Webinar 2 – what you need to be aware of when using ECMWF's ML models

Machine learning for operational forecasters, November 2025

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ECMWF

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!

An AIFS guide for operational forecasters

#1   Getting information and support

1.1   Where can I find AIFS documentation and news?

1.2   How can I get support for the AIFS?

#2   Using the AIFS

2.1   What AIFS data are available?

2.2   How can I access AIFS data?

2.3   How can I generate a forecast using the AIFS?

2.4   How can I suggest parameters for future AIFS versions? *(from previous webinar)*

2.5   How can I work with third-party models? *(from previous webinar)*

#3   Verifying the AIFS

3.1   How does the AIFS compare to the IFS?

3.2   How does the AIFS compare to other data-driven models?

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1.1 Where can I find AIFS documentation and news?

Machine Learning Services and Support

Created by Meghan Plumridge, last modified on Sept 15, 2025

Introduction

This is the user guide for machine learning (ML) services at ECMWF. For further support, please raise a ticket via the ECMWF Support Portal or reach out on our User Forum.

For Anemoi support, please create a Github issue for the specific package. Please note that Github issues are supported on a best-efforts basis.

- User Documentation
  - AIFS
  - ai-models
  - Anemoi
  - GPUs
- Further Resources

News Feed

Users may 'watch' this page to receive notifications of updates and follow our AIFS blog for the latest developments.

User Documentation

AIFS

`OPERATIONAL`

The AIFS is ECMWF's Artificial Intelligence Forecasting System. First launched in October 2023, the AIFS generates deterministic and ensemble weather forecasts from machine learning models.

- The AIFS single model has been operationally supported at ECMWF since 25 February 2025.
- The AIFS ensemble model has been operationally supported at ECMWF since 1 July 2025.

Details about the current operational versions of AIFS models, and a log of past model versions, can be found on AIFS Version History.

Users can acquire model output data from and generate forecasts with the AIFS models using the open-source Anemoi framework.

Meteorological information about the AIFS, including a guide for forecasters, is documented in the Forecast User Guide: Section 2.1.6 Machine Learning models.

How-to guides

- How to: Access AIFS model output data

https://confluence.ecmwf.int/display/UDOC/Machine+Learning+Services+and+Support

Other resources:

AIFS blog

AIFS upgrades

AIFS model card

Forecast user guide

1.2   How can I get support for the AIFS?
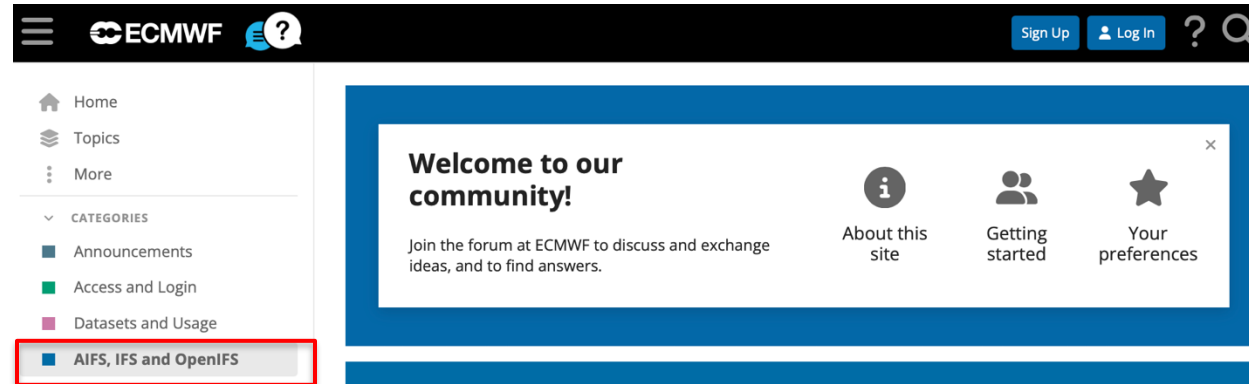
ECMWF User Forum:

Link: https://forum.ecmwf.int/

For: News and community engagement

Example: "*When will AIFS ENS tropical cyclone track forecasts be available?*"

ECMWF Support Portal:

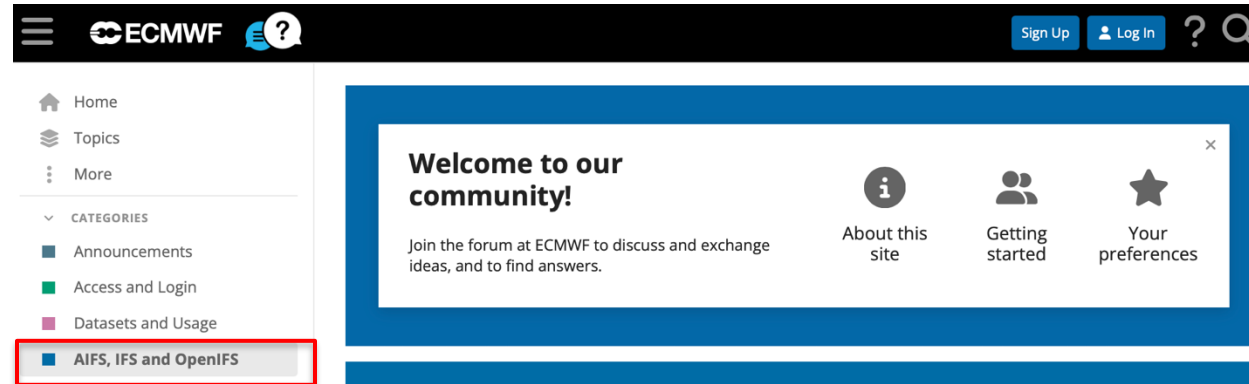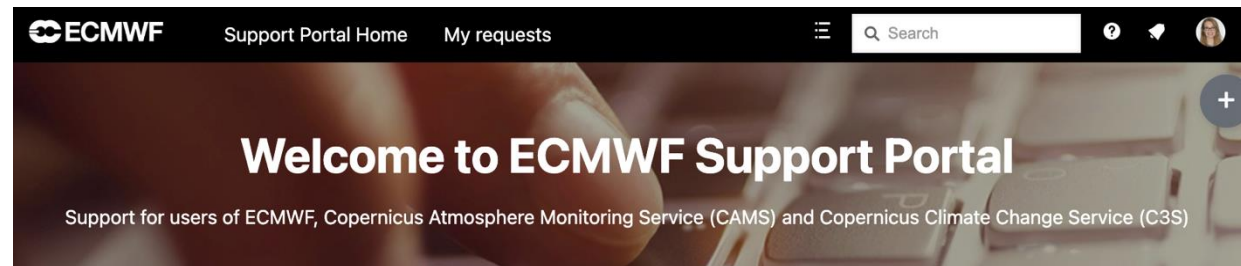

Link: https://confluence.ecmwf.int/site/support

For: Data licensing, computing issues

Example: "*I'd like to purchase a licence to use the ecCharts web service.*"

1.2 How can I get support for the AIFS?

ECMWF User Forum:

Link: https://forum.ecmwf.int/

For: News and community engagement

Example: "*When will AIFS ENS tropical cyclone track forecasts be available?*"

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3.1   How does the AIFS compare to the IFS?

3.2   How does the AIFS compare to other data-driven models?

2.1 What AIFS data are available?

	AIFS Single	AIFS ENS
Dataset description:	https://www.ecmwf.int/en/forecasts/datasets/set-ix	https://www.ecmwf.int/en/forecasts/datasets/set-x
Forecast runs per day:	00, 06, 12 and 18	
Time steps:	6-hourly	
Forecast length:	15 days	
Grid resolution:	N320 Gaussian grid, equivalent to 0.25° lat/lon resolution (≈32 km)	
Vertical resolution:	Provides fields at the surface on 13 pressure levels and 2 soil levels	
Output parameters:	24 surface parameters 6 pressure level parameters 2 soil level parameters TC forecasts for named storms	Compared to AIFS Single: + Post-processed products – Convective precipitation – Volumetric soil moisture – TC forecasts

2.2   How can I access AIFS data?

	Product Type	ECMWF Members	WMO Members	Commercial Customers	Researchers	Public
Real-time	Open data	✔	✔	✔	✔	✔
	Open charts	✔	✔	✔	✔	✔
	ecCharts	✔	✔	📄	📄	✘
	PREd	✔	📄	📄	📄	✘
Historical	Archive catalogue	✔	📄	📄	📄	✘
	MARS catalogue	✔	✘	✘	✘	✘

Further information can be found at:

1) https://confluence.ecmwf.int/display/DAC/Accessing+ECMWF+data+and+charts

2) https://www.ecmwf.int/en/forecasts/access-forecasts/ordering

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2.2   How can I access AIFS data?

Real-time open data

o   All AIFS data are available

o   Global coverage on a 0.25° lat–lon grid

o   Accessible from a range of platforms through the [ecmwf-opendata package](#)
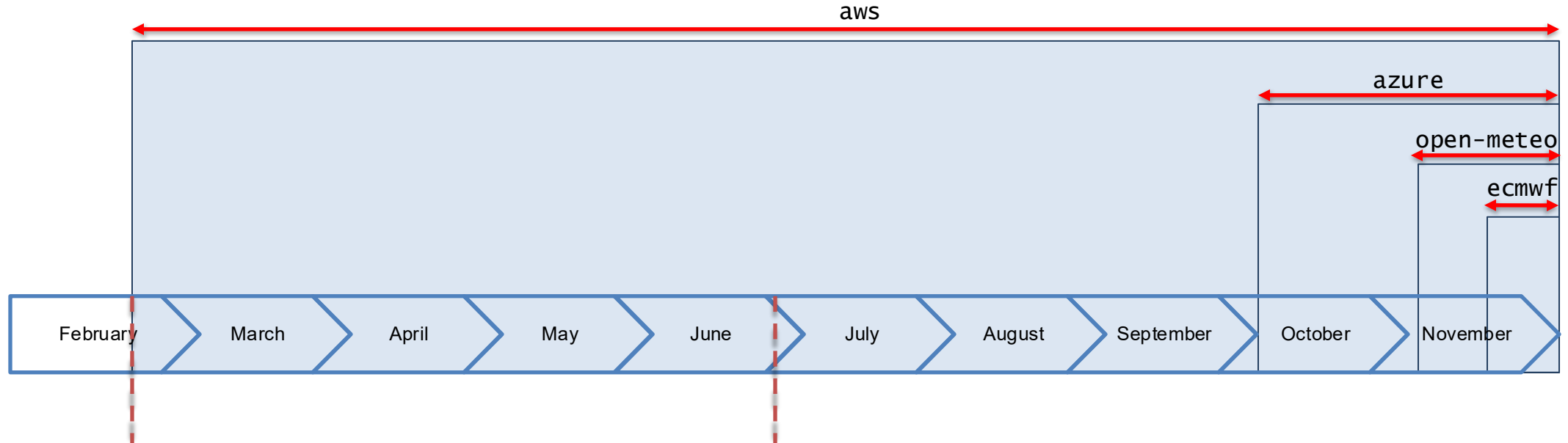
aws

azure

open-meteo

ecmwf

| February | March | April | May | June | July | August | September | October | November | |

25 February 2025
Implementation of
AIFS Single

1 July 2025
Implementation
of AIFS ENS

2.2   How can I access AIFS data?

Real-time open data

o   All AIFS data are available

o   ...

o   ...

Notes

#1   The   ECMWF   server   can   reach   capacity   during   peak   times. Users   are   encouraged   to   access   open   data   from   other   platforms using the **ecmwf-opendata** package. For example:

```
client = Client(source="aws", model="aifs-ens")
```

#2   All   platforms   hosting   AIFS   open   data   can   be   found   here: https://confluence.ecmwf.int/display/DAC/ECMWF+open+data%3A+real-time+forecasts+from+IFS+and+AIFS.

February

November

25 February 2025
Implementation of
AIFS Single

1 July 2025
Implementation
of AIFS ENS

2.2 How can I access AIFS data?

Real-time open data

```
% grib_ls -p edition,date,dataType,gridType,stepRange,shortName,level,typeOfLevel 20251116060000-6h-oper-
fc.grib2

20251116060000-6h-oper-fc.grib2
edition     date        datatype    gridType    stepRange   shortName   level   typeOfLevel
2           20251116    fc          regular_ll  6           mcc         800     isobaricLayer
2           20251116    fc          regular_ll  6           z           400     isobaricInhPa
2           20251116    fc          regular_ll  6           vsw         1       soilLayer
2           20251116    fc          regular_ll  6           vsw         2       soilLayer
2           20251116    fc          regular_ll  6           q           925     isobaricInhPa
2           20251116    fc          regular_ll  6           u           600     isobaricInhPa
2           20251116    fc          regular_ll  6           hcc         450     unknown
2           20251116    fc          regular_ll  6           sot         1       soilLayer
2           20251116    fc          regular_ll  6           sot         2       soilLayer
2           20251116    fc          regular_ll  6           w           925     isobaricInhPa
```

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2.2 How can I access AIFS data?

Real-time open data


```
client.download(
param="mcc",
type="fc",
step=6", )
```

```
% grib_ls -p edition,date,dataType,gridType,stepRange,shor          0251116060000-6h-oper-
fc.grib2

20251116060000-6h-oper-fc.grib2
edition       date        datatype    gridType      stepRange    shortName     level      typeOfLevel
2             20251116    fc          regular_ll    6            mcc           800        isobaricLayer
2             20251116    fc          regular_ll    6            z             400        isobaricInhPa
2             20251116    fc          regular_ll    6            vsw           1          soilLayer
2             20251116    fc          regular_ll    6            vsw           2          soilLayer
2             20251116    fc          regular_ll    6            q             925        isobaricInhPa
2             20251116    fc          regular_ll    6            u             600        isobaricInhPa
2             20251116    fc          regular_ll    6            hcc           450        unknown
2             20251116    fc          regular_ll    6            sot           1          soilLayer
2             20251116    fc          regular_ll    6            sot           2          soilLayer
2             20251116    fc          regular_ll    6            w             925        isobaricInhPa
```

Notebooks are available! Demonstrating how to:
- Use **ecCodes** to inspect GRIB data
- Use **ecmwf-opendata** to retrieve all or a subset of AIFS data

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2.2   How can I access AIFS data?

Real-time open data

Static charts are available for a subset of AIFS products:

- **MSLP +**
  850 hPa wind | 200 hPa wind | 100 m wind | Precipitation

- **Geopotential +**
  Temperature | Wind

- And **many others** (2 m temperature, 2 m dewpoint temperature, total accumulated precipitation, total cloud cover, total column water, total snowfall…)

Charts can be viewed, shared and downloaded for 31 subareas (Africa, Europe, Pacific) or with global coverage

Alternatively, you can generate plots yourself with AIFS open data!
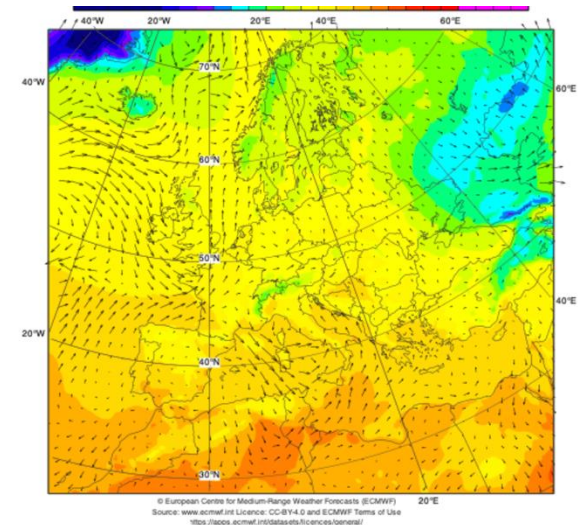
To generate the png file you can run the following cell.

```
png = mv.png_output(
    output_name = "aifs_single_medium-2t-wind",    # specify relative or full path
    output_title = "aifs_single_medium-2t-wind",    # title used by a viewer
    output_width = 1000,                             # set width in pixels
)
mv.setoutput(png)
mv.plot(view, t2m, t2m_shade, wind_vector, wind_arrows, title, ecmwf_text)
```

https://github.com/ecmwf/notebook-examples/tree/master/opencharts

2.2   How can I access AIFS data?

Product Type	ECMWF Members	WMO Members	Commercial Customers	Researchers	Public
Open data	✓	✓	✓	✓	✓

Real-time

Historica

Note

Open data are available under the **Creative Commons CC-BY-4.0 licence,** and therefore subject to attribution requirements.

