

ECMWF progress and plans

Andy Brown and Florian Pappenberger



Three sites: one 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.





ECMWF STRATEGY 2021-2030



The strength of a common goal

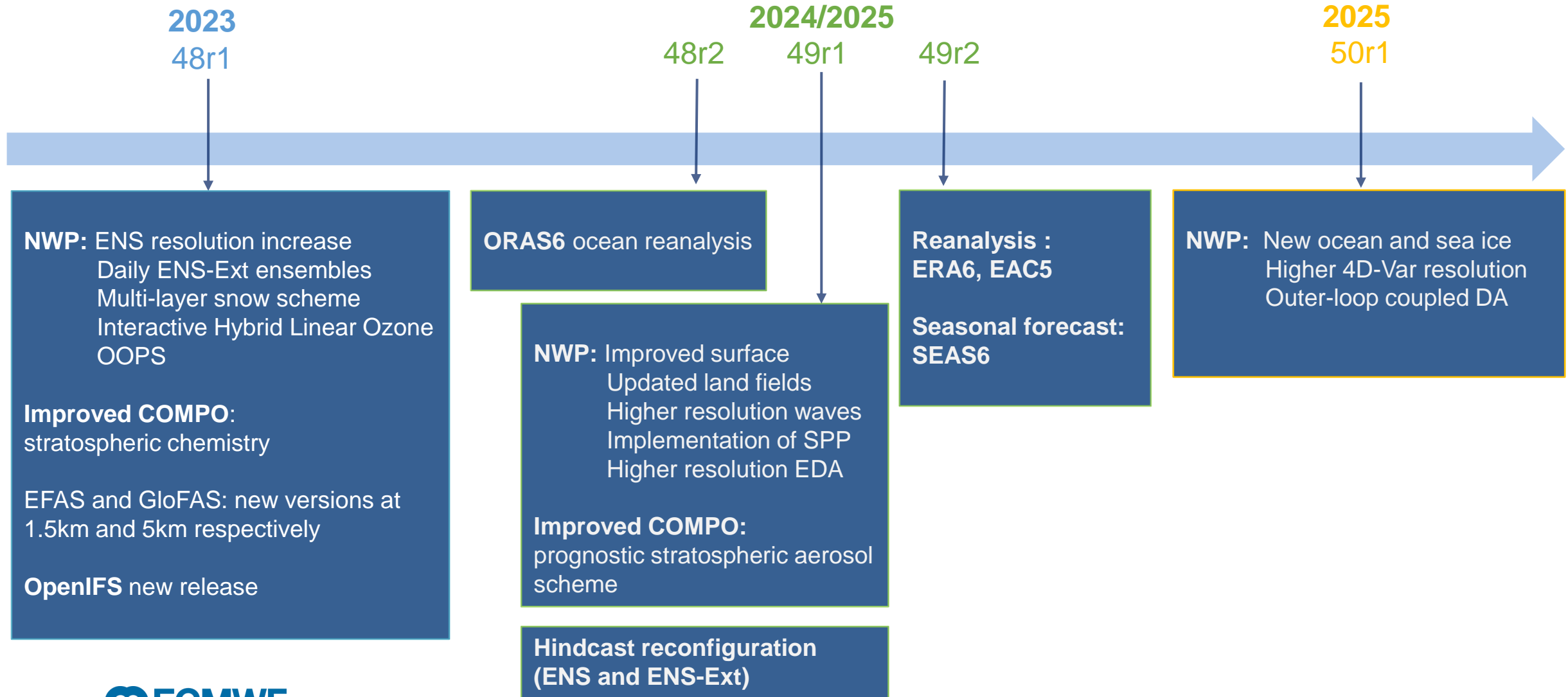
Existing strategy 2021-2030

Usual 5-yearly update 2026-2035

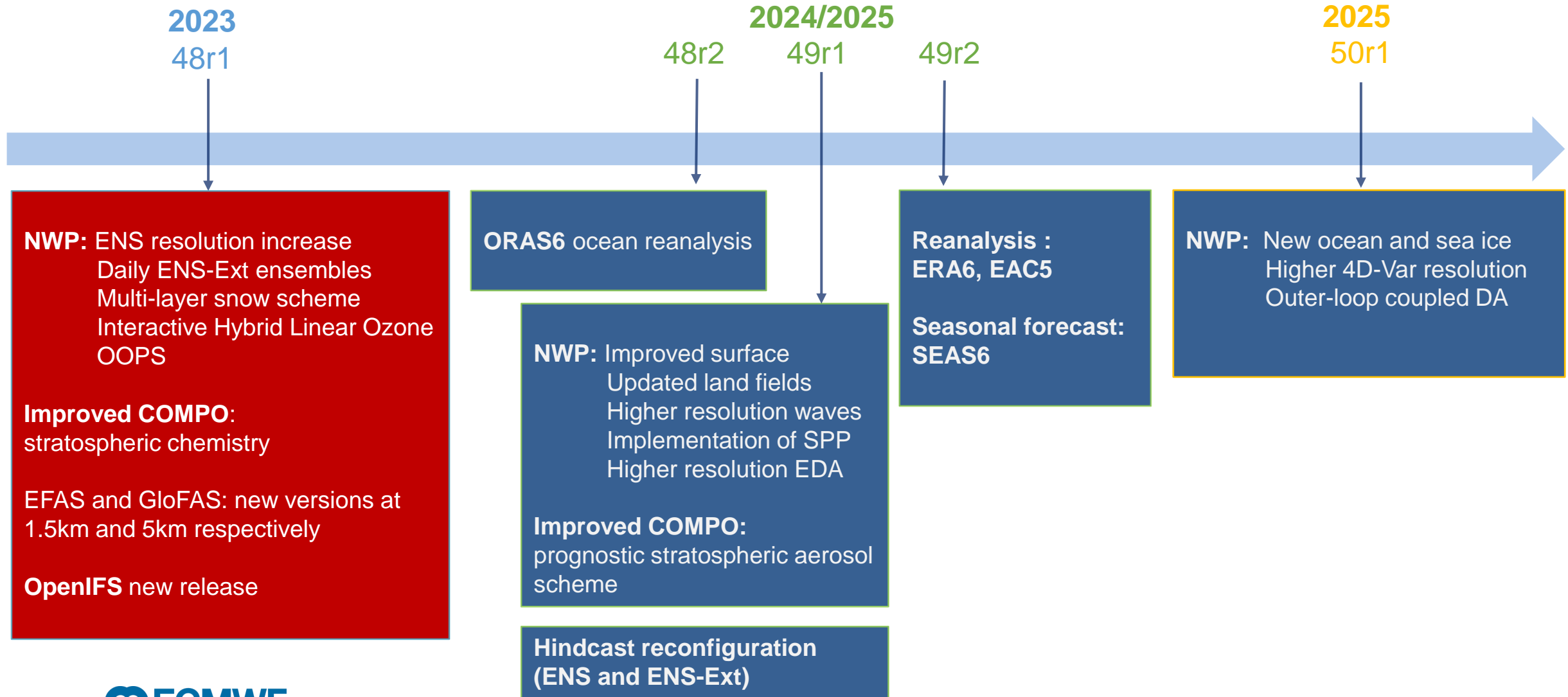
AI/ML, HPC/cloud, DestinE,
increased demand for environmental
products and services.....

Update 2025-2034

Integrated Forecast System (IFS) upgrades

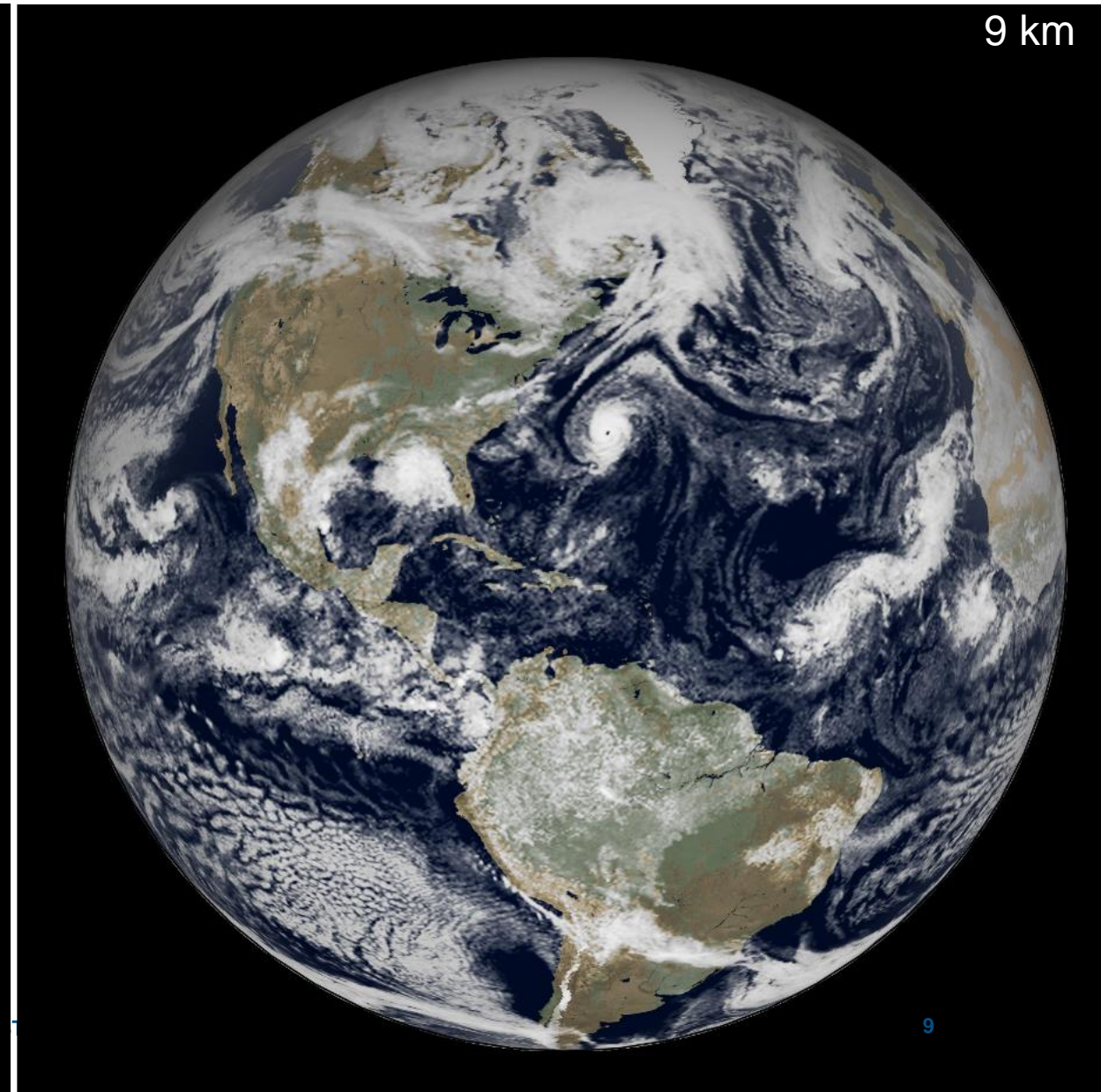
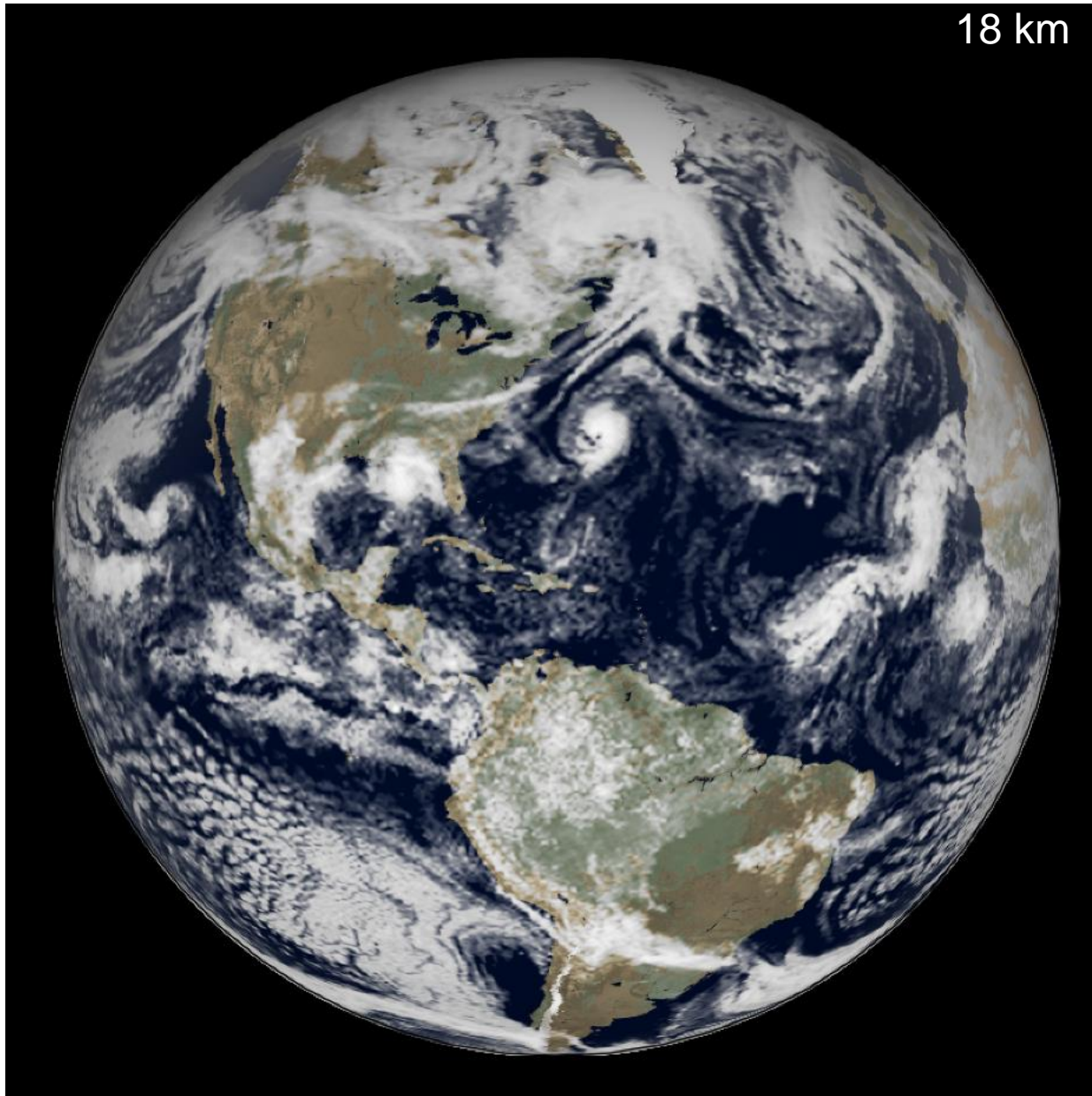


Integrated Forecast System (IFS) upgrades



Medium range ensemble: 18 km to 9 km (same as HRES)

