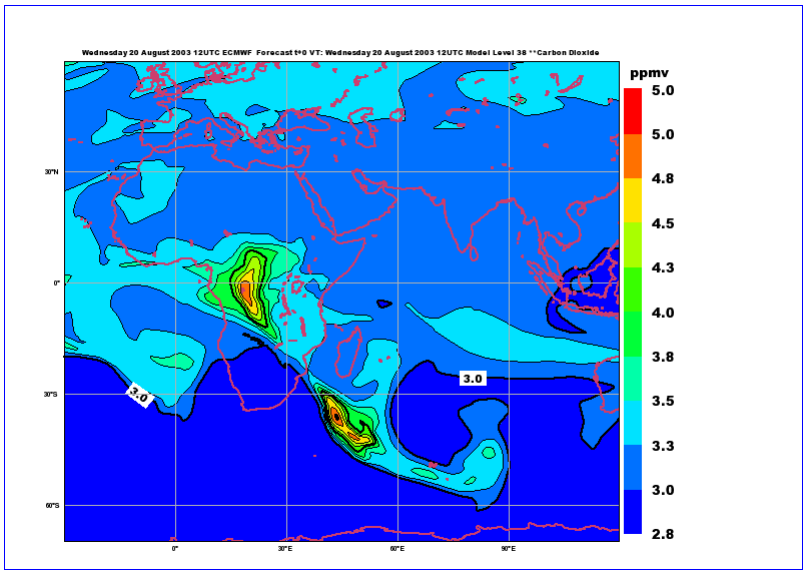


Fire emissions prescribed in model simulation

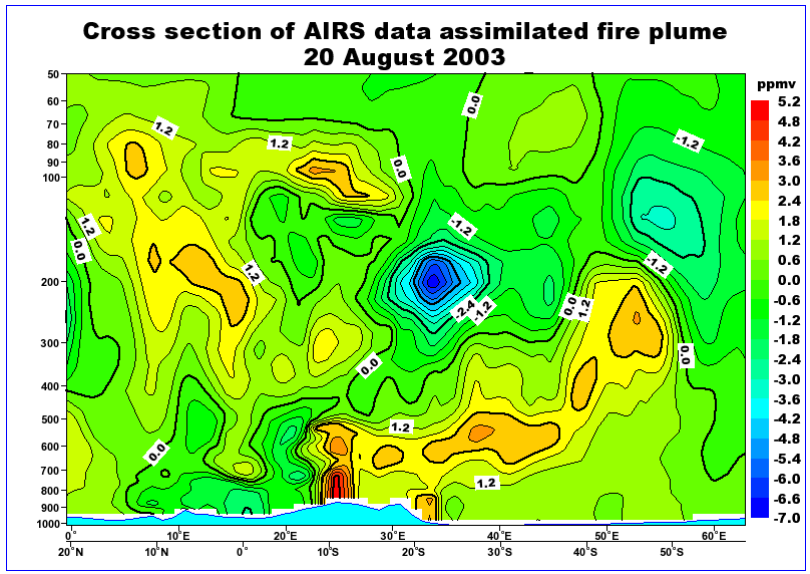


Cross-section of plume from simulation





Cross-section of AIRS data assimilated fire plume



Extent of plume from simulation

