UNIVERSITY of WISCONSIN
UWMILWAUKEE

Predictability and Dynamics of the Overland Reintensification of Tropical Storm Erin (2007)

Clark Evans (a.clark.evans@gmail.com), UW-Milwaukee
Russ Schumacher, Colorado State University

Introduction

Previous research (Evans et al. 2011, *Mon. Wea. Rev.*) illuminated the contributing role of land-surface interaction to the overland reintensification of Tropical Storm Erin (2007) across Oklahoma. Specifically, enhanced soil moisture across the southern Great Plains – particularly that across south-central Texas associated with Erin itself – permitted the maintenance of boundary layer moisture against vertical mixing along inflowing trajectories. This promoted the development of robust convective updrafts in Erin's inner core and, in turn, enabled Erin to reintensify over land. In this follow-up study, utilizing ensemble-based methods, we seek to quantify the predictability and dynamics of this atypical overland reintensification.

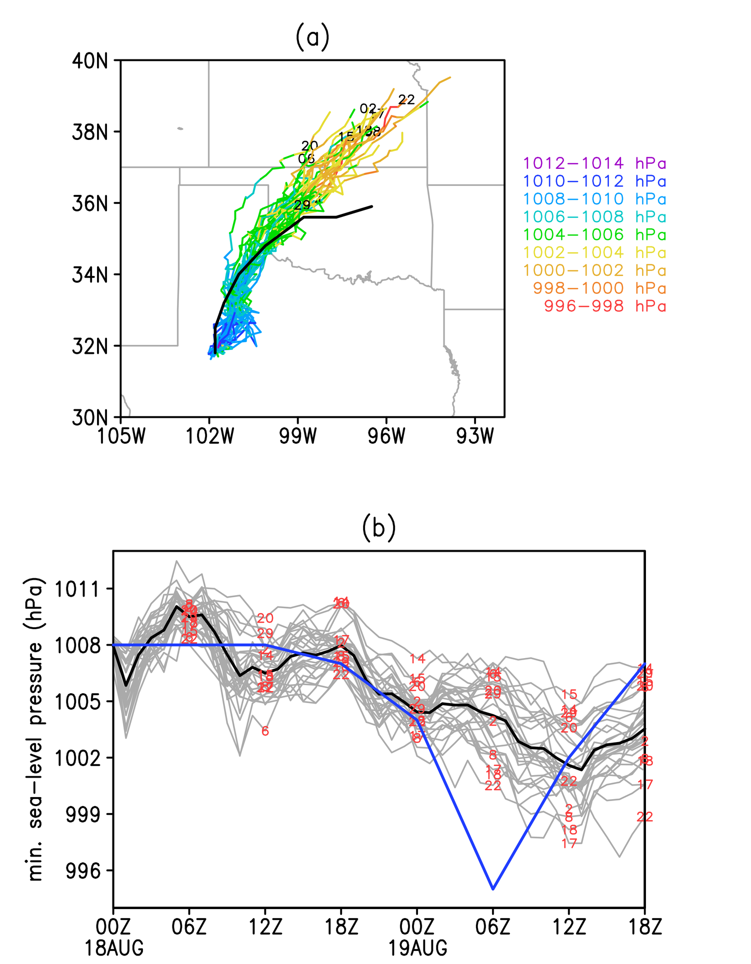

Figure 1: (a) Simulated Erin tracks (shaded) and the NHC "best track" (black). (b) Minimum sea level pressure (hPa) from all ensemble members (grey), the ensemble mean (black), and the NHC "best track" (blue). Red numbers indicate the five strongest and weakest forecasts of Erin.