Extended range ensemble: 50+1 members twice weekly to 100+1 members every day



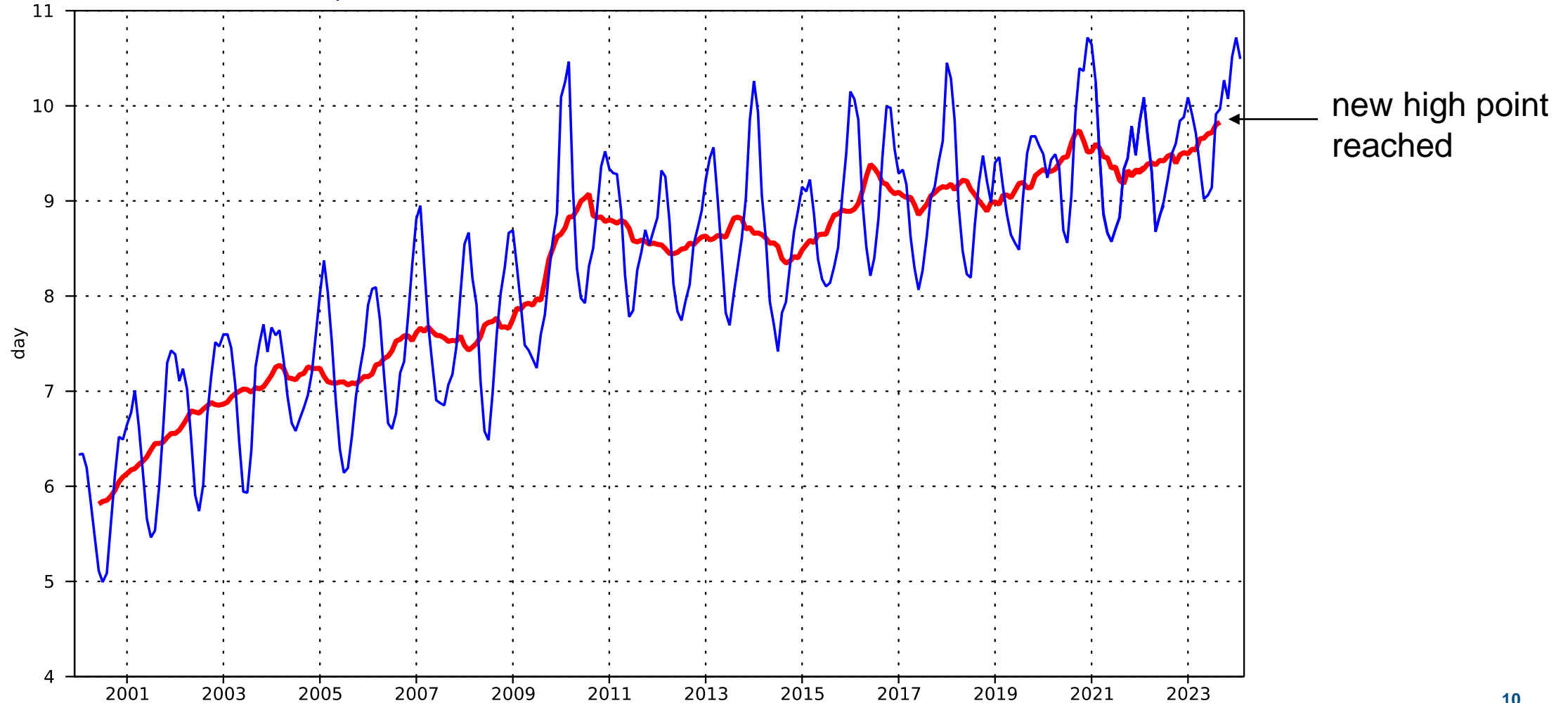
Evolution of ENS upper-air forecast skill

News on ECMWF's forecast performance
Speaker: Thomas Haiden

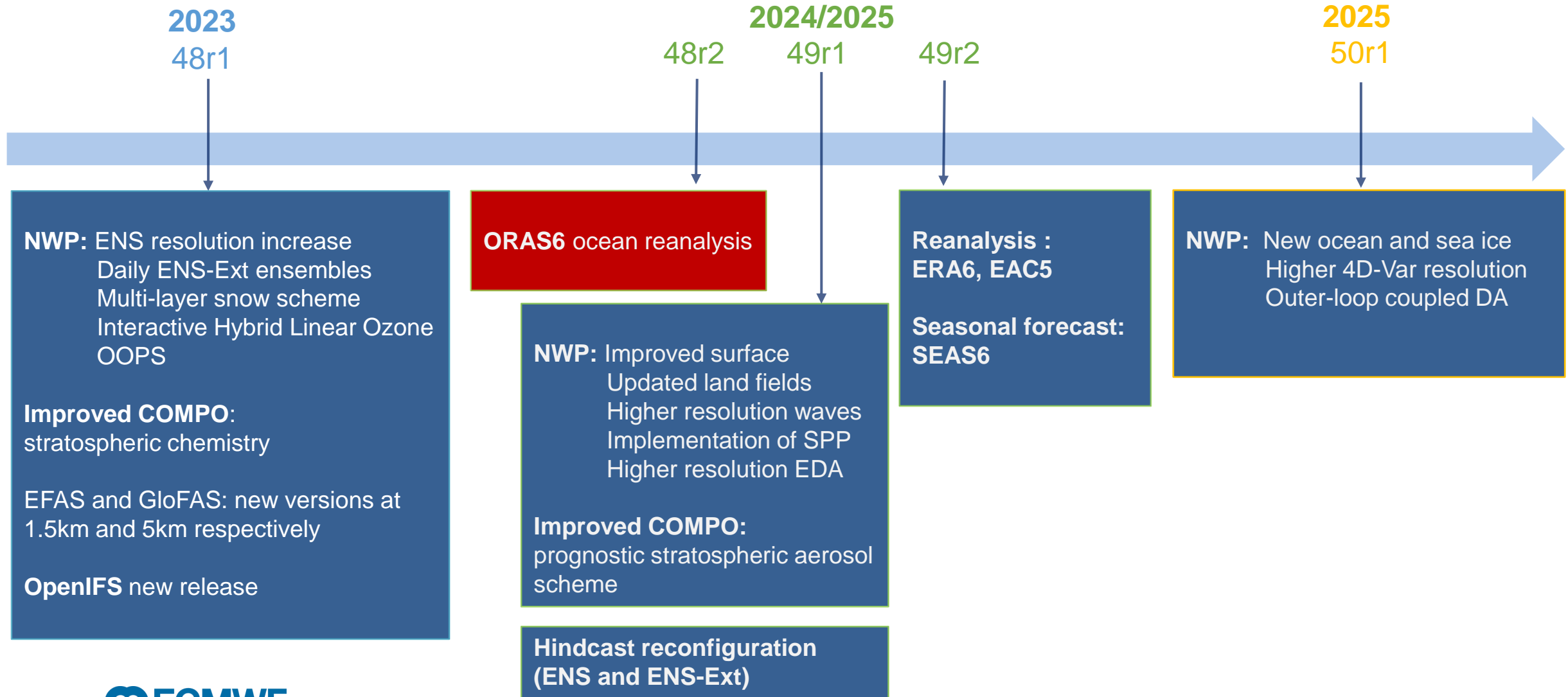
Continuous ranked probability skill score | 850hPa temperature

NHem Extratropics

T+12 T+24 ... T+360 | oper_ano d enfo 0001 00z,12z beginning



Integrated Forecast System (IFS) upgrades



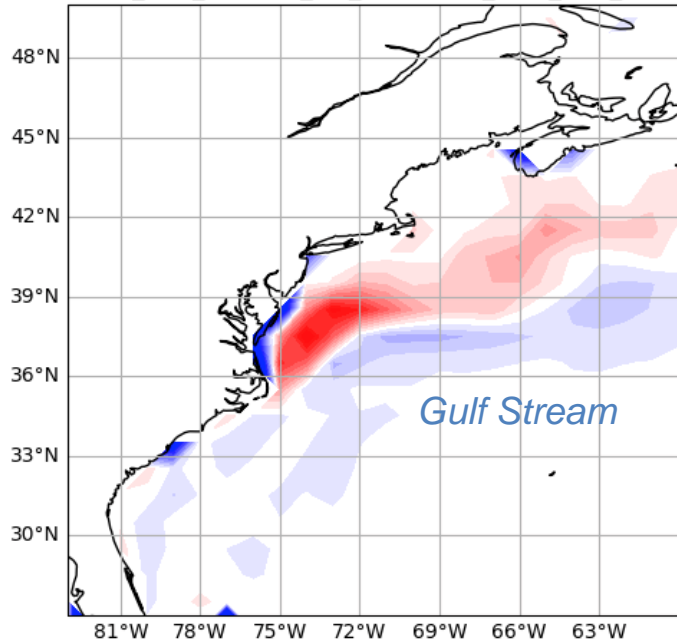
New ocean reanalysis performance

Mean SST biases (2015-2021)

Verf. CCIv2 SST

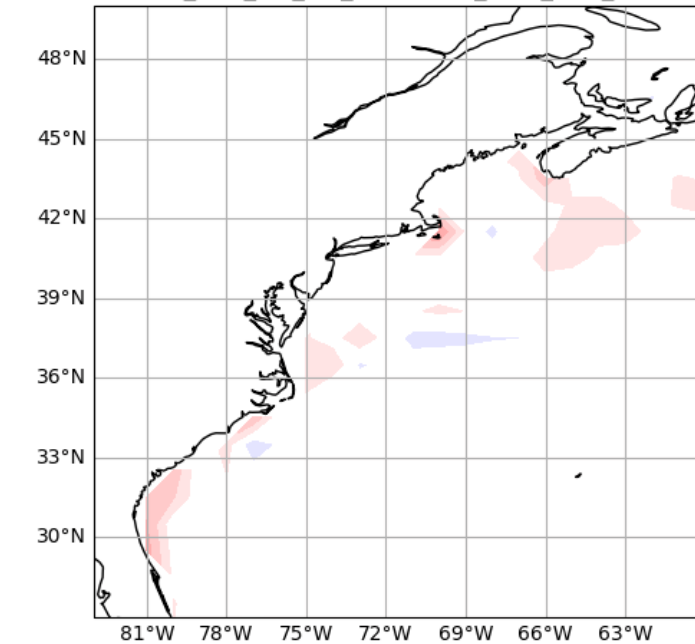
ORAS5

0001_cci2_sosstsst_tos_20152021_r1x1_bias_1.nc

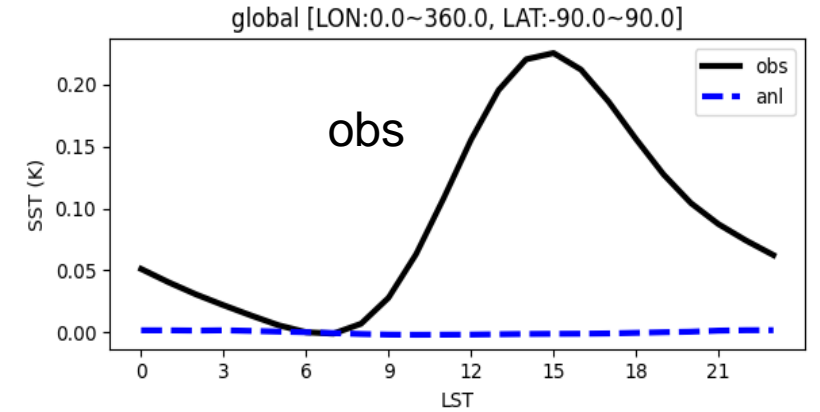


ORAS6

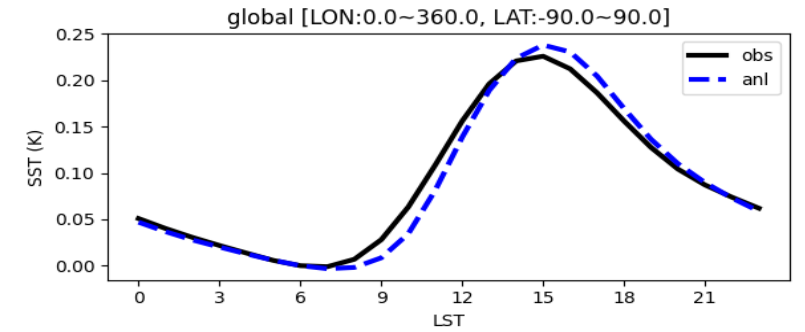
i5ou_cci2_tos_tos_20152021_r1x1_bias_1.nc