Cross-section of plume from AIRS assimilation

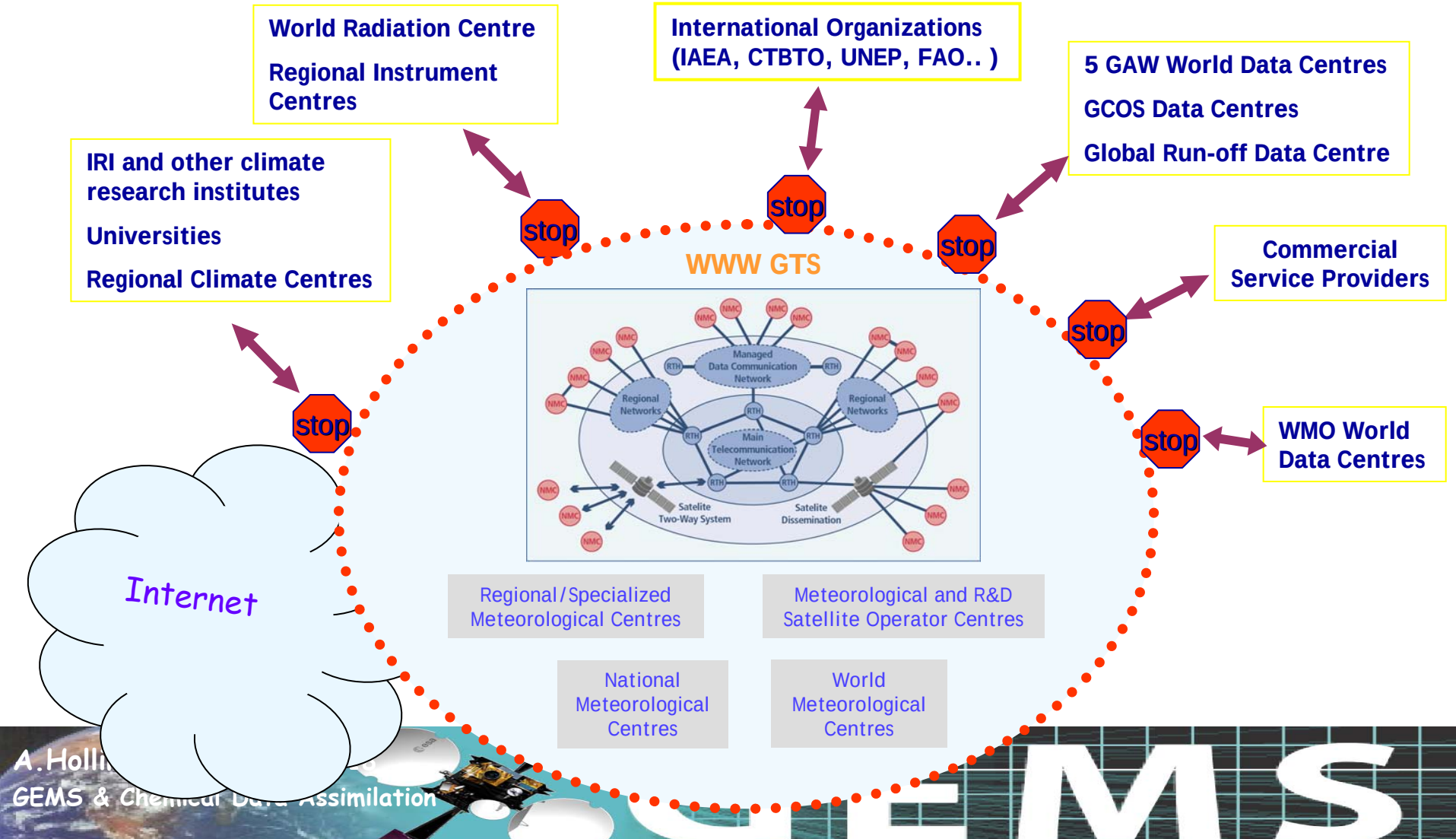
Data acquisition and coding

- 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

WMO GTS: Current situation

Information exchange – multiplicity of procedures; real-time and non-real time; push & pull

