ECMWF MS/CS “Green Book” Report 2024

Section 1: Background

1.1 Country

Latvia

1.2 Author(s)

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1.3 Organisation

Latvian Environment, Geology and Environment Centre

Section 2: Summary of major highlights

The ECMWF deterministic and ensemble model outputs and various derived products are detailed in this report and are used extensively in the operational work of LEGMC in fields of meteorology, hydrology, and climatological analysis. ECMWF model output data are integrated in the forecaster workstation SmartMet (FMI), where generation of forecasting products for clients takes place. The direct use of ECMWF model output data and all products derived from this data are detailed and monthly deterministic verification results of ECMWF, AROME-MetCoOp Ensemble mean, and LEGMC forecaster model output are presented. Two cases studies are noted with additional figures of model output and relevant real-life examples for when the ECMWF model exhibited performance that can be considered unique, specifying the positives and negatives of the behaviour.

Section 3: Forecast Products

3.1. Direct use of ECMWF forecast products

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

Medium range forecast data can be considered as the most important ECMWF data category for LEGMC daily operations. It is used to generate the official LEGMC forecast data (mainly after the second day) and some additional products. Mainly the data is used on our workstations where data can be not only viewed, but also semi-automatic and manually post-processed. ECMWF HRES (both surface and upper level), ECMWF hourly, Ensemble (mean parameters and probabilities) as well as ECMWF Wave model are used daily.

At the moment there is one parameter (LITOTA) that is being used to generate a lightning probability product that is being used daily by forecasters. Upper-level data two times a day is used for the preparation of upper-level frontal analysis chart. Some HRES parameters are being calibrated. Surface and upper-level data is occasionally on forecasters workstation are used for potential pollution trajectory calculations in case of events with radioactive substances.

Alternatively, in case of technical problems we also use medium range products in the ecCharts environment for the preparation of basic text forecasts and manual products including meteorological forecasts for aviation or use the platform in cases when the workstation is not available for someone.

ECMWF HRES (both surface and upper level) data are provided for modelling of the diffusion of radioactive contamination in case of any incident.

ECMWF HRES and EPS data (air temperature, precipitation amount, mean sea level pressure, total cloud cover, wind speed and relative humidity) are used like input data for hydrological model.

b) Extended Range (monthly)

Weekly air temperature, precipitation amount and their anomaly forecasts are being prepared weekly for a major client in the energy sector.

Consultations on expected range weather conditions are prepared based on available products on ECMWF website and in ecCharts environment. Main users are agricultural and energy sectors, civil protection authorities.

Extended range EPS data (air temperature, precipitation amount, mean sea level pressure, total cloud cover, wind speed and relative humidity) are used like input data for hydrological model.

c) Long Range (seasonal)

Long range data (air temperature, precipitation amount, mean sea level pressure, total cloud cover, wind speed and relative humidity) are used like input data for hydrological model.

Consultations on long range weather conditions are prepared based on available products on ECMWF website. Main users are agricultural and energy sectors.

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

CAMS data are used from services available at https://atmosphere.copernicus.eu/ (ultraviolet radiation index, air quality forecasts).
Forest fire index is calculated using meteorological observation data from our stations and forecasts data from ECMWF (HRES). Like additional source of information products from https://forest-fire.emergency.copernicus.eu/ are used.

3.2. Cycle 48r1

a) <u>Positive</u> impacts of model cycle 48r1

More realistic looking ensemble model fields (depicting slightly smaller scale features) on our workstation. Verification of the actual results, however, is not done.

b) <u>Negative</u> impacts of model cycle 48r1
None to note.

None to note.

c) Systematic changes in forecast output since model cycle 48r1 was implemented

None to note.

3.3: Derived Fields

As noted in Section 3.1. ensemble mean parameters and probabilities are generated for daily forecaster use, but there are several parameters further developed that are based on ECMWF model output and meant to facilitate the daily forecaster work and are also used to produce data-driven recommendations in terms of warning level and spatial extent for various weather alarms.

As distinct derived products that use ECMWF model output, LEGMC can note three:

a) Thunderstorm probability

LEGMC uses the ECMWF model output to produce a post-processed '*thunderstorm probability'* parameter. This parameter is post-processed based on lightning flash density – averaged total lightning flash density ('*litota1*' parameter from the catalogue). The particular post-processing methodology selected for implementation (Bouttier and Marchal, 2020) divides this post-processing process into three parts:

1. Generation of thunderstorm pseudo-observations
2. Post-processing of lightning strikes
3. Calibration of probability values

The pseudo-observations are generated from the NORDLIS lightning location network around the Baltic States domain and the post-processed domain encompasses fully the domain that is relevant for LEGMC forecasters. The calibration of the resultant probability values as specified by the particular methodology was based on two years of thunderstorm pseudo-observation data.

b) Calibrated forecasts

LEGMC calibrates ECMWF HRES output with the adaptive Kalman filter approach (Raman, 1970), calibrating four parameters: 2-meter temperature, 10-meter wind speed, relative humidity and pressure. A full year of observation data is used to estimate the filter parameters, and the calibrated forecast is done for the next 72-hour period. Current work is being done to test and implement various approaches to also calibrate ENS precipitation output.

c) Solar energy generation forecasts

LEGMC uses two ECMWF radiation parameters to derive a solar energy generation forecast for particular locations. We use "Total sky direct short-wave (solar) radiation at surface" (shortname fdir) un "Surface short-wave (solar) radiation downwards" (shortname ssrd) to create physics-based forecasts using meteorological data. 2-meter air temperature and relative humidity data are added for a more precise model building.

