Developments of the ECMWF Integrated Forecasting System

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and colleagues

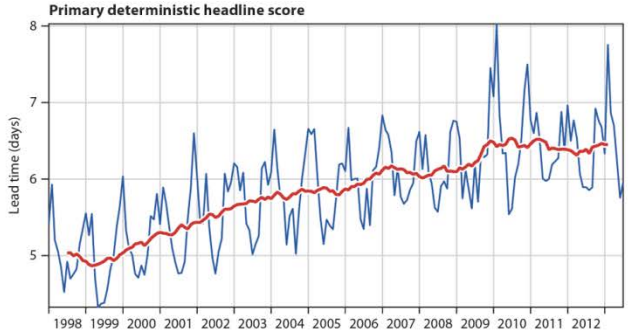
The operational forecasting system

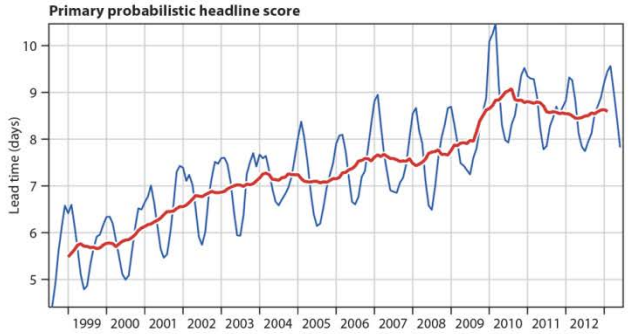
- **High resolution deterministic forecast (HRES):**
  - **twice a day 16 km 137-level, to 10 days ahead**
- **Ensemble forecast (ENS):**
  - **twice a day, 32 km (64 km after day 10) 91-level, to 15 days ahead**
  - **50 perturbed members (account for initial and model uncertainties)**
  - **Monday/Thursday 00 UTC extended to 1 month ahead (Monthly Forecast)**

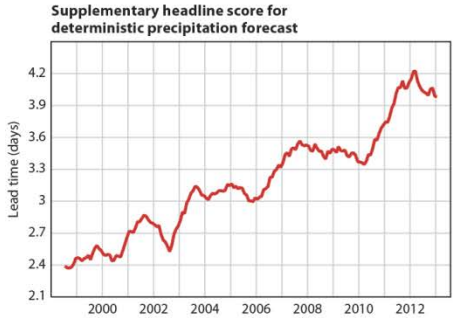
- **Ocean waves: twice a day**
  - **Global: 10 days ahead at 28 km**
  - **European Waters: 5 days ahead at 10 km**
  - **Ensemble: 15 days ahead at 55 km**
- **Seasonal forecast: once a month**
  - **51 members, 80 km 91 levels, to 7 months ahead**

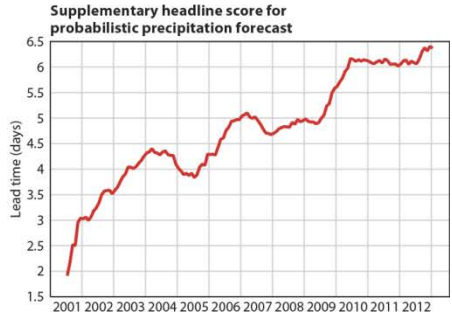
Forecast performance

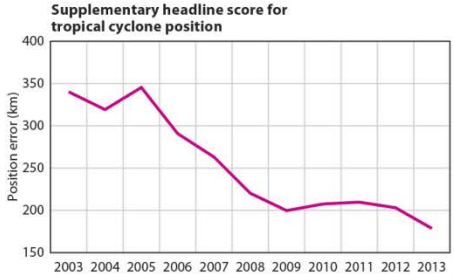
- **6 headline scores**
  - **HRES and ENS upper-air skill**
  - **HRES and ENS precipitation**
  - **Severe weather: TC position and EFI for extreme wind**
- **Wide range of additional verification and in-depth diagnostics**
- **Comparison with other centres**
- **Comparison with reference systems**
- **Evaluation for severe weather**

