Green Book Reports 2024

“Use and Verification of ECMWF products in Member and Co-operating States (from January 2022)”

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Big Thanks to all MS/CS contributors!

ECMWF

This Year

Feedback on new approach mostly positive or very positive; we are likely to keep this 😀

- Different strategy adopted for collecting feedback…

- Two options given for MS/CS reporting:
  - **1.** Classical word/pdf document, with headings from our template, to email to ECMWF
  - **2.** Online survey, with equivalent questions, and with image upload options
    - Permitted word count per section was high (just one user exceeded!)

- Anticipated Benefits of **option 2**:
  - Could be easier for users, might encourage more responses
  - Somewhat easier for ECMWF to collate responses
  - Yes/No answers easier to accommodate
  - Easier for multiple users in a given MS/CS to add their input
    - Form could be saved and reloaded (with a shared password)

Report Structure:

This presentation relates to Use and Verification of ECMWF products in Member and Co-operating States, since January 2022:

Section 1: Background

Section 2: Summary of major highlights

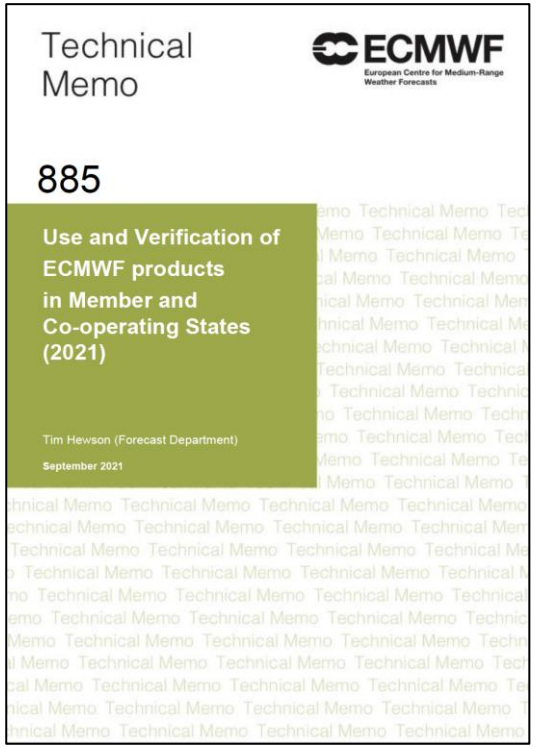
Section 3: Forecast Products

Section 4: Verification

Section 5: Output Requests *(not covered today, lack of time)*

Section 6: References

Section 7: Additional comments and Feedback



Last time (2021)

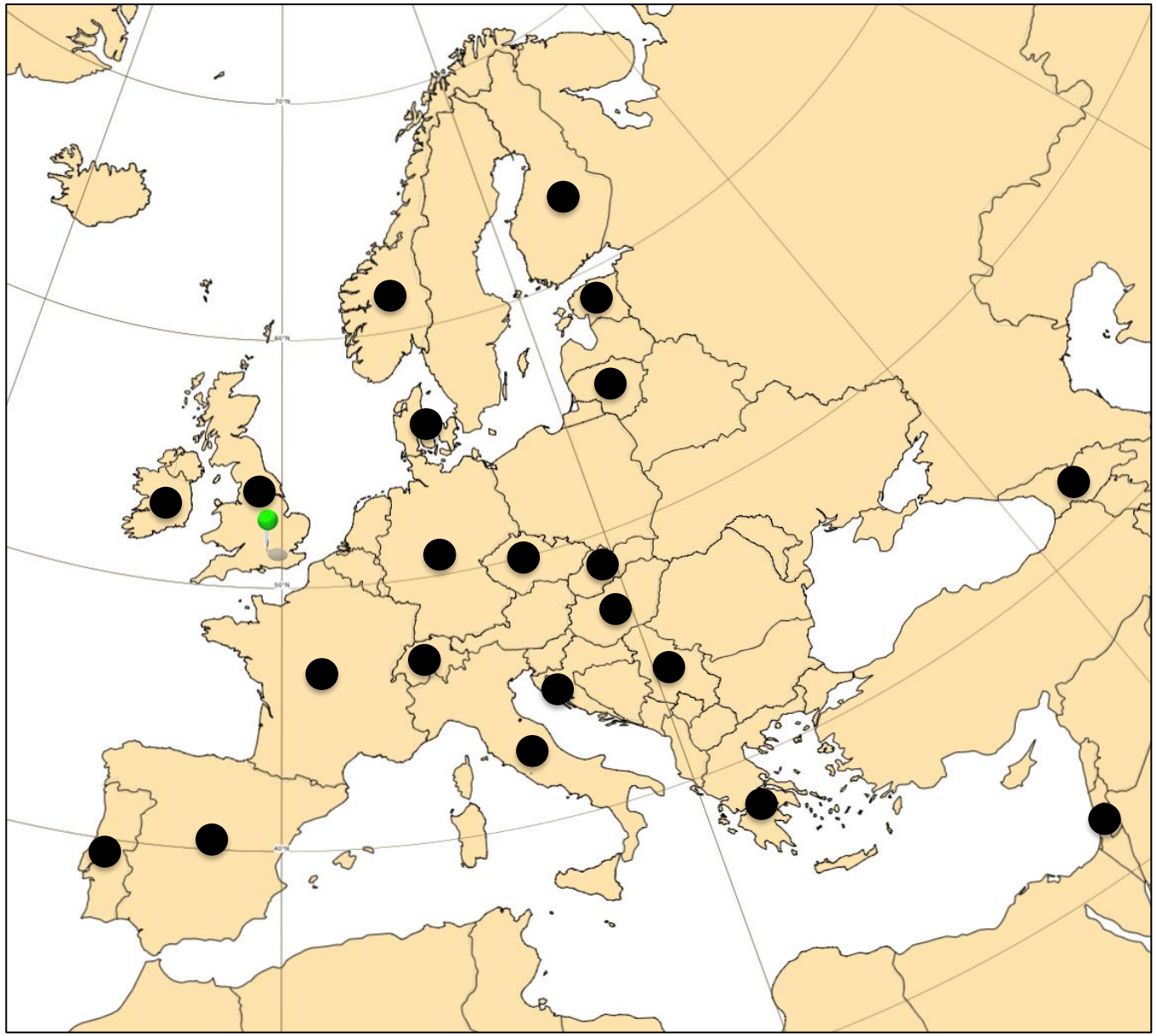
Q1.3 – Your Organisation

21 responses (so far!)

In 2021 - the last survey of this type - there were 26 responses

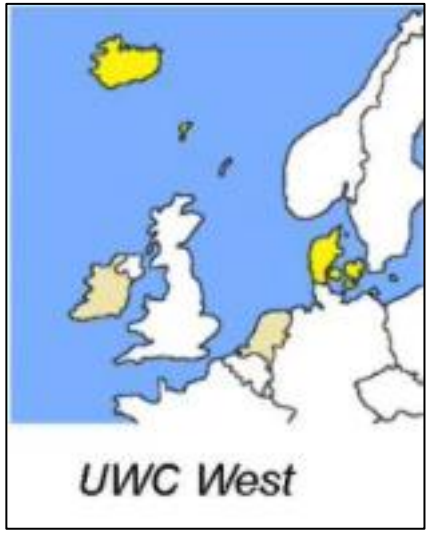
11 completed the online survey

10 provided a traditional word/pdf report



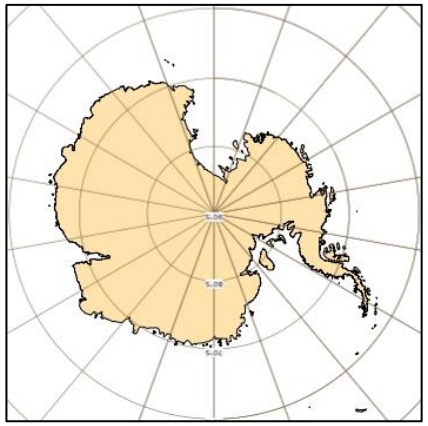
Q2: Please detail major highlights since January 2022

- Croatia:
  - ECMWF used for Short range to Long range
  - Extensive forecaster's survey carried out
  - Convective precip distribution / amounts are the main concern
- Czech Republic:
  - ECMWF used for Short and Medium range
  - Intercompared with other models on Visual Weather platform
- Denmark
  - Co-production arrangement established (United Weather Centres West)
  - BCS for LAM-EPS now come from ECMWF
- Estonia
  - 48r1 gives larger output files (!)
  - Bigger uptake than ever of ECMWF outputs / tools / applications
  - Wave / ocean models now running on ECMWF ATOS
- Finland:
  - ECMWF used mainly D2 onwards
  - Good to see 48r1 higher resolution and multi-layer snow scheme
  - Very pleased to see AI/ML techniques explored at ECMWF (also ongoing at FMI)



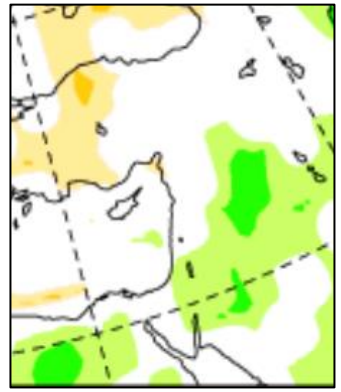
Q2: Please detail major highlights since January 2022

- France:
  - ECMWF outputs very widely used
  - Key request now: 1 year of data from new cycles, in advance, for calibration purposes
- Georgia:
  - Meteogram outputs have improved
  - Thanks for correcting many cartographic errors (place names / locations in Georgia)!
- Germany: *(no highlights reported)*
- Greece:
  - ECMWF data used up to day 7 for land, sea and aviation (extended/seasonal much less used)
  - ENS usage maximized for days 4 to 7. EFI has become increasingly popular
- Hungary:
  - Objective verification continues, for medium to seasonal time ranges
- Italy:
  - ecPoint (95th percentile), freezing rain and other products in ecCharts important for civil protection
  - Products use goes beyond Italy – e.g. many wave products for “Wheel On the World”, others for Antarctica
  - Daily issue monthly forecast charts (48r1) are important for them



Q2: Please detail major highlights since January 2022

- Ireland:
  - ECMWF output mainly used for day 3 to day 10; directly and for LBCs
  - Main users: Forecasting, Flood forecasting, Climate Services and Research and Applications division
  - Seasonal outlooks now routinely produced using C3S multi-model data
- Israel:
  - Little recent change in ECMWF data usage
  - 48r1 welcomed, forecast quality improved for some variables, and LAM forecast quality from BCs
  - Seasonal rainfall forecasts important: 2022/23 forecasts were OK, 2023/24 less good
- Lithuania:
  - Little recent change in ECMWF data usage
  - Intensive usage in everyday work: directly for medium range, whilst BCs benefit short range LAM
- Norway:
  - Automated online yr.no forecasts now go out to day 21 (following daily extended range forecasrs in 48r1)
- Portugal:
  - Report includes verification of 47r3 and 48r1 output
- Serbia:
  - Big uptake of MetView-Python internally, to create multiple forecast products on internal web pages



Q2: Please detail major highlights since January 2022

- Slovakia:
  - Operational downloads of CAMS EUROPE output introduced for chemical transport model
- Spain:
  - ECMWF products are fundamental for short range through to seasonal
  - 48r1's higher resolution was very well received, although model biases remain
- Switzerland: *(no highlights reported)*
- UK:
  - ECMWF output widely used by forecasters and hydrometeorologists: main focus is week 2
  - Met Office models also widely used; automated and subjective multi-model blending take place
  - The BC programme, which UKMO joined, and the pre-delivery schedule were both very beneficial

Q3: Direct use of ECMWF products

Medium Range (MR), Extended Range (XR), Long Range (LR)

- All centres use data for medium range, and most for short range too - directly and/or for BCs for LAMs (deterministic and increasingly EPS too)
  - Typically, ECMWF output becomes the main forecast data source around day 3
- Output for extended ranges is also widely used, though not everywhere
  - Recent initiatives have been exploiting XR for improved outputs – e.g. in Ireland / Norway
- Long range output is also used in some countries, passively or actively
  - In some countries LR output assumes high importance – e.g. Israel due to water resource issues
  - In others there is clear recognition of low skill levels for Europe – e.g. Norway

- Main changes in usage since the last Green Book reporting cycle (2021) have been in LAM BC uptake, and extended range exploitation

Product Classes Referenced

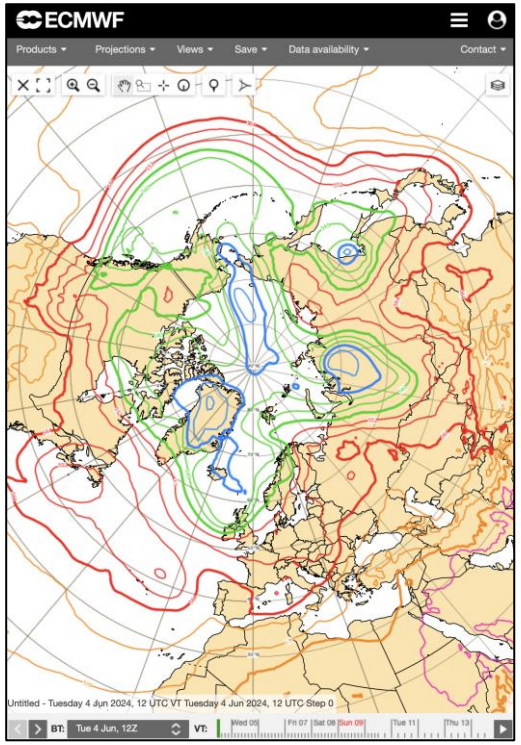
- EFI/SOT in various guises
- Visibility meteograms
- ecPoint-Rainfall
- Precipitation type products
- Lightning
- Convective indices
- CAT
- Cyclone database
- Weather Regimes
- Vertical profiles
- TC-related
- Meteograms
- …

…and the usual mslp and rainfall, Z500, T850, basic probability products, etc…

Access mechanisms:

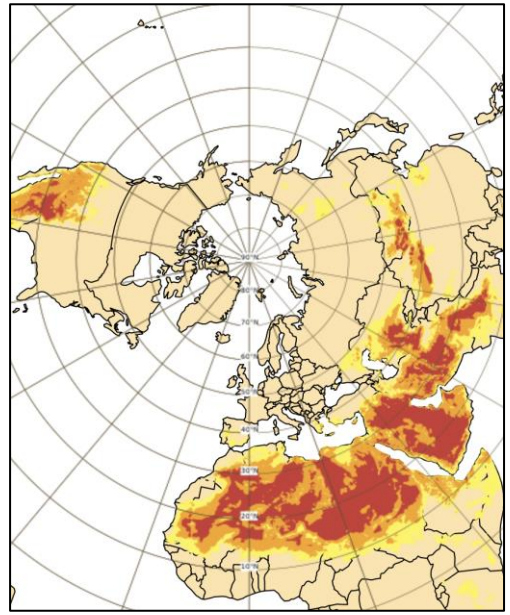
Own workstations (via disseminated fields)
Intra-organization websites
OpenCharts
ecCharts

Again some comments that ecCharts can be a bit slow



Q3.1d: CAMS and Fire-related outputs

- **9/22** countries reported using CAMS products
  - Dust aerosol optical depth often mentioned
  - UV-related outputs also referenced
  - Some services make much more detailed use of multiple parameters (e.g. Hungary)