An example attribution could be:
"*Adapted from "ECMWF IFS 15-day Forecast Data" by ECMWF, licensed under CC BY 4.0, available at https://data.ecmwf.int/forecasts/.*"

See https://www.linkedin.com/posts/ecmwf-users_ecmwf-opendata-forecasting-activity-7338934286546358274-aw2K?utm_source=share&utm_medium=member_desktop&rcm=ACoAABf3au0B8OMSWNLk-lvysZJpyOCy4vbe2lA for more details

Furthe
1) htt
2) https

2.2 How can I access AIFS data?

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Real-time	Open data	✓	✓	✓	✓	✓
	Open charts	✓	✓	✓	✓	✓
	ecCharts	✓	✓	📄	📄	✗
	PREd	✓	📄	📄	📄	✗
Historical	Archive catalogue	✓	📄	📄	📄	✗
	MARS catalogue	✓	✗	✗	✗	✗

Further information can be found at:

1) https://confluence.ecmwf.int/display/DAC/Accessing+ECMWF+data+and+charts

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2.2　How can I access AIFS data?

ecCharts

- ecCharts is a restricted web service providing additional functionality e.g. probing.

- More AIFS 'layers' are available here.
  See the full list of layers at:
  https://eccharts.ecmwf.int/tools/layer-list/
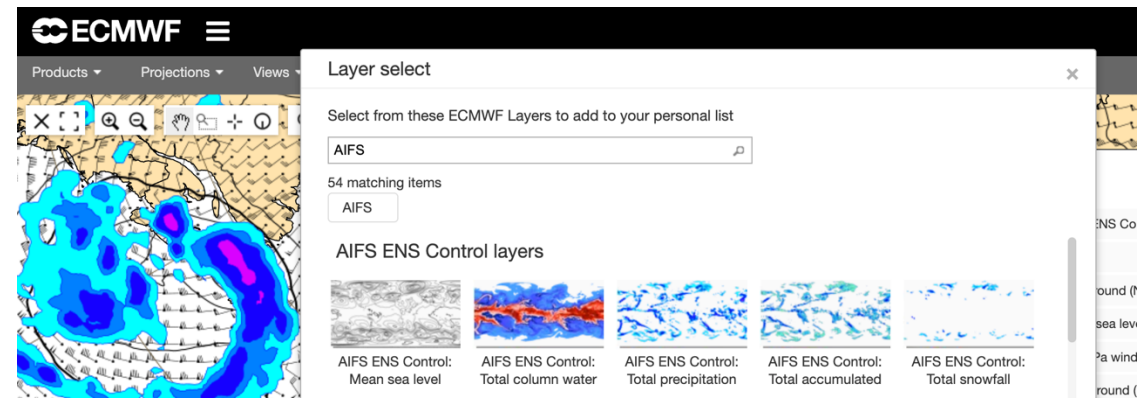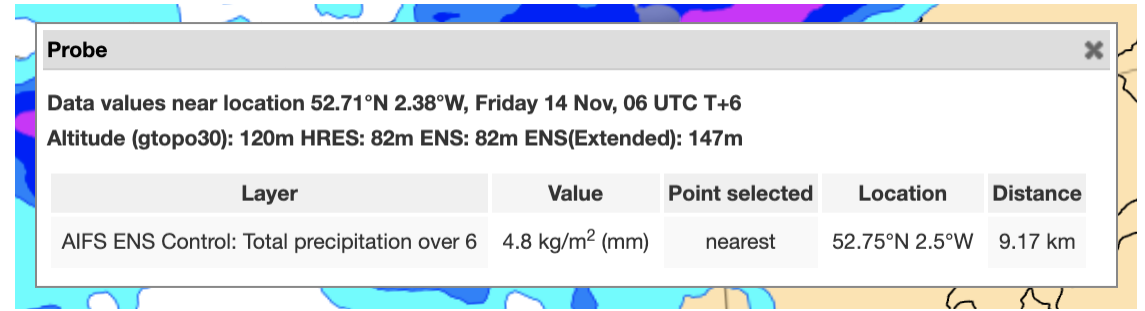
- WMO members have one free account per institution:
  https://confluence.ecmwf.int/display/DAC/Request+change+of+WMO+account

2.2   How can I access AIFS data?

Bespoke data

Real-time data:

- [Real-time catalogue](#)

- Files use ECMWF's new file naming convention

- Data can be delivered as soon as the data are produced, or according to a schedule.

Historical data:

- [MARS archive catalogue](#)

- AIFS Single data from February 2024

- AIFS ENS data from July 2025

```
disseminate,
  class          = ai,
  stream         = oper,
  expver         = 0001,
  domain         = g,
  model          = aifs-single,
  type           = fc,
  levtype        = sfc,
  param          = msl/10u/10v/2t/2d/tp/sf/ssrd/100u/100v,
  time           = 0000/0600/1200/1800,
  step           = 0/to/360/by/6,
  area           = 90/-180/-90/180,
  grid           = .25/.25
```

Time (4 values)	Step (61 values)	Parameter (14 values)
00:00:00	0	2 metre dewpoint temperature
06:00:00	6	2 metre temperature
12:00:00	12	10 metre U wind component
18:00:00	18	10 metre V wind component
	24	Convective precipitation
	30	Geopotential
	36	Land-sea mask
	42	Mean sea level pressure
	48	Skin temperature
	54	Slope of sub-gridscale orography

2.2 How can I access AIFS data?

Bespoke data

Real-time data:

- [Real-time catalogue](#)

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```
disseminate,
  class           = ai,
  stream          = oper,
  expver          = 0001,
  domain          = g,
  model           = aifs-single,
  type            = fc,
  levtype         = sfc,
  param           = msl/10u/10v/2t/2d/tp/s...
  time            = 0000/0600/1200/1800,
  step            = 0/to/360/by/6,
  area            = 90/-180/-90/180,
  grid            = .25/.25
```

Historical data:

- [MARS archive catalogue](#)

- AIFS Single data from February 2024

- AIFS ENS data from July 2025

Note: Configuring bespoke AIFS data requires the use of our custom MARS and dissemination syntax.

See https://confluence.ecmwf.int/display/UDOC/Keywords+in+MARS+and+Dissemination+requests for details of each keyword.

36	Land-sea mask
42	Mean sea level pressure
48	Skin temperature
54	Slope of sub-gridscale orography

An AIFS guide for operational forecasters

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2.3   How can I generate a forecast using the AIFS?

Notebooks for the models are available on HuggingFace

- <u>AIFS Single</u>
- <u>AIFS ENS</u>

1) Import packages (including Anemoi)

2) Retrieve initial conditions from ECMWF open data

3) Load the model checkpoint

```
checkpoint = {"huggingface":"ecmwf/aifs-single-1.1"}
```

4) Generate a forecast on GPUs

```
for state in runner.run(input_state=input_state, lead_time=12)
    print_state(state)
```

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2.3 How can I generate a forecast using the AIFS?

Notebooks for the models are available on HuggingFace

Welcome to ECMWF HuggingFace!

- AIFS Single
- AIFS ENS

1) Import packages (including Anemoi)

anemoi

2) Retrieve initial conditions from ECMWF open data

ecmwf-opendata

- Forecasts generated from open data will differ from ECMWF's forecasts due to differing interpolation pathways

3) Load the model chec...

Open data interpolation

o1280

0.25°

n320

4) Generate a forecast or...
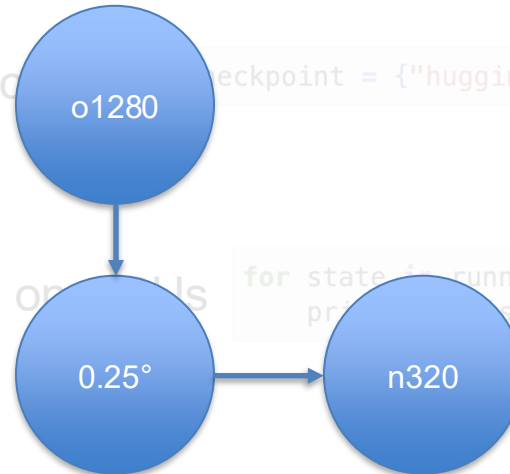
ECMWF's operational interpolation

o1280
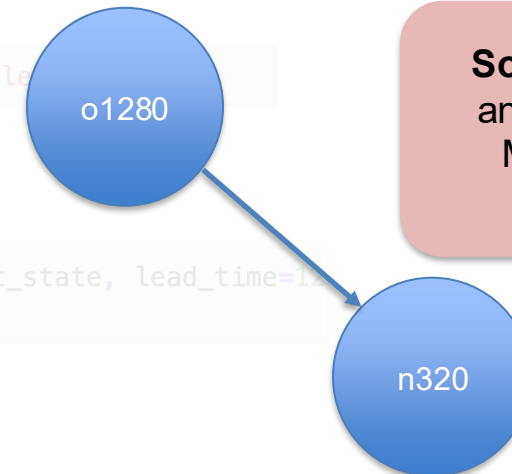
n320

Solution: Retrieve IFS analysis data from the MARS archive with grid=n320.

2.3   How can I generate a forecast using the AIFS?

Notebooks for the models are available on HuggingFace

- AIFS Single
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```
checkpoint = {"huggingface":"ecmwf/aifs-single-1.1"}
```

4) Generate a forecast on GPUs

```
for state in runner.run(input_state=input_state, lead_time=12)
    print_state(state)
```

- The FlashAttention library only supports Nvidia and AMD GPUs
- Member State users can access ECMWF GPUs through their Computing Representative

An AIFS guide for operational forecasters

2.4   How can I suggest new parameters for future AIFS versions?

Coming soon!

Version 2 of AIFS Single and AIFS ENS will be released in Q1 2026, including new parameters which will be announced soon.

A thread will be created on the user forum, listing all new parameters and giving users an opportunity to suggest additional parameters for future AIFS upgrades.

Want to get updates about future AIFS cycle upgrades?

- **Send an email** to forecast_changes-request@lists.ecmwf.int with "**Subscribe**" as the subject

- **Join our user forum** at https://forum.ecmwf.int/ and **'watch'** the announcements

- **Follow our LinkedIn channel** on https://www.linkedin.com/showcase/ecmwf-users/posts

2.5 How can I work with third-party models?
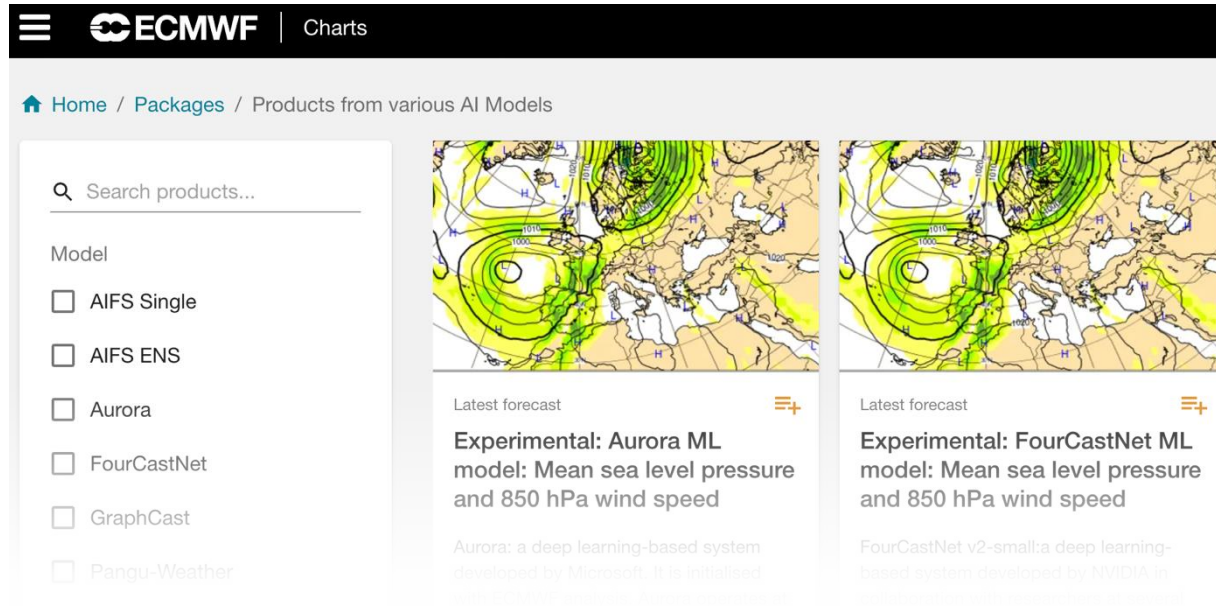
- ECMWF runs several third-party data-driven weather forecasting models.

- The models are run daily, for comparison with the AIFS.

- Graphical output is publicly available on the OpenCharts platform, including plots measuring the performance of the AIFS and these third-party models.

Note: Raw output data are not available to users; users can generate forecast products themselves using the **ai-models** package.

How can we make the AIFS more user friendly for you?

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3.1   How does the AIFS compare to the IFS?

