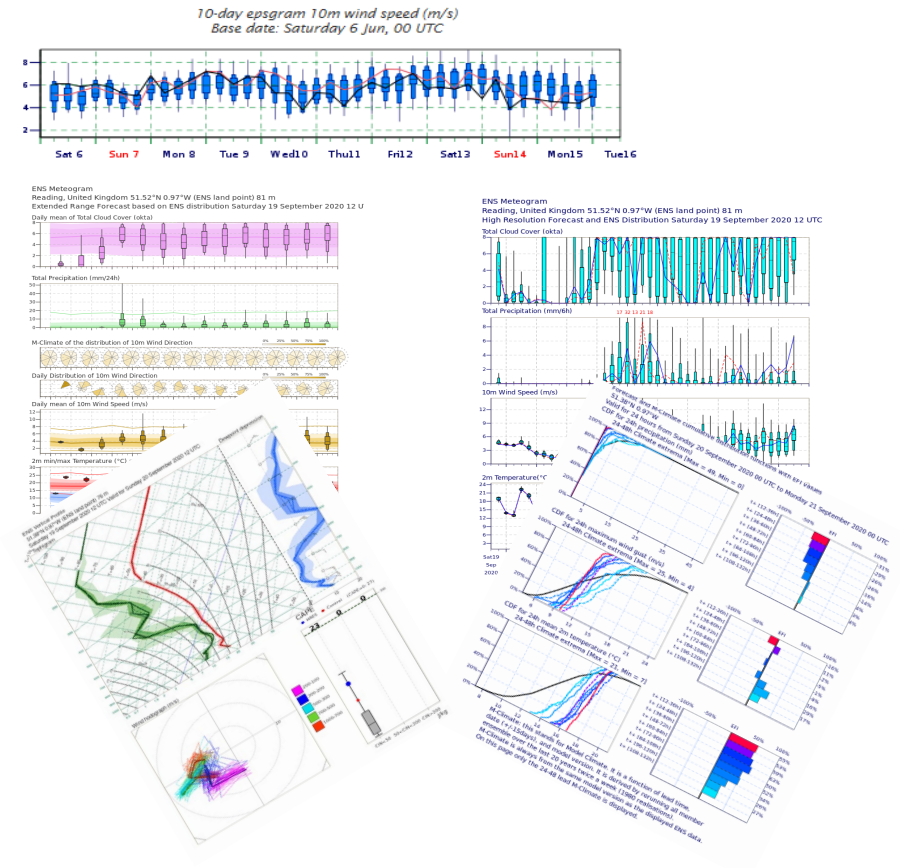


# Meteograms with changing resolution and visibility meteograms

Cihan Sahin, Axel Bonet, Sylvie Lamy-Thepaut, Tim Hewson & Many other colleagues



# Ensemble Meteograms (point data)

Point data in graphical form come in different shapes but all based on Ensemble data

- 10-day meteograms
- 10-day meteograms for wave parameters
- 15-day meteograms
- 15-day meteograms with model climate
- Plumes
- Precipitation type
- Visibility meteogram
- EFI and CDF diagrams
- ENS Vertical profiles
- Extended range meteograms (Anomalies)
- Extended range CDFs

The screenshot displays the ECMWF charts website interface. On the left is a search and filter sidebar. The main area shows a grid of product thumbnails, each with a title, a small preview image, and a brief description.

**Search products...**

**Range**

- Medium (15 days)
- Extended (42 days)
- Long (Months)

**Type**

- Forecasts
- Verification

**Component**

- Surface
- Atmosphere
- Next IFS version (cy48r1)

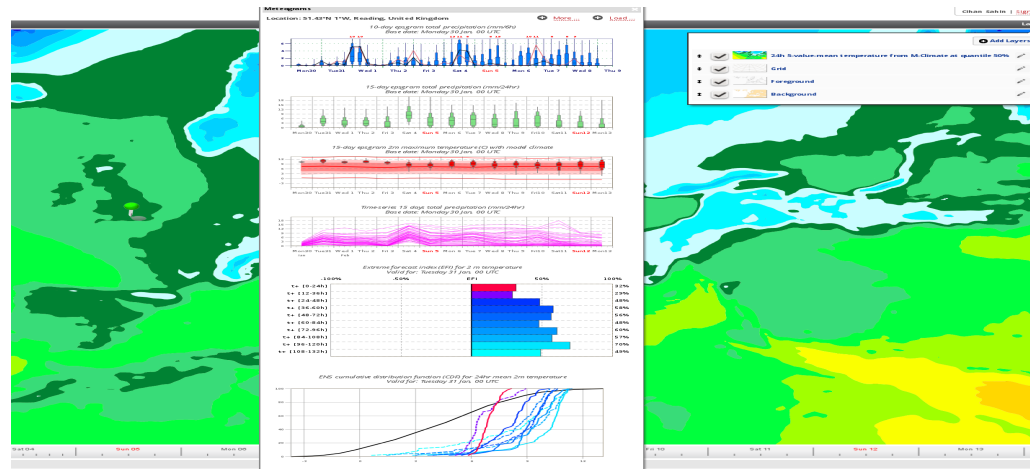
**Product type**

- High resolution forecast (HRES)
- Ensemble forecast (ENS)
- Combined (ENS + HRES)
- Extreme forecast index
- Point-based products
- Atmospheric composition

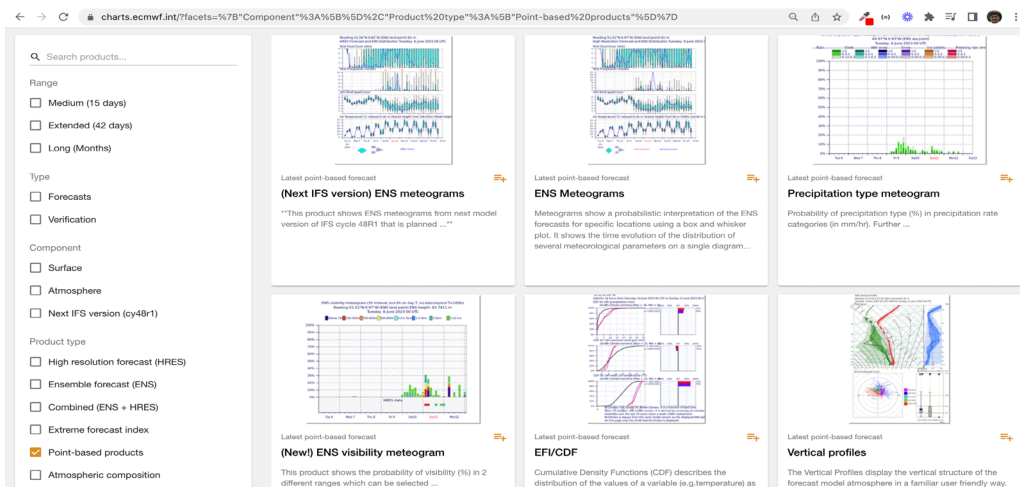
**Product Grid:**

- (Next IFS version) ENS meteograms**: Latest point-based forecast. \*\*This product shows ENS meteograms from next model version of IFS cycle 48R1 that is planned ...\*\*
- ENS Meteograms**: Latest point-based forecast. Meteograms show a probabilistic interpretation of the ENS forecasts for specific locations using a box and whisker plot. It shows the time evolution of the distribution of several meteorological parameters on a single diagram...
- Precipitation type meteogram**: Latest point-based forecast. Probability of precipitation type (%) in precipitation rate categories (in mm/hr). Further ...
- (New!) ENS visibility meteogram**: Latest point-based forecast. This product shows the probability of visibility (%) in 2 different ranges which can be selected ...
- EFI/CDF**: Latest point-based forecast. Cumulative Density Functions (CDF) describes the distribution of the values of a variable (e.g.temperature) as
- Vertical profiles**: Latest point-based forecast. The Vertical Profiles display the vertical structure of the forecast model atmosphere in a familiar user friendly way.

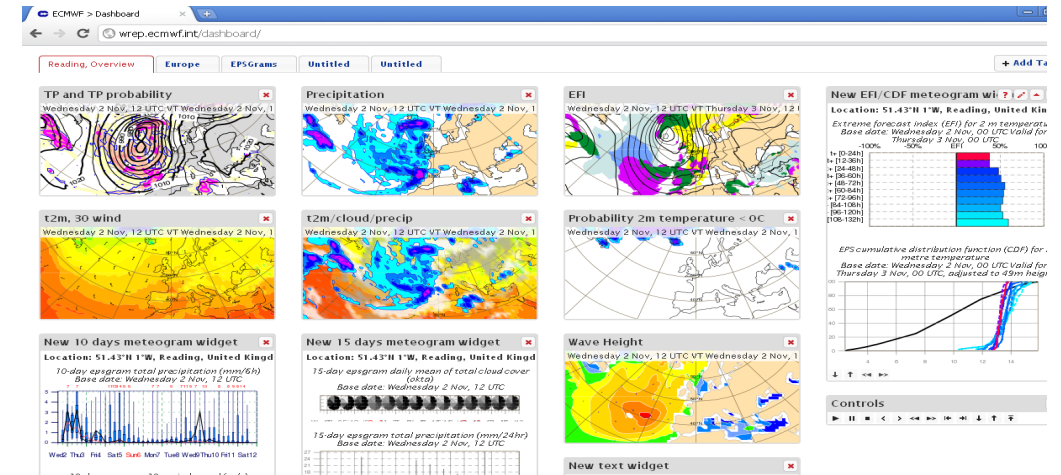
# Access to Meteograms



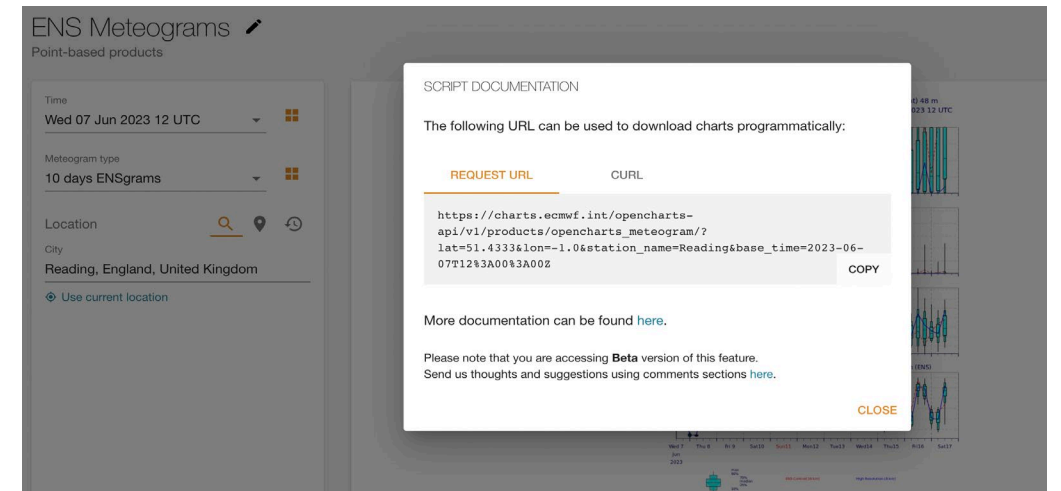
ecCharts (An interactive application for expert users)



Opencharts (General public access)

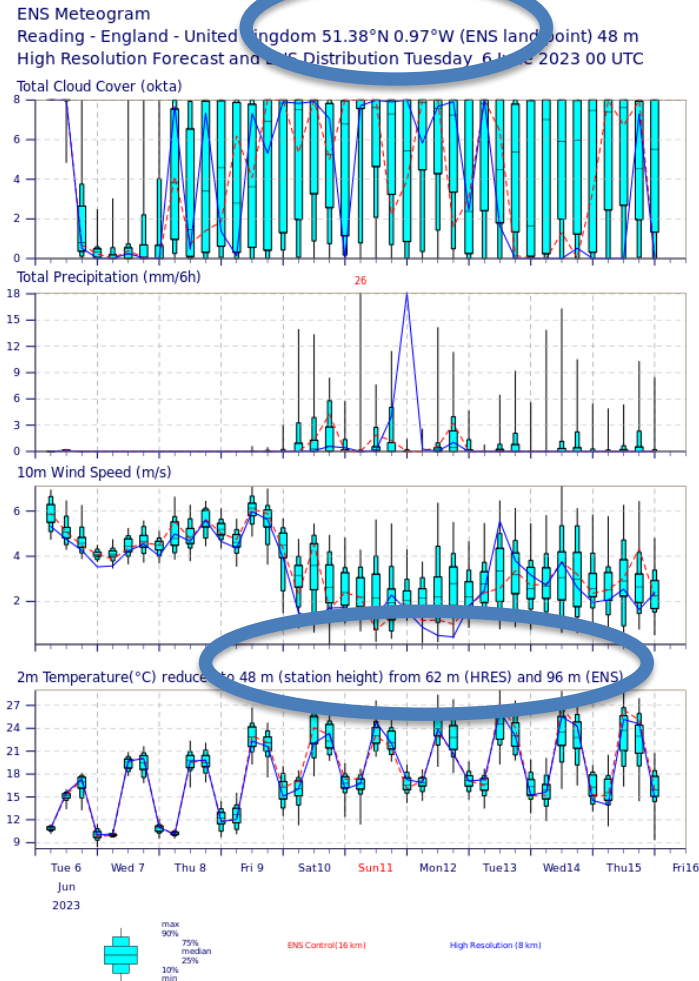


Dashboard (A portal to visualise product collectively)

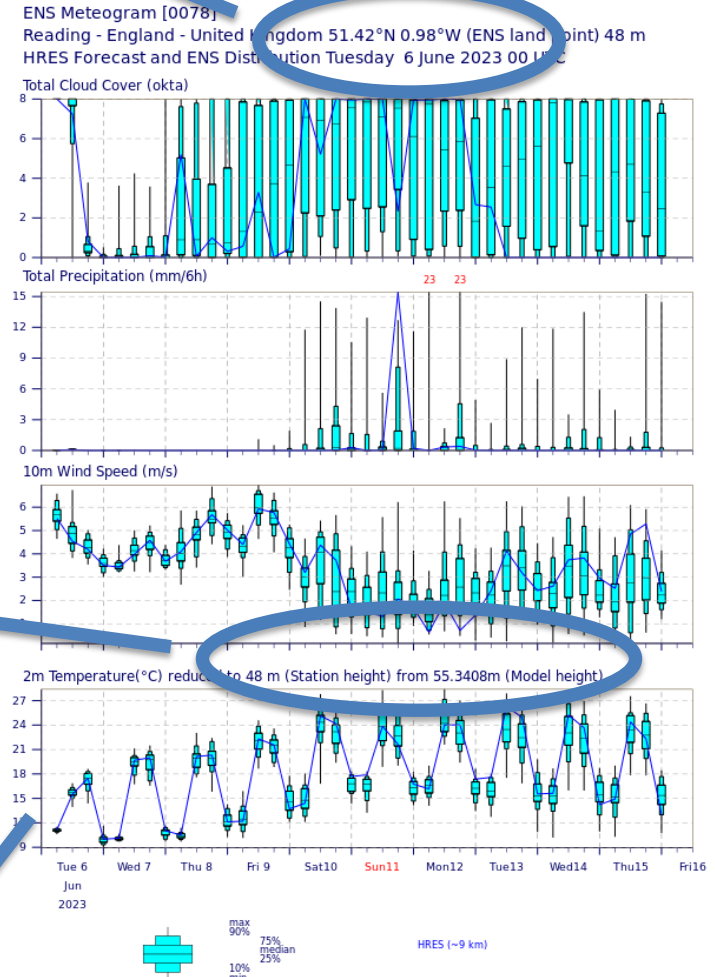


Batch Access to Graphs & WebAPI access to data

# 48r1 changes



Different nearest grid point – mostly closer



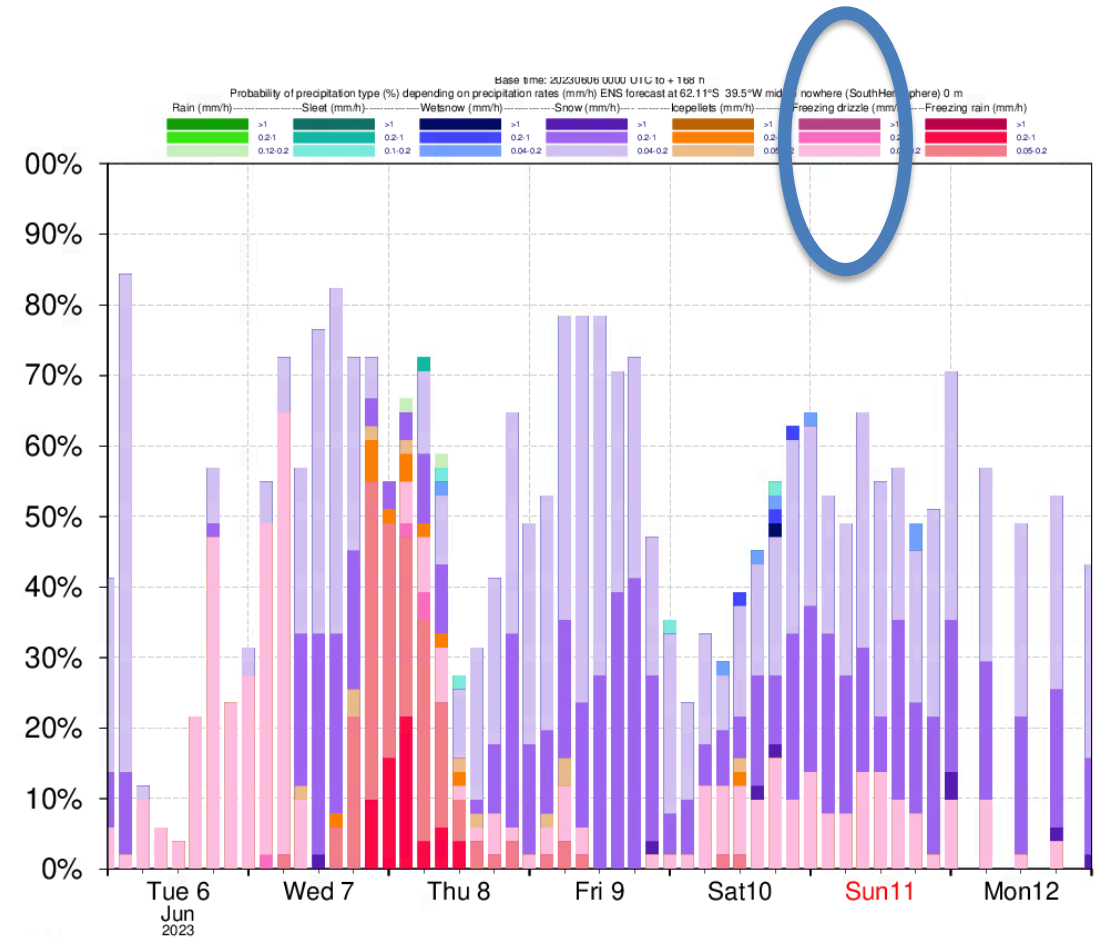
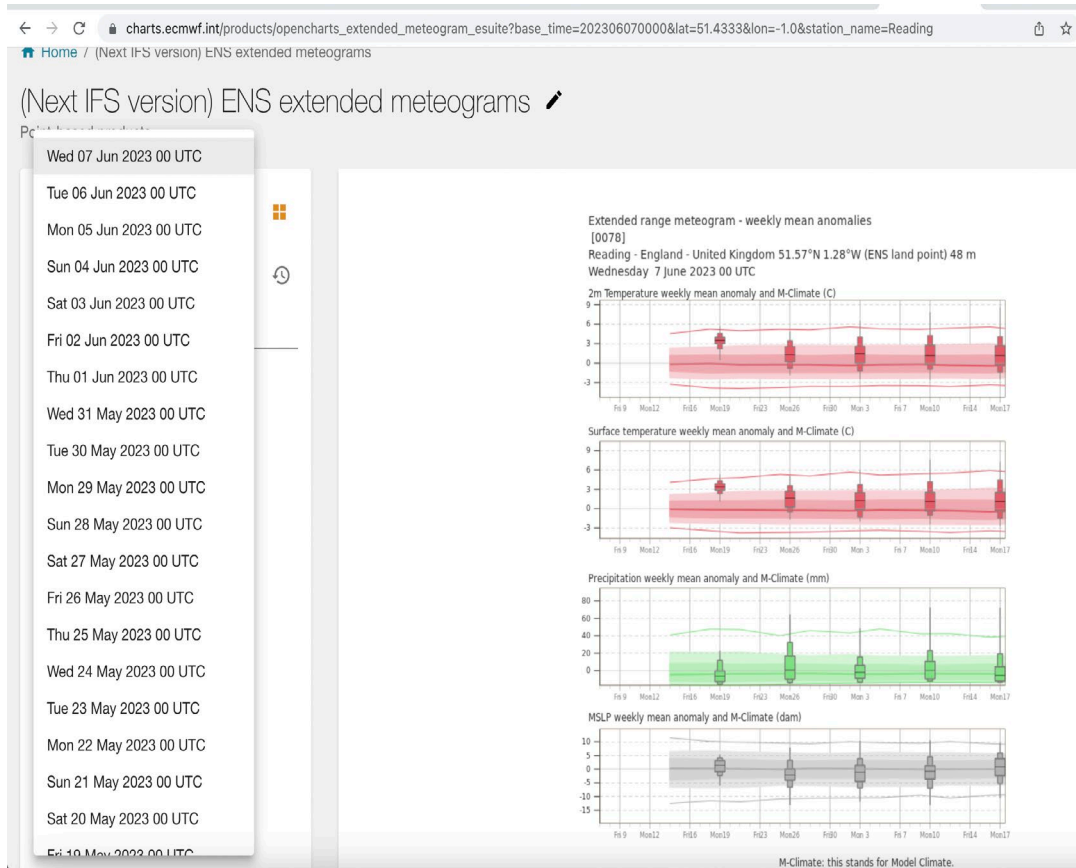
HRES model orography T correction different

