ECMWF

Green Book 2024 - aka Use and verification of ECMWF products in the Member and Co-operating States

Fields marked with * are mandatory.

Introduction

Welcome to ECMWF new "Green Book" online submission system (aka "Use and verification of ECMWF products in the Member and Co-operating States")

This time we have two options for completion:

- Filling out the online questionnaire below (new for this year based on feedback from the Meteorological Representatives meeting in November 2023)
- Producing a single report offline (as done in previous years), and emailing the report as detailed in Section 1.

Both methods ask the same questions, however the questionnaire method requires no formatting and aims to make analysis of all responses easier. The questionnaire option also allows you to part-complete, and save your entries to come back to later (using the "Save as Draft" button in the top right corner of this page). Note that the EUSurvey page will timeout after 60 minutes of no activity, responses are usually saved however to be sure please "Save as Draft" to avoid losing responses.

The deadline for all submissions is 23:59UTC on Wednesday 15th May 2024

A summary of responses will be presented at UEF2024 with a summary report available in the ECMWF Publications library in due course.

Section 1: Background - please fully complete

* **1.1 Which Country is your submission for?**

HR - Croatia

* **1.2 Please provide your name(s)**

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* **1.3 Please provide your organisation**

Croatian Meteorological and Hydrological Service

* **1.4 Please select your preferred submission method:**

- ○ Producing a single report offline
- ◉ Online questionnaire

Online questionnaire

Please answer the following questions, and illustrate your answers, where appropriate, by also uploading clearly annotated images with image/figure numbers (max 1MB per file). More questions or options may appear, depending on answers to particular questions. Mandatory questions are marked with a '*'. Free text boxes have no word limit, answers don't need to fit the box size given, the boxes expand.

Responses to the questionnaire can be saved and returned to at a later date before submitting. To do this click the 'Save as Draft' button on the left, this will provide you with a link which you can return to to continue /complete your submission.

Section 2: Summary of major highlights

* **Please detail major highlights since January 2022**

You may wish to complete this section at the end, after completing all others.

The Croatian Green Book report of 2024 highlights two major things. First is an improved and extended Forecasters' survey aimed to a subjective evaluation of the ECMWF products and fields. This time forecasters have been also asked if they use a certain product or not in order to evaluate the relevance of the product for the operational work. Unfortunately, some products like Sunshine duration and Point rainfall still haven't reached the fertile ground in Forecasting offices in Croatia. Second is a comprehensive list of cases with dates and descriptions when some ECMWF forecasts in range from short-range to seasonal were very bad, unsatisfactory or particularly good. In short-range most complaints on bad or unsatisfactory forecast were in cases of precipitation distribution and amount particularly when convection is dominant process. Accompanying weather types in most of such situations were upper level low or front side of upper level low/trough. Interestingly, Stratospheric Sudden Warming was reported as good forecast indicator for colder weather in extended range.
Finally, at Croatian Meteorological and Hydrological Service ECMWF is still considered as the main source of high quality and reliable products and forecasts in the operational work, from short-range to long-range.

Section 3: Forecast products

3.1. Please outline what direct use you make of standard ECMWF model products (on ecCharts / OpenCharts / own workstation), for operational duties, in the following 4 categories (noting that new AI model output should be dealt with separately, via question 3.4).

* **a) Medium Range (e.g. for high impact weather forecasting)**

Standard Medium Range HRES products are visualized on our in house server (using Metview) and much more our own server/workstation environment called Visual Weather. The ecCharts (mostly predefined in Chart dashboard app) are used a lot, particularly for medium range ENS data which are hard to process in house due to big data volumes. A permalink method is widely utilized as well, mainly for retrieving different kind of ENS meteograms, vertical profiles and EFI maps. The OpenCharts are used less for HRES but regularly for ENS products.

* **b) Extended Range (monthly)**

Basic Extended Range products (weekly means, anomalies and probabilities of 2m and 850hPa temperature, precipitation, MSLP and AT500) are visualized on our in house server, but much more of the available Extended Range products are monitored on the OpenCharts or retrieved as permalink. Our server /workstation environment is not used in this case, except for a creation of tailored product for our customers.

* **c) Long Range (seasonal)**

The way of direct use of Long range products is similar to the Extended Range. Basic products (monthly and quarterly means, anomalies and probabilities) are visualized on our in house server, but most of the available Long Range products are monitored on the OpenCharts. Our server/workstation environment is not used in this case, except for a creation of tailored product for our customers.

* **d) CAMS and Fire-related output (ecCharts mainly)**

Some CAMS products are used on the ecCharts, but mostly we refer to the Copernicus web page the monitor the available CAMS products, particularly dust. Different kind of Forest fire-related products have become available on the ecCharts, but still not used much. Till now, forest fire related products were inspected mainly on the EFFIS web page.

3.2. ECMWF cycle 48r1 went live at the end of June 2023. Changes included a much higher resolution medium range ensemble, and much more frequent monthly forecasts.

* **a) Please describe any <u>positive</u> impacts of model cycle 48r1 for your service**

Although there is now systematic verification regarding medium range ensemble at our Service, ten months of the use experience in the Forecasting department has led to a subjective positive impression that the ensemble behavior became more reliable at longer lead times (e.g. beyond day 6 or 7). In other words one can rely more on the ENS uncertainty in case large uncertainty exists. For instance, before it was a quite common case that the ensemble eventually would follow the HRES and Control development of weather situation. Now with the higher resolution ENS, the resolution as same as HRES, this behavior is not obvious any more.
Another positive impact is much frequent use of extended range (monthly) forecast among forecasters in our Service as well as availability of new products.
Positive impact comes also from using cy48r1 e-suite LBCs inside assimilation cycle when compared to current operational forecast (where current operational LBC were used), more on that in section 4.1.a of the report.

If you have any annotated graph/diagram/plot that would help clarify your answer to the previous question, please upload here.
File types: most accepted, File Size: max 1MB per file.

* **b) Please describe any <u>negative</u> impacts of model cycle 48r1 for your service**

No negative impacts have been noticed.

If you have any annotated graph/diagram/plot that would help clarify your answer to the previous question, please upload here.
File types: most accepted, File Size: max 1MB per file.

* **c) Have you noticed any systematic changes in forecast output since model cycle 48r1 was implemented?**

- ○ Yes
- ◉ No

* **3.3: Do you modify ECMWF model output to create 'derived fields' (e.g. post-processed output, regimes, probabilities).**

- ◉ Yes
- ○ No

Please describe what you modify and how

Our server/workstation environment called Visual Weather allows easy creation of derived fields. Although not many new fields have been derived since the last report, some can be mentioned again: probability of road icing, frost alert, guidance for fog development, guidance for deep moist convection, heat wave indicator.
A tool called Field Diagnostics, designed to derive new fields out of raw model output is used to derive, e.g. thunderstorm indices, fire weather indices. One example of the new fields is a precipitation type-intensity product derived using precipitation type and precipitation rate fields. A plot of this derived field is shown in Figure 1 (precip_type-intensity.png).
In our Forecasting department a simple post-processing of minimum and maximum temperature forecast is done using Visual Weather. Model tendency of minimum 2-m temperature forecast between two consecutive days is added to measurement values (min temp. from 06 UTC) in order to obtain corrected forecast of minimum temperature for station location for tomorrow. Analogously, model tendency of maximum 2-m temperature between three consecutive days (from two runs) is added to measurement values (max temp. from 18 UTC yesterday) in order to obtain corrected forecast of maximum temperature for station location for tomorrow. A method has proven to be very accurate in cases when weather is not changing significantly and it is very efficient in bias removal - verification of this method in comparison to raw output was performed three years ago using four-year dataset. Results for Tmax and Tmin forecasts for tomorrow ("za sutra") for coastal station Split-Marjan are shown in Figure 2 (Bias_Tmax_St.png) and Figure 3 (Bias_Tmin_St.png).
First five bars are different models biases including the bias of average (Avg) of "poor man's" ensemble of all models, following five bars are biases of post-processed values using tendencies (Ten), respectively, and the last black bar is bias of human forecaster. EC00 and EC12 are ECMWF model run 00 UTC and 12 UTC.
For mountainous stations the tendencies of appropriate pressure level temperature are used instead of 2-m temperature.
In order to provide an unified pointwise direct model prognostic information for public at Service's website, instead showing two different model forecasts for cities, blending of ALADIN 3-day and ECMWF 7-day forecasts is used. Mesoscale model 0-72h forecasts are merged with global model 75-132h forecasts near the forecast range of the merge (72h). Joint 7-day ALADIN and ECMWF forecast is presented in meteograms and published on https://meteo.hr/prognoze_e.php?section=prognoze_model&param=7d.

If you have any annotated graph/diagram/plot that would help support your answer to the previous question, please upload here.
File types: most accepted, File Size: max 1MB per file.

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e861d27d-826e-4c9a-b48e-d311a6314ed1/Figure3_Bias_Tmin_St.png

* **3.4: Do you currently use Artificial Intelligence (AI) and/or Machine Learning (ML) techniques in your service, in conjunction with standard ECMWF model output?**

- (•) Yes
- ( ) No

Please describe any such techniques and/or any future plans you have in this area

AI and/or ML techniques are not applied in conjunction with ECMWF model, but with our ALADIN limited area model. However, ERA 5 reanalysis data are used for the development of statistical models and 'training' of air quality models based on neural networks. A near future plan is to apply AI/ML techniques in order to produces blended ALADIN-ECMWF products, e.g. meteograms.

If you have any annotated graph/diagram/plot that would help support your answer to the previous question, please upload here.
File types: most accepted, File Size: max 1MB per file.

* **3.5: Does your NMHS use ECMWF data for modelling purposes - e.g. by providing initial/boundary conditions for limited area model runs, or for hydrological models, or for dispersion models, etc...**

- (x) Yes
- ( ) No

Please describe these activities

Regarding Limited area modelling: ECMWF lateral boundary conditions (LBC) are used for running a 72hr forecast with ALADIN-HR4 (4km horizontal grid spacing) and ALADIN-HR2 (2km horizontal grid spacing) operational runs. Due to time constraints for availability of ALADIN 72hr forecast ECMWF LBCs in production are used in so-called lagged mode (ECMWF forecast initialized 6h earlier than ALADIN initial time is used as LBC). As no SST data assimilation is performed locally, the initial SST is taken as a copy from global model analysis. Since 6th Feb 2018, hourly LBCs are provided by ECMWF but still in operations 3-hourly coupling is used. Also, from June 2020 model configuration 903 is used for generation of LBC with same horizontal grid spacing as before. Possible upgrade of LBCs in both horizontal and vertical resolution was tested, more on this in the section 4.1.a of the report. To provide detailed forecast of height and direction of wind waves, Wind Wave Model (WWM) was set up at DHMZ. WWM is run once per day with boundary data at the Otranto strait obtained from the global WAM model.

Regarding Climate Modelling: The first set of non-hydrostatic DHMZ-RegCM simulations, performed using ECMWF HPC, covered the period 1999-2012 and were forced by ERA-Interim over the larger Alpine region. The next set of simulations was by forcing the RegCM, over the same domain, with the CMIP5 global climate model EC-EARTH. The non-hydrostatic version of RegCM was initialized by EC-EARTH at 12.5 km horizontal resolution, and nested 4 km simulation for the period 1995 – 2005. The simulations were run on the HPC in Reading. The last ten years of 21st century (2090-2099) will be simulated, using the same global model and according to the RCP8.5 scenario. The use of the new HPC in Bologna requires testing the RegCM according to the best performance and the available CPU. RegCM simulations based on 12 km resolution and hydrostatic model's version were used together with two other regional models (RCA4 and CCLM4) to support Eight National Communication of the Republic of Croatia under the United Nation Framework Convention on the Climate Change (https://klima.hr/razno/publikacije/8NIKP_DHMZ.pdf). RCMs were forced by the same four GCMs (CNRM-CM5, EC-Earth, MPI-ESM and HadGEM2). Ensemble of 12 members were used to obtain future temperature and precipitation change as well as the change of their extreme parameters in the period 2041-2070 vs. 1981-2010 for RCP4.5 scenario. Research on evaluation of CNRM-ALADIN RCM regarding modelled extreme precipitation over the Dinaric Alps is published in Ivušić et al (2021).The performance of two different configurations of CNRM-ALADIN was investigated including several sensitivity tests on specific parameters within a configuration. All simulations were driven by the ERA-Interim reanalysis within the Med-CORDEX domain at a 12.5 km horizontal resolution. Furthermore, the future changes in extreme precipitation over the same area are investigated. This analysis encompasses all available EURO-CORDEX projection simulations, including the recent simulations within the C3S production of European climate projections at high horizontal resolution, which are stored in the Climate Data Store (CDS). Both studies utilize the MESCAN regional precipitation analysis system as a reference dataset, which has been upscaled from its original horizontal resolution of 5.5 km to 12.5 km. MESCAN was downloaded from the MARS meteorological archive. Additionally, in response to a client's requests, ERA5 reanalysis data was obtained using the Climate data store ERA5 daily statistics calculator. The downloaded data included variables such as the u and v components of wind, total and low cloud cover, 2 m temperature and dewpoint temperature, mean sea level pressure, mean total precipitation rate, and K index. The data covered the period from 1991 to 2020. C3S snow indicators data for Europe from 1950 to 2100 derived from reanalysis and climate projections are used for to fulfil a request for mountain tourism study

Regarding Hydrological modelling: the Operational hydrological forecasting system within MIKE11 software is based on the real-time data received from available online stations in Croatia, Slovenia and Bosnia and Herzegovina, relevant online data received from Slovenia and Hungary and temperature and precipitation forecast from the NWP models ALADIN (4 km resolution, 2 km resolution lead time 0-71 h, 4 runs per day - 00, 06, 12 and 18 UTC) and ECMWF (10 km resolution, lead time 72-120 h, 2 runs per day - 00, 12 UTC). The hydrological forecasting models are mainly driven by the precipitation input. The models have to deal with uncertainty in rainfall, which is usually the largest source of uncertainty in hydrological modelling.