3.4: Artificial Intelligence (AI) / Machine Learning (ML) techniques

LEGMC has preliminary plans to potentially implement some ML techniques to work with the radiation parameters mentioned in Section 3.3 to further develop solar energy generation frameworks. LEGMC also plans to incorporate ML techniques to potentially blend ECMWF model output with radar data from OPERA composites or satellite data to improve the existing STEPS approach in precipitation nowcasting implemented at LEGMC.

3.5: Dynamical Adaptation

LEGMC does not run its own LAMs.

3.6: Data-driven (AI) models

a) ECMWF’s real-time AI model initiative

LEGMC is aware of these initiatives and support further development, but do not have more detailed feedback to provide at this time.

b) Use of AI forecasts for operational purposes

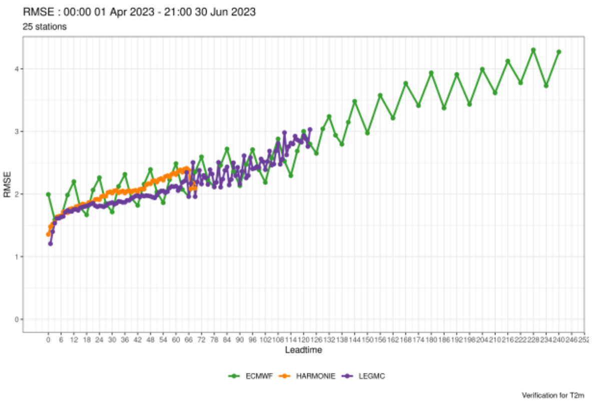
None.

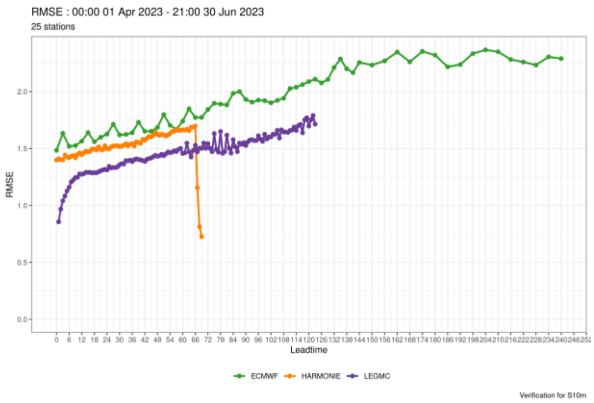
Section 4: Verification

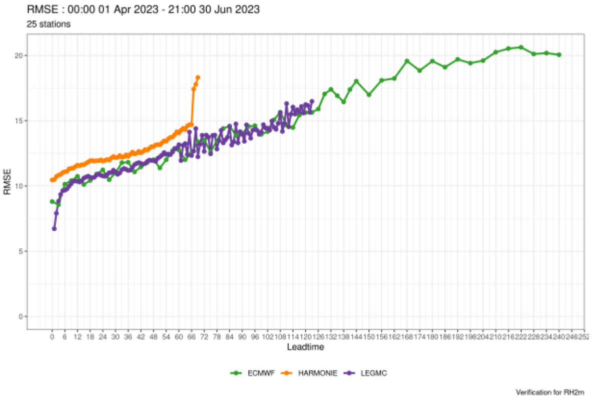
4.1 Raw model output from ECMWF, and other operational models/ensembles

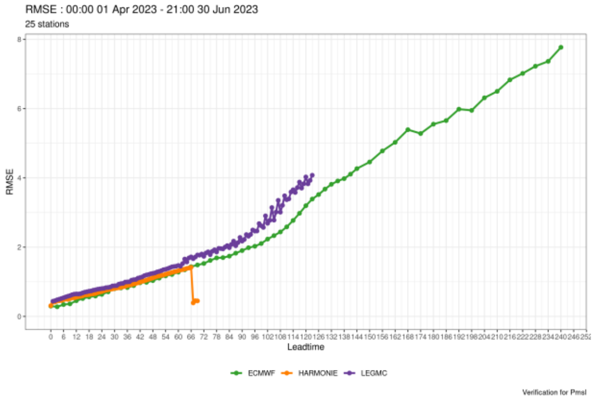
At LEGMC, verification procedures have been updated with emphasis on incorporating HARP functionality to ensure availability of all relevant verification methodologies and easy interpretation of local verification results for outside communication. As of right now, spatial verification and probabilistic verification are still in development, but verification of ECMWF HRES (ECMWF) model runs at 00 and 12 UTC, AROME-MetCoOp Ensemble mean (HARMONIE) and LEGMC forecaster (LEGMC) output is performed daily and monthly (every month for the last three months). Results over the three-period before and after the introduction of model cycle 48r1 are shown below with additional results for the winter season. Only the short-range and medium-range outputs are verified quantitatively with HARP.