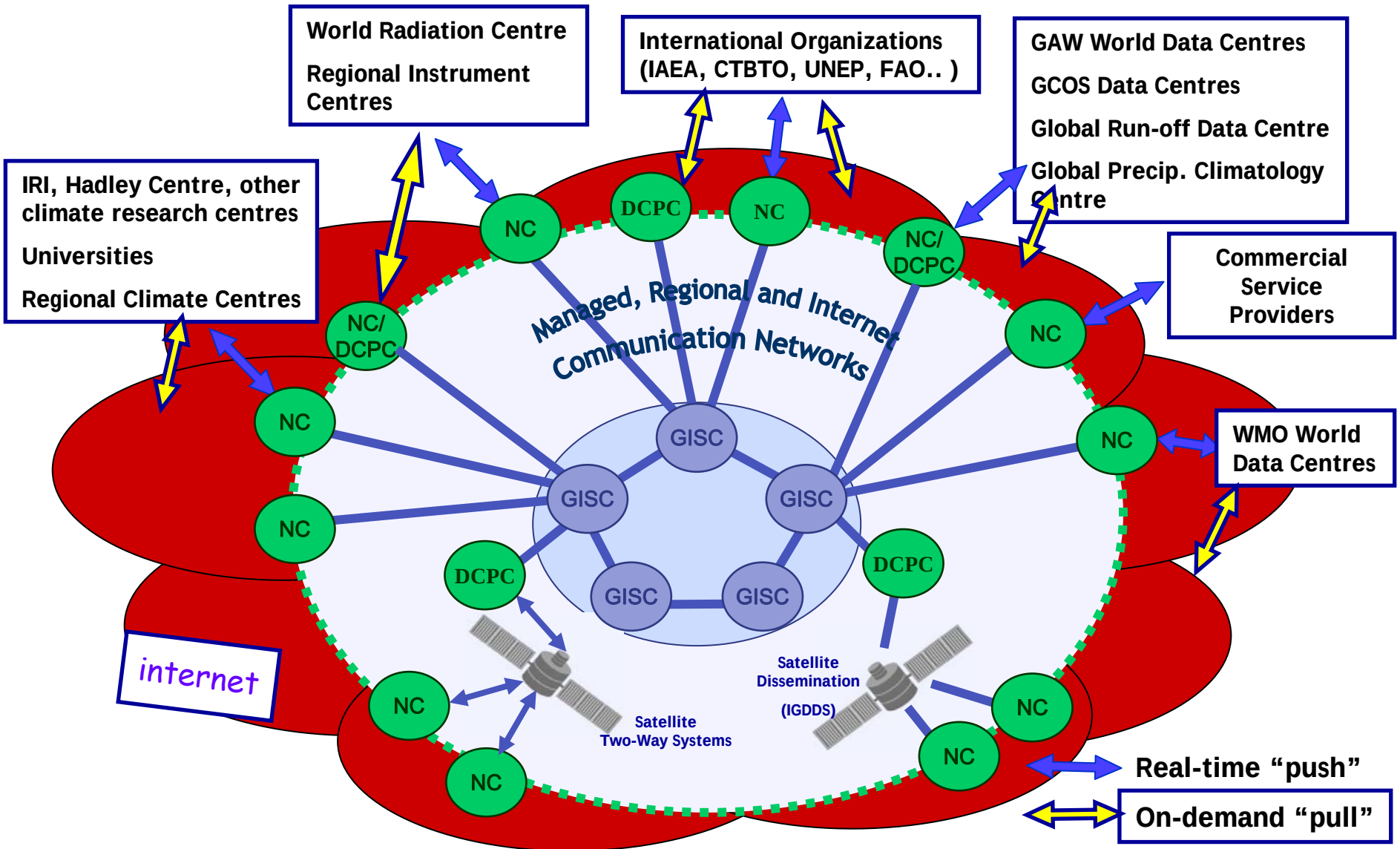
Information management – multiplicity of data formats; few/uncoordinated metadata & catalogues



WIS: WMO Information System

Information exchange – common procedures; real-time and non-real time services

Information management – few standard data formats; coordinated metadata & catalogues



END

thank you for your attention!

www.ecmwf.int/research/EU_projects/GEMS

- Access to forecast data
- A say in the non-local products
- Continuity of service to users

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

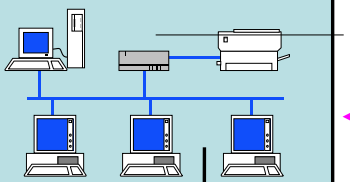
Global Core Service

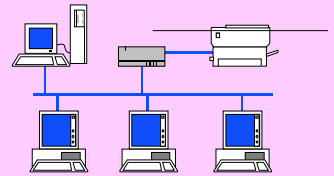
National / Regional Air Agencies

Weather Data

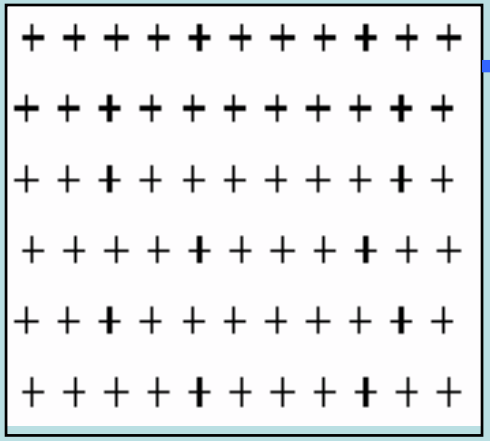
AQ Data

Emissions Inventory

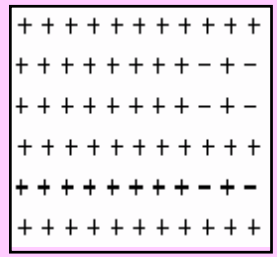




O_3 /NO_2 Data / Movies



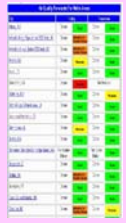
Global Forecast Pollutant Concentration Fields