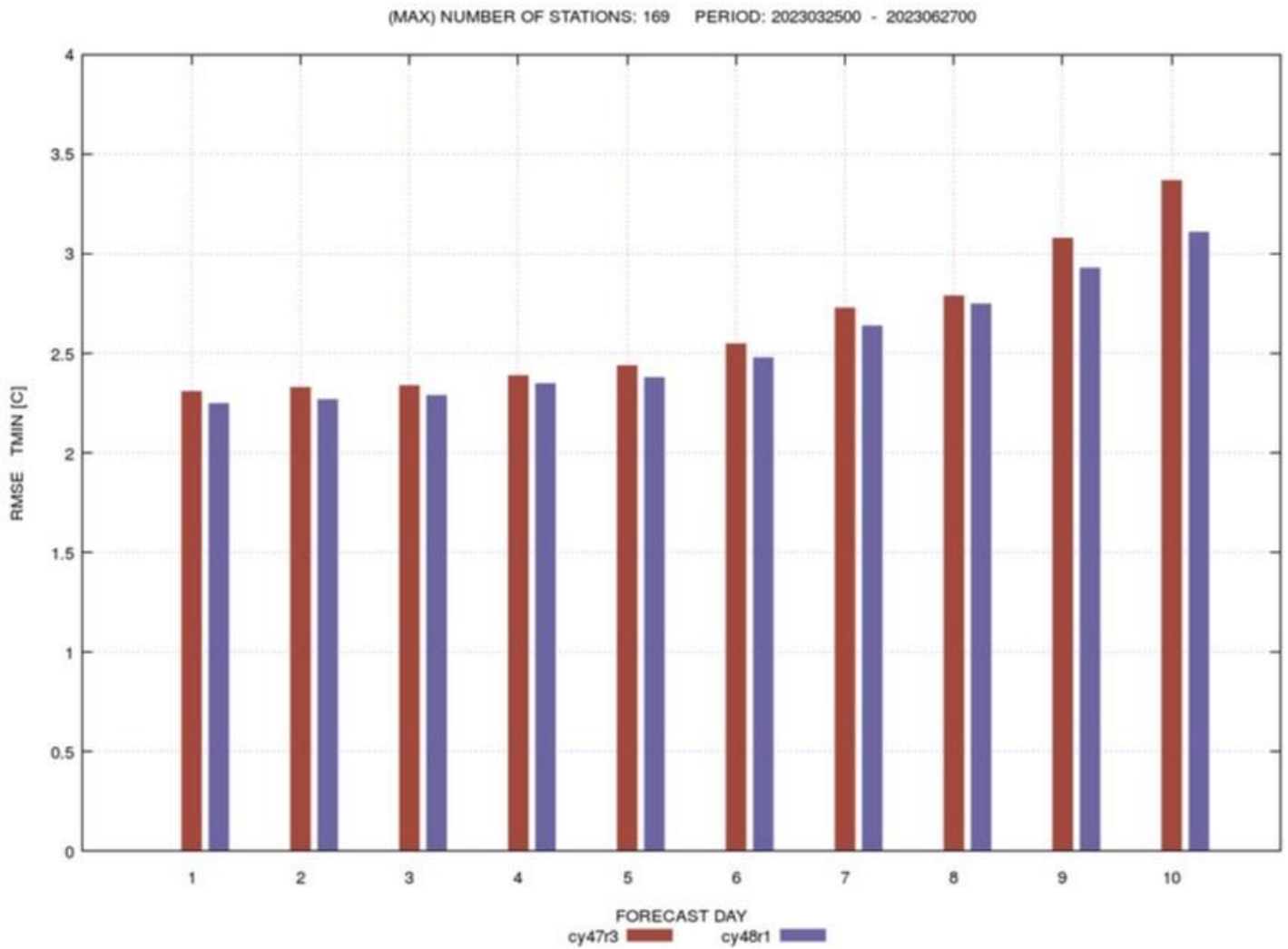
- **6/22** countries reported using fire-related outputs
  - Some references to ARISTOTLE project (specific ARISTOTLE options in ecCharts)
  - Some reference to EFFIS website

- **ECMWF cycle 48r1 went live in late June 2023**
- **First ECMWF cycle to run on the ATOS HPC in Bologna**

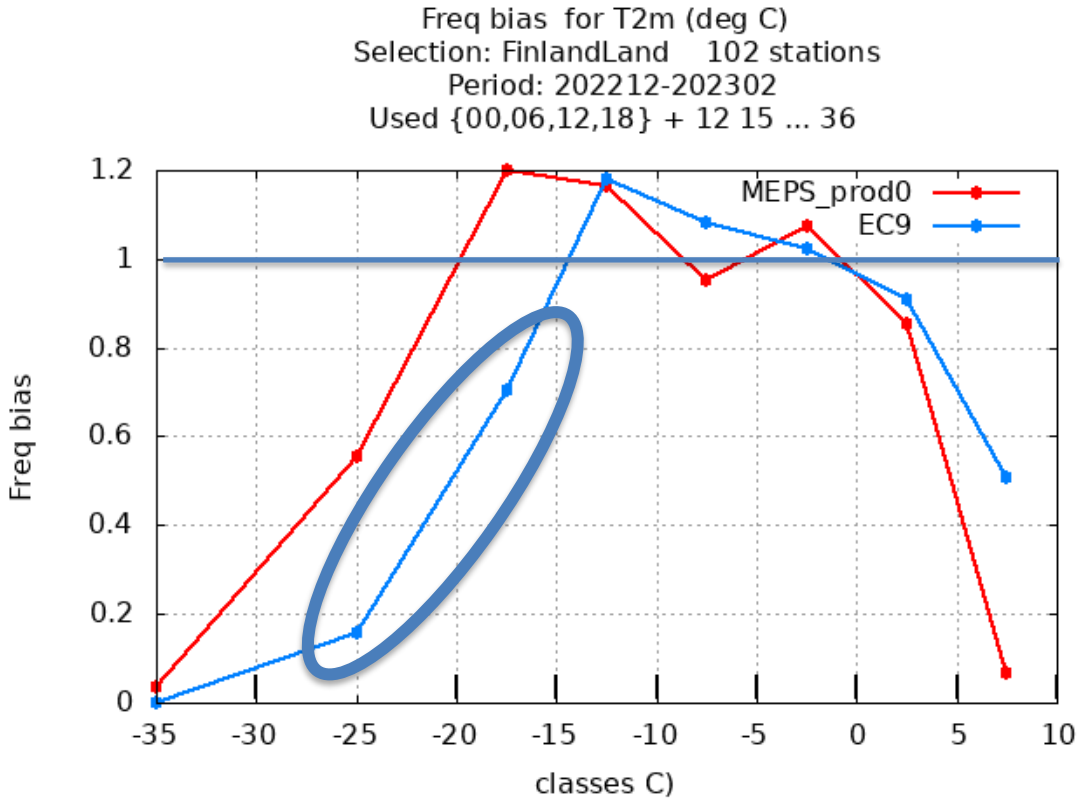
Q3.2a: Please describe any Positive Impacts of 48r1 for your service

- Most services mentioned:
  - Higher resolution brought positive impacts for them
  - More frequent Extended Range forecasts were very helpful
- Some mentioned:
  - Like more members in extended ranges
  - Rainfall in mountainous areas in medium range better
  - Minimum temperature in Portugal
  - Resolution consistency between HRES and ENS delivered physical consistency
  - Scrapping a resolution change, and running two parallel suites made things less ‘messy’
  - Some said it was not possible to see any changes in accuracy
  - Better visibility forecasts
  - Multi-layer snow helpful for 2m temperature forecast accuracy
  - Wind speed biases reduced

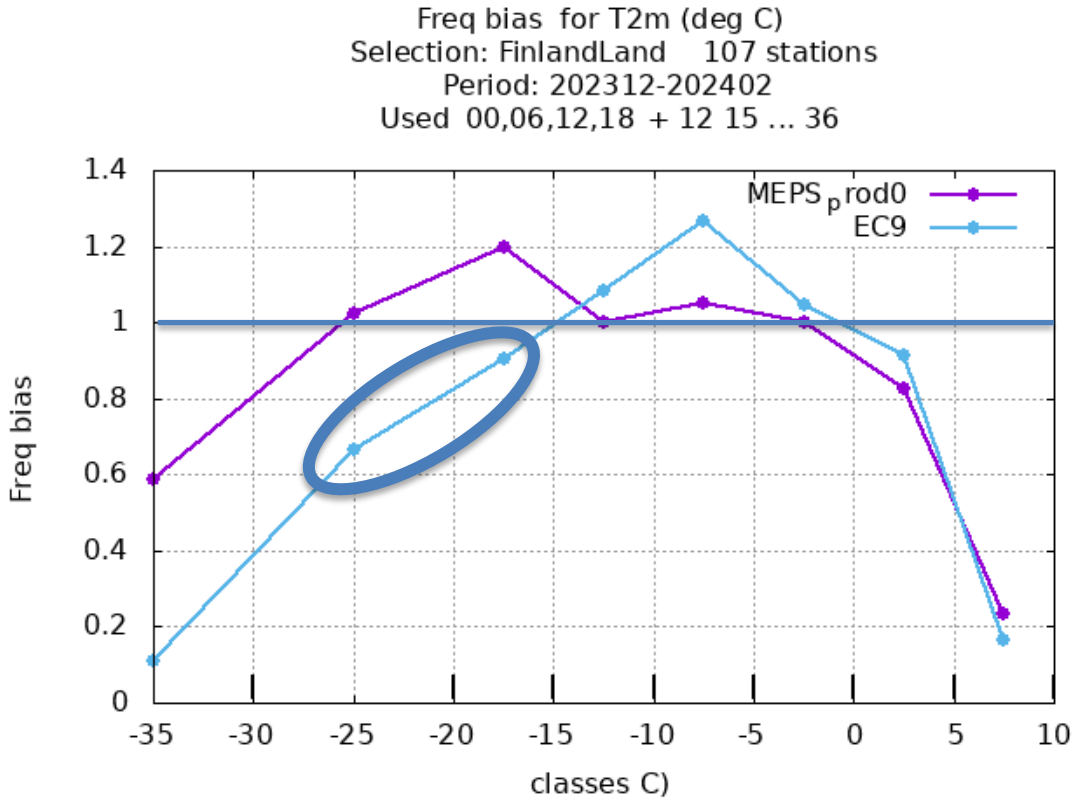
Portugal HRES 2m temperature minima RMSE (D1-10)



Finland winter-time 2m temperature biases (T+0 – 36)

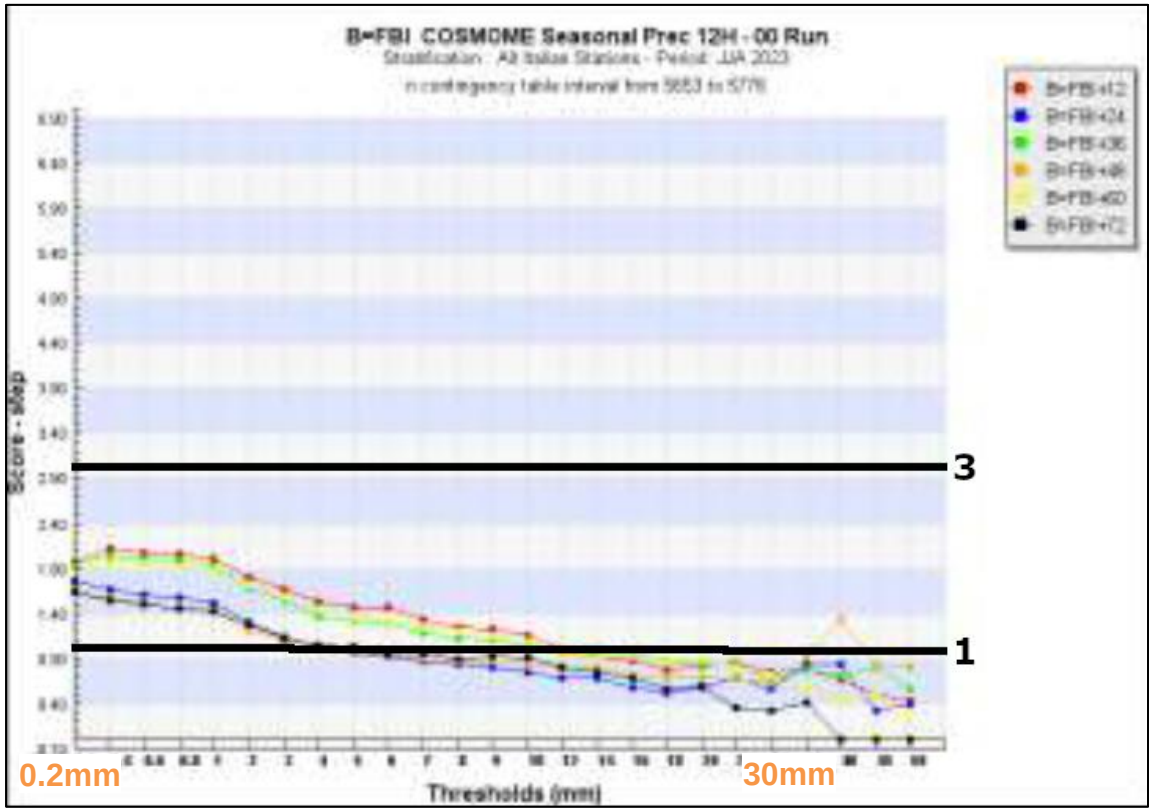


47r3 (2022/3)

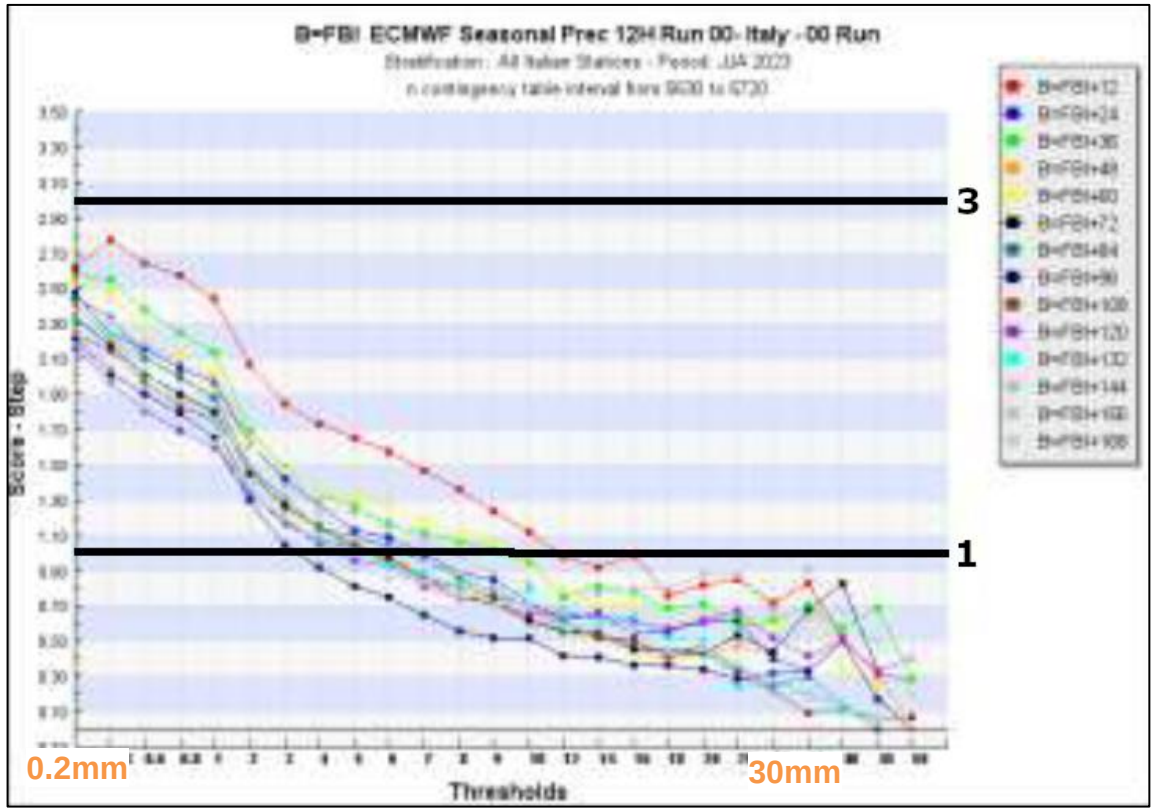


48r1 (2023/4)