a) Short Range and Medium Range

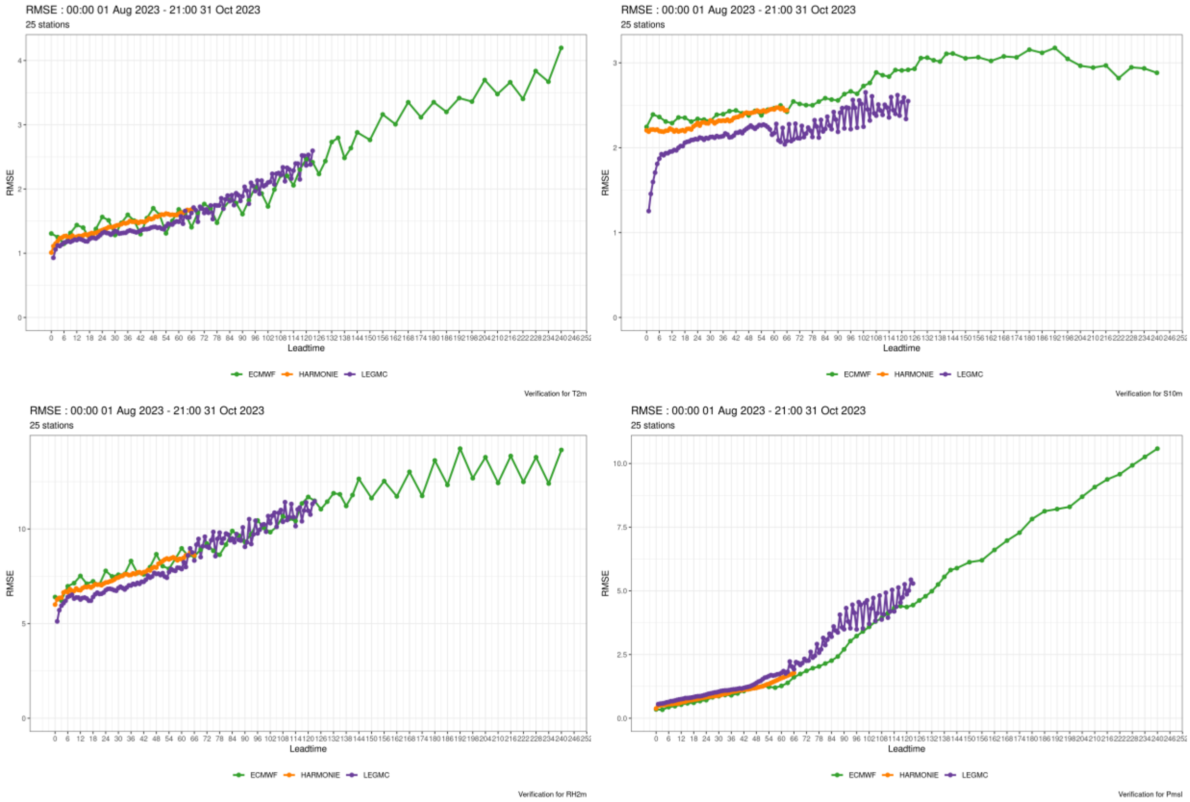








Verification results for the three-month period April-June 2023



Verification results for the three-month period August-October 2023

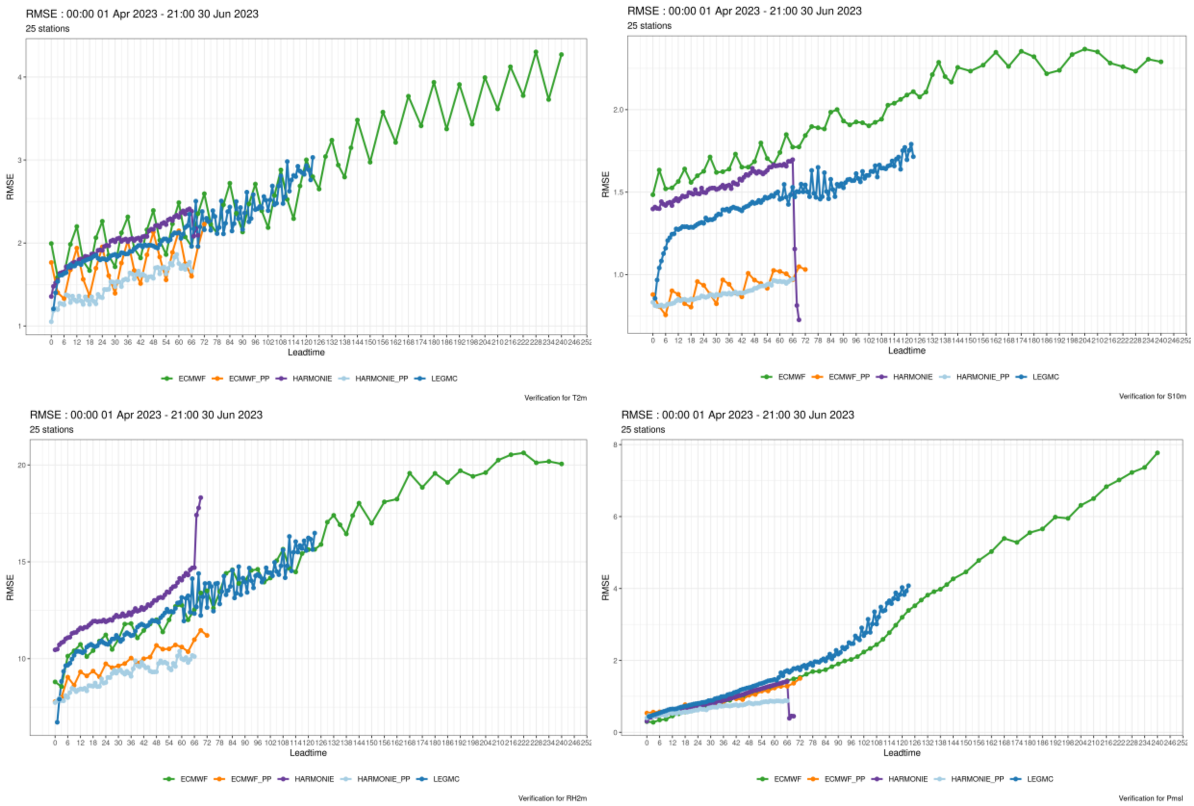
When comparing these two three-month periods with relation to the change to model cycle 48r1, with relation to HARMONIE model, the variability in T2m and S10m was decreased and the RMSE results are comparable. Also notable is the relative increase in RMSE for RH2m as both HARMONIE and LEGMC show improvement for almost all lead times.