Regional Forecast Pollutant Concentration Fields

Commercial Air Quality Providers

Media



Public

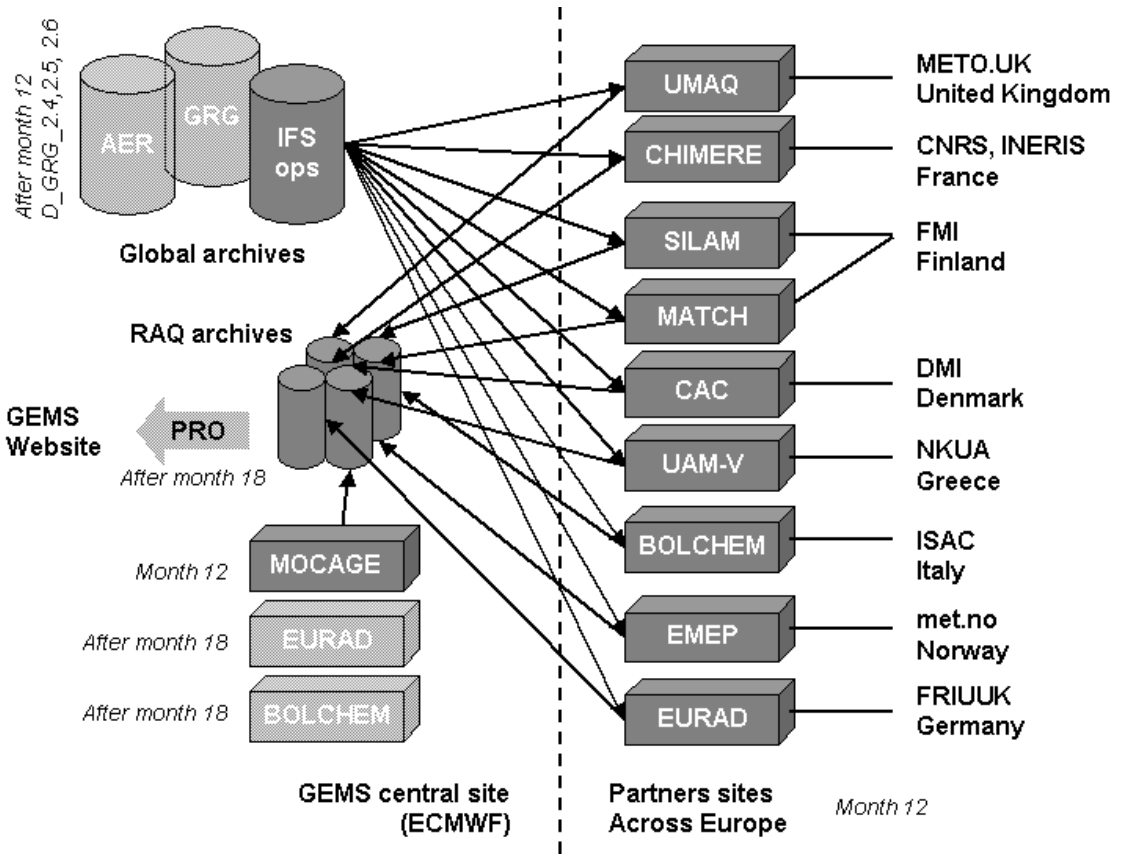
City-specific AQI forecasts

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



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…

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

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

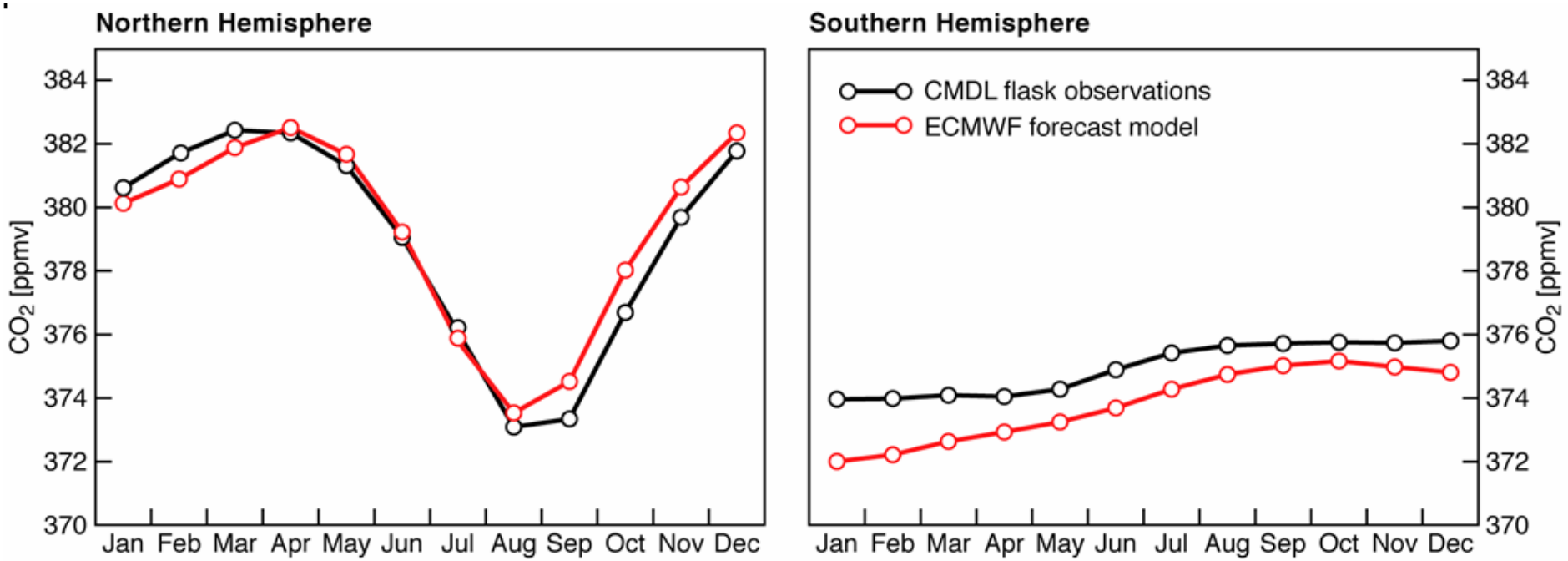
- Further development of the global assimilation systems, esp. IFS/CTM coupling & new aerosol model (4Q 2006 – 1Q 2007)
- Separate analyses of (i) CO_2, (ii) some reactive gases & (iii) aerosols for 2003/4 (4Q 2006 - 3Q 2007)