Control removed (No red lines)



# Other changes ...

## Freezing drizzle added

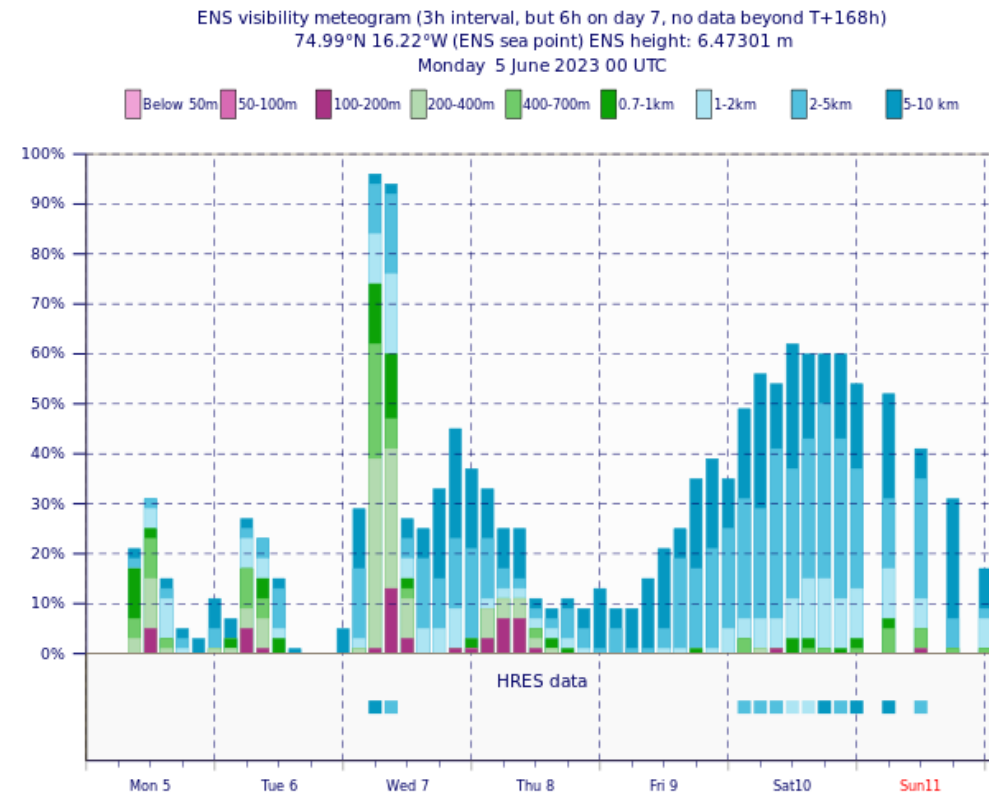
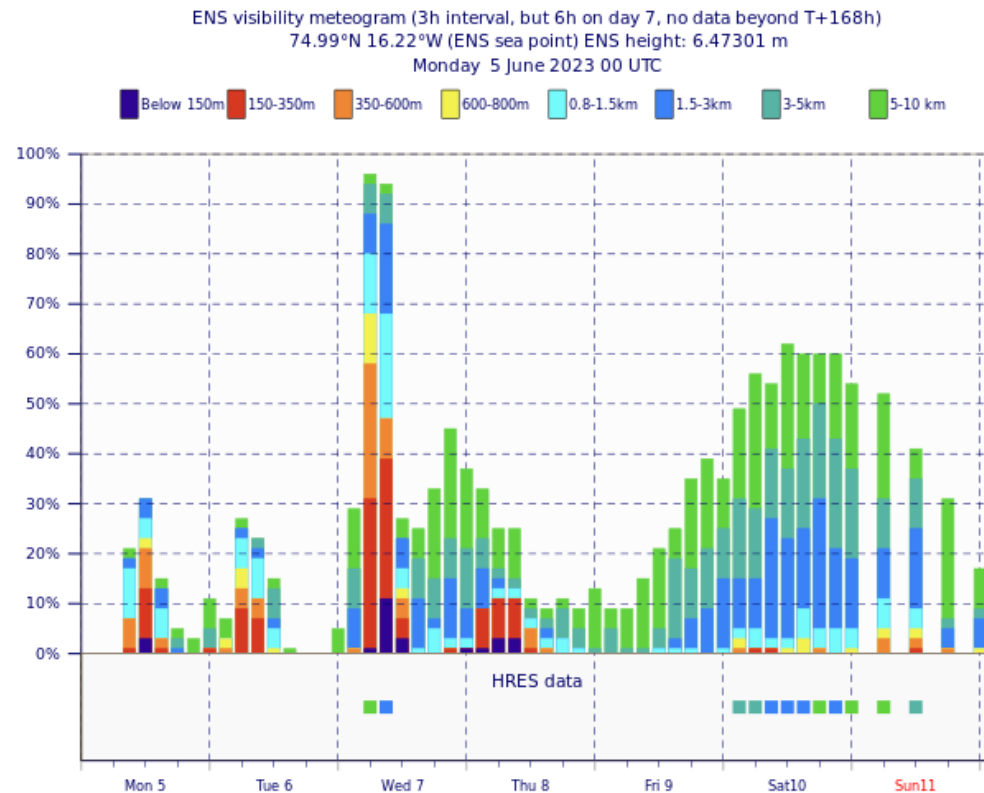


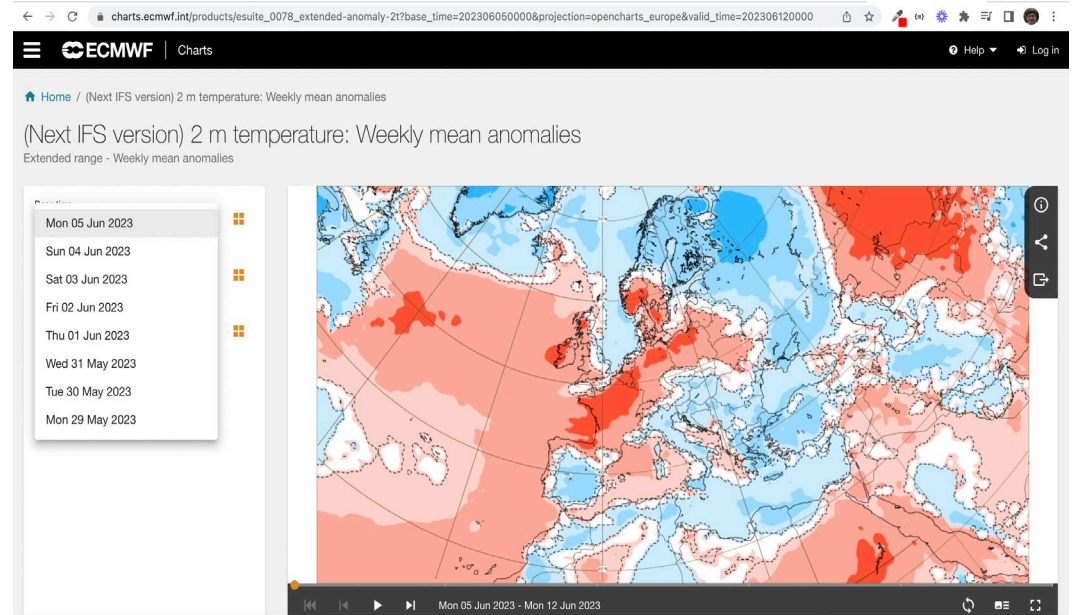
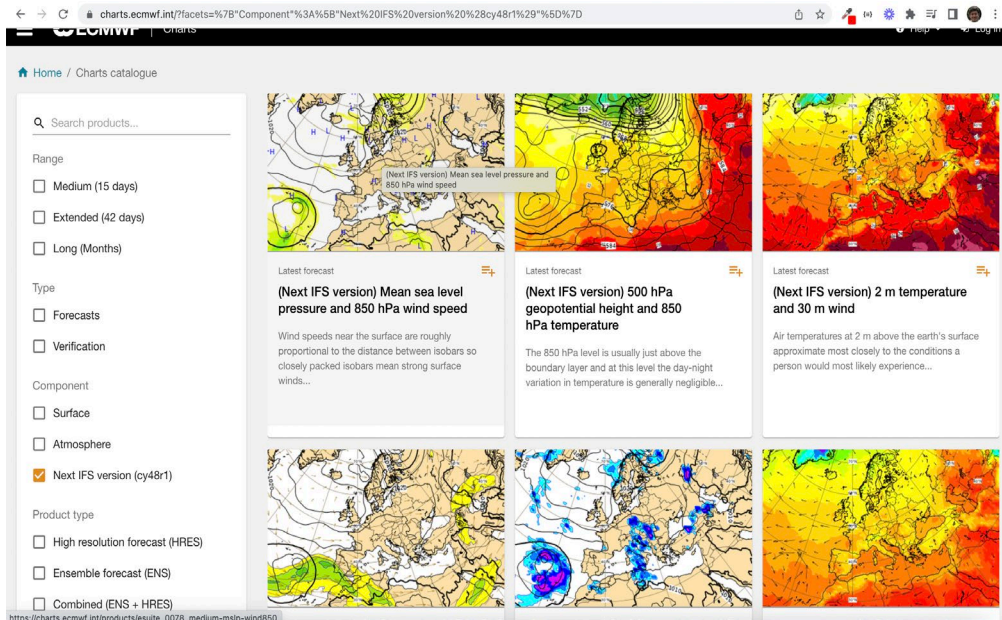
Thanks to Esti for the plot

Freezing drizzle will also be on Precipitation type/Most probable precipitation type maps

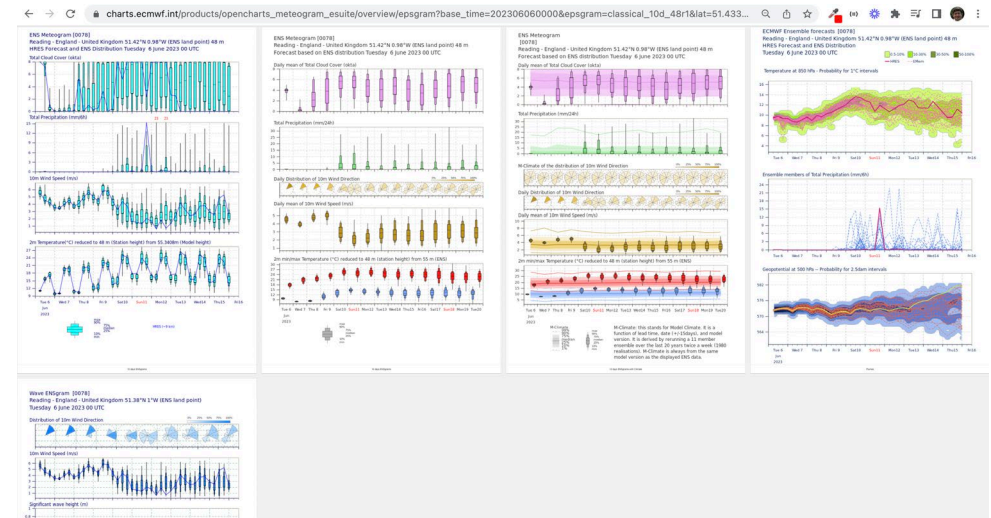
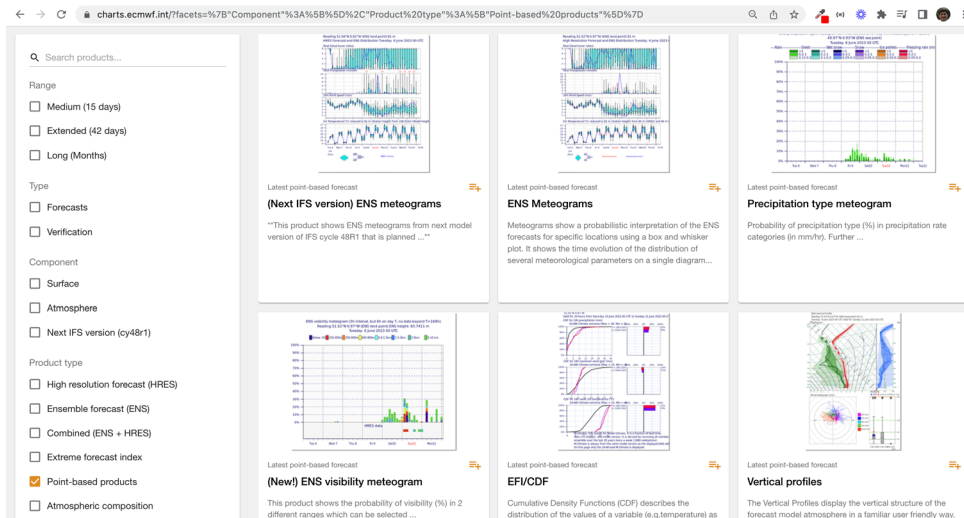
# New visibility meteogram

- A collaborative work with Hungarian Met Service (Thanks to Istvan and Livia)
- Aviation requirements (ICAO ranges) & General public requirements (Lower visibility highlighted)
- HRES displayed at the bottom





## Cycle 48r1 products available on charts.ecmwf.int and ecCharts.



# Convection products

Plans and Changes

Ivan Tsonevsky

[Ivan.Tsonevsky@ecmwf.int](mailto:Ivan.Tsonevsky@ecmwf.int)



# ECMWF-ESSL collaborations

Technical  
Memo



852

**An overview of Convective Available Potential Energy and Convective Inhibition provided by NWP models for operational forecasting**

Pieter Groenemeijer<sup>1</sup>, Tomáš Pučík<sup>1</sup>,  
Ivan Tsonevsky<sup>2</sup>, Peter Bechtold<sup>3</sup>

<sup>1</sup> European Severe Storms Laboratory (ESSL)

<sup>2</sup> ECMWF Forecast Department

<sup>3</sup> ECMWF Research Department

November 2019

Technical  
Memo



879

**Vertical wind shear and convective storms**

Tomáš Pučík<sup>1</sup>, Pieter Groenemeijer<sup>1</sup>,  
Ivan Tsonevsky<sup>2</sup>

<sup>1</sup> European Severe Storms Laboratory (ESSL)

<sup>2</sup> ECMWF, Forecast Department

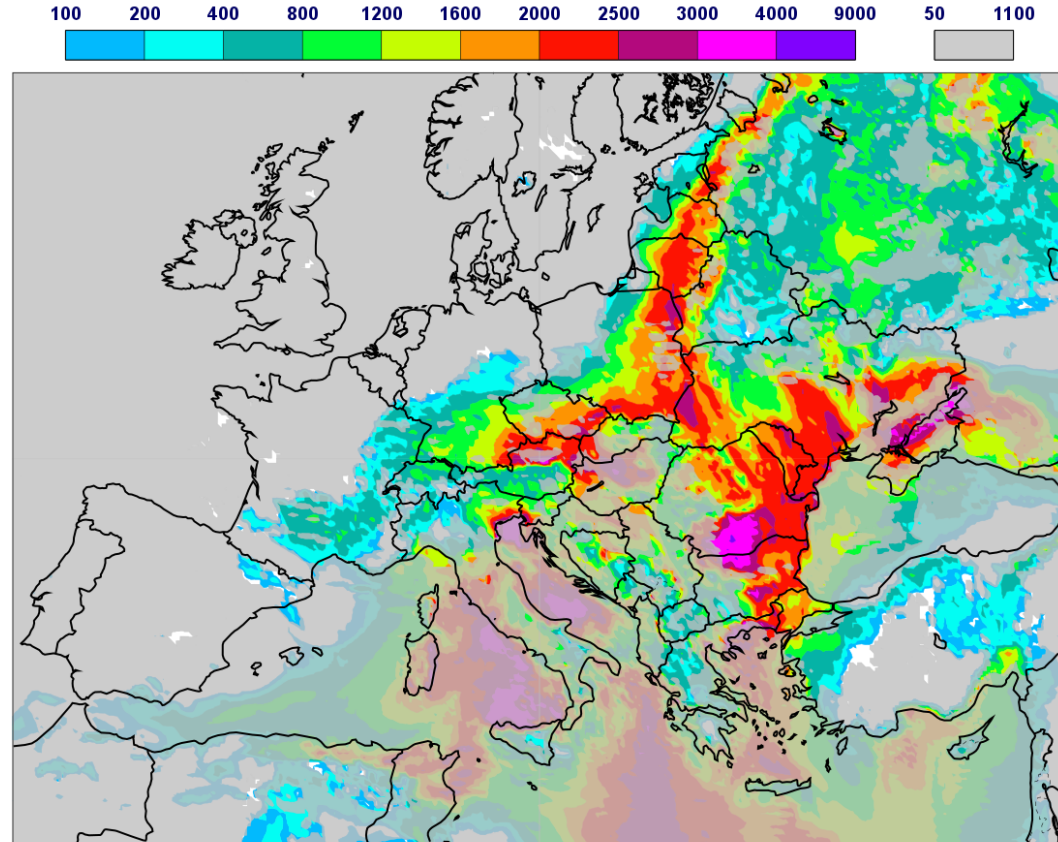
January 2021

- Revision of CAPE and CIN parameters from IFS
- Vertical wind shear and convective storms – an overview
- Forecasting convective hazards – large hail, strong winds

# Revised CAPE and CIN from the IFS

MUCAPE/MUCIN; ECMWF HRES T+108h

VT: Thu 24 June 2021 12 UTC



- Various CAPE and CIN parameters:
  - ✓ MUCAPE/MUCIN
  - ✓ MLCAPE/MLCIN for 50- and 100-hPa mixed layers;
- MUCAPE/MUCIN:
  - ✓ no surface layer considered, instead 30-hPa mixed layer parameters for each model level in the lowest 60-hPa layer;
  - ✓ as before the search for the most-unstable parcel goes up to 350-hPa pressure level
  - ✓ departure level in Pa of the most-unstable parcel provided as a model output
- Revised computation:
  - ✓ uses virtual potential temperature instead of equivalent potential temperature as before
- Still few technical things to sort out.