Global-mean SST Diurnal Cycle

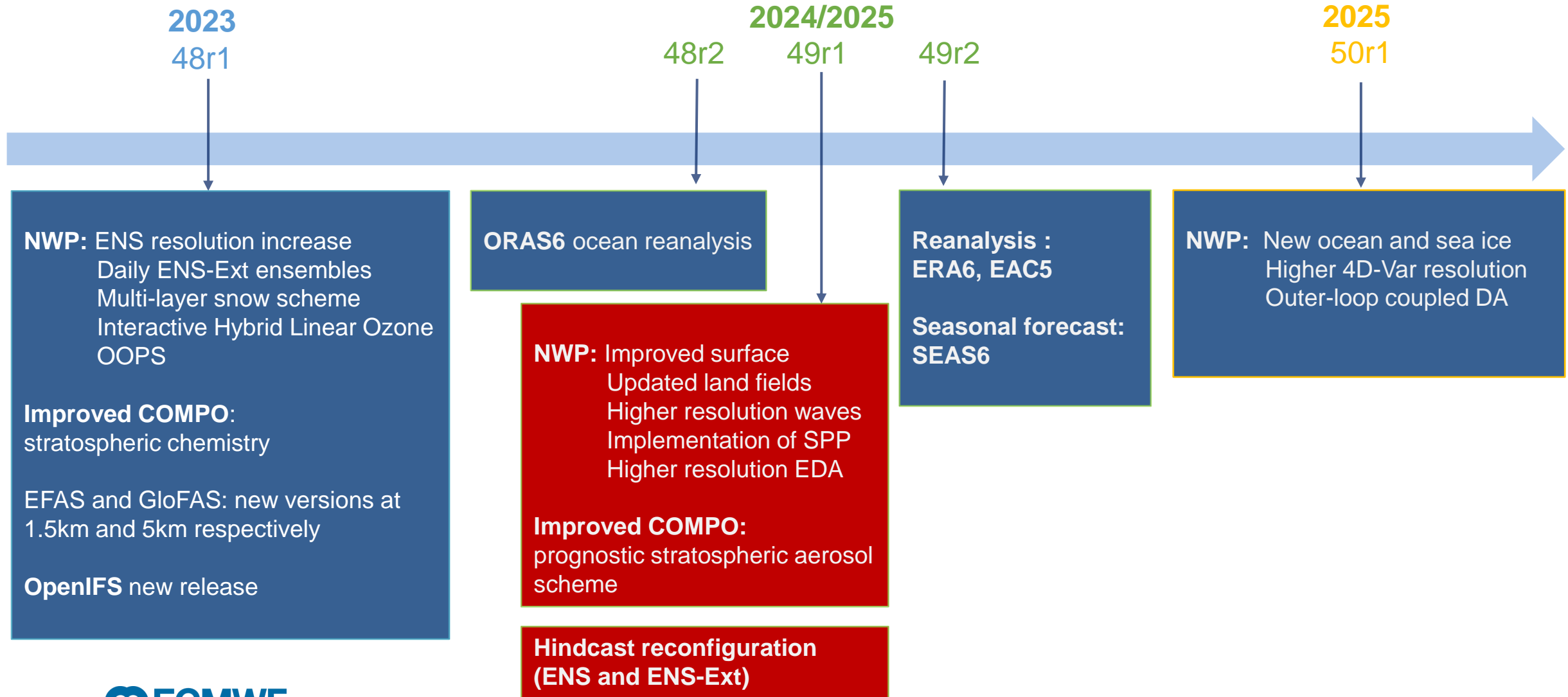


ORAS5 doesn't have a diurnal cycle



ORAS6 has a diurnal cycle close to observation

Integrated Forecast System (IFS) upgrades



Summary of contributions to cycle 49R1

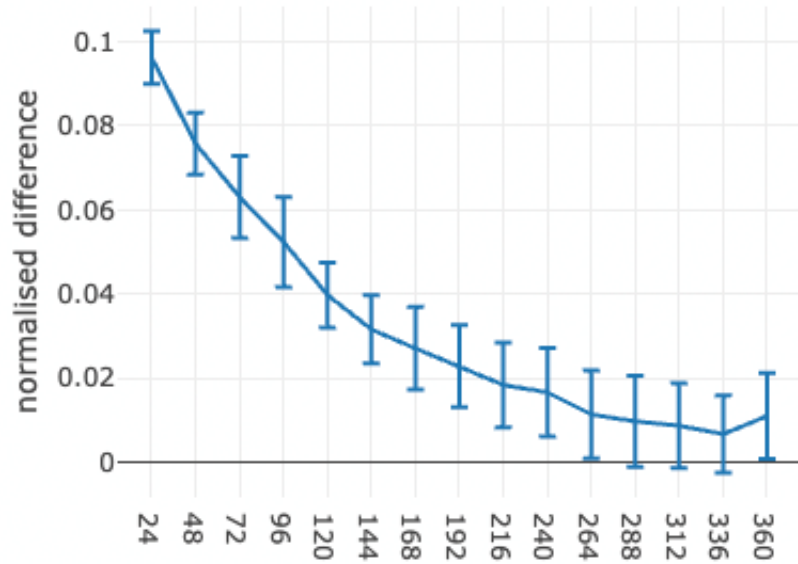
Model changes

Data assimilation changes

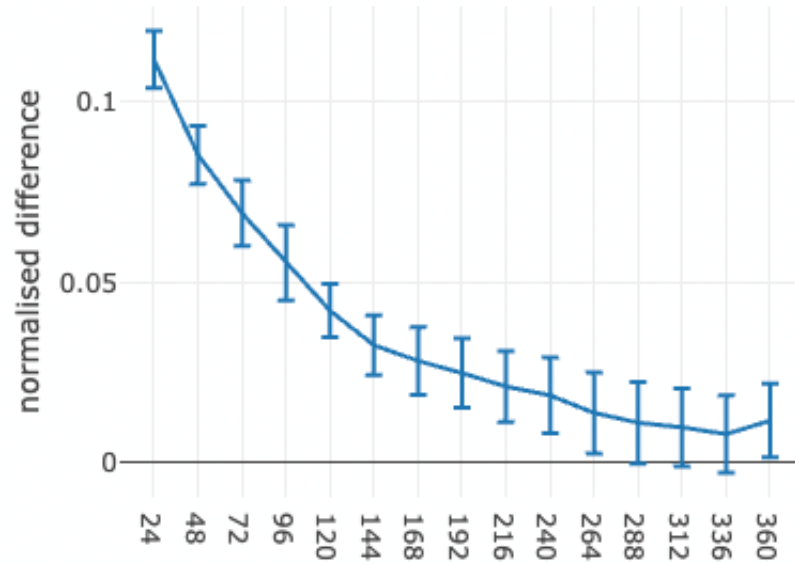
- **V1 – Microwave and RTTOV assimilation package**, including updates to RTTOV and all-sky all-surface assimilation of sea-ice areas for GMI/ASMR2 amongst other changes.
- **V2 – Wave model and convection package**, including waves on Tco grid, new wind input parameterizations, sea-state dependent heat and moisture fluxes, hourly wave DA, improved CAT diagnostics, and updated non-orographic GWD.
- **V3 – Non-microwave observations package**, including observation updates from IR and active sensing groups.
- **V4 – Land-surface model updates**, including updated climate fields, modified vegetation properties, activation of urban tile, updated T2m interpolation, and shadowing of snow under high vegetation.
- **V5 – T2m assimilation package**, activates assimilation of T2m observations.
- **V6 – VarQC and stratospheric balance assimilation package**, including activation of VarQC in first trajectory, increased weight to GRAS/COSMIC-2 measurements, and activation of stratospheric balance in 4DVar.
- **V7 – Land-surface assimilation package**, including changes to soil moisture background errors, updates to snow assimilation, and lapse rate correction for T2m assimilation.
- **V8 – Activation of the Stochastically Perturbed Parametrizations (SPP) scheme**, which replaces the Stochastically Perturbed Parametrization Tendencies (SPPT) scheme in all IFS ensemble configurations.
- **V9 – Physics and numerics contributions**, which includes ecRad optimizations, improved 10m wind diagnostics, improvements in TOA radiation budget, flexible aerosol treatment in radiation, time-dependent methane oxidation, and reordering sequence of physics chain in IFS.
- **V10 – Atmospheric composition package**, including revisions to aerosol optical properties, chemistry updates, and many other changes.
- **V11 – Other technical/neutral changes**, including bit-identical Ensemble control forecast and HRES.
- **Updates to EDA**, including Tco1279 FC+Traj, soft recentering, and new climatology for SES calculation.

T2m verification against observations (NHEM, winter 2022/23)

2t|0|n.hem|rmsef|ob



2t|0|n.hem|crps|ob



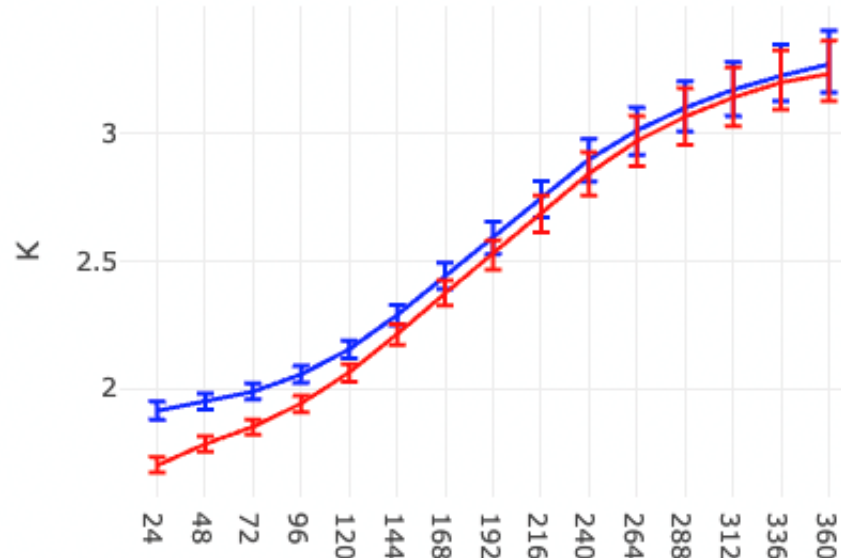
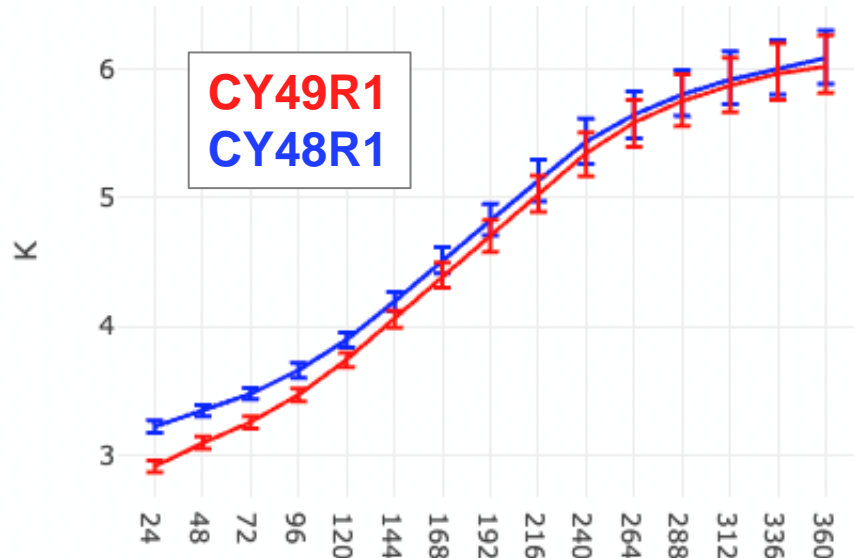
CY49R1 improves NHEM T2m forecasts.

- Impact from several contributions.
- Largest impacts during NHEM winter.

RD esuite ensemble scores

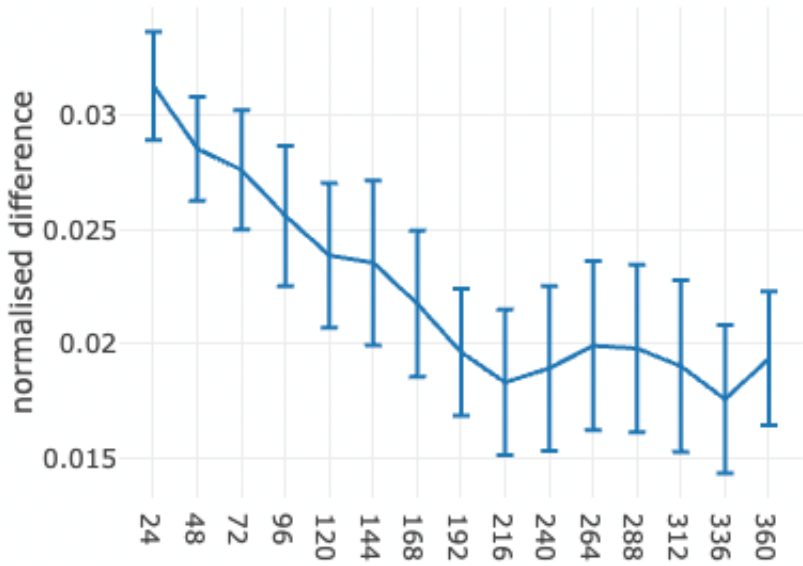
Region (season)	CRPS (day 5)	RMSE (day 5)
N. Hem (DJF)	4.2 %	4.0 %
Tropics (DJF)	2.5 %	1.8 %
S. Hem (DJF)	0.3 %	0.6 %
N. Hem (JJA)	0.7 %	1.4 %
Tropics (JJA)	-0.7 %	-1.5 %
S. Hem (JJA)	-0.2 %	0.0 %

Bold values significant at 95% confidence level

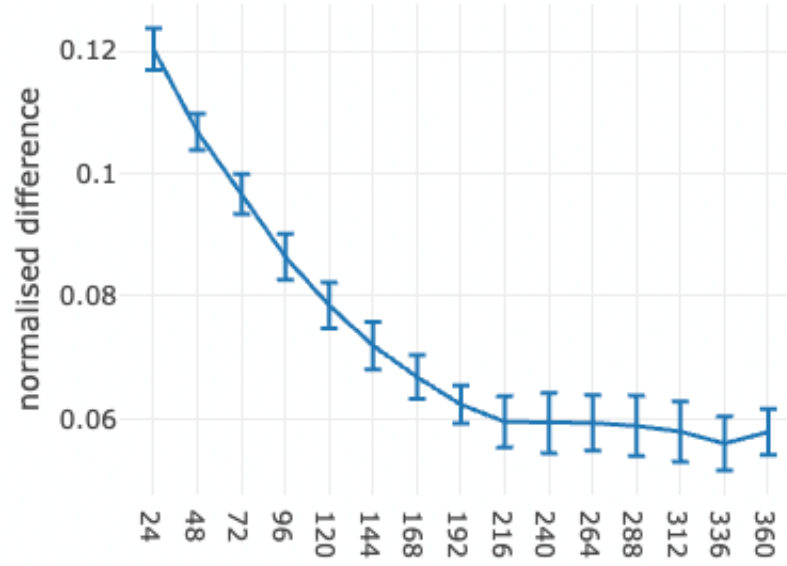


10m wind verification against observations (NHEM, winter 2022/23)

10ff|0|n.hem|rmsef|ob



10ff|0|n.hem|crps|ob



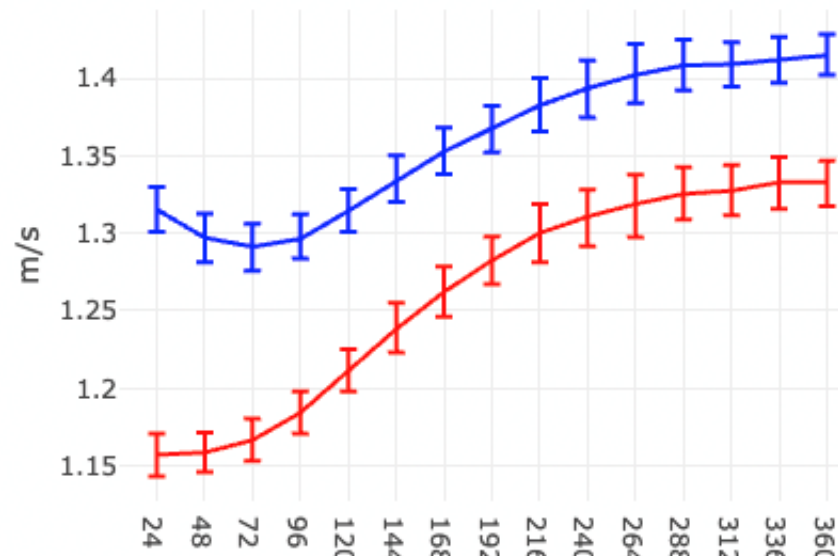
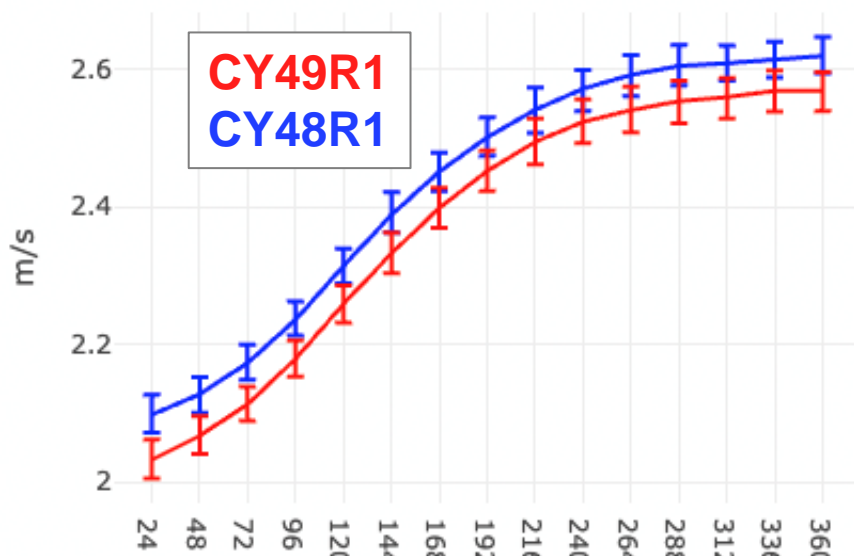
CY49R1 improves 10m wind forecasts.

- Impact from several contributions.
- Increased spread from SPP is important.

