Ongoing and upcoming developments/products of the IFS forecast system at ECMWF plus other news from the ECMWF

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Presentation in the team atmosphere lunch
Atmospheric Science Seminar Series (ASSS)

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Outline

- The Scientific Advisory Committee at ECMWF
- Delivering global predictions – including ensembles.
- Overview of models and systems (numerics and grid design, parameterization, data-assimilation)
- HPC, scalability and software.
- Copernicus activities at ECMWF: CAMS (IFS-COMPO), C3S (reanalyses and seasonal prediction), CO2MVS (in the plans)
- Plans and strategy

Scientific Advisory committee (SAC)

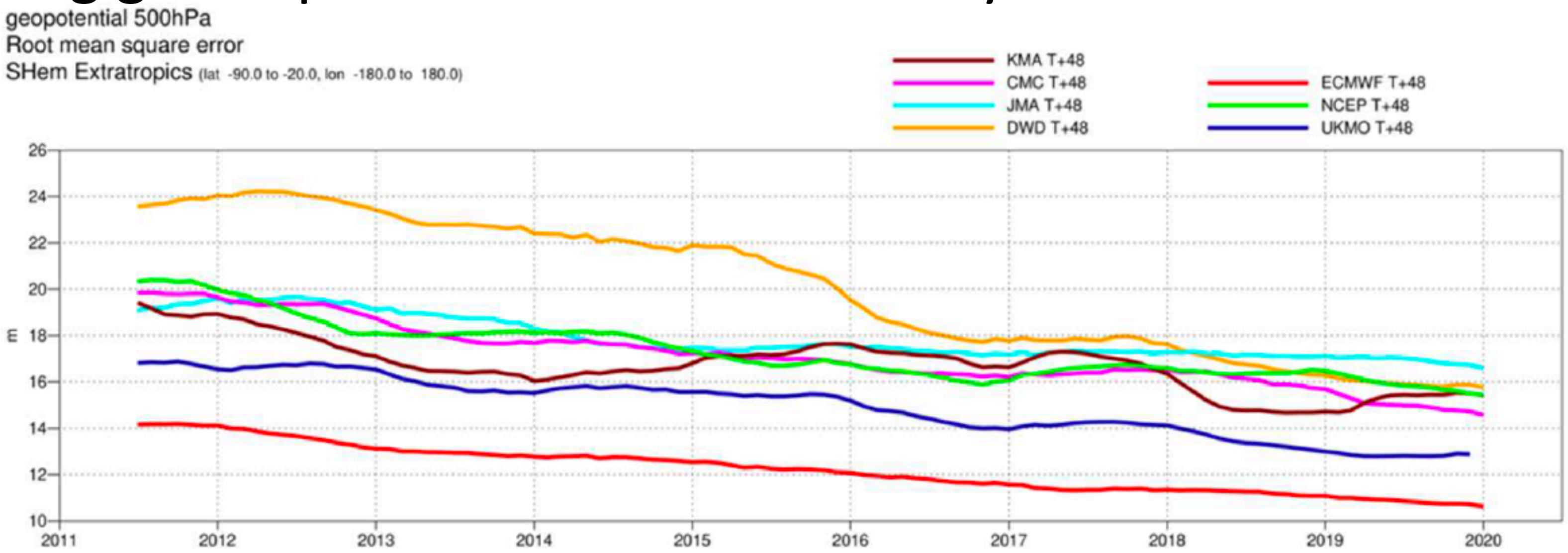
SAC: 12 members selected from the ECMWF member states. The chair is currently Inger-Lise Frogner from MetNo.