# mxcape6 and mxcapes6 use MUCAPE in 48r1

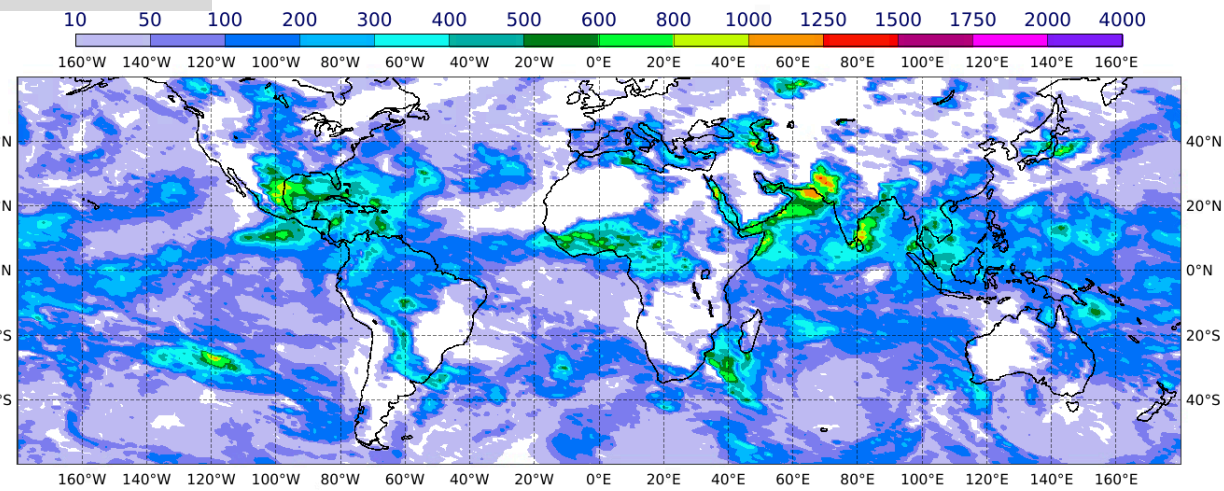
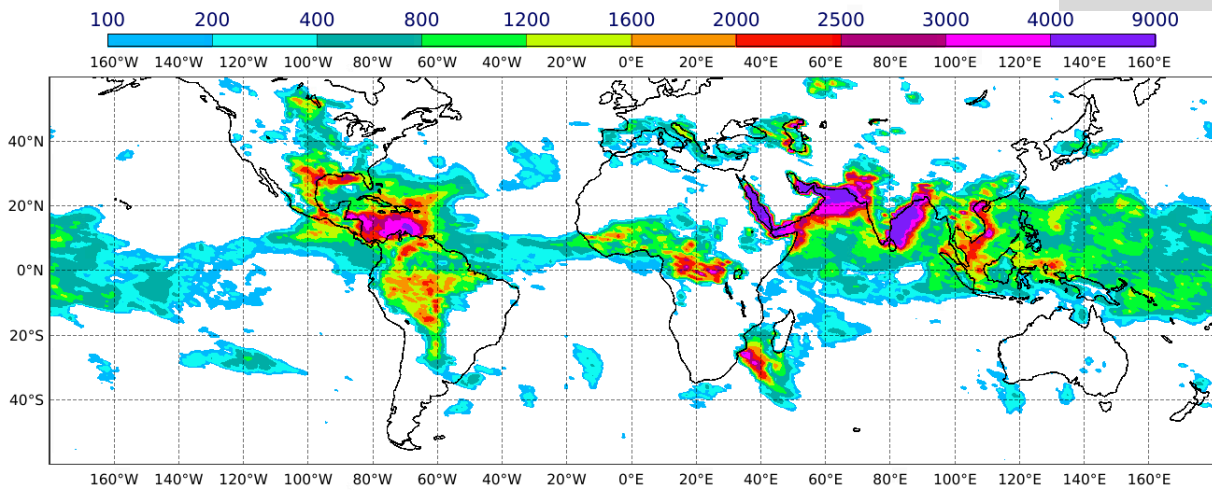
## Max CAPE in the previous 6 hours

## Max CAPE-shear in the previous 6 hours

Sunday 04 June 2023 00 UTC ecmf from t+12 to t+18 VT:Sunday 04 June 2023 18 UTC entireAtmosphere Maximum CA

Operational forecast

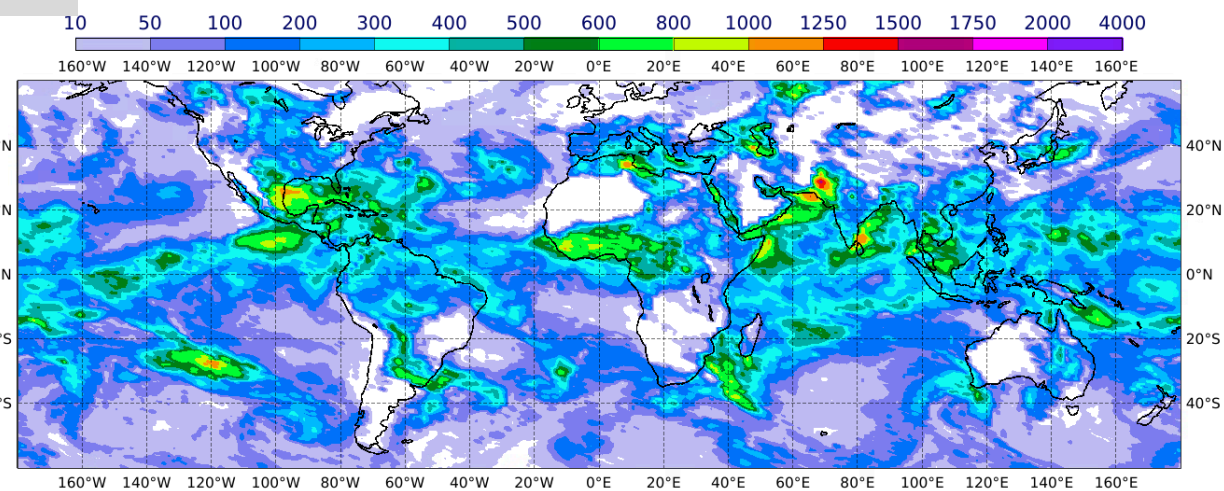
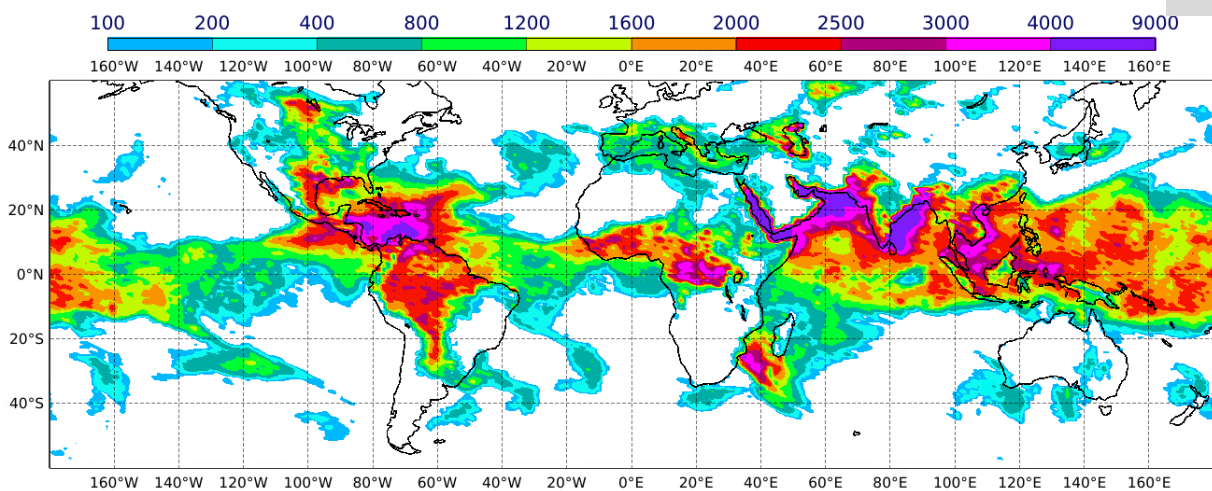
EC ecmf from t+12 to t+18 VT:Sunday 04 June 2023 18 UTC entireAtmosphere Maximum CAPES in the last 6 hours



Sunday 04 June 2023 00 UTC ecmf from t+12 to t+18 VT:Sunday 04 June 2023 18 UTC entireAtmosphere Maximum CAPE in the las

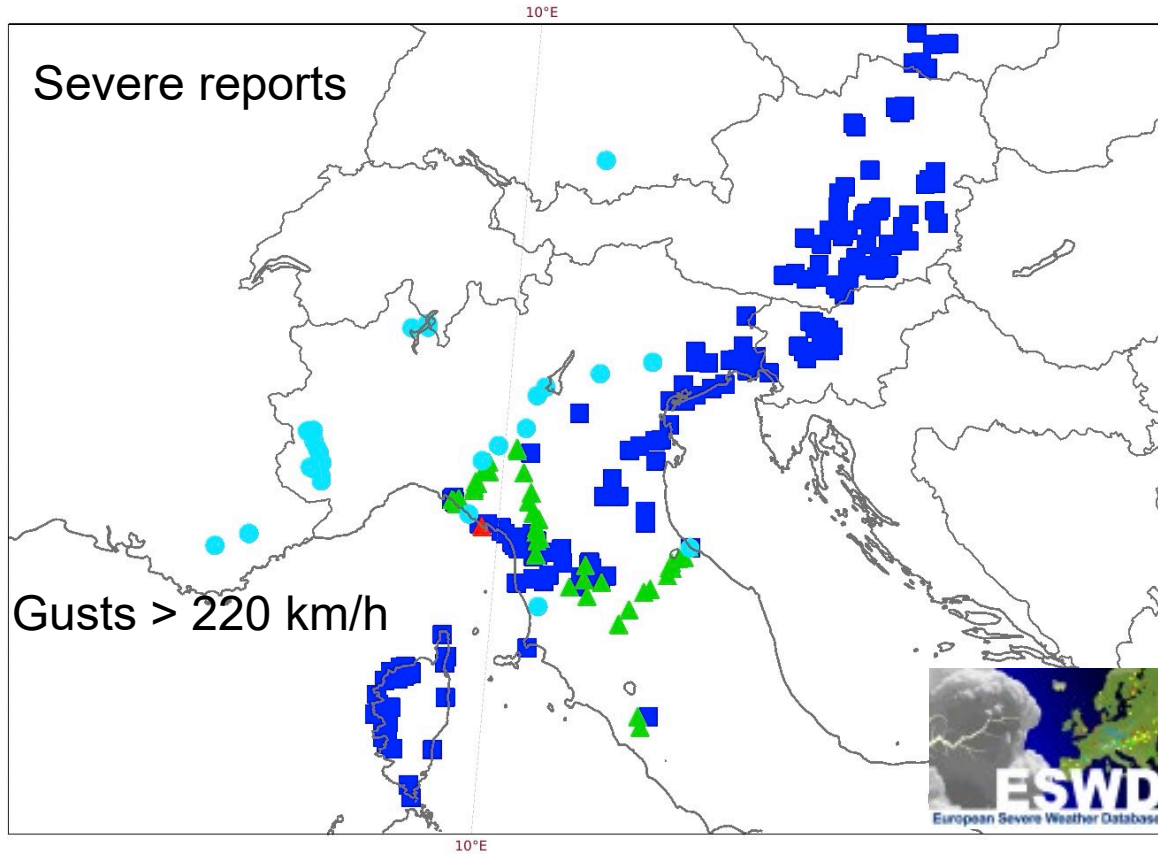
48r1

June 2023 00 UTC ecmf from t+12 to t+18 VT:Sunday 04 June 2023 18 UTC entireAtmosphere Maximum CAPES in the last 6 hours

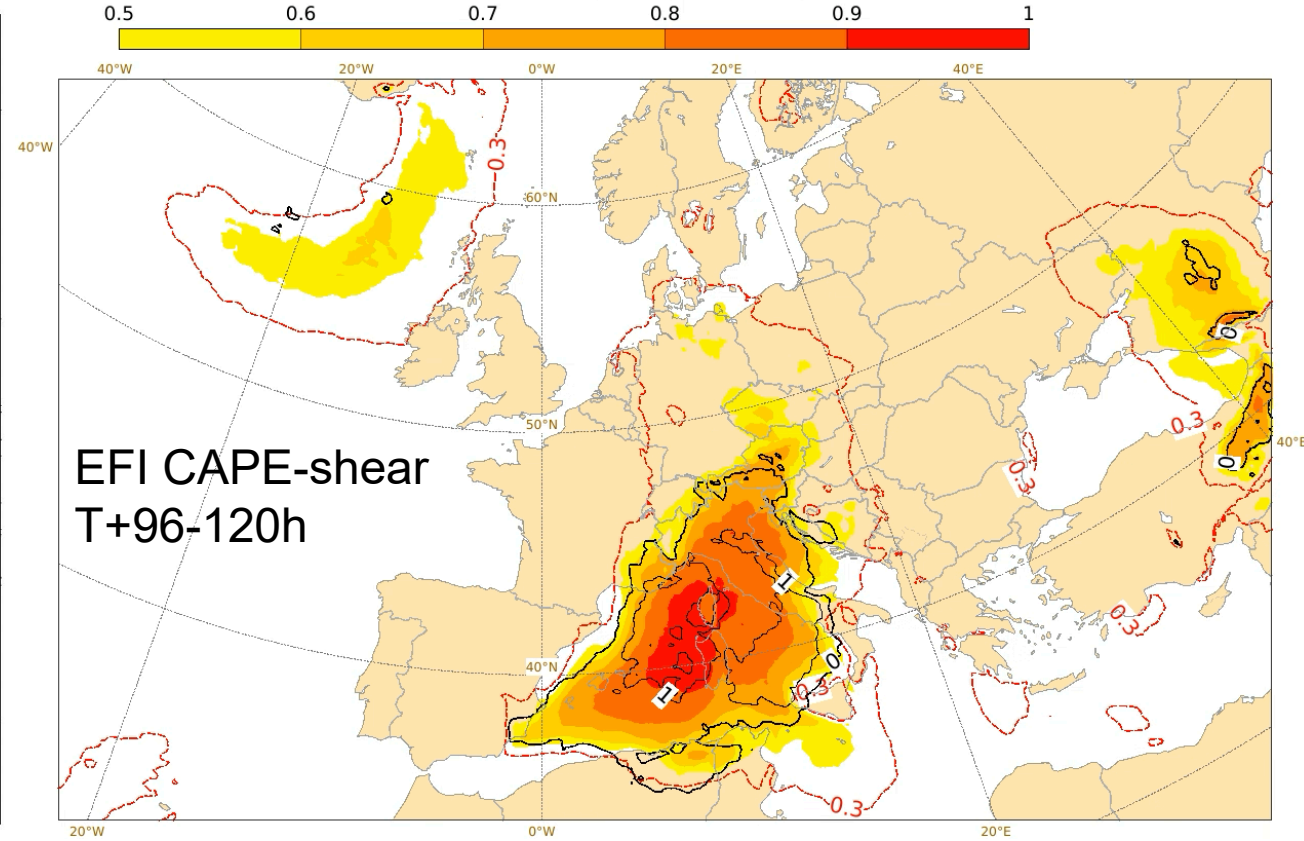


# Derecho – 18 August 2022

▲ tornado ▲ hail ■ severe wind ◆ lightning ● heavy rain



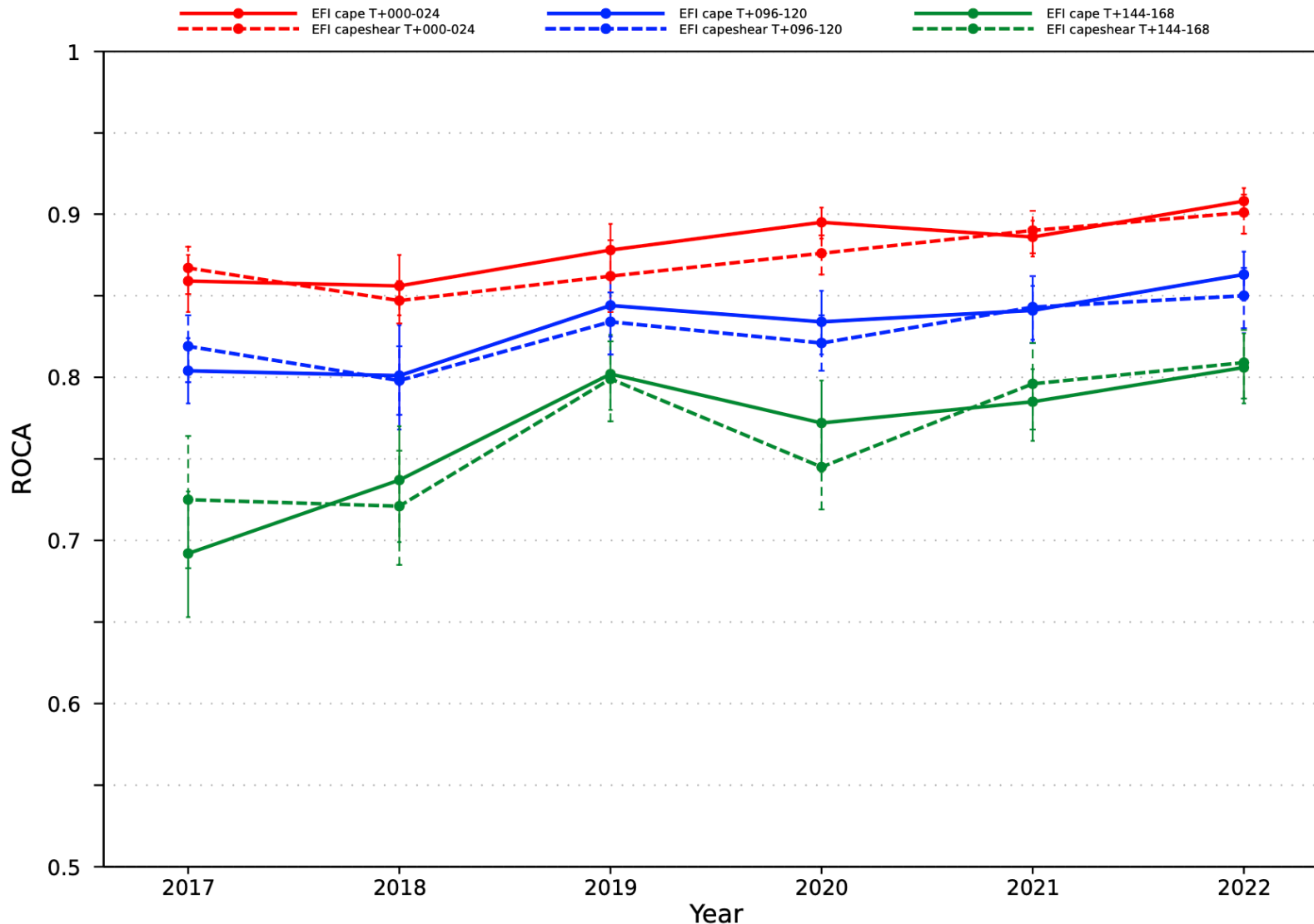
Sun 14 Aug 2022 00UTC @ECMWF expver = 1 VT: Thu 18 Aug 2022 00UTC - Fri 19 Aug 2022 00UTC 96-120h  
Extreme forecast index and Shift of Tails (black contours 0,1,2,5,8) for: CAPE-shear



- 12 fatalities associated with the derecho
- EFI for CAPE-shear – highlighted this severe convective outbreak in the medium range (5 to 7 days in advance).



# Verification of convective EFIs



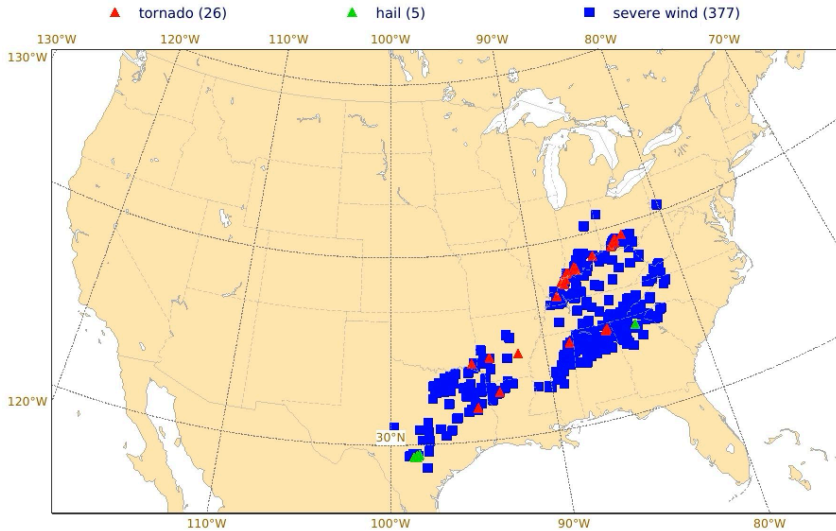
- EFI for CAPE and CAPE-shear has been verified against ESWD reports and ATDnet lightning (over Europe) and SPC reports (over the USA)
- Area under the ROC curve is used as a skill measure.
- Convective season (April to September) skill scores shown on the plot.
- So far we notice an upward trend in the skill scores.

