Developmental Testbed Center Visitor Program Final Report: Object-based time-domain diagnostics for high-resolution ensemble forecasting and evaluation in NOAA/HWT Spring Forecasting Experiments

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1. Background

The DTC has a long history of successfully supporting activities in annual NOAA/Hazardous Weather Testbed (HWT) Spring Forecasting Experiments by providing forecast verification metrics in near real-time using DTC's Model Evaluation Tools (e.g., Clark et al. 2012a; Jensen et al. 2010a, b). One of the main goals of this project is to enhance this HWT/DTC partnership through more direct interaction of Spring Forecasting Experiment organizers with DTC to provide the types of displays and diagnostics most relevant to HWT interests. The recent development of the Method for Object-based Diagnostics Evaluation Time-Domain (MODE-TD; Davis et al. 2009) offers a unique opportunity for enhancing this partnership because consideration of the time-dimension in an object-based framework allows straightforward diagnosis of convective system properties most important to HWT interests including initiation, timing, evolution, translation speed, and maximum intensity. Some of the unique diagnostics and verification strategies made possible by MODE-TD have already been illustrated in Clark et al. (2014), work that emanated from a previous DTC Visitor Program project.

After discussion with the DTC collaborators Tara Jensen and Randy Bullock it was decided to narrow the focus on this project to using MODE-TD for identifying simulated supercells in high-resolution model data. There were many challenges in formulating and applying MODE for this purpose, so much of the two two-week long visits were spent on development and testing of the algorithm. Fortunately, I was able to work closely with Randy Bullock, and he was very instrumental in getting MODE-TD to work effectively for the proposed application. Further testing, coordination, and development of the website for forecast visualization was accomplished at the PI's home institution. Overall, similar to my past experience with the DTC Visitor Program, working on this project was very productive and rewarding and the support staff at DTC went above and beyond to make it successful. Currently, an article describing the idea of using MODE-TD for identifying simulated supercells is in preparation. Because this application is meant to be a forecasting tool, the article will be submitted to the National Weather Association *Journal of Operational Meteorology*.

2. Project Goals and Motivation

The specific goal of this project is to use MODE-TD as a *forecasting* tool, which was an application of MODE first proposed by Gallus et al. (2010) and differs from traditional applications of MODE geared towards verification. Furthermore, the use of MODE-TD as a forecasting tool follows the concept of "feature-specific prediction" proposed by Carley et al. (2011), which involves identifying features of potential interest in forecast fields and presenting them as guidance. Because this strategy extracts from very large datasets model output fields deemed most relevant to a particular forecasting application, it has the potential to greatly enhance forecaster efficiency. Carley et al. (2011) summarize feature-specific prediction by three simple steps: 1) determination of the feature type of interest, 2) feature identification and tracking, and 3) presentation to the forecaster for evaluation. The particular feature of interest in this project is simulated supercells as depicted by the NSSL-WRF model. The NSSL-WRF is an experimental 4-km grid-spacing configuration of the WRF model run twice daily at 0000 and 1200 UTC using NOAA computing resources with forecasts to 36 h covering a CONUS domain. The NSSL-WRF modeling framework has been used in NOAA/HWT Spring Forecasting Experiments since 2006 and was developed to provide storm-scale guidance to SPC forecasters and serve as a testing ground for the development and application of storm-scale model diagnostics. Supercells were chosen for examination because previous work has shown that the NSSL-WRF is capable of resolving large mesocyclone-scale circulations. Furthermore, although simulated storms using 4-km grid spacing are often unrealistically large, the NSSL-WRF often depicts realistic supercell structures as depicted by simulated radar reflectivity. Finally, forecasting supercells is of particular interest to the NOAA/HWT Spring Forecasting Experiment because supercells are responsible for a disproportionate share of severe weather reports compared to other types of convective modes (e.g., Doswell 2001).

