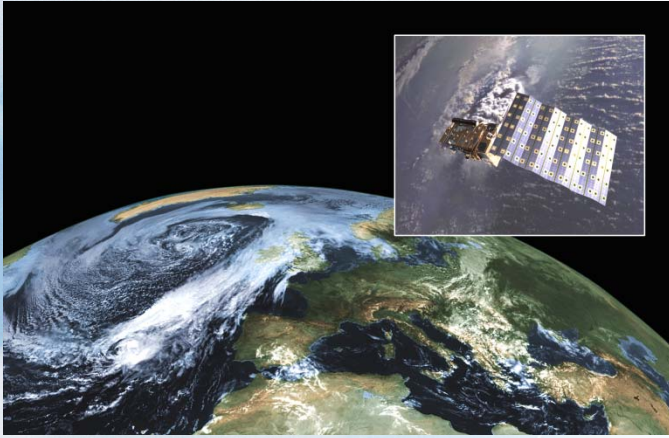# Development of the ECMWF forecasting system

Erland Källén
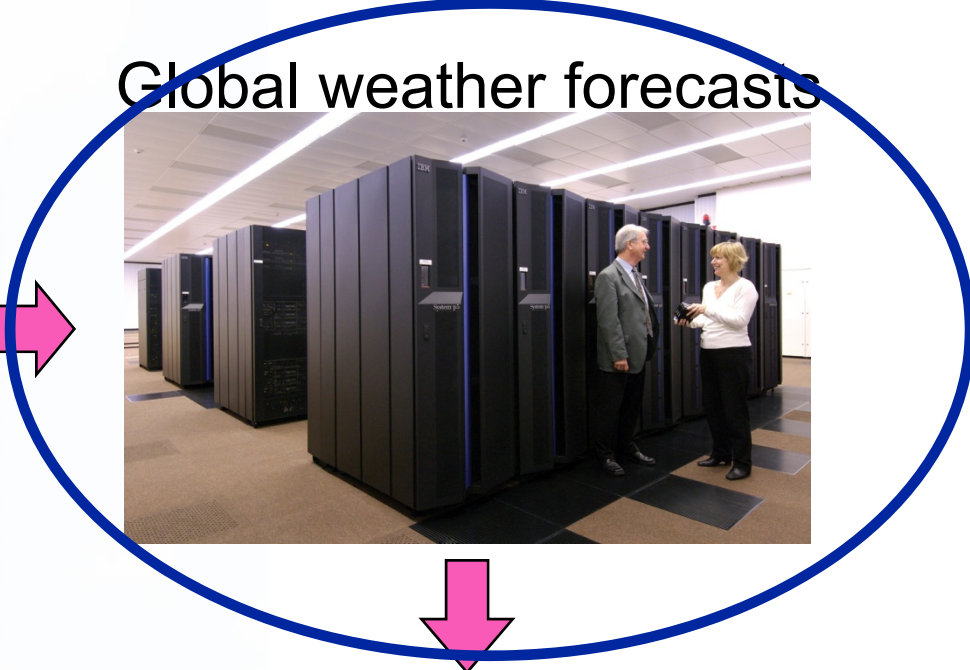
Director of Research

ECMWF

ECMWF

Outline

- Forecasting system
  - Observations
  - Forecast model
- Data assimilation
- Increasing resolution
- Atmospheric composition
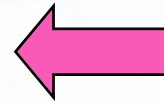- Seasonal forecast
- Reanalysis – climate monitoring

