

HailSens360

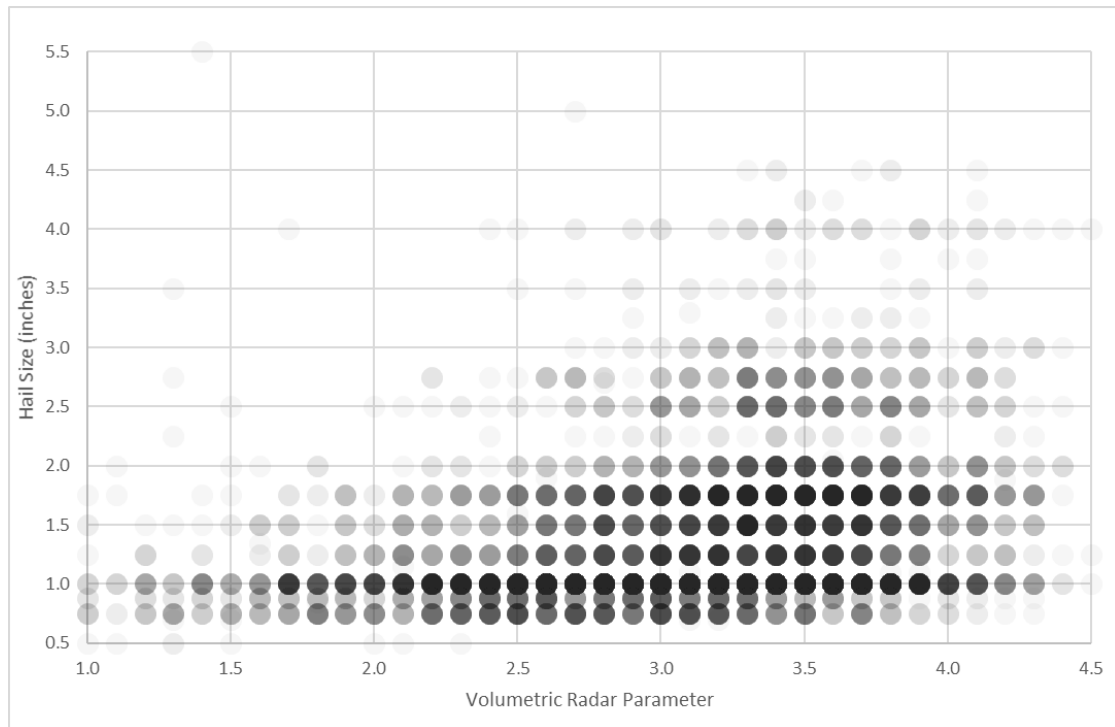
From radar data to hail size

KISTERS Group



Potential hail size occurring in convective cells can be estimated from radar data. In HailSens360, we use a volumetric radar parameter (derived from 3D-radar data) to derive the maximum hail size.

The following figure is based on several thousands of severe hail events from NCEI's Storm Events Database. For every hail event, we derived the volumetric radar parameter from historical radar data. The dots symbolize the hail size in inches (left axis) and the highest corresponding volumetric radar parameter in the near vicinity and time (bottom axis). The darker the dots, the more frequently the respective combination occurred.



The figure shows that specific hail sizes occur at a relatively large range of volumetric radar parameters. This has different reasons. The volumetric radar parameter is derived from the vertical distribution of the returned radar signal up to a high altitude above the surface, while the observed hail size is the one that actually made it to the ground.

Due to the turbulent nature of hail storms, the hail falling to the ground can be of different size than the one observed by the radar at larger heights. That is why we not only use the radar data at the reported location but also within the vicinity to find the highest value. In that respect, we investigated the optimal distance/box sizes to the reported location using different area scenarios.

Furthermore, the observed hail size in the database is a maximum hail size report on a specific point and might not be representative for the specific hail storm.

Although the possible range for the hail size is relatively large for a specific volumetric radar parameter, one can see in the figure that there is a relation. Higher volumetric radar parameters are correlated to larger hail sizes. We used the upper quartile of the maximum hail sizes for a specific volumetric parameter value. These percentiles can be fitted to a trend line. We compared numerous fitting equations and their quality to come to the best fit selection.

Nowcast – from continental to local scale

In our terminology, nowcasts are short range forecasts based on latest radar observations. Sequences of at least two of the latest volumetric radar parameter images are used to calculate motion of the intensity pattern by optical flow methods. The intermediate step is a displacement vector at each point of the last radar image. The nowcast extrapolates the future position of each intensity of the last radar image along the trajectories given by the calculated velocity field (Figure 1).