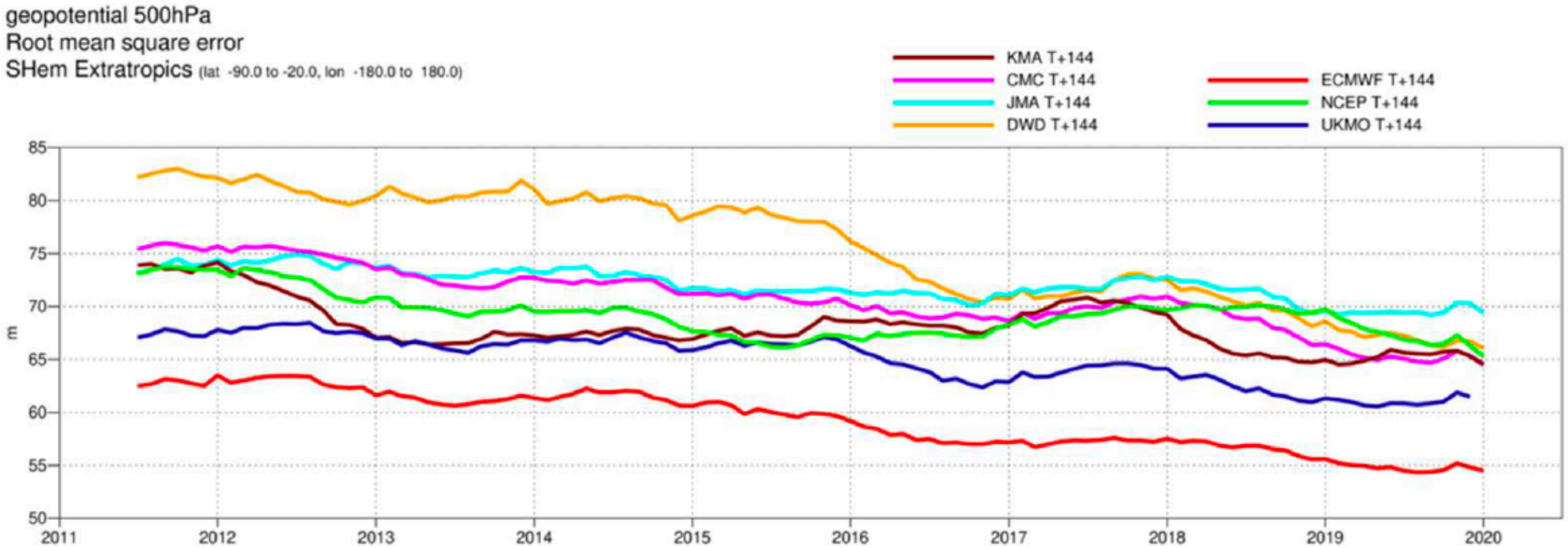
Together with Alain Joly from Meteo France I am “responsible” for the dynamical core design advices, i.e. how to numerically solve the 7-9 coupled non-linear partial differential equations representing the governing physical laws of the atmosphere:

- Navier-Stokes equation (2 – 3 equations)
- Thermodynamic equation (1st equation of thermodynamics)
- Continuity equation for (dry) air
- Continuity equation for water vapor
- Continuity equation for cloud liquid water
- Continuity equation for cloud ice
- Continuity equation for ozone
- (Many more continuity equations in CAMS)

Alain is furthermore an expert in computational science.