RD esuite ensemble scores

Region (season)	CRPS (day 5)	RMSE (day 5)
N. Hem (DJF)	7.8 %	2.4 %
Tropics (DJF)	6.8 %	1.9 %
S. Hem (DJF)	3.8 %	1.4 %
N. Hem (JJA)	3.6 %	1.1 %
Tropics (JJA)	5.3 %	0.8 %
S. Hem (JJA)	5.1 %	1.1 %

Bold values significant at 95% confidence level



49R1 RD esuite: score cards (summer + winter combined)

Update on ECMWF
Product Development
Speaker: Matthieu
Chevallier

ENS Control (=HRES) (324 forecasts)

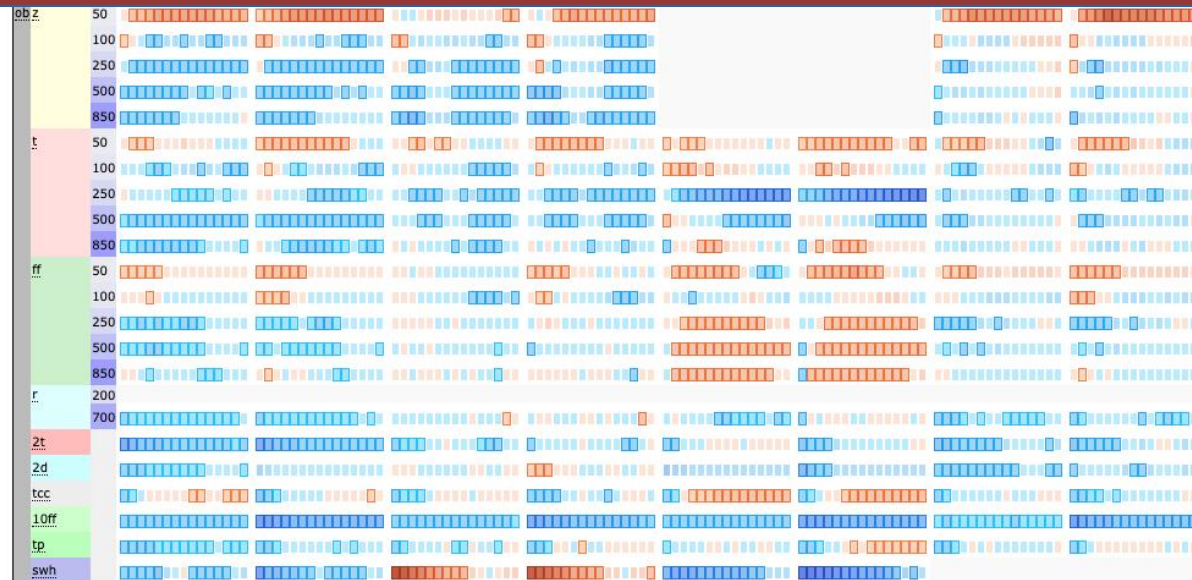
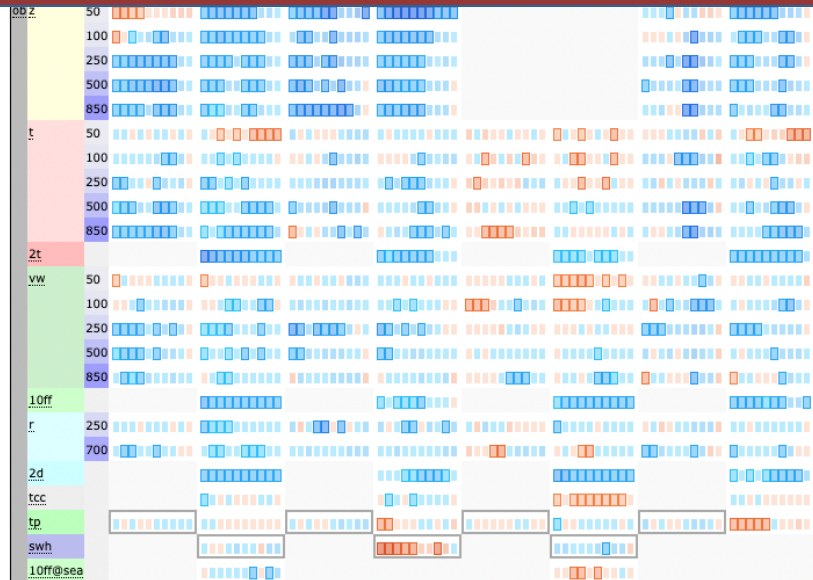
50-member ENS (152 forecasts)

shaded boxes for confidence boundaries: ● 95% ○ 50%/95% ○ 95%/99.7% || ○ significance triangles || ○ bars

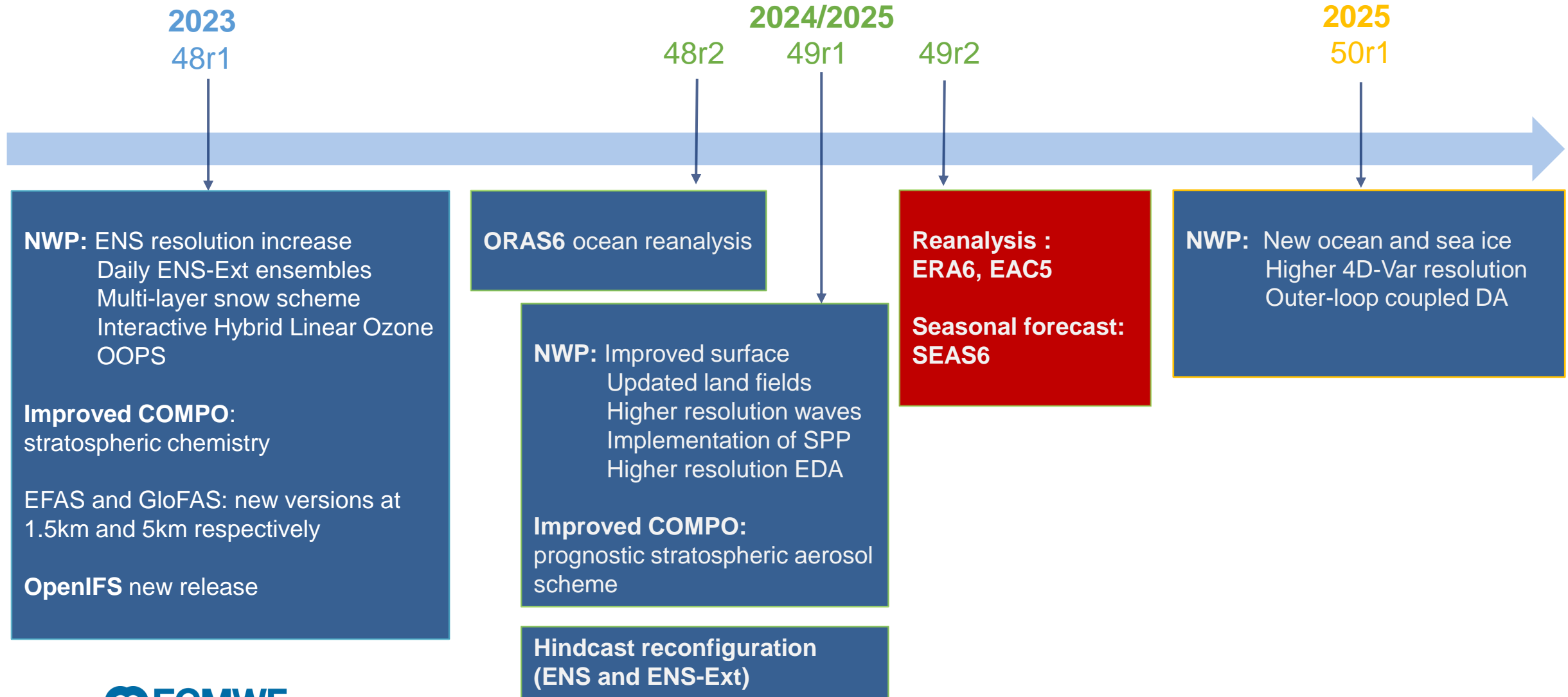
shaded boxes for confidence boundaries: ● 95% ○ 50%/95% ○ 95%/99.7% || ○ significance triangles || ○ bars

Own analysis

Observations



Integrated Forecast System (IFS) upgrades

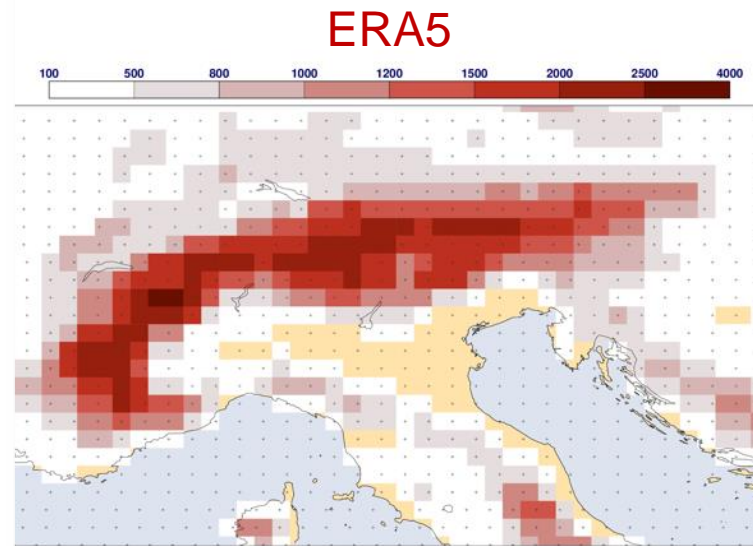
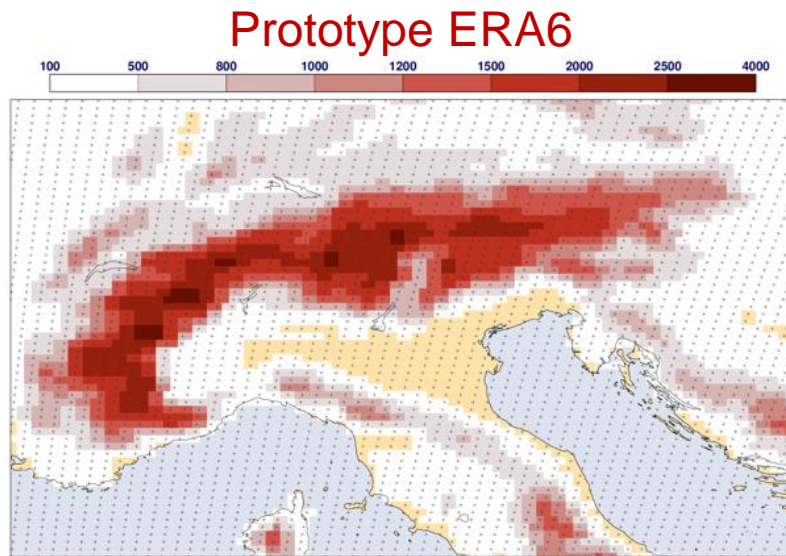


From ERA5 to ERA6; new climate dataset is being developed

ERA5 is *the* world-leading climate dataset for many applications.

Preparations of its follow-up, ERA6 are well underway:

- Taking onboard recorded user requirements from our huge ERA5 user base (over 160,000)
- Will capitalize on an additional **8 years of R&D** at ECMWF plus increased compute power
- Double the atmospheric resolution: **14km globally** vs 31km; **ocean waves 14km** vs 40km.
- Has coupling with the ocean, providing additional information on the climate system.

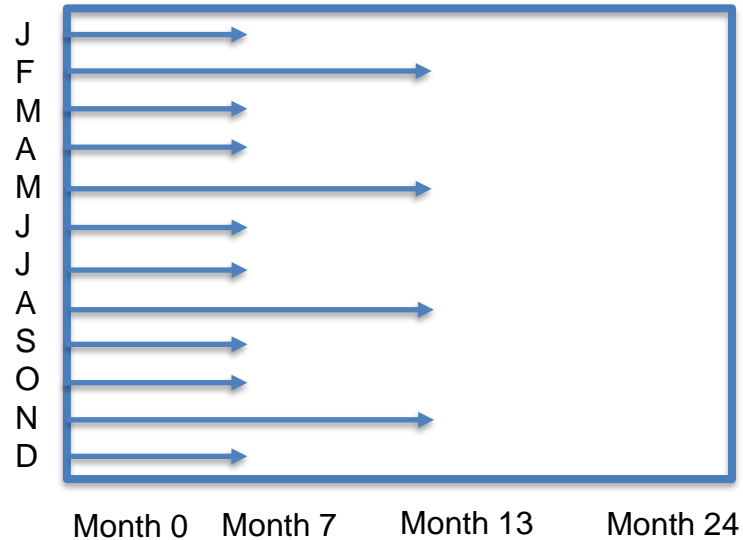


ERA6 to start production in early 2025
Aim to make the first 20 years (2006-2026) available around Autumn 2026

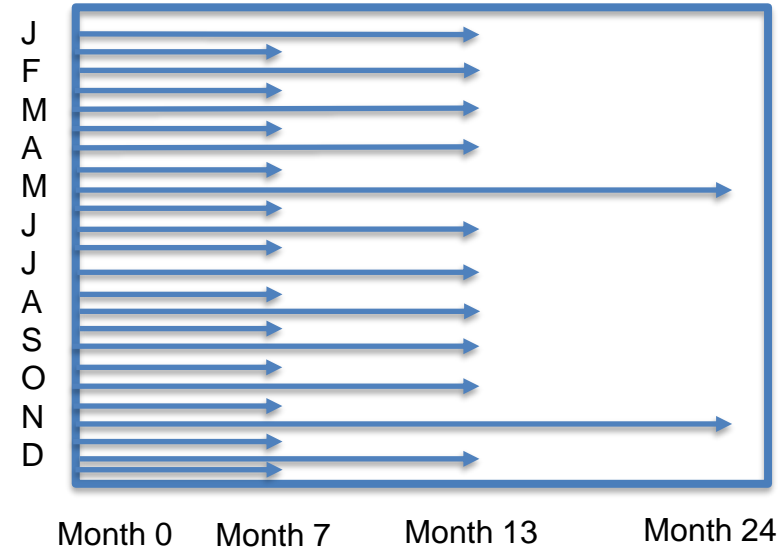
SEAS6 Real-time forecast enhancements at a glance:

- 7m twice a month (101 members)
- 13m every month (33 members)
- 24m twice a year (33 members)

SEAS5



SEAS6



SEAS6 Reforecasts

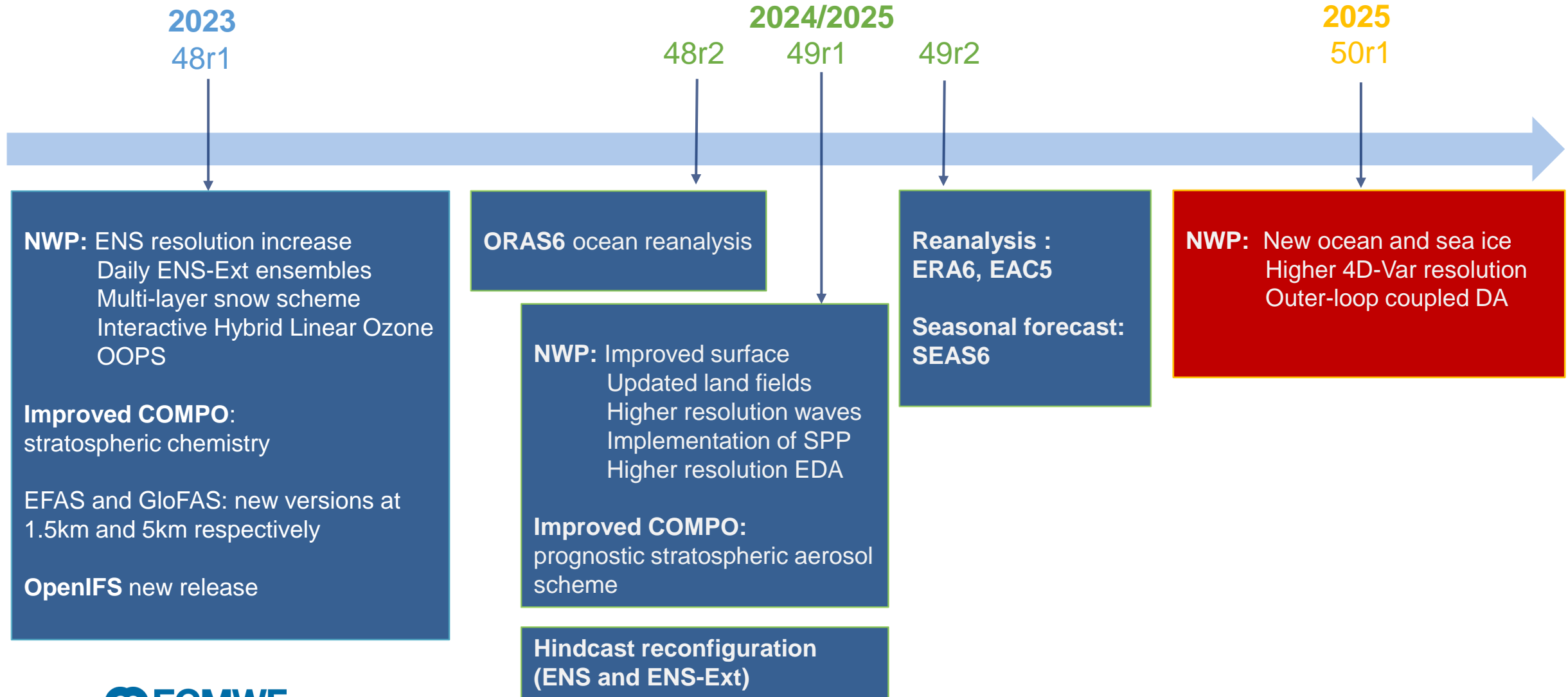
Main set 1993-2022

7m fc: 33 members twice a month
13m fc: 22 members monthly
24m fc: 22 members twice a year

