

“Weather Data Information Supersite” Candidate Flagship

Baudouin Raoult
European Centre for Medium-Range Weather
Forecasts (ECMWF)

■ Member States ■ Co-operating States ■ Under negotiation

ECMWF

An independent
intergovernmental
organisation

established in 1975

with
19 Member States
15 Co-operating States

Supporting States and Co-operation

Austria
Belgium
Denmark
Finland
France
Germany
Greece

Iceland
Ireland
Italy
Luxembourg
The Netherlands
Norway
Portugal

Spain
Sweden
Switzerland
Turkey
United Kingdom

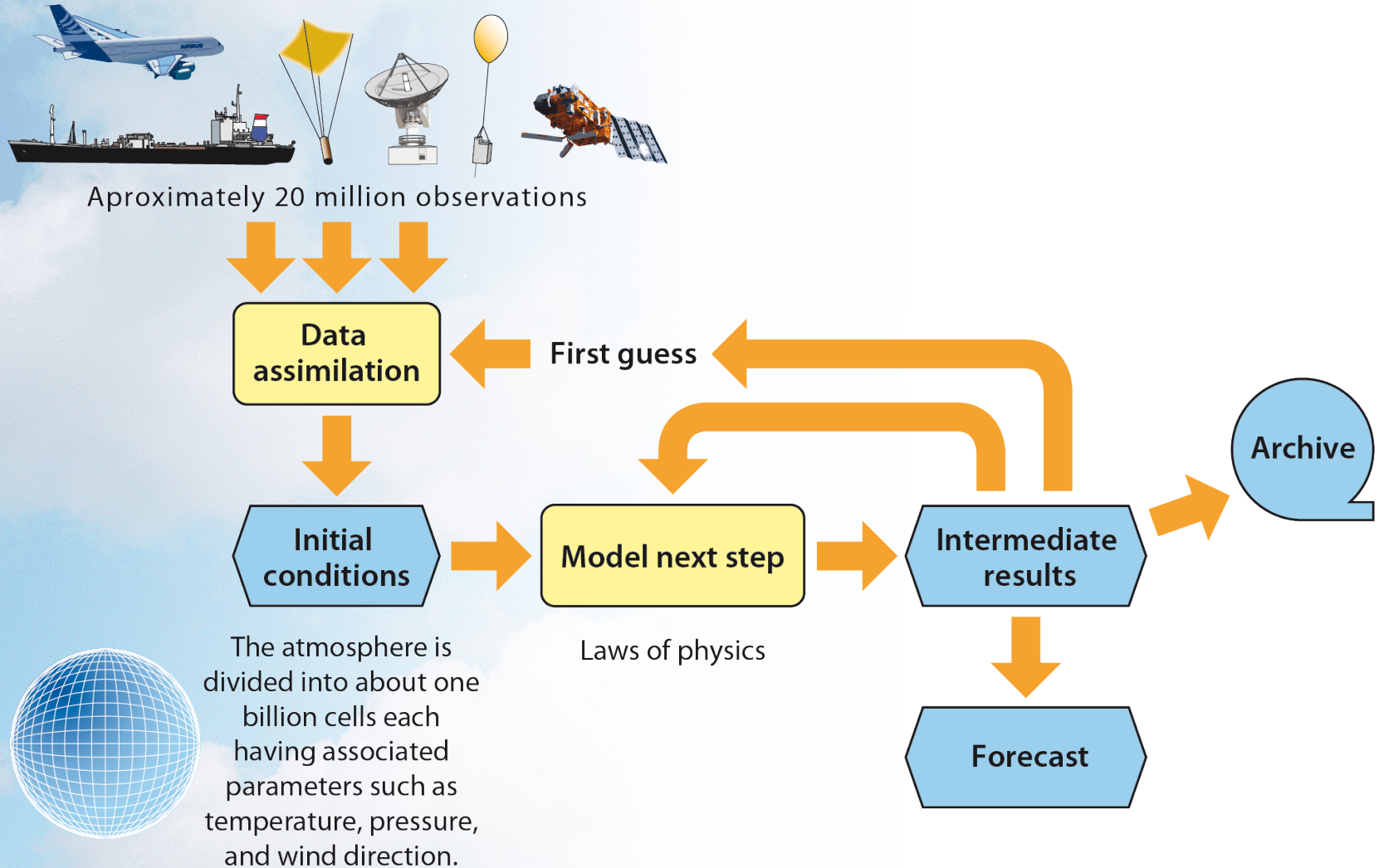
Co-operation agreements or working arrangements with:

Bulgaria
Czech Republic
Croatia
Estonia
former Yugoslav Republic of Macedonia
Hungary
Israel

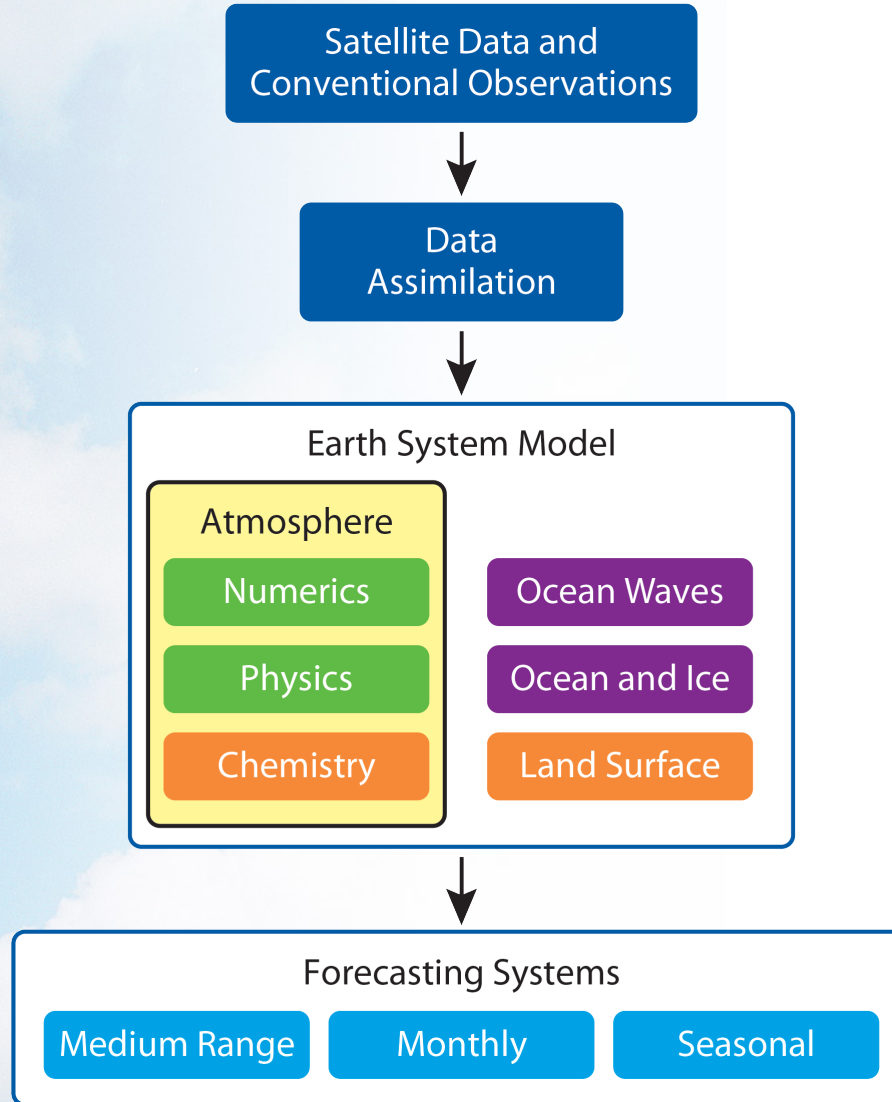
Latvia
Lithuania
Montenegro
Morocco
Romania
Serbia
Slovakia
Slovenia