3.2   How does the AIFS compare to other data-driven models?

AIFS-Single

Operational since 25.2.2025; Lang et al (2024a)
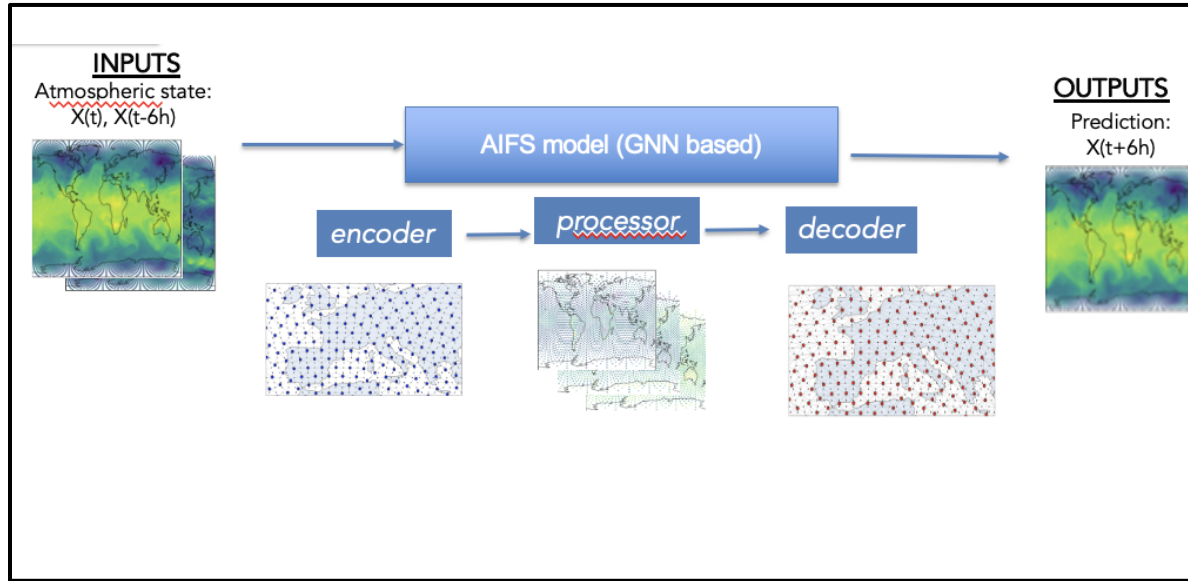
AIFS-ENS

Operational since 1.7.2025; Lang et al (2024b)
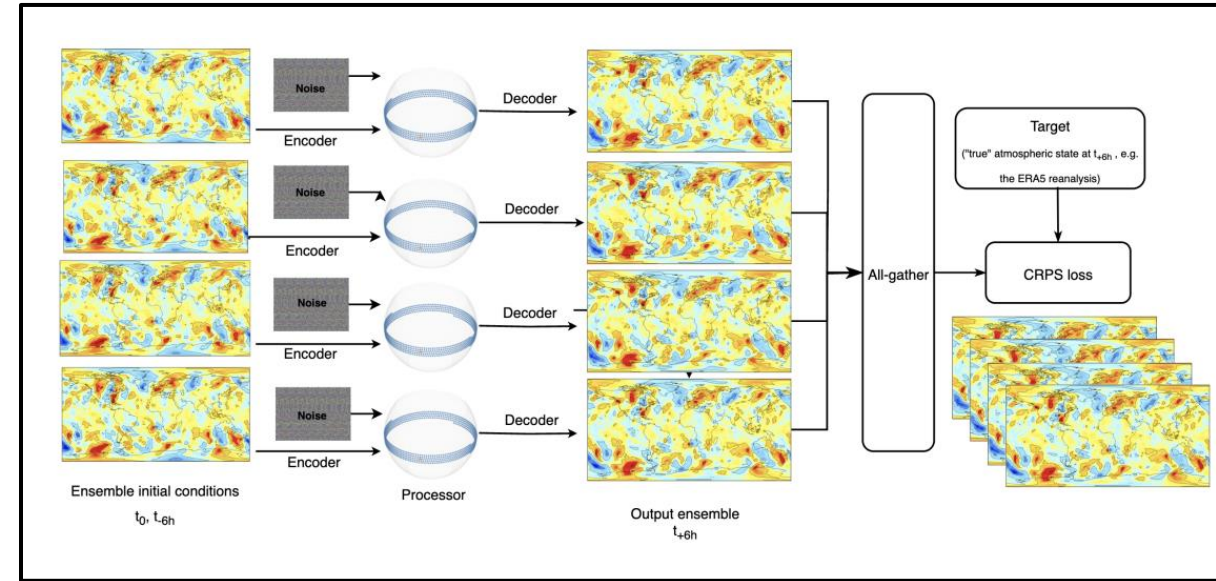
500 hPa geopotential height and 850 hPa temperature

https://charts.ecmwf.int
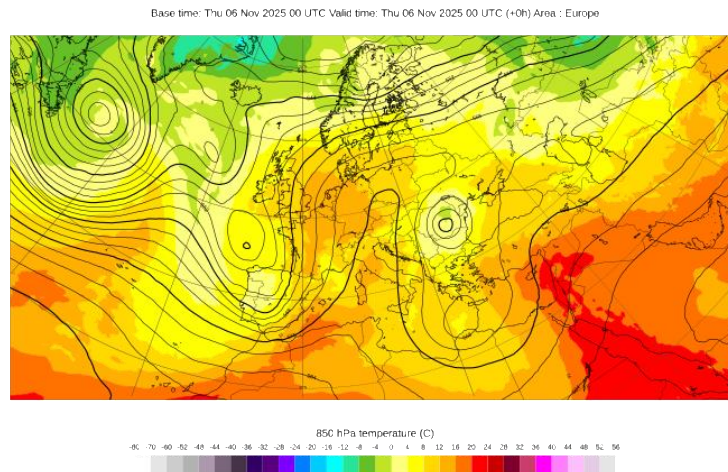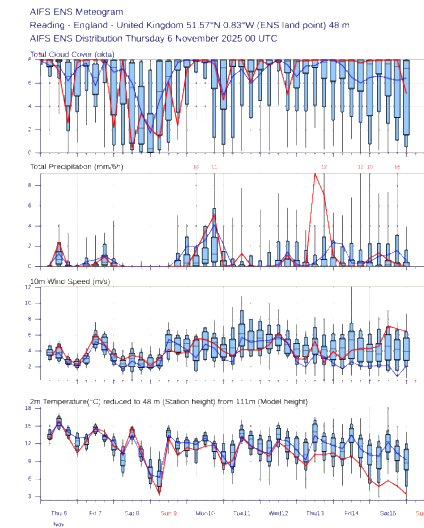
IFS-CF and AIFS-Single (example of a 5-day forecast)

Rain and mean sea level pressure

Base time: Sun 02 Nov 2025 12 UTC Valid time: Fri 07 Nov 2025 12 UTC (+120h) Area : Europe Interval (hr) : 6
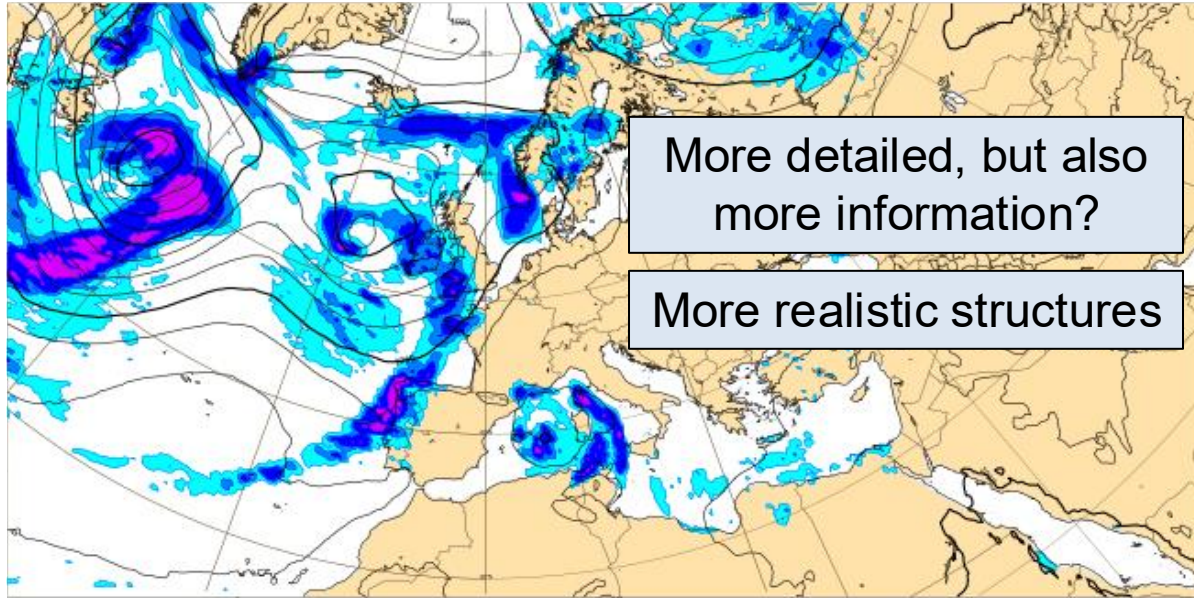
More detailed, but also more information?

More realistic structures

Total precipitation over the last 6 hours (mm)
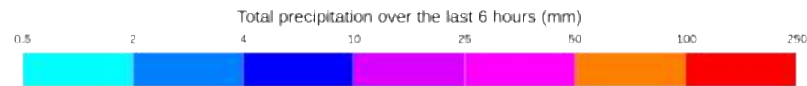
Physics-based model
(IFS-CF)
[former HRES]

AIFS Single: Rain and mean sea level pressure

Base time: Sun 02 Nov 2025 12 UTC Valid time: Fri 07 Nov 2025 12 UTC (+120h) Area : Europe Interval (hr) : 6
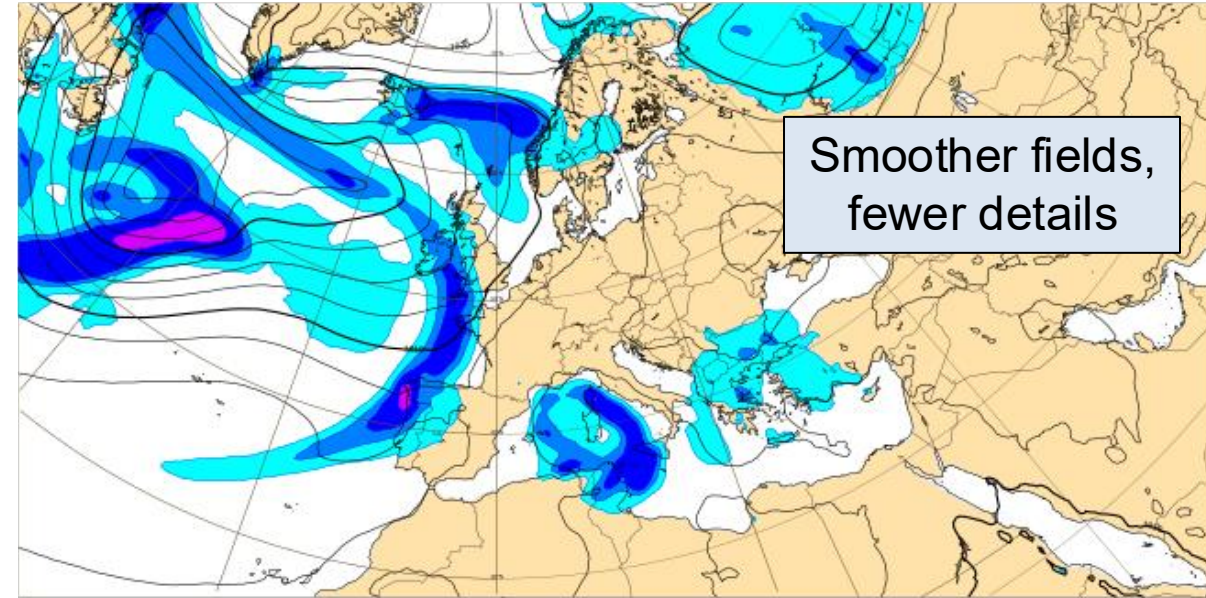
Smoother fields, fewer details

AIFS Single: Total precipitation over 6 (kg/m2 (mm))
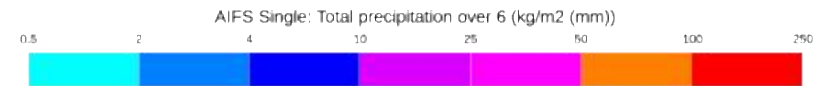
ML model
(AIFS-Single)

Precipitation forecast skill: dry vs light vs moderate/heavy
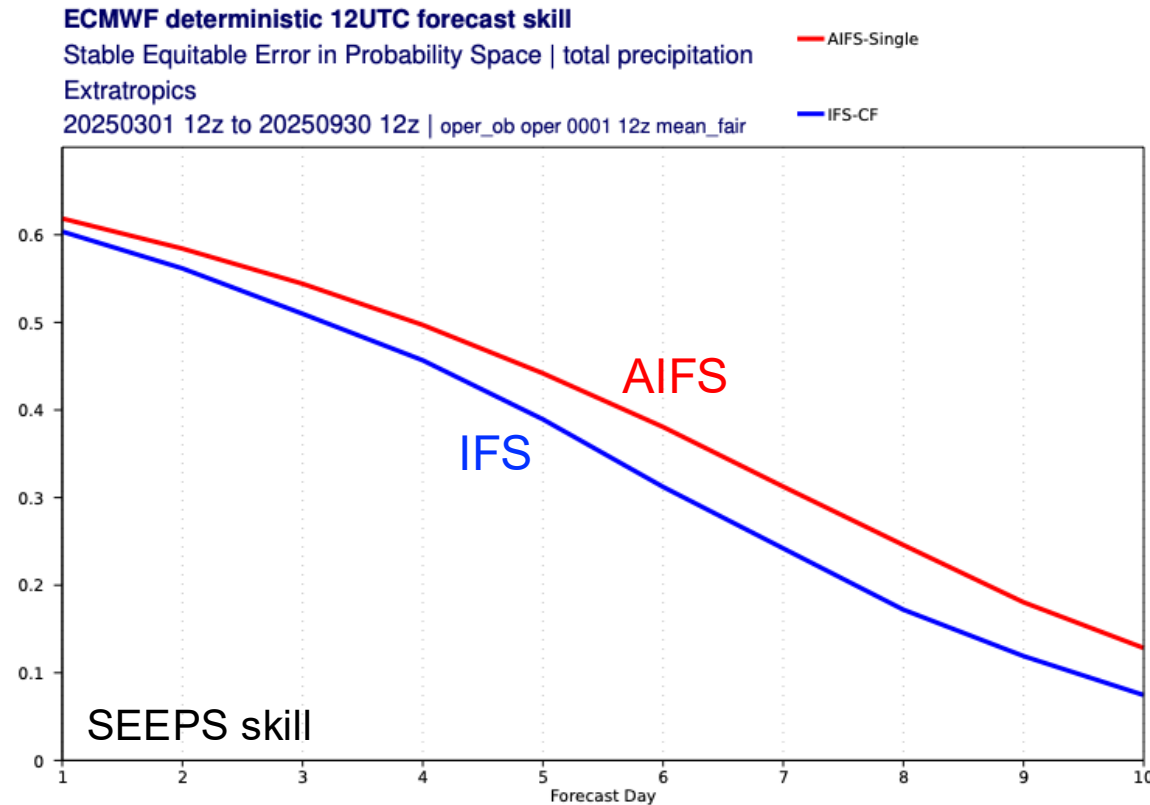
Northern Extratropics
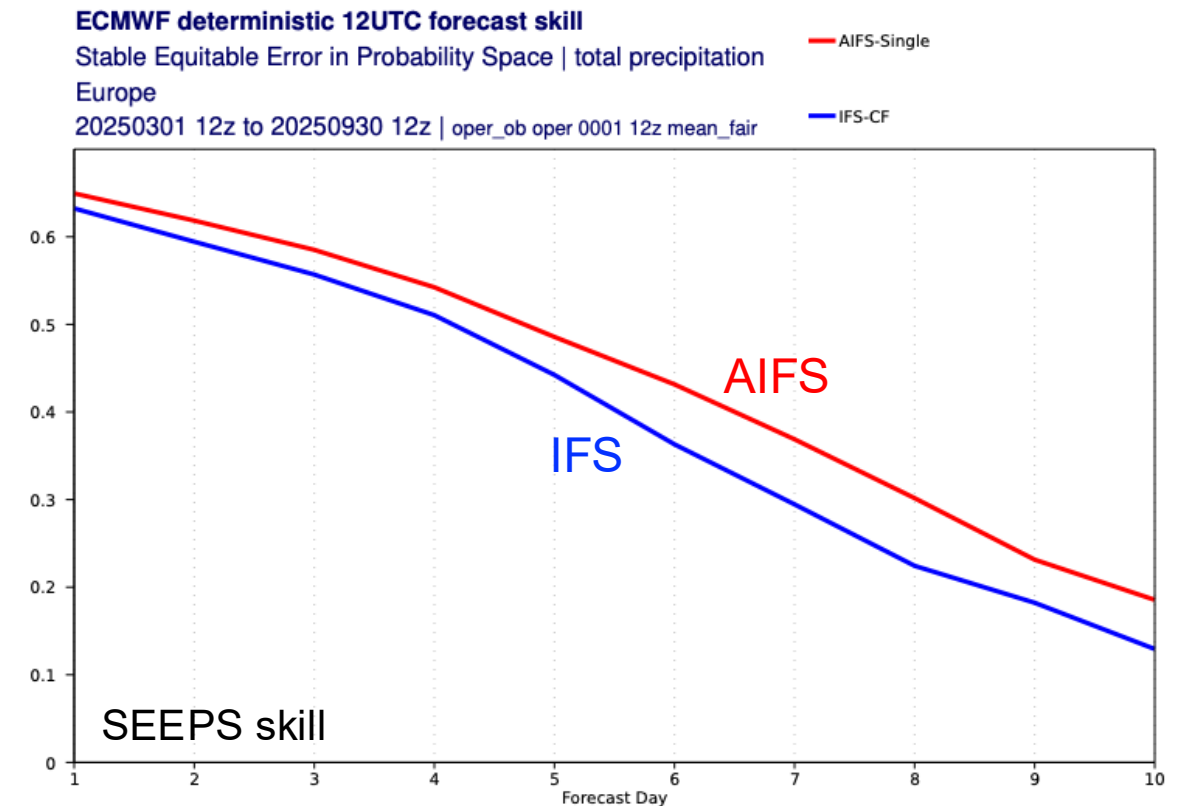
Europe

