



Earth Observations for Resilience: Forecasting, Early Warnings and AI-Enhanced Earth-System Monitoring at European and Global Scale

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European Centre for Medium-Range Weather Forecasts

ECMWF's mission:

Deliver **global numerical weather predictions**

focusing on the medium range and

monitoring of the Earth system

to and with our Member States.

European co-operation at its best
with cooperation agreements with
USA, Canada, China,
Japan, Australia...

Key facts

- 23 Member States
- 12 Co-operating States
- > 500 staff - 3 locations

- **24/7 operational service**
- **Research institution**



Numerical Weather Prediction

800 millions a day

Obs

Obs

Obs

Obs

6 UTC 9 UTC 12 UTC 15

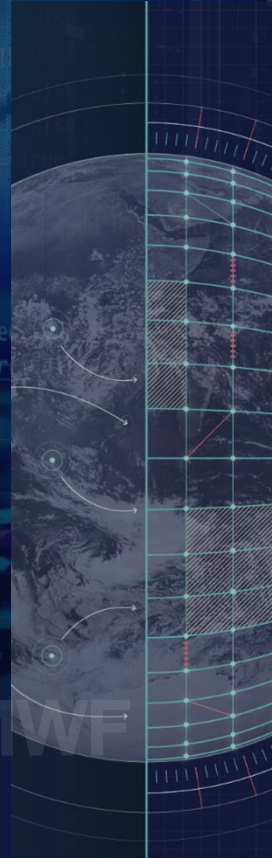
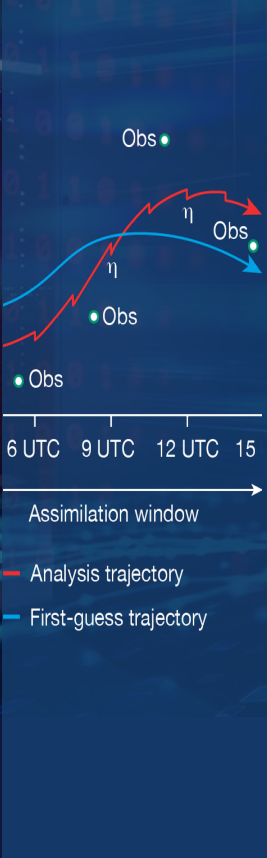
Assimilation window