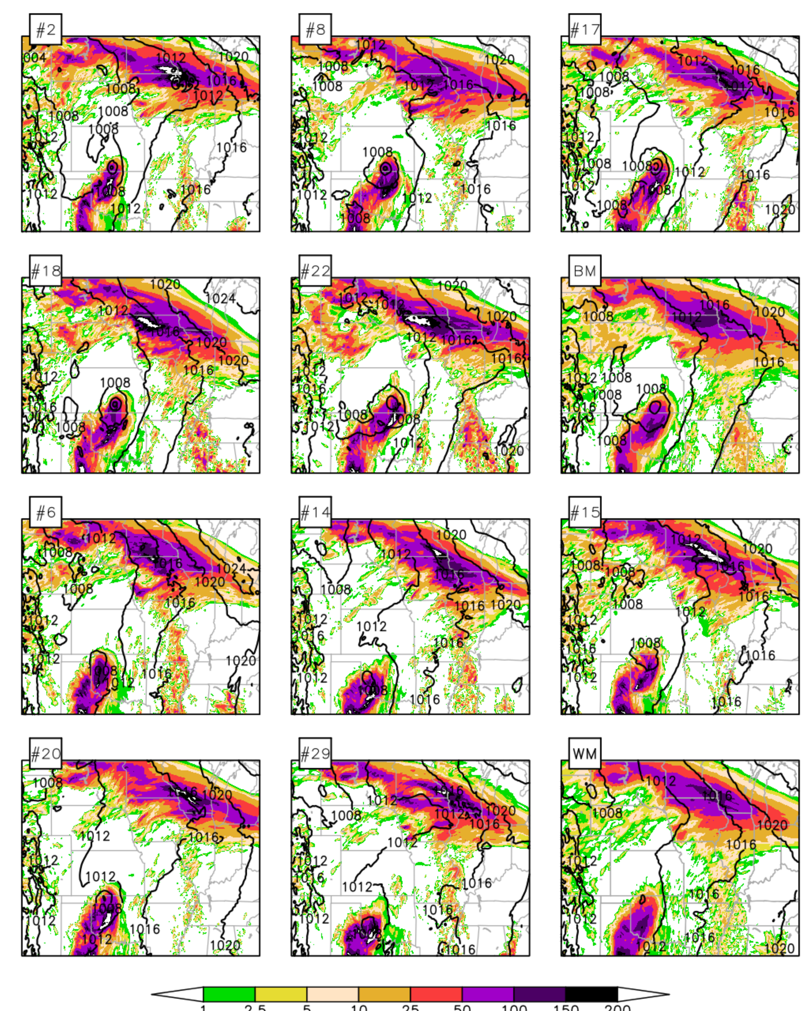

Figure 2: 24-h accumulated precipitation (mm, shaded) and mean sea level pressure (hPa, contoured) valid 1200 UTC 19 August 2007 from the five (a-e) strongest and (g-k) weakest forecasts. The strongest and weakest composite means are presented in panels (f) and (l), respectively.

Numerical Experiment Configuration

The ensemble adjustment Kalman filter embedded within the Data Assimilation Research Toolkit (DART; Anderson et al. 2009, *Bull. Amer. Meteor. Soc.*), in conjunction with the Advanced Research version of the Weather Research and Forecasting model (WRF-ARW) version 3.4.1, is utilized to assimilate observations and generate initial conditions for ensemble forecasts. A thirty-member ensemble with 36 km horizontal grid spacing is run during the assimilation process over a domain that encompasses much of North America. Assimilated observation types and the parameters utilized to assimilate those observations follow those of Schumacher and Clark (2014, submitted to *Mon. Wea. Rev.*). The ensemble is initialized at 1800 UTC 17 August 2007 by adding thirty random draws of the NCEP background error covariance matrix to the 0-h GFS analysis. Observations are assimilated until 0000 UTC 18 August 2007, at which time the updated ensemble initial conditions are utilized to initialize a thirty-member ensemble of convection-permitting numerical simulations (dx = 4 km, 51 terrain-following vertical levels). Simulations extend forward 42 h and are conducted over a domain encompassing the central United States. Physical parameterizations utilized include the Morrison microphysics, YSU boundary layer, RRTMG shortwave and longwave radiation, and NOAH land-surface parameterizations. Lateral boundary conditions are obtained from the 1800 UTC 17 August 2007 GFS model forecast and are perturbed every 6 h utilizing the fixed covariance perturbation method of Torn et al. (2006, *Mon. Wea. Rev.*).