# Severe Convection – USA, 2-3 March 2023

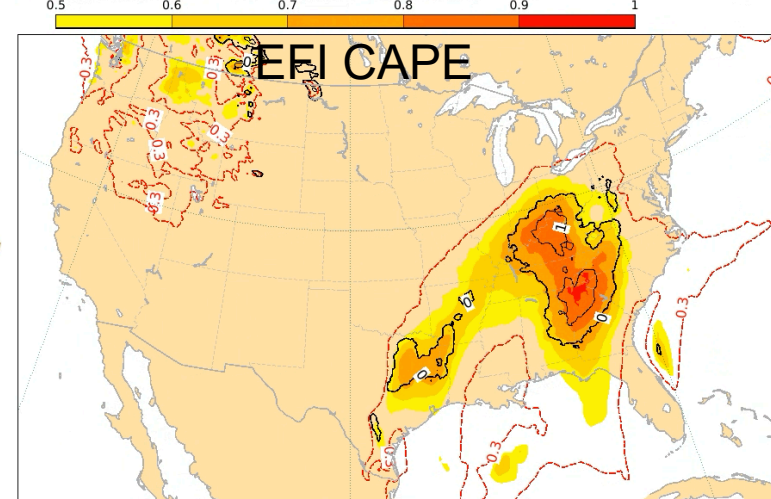
## Operational

## 48r1

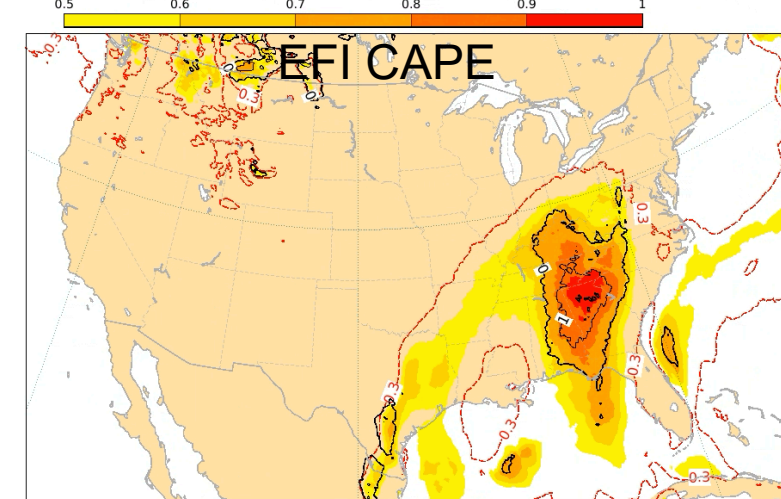
Severe weather reports for Friday 03 Mar 2023



Thu 02 Mar 2023 00UTC @ECMWF expver = 1 VT: Fri 03 Mar 2023 00UTC - Sat 04 Mar 2023 00UTC 24-48h  
Extreme forecast index and Shift of Tails (black contours 0,1,2,5,8) for: CAPE

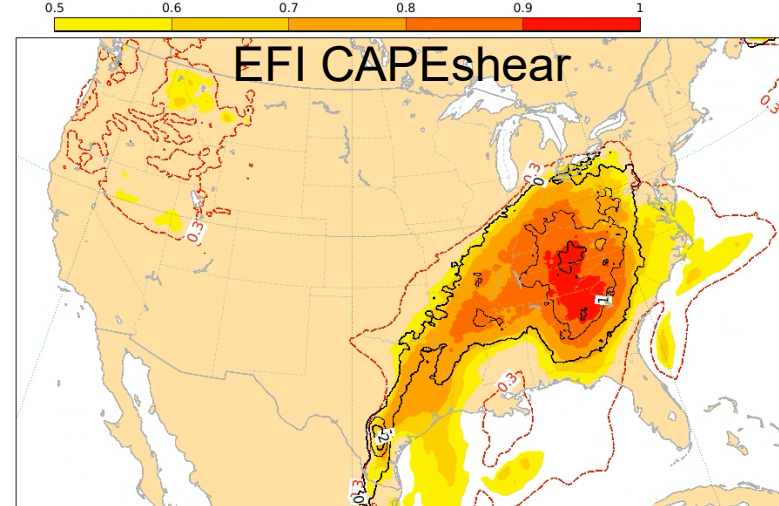


Thu 02 Mar 2023 00UTC @ECMWF expver = 78 VT: Fri 03 Mar 2023 00UTC - Sat 04 Mar 2023 00UTC 24-48h  
Extreme forecast index and Shift of Tails (black contours 0,1,2,5,8) for: CAPE

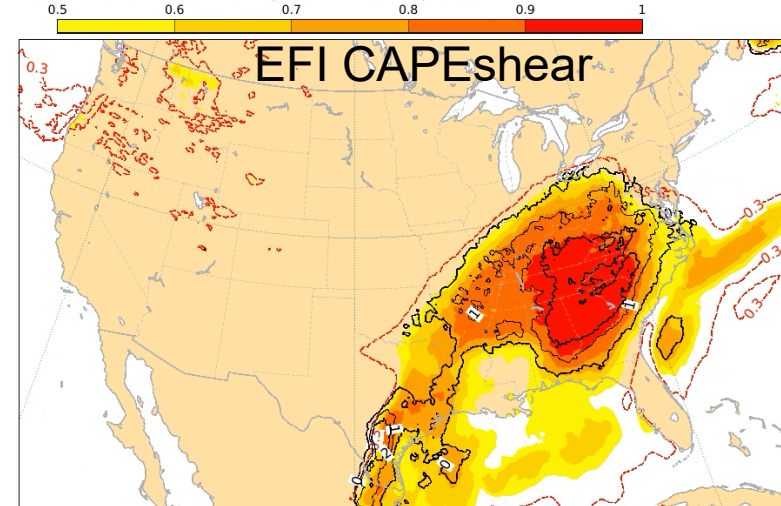


- Convective EFIs use mxcape6 and mxcapes6 and therefore they will make use of the MUCAPE parameter implemented with IFS cycle 47r3.
- No striking differences as expected.
- Both versions, the operational and 48r1, captured well severe convection over the USA.

Thu 02 Mar 2023 00UTC @ECMWF expver = 1 VT: Fri 03 Mar 2023 00UTC - Sat 04 Mar 2023 00UTC 24-48h  
Extreme forecast index and Shift of Tails (black contours 0,1,2,5,8) for: CAPE-shear



Thu 02 Mar 2023 00UTC @ECMWF expver = 78 VT: Fri 03 Mar 2023 00UTC - Sat 04 Mar 2023 00UTC 24-48h  
Extreme forecast index and Shift of Tails (black contours 0,1,2,5,8) for: CAPE-shear

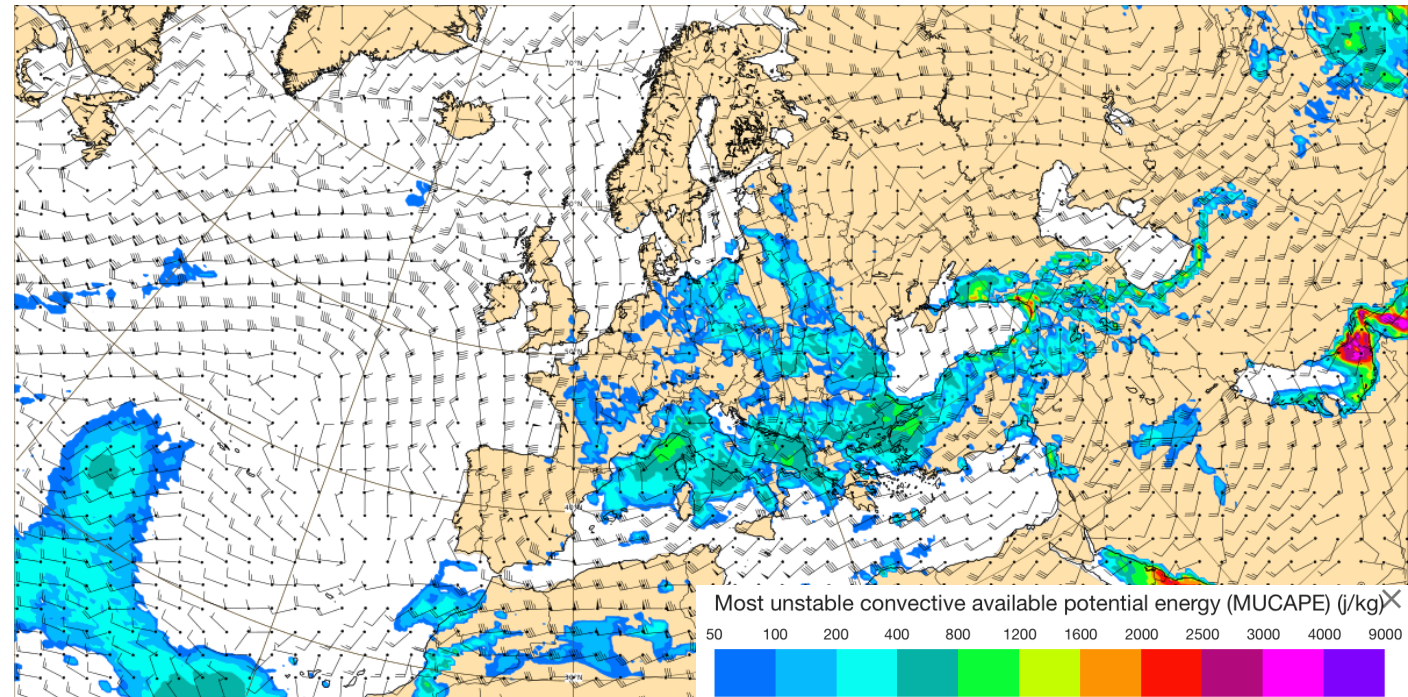
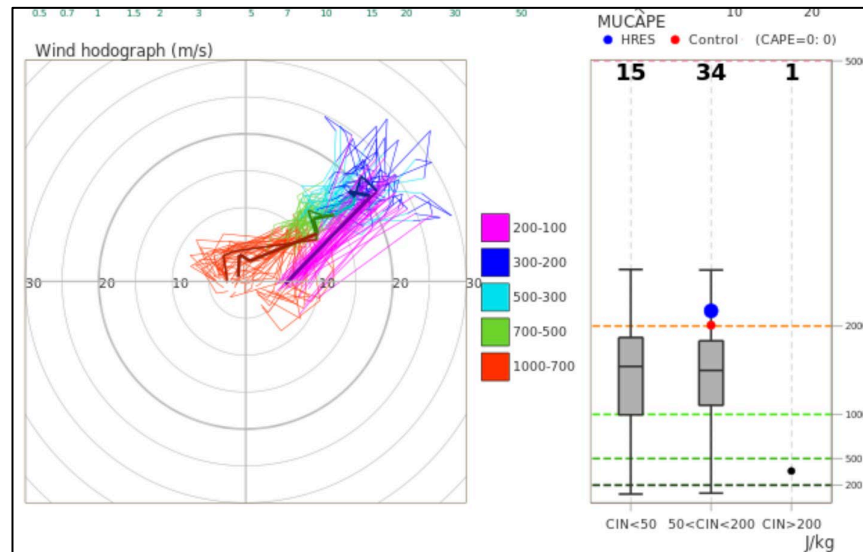


# Plans for 49r1

Parameter details	
Parameter ID	228236
Name	Most-unstable CIN
Short Name	mucin
Units	J kg <sup>-1</sup>
Description	Convective Inhibition (CIN) is a measure of the amount of energy needed to be overcome for storm initiation. CIN reflects the strength of the capping inversion. In the IFS MUCIN refers to the most unstable parcel (the parcel with the largest CAPE) found in the atmosphere from the surface up to 350 hPa. For all the model levels in the lowest 60 hPa, 30-hPa mixed-layer parameters are used.
Insert date	2020-10-09
Update date	2020-10-09
Contact	ECC-1155

- "Old" CAPE will be stopped. New parameters shown on the web.
- CIN will be renamed to MUCIN and parameterID changes as well from 228001 to 228236

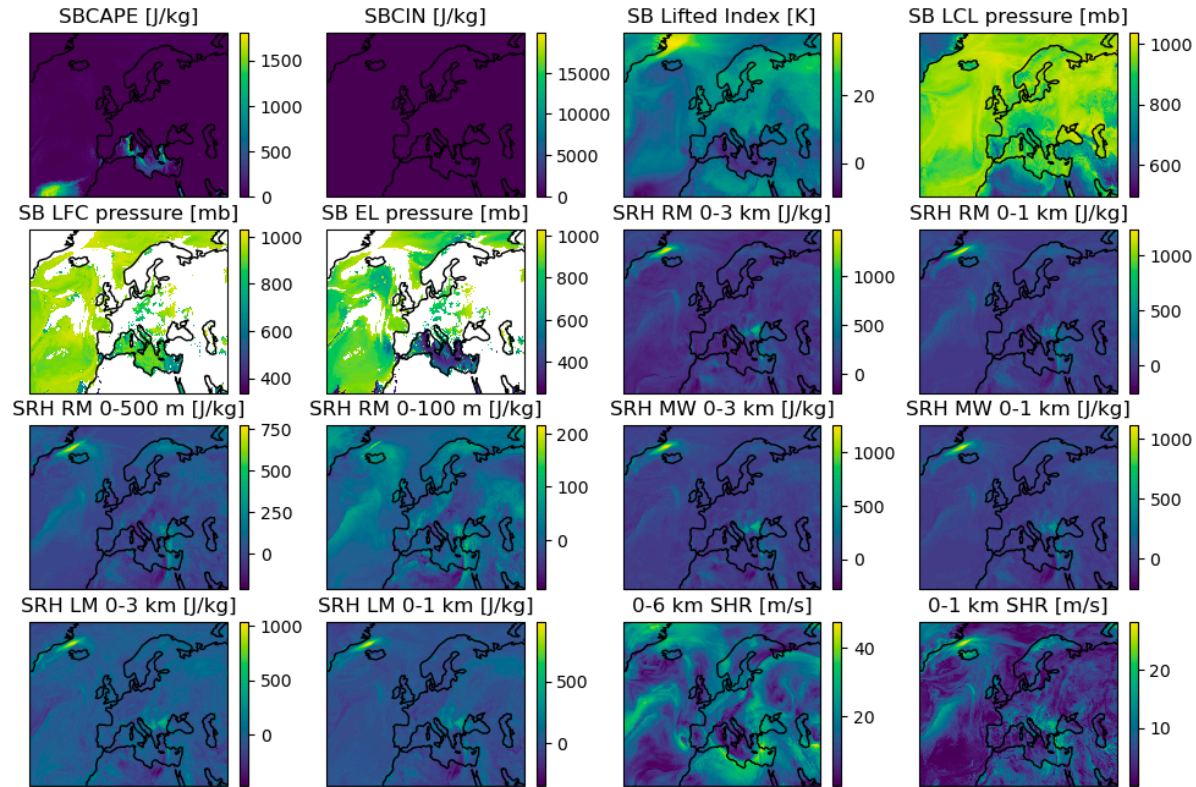
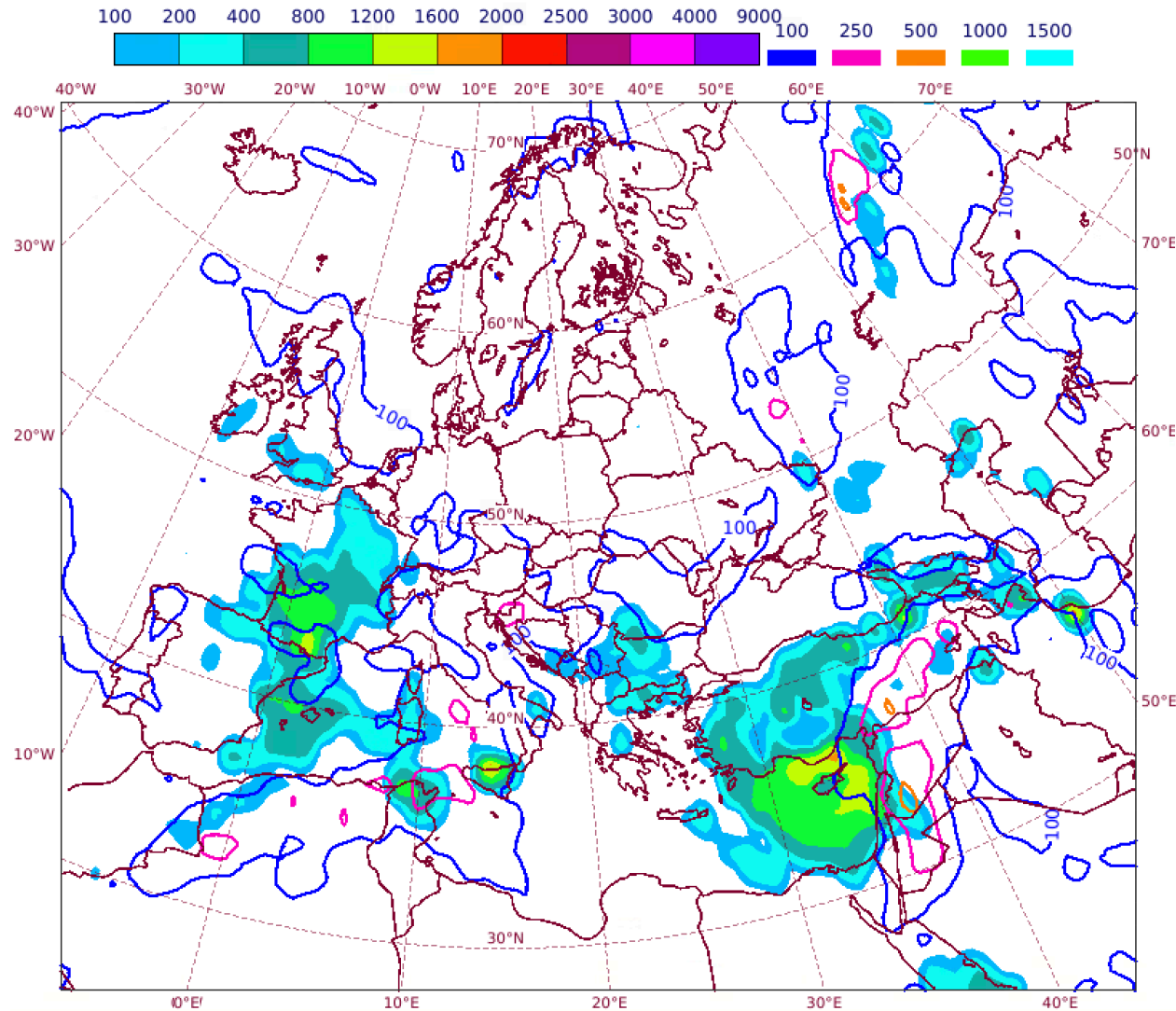
## 0-6km wind shear and MUCAPE





# Storm Relative Helicity

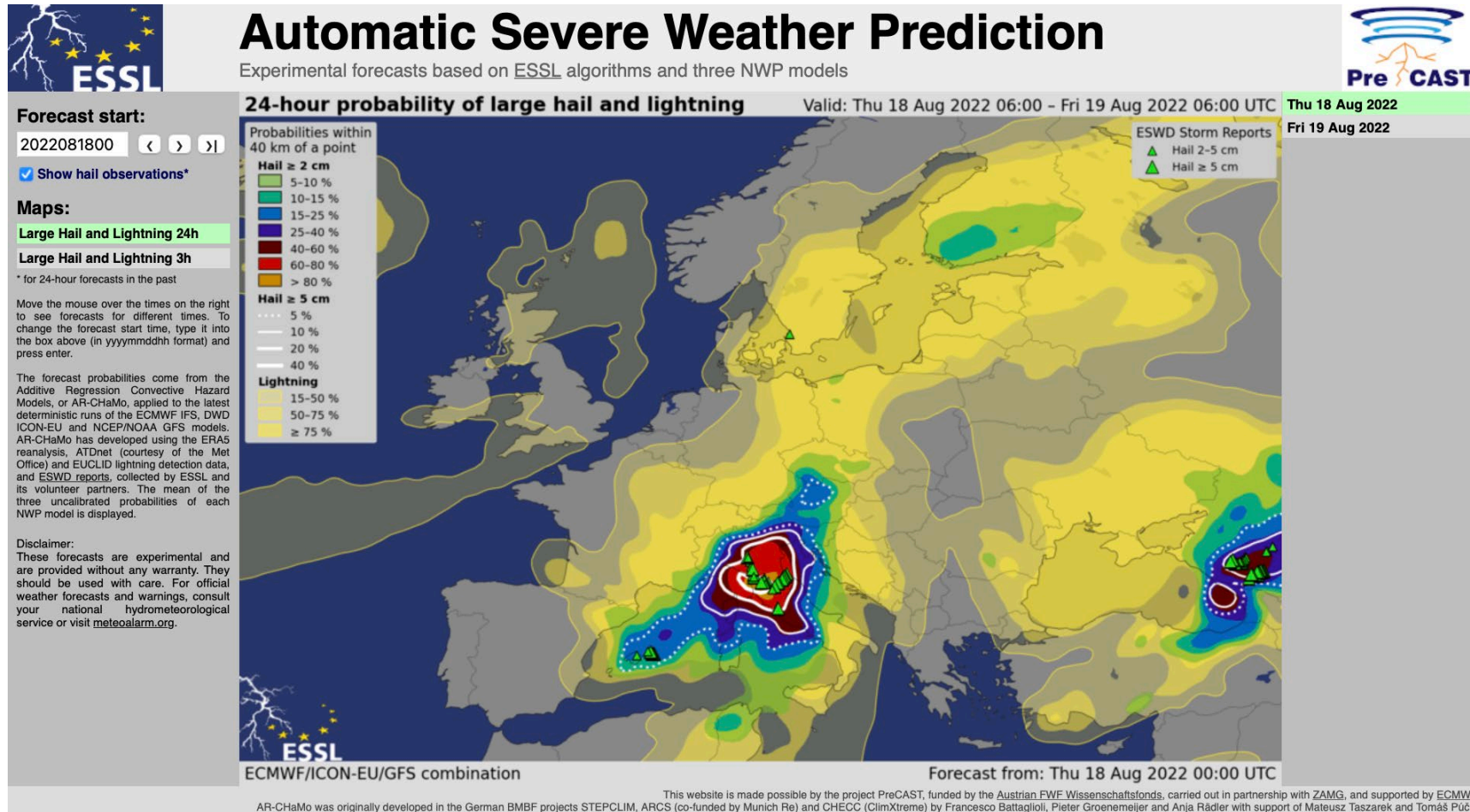
28 Apr 2023 00 UTC; ECMWF VT: 06 May 2023 12 UTC  
MUCAPE and SRH03RM



- Computational code for a number of convective parameters including SRH has been provided by ESSL as a Jupyter notebook.
- On LHS an example of MUCAPE (shaded) and 0-3 km SRH for a right-moving storm (contours)



# Probability of convective hazards



- Probability of lightning, large hail (and severe wind gusts) using AR-CHaMo.
- An example – hailstorms during a derecho event – 18 Aug 2022.
- AR-CHaMo + ECMWF ENS – PreCAST & ECMWF-ESSL collaborative project

More on poster P41.

