Welcome!

Webinar series aims:

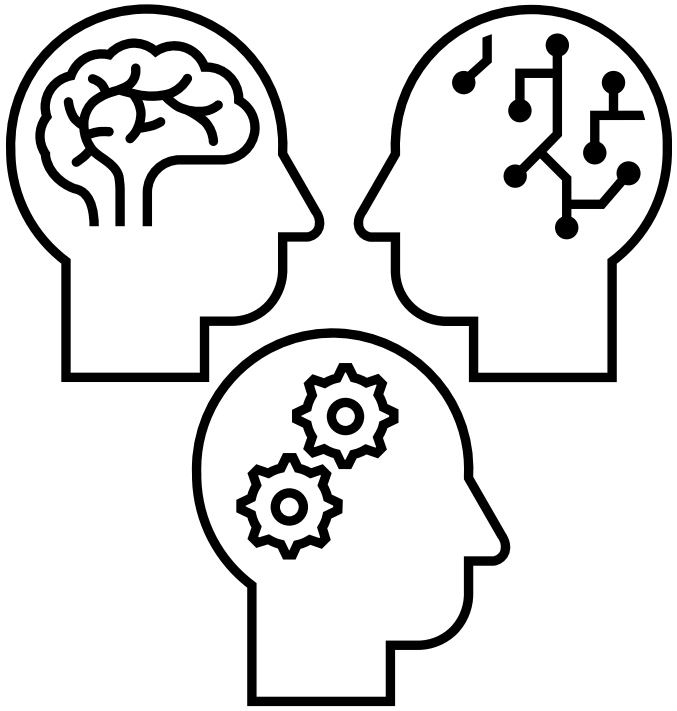
- Provide **operational forecasters** with what you might need to know to use ECMWF machine learning model outputs effectively
  - Basics of the models (Webinar 1)
  - Accessing forecast products (Webinar 1)
  - Known issues (Webinar 2)
  - Verification (Webinar 2)
  - Case Studies (Webinar 3)
- **Encourage use**, and feedback, of ECMWF machine learning models

Please type questions in the chat – ECMWF colleagues are online to answer, we will also answer some at the end of the webinar

Your comments on your use of ML models are very welcome – we would like to better understand how you use them!

Machine Learning in NWP: Example of cases

Linus Magnusson and colleagues at ECMWF

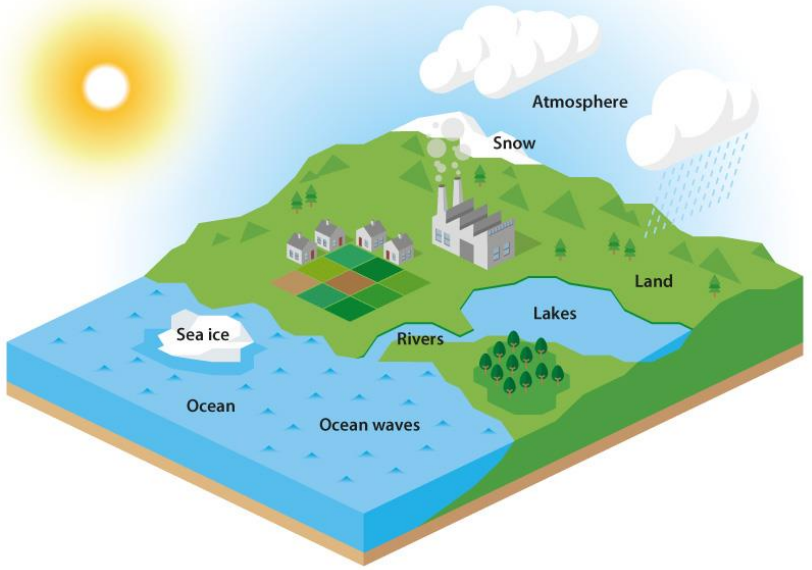


ECMWF

Physics-based forecast systems using IFS model

Medium-range

- Atmosphere: 9 km
- 15 days lead time
- 50 ensemble members + 1 unperturbed control forecasts
- Distributed around 8 hours after initialisation time*



Sub-seasonal

- Atmosphere: 36 km
- 6 weeks lead time
- 101 ensemble members
- Initialised every day at 00UTC
- Distributed in the evening (UTC time)

Seasonal (SEAS5)

- Atmosphere: 36 km
- 7 months lead time
- 51 ensemble members
- Initialised 1st every month
- Distributed 5th every month

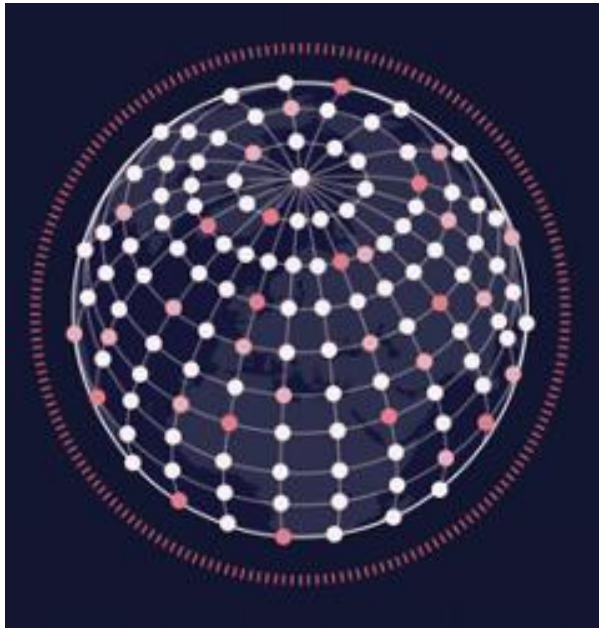
ECMWF

* In the assimilation system, it has used observations +3h after the labelled initialisation time

Machine-learning based forecast systems using AIFS model

Medium-range deterministic AIFS-single v1.1

- Atmosphere: AIFS Model v1.0 using **MAE loss**, N320 (0.25°, ~25 km)
- 15 days lead time
- Initialised from physics-based analysis



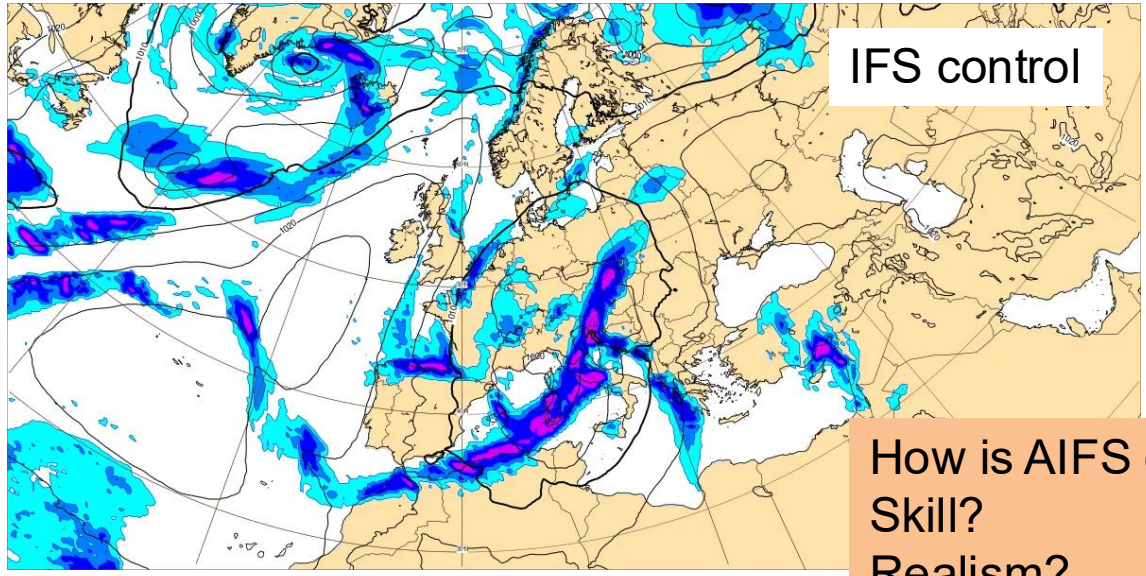
Medium-range ensemble AIFS-ENS v1.0

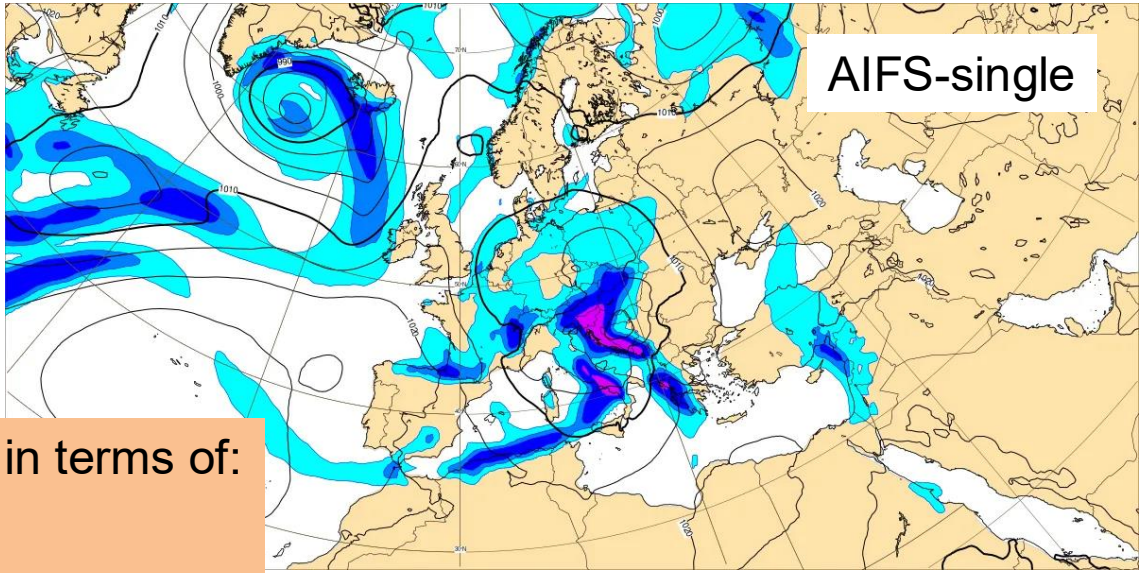
- Atmosphere: AIFS Model v1.0 using **CRPS loss**, N320 (0.25°, ~25 km), 13 vertical levels
- 15 days lead time
- 50 ensemble members + 1 unperturbed** control forecasts
- Same initial conditions including perturbations as physics-based ensemble

* In the assimilation system, it has used observations +3h after the labelled initialisation time
** With the use of CRPS-loss, also the control forecast include the “noise” to simulate model uncertainty

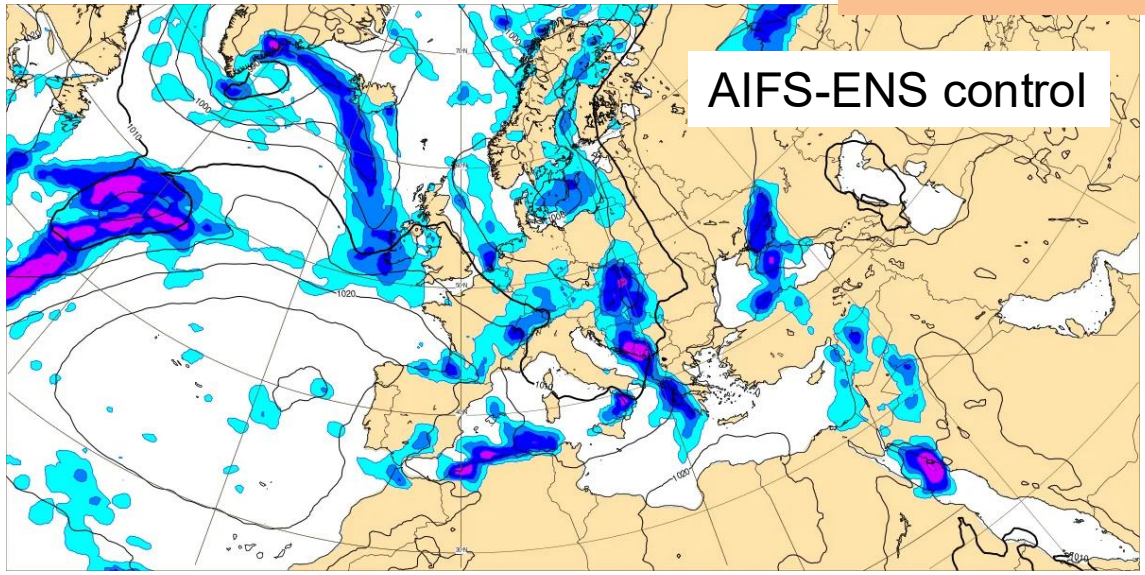
ECMWF

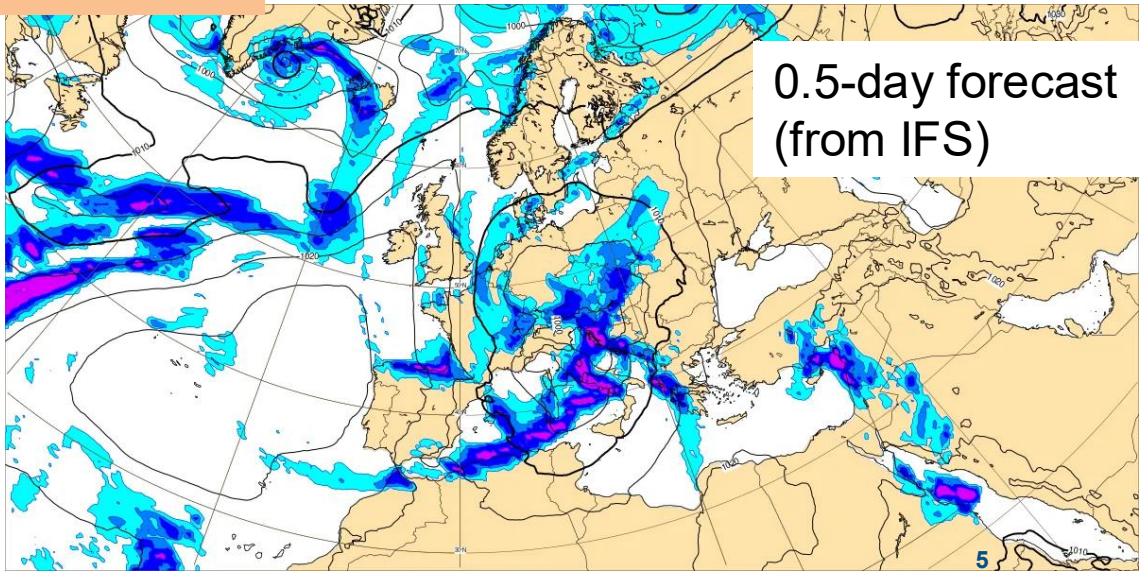
So here are forecast (MSLP and precipitation) from a 6 days ago:





How is AIFS doing in terms of:
Skill?
Realism?
Extremes?





Evaluation results on the ECMWF web:

Home / Charts catalogue

Search products...

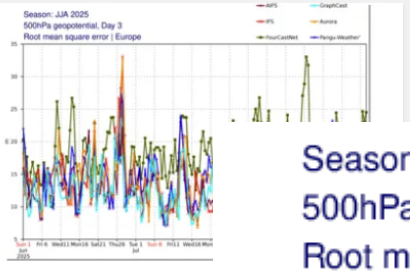
Range
- [ ] Medium (15 days)
- [ ] Sub-seasonal
- [ ] Seasonal

Type
- [ ] Forecasts
- [x] Verification

Component
- [ ] Surface
- [ ] Atmosphere

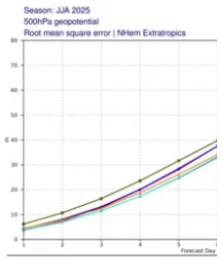
Product type
- [ ] Control Forecast (ex-HRES)
- [ ] Ensemble forecast (ENS)
- [ ] Extreme forecast index
- [ ] Point-based products
- [x] AIFS Single
- [ ] AIFS Ensemble forecast
- [ ] AIFS ENS Control
- [ ] Experimental: Machine learning models
- [ ] Atmospheric composition

Parameters



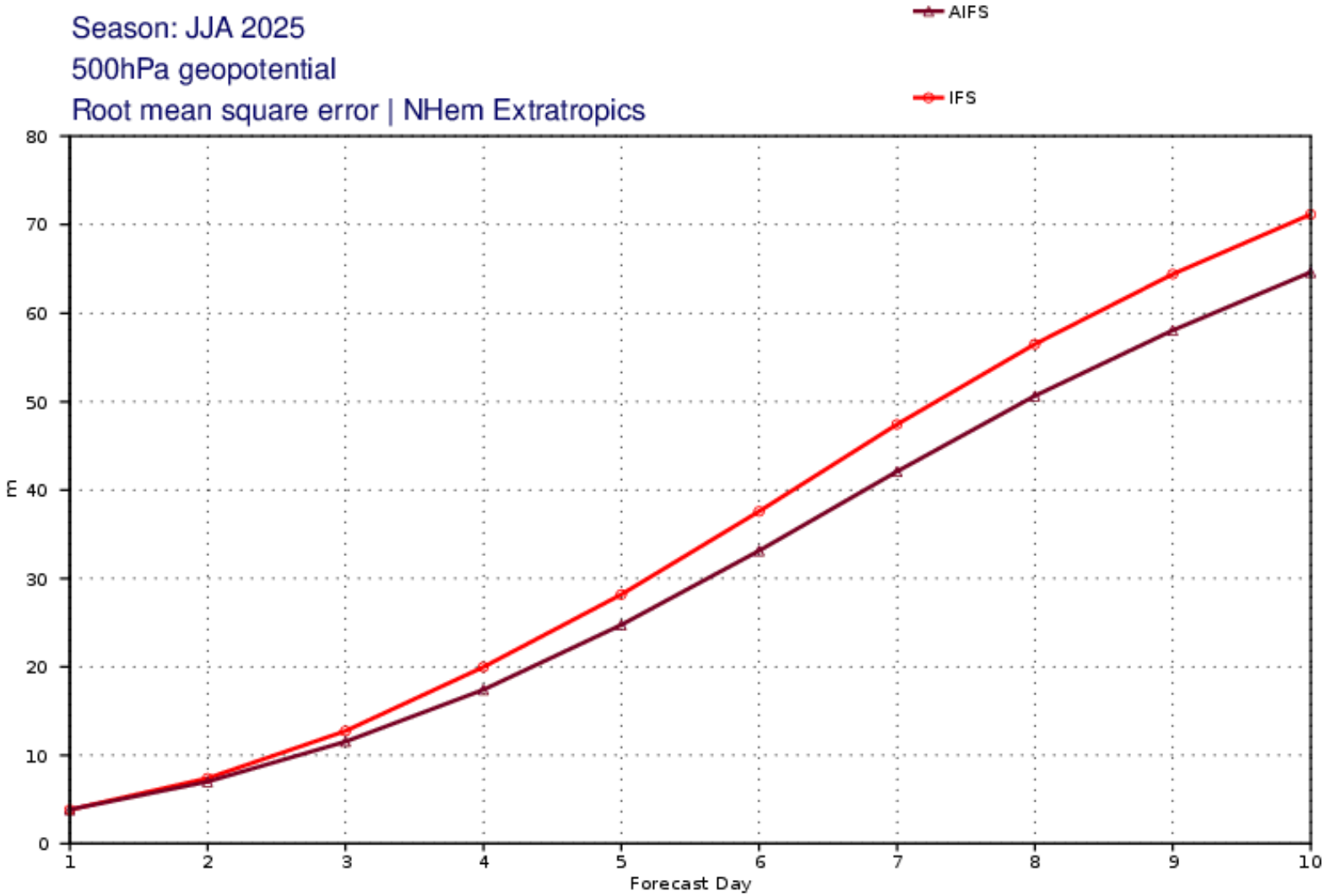
Daily scores of forecas
parameters by experin
learning models

These plots compare recent IF
AIFS daily verification scores f



Scores of forecasts of
parameters by experin
learning models

These plots compare recent IF
AIFS verification scores for 50



ECMWF EUROPEAN C

Extreme weather cases

Pages / Forecast User Portal Analytics Edit View inline comments Save for later Watching Share

Severe Event Catalogue

Created by Florian Pappenberger, last modified by Timothy Hewson on Nov 09, 2022

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On this space we collect material for evaluation of severe/extreme weather events. The focus is on the meteorological conditions and the forecast performance. The amount of material differs from case to case, and we are not claiming to give the full picture of the cases here. Users are welcome to contribute with material for the cases by using the comment function in the bottom of each page. To suggest a new case to evaluate, please contact us at the email address given below. If you have any initial comments and material, please include them in the mail.

