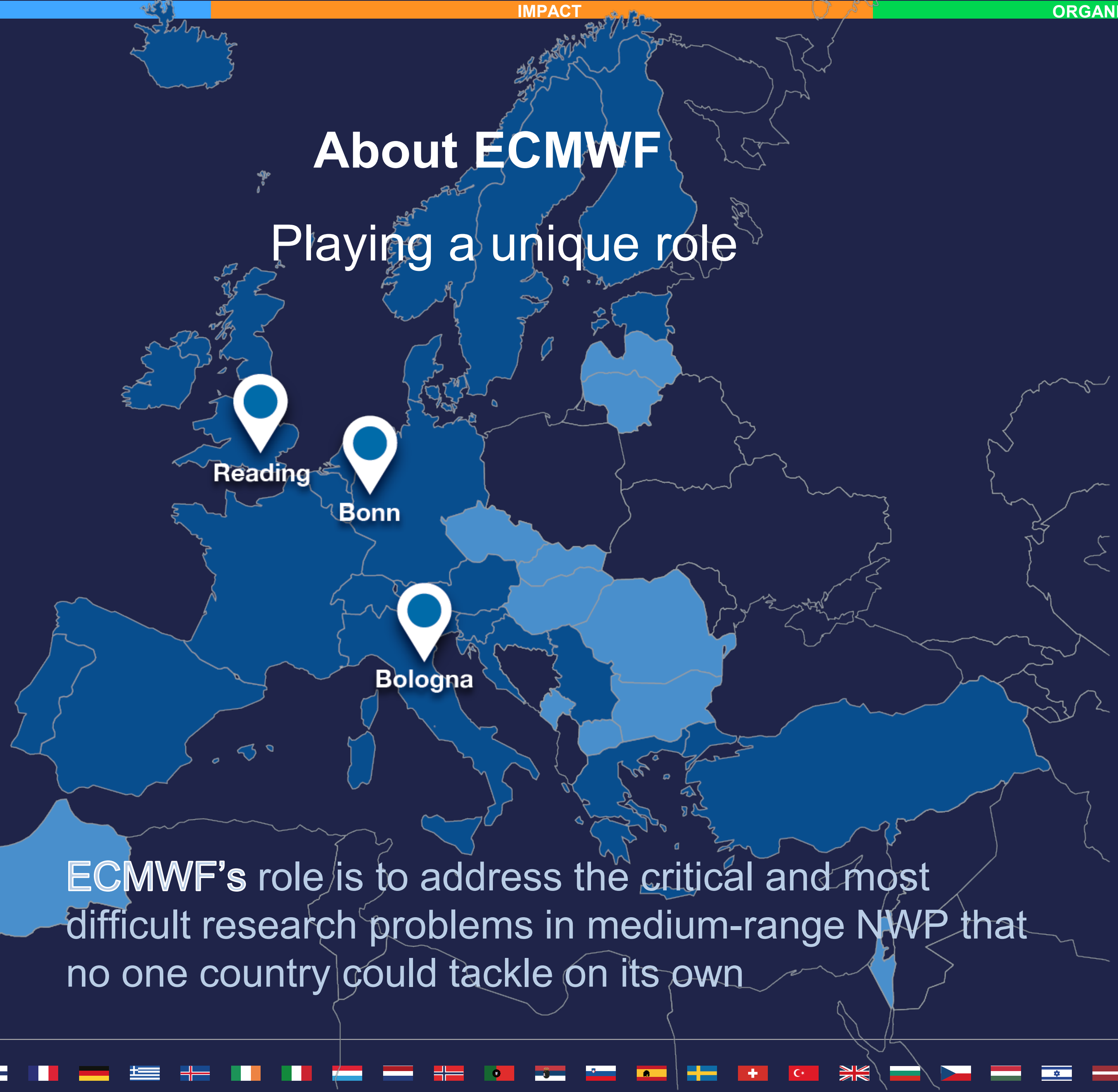
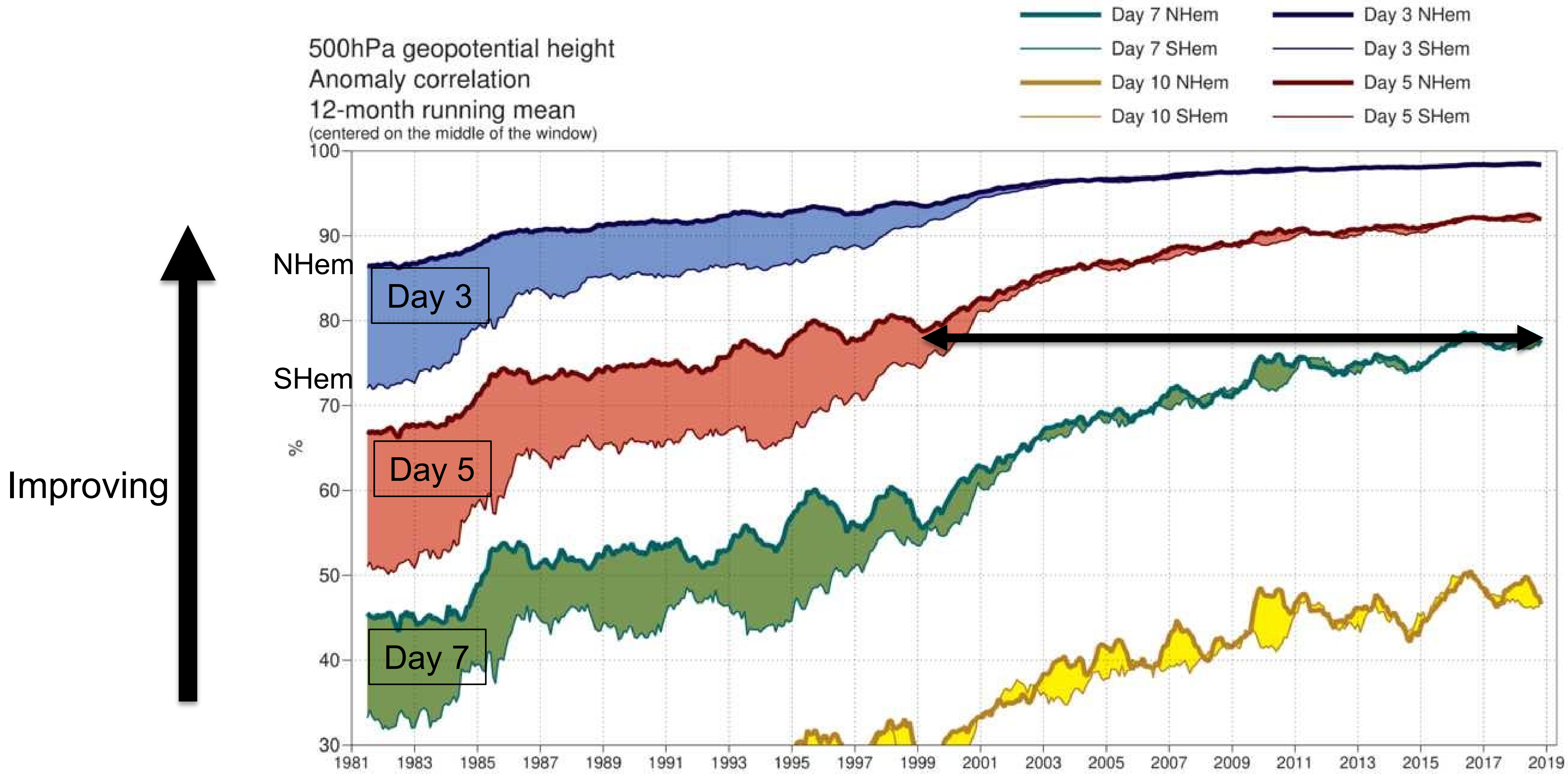
About ECMWF