# Precipitation Types : an upgrade in 48r1

Tim Hewson

tim.hewson @ ecmwf.int

Thanks to Esti Gascon, Richard Forbes, Axel Bonet

# Precipitation Types

- From cycle 48r1 onwards we will diagnose these precipitation types (for precipitation falling at valid time) :
- Previously freezing drizzle would have been in the “rain” class
- Now it’s a separate entity...

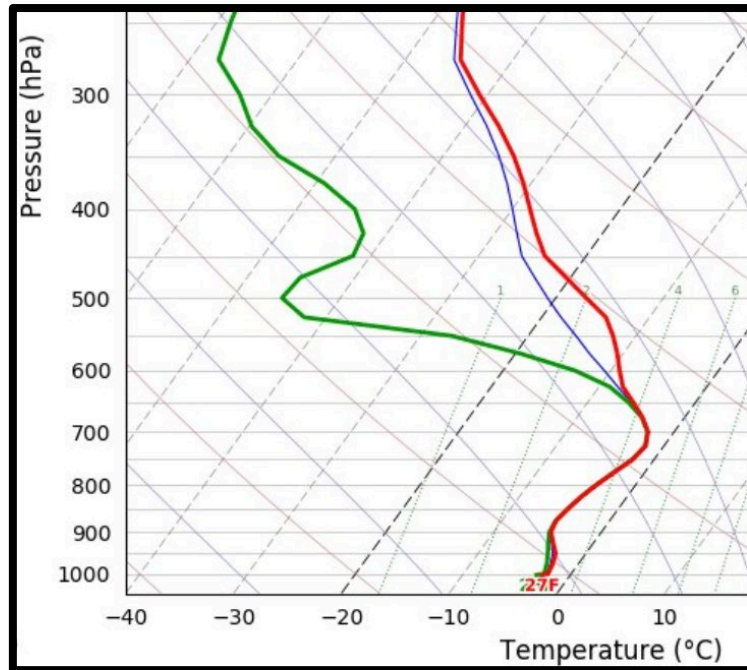
**New**



Code	Description	Severity
0	No precipitation	0
1	Rain	1
3	Freezing rain	7
5	Snow	4
6	Wet snow	5
7	Mixture of rain and snow	2
8	Ice pellets	3
12	Freezing drizzle	6

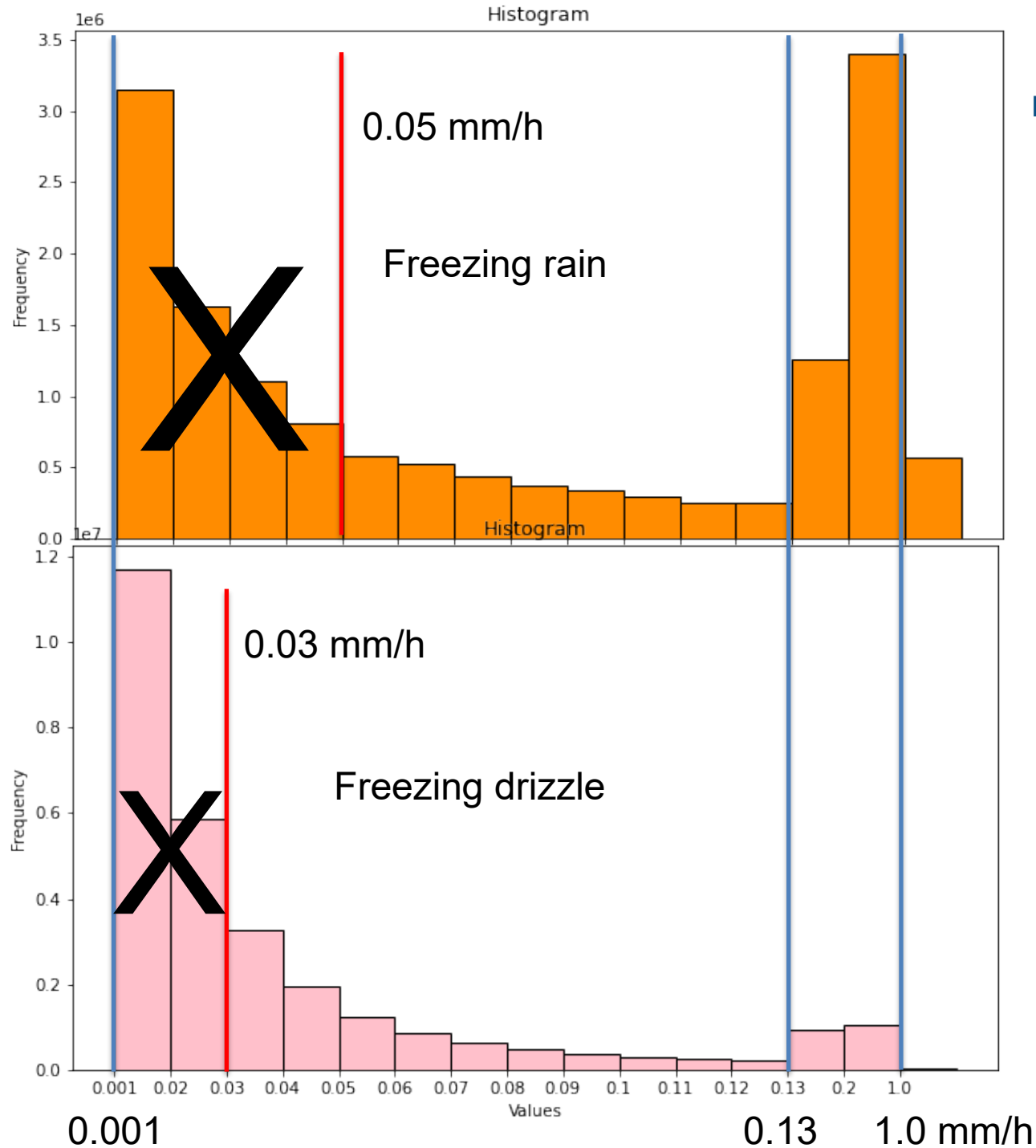
# What is Freezing Drizzle ?

- Freezing drizzle, as defined for our IFS output, is liquid precipitation falling through air with a temperature  $<0^{\circ}\text{C}$ , that has no ice phase history at higher altitudes
- This implies a relatively shallow cloud source
- Hence rates tend to be low, and droplet size small
- Hence the term “freezing drizzle” (though small raindrops would be possible)



- Given more moisture at high levels – this would be snow
- Given higher temperatures  $\sim 650\text{-}850\text{mb}$  ( $>0^{\circ}\text{C}$ ) - this would be freezing rain (or ice pellets)



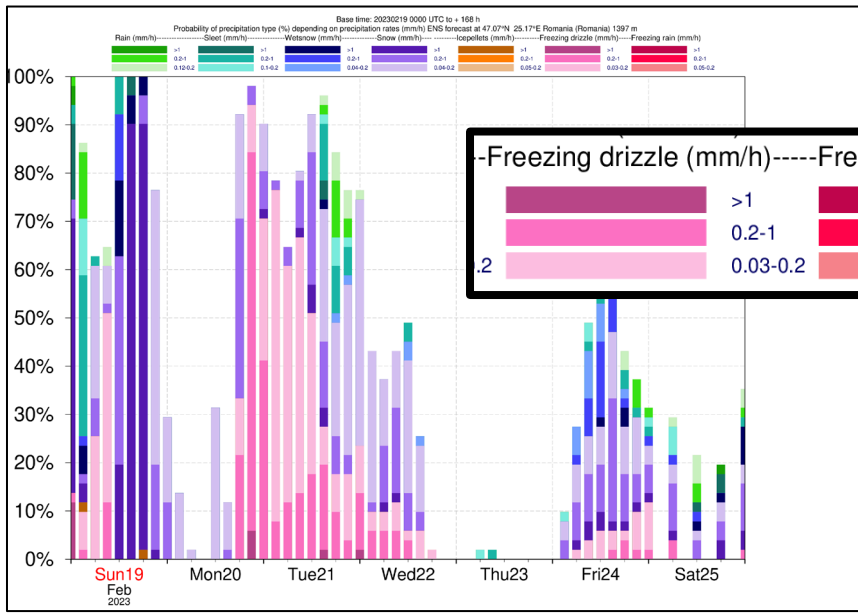


## Frequency distributions of precipitation rates for two precipitation types – 48r1 HRES forecasts for test period in winter 2022/3

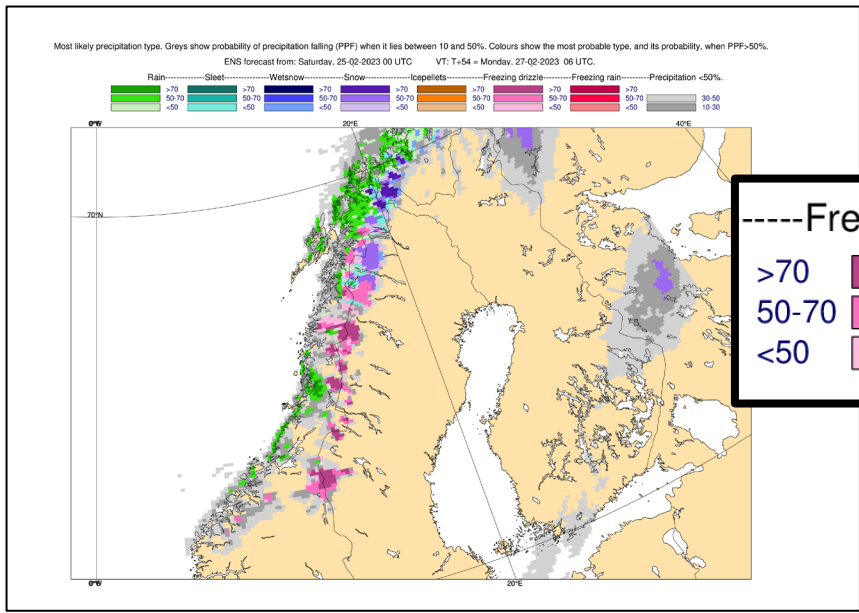
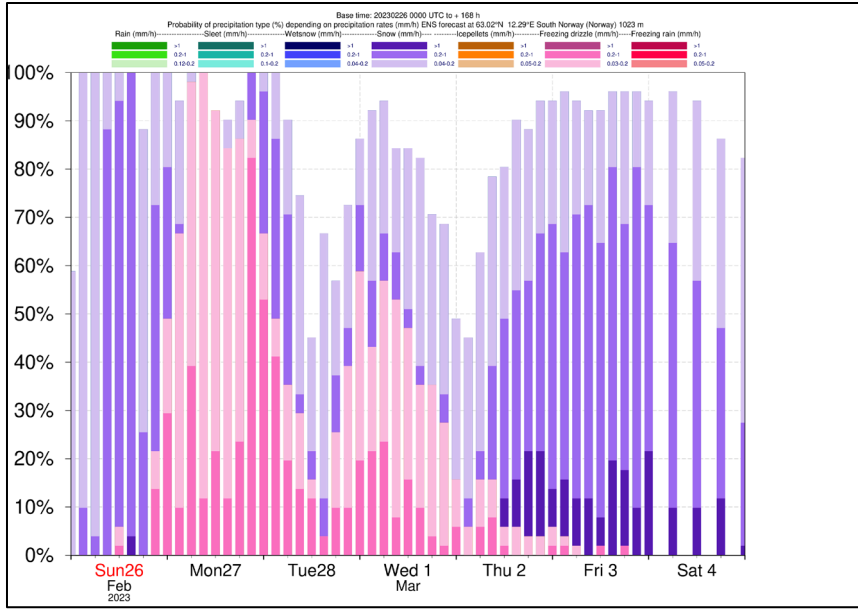
- When a certain precipitation type is diagnosed, what is the precipitation rate?
- Extremely low rates can be delivered by the model, but are of no practical relevance
- Therefore for products (ecCharts and OpenCharts) we use a cut-off minimum rate for each precipitation type
- The strategy for minimum rate selection is to minimize frequency of occurrence bias, versus manual synop obs
- For freezing drizzle we do not have enough observations to do this successfully
- One intrinsically expects freezing drizzle to have lower rates overall than freezing rain (due to implied lesser cloud depth) – as histograms here show
- We compromised and set the minimum rate accepted rate to 0.03mm/h (versus 0.05mm/h for freezing rain)

So how will the resulting products look different ?

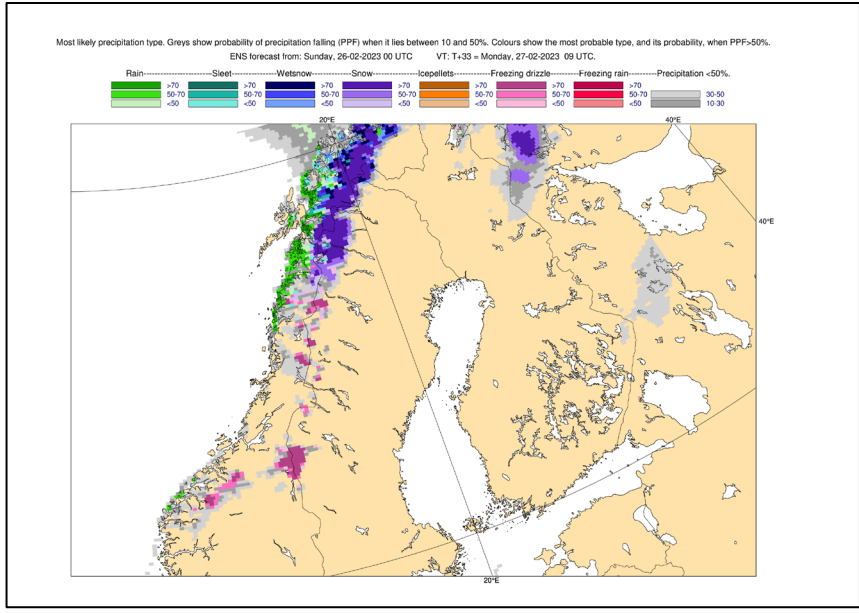
Examples follow:



### Precipitation Type Meteograms



### Most Probable Precipitation Type



## What products/variables will be affected ?

- Precipitation Type meteograms (OpenCharts, ecCharts)
- Most Probable Precipitation type maps (OpenCharts, ecCharts)
- HRES instantaneous precipitation type (ecCharts – can tailor the minimum rate threshold)
- Instantaneous precipitation type (model output)
- Accumulated freezing rain (freezing drizzle accumulation now included) (ecCharts, OpenCharts, model field)
  
- Most severe precip type in last 1,3,6 hours (new model output variable, includes fz drizzle)
- Most common precip type in last 1,3,6 hours (new model output variable, includes fz drizzle)

## What else will change ?

- Following the minimum-rate-recalibration exercise we will be making the following additional change:
  - Snow & wet snow minimum rates will change from 0.05 to 0.04mm/h
  - This relates to a characteristic of 48r1 which is to generate 5% less snow
  - This should help keep the frequency of occurrence of both these precipitation types the same on products as they are in observations
- We do not see much lead-time dependence of frequencies of occurrence in different types in forecasts – expected but also a relief (!)



We welcome feedback on these new developments at UEF next year 😊

(or whenever you are ready!)

# ENS Extended Range Forecasts

... products

Fernando Prates & Laura Ferranti

[fernando.prates@ecmwf.int](mailto:fernando.prates@ecmwf.int) [laura.ferranti@ecmwf.int](mailto:laura.ferranti@ecmwf.int)

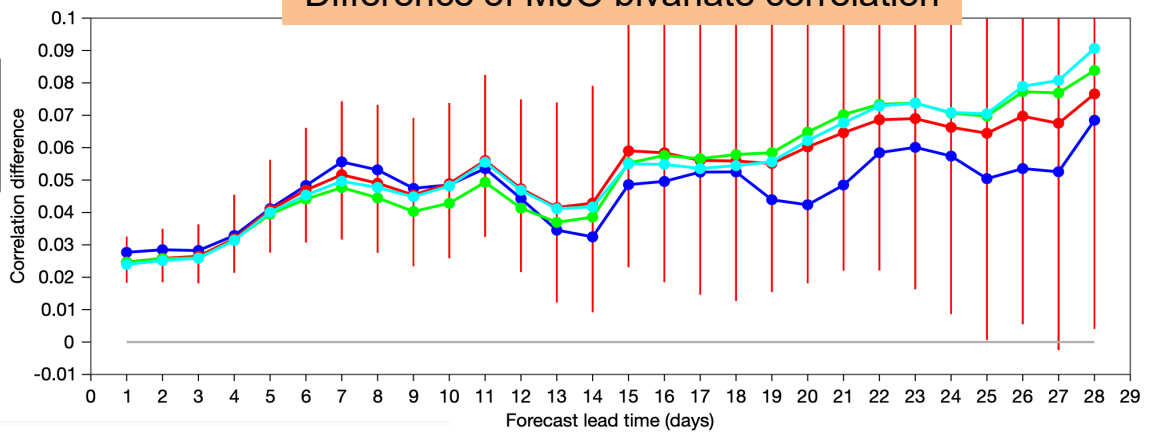
# New ENS Extended Range Forecast

- A new configuration to meet the user's' feedback (survey 2021) will be implemented on 27<sup>th</sup> June
- ENS frequency and ENS size matters
  - From Mon & Thu to daily (00Z) forecasts
  - From 51 to 101 ENS members
- ENS Extended decoupled from the ENS Medium Range
  - Forecasts  $T_{co}319$  from 0 to 46 days
  - Hindcasts  $T_{co}319$  from 0 to 46 days (20-years, 11 members, Mon & Thu)
- CY49r1 Hindcasts (next year):
  - 10 perturbed members +CTRL runs on fixed dates once every 2 days, over the past 20-years

# Skill sensitivity of the forecast configuration - frequency

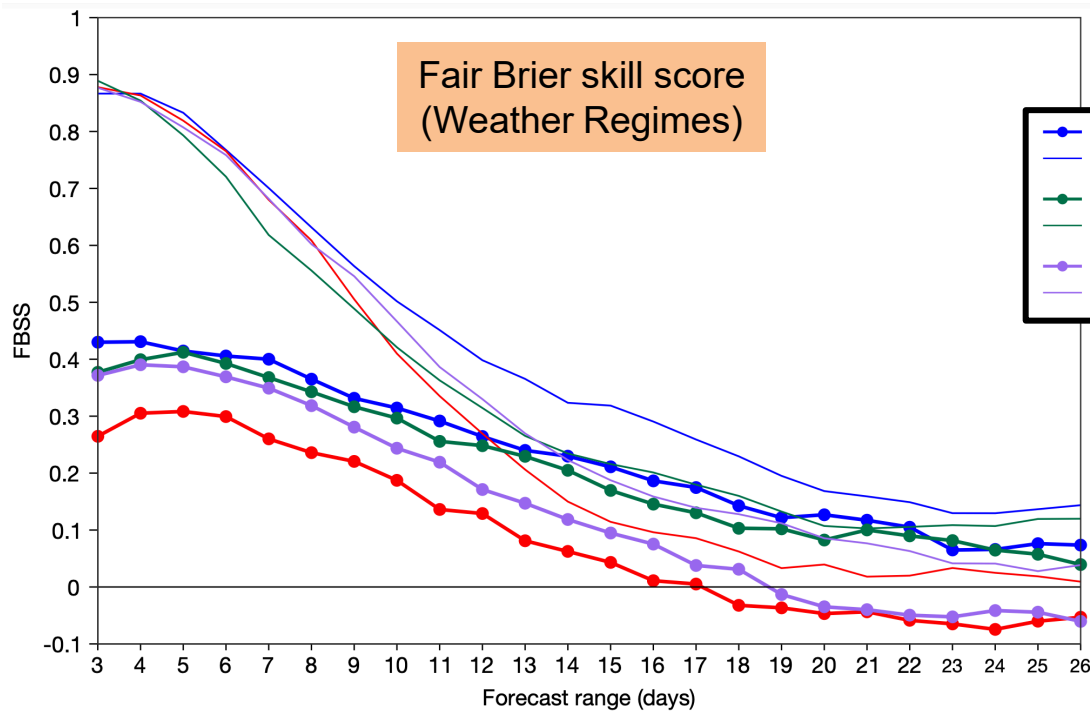
- Difference between forecasts starting on day 0 and 3 days earlier
- Difference between lagged forecasts starting on days 0 to -1 and forecasts starting 3 days earlier
- Difference between lagged forecasts starting on days 0 to -2 and forecasts starting 3 days earlier
- Difference between lagged forecasts starting on days 0 to -3 and forecasts starting 3 days earlier