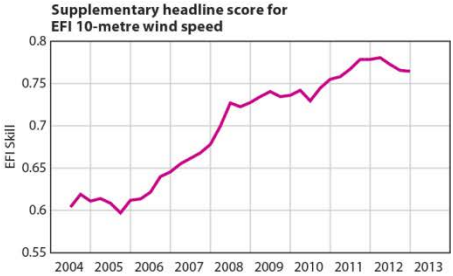




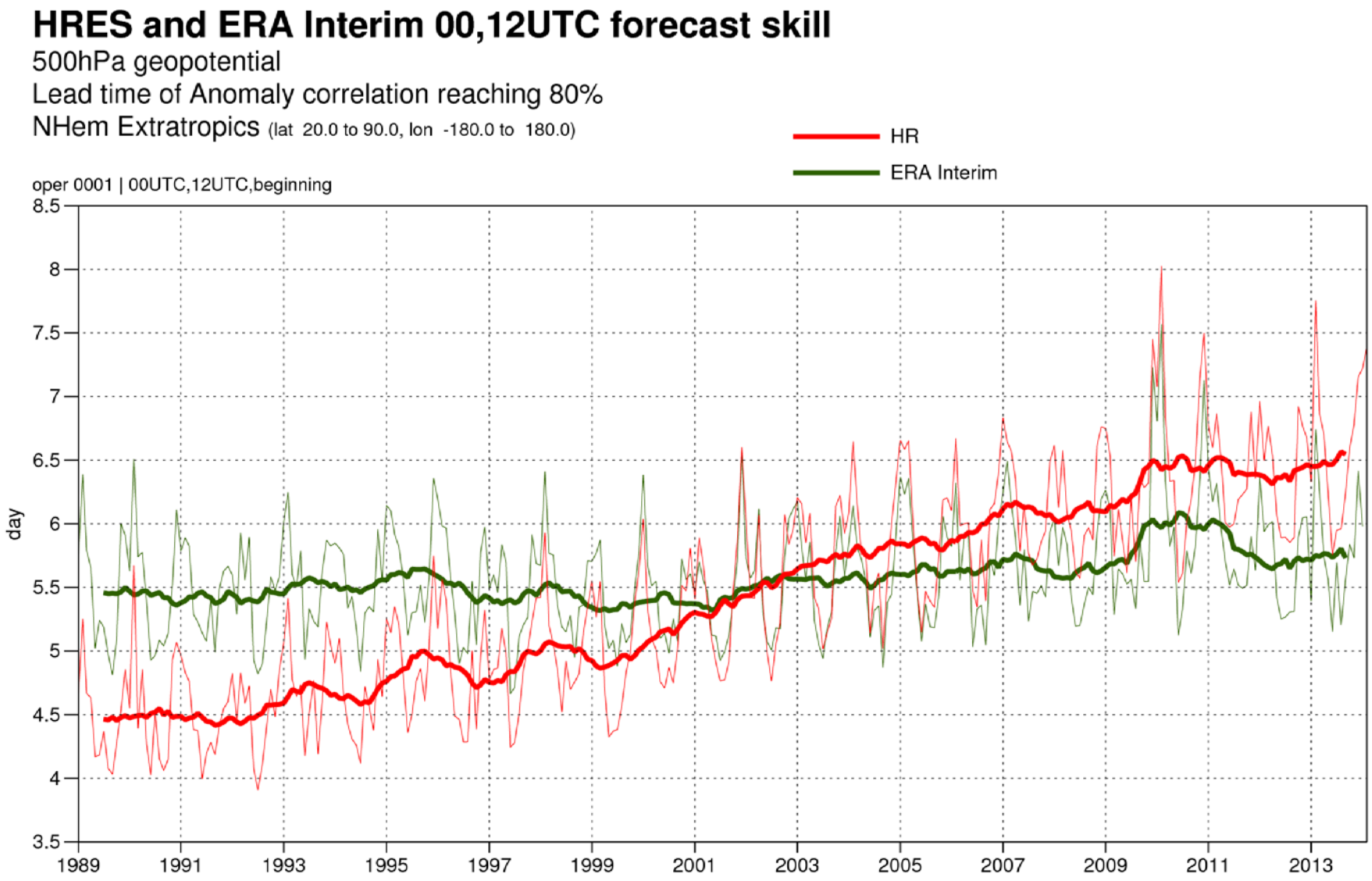






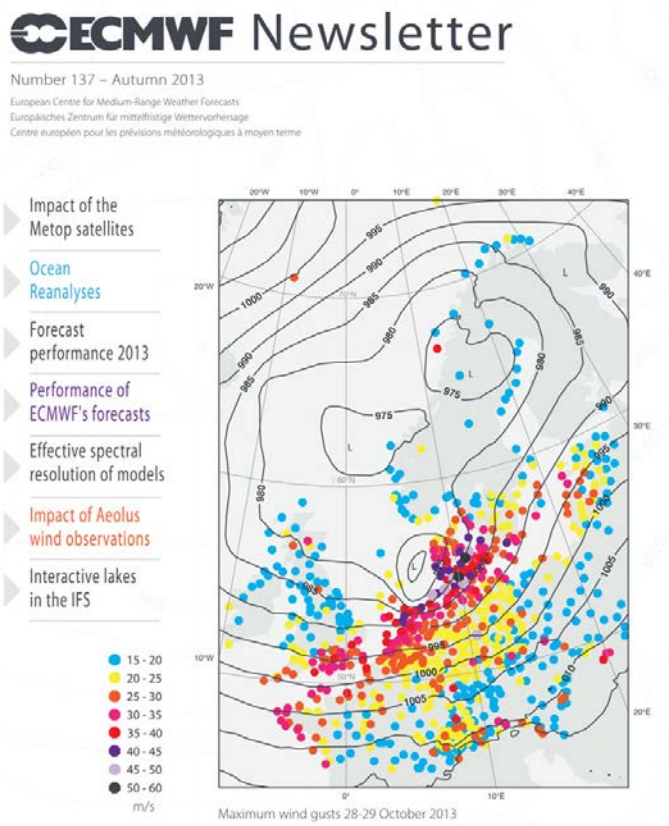


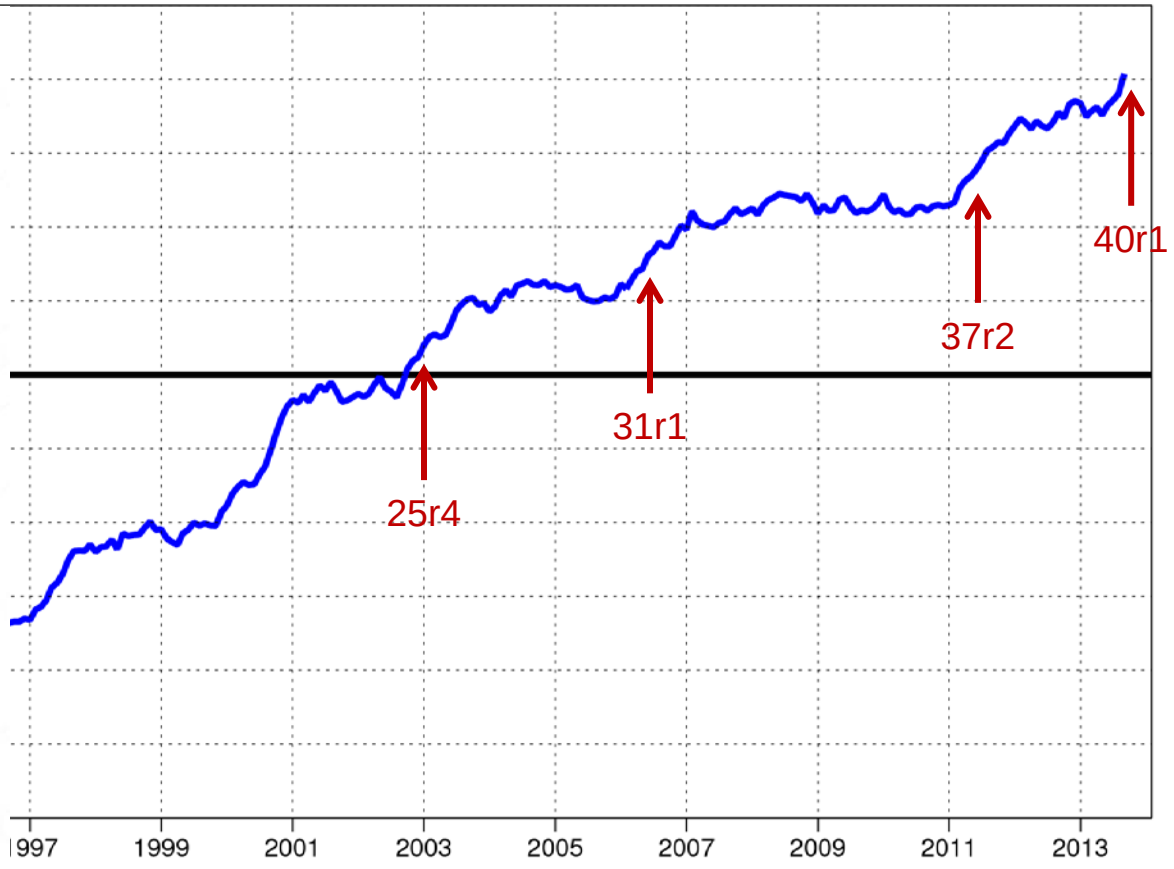
Z500 Time series of ACC=80% N hemisphere



Z500 N hemisphere HRES v ERA-I

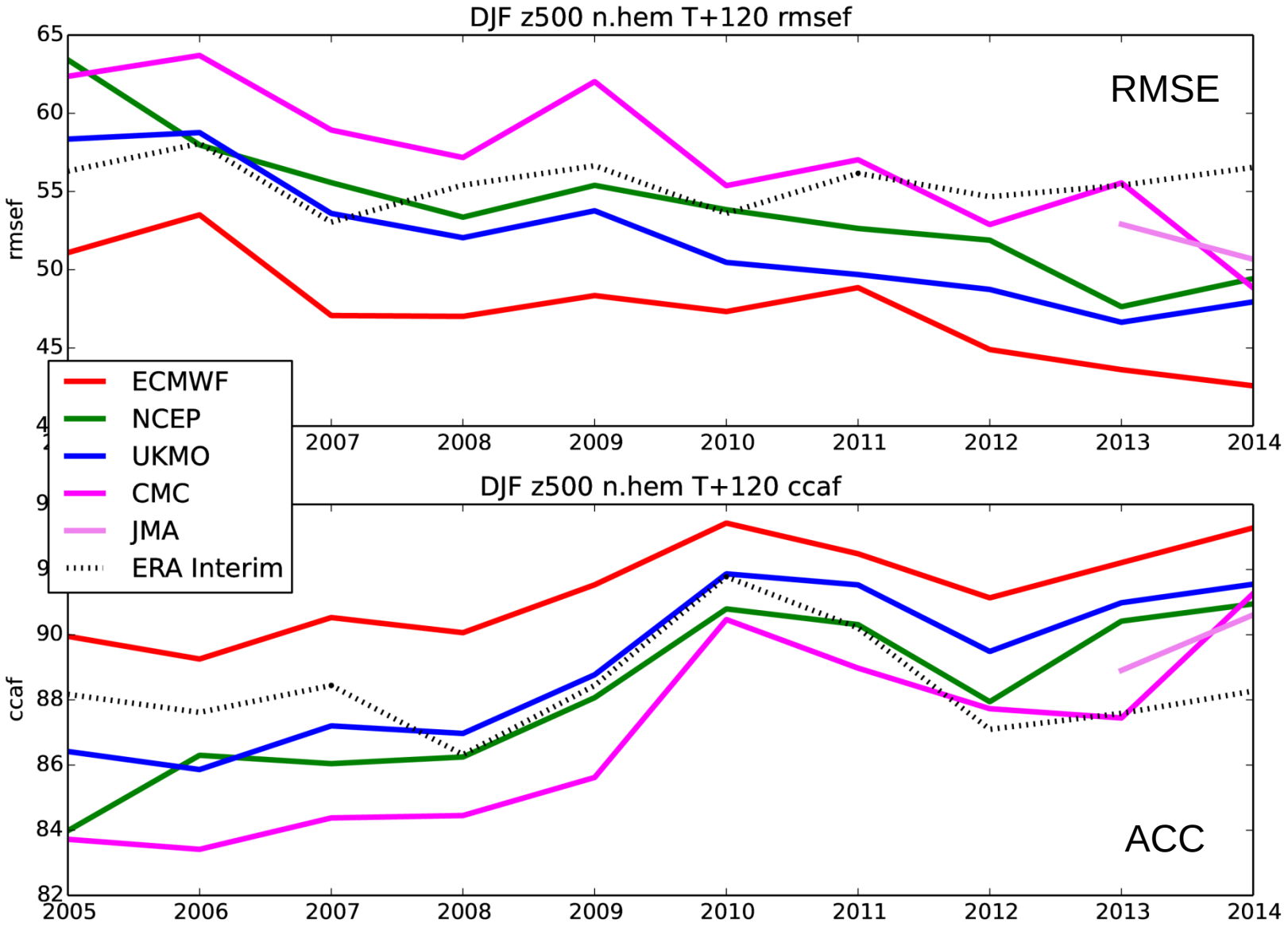
HRES - ERA
500hPa geopotential
Anomaly correlation
NHem Extratropics (lat 20.0 to 90.0, lon -180.0 to 180.0)
T+0 T+12 ... T+240
oper_an-era_an od-ei oper 0001 | 00UTC,12UTC,beginning