Contact email address	servicedesk@ecmwf.int

(Please note that some of the links on the pages are only accessible from ECMWF.)

Navigation

List of (recent) cases

- 202404 - Snowfall / Cold - Sweden / Finland
- 202404 - Rainfall - UAE
- 202404 - Rainfall - Brazil
- 202404 - Cold -Europe

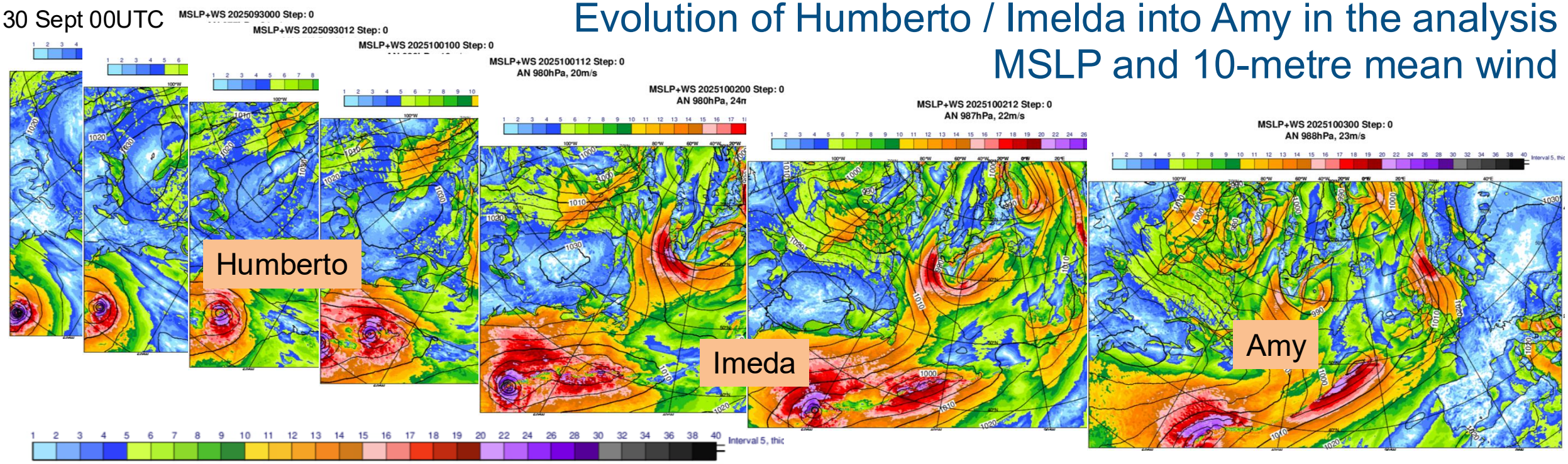
Search (for old cases enter the year and month of the event, as yyyymm)

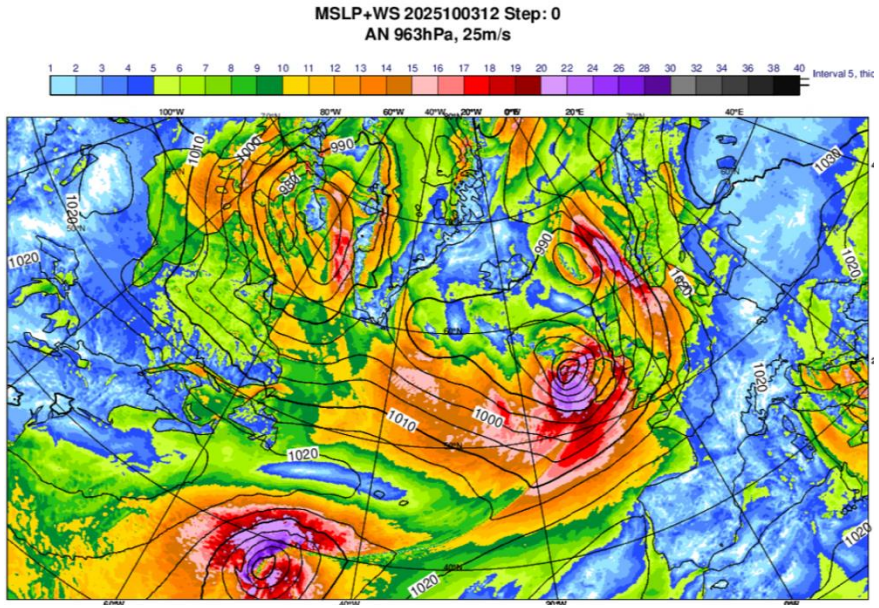
Screenshot

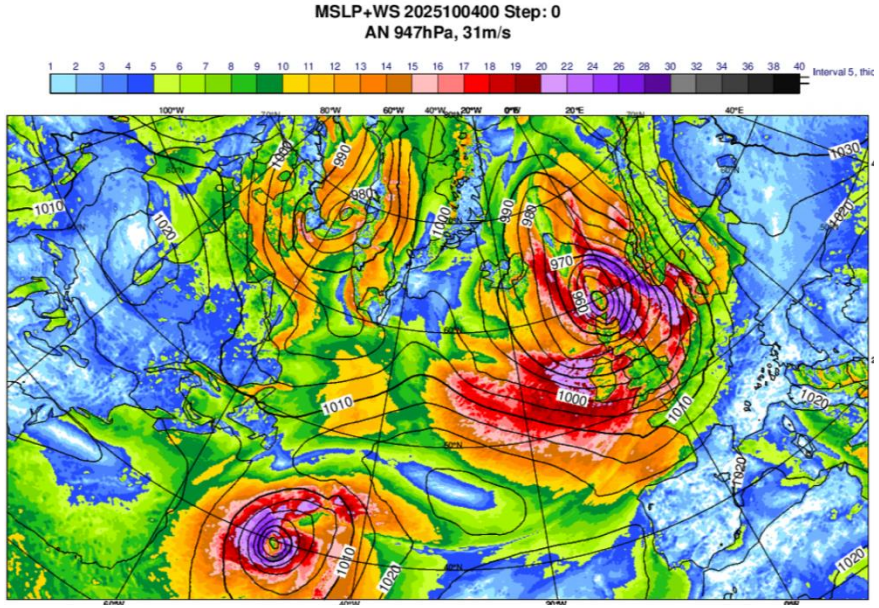
AIFS cases usually included in the ECMWF Severe Event Catalogue https://confluence.ecmwf.int/display/FCST/Severe+Event+Catalogue

Evolution of Humberto / Imelda into Amy in the analysis
MSLP and 10-metre mean wind

30 Sept 00UTC



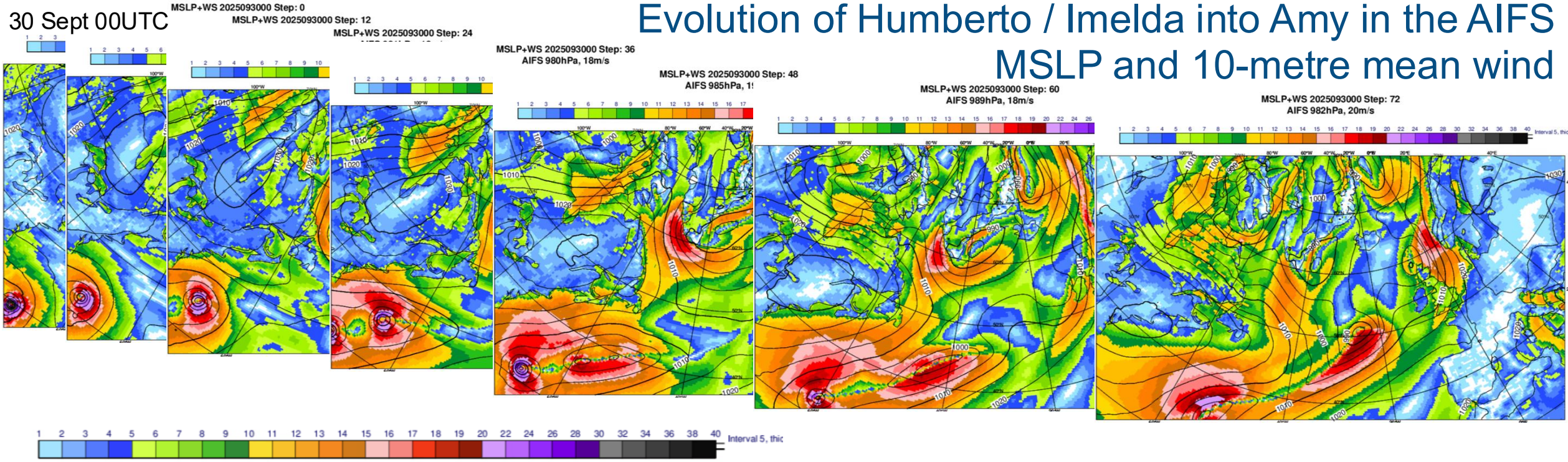


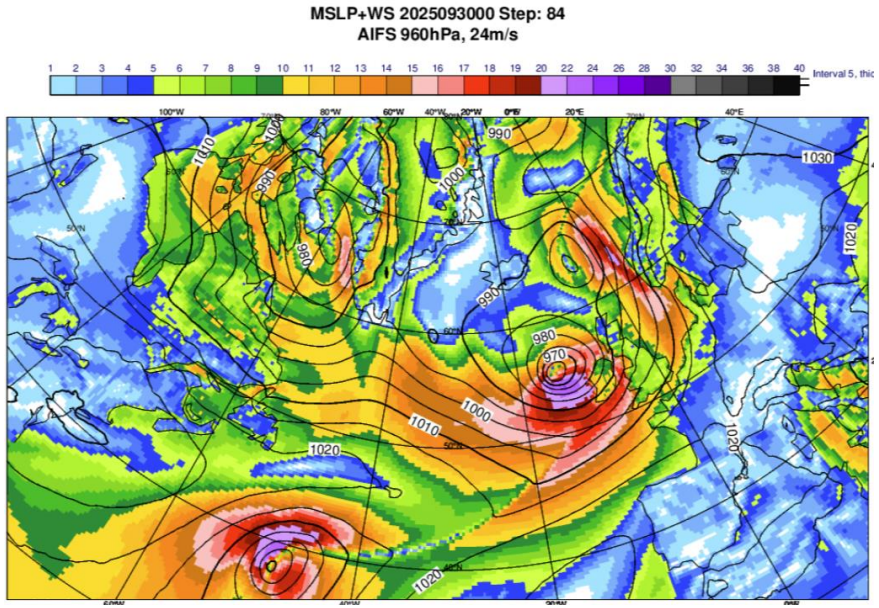


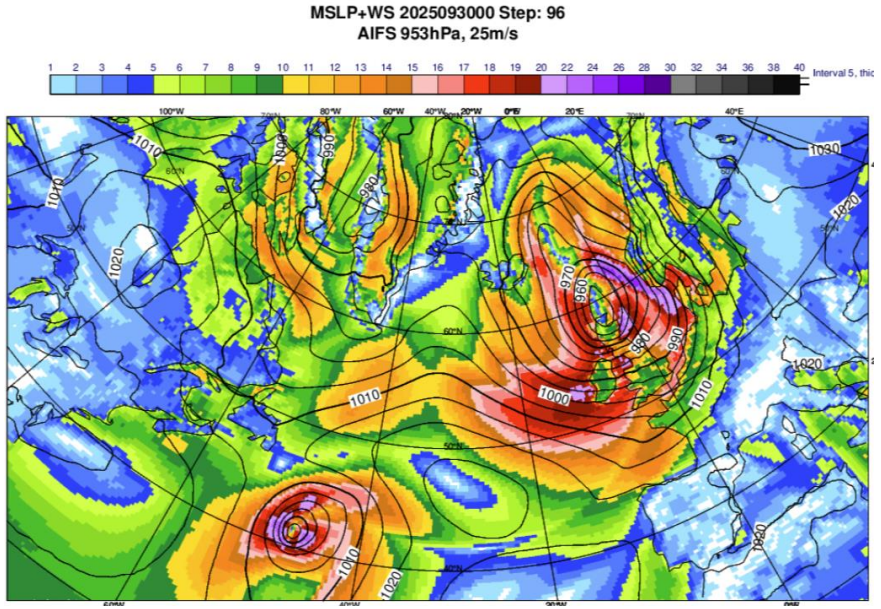
4 October 00UTC

Evolution of Humberto / Imelda into Amy in the AIFS MSLP and 10-metre mean wind

30 Sept 00UTC







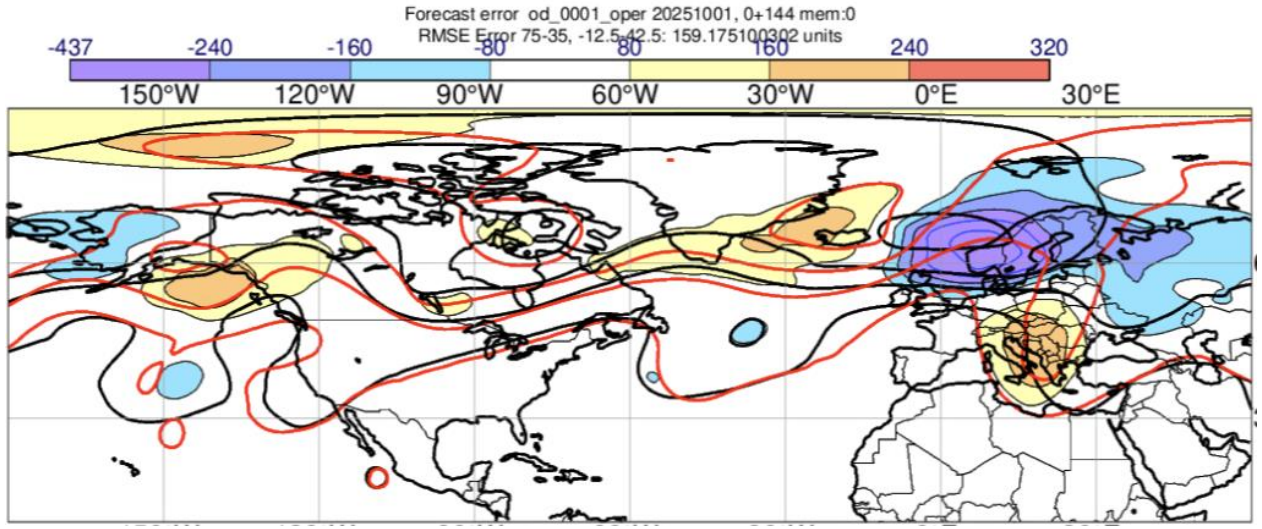
4 October 00UTC

Error in day-6 forecasts

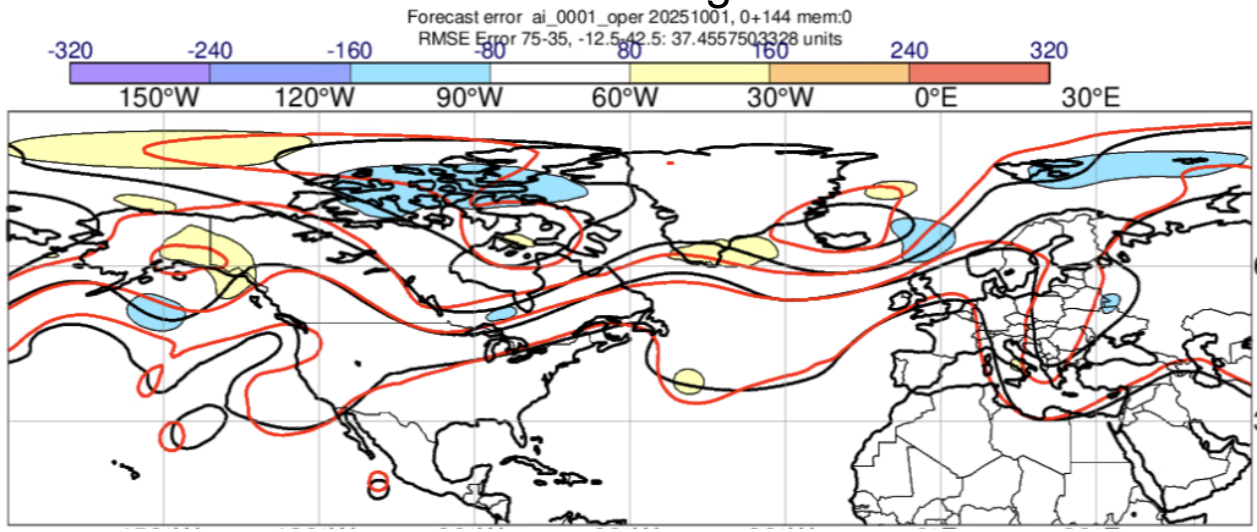
2025-10-01 00UTC +144h

Z500 forecast (black), analysis (red) and error (shading)

