# GEMS: *Global Earth-system Monitoring using Space and in-situ data*

| | |
|---|---|
| **Coordinator** | **A.Hollingsworth (ECMWF)** |
| **Projects** | **Leadership** |
| **Greenhouse Gases** | **P.Rayner (F)** |
| **Reactive Gases** | **G.Brasseur (D)** |
| **Aerosol** | **O.Boucher (UK)** |
| **Regional Air Quality** | **V-H.Peuch (F)** |
| **Validation** | **H.Eskes (NL)** |
| **Global Production System** | **A.Simmons, H.Boettger, (ECMWF),** |

*GMES Integrated Project,*
*12.5MEuro, 30 Institutes, 14 Countries*
*www.ecmwf.int/research/EU_projects/GEMS*

# Contents of the Presentation

- The GEO / GMES context
- Motivations & Objectives
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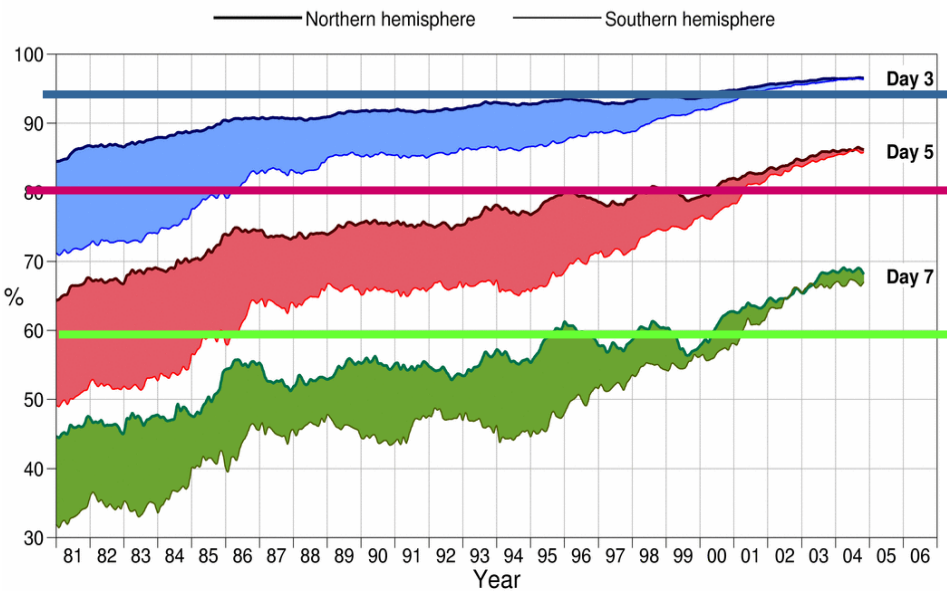
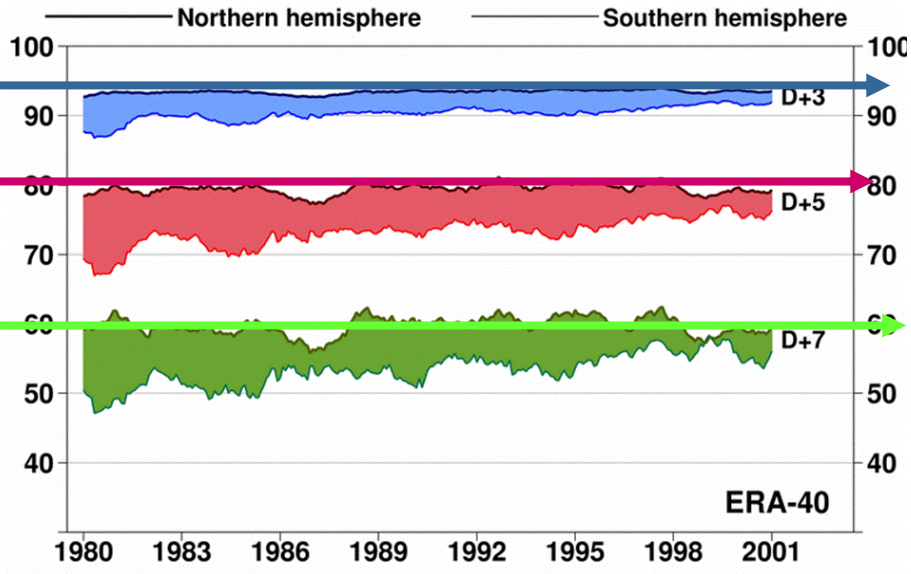
- A flying start
- Issues for the transition to operations in 2009

# The interaction of observations & science & the skill of forecast deliverables :a virtuous circle!

- Observations are essential to the forecast process
- Gains in forecast skill came mainly from the science
- Operations shows steady improvement – a virtuous circle



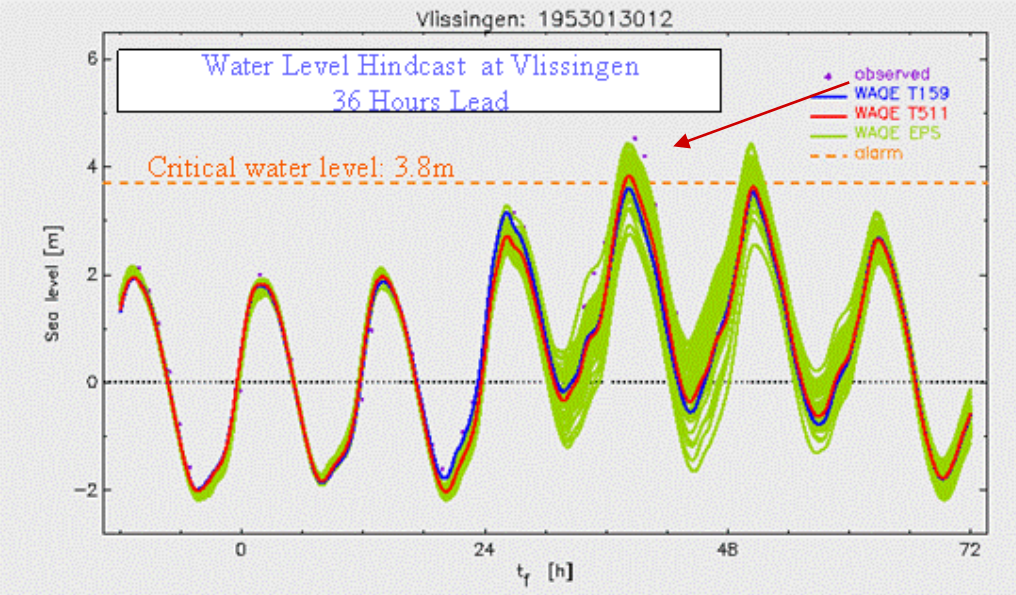



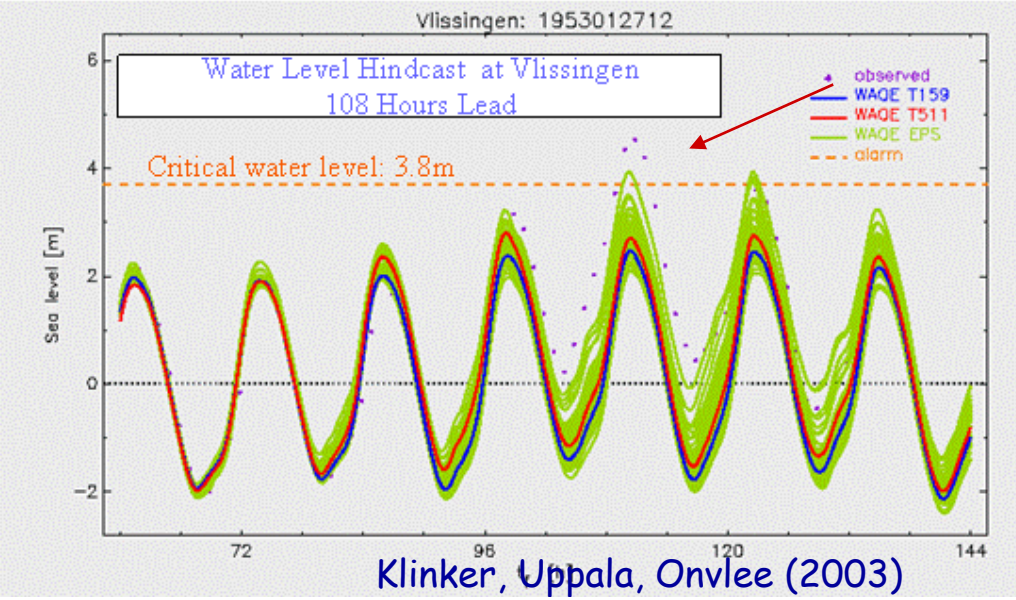

- Operational forecasts
- 1981-2005
- Evolving forecast system

- ERA-40 re-forecasts
- 1980-2002
- Uniform forecast system

# Operational storm-surge forecasts in the North Sea

- Coupled Earth_system / storm-surge model is operational in the Netherlands
- Example: Ensemble storm surge re-forecasts for the disaster in Netherlands, 1 Feb 1953, 2000 deaths, no warnings
- Similar re-forecast studies are underway for other European disasters



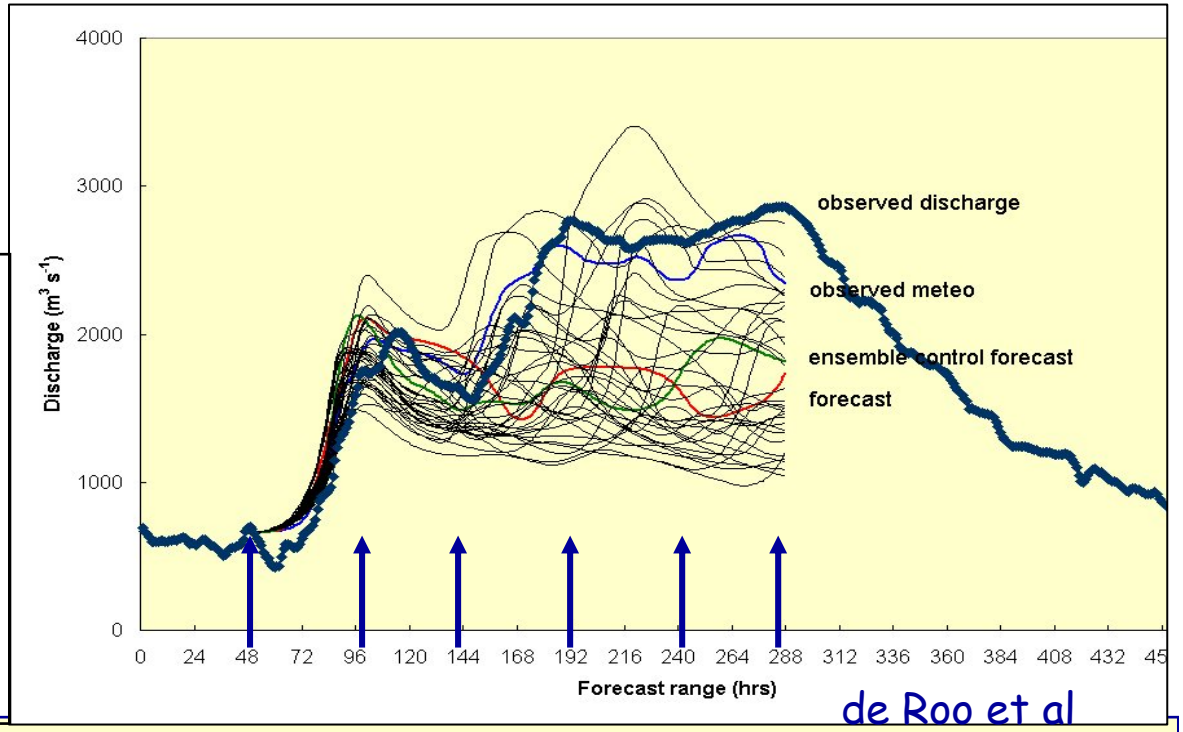




Klinker, Uppala, Onvlee (2003)

# Pre-operational European Flood Alert System

- Distributed hydrological model (LISFLOODcoupled to Earth-system models (ECMWF, DWD)
- Provides medium-range flood alerts (beyond 3 days) for large trans-national basins
- Pre-operational test  period 2003-2006
- Doing well on current floods in Central Europe

The example shows
10-day ensemble forecasts
with coupled model
(ECMWF/ LISFLOOD)
for Meuse flood,
Jan 1995