Regarding Air Quality modelling: Air Quality Modelling is currently making use of ECMWF supercomputer (ATOS-HPC) resources for running LOTOS-EUROS chemical transport model, for which IFS meteorological fields (F1280 grid) and CAMS data are used as drivers. Data is accessed trough MARS. Sets of parameters used are: IFS (surface and model levels, Fire emissions, CAMS boundary and lateral conditions (F256 grid).

In addition, IFS is used for WRF meteorological model on fine-scale resolution. Furthermore, emission data from CAMS are used for all numerical air quality models (LOTOS-EUROS, EMEP). ERA 5 reanalysis data are used for the development of statistical models and 'training' of air quality models based on neural networks (data taken from Copernicus Atmosphere Data Store). So far, ECMWF meteorological data are validated implicitly.

If you have any annotated graph/diagram/plot that would help support your answer to the previous question, please upload here.
File types: most accepted, File Size: max 1MB per file.

*** 3.6: In the last year or so ECMWF has made available, on ecCharts and OpenCharts, selected fields from AI models (e.g. Pangu Weather, AIFS). Were you aware of this?**

- (x) Yes
- ( ) No

*** a) What are your views on this initiative?**

In the Forecasting department of our Service, we always look forward to new models and technologies, so AI models are welcome. Since started to be available, outputs from AI models have being occasionally monitored both on ecCharts and OpenCharts, but not exactly operationally used. In-house visualization is done as well, all available AI model fields are visualized, but also monitored only occasionally. The usage of AI models will probably grow in the future if they become more comprehensive and apparently more accurate than the standard numerical atmospheric models.

* **b) Do you currently use AI forecasts for operational purposes?**

- ( ) Yes
- (•) No

What would you need in order to use AI models in your forecast activities?

Currently AI models are not operational used in the forecast activities in our Service, just occasionally monitored as already mentioned. In our opinion, to become comparable to standard models regarding operational purposes, more than some basic surface and pressure level parameters AI models provide are needed. Moreover, not all AI model provide precipitation (including types of solid precipitation), the variable the hardest to be accurately forecast, particularly its extremes and deep moist convection. Also finer spatial resolution will be needed, particularly in case of small country with complex orography such as Croatia is. For capturing uncertainty in longer lead times, we would still rather rely on real ensemble forecast than quasi-ensemble made of a few different AI models.

Section 4: Verification

ECMWF does extensive verification of its products in the free atmosphere. However, our verification of surface parameters is more limited and can be constrained to only using synoptic observations. More detailed verification of these surface weather parameters by National Services is always valuable to us. We are most interested in results for the last 1 or 2 years. Also, any evidence you have of performance changes since the introduction of cycle 48r1 would be very valuable.

* **4.1 Do you routinely verify <u>raw model output</u> from ECMWF model(s) and/or other operational models /ensembles?**

- (•) Yes
- ( ) No

Please describe your verification activities and show and discuss related scores in the the two lead-time categories shown below, including, where possible, comparisons with your own models /ensembles, and other models/ensembles.
Ideally focus on surface weather parameters in your own territory. Inclusion of conditional verification results is also strongly encouraged - e.g. stratification by a weather type - as these can provide very useful insights into model weaker points.

a) Short Range and Medium Range

Concerning short range and medium range forecast, only short range is verified routinely. For medium range, including ensemble forecasts, some subjective evaluation will be shown in the section 4.3 of the report.

In the short range category results of the real-time verification of minimum and maximum 2-m temperature for the next day in 2023 and in winter (DJF) of 2023-24 will be presented as well as some verification updates in the scope of South-East European Multi-Hazard Early Warning Advisory System (SEE-MHEWS) in 2020, particularly for 24-h accumulated precipitation.

The main goal of the verification of min and max 2m-temperature is to evaluate particularly human forecasters' performance but also to compare it to available NWP models. A method used is grid-to-point, where gridded values of direct model outputs are interpolated to SYNOP observation points and verified. As Visual Weather normally interpolates gridded data of the numerical models, interpolated grid-to-point method is natural and simplest choice, rather than nearest point method. Forecasters' use these interpolated model values as guidance for making their own forecasts. Tables of the ECMWF HRES guidance shown and explained in Figure 4 (tx-tn_ECMWF-guidance.pdf).

Models included in the verification are: ALADIN 4 km (00 UTC run), DWD ICON 6.5 km (00 UTC run) and ECMWF HRES (00 UTC run, operational suite), referred as Ala4, DWD and EC, respectively. DHMZ's forecasters are referred as D1. Continuous verification scores were calculated for each synoptic station but also aggregated for all stations (32 stations, including three mountainous) and include Bias, MAE and RMSE.

In the year 2023 and in winter of 2023-24 aggregated scores for the maximum and minimum 2-m temperature forecast from yesterday are shown in Figure 5 (scores-all-2023.png) and Figure 6 (scores-all-winter-2023-24.png). Scores of EC were comparable to other higher resolution models, although negative bias and errors for maximum temperature forecast are bigger, particularly in the warm part of the year. For minimum temperature EC was as good as other models and has almost no bias, same as the forecasters who demonstrate best verification results and, in the end, add certain value. EC scores for minimum temperature did not change much throughout the year. If verification results for bias are shown for each station as in Figure 7 (bias-tmax-2023.png), Figure 8 (bias-tmin-2023.png), Figure 9 (bias-tmax-summer-2023.png), Figure 10 (bias-tmin-summer-2023.png), it is evident that overall negative bias of EC in maximum temperature forecast in summer and through the year comes for stations at Adriatic Sea or near it. This is mainly due the fact that coarse resolution of EC do not represent well the coastline, small islands and steep topography near the coast. In higher resolution this effect is less pronounced, however they still show negative bias. The max temp. bias of inland stations can be considered smallest in EC forecasts. EC bias problem at the Adriatic sea and near it exists also for minimum temperature but is less pronounced and displays spatial variability. While station which are located in the model's sea have positive bias (smaller in summer), those near the coast have too much influence of higher elevation model's land topography and therefore negative bias. Overall, EC bias in minimum temperature is better then for maximum and on average for all stations is close to zero. As our domestic model ALADIN heavily overestimates minimum temperature in the continental part of the country, for minimum temperature forecast EC is mainly used. Mountainous stations show strong positive bias both in max and min temperature due to bad representation of their altitude in the EC model. To conclude heavy underestimation of EC max temperature at seaside can be bias corrected. As explained in section 3.3. of the report (verification is given as well), our simple post-processing algorithm makes ECMWF temperature forecasts at seaside and in mountains very usable.

A 24-hour precipitation verification within South-East European Multi-Hazard Early Warning Advisory System was explained in the report of 2021 but was in the mean time extended to 229 station of the region of interest that incudes Albania, Bosnia and Herzegovina, Montenegro, North Macedonia, and Serbia.

Continuous variable verification methodology show usefulness of the models to serve as a basis for early warning systems in South-East Europe, but also reveal some weaknesses. Moment-based statistical verification suggests that model accuracy is within expected limits. Best results averaged over all stations are achieved for correlations by the ECMWF model (0.45), for systematic errors by COSMO (0.15 mm/24h), and for mean absolute errors and root mean square errors by ECMWF model (2.92 mm/24h and 10.01 mm/24h), but differences among the models are quite small. Systematic errors and correlations are less spatially variable, while, in contrast, mean absolute errors and root mean square errors show distinct geographic variability, see Figure 11 (SEE-MHEVS.png). It is clearly noticeable that models are of lower accuracy in the mountainous areas of Dinaric Alps and near the coast. Since heavy precipitation is the main focus of the SEE-MHEWS-A project, categorical verification was performed in addition to moment-based statistical verification. Due to large surface inhomogenities among countries (terrain, proximity to the sea), verification was made for each country separately. As expected, all models are the most successful in the dry day category with equitable threat score (ETS) reaching up to 0.6 (Bosnia and Herzegovina and Montenegro). The lowest models' accuracy is found for Albania, where Dinaric Alps are the highest and most complex. The worst scores among all precipitation categories are typically found for the rarely occurring low precipitation category (between 0.3 mm/24 h and 1 mm/24h). Results do improve in higher precipitation categories, that is, with increasing precipitation amounts but comparison among models yields mixed results. Regarding heavy precipitation over 30 mm /24 h and over 60 mm/24 h, although results are far from perfect, all models show skillful predictions and none of the models show considerably more strengths than others. Extremal dependence index (EDI) ranges from 0.45 up to 0.85 depending on the model and country; the only exception being Albania with somewhat lower models' performance and generally the lowest precipitation predictability.

The single-observation neighborhood approach (SO-NF) results show an improvement in ETS values with an increase of the spatial scale for the categories of events between the 6 and 30 mm/24h threshold. All models also improve ETS value at a certain spatial scale for events above 30 mm/24 h. At the highest precipitation category (above 30 mm/24h) and common spatial scale of ~45 km, models ECMWF and COSMO seem to perform somewhat better but differences among models are generally small and not statistically significant. The improvement of the results with the forecast neighborhood size that are noticed for most models and countries shows the benefits of the SO-NF approach in terms of recognizing additional forecasted values present in the proximity of the exact location, even though they were slightly displaced.

As part of the IFS cy48r1 e-suite, several alternatives for new lateral boundary conditions (LBC) for the LACE domain have been proposed. Different versions of LBCs were obtained for testing during May 2023 and were used by the ALADIN-HR40 configuration to generate 72-hour forecasts over a 14-day period. These forecasts were then validated against both surface and upper air measurements within the ALADIN-HR40 domain. The evaluation of surface parameters reveals no notable differences. Similar results were obtained for the upper air scores. Additionally, new LBC options were used inside assimilation cycle and again forecast experiment was made. Same as before small differences were present for different options but when compared to current operational forecast (where current operational LBC were used) it can be seen in Figure 12 (newLBC.png) that there is positive impact that comes from using cy48r1 e-suite LBCs.

If you have any annotated graph/diagram/plot that would help support your answer to the previous question, please upload here.
File types: most accepted, File Size: max 1MB per file.

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0ed37c42-6096-4583-83f4-4706e122801e/Figure11_SEE-MHEVS.png
8914ccfe-91f6-4061-98e4-e93ca8bba1ae/Figure12_newLBC.png
78b5a286-822c-441e-b150-7ab047f5146c/Figure4_tx-tn_ECMWF-guidance.pdf
c0ceefde-bcbe-41c5-8018-9e986690a0bc/Figure5_scores-all-2023.png
e40578bd-5a00-4c39-8185-4d62d78c2449/Figure6_scores-all-winter-2023-24.png
087bdceb-cef3-41bb-803a-80f8202d64ed/Figure7_bias-tmax-2023.png
5c1b833b-9e30-4c4d-8323-9818f9b3ca77/Figure8_bias-tmin-2023.png
c0dd9e7f-48c3-4e00-b2a8-f7032d77c982/Figure9_bias-tmax-summer-2023.png

b) Extended Range (Monthly) and Long Range (Seasonal)

No new extended range and long range forecast verification has been performed since the last report. This category of forecasts is not routinely verified, at least not objectively. However. some subjective evaluation is made and will be presented in the section 4.3 of the report.

If you have any annotated graph/diagram/plot that would help support your answer to the previous question, please upload here.
File types: most accepted, File Size: max 1MB per file.

