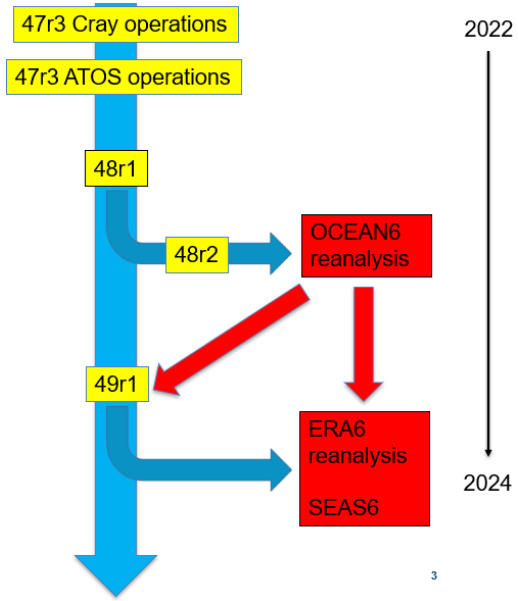
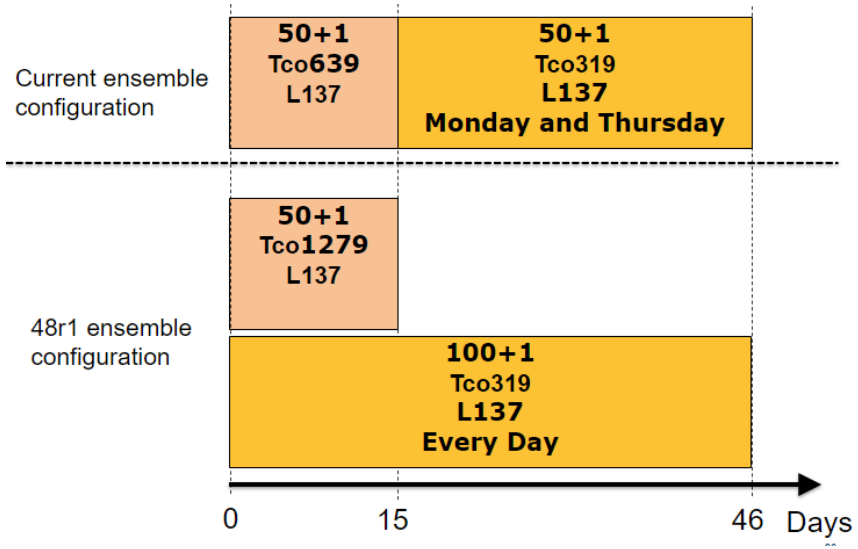
ECMWF: Status and Plans

ECMWF

Operational upgrades



Cycle 48r1



Publications

4. Refereed literature since preparation of last report

Agusti-Panareda, A., Barre, J., Massart, S., Inness, A., Aben, I., **Ades, M.**, Baier, B.C., **Balsamo, G.**, Borsdorff, T., **Bousserez, N., Boussetta**, S., Buchwitz, M., **Cantarello, L.**, Crevoisier, C., **Engelen, R.**, Eskes, H., **Flemming, J., Garrigues, S.**, Hasekamp, O., Huijnen, V., **Jones, L., Kipling, Z.**, Langerock, B., **McNorton, J.**, Meilhac, N., Noel, S., **Parrington, M., Peuch, V-H.**, Ramonet, M., **Razinger, M.**, Reuter, M., **Ribas, R., Suttie, M.**, Sweeney, C., Tarniewicz, J., Wu, L. (2023). Technical Note: The CAMS greenhouse gas reanalysis from 2003 to 2020, *Atmos. Chem. Phys.*, 23, 3829–3859, https://doi.org/10.5194/acp-23-3829-2023.

Agusti-Panareda, A., McNorton, J., Balsamo, G. et al. (2022). Global nature run data with realistic high-resolution carbon weather for the year of the Paris Agreement. *Sci Data* **9**, 160. https://doi.org/10.1038/s41597-022-01228-2

Ackmann, Jan et al. (2022). "Mixed-Precision for Linear Solvers in Global Geophysical Flows." *Journal of Advances in Modeling Earth Systems* 14.9: e2022MS003148.

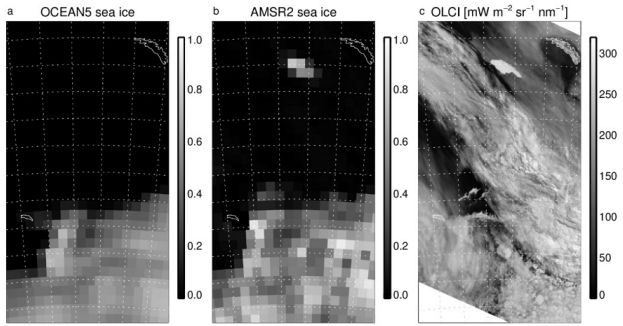
Ashkboos, Saleh et al. (2022). "ENS-10: A Dataset for Post-Processing Ensemble Weather Forecasts." *Advances in Neural Information Processing Systems* 35: 21974-21987.

Athanasiadis, Panos J., et al. including **C.D. Roberts** (2022). "Mitigating climate biases in the midlatitude North Atlantic by increasing model resolution: SST gradients and their relation to blocking and the jet." *Journal of Climate* 35.21: 6985-7006.

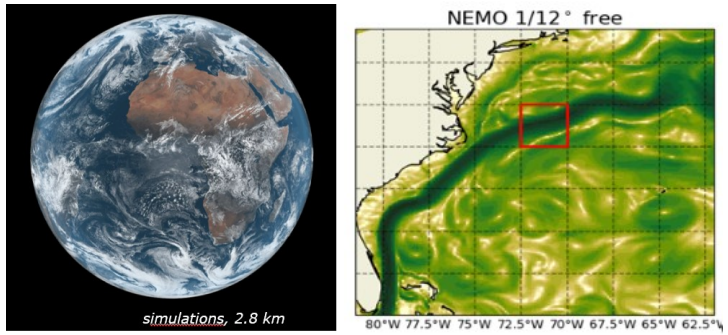
Aumann, H. H., Wilson, R. C., **Geer, A.**, Huang, X., Chen, X., DeSouza-Machado, S. & Liu, X. (2023). Global evaluation of the fidelity of clouds in the ECMWF Integrated Forecast System. *Earth and Space Science*, 10, e2022EA002652. https://doi.org/10.1029/2022EA002652

Bacour, C., MacBean, N., Chevallier, F., Léonard, S., **Koffi, E.N.** and Peylin, P. (2023). Assimilation of multiple datasets results in large differences in regional- to global-scale NEE and GPP budgets simulated by a terrestrial biosphere model, *Biogeosciences*, 20, 1089–1111, https://doi.org/10.5194/bg-20-1089-2023