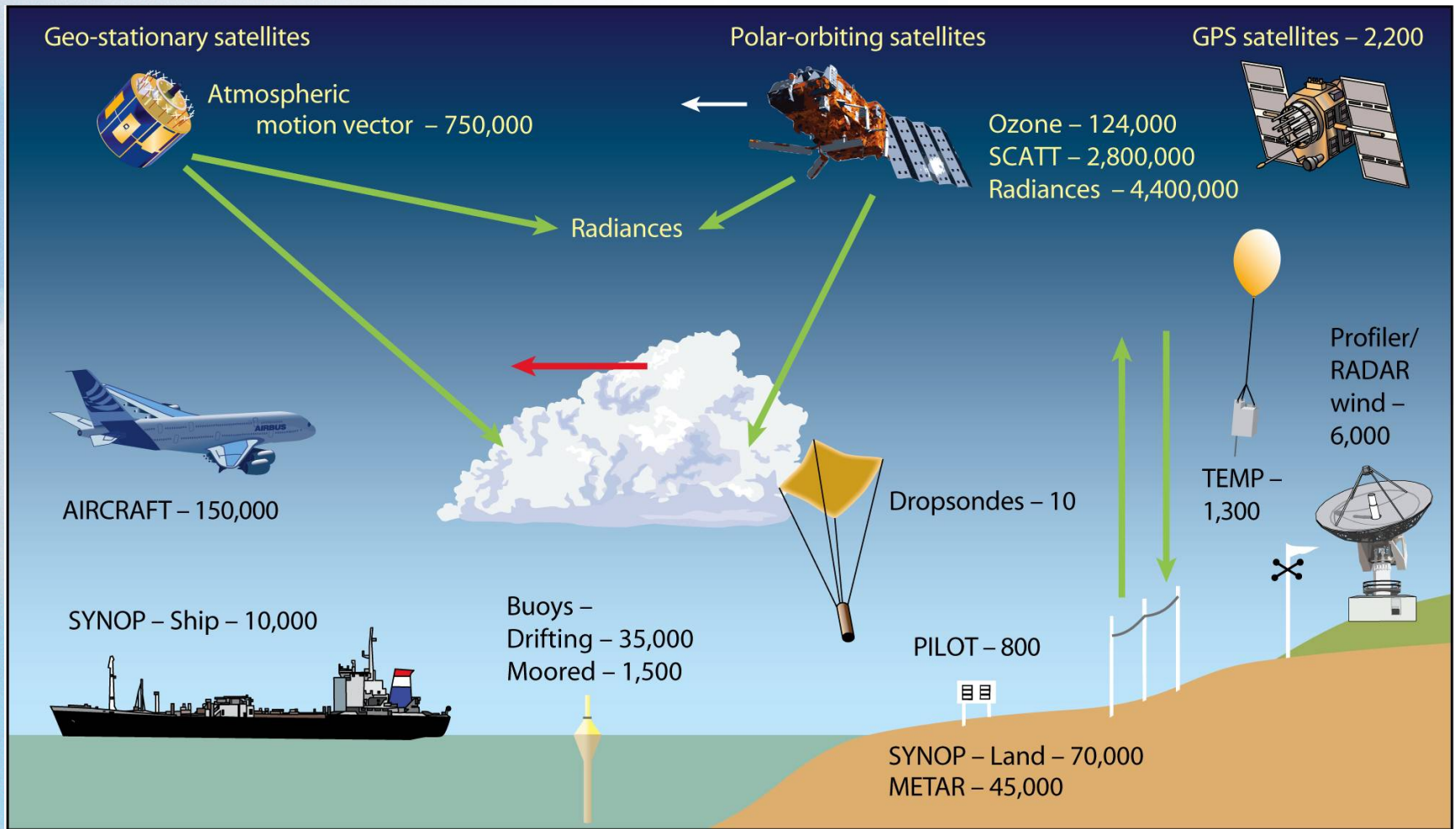
ACMAD
ESA
EUMETSAT
WMO
JRC
CTBTO
CLRTAP

A basic description of our models



The forecast process

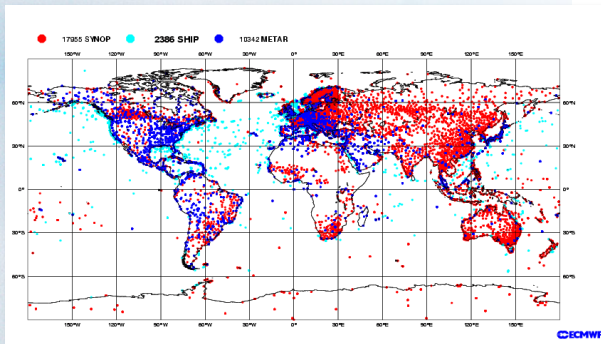




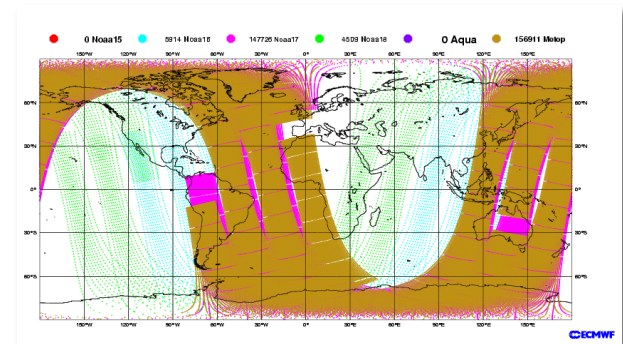
Data sources for the ECMWF Meteorological Operational System (EMOS)