Analysis trajectory

First-guess trajectory

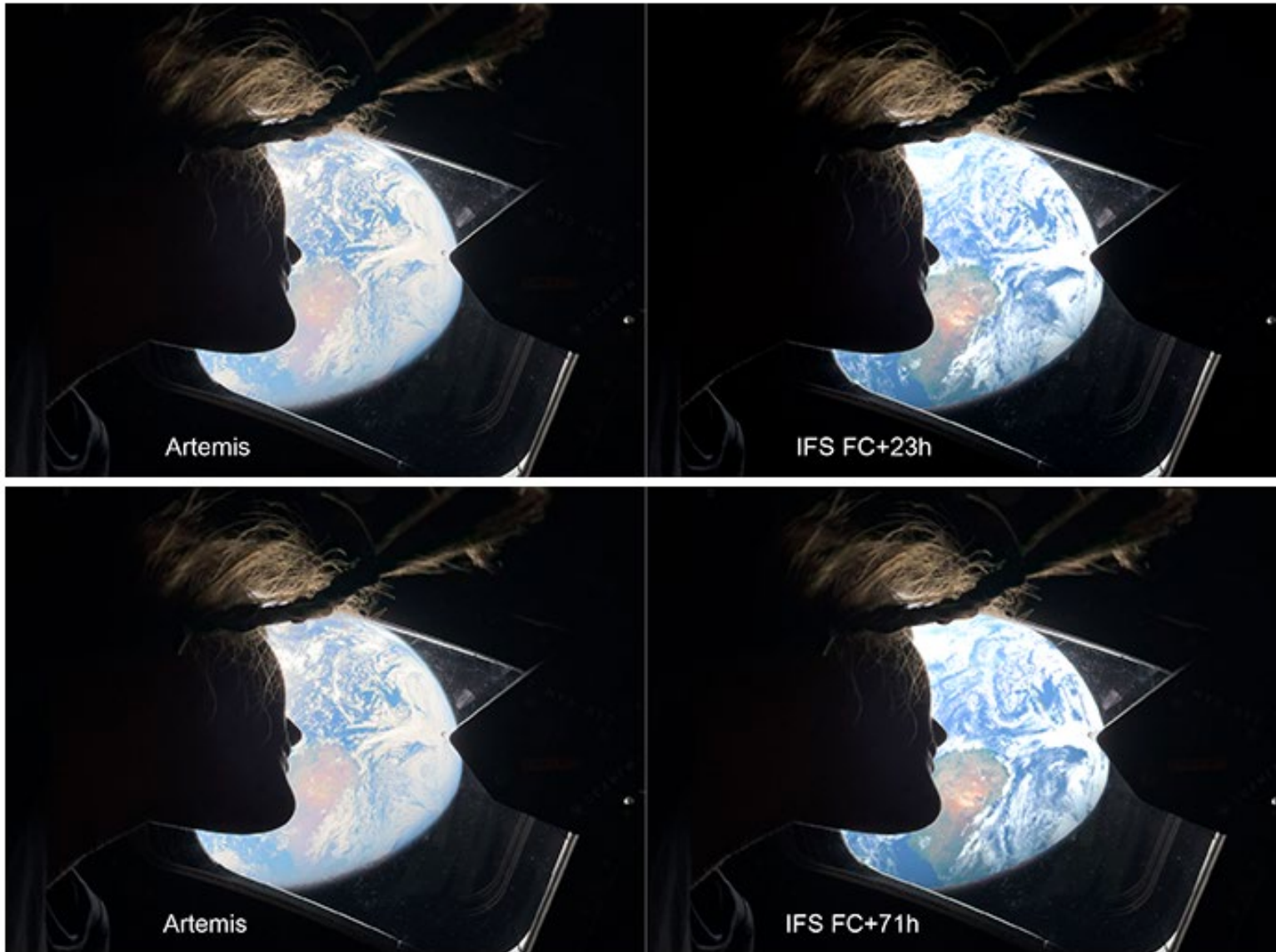
CECMWF

800 millions a day



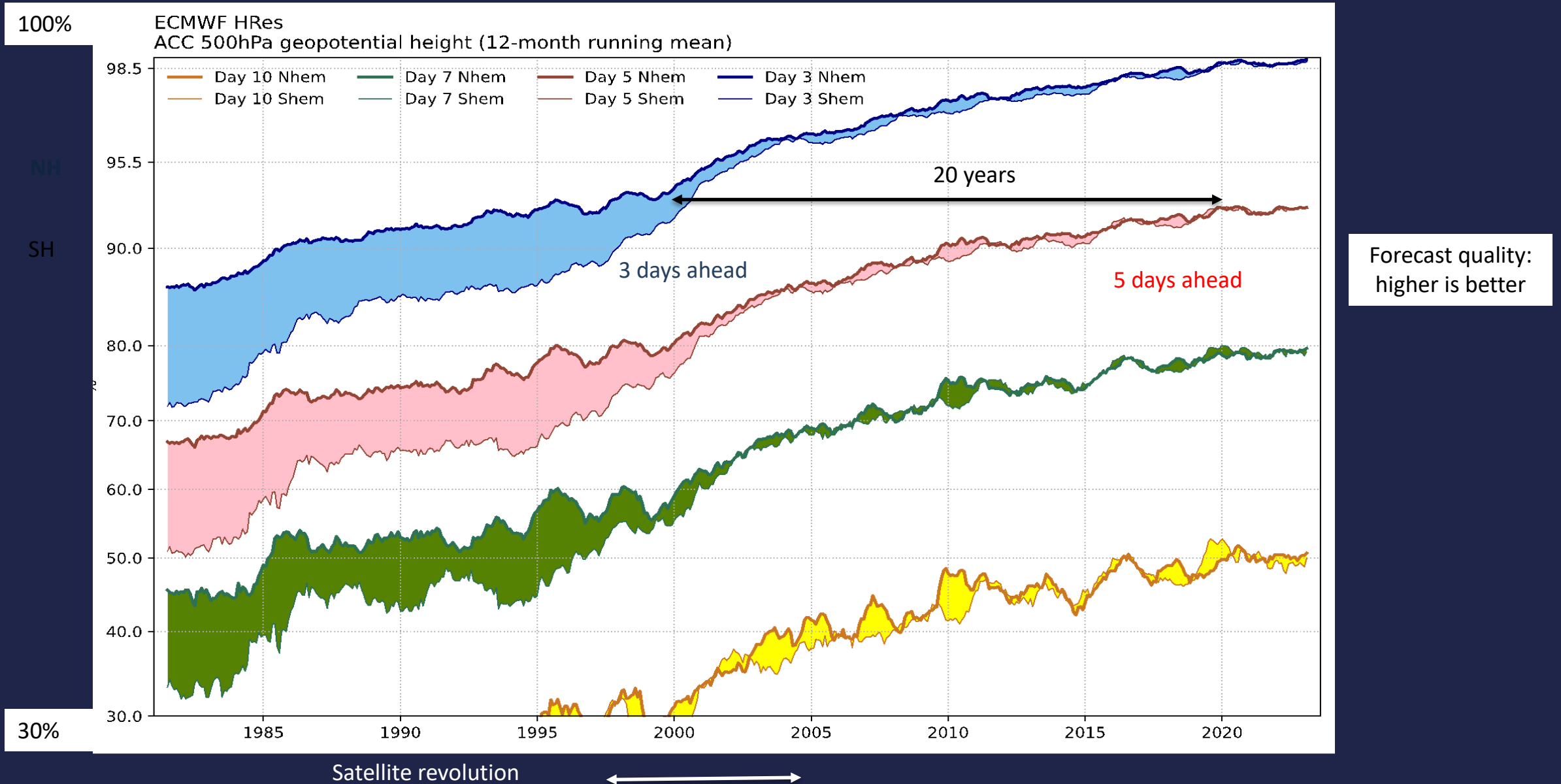
NASA Artemis II lunar flyby mission (Christina Koch) - ECMWF forecasts (2 April 2026)

