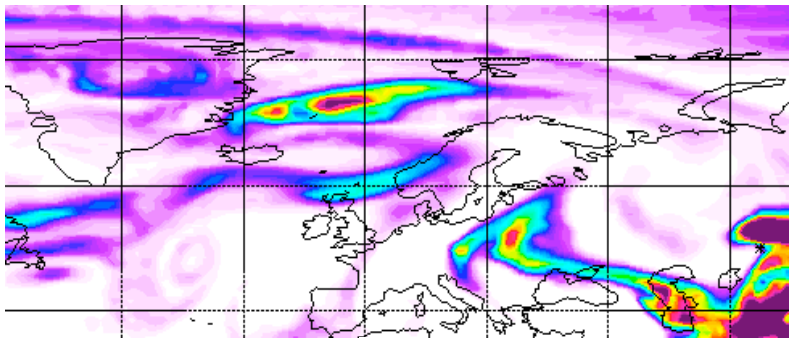
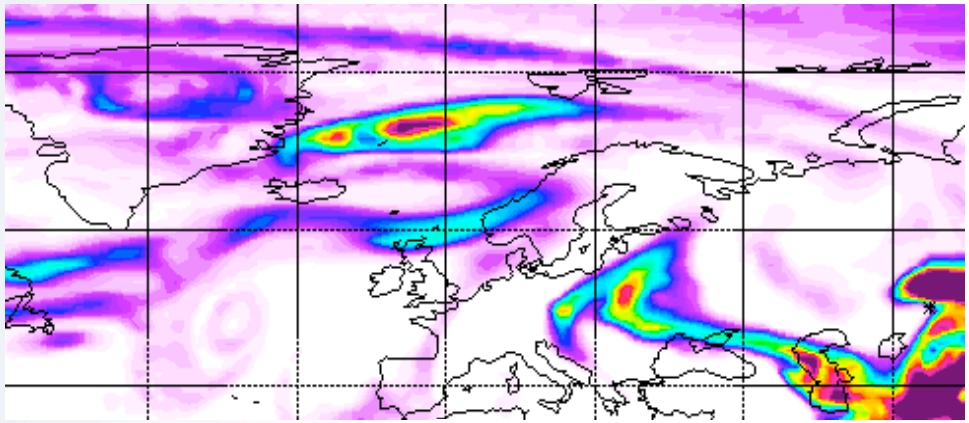
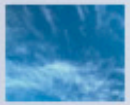
The Challenge of Monitoring and Predicting Chemical Weather

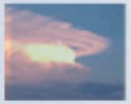
Guy Brasseur



Introduction: What is Chemical Weather?







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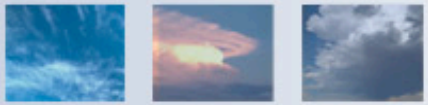
What is Chemical Weather?

- Local, regional, and global distributions of important trace gases and aerosols, and their variability on time scales of minutes to hours to days, particularly in light of their various impacts, such as human health, ecosystems, the meteorological weather and climate.

Lawrence et al.,
Environ. Chem., 2, 6-8, 2005



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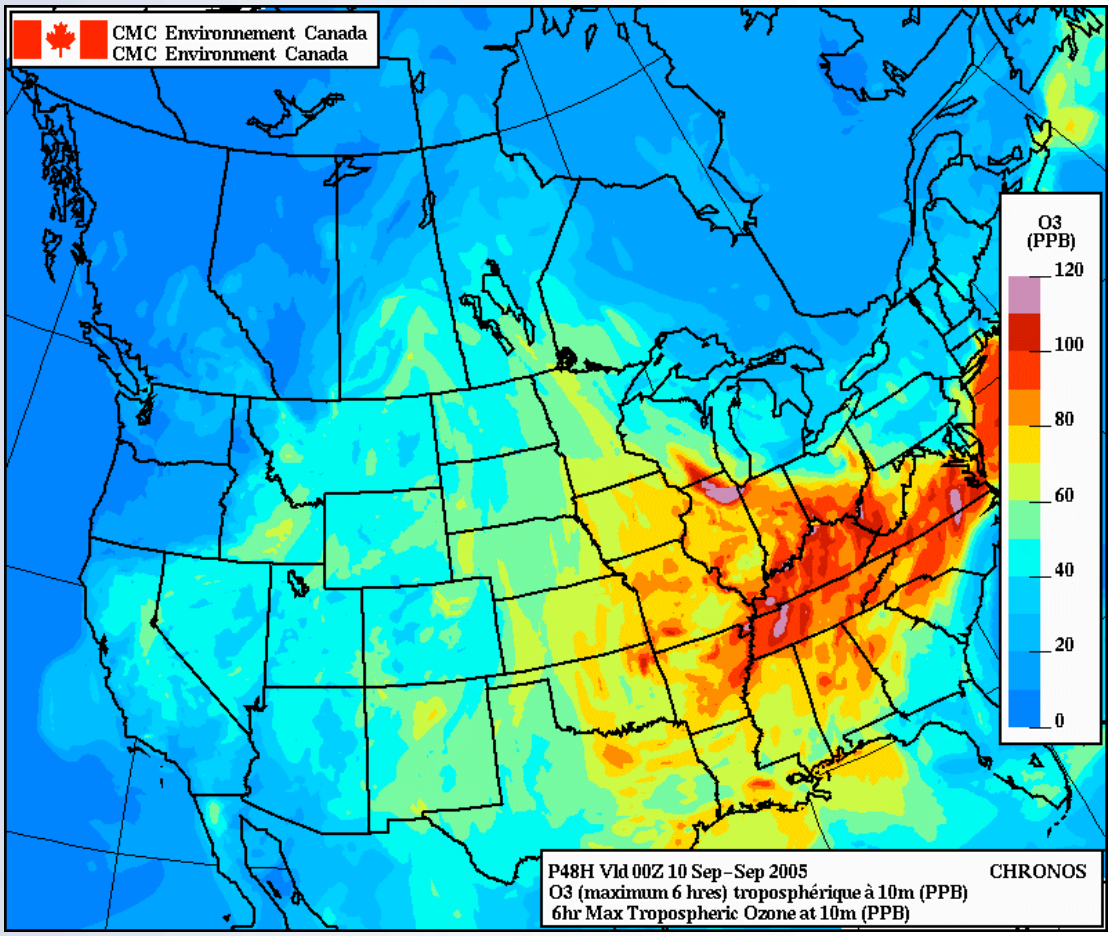
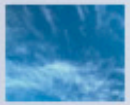
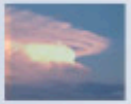
Ozone, 10 September, 2005

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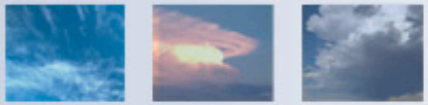
Importance of Chemical Weather

- Effects of air quality and chemical exposure on human health.
- Effects of gases and aerosols on ecosystems and agriculture
- Effects of air quality and visibility on tourism
- Effects of UV radiation on ecosystems and humans

- Improvements of numerical weather prediction models



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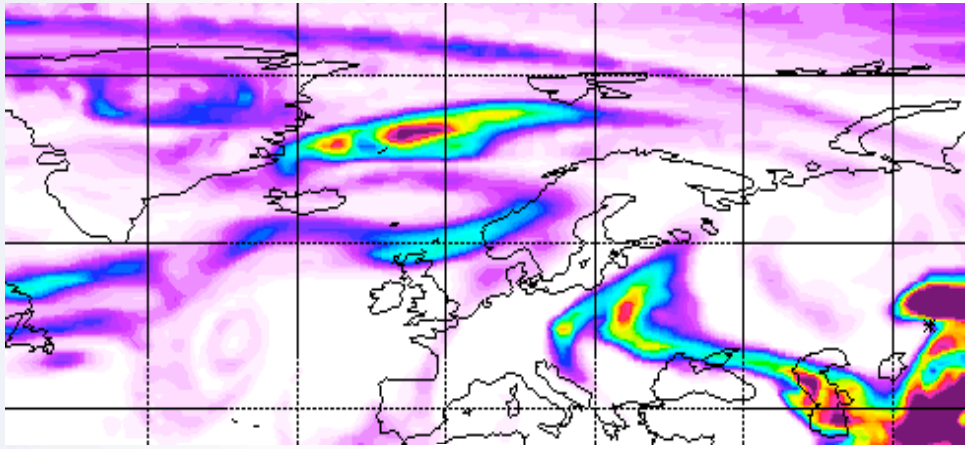
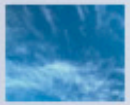
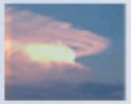
Global Observations of Chemical Weather







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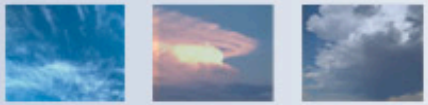
Observational platforms for chemical species

- Surface sites
- Research and commercial aircraft
- Sondes
- Remote sensing from the ground
- Remote sensing from space
- Monitoring vs research mode observations