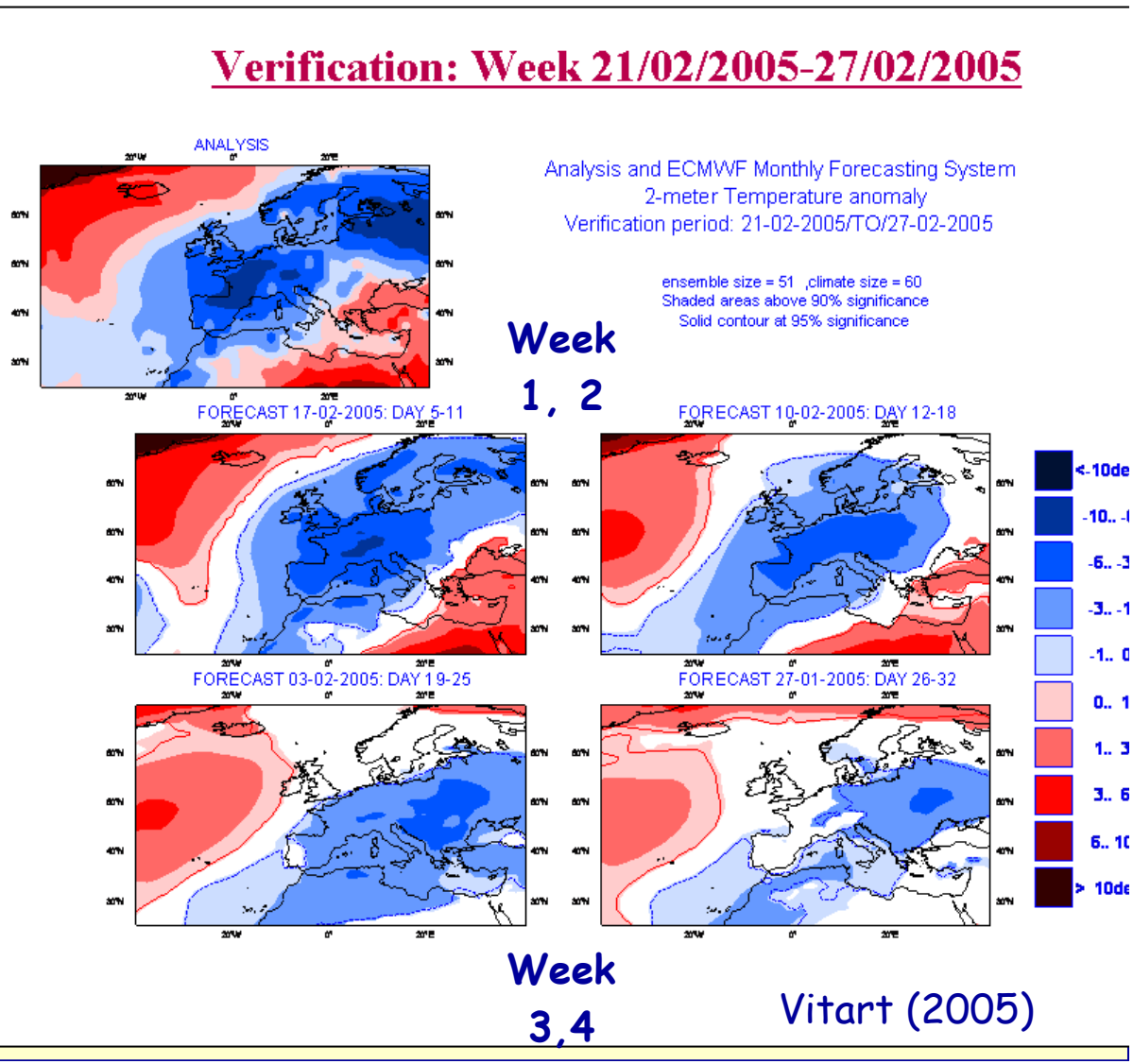

de Roo et al

# Good user-response to new operational weekly-to-monthly forecasts with coupled atmosphere-land-ocean model

- During winter 2004-5 the system provided good predictions of transition between flow regimes;
- The forecasts for weekly-mean two-metre temperature (T2m) for week-2 (days 12-18) show skill over persistence of the probabilities of the previous week
- Meteo France finds moderate skill in T2m forecasts for week-3 over France;

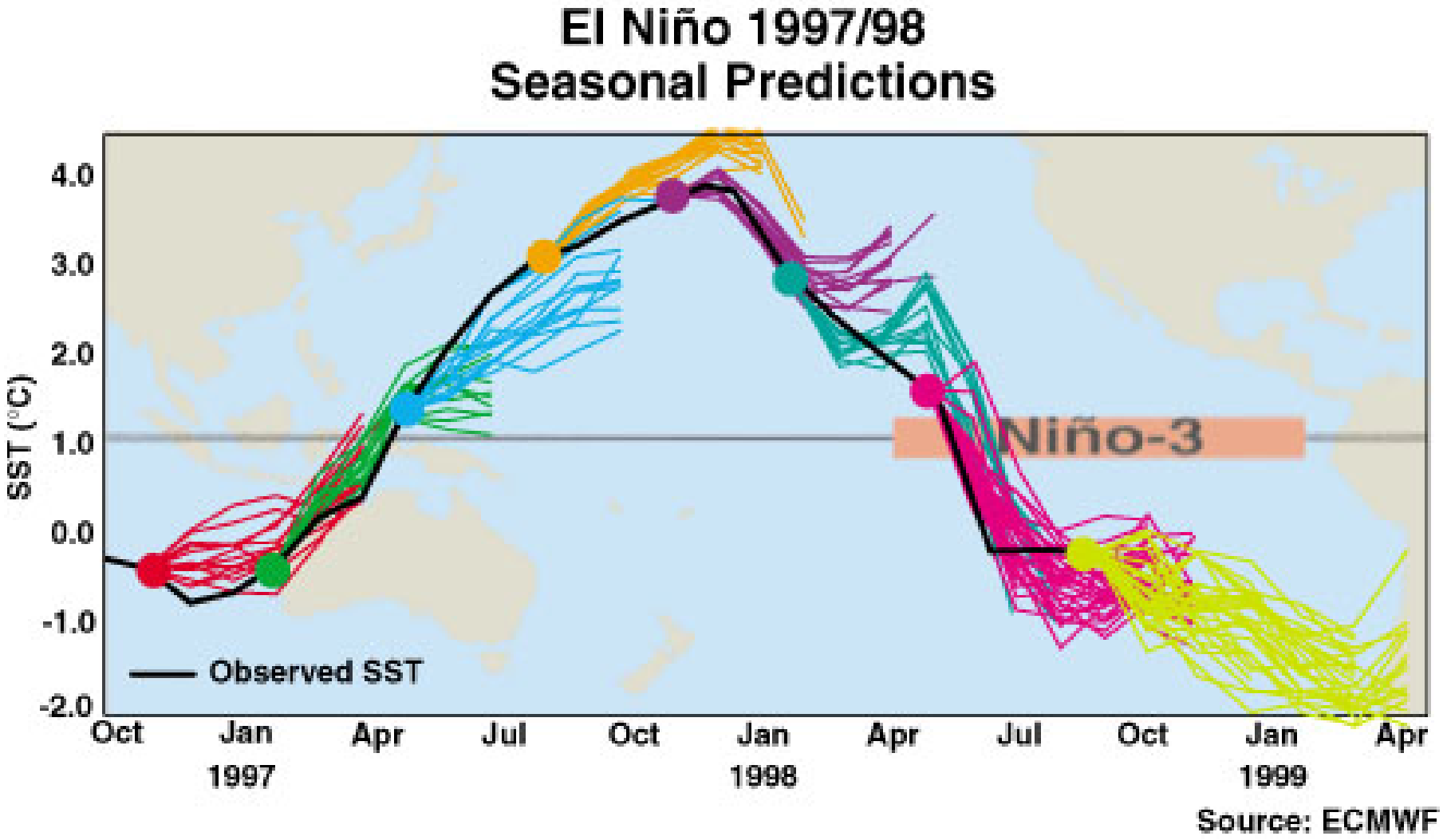
Forecasts are made on Thursday, processed & distributed on Friday

- Week 1 is day 5-11 (Monday to Sunday) from 17 Feb
- Week 2 is day 12-18 (Monday to Sunday) from 10 Feb
- Week 3 is day 19-25 (Monday to Sunday) from 3 Feb
- Week 4 is day 26-32 (Monday to Sunday) from 27 Jan



# El Nino Forecasts with coupled models for Atmosphere /Ocean-Wave / Ocean circulation

(fig. Courtesy of CLIVAR)

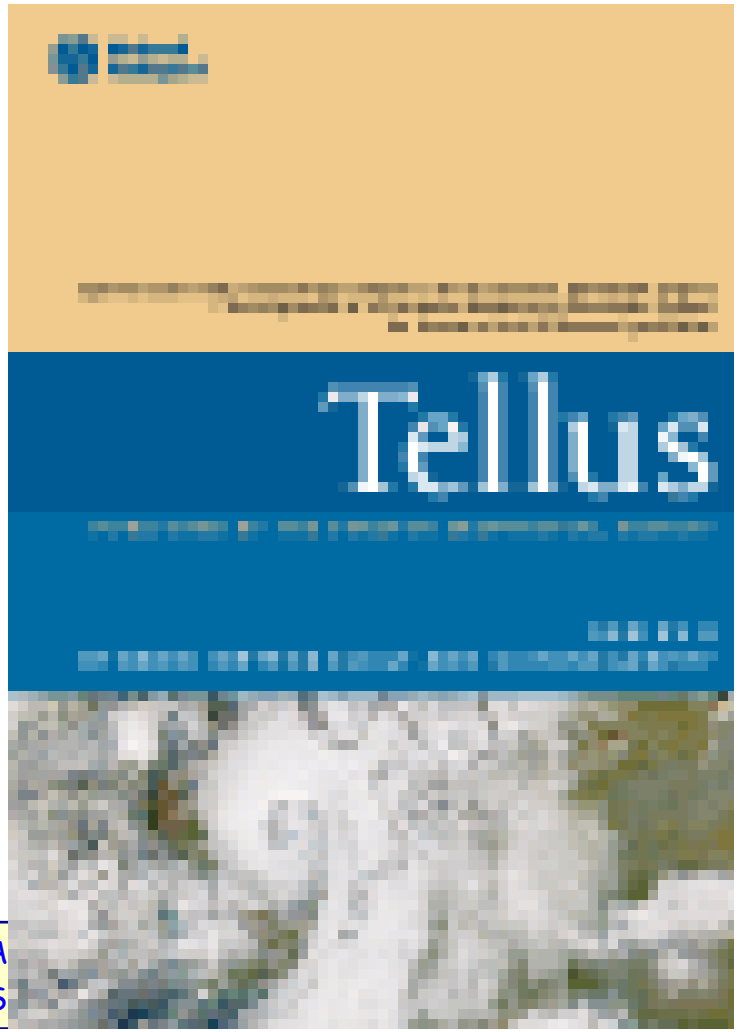


# New European operational multi-model multi-seasonal forecast system ECMWF, Meteo-France, UK Met-Office

DEMETER project demonstrated

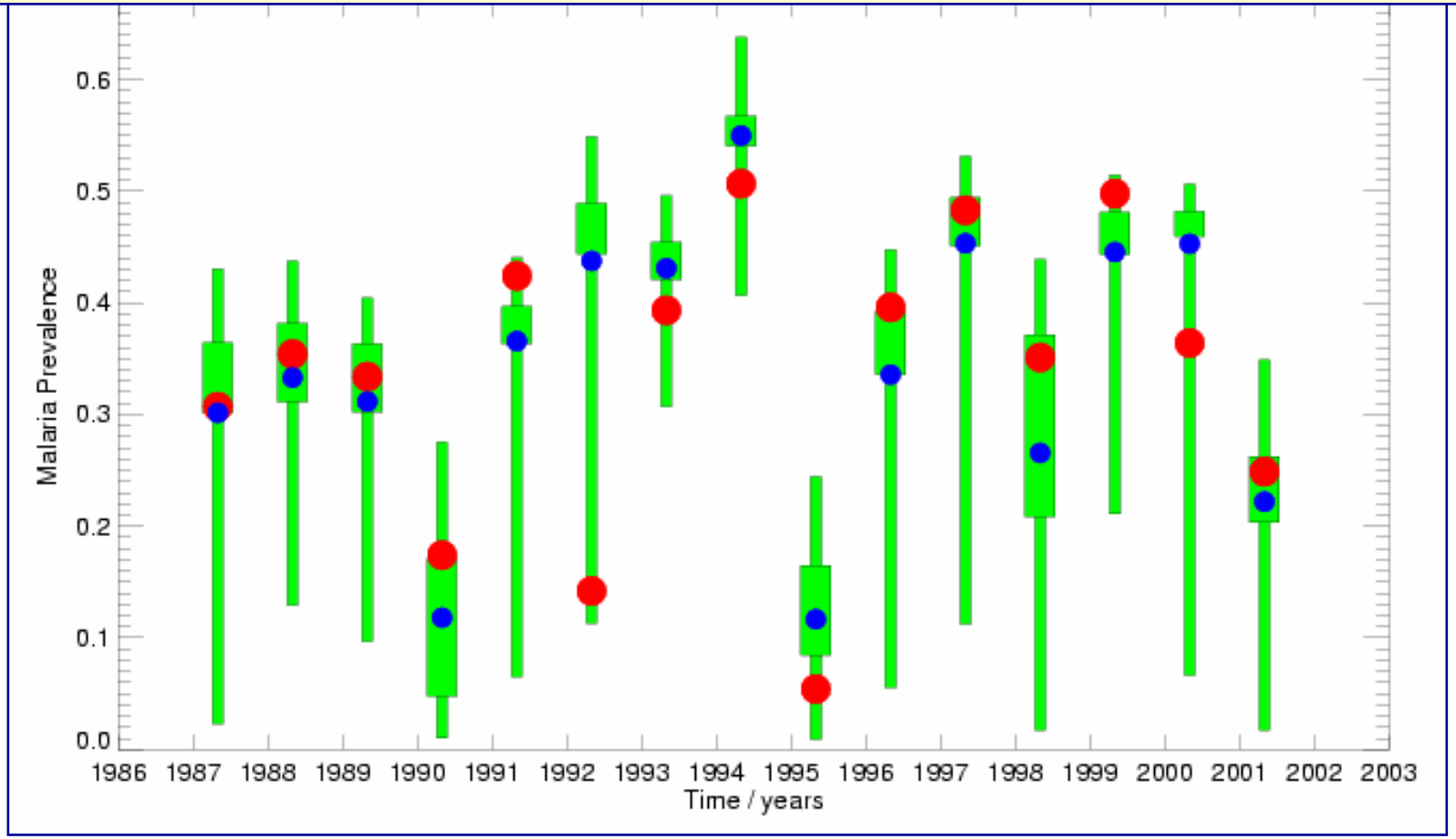
- value of multi-model system
- pre-operational multi-seasonal crop-yield forecast system (at EU's Joint Research Centre
- multi-seasonal crop yield forecasts in India
- Prototype multi-seasonal malaria forecast system in parts of Africa