Observations

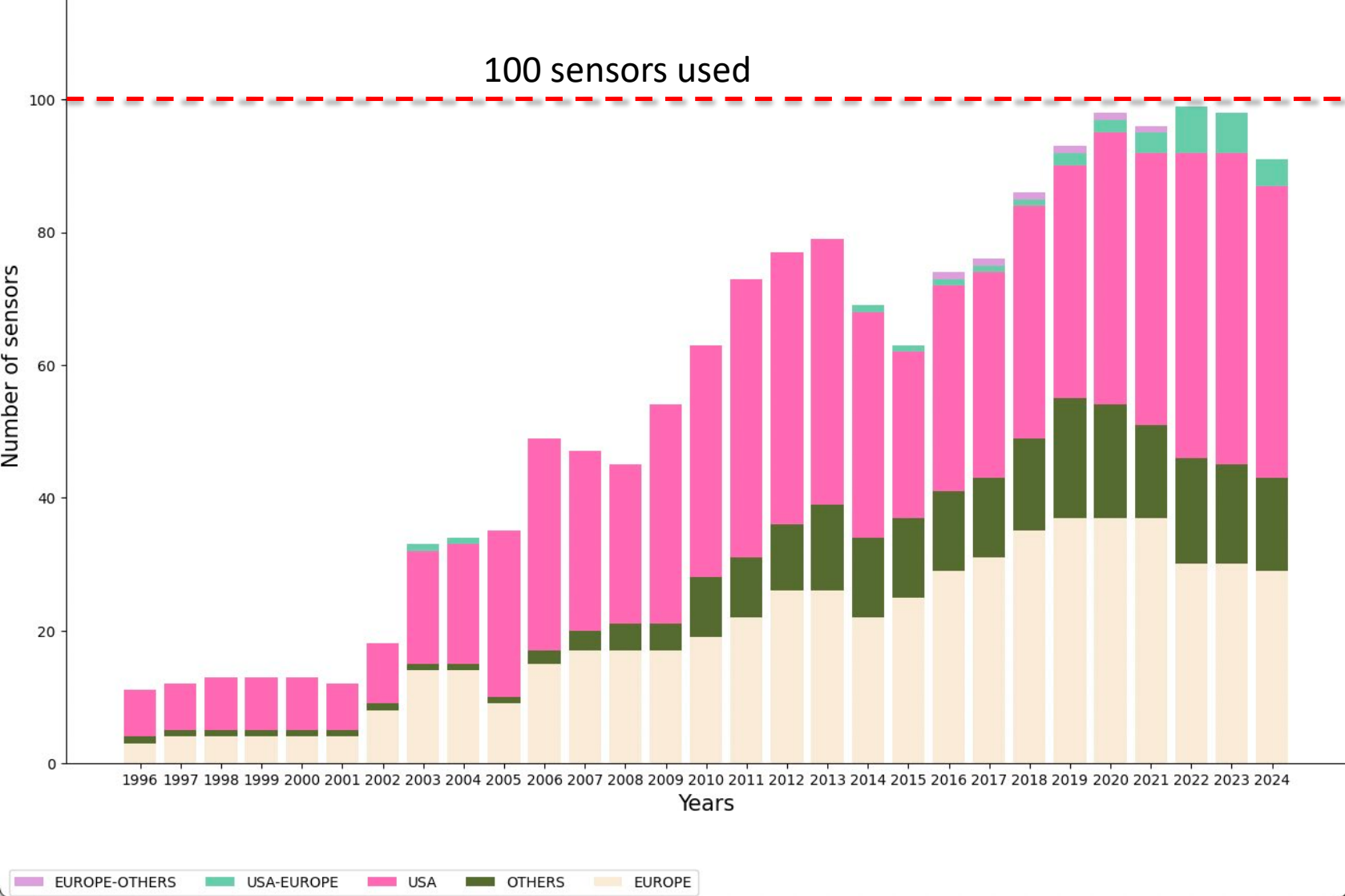


Simulations

The quiet revolution: better forecasts improving by one day per decade



Where do Satellite data come from?



USA

AQUA
AURA
C-NOFS
CORIOLIS
COSMIC2
COSMIC
DMSP
GOES
JPSS
PlanetIQ
POES
QuikSCAT
SAC-C
SMAP
TERRA

EUROPE

Aeolus
CHAMP
CRYOSAT
ENVISAT
ERS
JASON
METEOSAT
METOP
Sentinel
SMOS
TanDEM-X
Terra SAR-X