Coupled; all-sky, all surface

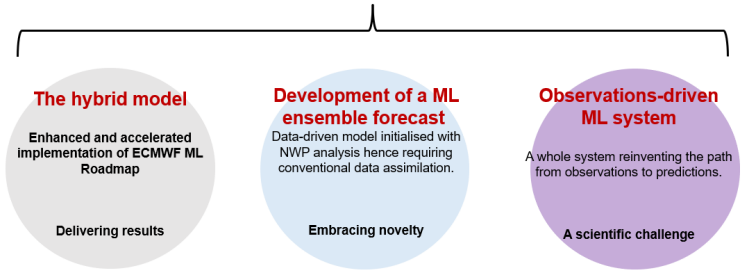


Towards high resolution (physical and computational science)

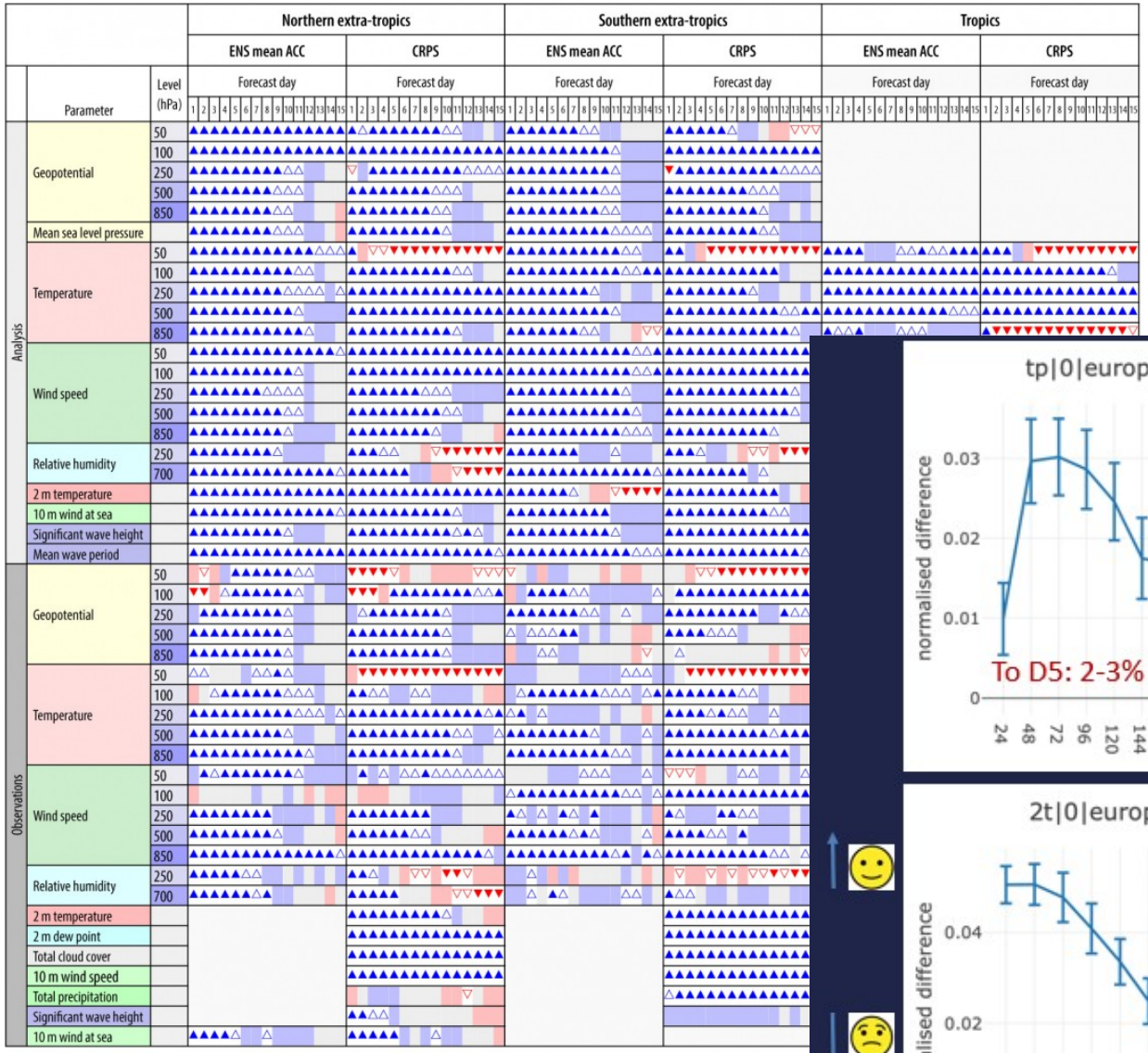


Machine learning

Project overview: different paths **towards a ML ensemble prediction at ECMWF**

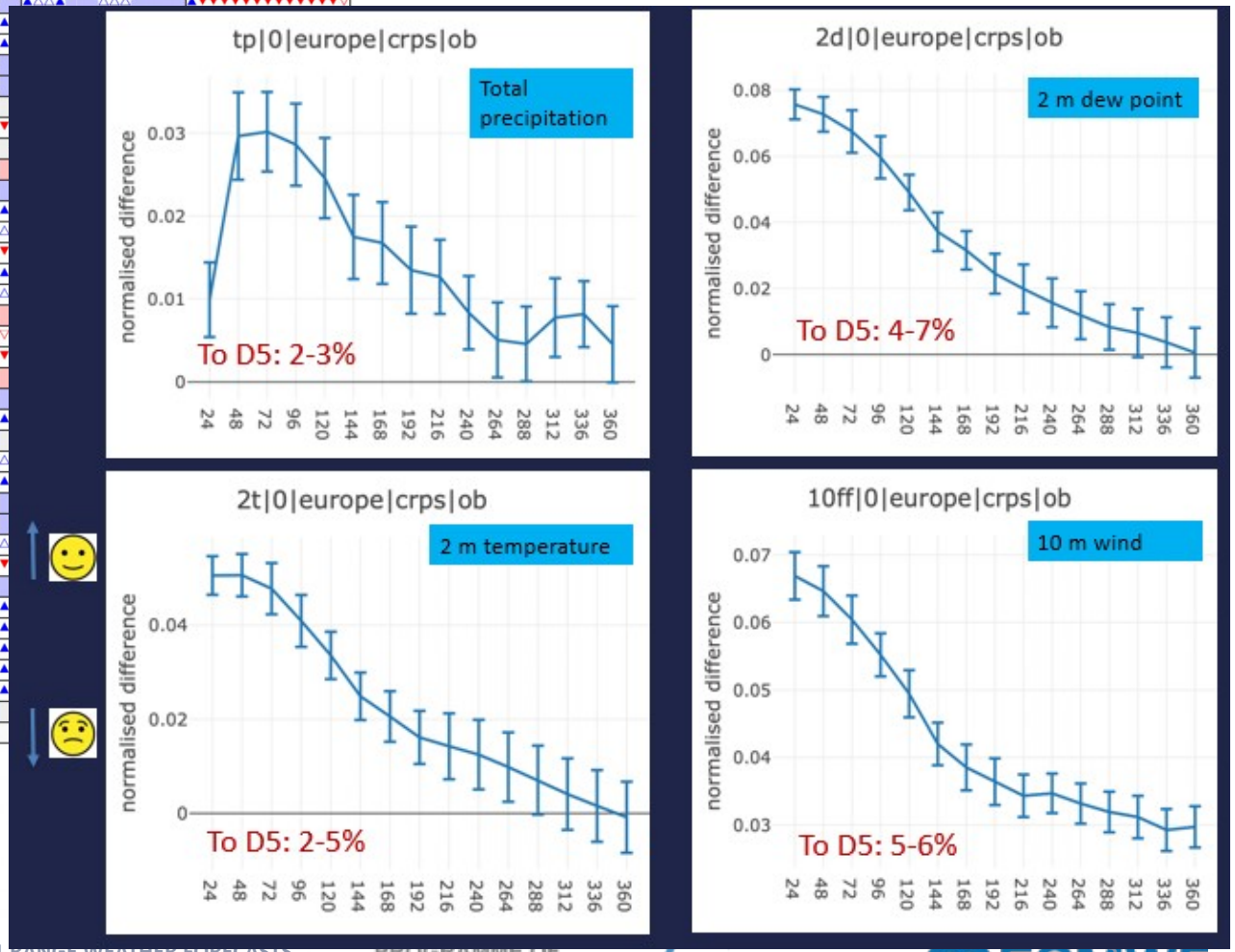


Cy48r1



Symbol legend: for a given forecast step...

- ▲ 48r1 better than 47r3 statistically significant with 99.7% confidence
- △ 48r1 better than 47r3 statistically significant with 95% confidence
- 48r1 better than 47r3 statistically significant with 68% confidence
- no significant difference between 47r3 and 48r1
- 48r1 worse than 47r3 statistically significant with 68% confidence
- ▽ 48r1 worse than 47r3 statistically significant with 95% confidence
- ▼ 48r1 worse than 47r3 statistically significant with 99.7% confidence