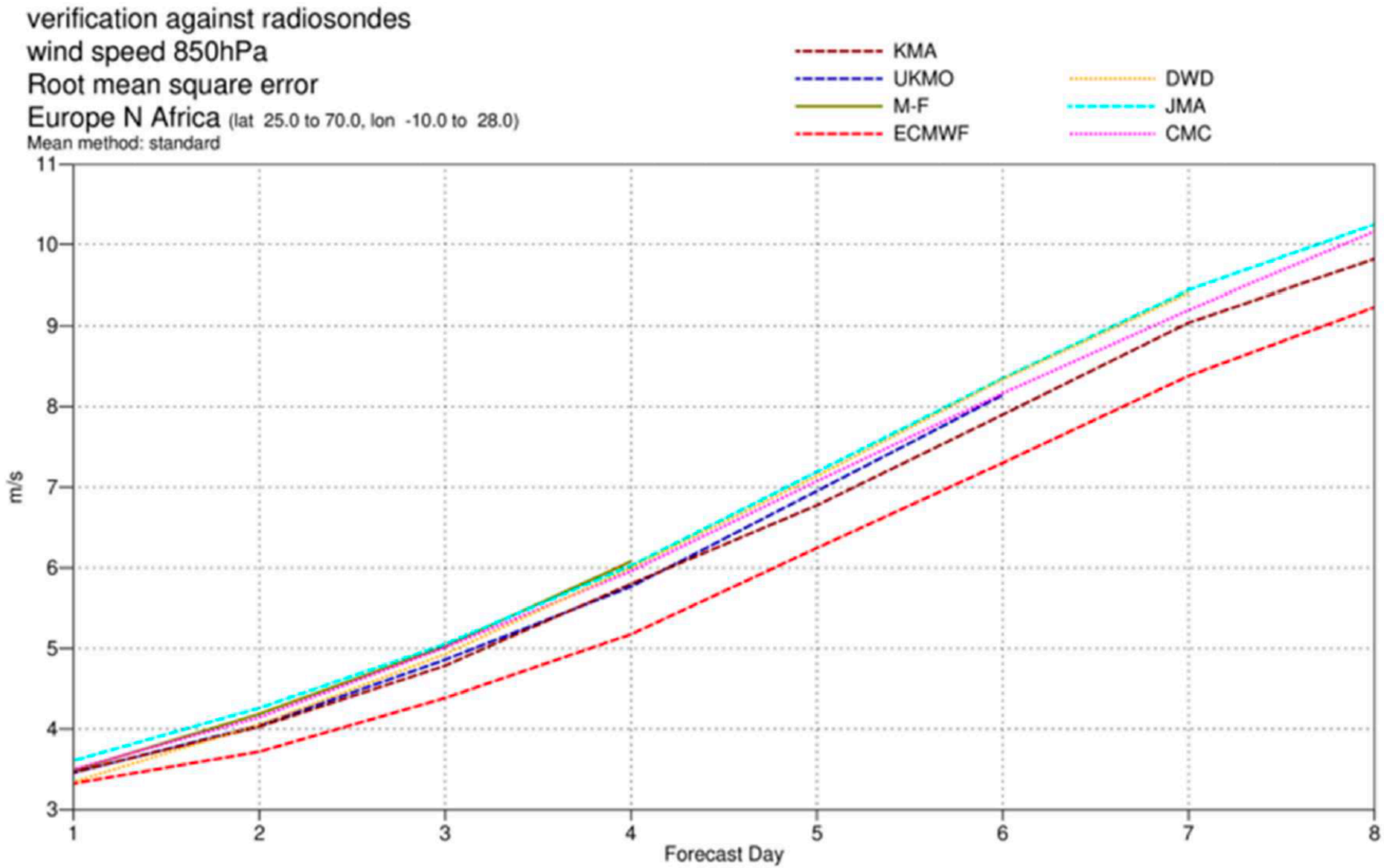
Delivering global predictions with the IFS system