USA-EUROPE

GRACE
JASON
Sentinel-6A
SPIRE-Lemur-3U
SPIRE

OTHERS

COMS-1
FY2
FY3
GCOM
GPM
HIMAWARI
HY2
INSAT-3D
KOMPSAT-5
MTSAT
OceanSat-2
SARAL
TRMM

EUROPE-OTHERS

MEGHA-TROPIQUES

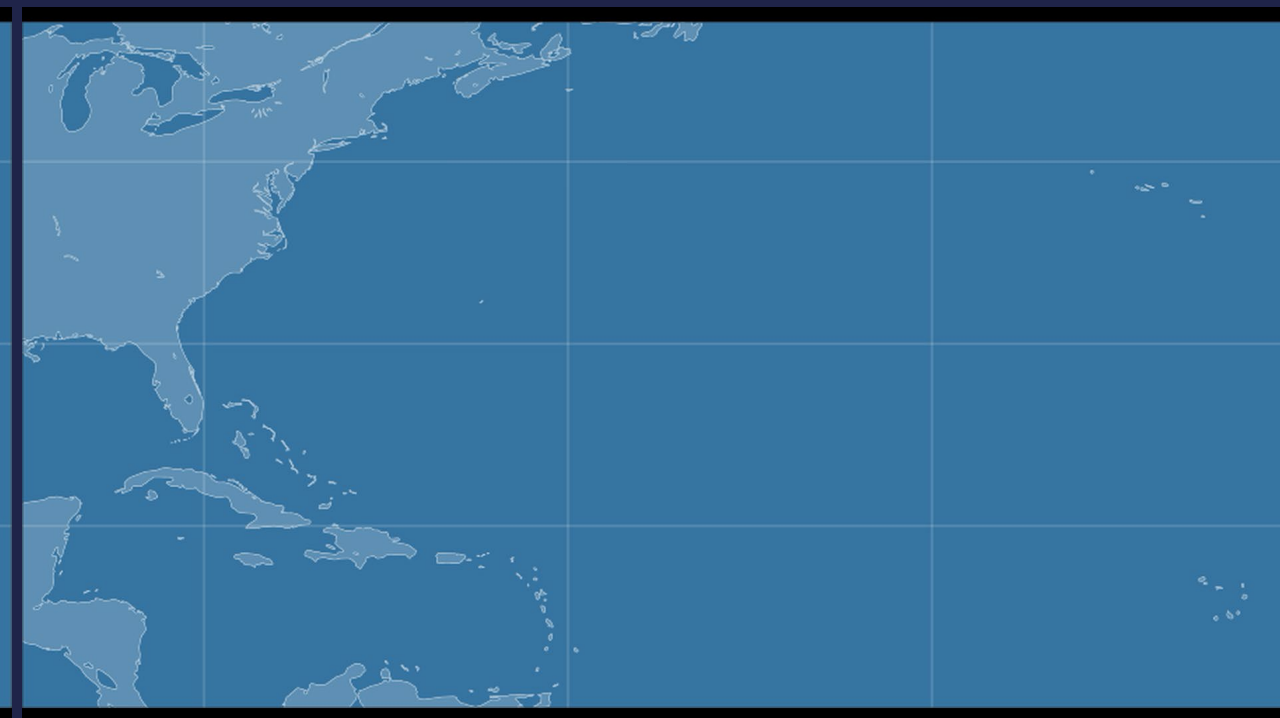
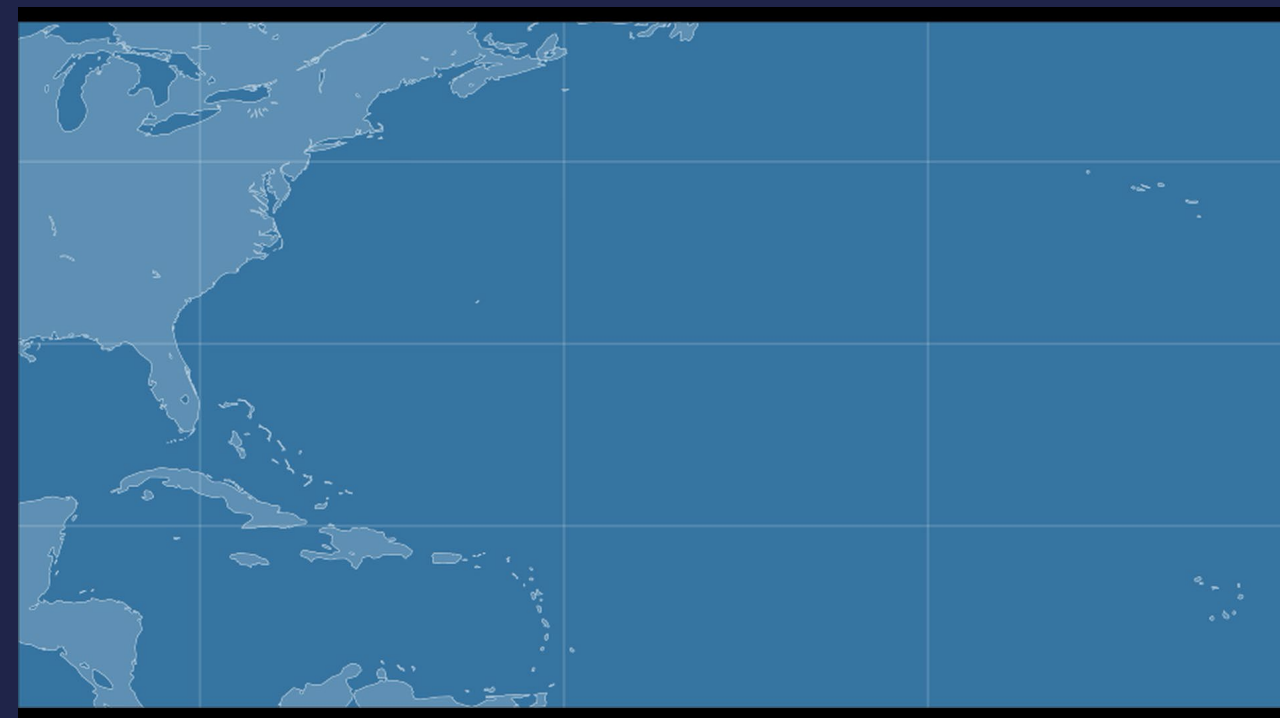
Data exchanged in real-time under the auspices of WMO



Without observations we would give no warning of life-threatening weather!

Hurricane Irma with Satellite Data

Hurricane Irma without Satellite Data



Irma caused an estimated **\$77 billion in damages and more than 130 fatalities** in 2017, in Barbuda (50% people became homeless), other Caribbean islands and USA

Today: the AI Machine Learning revolution

Defining the dataset, split, headline fields and metrics

2020 WeatherBench

Huawei – PanguWeather
0.25° hourly product

“More accurate tracks” than the IFS.