ECMWF
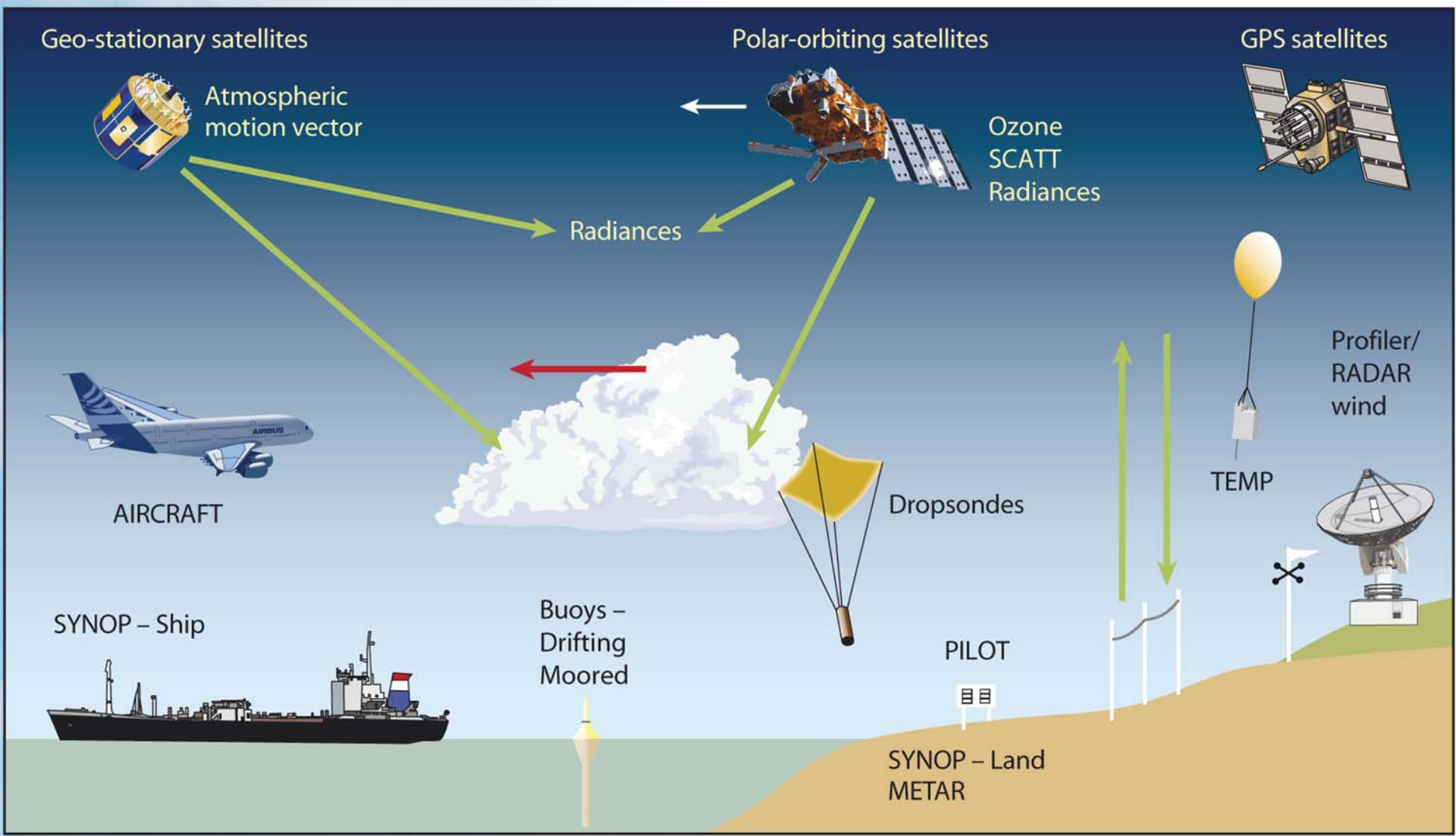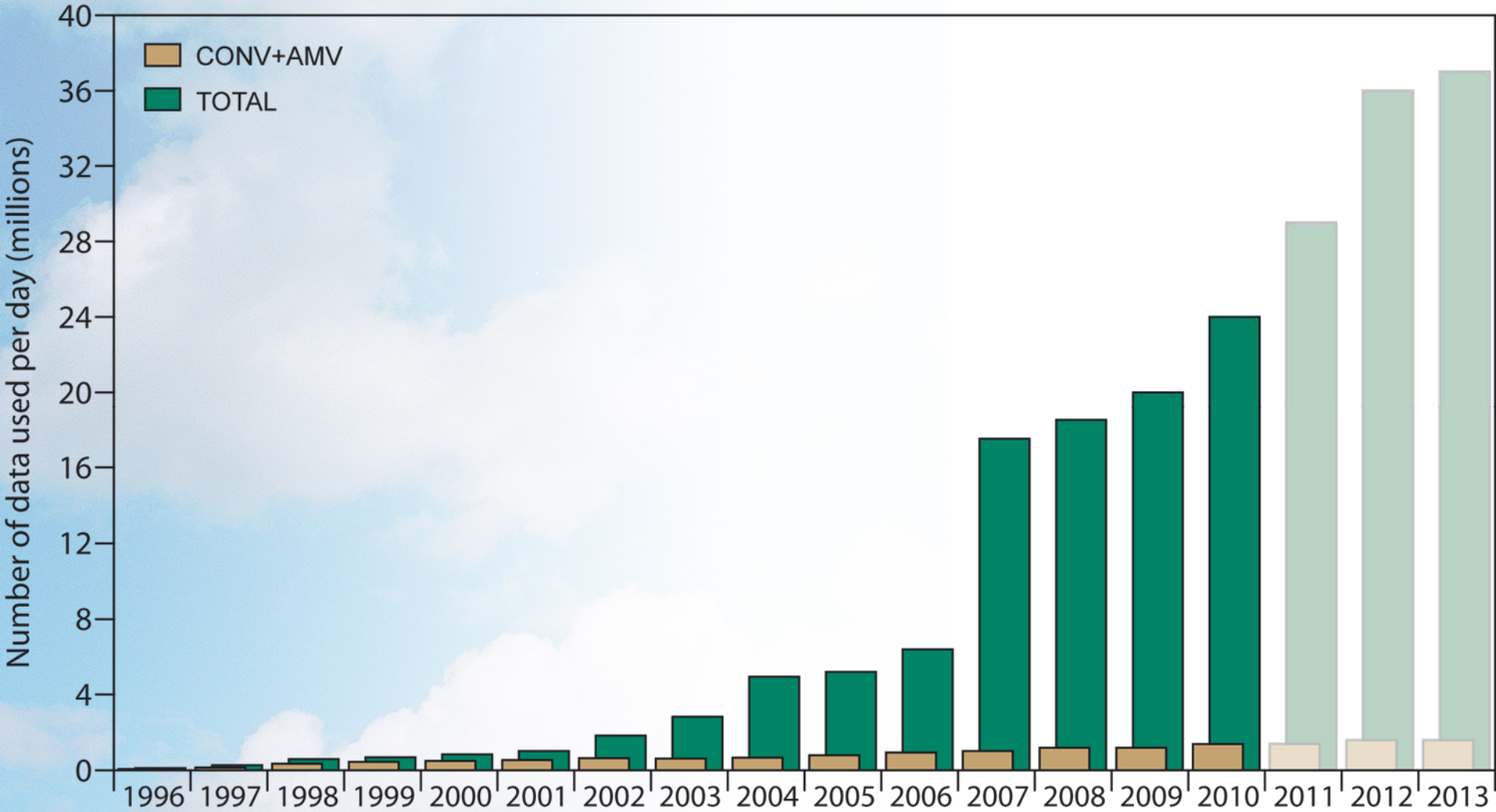
Global observations

Global weather forecasts

Users

National weather services

ECMWF

Observing system

Number of observations

# Present main operational forecast models

- Global forecast model
  - 16 km grid point distance
  - 91 vertical levels
  - Wind, pressure, temperature, humidity, clouds
  - Forecast range: 10 days (10 min time steps)
- Ensemble Prediction System
  - 50 parallel forecasts
  - Perturbed initial conditions and stochastic model error
  - 32 km grid point distance