- AIFS improves on IFS, especially in the medium range (by about 0.5-1 forecast days)
- Smaller benefit in the short range

Precipitation >30mm/24 hrs: equitable threat score (ETS)
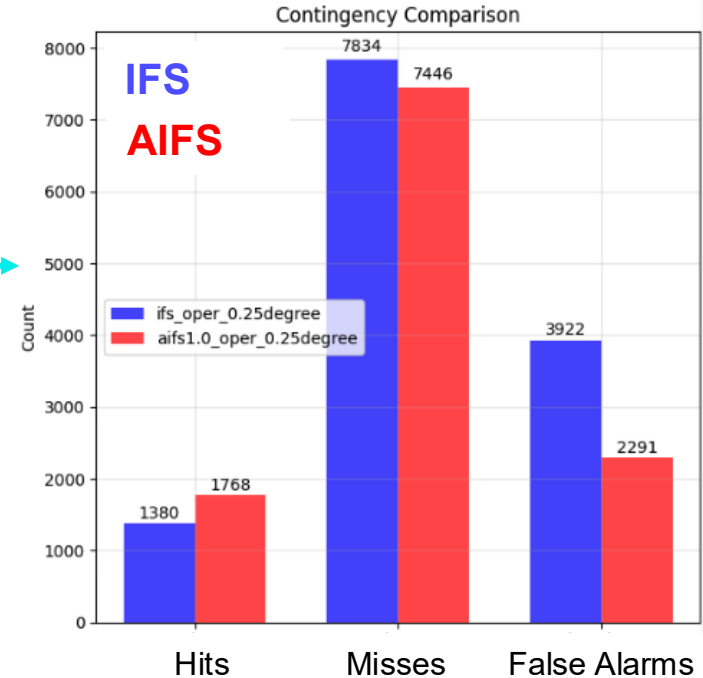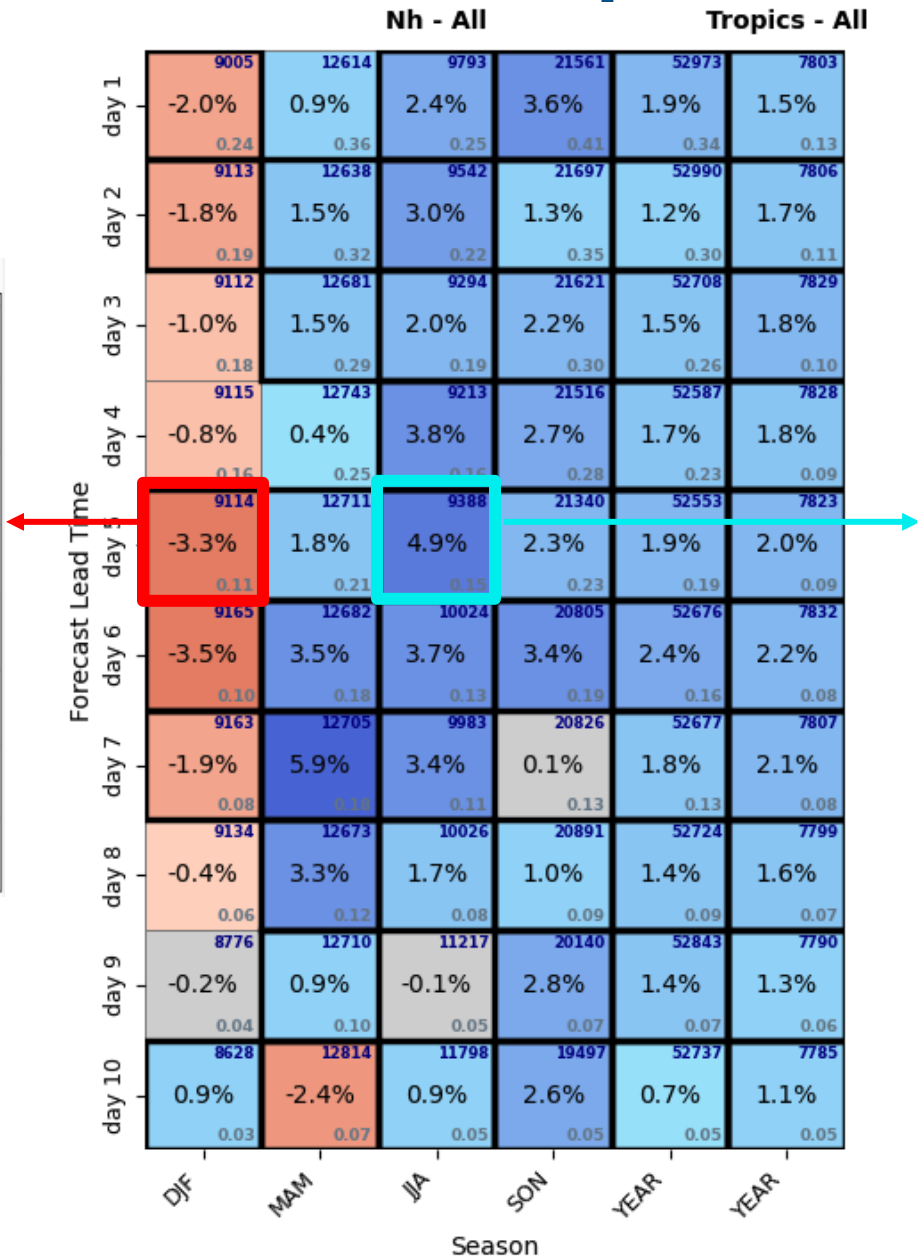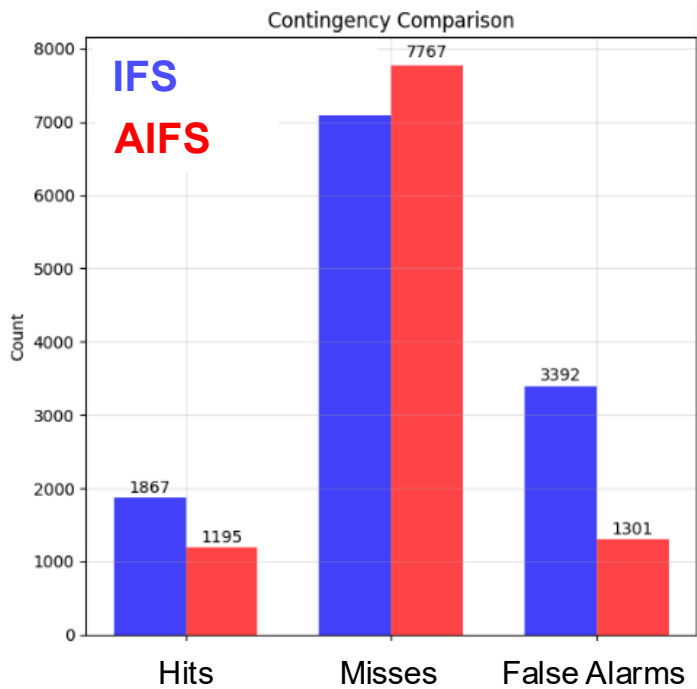
AIFS improvement stronger outside winter season

E. Gascon

IFS precipitation forecast skill gap Extratropics vs Tropics
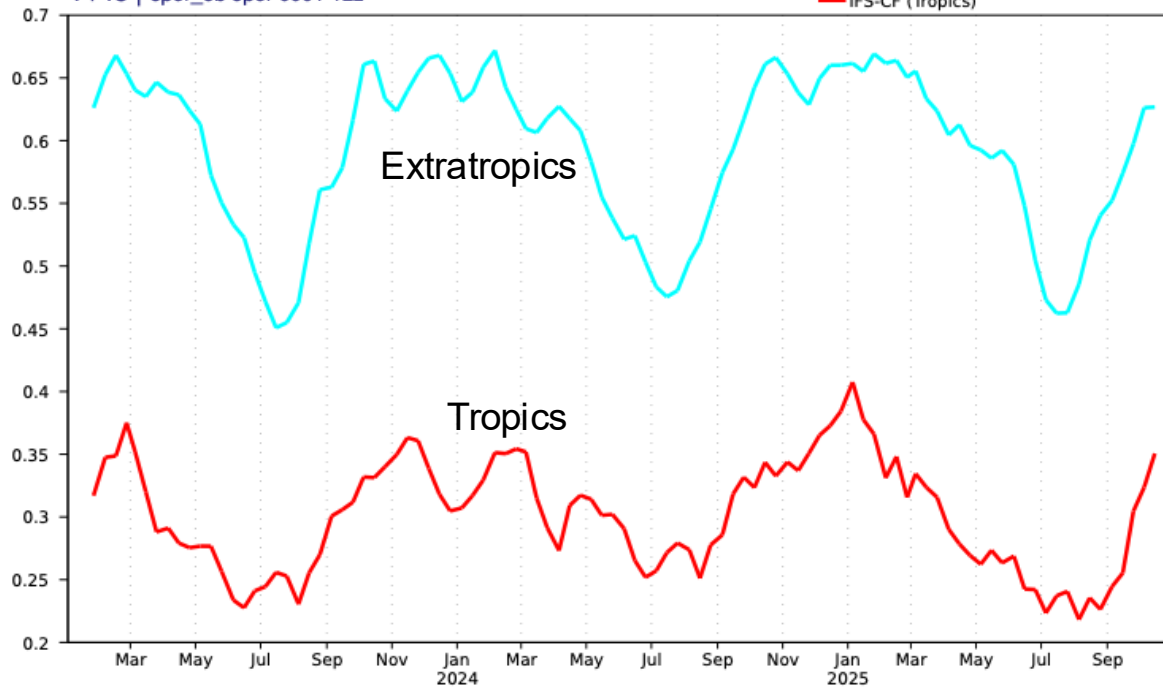
Day 2
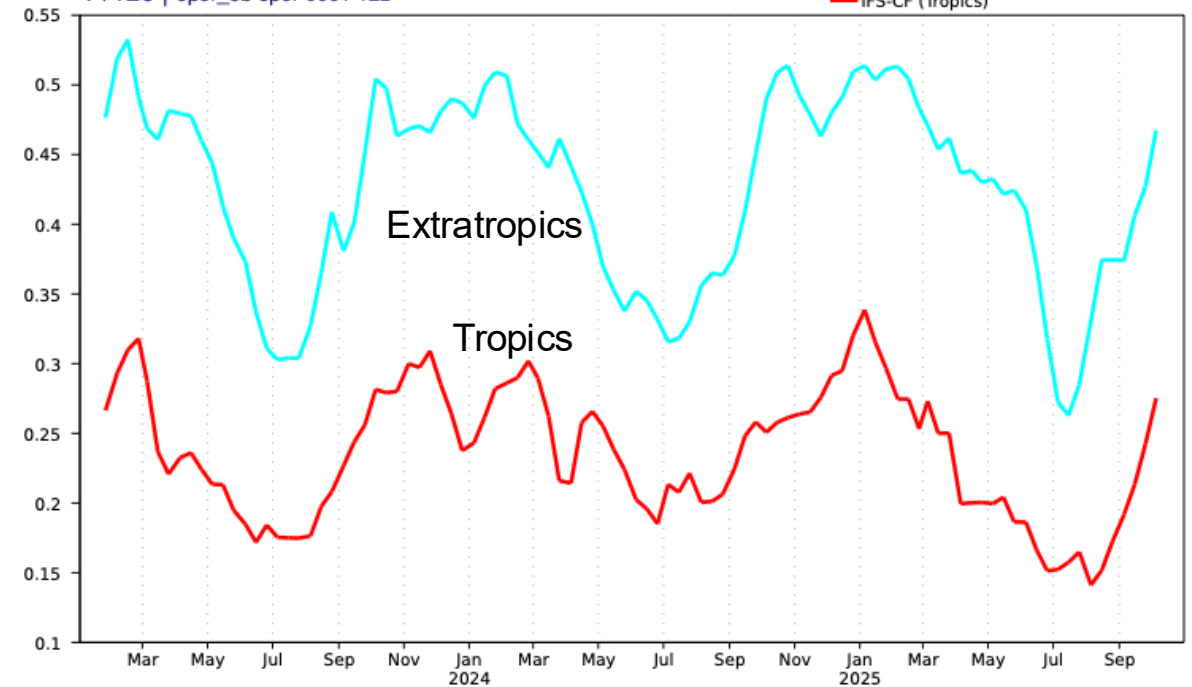
Day 5

- Extratropics almost twice as skillful than tropics in the short range
- Skill gap smaller at longer lead times