Nov 2022

Tropical cyclones

Microsoft – ClimaX

Forecasting various lead-times at various resolutions, both globally and regionally

Jan 2023

Global & Limited Area

NVIDIA – SFNO

0.25° 6-hour product

Extension of FourCastNet to Spherical harmonics, improved stability

Spherical harmonics

Jun 2023

2018

Exploring the concept

ECMWF staff
~500km ERA5 to predict future z500.
Similar work from Rasp and Weyn.

Feb 2022

Full medium-range NWP

Keisler - GraphNN
1°, competitive with GFS
NVIDIA – FourCastNet
Fourier+ , 0.25°
 $O(10^4)$ faster & more energy efficient than IFS

Dec 2022

Extensive predictions

Deepmind – GraphCast
0.25° 6-hour
Many variables and pressure levels with comparable skill to IFS.

Apr 2023

7-day+ scores improve

FengWu – China academia + Shanghai Met Bureau
0.25° 6-hour product
Improves on GraphCast for longer leadtimes (still deterministic)

Diffusion modelling

Alibaba – SwinRDM
0.25° 6-hour product
Sharp spatial features

Last months
FuXi
AtmoRep
FuXi-extreme
NeuralGCM
GenCast
...

impossible to keep this figure up to date

Artificial Intelligence: how does it work?

1. Observe

Every day, we collect **800 million** observations of Earth's atmosphere, wind, temperature and beyond

2. Absorb

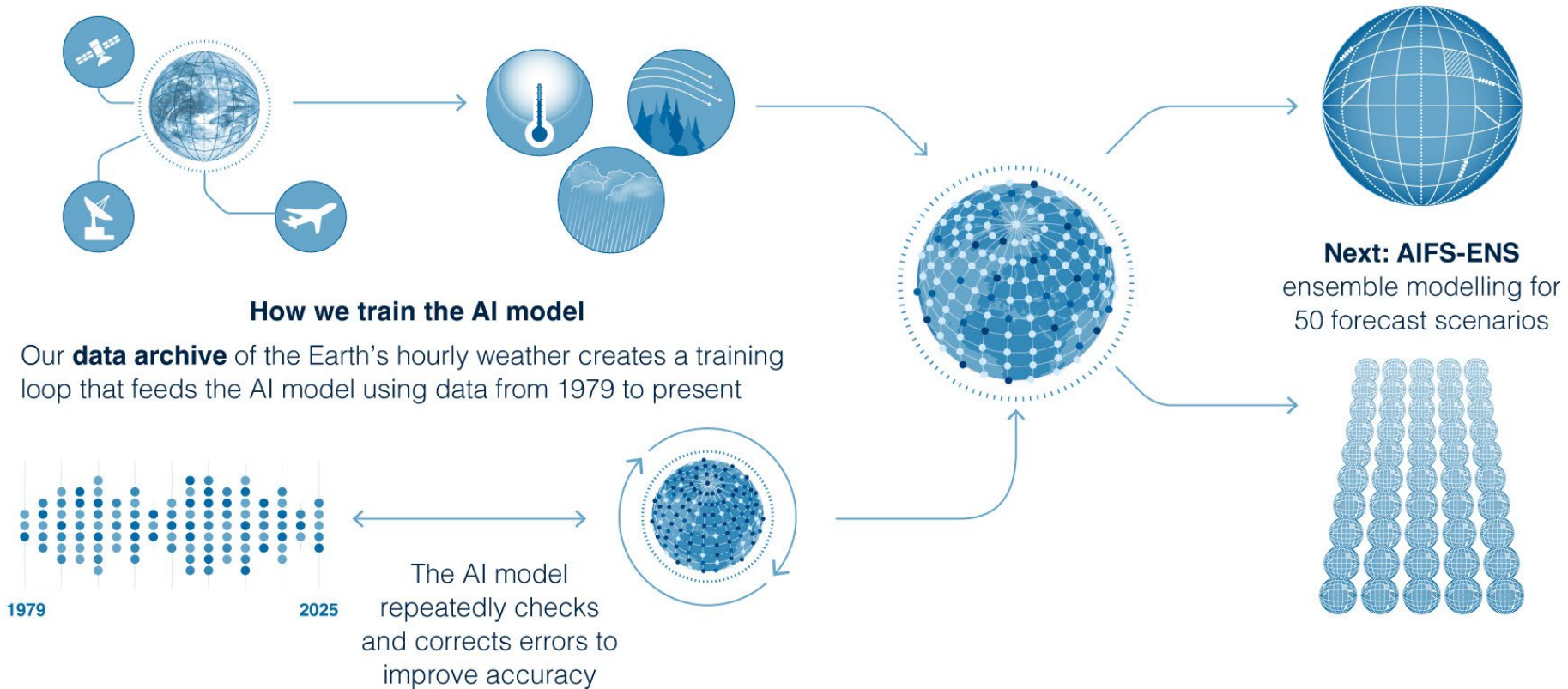
60 million quality-controlled observations are absorbed by our physics-based Integrated Forecasting System

3. Model

They feed the **AIFS'** new AI model, which predicts Earth's weather for the coming days