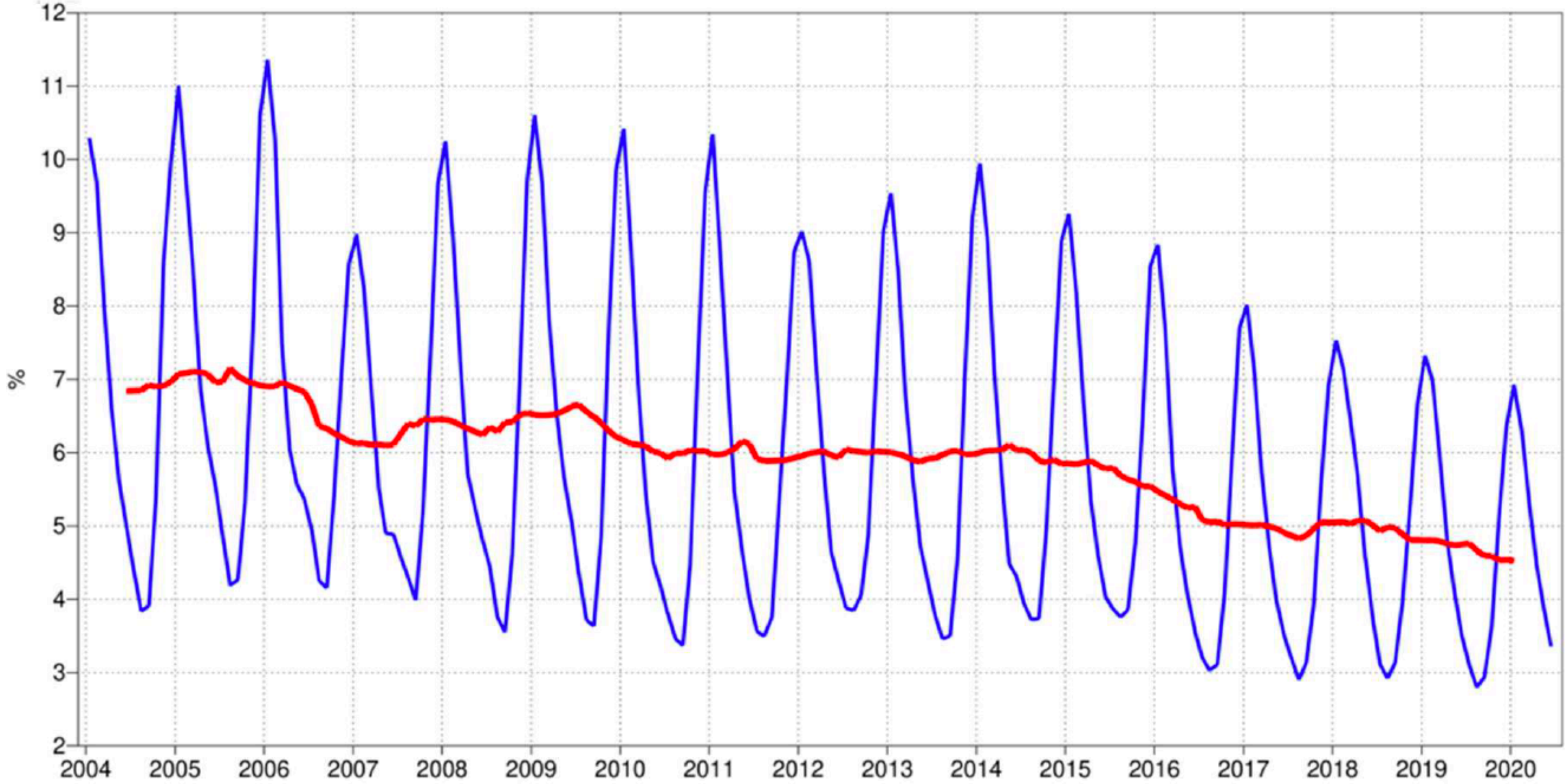
WMO-exchanged scores from global forecast centres. RMS error of 500 hPa geopotential height over northern (top box) and southern (bottom box) extratropics: six-day forecast error of model runs initiated at 12 UTC. **Each model is verified against its own analysis**. JMA = Japan Meteorological Agency, CMC = Canadian Meteorological Centre, UKMO = the UK Met Office, KMA = Korea Meteorological Administration, NCEP = U.S. National Centers for Environmental Prediction, DWD = Deutscher Wetterdienst.

Delivering global predictions with the IFS system



WMO-exchanged scores for verification against radiosondes: 850 hPa wind RMS error over Europe (annual mean August 2019–July 2020) of forecast runs initiated at 12 UTC.

