THE NWP ACTIVITIES AT CROATIAN METEOROLOGICAL AND HYDROLOGICAL SERVICE IN SPRING 2025

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Operational setup

Operational model configurations:

- **ALADIN-HR40**: Δx=4 km; 480x432x73; CY43T2; HYD dyn.; t=150 s; ALARO-1 phy.; IC: CANARI + 3DVar (3h-cycle, ENS B); 72h fcst.; LBC:IFS-3h (6-h lagged), 4 runs per day
- **ALADIN-HR20**: Δx=2 km; 450x450x87; CY43T2; NH dyn.; DFI ini.; t=60 s;ALARO-1 phy.; 72h fcst.; IC: ALADIN-HR40; LBC: IFS 1-h (6-h lagged); 4runs per day
- **HRAN**: Analog-based method - a statistical post-processing method that finds analogous situations in the previous (training) period and using a similarity metric predicts values that are observed under a “very similar” forecast; predictor weight optimization and statistical correction for rare events are used

All-sky assimilation of IASI data

The Metop satellites are Europe’s first operational meteorological satellites in polar orbit. Each Metop satellite carries the same sophisticated suite of instruments providing fine-scale global data. One such instrument is an Infrared Atmospheric Sounding Interferometer (IASI) that measures infrared energy emitted by the earth-atmosphere system in 8461 individual spectral channels with a spatial resolution of 50 km at nadir.

Conventional clear-sky data assimilation only considers data from regions without clouds, leaving the model underrepresented in cloudy areas. In preparation for the future hyperspectral infrared sounders, the assimilation of multilayer cloud-affected infrared radiances using the all-sky approach by Kozo Okamoto is explored. For this purpose, IASI data are used as a proxy.

The crucial part of the Okamoto approach is the observation error modeling where observation error assigned has the same size as the first guess departures standard deviation. In this sense, data is binned by the values of averaged cloud effect, defined as:

$$C_A = \frac{|B - B_{clr}| + |O - B_{clr}|}{2}$$

where B and B_{clr} are calculated simultaneously in RTTOV and represent model simulated brightness temperatures in cloudy and clear-sky scene for a given location. O is the observed brightness temperature. After that, linear fit to standard deviation values is performed, while defining minimum and maximum value that can be applied (where linear fit is a good approximation; **Fig 1**).