ECMWF, Meteo-France, UK Met-Office will launch a new multi-model seasonal forecast system in late 2005



# DEMETER ensemble seasonal forecasts of malaria prevalence in Botswana, 1987-2001, with coupled Earth-system / health models (Morse et all Tellus 2005)

Legend: Verification DEMETER-MM: Ensemble-mean Terciles




Time series for grid point in South Africa (17.5 S, 25.0 E)

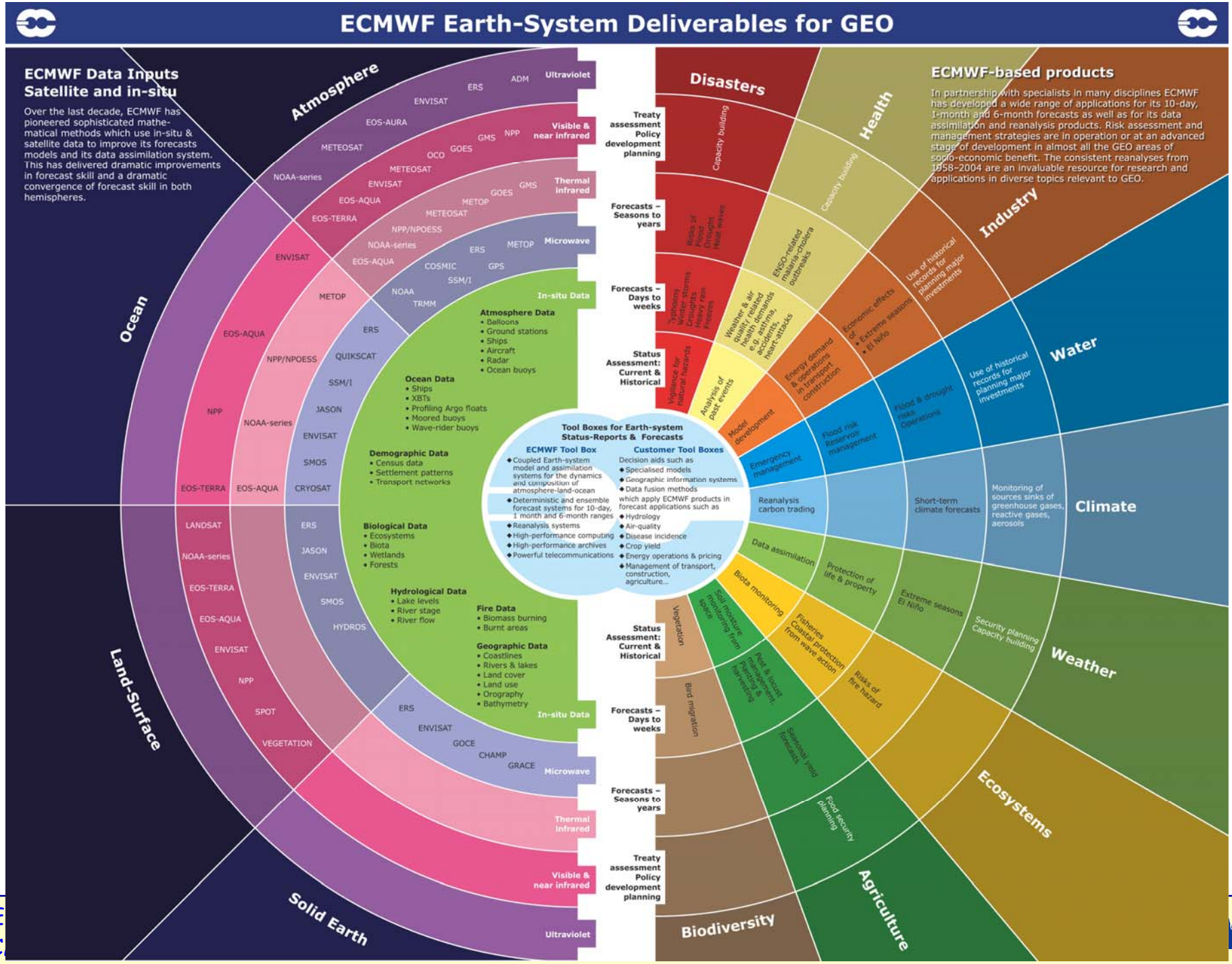
# The supply-chain for end-user predictions delivering socio-economic benefits

Observations

Global Earth-system forecast systems for Atmosphere, Land , Ocean, Chemistry, Biosphere -delivering deterministic and probabilistic forecasts

Coupled end-user models, delivering deterministic and probabilistic forecasts for

- storm-surge,
- hydrology,
- energy industry,
- health,
- crop-yields


ECMWF Earth-System Deliverables for GEO
ECMWF Data Inputs Satellite and in-situ
Over the last decade, ECMWF has pioneered sophisticated mathematical methods which use in-situ & satellite data to improve its forecasts models and its data assimilation system. This has delivered dramatic improvements in forecast skill and a dramatic convergence of forecast skill in both hemispheres.
ECMWF-based products
In partnership with specialists in many disciplines ECMWF has developed a wide range of applications for its 10-day, 1-month and 6-month forecasts as well as for its data assimilation and reanalysis products. Risk assessment and management strategies are in operation or at an advanced stage of development in almost all the GEO areas of socio-economic benefit. The consistent reanalyses from 1958–2004 are an invaluable resource for research and applications in diverse topics relevant to GEO.
Atmosphere
Ocean
Land-Surface
Solid Earth
Ultraviolet
Visible & near infrared
Thermal infrared
Microwave
In-situ Data
Treaty assessment Policy development planning
Forecasts – Seasons to years
Forecasts – Days to weeks
Status Assessment: Current & Historical
Tool Boxes for Earth-system Status-Reports & Forecasts
ECMWF Tool Box
Coupled Earth-system model and assimilation systems for the dynamics and composition of atmosphere-land-ocean
Deterministic and ensemble forecast systems for 10-day, 1 month and 6-month ranges
Reanalysis systems
High-performance computing
High-performance archives
Powerful telecommunications
Customer Tool Boxes
Decision aids such as
Specialised models
Geographic information systems
Data fusion methods
which apply ECMWF products in forecast applications such as
Hydrology
Air-quality
Disease incidence
Crop yield
Energy operations & pricing
Management of transport, construction, agriculture...
Atmosphere Data
Balloons
Ground stations
Ships
Aircraft
Radar
Ocean buoys
Ocean Data
Ships
XBTs
Profiling Argo floats
Moored buoys
Wave-rider buoys
Demographic Data
Census data
Settlement patterns
Transport networks
Biological Data
Ecosystems
Biota
Wetlands
Forests
Hydrological Data
Lake levels
River stage
River flow
Fire Data
Biomass burning
Burnt areas
Geographic Data
Coastlines
Rivers & lakes
Land cover
Land use
Orography
Bathymetry
Disasters
Health
Industry
Water
Climate
Weather
Ecosystems
Agriculture
Biodiversity
Capacity building
Risks of Flood Drought Heat wave
Typhoon Winter storms Drought Heavy rain Freeze
Vigilance for natural hazards
Analysis of past events
Model development
Emergency management
Flood risk Reservoir management
Flood & drought risks Operations
Use of historical records for planning major investments
ENSO-related malaria/cholera outbreaks
Weather & air quality related health demands e.g. asthma, accidents, heart-attacks
Energy demand & operations in transport construction
Economic effects of: • Extreme seasons • El Niño
Use of historical records for planning major investments
Reanalysis carbon trading
Short-term climate forecasts
Monitoring of sources sinks of greenhouse gases, reactive gases, aerosols
Data assimilation
Protection of life & property
Extreme seasons El Niño
Security planning Capacity building
Biota monitoring
Soil moisture monitoring from space
Fisheries Coastal protection from wave action
Risks of fire hazard
Vegetation
Bird migration
Pest & locust management, planting & harvesting
Seasonal yield forecasts
Food security planning
ADM
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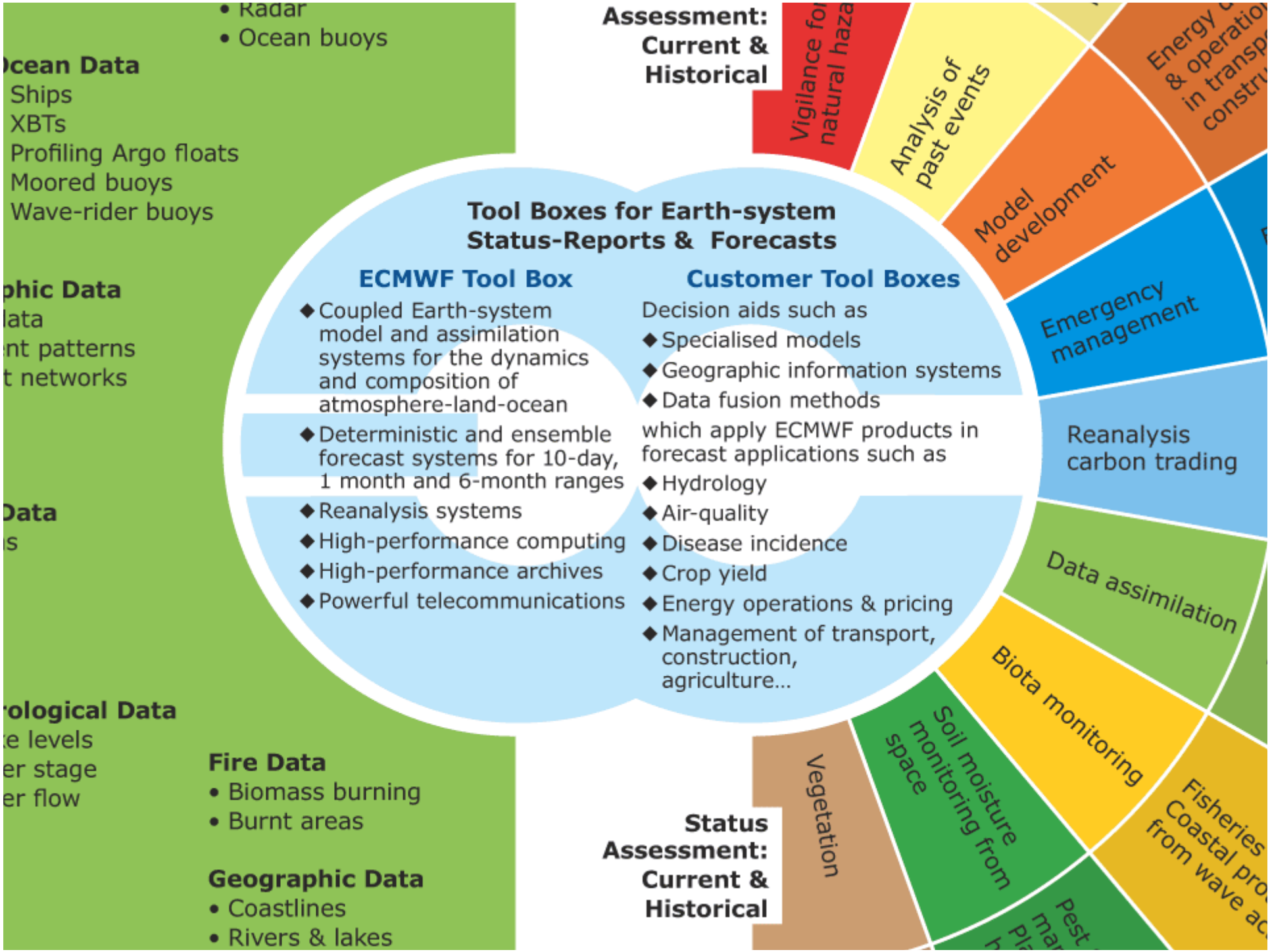
ENVISAT
EOS-AURA
METEOSAT
GMS
NPP
OCO
GOES
NOAA-series
METOP
EOS-AQUA
EOS-TERRA
NPP/NPOESS
COSMIC
GPS
SSM/I
NOAA
TRMM
QUIKSCAT
JASON
SMOS
CRYOSAT
LANDSAT
SPOT
VEGETATION
HYDROS
GOCE
CHAMP
GRACE


• Radar
• Ocean buoys
Ocean Data
Ships
XBTs
Profiling Argo floats
Moored buoys
Wave-rider buoys
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er flow
Fire Data
• Biomass burning
• Burnt areas
Geographic Data
• Coastlines
• Rivers & lakes
Assessment: Current & Historical
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Analysis of past events
Model development
Energy & operatio in transp constru
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Fisheries Coastal pro from wave ac
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Customer Tool Boxes
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◆ Specialised models
◆ Geographic information systems
◆ Data fusion methods
which apply ECMWF products in forecast applications such as
◆ Hydrology
◆ Air-quality
◆ Disease incidence
◆ Crop yield
◆ Energy operations & pricing
◆ Management of transport, construction, agriculture...

# Amended ECMWF Convention: CONVINCED that such a centre can make valuable contributions to developing the scientific basis for environmental monitoring…

**Article 2 - The purposes, objectives and activities**

1. The primary purposes of the Centre are the development of a capability for medium-range weather forecasting and the provision of medium-range weather forecasts to the Member States.