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

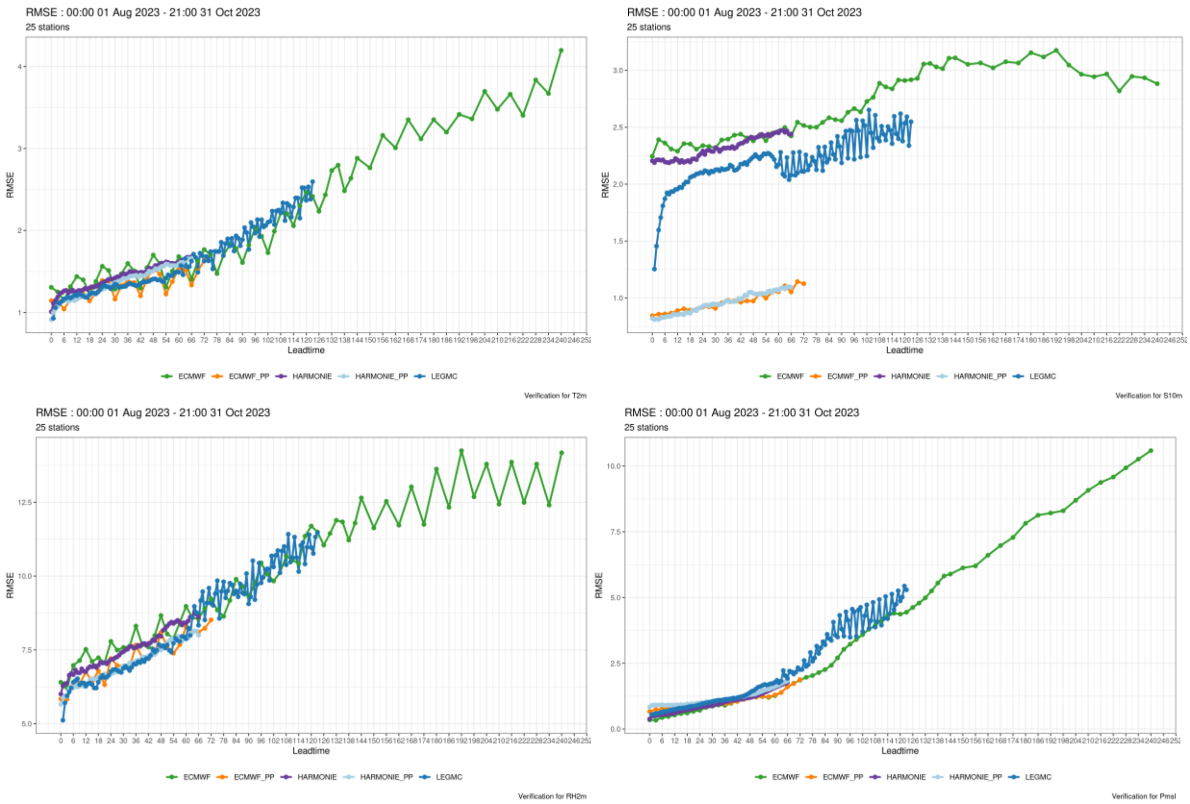
No quantitative verification is done.

4.2 Post-processed products and/or tailored products delivered to users

As detailed in Section 3.3 on derived products, LEGMC uses adaptive Kalmar filter to calibrate deterministic ECMWF and HARMONIE model output for the four meteorological parameters already shown and briefly discussed in Section 4.1. The calibration is done after every respective ECMWF or HARMONIE deterministic run and is available as an additional model output for the forecasters to evaluate and base their forecasts one. LEGMC plans to extend the parameters that are being calibrated, including also probabilistic calibration of precipitation. In this section, the previously shown verification results are expanded to include the calibrated ECMWF output (ECMWF_PP) and HARMONIE output (HARMONIE_PP), keeping the same two three-month periods and four meteorological parameters. To be able to see more minor differences, these plots do not have the vertical axes starting at 0, different from the previous plots. Again, RMSE is used as the verification metric to compare the results.



