Application of the WRF-HAILCAST model to the Croatian area - sensitivity to PBL schemes

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HRZZ Hrvatska zaklada za znanost

DHMZ

Motivation and General Framework

- Hail is a significant severe weather hazard in Croatia, often causing crop and property damage. On June 25, 2017, several MCSs developed over the Croatian region resulting in severe weather effects, including hail, over larger proportions of Croatia. That hail event is analyzed using **convection-permitting WRF-HAILCAST simulations**.
- **HAILCAST** forecasts the **maximum expected hail diameter** using a profile of the vertical updraft, temperature, liquid and ice water content from a given WRF timestep and grid columns.
- A set of numerical convection-permitting experiments are performed to assess the **sensitivity of the results to** different **microphysics and planetary boundary layer** (PBL) **parameterization schemes** and to provide guidance for WRF-HAILCAST tuning.
- The results are verified by observational (**hail pad, hail observations**) data as well as with **radar** measurements where available.

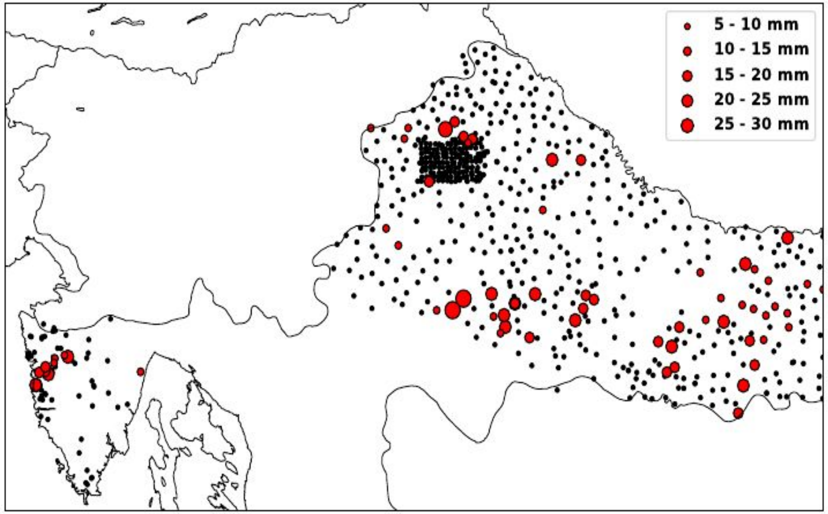
Available Observations

- **Hailpad network**

Hailpad network consists of **746 working hail pads** scattered over the region. On June 25, 2017, the network reported **73 records of hail** with **hailstone diameter** ranging **between 0.5 cm to 3 cm**. These observations are used for verification of WRF-HAILCAST results.

- **Radar**

Measurements from one of three **S-band Doppler radars** that cover a continental region of Croatia is used. Radar has **15 min volume scans**. **Zmax values** are analyzed.

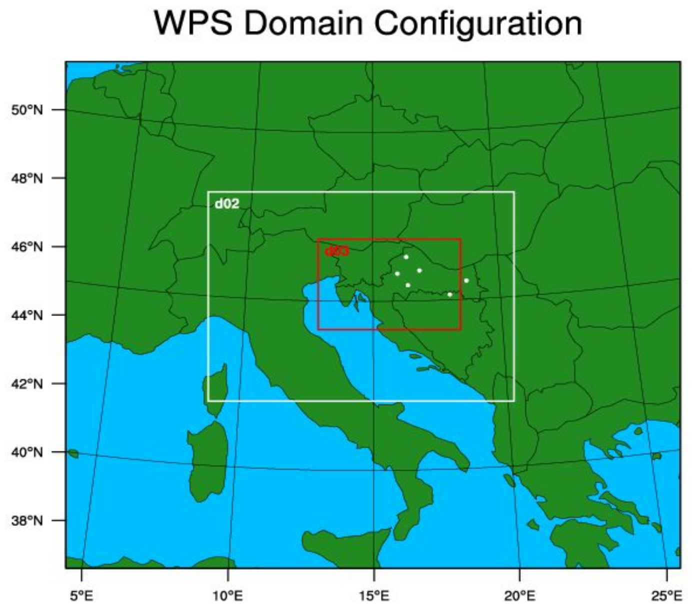


Hailpad network with hail measurements.

Black dots represent working hail pads, and red circles indicate those ones that reported hail. The size of the red circle indicates maximal reported hailstone diameter.