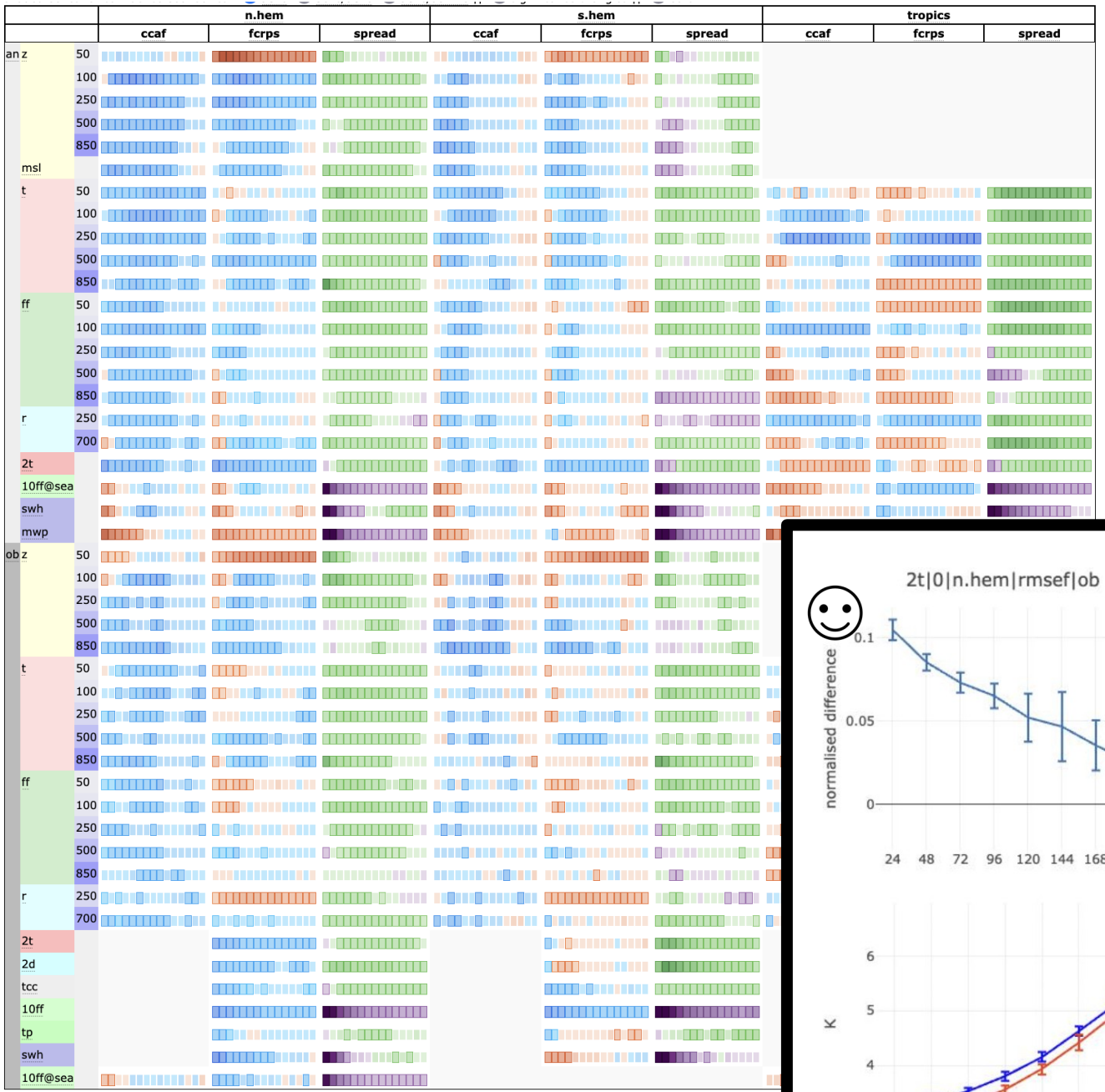


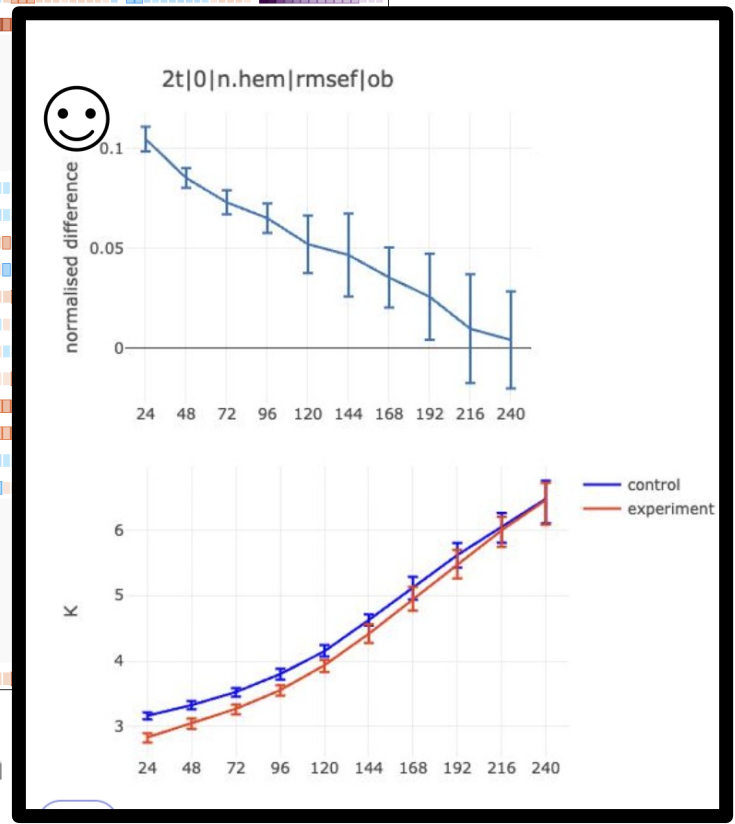
Cy49r1 v8

ENS scorecard comparing 49r1 v8 with 49r1 v0, at 9 km resolution.

Both use the 48r1 EDA so effects on the 49r1 EDA are not included

Based on data from the period Dec 2021 – Aug 2022.





ECMWF OpenIFS

Since Sept 2023:

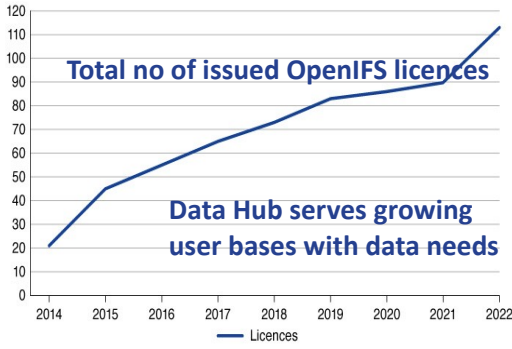
OpenIFS 48r1 *beta release* available, **full release** by Q4

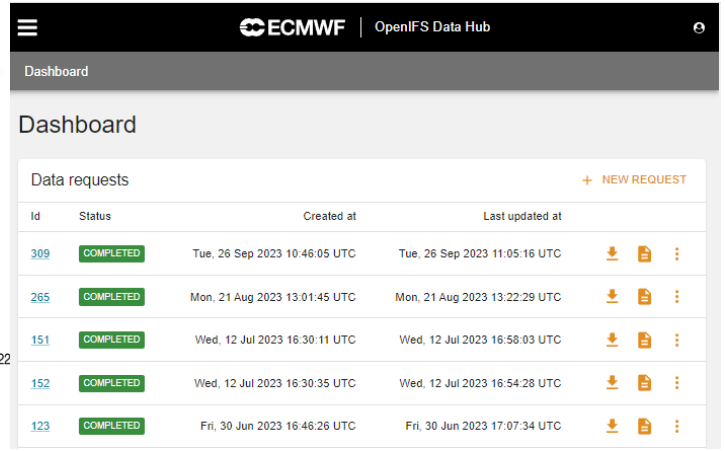
- in line with current operational IFS model cycle
- build procedure changed to ecBuild/cmake