Major assimilated data sets

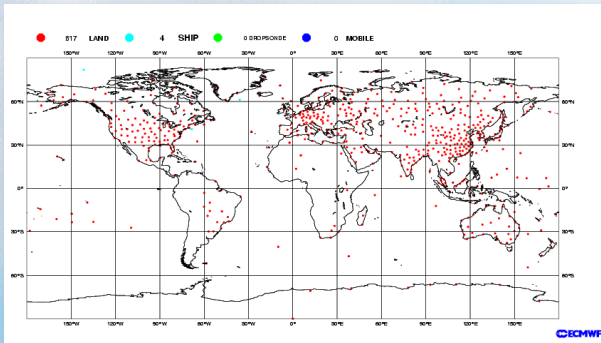
Surface stations



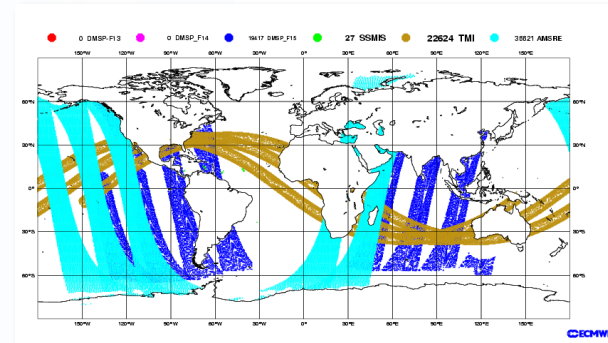
Polar, infrared



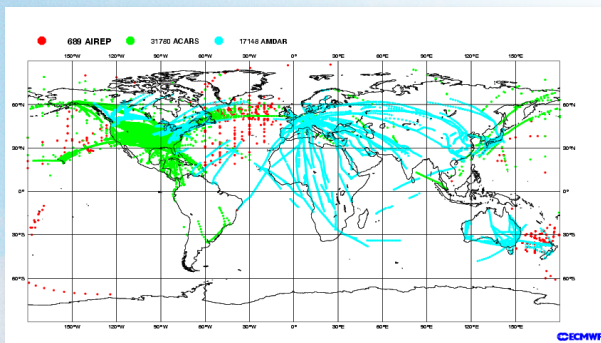
Radiosonde balloons



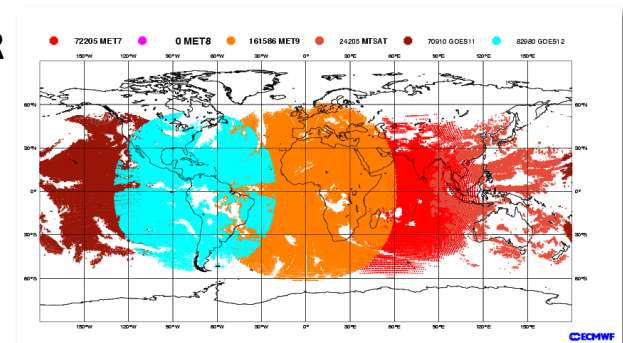
Polar, microwave



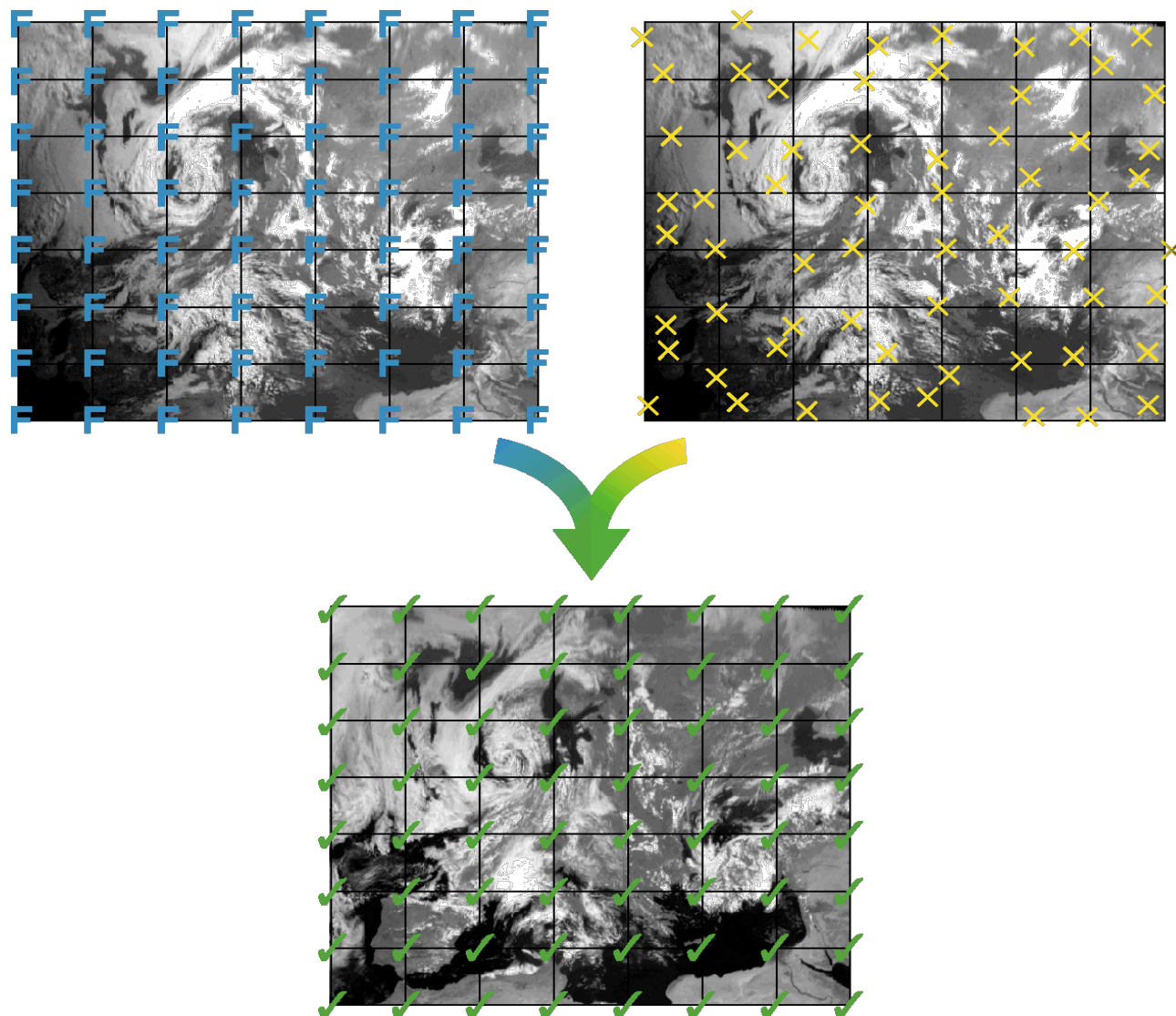
Aircraft



Geostationary, IR

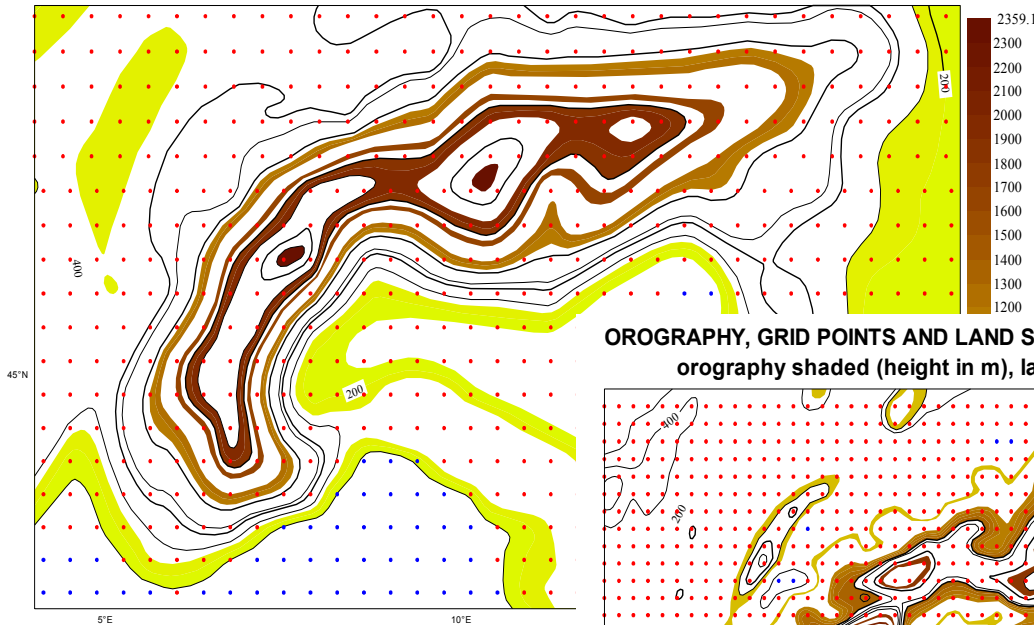


Data assimilation

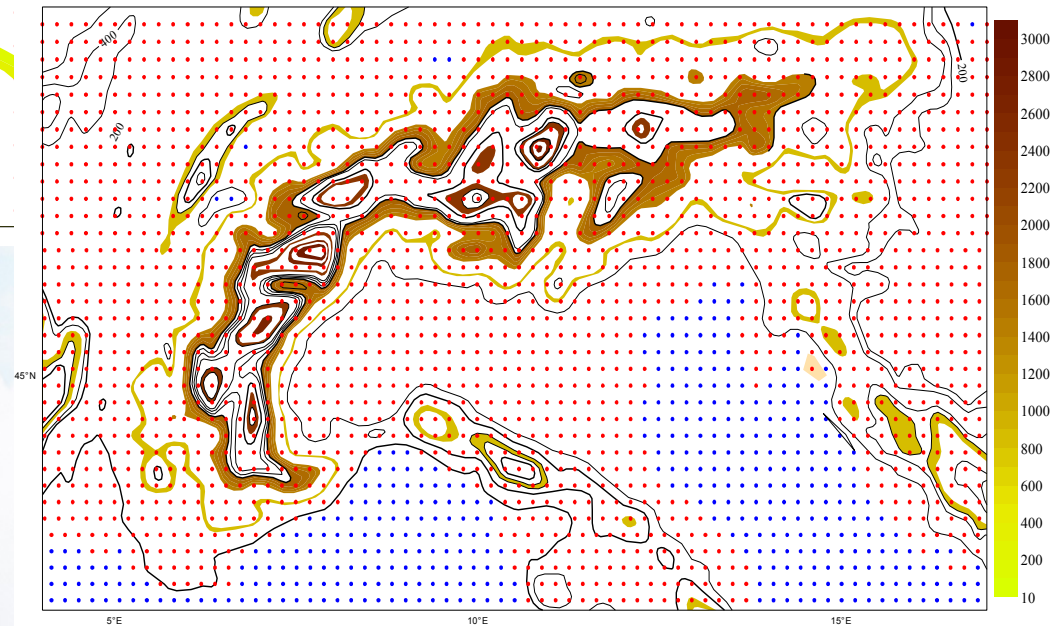


Model grids for ENS (32 km) and HRES (16 km)

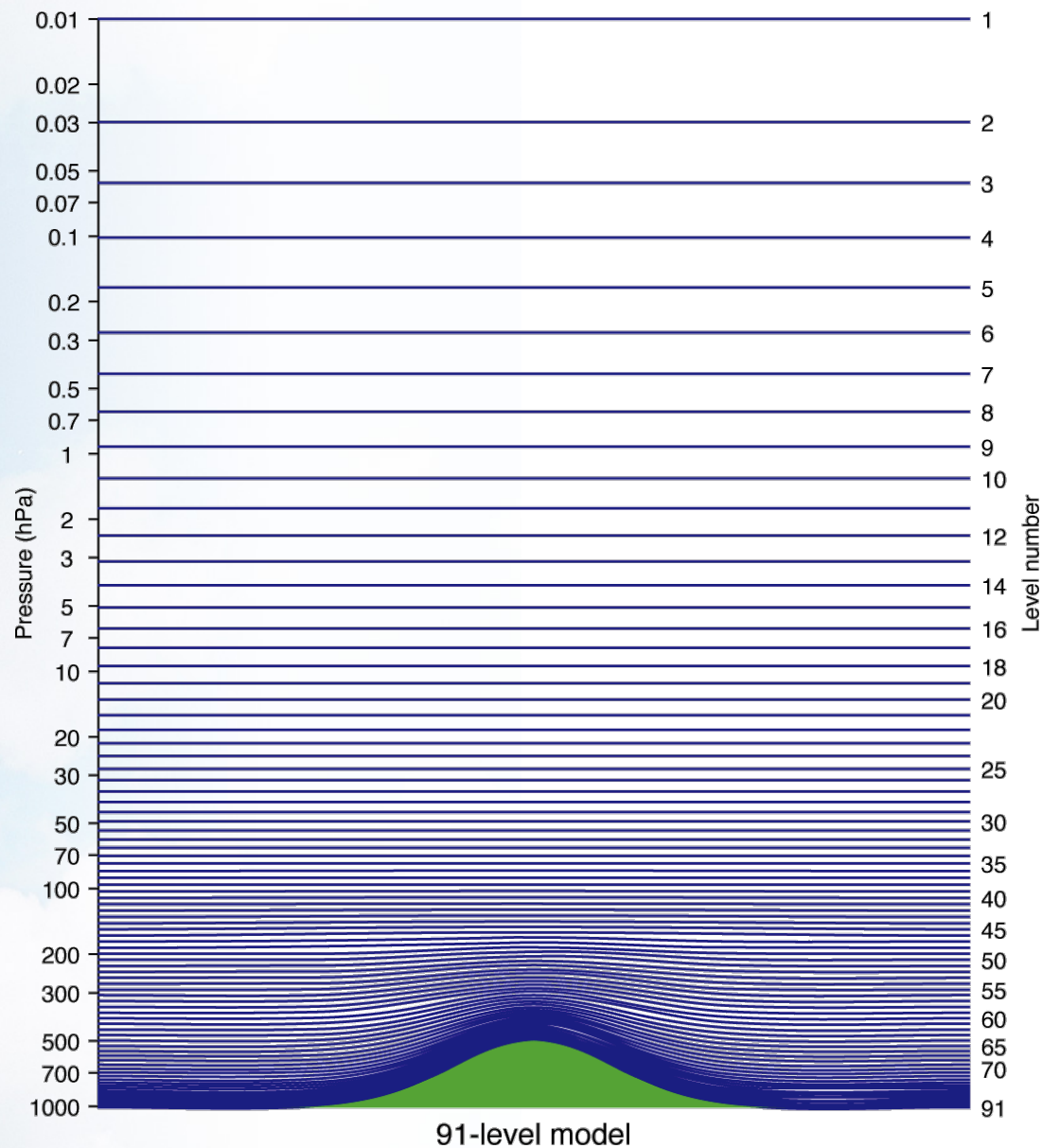
OROGRAPHY, GRID POINTS AND LAND SEA MASK IN TL 639 (EPS 2010) ECMWF MODEL
orography shaded (height in m), land grid points (red), sea grid points (blue)



OROGRAPHY, GRID POINTS AND LAND SEA MASK IN TL 1279 (OP 2010) ECMWF MODEL
orography shaded (height in m), land grid points (red), sea grid points (blue)

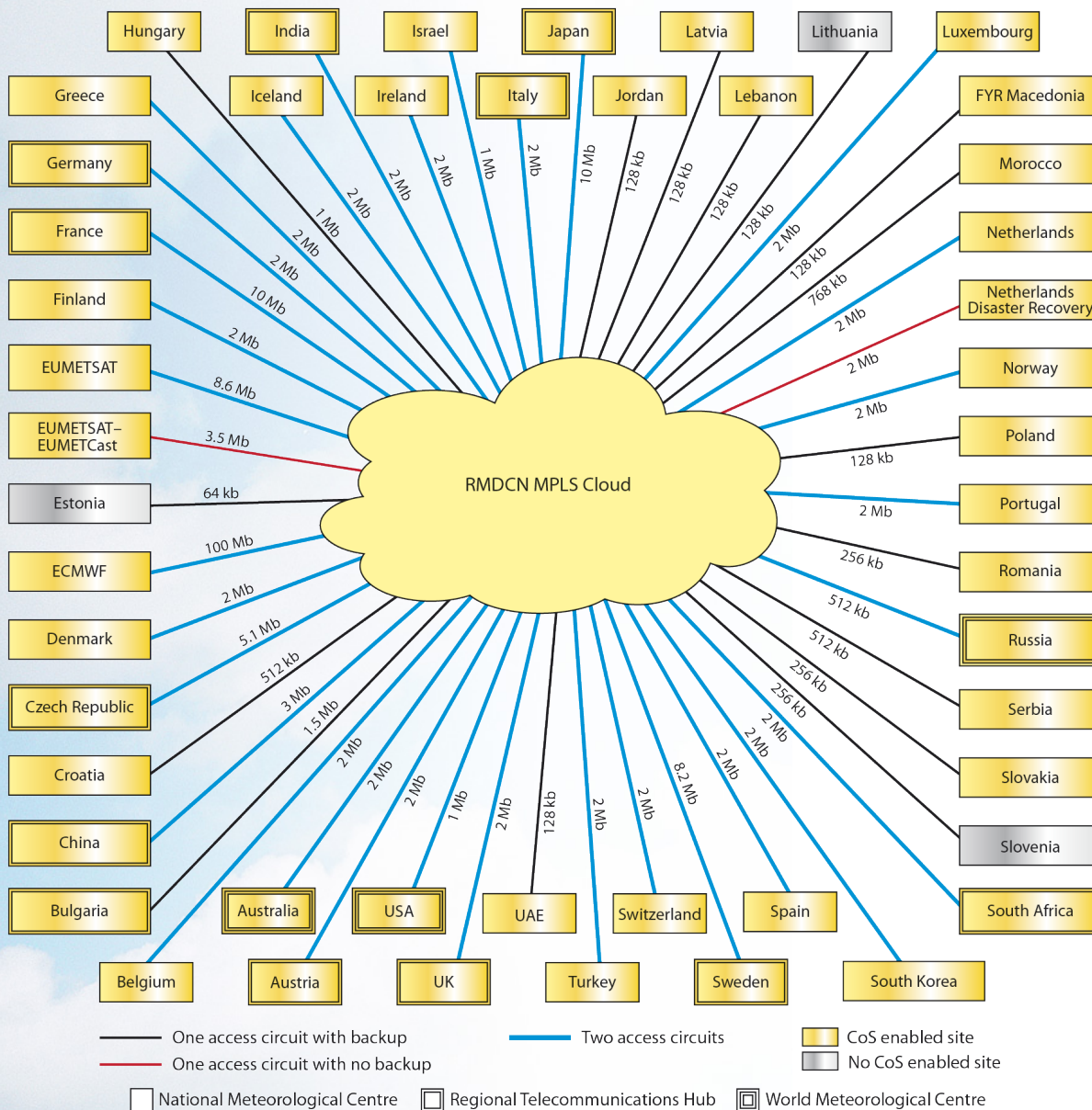


Operational model levels (91-level model)