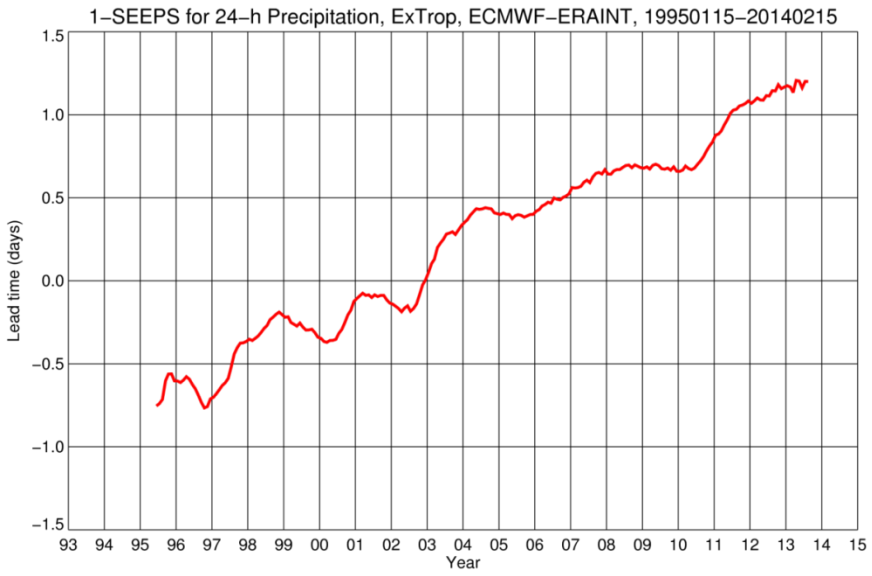


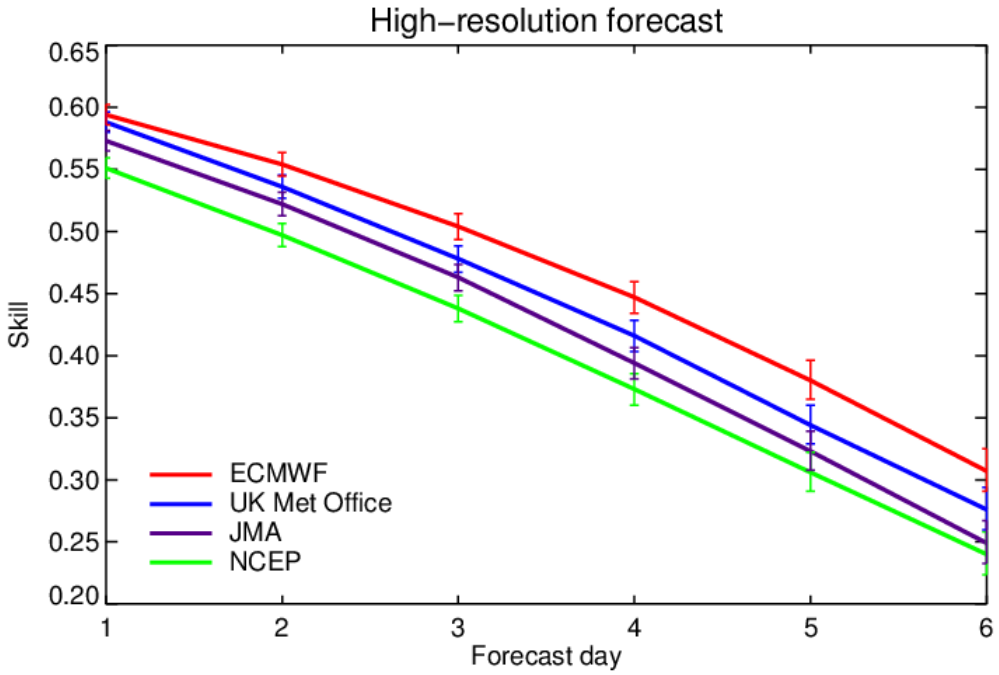
ECMWF

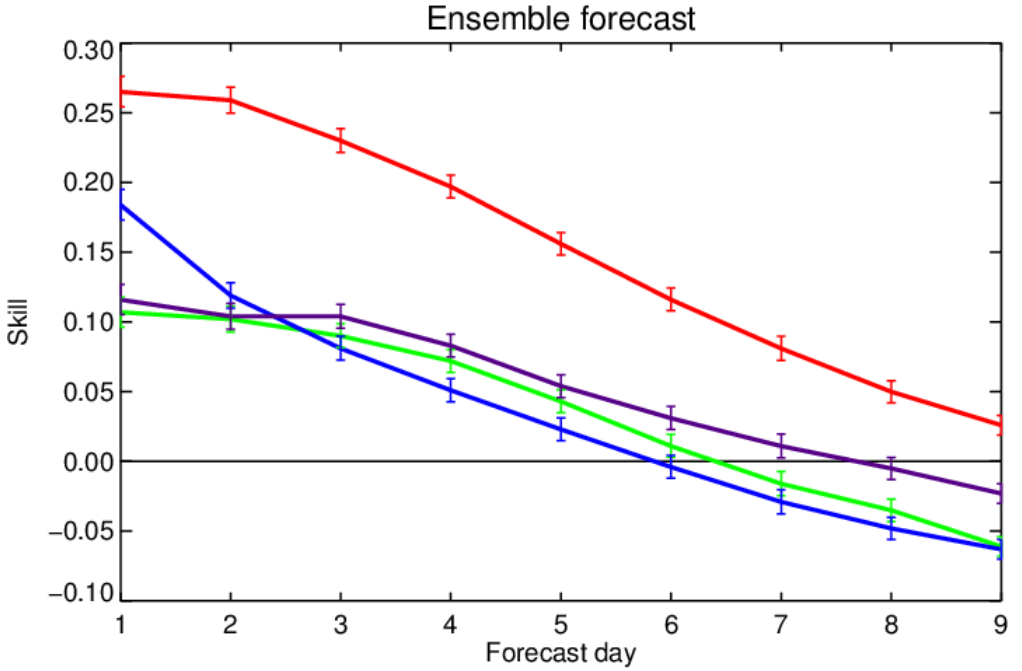
Other centres N hemisphere, D+5



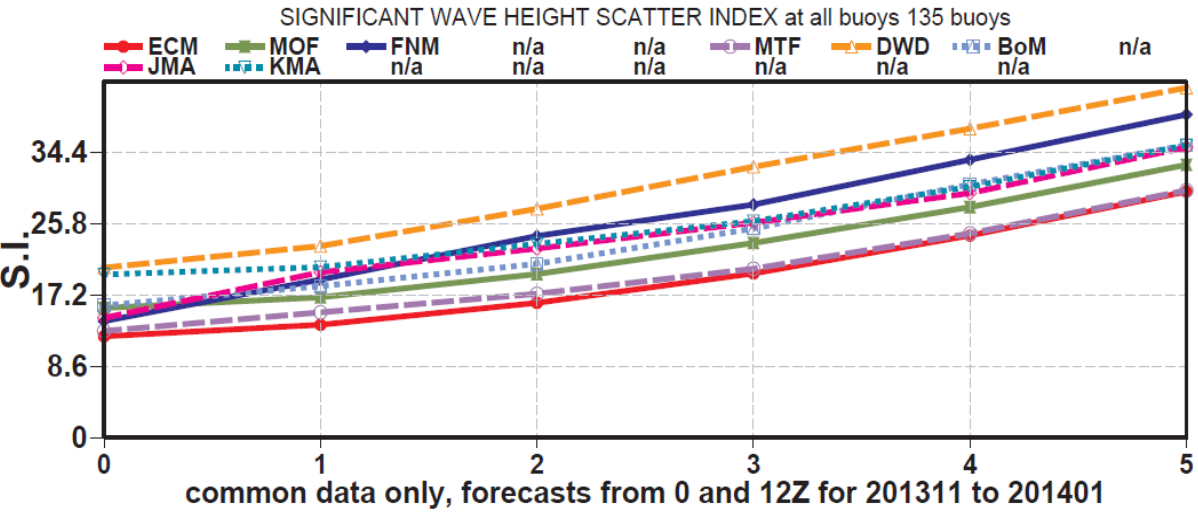
Precipitation skill

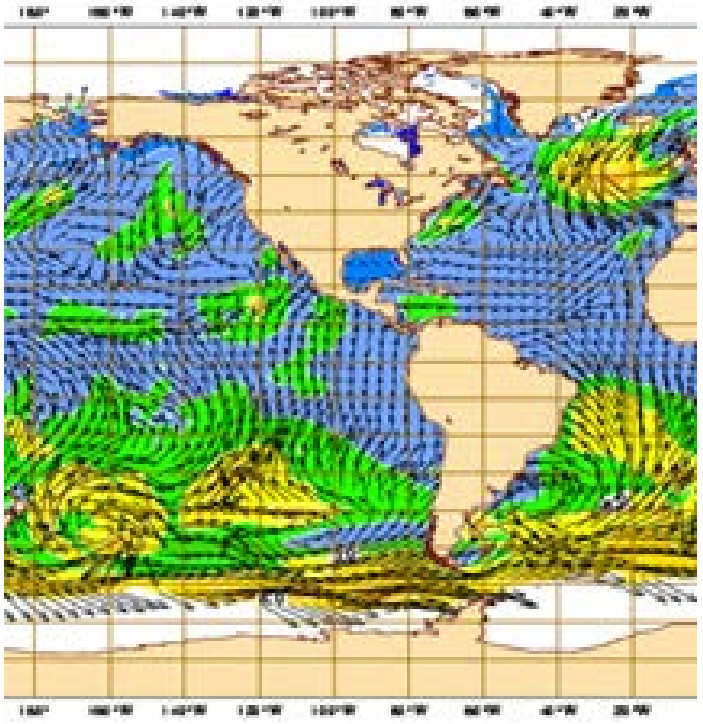






The errors of the ECMWF wave height forecasts (red) compared to other major global centres

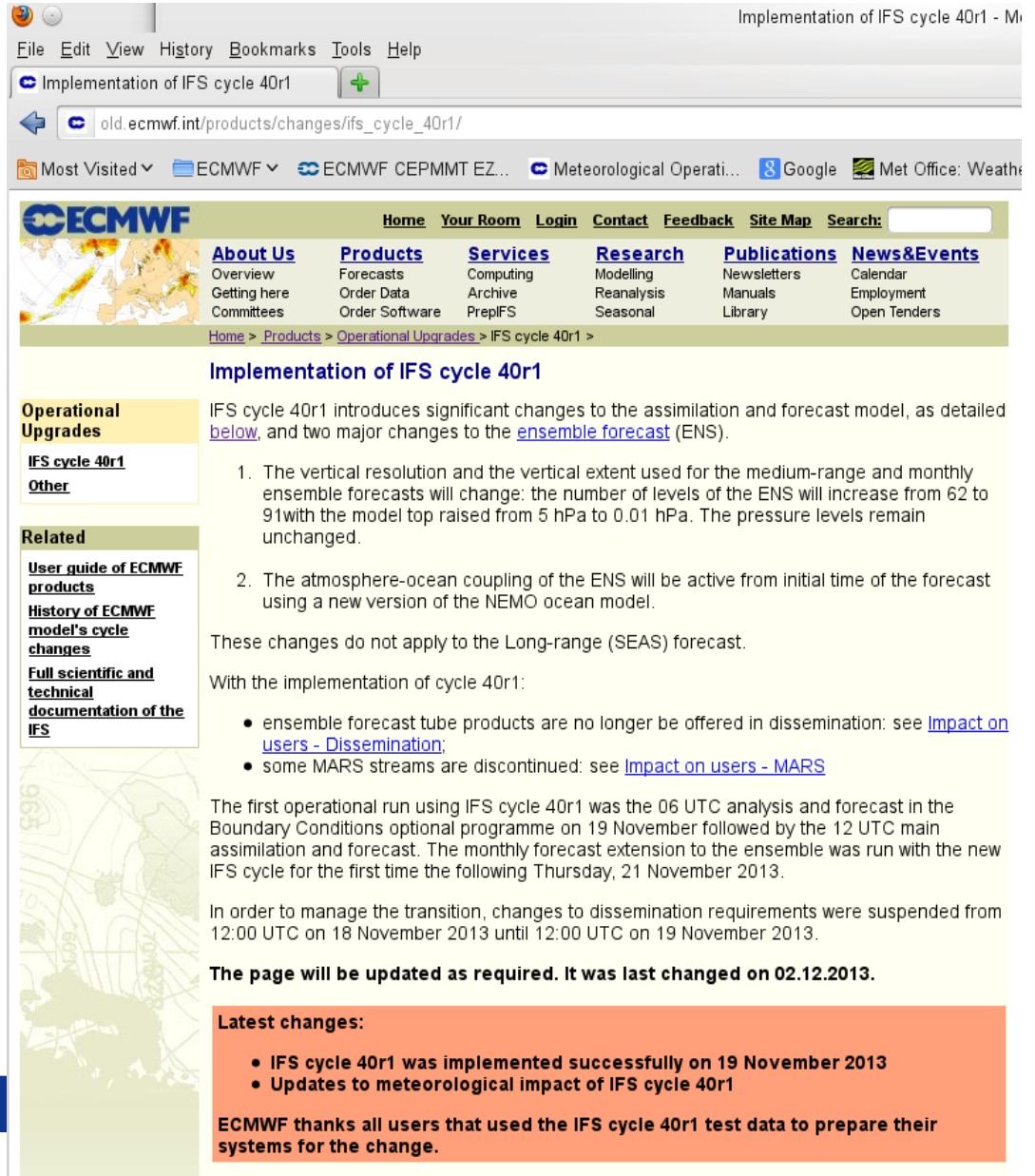




The scores for all centres are computed for a fixed set of ocean buoys in a verification project for the WMO-IOC Joint Technical Commission for Oceanography and Marine Meteorology. The error score is the scatter index (SI – the standard deviation of error normalised by the mean observed value) for forecasts of significant wave height out to five days ahead for the period January - March 2013.