* **4.2 Do you routinely verify <u>post-processed products</u> and/or tailored products delivered to users?**

- ( ) Yes
- (•) No

* **4.3 Do you perform any <u>subjective verification</u> of forecasts?**

- (•) Yes
- ( ) No

Please describe and illustrate any activities and results in this area

For a subjective evaluation purpose of ECMWF model fields and products, a survey is being carried out yearly in the Forecasting department. Different topics are proposed to the forecasters to state if they confirm/disagree/not sure/not using. Mostly evaluated were changes in fields and products brought by IFS cycle 47r3 available after October 2021 and unfortunately less by IFS 48r1 because the Green Book report was expected to be requested in June 2023. Twenty-two forecasters participated in the survey last year. The list of all topics and results of the survey is given in Figure 13 (survey_forecasters.png). Here are the results:

- Majority of forecasters agree that HRES cloud forecast has improved. However, there is a mixed opinion about the question if HRES distinguishes well between high, medium and low cloud cover (contrary to the result of the survey in 2021). Forecasters state that high cloudiness in the model occasionally represents as medium cloudiness in reality, similarly medium cloudiness in the model is sometimes actually low. Possibly, there is some cloud height threshold issue, other models forecasters use seem to be better in cloud height representation. There is a general opinion that fog/low stratus clouds are well forecast, both over land and sea, but still tend to disappear to early and are not always well spatially distributed, particularly if cases when not widespread. The same complaints are about the Visibility product which is generally considered reliable. It seems there is no interest in Sunshine duration in last 24 hours product as it's almost not used at all, same as in the survey of 2021.

- In case of precipitation forecast, majority of the forecasters are not sure if there are improvements in HRES, but according to mixed answers of this survey, extreme precipitation towards the end of forecast period seems to be smaller issue than was before. Still to wet during convective precipitation situations in the warm part of the year, given convective precipitation in the model appears spatially too spread, while showers are only isolated. Point rainfall probability product is rarely used and unfortunately still not popular between forecasters. But the popularity of the Precipitation type product is continouslly high as most forecasters confirm its reliability as well as the reliability of Probability of precipitation type. About the question on Freezing rain products, if these tend to overestimate freezing rain, although a big part of the forecasters has not been using them, some confirm overestimation but majority is not sure as freezing rain situations were very rare during latest winters.

- There is a mixed opinion about HRES temperature improvement, but majority disagree on question if there is weakness of the model in cases of temperature inversions - meaning it's quite good in forecasting temperature inversions. It has to be mentioned that HRES used to have a problem with too low minimum temperature during clear nights when snow cover was on the ground. It is partly confirmed again, however, in the latest winters snow was very rare so majority is not sure if the problem still persists. Although majority of forecasters is not using ENS vertical profiles, a big part of those who use confirm it's useful product.

- Forecasters in majority are also not sure if the HRES wind forecast has improved but many confirm improvement. However, wind forecast of ECMWF HRES is inferior to higher resolution models in areas of steep coastal terrain with strong down-slope NE wind in the lee of the Dinaric mountains called Bura. Significant wave height is used mostly by marine forecasters and none disagree about its reliability.

- Regarding fields and products aimed to forecasting deep moist convection processes, majority still think CAPE is unrealistic, especially over the sea and majority is not sure if CIN has improved. Interestingly, majority has negative opinion and some are not sure about reliability of the Lightning density as indicator of the likelihood of convection, especially when used as a standalone product. But in combination with other fields some said it was useful in some cases. The same applies for Lightning probability product. CAPE-SHEAR and EFI CAPE-SHEAR products are mostly considered not useful or even not used for forecasting convection, especially not for the purpose of forecasting type of convective organization. For this purpose forecasters rather use CAPE and SHEAR separately as ingredients.

- EFI of basic fields: precipitation, snow, wind, temperature (opposite to for instance EFI CAPE-SHEAR), belong to best evaluated products among forecasters. Most of them gave affirmative answer about the quality of basic EFI as indicator of anomalous weather.

- Meteograms and ENSgrams of all kind have always been favorite among forecasts. This includes also 15-days ENSgram product which is used a lot and those who use it state it's very useful or reliable. It has to be mentioned that forecasters also like Precipitation type ENSgram.

- When asking about jumpiness in HRES, majority disagrees and a big part of the forecasters is not sure about it. Rather interesting and a bit strange result is that nobody confirms HRES is still jumpy. Nevertheless, some positive feedback in comparison to the survey of 2021 can be seen. On the other hand, the half of the half of those who use monthly forecast state it is jumpy, e.g. forecast for later weeks is too much influenced by the current anomaly and new runs often display sudden change in the forecast.

- Monthly forecast products like Early warning for cold spells, Stratospheric Sudden Warning and Weather regimes in extended range are generally not used products as for aviation and marine forecasters monthly forecast is not part of the job. Just few forecasters are experts in monthly forecasts and they find these product reliable, except Weather regimes which seems to be marginally reliable due to mixed opinions.

- Seasonal forecasts, same as monthly forecasts, are not used in majority, but few expert users confirm big errors of monthly anomalies, particularly in long lead times.

If you have any annotated graph/diagram/plot that would help support your answer to the previous question, please upload here.
File types: most accepted, File Size: max 1MB per file.

1aedc1f6-0751-4983-b3d6-59bb352dea47/Figure13_survey_forecasters.png

4.4: Case Studies. Please describe and illustrate any case study verification you have undertaken. Examples of both good and bad model performance are welcome. Severe weather events (and non-events) are of particular interest to us.

a) Case Study 1 - Please describe the forecast(s) and what happened

First part of September 2021. HRES and ENS. Bad temperature forecast, especially inland. Anticyclone (radiation regime). Too warm in the morning, too cold during the day. And so for days.

Remark: a list of many cases is given in ECMWF_situation_of_poor(good)_forecasts.xlsx (in Croatian). Forecasters who reported each of the cases are known, but preferred to be anonymous.

If you have any annotated graph/diagram/plot that would help support your answer to the previous question, please upload here.
File types: most accepted, File Size: max 1MB per file.

78c283f0-7db4-496b-bf6a-2ee1388b5f75/ECMWF_situation_of_poor_good__forecasts.xlsx

Case Study 1 is an example of:

- ○ Good model performance
- ◉ Bad model performance
- ○ Mixed (good and bad) model performance
- ○ Other (please describe above)

Add another Case Study?

- ◉ Yes
- ○ No

b) Case Study 2 - Please describe the forecast(s) and what happened

March 2022. Seasonal forecast. In several consecutive runs, including the one from February, warm anomaly for March was forecast. It turned to be colder than normal. Weather situation was mostly long lasting high pressure field.

If you have any annotated graph/diagram/plot that would help support your answer to the previous question, please upload here.
File types: most accepted, File Size: max 1MB per file.

Case Study 2 is an example of:

- ○ Good model performance
- ◉ Bad model performance
- ○ Mixed (good and bad) model performance
- ○ Other (please describe above)

Add a third Case Study?

- ◉ Yes
- ○ No

c) Case Study 3 - Please describe the forecast(s) and what happened

12 July 2023. HRES and ENS. Neither HRES nor ENS (with any member) runs from day before caught the early morning severe convection (MCS) in the northern Adriatic and in the west of Croatia. Weakening thermobaric ridge over Croatia, cold front north-west of the Alps. A severe storm with strong winds that toppled trees, broke branches, threw things in the capital city of Zagreb... a fierce reaction from the public because T-storm was not forecast and we could not forecast it on the basis of anything. Unfortunately we do not work night shifts. Analyses showed it actually started on Tuesday late evening in the north of Italy and overnight it moved through Slovenia to Croatia. Everything happened in the middle of a heat wave and a red heat warning, in fact a sunny and stable hot day was expected.

If you have any annotated graph/diagram/plot that would help support your answer to the previous question, please upload here.
File types: most accepted, File Size: max 1MB per file.

Case Study 3 is an example of:

- ○ Good model performance
- ● Bad model performance
- ○ Mixed (good and bad) model performance
- ○ Other (please describe above)

Add a forth Case Study?

- ● Yes
- ○ No

d) Case Study 4 - Please describe the forecast(s) and what happened

> 14-22 January 2023. HRES and ENS. Quite jumpy and unreliable with precipitation, especially in the type of precipitation. Huge low over Europe, series of cyclogenesis in the Mediterranean in the SW flow aloft. The model runs at the beginning of the period gave a lot of snow, and then every day a slightly different annoying forecast.

If you have any annotated graph/diagram/plot that would help support your answer to the previous question, please upload here.
File types: most accepted, File Size: max 1MB per file.

Case Study 4 is an example of:

- ○ Good model performance
- ○ Bad model performance
- ● Mixed (good and bad) model performance
- ○ Other (please describe above)

Add a fifth Case Study?

- ● Yes
- ○ No

e) Case Study 5 - Please describe the forecast(s) and what happened

> The end of the 1st and the end of the 2nd decade of January 2024. ENS Extended. Stratospheric Sudden Warming. Very good signal of colder weather.

If you have any annotated graph/diagram/plot that would help support your answer to the previous question, please upload here.
File types: most accepted, File Size: max 1MB per file.

Case Study 5 is an example of:

- (•) Good model performance
- ( ) Bad model performance
- ( ) Mixed (good and bad) model performance
- ( ) Other (please describe above)

Section 5: Output Requests

5. Please describe, and illustrate if necessary, any particular requests you may have for new or modified ECMWF products.

a) Product request 1 - title / summary

Radar reflectivity simulation

Product request 1 - description of request

Radar reflectivity simulations (max dBZ) for HRES and reflectivity threshold probability from ENS, if possible. Particularly in the future in case of higher IFS spatial resolution.

If you have any annotated graph/diagram/plot that would help support your answer to the previous question, please upload here.
File types: most accepted, File Size: max 1MB per file.

Add another Product Request?

- (•) Yes
- ( ) No

b) Product request 2 - title / summary

Automated Severe Weather Guidance

Product request 2 - description of request

Severe weather probabilities based on IFS ENS and algorithm similar to ESSL, if possible.Take a look at https://www.stormforecast.eu/

If you have any annotated graph/diagram/plot that would help support your answer to the previous question, please upload here.
File types: most accepted, File Size: max 1MB per file.

Add a third Product Request?

- (•) Yes
- ( ) No

c) Product request 3 - title / summary

Significant weather

Product request 3 - description of request

A kind of extension of precipitation type product with a fog and T-showers/storms if possible.

If you have any annotated graph/diagram/plot that would help support your answer to the previous question, please upload here.
File types: most accepted, File Size: max 1MB per file.

Add a forth Product Request?

- (•) Yes
- ( ) No

d) Product request 4 - title / summary

Heating/cooling degree days

Product request 4 - description of request

If possible, heating/cooling degree days on all temporal scales.

If you have any annotated graph/diagram/plot that would help support your answer to the previous question, please upload here.
File types: most accepted, File Size: max 1MB per file.

Add a fifth Product Request?

- (•)

Yes
No

f) Product request 5 - title / summary

Additional weather regimes in extended range and seasonal forecast

Product request 5 - description of request

If possible, extension of weather regimes probabilities to Greenland Anticyclone, Summer Atlantic Low, Summer Zonal, Summer Blocking.

If you have any annotated graph/diagram/plot that would help support your answer to the previous question, please upload here.
File types: most accepted, File Size: max 1MB per file.

Section 6: References

6. Are there any recent internal or external publications that relate to the questions in this survey? Please list them including the respective link/s. For any publications that cannot be readily downloaded via a link please attach a copy below (or email Becky Hemingway (becky.hemingway@ecmwf.int) and Tim Hewson (timothy.hewson@ecmwf.int) if too large to upload here).

Ivušić, S., Güttler, I., Somot, S., Guérémy, J.-F., Horvath, K. & Alias, A. (2021). Modelling extreme precipitation over the Dinaric Alps: An evaluation of the CNRM-ALADIN regional climate model. Quarterly Journal of Royal Meteorological Society, 147 (741, 4425– 4453), https://doi.org/10.1002/qj.4187

If you have any annotated graph/diagram/plot that would help support your answer to the previous question, please upload here.
File types: most accepted, File Size: max 1MB per file.

Section 7: Additional comments and Feedback

7.1. Please use the box below if you have additional comments on topics that have not been covered in any of the questions above

No additional comments. A list of topics is wide enough.

If you have any annotated graph/diagram/plot that would help support your answer to the previous question, please upload here.
File types: most accepted, File Size: max 1MB per file.