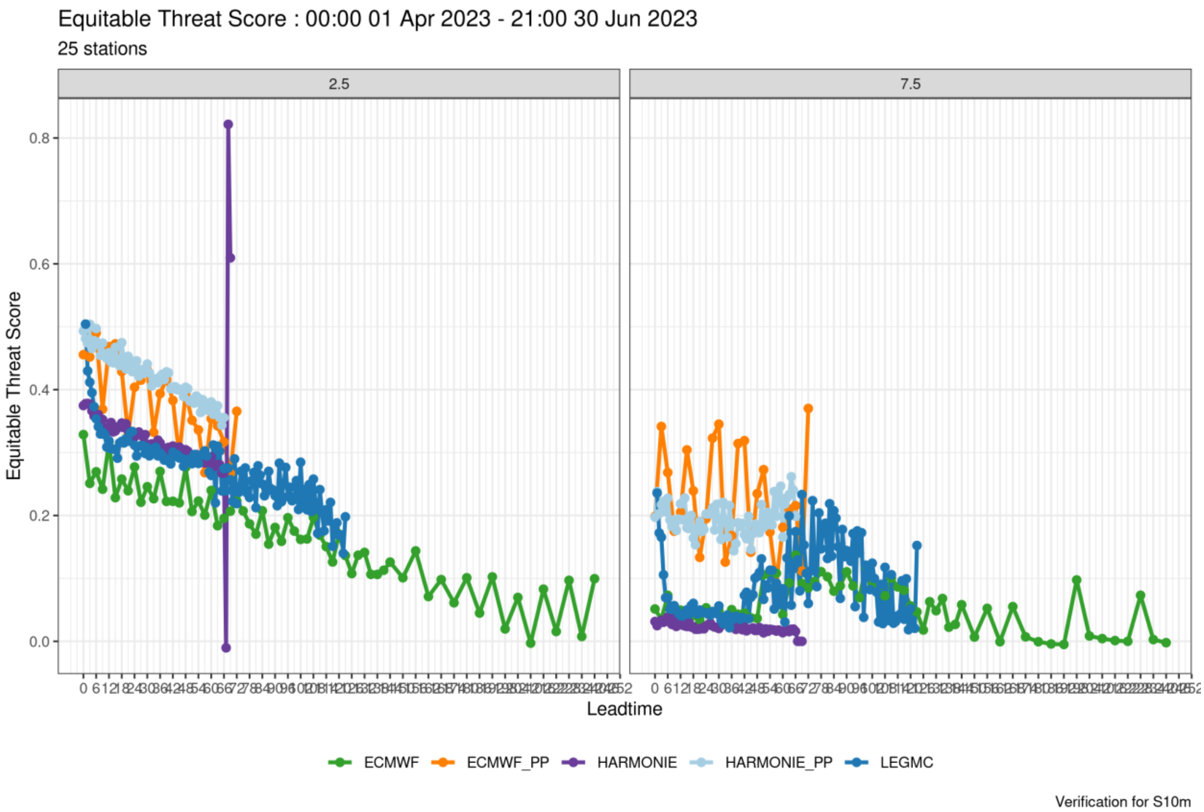
Verification results for the three-month period April-June 2023 (with calibrated forecasts)



Verification results for the three-month period August-October 2023 (with calibrated forecasts)

The inclusion of calibrated model output shows clear improvement for three parameters with Pmsl the only one where the results are grouped together with the calibrated output even increasing RMSE for the first 24 hours. A very significant improvement can be observed for S10m, where the

RMSE has decreased almost three-fold for all lead times. In addition to the previously shown results, it can be noted that for S10m the verification results show improvement also for varying value thresholds that can be applied to data. Below are the equitable threat score results for S10m with thresholds set at 2.5 and 7.5 ms^{-1}.



Verification results of different S10m value thresholds over the three-month period April-June 2023

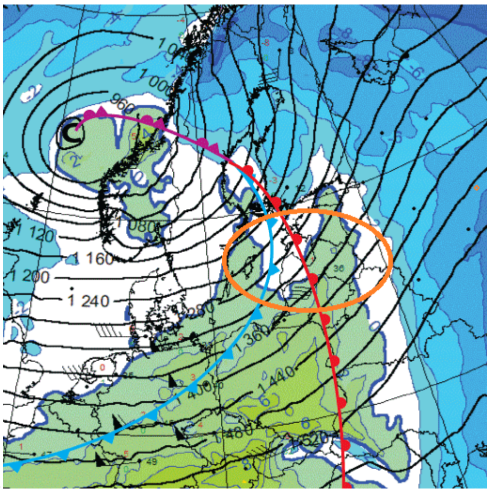
4.3 <u>Subjective verification</u>

Some subjective verification is described in the next subsection below.