Delivering global predictions with the IFS system. Ensemble verification



Evolution of the fraction of large 2m temperature errors (CRPS>5K) in the ENS at forecast day 5 in the extra-tropics. Verification is against SYNOP observations. 12-month running mean shown in red, 3-month running mean in blue.

Continuous ranked probability score (CRPS) is basically the mean square error (MSE) of your predicted cumulative density function (CDF) and the true CDF. More on this on the Tuesday where Aksel and I will discuss model validation.

Overview of models and options: the operational IFS system

Present operational cycle (October 2020): IFS Cycle 47r1

Main set-ups

- HRES (Deterministic): TCo1279/L137 resolution (corresponding to a horizontal grid spacing of about 9 km)
- ENS (Ensemble): TCo639/L91 with 52 members (corresponding to a horizontal grid spacing of about 18 km).
- Extended (< 46 days): Same as ENS resolution

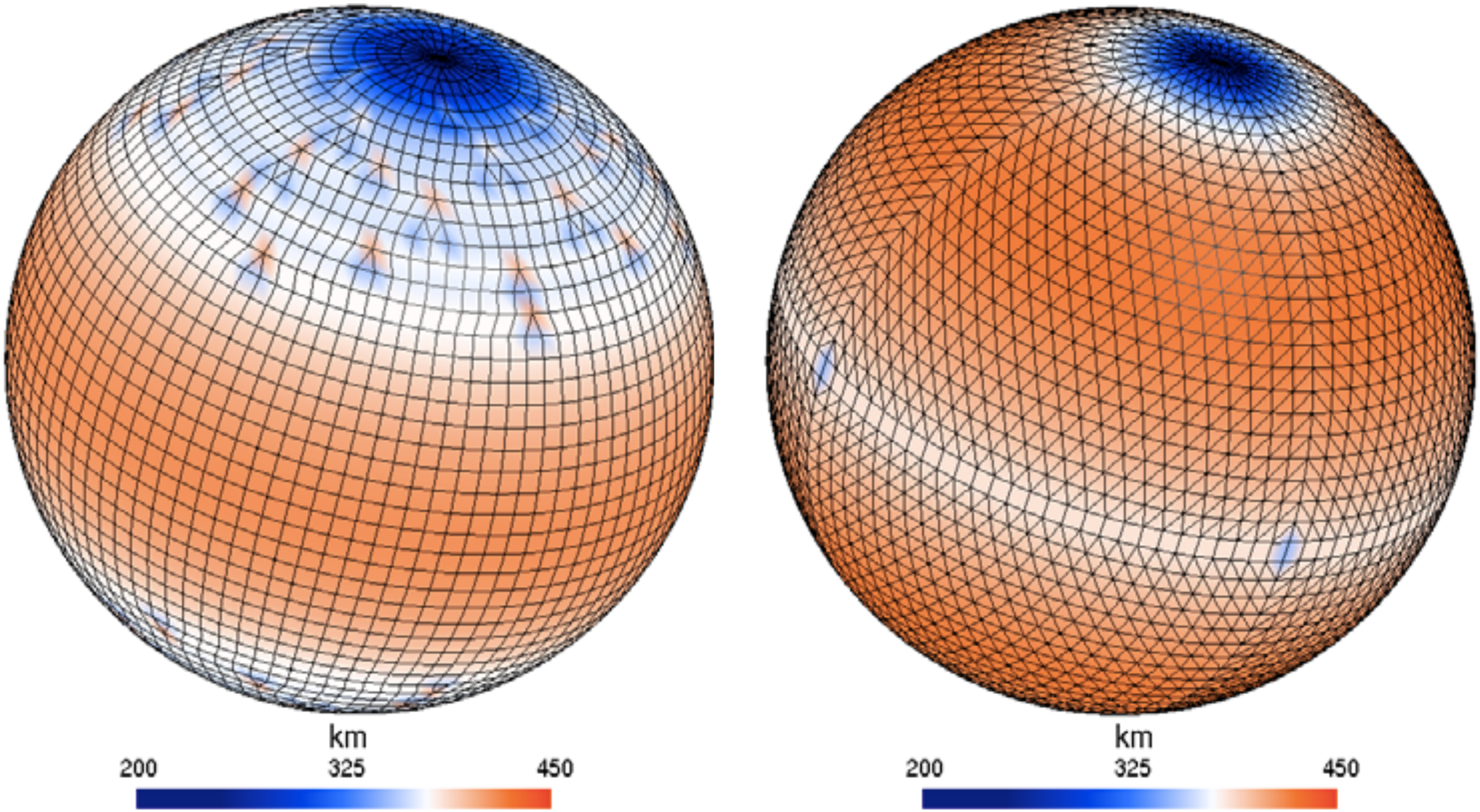
Advanced parameterization of all relevant diabatic physical processes, including a stochastic perturbed physics tendency scheme (SPPT).