- closely aligned with IFS working practice, which facilitates easier upgrades
- OpenIFS can now be run as 3D model or as SCM

6th OpenI
42 participants, showcase of OpenIFS/AC

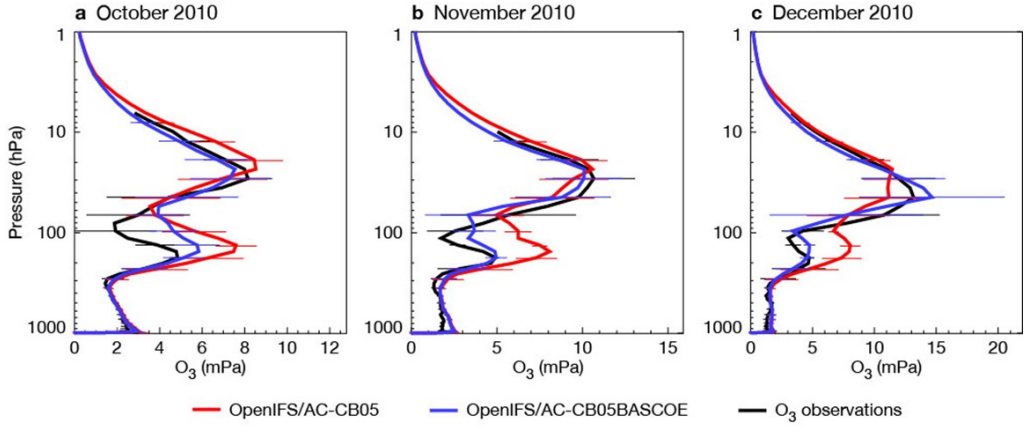
+ Rapidly increasing amounts of IFS code open source (e.g. land, waves, convection, gwd……)

Longer term approach to be discussed in context of new strategy





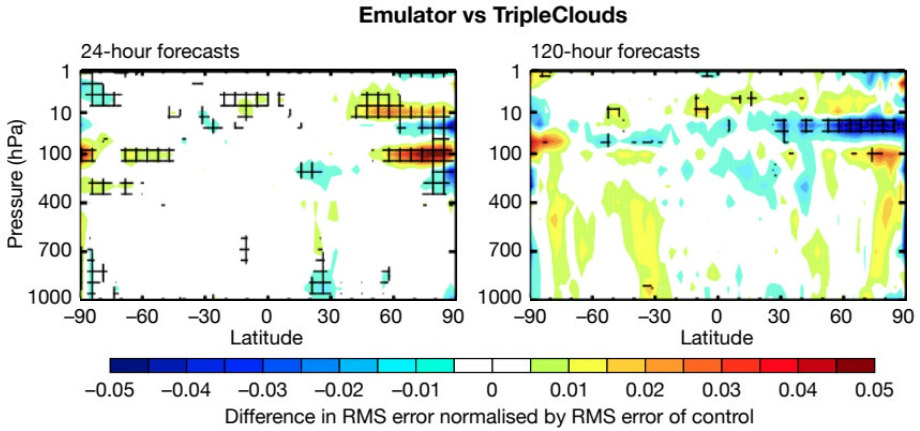
OpenIFS Data Hub publicly released in Bologna, May 2023
500+ GB of initial data provided since July 2023
supports data production for cycles 43r3, 48r1 and beyond