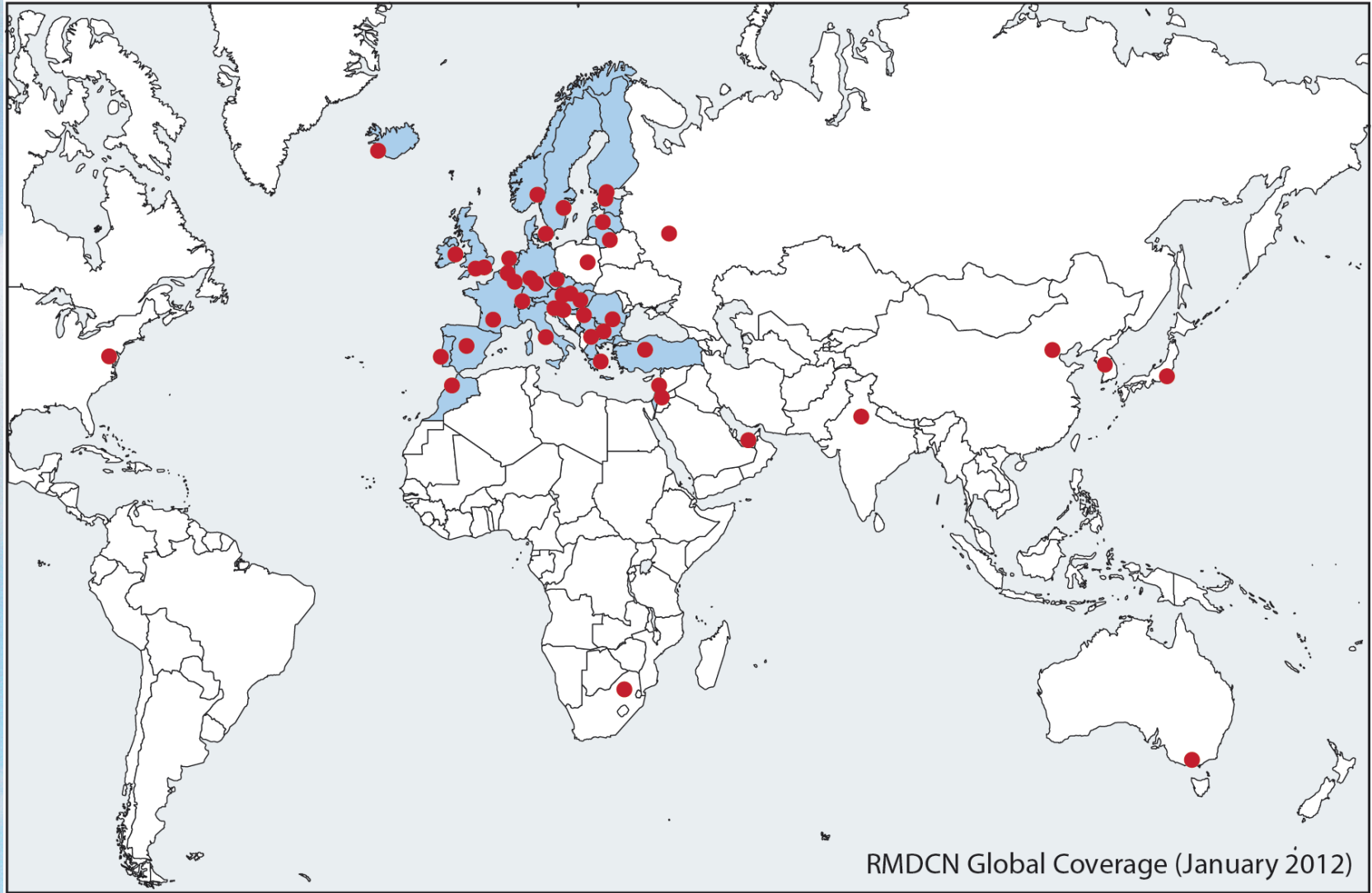


RMDCN – Regional Meteorological Data Communication Network

(January 2012)



RMDCN Connections



Supercomputers at ECMWF

- ECMWF has a long history of using High Performance Computing in NWP
 - 1978 – 1996: Cray (Cray-1A, XMP, YMP, C90, T3D)
 - 1996 – 2002: Fujitsu (VPP700, VPP700E, VPP5000)
 - 2002 – today: IBM (Power4, Power5, Power6)



Current system

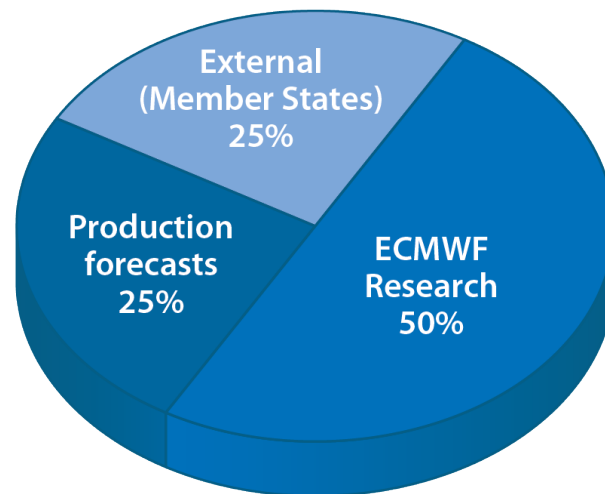
- **IBM Cluster 1600**

- Two identical systems for resiliency
- 310 Teraflops peak performance (310×10^{12})
- 20 Teraflops sustained on ECMWF's codes
- 16,640 processor cores
- Power consumption: 2.5 MW



- **Allocation of ECMWF's computing resources**

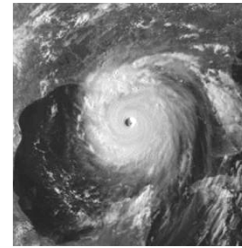
- 25% Operational activities
- 50% ECMWF research activities
- 25% Member State users (throughout Europe)



The ECMWF archive

- The largest NWP archive worldwide
- Built since ECMWF operations started in 1979
- Holds more than **22.5 petabytes**
- More than **23 terabytes** added daily
- Contains:
 - All observations used
 - All analyses
 - All forecasts
 - Reanalyses
 - Research experiments and projects
- Accessible by **registered users** in the Member States
- Holds several **publicly accessible** datasets

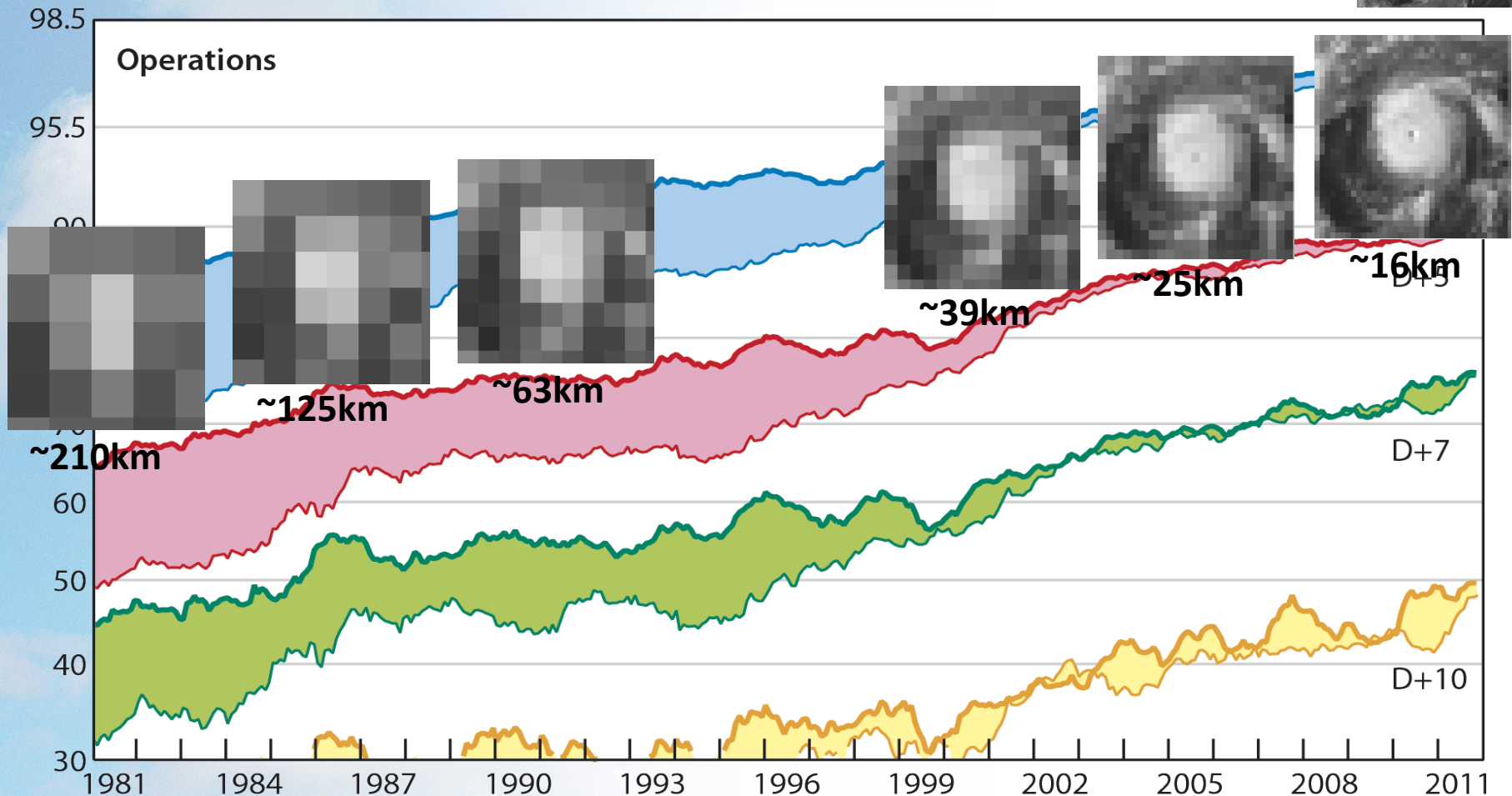
Evolution of ECMWF scores comparison northern and southern hemispheres