Difference of MJO bivariate correlation



**Vitart & Takaya, QJRMS, 2021**

Fair Brier skill score (Weather Regimes)



- Positive phase of North Atlantic Oscillation (bi-weekly forecasts)
- Positive phase of North Atlantic Oscillation (daily forecasts)
- Negative phase of North Atlantic Oscillation (bi-weekly forecasts)
- Negative phase of North Atlantic Oscillation (daily forecasts)
- Atlantic Ridge (bi-weekly forecasts)
- Atlantic Ridge (daily forecasts)
- Blocking (bi-weekly forecasts)
- Blocking (daily forecasts)

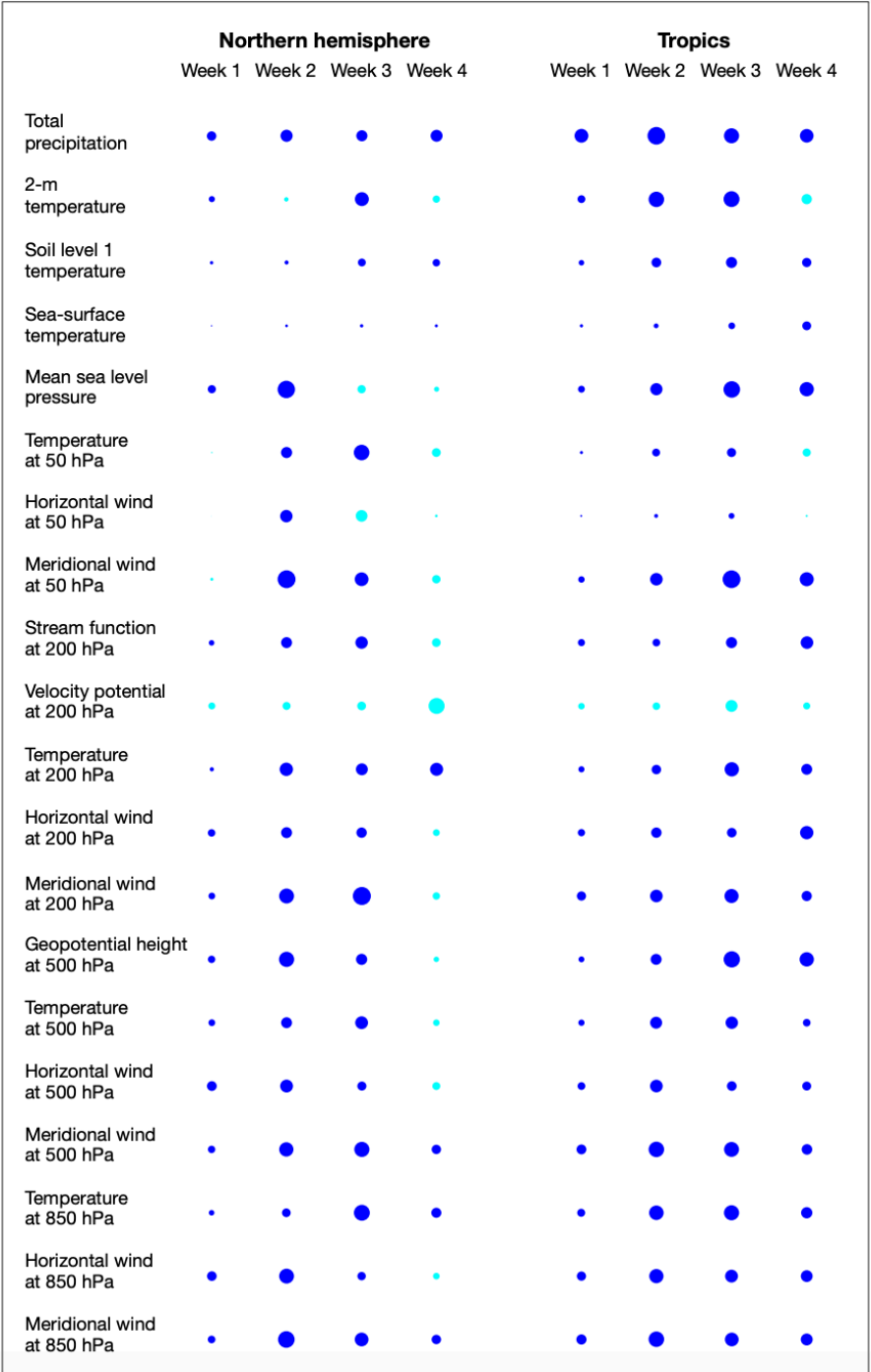
**Newsletter No. 173**

# Skill Sensitivity of ENS size: 51 vs 101 member

Skill score is significantly improved when ENS size 51 → 101

Difference in Continuous Rank Probability Skill Score

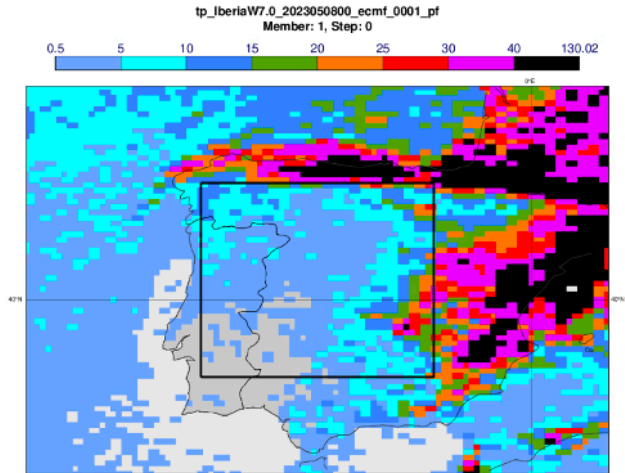
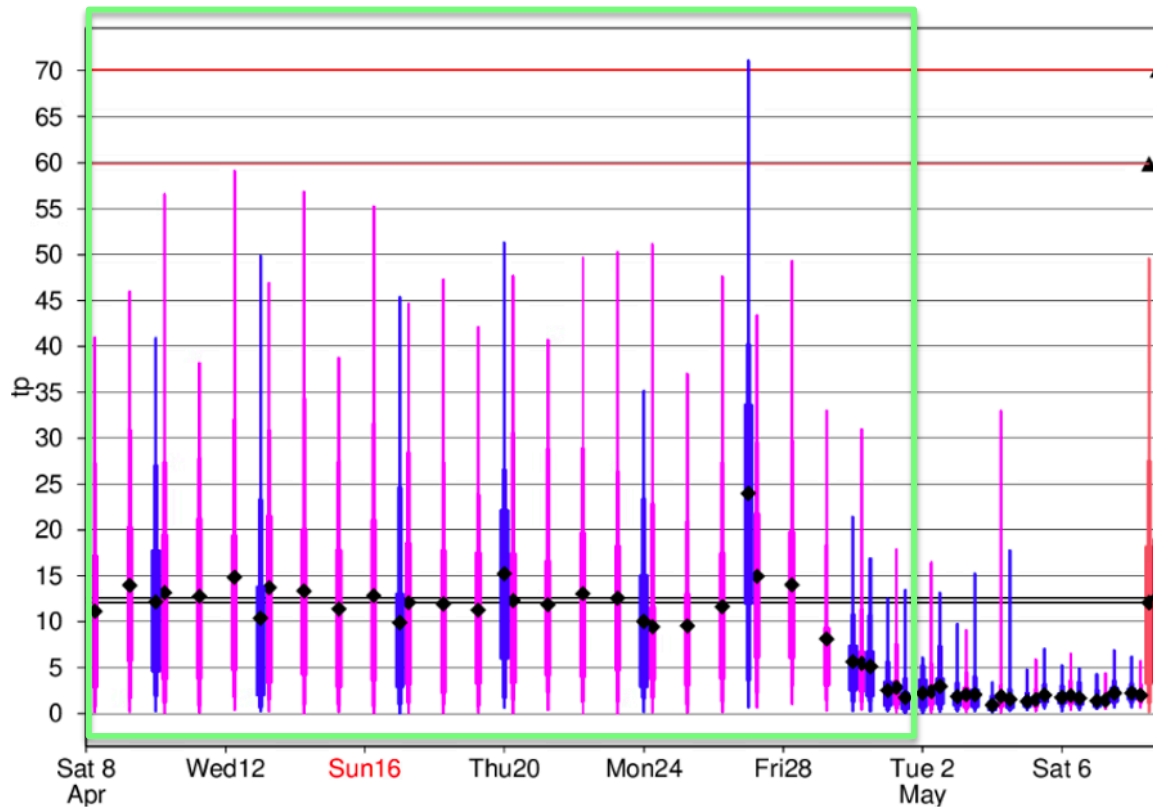
● Positive – significant	● Positive – not significant
● Negative – significant	● Negative – not significant





# New configuration performance

## Precipitation 8-15 May

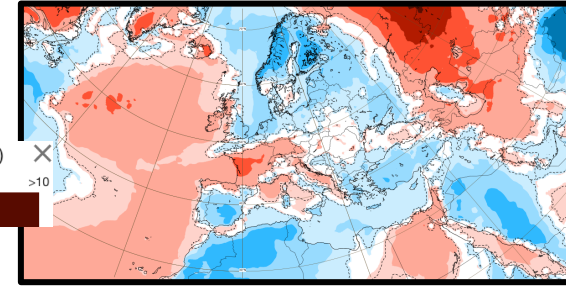
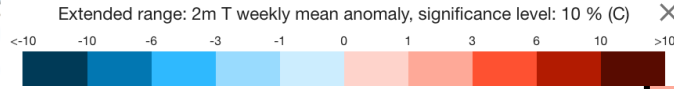


- ENS Operational**
- ENS reforecast Operational**
- ENS Extended 48r1**
- ENS Extended reforecast 48r1**
- ENS mean – diamonds**
- Reforecast maximum - triangles**

*Linus M., Daily Report, 8th May*

# New Configuration performance

**2mTemp**  
**Prob weekly lower tercile**

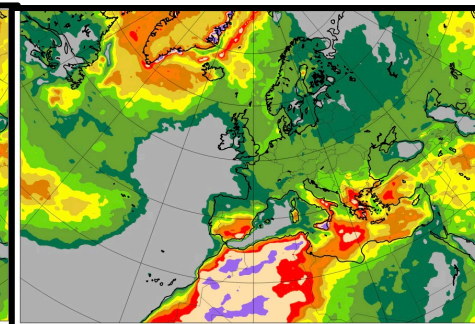
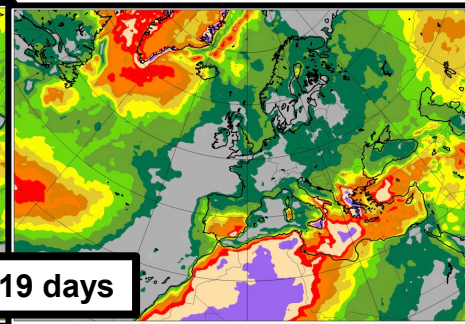
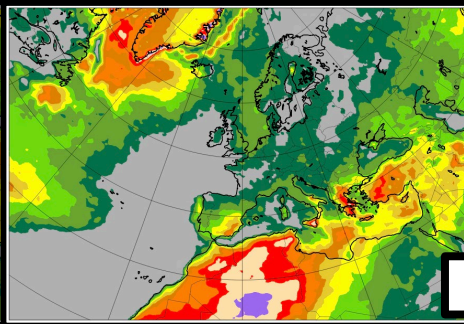
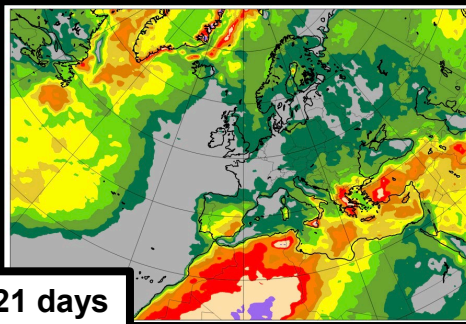