Italy JJA 12h rainfall frequency biases, different leads

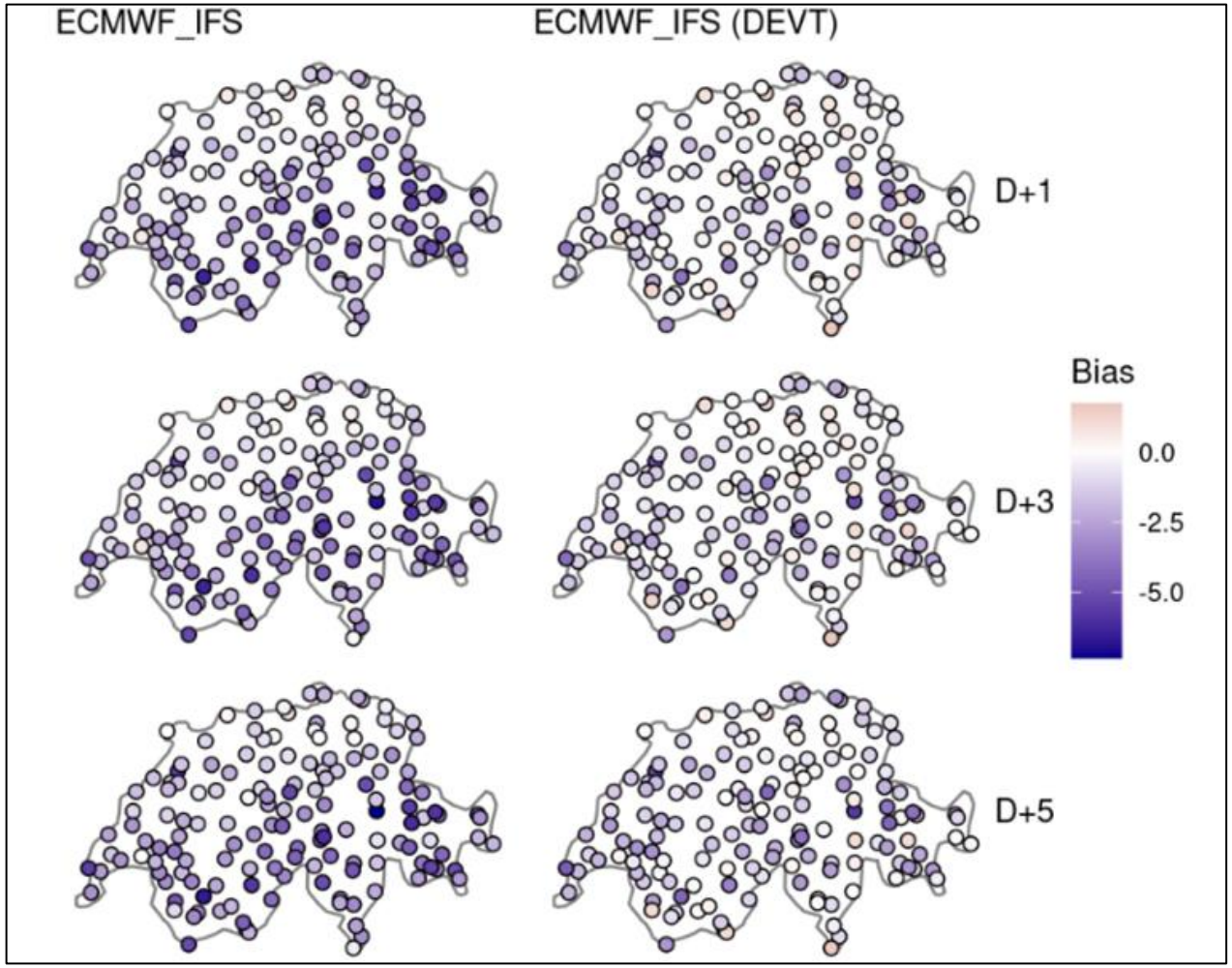


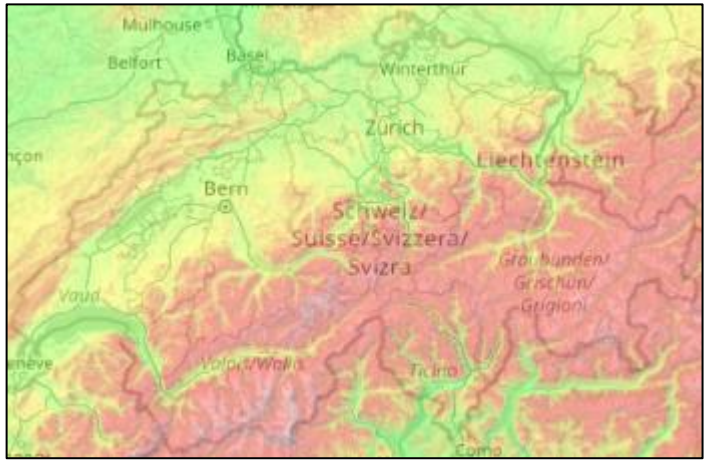
COSMO 5km



48r1 (9km)

10m windspeed biases – Switzerland – contiguous period in 2023





Switzerland topography
(https://en-gb.topographic-map.com)

Q3.2b: Please describe any Negative Impacts of 48r1 for your service

- **14/22** services had nothing negative to report (yet) 😀
- Some services mentioned:
  - Disappointment that some aspects had not apparently improved:
    - e.g. convective rain
    - Melt speed for snow on the ground still too slow (Ireland)
  - Some difficulties handling the much larger data volumes (Finland)
  - Big problem with post-processed 2m temperature forecasts arose immediately (France)
    - Lack of data for calibration cited as the cause
  - HRES and CONTROL not the same but should be (ECMWF did publicise this 'glitch')
  - Visibility in modest convective wintry precipitation now drops too low (Lithuania)

Q3.2c: Please describe any systematic changes in 48r1

- Nothing has been noticed !

Issue with French post-processed 2m temperature products last year

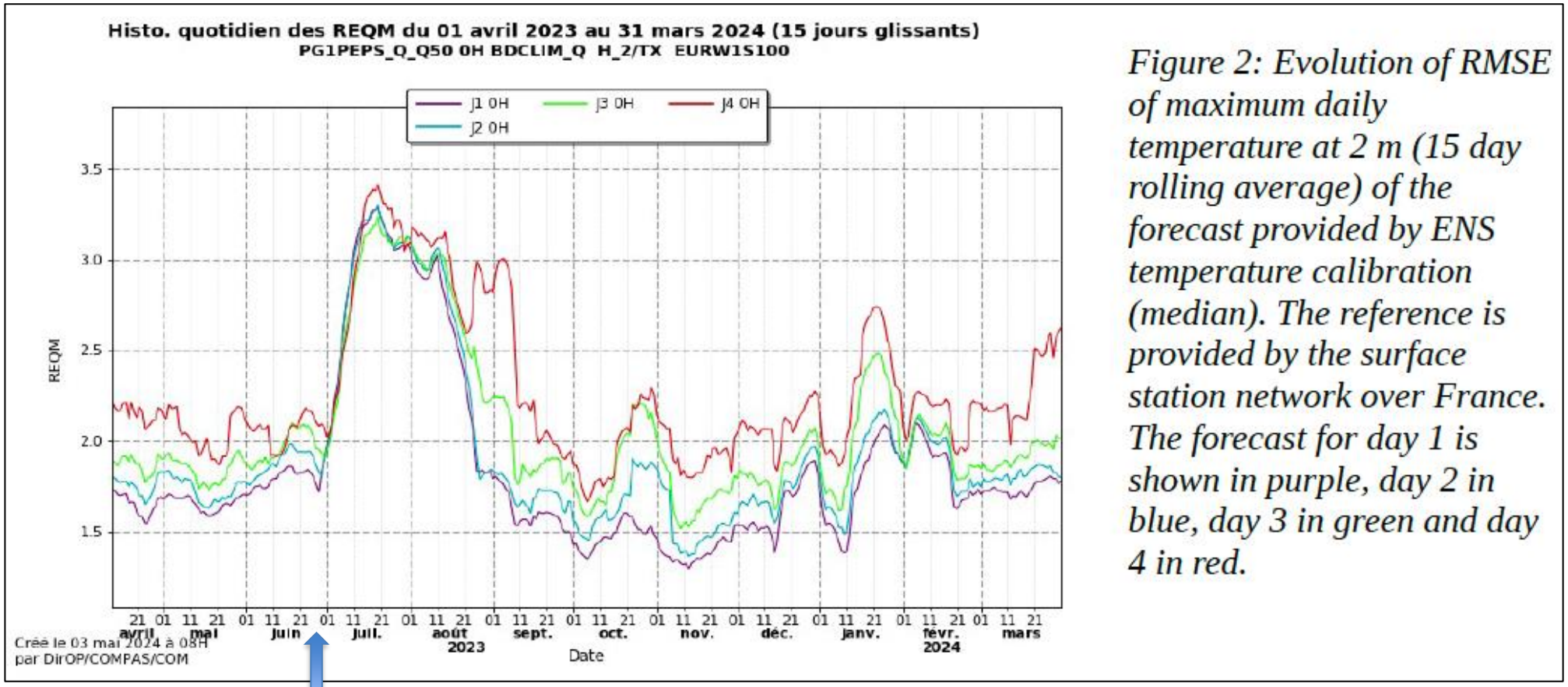


Figure 2: Evolution of RMSE of maximum daily temperature at 2 m (15 day rolling average) of the forecast provided by ENS temperature calibration (median). The reference is provided by the surface station network over France. The forecast for day 1 is shown in purple, day 2 in blue, day 3 in green and day 4 in red.

48r1 introduced

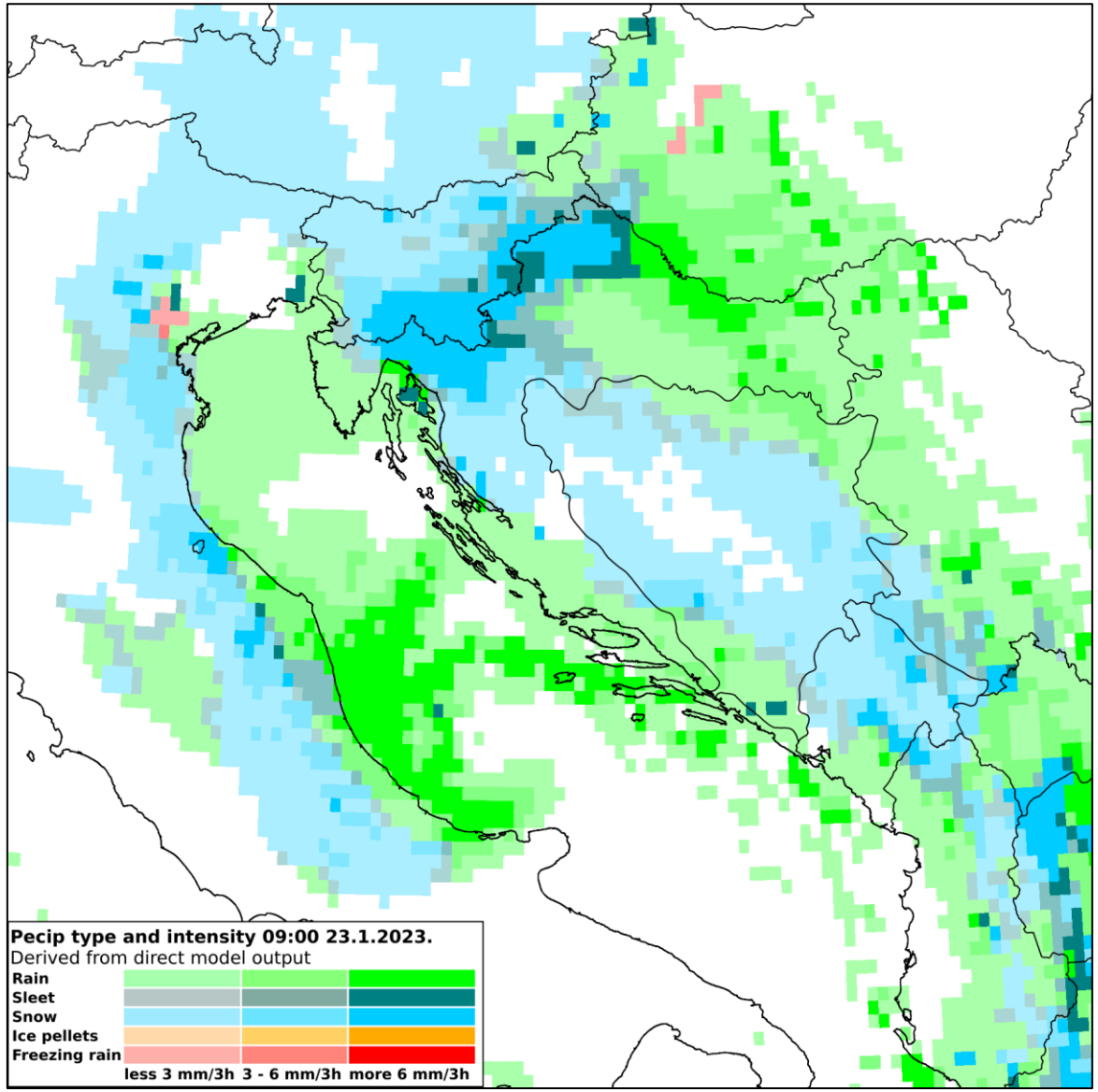
Q3.3: Do you create derived fields from ECMWF data ?