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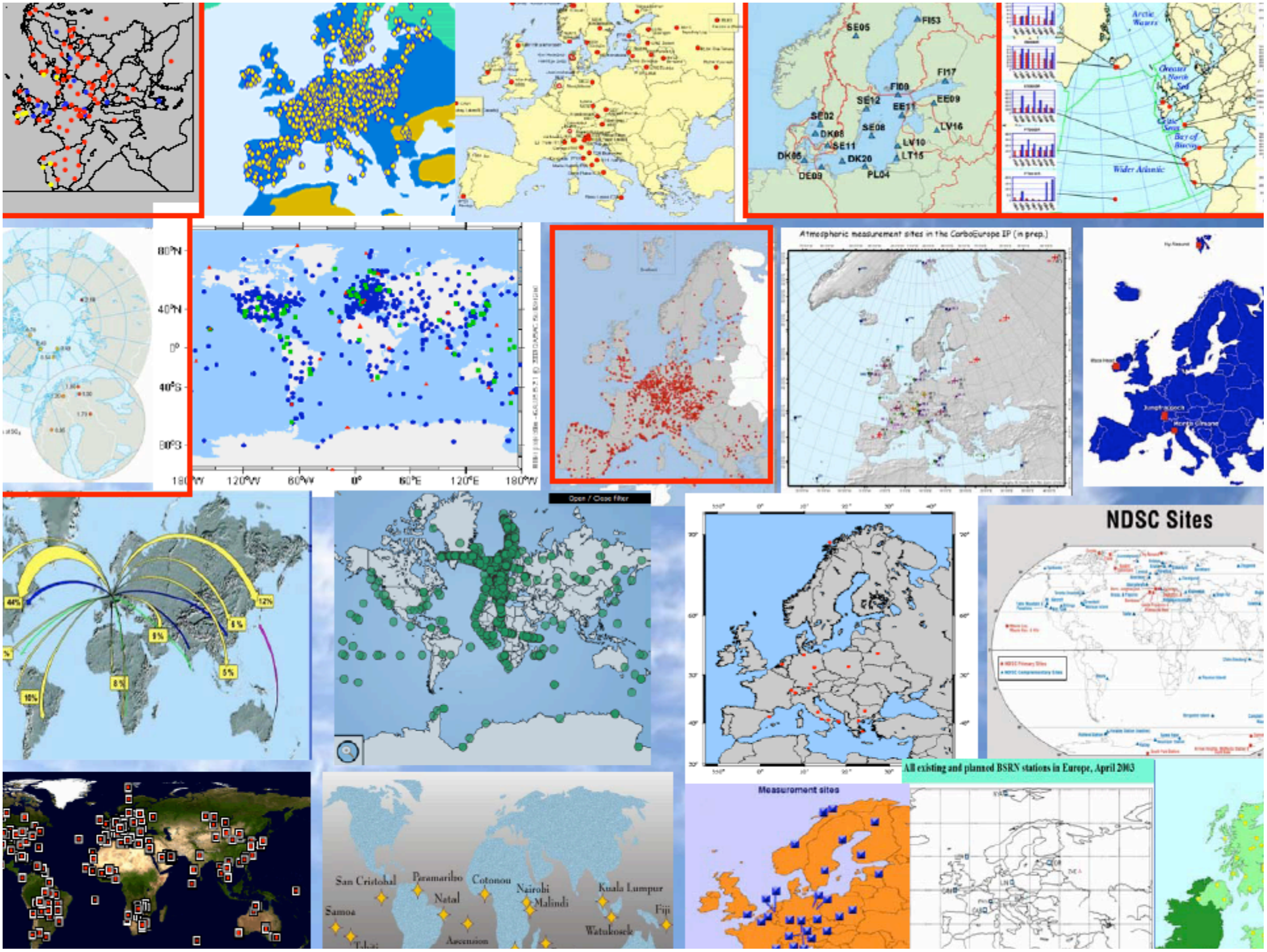
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FI53
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SE12
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SE02
DK08
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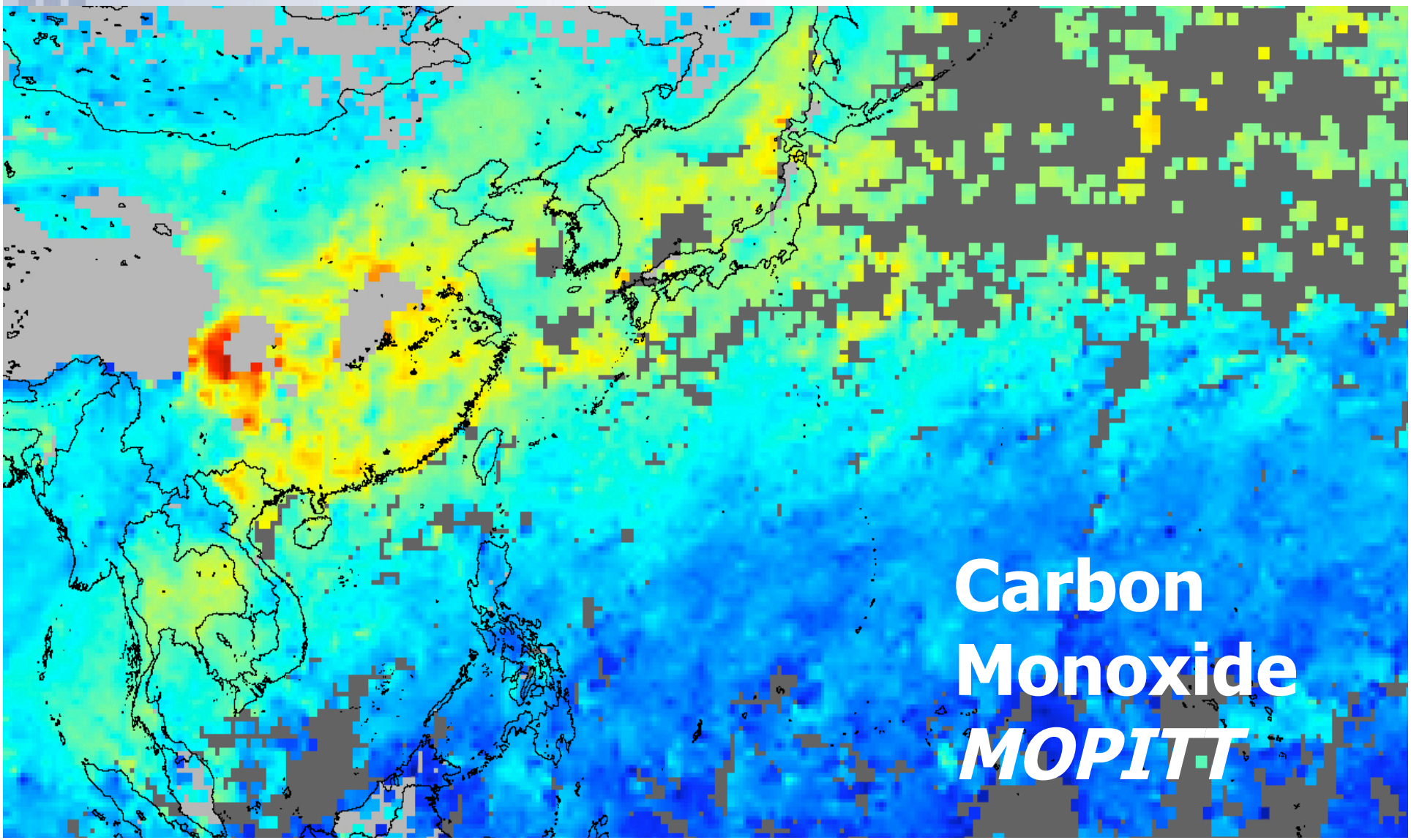
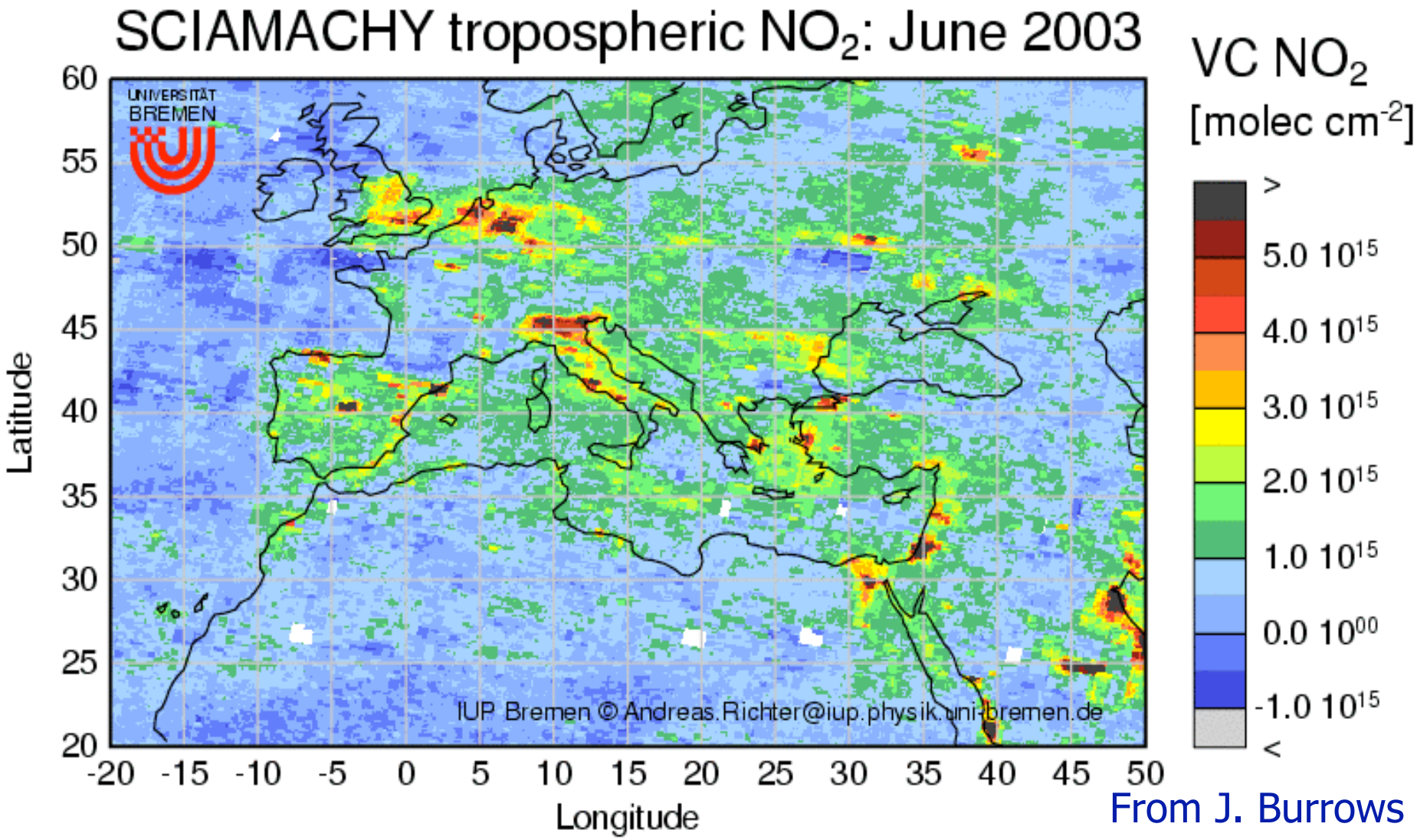
LV16
SE11
LV10
DK06
DK20
LT15
DE09
PL04
Arctic Waters
Greater North Sea
Celtic Seas
Bay of Biscay
Wider Atlantic
80°N
40°N
0°
40°S
80°S
180°W
120°W
60°W
0°
60°E
120°E
180°W
Atmospheric measurement sites in the CarboEurope IP (in prep.)
Open / Close filter
NDSC Sites
44%
12%
8%
8%
8%
5%
10%
San Cristobal
Paramaribo
Cotonou
Nairobi
Malindi
Kuala Lumpur
Natal
Samoa
Fiji
Watukosek
Ascension
Measurement sites
All existing and planned BSRN stations in Europe, April 2003