Playing a unique role

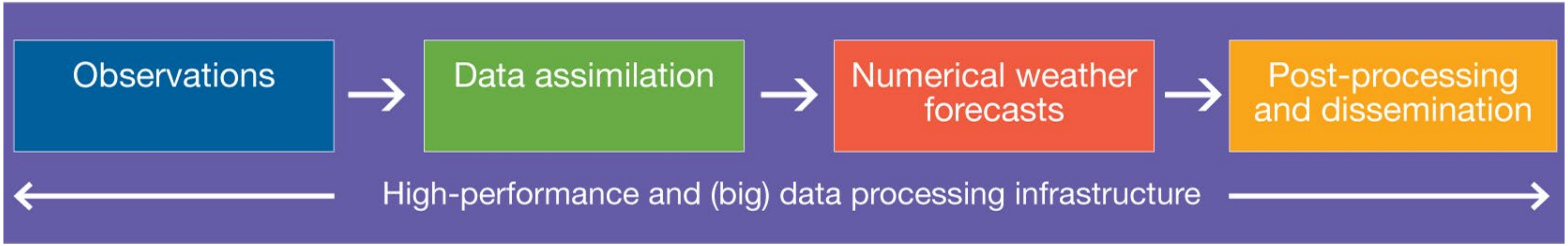


ECMWF's role is to address the critical and most difficult research problems in medium-range NWP that no one country could tackle on its own