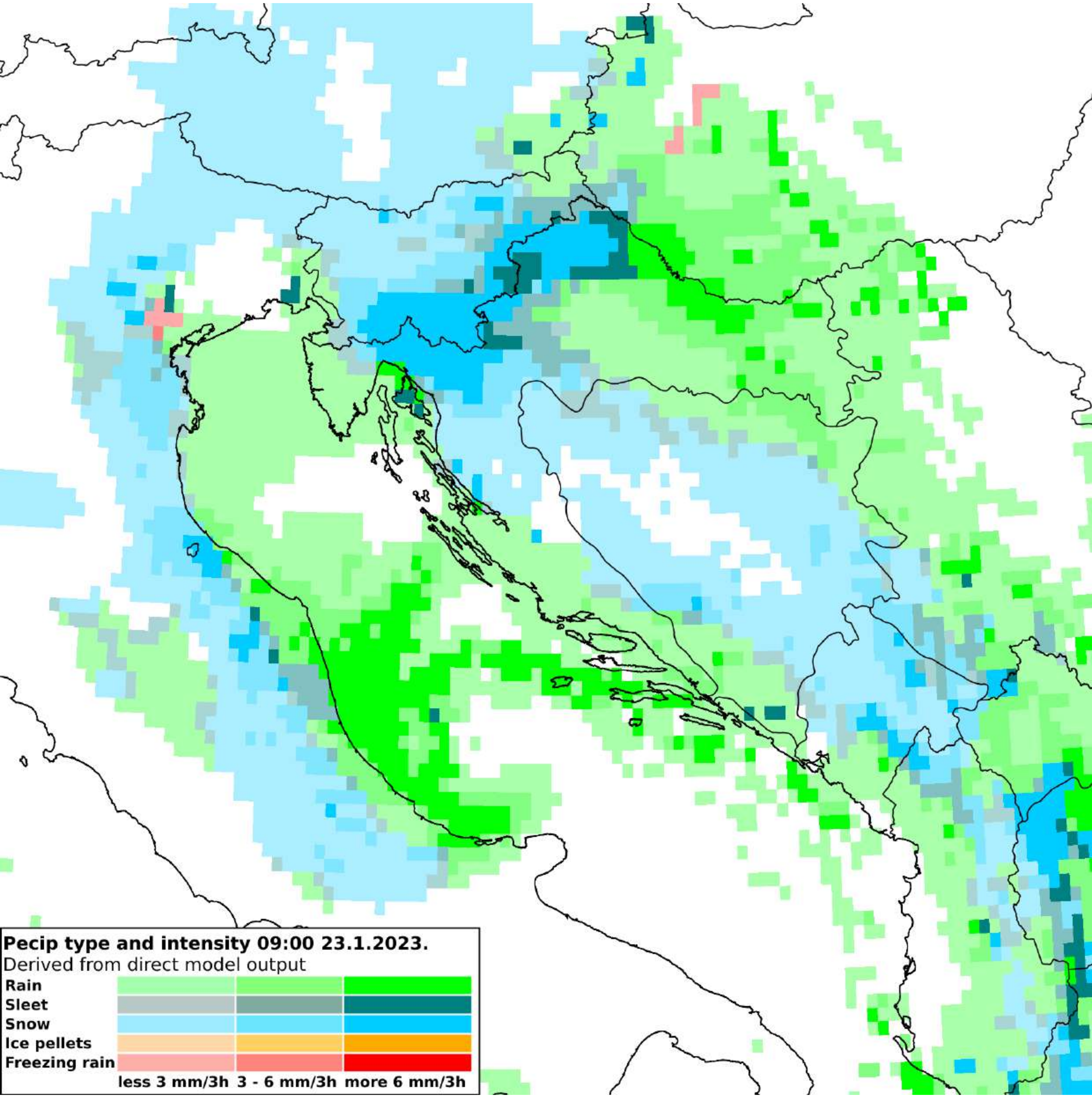
7.2. This is the first time we have used a survey style structure for Green Book submissions. You thoughts and feedback on this process are very welcome

A survey style is pretty convenient as you have access to the report from anywhere. A little bit strange is where to put captions for figures which are uploaded, in the text boxes or as a part of image file?
More than five case study examples would be fine. Please remove a warning of the limit of number of text characters as text boxes seem to accept any number. Web page for some reason jumps down when using Delete or BackSpace buttons no matter the browser used, it was quite annoying.

Thank you for taking the time to complete your Green Book report. Your feedback and comments are very valuable to us!

Contact

Contact Form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Derived from direct model output
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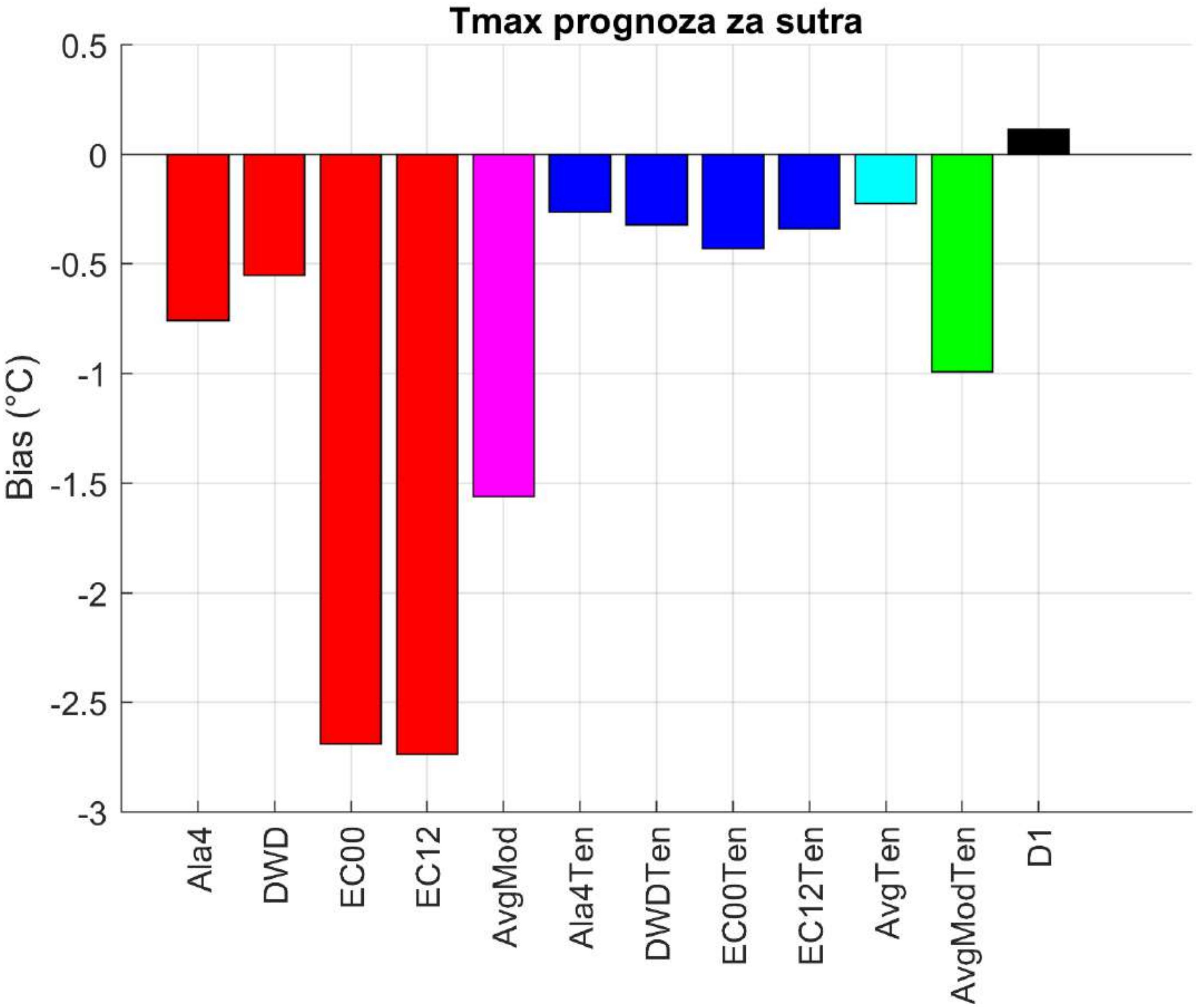
Sleet
Snow
Ice pellets
Freezing rain
less 3 mm/3h
3 - 6 mm/3h
more 6 mm/3h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-1.5
-2
-2.5
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Bias (°C)
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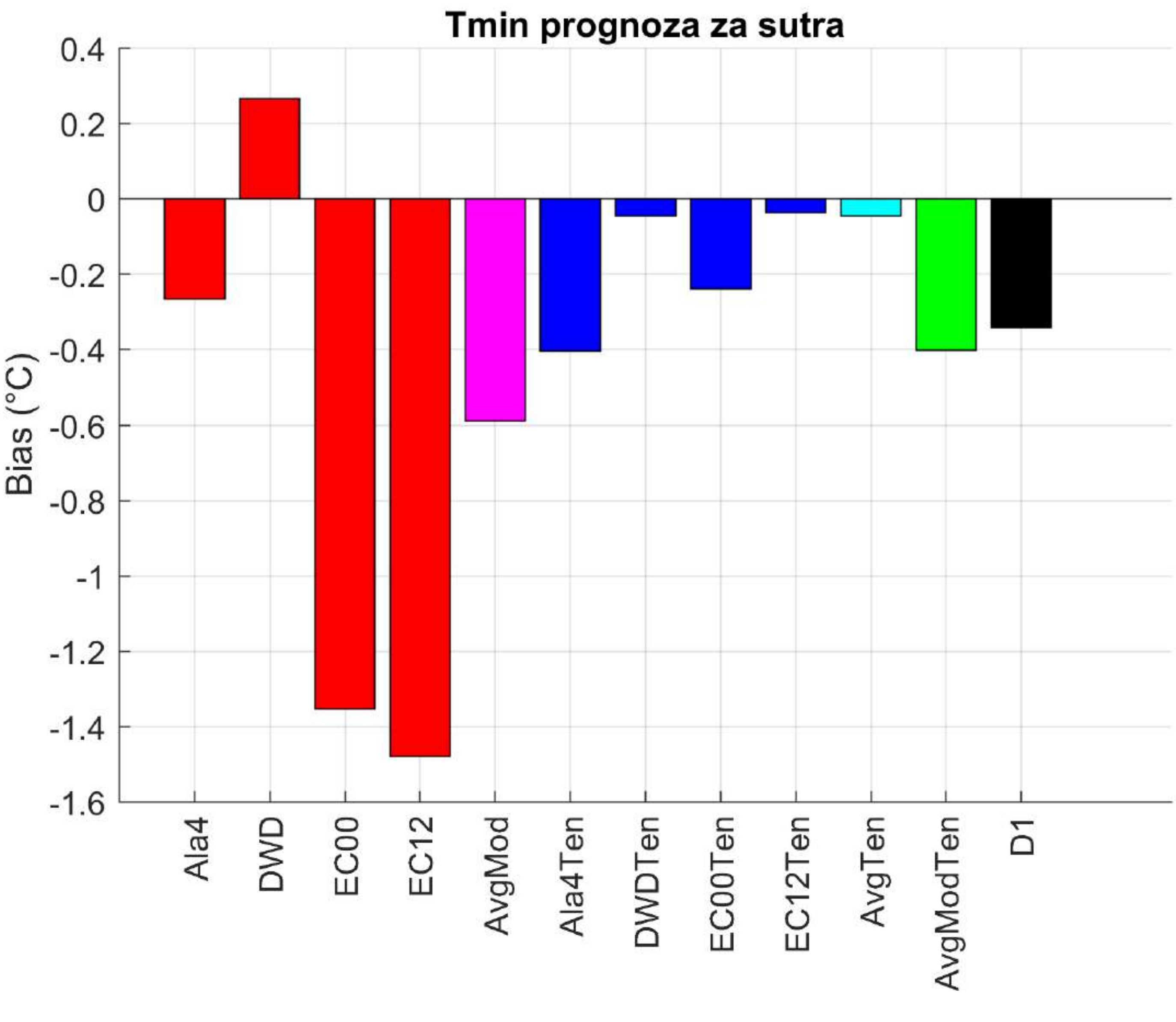
EC00
EC12
AvgMod
Ala4Ten
DWDTen
EC00Ten
EC12Ten
AvgTen
AvgModTen
D1


Tmin prognoza za sutra
Bias (°C)
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0.2
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
-1.4
-1.6
Ala4
DWD
EC00
EC12
AvgMod
Ala4Ten
DWDTen
EC00Ten
EC12Ten
AvgTen
AvgModTen
D1