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Operational model grid
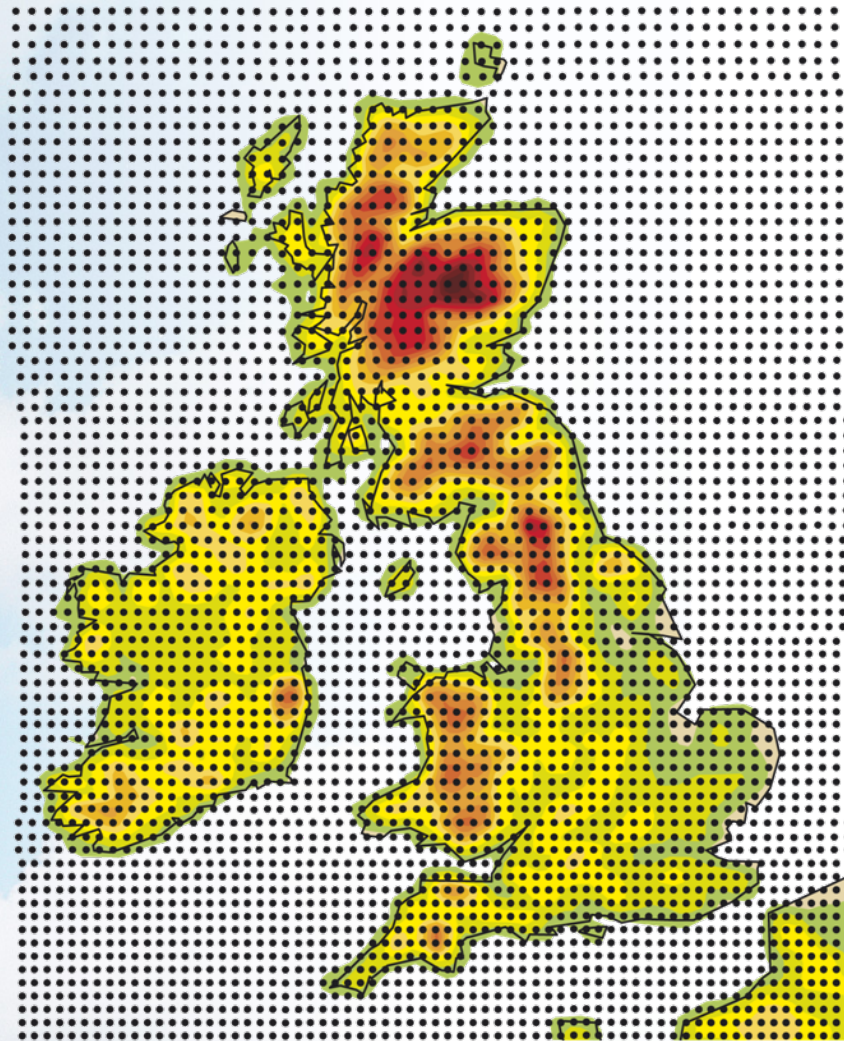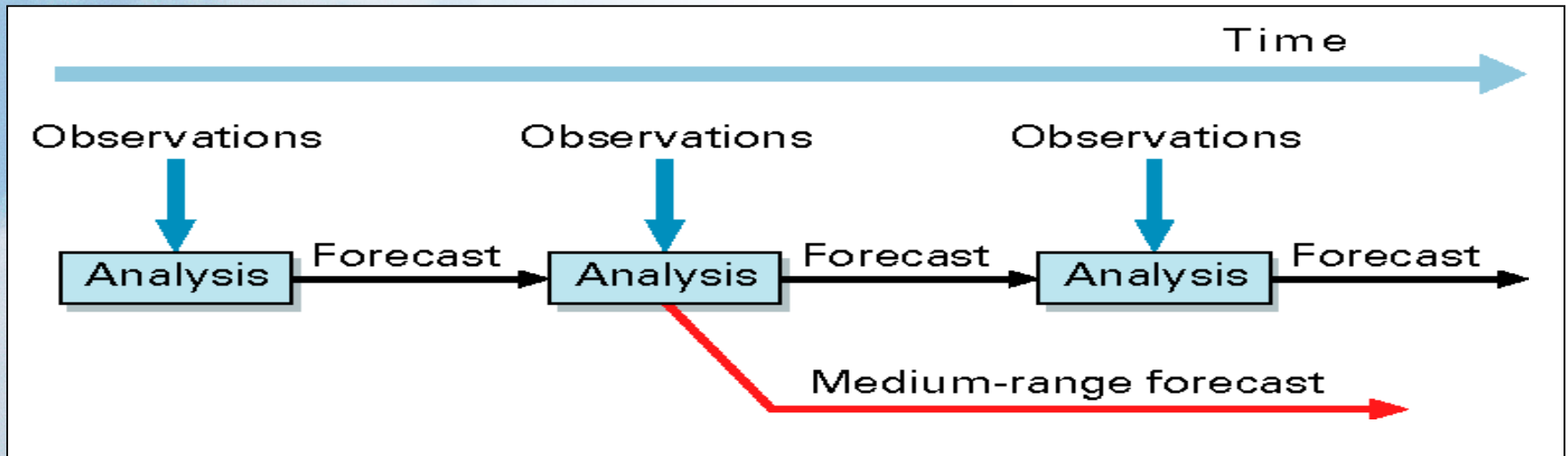
Forecast quality – Days of useful skill
## (500 hPa height, anomaly correlation>0.6, N. Hemisphere)
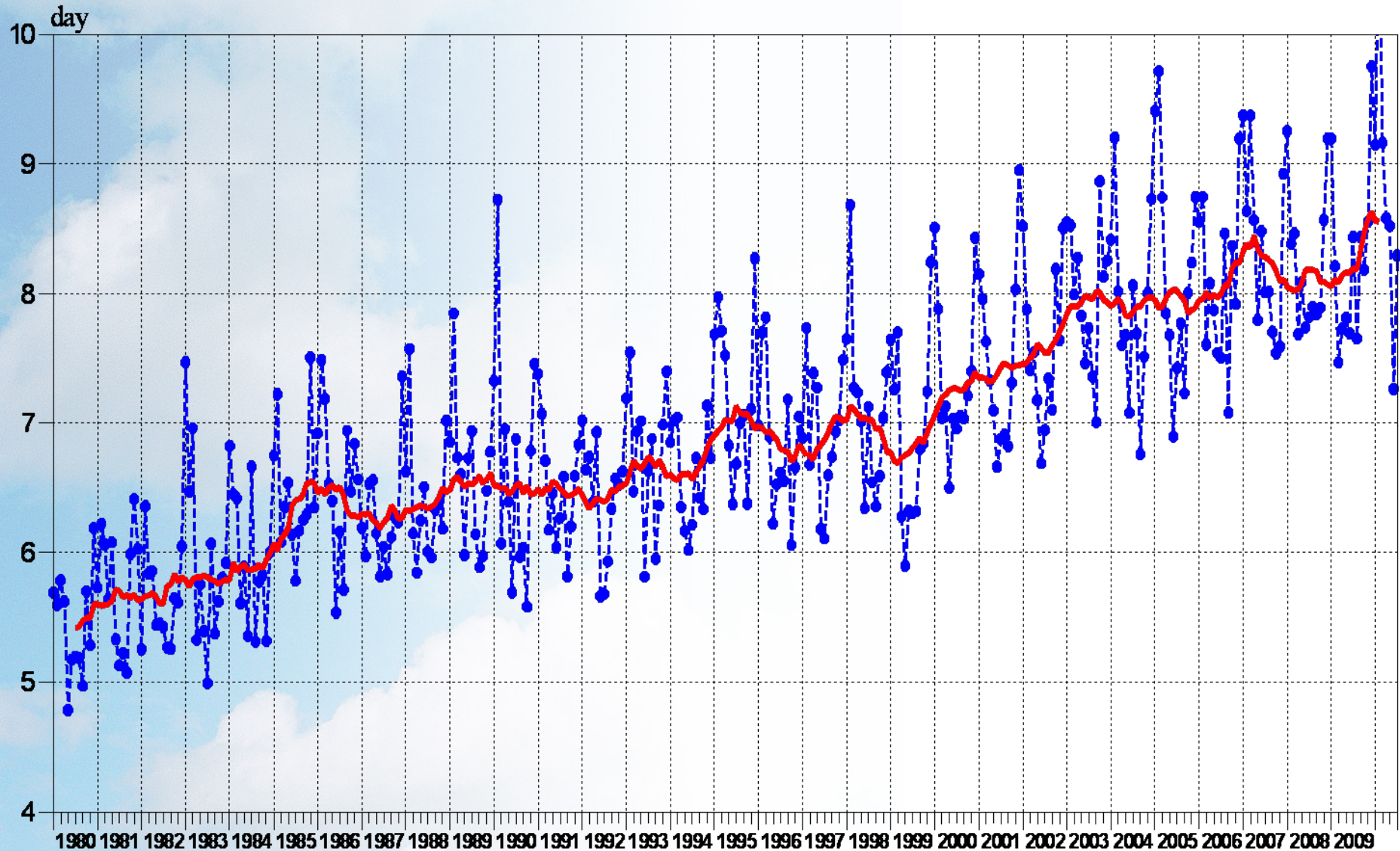
Data assimilation