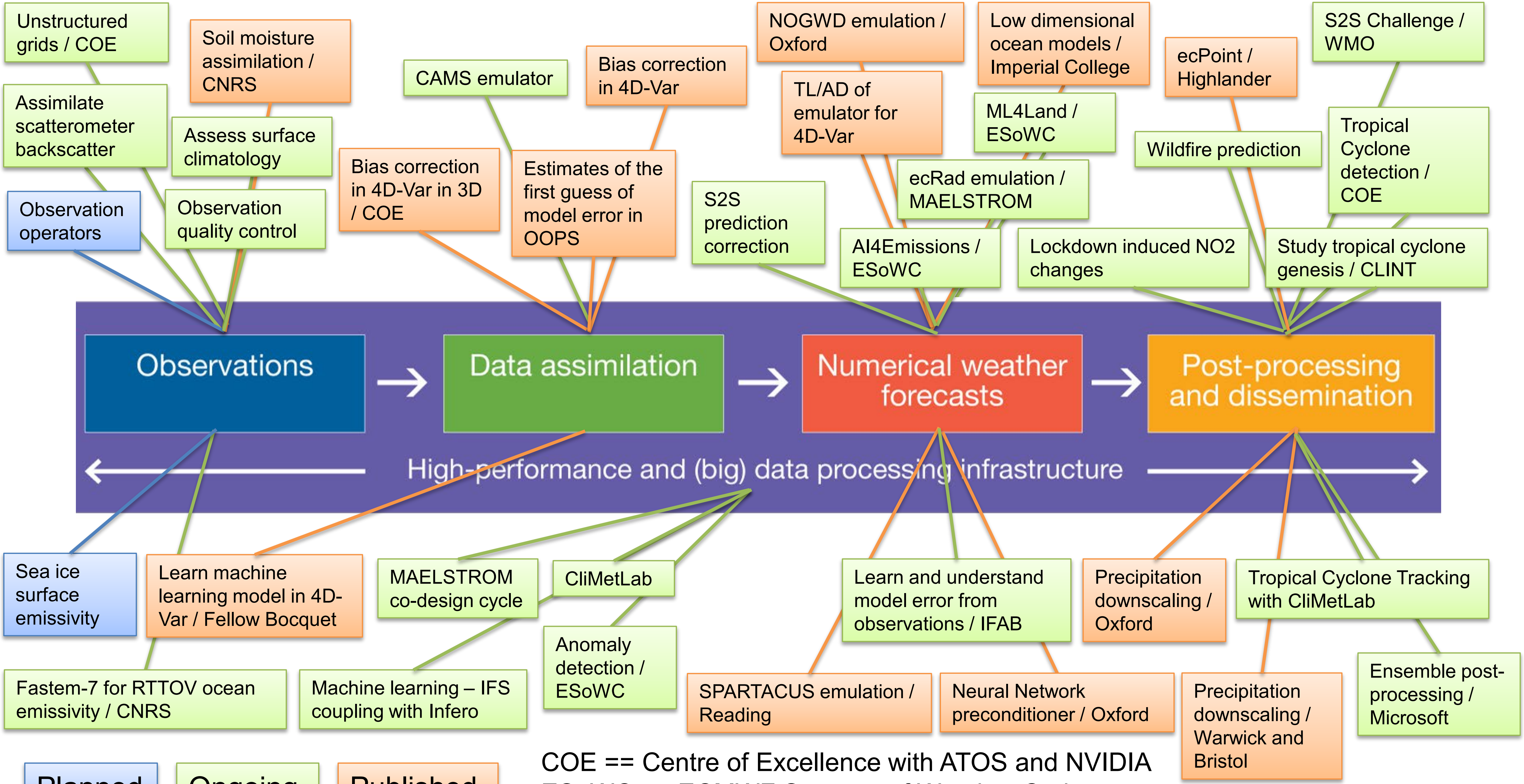
Dramatically improving accuracy………….