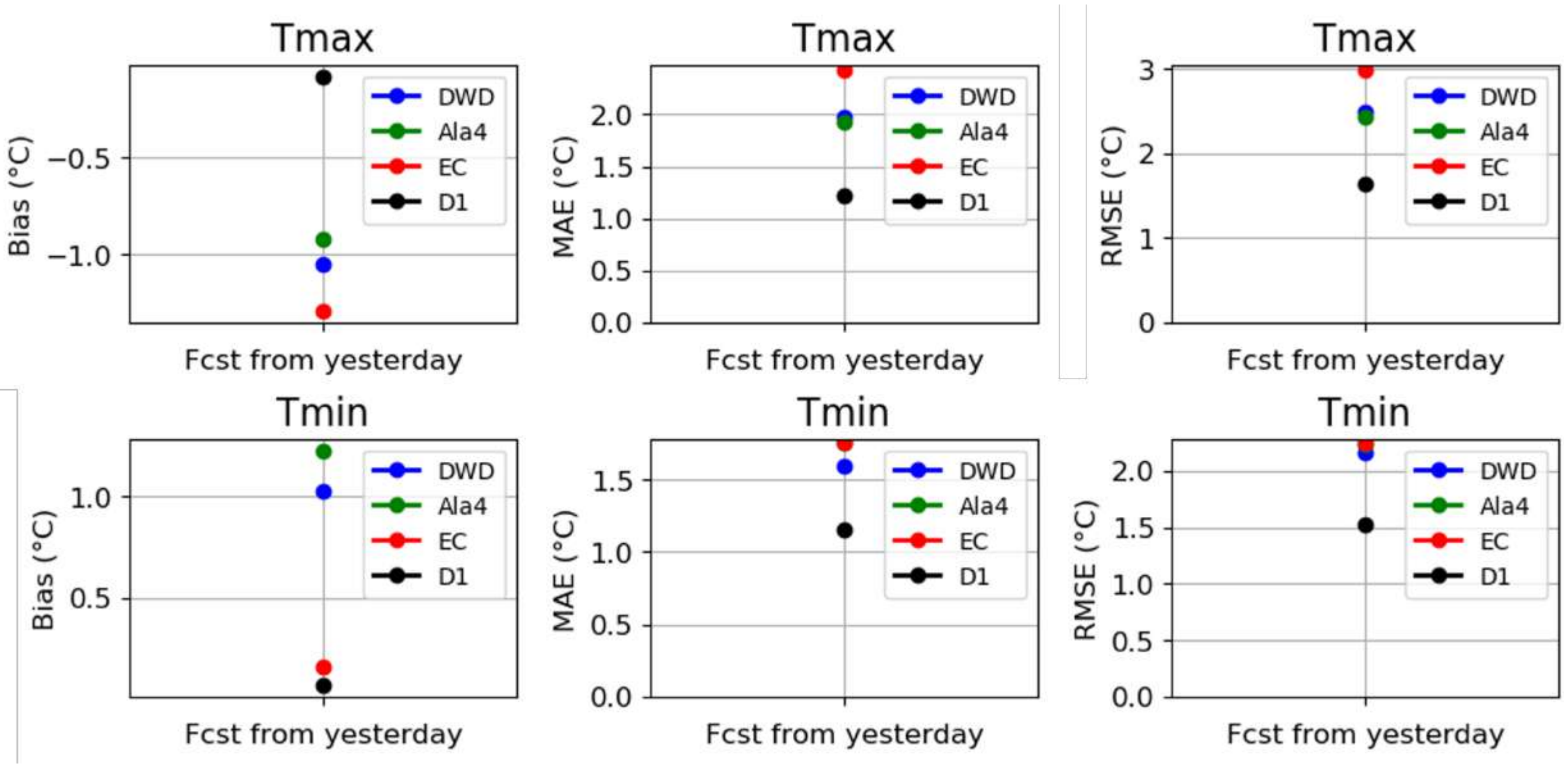
Below tables show maximum (left) and minimum (right) 2-m temperature yesterdays' ECMWF model forecasts for last 17 measurement days defined in columns („od dan prije“ means „from day before“ referring to a date in the column) and for locations in rows. Run is 00 UTC.

Values in tables serve as everyday ECMWF model guidance for making forecasts. Similar tables we have for all models. Tables are used also for quick evaluation of weather type related behavior and general performance of models' temperature forecasts in the last two weeks.

Explanation of colors: deviation of model forecast from measurement - gold is less than 0.5 °C (hit), white 0.5 to 1.4 °C, light 1.5 to 2.4 °C, darker 2.5 to 5 °C, darkest is more than 5 °C. From Poreč below are meteo stations at the coast and near it, while Puntijarka and Zavižan are mountainous stations.

Tmax ECMWF 00 / od dan prije	25.04.	24.04.	23.04.	22.04.	21.04.	20.04.	19.04.	18.04.	17.04.	16.04.	15.04.	14.04.	13.04.	12.04.	11.04.	10.04.	09.04.
VARAŽDIN	10.5	9.0	11.6	11.0	11.0	11.9	13.1	12.7	13.7	13.7	25.7	27.8	24.1	21.4	19.7	16.1	24.6
KRAPINA	10.3	9.6	8.4	10.6	11.9	12.1	12.9	13.2	14.0	14.8	25.7	28.1	23.8	21.8	20.4	17.3	24.8
KOPRIVNICA	11.8	9.8	16.3	11.9	11.5	11.7	13.4	13.5	13.7	14.4	25.8	27.5	23.8	21.7	20.2	16.8	25.2
KRIŽEVCI	11.8	10.0	15.9	12.0	11.3	11.2	13.3	13.4	13.7	15.2	25.6	27.7	24.1	21.9	20.2	16.4	25.0
PUNTIJARKA	10.7	9.6	9.7	11.0	11.7	10.8	12.3	12.7	13.7	16.6	24.8	27.7	23.6	21.6	20.1	16.7	24.7
ZAGREB/MAKSIMIR	12.1	10.6	11.6	11.8	12.5	11.1	13.0	13.3	14.2	17.1	25.0	27.9	23.8	22.1	20.2	17.2	24.9
ZAGREB-AD	13.0	11.3	13.0	12.6	13.0	11.6	13.9	13.9	14.5	18.5	25.5	28.6	24.1	22.5	20.5	17.8	25.6
BJELOVAR	13.1	10.2	16.9	12.4	12.0	10.9	13.5	13.8	13.7	16.7	26.6	28.1	24.0	22.1	20.5	16.9	26.0
BILOGORA	13.5	10.0	17.2	12.3	11.6	11.0	13.2	13.3	13.4	16.0	27.0	27.9	23.8	21.9	20.4	16.8	26.2
SISAK	15.0	11.5	17.3	13.5	12.4	10.9	14.3	14.5	14.3	20.9	27.8	29.4	24.6	22.9	20.9	18.1	27.3
DARUVAR	13.9	9.9	17.3	14.0	11.7	10.6	13.7	13.2	12.9	19.9	27.7	27.8	24.1	22.7	20.6	17.6	26.7
VIROVITICA	14.0	10.3	17.9	12.7	11.9	11.3	13.7	13.5	13.8	17.2	27.8	28.5	24.1	22.5	21.2	17.6	27.1
POŽEGA	14.1	12.3	18.5	14.0	11.1	14.0	13.6	13.3	10.6	20.5	27.6	27.5	24.0	23.1	20.8	18.8	27.1
SLAVONSKI BROD	14.9	13.9	19.1	14.0	11.4	15.5	14.0	13.8	10.1	22.7	28.6	28.0	24.4	23.5	21.5	19.9	27.7
BELI MANASTIR	14.0	12.4	19.7	13.6	12.2	15.8	14.2	14.0	13.9	19.4	28.7	28.1	24.7	23.5	22.5	20.7	27.4
OSIJEK ČEPIN	14.6	13.2	20.1	14.7	12.0	16.3	14.6	14.1	12.9	21.8	29.0	28.3	24.9	23.8	22.6	21.6	27.6
VINKOVCI	15.0	15.0	20.1	15.0	12.1	16.3	14.2	13.9	10.5	23.1	29.3	28.6	24.8	23.7	22.9	22.2	28.1
GRADIŠTE	15.5	15.3	20.5	14.9	11.9	16.7	14.5	14.1	10.9	24.2	29.5	28.8	24.8	24.1	22.9	22.4	28.3
VUKOVAR	14.7	14.8	20.1	14.9	12.6	16.4	14.1	14.0	10.6	23.6	29.6	28.5	25.1	24.1	23.0	23.1	27.8
KARLOVAC	13.5	11.5	9.4	12.3	13.3	10.8	14.2	14.1	14.1	21.0	25.2	30.1	24.5	22.1	20.2	18.6	26.0
OGULIN	8.9	8.3	5.0	8.9	10.3	7.8	12.1	11.2	12.4	21.2	21.4	27.1	22.3	19.6	16.7	15.4	22.3
Plitvička jezera	9.6	6.2	5.7	7.4	7.3	7.2	9.6	8.8	8.9	20.4	21.3	25.2	19.7	17.6	14.0	14.0	21.8
PARG	3.1	4.3	1.4	4.9	7.0	5.2	9.5	6.0	8.9	13.4	17.8	22.4	20.9	17.0	15.6	11.7	17.6
Delnice	4.6	5.7	1.7	5.7	7.6	5.2	9.7	7.4	9.5	15.4	17.1	22.0	20.8	16.7	14.2	12.2	17.3
GOSPIĆ	9.3	9.7	6.6	10.8	8.6	6.9	11.4	10.3	10.6	19.9	20.1	24.1	22.1	19.5	15.7	16.8	20.5
ZAVIŽAN	7.9	7.9	5.2	9.1	8.4	7.6	9.9	8.3	10.0	18.4	19.5	22.0	21.5	19.1	16.5	15.0	18.5
Poreč	13.1	11.2	13.4	12.8	14.8	14.7	14.2	12.8	14.4	18.7	20.9	21.8	21.6	19.6	19.1	19.6	19.9
Pula	13.4	12.3	12.9	13.9	14.3	13.8	15.1	14.6	16.0	19.6	20.2	21.8	21.5	22.0	19.8	19.1	17.9
PAZIN	11.1	11.4	11.0	11.4	13.2	12.1	14.5	12.6	14.8	19.2	22.6	25.4	26.1	23.4	22.1	19.2	20.5
RIJEKA KOZALA	9.6	9.7	9.6	11.2	12.7	11.3	13.5	12.5	13.5	16.9	18.7	21.4	23.7	22.2	20.0	17.5	18.5
SENJ	10.3	10.2	7.3	11.2	11.7	10.1	13.8	12.7	13.5	19.8	19.8	21.6	24.0	21.0	17.8	16.7	17.6
RAB	12.5	11.7	12.9	15.2	13.4	12.8	14.3	14.7	15.5	19.7	19.9	19.9	20.5	19.5	18.8	18.4	17.3
MALI LOŠINJ	13.0	11.8	12.6	15.1	13.2	13.5	14.8	14.9	15.3	17.5	17.4	18.1	18.3	17.4	16.8	17.0	16.2
KNIN	12.5	10.4	16.9	14.4	10.7	11.6	14.2	13.4	11.4	21.7	23.4	24.5	24.2	23.5	20.7	22.1	22.6
Imotski	12.1	10.0	15.9	13.7	11.7	11.6	13.2	12.0	11.1	18.8	21.7	24.1	23.9	23.4	22.9	19.6	20.2
ZADAR PUNTAMIKA	13.0	12.0	14.6	15.9	14.1	14.1	15.1	15.1	16.3	20.9	19.9	20.2	19.9	19.4	18.8	19.6	18.7
ŠIBENIK	14.1	13.0	17.4	16.4	14.8	14.2	17.2	15.3	15.6	23.0	23.0	22.3	25.4	25.1	23.4	21.0	21.9
SPLIT MARJAN	13.9	11.8	16.9	15.9	14.7	13.8	17.3	15.1	14.8	21.2	22.4	21.5	23.9	23.5	22.5	20.5	20.0
HVAR	14.1	13.2	16.3	16.0	15.2	14.5	16.9	14.8	16.4	20.1	20.6	18.9	19.4	19.2	19.6	18.4	19.3
KOMIŽA	13.8	13.1	15.6	15.7	14.4	14.2	15.5	14.3	15.9	19.2	18.0	17.8	18.4	17.8	17.8	16.3	16.8
LASTOVO	14.4	15.2	16.0	15.6	15.1	15.4	16.7	15.0	16.8	19.3	18.5	19.3	19.0	18.7	18.9	16.3	17.1
MAKARSKA	12.9	11.0	16.0	14.1	13.3	12.3	14.8	13.0	14.4	19.8	21.4	23.0	23.2	22.8	22.4	19.1	19.9
PLOČE	14.9	13.3	17.4	16.4	15.7	14.9	17.4	16.2	15.1	21.3	22.7	24.7	25.3	25.2	24.6	20.4	21.3
DUBROVNIK	13.6	13.5	15.7	14.8	14.2	15.0	17.3	14.4	15.7	20.0	21.1	21.9	22.3	22.0	21.2	18.3	18.6