- Variational data assimilation
- Ensemble of Data Assimilations (EDA)

ECMWF

Data assimilation system (4D-Var)

> - **The observations correct errors in a short range forecast from the previous analysis time.**
> - **Every 24 hours we assimilate $2 \cdot 10^7$ observations to correct the model's virtual atmosphere ($2 \cdot 10^9$ variables).**
> - **4-dimensional interpolation in space and time, 4D-Var; takes as much computer power as the 10-day forecast.**

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Speed-up of 4D-Var
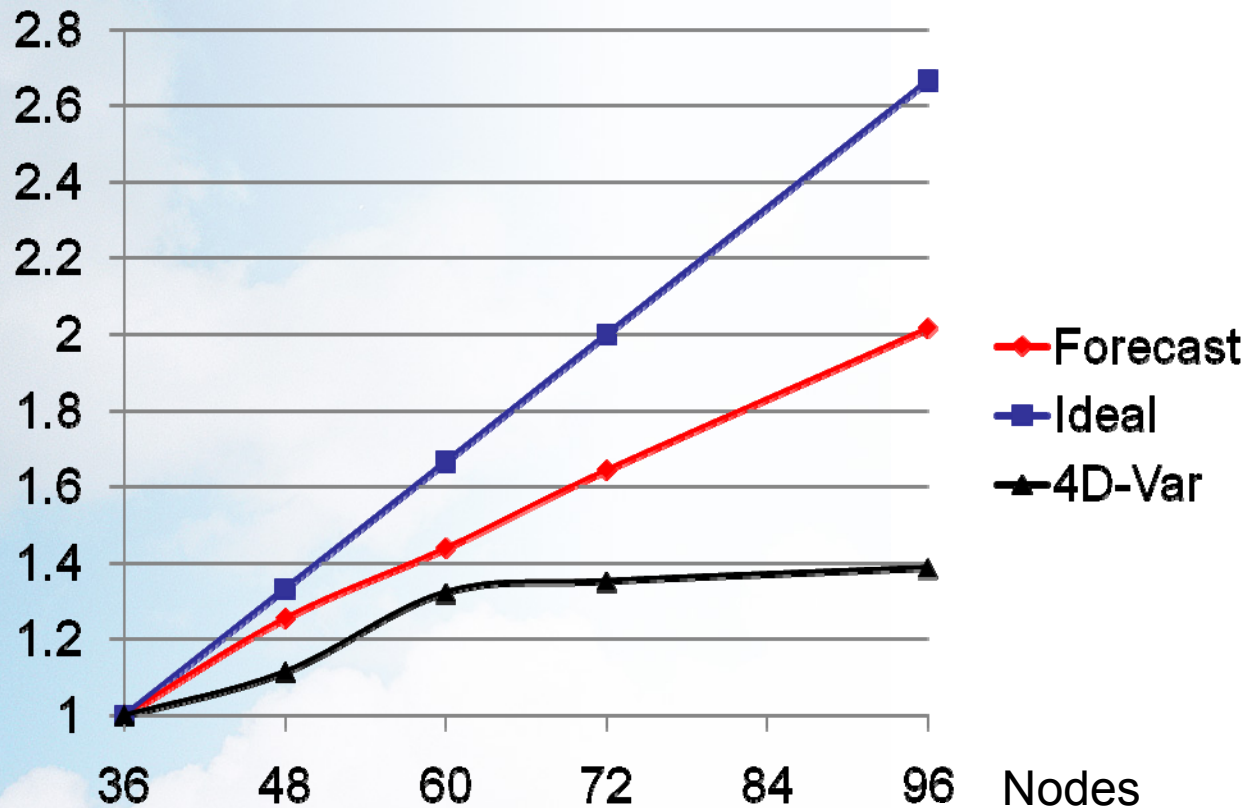
Ensemble of Data Assimilations (EDA)

- Perturbed observations
- Perturbed sea surface temperatures
- Stochastic model error