Other:

SEAS5 (long range): IFS Cycle 43r1 with resolution TCO319/L91 coupled to NEMO and LIM2 sea ice. Now in single precision, saving some 30%!

ERA5: CY41R2 with native resolution T639/L137 (Gaussian grid)

Overview of models and options – the octahedral grid representation



Left: (quasi-) linear grid as used previously and still in EC-Earth. Right: octahedral mesh (used in the operational IFS)

Overview of models and systems – different dynamical cores

Operational IFS model: hydrostatic model with a pressure based vertical coordinate (hybrid sigma – pressure). Still a semi-Lagrangian (now with quintic vertical interpolation), semi-implicit spectral transform model. This version of IFS is expected to work well into the “gray zone” (3 – 5 km), so, it will likely survive even beyond 2025. This dynamical core is probably the most efficient one world wide, particularly when it comes to so-called multi-tracer efficiency (important in Copernicus Atmospheric Monitoring Service - CAMS).

NH-IFS: a non-hydrostatic version of IFS, which is also using a pressure based vertical coordinate (with option for finite elements), and with the semi-Lagrangian, semi-implicit spectral transform formulation. Except for being global, the dynamical core of this model is very similar to the regional Arome model (on which HARMONIE is based). Not as efficient as IFS – but there should be room for further optimizations.

IFS-FVM: a new finite volume (i.e., **formally locally mass-conserving**) based version of IFS which integrates the fully compressible equations using semi-implicit time stepping and non-oscillatory forward-in-time (NFT) Eulerian advection. It is utilizing a generalized height-based vertical coordinate, and flexible horizontal meshes (i.e., also the octahedral grid can be used).

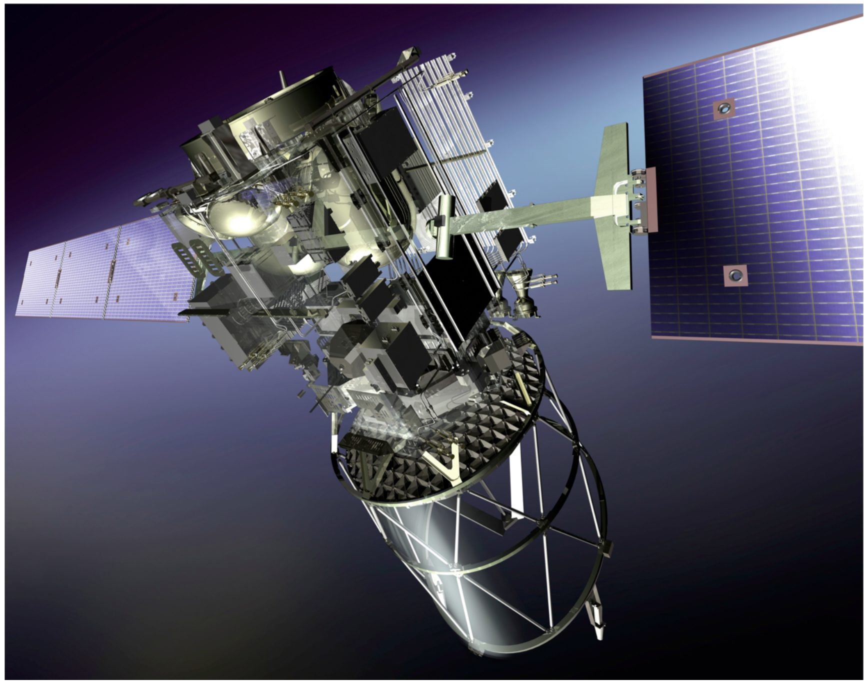
When tested on common adiabatic global baroclinic test cases the three models behave similarly. Still, however, NH-IFS and IFS-FVM are considerably less efficient than IFS.