New model cycles

- Typically 2 per year
- Fax announcement
- Web page for information on operational model changes
  - Technical details
  - Meteorological changes
  - Verification results
- Test data



Cycle 38R2 (June 2013): Main contents

Number of levels increased from 91 to 137 in high-resolution forecast model (HRES), the ensemble of data assimilations (EDA), the main assimilation (4DVAR) and the Boundary-Conditions (BC) optional programme

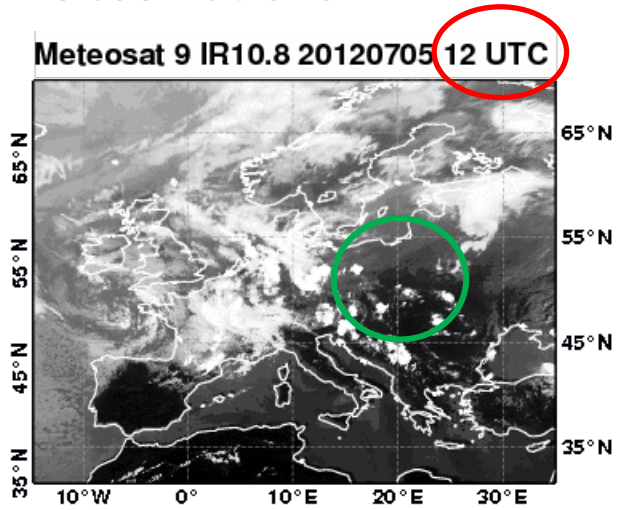
- Revised background error variances at 137 levels based on IFS cycle 38r1
- Revised EDA calibration and filtering for 137 levels
- Flow dependent, unbalanced errors in EDA
- Modification of surface drag
- Modified test parcel entrainment in boundary layer and shallow convection, auto-conversion
- Adjustment of non-orographic gravity wave drag to be consistent with System-4
- SV retuning in ENS

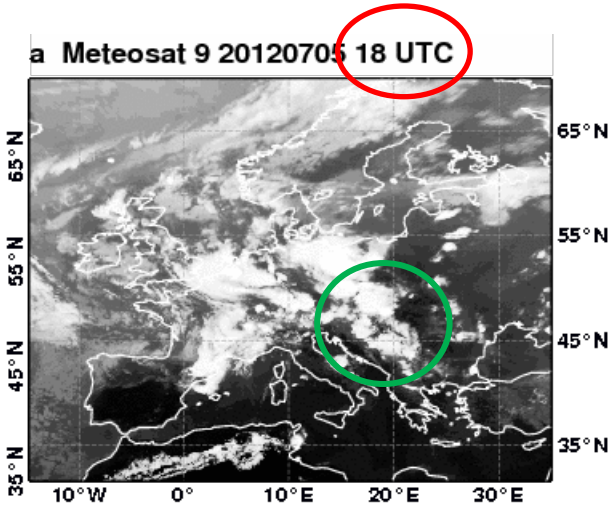
Cycle 40R1 (November 2013) includes:

- **ENS:**
  - **Vertical resolution and extent increased: from 62 to 91 levels, with the model top raised from 5 hPa to 0.01 hPa**
  - **Atmosphere-ocean coupling from initial time of the forecast using a new version of the NEMO ocean model**
  - **perturbation of land surface initial conditions**
- **HRES and ENS**
  - **Convection: improved diurnal cycle of precipitation**
  - **A package of changes introduced to stable boundary layer diffusion, turbulent orographic drag, orographic gravity wave drag and surface-atmosphere coupling over forests, which improves boundary layer winds (e.g. at wind turbine hub height) and improves northern hemisphere winter scores**