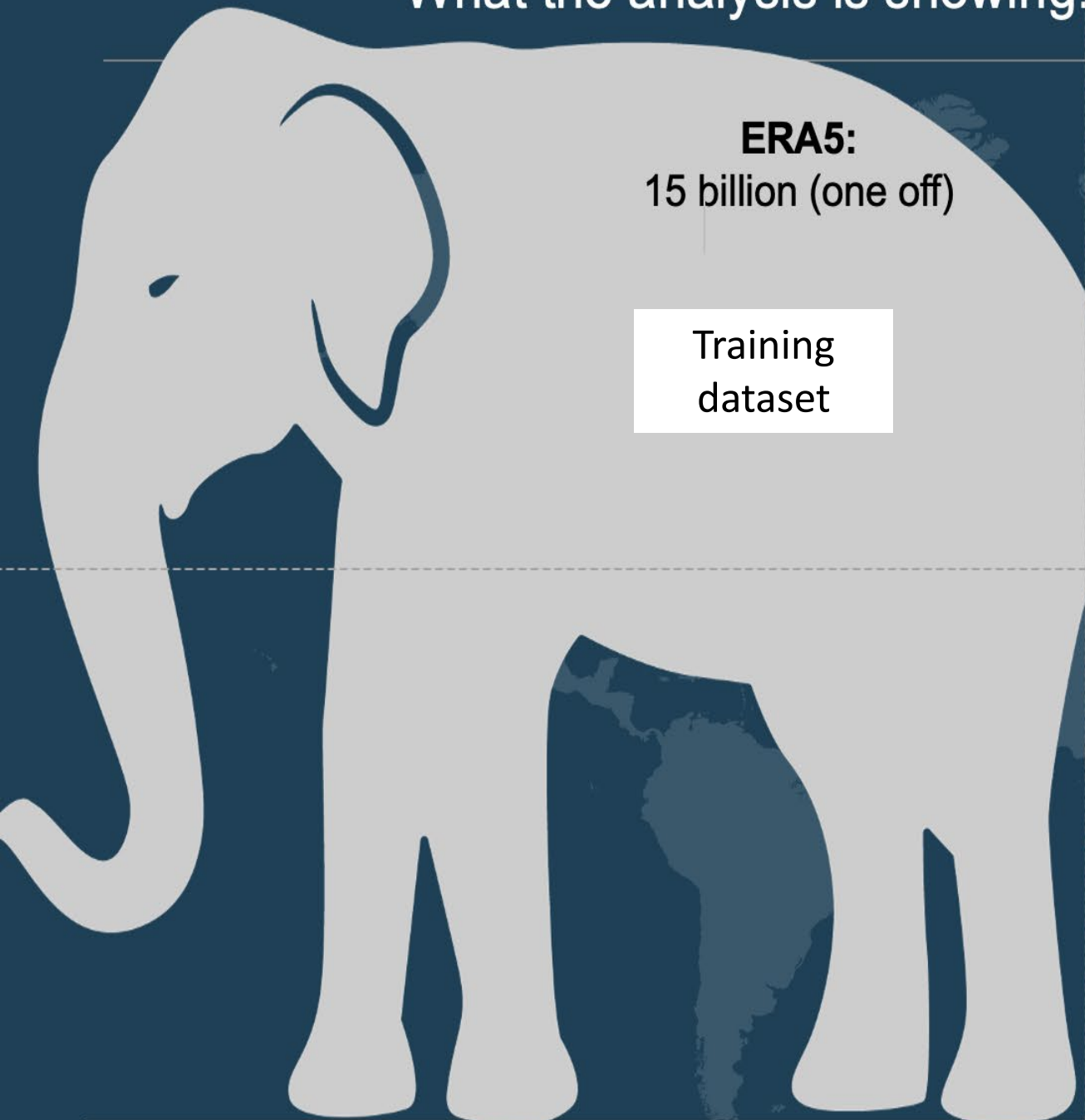
4. Predict

Now: AIFS-Single one forecast at a time



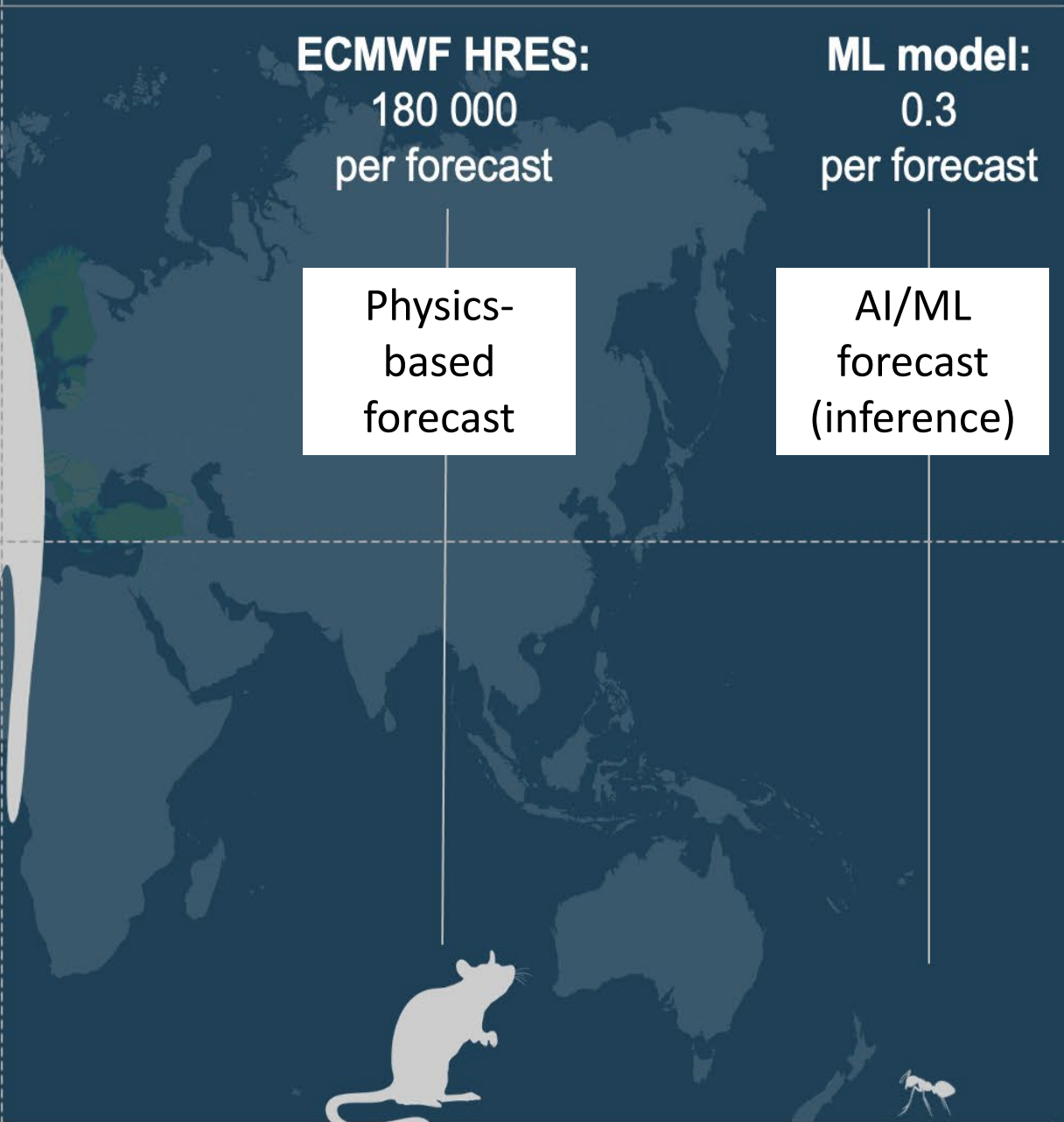