OpenIFS/AC composition modelling now includes
Strat (BASCOE) + Trop (CB05) + AER in OpenIFS 48r1 (single code base)

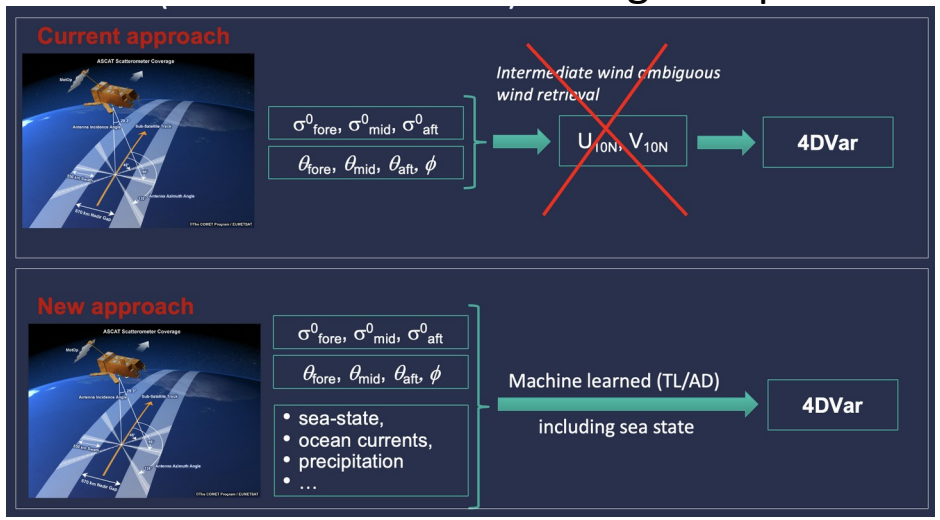
HPC, COMPUTATIONAL SCIENCE, BIG DATA, AI – HIGHLIGHTS

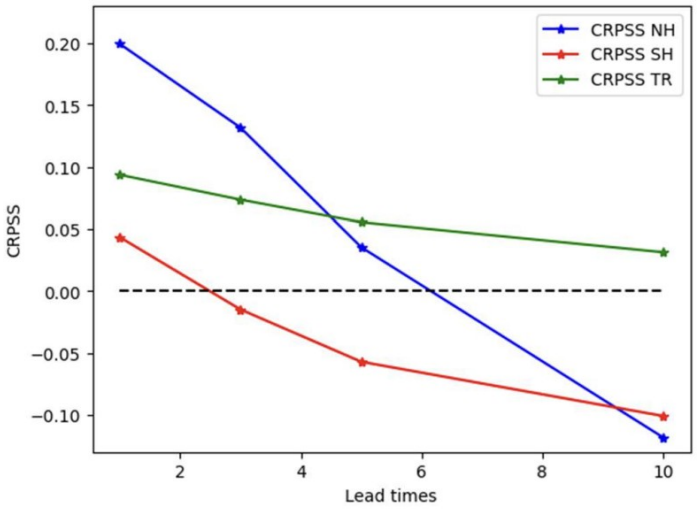
Many applications of hybrid NWP with ML



Further improvements in radiation emulation nearing complete neutrality

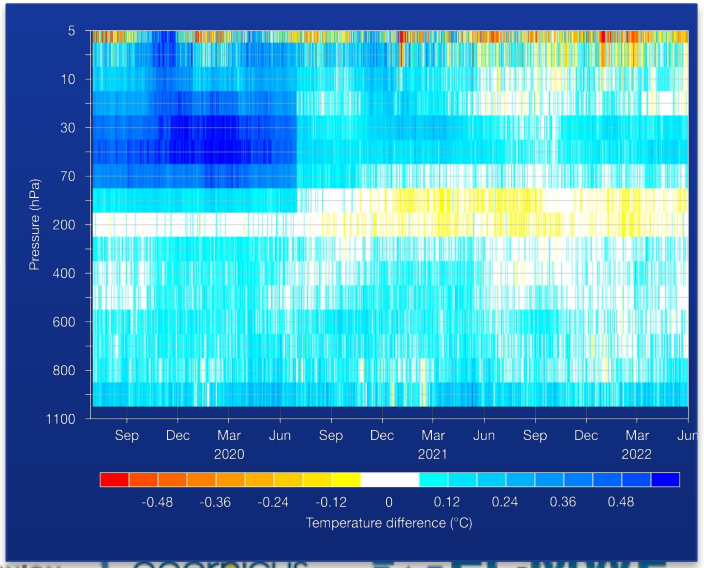
Direct assimilation of SCAT sigma0 observations using ML operator