Numerical Weather Prediction



Machine learning at ECMWF

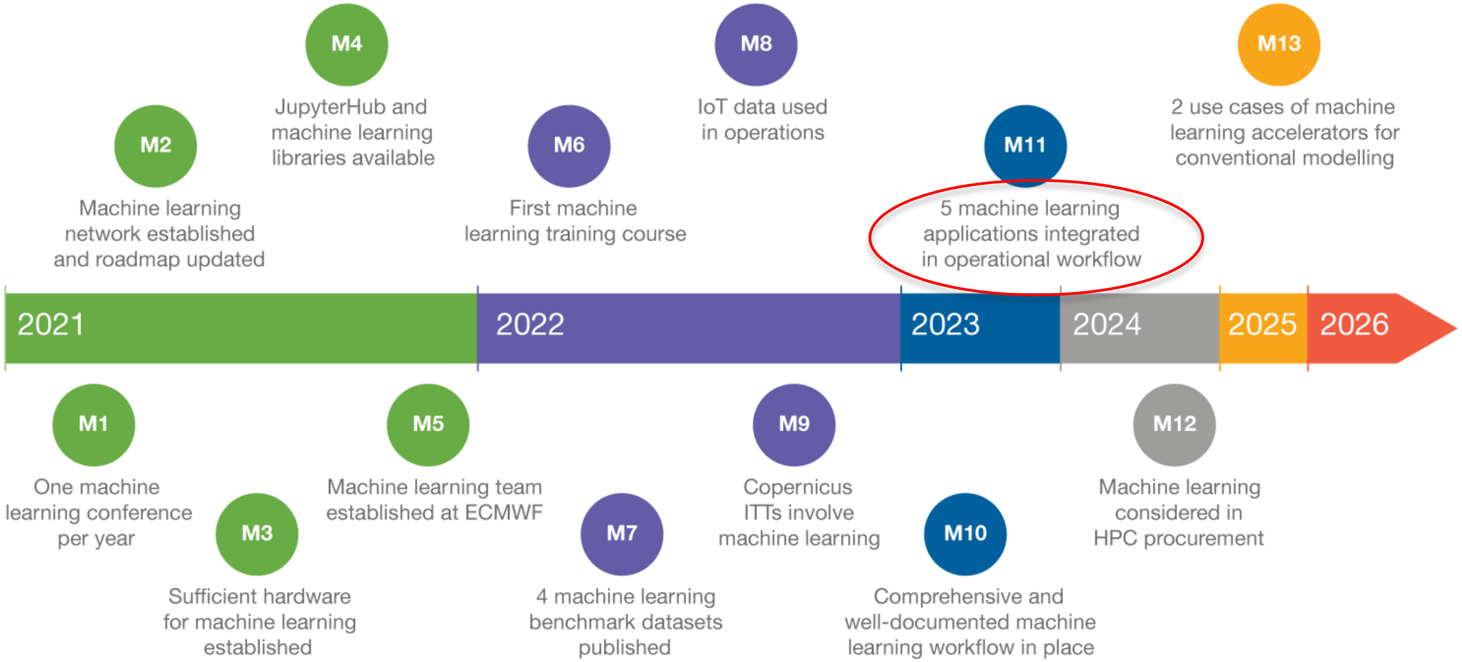


Planned Ongoing Published

COE == Centre of Excellence with ATOS and NVIDIA
ESoWC == ECMWF Summer of Weather Code

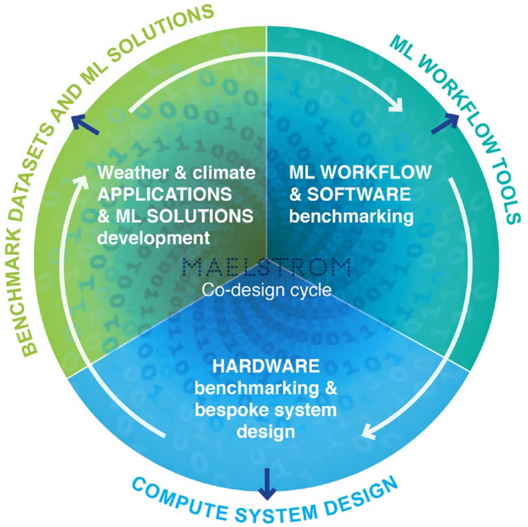
Machine learning roadmap

https://www.ecmwf.int/en/elibrary/19877-machine-learning-ecmwf-roadmap-next-10-years



Vision 2031

- It is difficult to distinguish between machine learning and domain sciences
- Data handling fully capable to serve machine learning needs
- Fully supported diagnostic tools via trustworthy AI
- Physical constraints can be represented in deep learning
- Use of machine learning as easy and normal as data re-gridding
- Unsupervised learning and causal discovery used on a regular basis
- Machine learning solutions from end-users integrated in workflow



MAELSTROM

Objective 1
Explore machine learning applications across the weather and climate prediction workflow and apply them to improve model efficiency and prediction quality.