Score = SEEPS

Precipitation forecast skill gap Extratropics vs Tropics
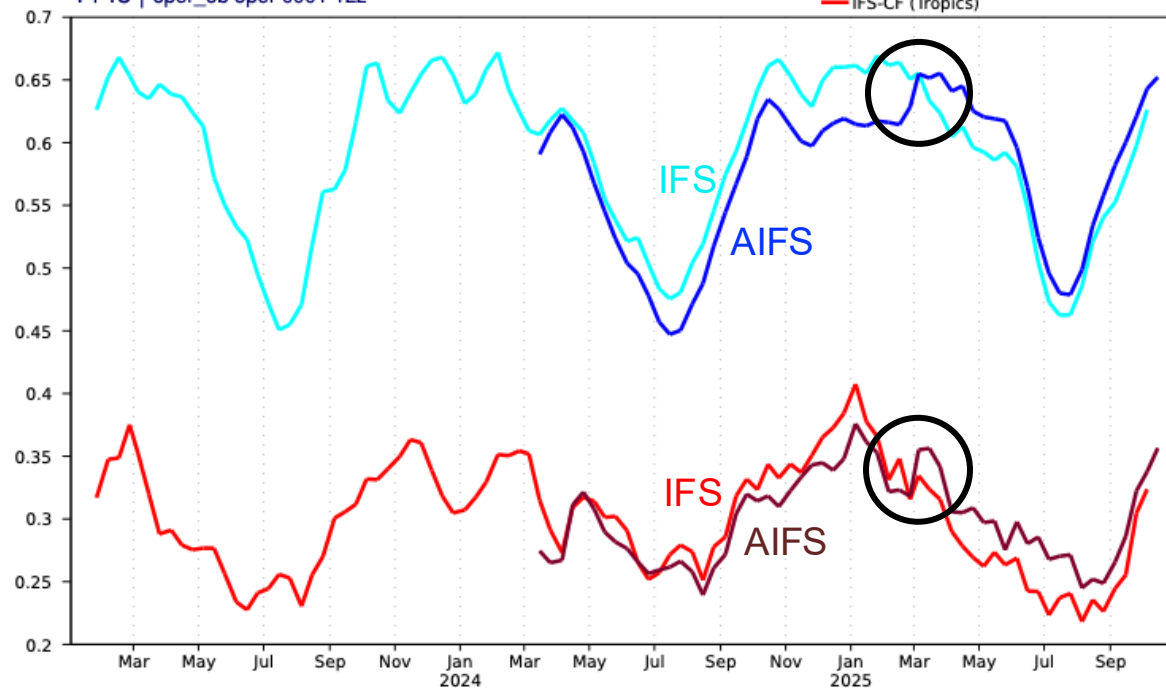
Day 2
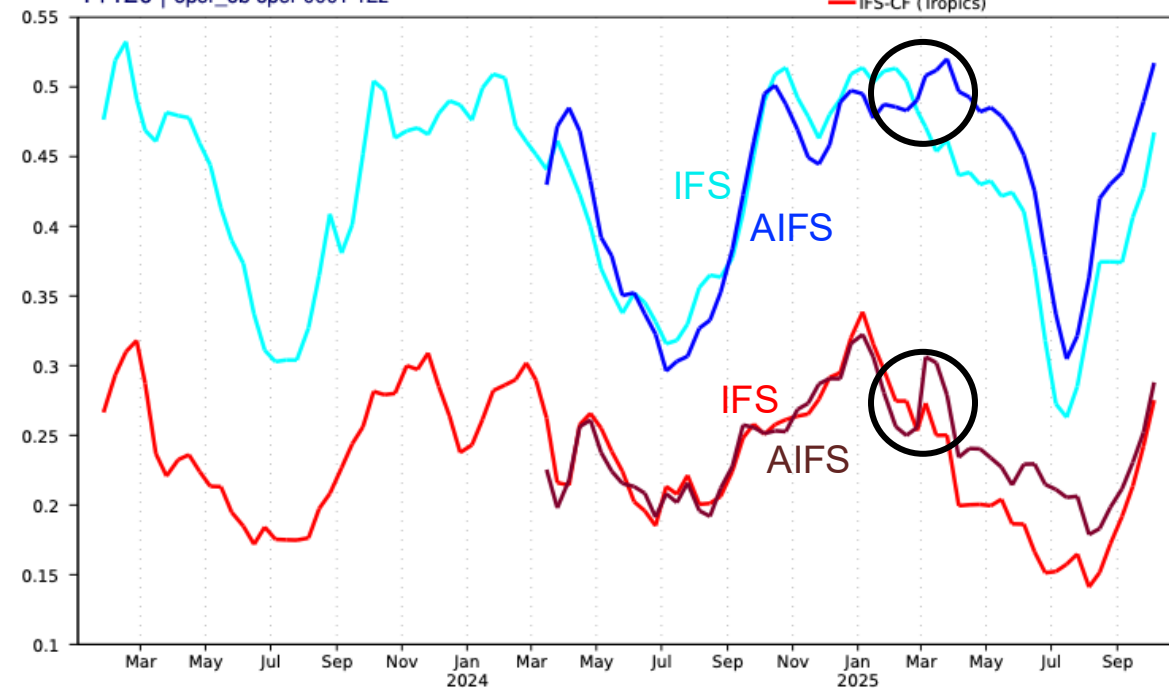
Day 5

- AIFS does not (yet) reduce the forecast skill gap significantly
- New AIFS version (since March 2025) provides improved precipitation
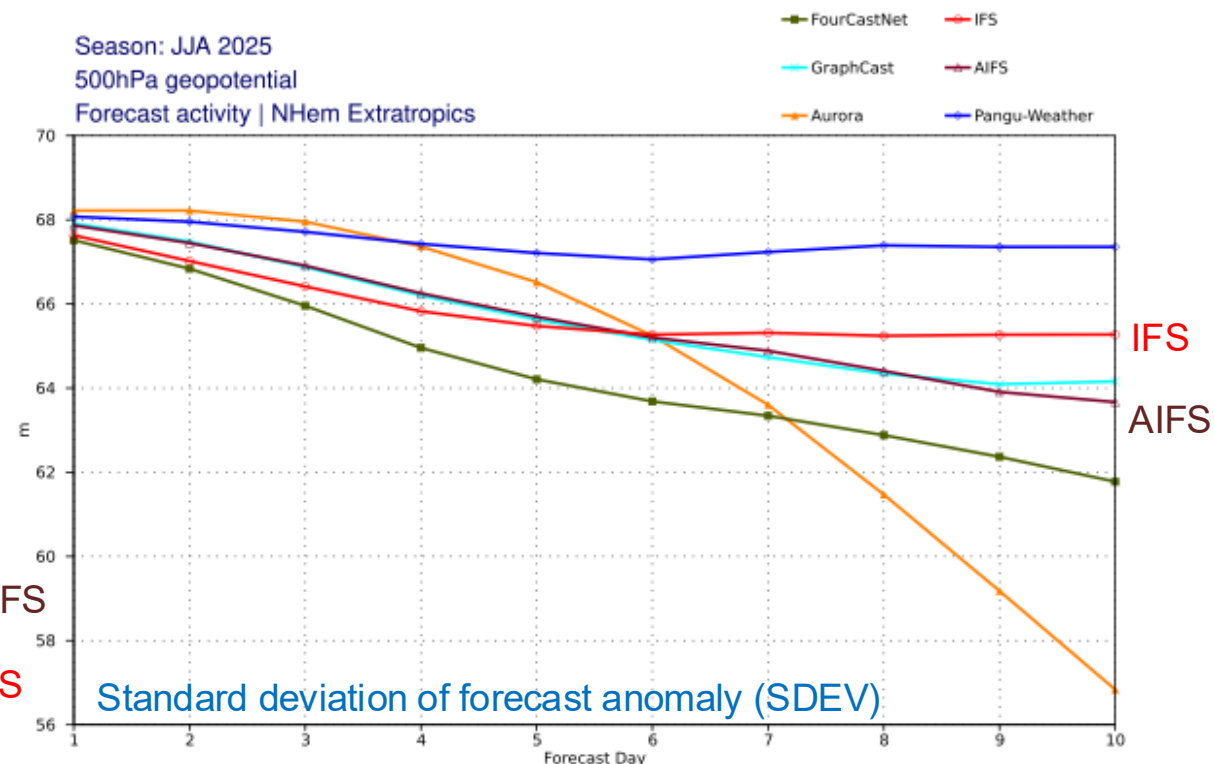
Score = SEEPS

Surface parameters: ML models vs IFS (JJA 2025, Europe)
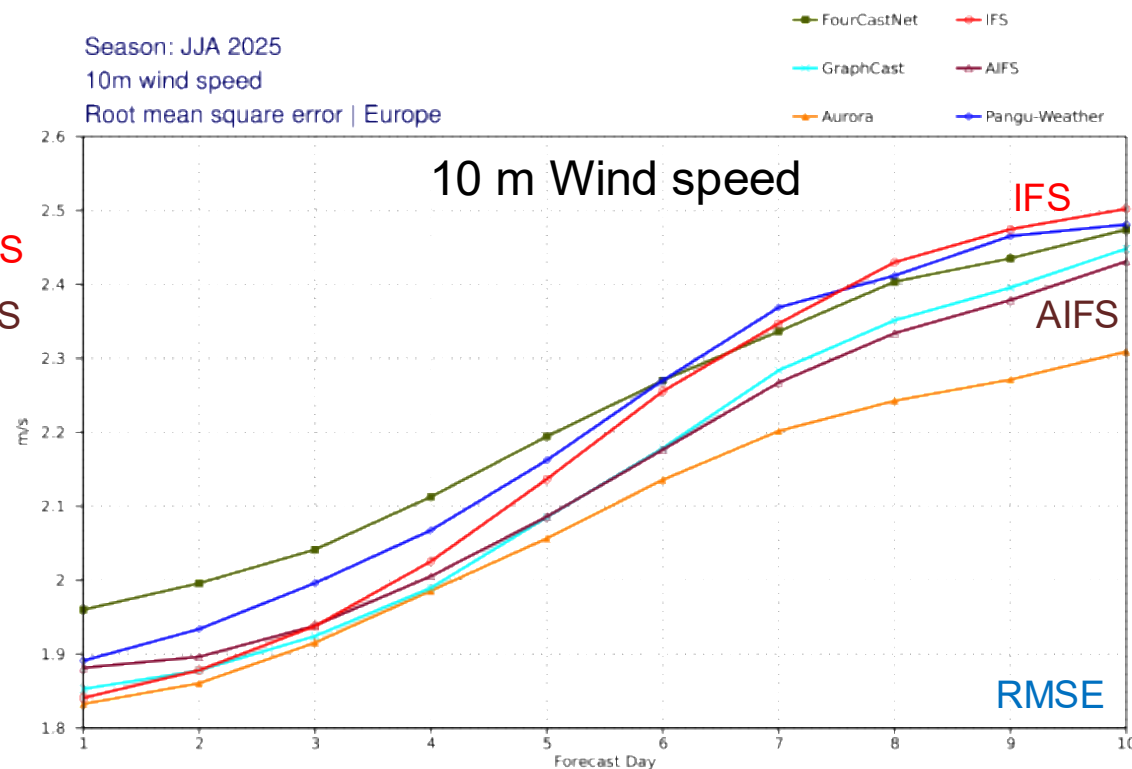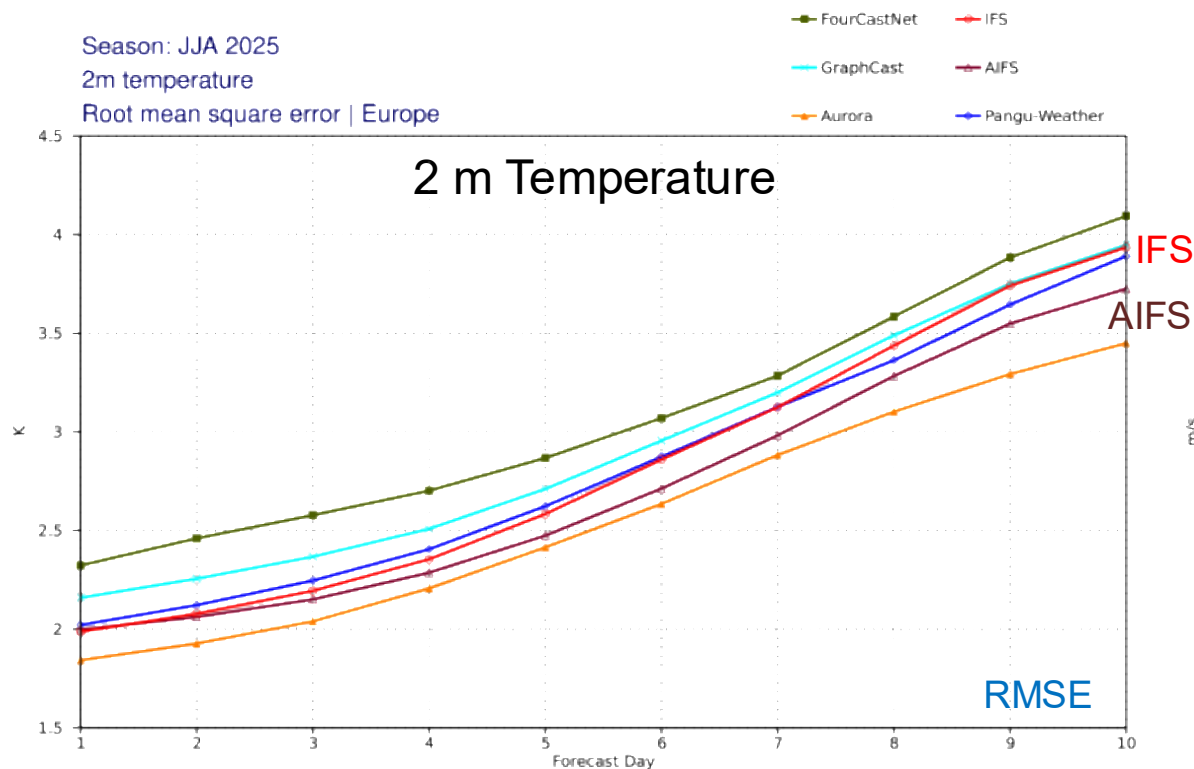
Negative bias for a lower-bounded quantity like wind speed (precipitation, radiation) helps reduce RMSE
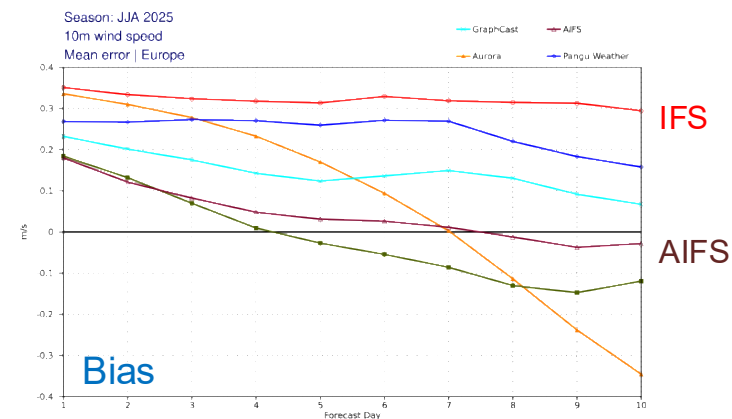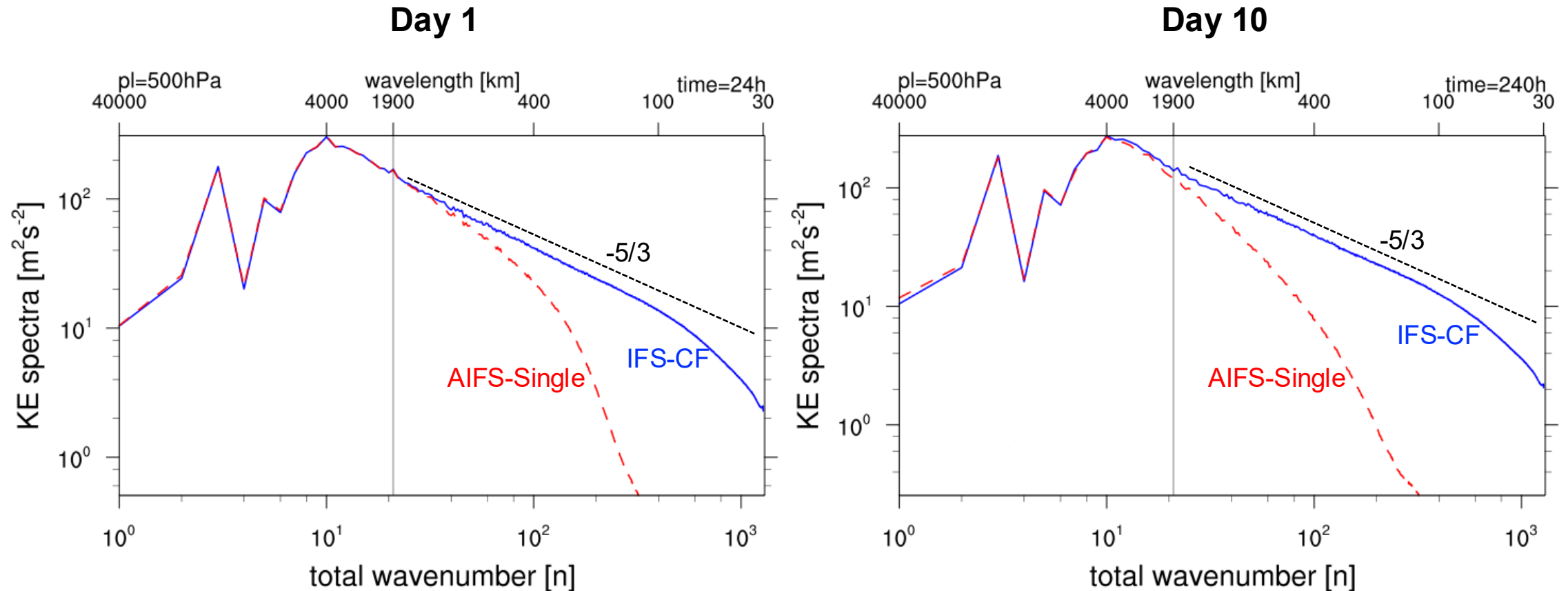
Upper-air parameters: ML models vs IFS
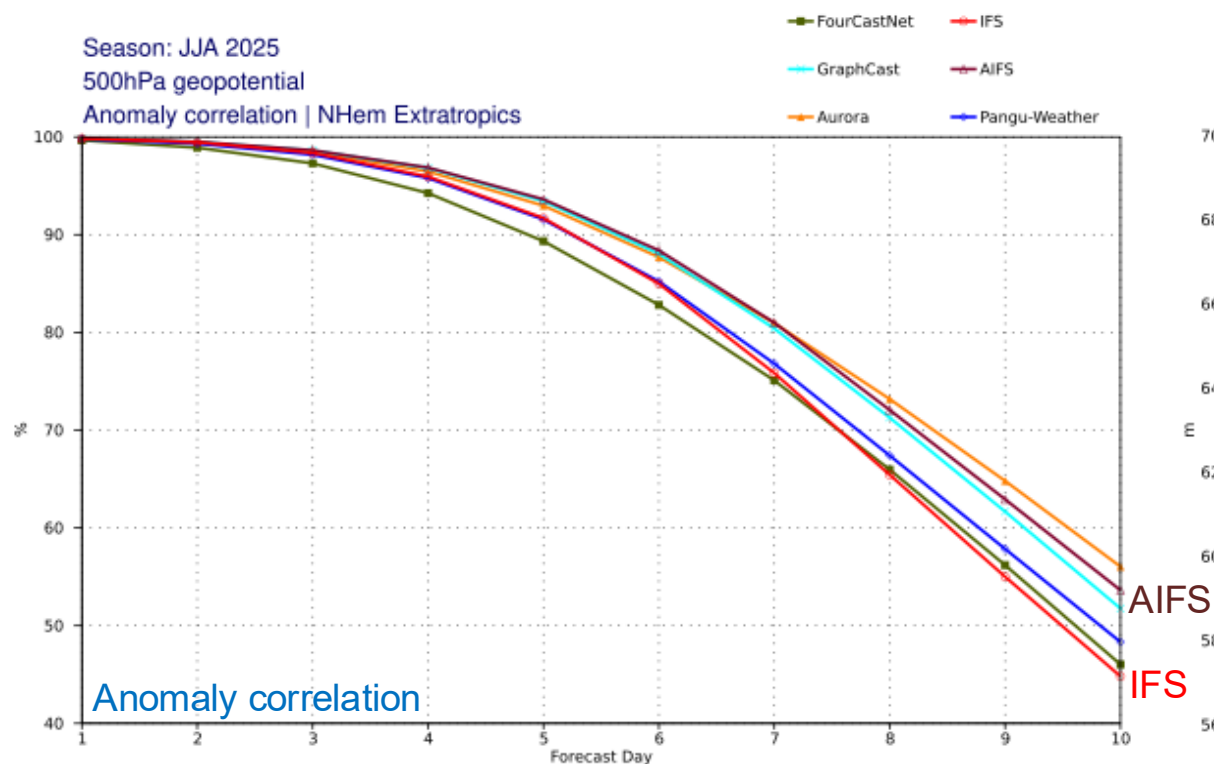
**Forecast skill**