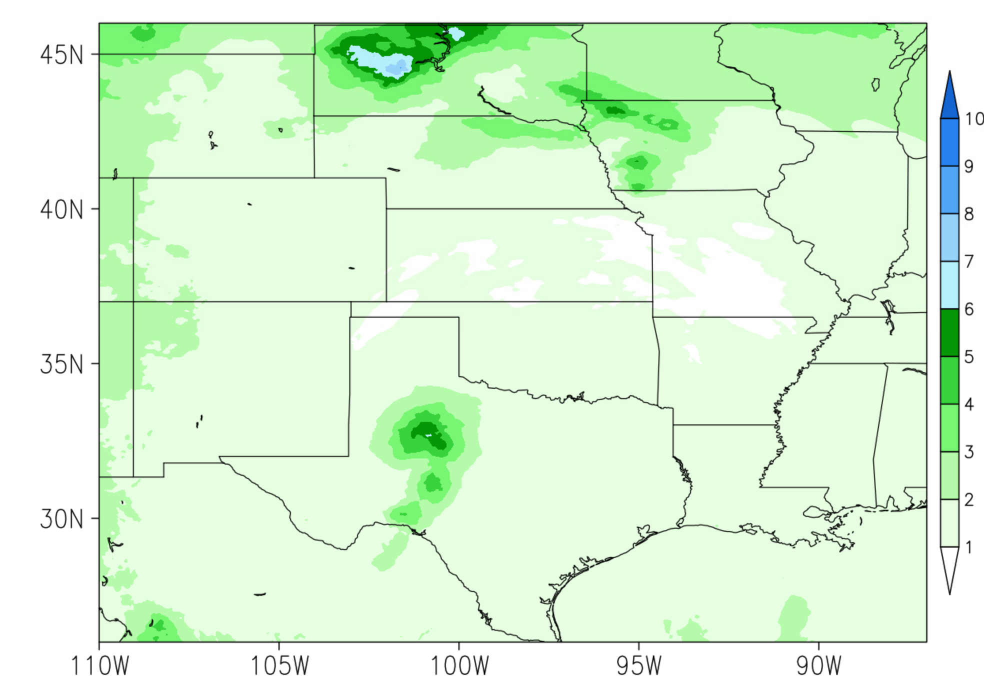

Figure 3: Vertically-averaged root mean difference total energy (m s^{-1}, shaded), computed following Melhauser and Zhang (2012, *J. Atmos. Sci.*) at 0600 UTC 18 August 2007.

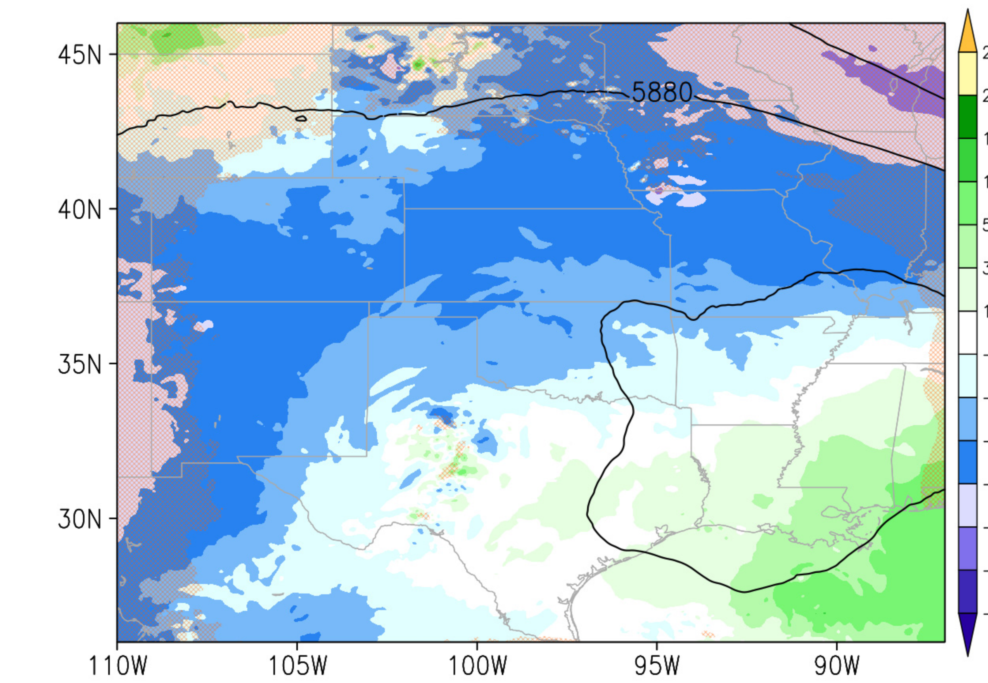

Figure 4: Strongest minus weakest composite difference in 500 hPa height (m, shaded), standard deviation of 500 hPa height (hatched at 7.5 m), and ensemble mean 500 hPa height (m, contour) at 0600 UTC 18 August 2007.