WRF Simulation Settings

- **WRF 3.8.1** model coupled with **HAILCAST-1D** model
- Simulation period 24.06. 00:00 - 26.06. 00:00 UTC
- Domain settings:
  - **9, 3, 1 km** horizontal resolution
  - 204x180, 304x208, 424x289 points
  - **66 vertical levels**
- Forcing data: **ECMWF analysis**, 0.125°, 6-hourly
- **d02, d03 - no cumulus parameterization** (CPM)
- Physics options:
  - longwave radiation: RRTM
  - shortwave radiation: Dudhia scheme
  - Unified Noah LSM
- Hail-related variables - max. hailstone diameter (from HAILCAST)



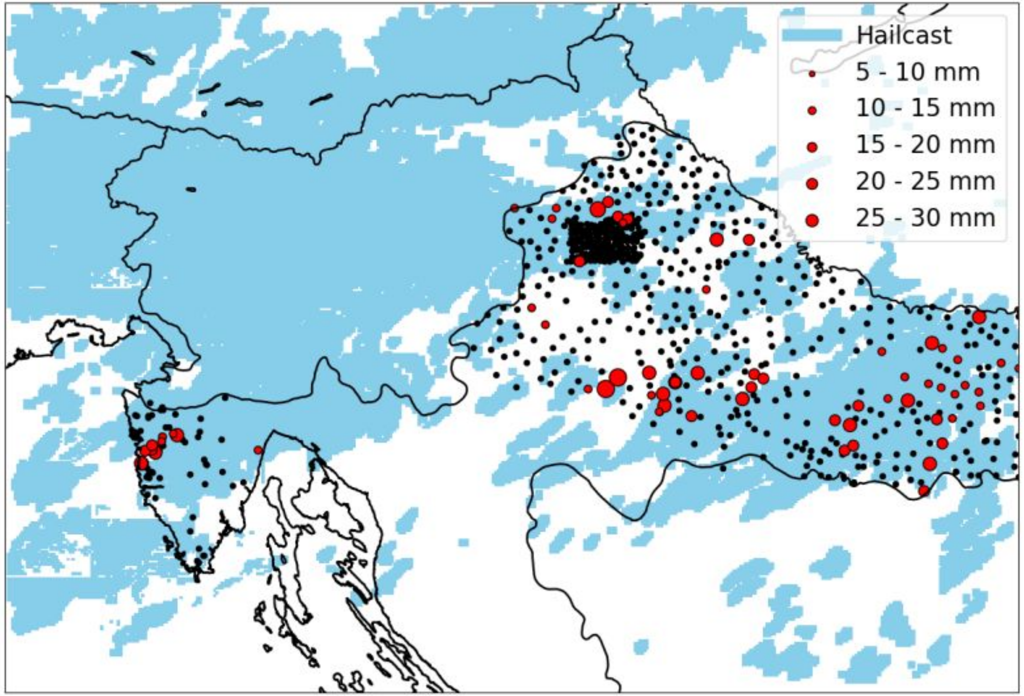
PBL and Microphysics Sensitivity Tests

- **PBL options** used:
  - Mellor-Yamada-Nakanishi-Niino (**MYNN**) 2.5 level TKE scheme
  - Bougeault and Lacarrere (**BouLac**) PBL scheme
  - Yonsei University (**YSU**) scheme

- **Microphysics options** used:
  - Morrison 2-moment scheme (**Morr**)
  - Lin et al. scheme (**LIN**)
  - WSM 6-class scheme (**WSM6**)
  - Thompson scheme (**Thomp**)

PBL	Microphysics
MYNN	Morr
MYNN	LIN
MYNN	WSM6
BouLac	Morr
BouLac	LIN
BouLac	WSM6
BouLac	Thomp
YSU	Morr
YSU	LIN
YSU	WSM6

