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Wet Weeks in the Warm Season: Processes Supporting Widespread, Multi-day Precipitation Episodes

Russ S. Schumacher

Department of Atmospheric Science, Colorado State University, Fort Collins, CO

1. Introduction

Multi-day periods in the warm season in which heavy precipitation falls across a large region are not always well predicted even a few days in advance of the onset of heavy rain. Yet these events are also very important in the context of seasonal climate prediction, as an event of this type can result in a large fraction of the rainfall in a particular region. This research will outline some of the processes typically associated with widespread heavy rainfall and will evaluate the performance of global ensemble prediction systems for several recent events.

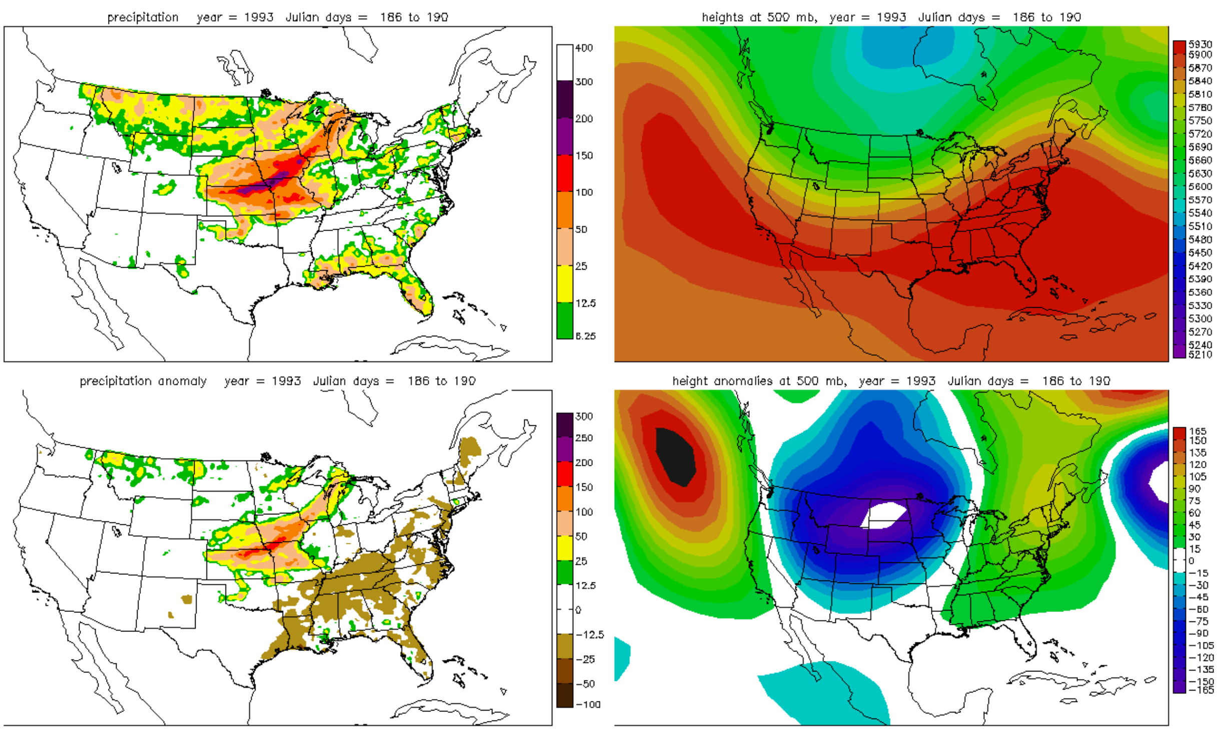

Fig. 1 (upper left) CPC analysis of total precipitation (mm) from 1200 UTC 3 July to 1200 UTC 8 July 1993. (lower left) As in the upper left, but for the precipitation anomaly. (upper right) Average 500-hPa geopotential height (m) from 4-8 July 1993 from the NCEP-NCAR Reanalysis (Kalnay et al. 1996). (lower right) 500-hPa geopotential height anomaly from 4-8 July 1993.

2. Case selection

The Climate Prediction Center's (CPC) US daily precipitation analysis (Chen *et al.* 2008), which has 0.25° grid spacing, was used to identify all 5-day periods during 1948—2011 where over 350 grid points had precipitation exceeding 100 mm (4 inches) of rainfall. Over this period, there were 22 cases identified in June, July, and August, after removing overlapping 5-day periods.

Correspondence to: Russ Schumacher, Department of Atmospheric Science, Colorado State University, 1371 Campus Delivery, Fort Collins, CO 80523; E-mail: russ.schumacher@colostate.edu.