Air Pollution becomes a global problem

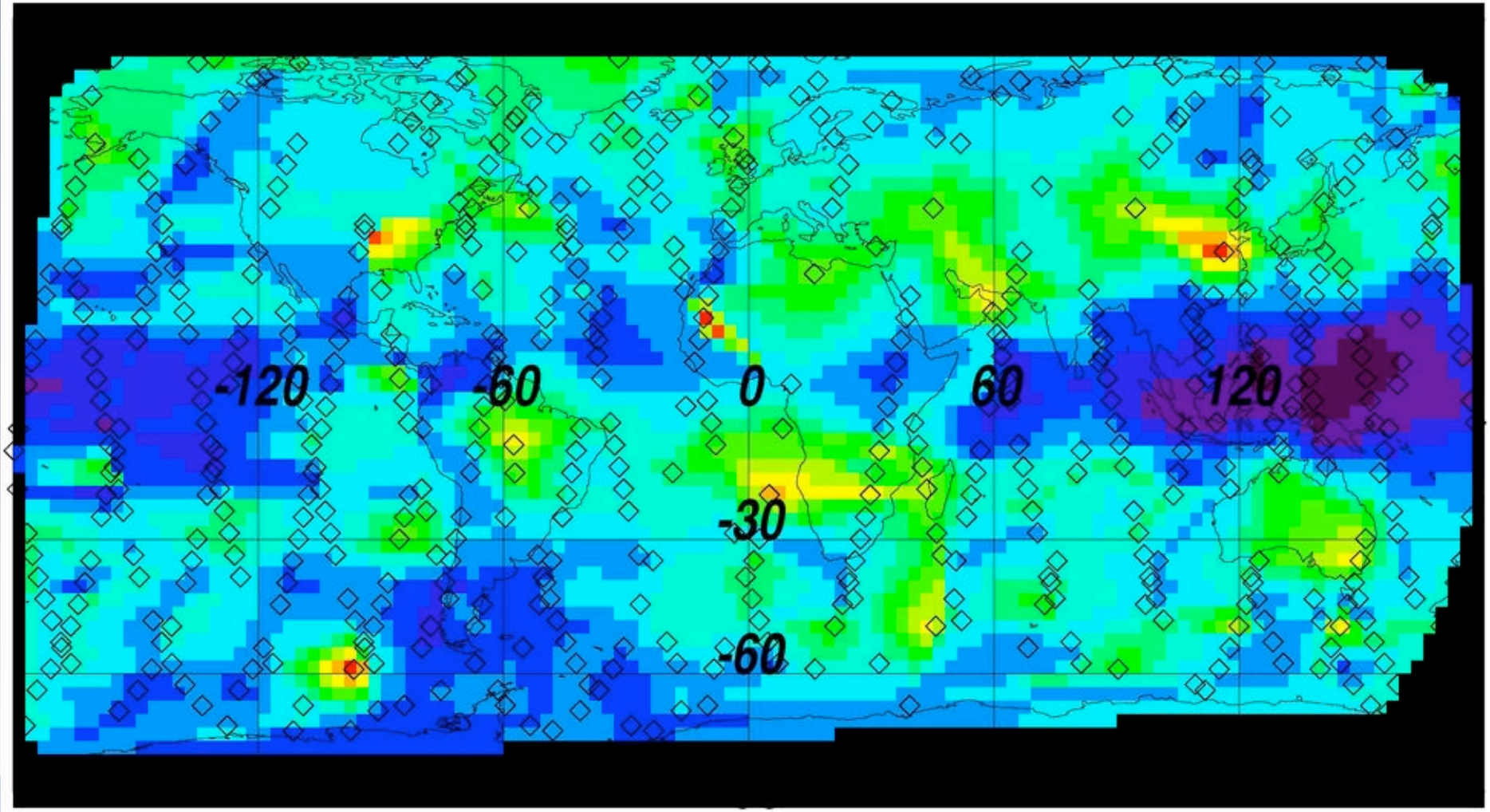


Chemical Weather seen from Space



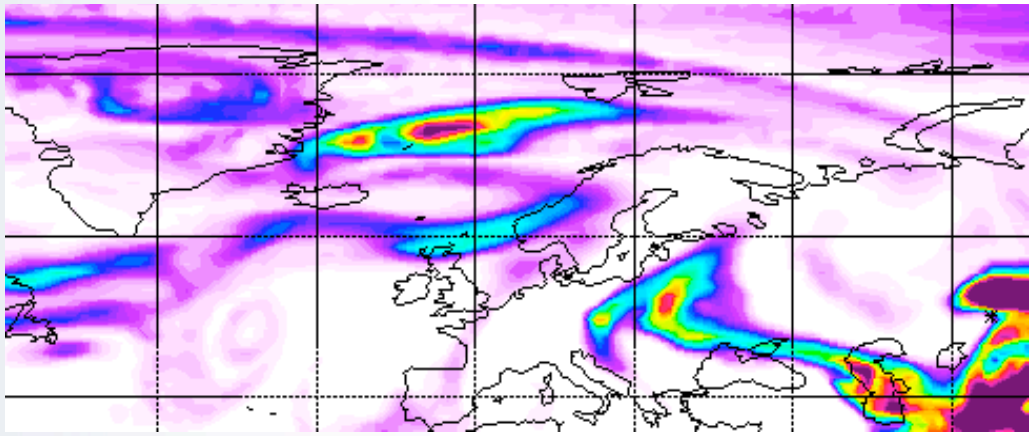
From J. Burrows

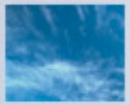
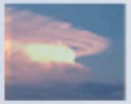
TES Lower Tropospheric Ozone (Surface - 500 hPa)



From JPL

Operational Systems:
Data Assimilation and Model Prediction

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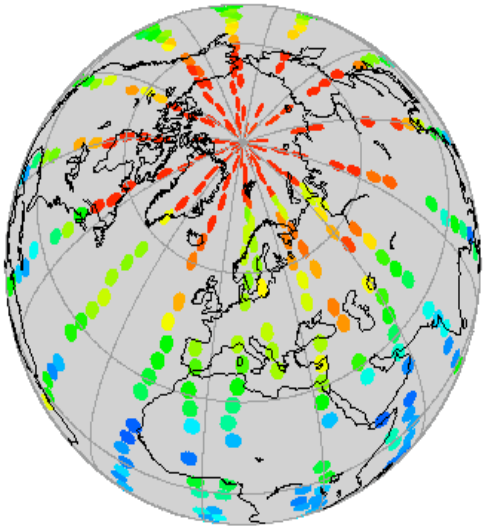
Data Assimilation