WRF - HAILCAST simulation results

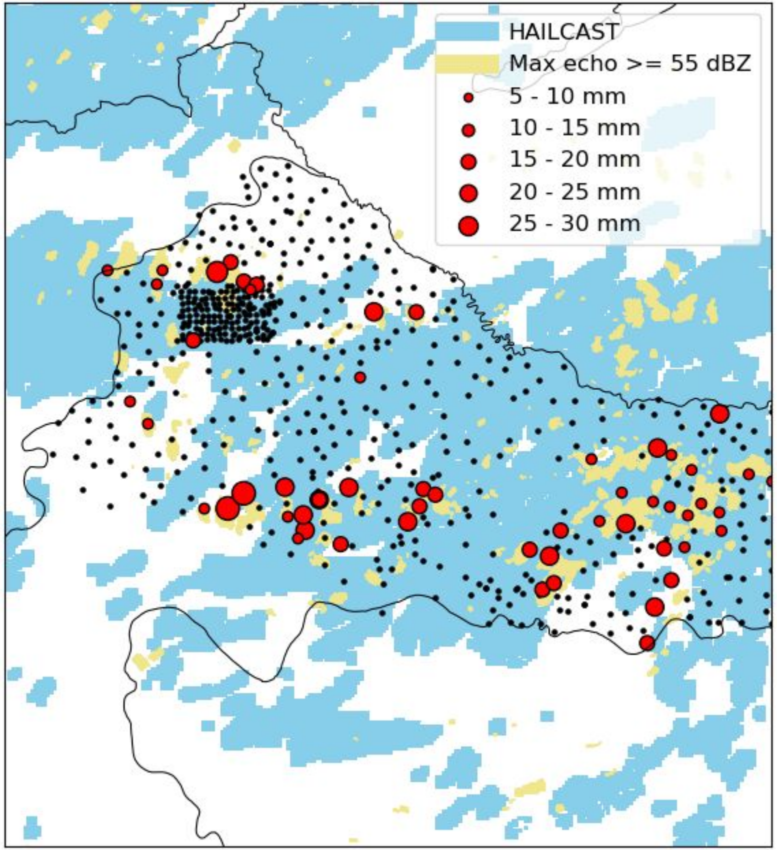


Results for MYNN - Morrison setup.

The blue area indicates locations at which hail was forecasted within the span of 24 h. Black dots represent hail pads. Those pads that registered hail are marked with red circles. Maximal hailstone diameter is represented with the size of a red circle.

Here we can clearly see that the model overforecasts the area. That is true in most of the analyzed simulations.

WRF - HAILCAST vs Zmax



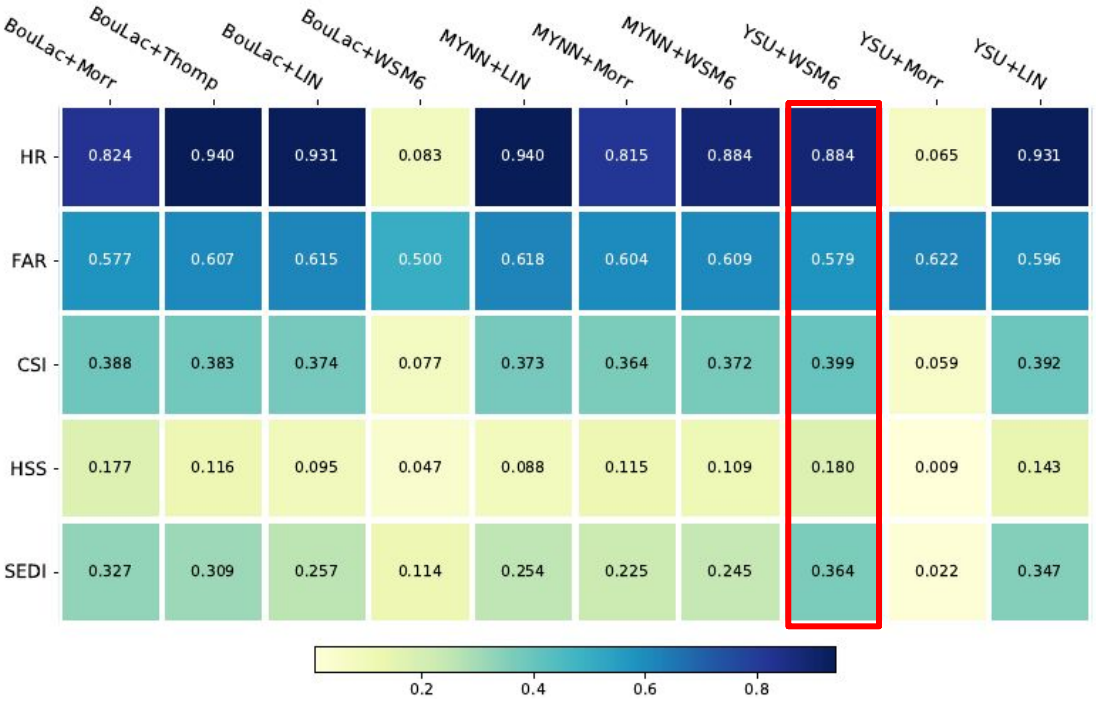
YSU - WSM6 setup vs Zmax.

On the figure, the blue area represents locations with simulated hail and brown shading indicates the area with Zmax values >= 55 dBZ. Zmax values bigger or equal to 55 dBZ indicate that hail is probable.