2. The objectives of the Centre shall be:

a) to develop, and operate on a regular basis, global models and data-assimilation systems for the dynamics, thermodynamics and composition of the Earth's fluid envelope and interacting parts of the Earth-system, with a view to:

i. preparing forecasts by means of numerical methods;
ii. providing initial conditions for the forecasts; and
iii. contributing to monitoring the relevant parts of the Earth-system;

b) to carry out scientific and technical research directed towards improving the quality of these forecasts;

# Motivations for GEMS

- BETTER OPERATIONAL SERVICES
  - Excess deaths in summer 2005:- 18K in France, 35K in western Europe.
  - Europe needs improved operational warnings for Meteorological / Air-quality natural disasters
  - GEMS will provide such warnings
- SCIENCE
  - GEMS will synthesise all available data into accurate 'status assessments'.
  - GEMS products will facilitate study of many science questions on the sources, sinks transport, and processing of atmospheric trace constituents,
- TREATY ASSESSMENT & VALIDATION
  - Conventions (Kyoto, Montreal, LRTAP) and IPCC need best estimates of sources/ sinks/ transports of atmospheric constituents.
    - GEMS will meet the needs in a comprehensive manner, including the requirements of the GCOS Implementation Plan

# Objectives of GEMS (i): Global Operational System for Monitoring & forecasting Atmospheric Composition

## GLOBAL OPERATIONAL SYSTEM

- Develop and implement by 2009 a validated, comprehensive, and operational global data assimilation / forecast system for atmospheric composition and dynamics,
- combine remotely sensed and in-situ data
- Monitor tropospheric & stratospheric atmospheric composition

## MONITORING & FORECASTING

- Operational deliverables will include current and forecast three-dimensional global distributions (four times daily with a horizontal resolution of 50km, and high vertical resolution of key atmospheric trace constituents including
- 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 10-parameter representation, later ~ 30)

# Objectives of GEMS (ii): -Regional Air-Quality Forecasts -Retrospective Analyses -Variational Inversion Techniques

- Provide initial and boundary conditions for operational regional air-quality and 'chemical weather' forecast systems
  - improved operational real-time air-quality forecasts
  - a methodology for assessing the impact of global climate changes on regional air quality.
- 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)
  - Validation material for the project itself,
  - A service to the wider science community (inc. GCOS).
- State-of-the-art variational estimates of the sources, sinks and inter-continental transports, of many trace gases and aerosols;
  - based on the retrospective analyses, and later on operational analyses,
  - designed to meet policy makers' key information requirements relevant to the Kyoto and Montreal protocols and to the UN Convention on Long-Range Trans-boundary Air Pollution.

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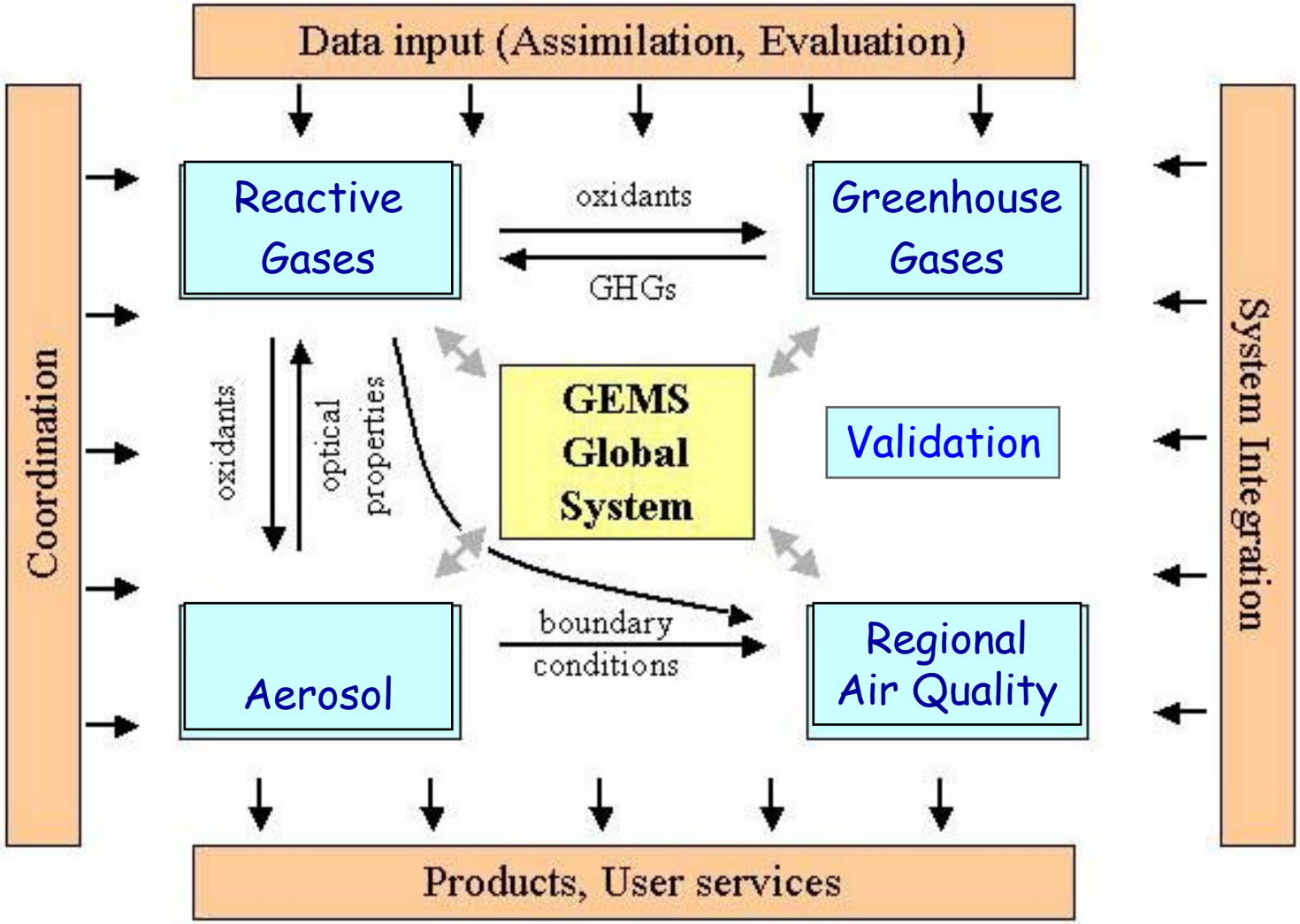
# GEMS organisation

## GEMS is organised in 6 projects



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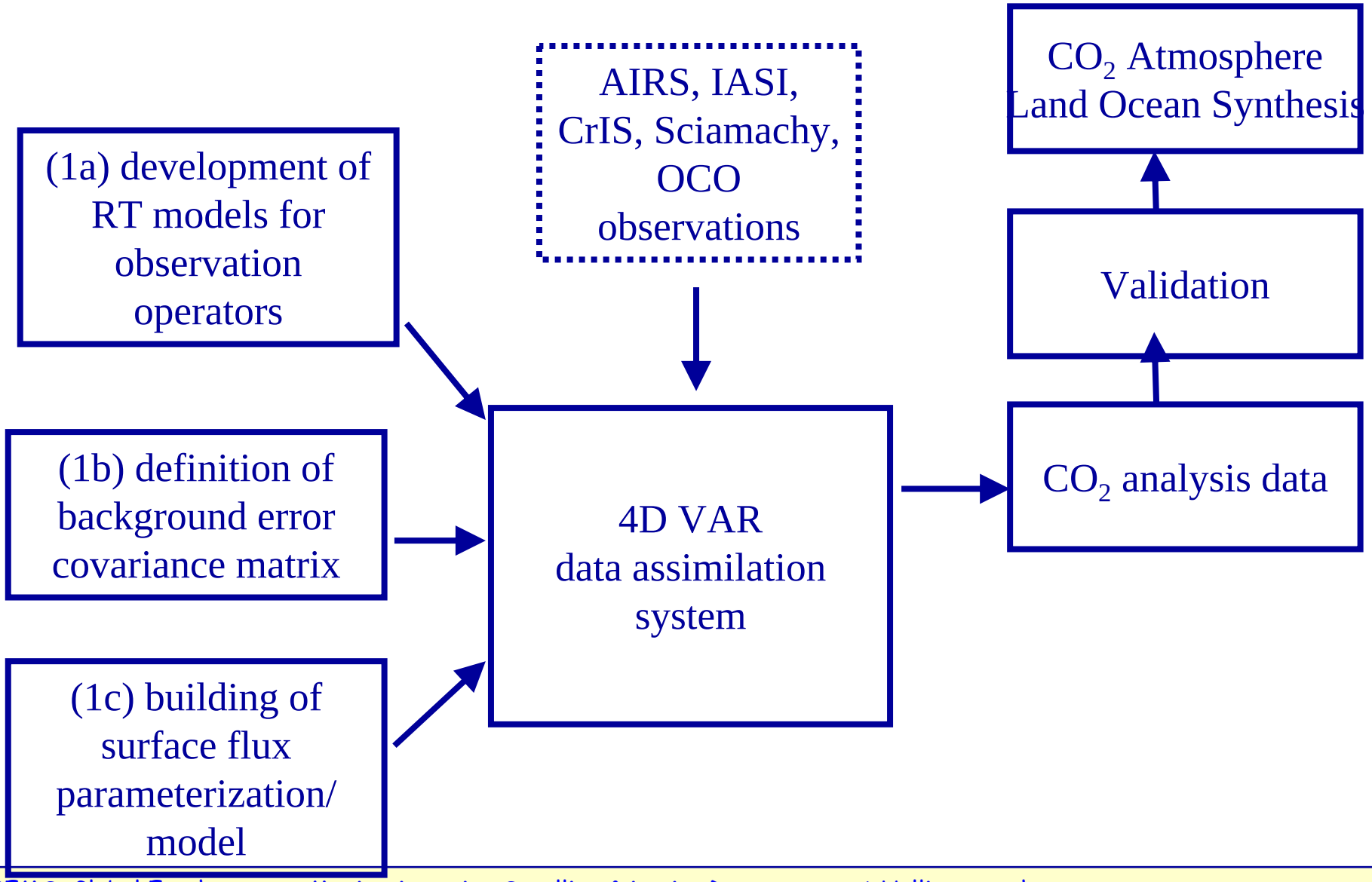
# Greenhouse Gas Activities



# Greenhouse Gas Deliverables

- Daily assimilation of all available satellite data (Advanced sounders, OCO, GOSAT) on $CO_2$, CO, $CH_4$, $N_2O$
- Monthly / Seasonal variational inversions of both in-situ (e.g. flask) and satellite data to provide estimates of surface fluxes
- The same technology can be used to estimate surface fluxes of other atmospheric constituents

# GEMS Greenhouse Gas Partners

| | | |
|---|---|---|
| 1. | ECMWF | |
| 2. | The Met Office | UK |
| 3. | Laboratoire de Météorologie Dynamique/CNRS | F |
| 4. | Laboratoire des Sciences du Climat et de l'Environnement | F |
| 5. | Max-Planck-Institut für Biogeochemie, Jena | D |
| 6. | JRC, Institute for Environment and Sustainability | EU |

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# Motivations for the Aerosol project

Aerosols are:-

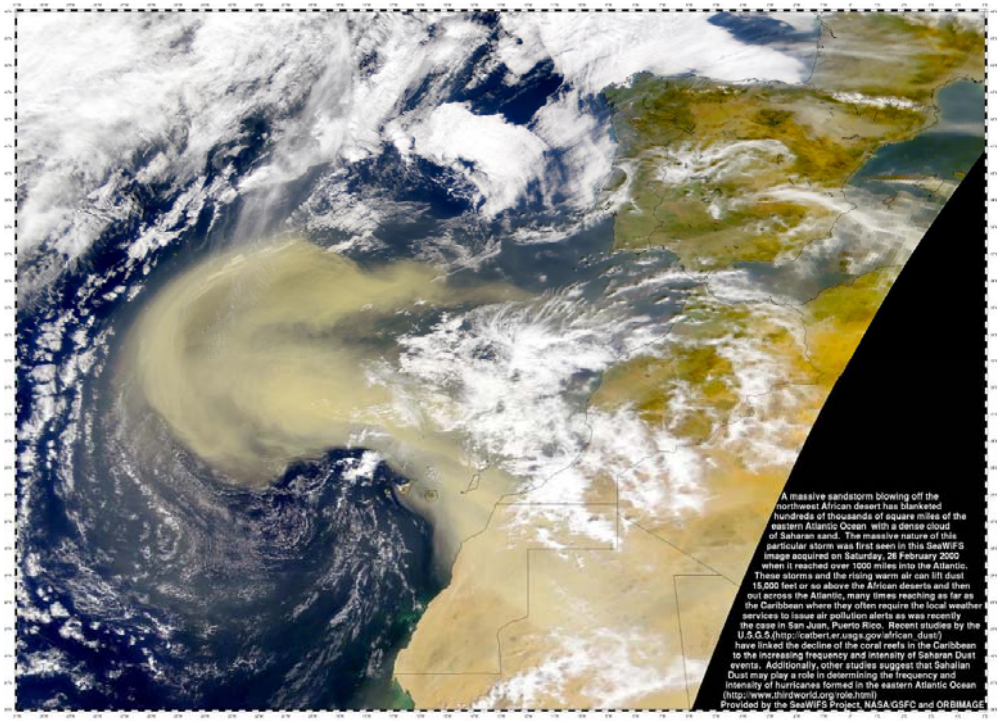
- An emerging issue for NWP.
  - Neglect of aerosol is the largest error in model clear sky radiation calculations (50W/m**2)
  - Neglect of aerosol can lead to large errors (0.5K) in the forward calculations for advanced sounders.
  - The aerosol element of GEMS is likely to be the first GEMS element included in the operational suite

- An important issue for public health (e.g. forthcoming EU directive on PM2.5)
  - GEMS variational estimates of aerosol sources may be of help for regulatory purposes

- An important issue for climate
  - Aerosols may mitigate the impact of greenhouse gases through 'global dimming'?