Δx_1

Δx_2

Δx_3

Δx_4

X_0

4DVAR

X_{+12h}

$\longrightarrow$ **Ensemble initial perturbations**
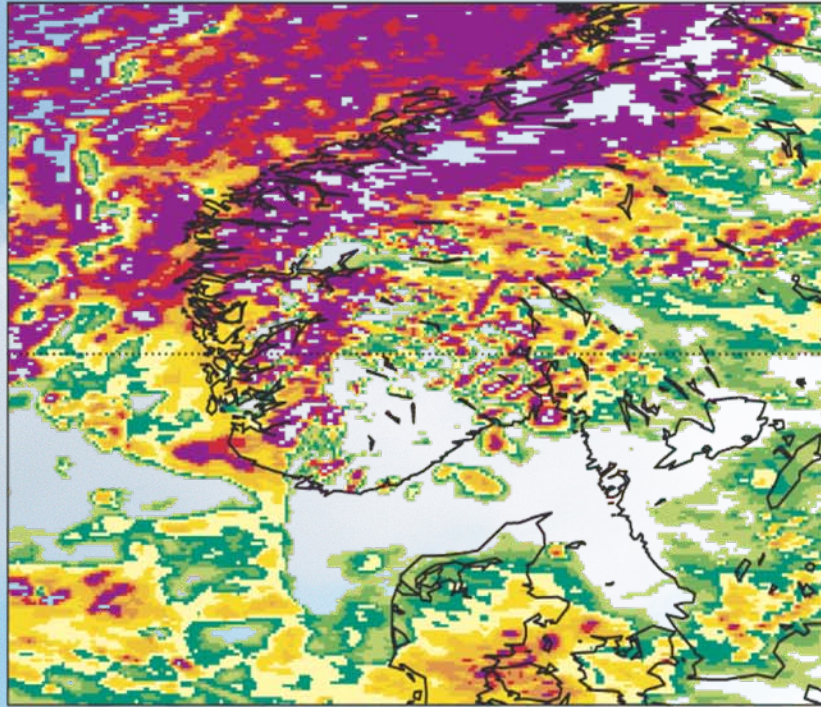
ECMWF
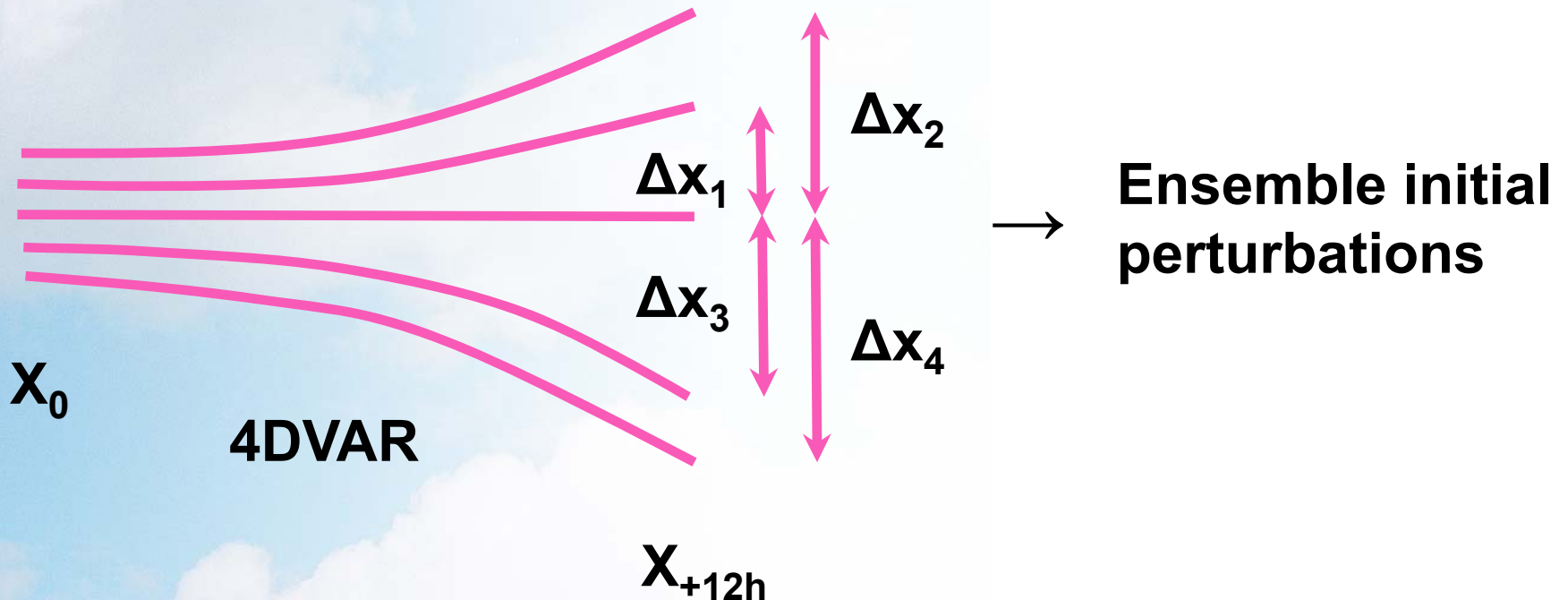
Increasing resolution

- Vertical resolution
  - 91 → 135 levels by year 2011
- Horizontal resolution
  - 16 → 10 km by year 2015

- Beyond 2015
  - 10 km → 5 km (≈ year 2020)

- Non-hydrostatic model formulation
- Fast Legendre transforms
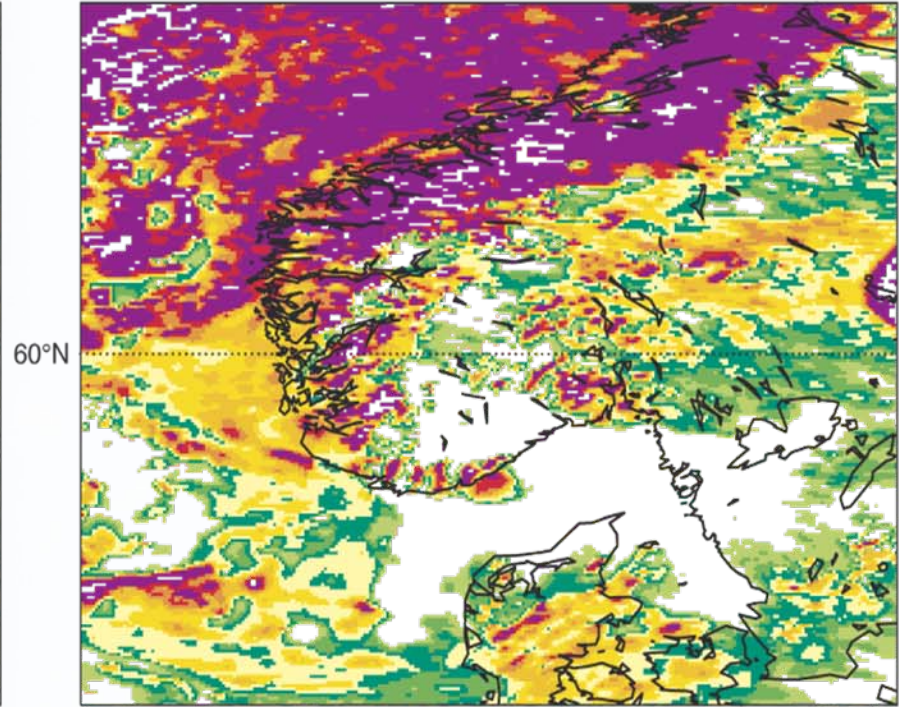
ECMWF