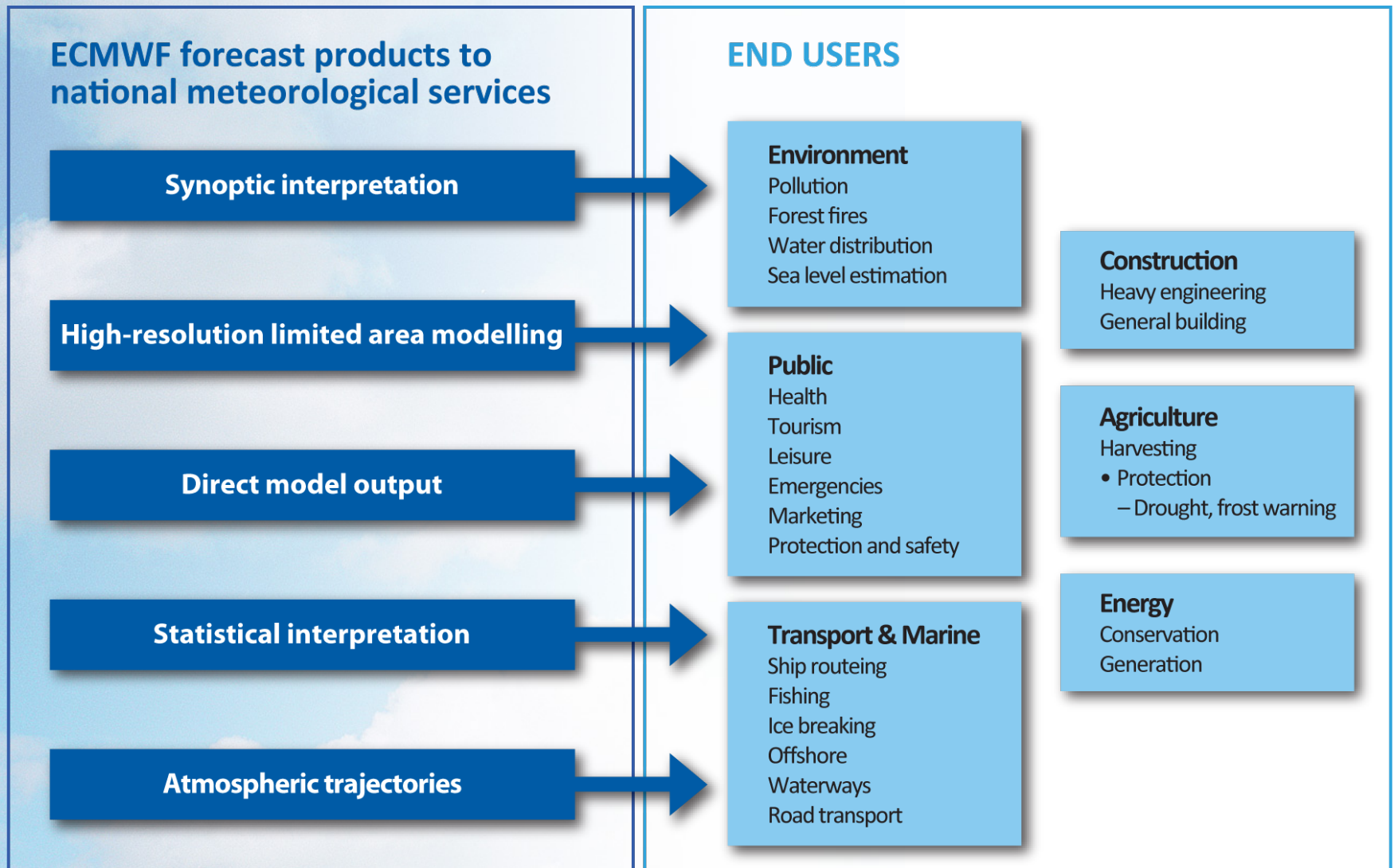
Anomaly correlation of 500 hPa height forecasts

— Northern hemisphere

— Southern hemisphere



Application and use of ECMWF products in the Member States



ECMWF interest in Helix Nebula

- The Group on Earth Observations (**GEO**) started implementing the Global Earth Observation System of Systems (**GEOSS**). **GEOWOW**, short for “GEOSS interoperability for Weather, Ocean and Water”, is a **EU funded project** supporting this objective.
- GEOWOW’s main challenge is to improve Earth observation data **discovery**, **accessibility** and **exploitability**, and to evolve GEOSS in terms of interoperability, standardization and functionality.
- In the context of GEOWOW, ECMWF has been introduced to the Helix Nebula initiative by Terradue
- ECMWF is considering building this flagship on two core GEOSS data sets to which it is contributing:
 - The **TIGGE dataset**, in the context of GEOWOW
 - The **ERA dataset** (ECMWF re-analysis) in the context of other EU funded projects.



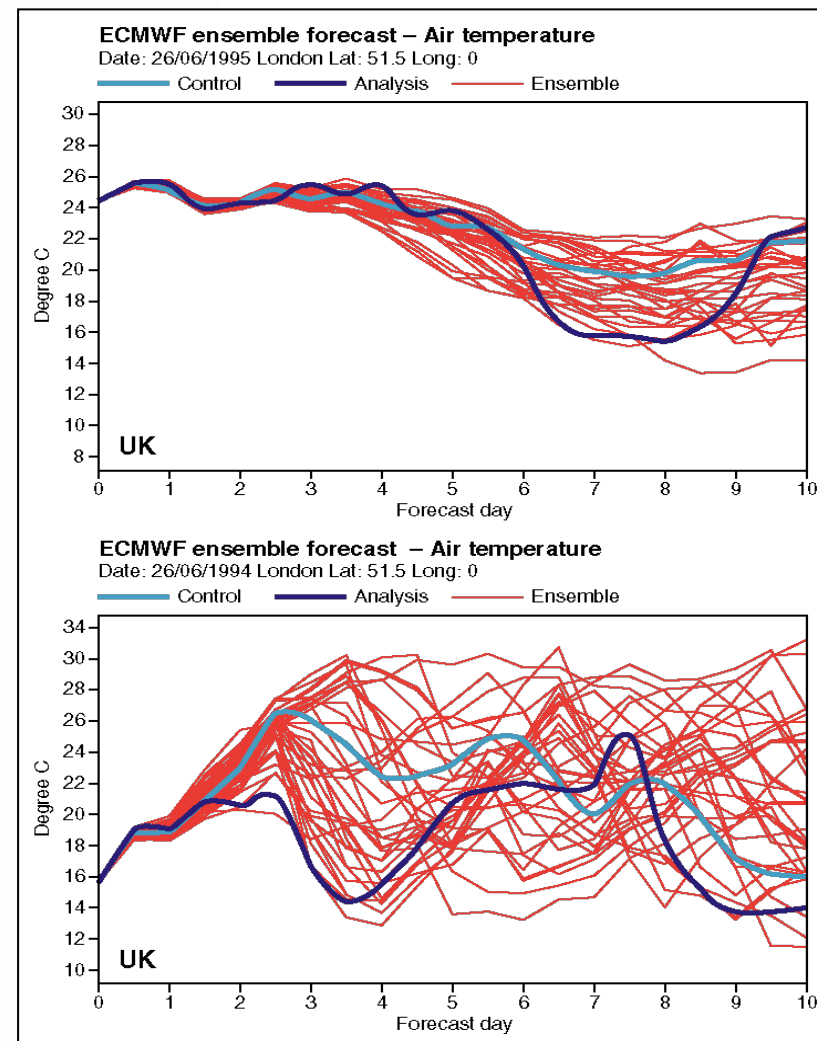
The TIGGE dataset: Chaos and weather prediction

The atmosphere is a chaotic system

- Small errors can grow to have major impact (**butterfly effect**)
- We can **never** perfectly measure the current state of the whole atmosphere
- This limits detailed weather prediction to a **week** or so ahead

Ensemble Forecasts

- Parallel set of forecasts from very slightly **different initial conditions** and model formulation
- Assess **uncertainty** of today's forecast

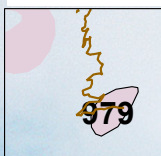
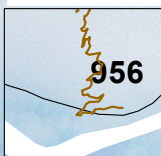