ENVISAT MIPAS
Ozone VMR at 56 hPa

Mar 17, 2004
Northern Hemisphere



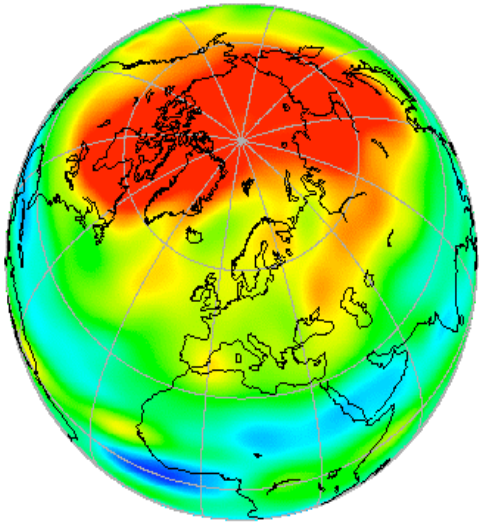
Scan Pattern
Level2 Version 4.61 / ESA
http://wdc.dlr.de

Volume Mixing Ratio
0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5

DLR

MIPAS Ozone at 56 hPa
Volume Mixing Ratio

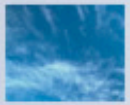
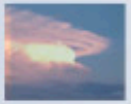
Mar 17, 2004
Northern Hemisphere



Assimilated MIPAS Observations
DLR-ROSE Version 2.7
http://wdc.dlr.de

ppm(v)
0 1 2 3

DLR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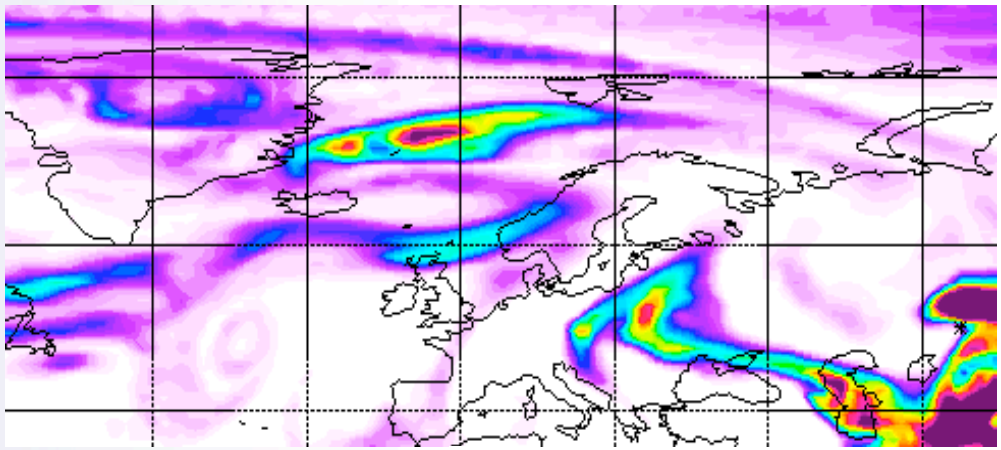
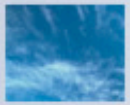
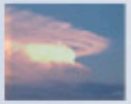
Modeling of Chemical Weather







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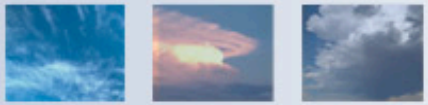
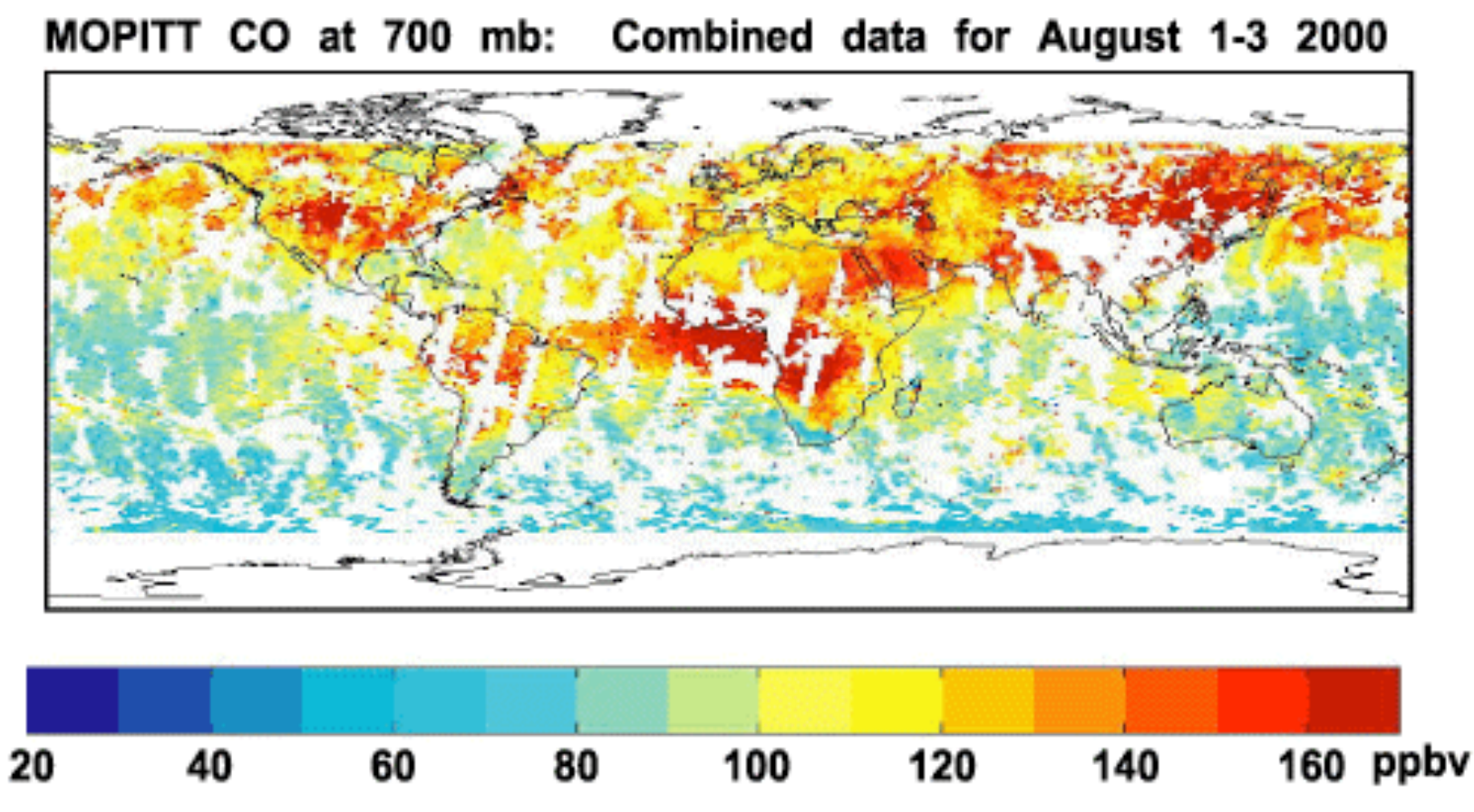
Models must accurately account for:

- **Emissions** (both anthropogenic and biogenic, including demography, shift in seasonal temperatures and the effect on energy consumption, plant and forest species, atmosphere-ocean interaction)
- **Transport** (wind, convection, mixing properties in the ABL)
- **Chemical and physical transformations** (rh, q, cloud cover and type, T, albedo and its effect on photolysis rates)
- **Removal** (precipitation frequency and amount, surface properties)