Objective 2
Expand software and hardware infrastructure for machine learning.

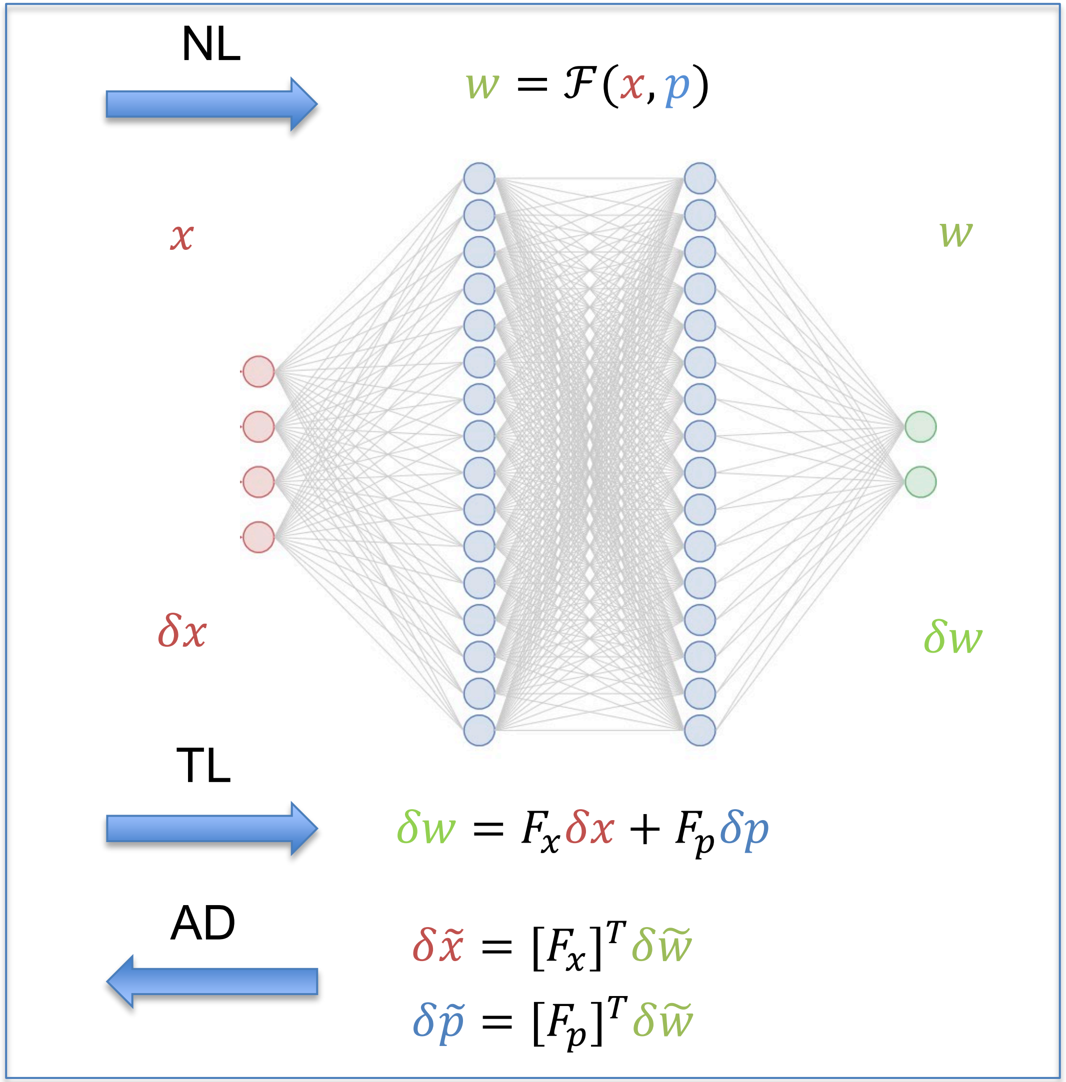
Objective 3
Foster collaborations between domain and machine learning experts with the vision of merging the two communities.