Our algorithm determines in a first step coherent areas of hail situations. Applying optical flow methods on such area selections gives much better results than on a very large domain as the US and it reduces computation time. Finally, we compose these areas and extrapolate the nowcast for the whole domain at once.

Depending on patterns, distributions, motions and evolutions on a radar image sequence the different optical flow methods lead to different nowcast quality. That is why we decided to use more than one [pySTEPS](#) method. We combine [DARTS](#), [VET](#), [Proesmans](#) and [Constant](#) on an area selection and finally apply the one that best transforms the second last radar image into the most recent one.

The extensive calibration of the equations between volumetric radar and hailsize, in combination with the research on how to select different optical flow methods and their respective parametrisation to optimize the results, make this a unique product.

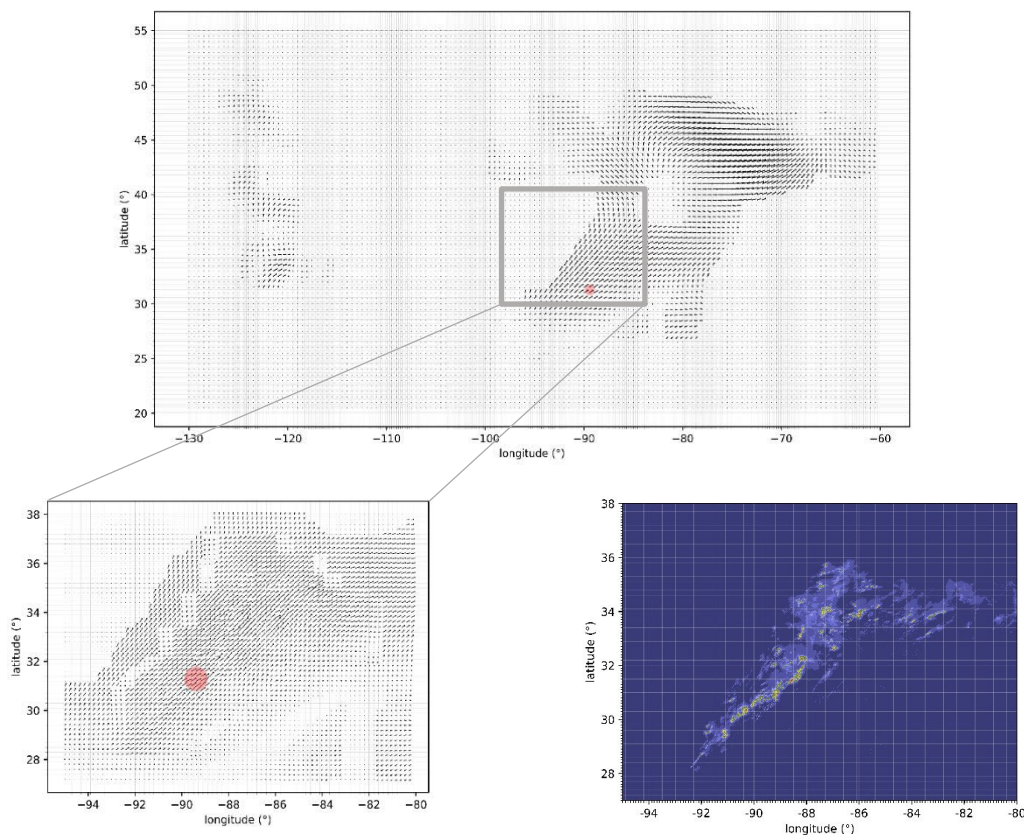


Figure 1: Illustration of the way from large continental scale to very small local scale of a severe hail event on 4 January 2023 at 06:18 UTC. On top: Example of displacement speed and direction within the whole domain. Lower left: Zoom in of the motion vector field that is applied to the volumetric radar parameter intensities on lower right. The red mark denotes the area around Baton Rouge, Hattiesburg with severe hail observed.