3. Methodology

For supercell identification and tracking, the model diagnostic updraft helicity (UH) is used (e.g., Kain et al. 2010), which is the product of vertical velocity and vertical vorticity integrated over the 2 to 5-km above ground level. UH has been found to be a very useful field for identifying supercells in high-resolution forecasts (e.g., Kain et al. 2010; Clark et al. 2012b). However, because supercells evolve on very short time scales, model output frequency of about 5 minutes is needed for tracking, which results in very large data volumes that can inhibit efficient data processing. To mitigate the data volume issues, a new technique for outputting UH was developed. Instead of outputting entire forecast grids every 5 minutes, we output to a text file coordinates and values of UH for grid-points where UH was greater than 20 m^2s^{-2}. The 20 m^2s^{-2} was chosen based on past experience during the NOAA/HWT Spring Forecasting Experiments and analyses by Sobash et al. (2011) suggesting that 20 m^2s^{-2} is approximately a lower bound for distinguishing simulated storms with supercellular characteristics.

For supercell identification, the basic strategy was to "reconstruct" the 5-minute forecast grids of UH from the text files of UH coordinates and values and then input these grids into MODE-TD. For the initial identification of time-domain objects, a minimum threshold of 25 m^2s^{-2} was used and the objects had to consist of at least 10 grid-points. After time-domain objects were identified, two additional criteria were imposed for the UH objects to be considered supercells. First, the UH object was required to have a duration of at least 1 h or greater. This requirement was easily imposed because MODE-TD provides start and end times of objects. The duration 1 h was chosen rather arbitrarily, but appeared to distinguish well *sustained* mesocyclone-scale circulations, a defining characteristic of supercells. Second, the UH objects had to contain at least one grid-point with UH greater than 75 m^2s^{-2}. Enforcing this "double threshold" filtered out relative weak, but sustained swaths of UH that may have simply resulted from relatively strong vertical velocity, without a co-location of significant vertical vorticity.

One of the biggest challenges during the initial stages of this work project was the time it took for data processing and subsequent execution of MODE-TD software. Converting the UH text files into the NETCDF format required for input into MODE-TD, thresholding the fields, and finally outputting time-domain object attributes took about 40 minutes during initial tests. However, working closely with the MODE-TD developer, Randy Bullock, a number of changes were made in the data processing steps, as well as in the execution of MODE-TD software to speed up this process to about 15 minutes.

After supercells were identified using the UH time-domain objects, geographic information from each supercell object was combined with the attributes computed from MODE-TD into a shapefile.

Then, the shapefile was converted to a format known as “GeoJSON”, which allowed for display via an interface called “Openlayers”, which is essentially as open source version of Google Maps. This interface was tested during the 2013 NOAA/HWT Spring Forecasting Experiment and was developed in collaboration with Chris Karstens (CIMMS/NSSL). The interface was named the NSSL Experimental Data Explorer. The combination of geographical information and object attributes and subsequent display facilitated the third step of feature-specific prediction – presentation to the forecaster for evaluation. Figure 1 shows an annotated example of this display for supercells that were simulated by the NSSL-WRF initialized 0000 UTC 19 May 2013, a day during which multiple tornado-producing supercells occurred over central Oklahoma. The display interface allows many user-interactive features including zooming capabilities and the ability to click on supercell objects and choose from a number of associated attributes (e.g., maximum UH intensity) or environmental fields (e.g., CAPE and height of the lifting condensation level) to plot their evolution as a function of supercell object lifetime.