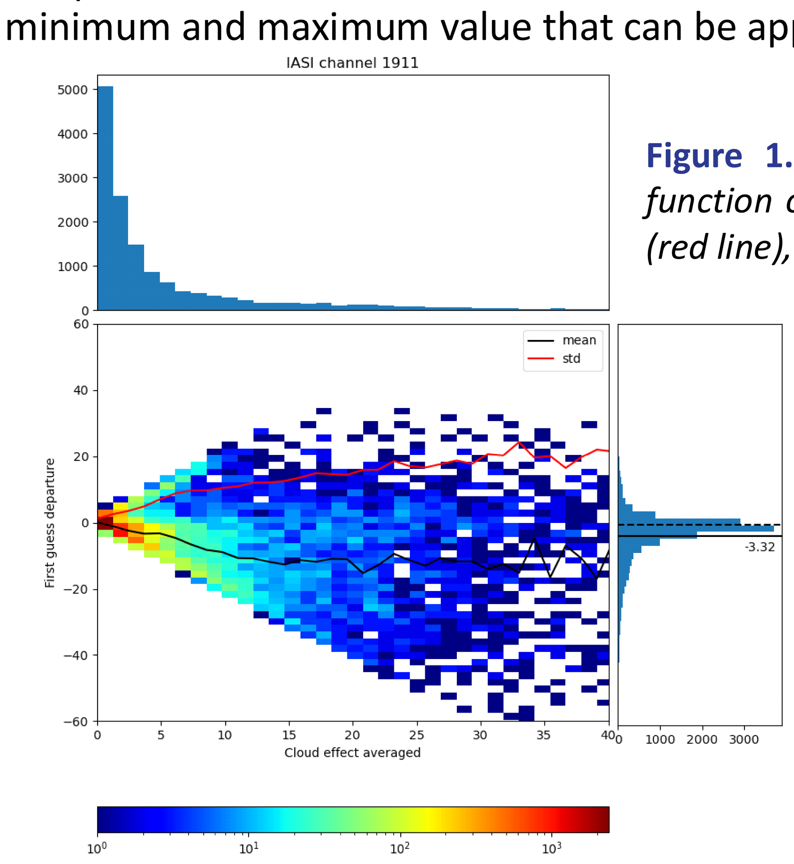

Figure 1. *2D histogram of first guess departure as a function of the averaged cloud effect; Standard deviation (red line), mean (black line)*

The observation error is then defined as:

$$O_{err} = \frac{\sigma_{cld} - \sigma_{clr}}{C_{cld} - C_{clr}}(C_A - C_{clr})$$

where σ_{clr} and σ_{cld} are minimum and maximum values of standard deviation that can be applied and C_{clr} and C_{cld} are averaged cloud effect value at which they are assigned.

Observation error modeling was technically implemented into the CY48T3. For testing purposes 3DEnVar member of the C-LAEF 1k (Convection-permitting Limited-Area Ensemble Forecasting) system was used. Four water vapor channels were selected to be assimilated in all-sky mode: 2951, 2958, 3049 and 3105, while the rest of the channels were assimilated in the clear-sky mode.

Looking at the case of 20.01.2025., it can be seen that dynamical assignment of observation errors for all-sky channels performs as intended. Therefore, this setup can be used as the base for further development (**Fig 2**).