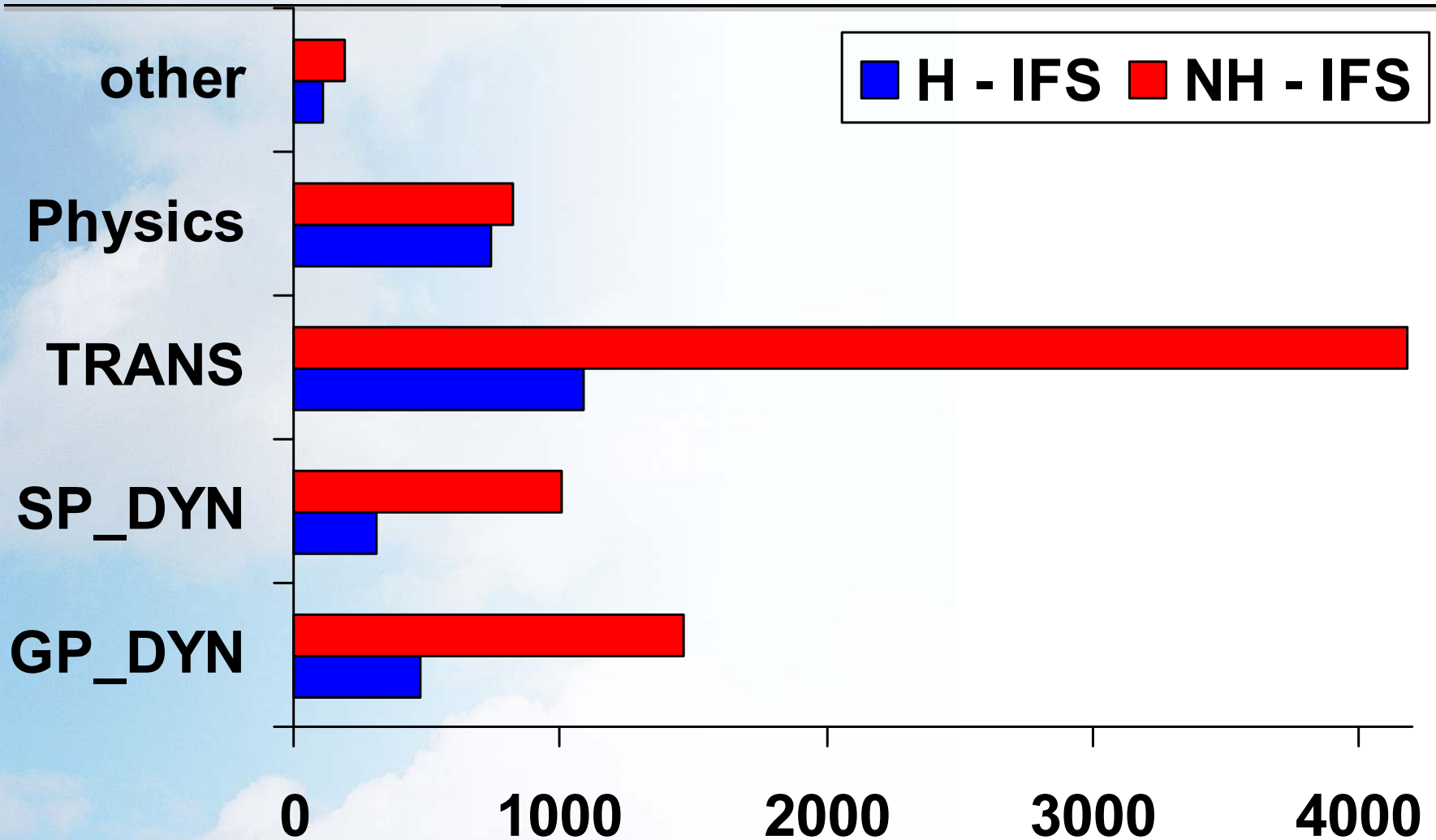# Orography T3999 (~5km)
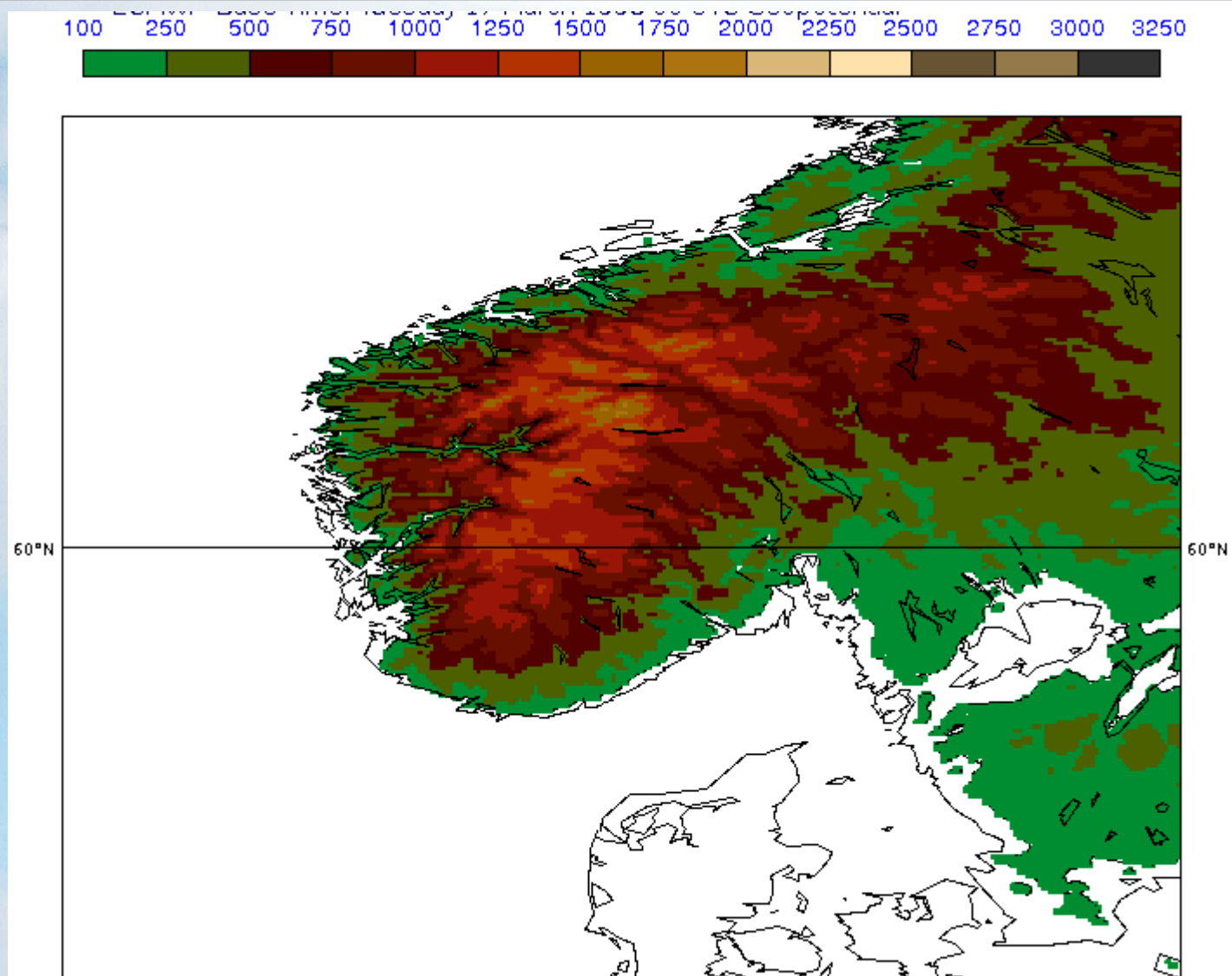
Cloud cover 24h forecast T3999 (~5km)