Objective 4
Develop customised machine learning solutions for Earth system sciences that can be applied to various applications and at scale on current and future supercomputing infrastructure.

Objective 5
Train staff and Member and Co-operating State users and organise scientific meetings and workshops.

Research highlight: Data assimilation

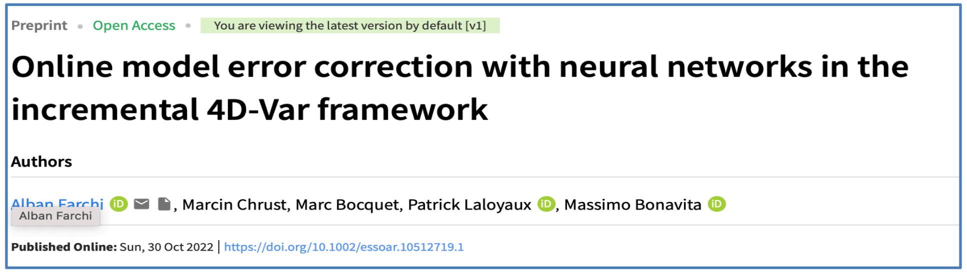
Towards online training of neural networks in the IFS 4D-Var



From offline, TensorFlow-based training of Neural Networks towards online learning within the ECMWF 4D-Var framework

FNN (Fortran Neural Network) **library**

- Fortran implementation of sequential Neural Networks equipped with tangent linear and adjoint operators required by incremental 4D-Var
- Tested for learning model error in a QG model (Farchi et al., 2022) and now implemented in the IFS.
- Potential applications: model error, observation bias, physics parametrizations, ..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Online model error correction with neural networks in the incremental 4D-Var framework

Authors

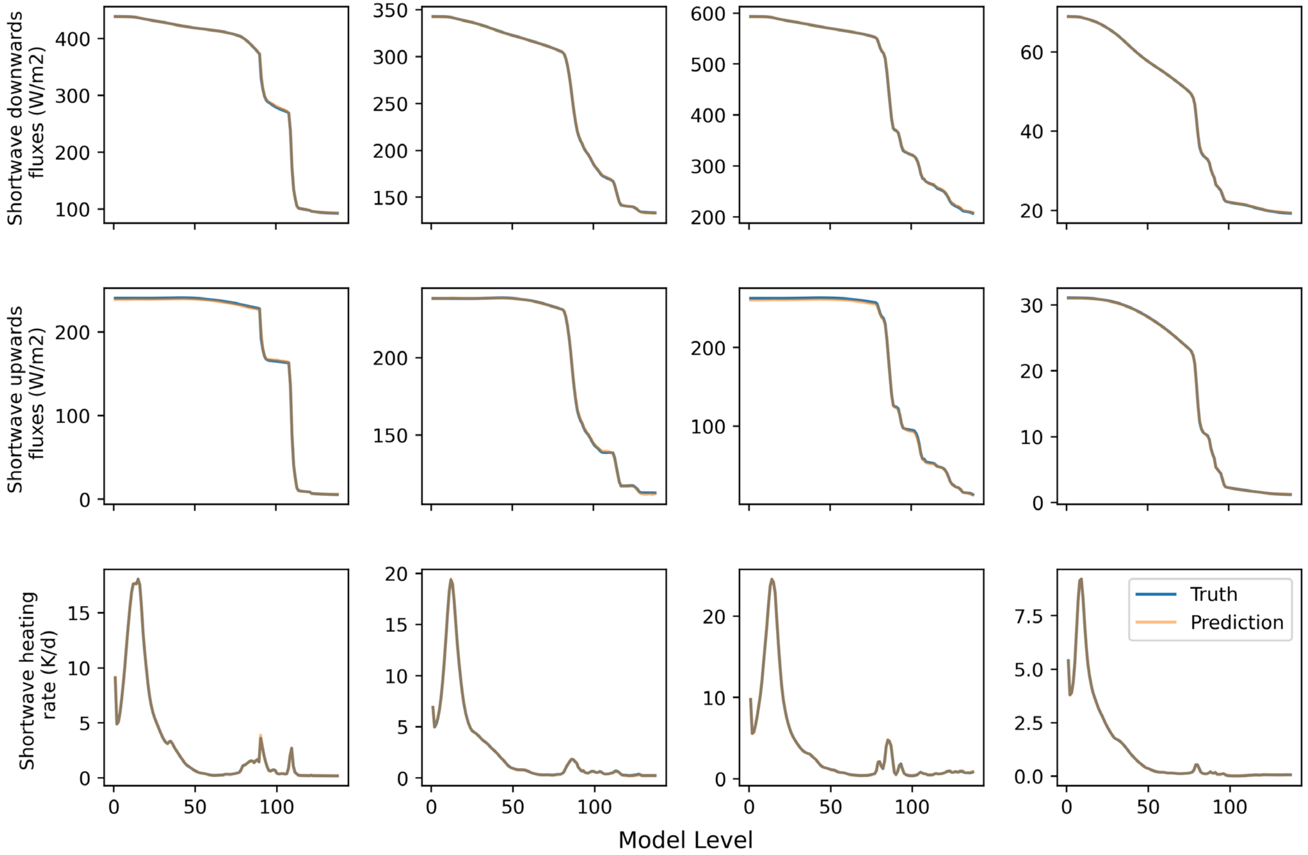
Alban Farchi, Marcin Chrust, Marc Bocquet, Patrick Laloyaux, Massimo Bonavita