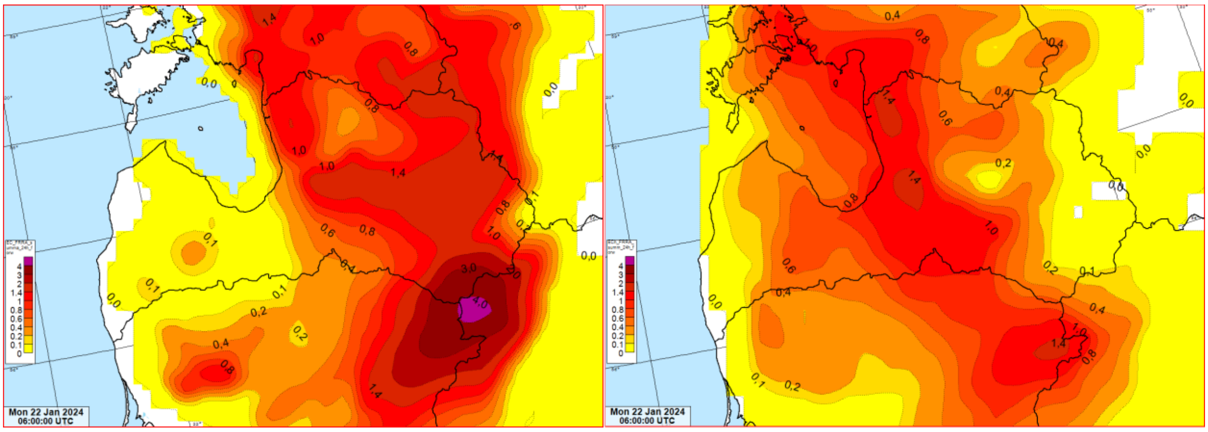
4.4 Case Studies

a) Case Study 1

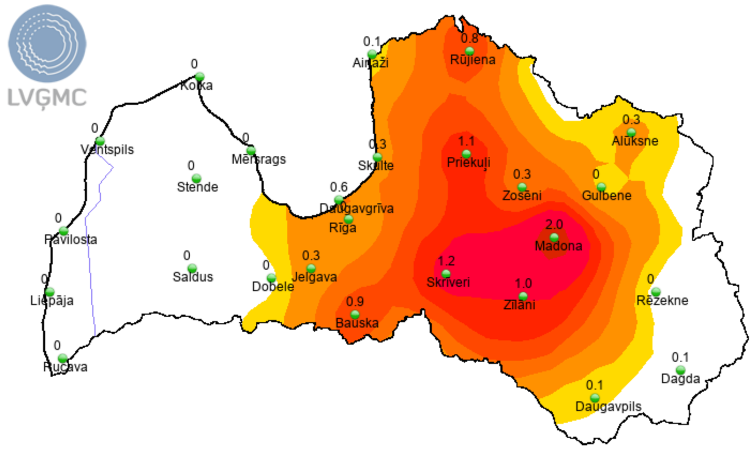
On 22.01.2024 a narrow warm sector crossed Latvia. From the forecasts it seemed like a classic freezing rain case and forecasters expected freezing precipitation from the very beginning. However, the total freezing precipitation amount (accumulated freezing rain) in ECMWF and ECMWF hourly data was rather large to even extreme (1-4 mm). Most of these classic situations in the region tend to bring much lower amount of freezing precipitation, so this was quite uncommon.
From the observation data the maximum amount of accumulated freezing rain was 2 mm, therefore we consider that the model performed well, as this, probably, is not the “easiest” model field to calculate.



Synoptic situation – frontal analysis at 850 hPa (22.01.2024 12 UTC)

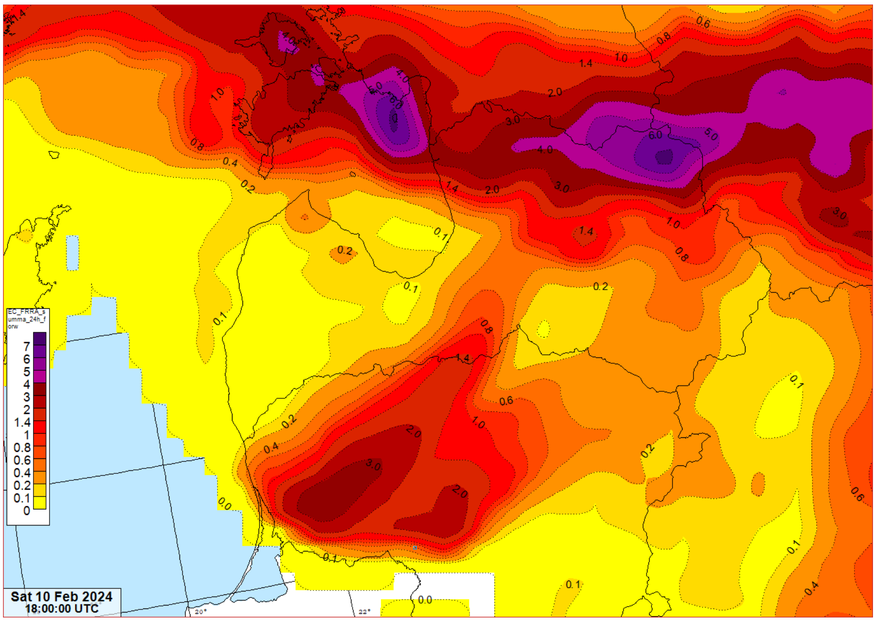


ECMWF (left) and ECMWF hourly (right) accumulated freezing rain (18h period).