# AEROSOL: Deliverables

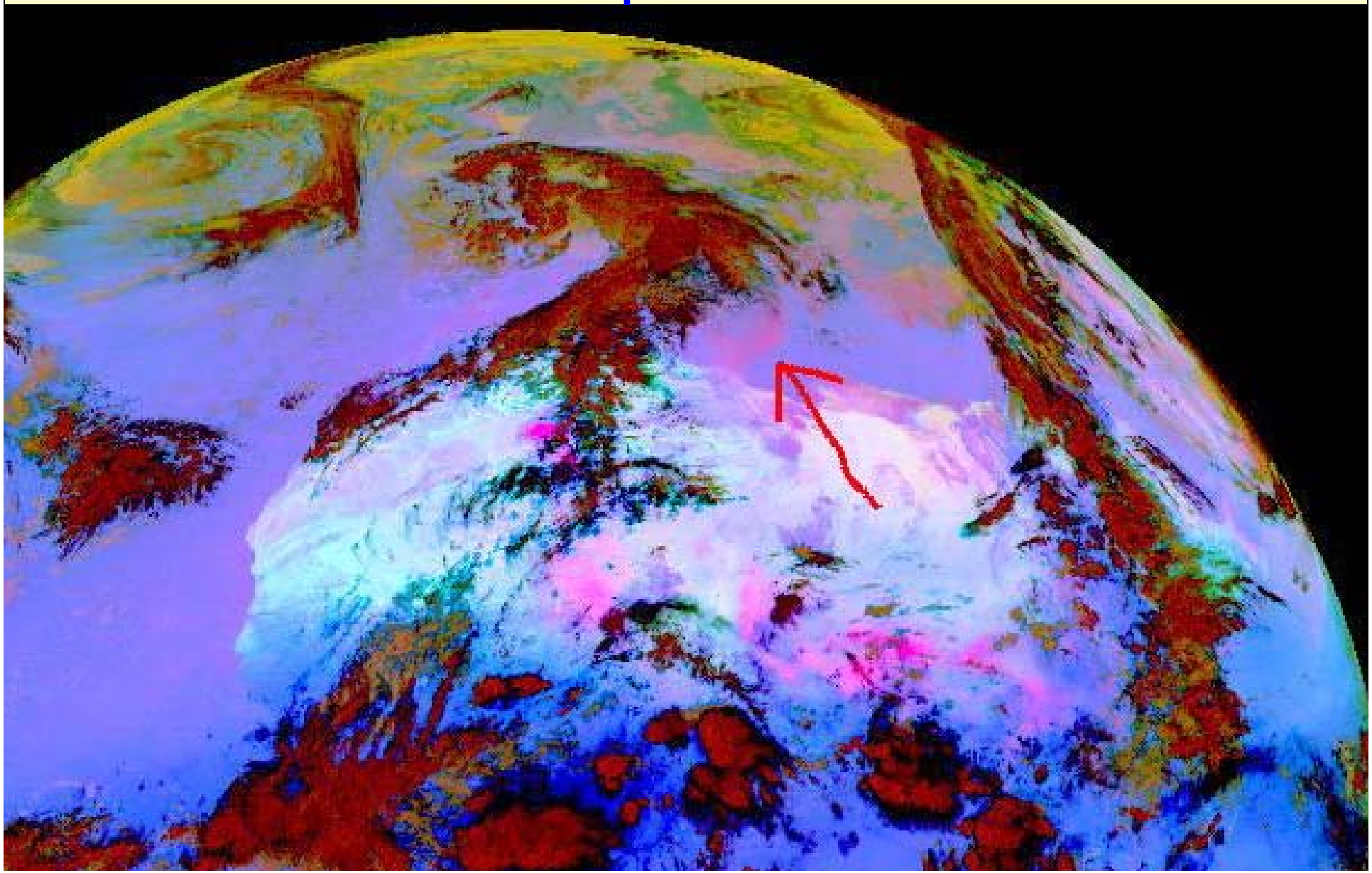
- Model and assimilate global aerosol information
- Instruments: MERIS, MODIS x 2, MISR, SEAWIFS, POLDER, then VIIRS on NPP, VIIRS & APM on NPOESS,
- Initially 10 parameters
  =>30 parameters
- Global Monitoring
- Global Forecasts
- Boundary info. for
  Regional models



# GEMS Aerosol Partners

| | | |
|---|---|---|
| 1. | ECMWF | |
| 2. | The Met Office | UK |
| 3. | Laboratoire d'Optique Atmosphérique, Unversité de Lille | F |
| 4. | LSCE/ CEA, Orme des Merisiers | F |
| 5. | Max-Planck Institut fuer Meteorologie, Hamburg | D |
| 6. | Finnish Meteorological Institute, Helsinki | Fin |
| 7. | DWD Meteorological Observatory, Hohenpeissenberg | D |
| 8. | Service d'Aéronomie, UPMC/CNRS, Paris | F |
| 9. | Dept. of Physics, National University of Ireland, Galway | Irl |
| 10. | Royal Meteorological Institute of Belgium, Brussels | B |

# Saharan dust in the Mediterranean on 24 April 2005 was associated with apparent changes in Sea Surface temperatures



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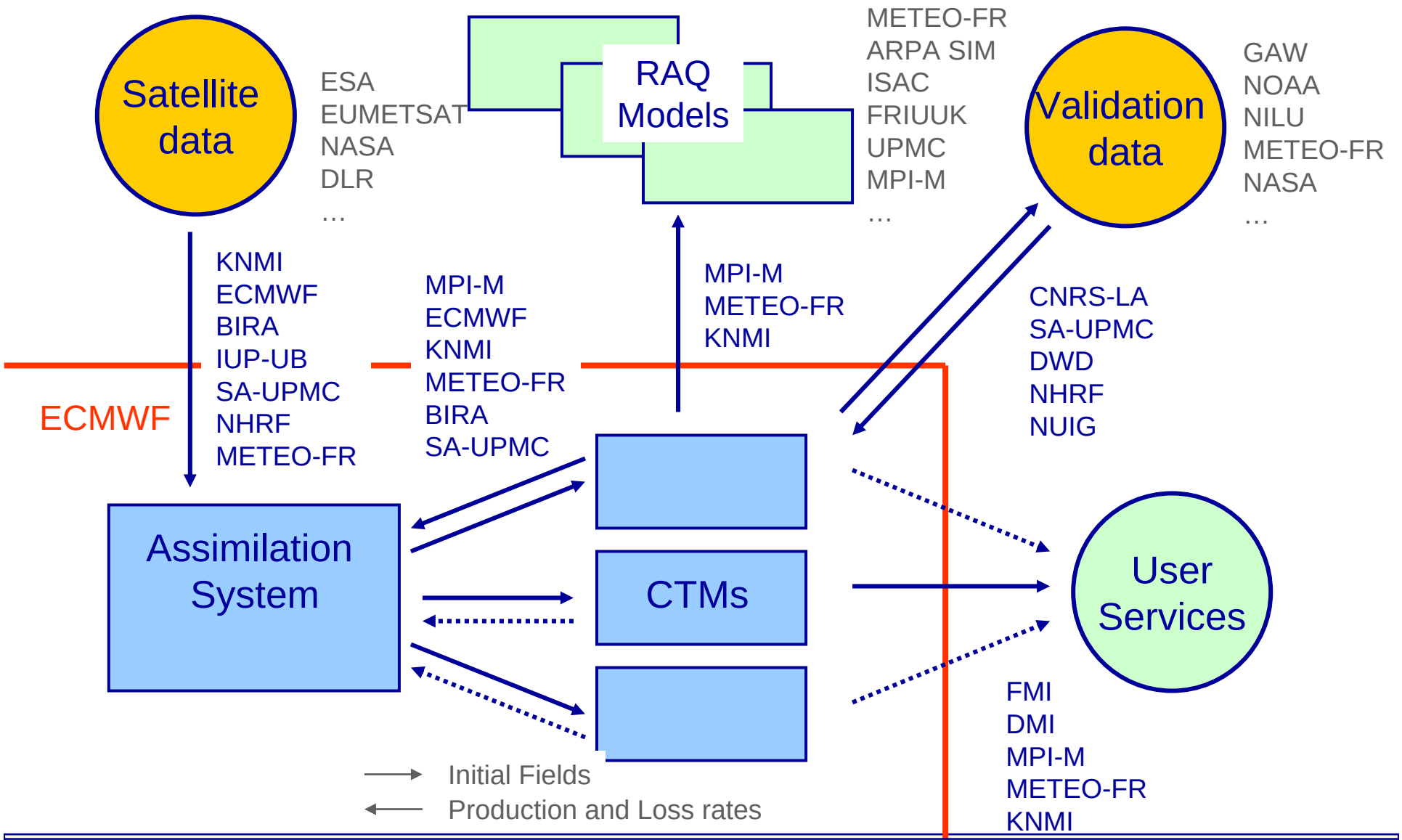
# REACTIVE-GASES: Deliverables & Approach

- **Deliverables**
  - Monitor the global 3D / temporal distributions, transports, sources/sinks of key species such as $O_3$, $NO_2$, $SO_2$, $CH_2O$..
  - Forecast Global Chemical Weather, including UV-B
  - Initial and boundary conditions for regional Chemical Weather and Air-Quality Forecasts.
- **Modelling & Assimilation Approach**
  - Tight coupling of the assimilating weather model (IFS) and a Chemical Transport Model (CTM ) to maintain good advection, and good chemical profiles.
  - Copy frequently (2-hours?) the chemical fields from the assimilating model IFS => CTM (Chemical Transport Model)
  - Copy frequently (2-hours?) the Production and Loss rates from CTM => IFS

# Data Flow and Responsibilities in GEMS Reactive Gas project




Courtesy: M.Schultz

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# Regional Air Quality Objectives

- **Evaluate the impact on Regional Air-Quality forecasts of global information on Long-Range Transport of Air Pollutants.**
- **Initiate routine production at, & cooperation between, national air quality forecast centres for data access, skill evaluation & forecast comparisons.**
- **Improve continental to regional scale air quality models, the statistical post-treatment of forecasts, & explore multi-model ensemble approaches.**
- **Improve our understanding of the health impacts of air quality and incorporate air quality forecast information into a health forecast.**
- **Assess the effects of global variability on regional air quality and provide background for policy evaluation and evolution.**

# GEMS Regional Air Quality Partners

| | | |
|---|---|---|
| 1. | The Met Office | UK |
| 2. | CNRS: LMD / LA / LISA | F |
| 3. | Max-Planck Institut für Meteorologie | D |
| 4. | Koninklijk Nederlands Meteorologisch Instituut | NL |
| 5. | Finnish Meteorological Institute | Fin |
| 6. | Danmarks Meteorologiske Institut | DK |
| 7. | Université Pierre et Marie Curie, Service d'Aéronomie | F |
| 8. | LCAE, University of Athens | H |
| 9. | Météo-France, CNRM | F |
| 10. | ARPA Emilia Romagna, Servizio Idro-Meteorologico | I |
| 11. | Institute of Atmospheric Sciences and Climate/ CNR | I |
| 12. | Meteorologisk Institutt Oslo | N |
| 13. | Rheinisches Institut für Umweltf. Universität Köln | D |
| 14. | Inst. Nat. de l'Environnement Industriel et des Risques | F |
| 15. | Czech Hydrometeorological Institute | CZ |
| 16. | Irish Environmental Protection Agency | Irl |
| 17. | Polish Institute of Environmental Protection | P |
| 18. | Imperial College London | UK |

# GEMS Validation Partners

| | | |
|---|---|---|
| 1. | Max-Planck Institut für Biogeochemie | D |
| 2. | Koninklijk Nederlands Meteorologisch Instituut | NL |
| 3. | Danmarks Meteorologiske Institut | DK |
| 4. | Dept. Of Physics, National University of Ireland –Galway (Mace Head) | IRL |

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# Schedule of GEMS work at ECMWF

| | |
|---|---|
| **Year 1**<br>May 05+12 mo. | • Build and validate 3 separate assimilation systems for Greenhouse gases, Reactive gases, Aerosol.<br>• Acquire data; build web-site |
| **Year 2**<br>May 06+12 mo. | • Produce 3 different reanalyses for GHG, GRG, Aerosol<br>• Make reanalyses available for validation by all partners<br>• Provide feedback to data providers |
| **Year 2-2.5**<br>May 07 + 6 mo. | • Merge the 3 assimilation systems into a unified system;<br>• Upgrade the models and algorithms based on experience |
| **Year 2.5-3.5**<br>Nov 07+ 12 mo. | • Build operational system, & interfaces to partners<br>• Produce unified reanalyses for GHG, GRG, Aerosol |
| **Year 3.5 - 4**<br>Nov 08+ 6 mo. | • Final pre-operational trials<br>• Documentation & Scientific papers |

# GEMS Team at ECMWF

| | | | |
|---|---|---|---|
| | | | |
| Modelling | Greenhouse gases | 1 | |
| | Reactive gases | 1 | |
| | Aerosol | 0.5 | |
| | | | 2.5 |
| | | | |
| Assimilation | Greenhouse gases | 1 | |
| | Reactive gases | 1 | |
| | Aerosol | 1 | |
| | Chemical Transport Models & PREPIFS | 1 | |
| | | | 4 |
| Operations | Observations & Archives | 1 | |
| | Web / Verification/ Access | 1 | |
| | | | 2 |
| Coordination | | 1 | 1 |
| | TOTAL | | 9.5 |

# Contents of the Presentation

- The GEO / GMES context
- Motivations & Objectives
- Organisation of GEMS in Projects
  1. Greenhouse Gas Deliverables, partners, data
  2. Aerosol Deliverables, partners, data
  3. Reactive Gas Deliverables, partners, data
  4. Regional Air Quality Deliverables, partners, data
  5. Validation
  6. Production team at ECMWF & Schedule
- **A flying start**
- Issues for the transition to operations in 2009

# GEMS has made a flying start

- The team is in place at ECMWF and work has begun on all aspects of GEMS
- Preparations are well in hand for satellite data acquisition.
- The IFS now has provision for advecting many new variables, needed for gases and aerosols.
- Active collaboration underway with the main modelling partners
- The FP_5 *COCO* project on *CO2* has prepared much of the assimilation science for the greenhouse gas project.
- The FP_6 *HALO* project has helped define the requirements for surface emissions.