Published Online: Sun, 30 Oct 2022 | https://doi.org/10.1002/essoar.10512719.1

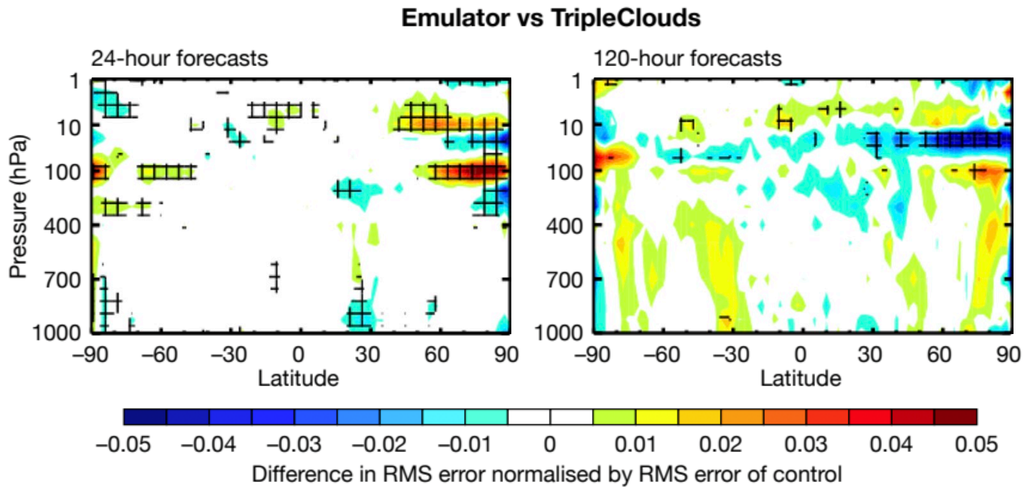
Research highlight: application in model component

The radiation scheme is an expensive model component, being run at with a coarser timestep and spatial grid.

Can we accurately emulate the radiation scheme using neural networks?



Example column predictions comparing existing scheme with neural network.



No degradations in forecast below 100hPa.
Faster than existing scheme decoupled from IFS.

Next steps: GPU use within IFS.

Matthew Chantry, Robin Hogan, Peter Dueben @ ECMWF
Peter Ukkonen @ DMI

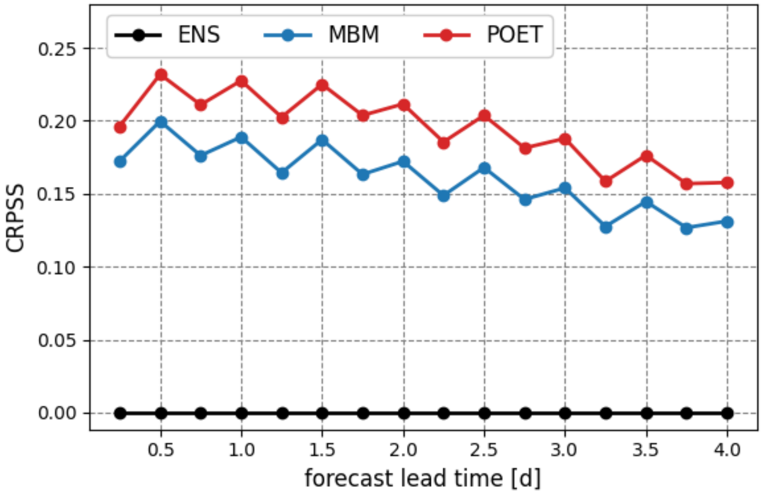
Research highlight: application in post-processing, collaboration with Microsoft