Overview of models and systems – data assimilation

IFS includes a state of the art 4D-Var data assimilation system.

Since cycle 46r1 a so-called continuous data assimilation method is used, where even lately arriving observations can be assimilated. (see, e.g., this link)

Myriads of data are assimilated. One particularly successful new source of data is from ESAs Aeolus mission. ECMWF has played a fundamental role in this success which, otherwise, could have resulted in a fiasco. This is because, said in simple words, that the 4D-Var system can be used indirectly to dynamically correct for even huge biases in satellite instruments (a problem, which as far as I remember was caused by unexpected cosmic ray impact on individual sensor cells).



ESA's Aeolus mission, where the ECMWF plays an important ground segment role

HPC, scalability and software (just a few notes).

The move to the new Atos HPC in Bologna. Test by later part of 2021. Should be fully operational by the end of 2022.

Single precision

Atlas: data structure library. This is a fundamentally important software package needed for, e.g., multigrid applications, efficient coordinate transformations and interpolations on the sphere. If not yet, it should become publically available and could indeed be relevant for the HIRLAM community (if this is not already the case?).

OOPS - Object-Oriented Prediction System. This is a project under ongoing developement, aiming at a more flexible code system. Planned for Bologna.

Important projects (also part of future plans – next slide):
EsiWACE2: perform scalability studies on pre-exascale machines of EuroHPC once these machines become available.