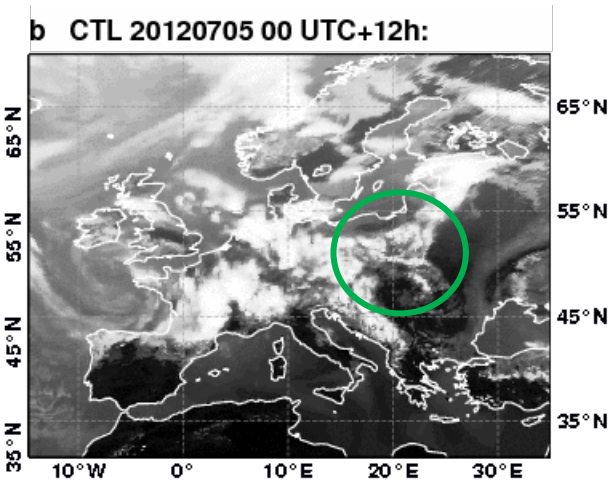
Cycle 40R1: Diurnal cycle convection

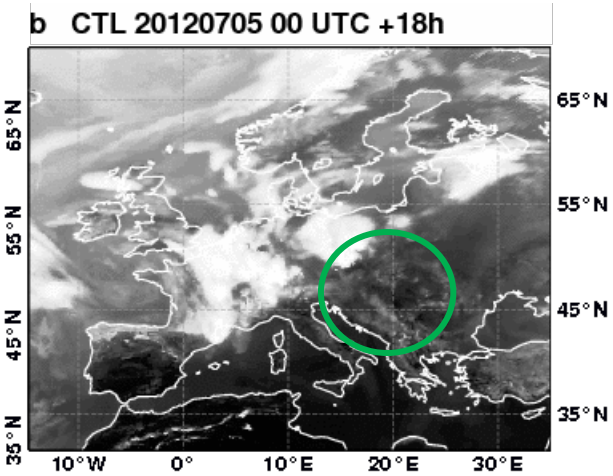
Observations



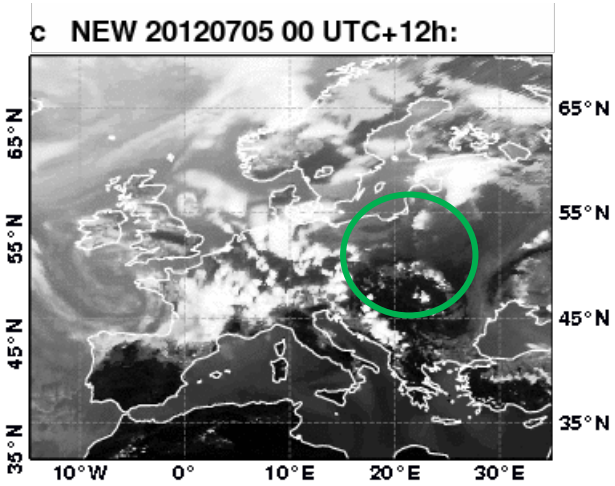


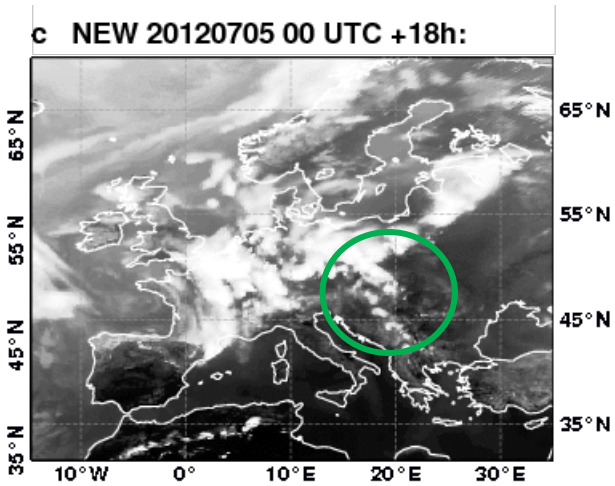
Current scheme



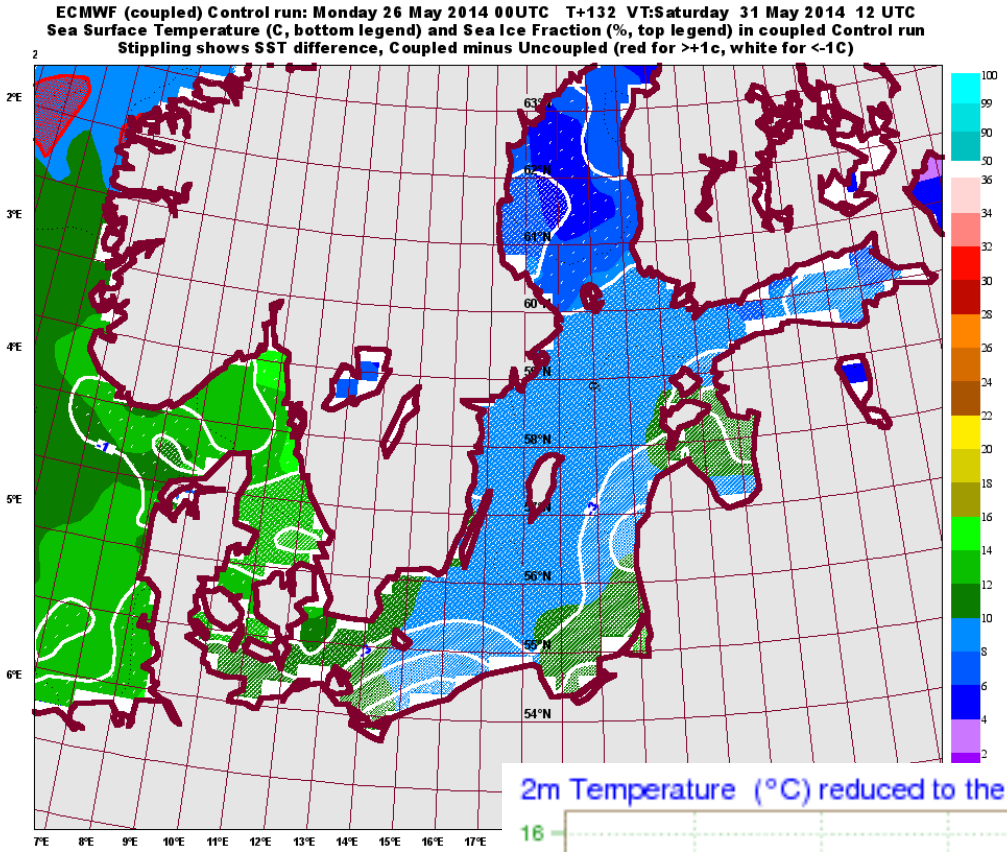


New scheme

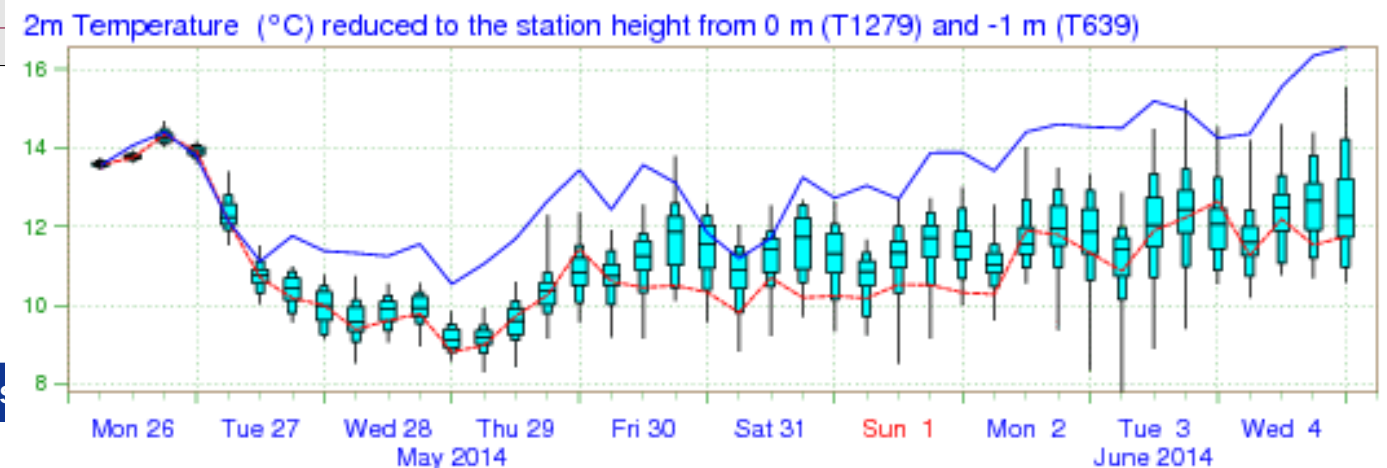




Coupled ocean from beginning of forecast



ENS coupled throughout
HRES not coupled



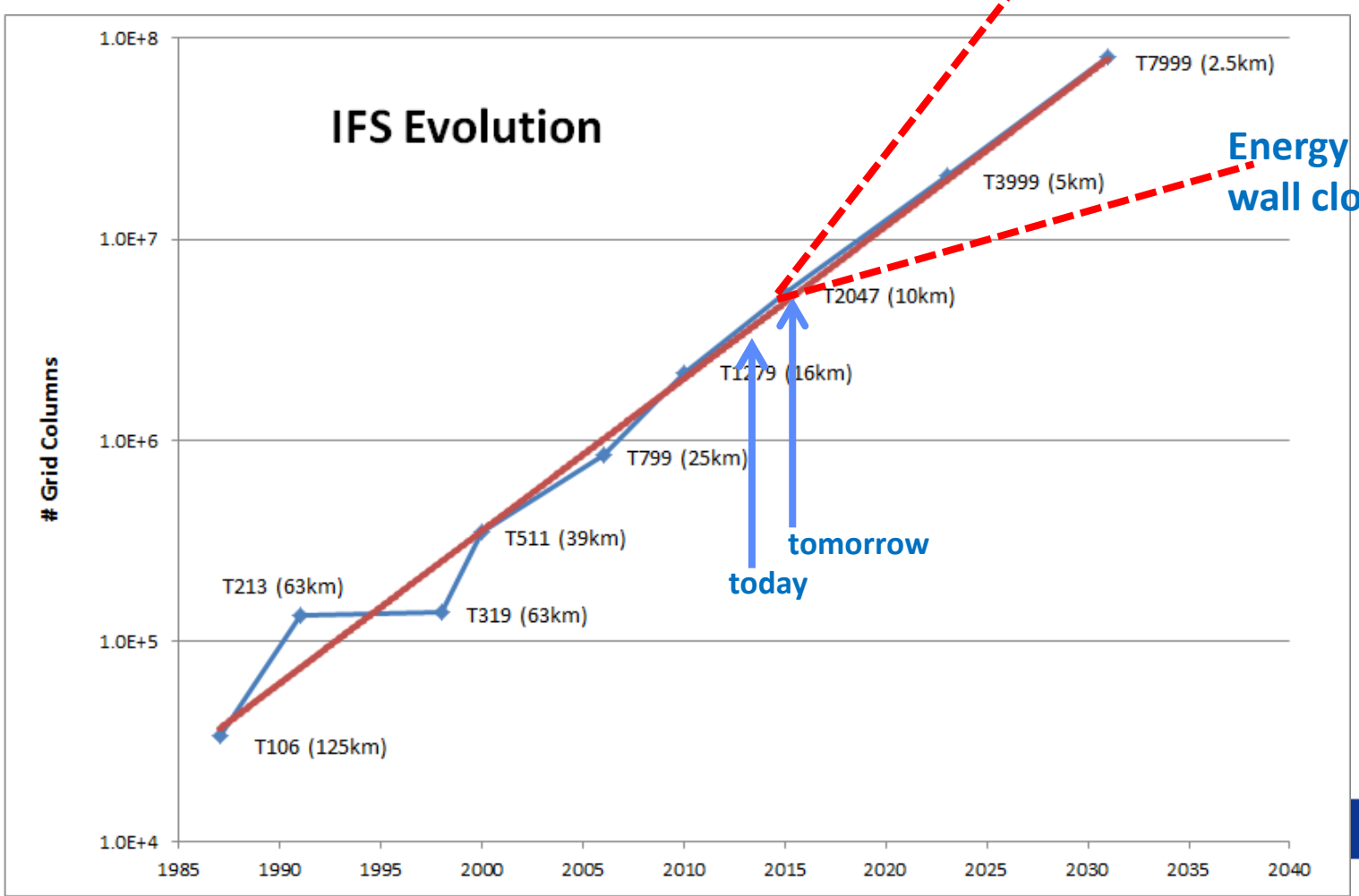
Cycle 40R3 (autumn 2014) includes:

- **cloud scheme: rain evaporation/autoconversion/accretion, riming (less drizzle, reduced T-bias)**
- **instantaneous precipitation rates, max/min total precipitation rate in a period, precipitation type, "instantaneous" wind gust and visibility**
- **lake model (FLAKE) (better surface-atmosphere interaction)**
- **twice weekly 11-member reforecasts (more frequent updates of calibration)**