- **18/22** Services said “yes”
- Some topics mentioned:
  - yr.no outputs
  - Contaminant tracing
  - Thunderstorm indices, heat wave indicators, precip type – intensity product
  - Bias-corrected temperature forecasts
  - Multi-model blending
  - Dust cross-sections
  - Seamless meteograms
  - ecPoint products
  - Lapse rates in atmospheric layers
  - Vorticity and thermal advection
  - Coloured wind directions
  - Irradiance
  - Region-specific clustering
  - Snowpack evolution
  - CAMS-based duststorm warning products
  - Tercile summary charts for extended range

Precip Type – Intensity

Deterministic

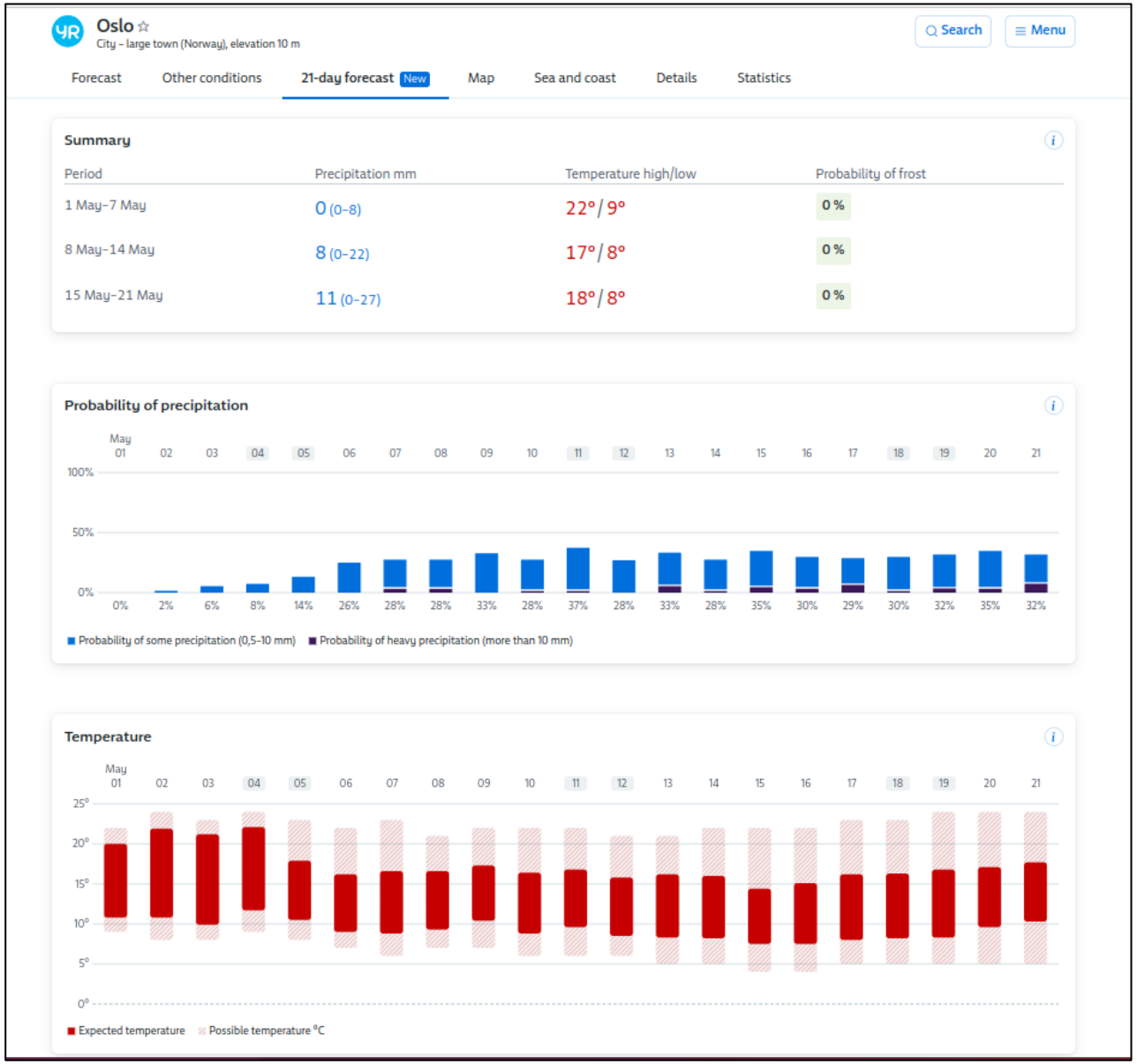
Croatia



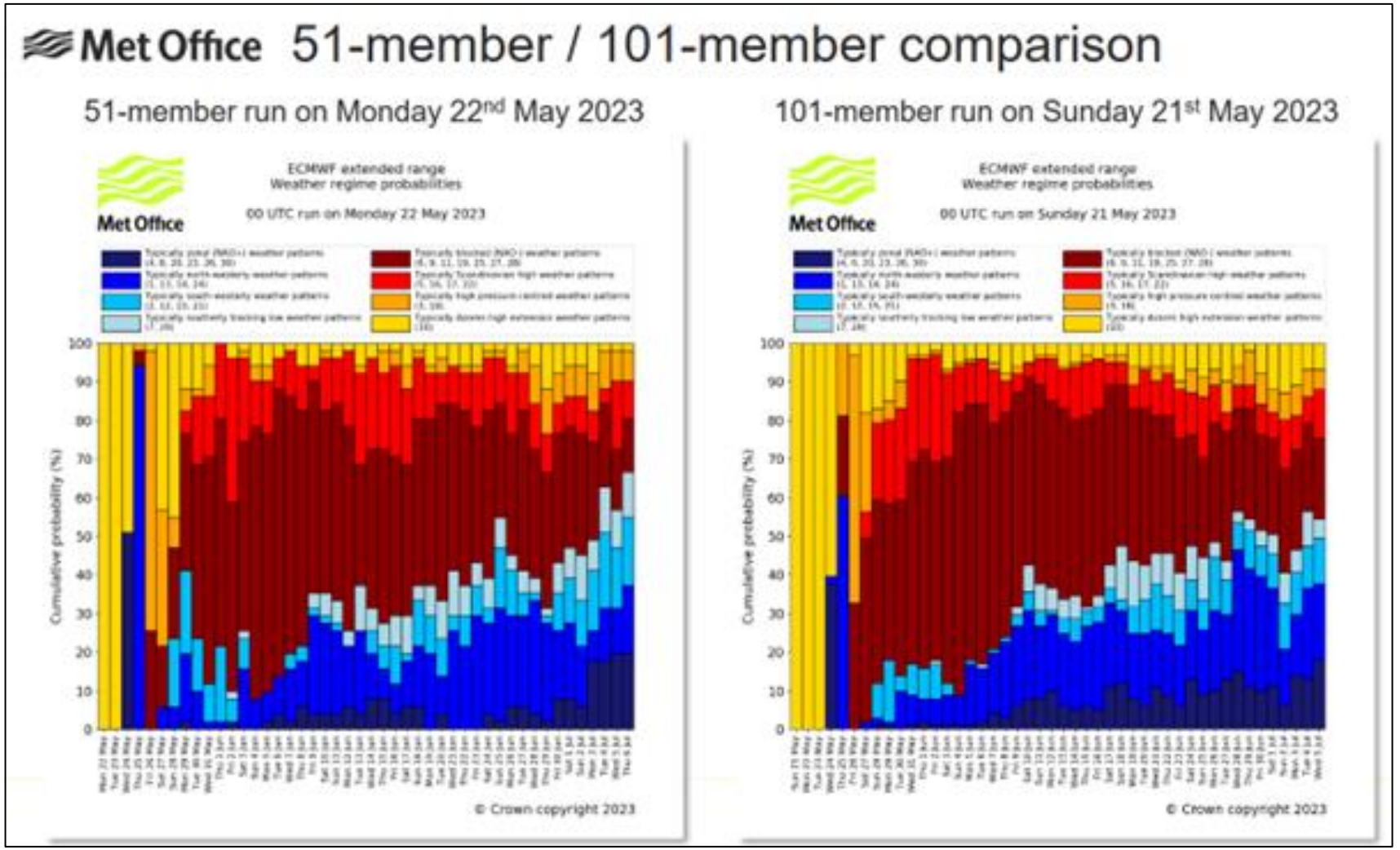
yr.no 21-day meteogram

Daily Updates

Norway



Met Office “DECIDER” regime output (UK-centred)



Extended Range

Tercile summaries (most populated class shown)

4 probability levels in each

Switzerland

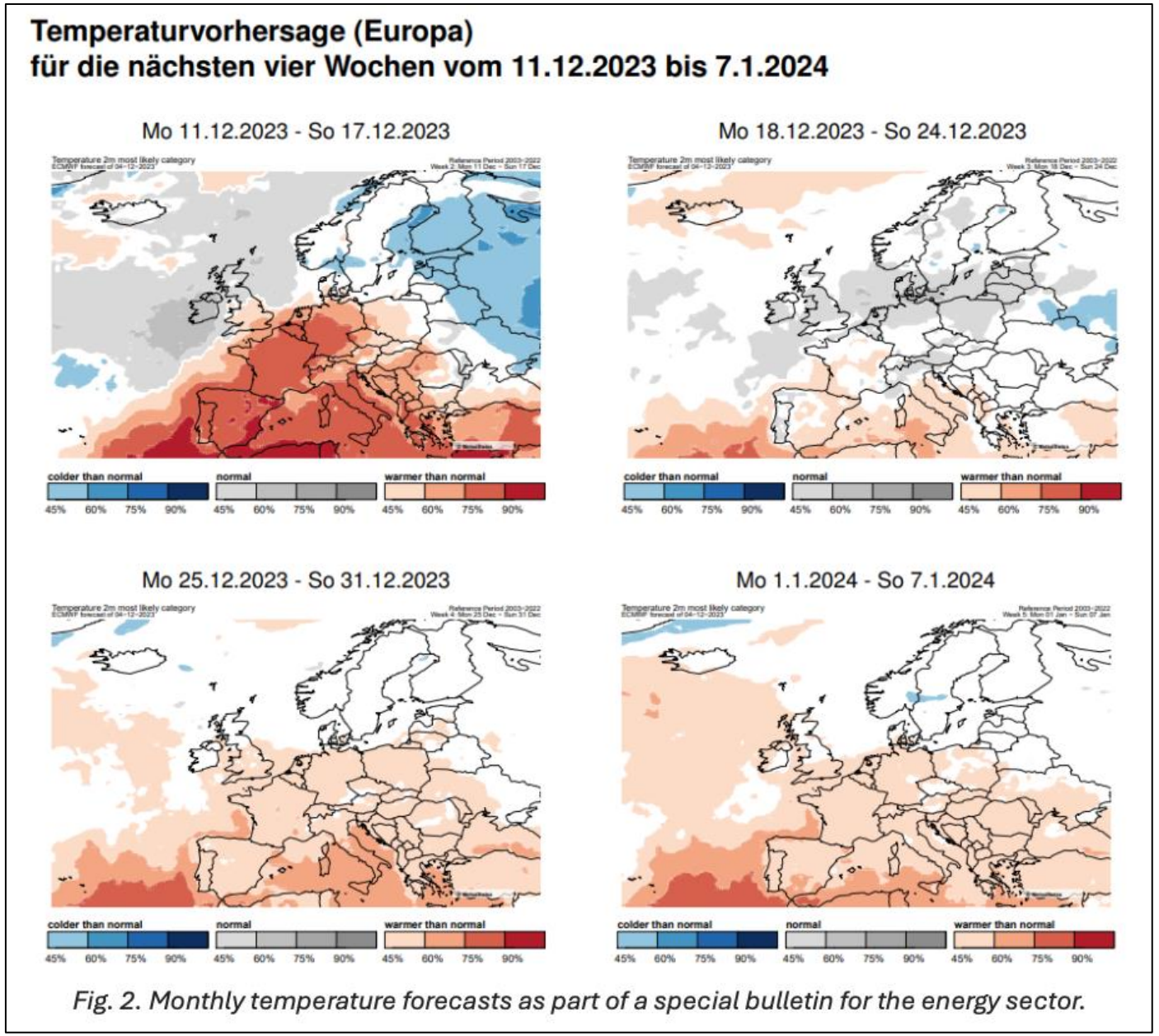


Fig. 2. Monthly temperature forecasts as part of a special bulletin for the energy sector.

Q3.4: Do you currently use ML/AI techniques, with ECMWF outputs ?

- **6/22** Services said “yes”
- Some Examples
  - ML/MOS on HRES+CAMS+station measurements for air quality. Marked improvements! (Germany)
  - MOS/EMOS/Random Forests to give km-grid forecasts of 2m temperature (France)
    - Gusts and rainfall to be added, but due to slow data downloads that is on hold.
  - Exploring data-driven LAM forecasting (Denmark, Spain)
  - Regime classification with convolutional neural networks (Spain)
  - Gradient-boosting random-forest based error correction for several parameters (Finland)

Q3.5: Do you currently use ECMWF data as inputs for modelling (e.g. BCs)

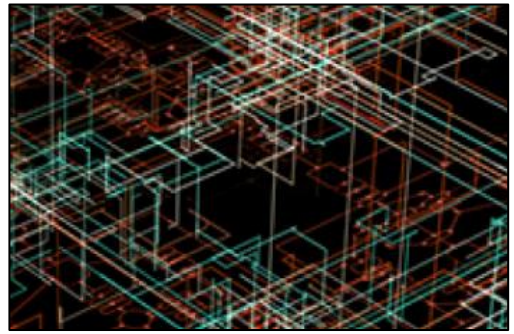
- **19/22** Services said “yes” – activities in this field are extensive
- Use as BCs for LAMs is very common (growth area generally, including ENS BCs), remote areas also
- Sea, Wave, Surge, Sea ice and Hydrological data input usage also widely noted
- Chemical species modelling quite widespread
- Dispersion / trajectory modelling quite common
- Nowcasting system mentioned once

- Responses to this question quite similar to those received in 2021

Q3.6 / 3.6a : In the last year ECMWF has made available on ecCharts and OpenCharts real-time output from AI models – e.g. AIFS.

Were you aware? What are your views?

- **17/22** Services were aware
- “Very welcome”, “Helps build trust”, “Impressive that you have done this”, “Interesting”
- “Don’t oversell (limited output variables)”
- “Need more on reliability and accuracy”
- “Potential is huge. ECMWF cannot miss out!”
- “How far out can AI models be skillful?”
- “They look surprisingly good”
- “We salute ECMWF’s leadership here!”



Q3.6b : Do you currently use AI models operationally

- **21/22** said “no” (UKMO said yes, occasionally)

Q3.6b What would you need in order to use AI models for forecasting?

- Training / seminars
- Info on pros and cons of AI versus physics-based
- Shared experiences with other Met Services
- Many more parameters are needed (e.g. solid precipitation)
- Higher resolution needed, especially for topographically complex countries like Croatia
- More staff !
- Knowledge of limitations
- More knowledge of how it all works
- Verification of different types
- Information on AI model performance for extreme events – ref: distribution tails

Verification

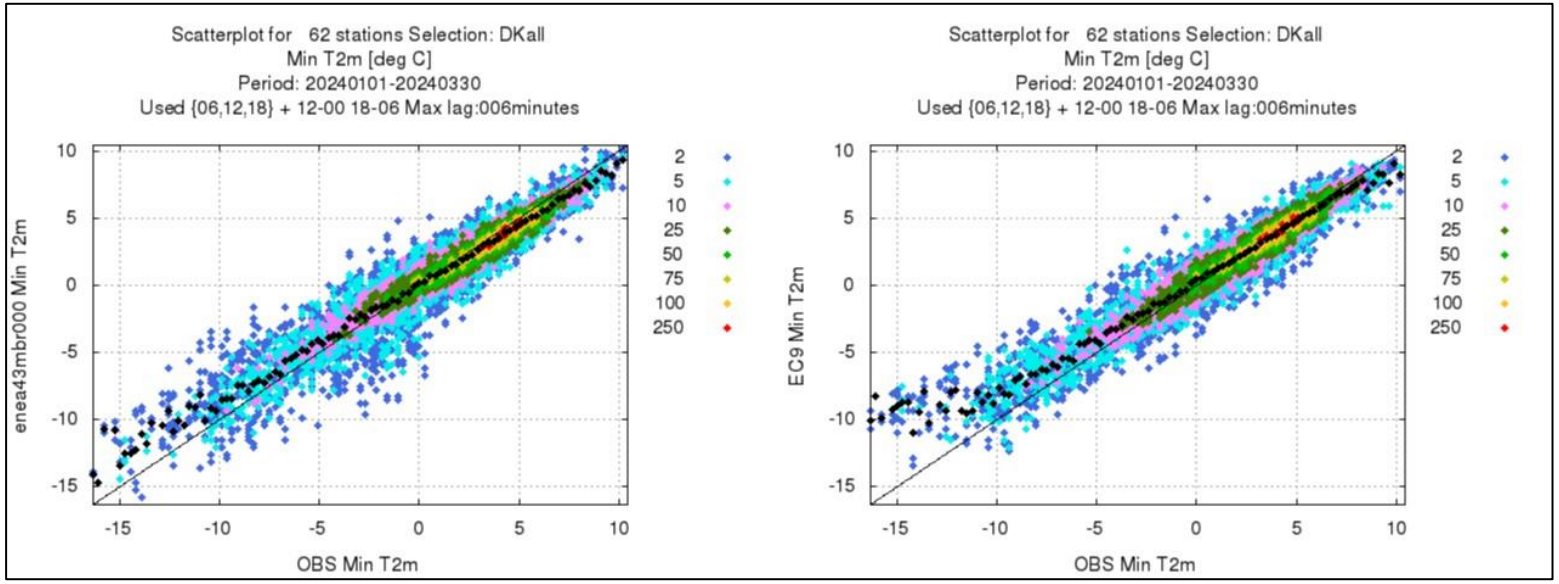
Wealth of results reported – summarised here, with examples !

