Hailstorm in Eastern Croatia

- analysis and forecasting potential by convection-permitting numerical model

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INTRODUCTION AND MOTIVATION

Warm seasons of 2021 was quite exceptional if we consider the hail occurrence in the continental part of Croatia. One of the major events occurred on 25 June near the town of Požega due to hail size and damage.

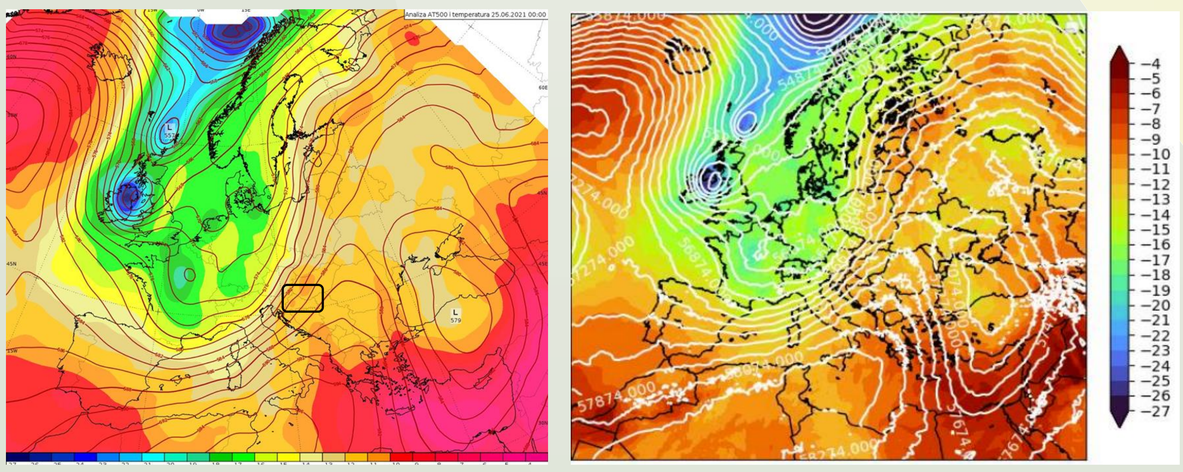
This work aims to explore the atmospheric conditions present during this hailstorm but also a forecasting potential of such events using the convection-permitting km-scale numerical models.

Convection-permitting km-scale WRF model is utilized to inspect the ability of the WRF model to reproduce the atmospheric conditions leading to the formation and evolution of an extremely damaging hailstorm. Additionally, the ability of HAILCAST and Lightning Potential Index (LPI) diagnostics to reproduce the main characteristics of observed hail and lightning is explored. HAILCAST is a one-dimensional hail growth model that forecasts the maximum hail diameter at the ground. Similarly, LPI highlights the areas with the potential for developing lightning activity. Moreover, the sensitivity experiments are performed to investigate the impact that convection parameterization has on the simulated timing and characteristics of convection.

Synoptic analysis

Ahead of an advancing trough that stretched from Scandinavia to the western Mediterranean, all necessary ingredients for severe deep moist convection (DMC) were recognized. Convective initiation started first in Bosnia and Herzegovina (BH) ahead of the surface cold front. For damage in the vicinity of town Požega, most important were convective cells that were advected into the area of Slavonian Posavina. They experienced "explosive" development, and then moved in the southwestern and southern flow across western Slavonia.

WRF model, when run at the km-scale resolution (1.5 km) reproduced the synoptic conditions very well.