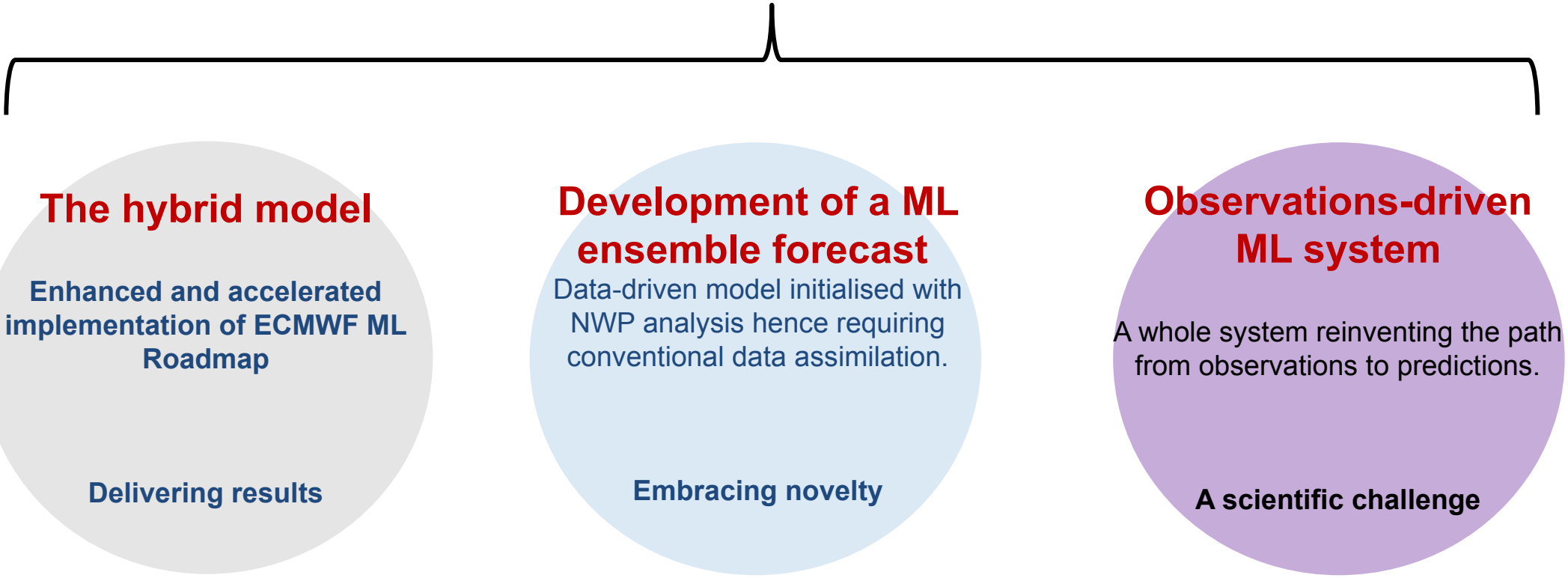


Uncertainty estimation for deterministic Destination Earth forecasts

NN training within weak-constrained 4Dvar



Project overview: Enhanced ML efforts at ECMWF

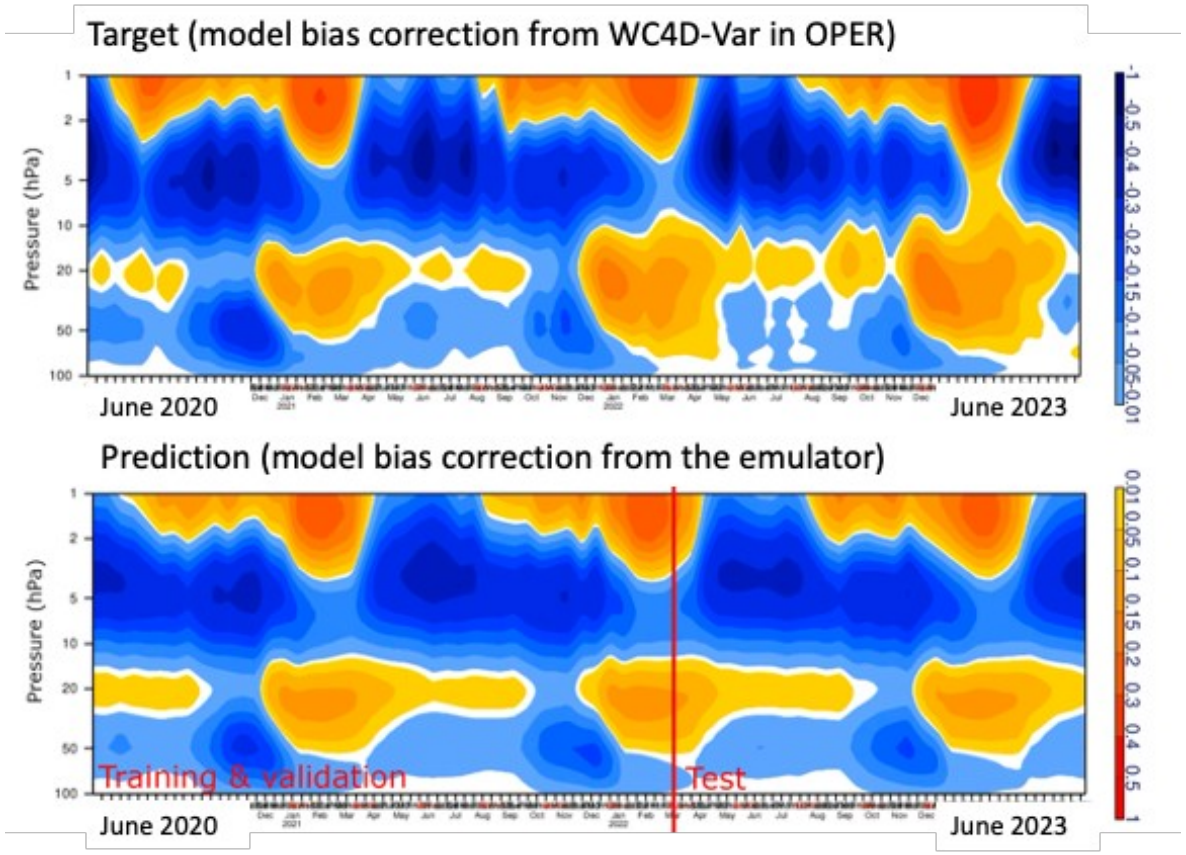


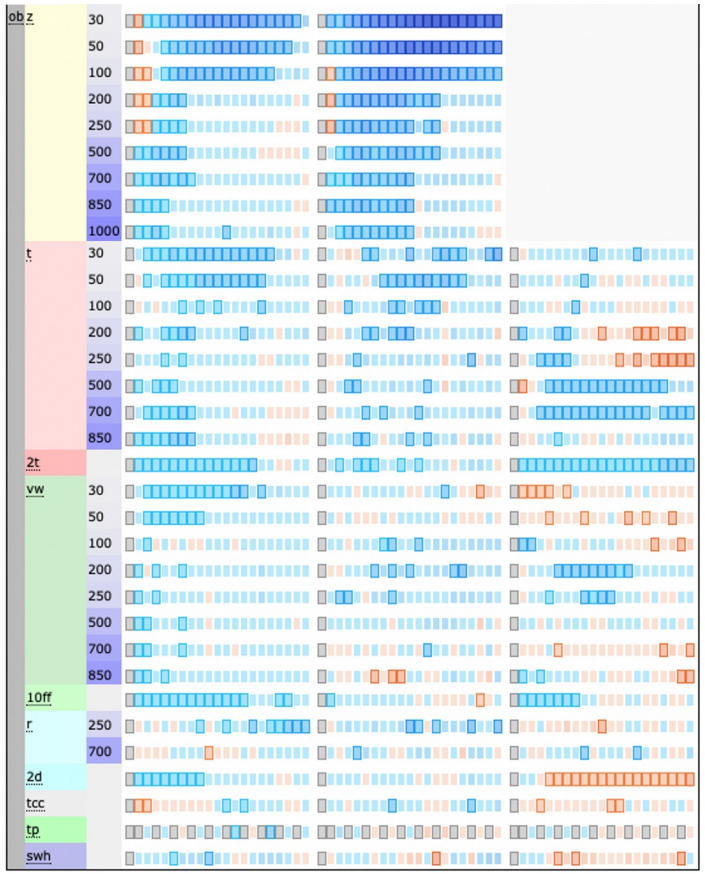
Subject to agreement of both ECMWF and EUMETNET Councils, ECMWF collaborative project with Member States envisaged to be one project of a EUMETNET programme

Exploiting Neural Networks (NN) trained in the DA to correct model error beyond the DA

