Analysis of modeled hail parameters obtained by numerical mesoscale WRF-HAILCAST model

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Aim & Motivation

- **Knowledge about hail characteristics** in the continental part of Croatia, in comparison to the coastal parts, **is extremely disproportionate**.
- Due to the long history of hail suppression activities in the northern (lowland) part of Croatia, **hailpads** have been placed **at main meteorological stations**, as well as **on a specially designed polygon in north-western Croatia**.
- The existing analyses of measurements shows that **parts of western and central Croatia have the highest frequency of intense hail** (mostly observed near the western isolated mountains).
- The aim was **to examine processes leading to hailstone growth and to provide guidance for hailcast results tuning**.

Model & Simulation specifications

- **WRF-ARW 3D nonhydrostatic mesoscale model**
- A two-way nested configuration with **grid spacing of ? km, 3 km and 1 km** (on the Lambert conformal projection)
- 65 terrain-following coordinate levels with the lowest level at about 25 m
- **Initial and boundary conditions from ECMWF**
- Runned from **30 July at 00:00 UTC to 06:00 UTC of 31 July 2014**
- WRF dynamic and physical options for all domains:
  - Mellor-Yamada Nakanishi and Niino Level 2.5 PBL,
  - a rapid radiative transfer model for longwave radiation and a Dudhia scheme for the shortwave radiation,
  - Morrison double-moment scheme for microphysics with double-moment ice, snow, rain and graupel for cloud-resolving simulations,
  - MYNN surface layer Nakanishi and Niino PBL's surface layer scheme,
  - Noah LSM: unified NCEP/NCAR/AFWA scheme with soil temperature and moisture in four layers, fractional snow cover and frozen soil physics.

Episode: 30 - 31 July 2014

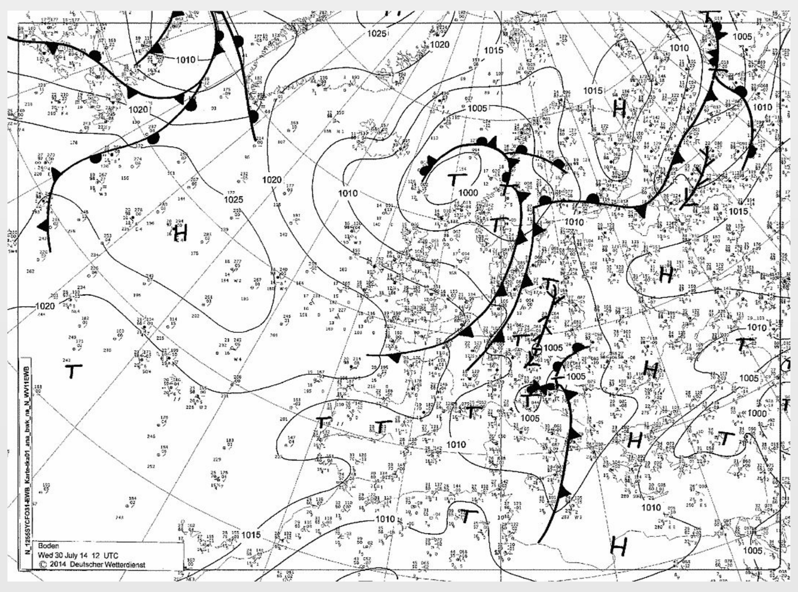


Figure 1: Surface diagnostic chart at 12 UTC on 30 July 2014 for Europe (Source: wetter3.de).

Croatia is under influence of low pressure system. Winds are moderate and predominantly from eastern to southeastern directions over the target area.