Ensemble Forecast Variability

Ensemble forecast tracks (Fig. 1a) are clustered about the forecast track of Erin from the 1800 UTC 17 August 2007 GFS forecast and are biased to the left of Erin's observed track. There exists substantial along-track variability along this track, however, with the slowest-translating Erin vortices located ≈500 km to the southwest of the fastest-translating Erin vortices by the end of the ensemble forecast. Ensemble forecast intensities vary by ≈8 hPa during the reintensification period (Fig. 1b) and are slightly weak-biased compared to observations. Interestingly, the location of the rainfall maximum associated with the predecessor rain event across the Upper Midwest in the weaker Erin forecasts more closely resembles observations than does that in the stronger Erin forecasts (c.f., Fig. 2 to Fig. 1 of Schumacher et al. 2011, *Mon. Wea. Rev.*).

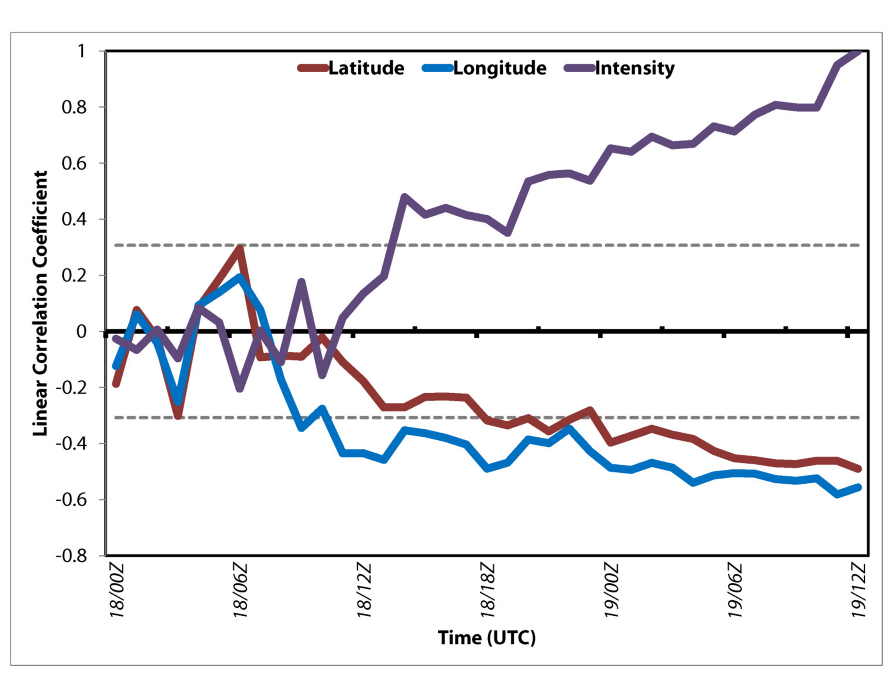

Figure 5: Linear correlation coefficient computed between the minimum sea level pressure valid at 1200 UTC 19 August 2007 and (Erin's latitude (red), longitude (blue) and minimum sea level pressure (purple) between 0000 UTC 18 August and 1200 UTC 19 August 2007.