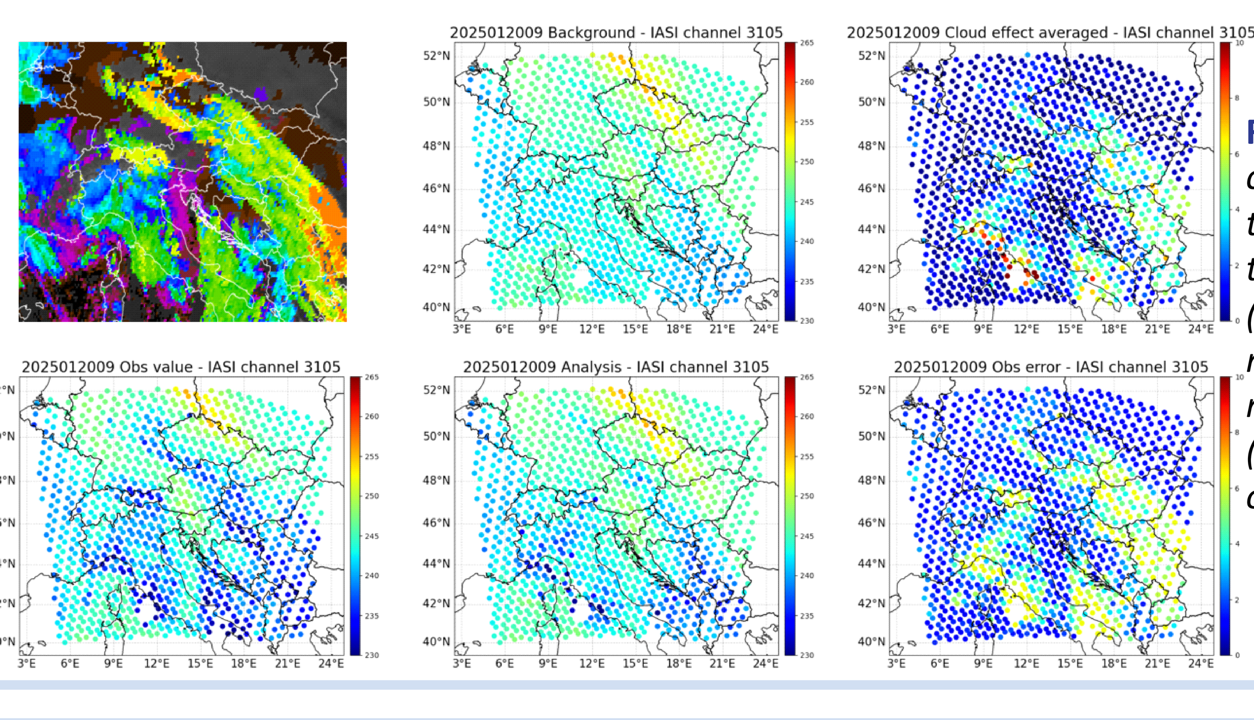

Figure 2. *Case 20.01.2025.: cloud top product (Eumetview; top left); brightness temperatures – observations (lower left), background (top middle), analysis (lower middle); averaged cloud effect (top right); assigned observation errors (lower right)*

Universal Thermal Climate Index (UTCI) and thermal strain mortality in Croatia (2006-2022)

- Examined the relationship of the Universal Thermal Climate Index (UTCI) mortality caused by thermal strain in Croatia -> from measurements on 4 stations for period 2006-2022
- For cold/hot conditions calculated the UTCI index values [°C] below/above which averaged difference of relative mortality from expected mortality is increased and statically significant on a level of significance of 0.05 :
  - •Cold conditions- UTCI is in moderate stress category for all stations – lowest values for mountain station Gospić, highest for maritime stations Dubrovnik
  - •Hot conditions- UTCI is in strong heat category for maritime stations Dubrovnik (highest values) and Split-Marjan and in moderate stress categories for continental station Zagreb-Maksimir and mountain Gospić (lowest values)

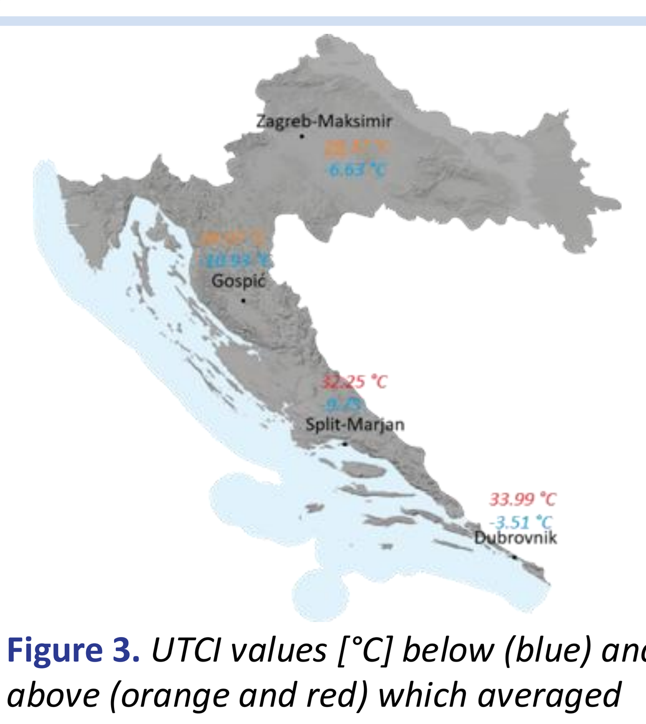

Figure 3. *UTCI values [°C] below (blue) and above (orange and red) which averaged difference of relative mortality from expected mortality is increased and statically significant on a level of significance of 0.05 at 4 stations in Croatia over period 2006-2022.*

Neighborhood Ensemble altitude Correction (NEA)