What the analysis is showing: potential gain in time and energy

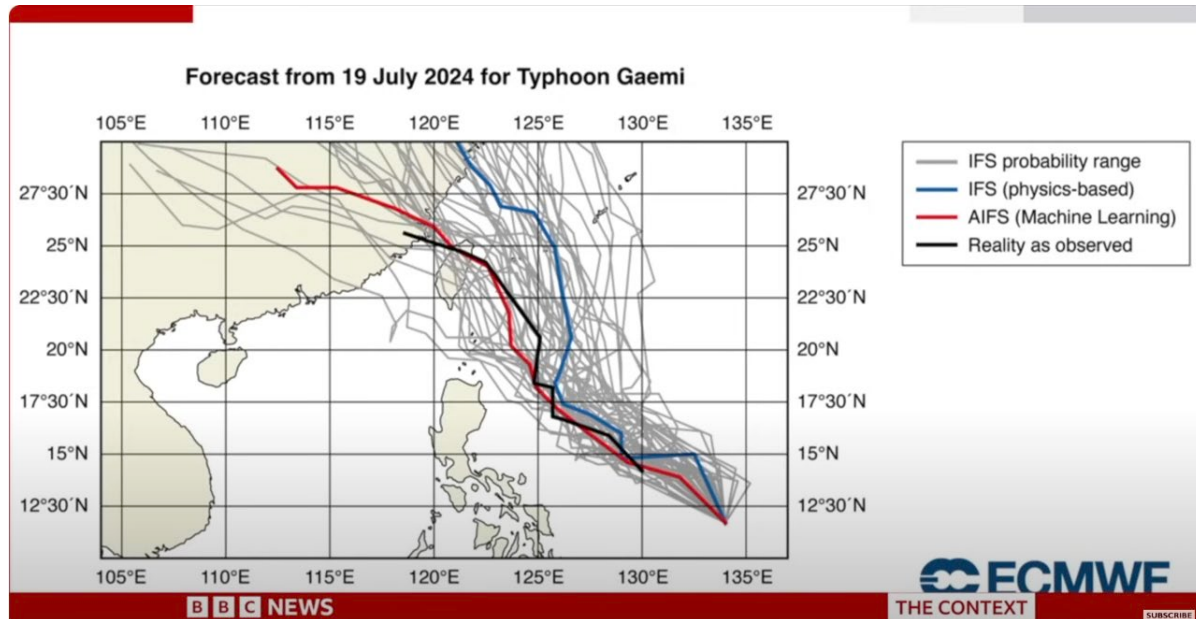


ERA5:
15 billion (one off)