Tmin EC 00 / od dan prije	26.04.	25.04.	24.04.	23.04.	22.04.	21.04.	20.04.	19.04.	18.04.	17.04.	16.04.	15.04.	14.04.	13.04.	12.04.	11.04.	10.04.
VARAŽDIN	1.6	3.0	4.3	5.7	0.8	3.7	5.3	1.8	3.6	2.5	11.8	16.7	13.4	10.1	9.2	10.0	12.0
KRAPINA	1.2	3.1	4.6	4.9	0.5	3.2	4.2	2.4	2.3	2.6	12.6	14.6	10.7	9.8	9.4	9.8	12.2
KOPRIVNICA	3.1	2.5	5.1	6.4	1.5	4.0	4.9	2.7	4.2	3.6	12.1	15.1	13.5	10.4	10.2	10.5	12.1
KRIŽEVCI	2.4	2.9	5.0	5.9	1.6	4.2	3.8	3.1	3.8	2.8	12.5	13.3	11.9	9.7	11.0	10.8	12.4
PUNTIJARKA	2.9	2.7	4.8	4.9	0.7	3.2	4.9	3.0	2.5	2.0	14.2	13.4	12.8	12.4	10.0	9.6	12.7
ZAGREB/MAKSIMIR	2.8	3.5	5.7	5.7	0.9	4.1	4.7	2.8	2.8	2.7	13.8	12.4	12.8	11.6	10.8	10.4	12.3
ZAGREB-AD	2.0	3.1	6.4	6.2	1.0	4.4	4.1	2.7	2.9	3.1	12.7	13.0	11.3	10.0	10.1	10.0	11.6
BJELOVAR	3.1	1.8	5.6	6.7	1.6	4.3	4.0	3.1	3.8	3.9	12.8	14.5	10.8	9.6	11.2	10.7	12.6
BILOGORA	3.6	2.3	6.0	6.2	1.7	4.4	5.0	3.0	3.9	4.6	12.0	14.9	13.2	9.2	10.7	10.4	12.6
SISAK	2.1	3.3	6.8	6.7	1.8	5.5	3.4	2.5	2.1	3.6	12.4	15.8	10.8	9.5	10.4	10.5	11.7
DARUVAR	4.4	1.4	6.0	5.7	1.5	4.8	4.3	2.8	2.7	4.4	14.4	14.4	13.4	11.2	11.0	9.7	13.1
SLAVONSKI BROD	3.8	4.1	7.8	5.5	1.0	5.5	3.8	3.8	3.1	4.7	12.9	10.1	10.6	9.2	10.0	10.4	12.8
OSIJEK ČEPIN	3.4	2.3	8.7	6.2	2.8	5.4	3.4	4.0	4.5	5.2	13.5	12.9	11.9	10.4	11.7	10.7	14.2
VINKOVCI	3.6	3.5	8.0	6.1	3.0	5.5	3.4	4.3	4.7	5.2	13.4	13.7	11.4	10.3	12.2	10.7	13.5
GRADIŠTE	3.6	4.4	8.0	5.6	3.0	5.7	3.0	4.6	4.6	5.1	13.6	13.3	10.9	10.2	12.0	11.2	13.1
KARLOVAC	2.0	2.3	6.5	5.5	2.1	4.6	3.3	3.8	2.1	2.8	13.3	12.1	9.7	9.2	10.3	10.8	10.6
OGULIN	-0.2	-0.4	4.2	2.5	0.2	2.3	1.8	1.6	1.8	1.8	12.6	12.0	8.5	11.0	11.6	9.0	7.7
Plitvička jezera	1.7	-0.4	3.0	1.3	-0.7	0.8	1.7	0.7	1.7	1.3	13.4	14.9	10.8	10.6	9.9	7.2	11.8
PARG	-3.3	-2.6	0.4	-0.5	-1.9	-0.5	-0.4	-0.6	0.6	-0.1	9.2	8.8	9.3	9.4	7.4	5.7	6.9
Delnice	-1.0	-1.4	0.6	-0.2	-2.0	-1.0	1.7	-0.5	0.7	-0.8	10.7	12.7	11.7	7.5	7.9	6.1	8.2
GOSPIĆ	0.4	-1.0	3.0	1.2	-1.7	1.7	0.7	0.7	0.8	0.8	9.4	9.3	8.6	6.7	9.0	7.6	8.5
ZAVIŽAN	0.5	-0.3	2.4	0.8	-0.1	1.2	1.7	1.5	-0.1	0.4	13.3	12.8	13.4	10.1	10.3	7.8	10.3
Poreč	8.2	7.9	7.8	7.8	8.5	8.2	10.5	7.9	8.7	6.9	16.1	16.4	15.0	12.9	12.8	12.4	14.4
Pula	9.4	8.5	8.8	9.1	9.6	8.6	10.5	10.3	10.6	9.7	17.1	15.5	15.2	13.5	16.7	15.1	13.9
PAZIN	3.7	5.3	4.8	5.4	5.1	2.5	5.2	2.7	5.0	3.0	12.7	13.4	13.0	11.4	11.3	10.9	11.6
RIJEKA KOZALA	4.3	4.9	5.2	5.2	4.1	3.9	6.6	5.2	5.1	4.5	12.8	13.4	14.0	12.0	12.7	12.2	11.5
SENJ	3.5	3.3	6.2	4.1	3.5	5.2	6.2	5.7	4.2	4.2	17.3	13.2	12.8	12.3	14.2	11.1	9.8
RAB	11.0	9.1	9.2	9.3	9.4	9.4	11.7	10.5	10.4	10.1	18.3	17.2	17.6	16.3	16.0	15.5	15.0
MALI LOŠINJ	12.7	9.8	9.9	10.9	11.8	11.0	13.2	12.3	12.3	12.2	16.4	16.7	16.2	15.4	15.1	15.1	14.7
KNIN	2.5	0.4	5.5	4.1	1.8	4.6	3.1	5.6	2.2	5.1	12.8	11.9	8.2	11.0	10.7	11.3	11.3
Imotski	3.2	0.4	5.7	5.0	-0.1	4.8	0.3	4.1	1.8	6.8	11.4	11.6	8.9	9.3	8.9	11.0	10.3
ZADAR PUNTAMIKA	7.6	7.6	8.8	8.3	7.7	9.1	9.7	9.4	7.4	10.0	16.0	14.9	13.2	12.4	13.2	14.5	14.3
ŠIBENIK	7.4	6.6	9.0	12.2	7.2	8.4	9.0	9.5	6.9	9.2	17.5	13.4	12.7	13.8	13.8	14.7	17.0
SPLIT MARJAN	8.4	7.4	9.6	11.9	8.3	9.4	8.4	10.7	6.6	10.2	16.5	13.9	13.8	14.0	14.1	14.7	15.6
HVAR	11.7	10.4	10.7	14.0	11.2	11.5	12.6	11.4	10.6	12.5	17.2	16.2	15.9	15.1	15.0	15.1	16.6
KOMIŽA	13.7	12.0	12.1	15.3	14.0	12.5	13.9	12.4	12.9	12.8	17.3	17.1	16.4	16.2	15.9	16.0	16.1
LASTOVO	13.3	11.1	13.0	15.3	12.9	12.0	14.1	12.4	12.4	14.8	17.8	17.4	16.6	16.4	15.9	15.5	16.2
MAKARSKA	5.9	4.5	7.2	8.2	4.7	7.0	6.9	7.0	5.2	9.5	14.7	13.3	15.1	13.4	12.8	12.7	13.5
PLOČE	6.7	6.0	10.1	6.8	5.2	8.5	5.4	8.4	5.9	10.1	15.3	11.6	12.0	12.8	12.3	13.7	11.5
DUBROVNIK	8.8	8.7	10.9	9.7	7.4	8.4	7.2	9.4	8.6	14.7	17.9	14.1	14.1	14.6	13.5	13.1	13.3


Tmax
Bias (°C)
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−1.0
DWD
Ala4
EC
D1
Fcst from yesterday
Tmax
MAE (°C)
0.0
0.5
1.0
1.5
2.0
DWD
Ala4
EC
D1
Fcst from yesterday
Tmax
RMSE (°C)
0
1
2
3
DWD
Ala4
EC
D1
Fcst from yesterday
Tmin
Bias (°C)
0.5
1.0
DWD
Ala4
EC
D1
Fcst from yesterday
Tmin
MAE (°C)
0.0
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1.0
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D1
Fcst from yesterday
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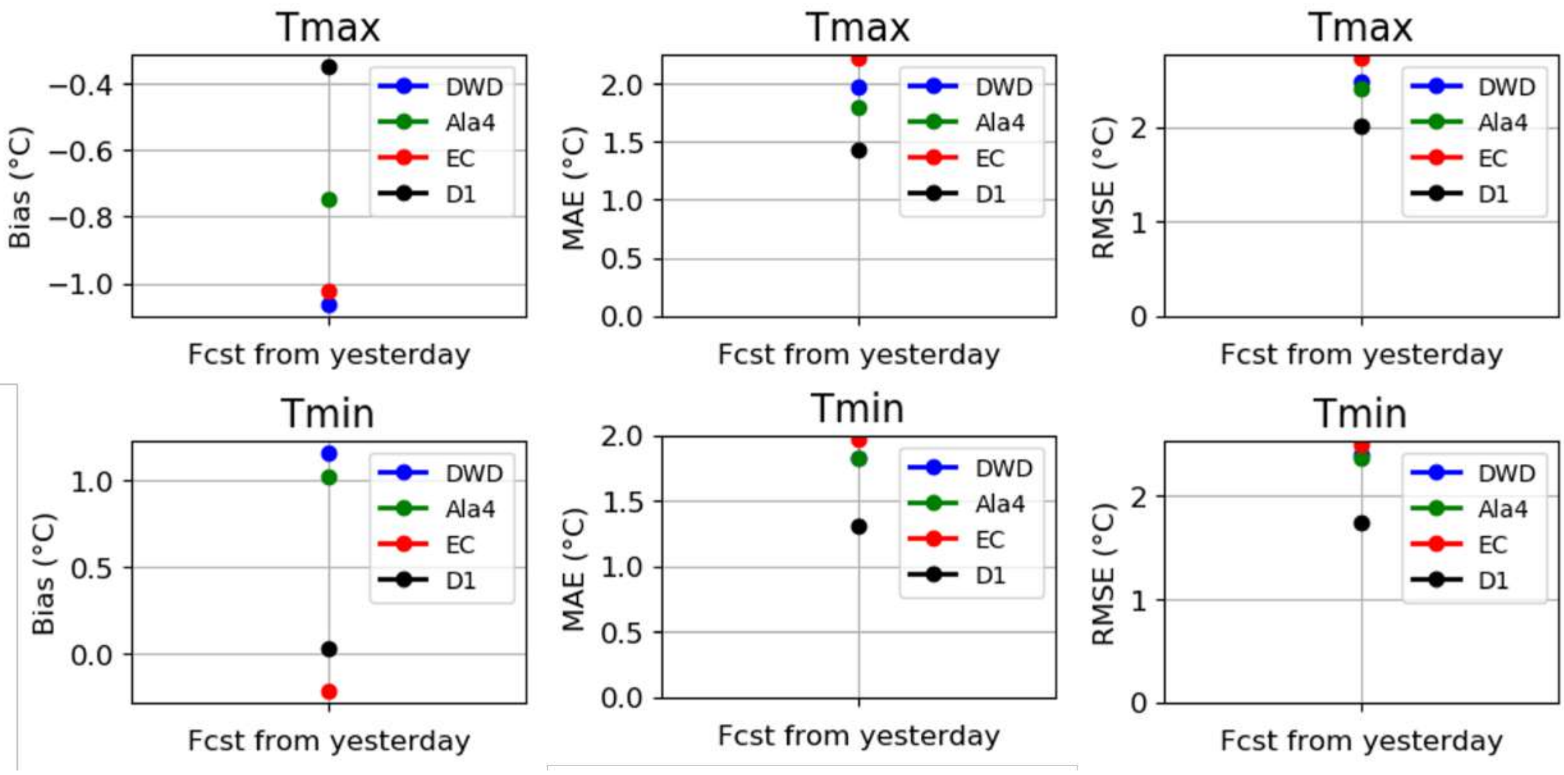
Fcst from yesterday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Bias (°C)
Fcst from yesterday
MAE (°C)
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Tmin
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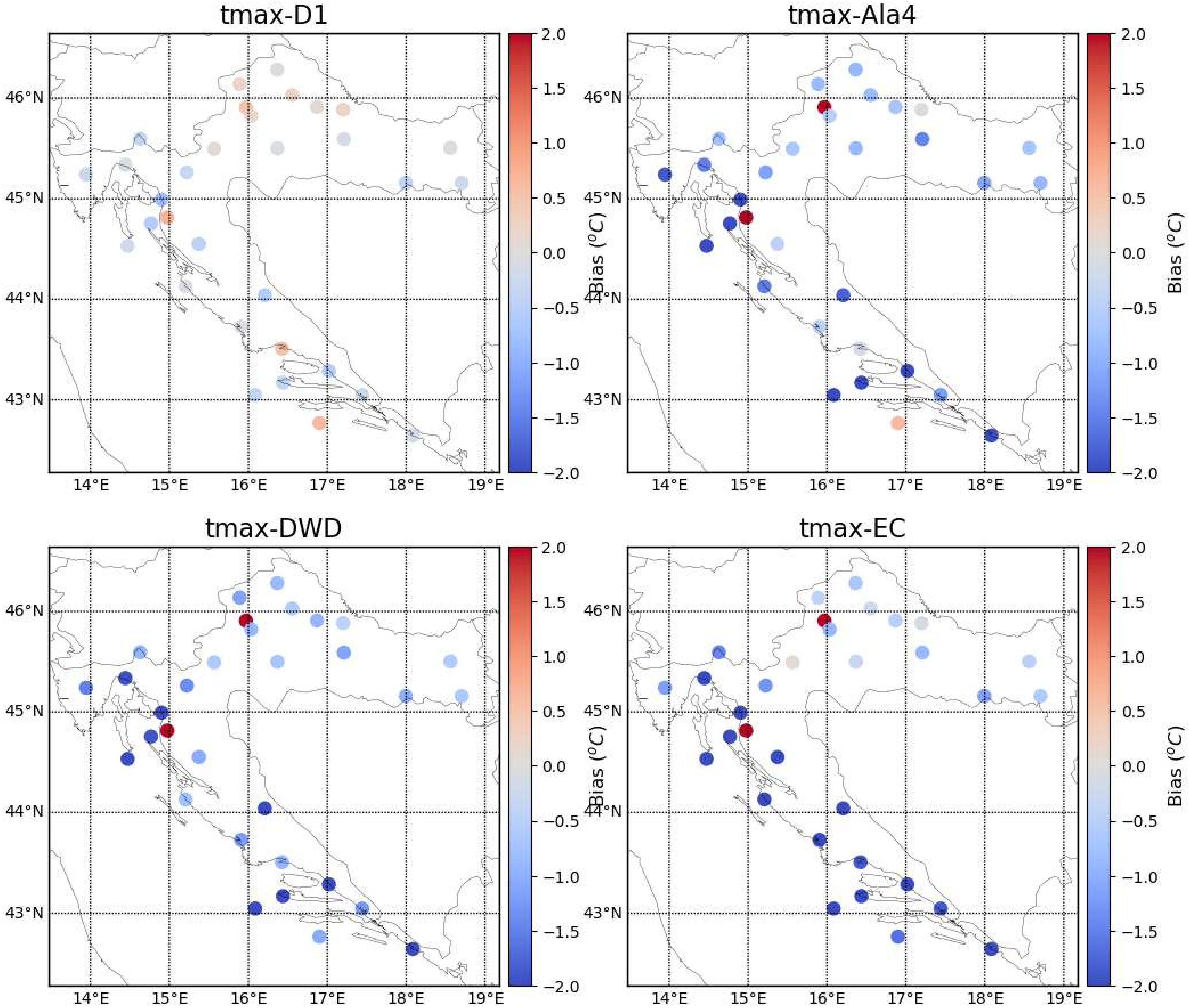
Ala4
EC
D1



