5th International Workshop on Climate Informatics
September 24-25, 2015
Hosted by the National Center for Atmospheric Research in Boulder, CO

A TRACK-BASED COMPARISON OF MODELED AND OBSERVED HAILSTORM PROPERTIES

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Abstract—**Track-based analysis of convection-allowing models is an efficient way to compare the properties of storms produced with different model configurations to observations. Storm morphology and evolution can be easily analyzed simultaneously. This project examines the properties of hailstorm proxy objects from a storm-scale ensemble and compares them with radar-observed hailstorms. An evaluation of successful matches by ensemble member is performed, and other properties of the forecast and observed hailstorms are examined.**

I. MOTIVATION

Convection-Allowing Models (CAMs), or numerical weather prediction models that explicitly depict deep convection without a parameterization scheme but do not resolve turbulence and cloud entrainment [1], have begun transitioning from research to operational use. Given the many parameterization schemes available, evaluation of the convection depictions from different parameterization combinations is necessary. For over a decade, the National Oceanic and Atmospheric Administration (NOAA)/Hazardous Weather Testbed (HWT) Experimental Forecast Program Spring Experiment [2] has subjectively and statistically evaluated deterministic and ensemble CAM runs in real-time. One evaluation method treats individual storms as objects and compares the statistical properties of the forecast and observed storm objects. Using an object-based approach greatly reduces the computational complexity of the analysis by distilling large grids into focused areas of interest. Object-based comparisons have been performed on rainfall events in [3] and [1] and on tornado tracks in [4]. Unlike earlier approaches, which either did not track objects over time or did not match forecast and observed tracks, this project matched forecast and observed hailstorm tracks and extracted properties associated with both.

The goal of this project is to compare the properties of different forecast and observed hailstorm tracks to determine which set of parameterizations consistently produced the most accurate storm representations. By using a spatiotemporal track matching scheme, forecasts from models with different configurations can be directly compared over a series of runs.

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II. METHOD

Model forecasts for this project come from the Center for Analysis and Prediction of Storms 2015 Storm-Scale Ensemble Forecast (SSEF) system. The SSEF consists of 12 WRF-ARW [5] models with varied combinations of microphysics and planetary boundary layer (PBL) parameterization schemes. The model domain extends over the contiguous United States at 3 km horizontal grid spacing and was initialized at 0000 UTC and output forecasts hourly for 60 hours. The SSEF was run every weekday from 12 May to 5 June 2015. Forecast hours 12 through 36 were analyzed. The hourly-maximum column-integrated graupel mass was used as a hail proxy.

The NOAA National Severe Storms Laboratory Multi-Radar Multi-Sensor (NSSL MRMS) radar mosaic was used to find observed hail swaths. The Maximum Expected Size of Hail (MESH) product provides an estimate of hail diameter at the ground based on storm characteristics. The Radar Quality Index, an automated measure of radar coverage, was used to identify valid areas of the domain for analysis. MRMS products are natively produced on a 1 km grid mesh, so the MRMS grid was interpolated to the model grid using cubic splines.

Forecast and observed hailstorm tracks are constructed by identifying storm objects in each time step and then using a tracking method to match objects between time steps. The enhanced watershed technique [6], a watershed transform constrained by additional size and intensity criteria, was used to identify hail swaths within the hourly maximum column-integrated graupel and observed hourly-maximum MESH fields. Objects were allowed to range in size between 10 and 100 pixels.

Objects were merged into tracks by using a hybrid motion adjustment and optimal matching method [7]. A

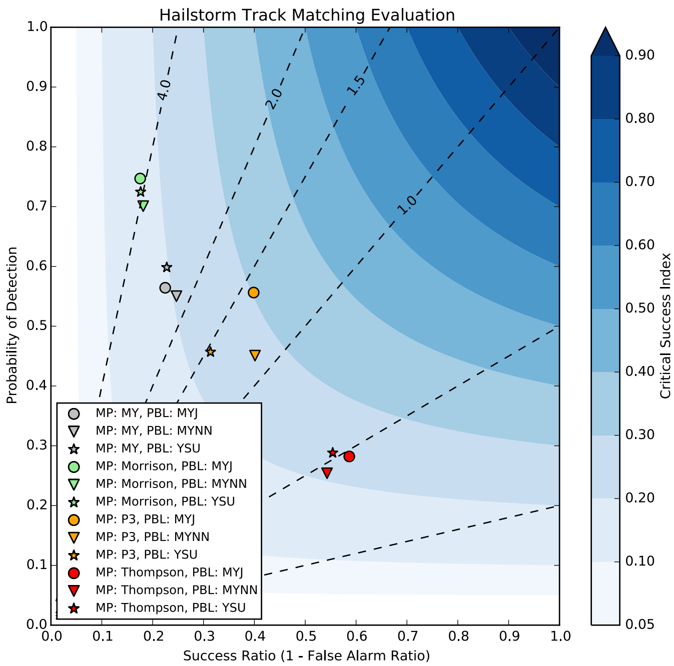

Fig. 1. Performance diagram evaluating how well modeled and observed hail tracks are matched by ensemble member. Color indicates the microphysics scheme, and the symbol indicates the PBL scheme.

cross-correlation filter identified the most likely motion vector. Objects would be considered for matching if the adjusted centroid distance was less than 30 km. The cross-correlation filter search radius was constrained to the shape of the object. Matching among forecast and observed hailstorm tracks was performed using the Hungarian matching method [8] but with a cost function that accounted for differences in centroid locations, times, and durations. To compare tracks with varying numbers of time steps, distances among all centroids were calculated, and then the mean of the minimum distance from each centroid to the centroids of the other object was used as the final cost function.

Evaluation of the matching procedure was performed by determining what proportion of forecast tracks were matched with observed tracks. Forecast tracks with no matching observed track were considered false alarms, and observed tracks with no matching forecast track were considered misses. With three-quarters of the full contingency table, the probability of detection (POD), false alarm ratio (FAR), critical success index (CSI), and frequency bias can be calculated. The performance diagram [9], a plot of POD versus 1-FAR, allows for the viewing of these four statistics simultaneously.

III. EVALUATION

Figure 1 shows a performance diagram indicating the relative skill of each member. The dotted lines indicate frequency bias, and the blue contours show different levels of CSI. The members are clustered by microphysics with smaller variations caused by the PBL scheme. The Morrison and Milbrandt and Yau members both produce more forecast than observed tracks resulting in a higher POD but also a high FAR. P3 retains a higher POD but with a reduced FAR, resulting in a more realistic depiction of hailstorm chances. The Thompson members produce fewer forecast hailstorms than observed such that 70% of observed storms are missed. The MYJ and YSU PBL schemes recorded similar statistics with all members, but the MYNN consistently had lower POD. Analysis of durations shows that tracks from all members follow similar exponential distributions and that the relative frequencies match observations. Additional analysis will examine the distributions of object properties plus space and time errors. Object properties will be compared by forecast hour, geographic area, and environmental conditions.

ACKNOWLEDGMENTS

This work was funded under the Severe Hail Analysis, Representation, and Prediction project through NSF Grant AGS-0802888.

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