Training
dataset



Operational Artificial Intelligence models started in 2025

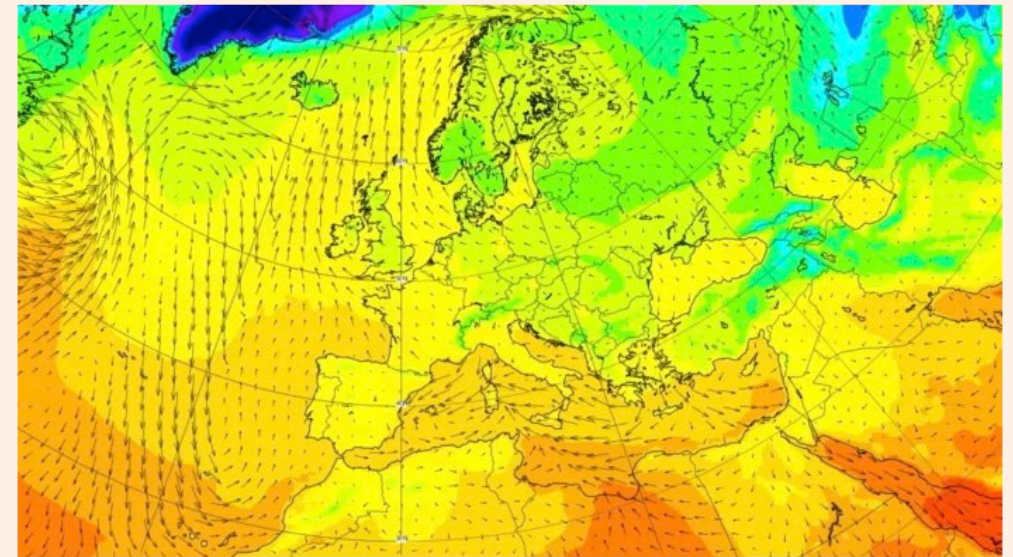


<https://on.ft.com/4id2QNv>

Artificial intelligence + Add to myFT

Weather forecasting takes big step forward with Europe's new AI system

Predictions for up to 15 days ahead expected to improve tracking of extreme events



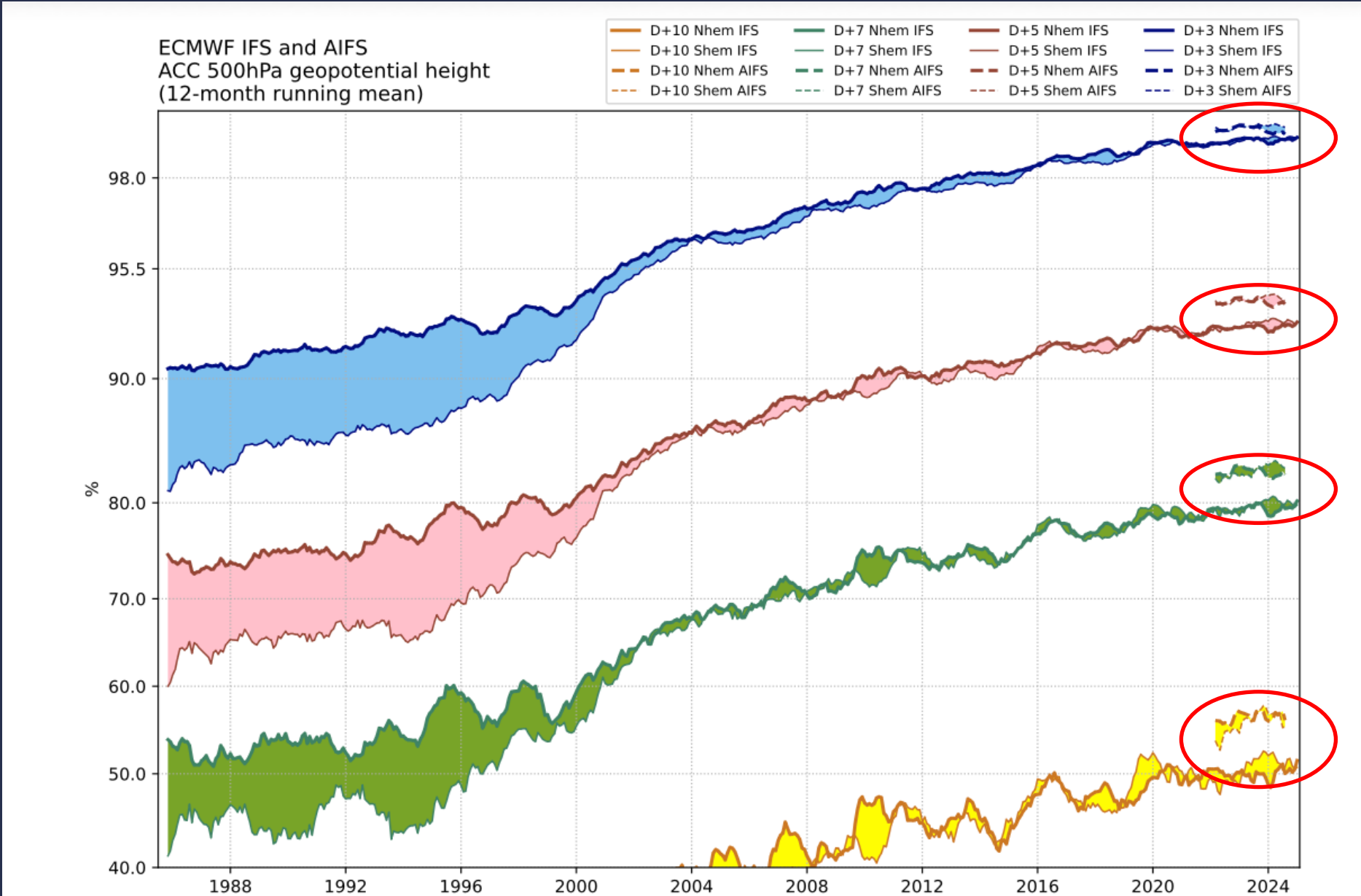
An AI forecast for Europe issued by ECMWF on Monday predicts temperature and winds on March 11 © ECMWF

Clive Cookson

Published FEB 25 2025

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AI delivers skill gains over physics-based models up to 10 years of R&D





Conclusions

Earth Observations are more than ever essential

Operational forecasts now **combine Physics-based
and data-driven methods**

Successful collaboration between big tech,
academia and meteorological organisations