tmax-D1
tmax-Ala4
tmax-DWD
tmax-EC
Bias (^oC)
46°N
45°N
44°N
43°N
14°E
15°E
16°E
17°E
18°E
19°E
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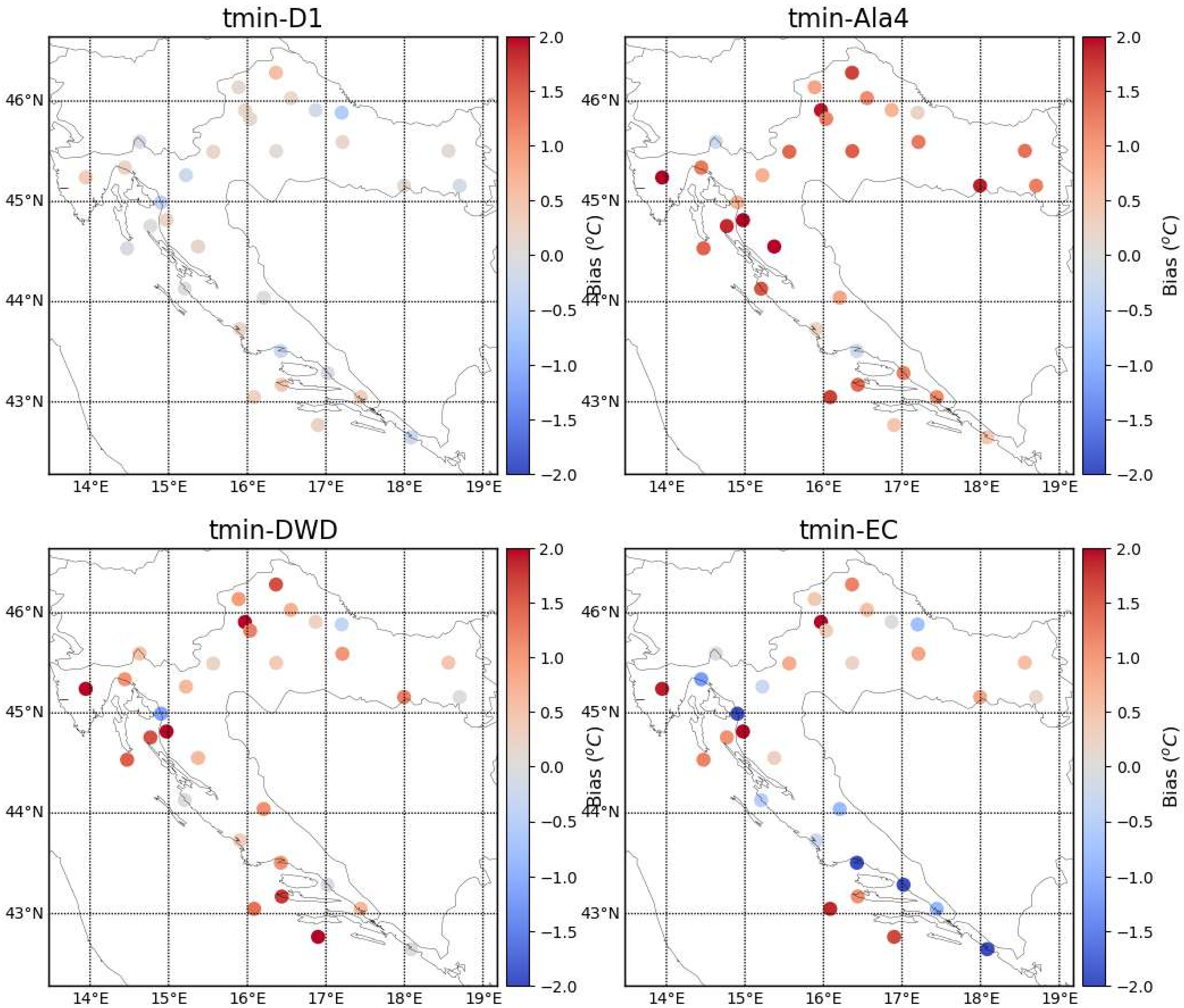
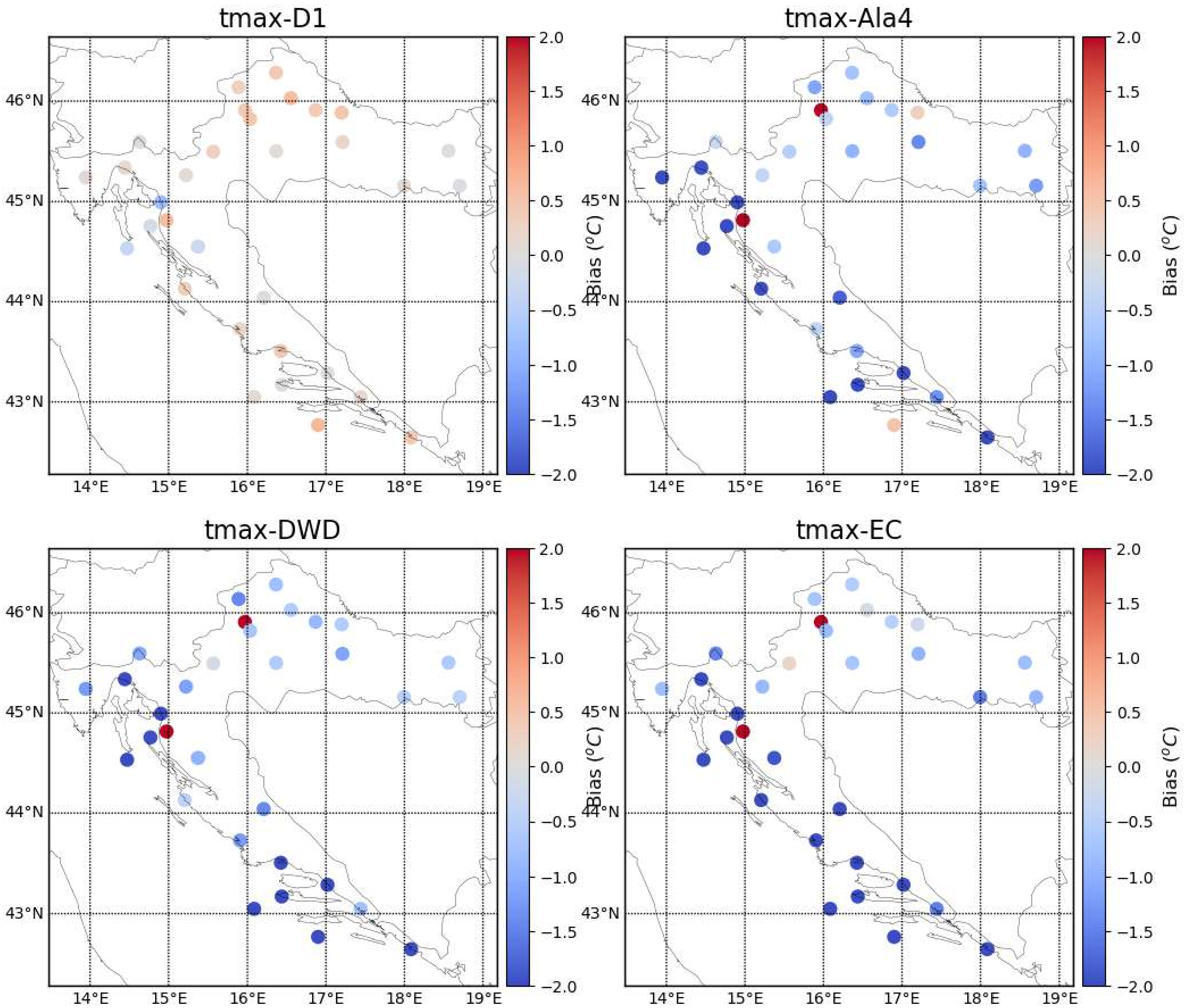
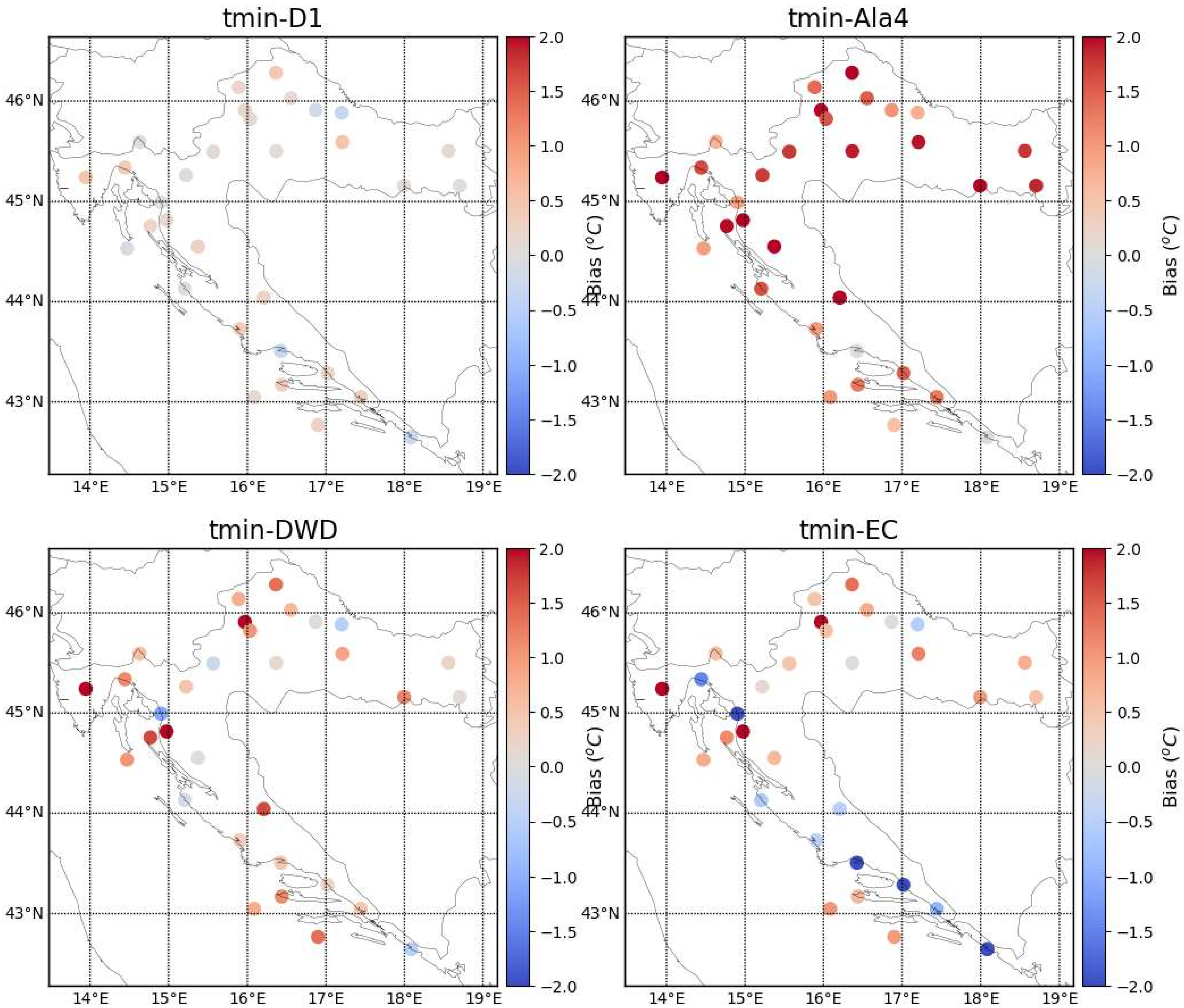
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0