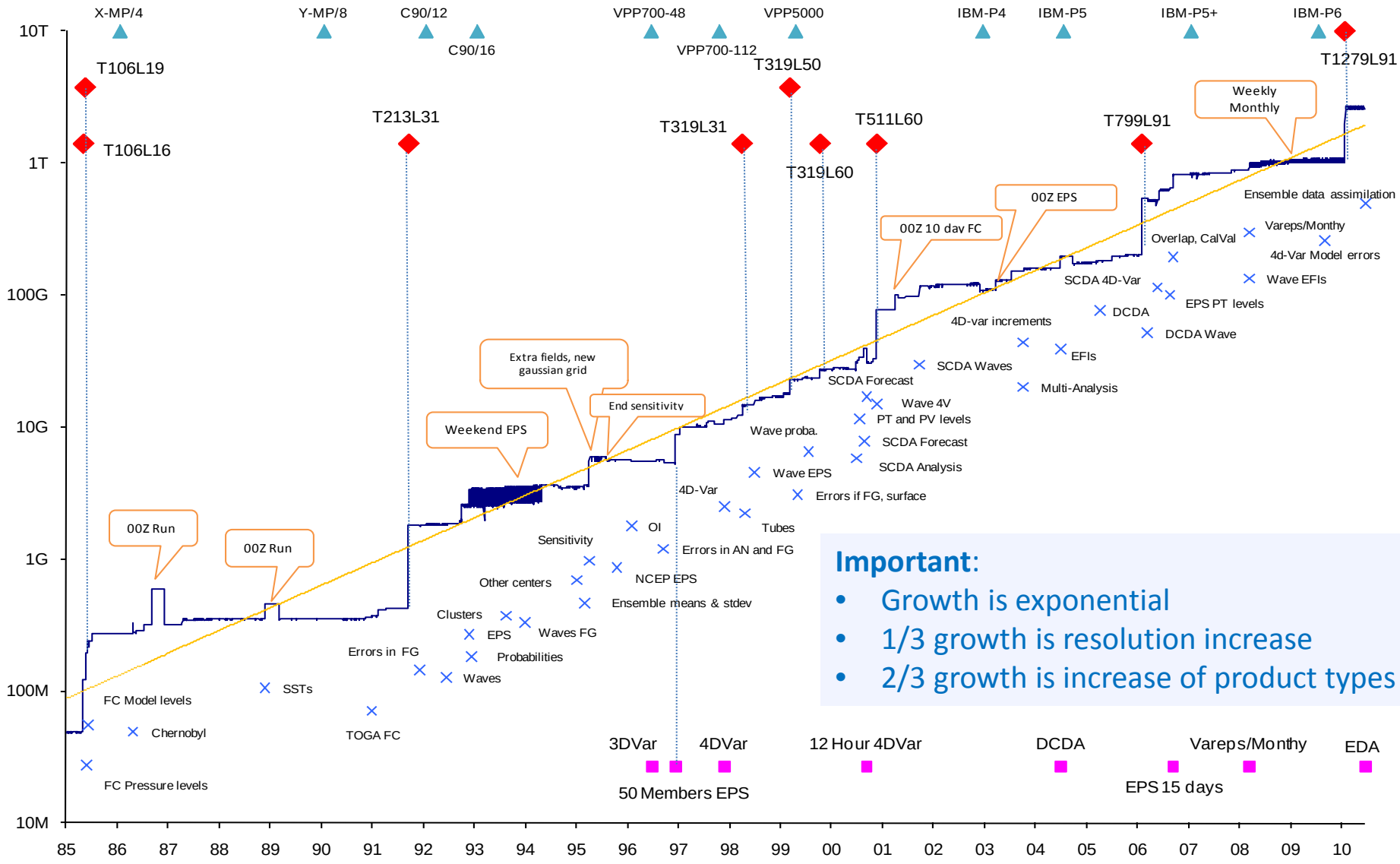
- **3x T255 inner loops in DA (higher res. first inner loops, more smaller scale increments)**
- **weighted sampling from more recent EDA (more day-to-day variability in background errors)**
- **Wave modified stress in coupled mode (more interaction between waves and ocean)**
- **MACC-II CO2/O3/CH4 climatologies (latest trace gas climatologies)**
- **new surface climate fields (land-sea mask, sub-grid orography, albedo)**
- **improved SL-trajectory (reduced noise in SSW events)**
- **RTTOV-11 (new IR spectroscopy) MHS in all-sky assimilation mode (improved moisture analysis)**
- **assimilation of GPS-RO with 2D operator (better representation of lower tropospheric variability)**

2015: increase in horizontal resolution

- **HRES/EDA/4DVAR: ~10 km grid (T2047)**
- **ENS: ~20 km grid (T1023)**



MARS archive volume

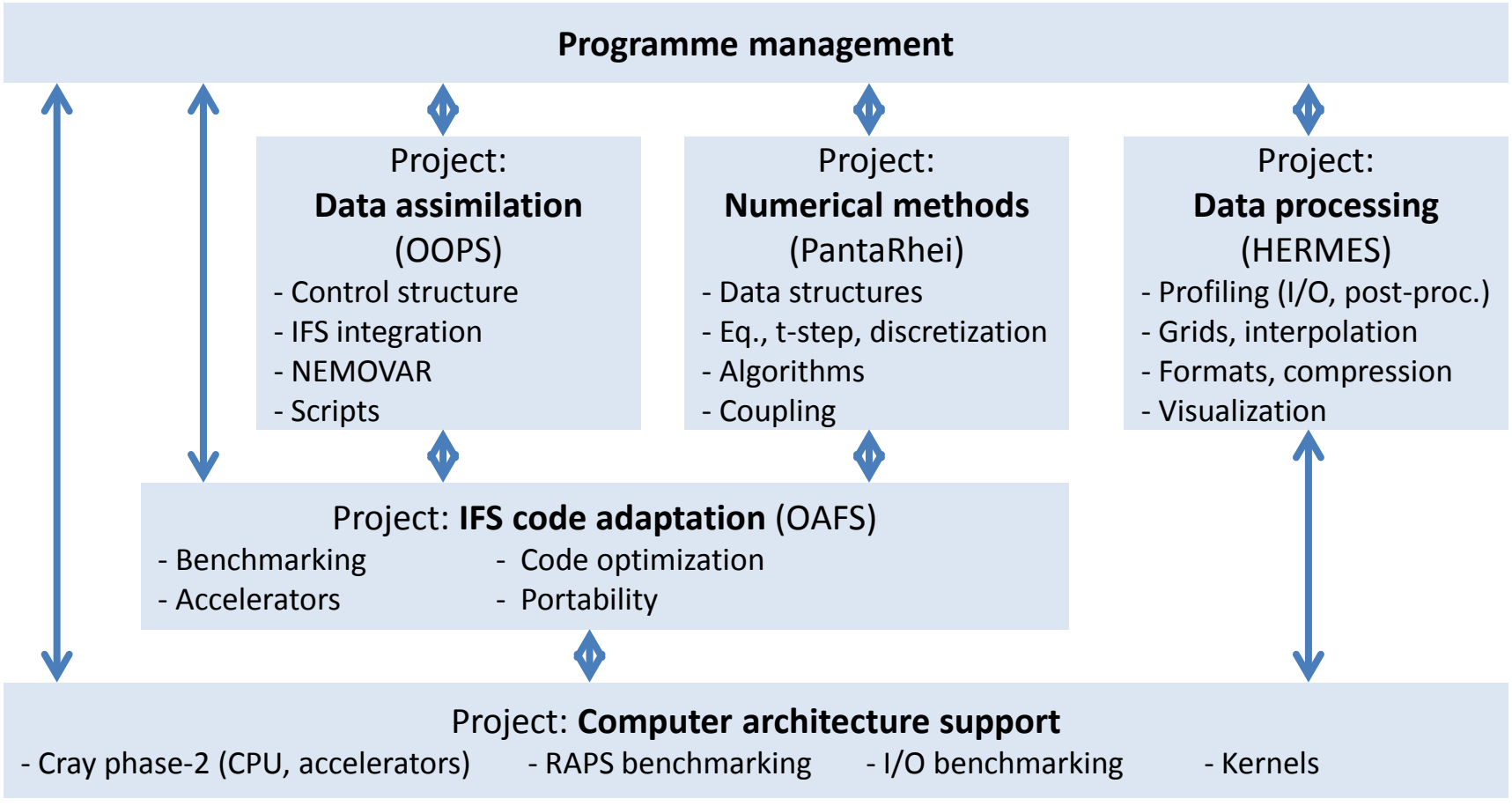


Important:

- Growth is exponential
- 1/3 growth is resolution increase
- 2/3 growth is increase of product types

Scalability Programme

- Implement a formal structure at ECMWF to coordinate science & software activities across departments for efficient exa-scale computing/archiving
- Coordinate activities with Member States, European HPC facilities, research centres, academia, vendors & international NWP centres