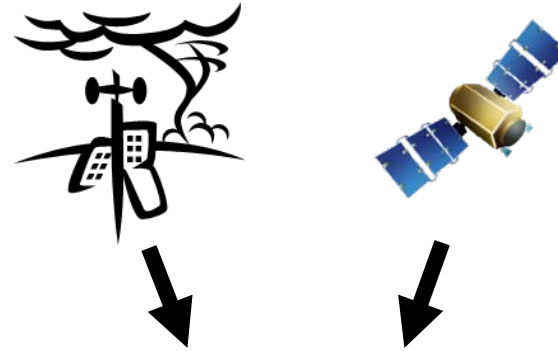a Non-hydrostatic simulation

b Hydrostatic simulation

60°N

0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
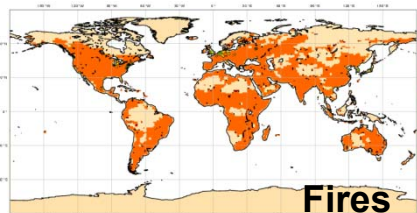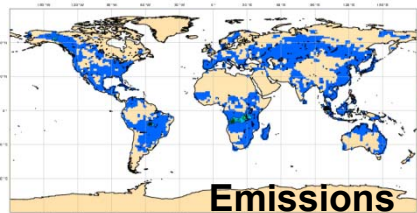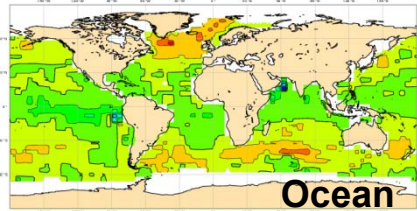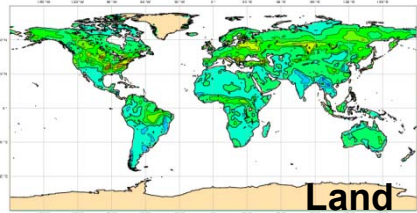
Computational Cost at T_L3999

Total cost increase for 24h forecast: H 50min vs. NH 150min

Greenhouse gas data assimilation

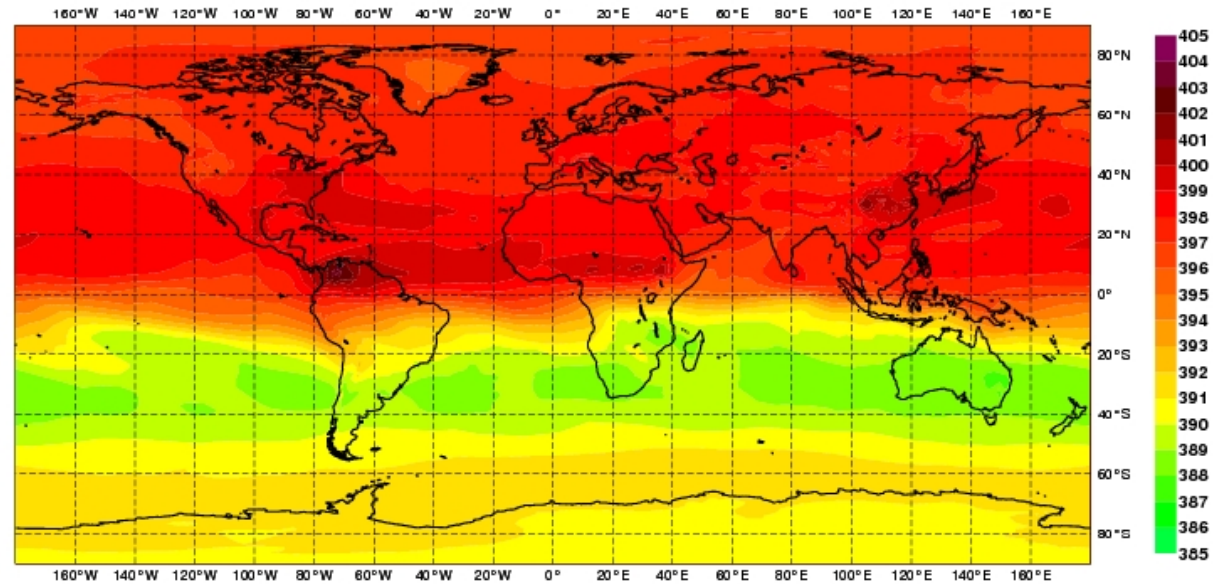**Observations**

Prescribed Fluxes

Land

Ocean

Emissions

Fires

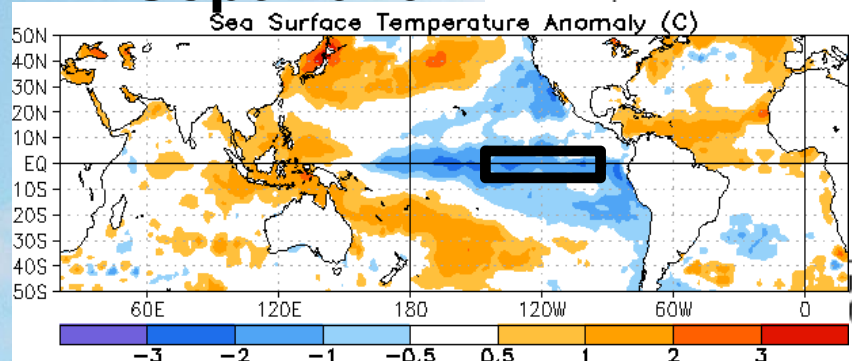MACC Delayed mode Global Monthly Mean April 2010
Mean Column CO2 Mixing Ratio [ppm]   mean: 394.25   max: 404.31
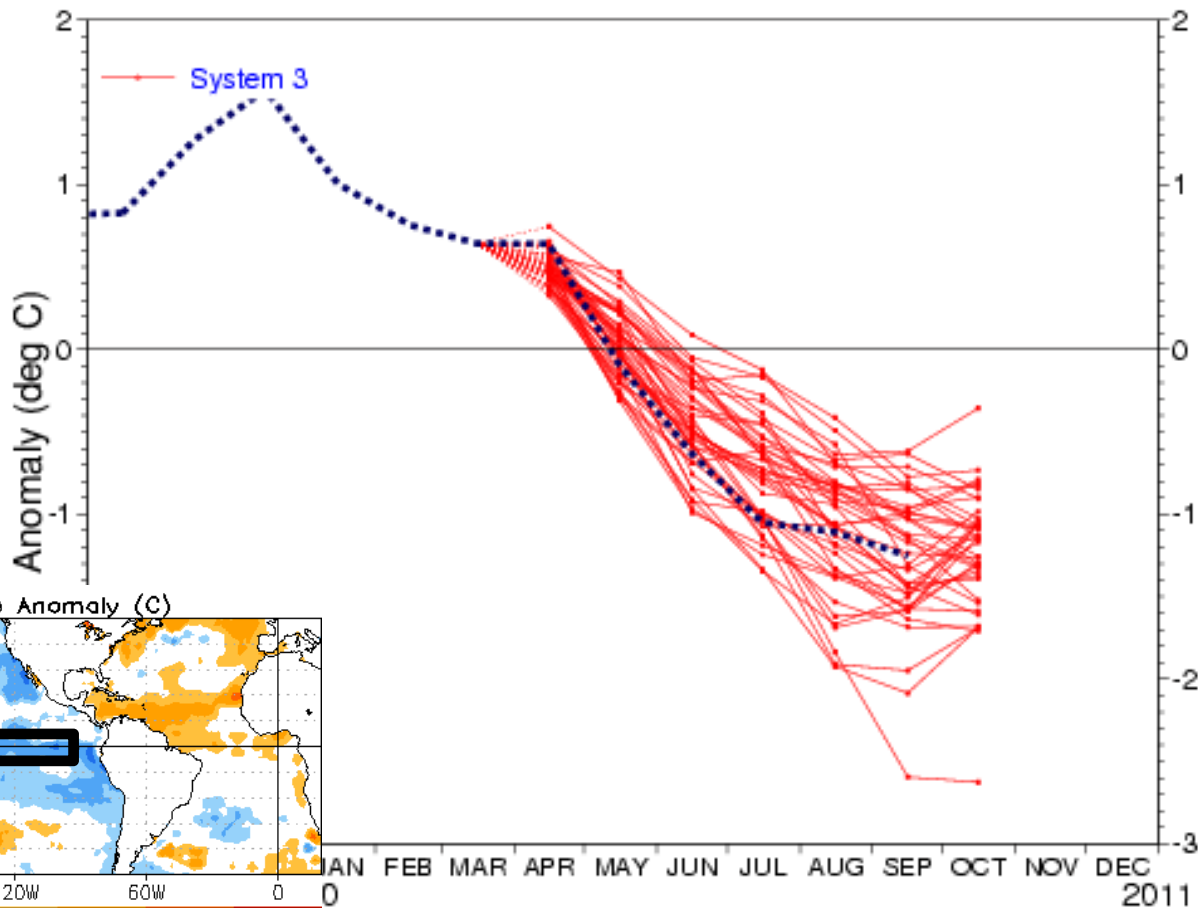
Data Assimilation (CO_2)