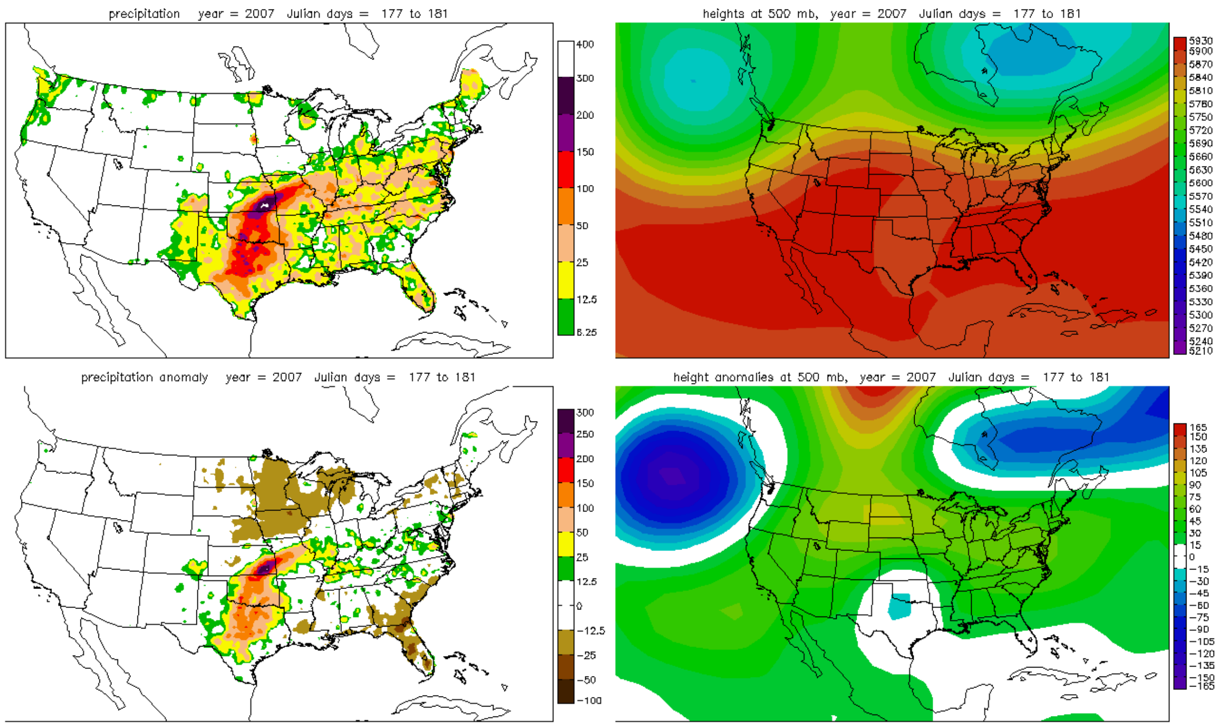

Fig. 2 As in Fig. 1, except the precipitation totals are for 1200 UTC 25 June to 1200 UTC 30 June 2007, and heights are for 26-30 June 2007.

3. Weather systems associated with widespread heavy rainfall in the warm season

Of the 22 warm-season events taking place during 1948—2011, 13 were associated with tropical cyclones. These events, while clearly important and impactful, were not the primary focus of this work. Six of the 22 events were associated with persistent, anomalous synoptic-scale troughs over the US. An archetypal example of this pattern was the widespread heavy rain and flooding during July of 1993 in the Midwest (Fig. 1). The June 2008 Midwest floods were also very similar to the 1993 floods in terms of their large-scale pattern (e.g., Bodner *et al.* 2011).

Two of the 22 events were associated with "predecessor rain events" (Galarneau *et al*. 2010), which occur when tropical moisture is transported ahead of an extratropical cyclone and lifted along a baroclinic zone in the midlatitudes. These occurred ahead of tropical cyclone Grace in 2003 and tropical cyclone Erin in 2007.

The last of the warm-season events identified here was associated with a long-lived mesoscale convective vortex (MCV) that remained nearly stationary for over a week from 24 June-1 July 2007 (Fig. 2; Schumacher 2011). Schumacher and Davis (2010) showed that at the medium range, this event was very poorly predicted in the European Centre for Medium Range Weather Forecasts (ECMWF; Fig. 3a) ensemble prediction system relative to other events of similar spatial and temporal scale. Lynch (2012) extended this analysis to the NCEP and UK Met Office global ensemble prediction systems and found similar results. (Fig. 3b).