- Novel approach for temperature postprocessing without using any observations.
- **NEA** involves finding the closest model point to the **Location of Interest** (**LoI**), forming a neighborhood ensemble, calculating the temperature lapse rate through linear regression of neighboring points' altitude and temperature, and applying this lapse rate to all neighboring points to obtain altitude-corrected temperatures. The ensemble mean of these corrected temperatures forms the final forecast (**Fig. 4**), accounting for model uncertainty due to the inability to resolve all processes at the model grid size scale.
- The method was thoroughly tested and validated using a one-year period and 36 surface stations in Croatia. Results are encouraging and show an **increase in forecast accuracy of about 10%** on average when compared to the default method of using the nearest model land point (NP; **Fig. 5**).
- NEA's performance is comparable to advanced analog-based method (AN; **Fig. 5**), especially during daytime, making it a robust solution for diverse terrains and operational settings.

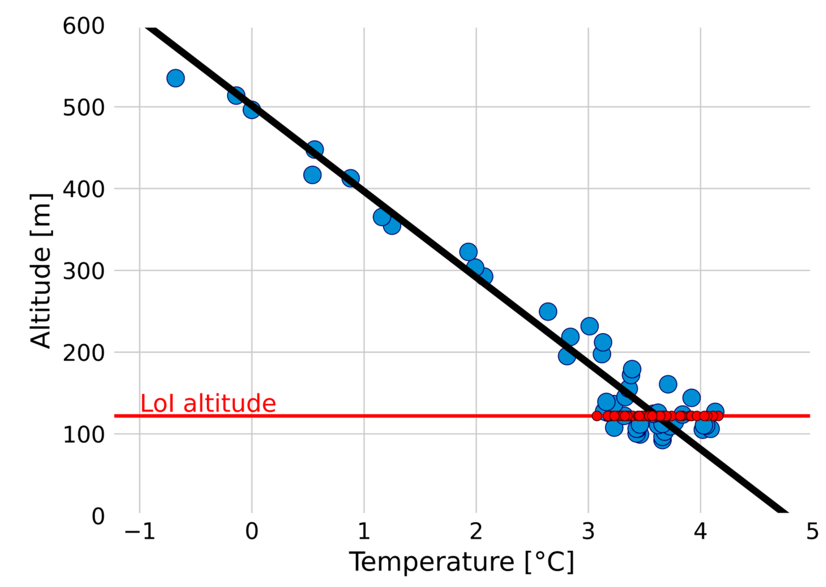

Figure 4. *Example of a linear regression between temperature and altitude of model grid points (blue dots). Model grid points with altitude-corrected temperatures are shown in red.*

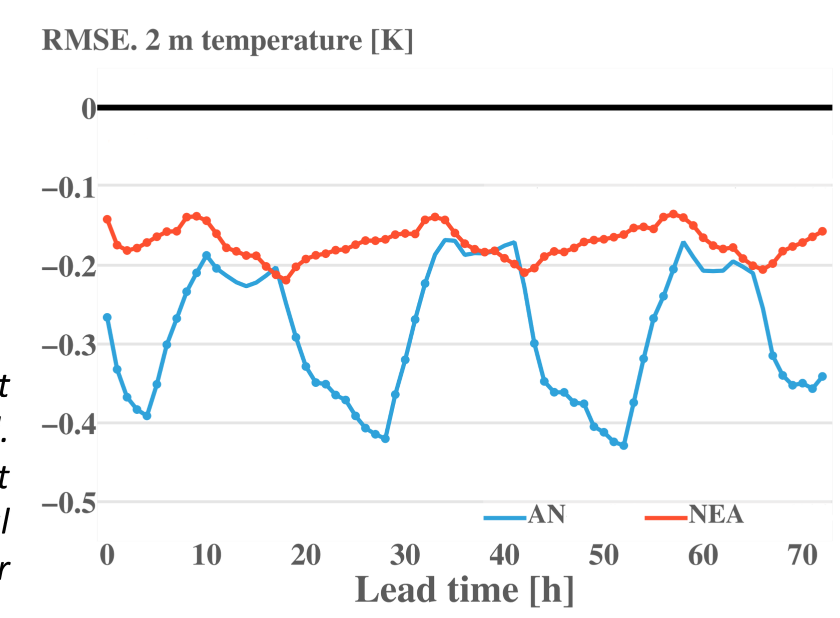

Figure 5. *RMSE of AN and NEA relative to the nearest point method (NP) for the verification period. Forecast ranges with statistically significant differences are marked with bullets. Statistical significance for NEA is calculated against NP, and for AN against NEA.*