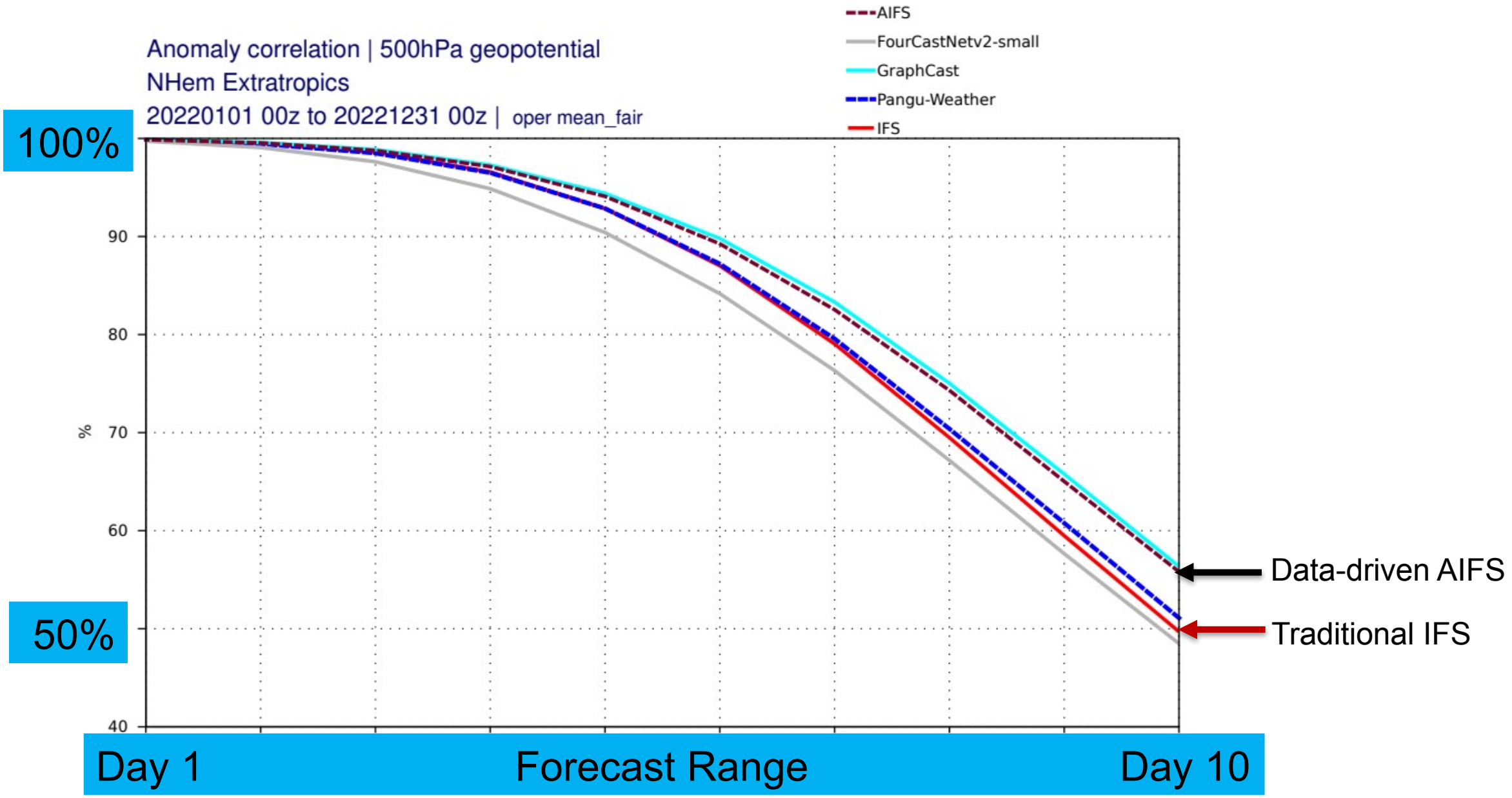
NN is trained **offline** to learn model **bias** from a well observed WC4D-Var, then applies state dependent corrections to reduce model bias artefacts in ERA6 analyses

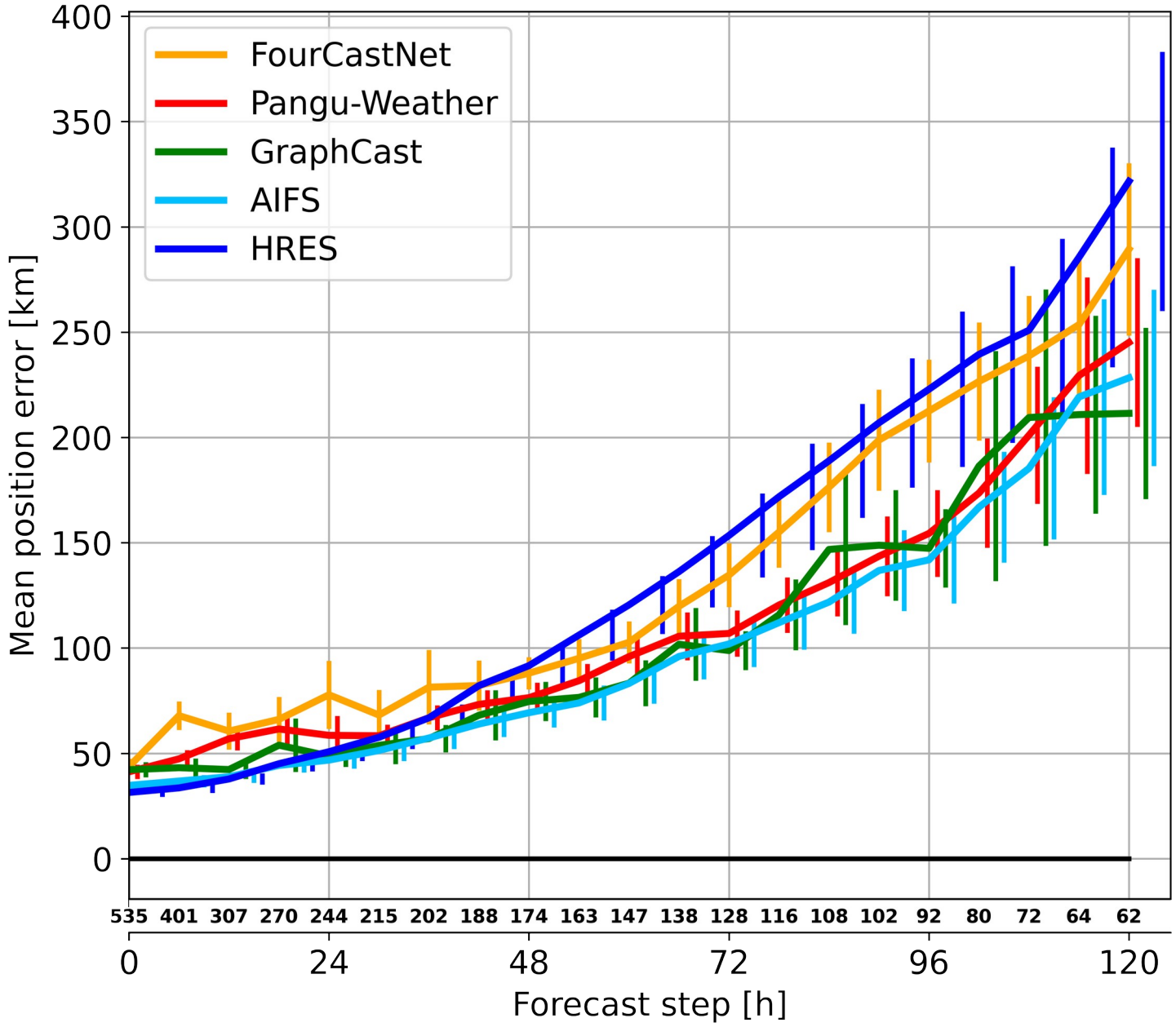
NN is trained **offline** to learn analysis **increments** , then applies state dependent corrections within the DA, but also the medium (extended) range forecast.