4. The June 2007 extreme rainfall in the Southern Plains

Ensemble-based synoptic analysis (*e.g.*, Hakim and Torn 2008) was employed using the ECMWF ensemble forecast initialized at 0000 UTC 24 June 2007. Schumacher (2011) found that the strength of an anticyclone over the southwestern U.S. was one of the key determining factors in the genesis and longevity of the MCV and associated rainfall over the Southern Plains. In ensemble members with a weaker anticyclone in the southwest, which was closer to the observed evolution, the incipient vortex encountered relatively weak vertical wind shear. This allowed deep convection to repeatedly form near the center of the vortex, which in turn caused the vortex to intensify, and so on (Fig. 4a). In members with a stronger anticyclone, however, the vortex experienced stronger vertical wind shear, which led to stronger steering flow as well as convection developing downshear of the vortex center, and the incipient vortex moved southwestward into Mexico and decayed without producing any extreme precipitation (Fig. 4b). These small differences in the midlevel flow configuration were associated with large differences in the location and intensity of precipitation over the southern Plains, and were thus responsible for the low skill and high uncertainty in the global ensemble forecasts.

5. Summary and conclusions

This research illustrates the variety of synoptic-scale patterns that can lead to widespread heavy precipitation in the warm season, including tropical cyclones, anomalous troughs, predecessor rain events, and long-lived mesoscale convective vortices. The upscale growth of mesoscale convection in late June 2007 led to rainfall of sufficient intensity and coverage to be relevant to regional climate, yet this event was poorly predicted and likely had low intrinsic predictability.

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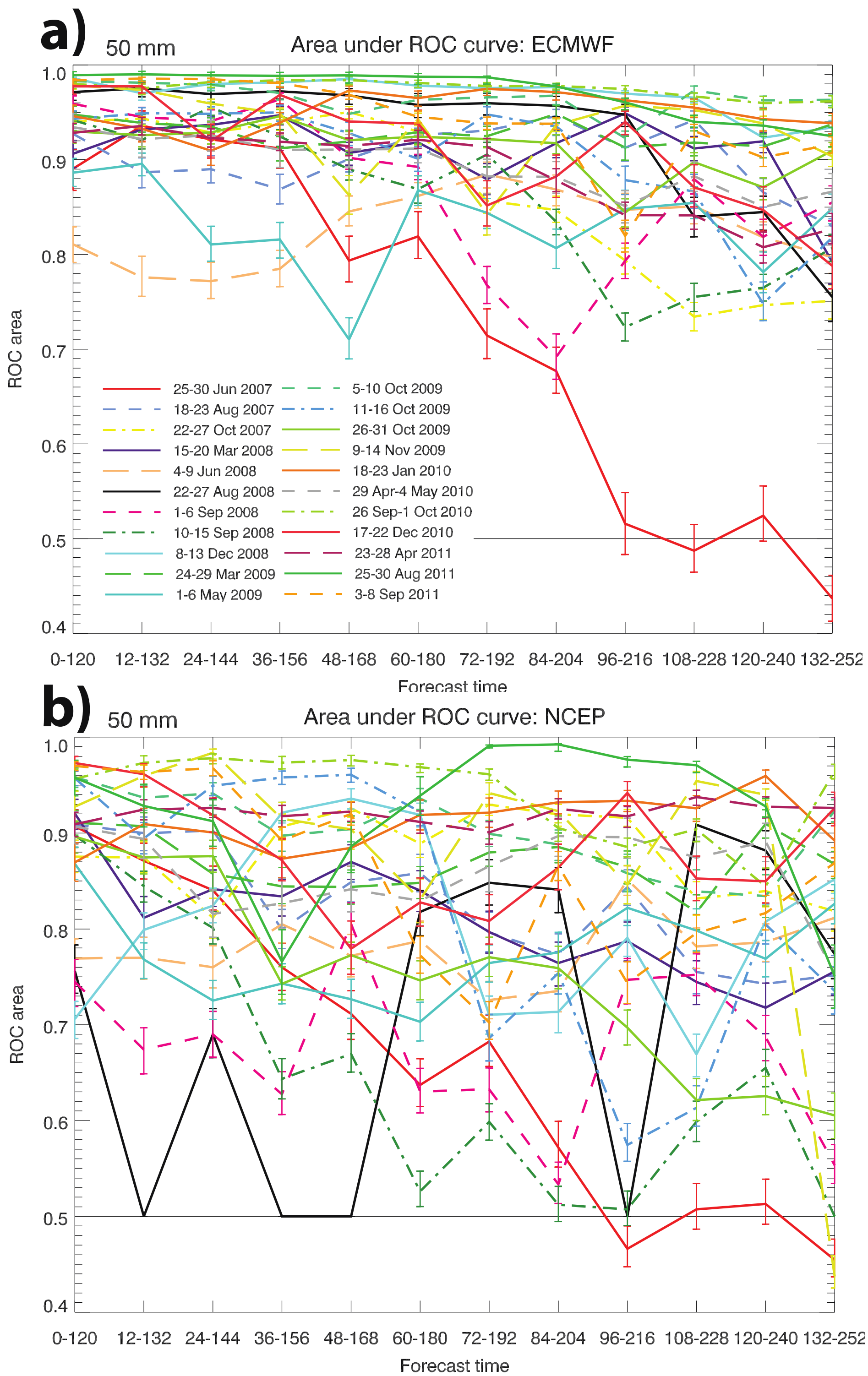