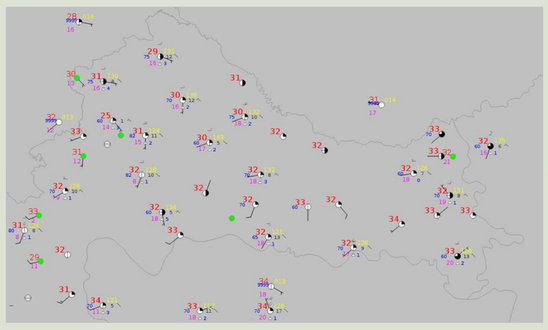


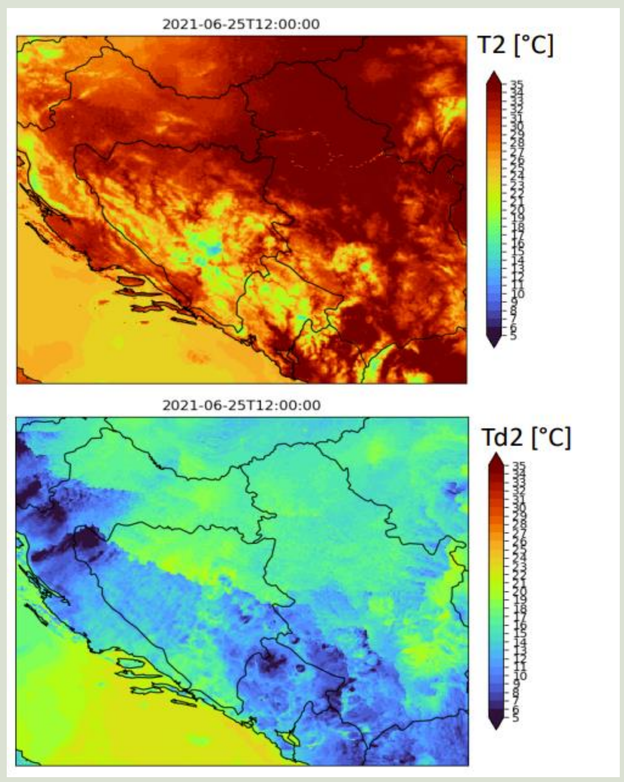
Synoptic analysis (left) and model simulation (right) of geopotential height (gpdam) of the isobaric surface 500 hPa, AT500 hPa, and air temperature (°C) at the isobaric surface 500 hPa, June 25, 2021 at 00 UTC (2:00 local time); black rectangle – affected area.

Mesoscale analysis

Favorable thermodynamic and dynamic conditions, i.e. all necessary ingredients for DMC were present in BiH and eastern Croatia in the afternoon of June 25, 2021.

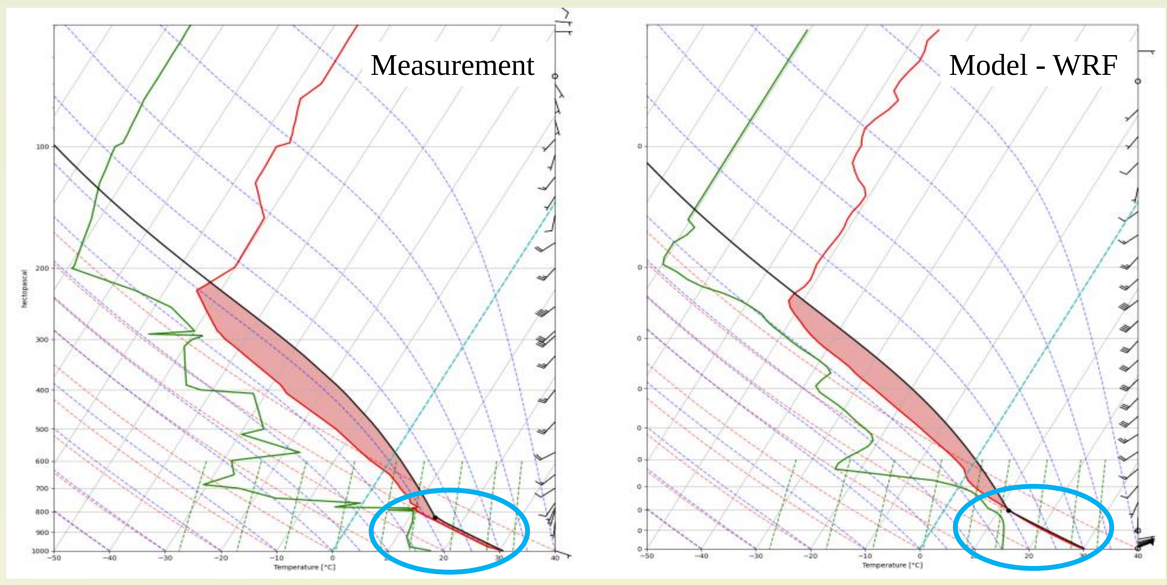
The described thermodynamic conditions, especially instability and low level moisture in the area of Slavonia were even more favorable for the occurrence of strong thunderstorms than in the area of Zagreb. According to radiosonding measurements in Szeged, Hungary (not shown), thermodynamic conditions were favorable along the entire supercell path, enabling the longevity of severe storm.