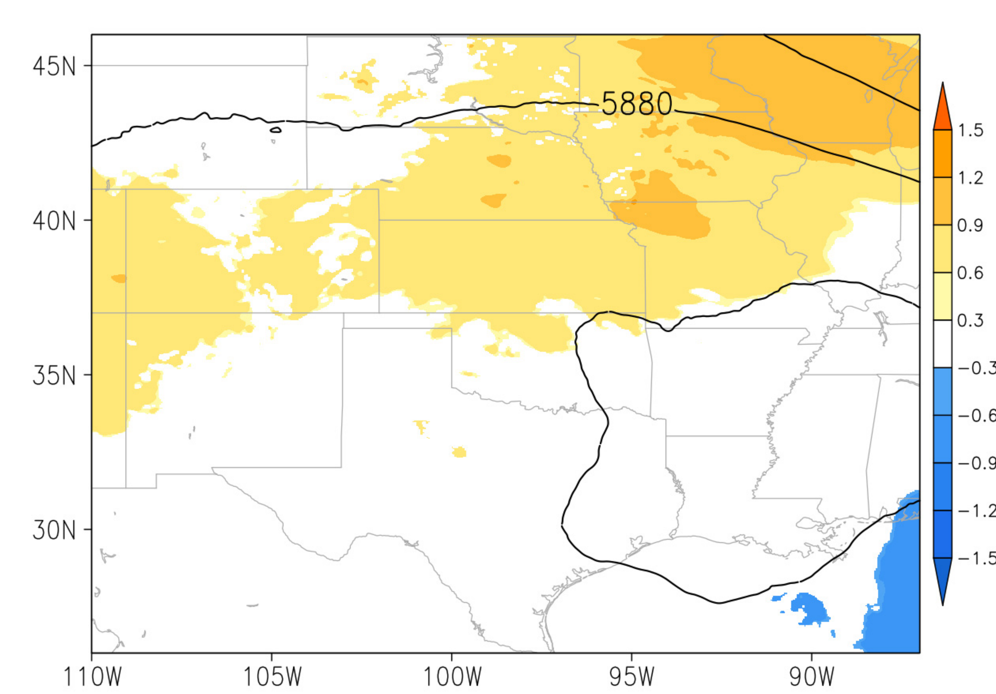

Figure 6: Sensitivity metric (shaded) between minimum sea level pressure at 1200 UTC 19 August 2007 and 500 hPa height (m; ensemble mean contoured) at 0600 UTC 18 August 2007. Sensitivity shaded only where the linear correlation is statistically-significant to >95% confidence.

Ensemble Spread and Predictability

Ensemble spread is at or below observational thresholds at the start of the ensemble forecast. However, the multivariate ensemble spread amplifies rapidly on the convective-scale (within the first 1-6 h; Figs. 3 and 4) and, subsequently, the mesoscale. Ensemble spread grows most rapidly with Erin; along the baroclinic zone across the northern Great Plains; and across the Intermountain West. The former two are associated primarily with deep, moist convection, whereas the latter is primarily associated with perturbations applied to the northern and western lateral boundaries. That selected members of the ensemble are able to reasonably replicate Erin's observed reintensification despite incorrectly forecasting Erin's track implies that it has limited predictability associated with its ties to inherently more predictable large-scale phenomena. However, the rapid growth (in both magnitude and scale) of ensemble spread associated with inherently less predictable deep, moist convection implies that there exists a low upper bound to such predictability.

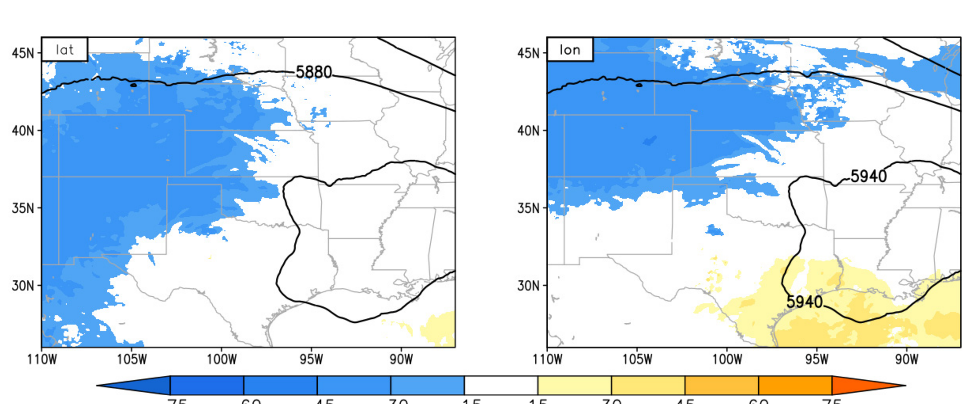

Figure 7: Sensitivity metric (shaded as in Figure 6) between Erin's simulated position (left: *y* grid point or latitude, right: *x* grid point or longitude) at 1200 UTC 19 August 2007 and 500 hPa height (m; ensemble mean contoured) at 0600 UTC 18 August 2007.