Fig. 3 Area under the receiver operating characteristic (ROC) curve for forecasts of 50 mm of rainfall in the (a) ECMWF and (b) NCEP ensemble prediction systems. Confidence intervals were calculated using a 1000-sample bootstrap resampling. A perfect forecast has ROC area of 1; a random reference forecast has area 0.5. The red lines represent the June 2007 event discussed in section 4. From Lynch (2012).

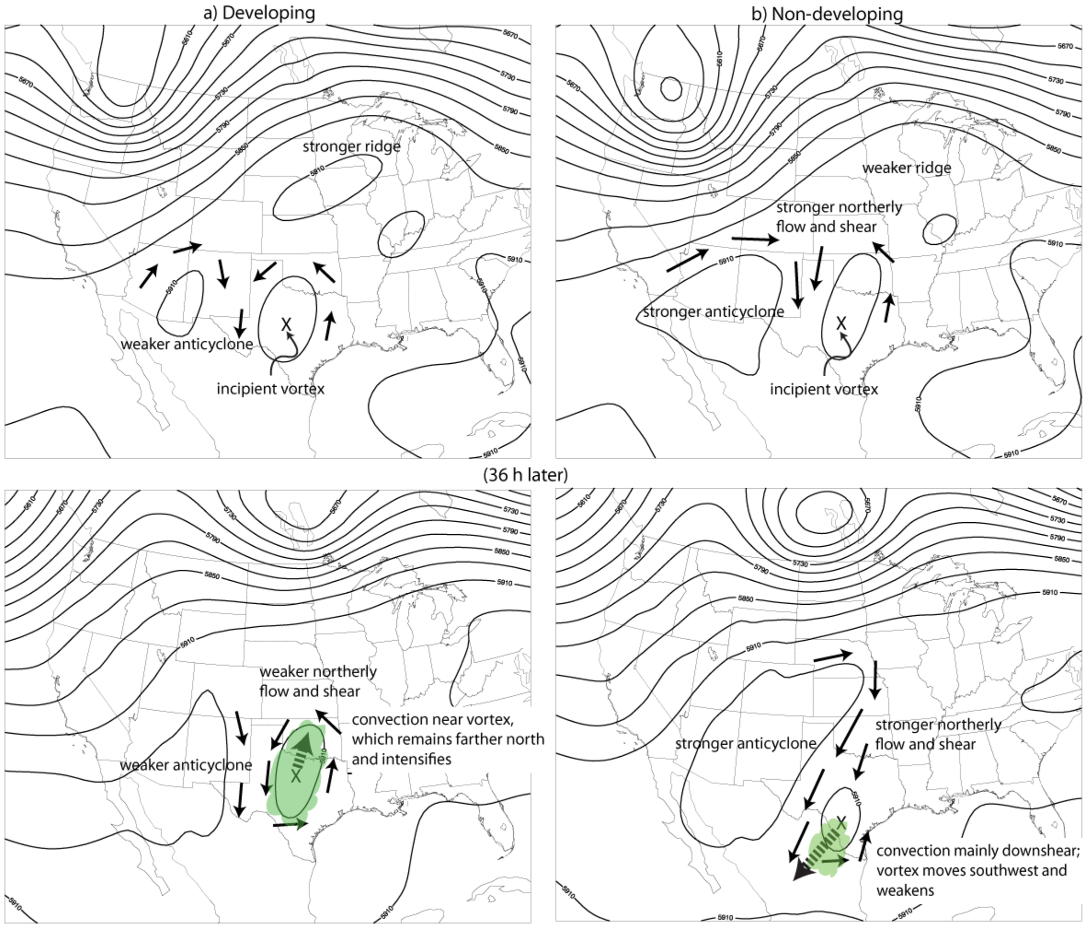

Fig. 4 Schematic diagram illustrating the large-scale factors leading to (a) development and (b) non-development of a long-lived vortex and associated widespread rainfall, as indicated by differing ensemble members. The 500-hPa height pattern at an earlier time, and 36 later, are shown for both instances. Black arrows denote representative flow vectors. The ``X" indicates the location of the 500-hPa vorticity maximum, gray shading indicates the location of deep convection, and the dotted arrow indicates the movement of the vortex over time. From Schumacher (2011).

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