Hail events typically evolve quickly. Hailstone size significantly increases or decreases within an hour, so within the time frame of our nowcast. A lot of research was done on box sizes and lead times of our nowcast to optimize its operational use. Selecting the criterium that a location should be 'alarmed' if hail size of at least 1 pixel in the surrounding area is predicted higher than 0.35 inches led to an optimal operational use of the HailSens360 nowcast with 25x25 pixel boxes and a lead time of 60 minutes. As an example, for the above described hail event, the 60 minutes nowcast achieved a hit rate of about 90% for hailstones larger than 0.75 inches by a false alarm rate of just 0.16 %. These are typical numbers when validating hail events.

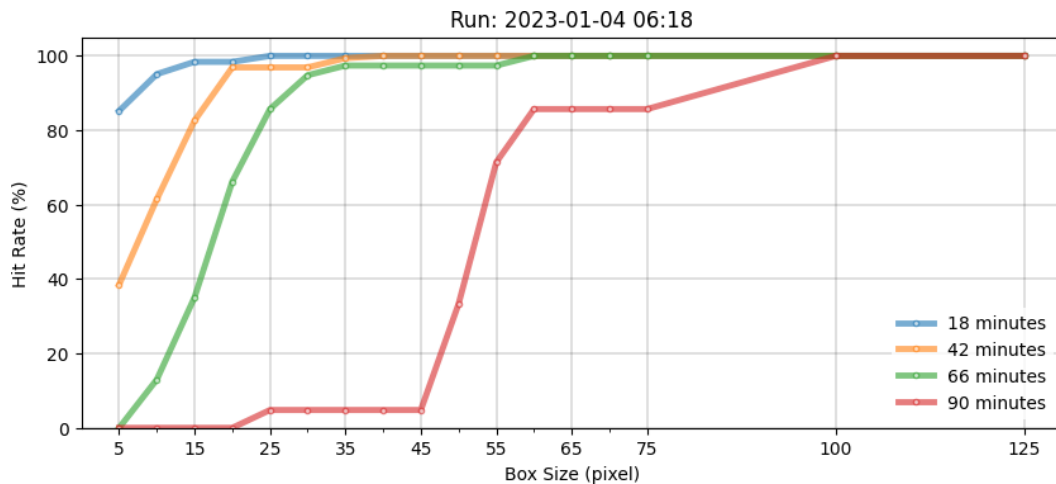


Figure 2: Dependency of hit rate and location box size for different lead times. As from the above, hit rates of about 90% are achieved for 60 min lead times using box sizes of 25x25 pixels. The dependency of box size vs lead times can support the optimisation of alarming thresholds for specific assets.

As from the above-mentioned research, we observe frequently reliable high hit rates at least until 60 minutes nowcasts with the suggested location definition of 25 pixels. Beyond that lead time, hit rates drop off and can get much lower. As a result, the last 30 minutes of the 90 minutes nowcast should generally be considered as indicative. The lead time dependency shown in Figure 3 can offer a good guidance for decisions based on our hail size nowcast.

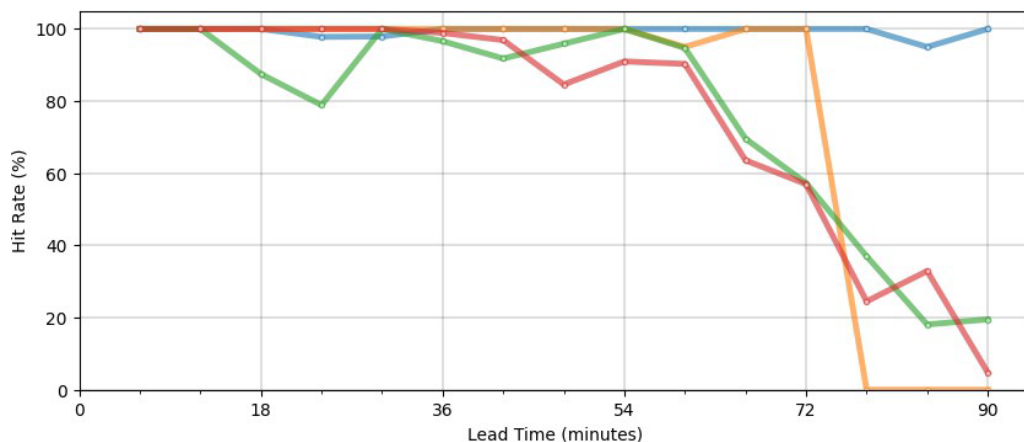


Figure 3: Lead time dependency of the hit rate for 4 nowcasts in different situations. Typically nowcast are very reliable with a 60 min leadtime, for longer periods nowcast should be considered as indicative.