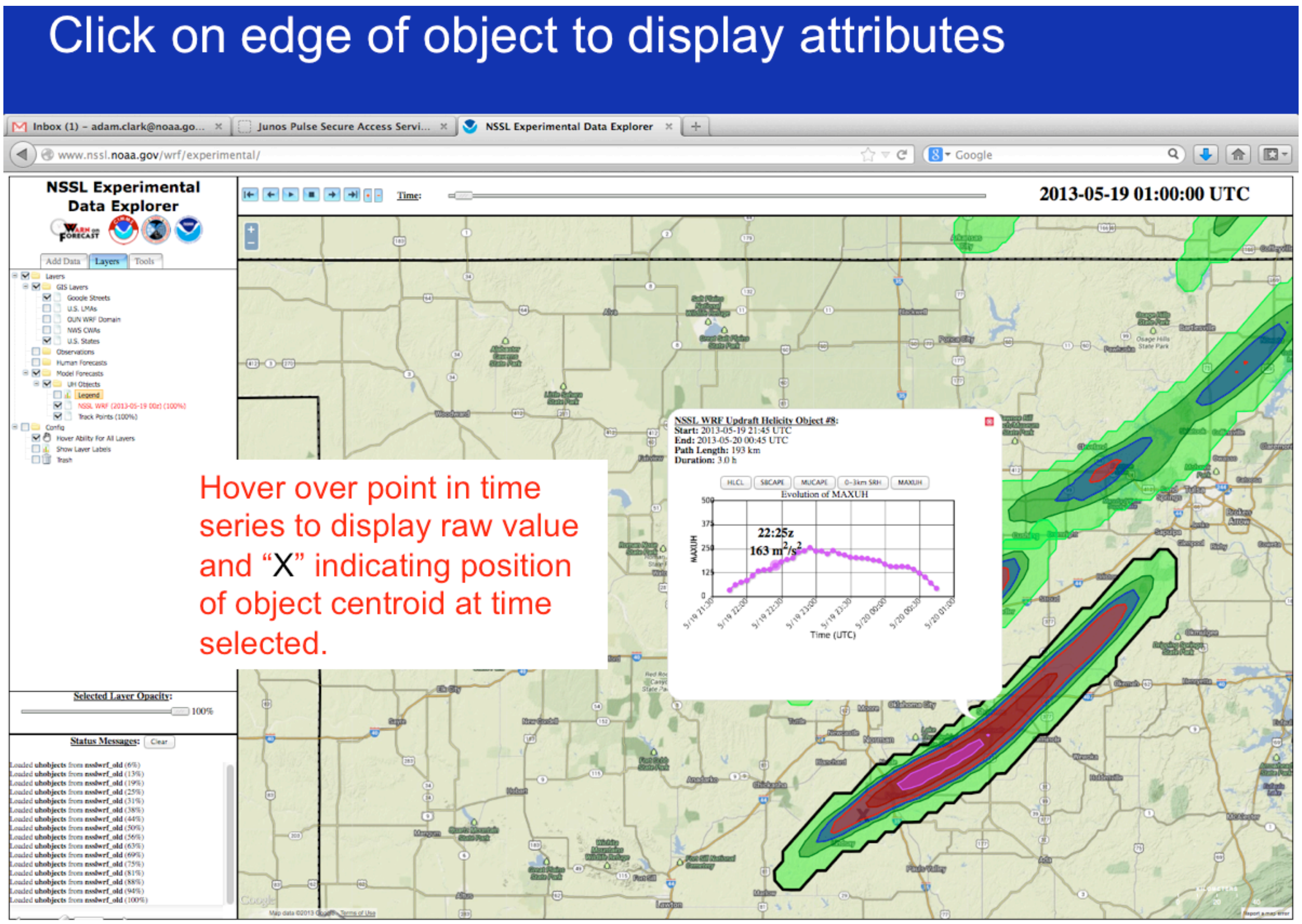

Figure 1 Annotated example display from the NSSL Experimental Data Explorer for supercells identified from the 0000 UTC 19 May 2013 initialization of the NSSL-WRF.

4. Results and Future Work

The supercell identification algorithm is now automated and, similar to the 2013 Spring Forecasting Experiment, real-time displays will be available during the 2014 Spring Forecasting Experiment. Furthermore, the GeoJSON files that contain MODE-TD attributes are part of the fields provided to users via the NSSL ftp server. Further work is planned to advertise and describe these products on a new website for the NSSL-WRF model that is in development. Also, we have recently begun running a real-time NSSL-WRF based ensemble. The supercell identification algorithm will be run on the individual ensemble members in addition to the regular NSSL-WRF run. Additional challenges are related to the supercell identification criteria, which are relatively simple and often identify mesocyclone-scale circulations that are not associated with supercells. This is a difficult challenge and future work will have to use fields other than UH to distinguish non-supercell mesocyclone-scale circulations (e.g., Clark et al. 2014).

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