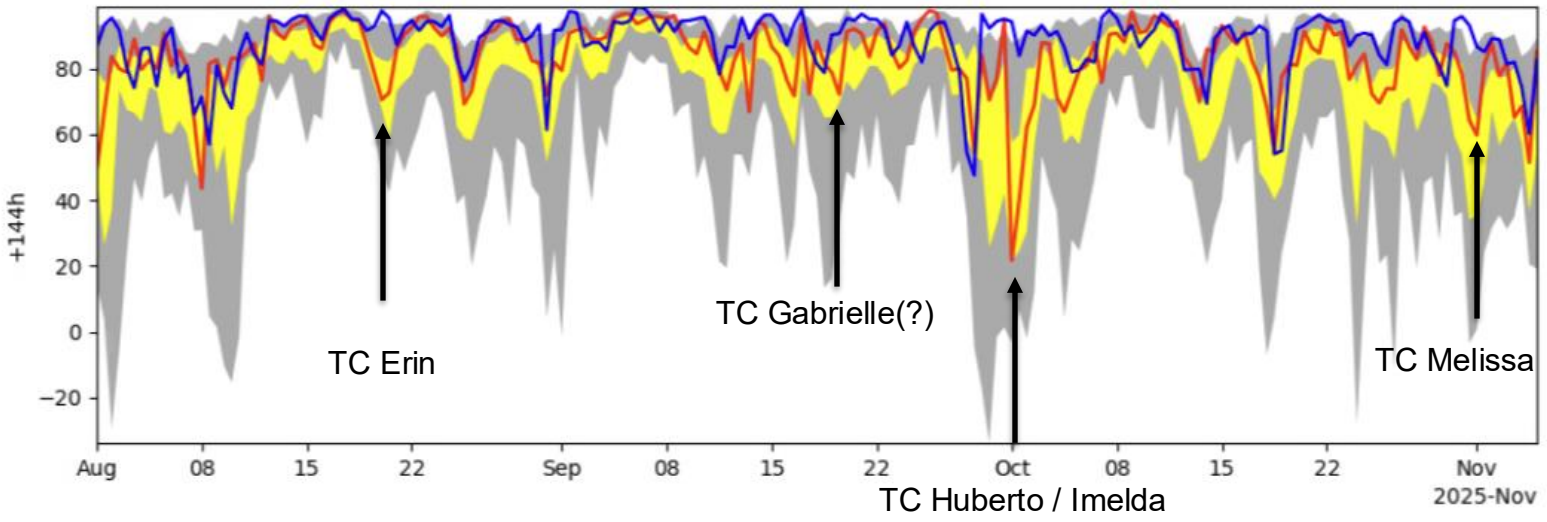
IFS control



AIFS-single



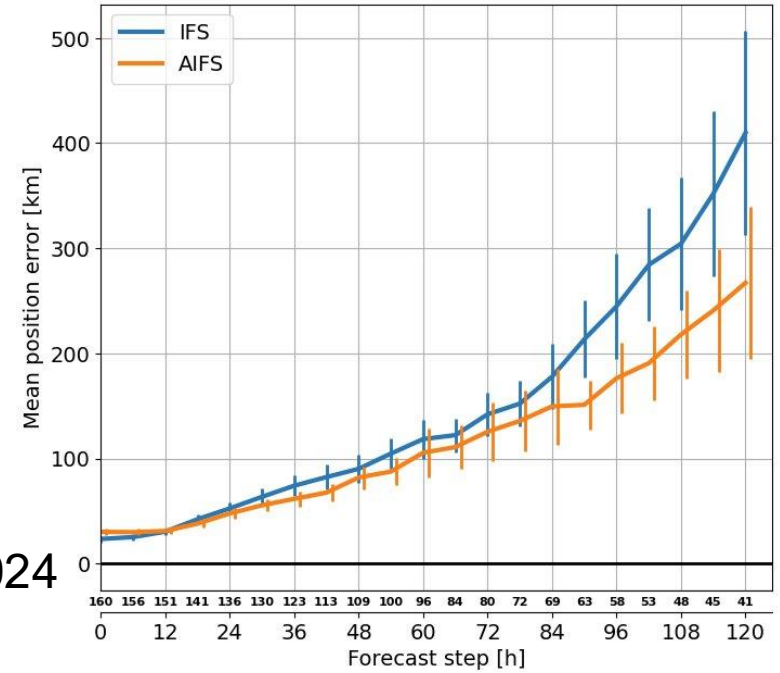
Anomaly correlation coefficient for z500, day 6 over Europe



IFS control – red

AIFS-single – blue

Tropical cyclone track error

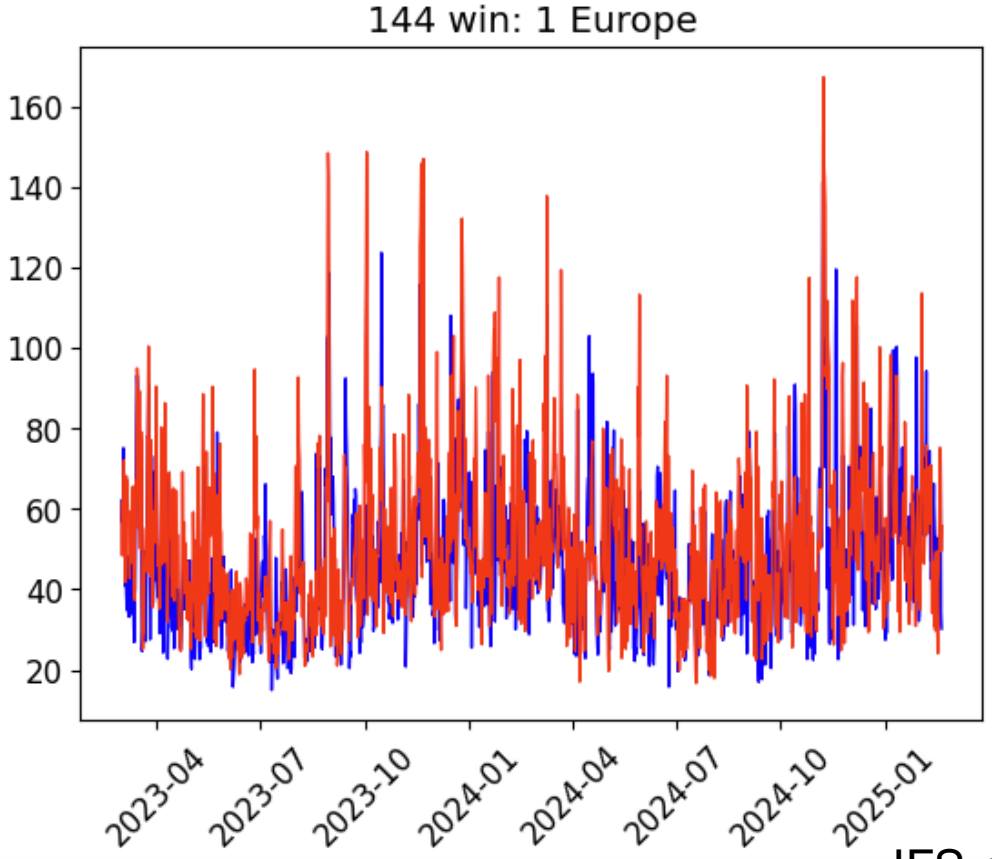


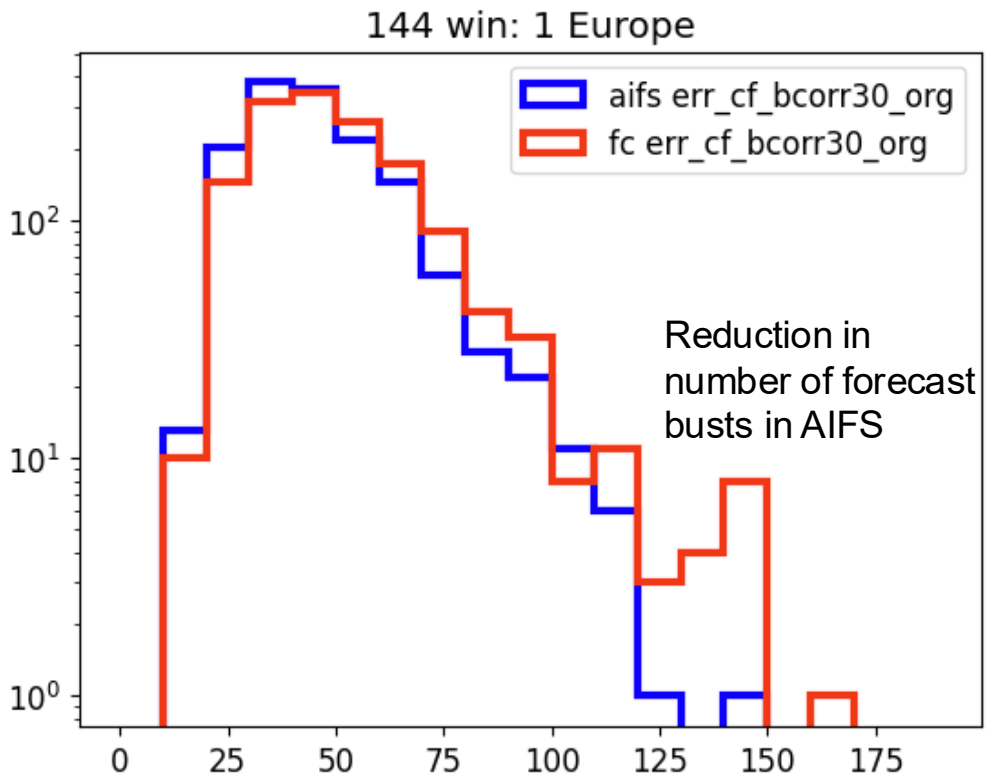
Basin: North Atlantic

Period: 1 Jun – 30 Nov 2024

Thanks to Michael Maier-Gerber

Frequency of large errors over Europe day 6
RMSE for z500, March 2024 – mid-Feb 2025

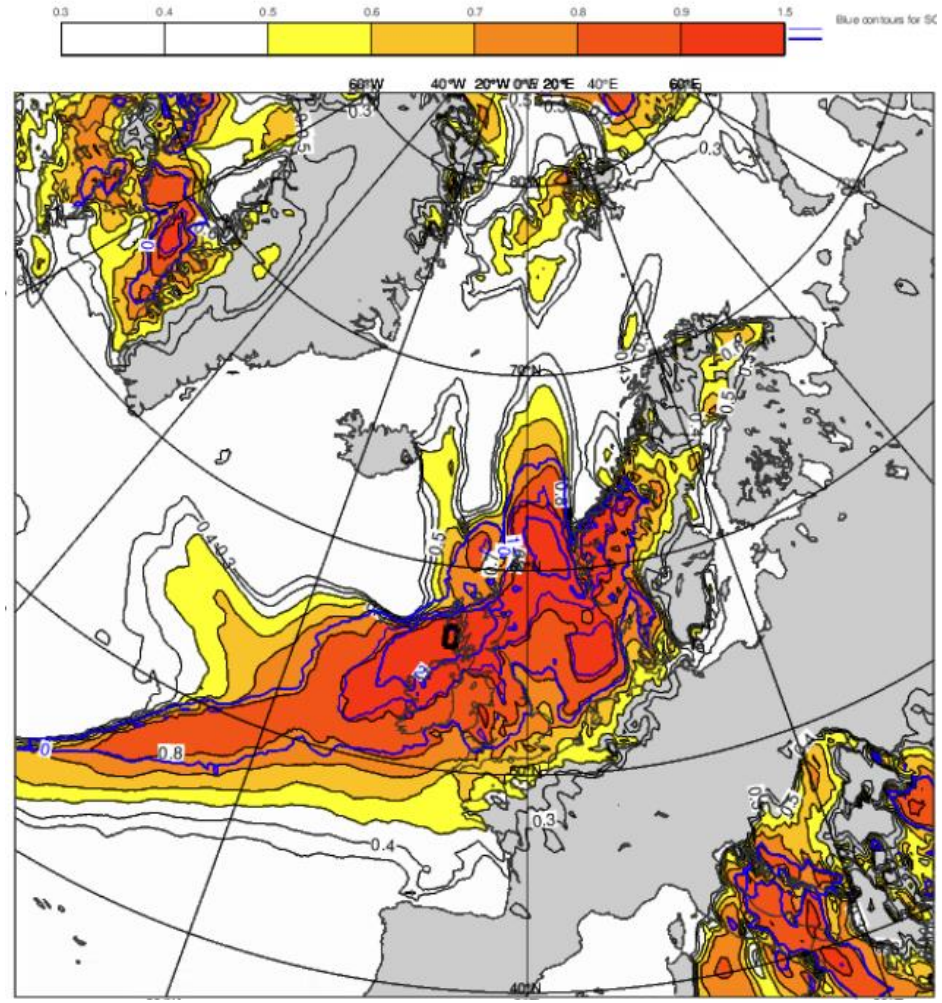


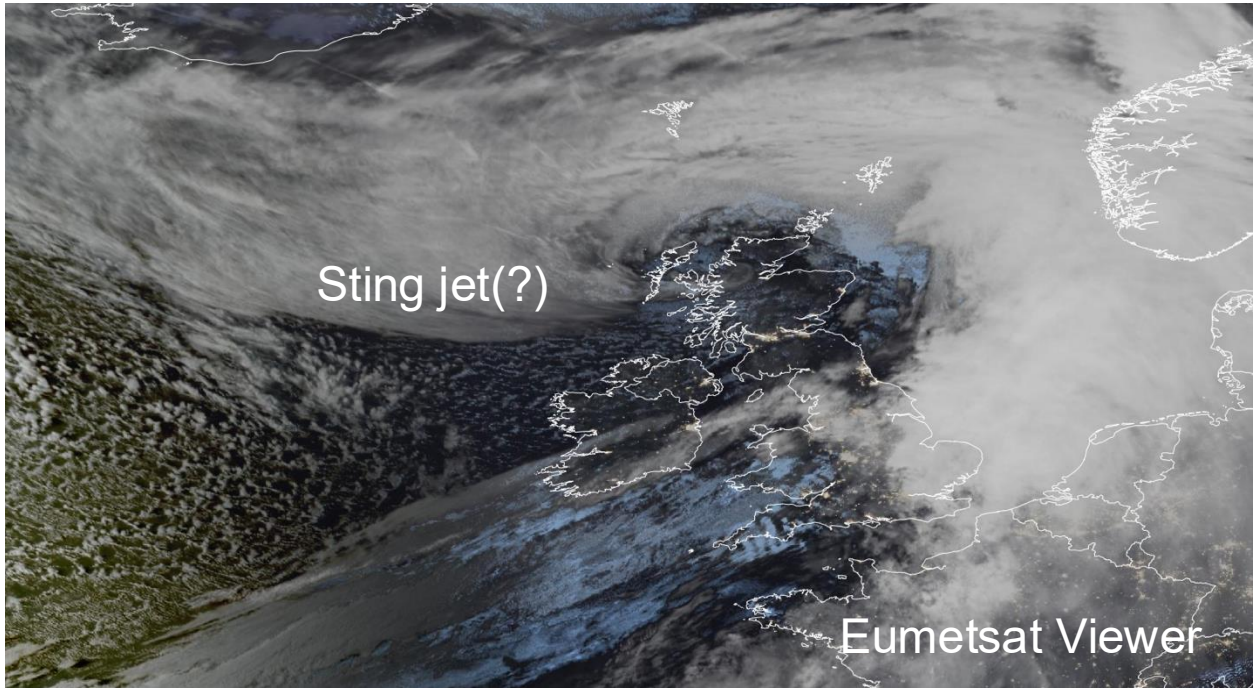


IFS control – red
AIFS-single – blue

Storm Amy 3-4 October 2025

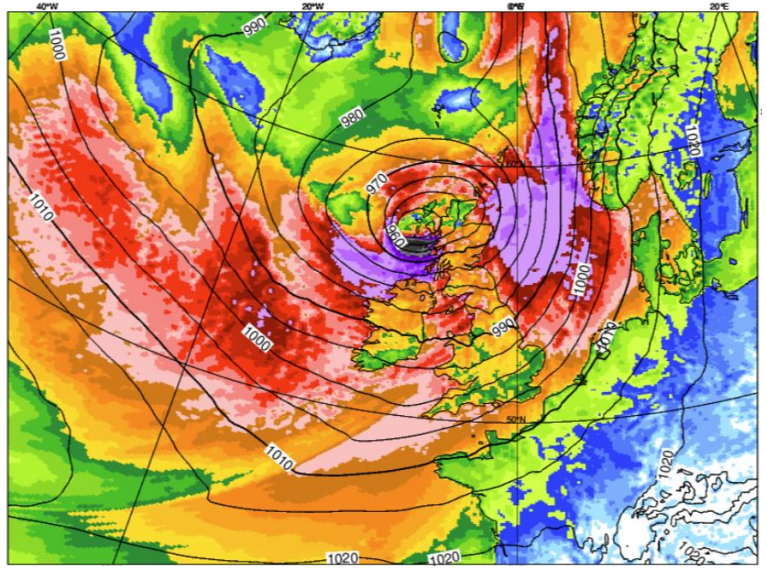
Extreme forecast index for maximum wind gusts for 3 October (1-day forecast)