To verify WRF-HAILCAST results in regard to Zmax values allowable displacement of 10 km is defined; it is acceptable that forecast is displaced 10 km from observations and still be useful.

The domain is divided into 10x10 km neighborhood windows, contingency table and categorical skill scores are computed.

WRF - HAILCAST vs Zmax - Performance Diagram



Performance Diagram.

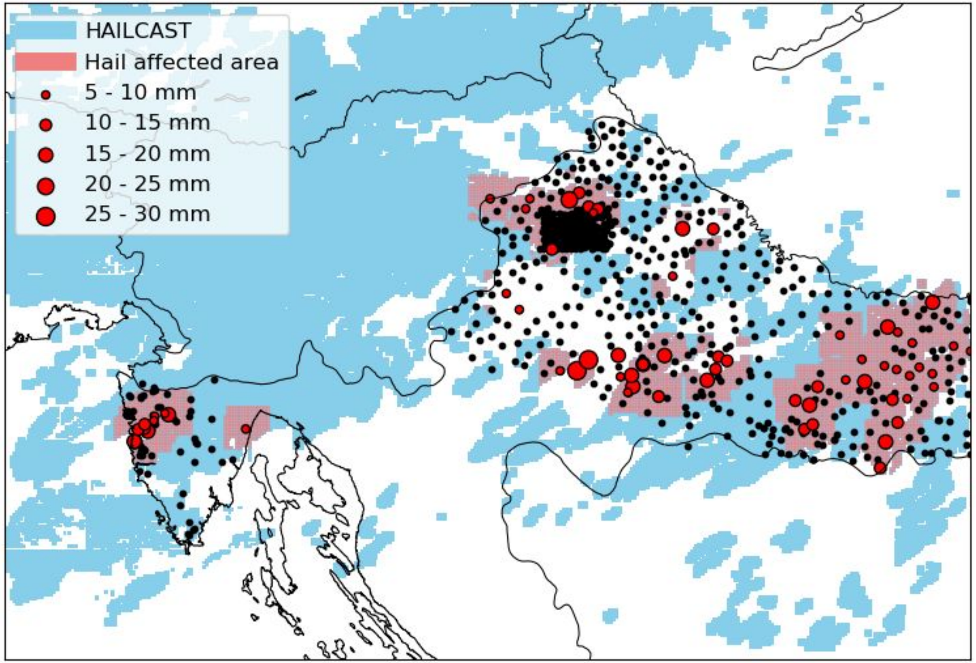
FAR, CSI, HSS, and SEDI suggest the best PBL - Microphysics setup for this case is YSU - WSM6.

BouLac - WSM6 and YSU - Morr performed the worst with hit rates (HR) smaller than 10 %.

It is important to note that some of the mismatching of WRF - HAILCAST and Zmax fields is due to radars relatively scarce sampling frequency.