Supplementary set :

Back extension to 1961 for all
Enhanced ensemble (up to 55
members) for 7m fcs quarterly

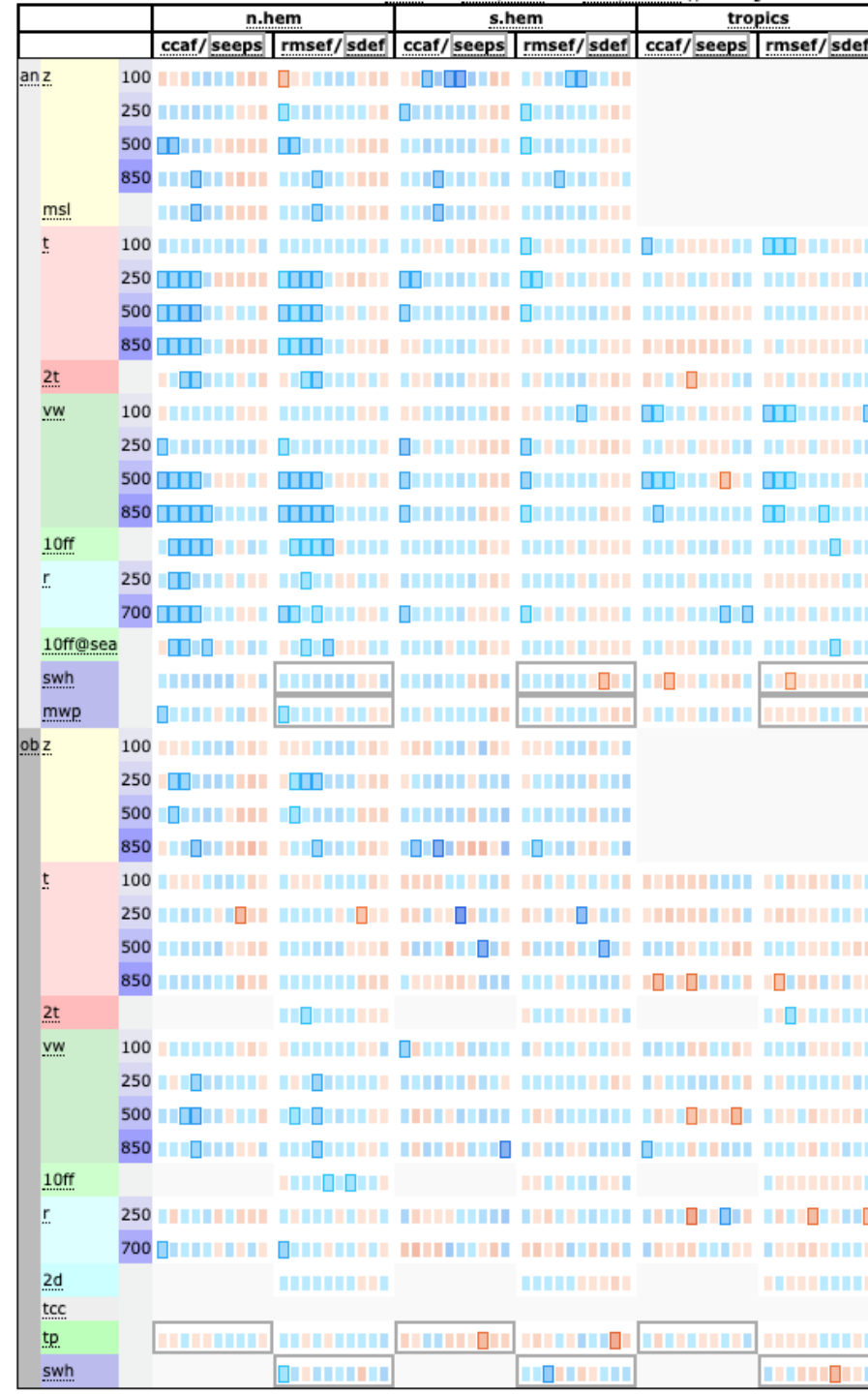
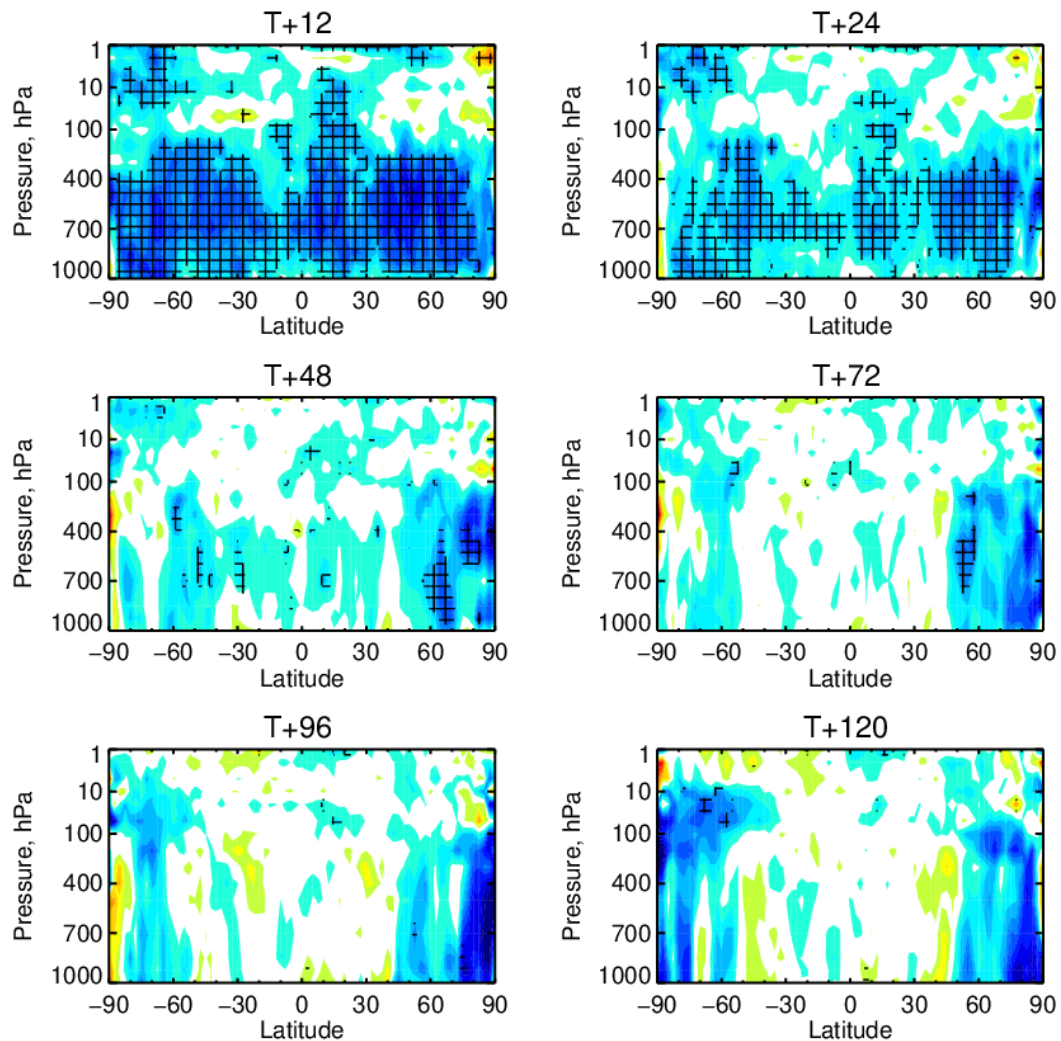
Integrated Forecast System (IFS) upgrades



Higher-resolution 4D-Var data assimilation

Change in RMS error in VW (TCo511_399-TL511_control)

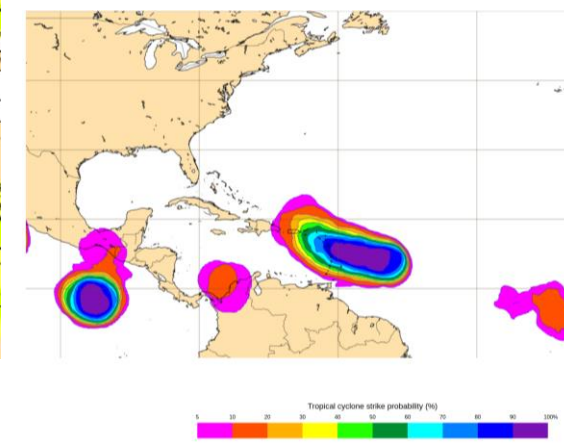
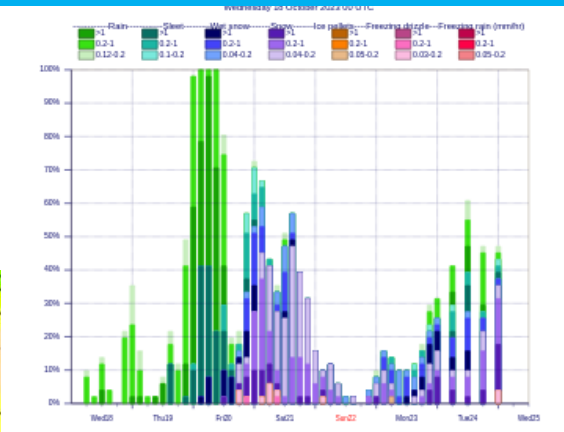
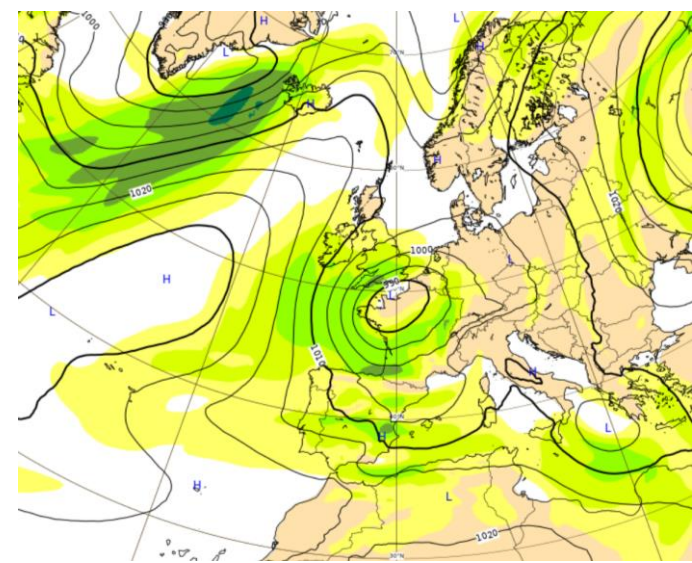
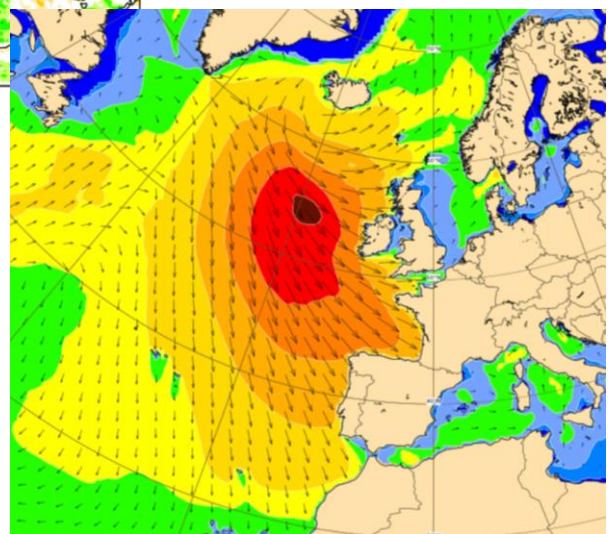
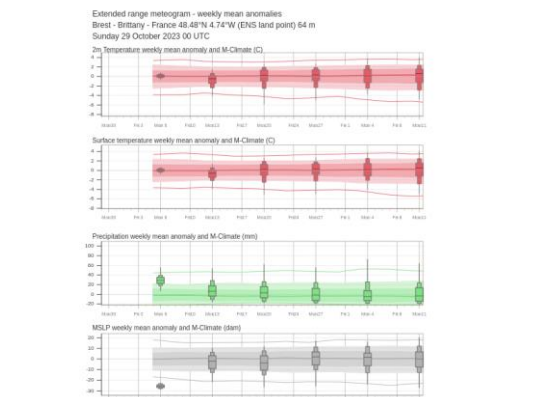
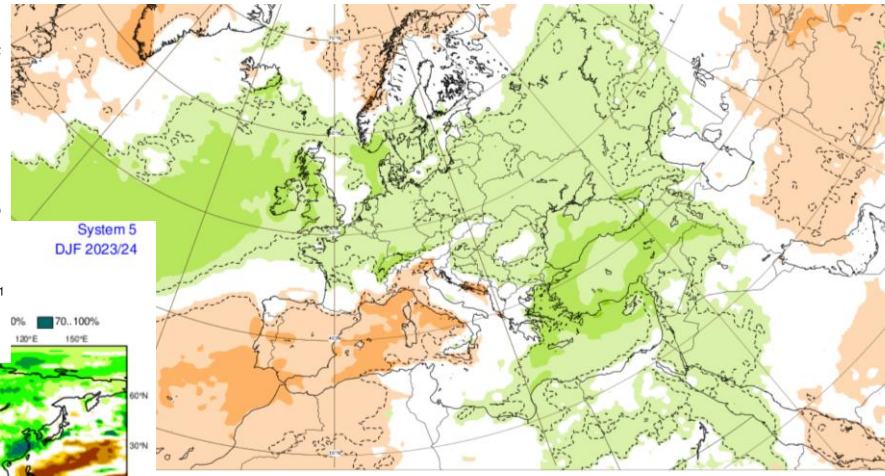
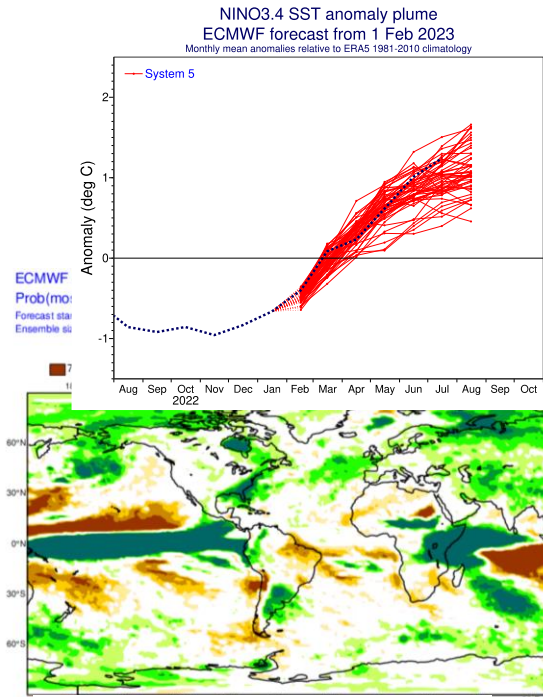
1-Jun-2022 to 31-Aug-2022 from 164 to 183 samples. Verified against own-analysis. Cross-hatching indicates 95% confidence with Sidak correction for 20 independent tests.