Q4.1 Please describe your verification activities, with results…

- LAMs tend to outperform HRES/ENS at short leads for many parameters, though not all
  - This seems different to 3 years ago – LAM skill on the rise, in relative terms
    - Due to (?) higher resolution versus IFS, IFS BCs, increasingly co-ordinated modelling efforts
  - It may be that impact of IFS resolution upgrade to 9km is not yet fully covered in results
- German ICON global model increasingly competitive, and leads ECMWF in DWD verification
- Frequency bias for rainfall is clearly better in LAMs (though LAMs can be too wet)
  - Many reiterate this IFS "deficiency", as in previous years (ecPoint output addresses this very well)
- Extremes of heat and cold tend to not be extreme enough in the IFS
- Already documented IFS characteristics were regularly highlighted (e.g. topographic enhancement and rain shadow underdone, due to lower resolution; winds too low over mountains; …)

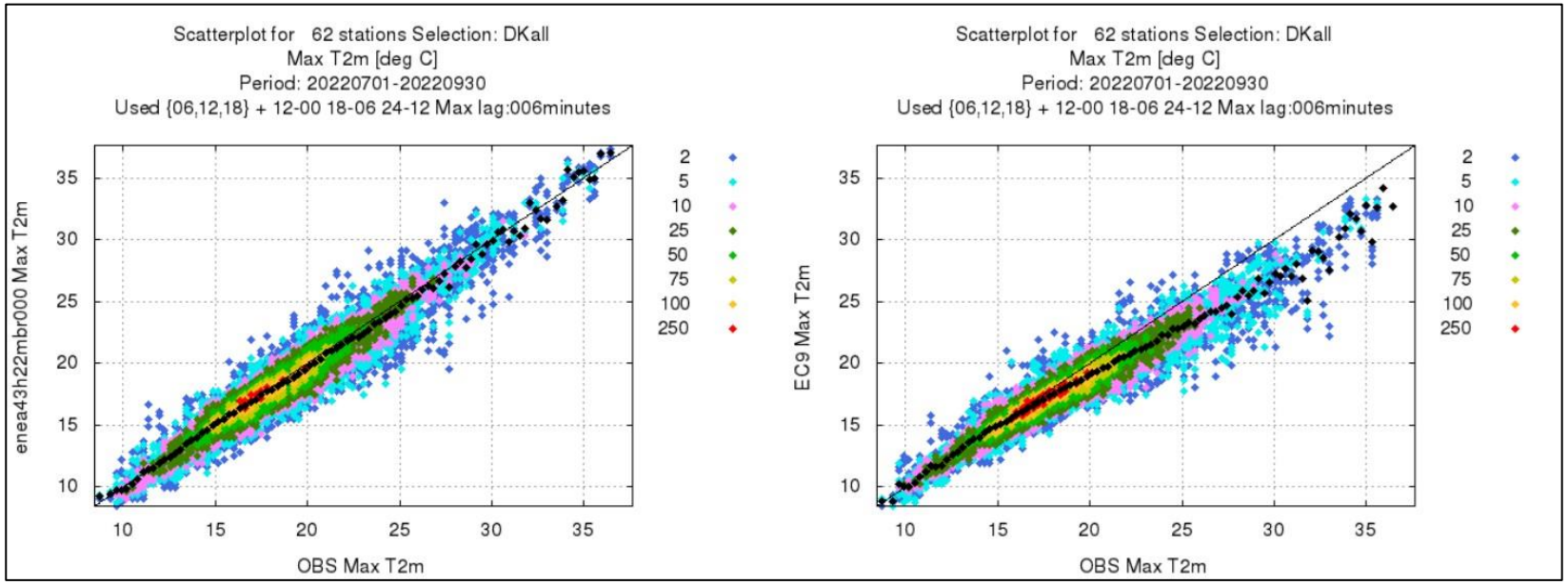
FINLAND – 2m temp extremes (min/max) not extreme enough in IFS

MIN



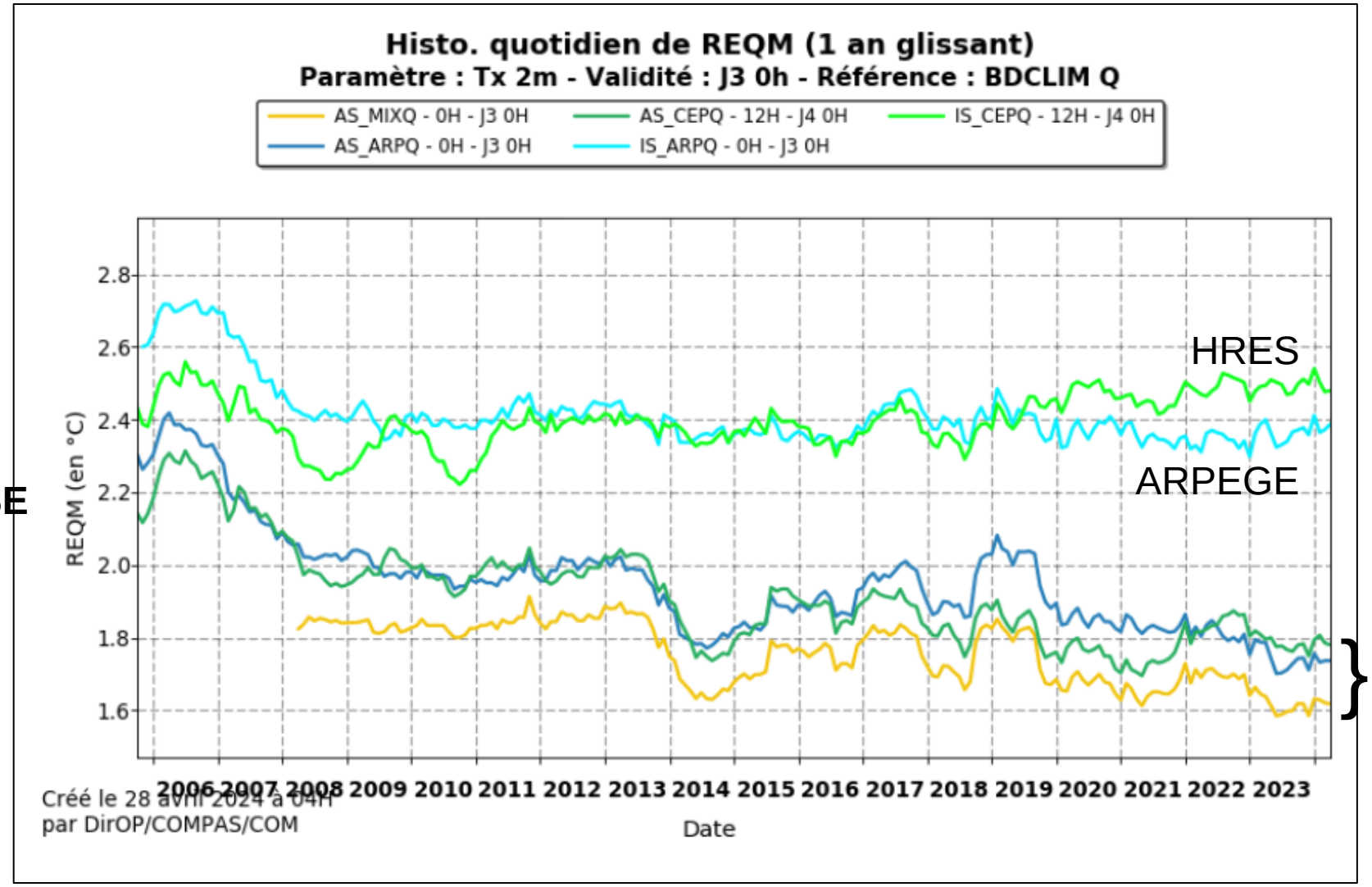
MEPS **HRES**

MAX



FRANCE – D3 2m max temp – ARPEGE gaining (“new” cold bias problem in IFS)

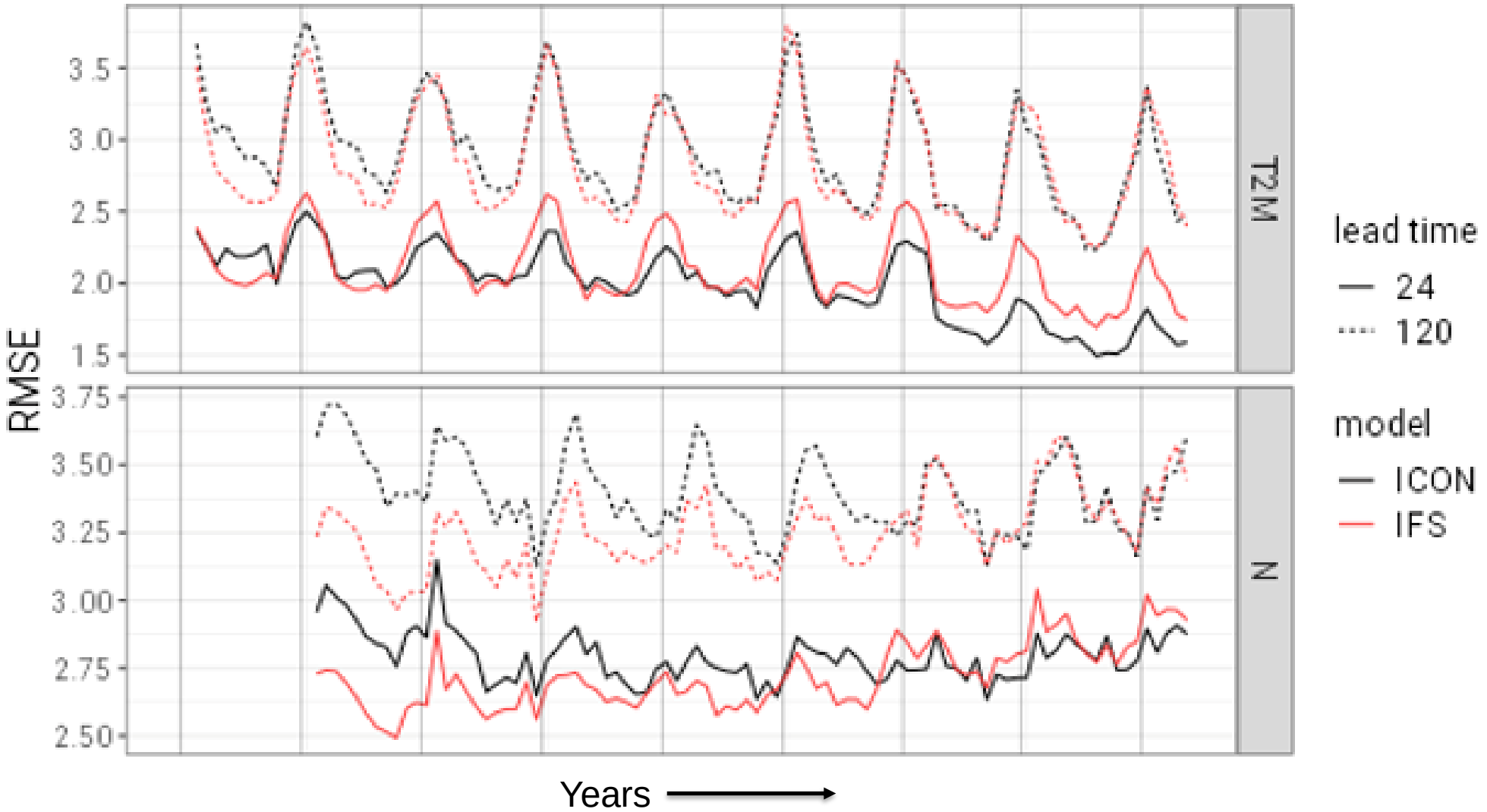
RMSE



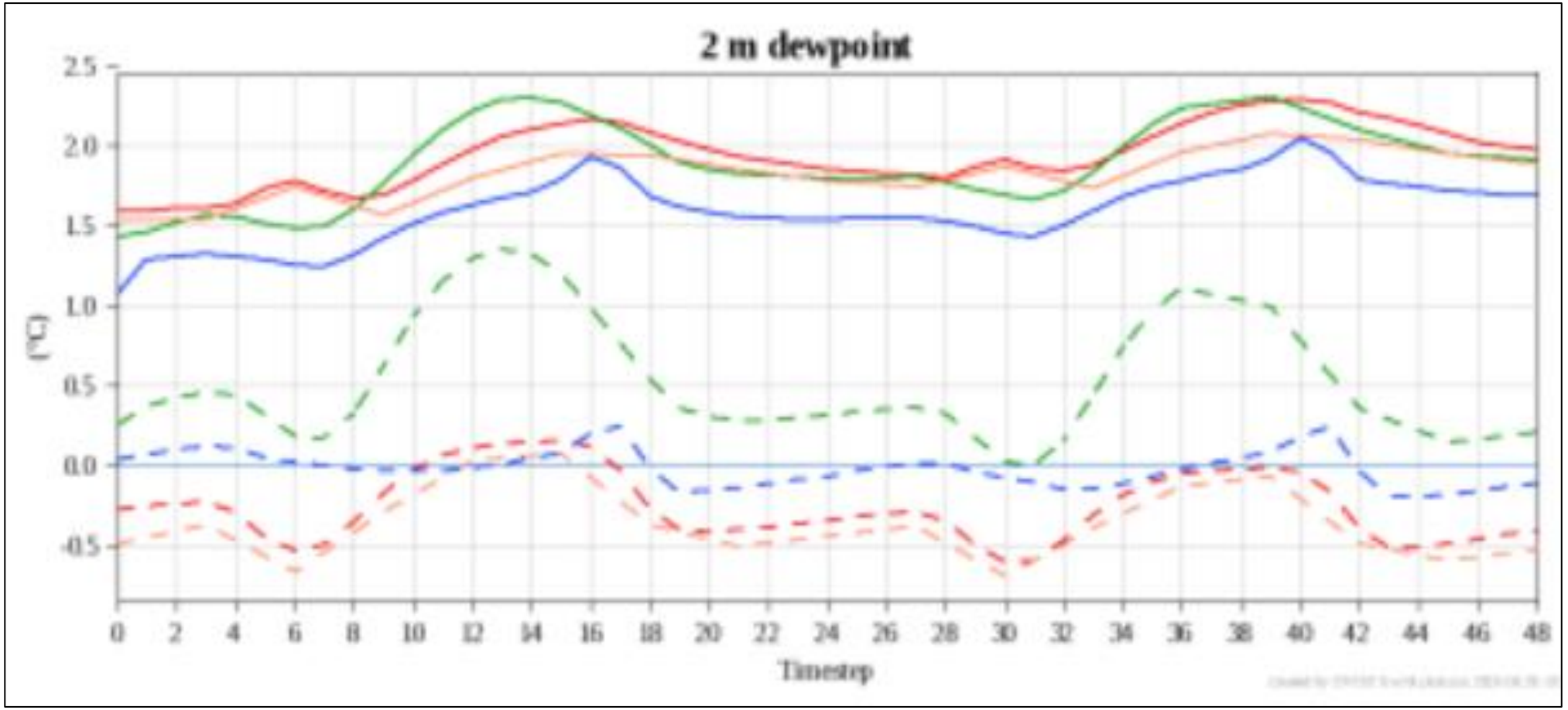
Post-Processed

PP impact also growing over the years !