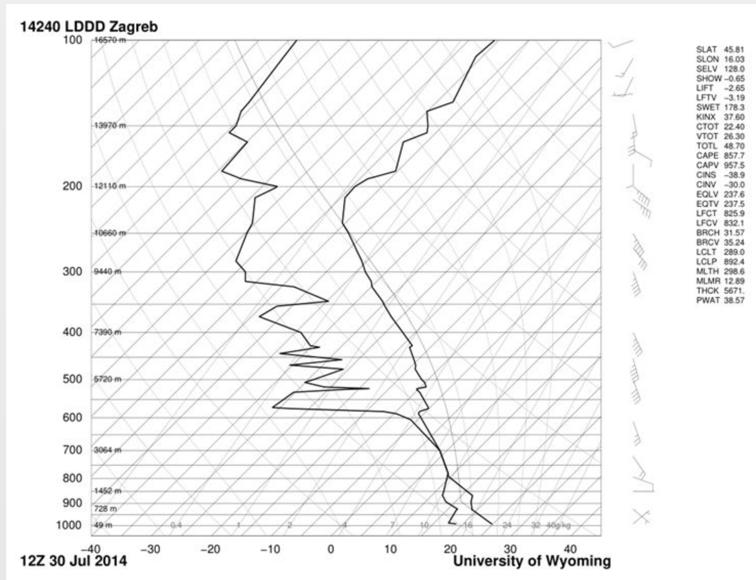


Figure 2: Sounding from Zagreb, Croatia at 30 July 2014 at 12 UTC. CAPE (CAPE = 857.7 J kg-1), LI index (LIFT = -2.65) and K Index (KINX = 37,60) indicate a strong potential for convective activity. Freezing level is found on 650 hPa and cloud base on 800 hPa. Strong dew point depression begins above 600 hPa.

WRF-HAILCAST Results

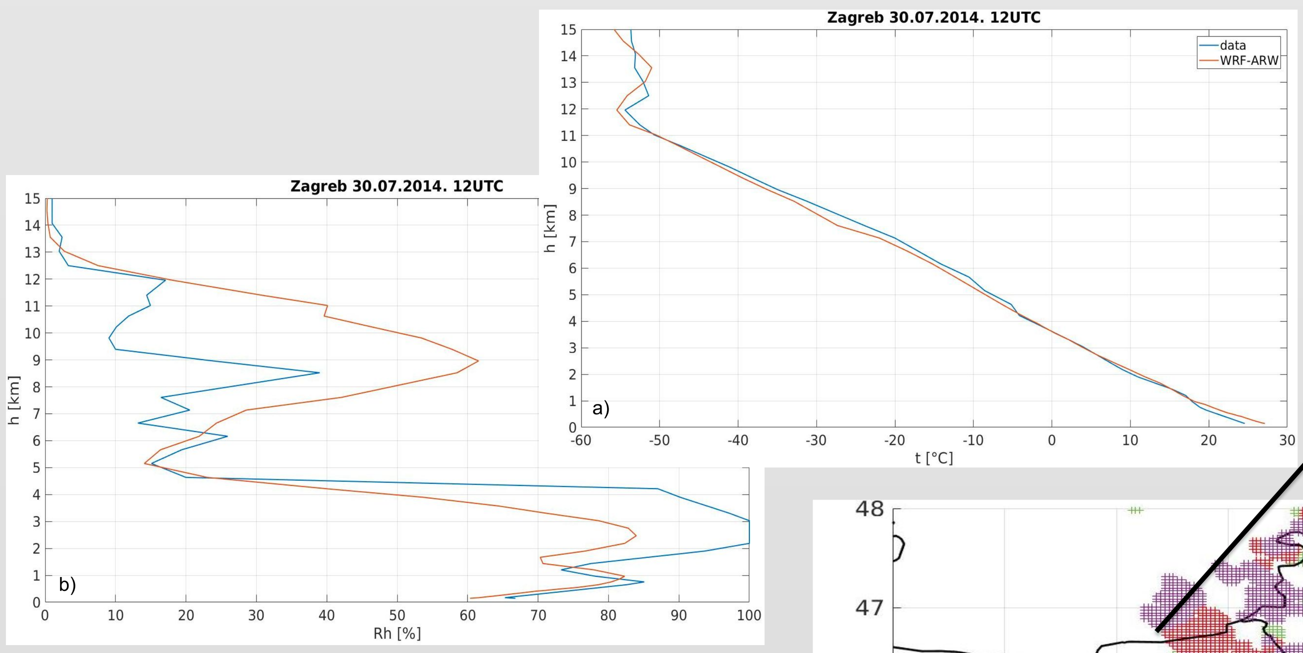


Figure 3: **Measured and modelled vertical profiles of** (a) **temperature and** (b) **relative humidity** at Zagreb Maksimir station at 12 UTC on 30 July 2014. They are strongly correlated for both parameters (also fig 7). The model slightly underestimates relative humidity in 1.5 to 4 km layer.