Products meeting users' needs

Update on ECMWF Product Development
 Speaker: Matthieu Chevallier

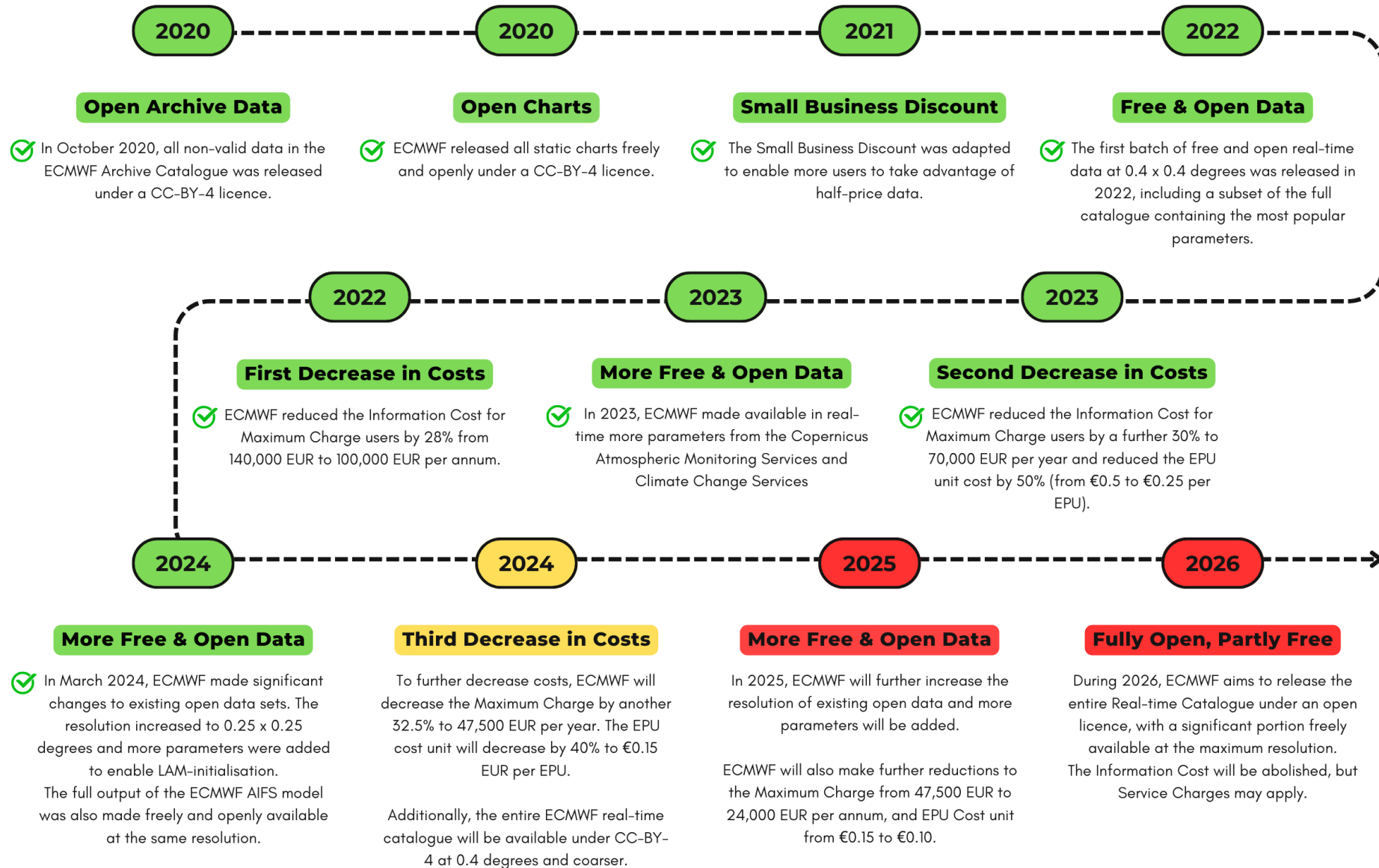
Latest developments on ECMWF's graphical products and apps
 Speaker: Cihan Sahin



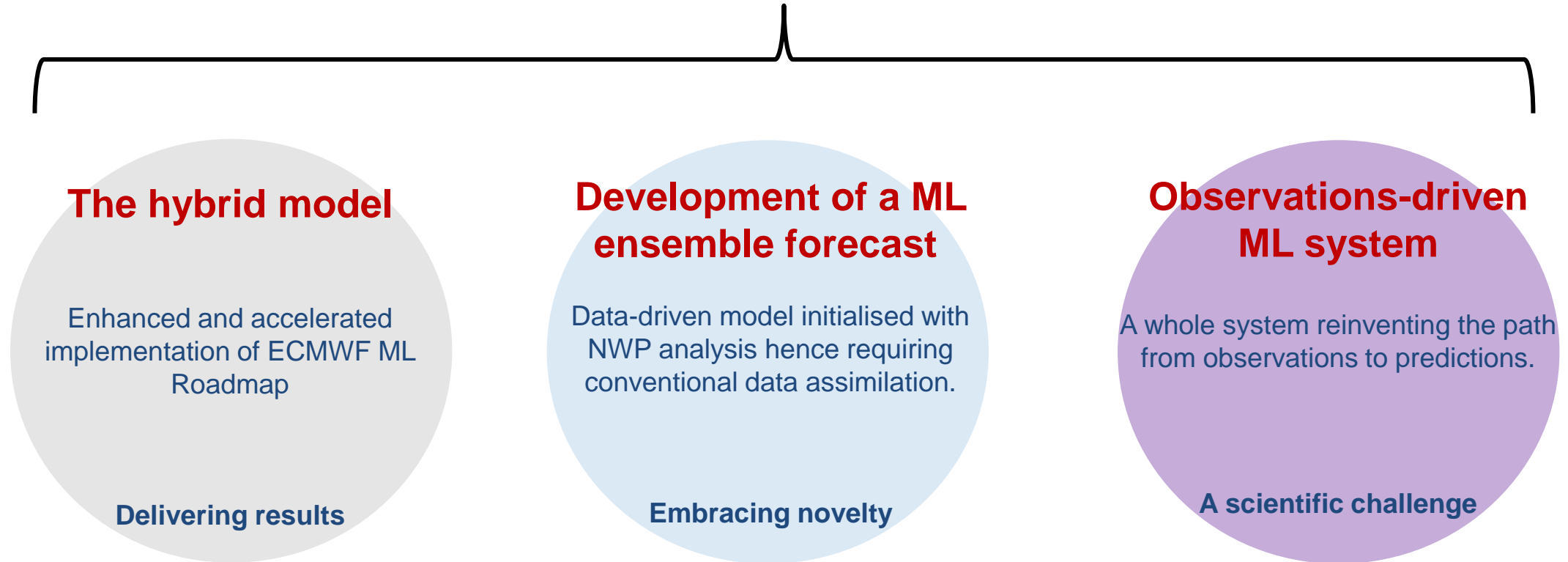
The open data goal



ECMWF's Open Data Timeline



Enhanced ML efforts at ECMWF – project overview

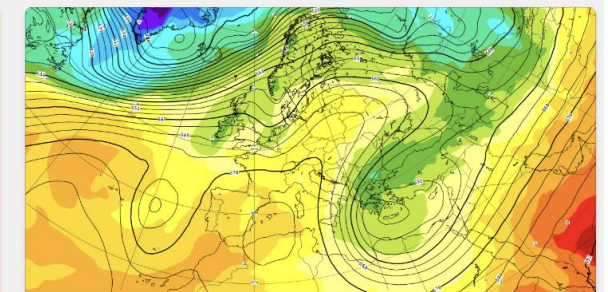
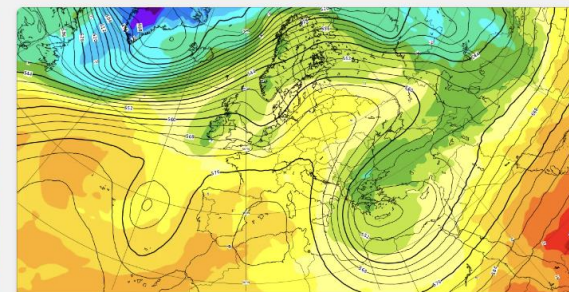
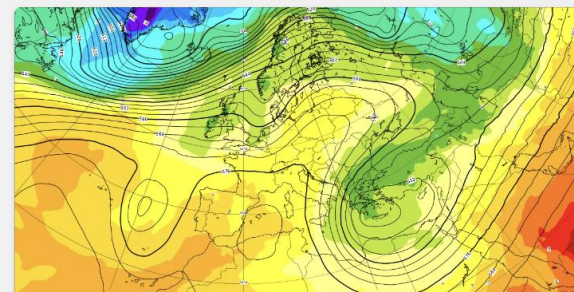
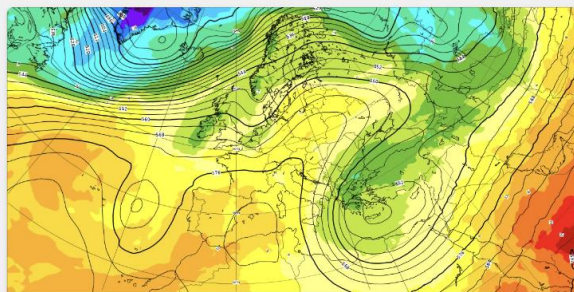
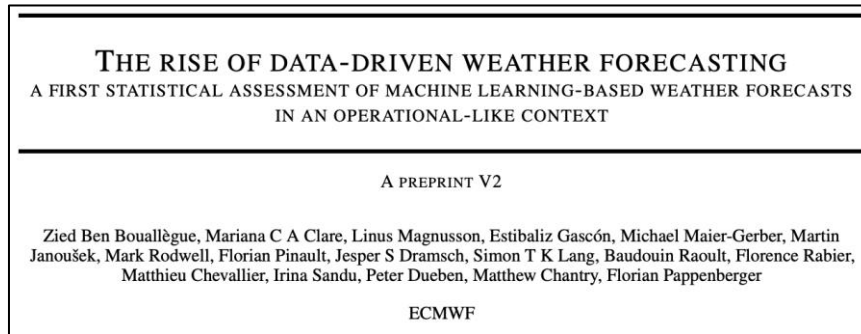


ECMWF collaborative project with Member States as one project of a EUMETNET programme

Step 1: Evaluation in an operational setting

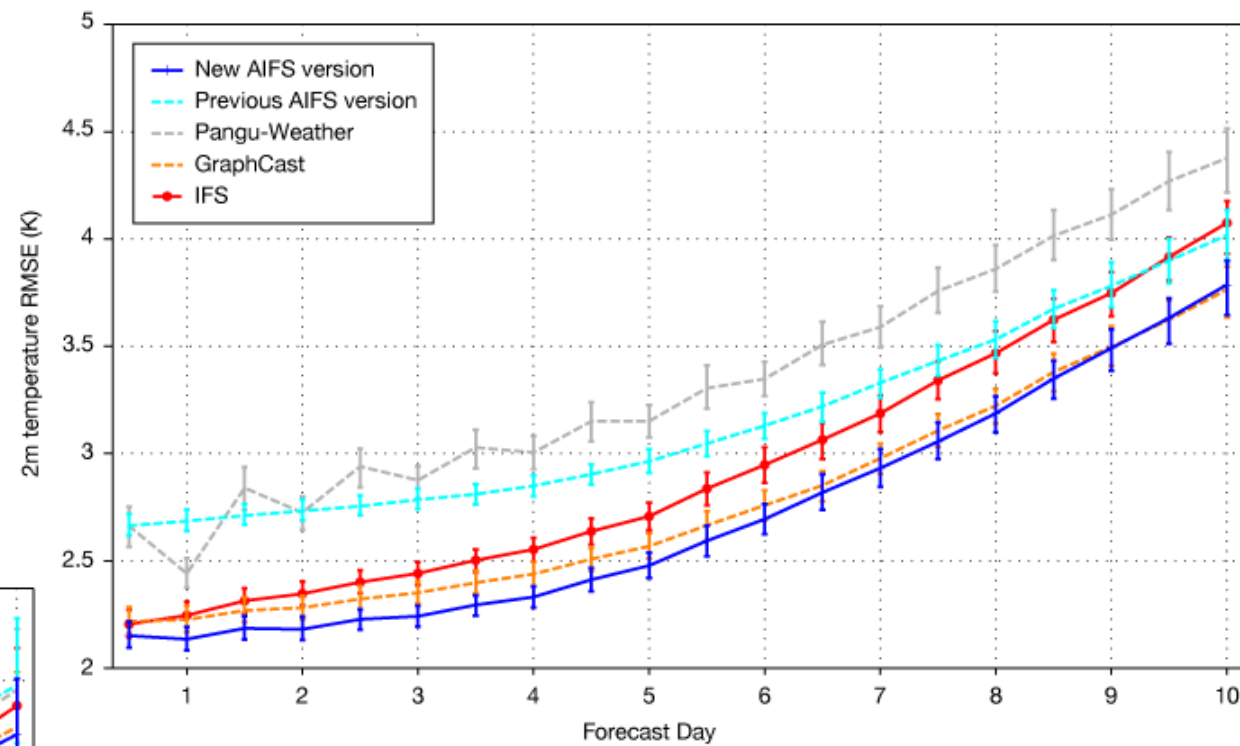
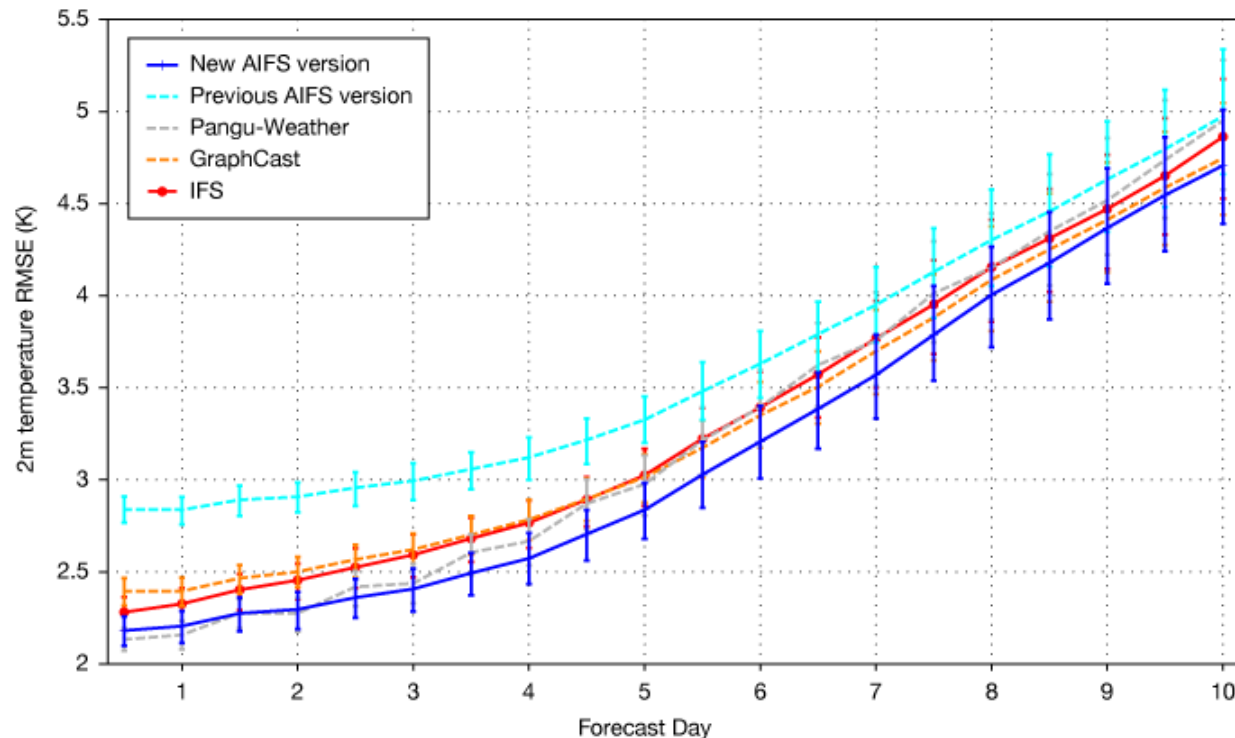
How to establish trust in a new type of forecasting system?