- Refinement and integration of the global assimilation system (4Q 2006 - 3Q 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)

WIS

Information exchange – common procedures; real-time and non-real time services

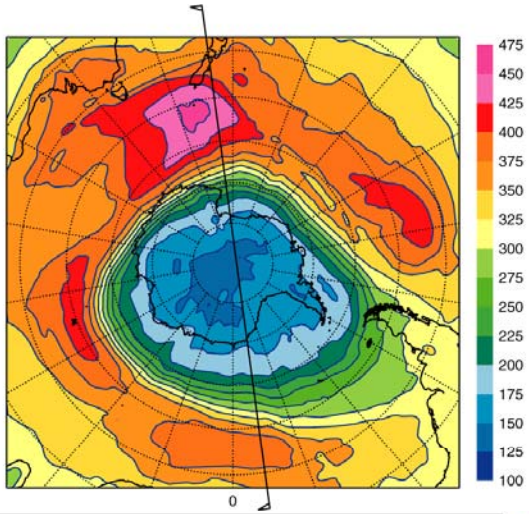
Information management – few standard data formats; coordinated metadata & catalogues

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



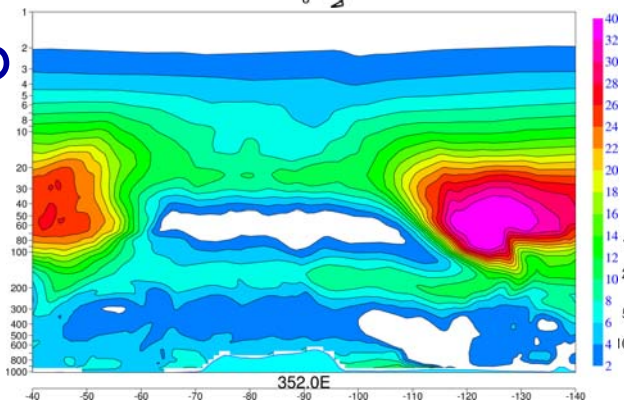
From model run with meteorological fields corrected every 12 hours and specified climatological surface fluxes of CO_2

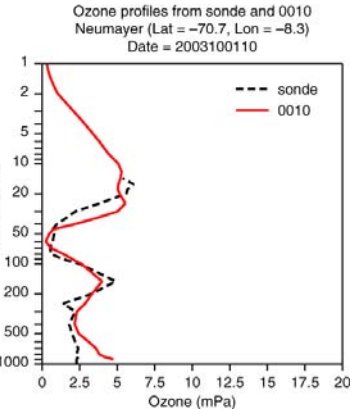
Ozone Hole 1 Oct 2003 in ECMWF assimilation



a

b





c

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