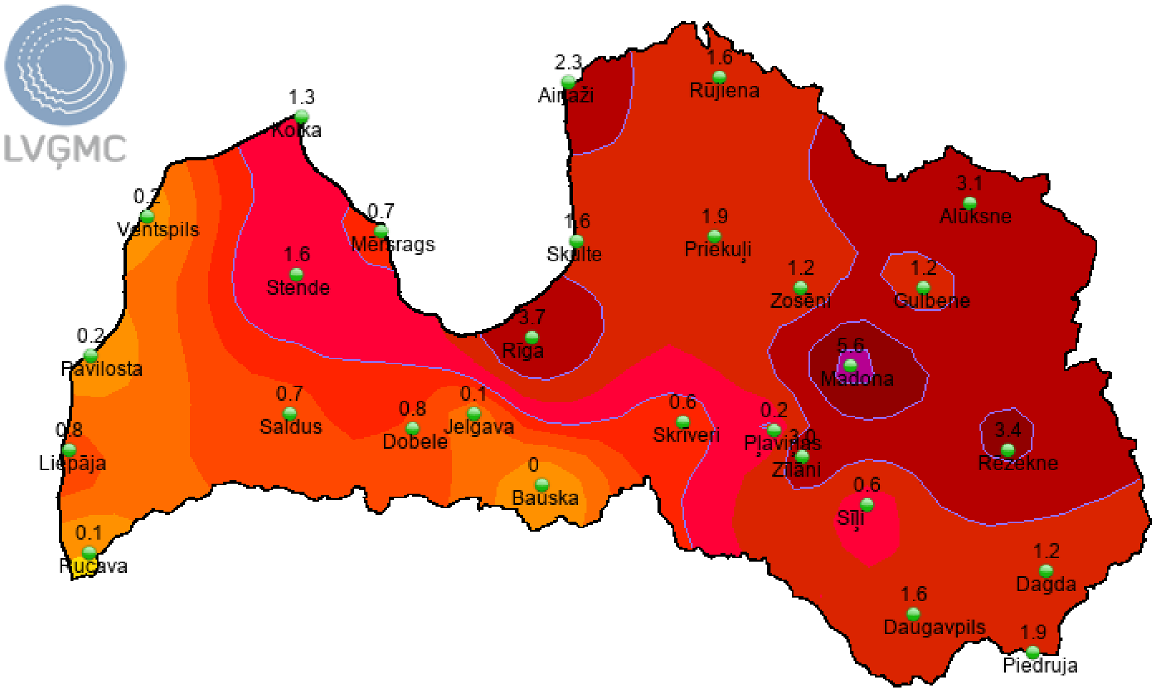


Observed freezing precipitation accumulation for the same period (22.01)

Three weeks later, on 10.-13.02.2024 even more severe case with stationary / very slow-moving warm front occurred. ECMWF HRES calculated freezing precipitation amount of 5-7 mm locally (in a 3-day period). The maximum observed amount for the same period was 5.6 mm which can be considered as a very accurate forecast. The area of maximum values was observed in a slightly different location, however not very far.



ECMWF freezing precipitation amount accumulation from 10.02.2024 evening till 13.02.2024 evening, mm

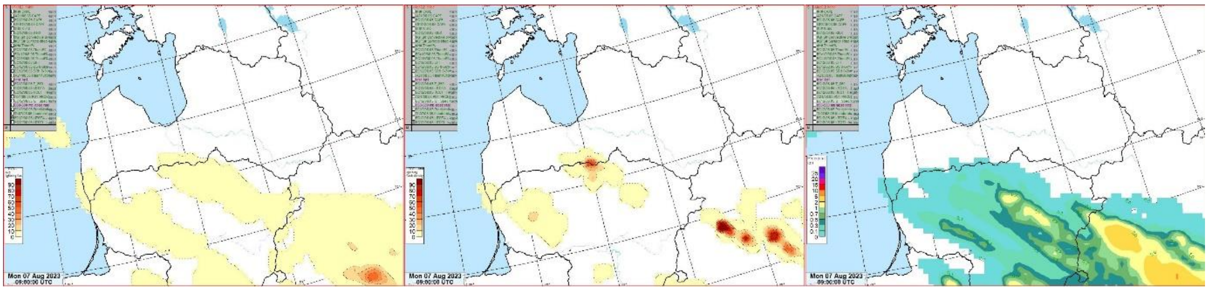


Observed freezing precipitation accumulation for the same period (10-13.02.2024)

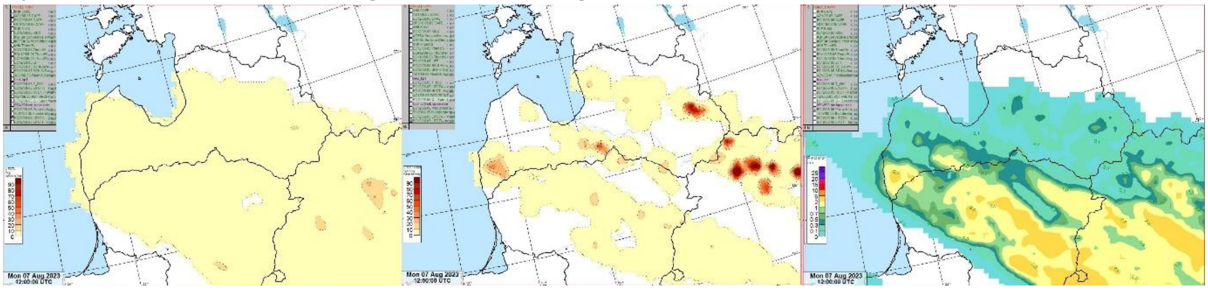
The second case had a major impact in the eastern part of Latvia. The road conditions were classified as critical, considerable number of people were left without power and the damage to some types of trees, as they were bent over from the weight of ice, could be still noticed later in the year.