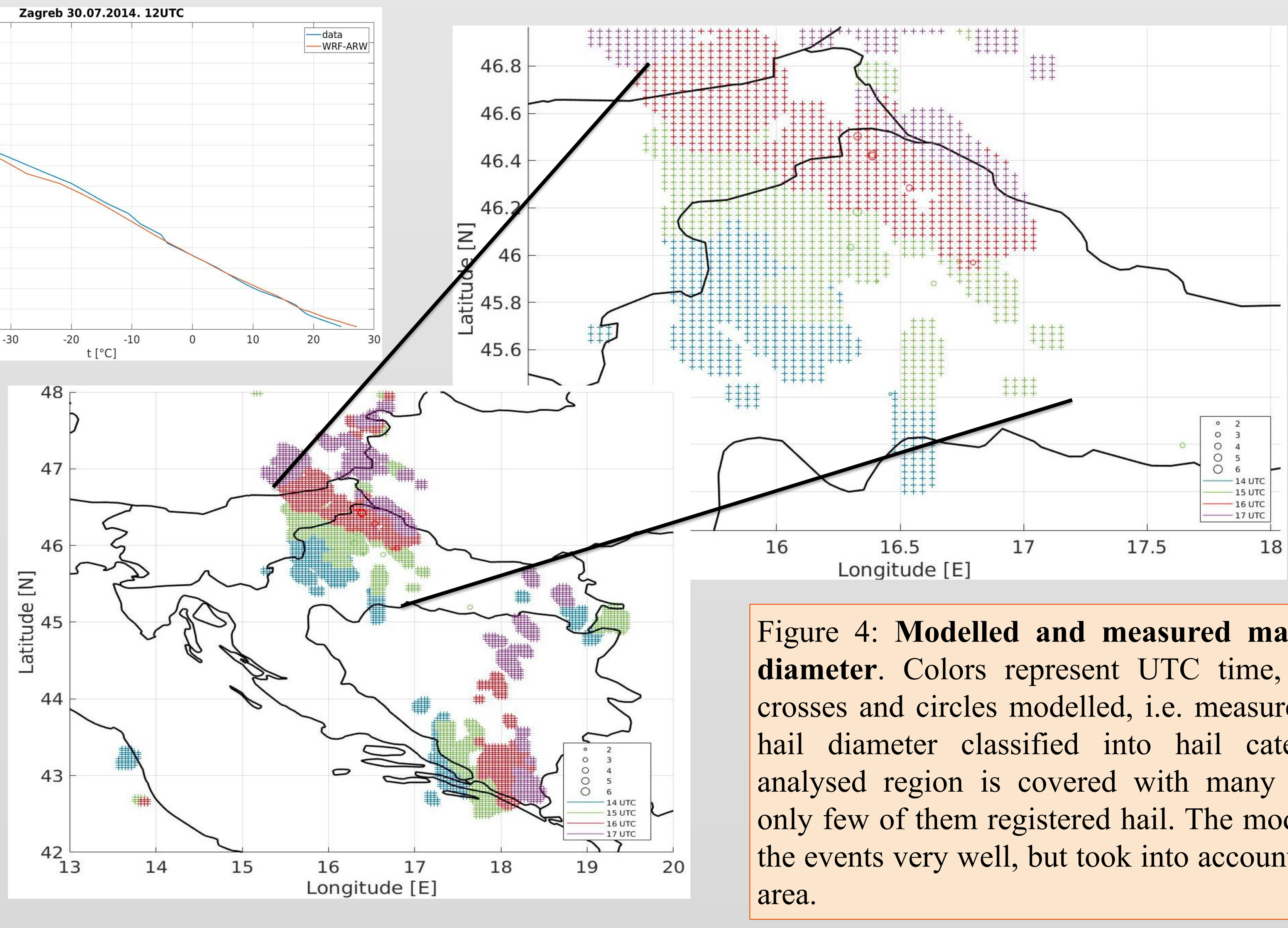


Figure 4: **Modelled and measured maximum hail diameter**. Colors represent UTC time, size of the crosses and circles modelled, i.e. measured maximum hail diameter classified into hail categories. The analysed region is covered with many hailpads but only few of them registered hail. The model simulated the events very well, but took into account too large an area.