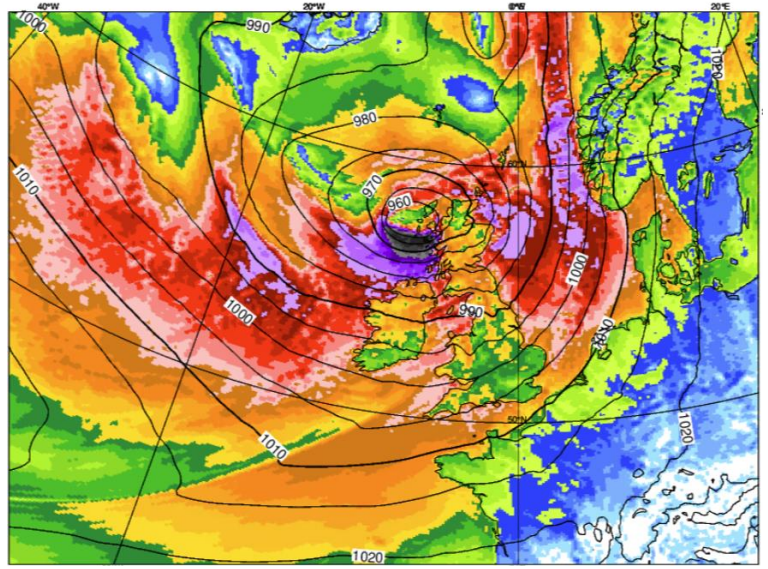


42-hour forecasts for Storm Amy valid 3 October 18UTC

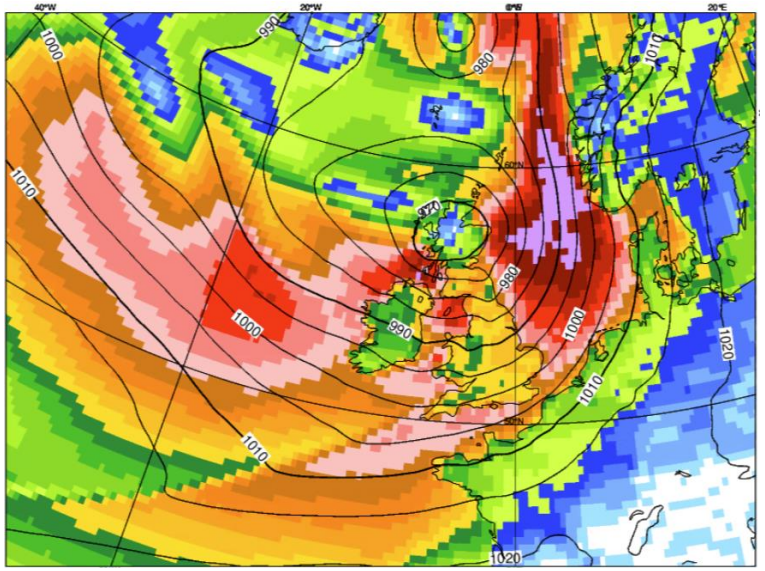
Analysis

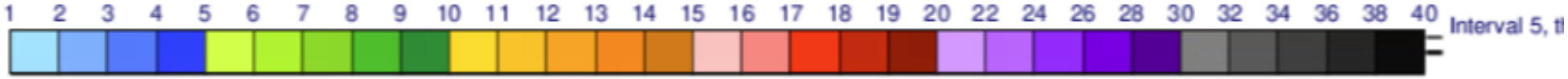


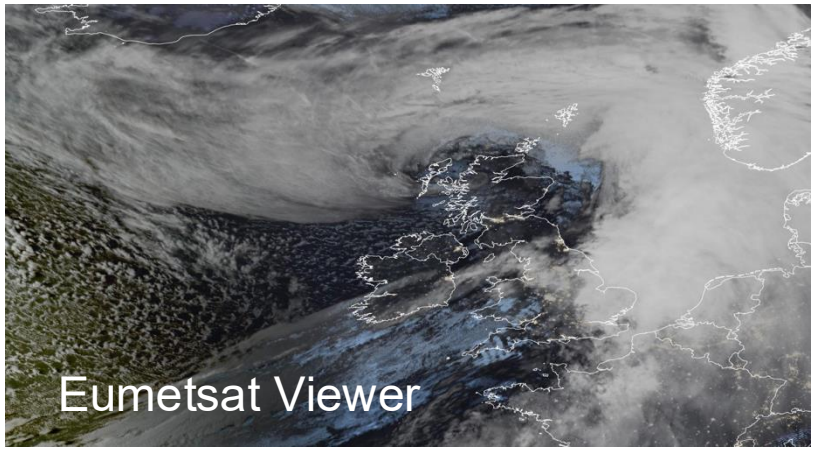
IFS CF



AIFS-single v1.1

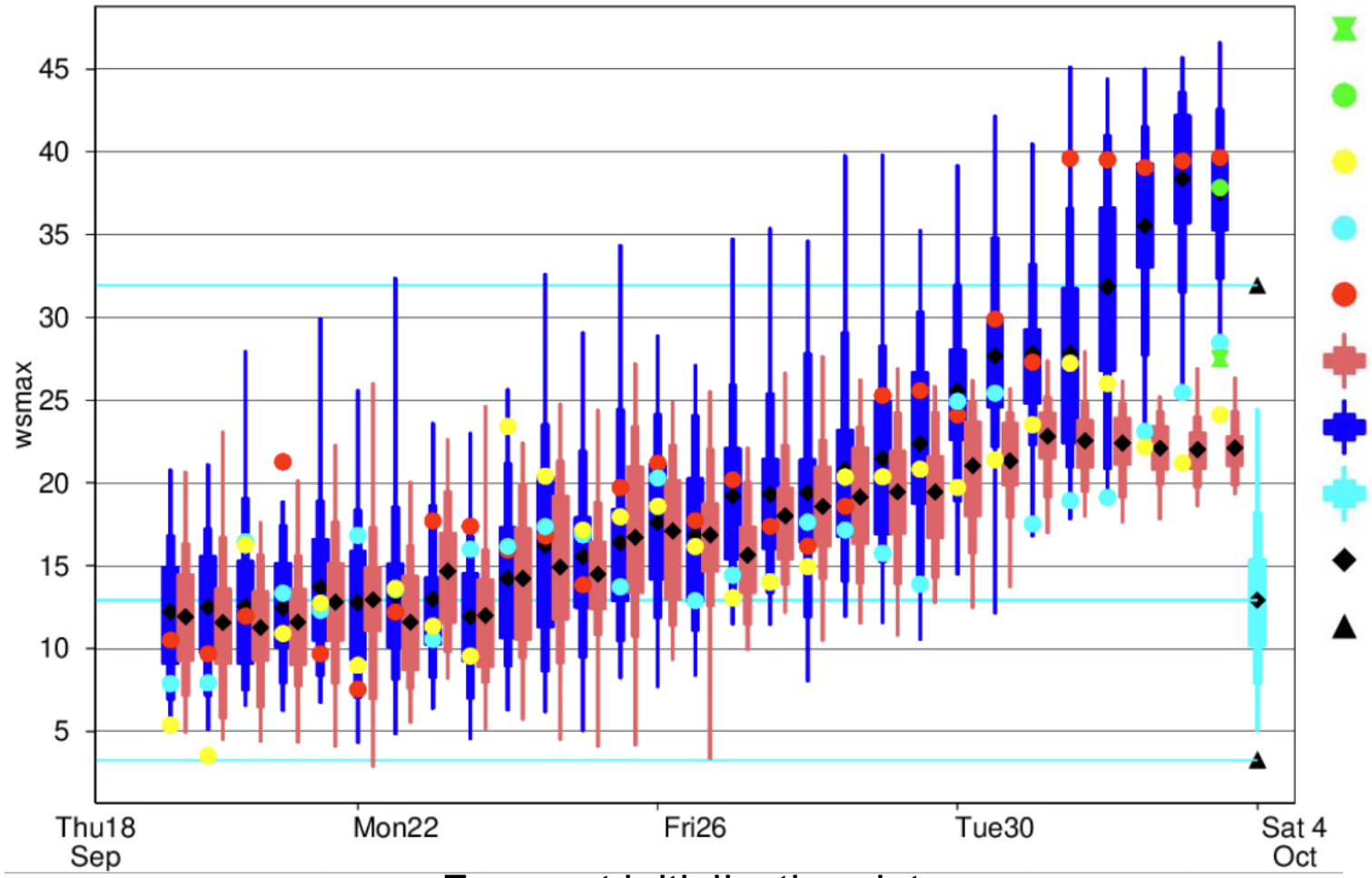


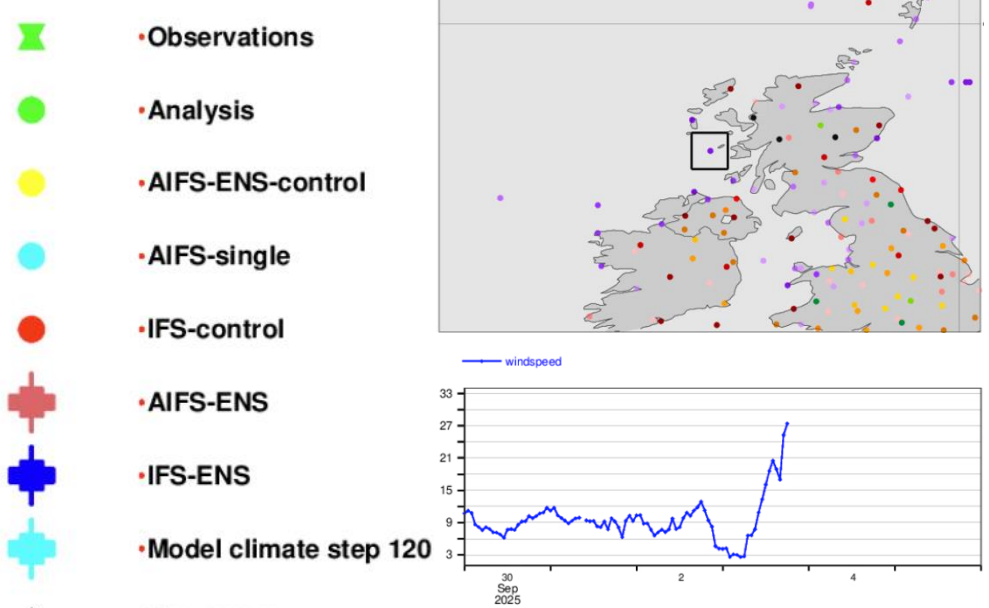




ECMWF

Summary of all forecast for the event:
24-hour maximum* 10-metre mean wind** in a 1x1 degree box





Tiree station failed during the event

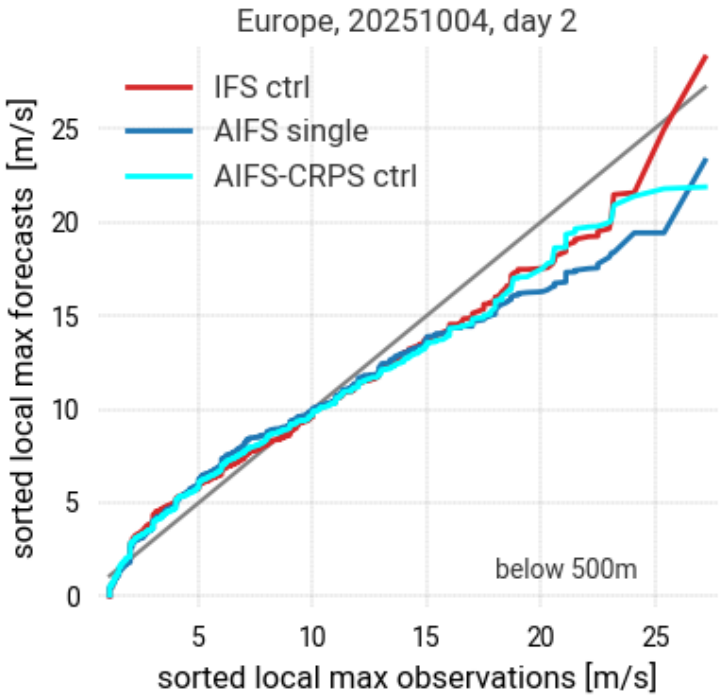
* Based on 6-hourly output

** Maximum wind gusts not yet in AIFS

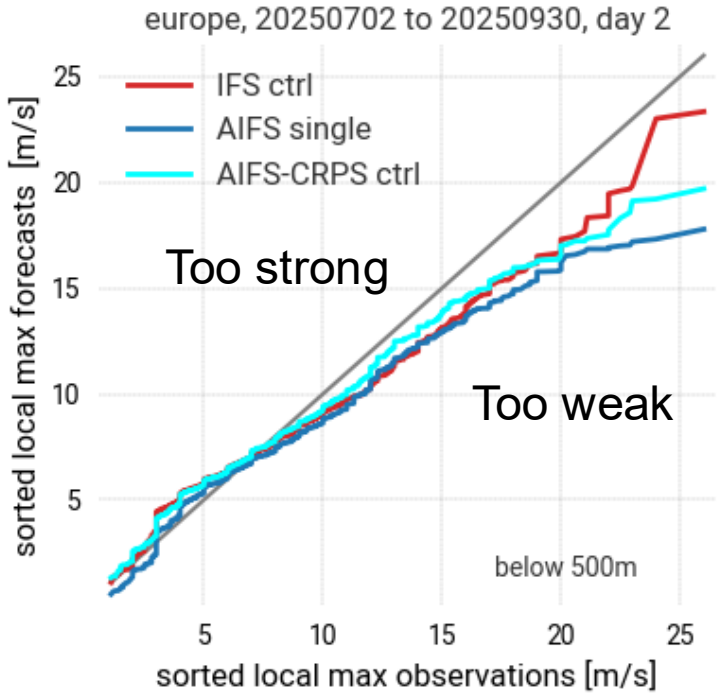
Quantile-quantile plots for 10-metre mean wind

Stations below 500 metres

Storm Amy



3-month period

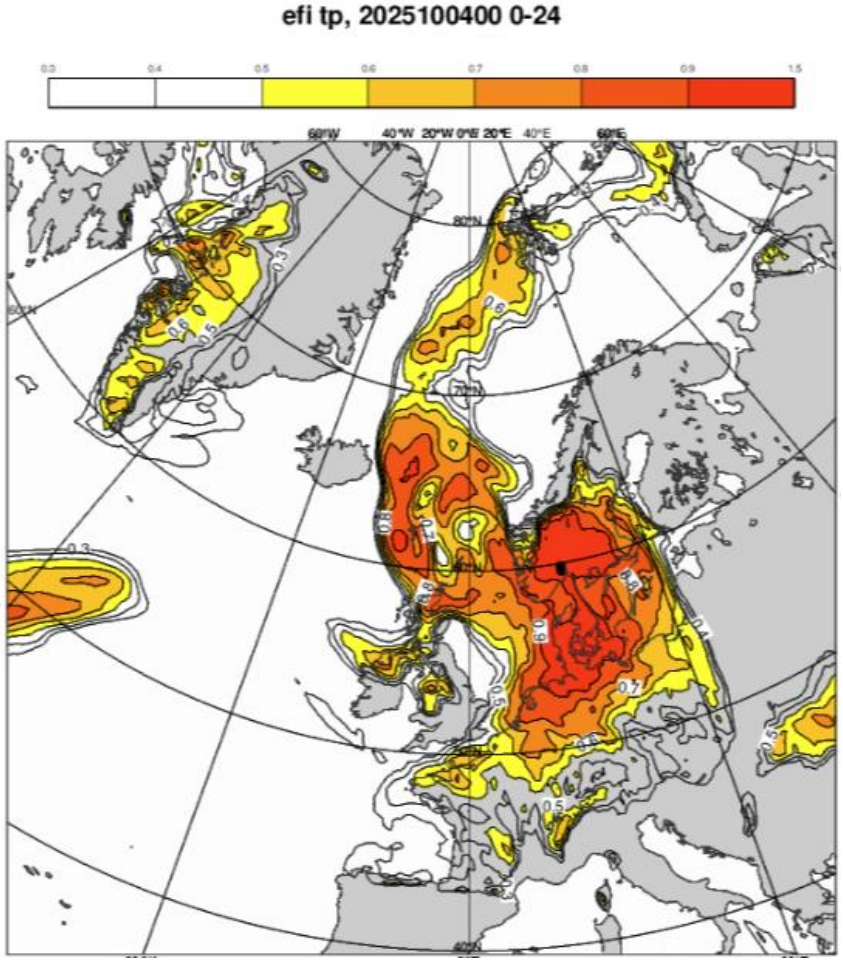


Thanks to Zied Ben-Bouallegue

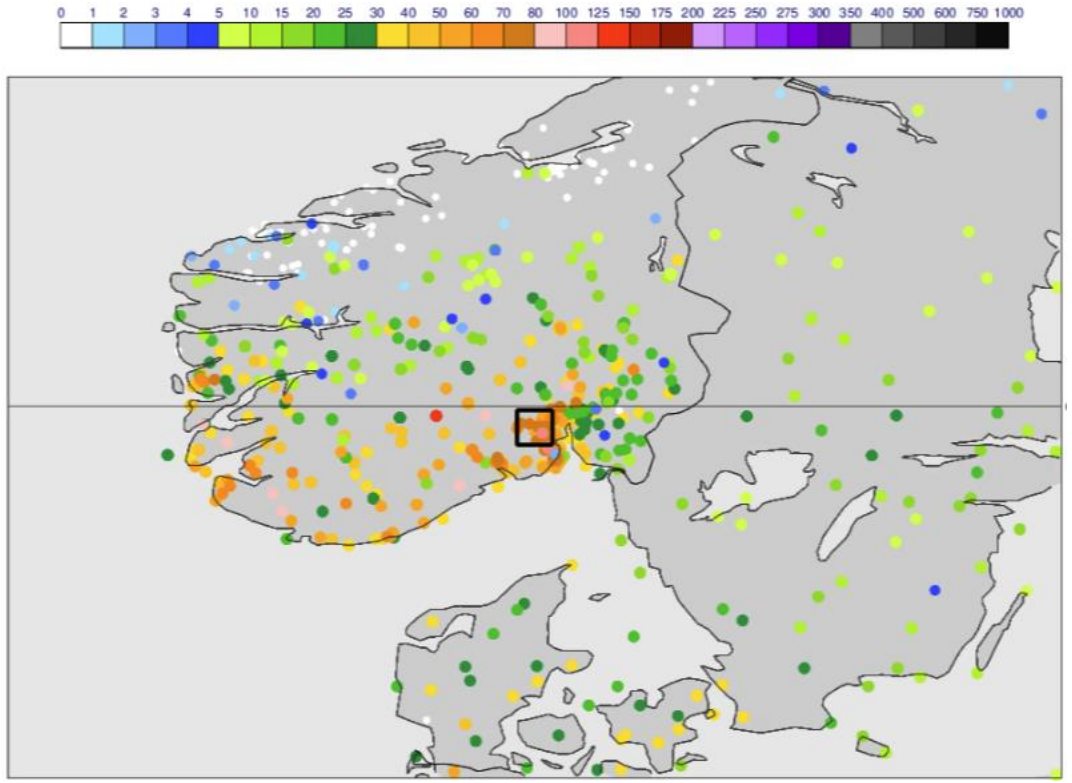
The most extreme wind speed is underestimated in AIFS
Similar conclusions as for previous storms (Ciaran, Eowyn)

Precipitation during Storm Amy over southern Norway

Extreme forecast index for precipitation for 4 October (1-day forecast)