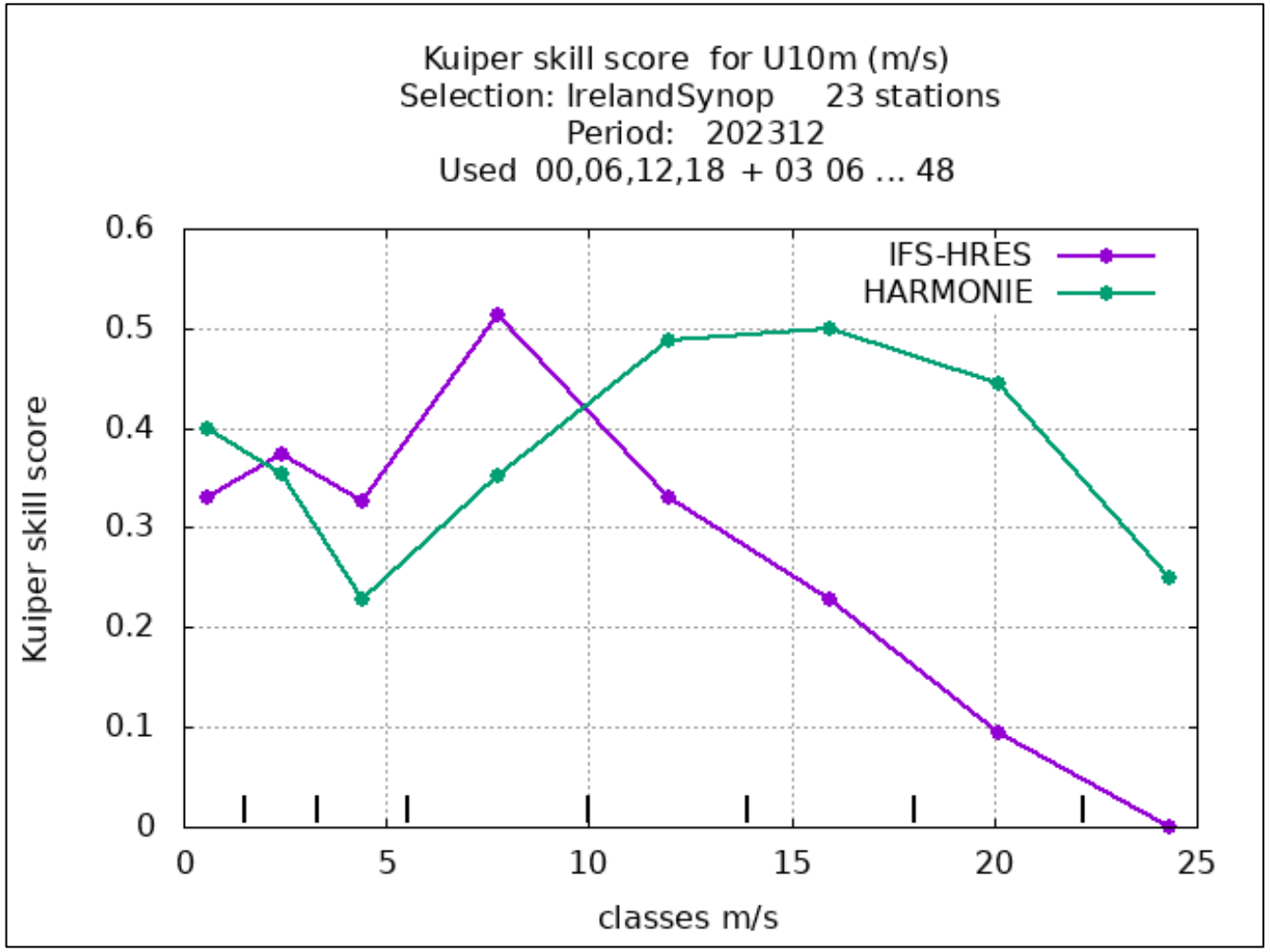
ICON gaining versus IFS over the years, for 2m temperature and cloud cover



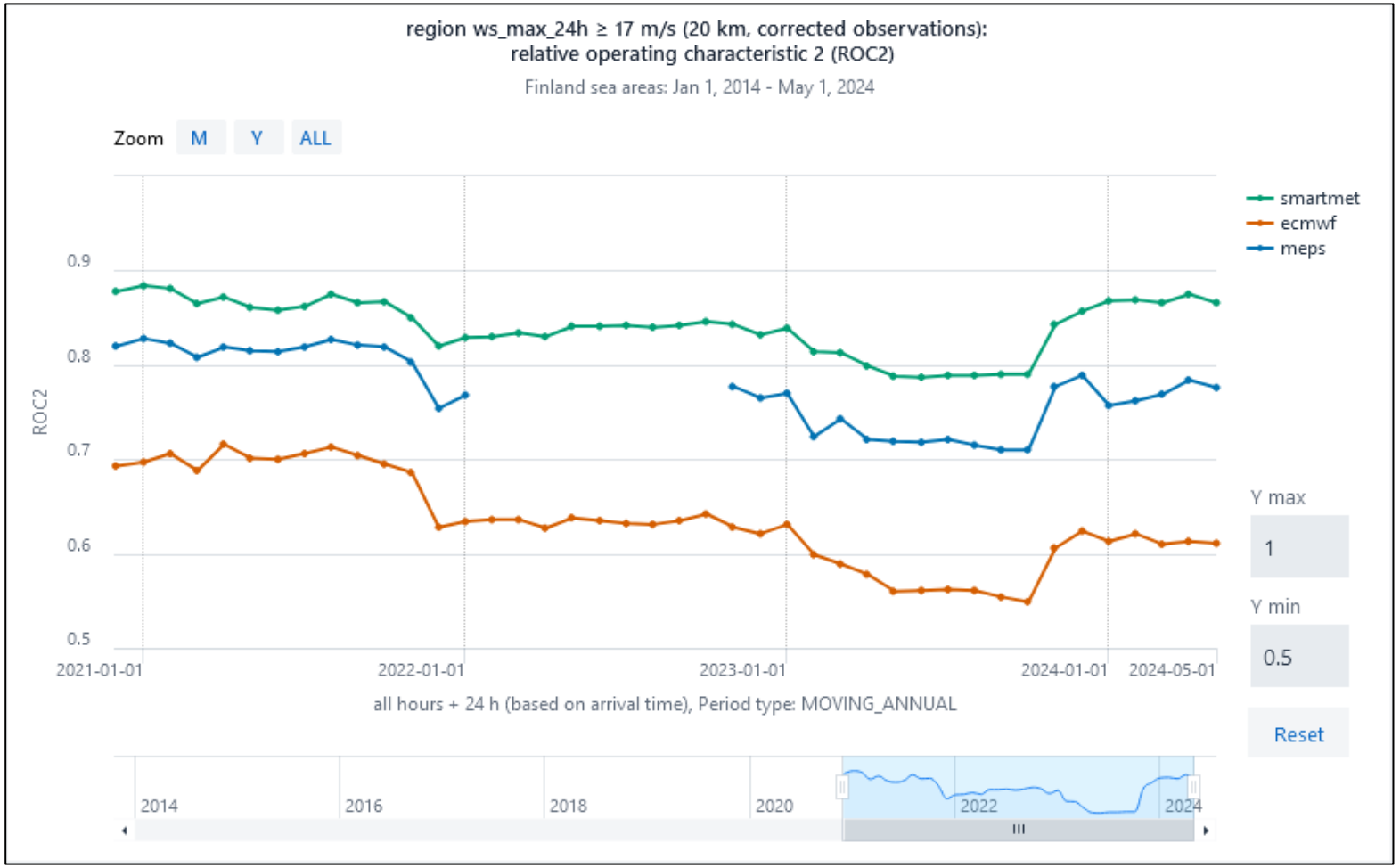
HUNGARY – HRES dewpoint errors impressively small



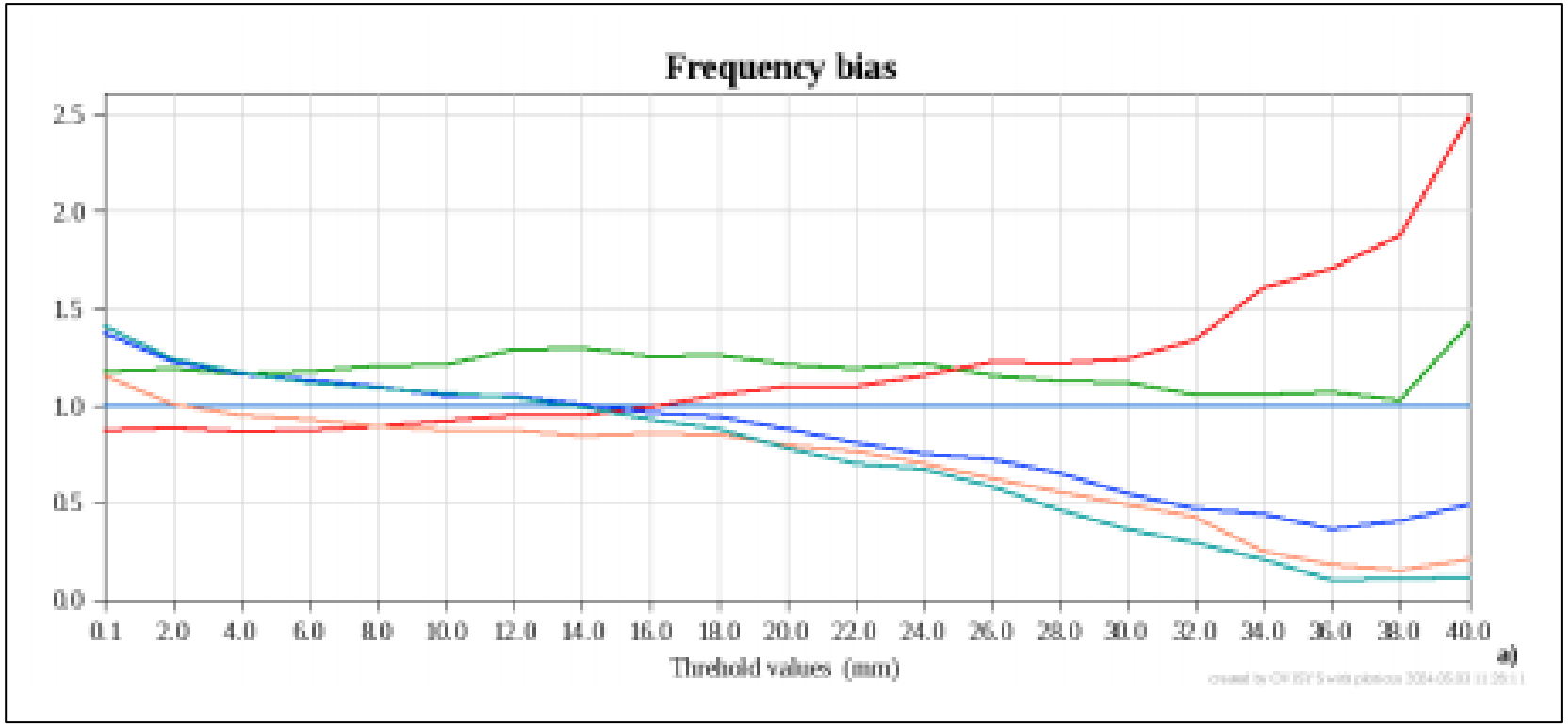
IRELAND – 10m wind – Harmonie LAM better than HRES for high speeds



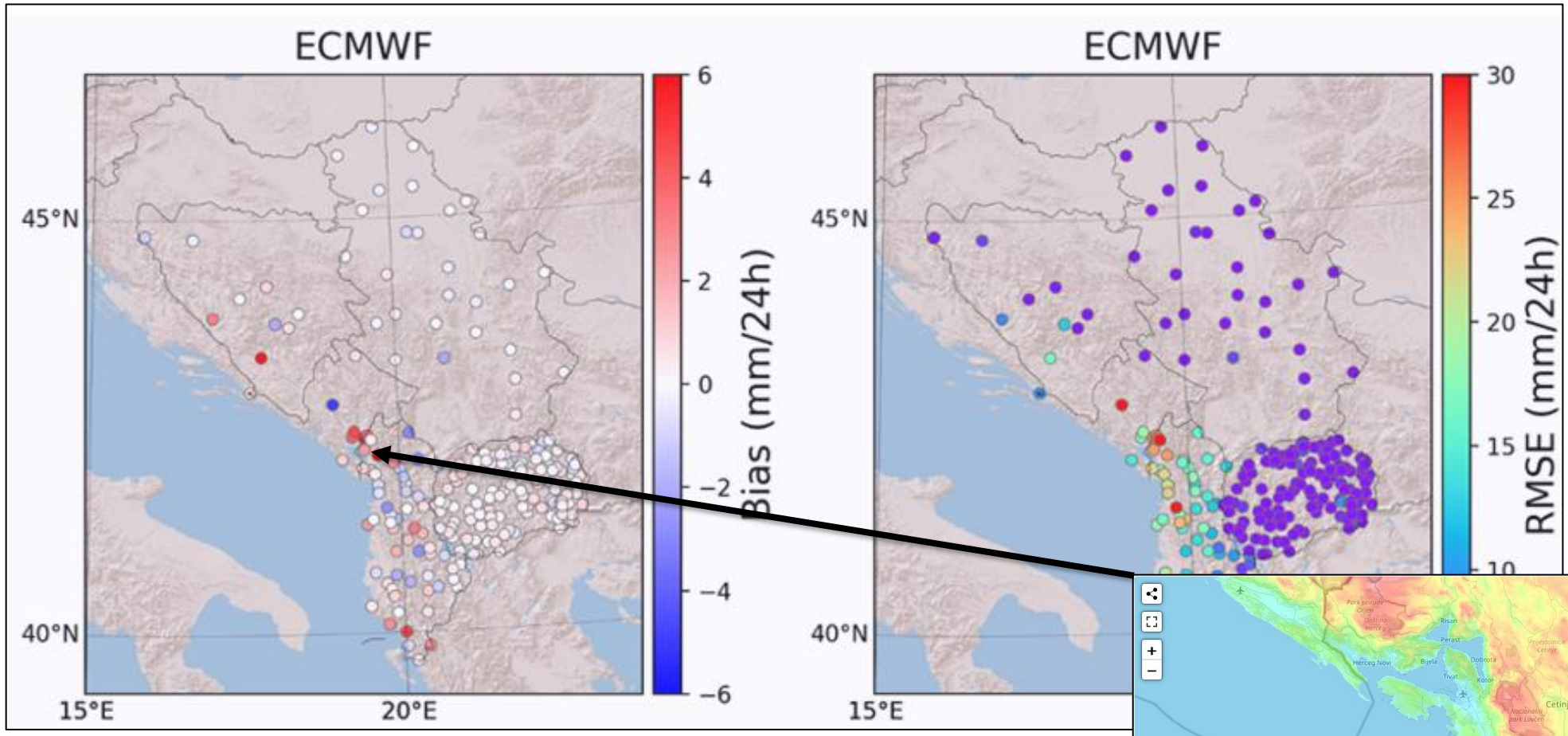
Finland gale verification: ROC area – MEPS better, ENS degrading over time (?)