Implementation of the INCA system

•The Integrated Nowcasting and Comprehensive Analysis (INCA) system has been installed and configured for the Croatian domain during the collaboration of DHMZ and GeoSphere Austria provided by EUMETNET-Weather Forecasting Cooperation.

•In the first phase of implementation of INCA into the operational system, results were analyzed on the case study of 19th July 2023, when the mesoscale convective system (MCS) struck several countries including Croatia (**Fig. 6**).

•The spatial distribution of precipitation reveals atmospheric characteristics during the passage of the MCS (**Fig. 7**). The precipitation analysis benefits from the integration of radar composite data and interpolated observations from automatic weather stations, enhancing accuracy.

•The temperature analysis is provided at a high resolution of 1 km, representing a significant advancement in capturing fine-scale variations (**Fig. 8**).

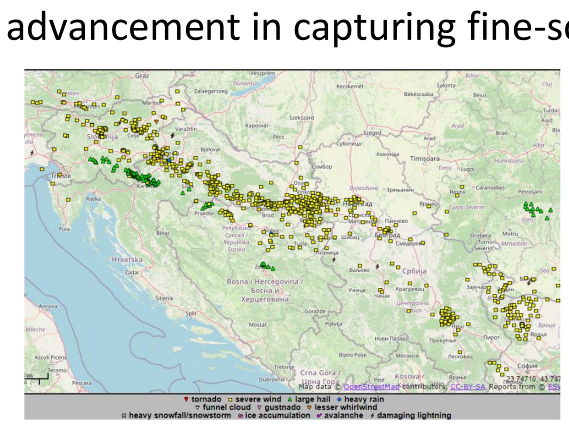

Figure 6. *Reported severe weather conditions 19th July 2023 from European Severe Weather Database. Yellow boxes represent severe wind, blue dots heavy rain, green triangles large hail, orange triangles lesser whirlwinds, and thunder icons represent damaging lightning.*