**BT: 15 May (Mon)**

**BT: 16 May (Tue)**

**BT: 17 May (Wed)**

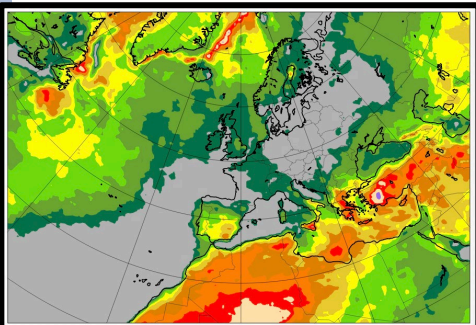
**BT: 18 May (Thu)**



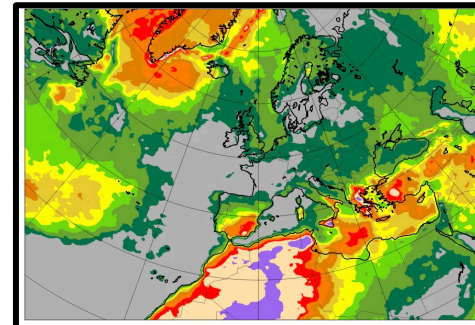
**VT: 29 May – 05 Jun 2023**

**BT: 15 May (Mon)**

**BT: 18 May (Thu)**

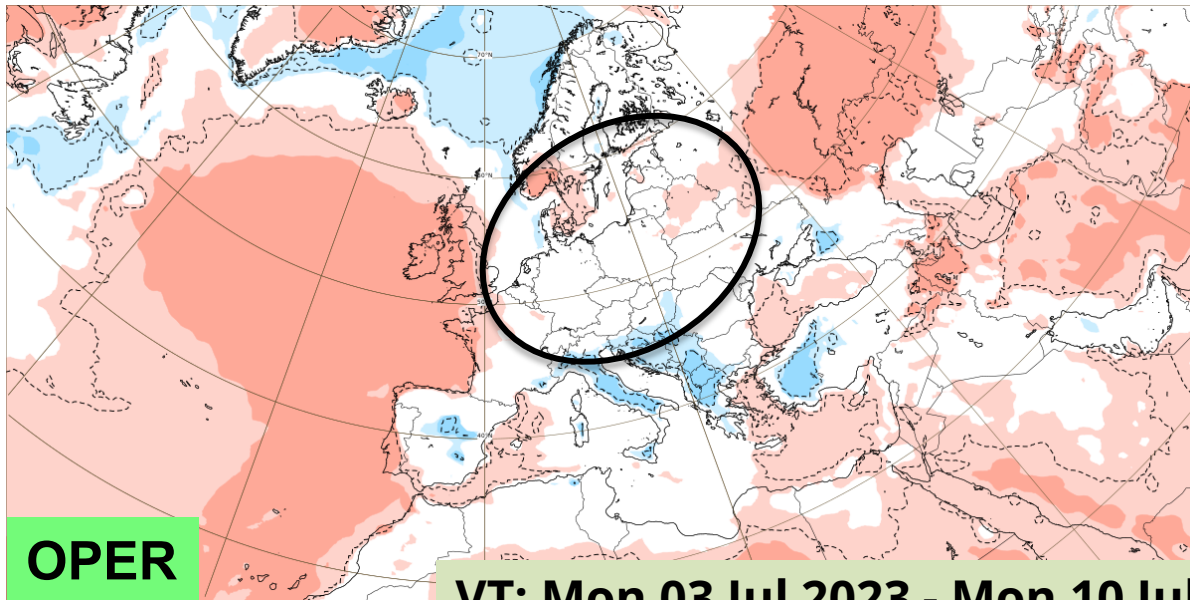


**ENS- Ext** captures better the tail of the probabilistic distribution across the North Africa



**Operations**

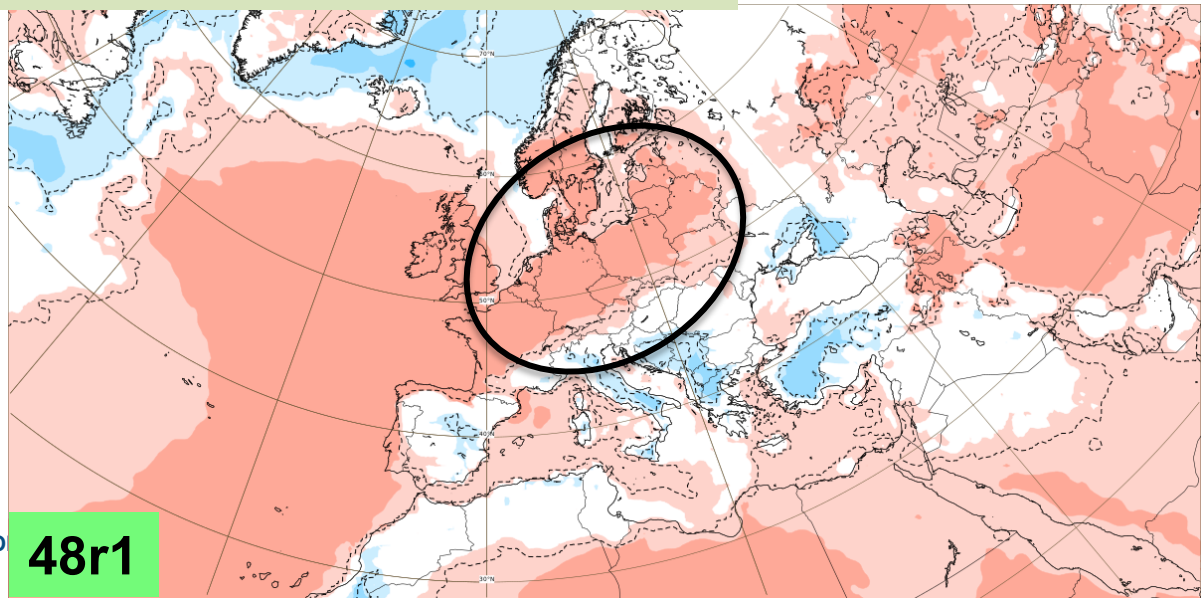
# New Configuration performance



**2 m temperature:  
Weekly mean  
anomalies**

**VT: Mon 03 Jul 2023 - Mon 10 Jul 2023**

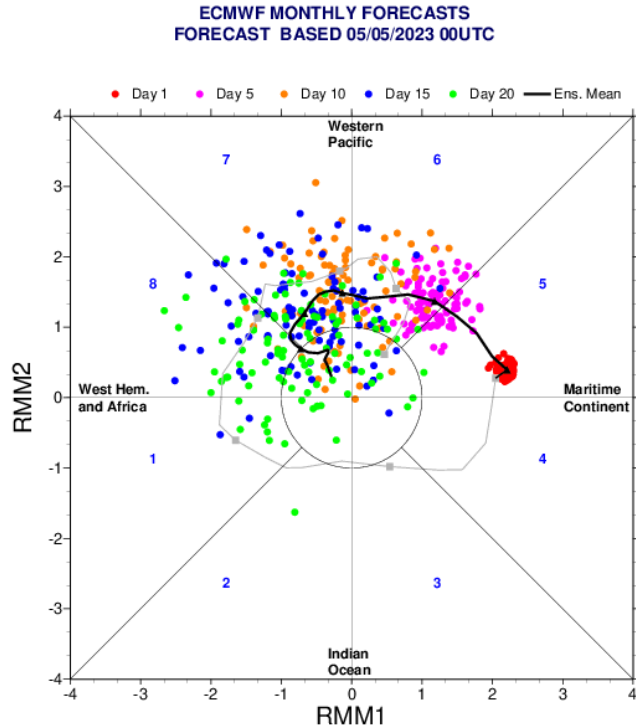
**BT: Thu 01 Jun 2023**



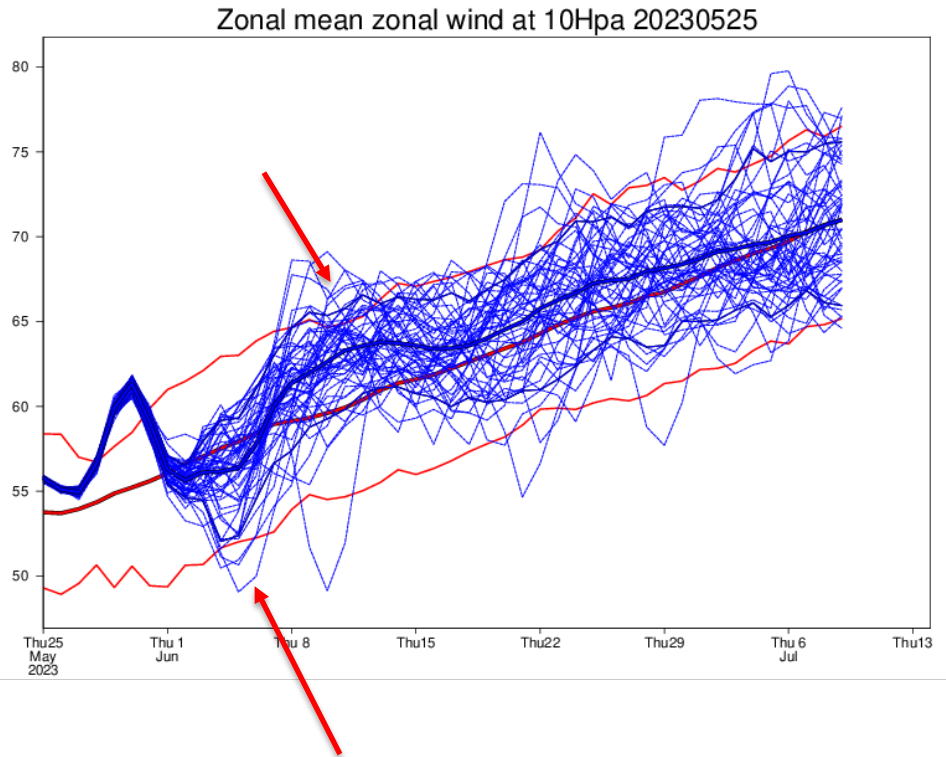


# ENS Extended Range Forecast Products (48r1)

## Madden-Julian Oscillation Index

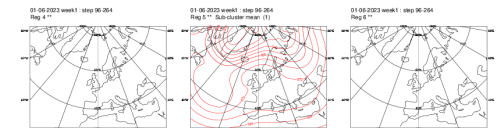
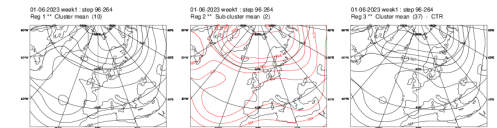
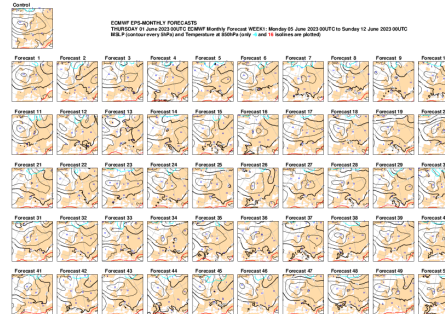


## ZMW South Hemisphere

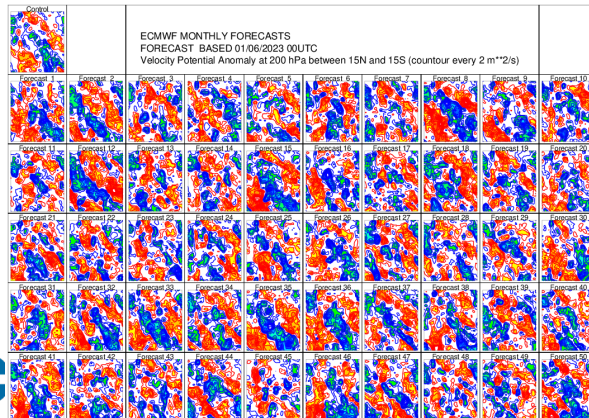
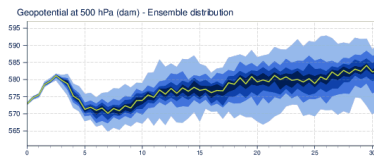
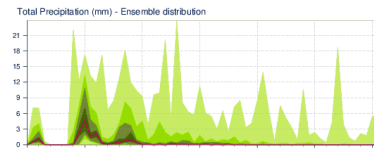
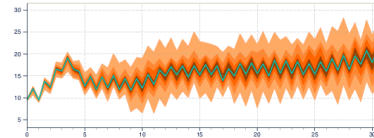


# Extended Range: discontinued products

- Stamp Maps (MSLP & Z500)
- Old regime product
- Plumes (to be revisited)
- MJO Hovmoeller stamp



ECMWF Ensemble forecasts for TURKEY - ANKARA  
 Location: 39.50°N 32.98°E  
 Base Time: Monday 5 June 2023 00 UTC



# Graphical products <https://charts.ecmwf.int>

The screenshot displays the ECMWF Charts website interface. At the top, there is a navigation bar with the ECMWF logo and 'Charts' text. Below this is a search bar and a 'Home / Charts catalogue' breadcrumb. The main content area is a grid of weather forecast charts, each with a title, description, and a 'Latest forecast' button. The charts are organized into two main sections: 'Extended (42 days)' and 'Next IFS version (cy48r1)'. The 'Extended (42 days)' section includes charts for Mean sea level pressure and 850 hPa wind speed, and 500 hPa geopotential height and 850 hPa temperature. The 'Next IFS version (cy48r1)' section includes charts for 2 m temperature and 30 m wind, and 100 m wind and mean sea level pressure. The charts use various color scales and contour lines to represent different meteorological variables. The interface also features a sidebar with filters for 'Type' (Forecasts, Verification) and 'Component' (Surface). At the bottom, there are filters for 'Parameters' (Wind, Mean sea level pressure, Temperature, Geopotential, Precipitation, Cloud).

ECMWF | Charts

Home / Charts catalogue

Search products...

## Extended (42 days)

Type

- Forecasts
- Verification

Component

- Surface

## Next IFS version (cy48r1)

- Ensemble forecast (ENS)
- Combined (ENS + HRES)
- Extreme forecast index
- Point-based products
- Atmospheric composition

Parameters

- Wind
- Mean sea level pressure
- Temperature
- Geopotential
- Precipitation
- Cloud

**(Next IFS version) Mean sea level pressure and 850 hPa wind speed**

Wind speeds near the surface are roughly proportional to the distance between isobars so closely packed isobars mean strong surface winds...

**Mean sea level pressure and 850 hPa wind speed**

Wind speeds near the surface are roughly proportional to the distance between isobars so closely packed isobars mean strong surface winds...

**(Next IFS version) 500 hPa geopotential height and 850 hPa temperature**

The 850 hPa level is usually just above the boundary layer and at this level the day-night variation in temperature is generally negligible...

**500 hPa geopotential height and 850 hPa temperature**

The 850 hPa level is usually just above the boundary layer and at this level the day-night variation in temperature is generally negligible...

**(Next IFS version) 2 m temperature and 30 m wind**

Air temperatures at 2 m above the earth's surface approximate most closely to the conditions a person would most likely experience...

**2 m temperature and 30 m wind**

Air temperatures at 2 m above the earth's surface approximate most closely to the conditions a person would most likely experience...

**(Next IFS version) Mean sea level pressure and 200 hPa wind**

Wind speed at 200 hPa highlights the jet stream (areas of strong winds in the upper troposphere) which can help identify movement and development of depressions...

**100 m wind and mean sea level pressure**

These charts show surface pressure patterns. Areas of high pressure (anticyclones) are usually associated with settled weather...



# Graphical products: <https://eccharts.ecmwf.int>

The screenshot shows the ECMWF eccharts interface. A 'Layer select' dialog box is open, displaying a search for 'extended range' which has returned 58 items. The items are categorized under 'Extended range: Anomalies' and include various weather parameters such as geopotential, temperature, precipitation, and wind. A text box on the right side of the screenshot states: '48r1 (0078) products are identified by a black solid line around the widget.'

Layer select

Select from these ECMWF Layers to add to your personal list

extended range

58 matching items

extended range

Extended range: Anomalies

Extended range: 500 hPa geopotential

Extended range: 500 hPa geopotential

Extended range: 2m temperature weekly

Extended range: 2m temperature weekly

Extended range: MSLP weekly mean

Extended range: MSLP weekly mean

Extended range: precipitation weekly

Extended range: precipitation weekly

Extended range: precipitation weekly

Extended range: surface temperature

Extended range: surface temperature

Extended range: 10hPa temperature

Extended range: 10hPa temperature

Extended range: Sunshine duration

Extended range: Sunshine duration

Extended range: 10 metre wind weekly

Extended range: 10 metre wind weekly

Extended range: 100 metre wind weekly

Extended range: 100 metre wind weekly

Extended range: 100 metre wind weekly

Extended range: 850 hPa wind weekly

Extended range: 850 hPa wind weekly

Extended range: 700 hPa wind weekly

Extended range: 700 hPa wind weekly

Extended range: 500 hPa wind weekly

Extended range: 500 hPa wind weekly

Extended range: 200 hPa wind weekly

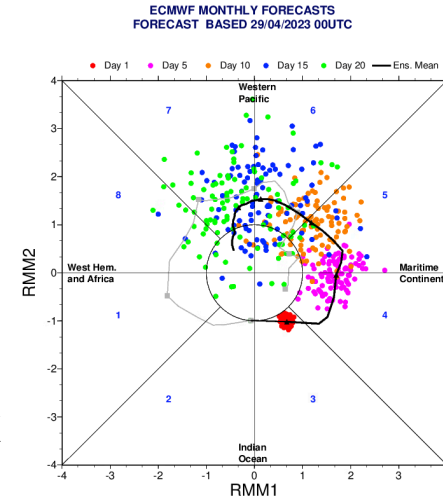
Extended range: 200 hPa wind weekly

Unfilled - Friday 2 Jun 2023, 00 UTC VT Friday 2 Jun 2023, 06 UTC Step 6

Sat 03 Sun 04 Mon 05 Tue 06 Wed 07

# Summary

- New ENS-Extended configuration is in-line with users demands
  - Increasing ENS **size** and **frequency**
- Benefit: increase of skill from forecasts issue twice a week to daily (MJO, Weather Regimes)
- Daily products (ex: weekly means) consistent with the new configuration including new product streams
- Hindcast configuration unchanged in 48r1 (10 ENS + CTRL x 20-years on Mon & Thu) but independent from ENS Medium Range hindcasts
- Newsletter article <https://www.ecmwf.int/en/newsletter/173>
- Confluence page <https://confluence.ecmwf.int/display/FCST/Implementation+of+IFS+Cycle+48r1>
- With the EN-Ext 48r1 provides more flexibility for the users to develop products



# The new snow scheme in IFS CY48R1

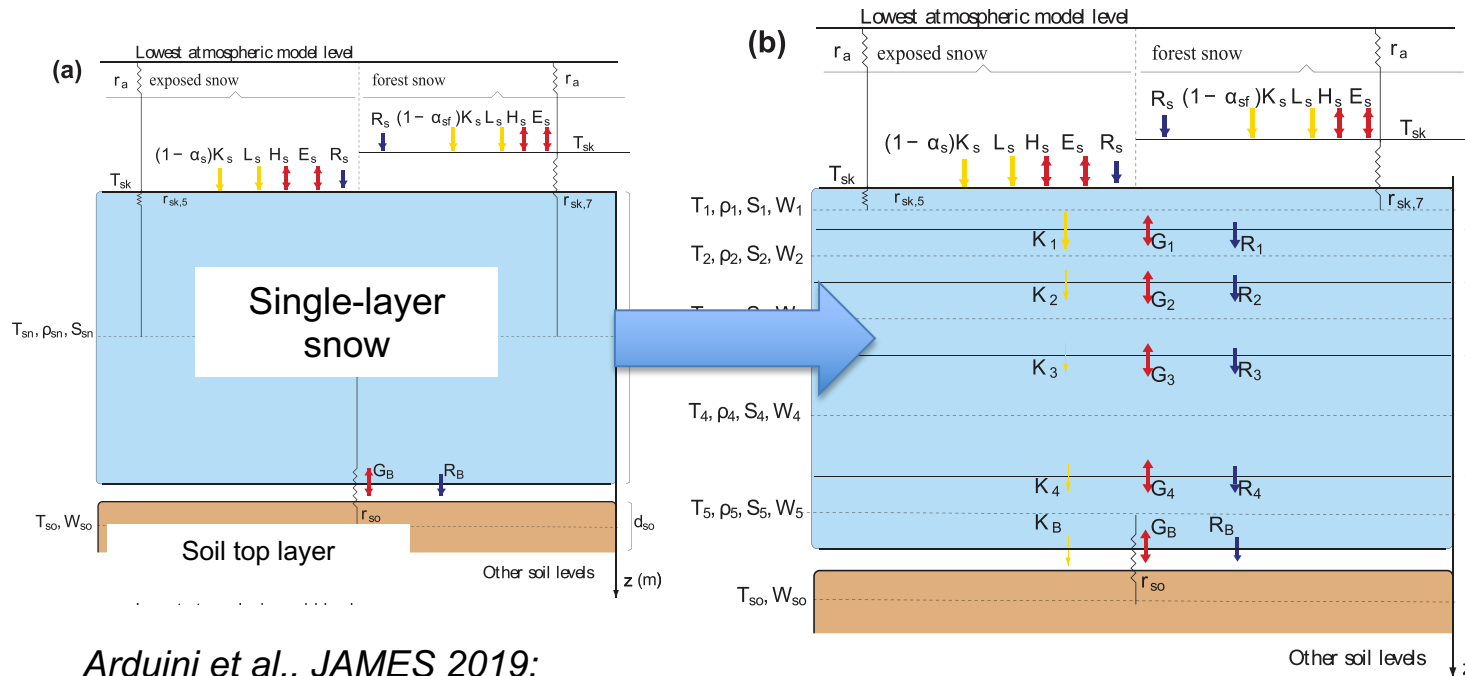
Gabriele Arduini

Earth System Modelling Section, Research Department

[Gabriele.Arduini@ecmwf.int](mailto:Gabriele.Arduini@ecmwf.int)

UEF2023

# A multi-layer snow scheme for the IFS CY48R1



- “Intermediate complexity”:
  - No microstructure
- 5-layer snow scheme
- SWE, density, temperature + **liquid water content** on 5-layers
- **Integrated** (“total”) variables still available as diagnostic output

Arduini et al., JAMES 2019;  
Boussetta et al., Atmosphere, 2021



# Technical details, MARS, metadata

- GRIB2 output, ccsds packingType
- “New” Levtype=sol ; typeOfLevel=”snowLayer”
- **SI units:** snow depth water equivalent is now in kg m<sup>-2</sup>
  - Difference of factor 1000 (i.e. density of water) compared to CY47R3!

## MARS Catalogue

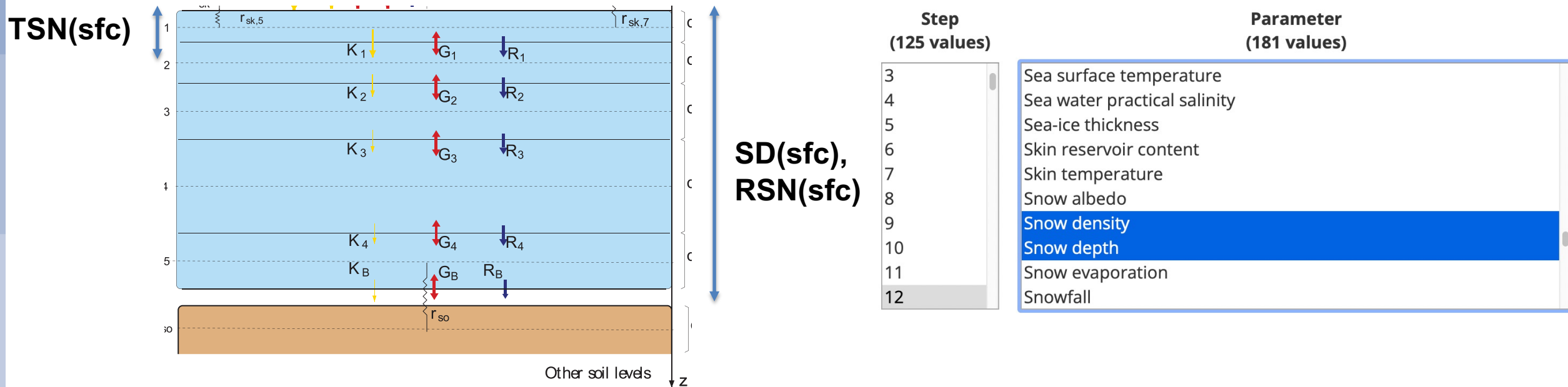
Step (125 values)	Level (5 values)	Parameter (4 values)
3	1	Liquid water content in snow pack
4	2	Snow density
5	3	Snow depth water equivalent
6	4	Temperature of snow layer
7	5	
8		
9		
10		
11		
12		

edition	dataType	stepRange	typeOfLevel	level	shortName	packingType	max
2	fc	3	snowLayer	1	sd	grid_ccsds	150.723
2	fc	3	snowLayer	2	sd	grid_ccsds	155.461
2	fc	3	snowLayer	3	sd	grid_ccsds	195.387
2	fc	3	snowLayer	4	sd	grid_ccsds	325.961
2	fc	3	snowLayer	5	sd	grid_ccsds	9400

# Backward compatibility: can I still use single-layer snow fields?

Backward compatibility is maintained:

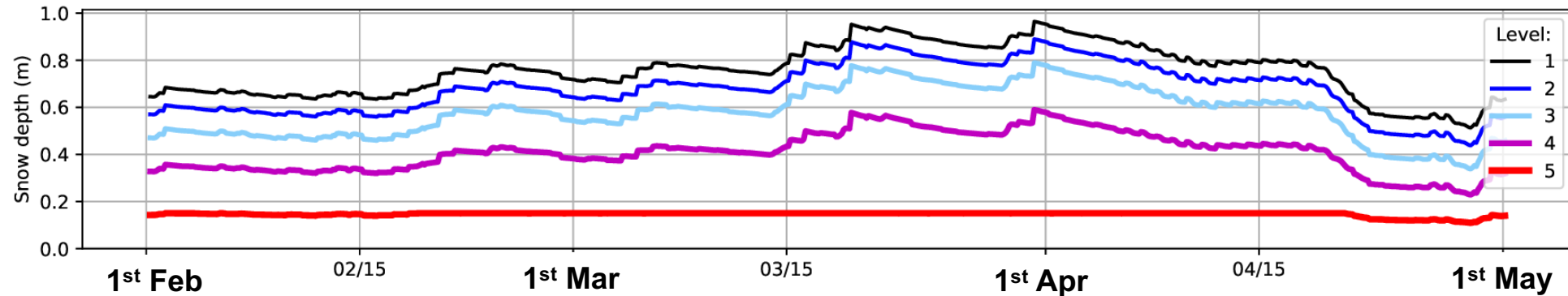
- **SD, RSN, TSN “single-layer” still part of levtype=sfc output**
  - SD(sfc), RSN(sfc) so that total snow depth can be computed as in previous cycles, e.g.  $\text{SnowDepth(m)} = 1000 * [ \text{SD(sfc)} / \text{RSN(sfc)} ]$
  - TSN(sfc) is equivalent to the temperature of the topmost snow layer (level=1)



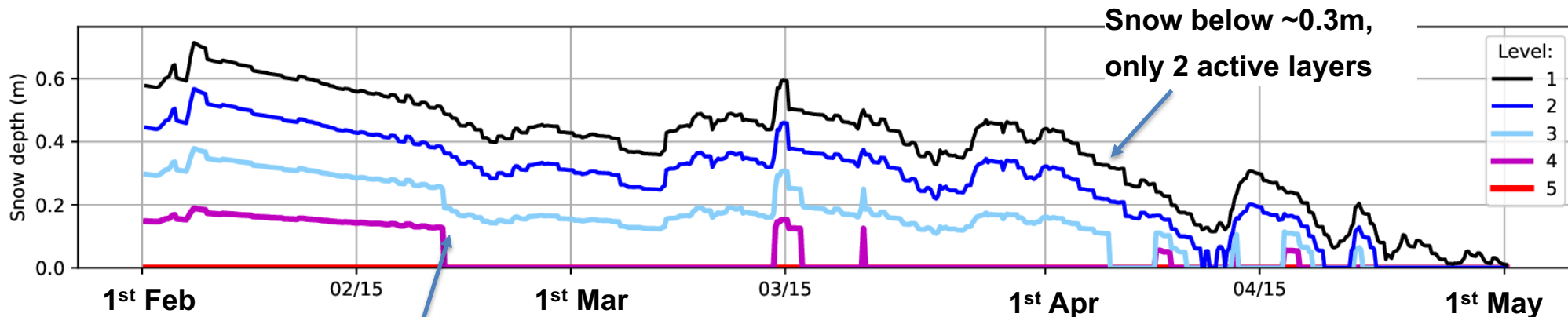
# Multi-layer snow scheme – Snow depth

- Finer vertical discretization for layer in contact with the atmosphere (level=1)
- Dynamical vertical grid: number of active layers depends on snow depth