WRF-HAILCAST vs. HAIL PADS

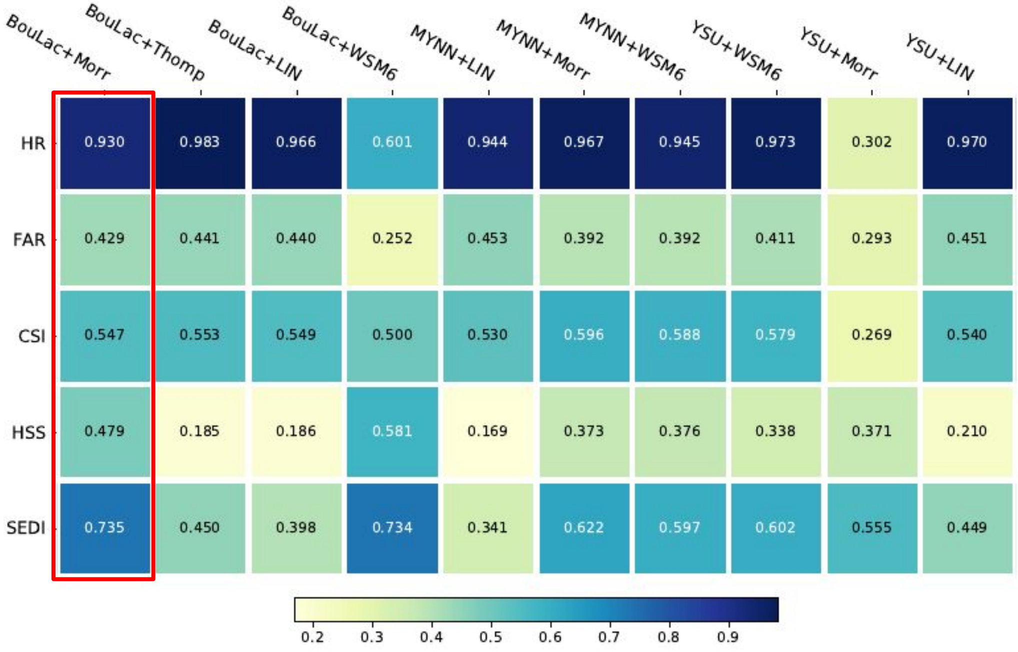
BouLac - Morrison Results



To verify model results regards to hail pad measurements we assume that the forecast can be displaced from observations up to 10 km and still be useful. Therefore, we define a hail affected area as (i) the area where hail was simulated and (ii) the area that is within 10 km from the pad that registered hail.

Considering hail affected area a contingency table was constructed. Every station that is within a hail affected area, even if hail was not observed at that particular station, is considered as a hit in the contingency table.

WRF-HAILCAST vs. HAIL PADS - Performance Diagram

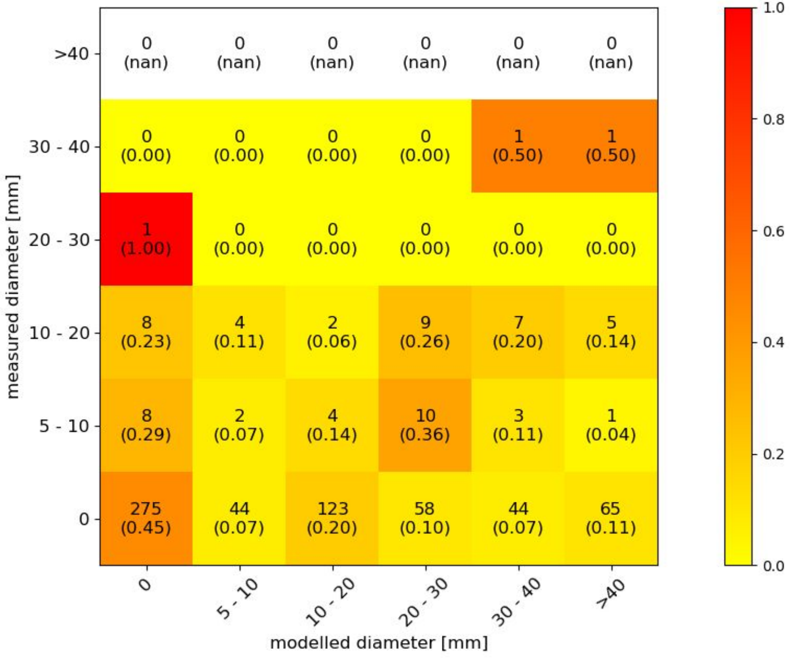


Performance Diagram.

It is important to notice that the differences between HR, FAR and CSI of different setups are small. On the other hand, values of SEDI and HSS fluctuate more.

Again, BouLac - WSM6 and YSU - Morr performed the worst with hit rates (HR) smaller than 60 % and 30 %, respectively. If we do not consider these setups, SEDI and HSS suggests BouLac - Morrison performs the best.

WRF-HAILCAST vs. HAIL PADS - Diameters



BouLac - Morrison hailstone diameter diagram.

A comparison between measured and modelled hailstone diameter is shown. Point to point verification is used - to every hail pad station, the maximal value of modeled hailstone diameter inside a radius of 2 km is assigned.

The number within each bin is the number of matched measured-modeled pairs; color shading is normalized by the total number of measured-modeled pairs inside each row. The perfect forecast would have maximal values on diagonal and zeroes elsewhere.

Here we can see that the model overpredicts an area; the majority of values are in the first row where no hail is observed. Moreover, it is clear that the model mostly overestimates measured diameters.

Conclusion

- Sensitivity of WRF - HAILCAST results to several PBL and Microphysics options is assessed. Simulation results are compared to radar Zmax values and hail pad observations.
- Several choices proved to be inadequate for the analysed case - Boulac - WSM6 and YSU - Morrison.
- Other options produced relatively similar results, however, YSU - WSM6 and BouLac - Morrison might be optimal choices for this particular case.
- Further testing needs to be done, including analysis of more cases and further testing of verification method thresholds.

Thank you for your time!

- For any discussion on the topic feel free to contact me via bmalecic@gfz.hr
- Skype is also preferred option