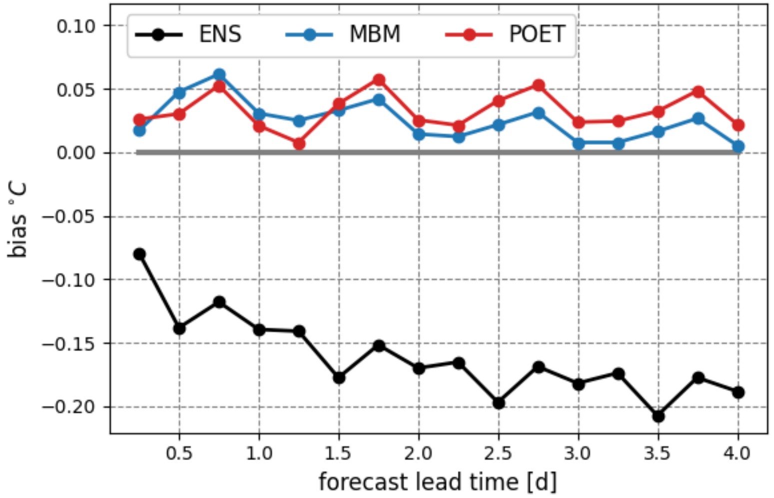
Can we correct the bias and spread of the operational ensemble?
Can we do this by training on a smaller ensemble hindcast?

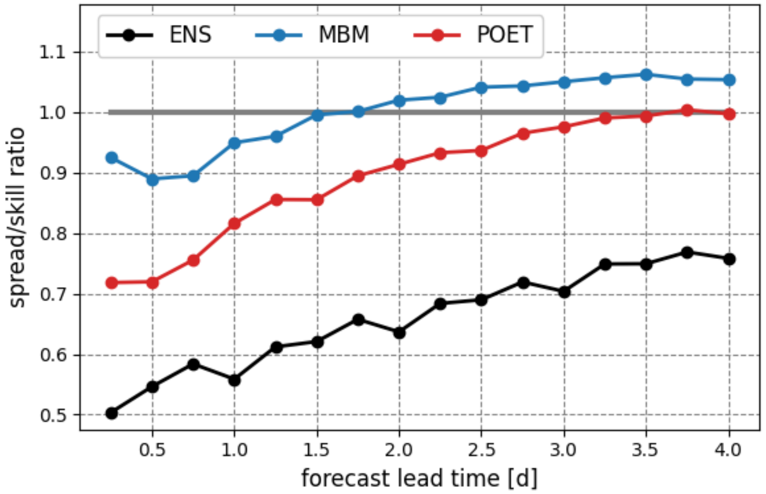
Focus on 2m-temperature predictions.

Compare transformer-based neural network (POET, 10^6 parameters), with member-by-member approach (10^8 parameters).

20% improvement in CRPS, significant reduction in bias, better calibrated spread/skill ratio.







Zied Ben Bouallegue, Matthew Chantry , Peter Dueben, Jesper Dramsch, Mariana Clare @ ECMWF
Jonathon Weyn @ Microsoft

Massive Open Online Course (MOOC) on Machine Learning in Weather & Climate

FREE course. Explores application of Machine Learning across main stages of numerical weather and climate predictions: from processing of input observations to their assimilation into models, and finally to forecasting and post-processing.

in partnership with

Register now at https://www.ecmwf.int/mlwc-mooc

- Launch on 9 Jan 2023, continues to March 2023. Estimated 3-4 hours of study per week, 36 hours total.
- In partnership with International Foundation on Big Data and Artificial Intelligence for Human Development (IFAB).
- Three tiers:
  - Tier 1: Introduction to Machine Learning in weather & climate
  - Tier 2: Concepts of Machine Learning
  - Tier 3: Practical Machine Learning applications in weather & climate
- Inlcudes videos, podcasts, Jupyter notebook practicals, interactive applications, challenges and much more…
- Will bring together experts and provide a shared vision across the communities of Earth system sciences, high-performance computing and Machine Learning.

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