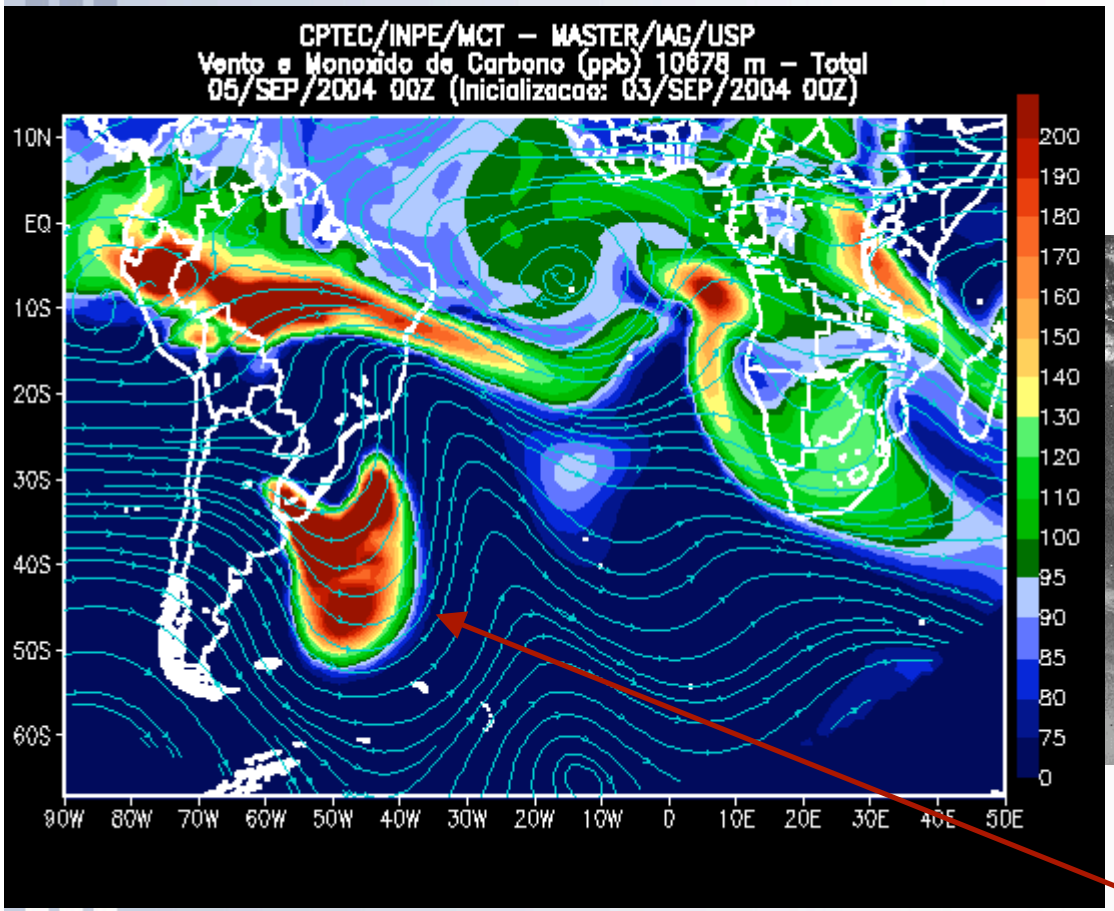
Intercontinental Transport



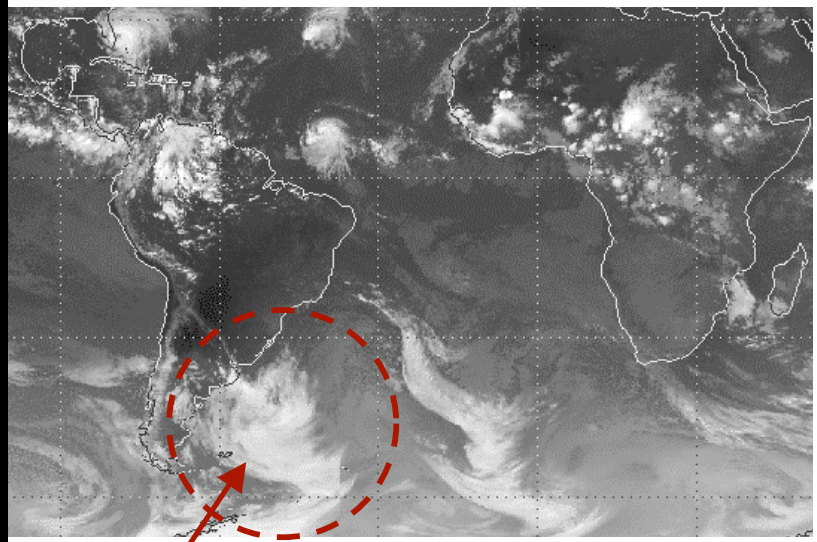
Histórico >>

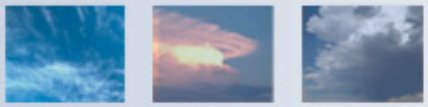
Poluição Atmosférica

Carbon Monoxide (ppb 10700 m)
Forecast for 3 and 4/September/2004



GOES+METEOSAT IR
2100Z/4/September/2004





Upper troposphere transport associated to the
a mid-latitude cold front approach

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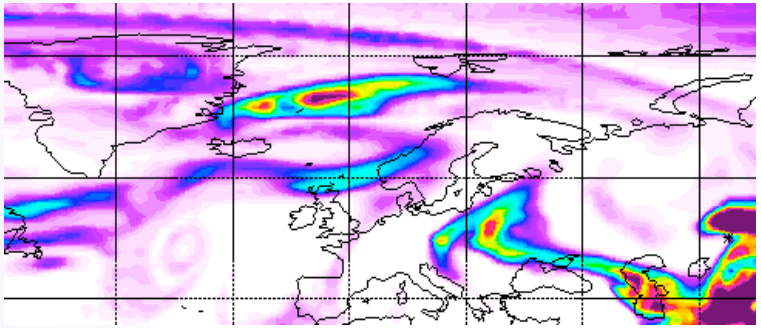
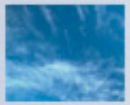
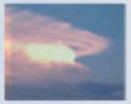
Focus in CTM-modelling vs NWP (from Ø. Hov)

Parameter	Numerical Weather Prediction	Chemical Transport Modeling
Wind speed	High wind speeds	Stagnant conditions
Wind direction	Not so important	Essential for S-R-relationships
Precipitation	Heavy rain	Length of dry periods; low intensity rain
Temperature	High and low temperatures, freezing	High temperatures – fast reactions and large biogenic emissions
Clouds	Cloud cover	Type, location, lifetime
Convection	Precipitation	BL ventilation
$\tau_{BL,res}$, H_{mix}	Not so important	Important
Specific humidity	Not so important	Important for [OH]
Ground surface	Important for fluxes of heat, momentum, moisture	Important for deposition, biogenic emissions

The EU/GEMS Project







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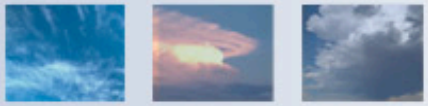
Objectives of GEMS: Global Operational System

- 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



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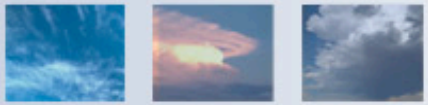
Monitoring and Forecasting

- Operational deliverables will include current and forecast three-dimensional ***global*** distributions (four times daily with a horizontal resolution of ***50 km***, 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)



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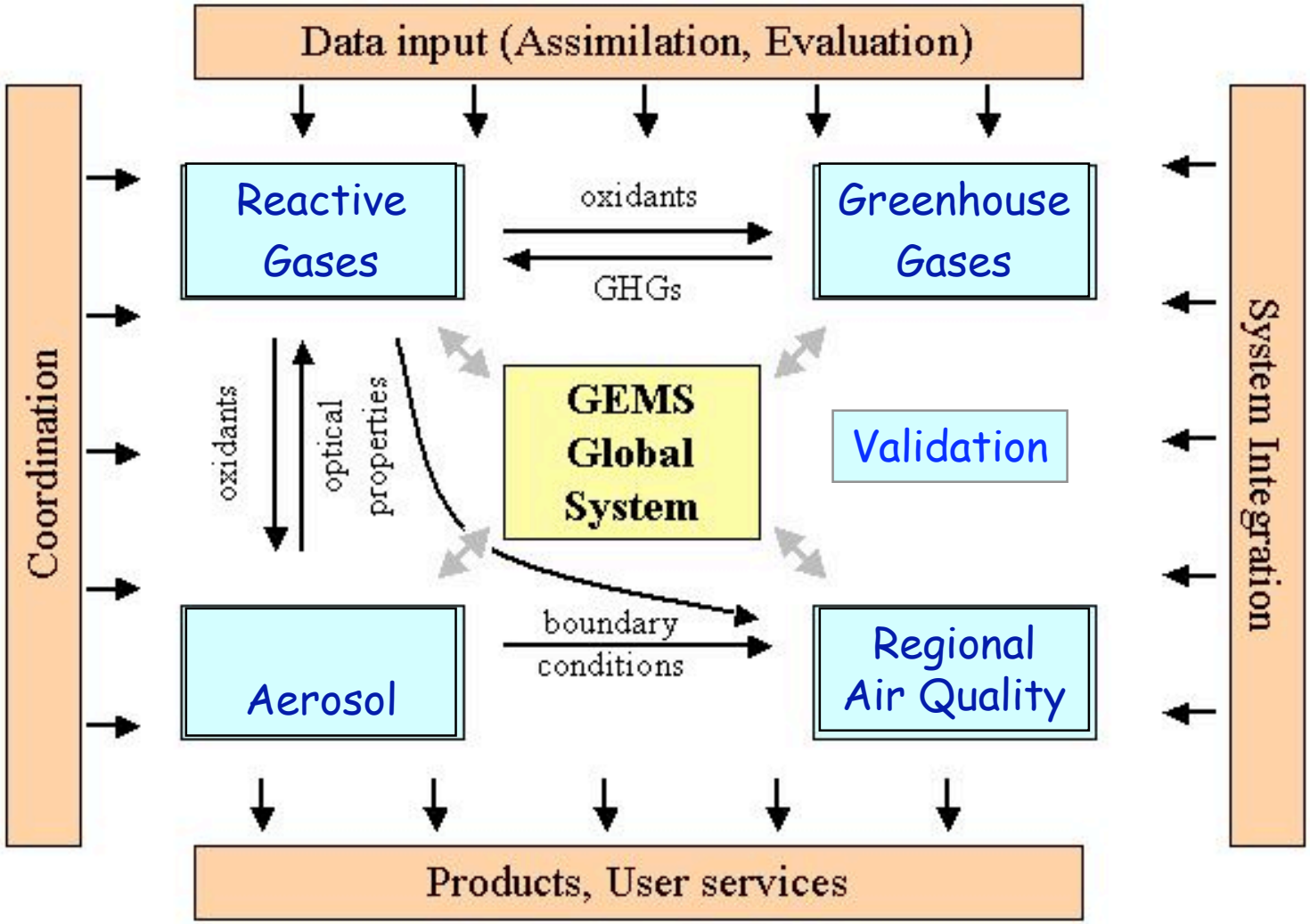
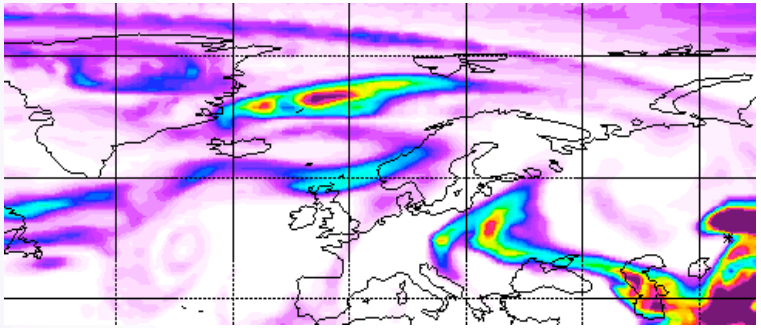
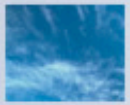
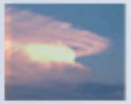
GEMS Organisation