Forecast activity

- Smoother fields help improve anomaly correlation
- ML models improve on physics-based even if activity level is OK
- But SDEV does not measure the spatial scale of variations
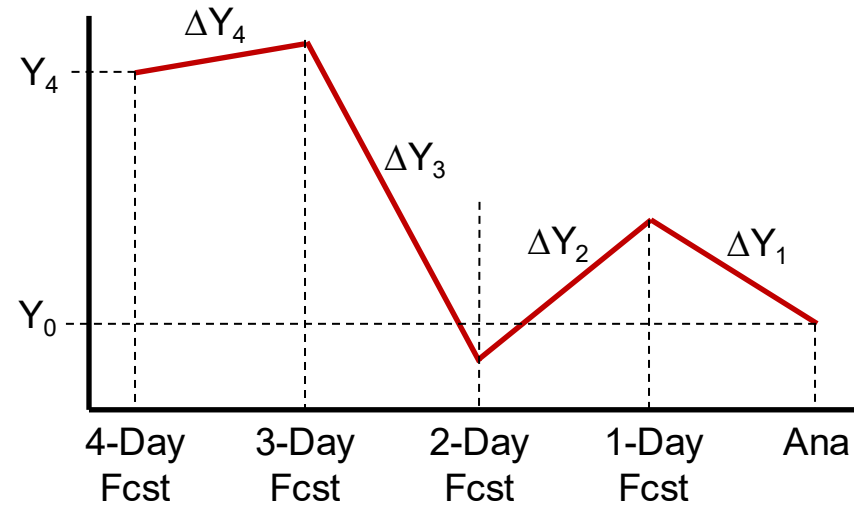
Forecast activity: spectra of 500 hPa kinetic energy

Day 1

Day 10

- IFS kinetic energy starts to drop off around 100 km
- AIFS kinetic energy drops off around 1000 km at Day 1 and 2000 km at Day 10

I. Polichtchouk

Measuring jumpiness ('flip-flop' behaviour)
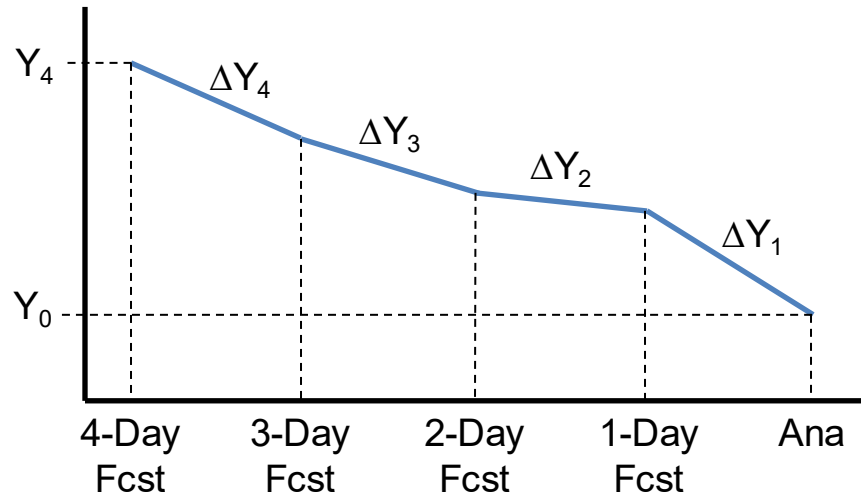
Monotonous approach towards analysis

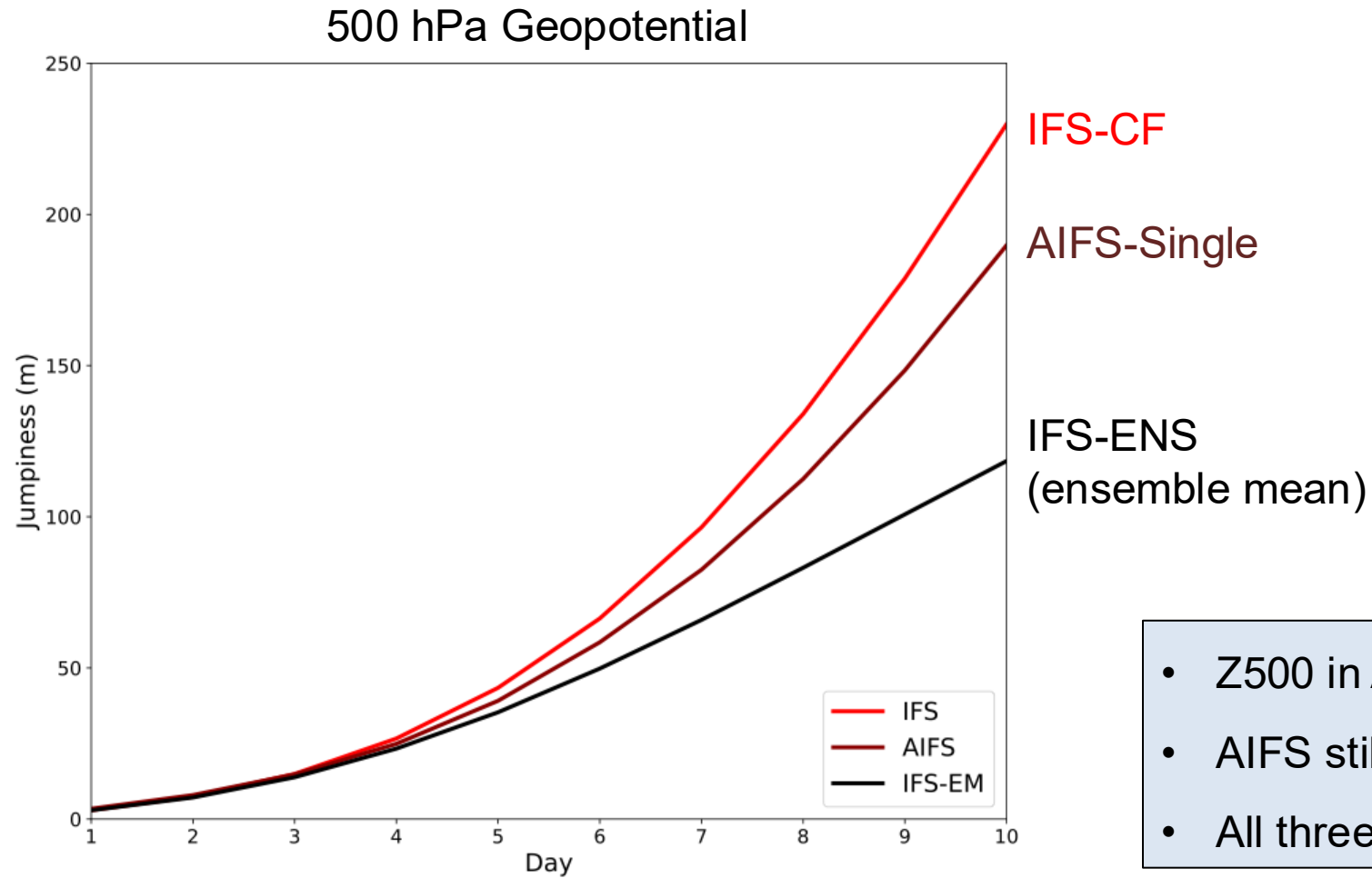$$\sum |\Delta Y_i| = |Y_4 - Y_0|$$

Jumpy approach towards analysis

$$\sum |\Delta Y_i| > |Y_4 - Y_0|$$

- Quantifying the smoothness of approach towards the observed value

Jumpiness: AIFS vs IFS

500 hPa Geopotential

IFS-CF

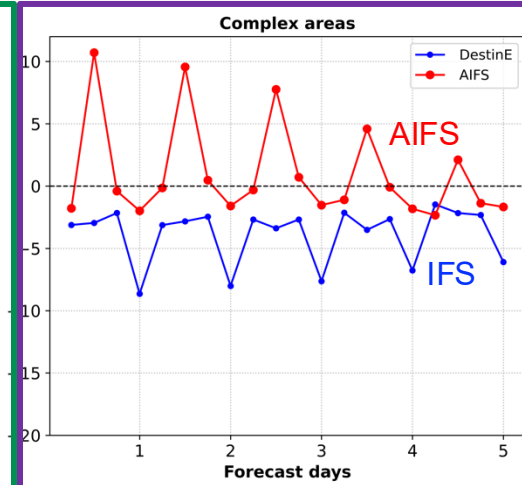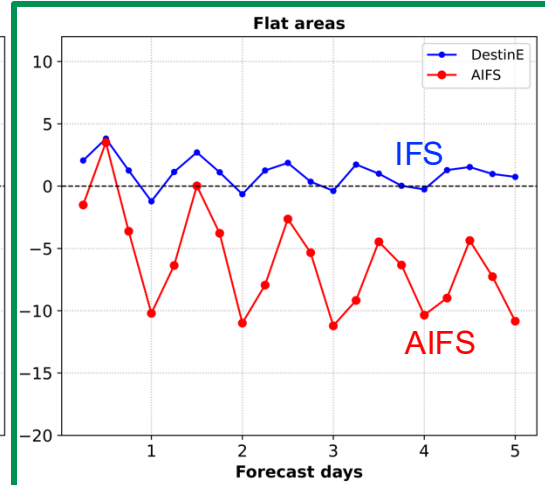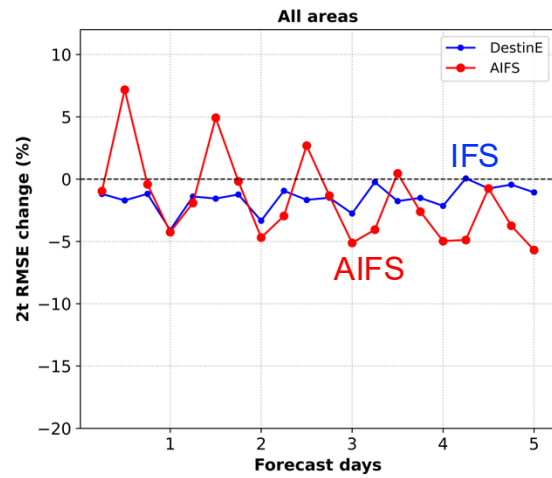AIFS-Single

IFS-ENS
(ensemble mean)