# Contents of the Presentation

- Motivations & Objectives
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- **Issues for the transition to operations in 2009**

# Importance for GEMS of real-time and archival access to In-situ observations

- The GEMS project needs (real-time and archival) access to a wide variety of in-situ observations for
  - Model development and assessment
  - Forecast verification
  - Cross-validation of other observations, esp. satellite data
  - Data assimilation
  - Data monitoring to assess long-loop stability and performance
- Some key data can be made available with good calibration in real-time
- Other key data need very careful calibration and so archival access is needed
- Access will require data sharing agreements between

  EMI & National Environment Agencies
- Access to Canadian and US hourly-reporting data presents no problem

# Issues in Transitioning the GEMS project to Operational Status from 2009 onwards.

- The GEMS project intends to be scientifically ready and technically ready to transition the global and regional GEMS systems to operational status by mid-2009.
- New institutional arrangements are needed to
  - fund operations, incl. human resources, computing & telecomms.
  - fund sustained research support
  - make and share observations, both real-time and archival
  - Disseminate products, both real-time and archival
- Actors in creating such institutional arrangements include
    - European Commission, EEA , ESA
    - National Environment Agencies
    - Nat.Met.Services, ECMWF, EUMETSAT & EUMETNET
    - Scientific and technical partners in GEMS, PROMOTE, and related GMES activities.
- Satellites: chemistry observations post-2010 are an issue.

# END

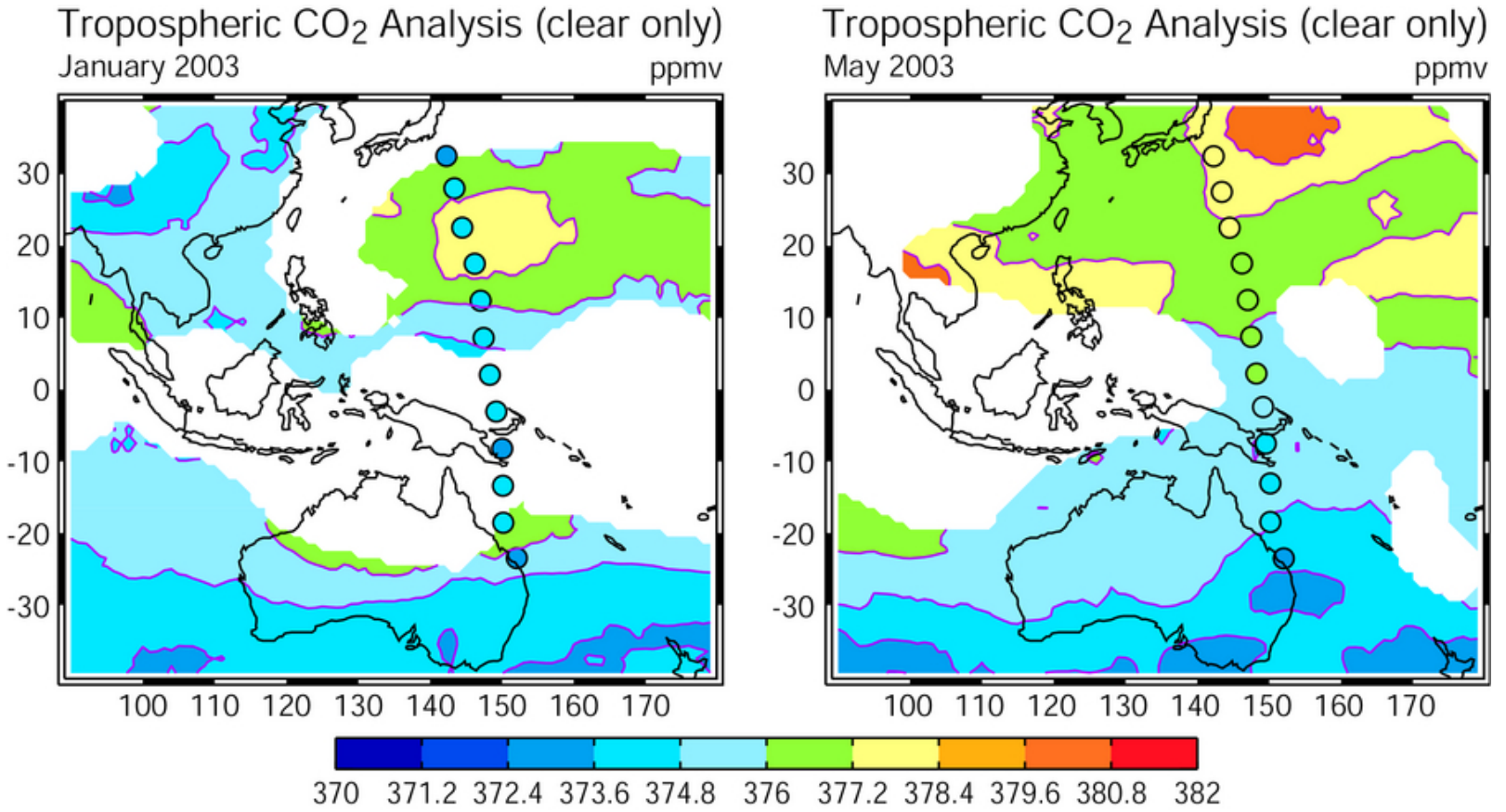
*thank you for your attention!*

*www.ecmwf.int/research/EU_projects/GEMS*

# BACK-UP SLIDES

Current status of off-line $CO_2$ calculations - comparisons with Japanese flight data

- good results for May 2003
- less favourable results for January 2003 (problem with detection of thin cirrus?).

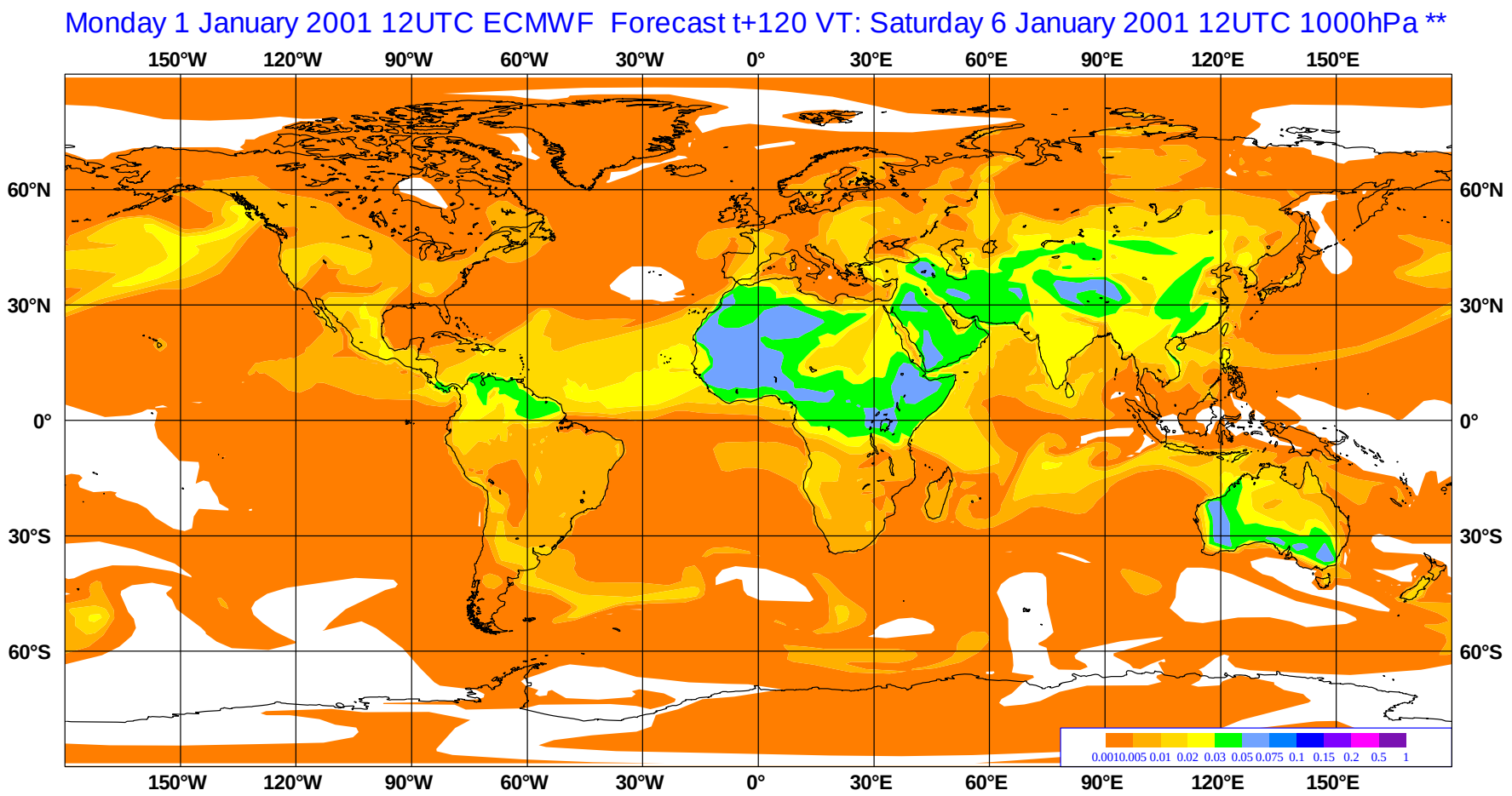



*R.Engelen*

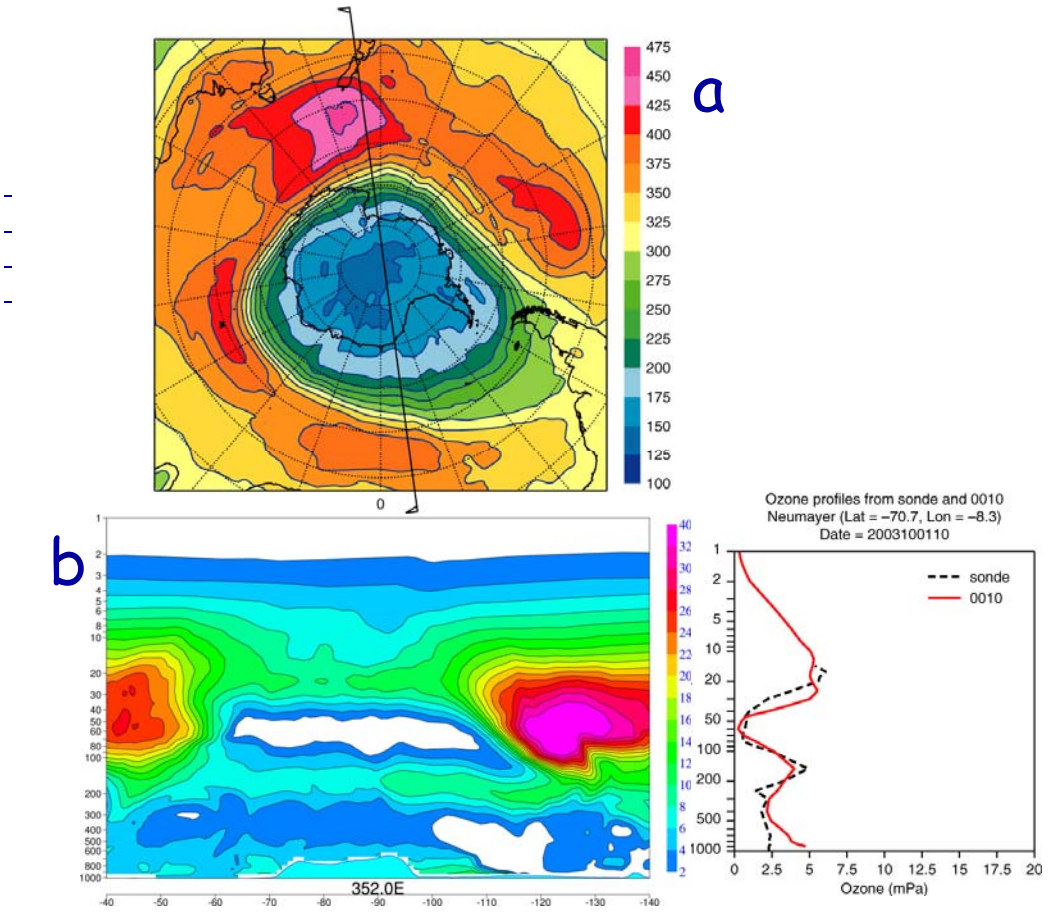
*Flight data kindly provided by H. Matsueda, MRI/JMA*