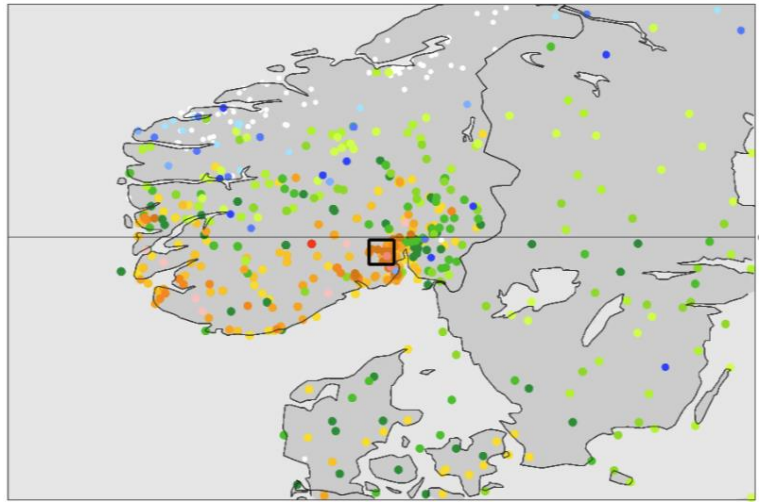


Observations of precipitation on 4 October

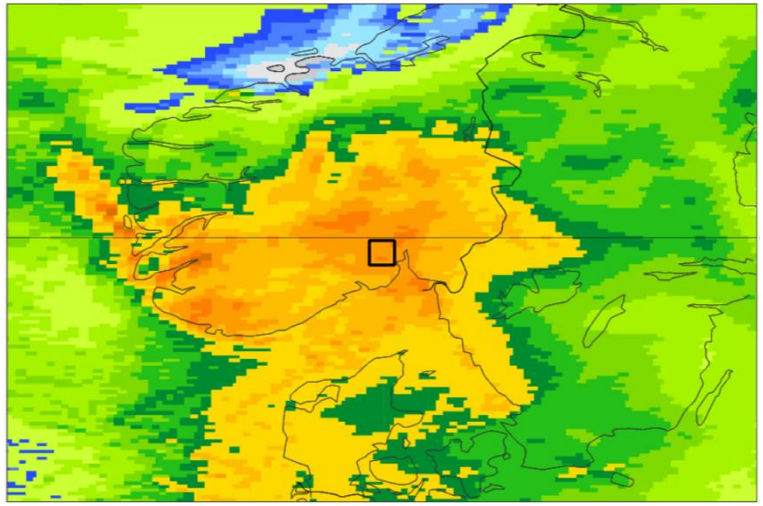


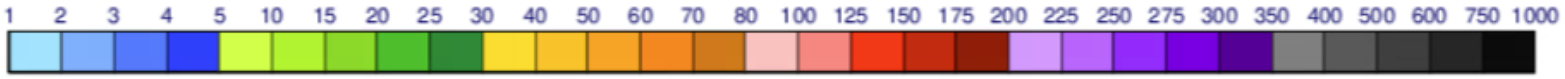
24-hour precipitation on 4 October in forecasts from 2 October

Observations

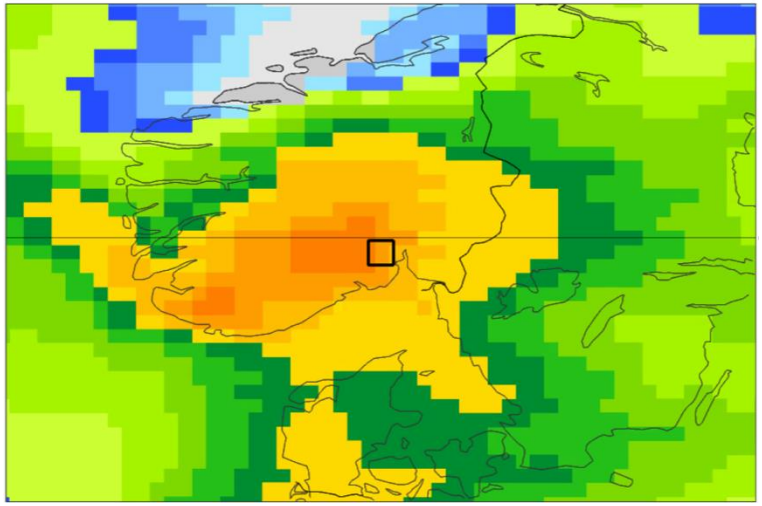


IFS ENS control

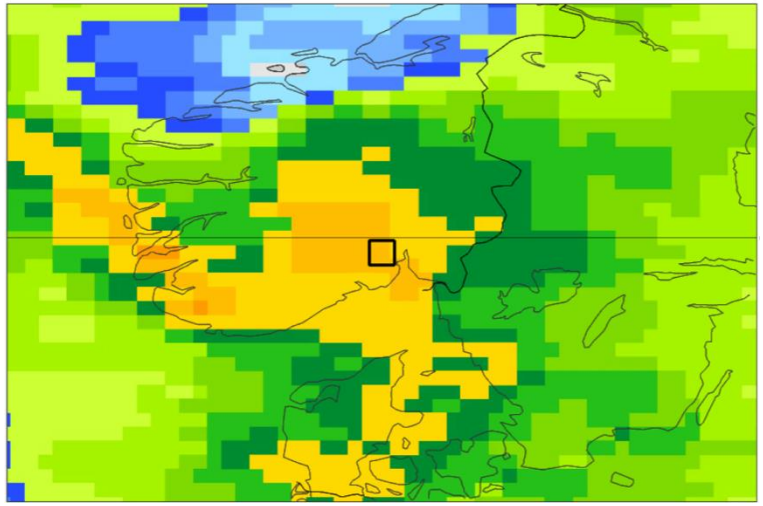




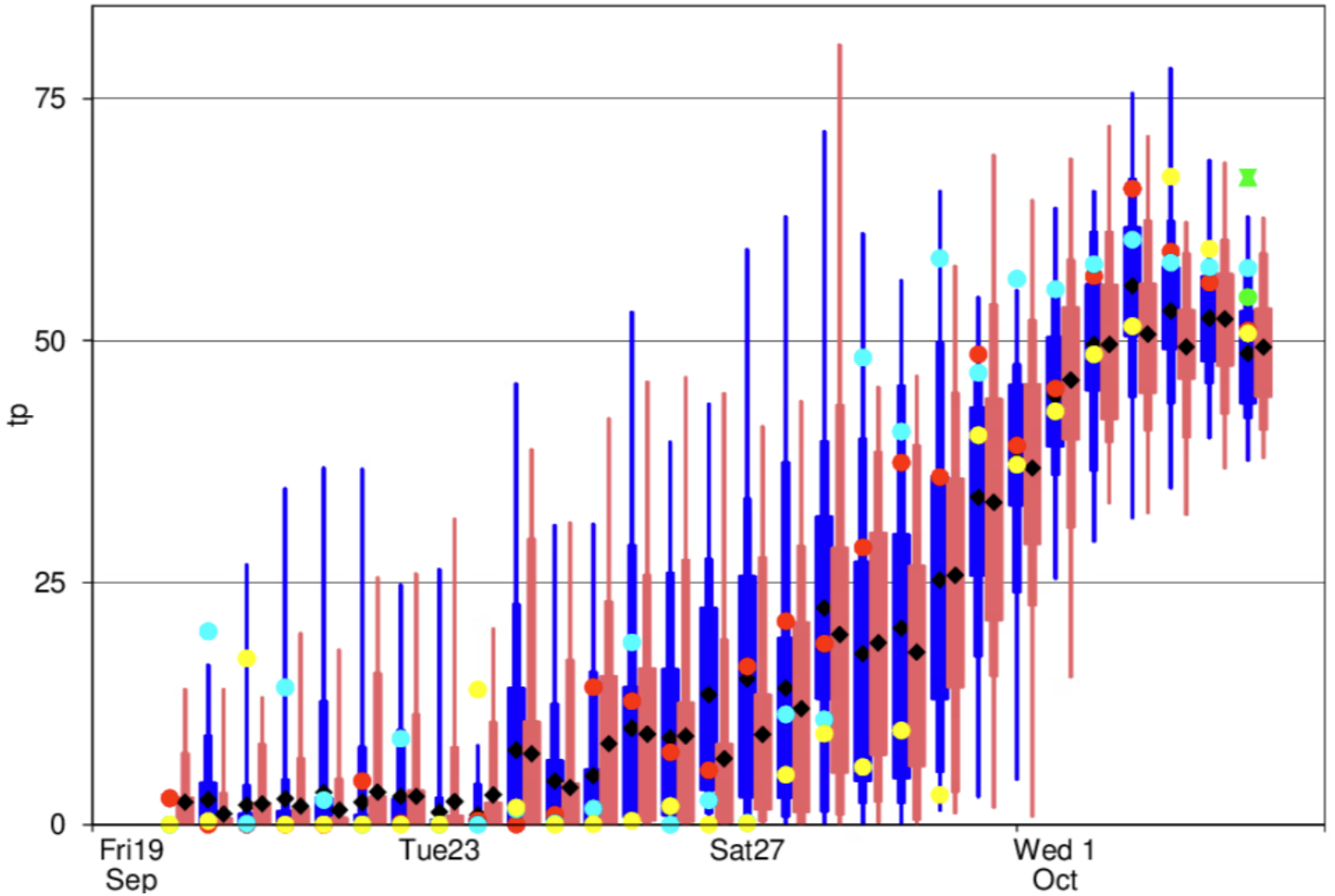
AIFS-single

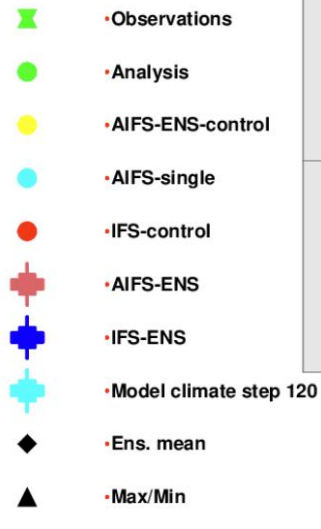


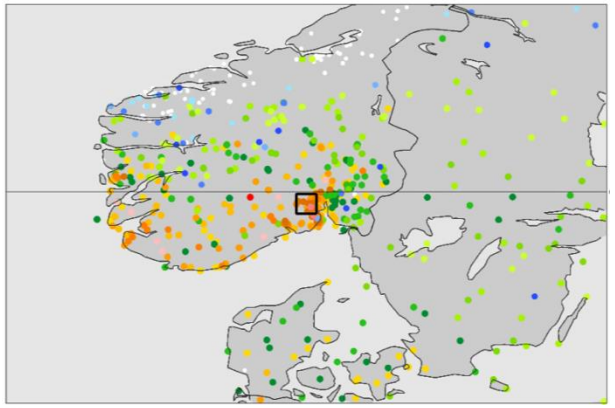
AIFS-ENS control



Summary of all forecast for the event:
Precipitation on 4 October in the box in south-eastern Norway



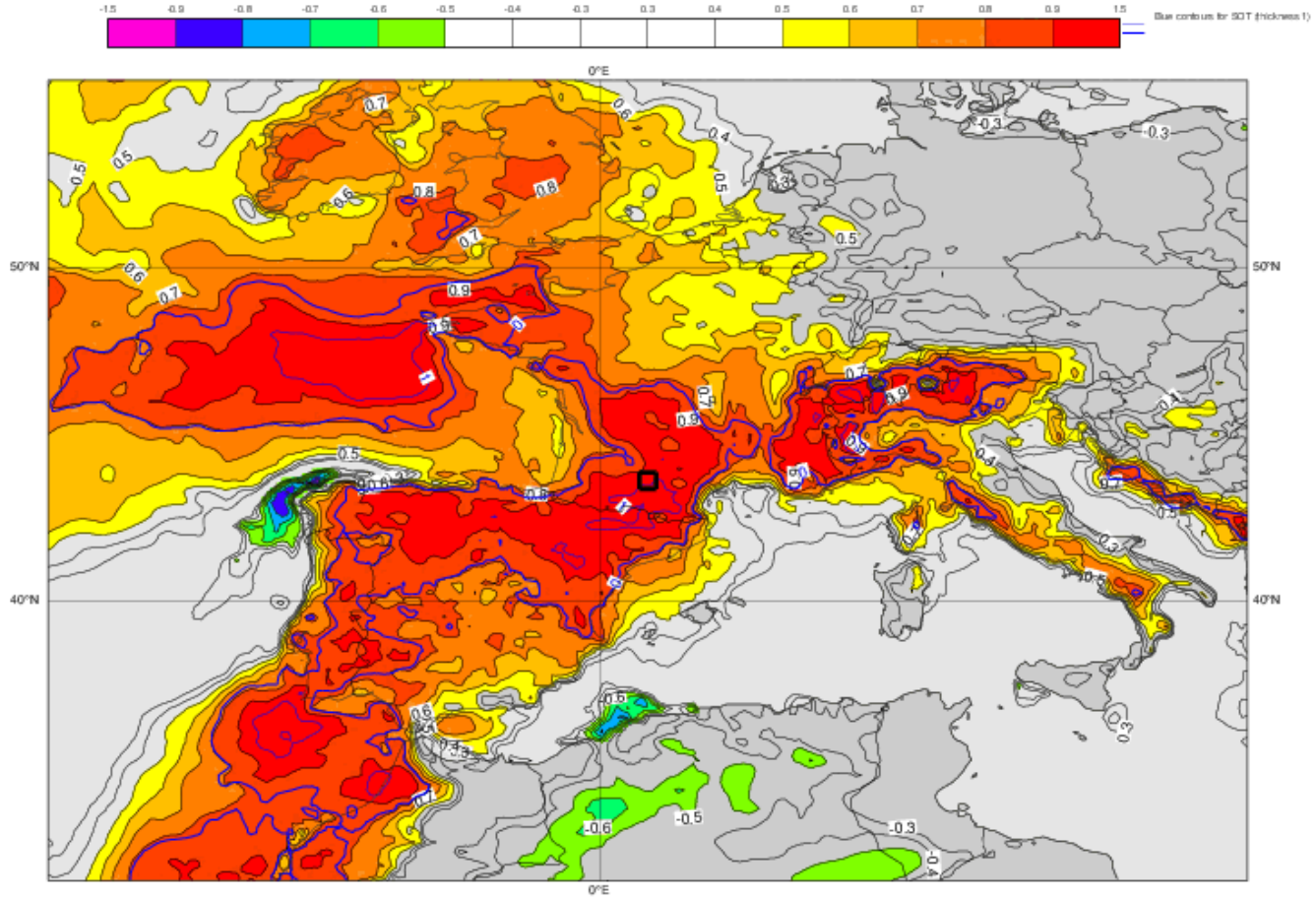




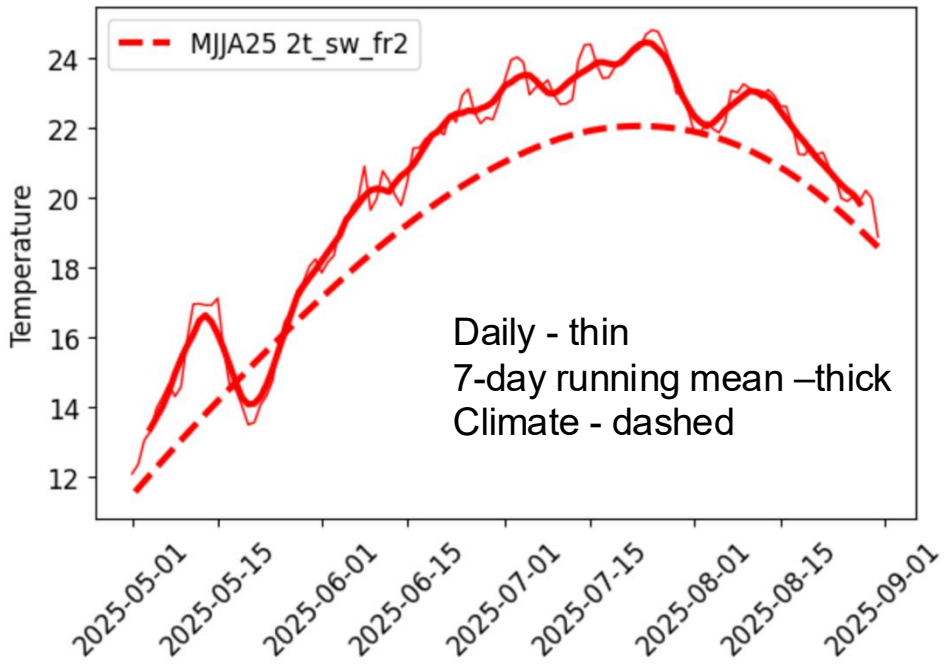
Precipitation performance varies in AIFS for different events - no strong conclusion yet

Western European heatwave 2025

Extreme forecast index for 11 August (1-day forecast)