AN 19871016, 06GMT

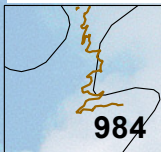
EPS Cont FC +66 h

MSLP 66-h forecasts for 16-Oct-1987

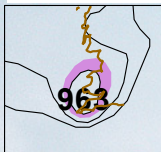
Multi-valued forecast, the EPS



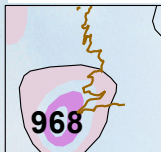
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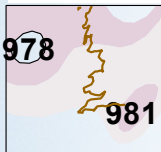
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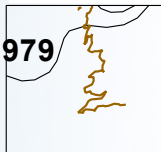
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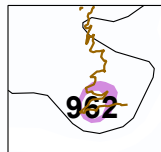
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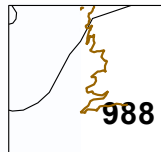
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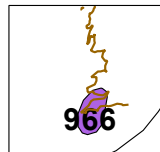
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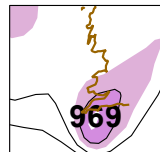
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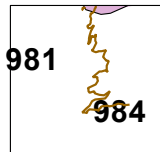
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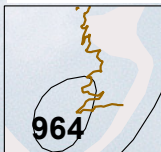
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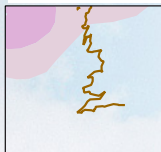
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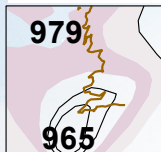
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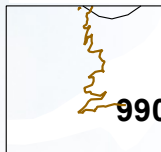
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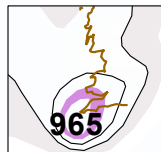
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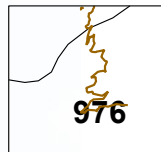
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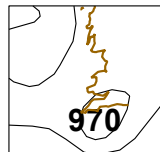
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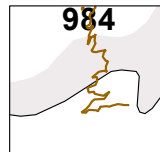
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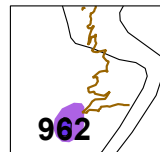
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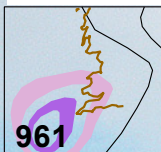
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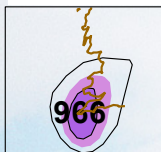
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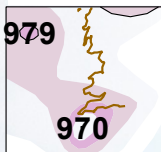
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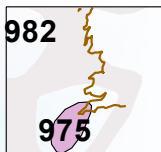
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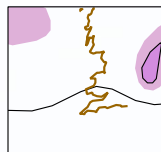
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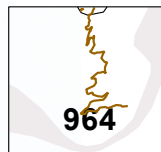
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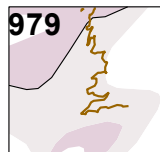
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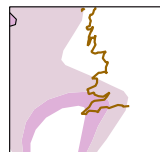
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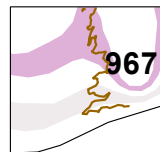
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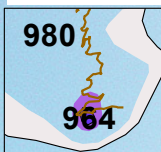
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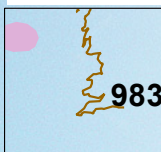
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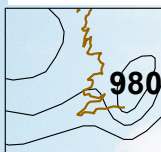
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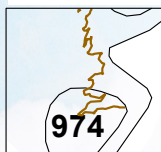
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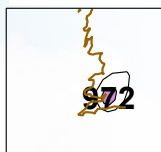
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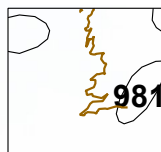
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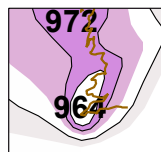
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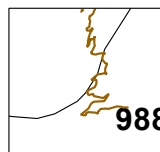
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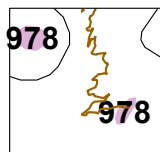
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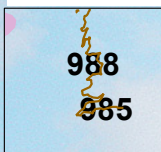
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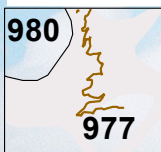
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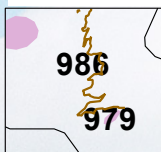
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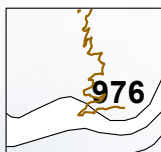
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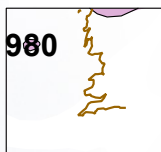
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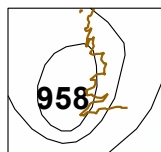
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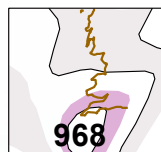
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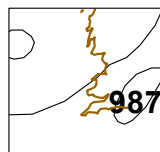
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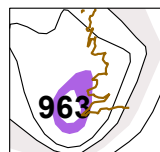
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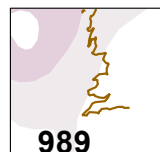
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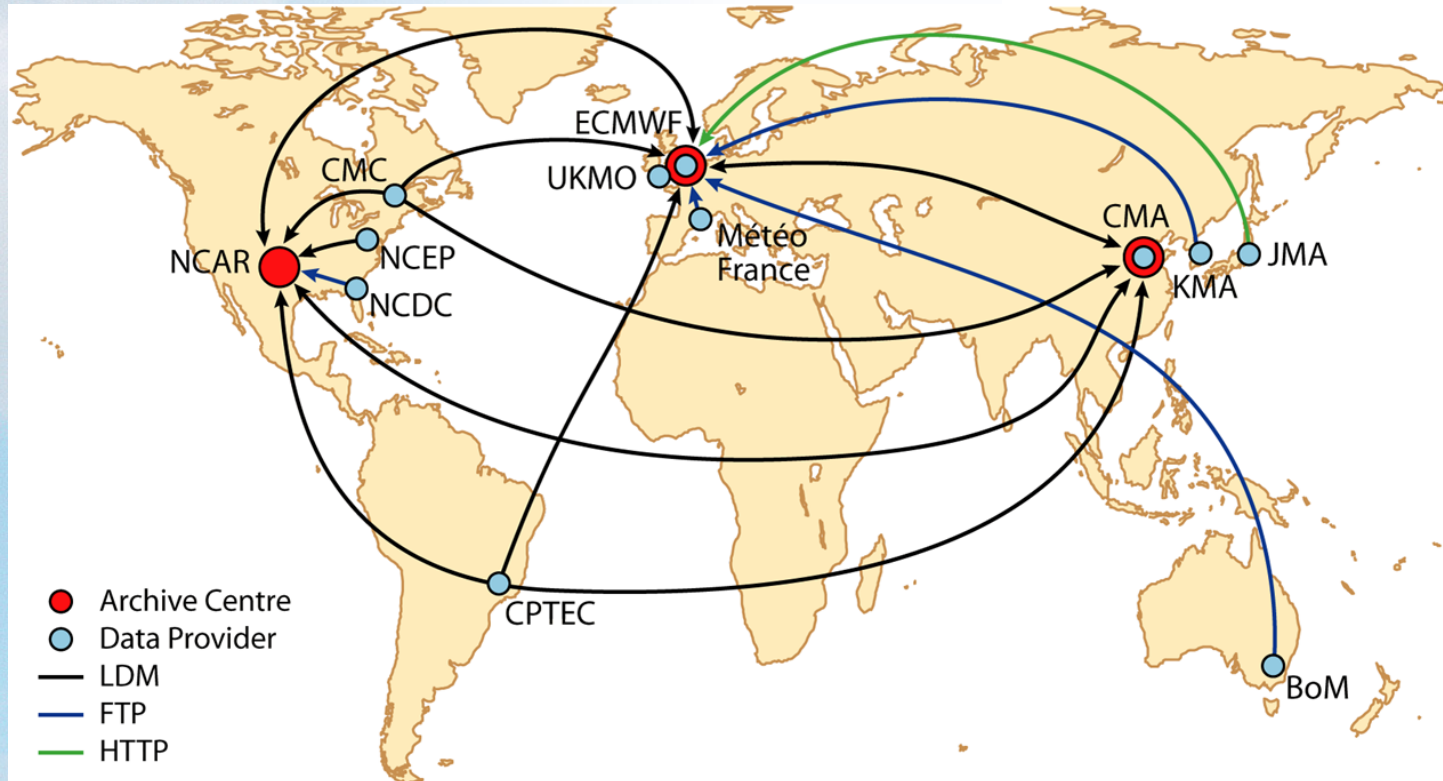


- mem no. 50 of 51 +66 h



The TIGGE dataset

- Around **500 GB** (≥ 1.6 million global meteorological fields) are now exchanged daily between **ten** Data Providers and three Archive Centres in near-real-time. The TIGGE database now contains global EPS data from all ten Data Providers, and holds more than **770 TB** of data ($\geq 3.4 \cdot 10^9$ global meteorological fields).



- Around **1,600** users have registered with the TIGGE data portal at ECMWF, of which a third are active, generating up to **20,000** requests per month.

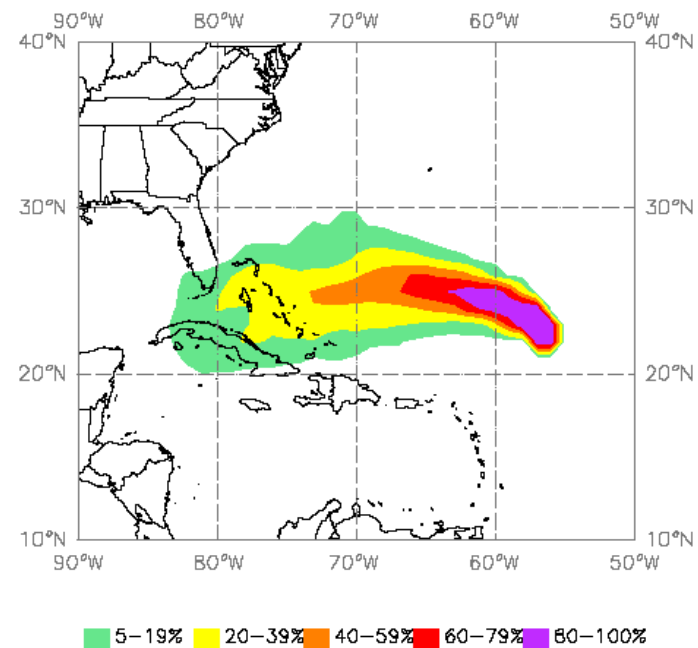
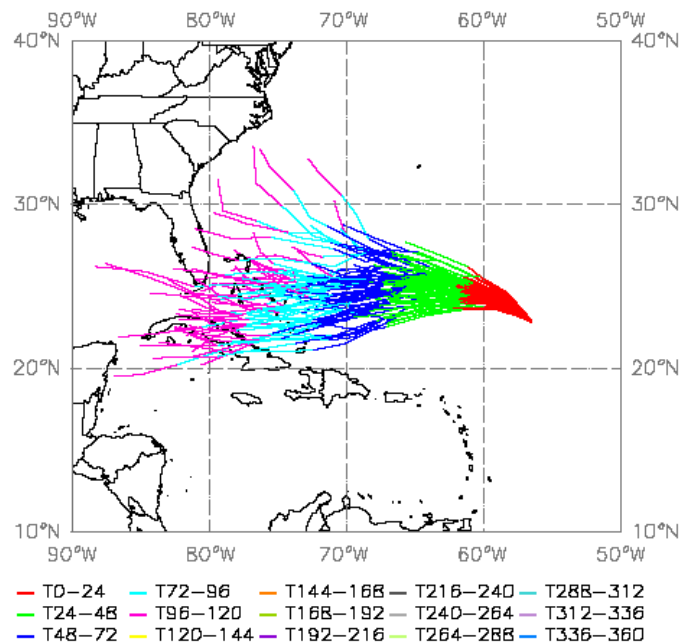
The THORPEX Interactive Grand Global Ensemble (TIGGE)