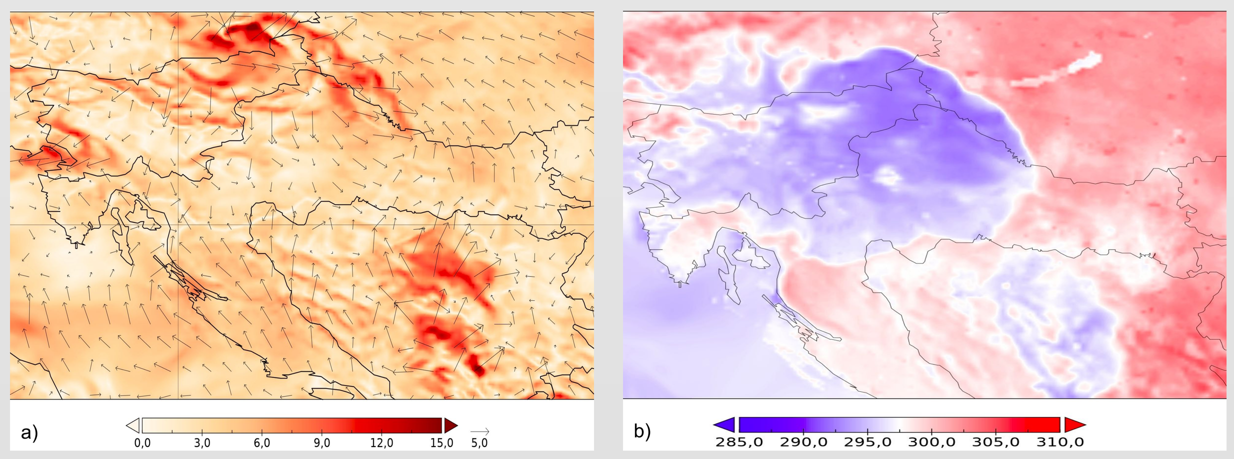
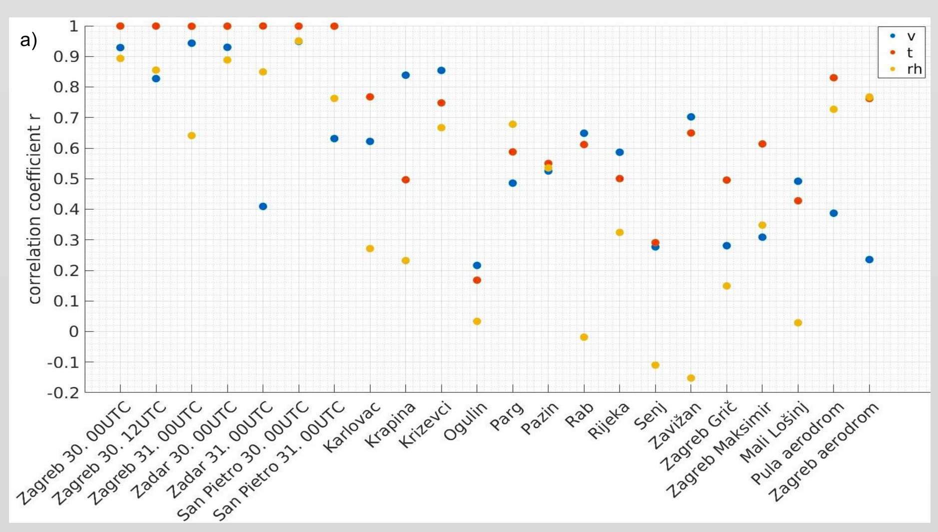


Figure 5: a) **Modelled wind vectors** (10 m a.g.l) and b) **2 m potential temperature** on 30 July 2014 at 16 UTC at 3 km resolution. There were **moderate to strong winds** in the areas where hail had been predicted. The temperature field indicates **cold pools** which are associated with storm propagation.