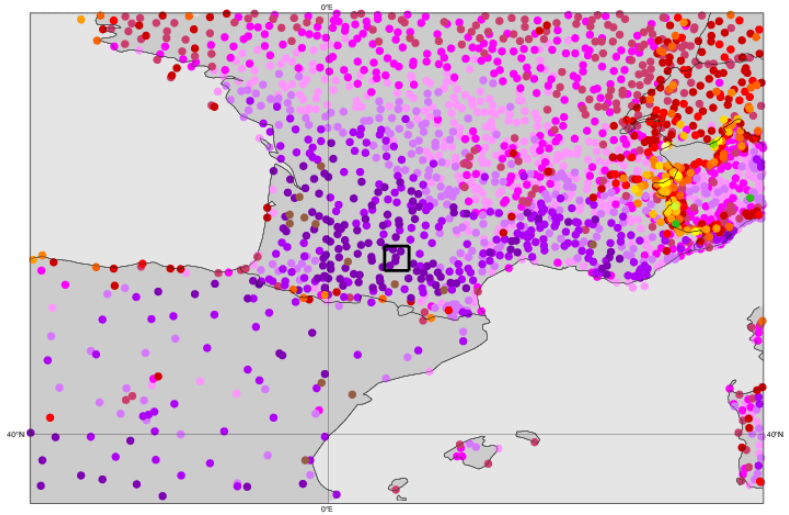


2-metre temperature in SW France

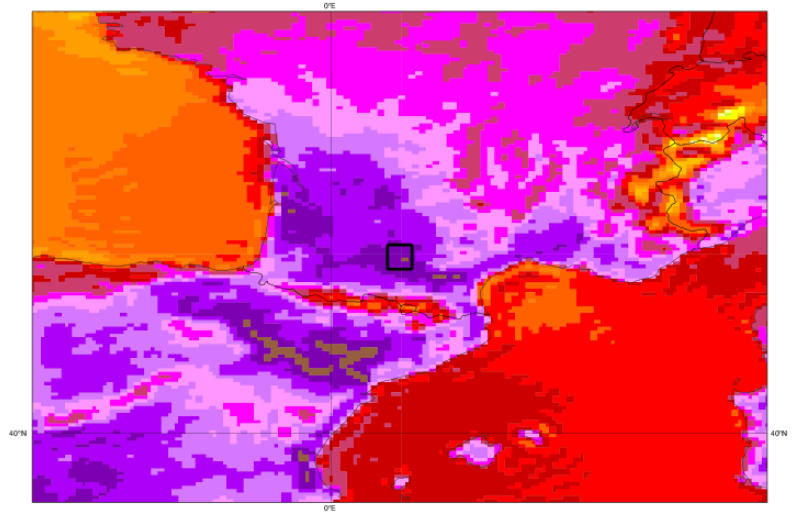


2-metre temperature 11 August 12UTC

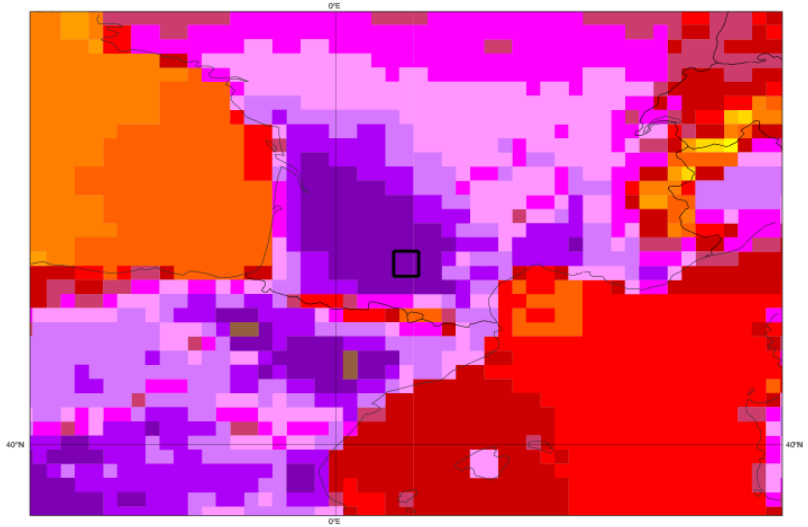
Observations



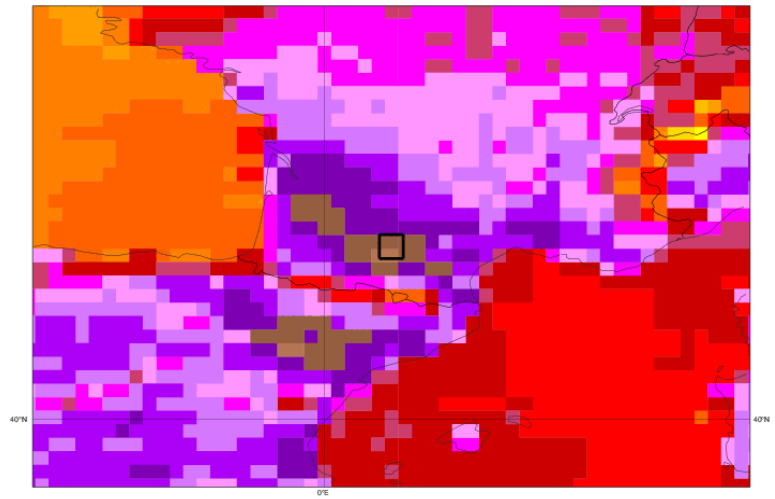
IFS ENS control +36h



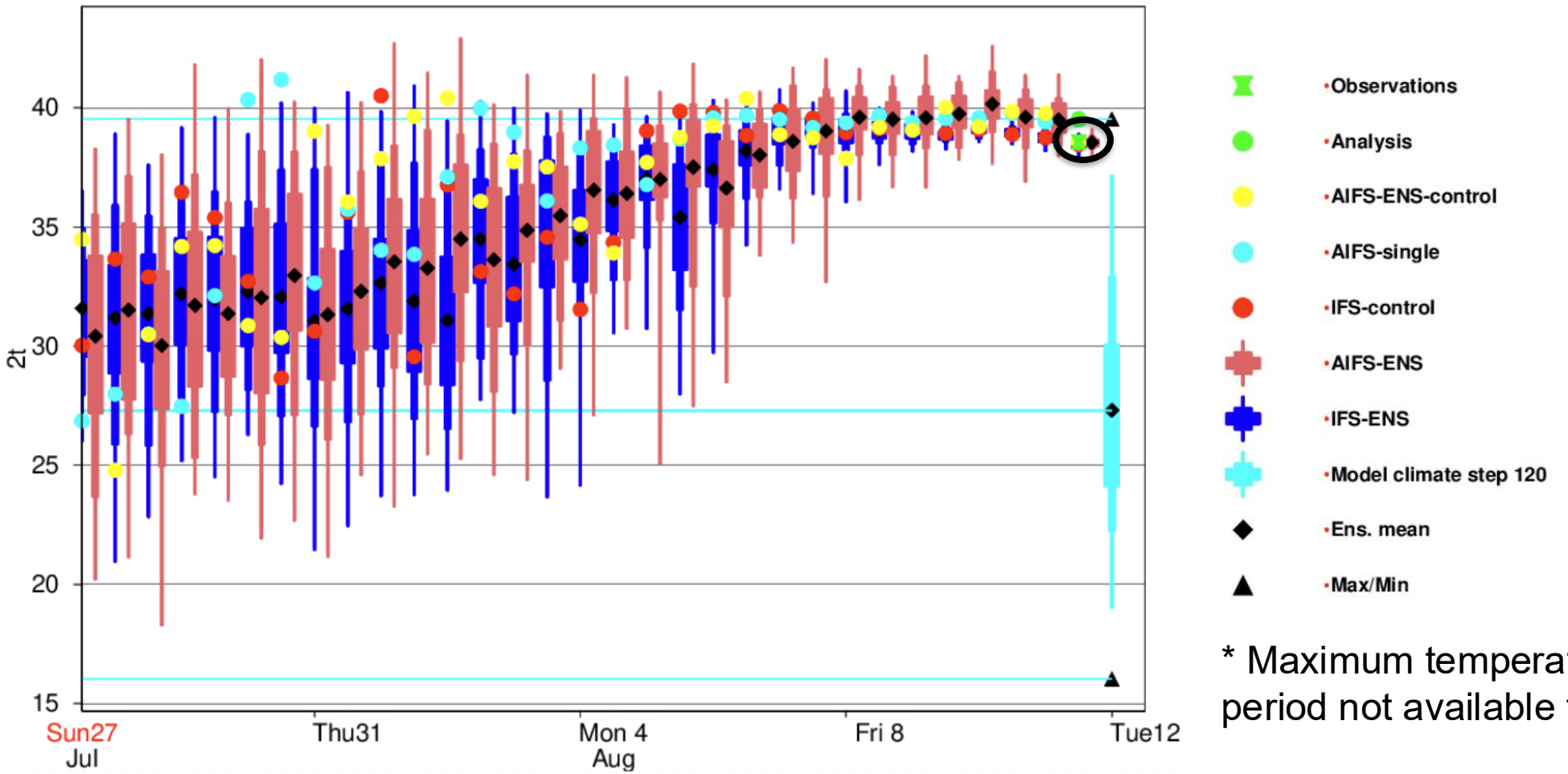
AIFS-single +36h



AIFS-ENS mem 1 +36h



2-metre temperature 31 August 12UTC* around Toulouse

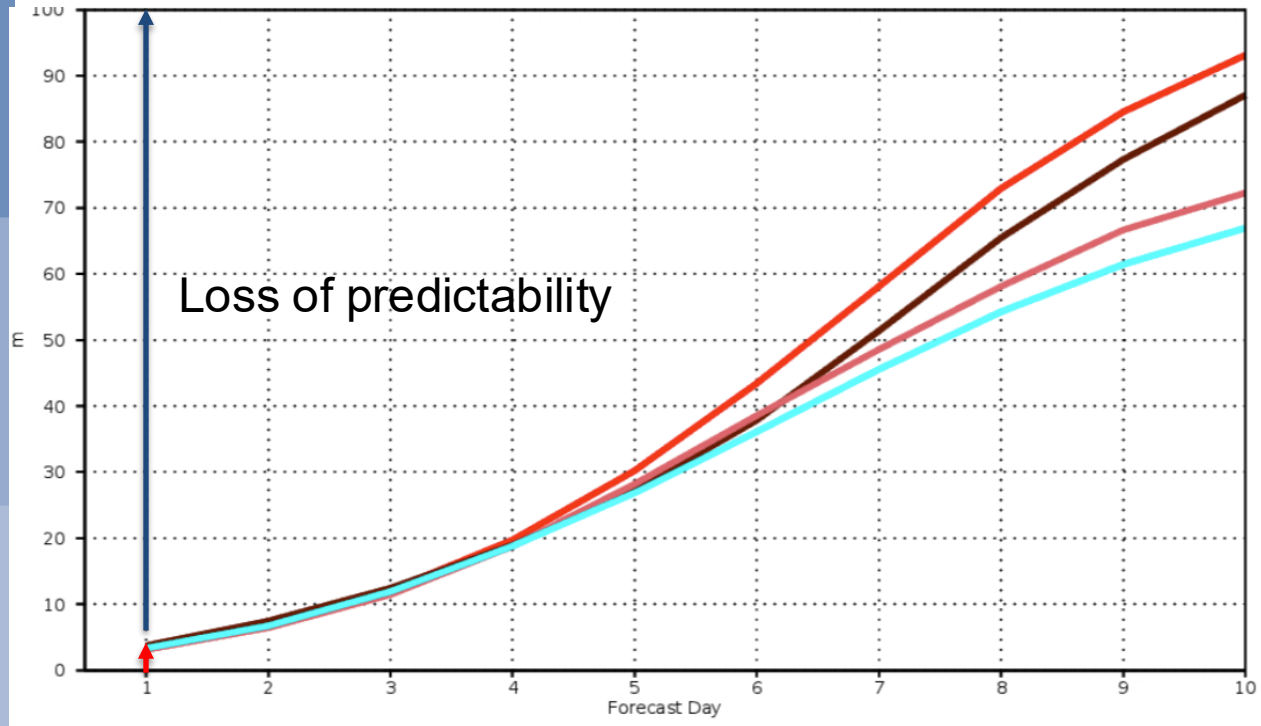


* Maximum temperature over a period not available from AIFS

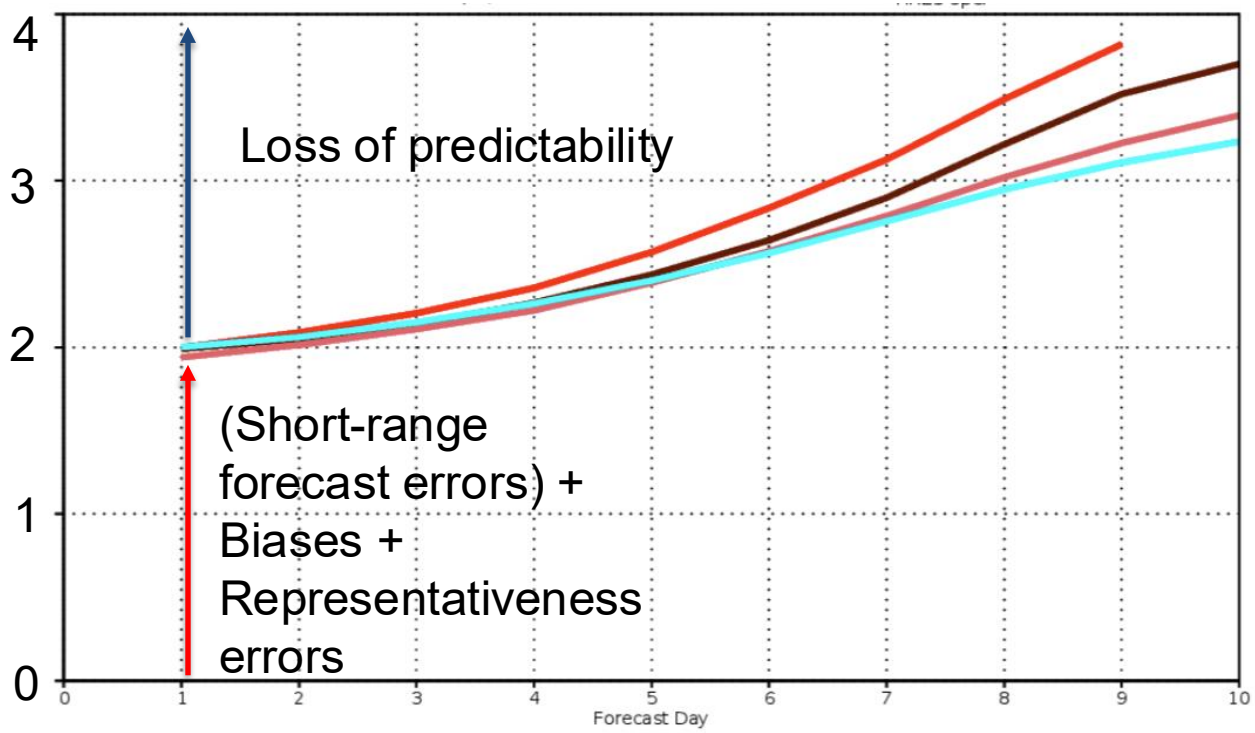
- More short-range spread in AIFS ensemble
- Similar level of medium-range predictability in IFS and AIFS ensembles. AIFS-single had a good early signal

RMSE over Europe - 1 July to 1 September

500hPa geopotential height (against analysis)

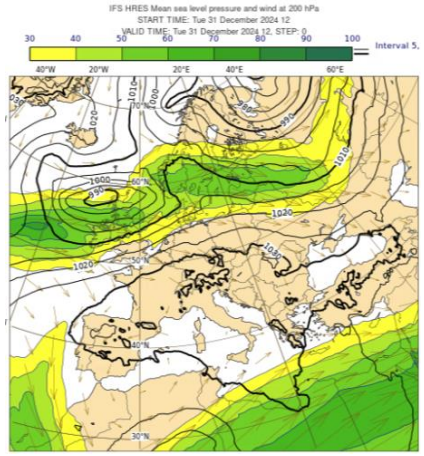


2-metre temperature (against obs)

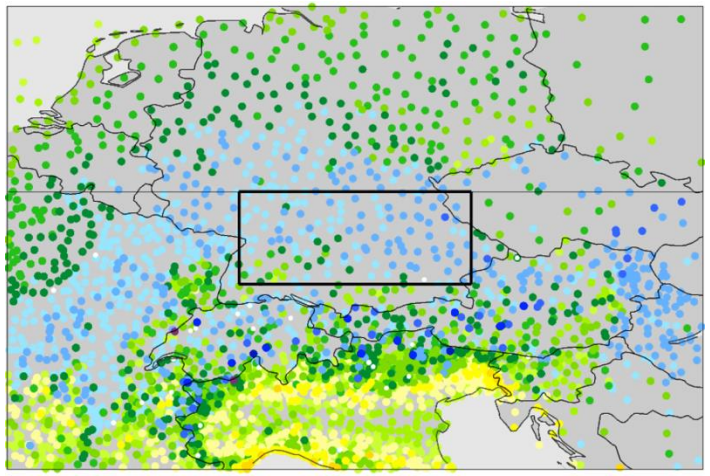


IFS control – red
AIFS-single - brown
IFS-ENS ensemble mean - pink
AIFS-ENS ensemble mean - cyan

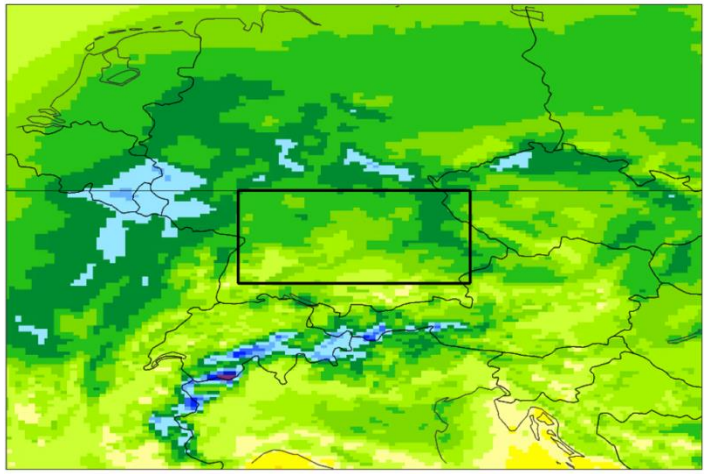
Winter-time temperatures:
Example valid 31 December 12UTC: 2-metre temperature



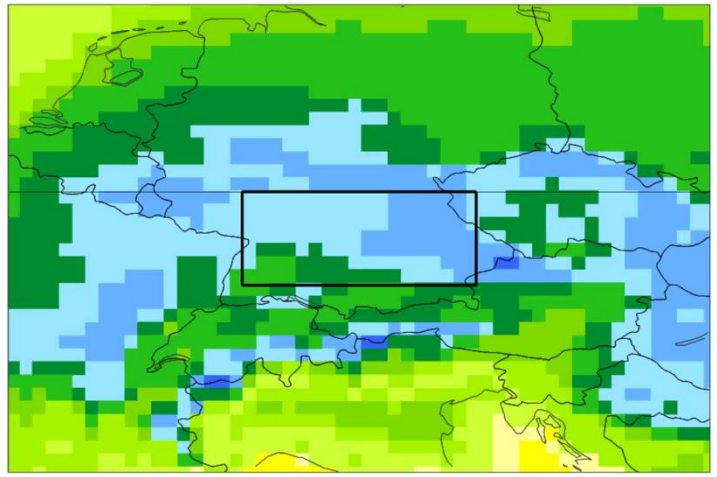
Observations

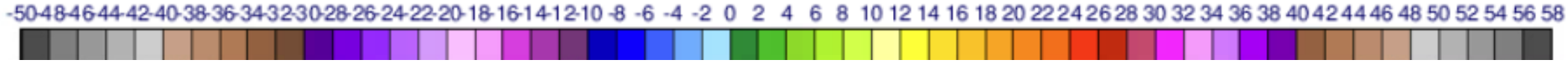


48-hour IFS Control



48-hour AIFS-single

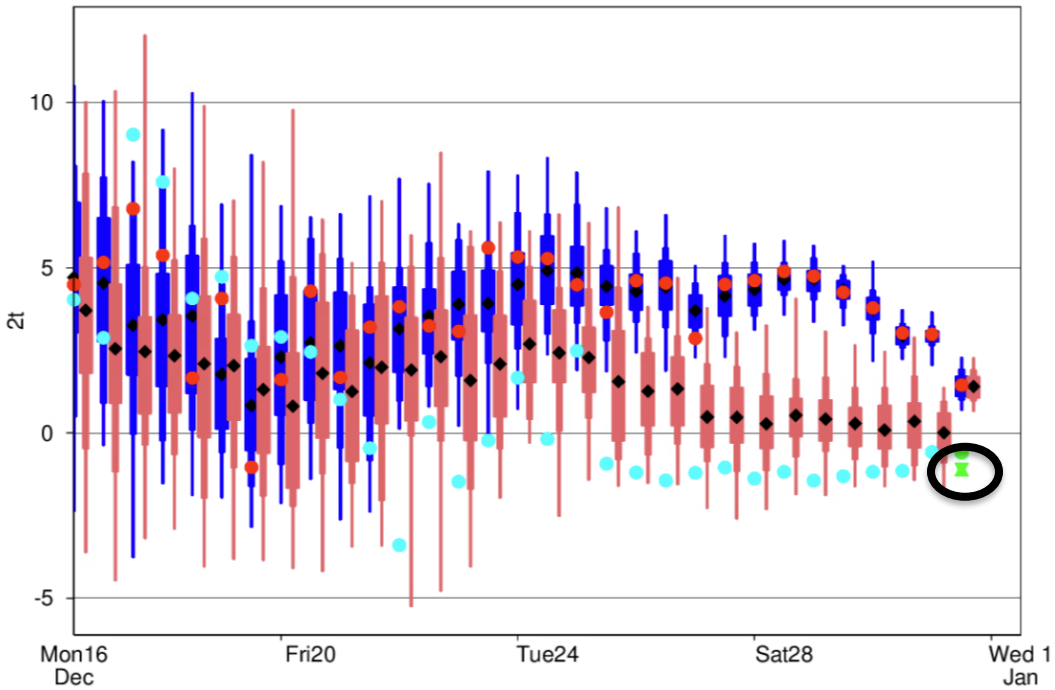


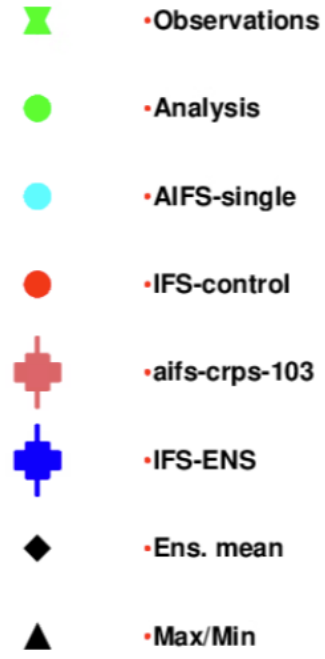


Karmouche et al. (2025):
AIFS blog: https://www.ecmwf.int/en/about/media-centre/aifs-blog/2025/verifying-2-m-temperature-forecasts-wintertime-anticyclonic