- A programme from the World Meteorological Organization (**WMO**) to:
 - Enhance **collaboration** on ensemble prediction, both **internationally** and between **operational** centres & **universities**.
 - Facilitate research on ensemble prediction methods, especially methods to **combine** ensembles and to **correct** systematic errors
- Research using TIGGE data
 - Over **60 research papers** using TIGGE data
 - **Improved understanding** of predictability & dynamical processes in the atmosphere
 - **Calibration** of ensemble forecasts (bias correction, downscaling)
 - Combination of forecasts from different centres (**multi-model**)
 - Development of new probabilistic forecast **products**
 - Multi-disciplinary applications (hydrological models for flood forecasting)

TIGGE: Tropical cyclones ensemble products

- Multi-model version of TC track / strike probability products

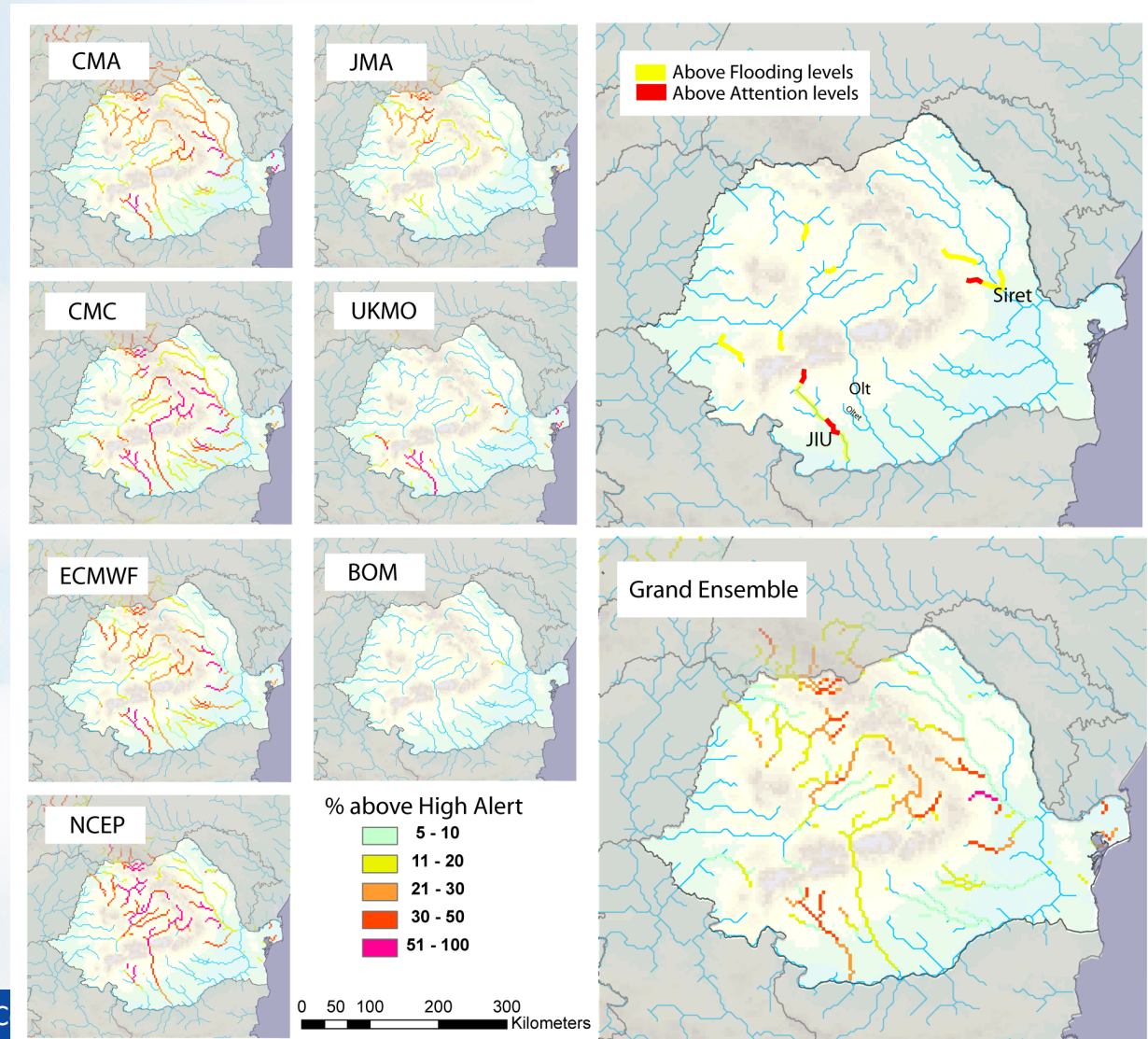


**Forecasting hurricane Ike using
combined TIGGE ensembles**

**Piers Buchanan,
Met Office**

TIGGE: Hydrological applications

- Flood alerts for Romania
- Comparison of different TIGGE models
- Combination of models (grand ensemble)



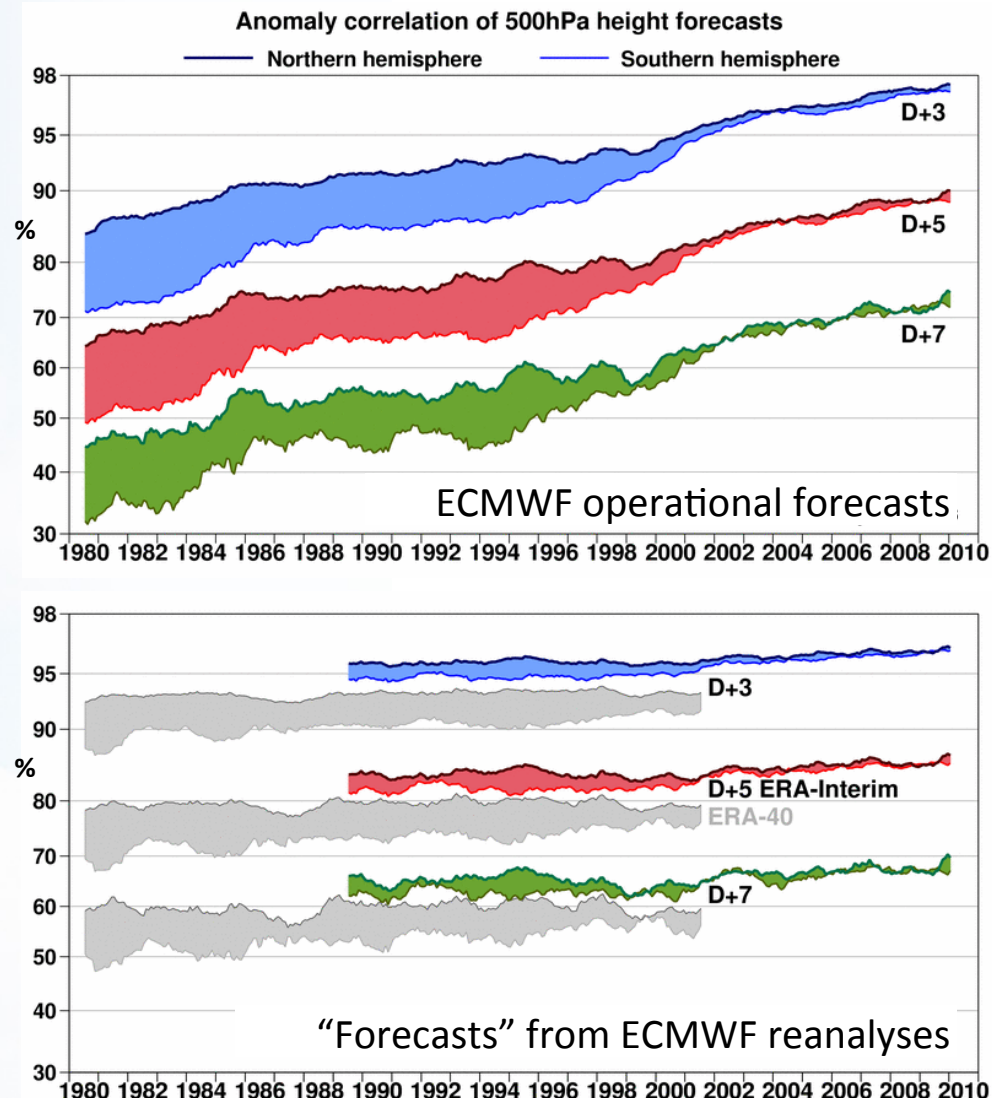
The ERA dataset: Atmospheric reanalysis

Reanalysis **reprocesses past observations** to reconstruct the evolution of the global atmosphere

It uses a fixed, **modern data assimilation system** developed for numerical weather prediction

The skill of re-forecasts shows **uniform quality** over the reanalysis period

Coming soon: 20th Century reanalysis: **100 years** of data, **1 Petabyte** dataset