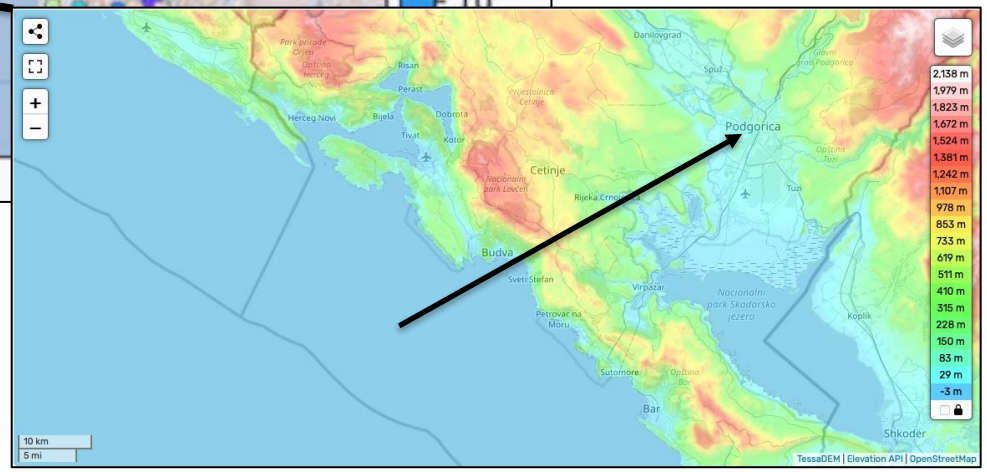


HUNGARY – ppn frequency bias – HRES as over Italy – AROME big totals issue



SEE-MHEWS rainfall verification – local (explainable) biases in complex topography





Q4.3 Do you perform any subjective verification of (IFS) forecasts…

- Many comments reflect already-known and already documented model characteristics
- From an in-depth Croatian survey, it is clear that forecasters can sometimes disagree on model characteristics, and changes in those with a new cycle
- Some miscellaneous comments:
  - Convection linked too much to model gravity waves
  - Lightning product underprediction for cold season marine convection
  - Lying snow and snow depths can be overdone
    - Messaging issue created for Met Office because of media using free online ECMWF charts
  - Convective gusts underdone
  - Temperature issues in complex topography (especially stable situations) 
- Some positive comments too !

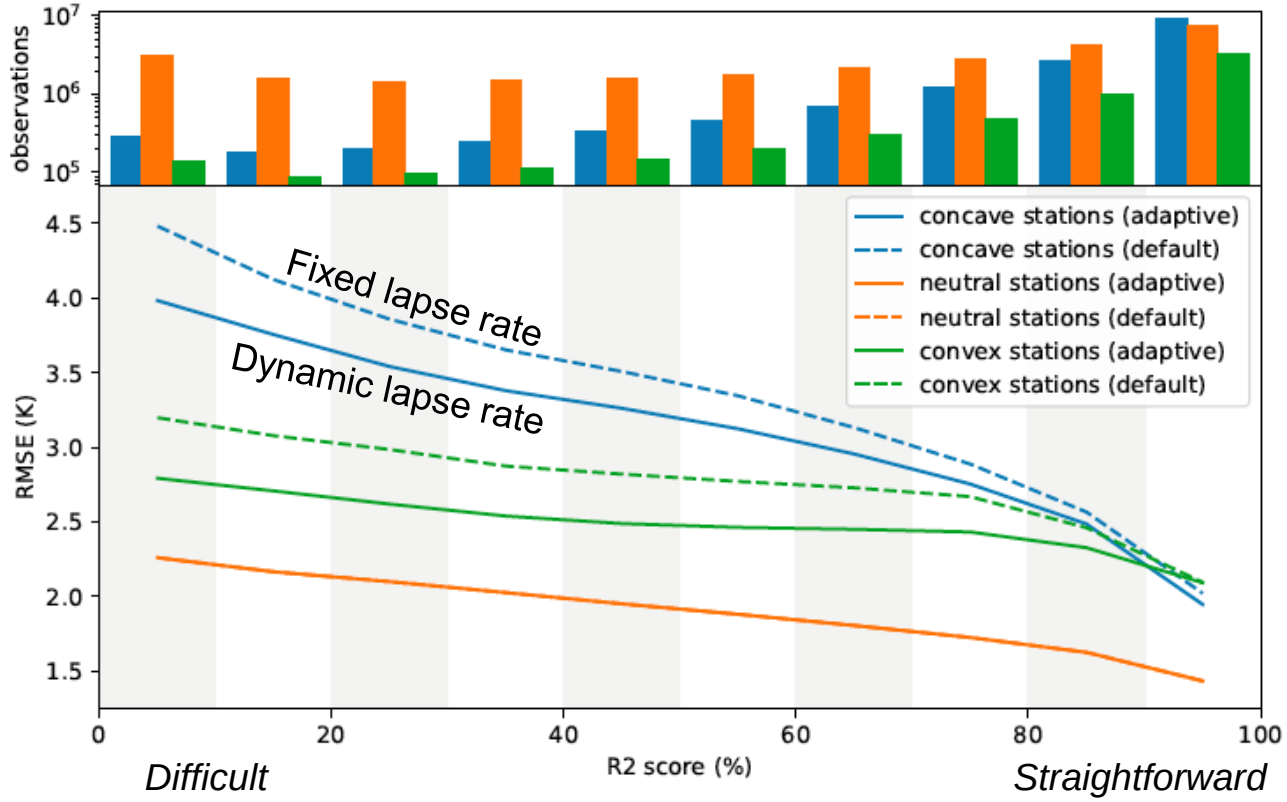


Fig. 15: RMSE prediction error of the adaptive lapse rate scheme compared to the default lapse rate estimator. Observations are binned according to the observed R^2 score. Histograms indicate the number of observations falling in each bin for valley-site, mountain-site and neutral stations. In situations of difficult local weather conditions (low R^2), predictions are improved by 10-20% for both valley and mountain stations.

Collaboration with Kevin Höhlein, Munich

ECMWF uses standard -6.5K/km lapse rate to adjust to station-model altitude differences (e.g. meteograms)

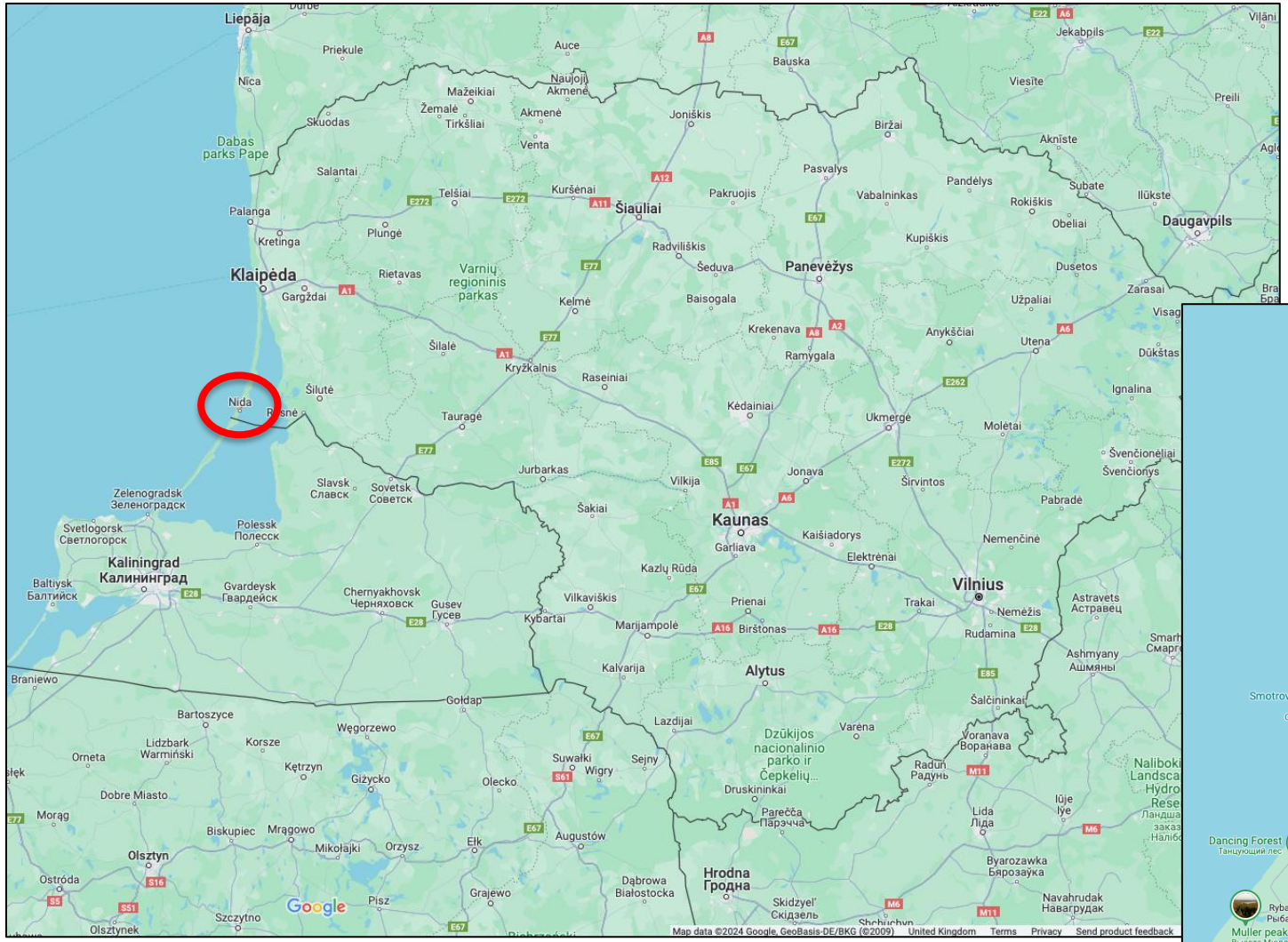
Could instead use model-based dynamic lapse rates (no training)

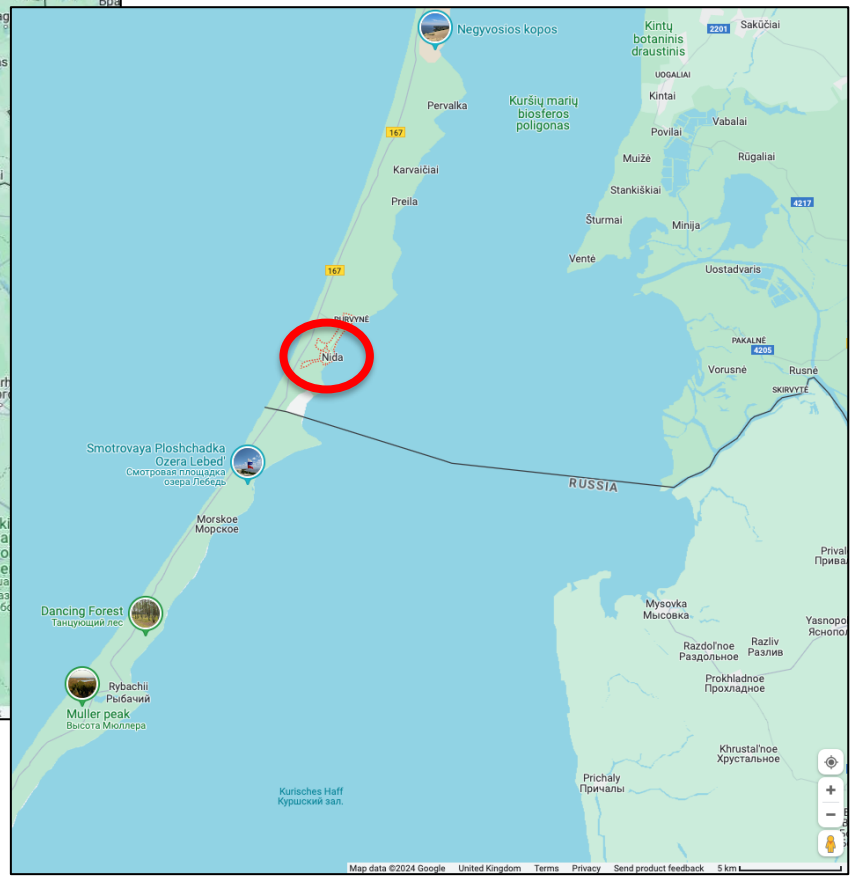
Improvements most notable in “difficult-to-forecast” situations