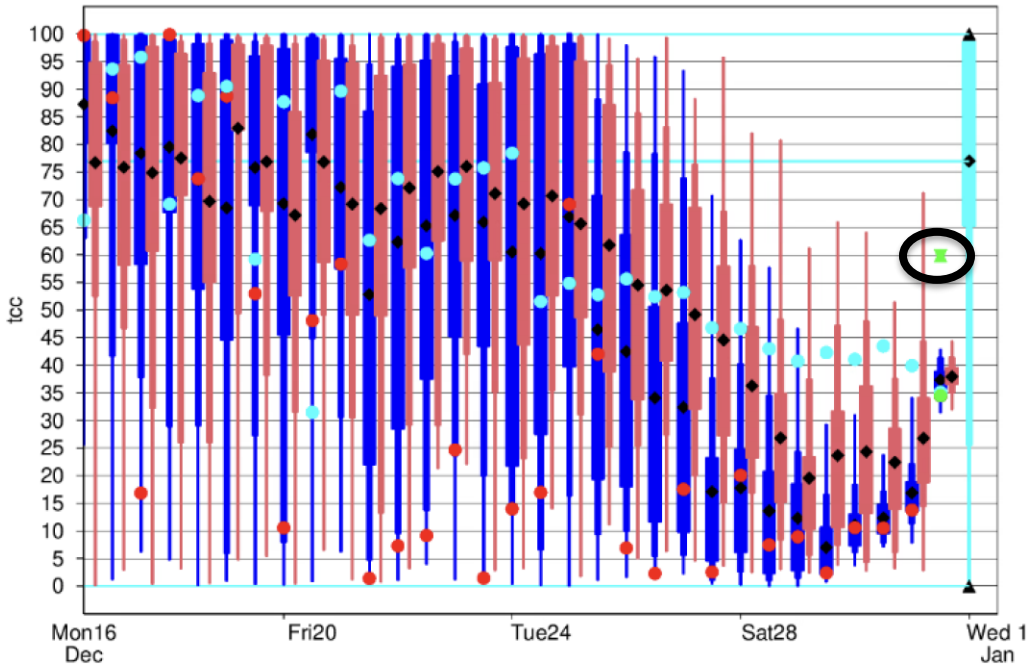
Forecast evolution for Southern Germany valid 31 December 12UTC

2-metre temperature





Total cloud cover



Too few clouds in IFS

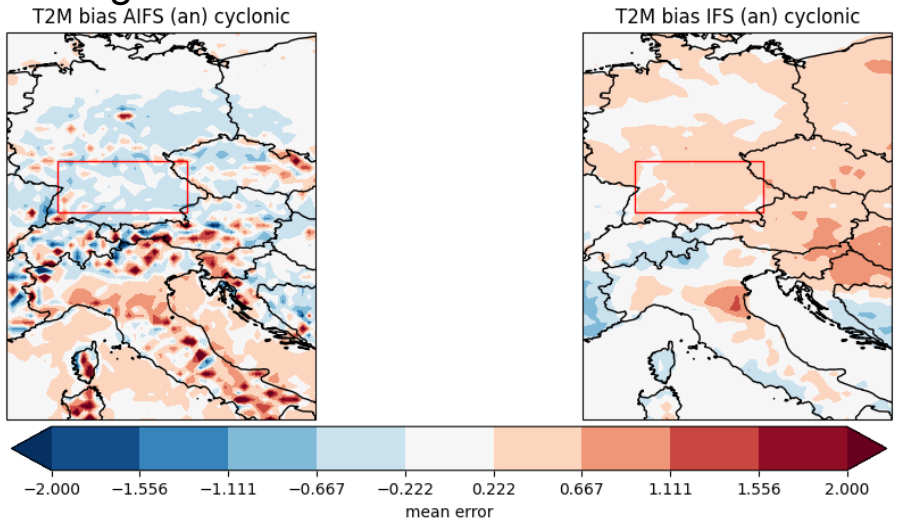
Conditional verification based on flow pattern, Winter 2024/2025

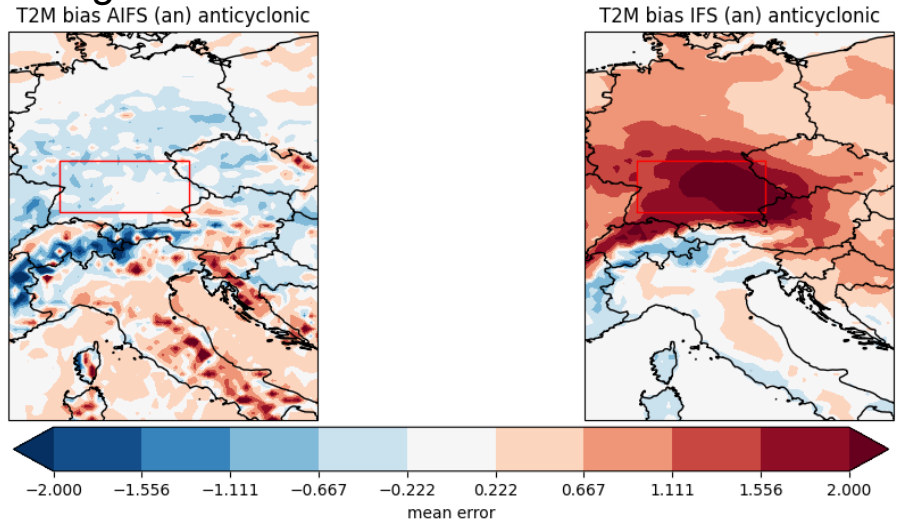
(verified against ECMWF analysis)

AIFS-single — Days with Cyclonic flow — IFS-control

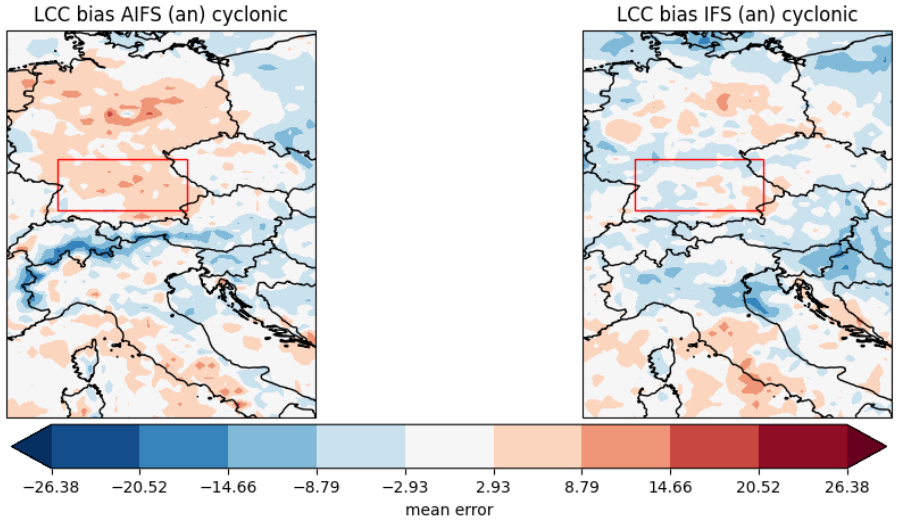
AIFS-single — Days with Anticyclonic flow — IFS-control

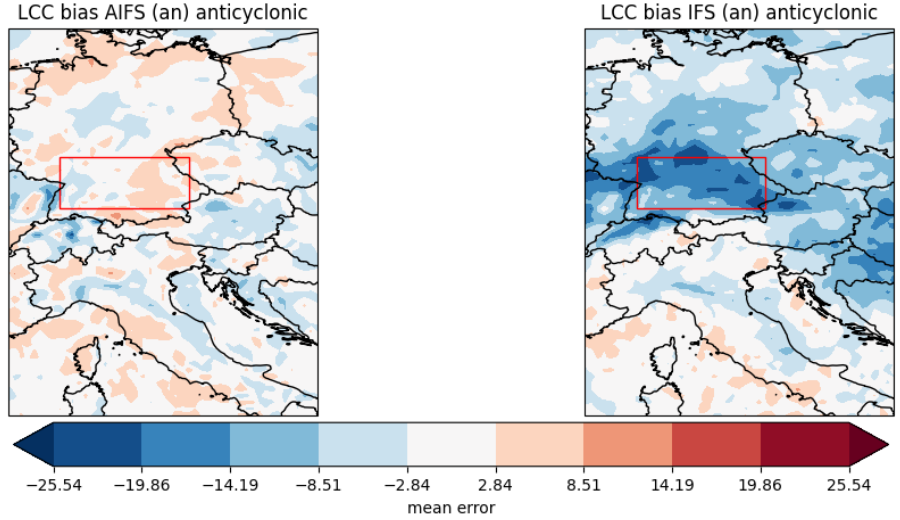
2-metre temperature





Low cloud cover

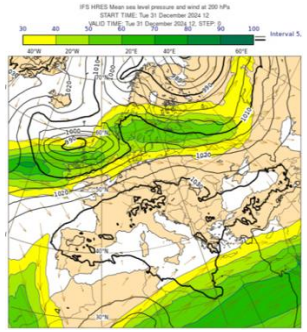


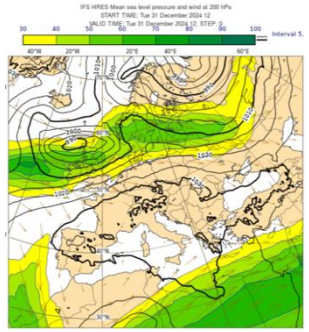


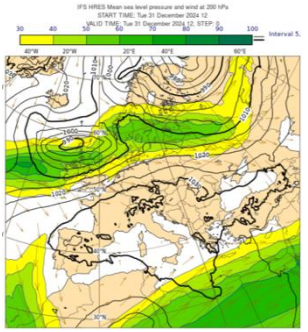
Bias, step +36h, validity dates (2024-10-02 12UTC - 2025-02-25 12UTC)

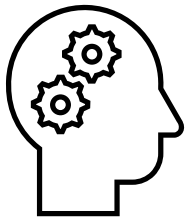
Flow conditions based on CURV index developed by Nigel Roberts, ECMWF

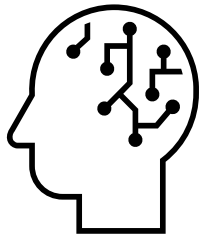
Thanks to Soufiane Karmouche and Maria Pyrina, ECMWF



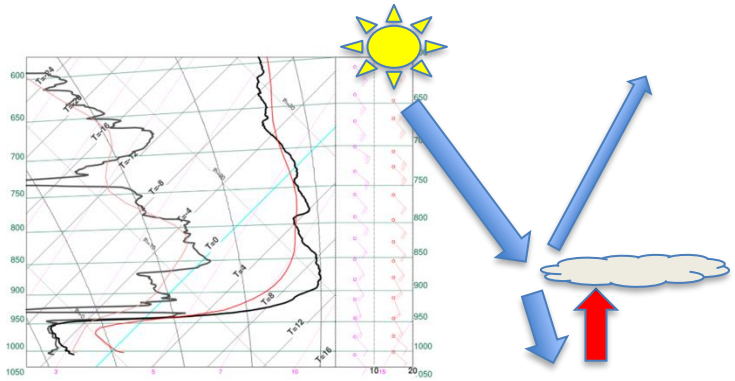


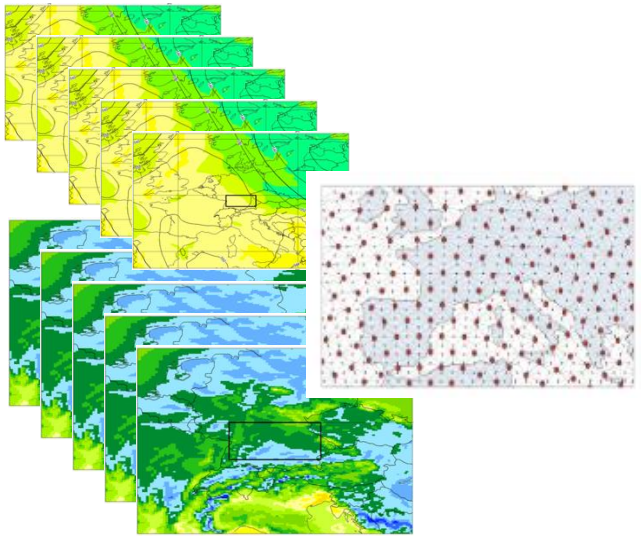






Ω + winter



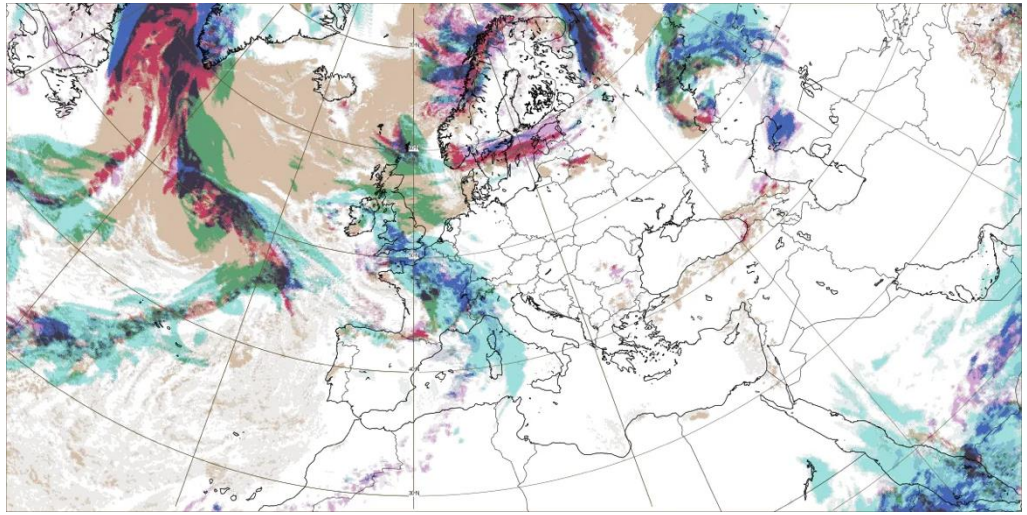


But not everything is perfect (yet) in the AI model world…

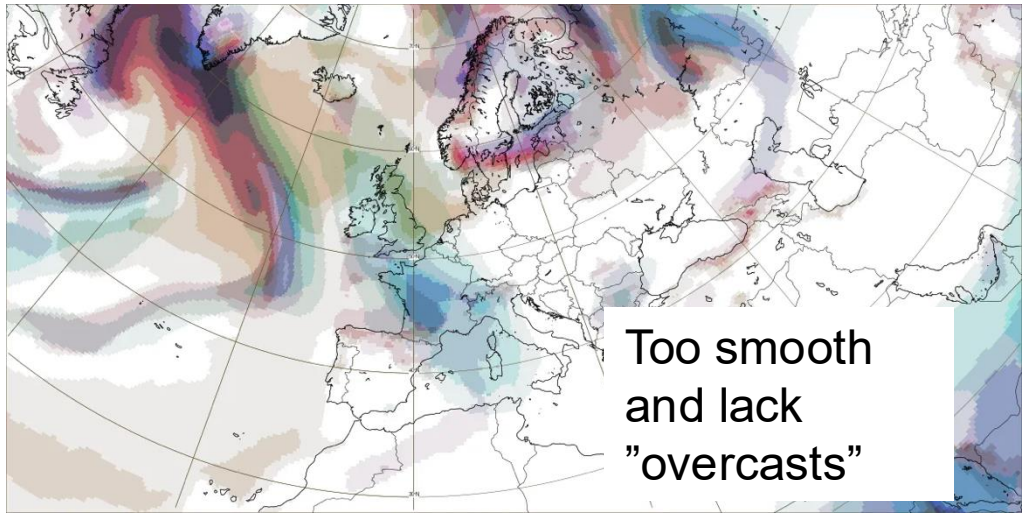
Remember that AIFS is still a very new model…