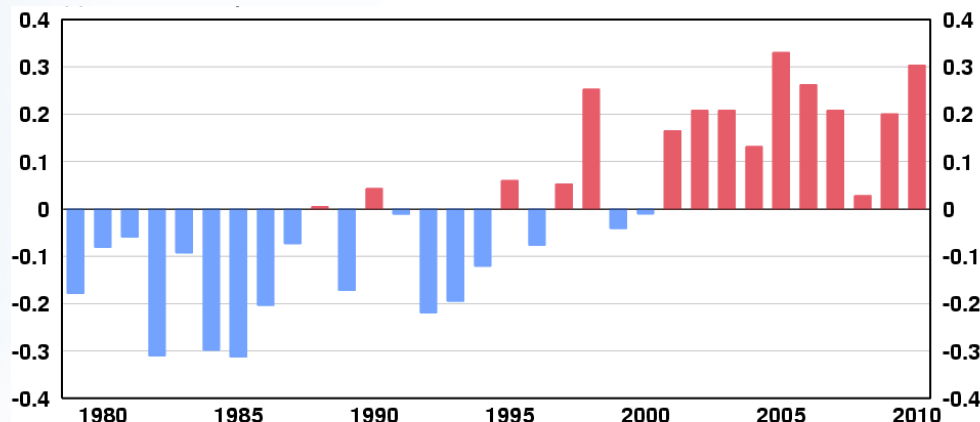


The ERA dataset: Climate change

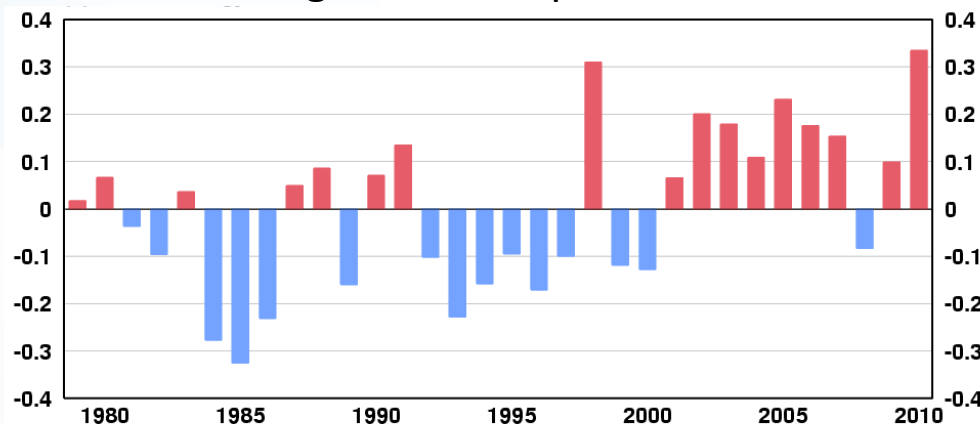
The reanalysis method

- Reanalysis combines **in-situ** observations with **satellite** data
- A forecast model is used to **infer** information about **unobserved parameters**
- The model enforces physical and dynamical **constraints** on the reanalysis products
- **Coherent** representation of atmospheric circulation, the hydrological cycle, heat and energy fluxes, ...
- Changes in the observing system can cause **errors** in trends

Annual changes in global mean temperature



Annual changes in atmospheric heat content



The ERA dataset: Reanalysis continued into the present allows to put weather events in the climate context

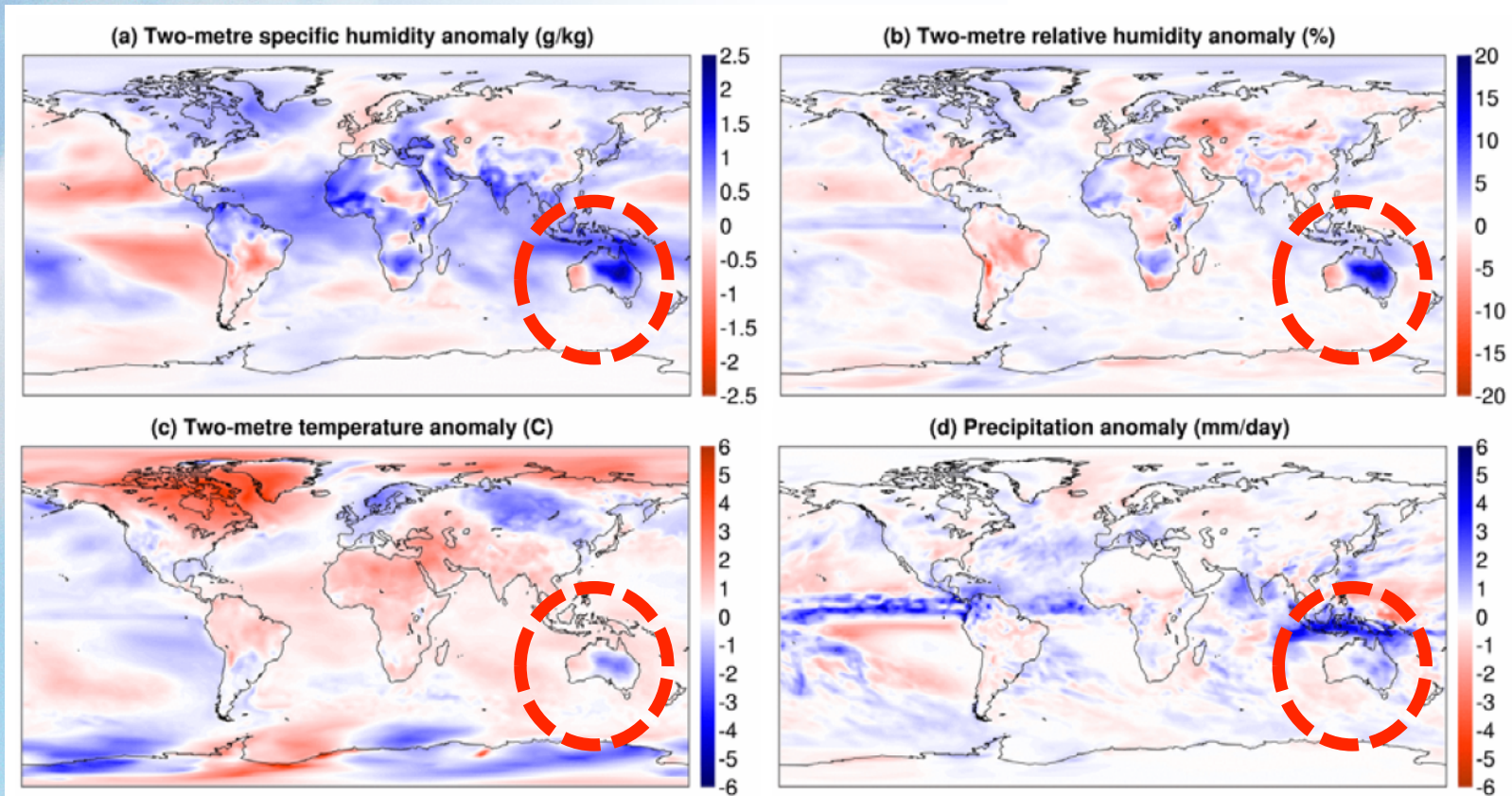


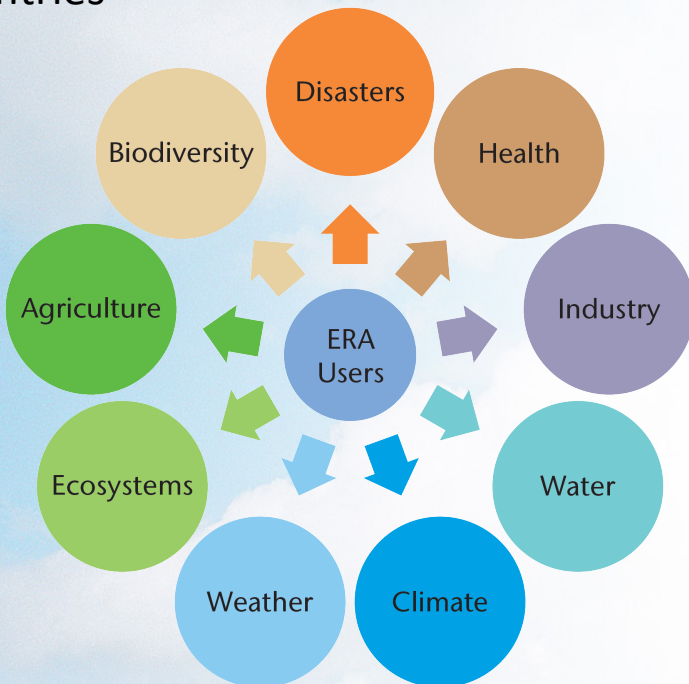
Figure SWV.2 Anomalies for the year 2010 relative to 1989-2009 means from ERA-Interim. (a): Specific humidity analysis at a height of 2m (g/kg). (b): Relative humidity analysis at a height of 2m (%). (c): Temperature analysis as a height of 2m (C). (d): Precipitation accumulated in the 12-24h range from twice-daily forecasts initiated at 00 and 12 UTC (mm/day).

Adrian Simmons, 2011

Atmospheric reanalysis – the user base

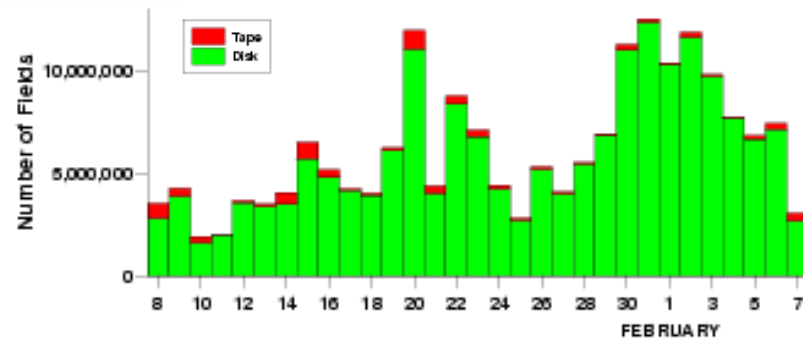
- Many users

- **10,000** registered users of ERA public data servers
- **≥5M fields retrieved daily** by ECMWF and Member-State users
- National **mirror sites** for ERA in many countries



Fields Retrieved from MARS

08 January - 07 February 2009



The screenshot shows the ScienceWatch.com website. The header includes the logo and navigation links: Interviews, Analyses, and Data & Rankings. The main content area features an article titled "EMERGING RESEARCH FRONTS - 2008" dated December 2008. The article mentions an interview with Sakari Uppala. A small photo of Sakari Uppala is shown next to the article text.

CHANGE 2007
SCIENCE BASIS

Helix Nebula flagship

- Main motivation
 - To gain a thorough **understanding** of cloud computing and its **cost model**, with a focus on the provision **of very large** datasets
- The benefit of the cloud is threefold:
 - The provision of virtual machines with the necessary software to retrieve, manipulate and plot the data in the most efficient fashion will already greatly **improve the access** to the datasets.
 - The ability to load some of the most popular part of the dataset on the cloud will allow users to take advantage of the **distributed** aspect of the cloud and investigate **parallel** data-mining algorithms such as map-reduce.
 - Finally, the cloud will allow users with very **limited bandwidth**, such as users from developing countries to access vast amounts of data and process them on the cloud, having only to transfer much smaller amount of **compressed information** to their site.

Thank you