Snow depth at Sodankyla, Finland; concatenated FC t+3 to t+24



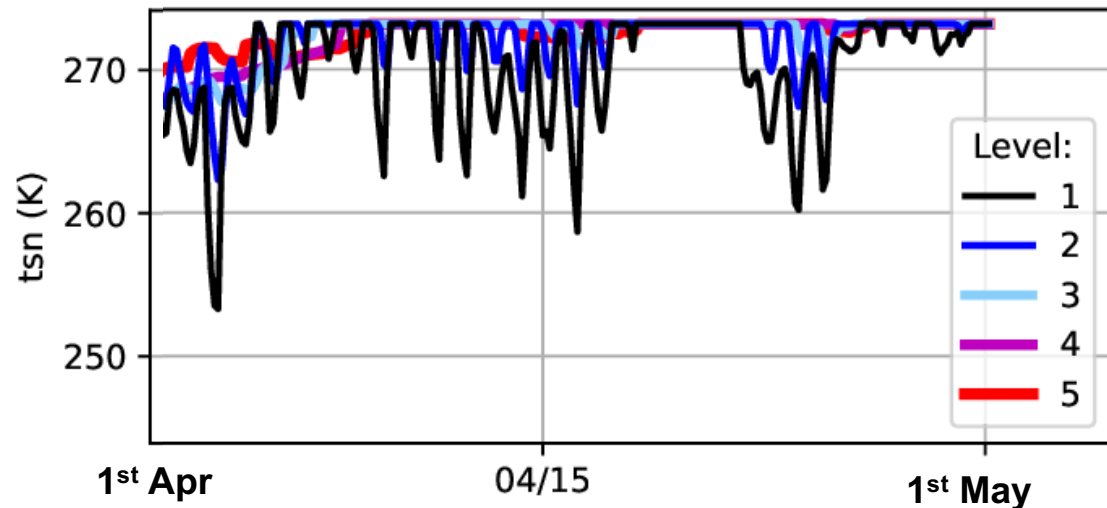
Snow depth near Bolzano, Italian Alps; concatenated FC t+3 to t+24



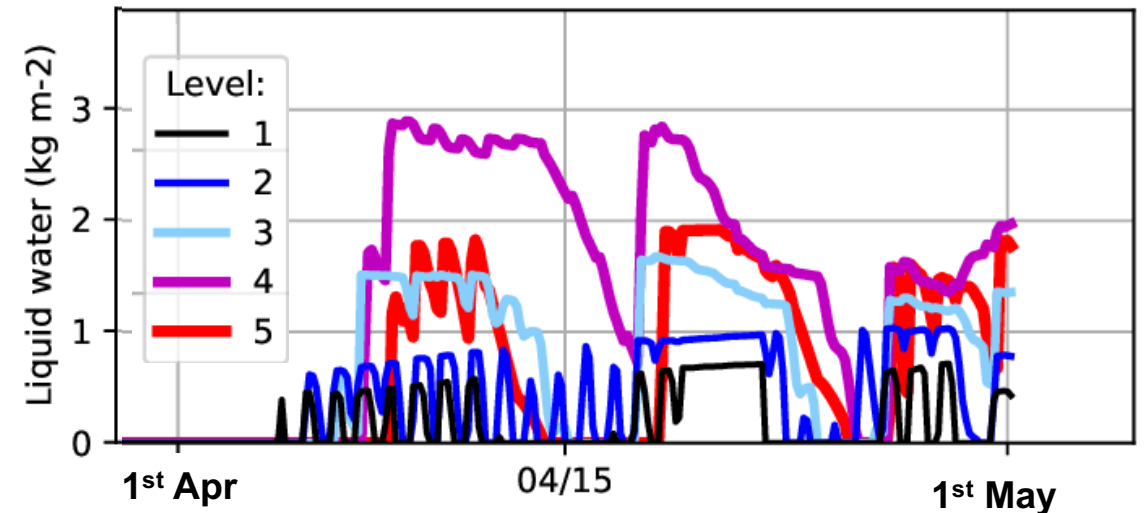
# Multi-layer snow scheme – Snow temperature

- Multiple snow layers allow representing multiple time-scales:
  - topmost snow layer reacting faster to atmospheric forcing
  - bottom layer responding to longer time-scales
- Liquid water content allow representing melting/refreezing cycles within the snowpack

Snow temperature at Sodankyla, Finland; concatenated FC t+3 to t+24



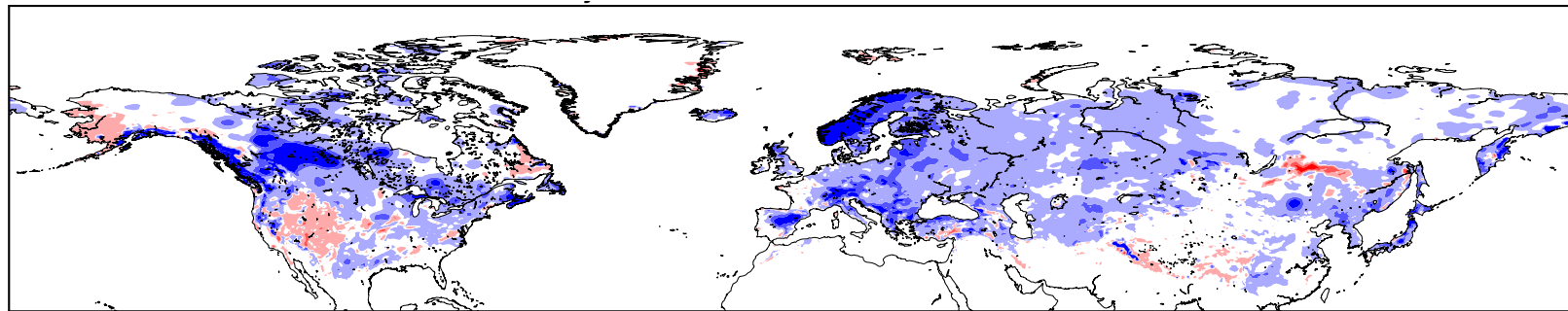
Snow liquid water content, Sodankyla; FC t+3 to t+24



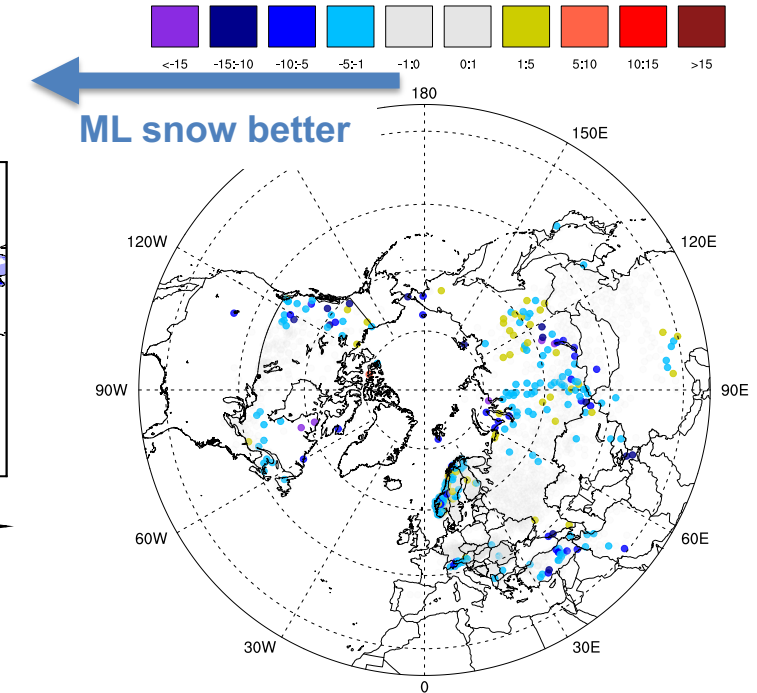
# Multi-layer snow scheme – improved snow forecast

- Improved snow depth in short-range forecasts
- Snow depth errors reduced for increased forecast range

RMS difference of analysis increments (12h forecast – analysis) of snow depth, between multi-layer and single-layer snow scheme, January 2021



RMSE difference of forecasts at day 5 (compared with synop station), Winter 20/21

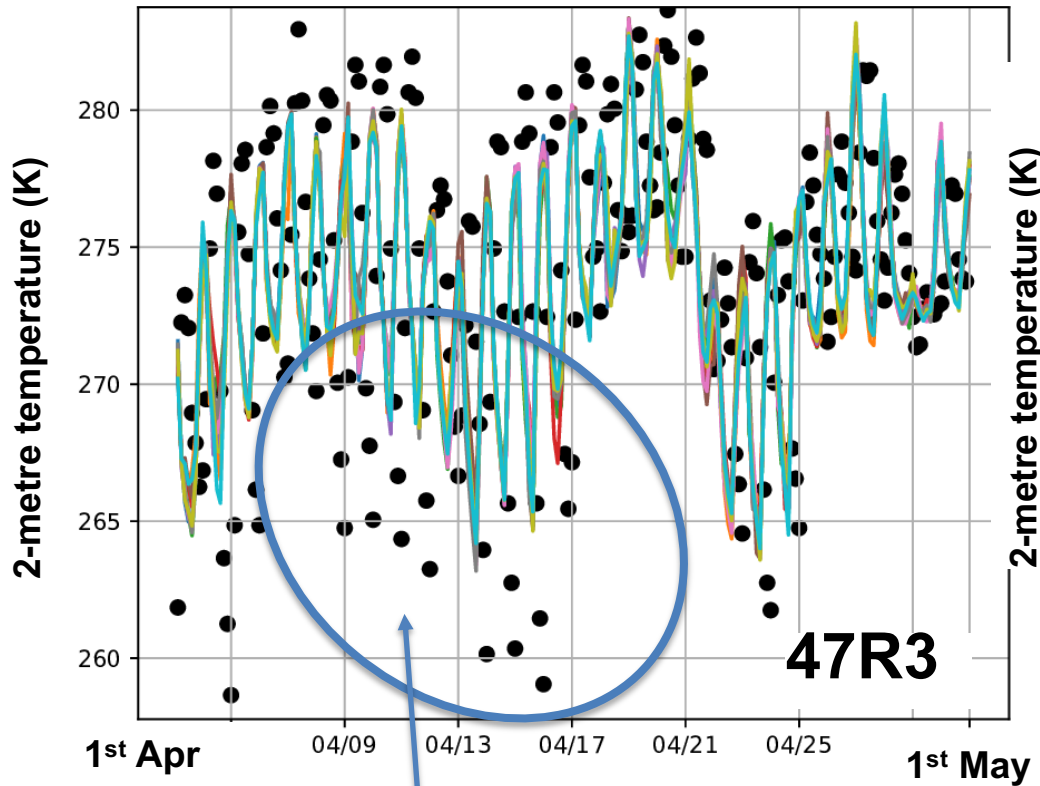




# Multi-layer snow scheme – impact on T2m ensemble

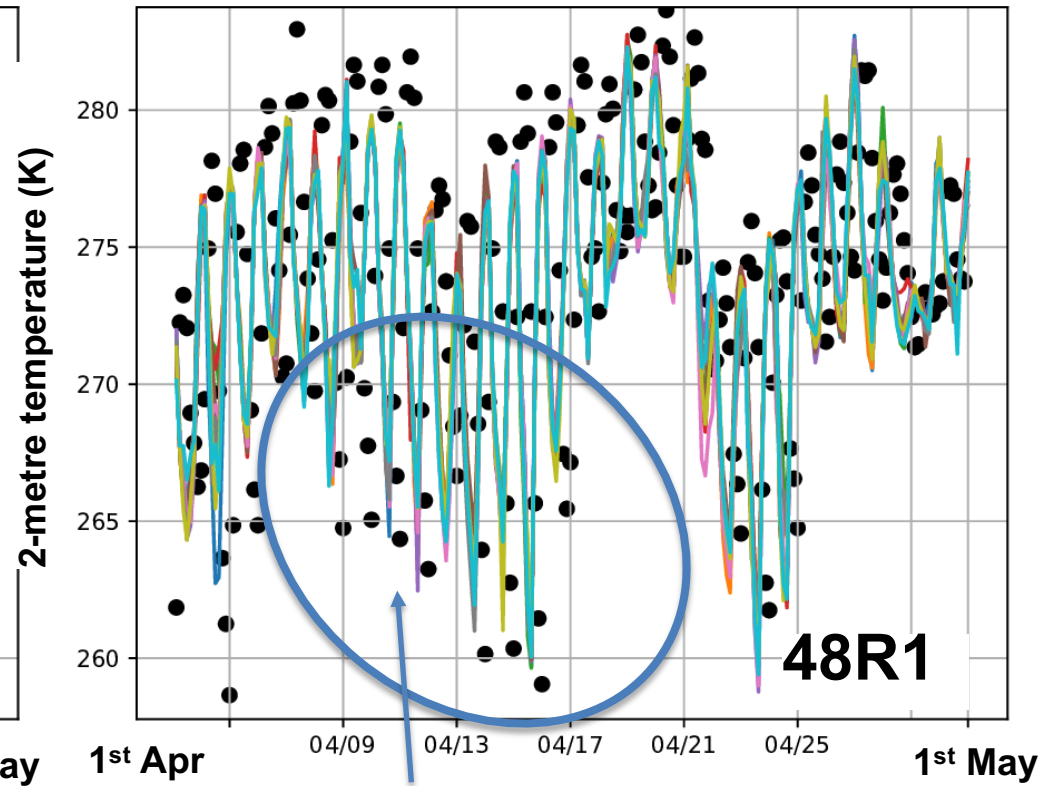
- Thinner top snow layer allow representing colder temperatures
- Increased ensemble spread over snow-covered surfaces

T2m at Sodankyla, ens o-suite 47r3, FC t+3 to t+24



Large minimum temperature errors

T2m at Sodankyla, ens e-suite 48r1, FC t+3 to t+24



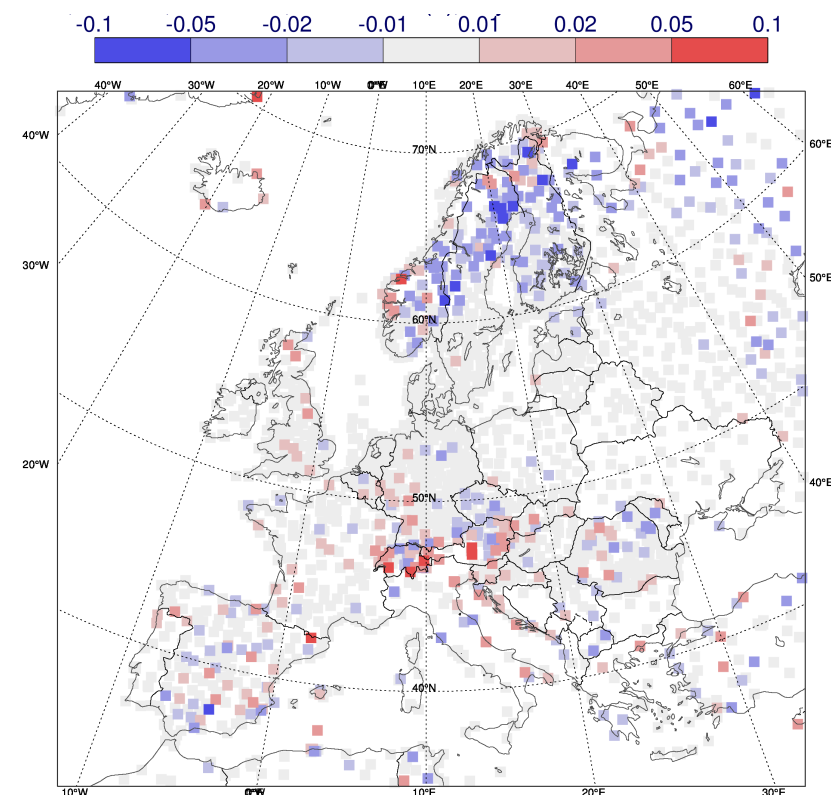
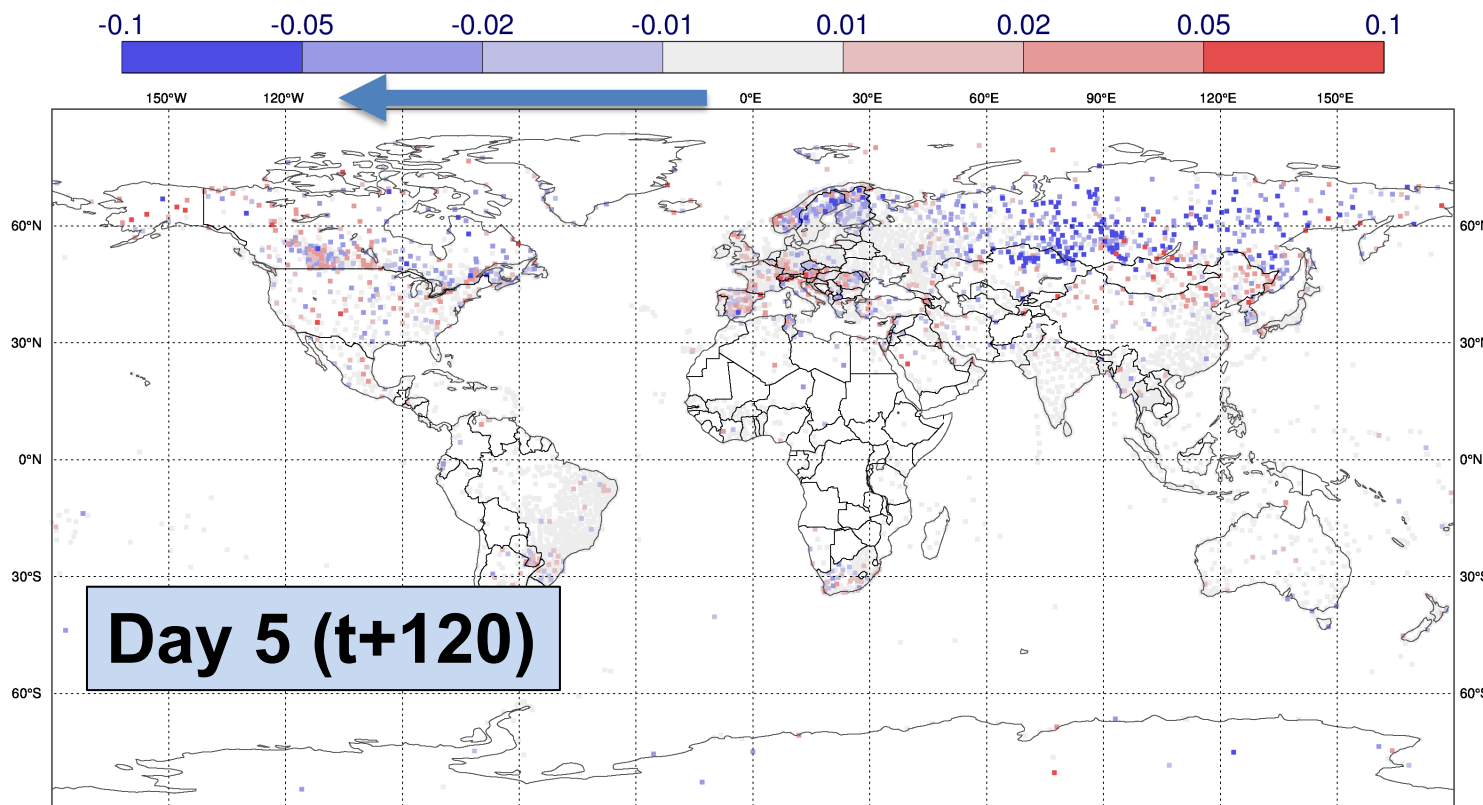
Errors reduced in 48r1

# Multi-layer snow scheme – improved ensemble forecasts

## Reduced fraction of large errors in ensemble

Fraction of CRPS errors in 2-metre Temperature > 5K in ensemble forecasts, Winter 2019/2020

Multi-layer snow reduces errors



# Summary

- A multi-layer snow scheme with up to 5 layers is introduced in CY48R1
- “Equivalent” single-layer snow fields are maintained in the output, derived from the multi-layer fields
- Snow depth forecasts generally improved at short and medium-ranges
- Increased T2m spread and better representation of minimum temperatures

## Questions?