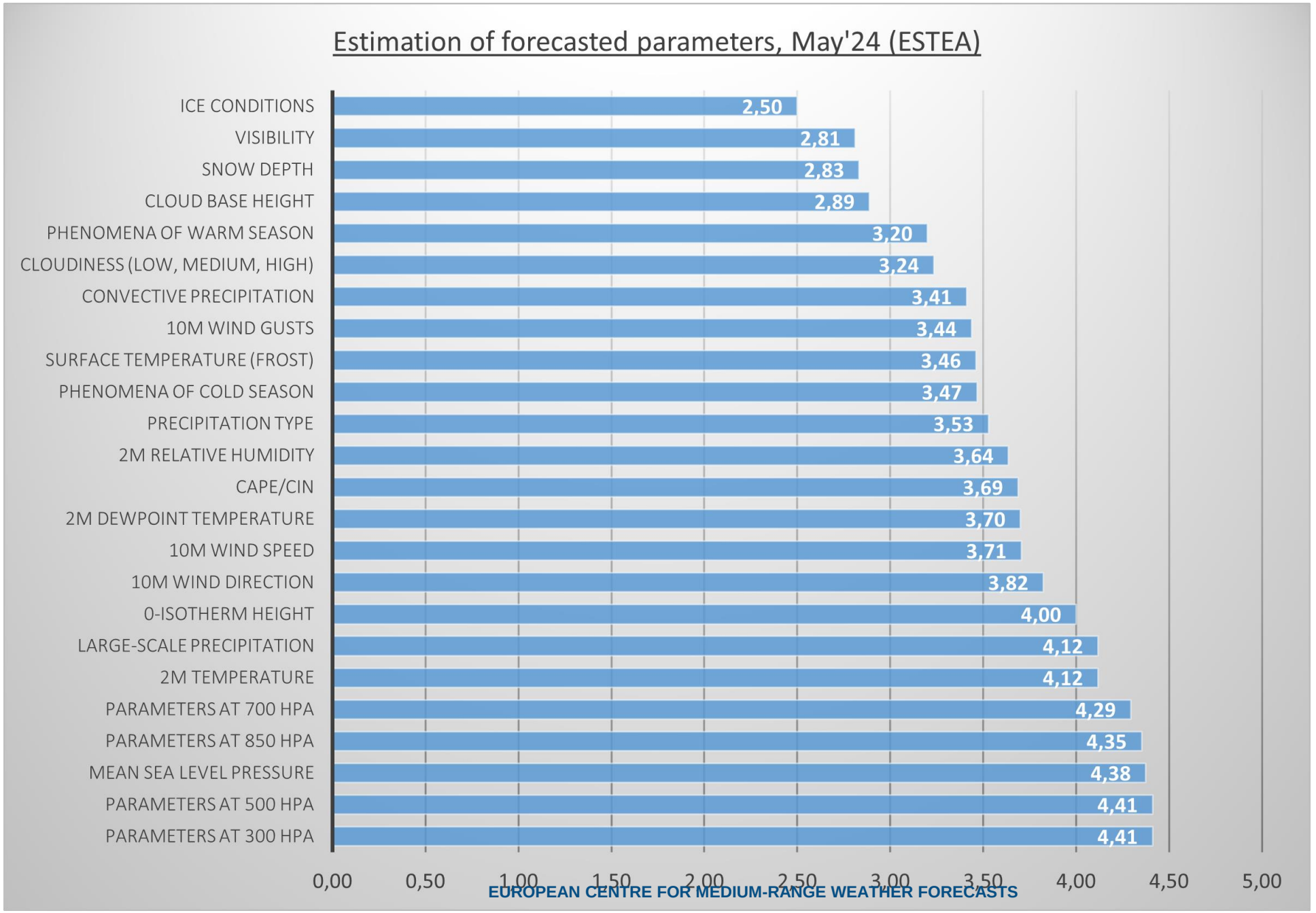
Forecast improvements ~double when cases where dynamic lapse rate ≈ fixed lapse rate are excluded (not shown)

1 year of global short range HRES 2m temperature verification (hourly obs)

LITHUANIA – “coastal site forecasts still problematic with 48r1”





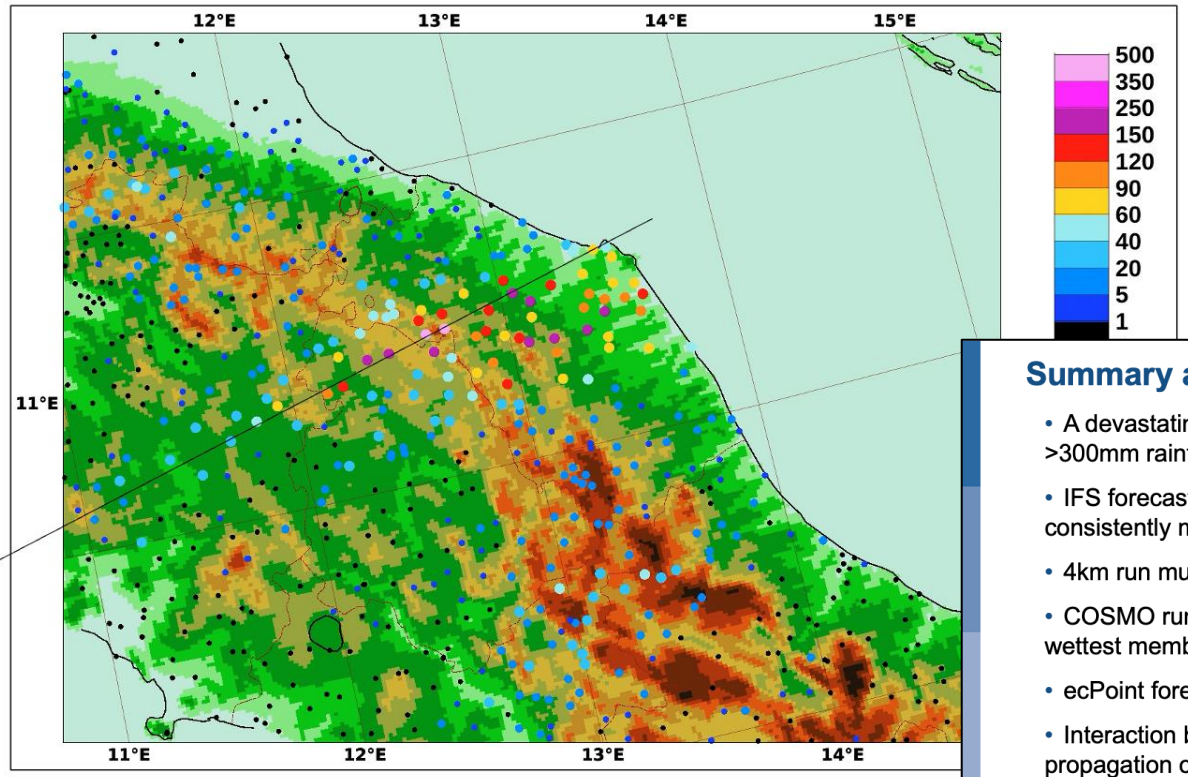


ESTONIA – forecaster “scores” for different IFS parameters

Q4.4 Please describe and illustrate any case study verification undertaken…

- Many cases, good and bad, were reported on for the Green Book
  - Thank you !
- Some cases had already been raised via the ECMWF service desk
- Others were already known to ECMWF, and had been thoroughly investigated
  - We perform daily real-time analysis of cases and model issues, on a rota basis:
    - Daily Reports and Weather Discussions…
- Two examples from Italy follow…

Bad Forecast – Le Marche Floods, Sep 2022



ECMWF EUROPEAN CENTRE FOR MEDIUM-RANGE WEATHER FORECASTS

- Studied at ECMWF
- Teleconf with Italian authorities

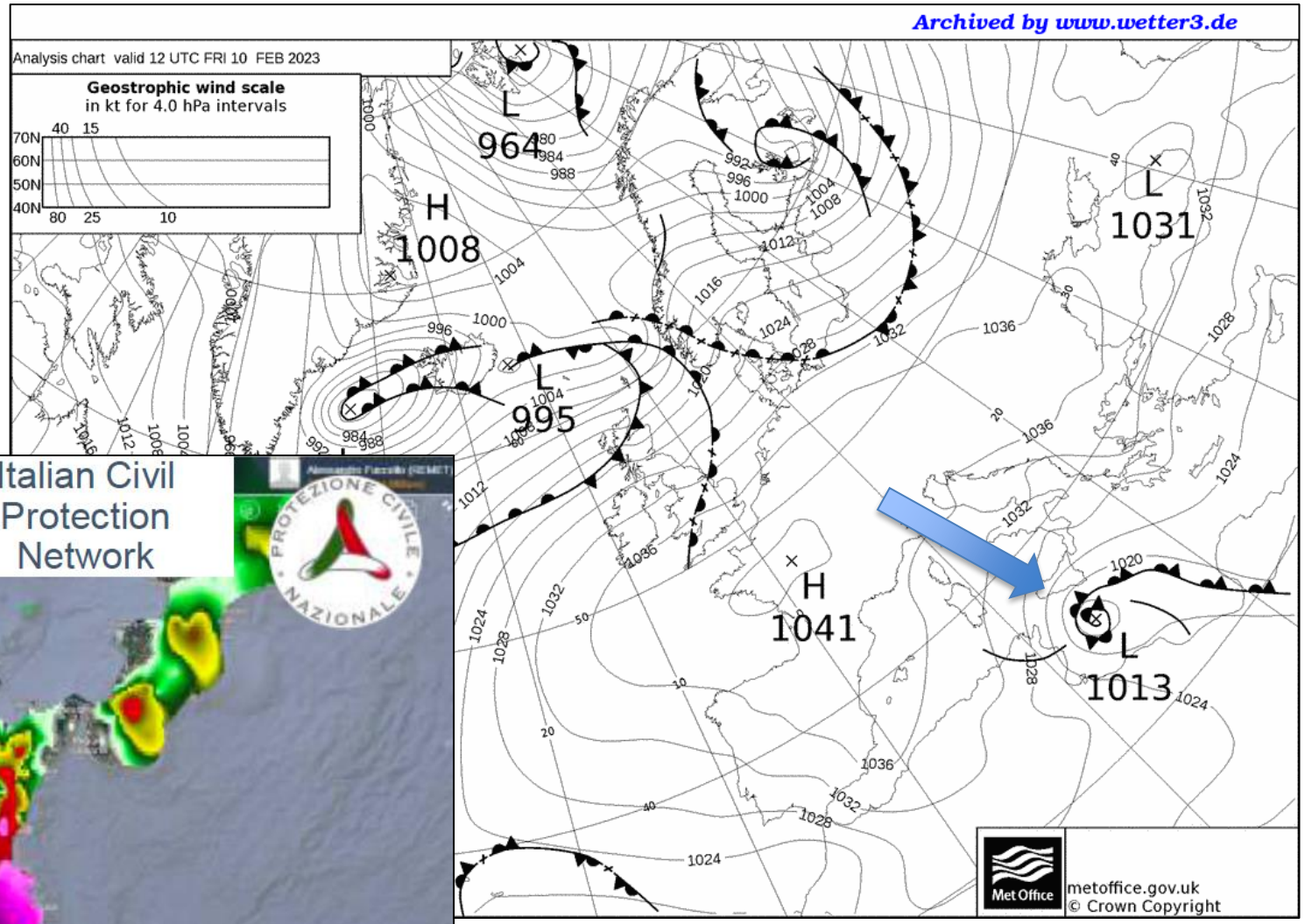
Summary and Outlook

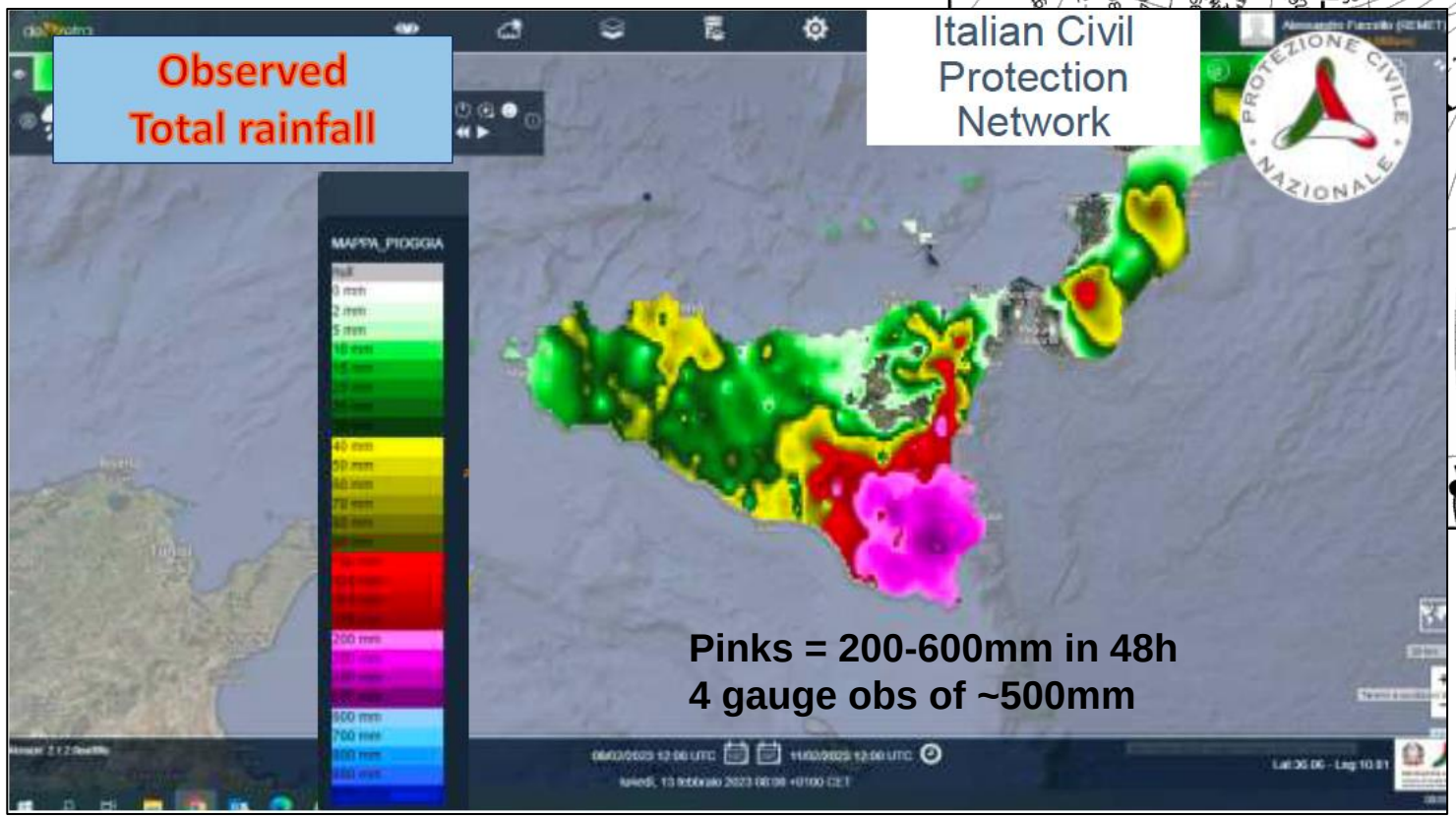
- A devastating set of flash flood events in the Le Marche region of Italy were characterized by peaks of >300mm rainfall in 6 hours
- IFS forecasts were very poor. They consistently showed potential for a major event (though not 300mm) but consistently misplaced this to the west
- 4km run much the same
- COSMO runs (2.2km with resolved deep convection) did much better, but still fell short of the peaks in the wettest member by 70%
- ecPoint forecasts not great – stymied by poor ENS representivity
- Interaction between topography and convection, mesoscale convective dynamics, and downstream propagation of convective cells in a high CAPE – high shear environment were all apparently important factors
- It may be that even 1km runs would fall short, due to the sharpness of a topographic ridge involved (?)
- Case study for Meteo-France hectometre modelling efforts (DestinE initiative) to help ?
- Maybe ECMWF can provide alerts to when its precipitation forecasts run a high risk of failure…

ECMWF EUROPEAN CENTRE FOR MEDIUM-RANGE WEATHER FORECASTS 30

Good Forecast – Cyclone Helios, Feb 2023

(Rain and wind)





Summary

- Just over half of MS/CS responded to ECMWF's call for Green Book contributions
- Many of the reports were quite comprehensive (e.g. many case studies, many product requests) !
- ECMWF outputs liked, respected and used from day 1 out to seasonal
- Multiple visualisations used operationally, including ECMWF's own; locally derived products also common
- LAMs, LAM-EPS systems tend to perform better for days 1 and 2, and are used more than IFS then
  - There seems to have been a step upwards in LAM quality (versus IFS) in the last 3 years
- Do not forget that ECMWF provides comprehensive guidance on IFS limitations (known model issues, forecast user guide), and in some cases products to address those (e.g. ecPoint-rainfall)
- Reactions to 48r1 were positive (higher res and more expansive extended range products well-liked)
- Great interest in data-driven (ML) models – ECMWF's quick work in this area greatly appreciated !
  - Much work to still do to grow trust and provide training, to enable operational usage. And more parameters needed.
- Case study reports very helpful to us!
- Technical memorandum to follow in due course. Will also need to manage the new product requests.