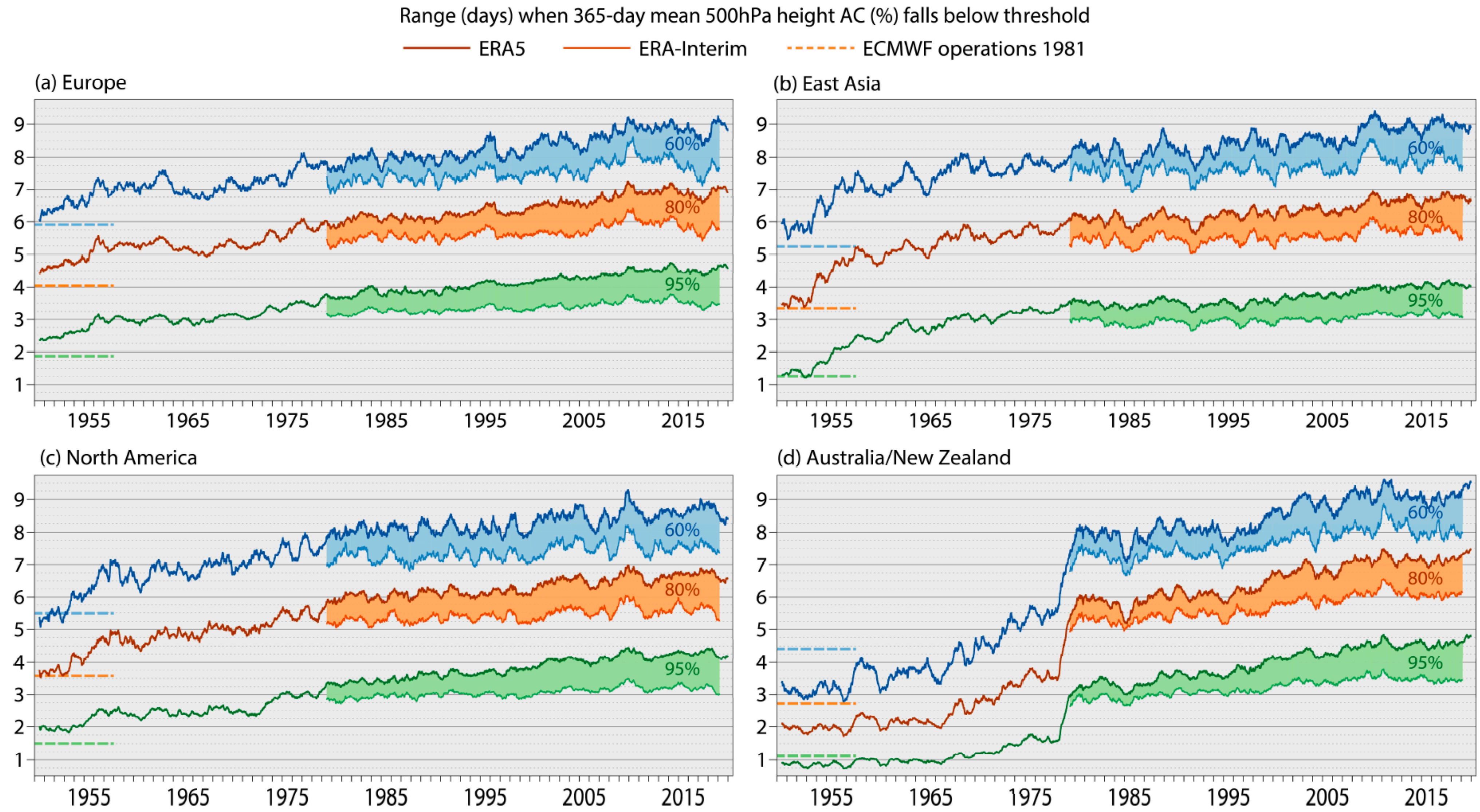
DYAMOND: participation of IFS in the DYAMOND project will also be continued in the second phase of the project. This will require us to run IFS with km-scale grid-spacing for 40 days during winter and in coupled mode, using both the wave and the NEMO model at ¼ degree resolution and another simulation exploring the grid-adaptive finite-volume FESOM2 model developed at AWI

In general: very strong focus on the usage of machine learning both for data-assimilation and parameterization.

Plans / Strategy: **just some highlights**

- Extended range: keep TCo639 but increase from L91 to L137
- Seasonal (S5 - > S6): keep TCO319 but increase from L91 to L137
- ENS: upgrade from L91 to L137.
- Almost full transition to single precission.
- Coupled data assimilation
- Improve the representation of physics in the grey zone.
- Very strong focus on the usage of machine-learning in multiple parts if the IFS system
- Adoption of a new ocean and sea-ice model
- New observations including EPS-SG, MTG and Sentinels-4 and -5
- Development of new reanalyses (ERA6) and seasonal prediction systems
- Gradually implementing the usage of GPUs and newer hardware designs into operations (when in Bologna)
- Destination Earth
- CO2MVS (a new Copernicus anthropogenic CO2 emissions monitoring & verification support capacity)
- OOPS in Bologna

Predictability dependence on observations



Range(days) at which running 365-day mean anomaly correlations of 500hPa height forecasts from 00 and 12UTC reach 95% (green), 80% (orange) and 60% (blue), for: (a) Europe; (b) East Asia; (c) North America; and (d) Australia/New Zealand from1950-2020. Also shown (dashed) is the skill of ECMWF operational forecasts throughout 1981. The heaviest lines denote ERA5, the thin lines denote ERA-Interim. Shading denotes the difference between ERA5 and ERA-Interim during the period for which both are available (1979-2019).