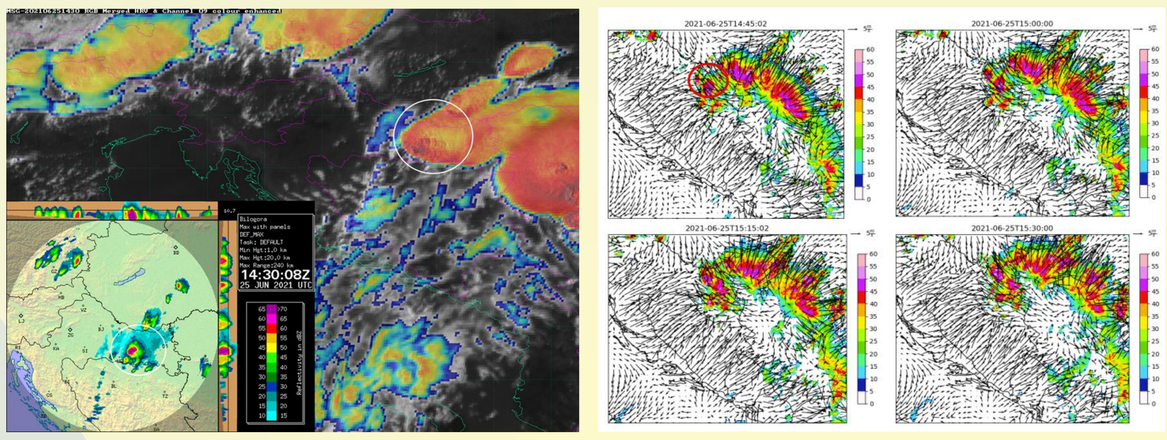
Comparison of SYNOP measurements at 12 UTC with simulated 2 m temperature and dew point temperaure shows a good reproduction by WRF model. High values of dew point temperature are present in the eastern part of Croatia which confirms that the model reproduced very well low level moisture as one of the ingredients for DMC.

Skew T – log p thermodynamic diagram for Zagreb-Maksimir, 25 June 2021 at 12 UTC



The model overall reproduces the vertical temperature profile well. But it fails in reproducing the dew point temperature change in the lowest 200 hPa of atmosphere (in reality the surface moisture was higher). Also, simulated LCL is at higher elevation compared to measurements, and simulated CAPE is slightly lower than measured. Wind speed and direction is quite well represented by the model. Radiosonding in Zagreb revealed deep layer shear values around 20 - 25 m/s which favored formation of a supercell storm.

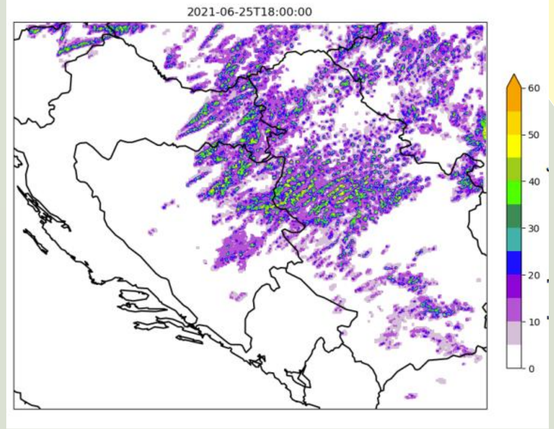
Evolution of convection



Convective activity in BH is very well reproduced by WRF simulations (seen in wind direction and speed as well in radar reflectivity signal), but initiation in the Posavina region started approximately 1 h later than in reality.

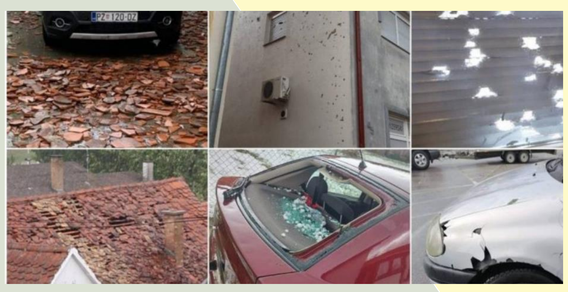
The supercell in its strongest mature phase is located just above Požega town and its surroundings. The satellite image shows the overshooting top as a dark red area, and a large anvil develops at the top of the storm cloud. On the anvil, a cold ring structure is observed within which is a less cold area of yellowish color. Measured radar reflectivity exists up to a height of 15 km, and within the clouds it reaches values higher than 65 dBZ, which indicates a very large hailstones. At the same time, the hail zone is very large. Simulations also show very high values of radar reflectivity as well as surface affected by convective system.

Area of simulated hail in the period 00-18 UTC



Hail was successfully simulated by model with the maximal size of the hailstone cca 5 cm.

ESWD reports for large hail (diameter ≥ 2cm) shows the most affected areas just in the vicinity of town Požega and later on at the border with Hungary. Also, some damaging wind reports are visible.



CONCLUSION

The results reveal that the WRF model, when run at convection-permitting resolution (1.5 km) can reproduce the synoptic and all the required mesoscale conditions (thermodynamic and dynamic) present during an extremely damaging hailstorm occurring over Croatia. Moreover, HAILCAST and LPI diagnostics reproduce hail and lightning characteristics comparable to those observed. Moreover, the sensitivity of the results on the type of convection parameterization in the outermost domains (13.5, 4.5 km) mostly in the timing but also characteristics of the simulated convection is found.