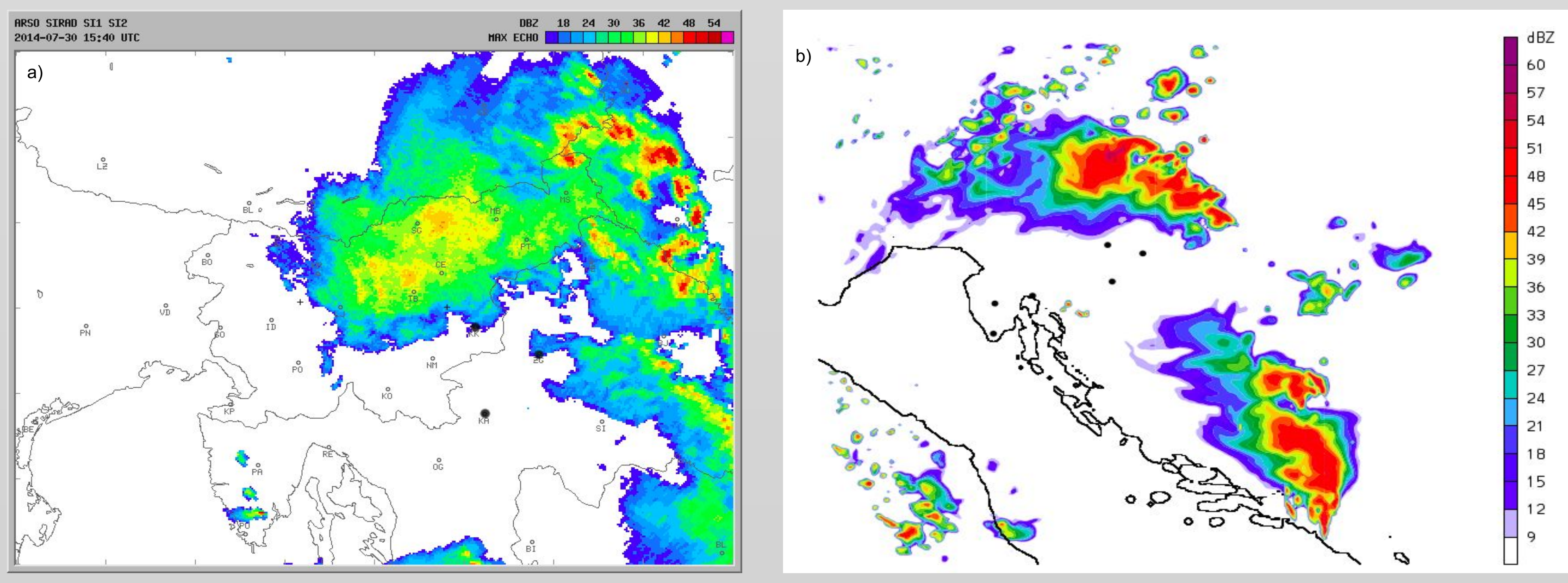
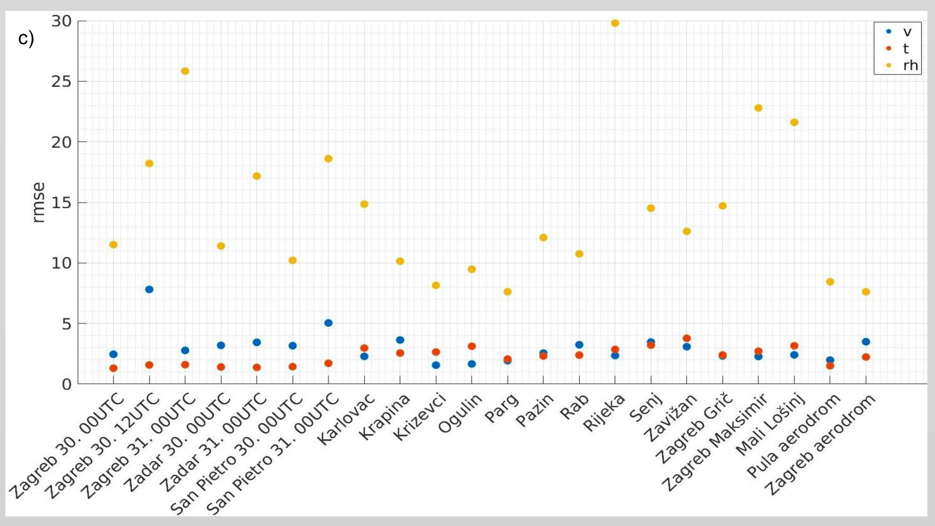
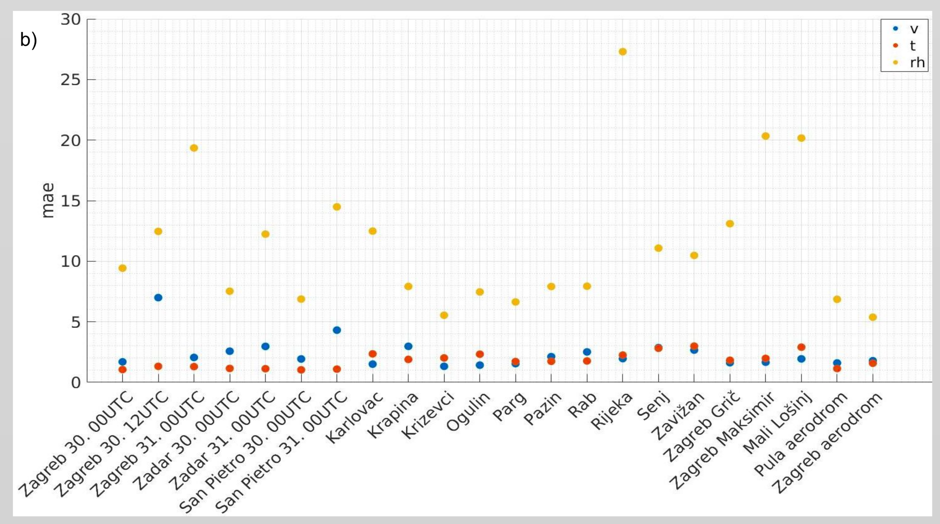