b) Case Study 2

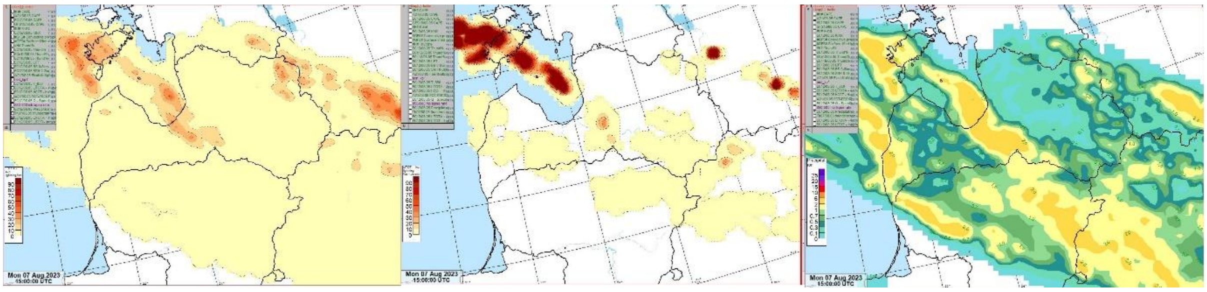
On 07.08.2023 severe thunderstorms occurred over the region of the Baltic countries. The usual parameters that describe the potential and the possible severity of convection were well within the values that would suggest an outcome of a well-developed MCSs structures or supercells. It was also expected that the convection will be strongly supported by a slow-moving frontal system over the region. Forecasters do not expect in these kinds of cases that a global model will depict a realistic outcome of how the storms will look in regards of precipitation and storm cloud distribution over area of interest, but nevertheless ECMWF HRES gave a good indication of what can be expected in general. However, the storms and especially the most severe one in reality appeared much earlier than HRES suggested. At least about 3 hours earlier.



09 UTC* from left to right - LITOTA, LOTOTI, precipitation amount mm/h
***just after the actual storm brought the most damage**

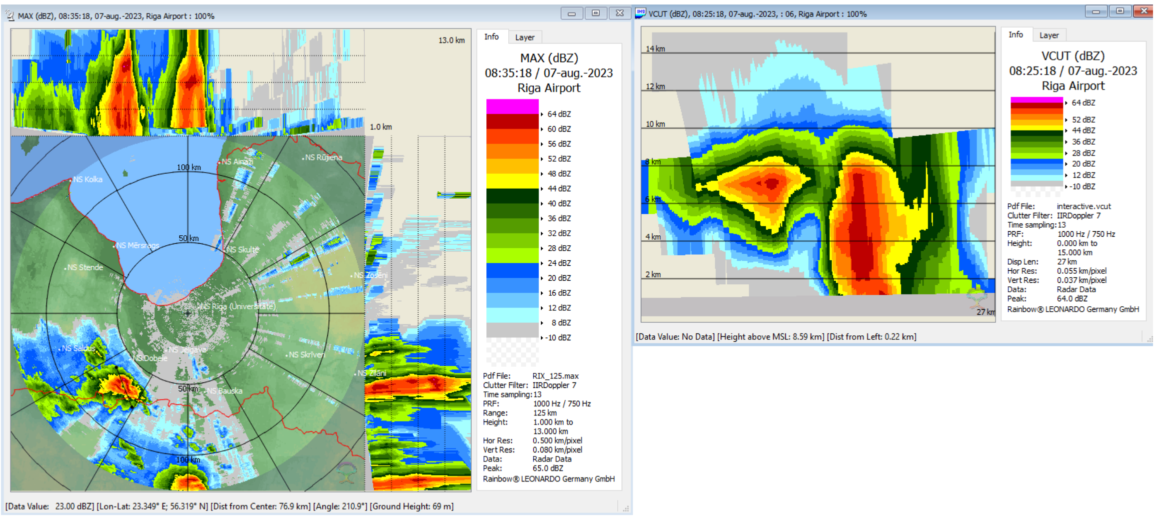


12 UTC from left to right - LITOTA, LOTOTI, precipitation amount mm/h



15 UTC from left to right - LITOTA, LOTOTI, precipitation amount mm/h

Observations



Storm at 8:35 UTC in southern part of Latvia, Maximum dBz and vertical cut.

The nearest observation site registered 33 m/s and about 22 mm of rain (3h period), however, the visual public observations suggest that by far the most severe impact was done by very large hail.

1. Avots: VUGD (twitter.com/ugunsdzeseji)

2. Avots: Gints Mucenieks (twitter.com/Gints_photo)

3. Avots: Laura Prūse

4. Avots: Laura Prūse

Observed wind and hail damage

Section 5: Output Requests

None to note.

Section 6: References

François Bouttier and Hugo Marchal. *Probabilistic thunderstorm forecasting by blending multiple ensembles*. Tellus A: Dynamic Meteorology and Oceanography, 72(1):1–19, 2020.

Mehra, Raman. *On the identification of variances and adaptive Kalman filtering*. IEEE Transactions on automatic control 15.2 (1970): 175-184.