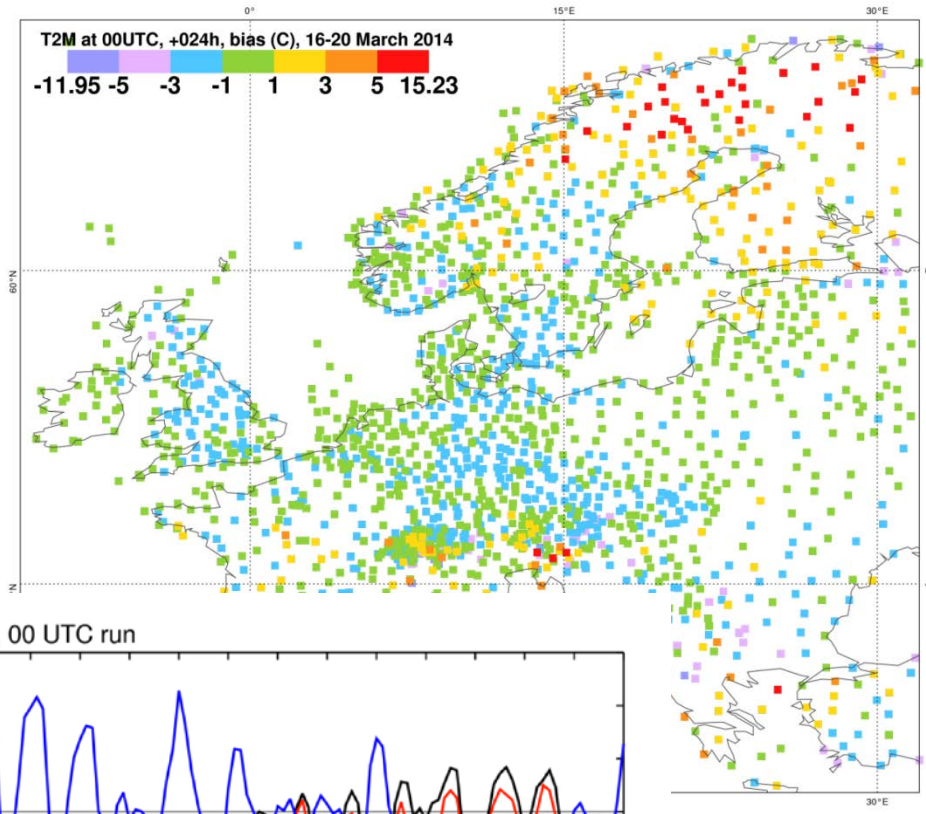
Scalability Project: Workshop

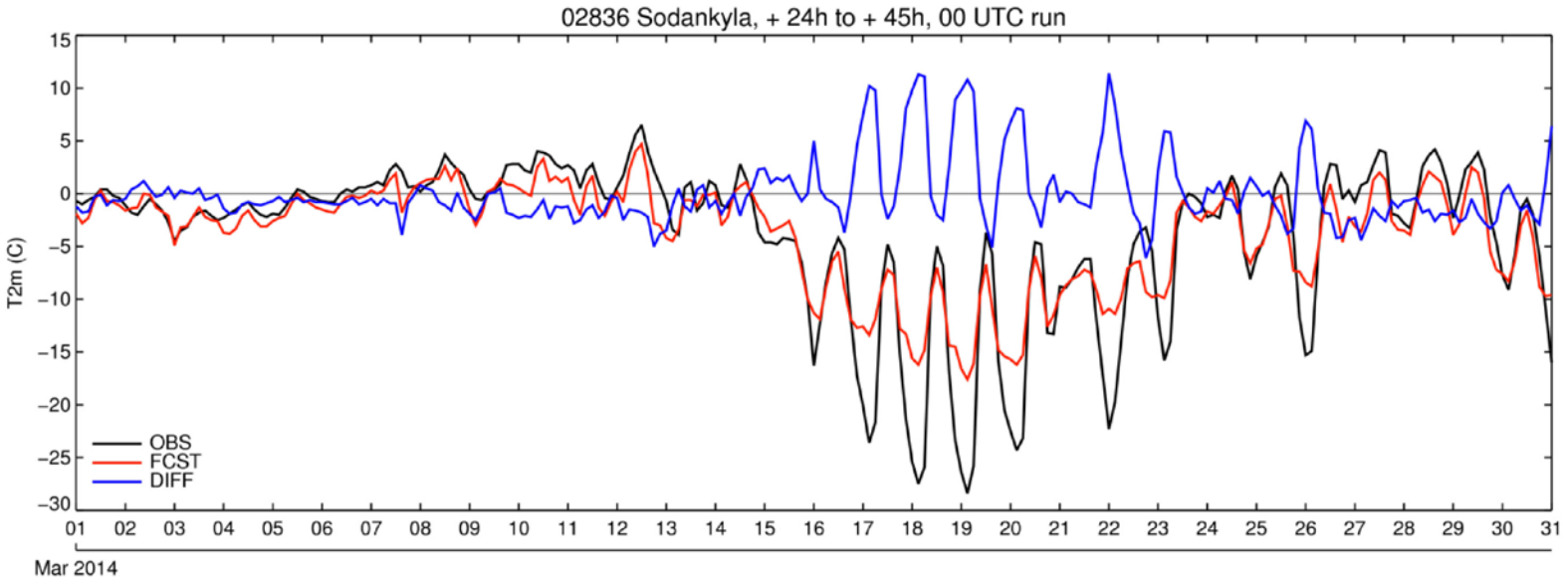
- **Scientific flexibility/choices:**
  - **E.g. which are the priorities between complexity, resolution, ensembles given scalability limitations?**
- **Numerical techniques/libraries:**
  - **E.g. what is the trade-off between accuracy and energy efficiency (e.g. double vs single precision)?**
- **Hardware/compilers:**
  - **E.g. how will the other components of an exa-scale system cope, e.g. Operating System, resource scheduler, workflow management, file system?**
- **I/O:**
  - **E.g. what needs to be archived/disseminated, what can be post-processed on the fly or recalculated?**
- **Benchmarking:**
  - **E.g. which components of the workflow should be benchmarked separately and how?**

http://old.ecmwf.int/newsevents/meetings/workshops/2014/Scalability/index.html

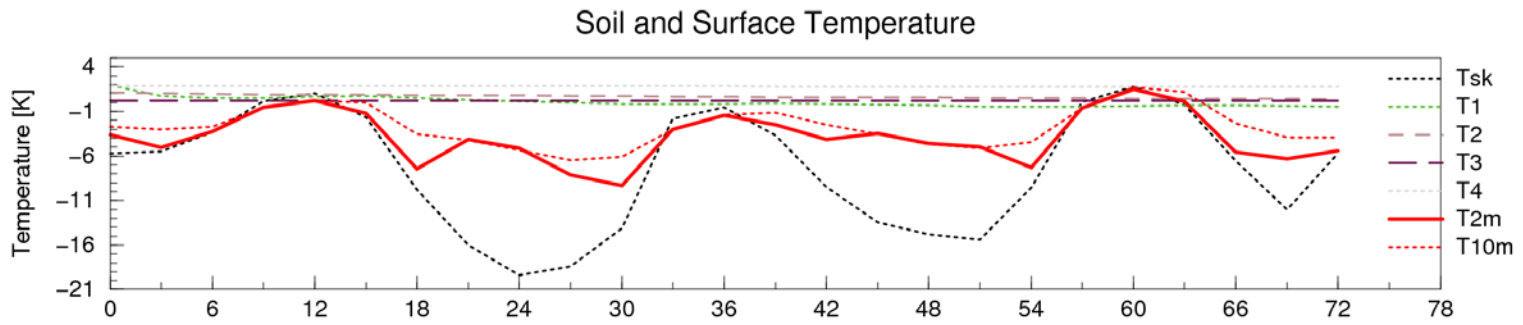
2m temperature errors

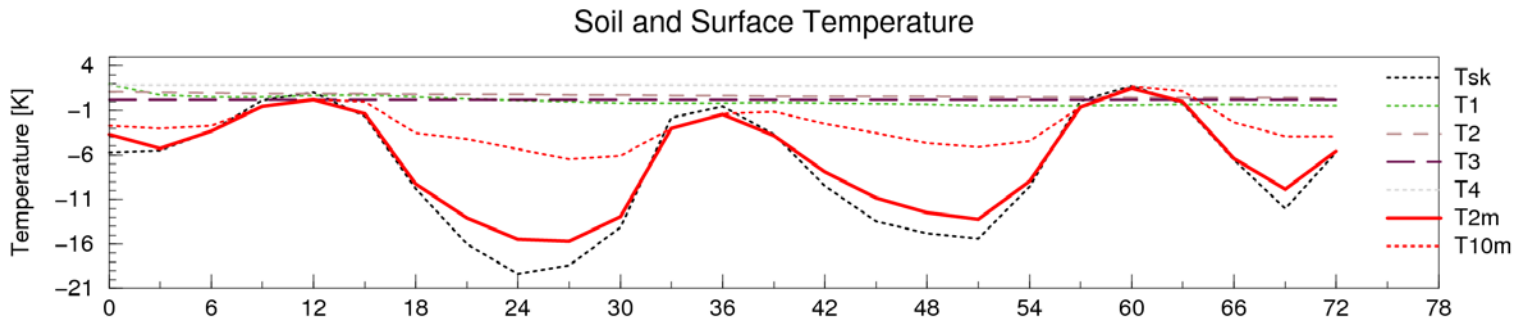
Positive 2m temperature bias in cases of strong surface inversions and very weak wind, may reach 10 K
Especially over snow, nighttime