Figure 6: (a) **Measured** (15:40 UTC) **and** (b) **modelled** (16:00 UTC) **maximum radar reflectivity** (dBZ). In northern Croatia, spots with maximum radar reflectivity above 40 dBZ occur. We can link some of these areas with observed hail (fig 4). The modelled maximum radar reflectivity affects much larger area and has slightly higher values. It consequently predicts widespread hail.





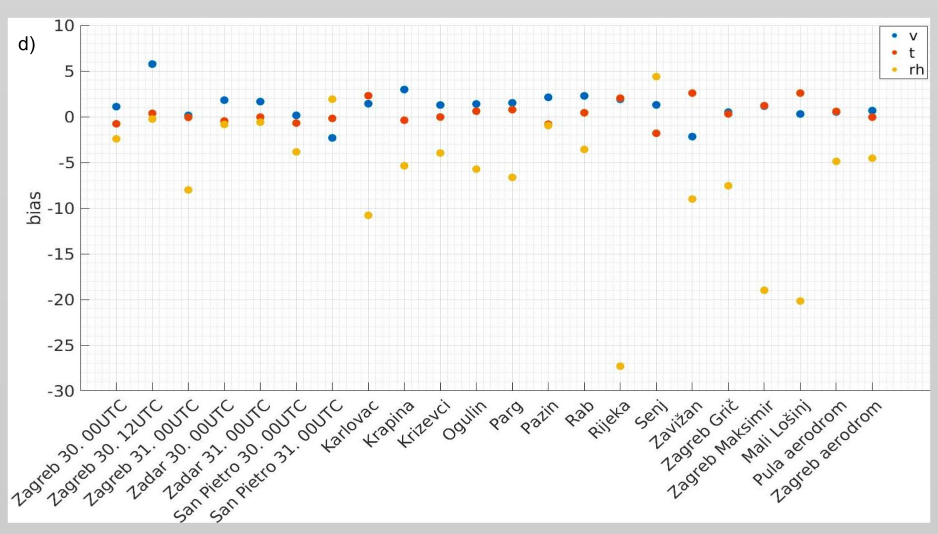


Figure 7: **Statistical parameters** for wind speed, temperature and relative humidity; a) **correlation coefficient**, b) **MAE**, c) **RMSE** and d) **bias.**

The model shows satisfying results, but their precision spatially fluctuates. The deviation of temperature and wind speed (Rmse) does not exceed 4 °C, i.e. 5 m/s. Wind speed is overestimated except at two stations, on the other hand the number of stations where temperature was overestimated equals the number of stations where it was underestimated (Bias). The deviation of relative humidity varied from around 7% to 30%; it is underestimated at all but two stations.

Summary

- **WRF - HAILCAST overestimated the values of analysed parameters, but in general, synoptic conditions favourable for developing stormy weather over northern Croatia are successfully reproduced.**
- **Measured maximum hail diameter in northern Croatia was successfully captured (both spatially and temporally), but the model overestimated the affected area.**

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