- Z500 in AIFS about 15% less jumpy than in IFS

- AIFS still far from ensemble mean

- All three very similar up to Day 3

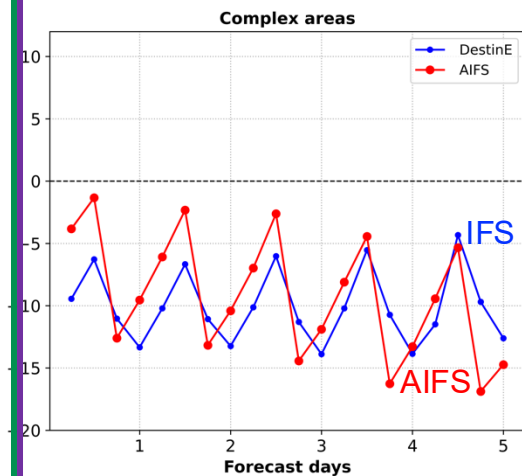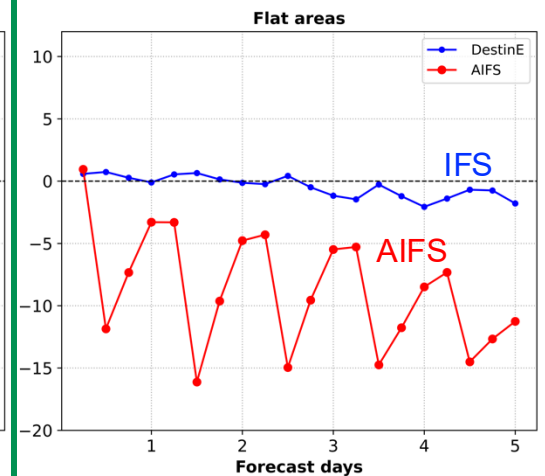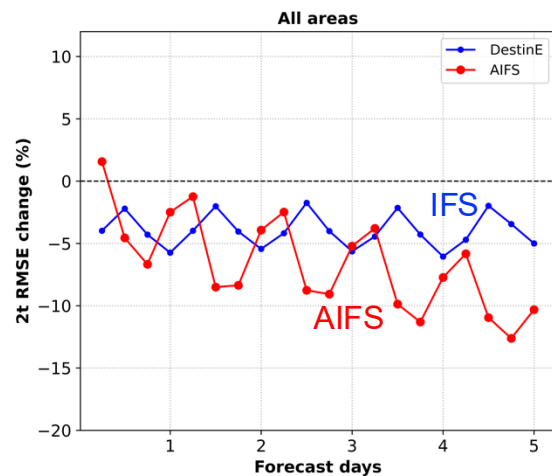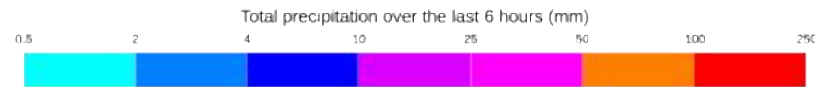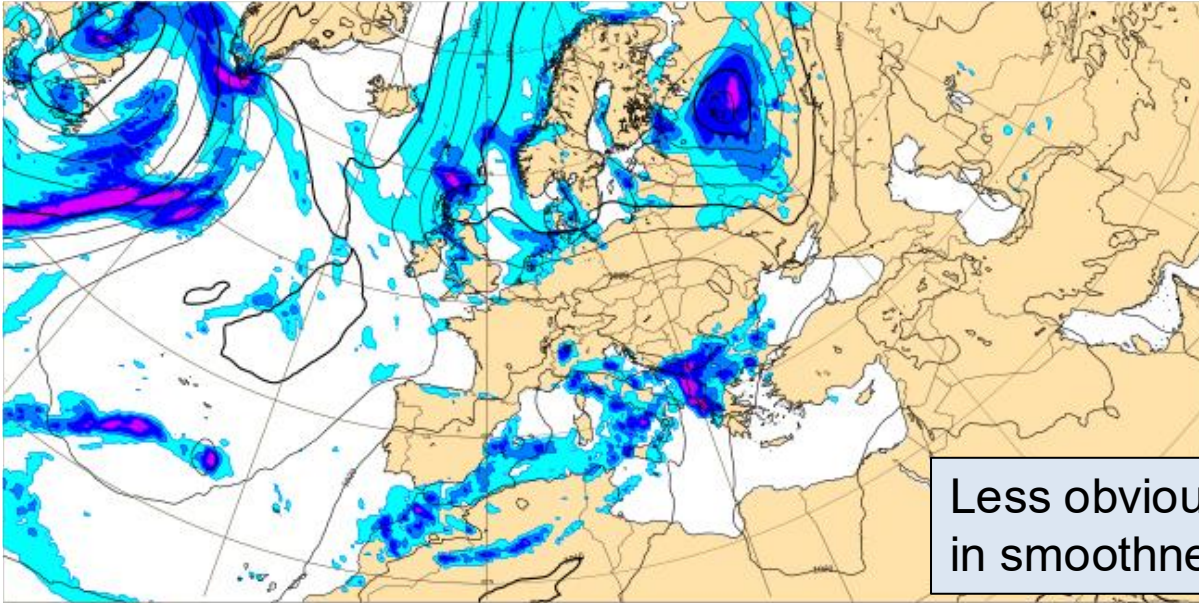# ML vs higher resolution: RMSE differences for T2m

- AIFS gives large improvement in flat areas
- High resolution IFS (4.4 km) gives more consistent improvement in complex terrain

M. Pyrina

AIFS-ENS

IFS-ENS and AIFS-ENS (example of a 5-day forecast)

Rain and mean sea level pressure

Base time: Thu 13 Nov 2025 12 UTC Valid time: Tue 18 Nov 2025 12 UTC (+120h) Area : Europe Interval (hr) : 6

AIFS ENS Control: Rain and mean sea level pressure

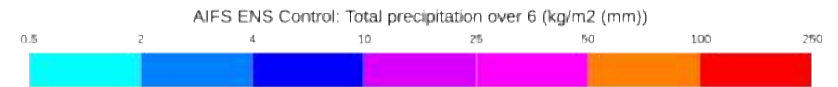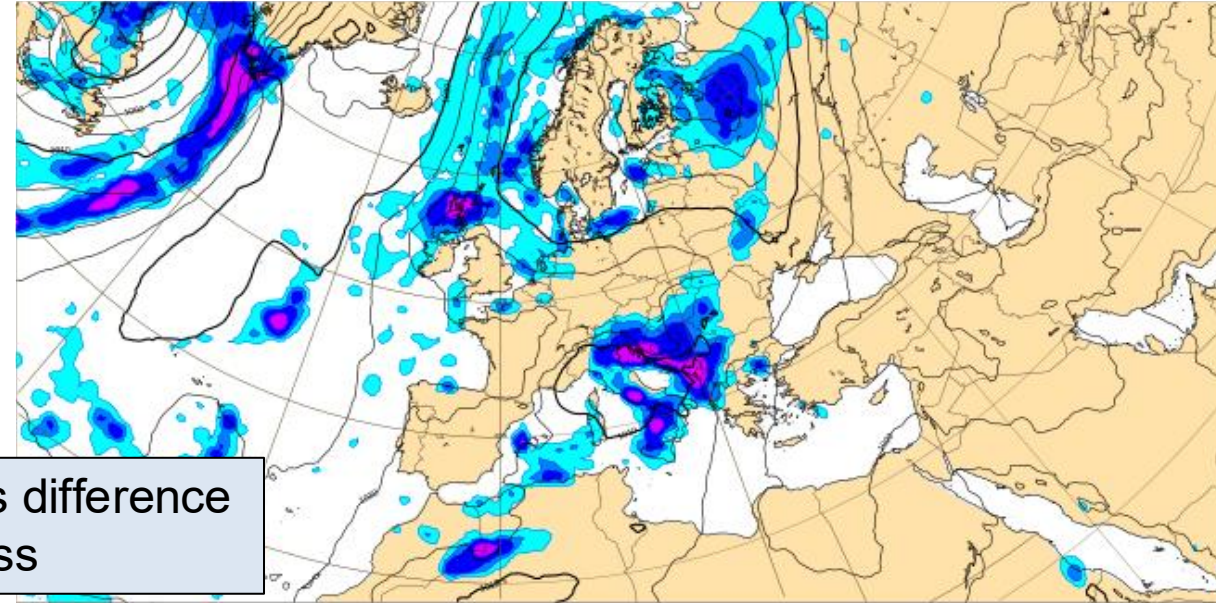Base time: Thu 13 Nov 2025 12 UTC Valid time: Tue 18 Nov 2025 12 UTC (+120h) Area : Europe Interval (hr) : 6

Less obvious difference in smoothness

Total precipitation over the last 6 hours (mm)

0.5   2   4   10   25   50   100   250

AIFS ENS Control: Total precipitation over 6 (kg/m2 (mm))

0.5   2   4   10   25   50   100   250

Physics-based model
(IFS-ENS)

ML model
(AIFS-ENS)

AIFS-ENS vs AIFS-Single: spectra

850 hPa temperature

Legend:
- 24h AIFS
- 240h AIFS
- 24h AIFS-CRPS
- 240h AIFS-CRPS

AIFS-ENS
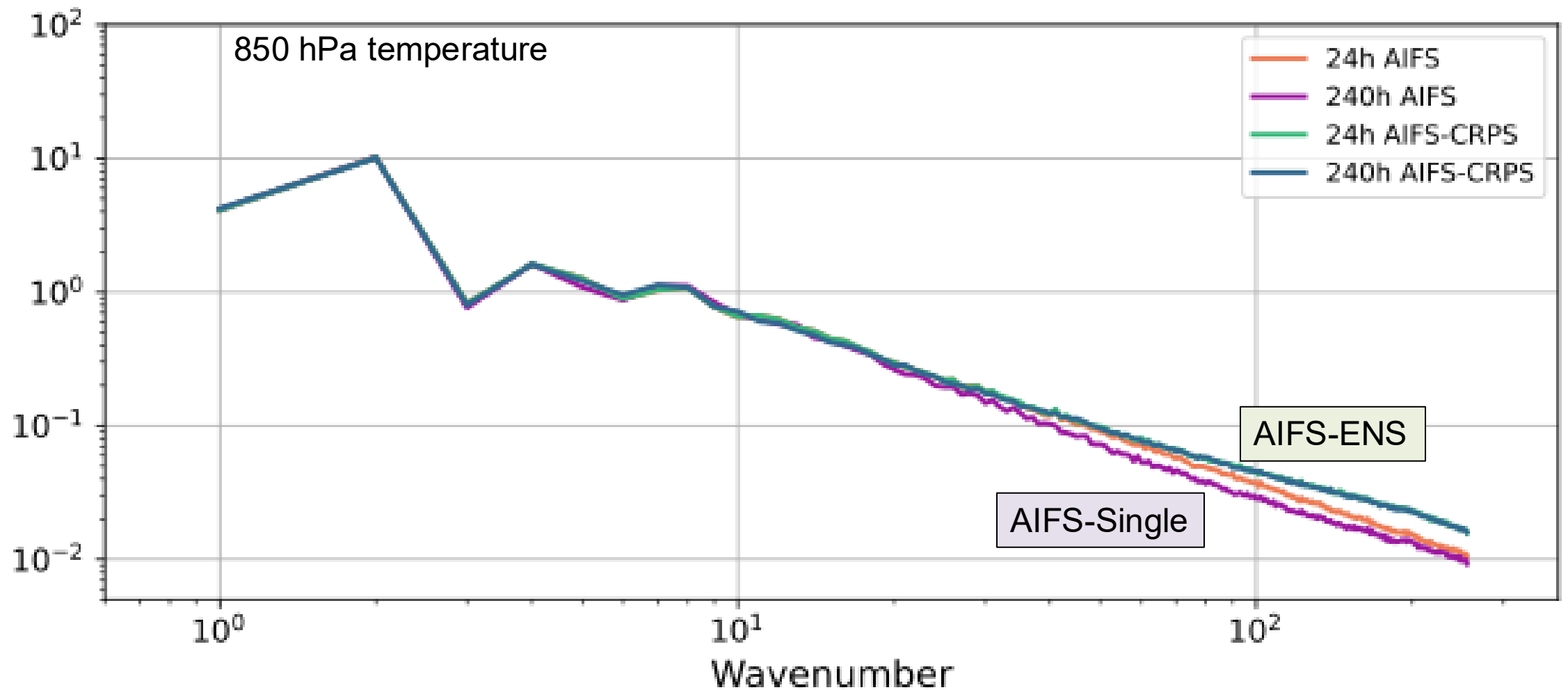
AIFS-Single

- AIFS-ENS keeps smaller scales better than AIFS-Single
- AIFS-ENS does not lose activity with lead time

S. Lang

Predicting the large-scale flow: 500 hPa anomaly correlation

Anomaly correlation | 500hPa geopotential
NHem Extratropics
20250701 00z to 20251020 00z | oper_an 0001 00z mean_fair

Legend:
- AIFS-EM (red dotted)
- IFS-EM (blue dashed)
- AIFS-Single (red solid)
- IFS-CF (blue solid)