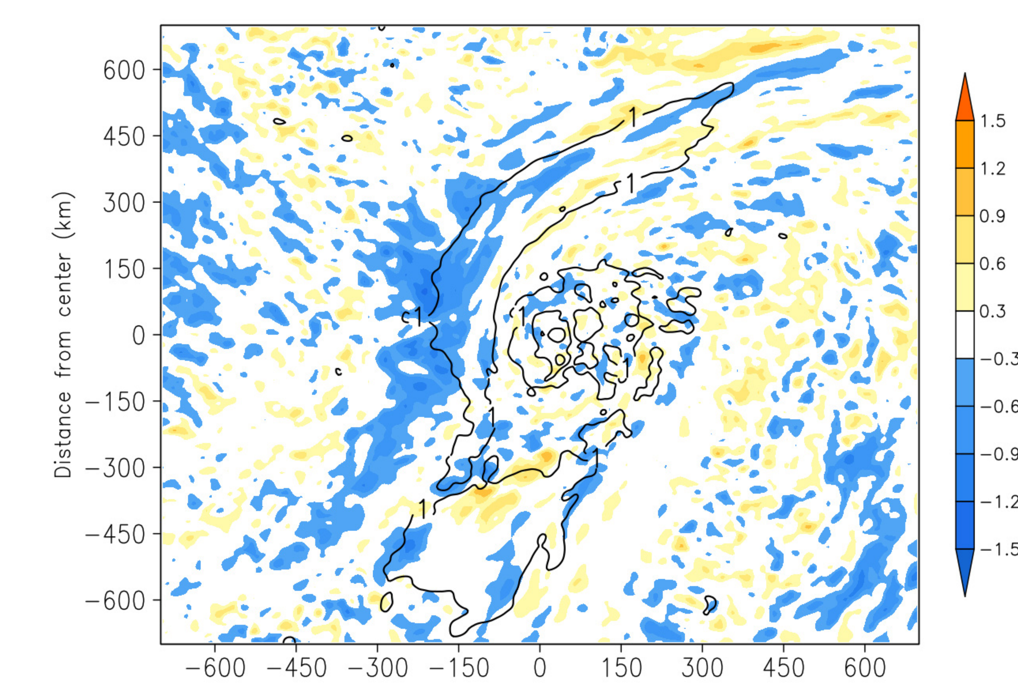

Figure 8: Sensitivity metric (shaded) between minimum sea level pressure at 1200 UTC 19 August 2007 and storm-centered isentropic potential vorticity (PVU; ensemble mean contoured) at 0300 UTC 19 August 2007.

Dynamics: Sensitivity and Correlation Analysis

Sensitivity (Torn and Hakim 2008, *Mon. Wea. Rev.*) and correlation (Sippel and Zhang 2010, *J. Atmos. Sci.*) analyses are conducted to identify correlations between Erin's peak simulated intensity and selected metrics. After 1500 UTC 18 August 2007, a stronger simulated Erin that is located further to the north and east is indicative (to >95% confidence) of a more intense Erin during the reintensification period (Fig. 5). At all lead times, a southward displacement of the synoptic-scale pattern is associated with a more intense Erin (Fig. 6) that is located further to the north and east during the reintensification period (Fig. 7). Finally, Erin's peak simulated intensity is sensitive after 0000 UTC 19 August 2007 to the structure of an upstream upper tropospheric potential vorticity streamer, whereby a wider potential vorticity streamer that more closely matches the horizontal scale of the reintensifying cyclone is associated with a stronger peak simulated intensity. Further investigation is necessary, however, to elucidate the precise physical connection underpinning these correlations.

Ongoing and Future Work

Questions remaining to be answered include:

1. What is the contribution of the forecast variability in the synoptic-scale pattern to Erin's simulated intensity?
2. What is the contribution of the potential vorticity streamer immediately upstream of Erin to Erin's simulated intensity?
3. What is the contribution of deep, moist convection to both Erin's predictability and simulated intensity?

We hypothesize that variability in the synoptic-scale pattern modulates the source region for inflowing lower tropospheric trajectories, thereby influencing boundary layer moisture content and simulated deep, moist convective intensity. We further hypothesize that the potential vorticity streamer influences Erin's simulated intensity through PV superposition and scale matching processes (e.g., Hanley et al. 2001, *Mon. Wea. Rev.*) and modulation of large-scale forcing for ascent. Focused sensitivity and correlation analyses and backward trajectory analyses are planned to test these hypotheses.