Chemical Weather in the Future:
Impact of Climate Change

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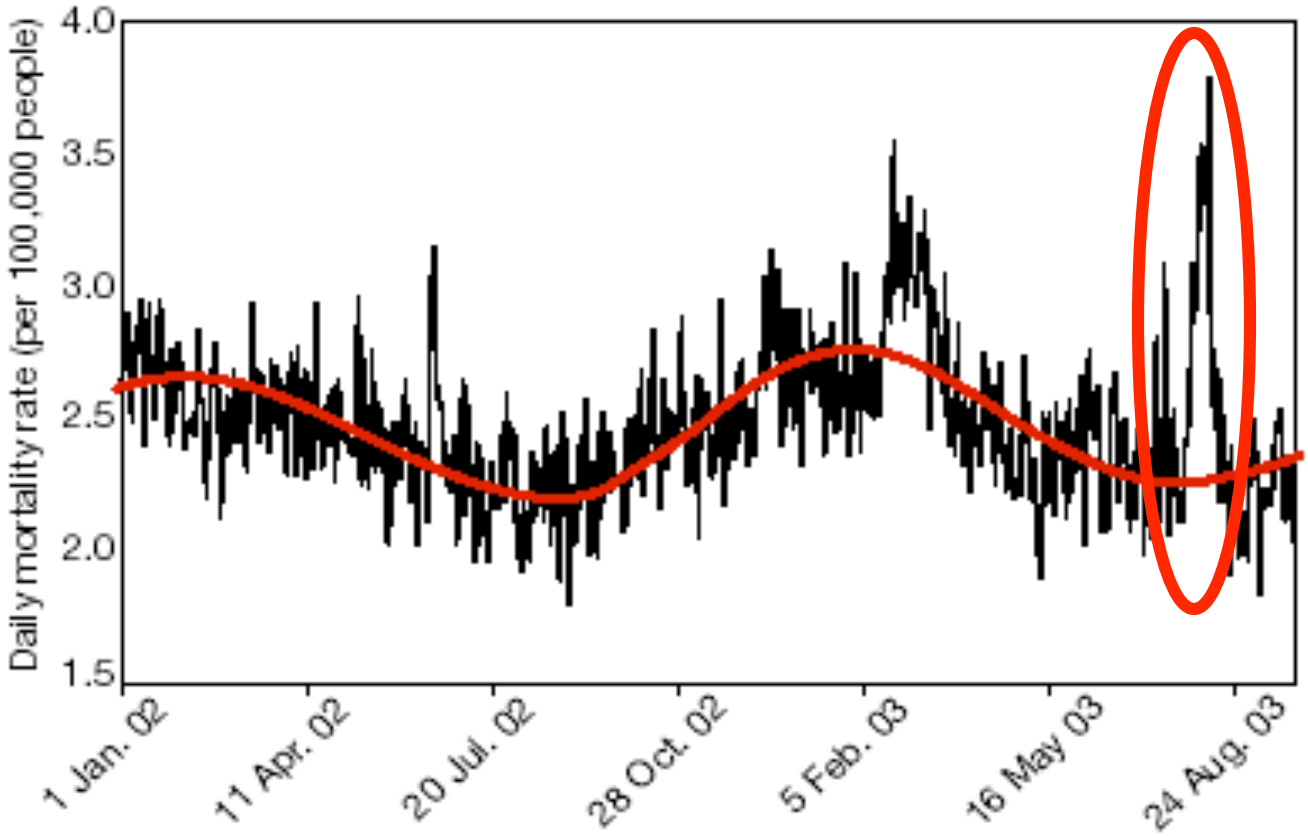
European summer drought 2003:

Crop damage 12,3 billion USD, forest fires Portugal 1,6 billion USD, thawing of tundra caused slides; 22,000-35,000 heat wave related deaths in Europe 1-15.8.2003, in France death rate increased by 54%, significant in all age groups above 45 years. Figure from Baden-Württemberg (Schär and Jendritzky Nature 2.12.2004 p. 560). 1/3 of deaths ozone related.



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In summer 2003, an unprecedented heat wave in Western Europe.

International Herald Tribune
Wednesday, September 10, 2003 | 5

Heat claimed 15,000 in France

Estimate by funeral director exceeds latest by government

From news reports

PARIS: The number of people who died in France because of the August heat wave is 15,000, the country's largest undertaker estimated Tuesday, placing the death toll about 3,500 higher than the official government figure.

Isabelle Dubois-Costes, a spokeswoman for General Funeral Services, said the revised total includes deaths from the second half of August, after record-breaking temperatures had abated.

Late last month, the government issued its official estimate of 11,435, but the Health Surveillance Institute, which calculated the death toll for the government, said Tuesday that the total only counted deaths through the first

died. At the time, the government put the figure at a maximum of 3,000.

The heat wave brought suffocating temperatures of up to 40 degrees Celsius (104 degrees Fahrenheit) in the first two weeks of August in a country where air conditioning is rare. The heat baked many parts of Europe, but nowhere was

The revised total includes deaths from the second half of August.

the toll higher than in France.

While the bulk of the victims — many

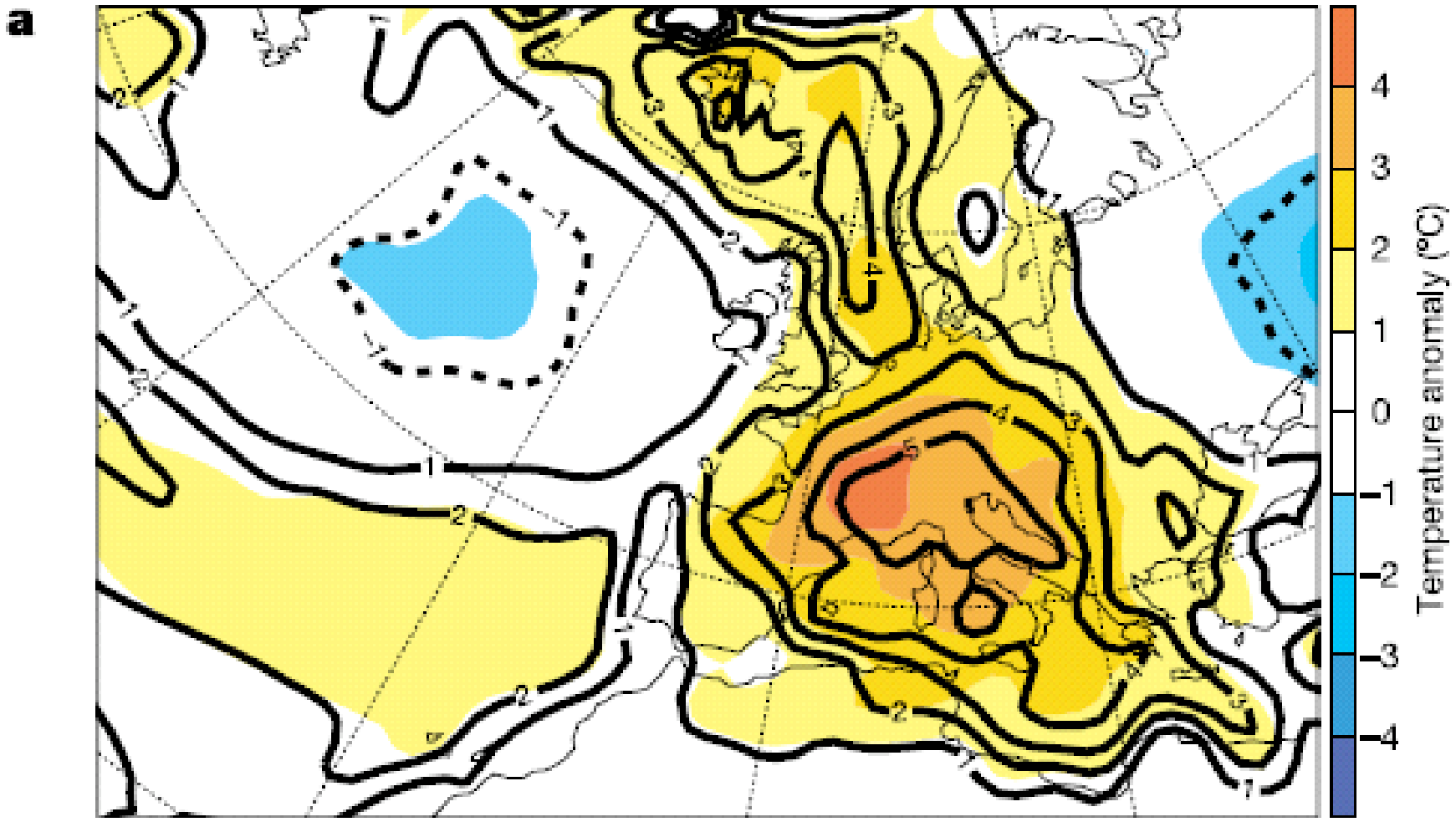
families were away on lengthy August vacations. Authorities reportedly had difficulty making contact with survivors who were away on vacation.