- Live daily forecasts provided openly
 - Only possible because of open-source contributions from NVIDIA, Huawei, Deepmind.
- Enables real time evaluation of extreme events by operational analysts.
 - As a community we can better identify strengths and weaknesses.



AIFS v0.2 – surface against observations

Northern hemisphere 2m-temperature

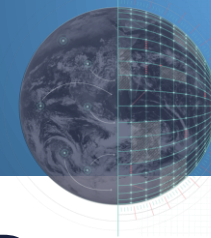


Southern hemisphere 2m-temperature

Lower = better

AIFS: a new ECMWF forecasting system
Speaker: Simon Lang

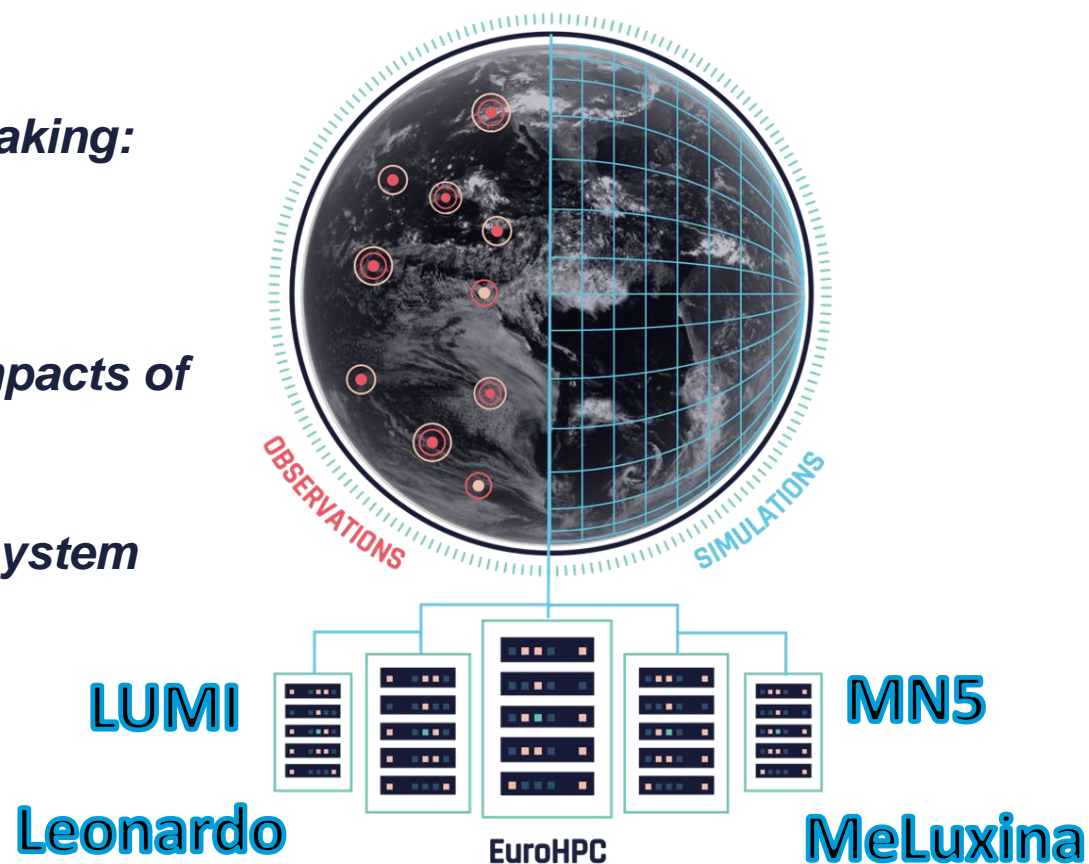
Forecast evaluation of AIFS
Speaker: Linus Magnusson

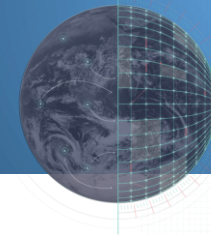


DESTINE: A DIGITAL REPLICAS OF OUR PLANET TO RESPOND AND ADAPT TO CLIMATE CHANGE AND EXTREME EVENTS

DestinE, in strategic partnership with EuroHPC Joint Undertaking:

- *Establishes bespoke cutting-edge simulation capabilities*
- *Provides Earth-system information at scales where the impacts of extreme events and climate change are felt*
- *Fosters an innovative and thriving AI-enabled digital ecosystem*



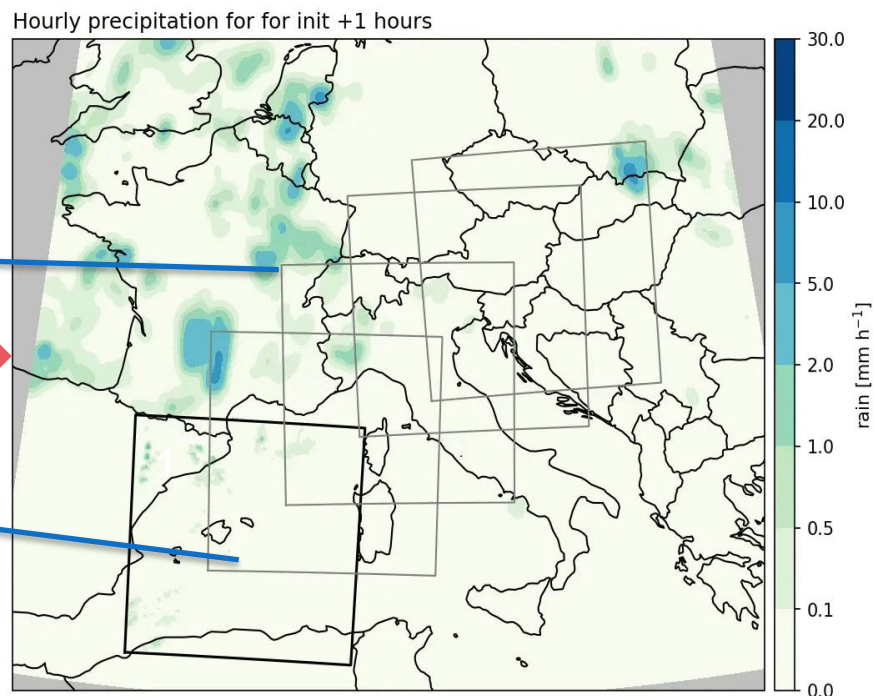


EXTREMES DT: A MAGNIFYING GLASS ON EXTREME EVENTS

Globally, 4 days ahead, 2-4km



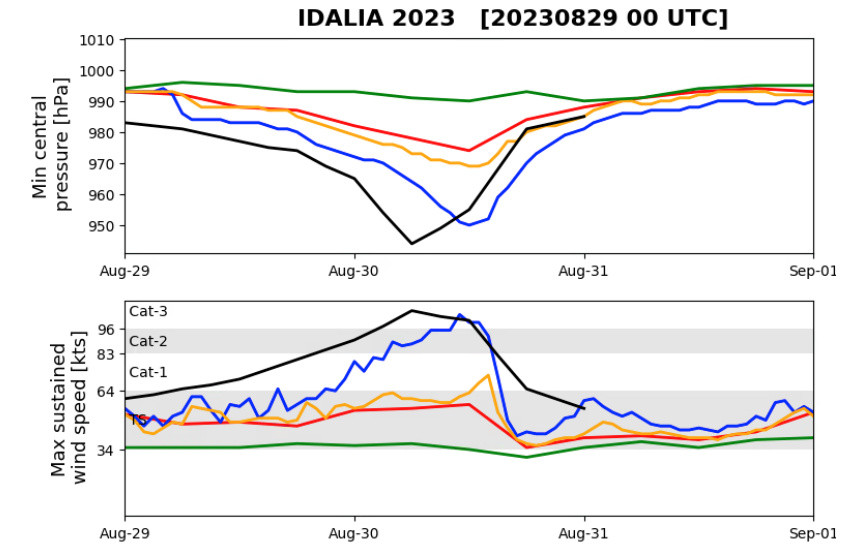
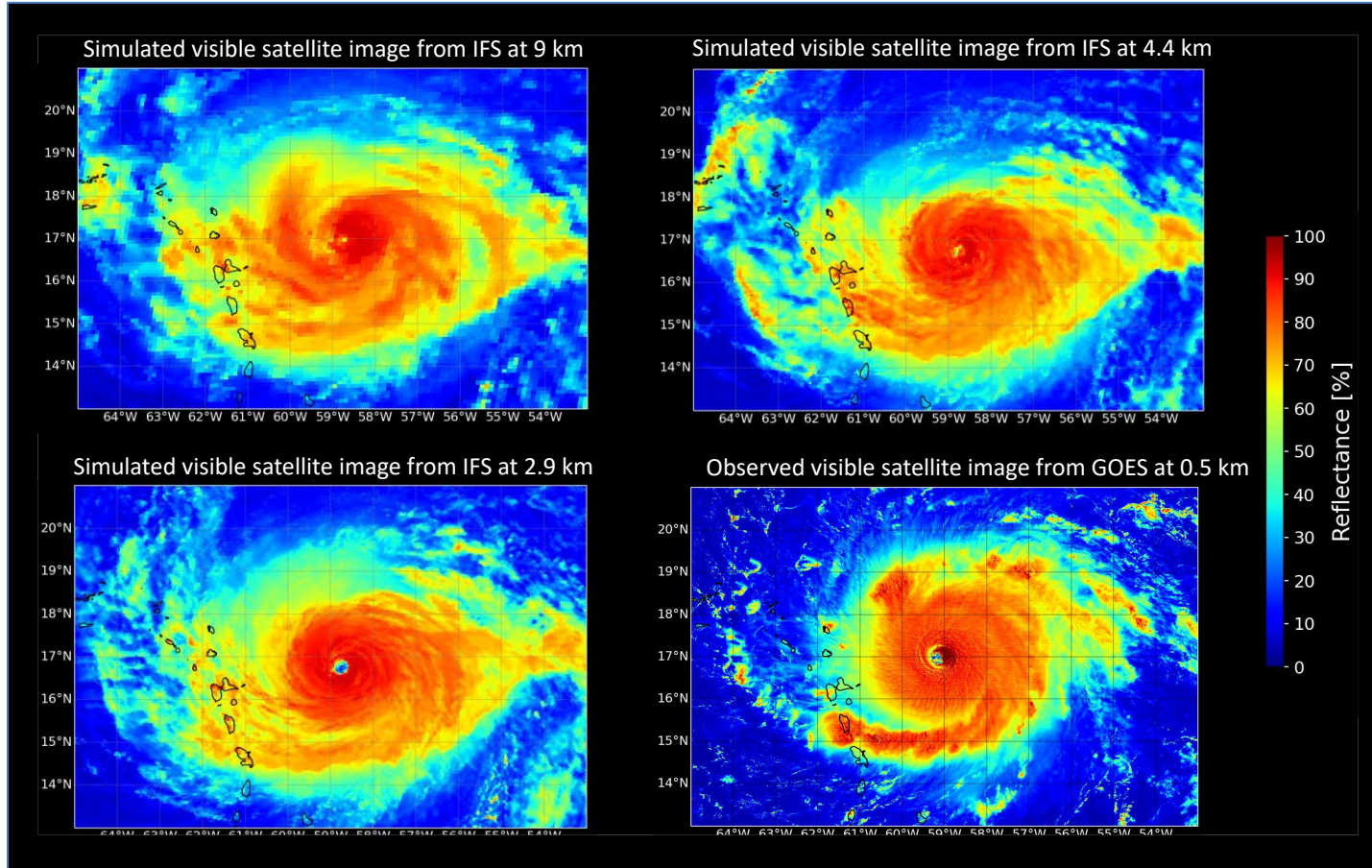
over Europe, 2 days ahead, 500-750m



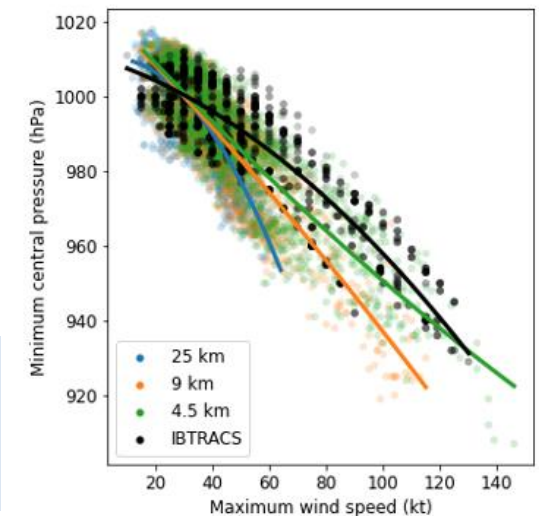
How will the approaching storm affect solar energy production?



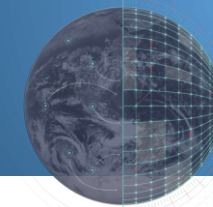
DestinE: How does km-scale benefit the representation of tropical cyclones?