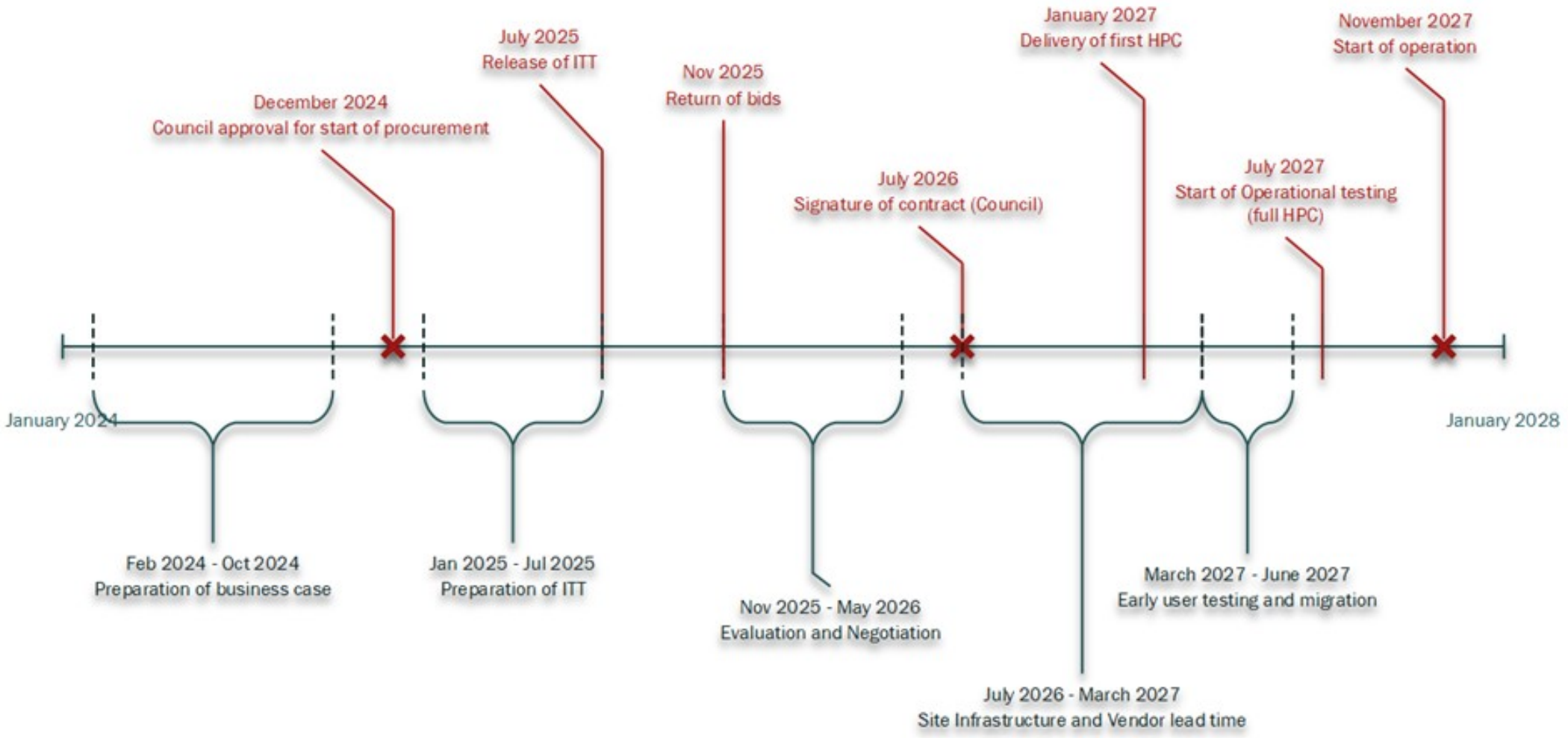


Also model parameter learning in DA (inspired by DWD work)


Anomaly correlation | 500hPa geopotential
NHem Extratropics
20220101 00z to 20221231 00z | oper mean_fair
AIFS
FourCastNetv2-small
GraphCast
Pangu-Weather
IFS
100%
90
80
%
70
60
50%
40
Data-driven AIFS
Traditional IFS
Day 1
Forecast Range
Day 10


FourCastNet
Pangu-Weather
GraphCast
AIFS
HRES
Mean position error [km]
400
350
300
250
200
150
100
50
0
535 401 307 270 244 215 202 188 174 163 147 138 128 116 108 102 92 80 72 64 62
0
24
48
72
96
120
Forecast step [h]

Next HPC: Outline timeline



Hybrid 2024 – Forecast component adaptation progress

Model component		Porting method	CPU run time	GPU (Nvidia)	GPU (AMD)
Dynamical core	Spectral Transform	Manual, OpenACC/OpenMP	16%	Optimising	Optimising
	Grid point dynamics	FIELD API + Loki (Fxtran)	10%	Porting	
	Semi-Lagrangian	Manual + Loki (Fxtran)	12%	Porting	
Physics	EC-physics	FIELD API + Loki	30%	Integrating	Porting
	Surface model	FIELD API + Loki		Porting	
	Radiation	Loki	5%	Porting	Porting
Wave model	Dy-core	Manual, OpenACC [CINECA]	8%	Optimising	
	Source term	FIELD API + Loki		Integrating	Porting
Atmospheric composition		FIELD API + Loki (bespoke)	N/A	Planning / clean-up	
Perturbation (for ensemble)		Manual + Loki	N/A		
Diagnostics	DDH	CPU-only	N/A		
	FULLPOS	Météo-France	6%		
Ocean model (NEMO)		CPU-only, separate MPI comms	6%		

Complete	Demonstrated	Working on it	External issues	Not started yet	Out of scope

Existing strategy 2021-2030

Usual 5-yearly update 2026-2035

AI/ML, HPC/cloud, DestinE, increased demand for environmental products and services……..

Planned update 2025-2034

Council discussions on process
Aiming for approval Dec 2024


ECMWF | EUROPEAN CENTRE FOR MEDIUM-RANGE WEATHER FORECASTS
ECMWF