Deterministic use of the ensemble:
ACC of ensemble mean
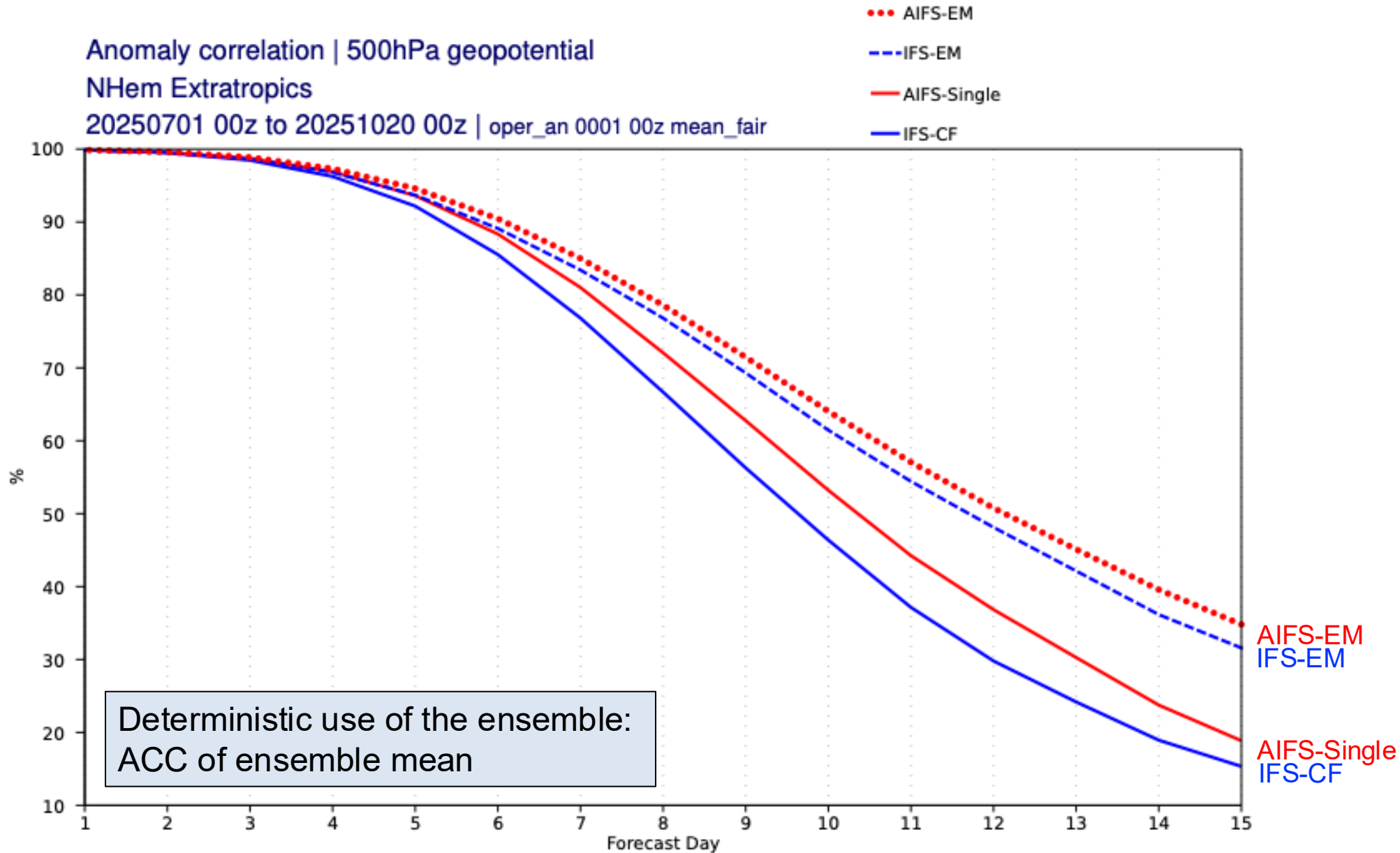
AIFS-ENS vs IFS-ENS: scorecard
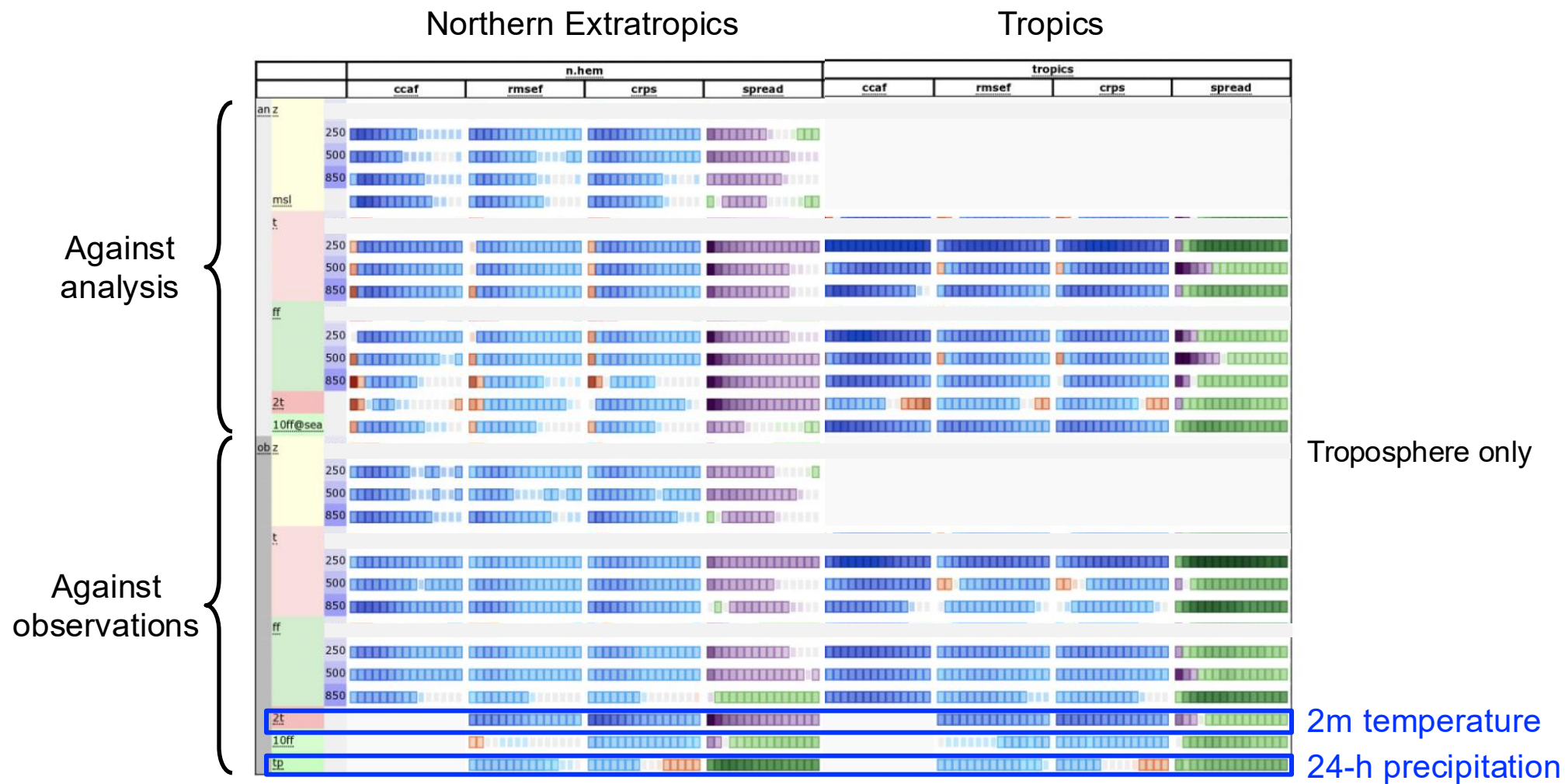
- AIFS-ENS gives large improvements across parameters, levels, lead times, domains
- Stratosphere issue (100 hPa) to be resolved by modified training

Lang at al. (2024)

ENS skill of 2 m temperature (July-Oct 2025)

Continuous ranked probability skill score | 2 meter temperature
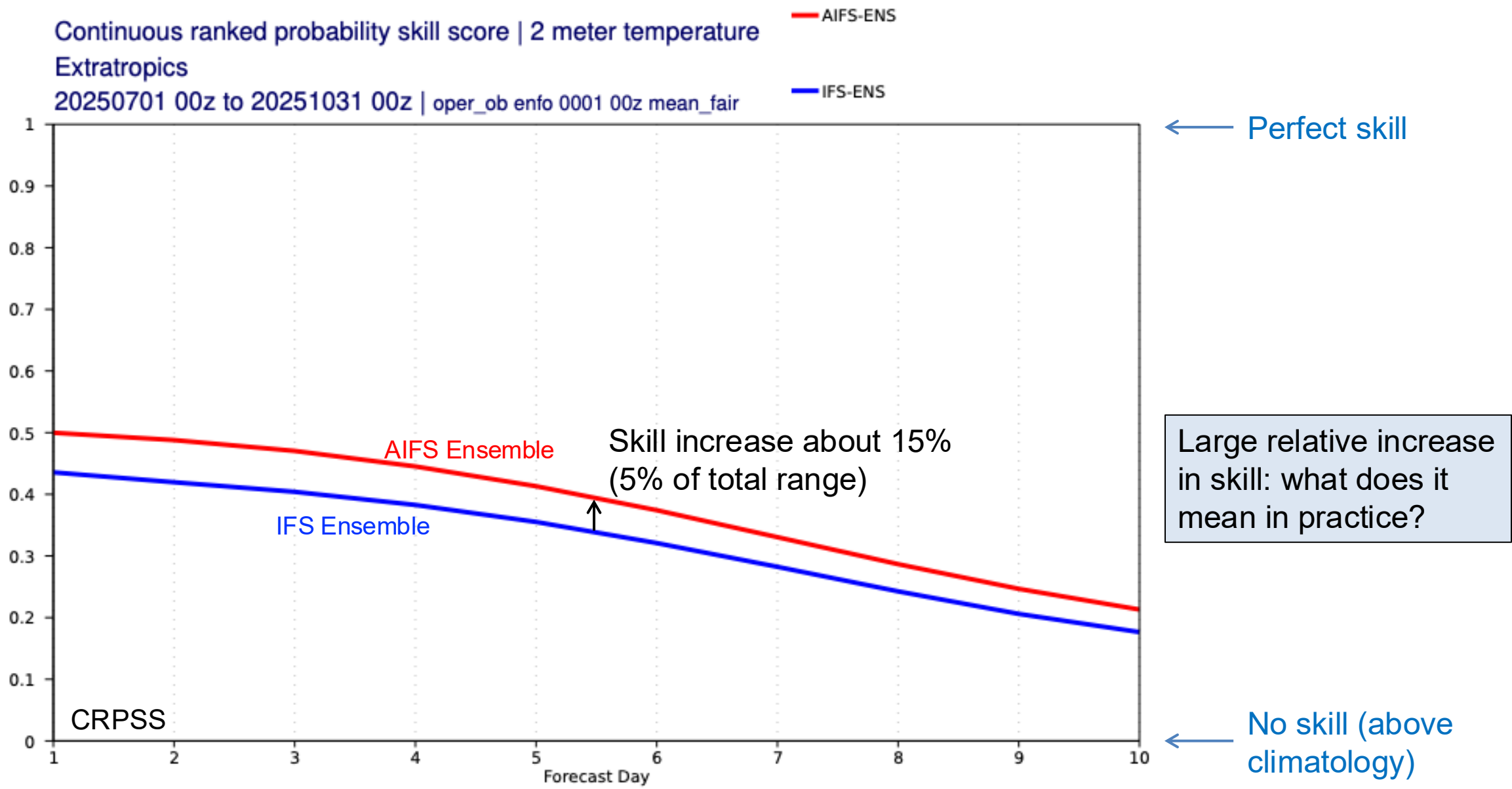Extratropics
20250701 00z to 20251031 00z | oper_ob enfo 0001 00z mean_fair

— AIFS-ENS
— IFS-ENS

AIFS Ensemble

IFS Ensemble

Skill increase about 15% (5% of total range)

CRPSS

Forecast Day

← Perfect skill

Large relative increase in skill: what does it mean in practice?

← No skill (above climatology)

ENS skill of 24-h precipitation (July-Oct 2025)

Continuous ranked probability skill score | total precipitation
Extratropics
20250701 00z to 20251031 00z | oper_ob enfo 0001 00z mean_fair

AIFS-ENS
IFS-ENS

Perfect skill

AIFS Ensemble

IFS Ensemble

Skill increase about 15%
(3% of total range)

Large relative increase
in skill: what does it
mean in practice?

CRPSS

No skill (above
climatology)
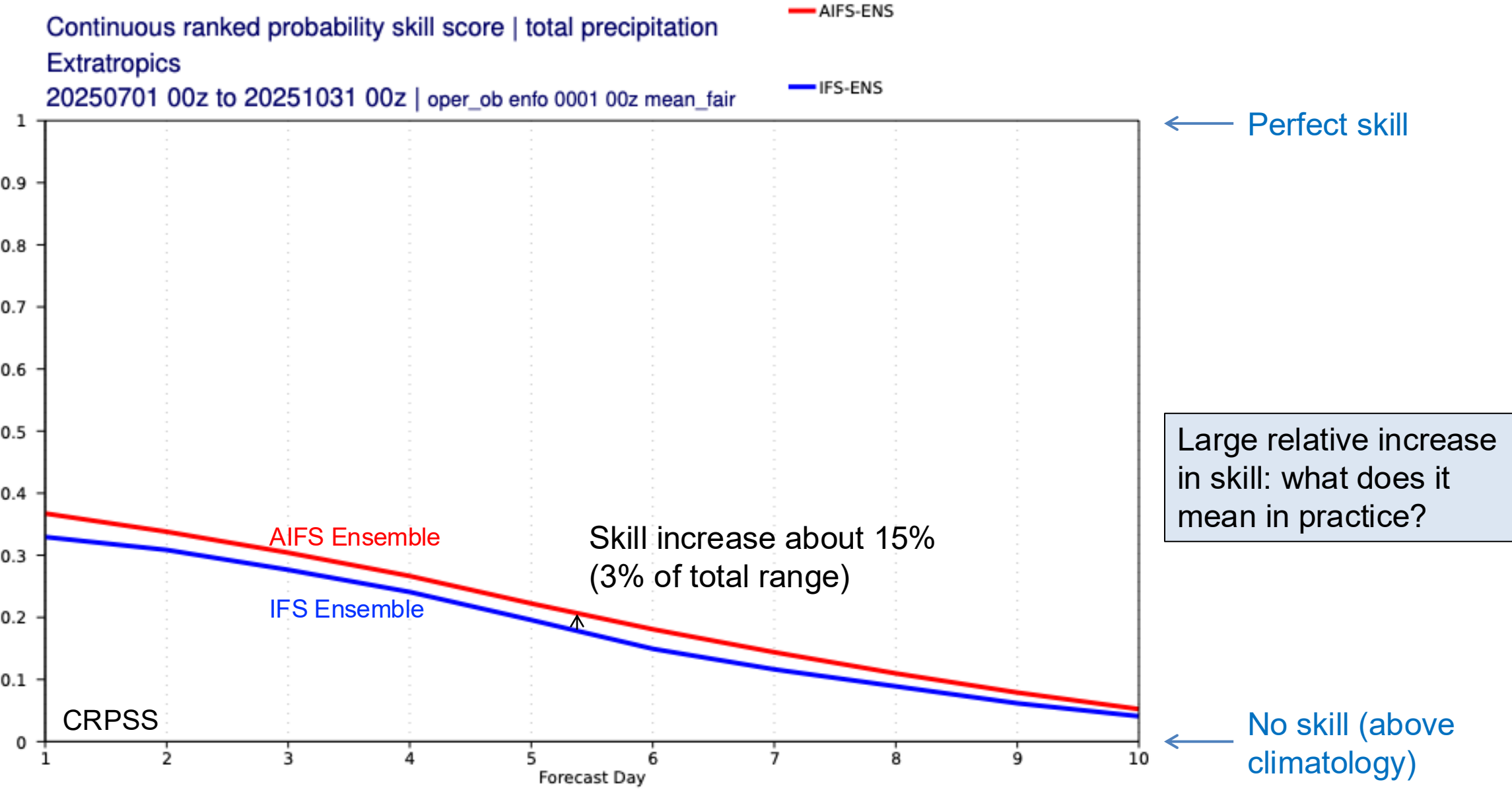
Concluding remarks

- ML forecasts bring substantial improvements

- Designed to minimize RMSE, CRPS

- Look at results from categorical verification

- Important to check forecast activity and spectra

- ML forecasts are less jumpy

- ML forecast for extremes: depends on parameter

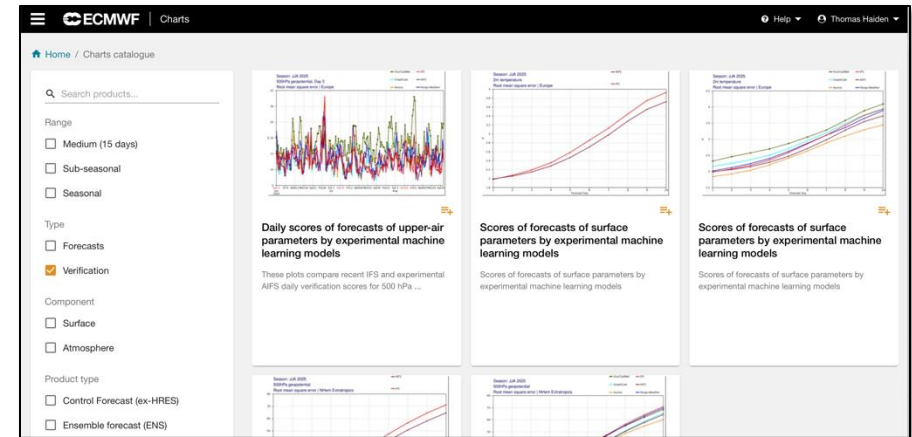- ML forecasts lack some of the physical consistencies built into physics-based models

→ ML Webinar #3 by Linus Magnusson on 25 November

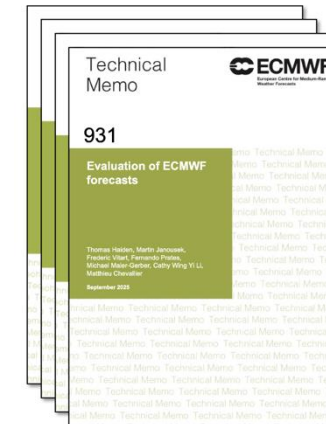

ECMWF

Verification resources & links

- ECMWF OpenCharts page: https://charts.ecmwf.int

    AIFS-Single only, AIFS-ENS to be added

- Annual ECMWF Tech Memo on forecast performance: https://www.ecmwf.int/en/publications/technical-memoranda

    Historically main focus on IFS but now including AIFS

- AIFS blog: https://www.ecmwf.int/en/about/media-centre/aifs-blog

    In-depth evaluations, case studies