Example of cloud forecasts, 14 August 2025 00UTC+144h

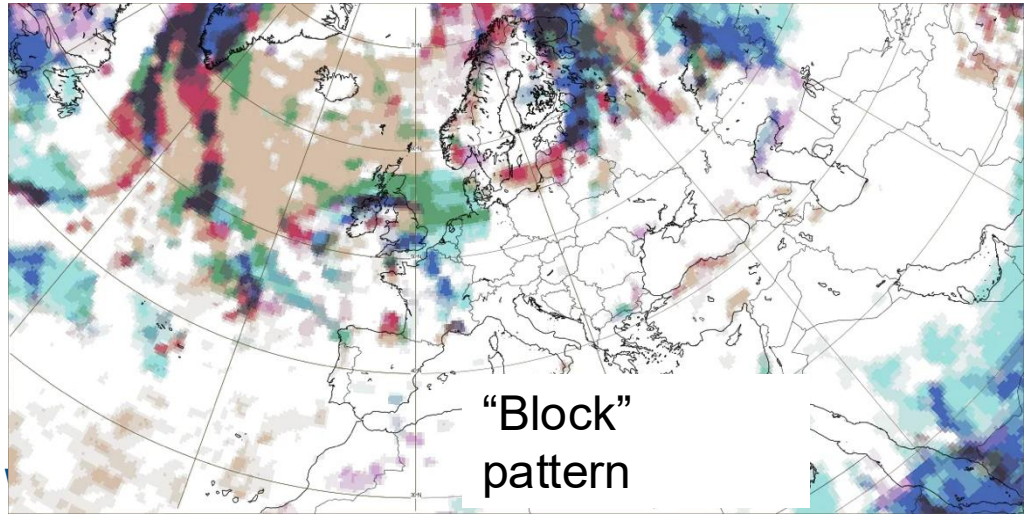
IFS CF

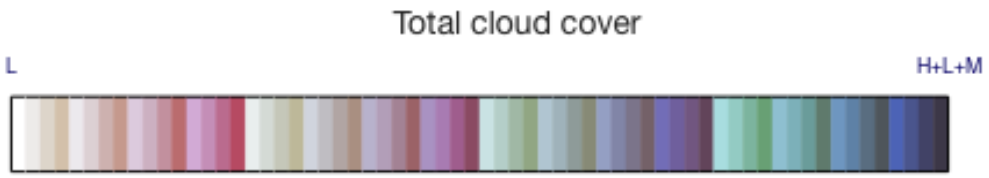


AIFS-single



AIFS-ENS control

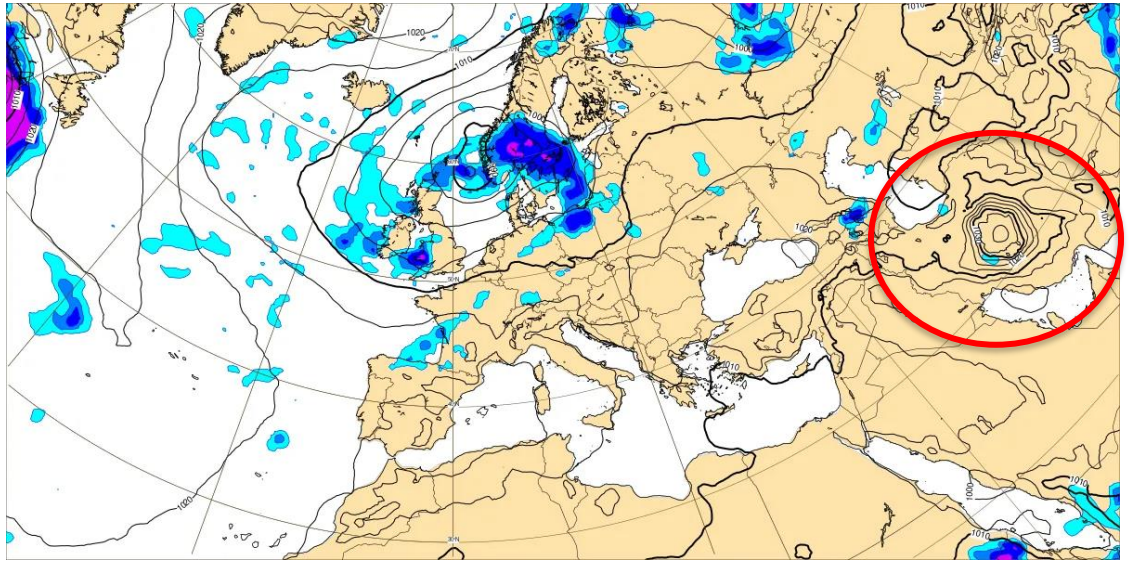




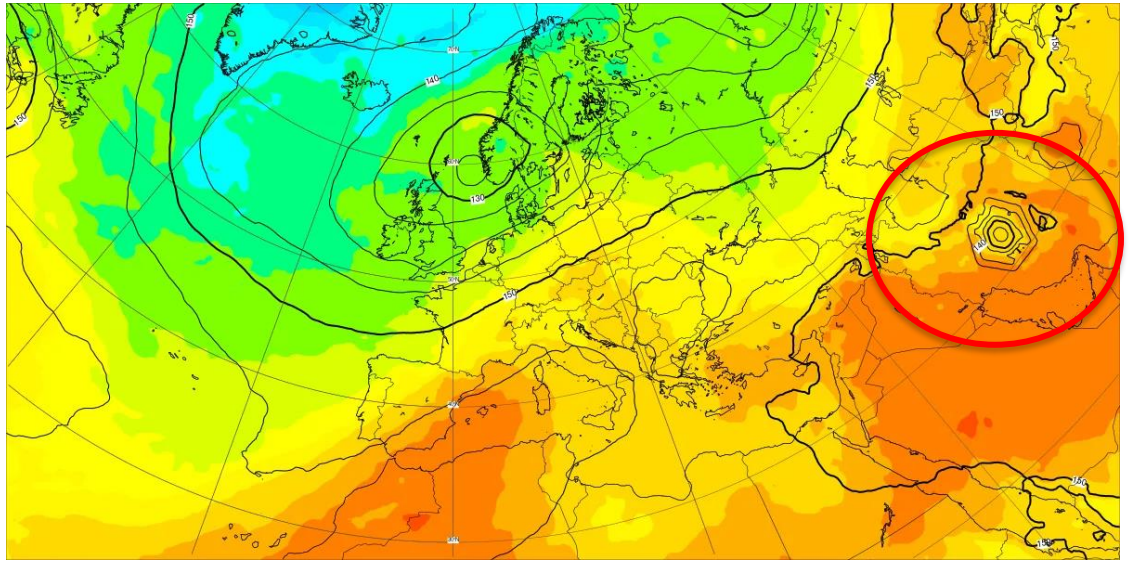
Problem over ”warm” orography in AIFS-ENS

Day 15 forecast from AIFS-ENS control

MSLP and precipitation



850hPa temperature and geopotential



Seems to develop after day 10

Should hopefully be solved in AIFS-ENS v2.0

Spurious snowfall in AIFS-ENS – 22 August

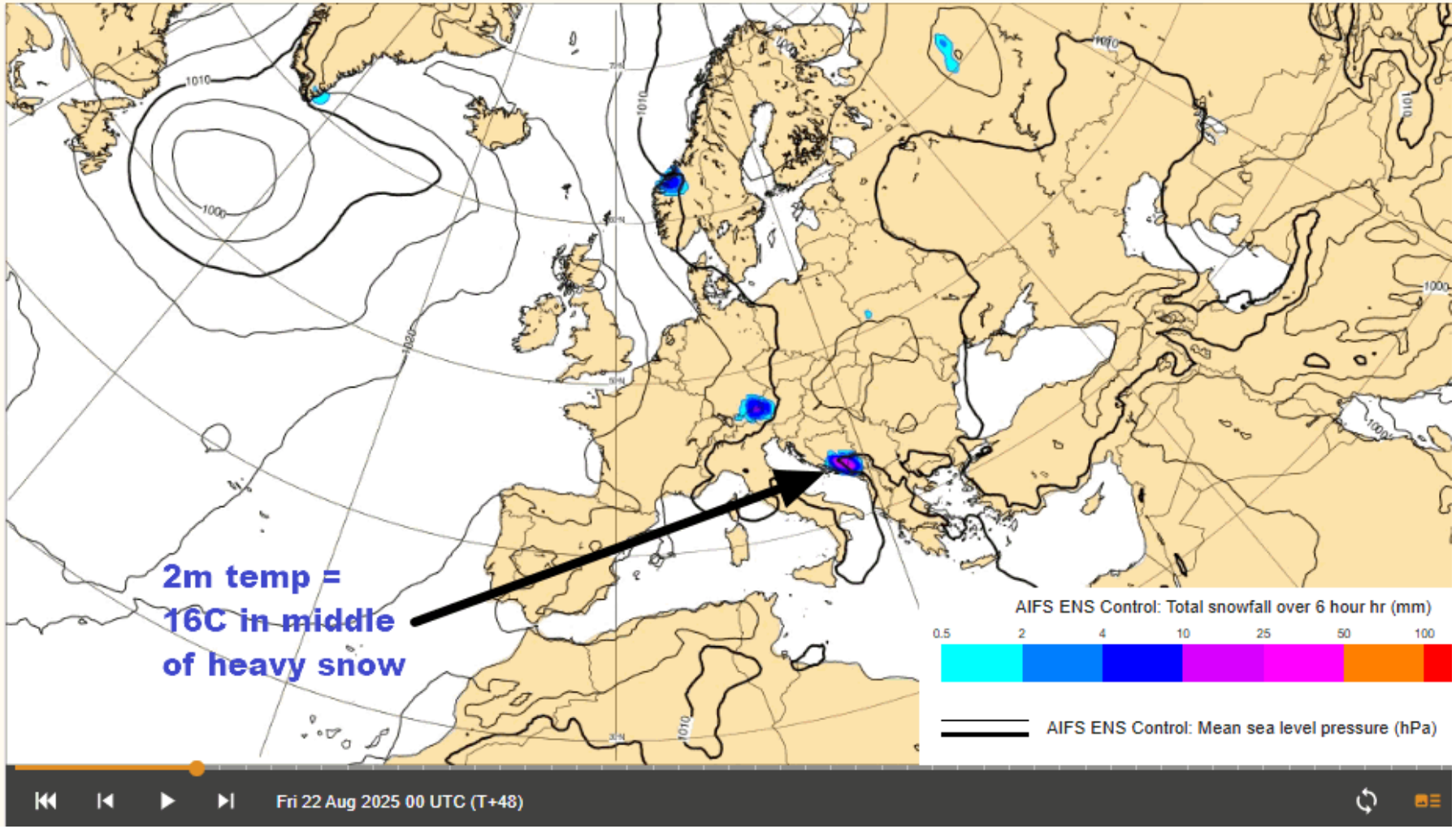
AIFS ENS Control: Total snowfall during last 6 hours

AIFS ENS

Base time
Wed 20 Aug 2025 00 UTC

Valid time
Fri 22 Aug 2025 00 UTC (T+48)

Area
Europe



Physical inconsistencies due to (dynamical) physical limits (not implemented explicitly in AIFS)

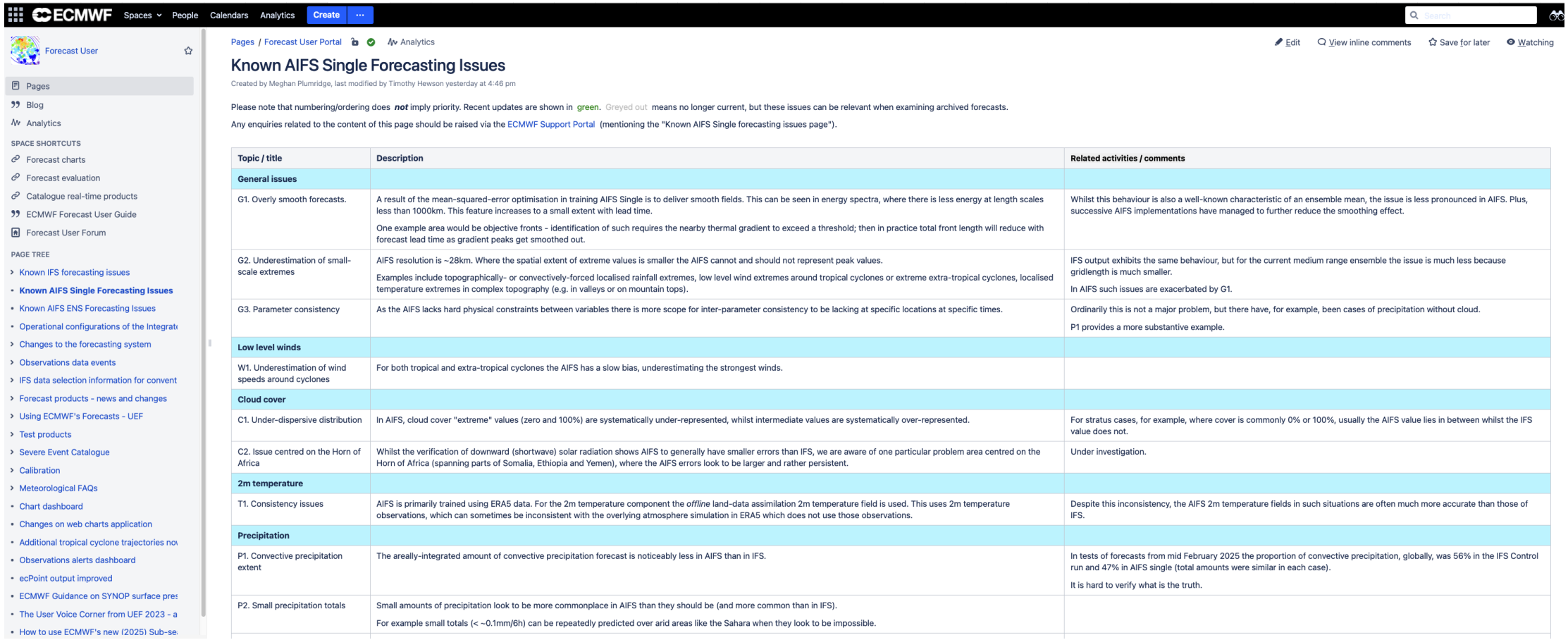
- 2-metre dew point temperature can be higher than 2-metre temperature
- Accumulated downward short-wave radiation at surface can be higher than the clear sky value
- …

- In the first version of AIFS, the precipitation could be negative but that is solved by an explicit limiter in the training now

- With more variables included in AIFS, the risk for physical inconsistencies increases (e.g with inclusion of snow depth in AIFS v2.0)

Known forecast issues page for AIFS-single / AIFS-ENS

(in a similar way as we document issues in IFS)



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ECMWF Forecast User Guide
Forecast User Forum

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Forecast products - news and changes
Using ECMWF's Forecasts - UEF
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Meteorological FAQs
Chart dashboard
Changes on web charts application
Additional tropical cyclone trajectories no
Observations alerts dashboard
ecPoint output improved
ECMWF Guidance on SYNOP surface pres
The User Voice Corner from UEF 2023 - a
How to use ECMWF's new (2025) Sub-se

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Known AIFS Single Forecasting Issues

Created by Meghan Plumridge, last modified by Timothy Hewson yesterday at 4:46 pm

Please note that numbering/ordering does ***not*** imply priority. Recent updates are shown in green. Greyed out means no longer current, but these issues can be relevant when examining archived forecasts.

Any enquiries related to the content of this page should be raised via the ECMWF Support Portal (mentioning the "Known AIFS Single forecasting issues page").

Topic / title	Description	Related activities / comments
General issues		
G1. Overly smooth forecasts.	A result of the mean-squared-error optimisation in training AIFS Single is to deliver smooth fields. This can be seen in energy spectra, where there is less energy at length scales less than 1000km. This feature increases to a small extent with lead time. One example area would be objective fronts - identification of such requires the nearby thermal gradient to exceed a threshold; then in practice total front length will reduce with forecast lead time as gradient peaks get smoothed out.	Whilst this behaviour is also a well-known characteristic of an ensemble mean, the issue is less pronounced in AIFS. Plus, successive AIFS implementations have managed to further reduce the smoothing effect.
G2. Underestimation of small-scale extremes	AIFS resolution is ~28km. Where the spatial extent of extreme values is smaller the AIFS cannot and should not represent peak values. Examples include topographically- or convectively-forced localised rainfall extremes, low level wind extremes around tropical cyclones or extreme extra-tropical cyclones, localised temperature extremes in complex topography (e.g. in valleys or on mountain tops).	IFS output exhibits the same behaviour, but for the current medium range ensemble the issue is much less because gridlength is much smaller. In AIFS such issues are exacerbated by G1.
G3. Parameter consistency	As the AIFS lacks hard physical constraints between variables there is more scope for inter-parameter consistency to be lacking at specific locations at specific times.	Ordinarily this is not a major problem, but there have, for example, been cases of precipitation without cloud. P1 provides a more substantive example.
Low level winds		
W1. Underestimation of wind speeds around cyclones	For both tropical and extra-tropical cyclones the AIFS has a slow bias, underestimating the strongest winds.	
Cloud cover		
C1. Under-dispersive distribution	In AIFS, cloud cover "extreme" values (zero and 100%) are systematically under-represented, whilst intermediate values are systematically over-represented.	For stratus cases, for example, where cover is commonly 0% or 100%, usually the AIFS value lies in between whilst the IFS value does not.
C2. Issue centred on the Horn of Africa	Whilst the verification of downward (shortwave) solar radiation shows AIFS to generally have smaller errors than IFS, we are aware of one particular problem area centred on the Horn of Africa (spanning parts of Somalia, Ethiopia and Yemen), where the AIFS errors look to be larger and rather persistent.	Under investigation.
2m temperature		
T1. Consistency issues	AIFS is primarily trained using ERA5 data. For the 2m temperature component the *offline* land-data assimilation 2m temperature field is used. This uses 2m temperature observations, which can sometimes be inconsistent with the overlying atmosphere simulation in ERA5 which does not use those observations.	Despite this inconsistency, the AIFS 2m temperature fields in such situations are often much more accurate than those of IFS.
Precipitation		
P1. Convective precipitation extent	The areally-integrated amount of convective precipitation forecast is noticeably less in AIFS than in IFS.	In tests of forecasts from mid February 2025 the proportion of convective precipitation, globally, was 56% in the IFS Control run and 47% in AIFS single (total amounts were similar in each case). It is hard to verify what is the truth.
P2. Small precipitation totals	Small amounts of precipitation look to be more commonplace in AIFS than they should be (and more common than in IFS). For example small totals (< ~0.1mm/6h) can be repeatedly predicted over arid areas like the Sahara when they look to be impossible.	

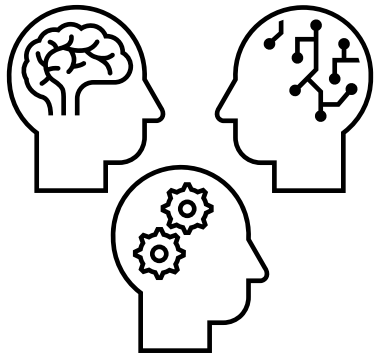
However, solving the issues require different strategies for an AI model compared to NWP

https://confluence.ecmwf.int/display/FCST/Known+AIFS+Single+Forecasting+Issues

https://confluence.ecmwf.int/display/FCST/Known+AIFS+ENS+Forecasting+Issues

Summary

- Different characteristics in AIFS-single and AIFS-ENS, but both:
  - Able to make very skilful prediction of the large-scale flow
  - Capture extremes, but missing the magnitude for some types of extreme weather
  - Improves on (conditional) systematic error in IFS
- Continued efforts in the evaluation team to find strange behaviours in AIFS
- AIFS limited by the skill of the training data (ERA5 + operational analysis)
  - Efforts to add observation data into training
- Under development:
  - Including more earth-system components (e.g waves)
  - Higher resolution (temporal and spatial)
  - Reforecast dataset
  - Sub-seasonal system
  - Hybrid model between IFS and AIFS



Further reading:

ECMWF newsletter articles over the past year about extreme events like Storm Eowyn, Storm Boris, …

AIFS: Lang et al., AIFS -- ECMWF's data-driven forecasting system https://arxiv.org/abs/2406.01465

AIFS-ENS: Lang et al., AIFS-CRPS: Ensemble forecasting using a model trained with a loss function based on the Continuous Ranked Probability Score
https://arxiv.org/html/2412.15832v1

AI-Model assessments: Ben Bouallègue et al., The Rise of Data-Driven Weather Forecasting: A First Statistical Assessment of Machine Learning–Based Weather Forecasts in an Operational-Like Context: https://doi.org/10.1175/BAMS-D-23-0162.1