# Five -day forecast, showing particulates at 1000HPa, starting from a climatological distribution of Desert Dust

(Benedetti, Morcrette, Hortal…)



# Ozone Hole 1 Oct 2003
# in ECMWF operational assimilation, with very simple Chemistry




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

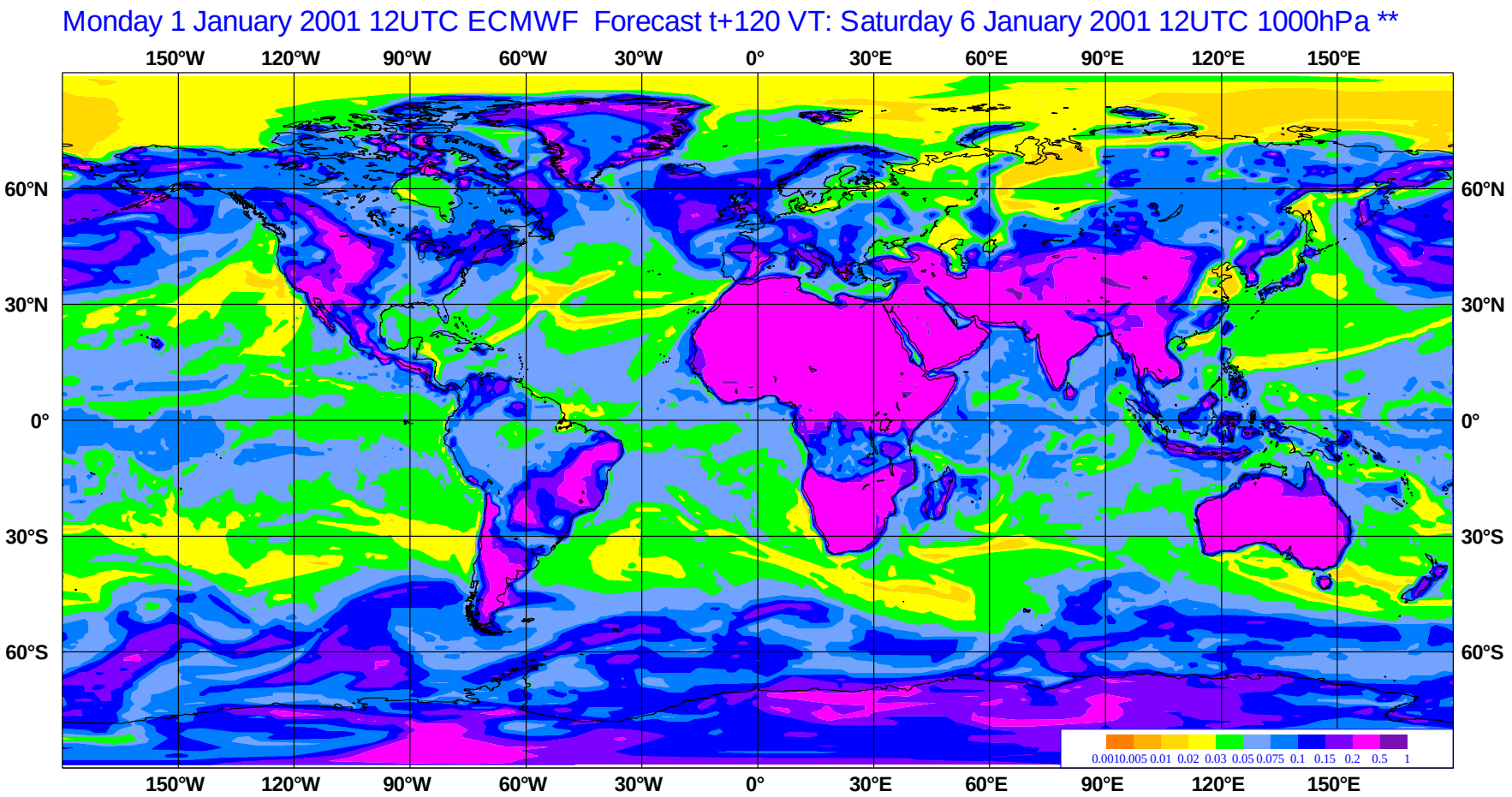
c) Comparison of (independent) ozonesonde profile data at Neumayer (70.7S 8.3W) with the assimilated field; the agreement is remarkable.



Courtesy: A.Dethof F

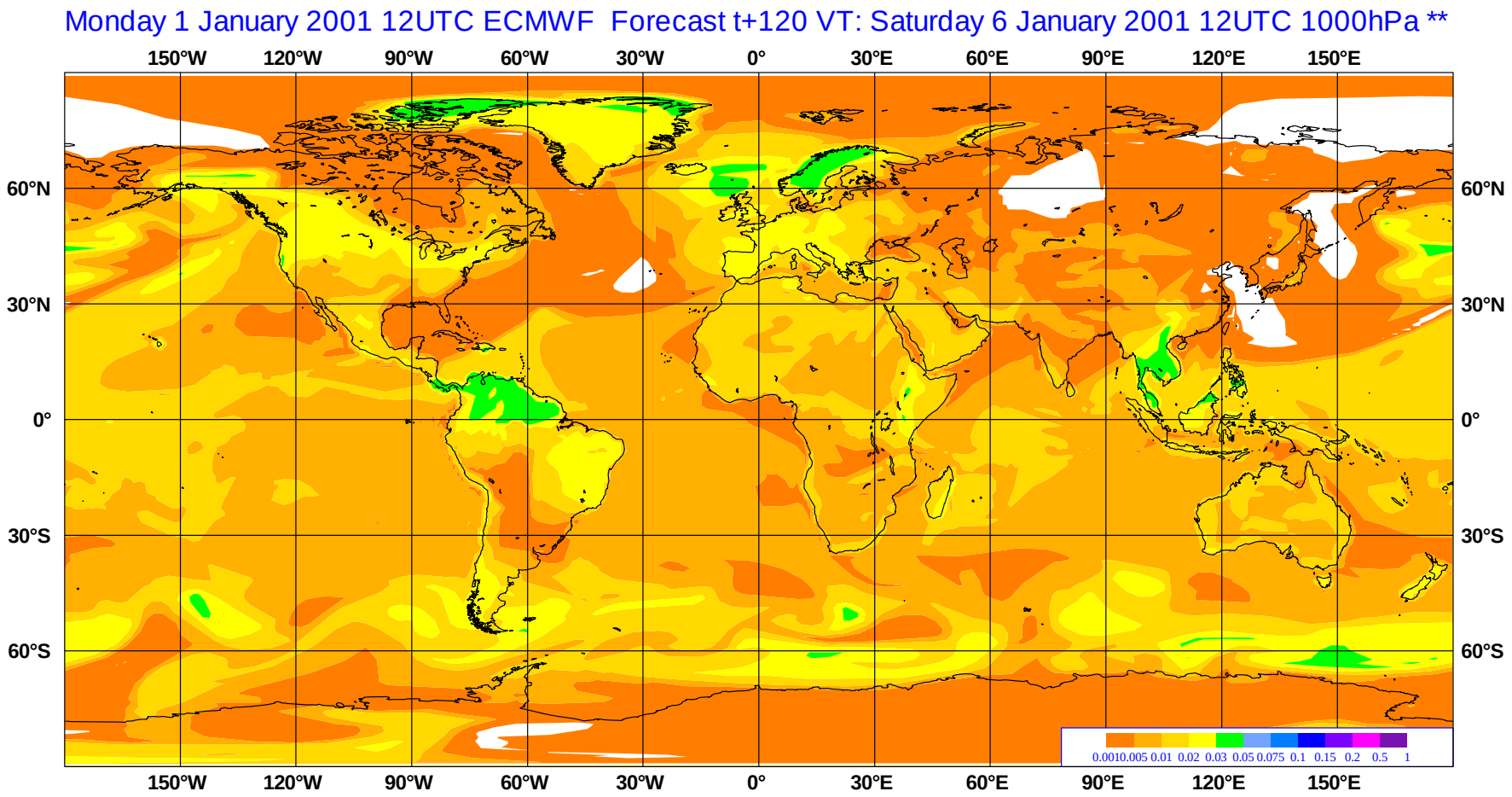
# Five -day forecast, showing particulates at 1000HPa, starting from a climatological distribution of Continental Particulates

(Benedetti, Morcrette, Hortal…)

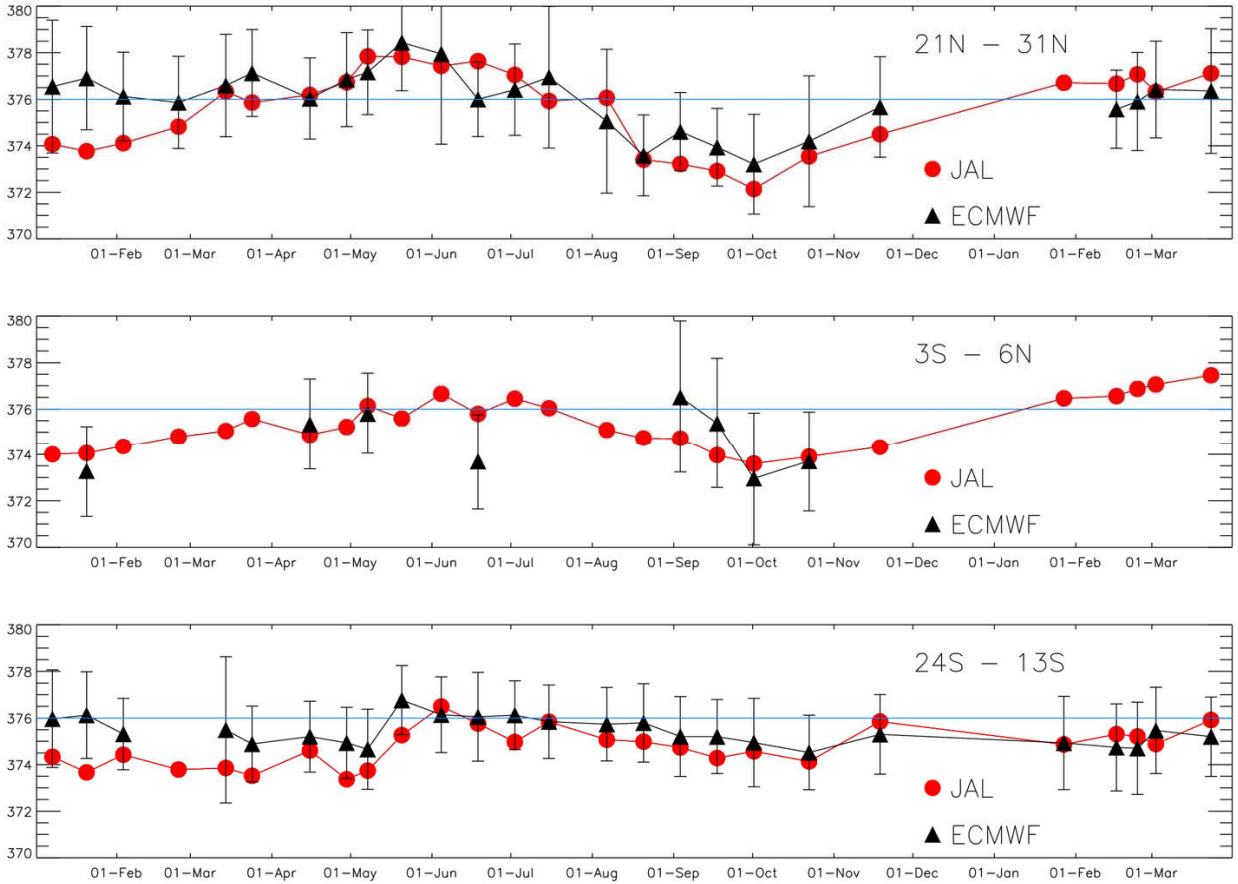


# Five -day forecast, showing particulates at 1000HPa, starting from a climatological distribution of Sea Salt

(Benedetti, Morcrette, Hortal…)