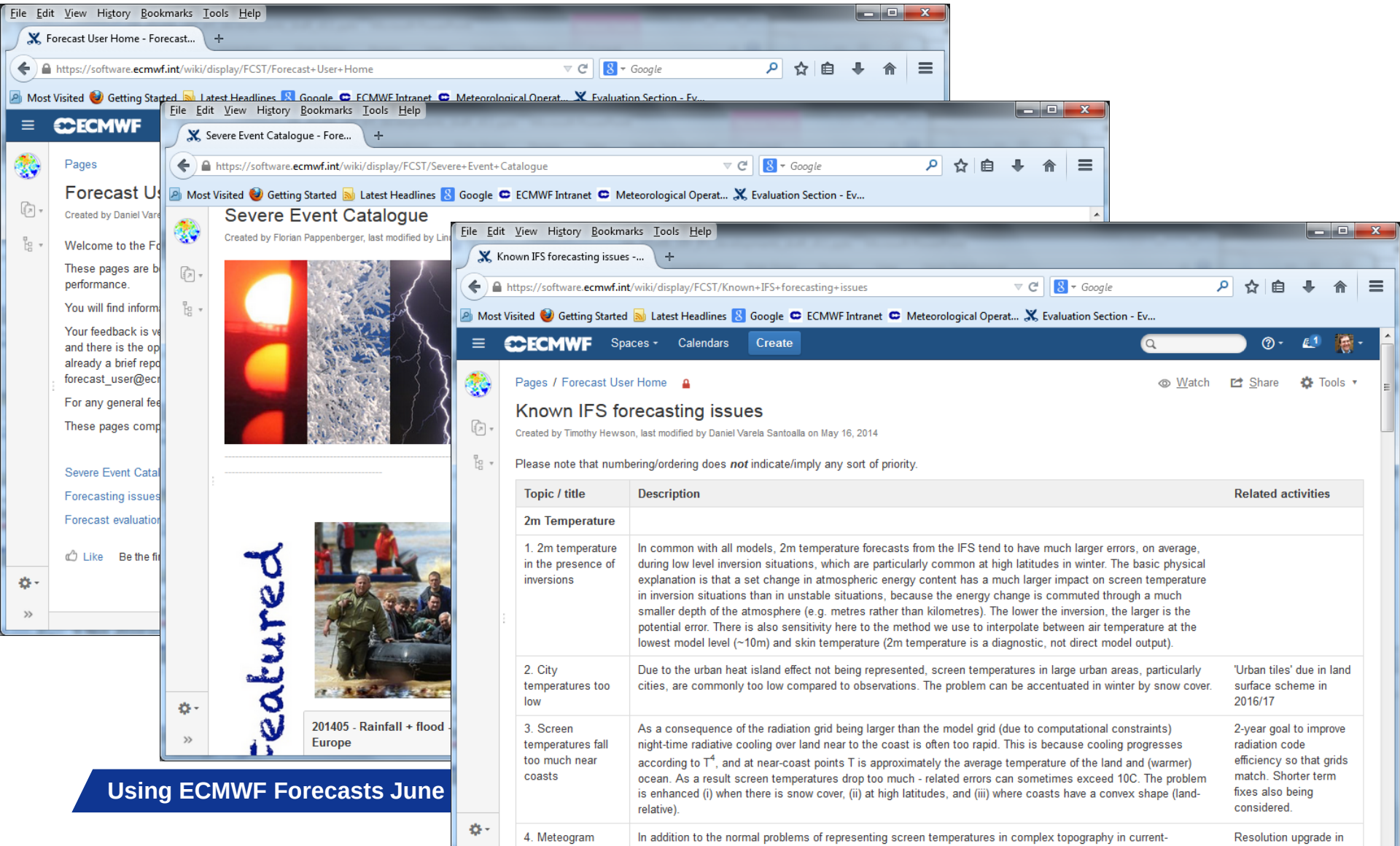
2m temperature errors





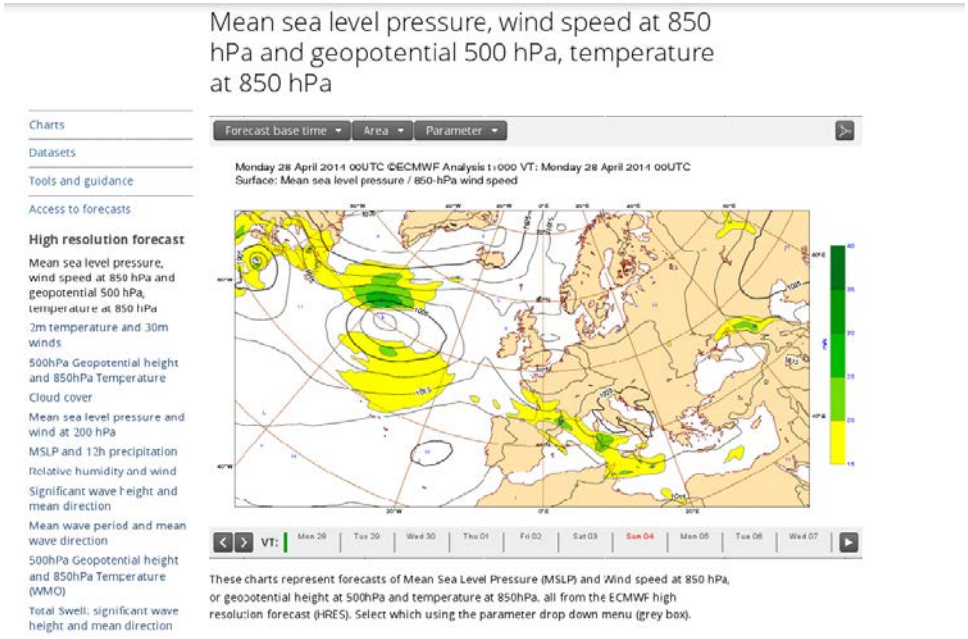
New forecast users web space

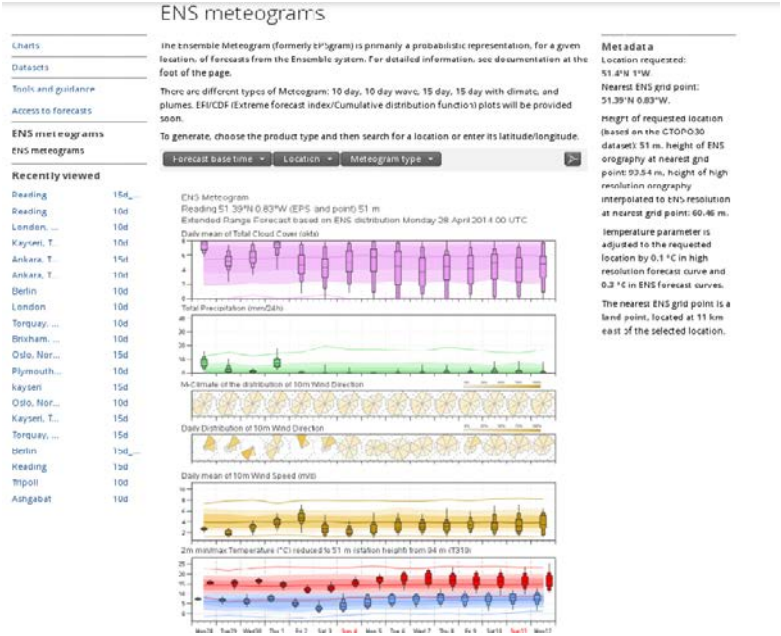
https://software.ecmwf.int/wiki/display/FCST/Forecast+User+Home



Charts on the new web site

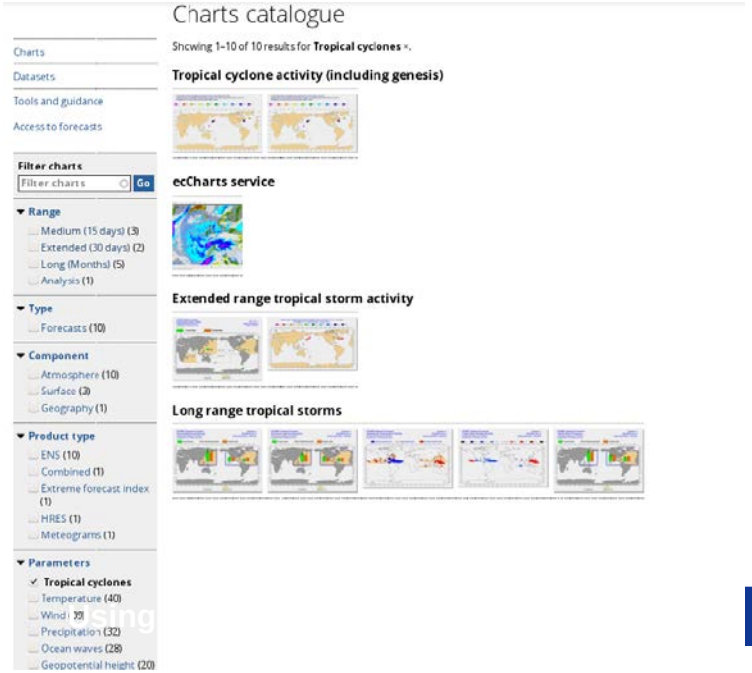
- **Modernize the look in the context of web2013 project**
- **New software infrastructure to allow new products & features**
- **Migration of essential products (~140) is completed**
- **New user interfaces for charts and meteograms**

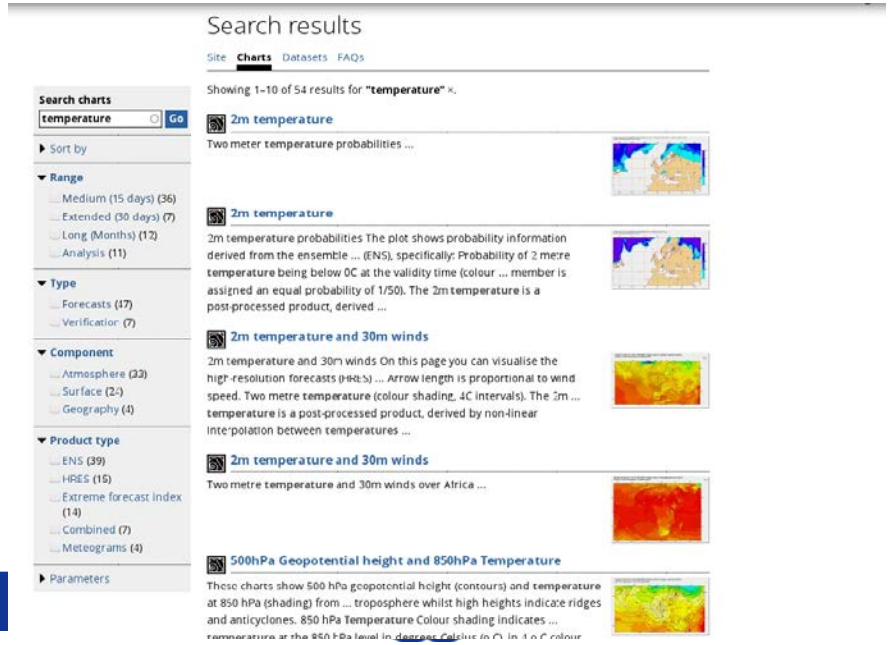




Navigation and discovery

- **Hierarchical navigation replaced with faceted navigation based on search facility**
- **Faceted navigation provides list of all products based on pre-defined facets (eg: Display all tropical cyclone products, display all temperature products …)**
- **An improved search facility**



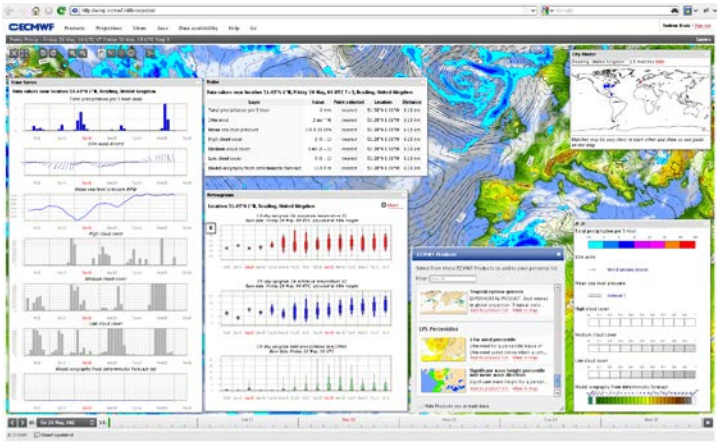


Future plans for web charts

- **Complete the migration of products (ie: Observation monitoring, tropical cyclone tracks, EUROSIP plots, Special projects …)**
- **Implementation of more advanced features such as “Your room”**
- **Start building interactive products (basic zoom and pan and click functionalities as in clickable EFI)**
- **Receive/revise/implement user feedbacks**
- **Most modern browsers are supported.**
- **Retirement of old web site and application framework.**

ecCharts updates

- **June 2014 focuses on content:**
  - **Additional EFI parameters: wind gust, snowfall, significant wave height, 2m max temperature, 2m min temperature**
  - **EFI parameters extended up to 7 days, 1-day ranges**
  - **250 hPa geopotential/temperature/relative humidity/wind/wind speed (HRES)**
  - **Relative humidity at 1000 and 925 hPa (HRES)**
  - **K-index**



- **November 2014 (content and software):**
  - **Revision and addition to combined probabilities**
  - **Total totals index, CIN**
  - **Zero degree level**
  - **Shift of tails**
  - **Specific humidity at 1000 hPa and 925 hPa,**
  - **Divergence at 1000 hPa, 925 hPa, 500 hPa and 300 hPa**
  - **Usability improvements**