A team of medial experts named by the Health Ministry to conduct the first official inquiry into the crisis issued a scathing report Monday that found "an error in anticipation, organization and coordination," and said "the response was not suited" to the situation.

The experts said the "compartmentalization" of services between the health and other ministries and workers in the field prevented a pooling of available information about the scope of the crisis.

French doctors on Tuesday reacted angrily to the government report.

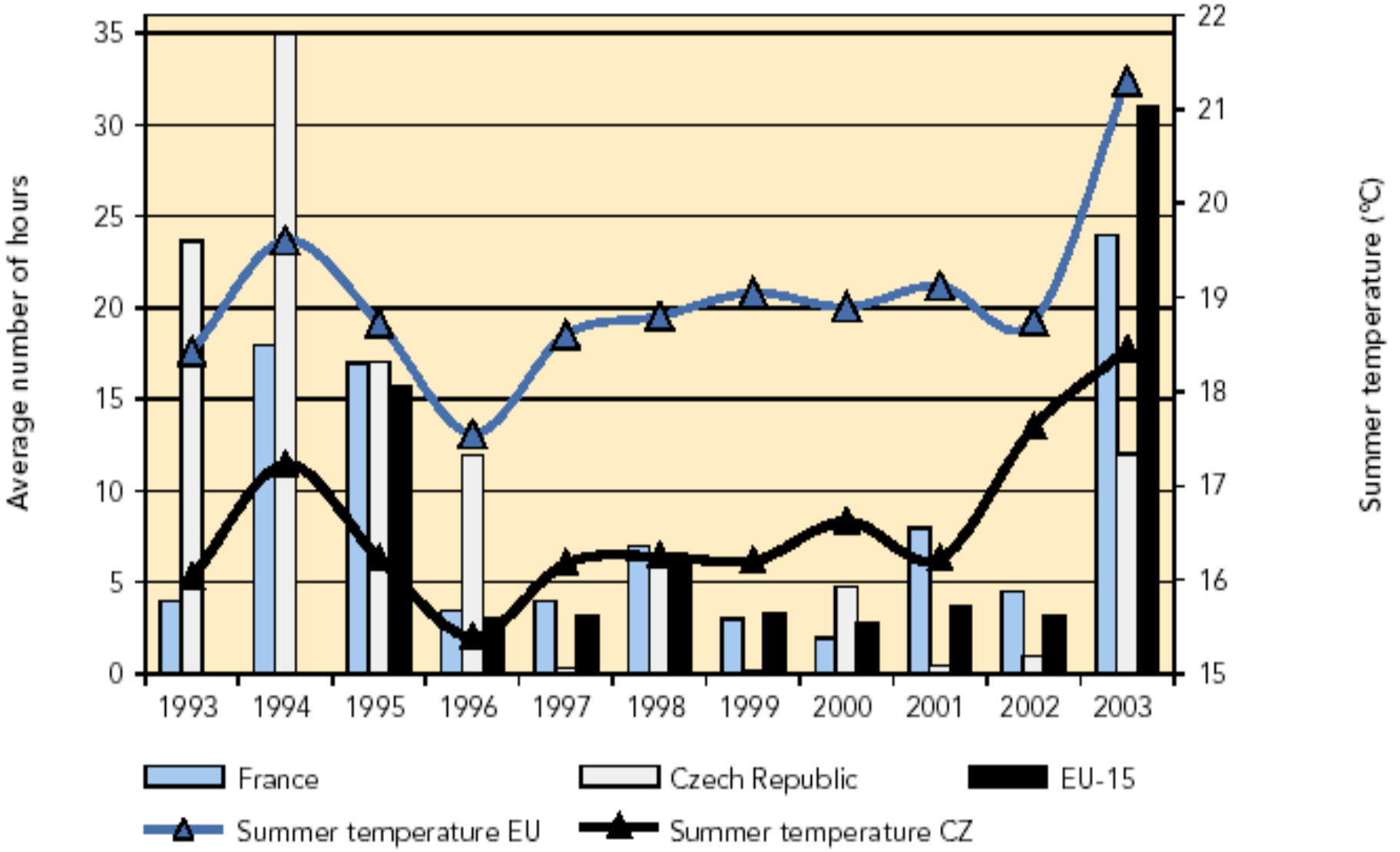
Gilles Brucker, director of the Health



Schär et al., 2004, Nature 427, 332-336

ESSL/ NCAR

Total number of hours with ozone concentration higher than 180 µg/m³ divided by the number of operational stations for France, the Czech Republic (CZ) and the European Union; average temperature for the period May–August for the Czech Republic and western Europe (http://www.klimadiagramme.de/Europa/special01.htm)



More Fires under climate Change?

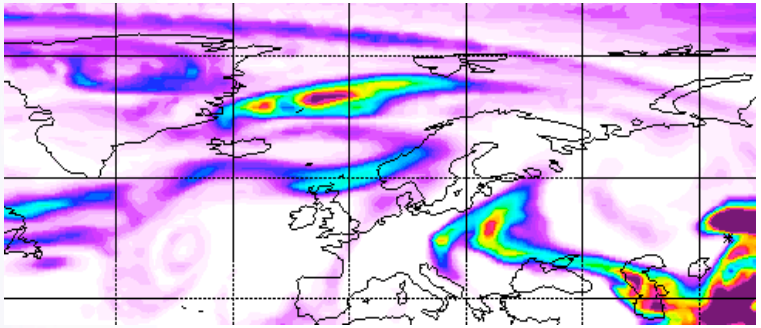
- August 2003: Hundreds of boreal forest fires in Russia and Canada and in the temperate forests of the USA (210.000km2 in Russia burnt)
- Northern summer 1998 boreal zone fires in Russia and Canada with plume smoke entering the lower stratosphere residing till October
- Significant increase in frequency and severity of boreal fires predicted under climate change (longer fire seasons and drier conditions)

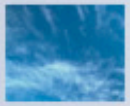
Fromm and Bevilacqua, Atm.Env. 2004, [illegible]

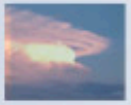
More lightning under climate change?

- The global surface source of NOx is about 40 MtN/a (50-50 anthropogenic and biogenic)
- Lightning source about 5 MtN/a (1-20 MtN/a range)

Conclusions







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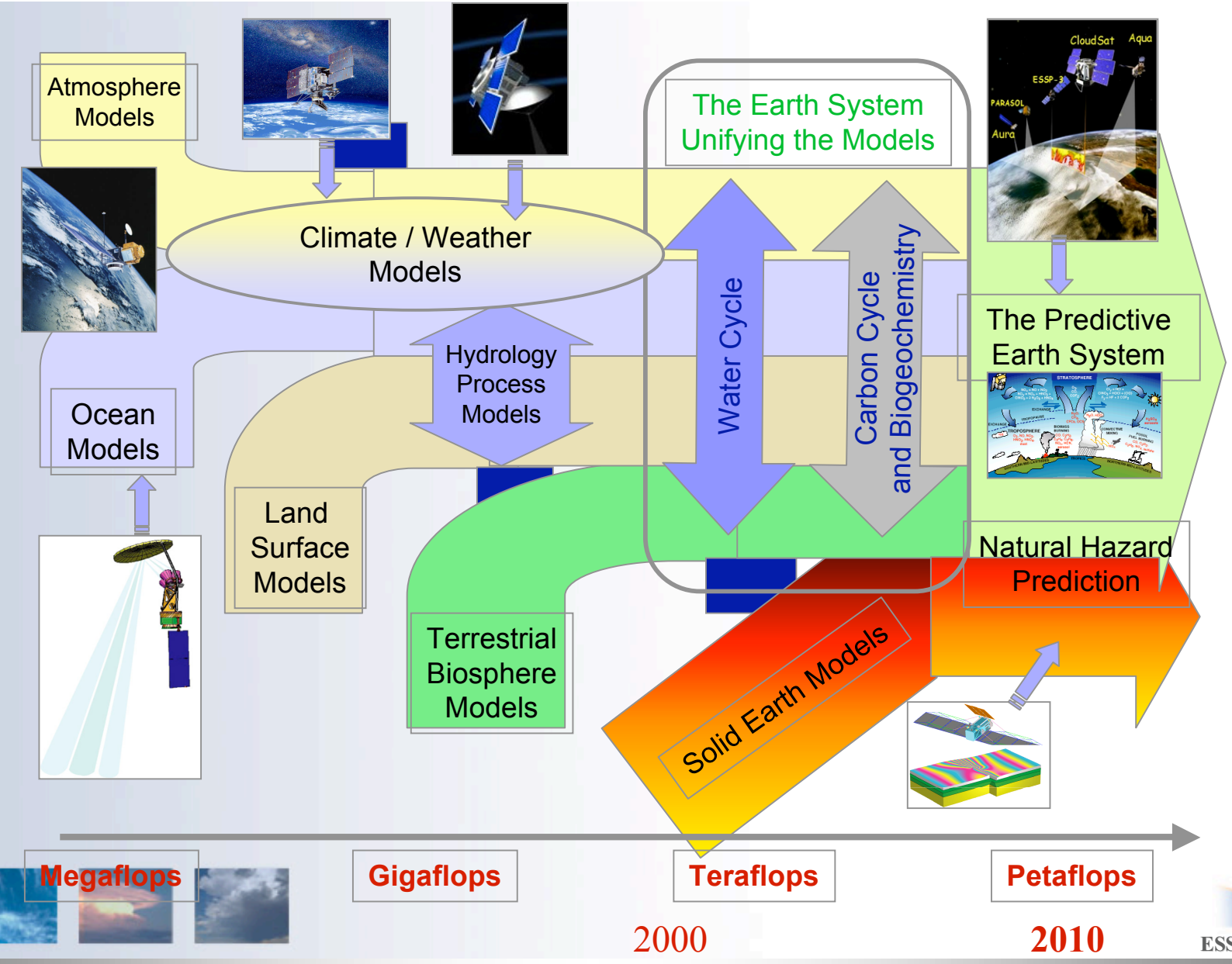
Towards Operational Earth System Monitoring, Assimilation and Prediction Systems