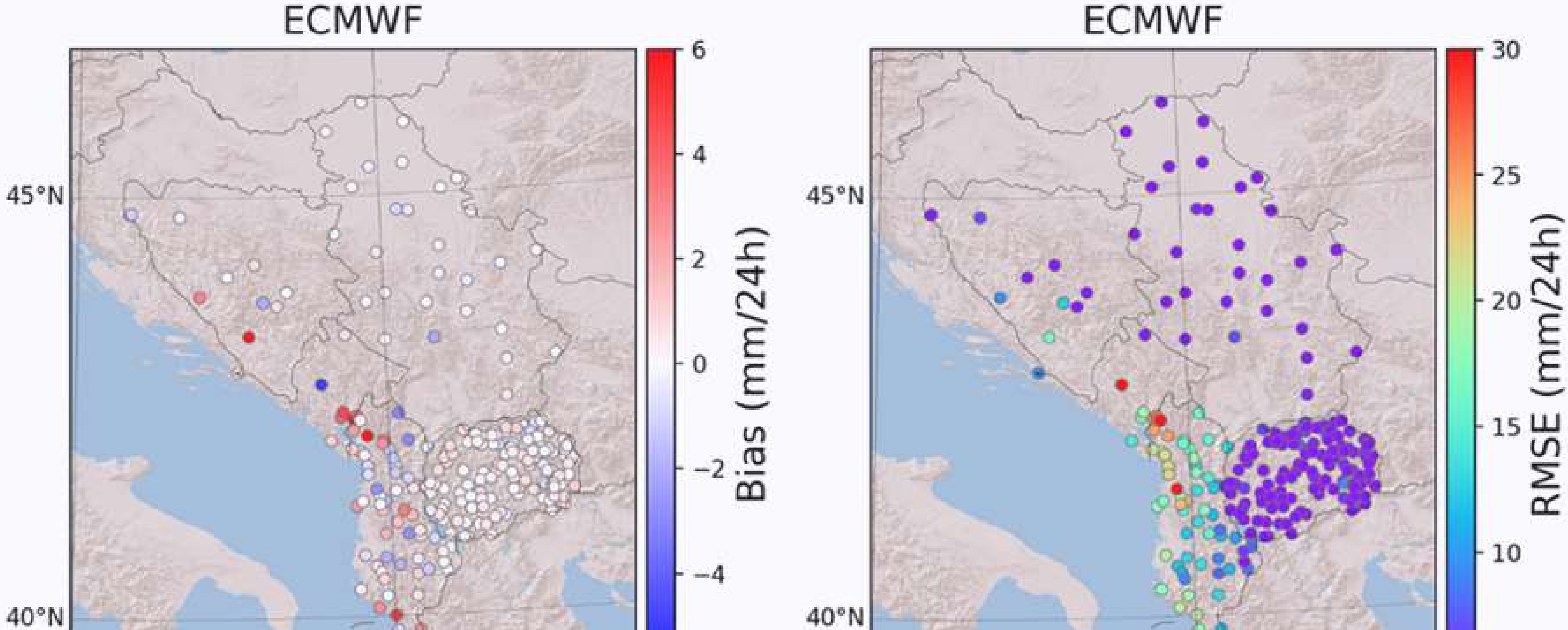


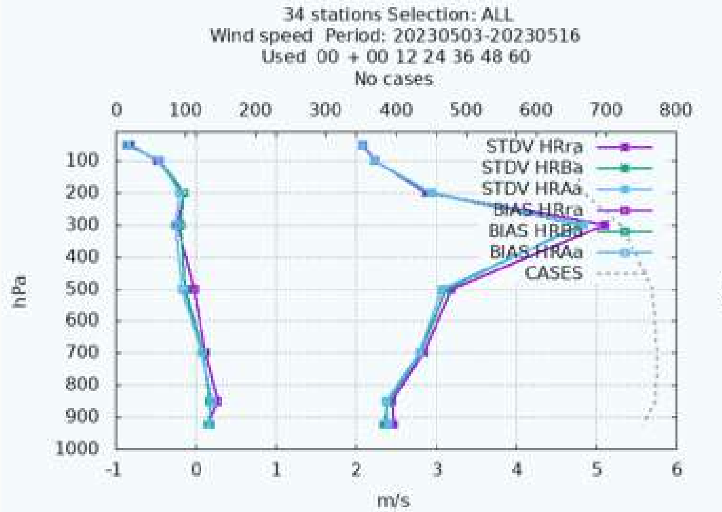
tmin-D1
tmin-Ala4
tmin-DWD
tmin-EC
46°N
45°N
44°N
43°N
14°E
15°E
16°E
17°E
18°E
19°E
2.0
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
Bias (^oC)

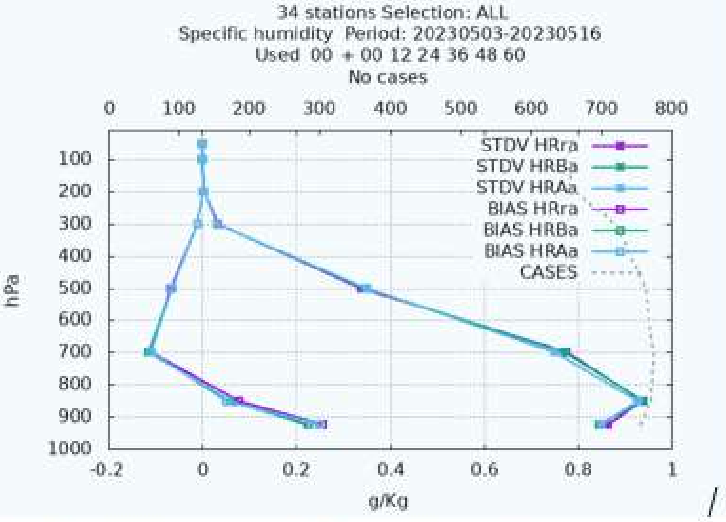

tmax-D1
tmax-Ala4
tmax-DWD
tmax-EC
Bias (^oC)
46°N
45°N
44°N
43°N
14°E
15°E
16°E
17°E
18°E
19°E
2.0
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0



tmin-D1
tmin-Ala4
tmin-DWD
tmin-EC
46°N
45°N
44°N
43°N
14°E
15°E
16°E
17°E
18°E
19°E
2.0
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
Bias (^oC)


ECMWF
45°N
40°N
15°E
20°E
6
4
2
0
−2
−4
−6
Bias (mm/24h)
ECMWF
45°N
40°N
15°E
20°E
30
25
20
15
10
5
RMSE (mm/24h)





Vertical profiles of standard deviation and bias calculated for forecast initialized from data assimilation cycle where new LBCs were used: wind speed (left) and specific humidity (right). Experiments are marked as: HR8ra (purple) - current operational settings, HRBa (green) – LBCs option B, HRAa (blue) LBC option A (same geometry as in current operations but produced from cy48r1 e-suite.

	HRES cloud forecast has improved	HRES precipitation forecast has improved	HRES temperature forecast has improved	HRES wind forecast has improved	"Jumpiness" (runs often change the "scenario")	Distinguishes well between high, medium and low cloud cover	Weak in temperatture inversion situations (underestimates inversion and low cloud cover)	Sunshine duration in last 24h overestimates sunshine	Towards the end of the forecast period sometimes produces extreme precipitation	Point rainfall probability (percentile) product is more reliable for intense precipitation than Total precipitation probability	The "precipitation type" product is reliable	The probability of precipitation type is a reliable product	Freezing rain product (accumulated and probability) overestimates "freezing" rain	The "visibility" product is unreliable in fog forecasting	There are problems with minimum temperatures in winter (especially with snow cover)
CONFIRM (%)	64	18	41	32	0	32	18	0	41	0	86	77	14	9	41
DISAGREE (%)	0	5	14	0	77	36	64	0	18	0	0	0	0	68	0
NOT SURE (%)	36	77	41	55	23	32	18	5	36	9	14	5	55	18	55
NOT USING (%)	0	0	5	14	0	0	0	95	5	91	0	18	32	5	5
RESULT DESCRIPTION	**majority confirm**	**majority not sure**	**mixed opinion**	**majority not sure, partly confirmed**	**majority disagree**	**mixed opinion**	**majority disagree**	**mostly not used**	**mixed opinion**	**mostly not used**	**mostly confirmed**	**majority confirm**	**majority not sure, partly nor used**	**majority disagree**	**majority not sure, partly confirmed**

	ENS vertical profiles are a useful product	CAPE unrealistic, especially over the sea	Convective inhibition (CIN) improved	The "lightning density and probability" products are reliable indicator of the likelihood of convection	Do you use the CAPE-SHEAR parameter for convection forecasting (especially type, organization)	EFI CAPE/CAPESHEAR are reliable for convection forecasting	EFI is a good indicator of extremes (generally for precipitation, wind and temp)	Significant wave height is reliable for forecasting waves in the open sea	A 15-day meteogram (with and without climatology) is reliable/useful	Monthly forecast is "jumpy" (too much influenced by the current anomaly)	"Early warning for cold spells over Europe" product proved to be reliable	"Stratospheric Sudden Warming" has been proven reliable	"Weather regimes extended range forecasts" proved to be reliable	Seasonal forecast sometimes has big errors of monthly anomalies (warm/cold, dry/rainy)
CONFIRM (%)	32	68	5	0	9	9	86	14	77	23	5	9	9	14
DISAGREE (%)	0	23	0	68	59	0	0	0	0	0	0	0	9	0
NOT SURE (%)	9	9	82	18	27	5	0	14	0	27	9	14	9	23
NOT USING (%)	59	0	14	14	5	86	14	68	23	50	86	77	73	64
RESULT DESCRIPTION	**majority not use, partly confirmed**	**majority confirm**	**majority not sure**	**majority confirms**	**majority disagree, partly not sure**	**mostly not used**	**mostly confirmed**	**majority not using**	**majority confirm**	**majority not use partly confirmed**	**mostly not used**	**majority not using**	**majority not using, mixed opinion**	**majority not using, partly confirmed**