2 seasons of DestinE fc



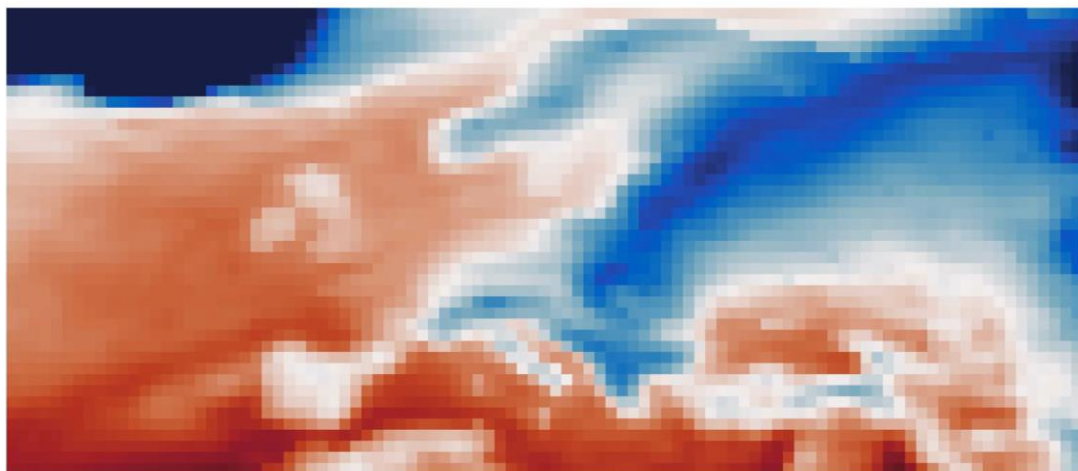
... improved mesoscale features, intensity but lingering slow propagation bias



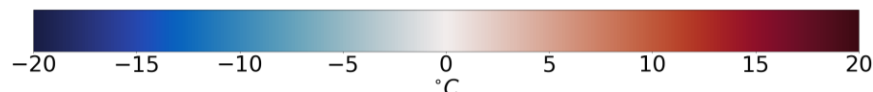
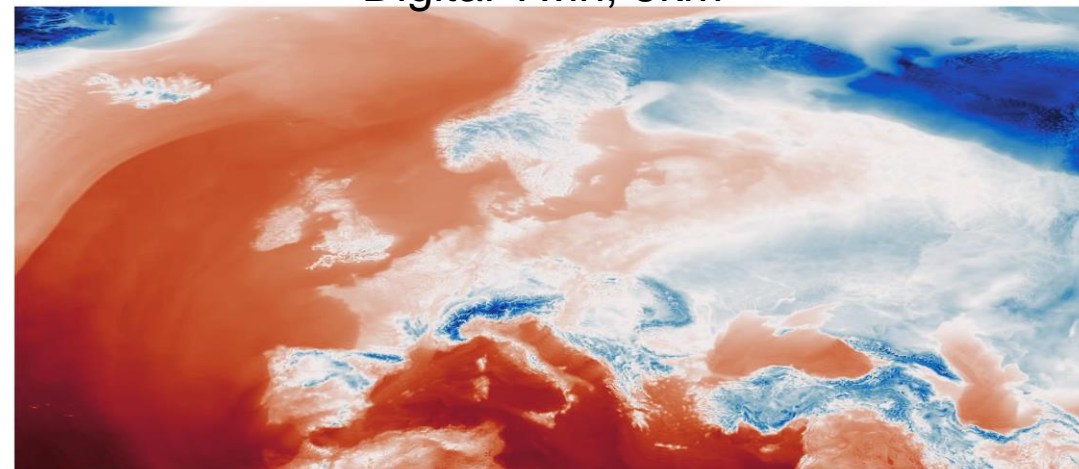
CLIMATE DT: GLOBALLY CONSISTENT CLIMATE INFORMATION AT KM-SCALE

To enable policy actions in support of climate change adaptation

IPCC AR6 (2021), 100km

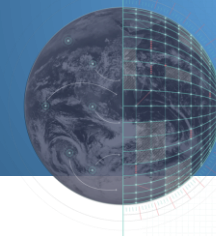


Digital Twin, 5km



End-to-end climate DT workflow, including selected applications, deployed on LUMI

First ever projections (2020-2040) at ~ 5km across earth-system components running now on LUMI with 2 models (IFS-NEMO, ICON), streaming information to selected applications ; and historical runs at 10km since 1990



AI ACTIVITIES IN PHASE 2

Towards a earth-system machine learning model leveraging DestinE data

Developing end-to-end workflows for ML model components like land, ocean, sea-ice, hydrology

Using data-driven methods for uncertainty quantification of Extremes and Climate DT

Climate emulator to rapidly explore 'what-if' scenarios **ITT NOW OPEN**

Enhanced interactivity

Developing a forecast-in-a-box concept.

ITT OPEN SOON

Building ML demonstrators for impact-sectors (e.g., health, agriculture, urban)

Develop of a weather and climate chatbot **ITT NOW OPEN**

Partnership and training

MOOC AI through the lens of the earth system

AI4Good

Ethical AI **ITT CLOSED**



- ECMWF: entrusted entity for **C3S** and **CAMS**



- ECMWF: contractor to EC Joint Research Centre (JRC) for operating:

- **CEMS-EWS Flood**
- **CEMS-EWS Fire**



Copernicus: a brief overview on the latest user-oriented advancements

Speaker: Stijn Vermoote

The Copernicus Data Stores operated by ECMWF

Speaker: Edward Comyn-Platt

Forecasting atmospheric composition at ECMWF: introduction to the Copernicus Atmosphere monitoring Service (CAMS)

Speaker: Laurence Rouil

Copernicus National Collaboration Programmes at ECMWF

Speaker: Cristina Ananasso

EUROPEAN STATE OF THE CLIMATE

SUMMARY 2023

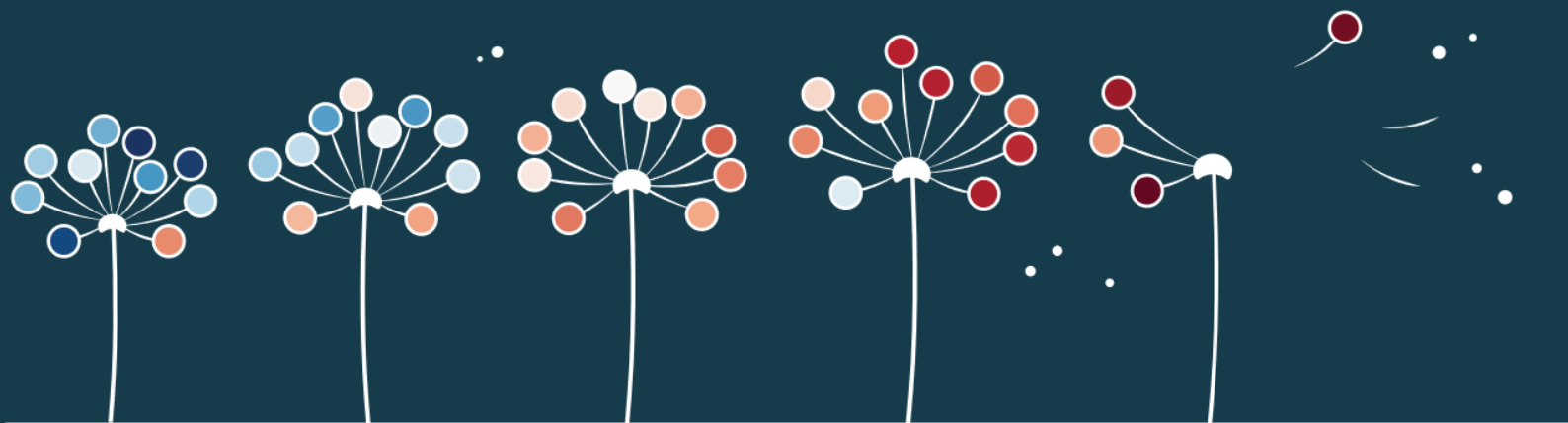
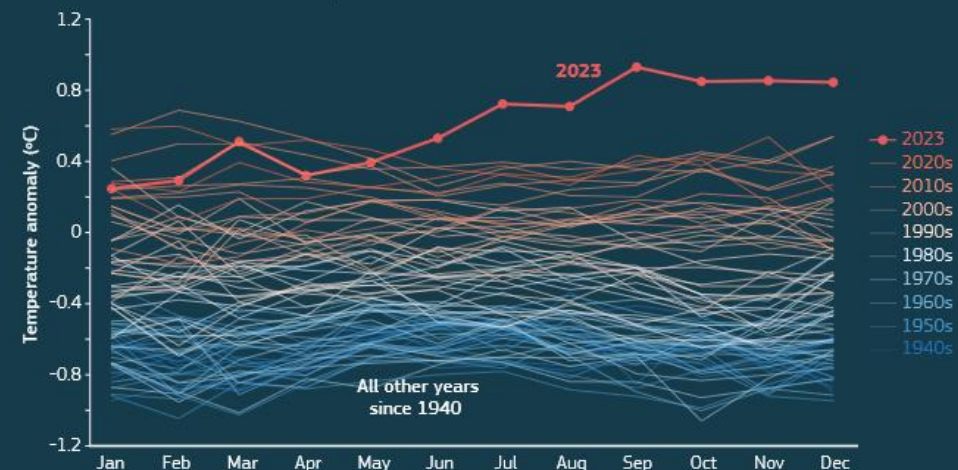
Globe in 2023

The *global context* is provided by C3S Climate Indicators.

Additional information about the global climate during 2023 can be found in the *WMO State of the Global Climate in 2023*, and the *C3S 2023 Global Climate Highlights*.

Global surface air temperature anomalies

Data: ERA5 1940–2023 • Reference period: 1991–2020 • Credit: C3S/ECMWF





Temperature

Global air temperature
+1.3°C Above pre-industrial level

European temperature (over land)
+2.3°C Above pre-industrial level

Arctic temperature (over land)
+3.3°C Above pre-industrial level



Greenhouse gases

Carbon dioxide (CO₂) concentration
419 ppm 2023 average

Carbon dioxide (CO₂) increase
+2.4 ppm per year Since 2010

Methane (CH₄) concentration
1902 ppb 2023 average

Ice and glaciers

Global glaciers
-8200 km³ Ice loss since 1976

European glaciers
-850 km³ Ice loss since 1976

Greenland Ice Sheet
-5470 Gt Ice loss 1972–2022

Arctic sea ice extent
-2.6 Mkm² September loss since the 1980s



Ocean

Global sea level
+10.3 cm Increase since 1993

Global sea surface temperature
+0.6°C Increase since 1980 (60°S–60°N)

Global ocean heat content
+0.22°C Increase since 1993 (upper 2000 m)



Serving our users: moving towards a Climate and Atmosphere Data Store



We have taken the feedback of CDS and ADS toolbox users onboard, and this has informed the design of the online development environment we will offer in the new system

- Jupyter Notebook online development environment
 - Synergy with training material to improve accessibility
- earthkit will be the supported user software
 - ECMWF wide software packages
 - Completely open-source and exportable (anyone anywhere)

earthkit is the namespace for ECMWF open-source python code

- It can be installed and used by anyone, anywhere
- It provides quality assured and supported software that ECMWF and C3S will use operationally
- Made up of sub-packages which address specific areas
 - Only need to install those which are relevant

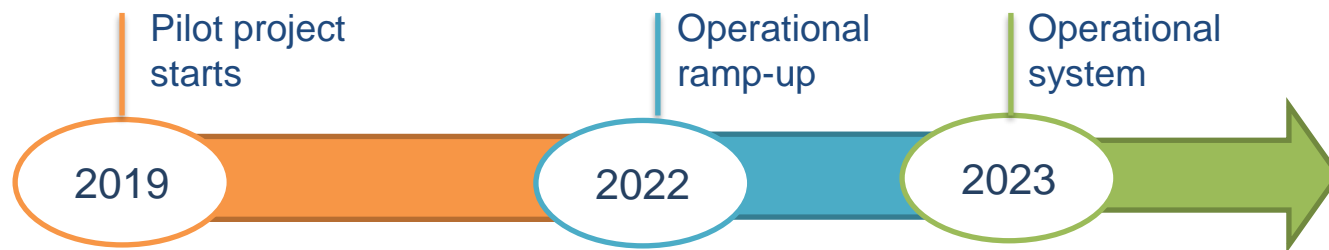


The Copernicus Data Stores operated by ECMWF

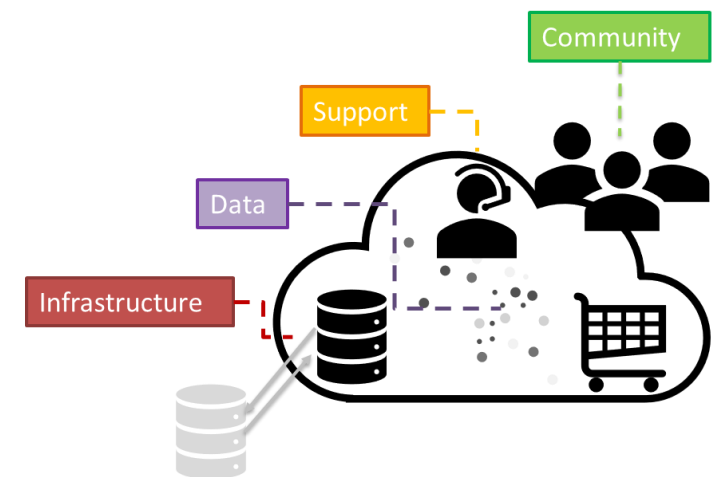
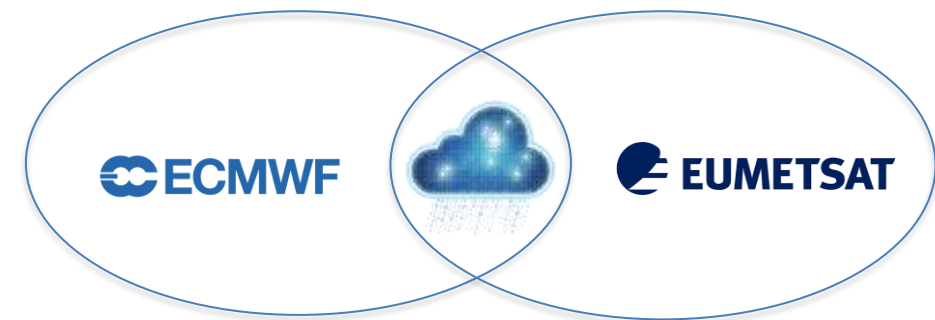
Speaker: Edward Comyn-Platt

European Weather Cloud

- Pilot project started 2019 by ECMWF and EUMETSAT
- Went operational October 2023
- ECMWF part deployed of the new operational infrastructure in ECMWF Bologna Data Centre
- EUMETSAT part running on public cloud infrastructure



- Online access to the cloud computing resources
- Flexibility in provisioning, managing and deleting resources on-demand
- Rich and fast data availability, with data locality for processing
- Community: knowledge, applications, synergies, collaborations
- Ongoing training webinars for users



www.europeanweather.cloud



CODE FOR EARTH

Innovation • Collaboration • Open Source Coding

Encouraging innovation,
Strengthening relationships
and Fostering collaboration

2024 edition has 13 teams
Coding phase 2 May – 31 August!

- Stream 1 – [Data visualization and visual narratives](#)
- Stream 2 – [Machine Learning for Earth Sciences applications](#)
- Stream 3 – [Software development for Earth Sciences applications](#)

Since 2018, the programme (previous ESoWC) produced 35+ open-source software developments highly beneficial to the activities at ECMWF and to users

Website:

<https://codeforearth.ecmwf.int/>

User engagement



The 'Green' Book

Use and Verification of ECMWF Products in the Member and Co-operating States: Survey Results

Speaker: Tim Hewson (ECMWF)

Thank you for your feedback!

Technical
Memo

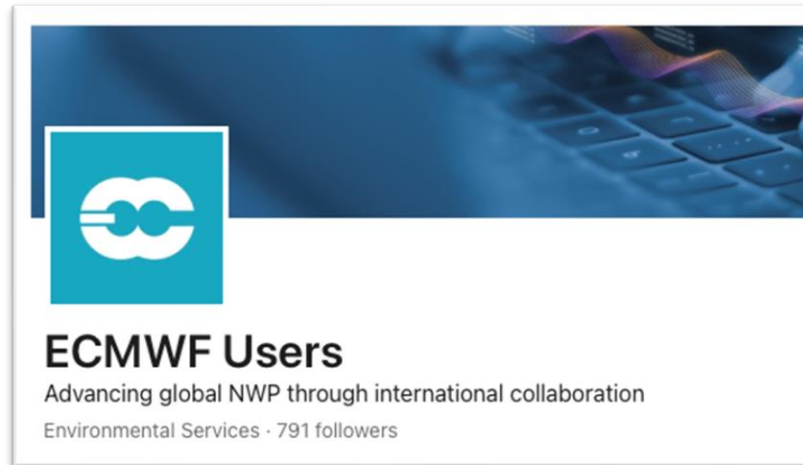


Use and Verification of
ECMWF products
in Member and
Co-operating States

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ECMWF's new user-focused LinkedIn channel

- Focused on current users of all ECMWF data & products
- Providing user-centric, in-depth information and added value with a high degree of technical information
- Community of 803 – and growing!



Topics: open data, cycle updates, data formats & naming, user events

-> We want to engage with our community: get in touch if you have a particularly interesting use-case to share or milestone to celebrate