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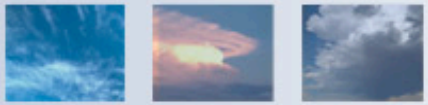
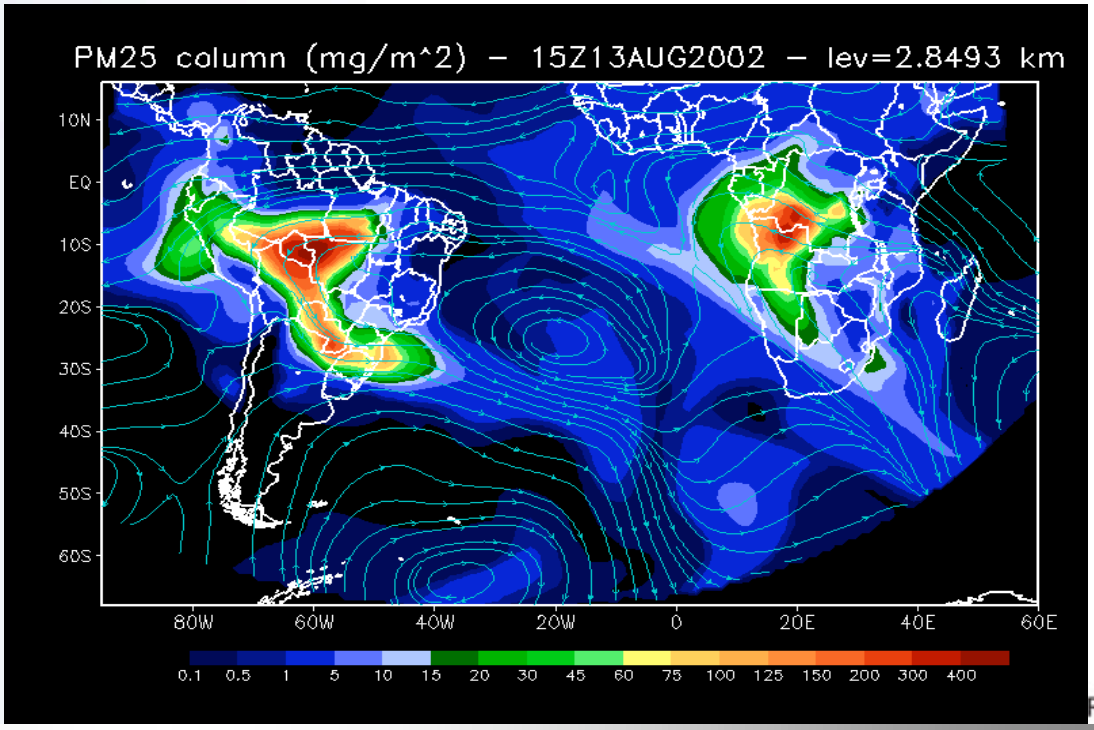
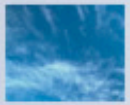
Issues

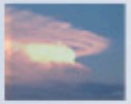
- An **integrated strategy** that combines space observations of chemical compounds with other types of measurements (ground, commercial aircraft, etc.) must be established, and a data system providing data for operational assimilation and prediction must be developed (IGACO).
- Operational aspects must be complemented by a strong **research** component, and adequate support.
- Powerful **supercomputers** and **data systems** are needed to perform the chemical weather predictions at sufficiently high resolution, and provide timely information to the public.



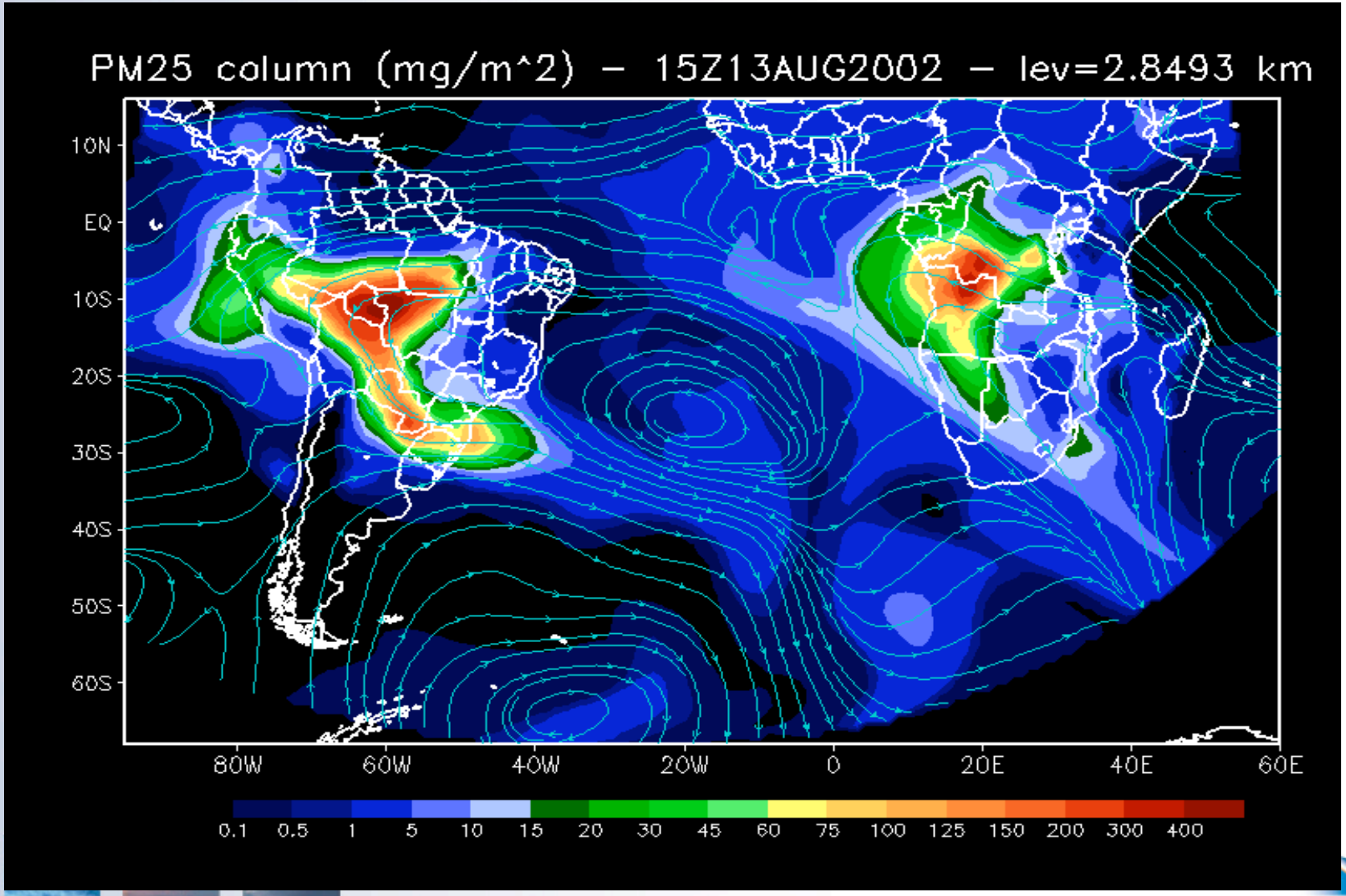
The End


PM25 column (mg/m^2) – 15Z13AUG2002 – lev=2.8493 km
10N
EQ
10S
20S
30S
40S
50S
60S
80W
60W
40W
20W
0
20E
40E
60E
0.1 0.5 1 5 10 15 20 30 45 60 75 100 125 150 200 300 400





Model output for PM2.5 column – Aug 2002 : South American and African biomass burning plumes



From INPE/CPTEC, Brazil

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