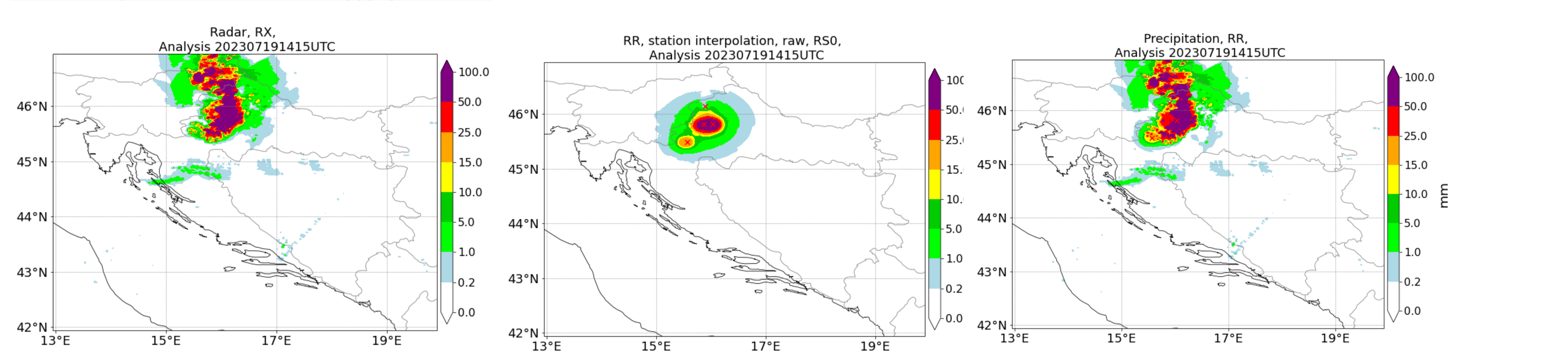

Figure 7. *Precipitation raw radar field (left), interpolated station’s observation (middle), and INCA analysis (right) at 19th July 2023 at 14:15 UTC at the begining of MCS impact at Croatia. Red crosses represent the station’s data taken into an analysis.*

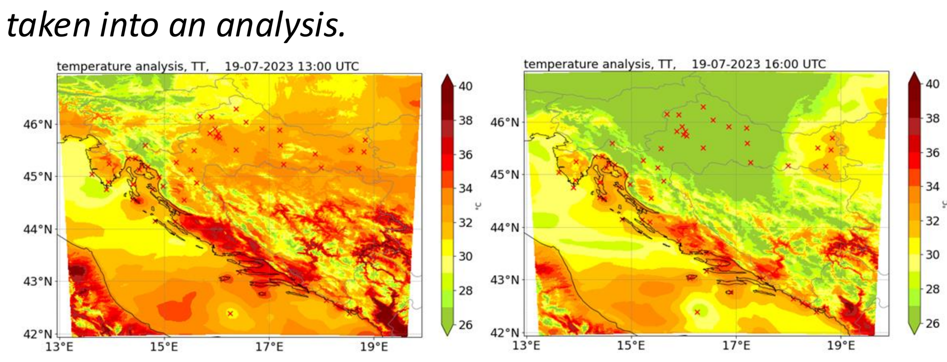

Figure 8. *Temperature at 2 m based on INCA analysis at 13 UTC (before the MCS impact ,left) and 16 UTC (after MCS crossed half of Croatian teritoy, right). Red crosses represent the station’s data taken into an analysis.*

Implementation and validation of OI analysis in a coupled ALARO/SURFEX system

- The configuration used was based on cy43t2 with a horizontal resolution of 1 km and Slovenian domain (1 h RUC at ARSO)
- The first guess for start of experiment was taken from the operational model. A dynamic adaptation was made for the .sfx file from the ELSCF file, after which the upper air and SURFEX fields were cycled.
- The evolution of SURFTEMPERATURE (soil temperature) from the guess file and X001TG1 (SURFEX counterpart) was compared to operational values across four locations from April 1st to April 8th, 2024. X001TG1 temperatures closely matched operational values, while SURFTEMPERATURE exhibited higher peaks (**Fig. 9**)
- Technical issues with CANARI, possibly related to input/output, need resolution for more accurate comparisons. Further tuning is necessary to enhance forecast accuracy.

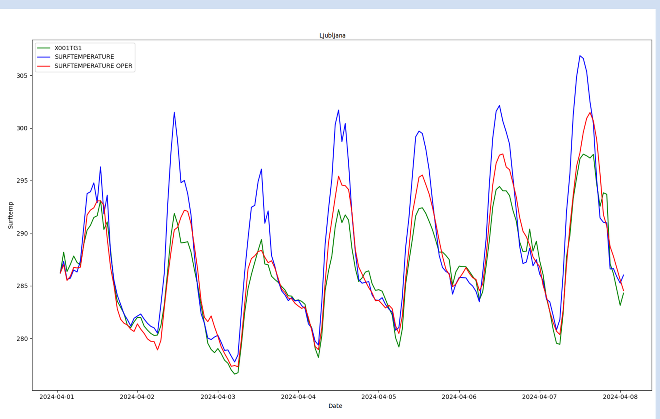

Figure 9. *Evolution of filed SURFTEMPERATURE and X001TG1 for Ljubljana from April 1st to April 8th 2024.*