# $CO_2$ Comparison with flight data from Japan Air Lines

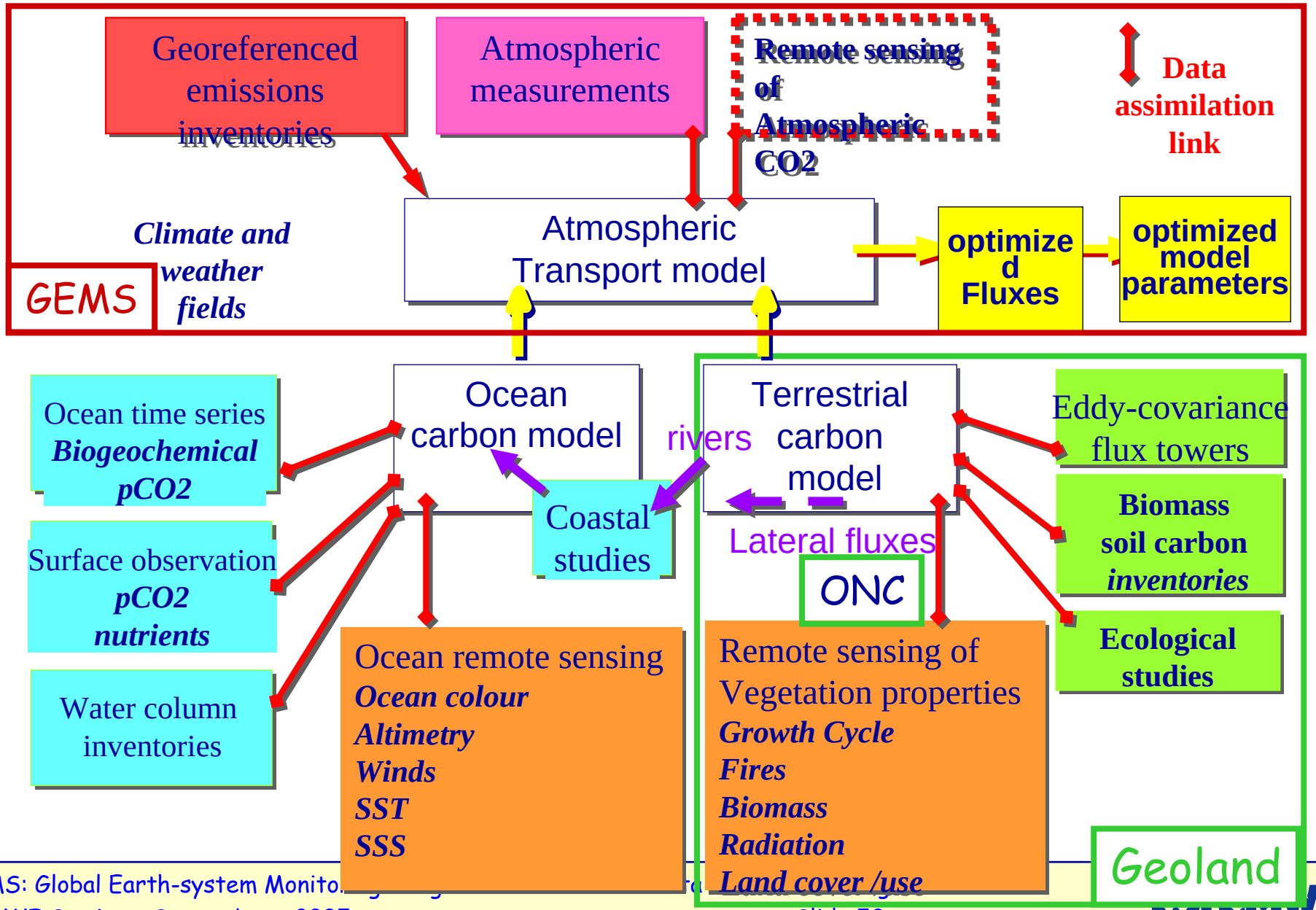



Flight data kindly provided by H. Matsueda, MRI/JMA

# Table 2.7.1 Satellite Data on Greenhouse Gases to be used in GEMS

| Agency | Mission | Instruments | Species | Data Volume/day of satellite life (MB/day) |
|---|---|---|---|---|
| ESA | ENVISAT | **SCIAMACH** | **$CO_2$, $N_2O$, CO, $CH_4$** | 11 |
| ESA | ENVISAT | **MIPAS** | CH4, N2O | 2 |
| | | | | |
| EUMET | METOP-1 | IASI | $CO_2$, $N_2O$, CO, $CH_4$ | 1500 |
| | | | | |
| NASA | AQUA | AIRS | $CO_2$, $N_2O$, CO, $CH_4$ | 280 |
| NASA | TERRA | MOPITT | CO, $CH_4$ | 64 |
| NASA | AURA | TES | CO, $CH_4$ | |
| NASA | AURA | HIRDLS & MLS | CO, $N_2O$, $CH_4$ | 16<br>4 |
| NASA | OCO | OCO | CO2 | 80 |
| | | | | |
| NESDIS | NPP | CrIS | $CO_2$, $N_2O$,CO, $CH_4$ | 280 |

# IGOS_P / IGCO
## Development of Carbon Cycle Data assimilation systems



# GEMS Reactive Gas Partners

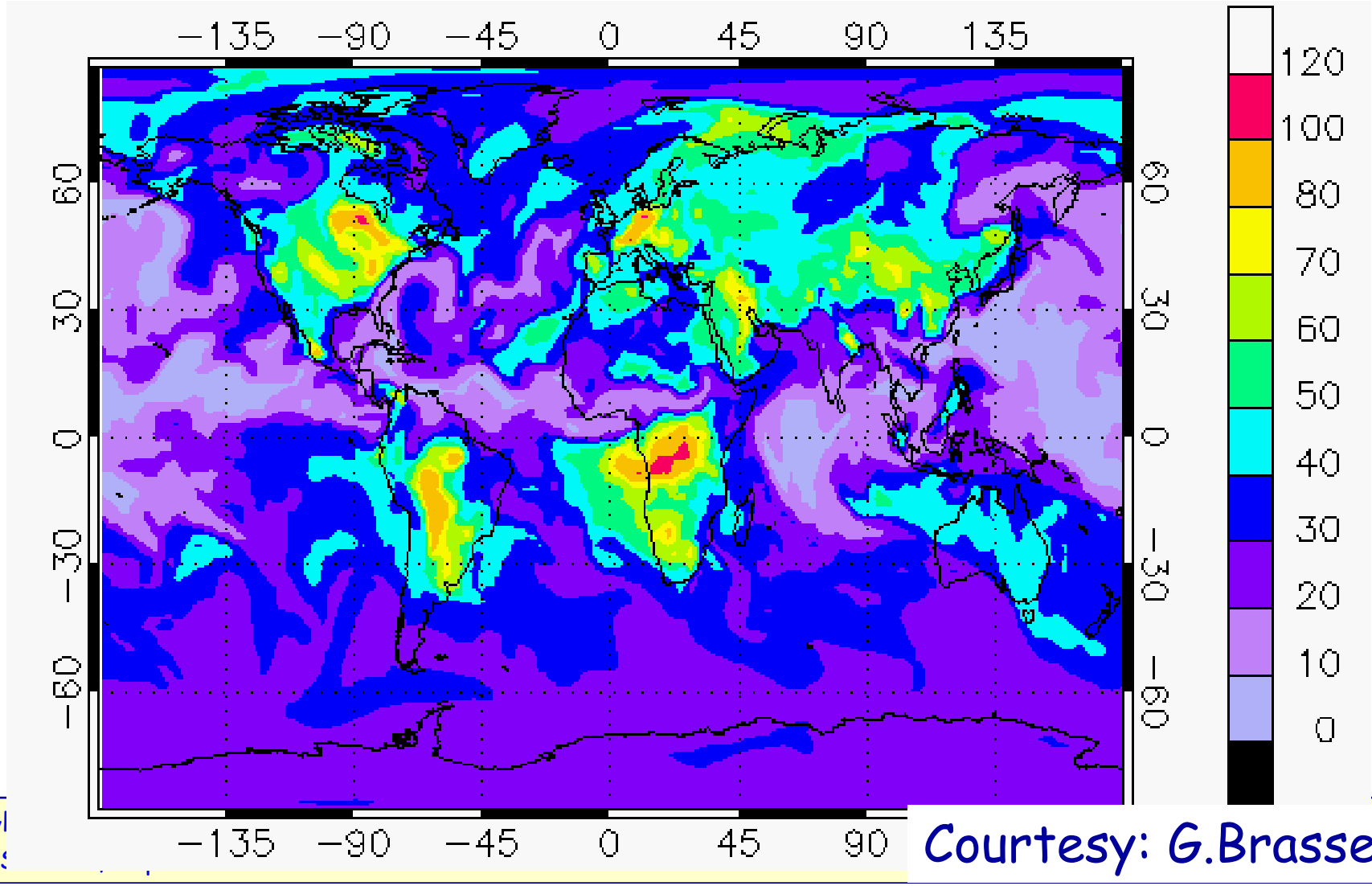
| | | |
|---|---|---|
| 1. | ECMWF | |
| 2. | Laboratoire d'Aérologie, Observatoire Midi-Pyrénées | F |
| 3. | Max-Planck Institut für Meteorologie, Hamburg | D |
| 4. | Koninklijk Nederlands Meteorologisch Instituut | NL |
| 5. | Belgisch Instituut voor Ruimte-Aeronomie, Brussels | B |
| 6. | Finnish Meteorological Institute | F |
| 7. | Danmarks Meteorologiske Institut | DK |
| 8. | Deutscher Wetterdienst, Hohenpeissenberg | D |
| 9. | Institut für UmweltphysikUniversität Bremen | D |
| 10. | Service d'Aéronomie, Université Pierre et Marie Curie, Paris | F |
| 11. | LCAE, University of Athens, | H |
| 12. | Météo-France, CNRM, Toulouse | F |

## Table 2.7.2 Satellite Data on Reactive Gases to be used in GEMS

| Agency | Mission | Instruments | Species | Data Volume per day of satellite life (MB/day) | |
|---|---|---|---|---|---|
| ESA | ENVISAT | SCIAMACHY | $O_3$, $NO_2$, $SO_2$, $CH_2O$ | 53 | |
| ESA | ENVISAT | GOMOS | $O_3$, $NO_2$ | 2 | |
| ESA | ENVISAT | MIPAS | $O_3$, $NO_2$ | 2 | |
| ESA | ERS-2 | GOME | $O_3$, $NO_2$, $SO_2$, $CH_2O$ | 19 | |
| | | | | | |
| EUMET | METOP-1 | GOME-2 | $O_3$, $NO_2$ | 152 | |
| EUMET | MSG | SEVIRI | $O_3$ | 10 | |
| EUMET | METOP-1 | IASI | $O_3$ | 1500 | |
| | | | | | |
| NASA | AQUA | AIRS | $O_3$ | 280 | |

**Modelling of Tropospheric Chemistry needs a full chemistry package and good surface emissions! Initially we shall bootstrap by coupling GCM & CTM**

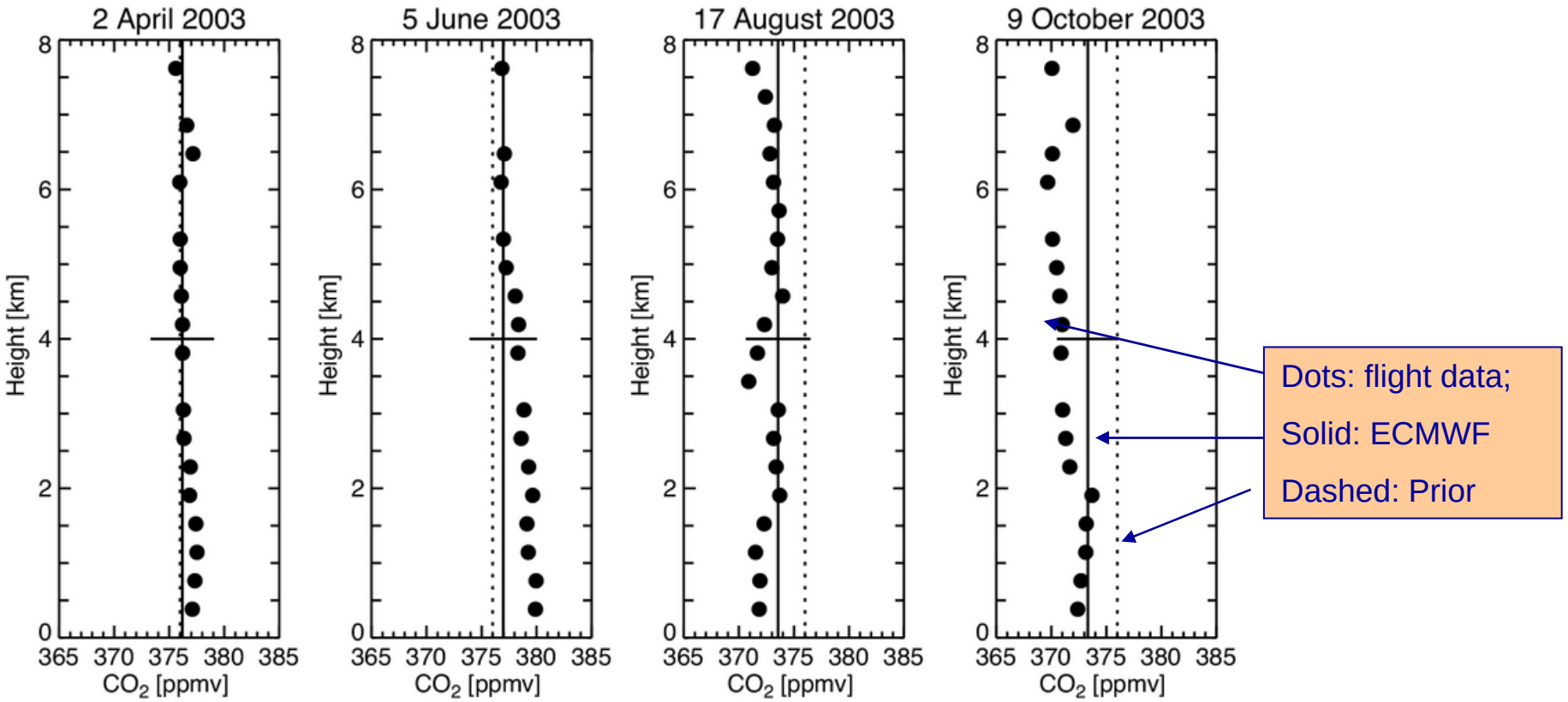
**Simulation of Ozone mixing ratio (nmol/mol) at 850 hPa for August 3, 2003, 1500 UTC as simulated with MOZART-2 CTM.**




GEMS: GI
ECMWF S

Courtesy: G.Brasseur

# $CO_2$ Comparison with NOAA/CMDL flight profiles at Molokai, Hawaii




Flight data kindly provided by Pieter Tans, NOAA/CMDL