Seasonal forecast

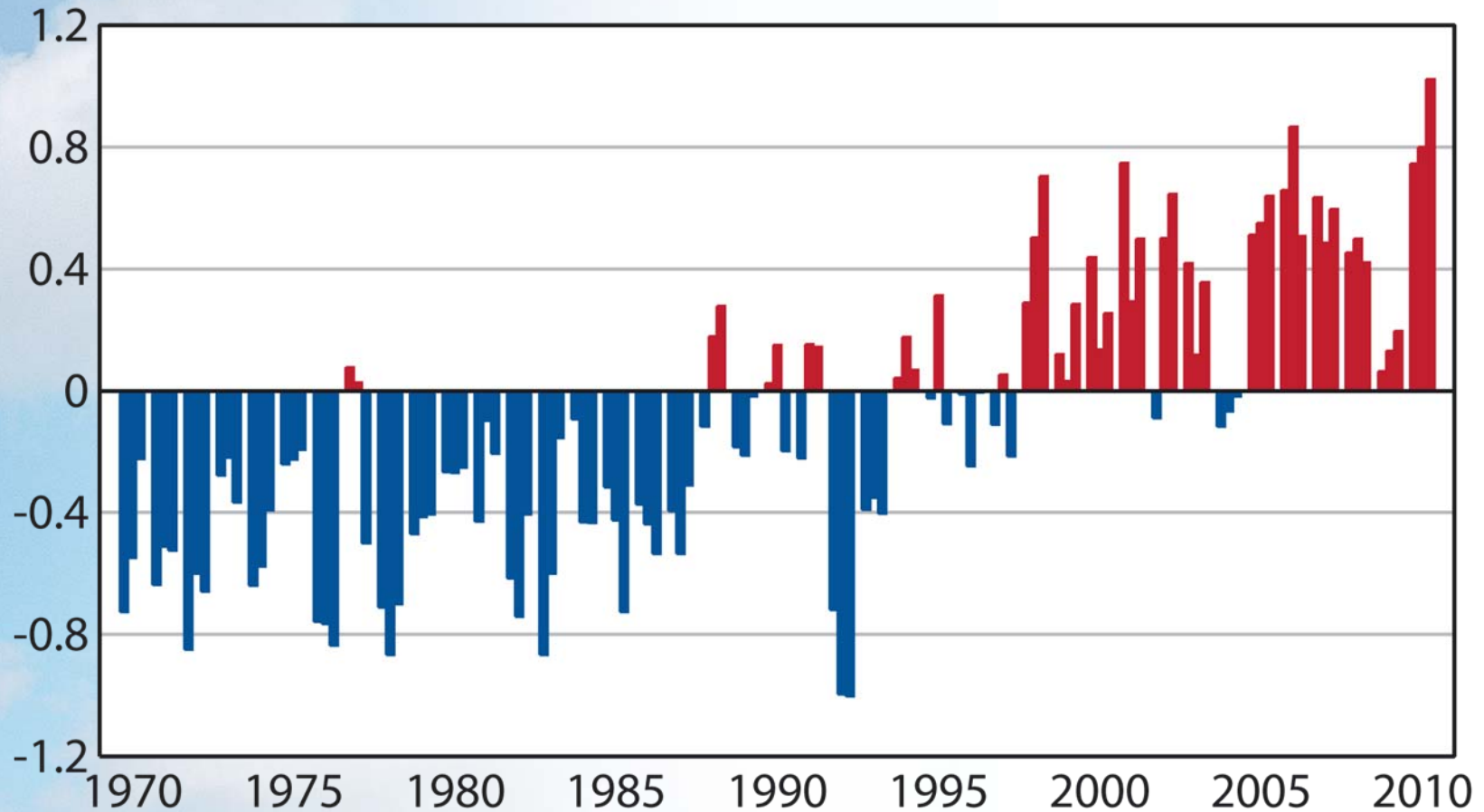NINO3 SST anomaly plume
ECMWF forecast from 1 Apr 2010
Monthly mean anomalies relative to NCEP adjusted OIv2 1971-2000 climatology

System 3

Sept 2010

Sea Surface Temperature Anomaly (C)

Forecast issue date: 15 Apr 2010

Summer temperature (May, June, July) anomaly Northern Hemisphere land areas

Summary

- Global data assimilation and forecasting
- Scalability
  - Data assimilation
  - Forecast model
- 4DVar/ensemble data assimilation
- Spatial resolution 16 → 10 → ≈5 km in ten years
- Atmospheric composition
- Seasonal forecasts
- Reanalysis – climate monitoring

ECMWF