Ensemble-Based Analysis of the May 2010 Extreme Rainfall in Tennessee and Kentucky

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Introduction

• From 29 April to 4 May 2010, persistent heavy rainfall occurred in the Ohio and Mississippi River valleys, with locations in central Tennessee accumulating more than nineteen inches of rain, the city of Nashville experiencing a historic flash flood (Fig. 1a).

• The synoptic-scale atmospheric pattern consisted of an upper level trough across the United States (Fig. 1b).

5-day precipitation between 0000 UTC 29 April 2010 – 1200 UTC 4 May 2010; Analysis 500-hPa height 0000 UTC 3 May 2010

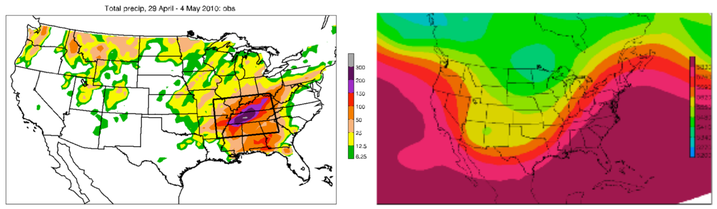

***Fig. 1**: (a) Climate Prediction Center (CPC) unified gauge-based precipitation analysis (mm) for the 120-h period 1200 UTC 29 April–1200 UTC 4 May 2010. The dashed black rectangle indicates the location for areal averaging of precipitation and other fields. (b) Analysis 500-hPa height 0000 UTC 3 May 2010 from European Centre for Medium Range Weather Forecasts (ECMWF)*

•The upper level trough and associated cyclone is causing southerly winds, which is then drawing in moisture from the Gulf of Mexico (Fig. 2).

Analysis 850-hPa temperature, height, and wind 0000 UTC 3 May 2010; Analysis total column water 0000 UTC 3 May 2010

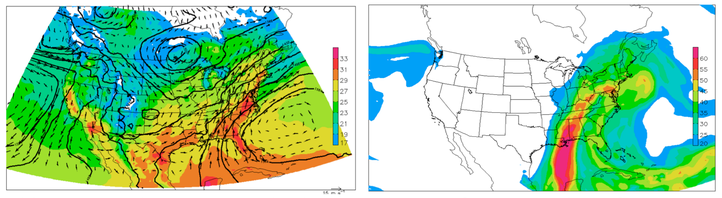

***Fig. 2** : (a) Analysis 850-hPa temperature, height, and wind 0000 UTC 3 May 2010 from ECMWF. (b) Analysis total column water 0000 UTC 3 May 2010 from ECMWF.*

• **Question to address: What were the key factors that were favorable for, or detrimental to, the development of widespread, multiple-day rainfall?**

Data and Methods

• To answer this question, global ensemble forecasts from ECMWF are used (51 members; T399); forecast data were obtained from the TIGGE portal at http://tigge.ecmwf.int

• Focus on the forecast initialized 1200 UTC 29 April 2010 because it had members with a very similar spatial distribution as the observed event as well as members with little to no resemblance (Fig. 3).

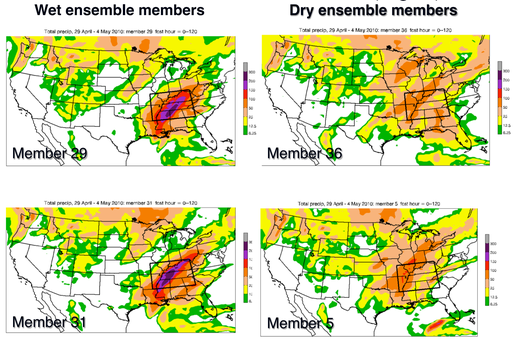

***Fig. 3**: As in Fig. 1a, except for examples of ECMWF ensemble members with "good" (left column) and "bad" (right column) 5-day total precipitation forecasts. Precipitation outside the US has been masked out for visual comparison with Fig. 1a.*

Data and Methods, continued

• Two primary analysis techniques:

• Analysis of linear correlation between area-averaged 84-h forecast rainfall to several atmospheric variables, following the approach of Hakim and Torn (2008), Hawblitzel et al. (2007), Sippel and Zhang (2008, 2010) and others

• Individual ensemble member analysis of "wet" and "dry" ensemble members to further explain physical processes in the model

Correlations

•A large core of positive correlation (r ~ 0.5) between 500-hPa height and total precipitation resides over the Pacific Ocean and western United States. This strong positive correlation is caused by the wet ensemble members having much higher heights off the coast of the western United States than do the dry ensemble members (Fig. 4a).

• Over the Midwestern United States, there is a positive correlation (r ~ 0.5), indicating as 850-hPa heights increase, area-averaged precipitation increases. When considered along with the maps of the total height field, this suggests that a weaker trough over the central United States was associated with more precipitation over the area of interest (Fig. 4b).

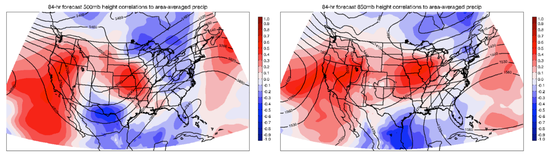

***Fig. 4**: (a) Correlation of 84-h forecast 500-hPa height (valid 0000 UTC 3 May 2010), and ensemble-mean 500-hPa height (contoured every 60-hPa). (b) Correlation of 84-h forecast 850-hPa height (valid 0000 UTC 3 May 2010), and ensemble-mean 850-hPa height (contoured every 30-hPa).*

• A similar relationship exists between the total column water and the development of heavy rainfall later, a higher total column water corresponding to the development of more rainfall (Fig. 5).

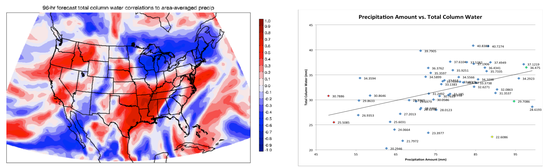

***Fig. 5**: (a) Correlation of 96-h forecast total column water (valid 0000 UTC 3 May 2010) (b) Scatter plot of the 51 ensemble members, with 96-h forecast total column water, averaged over the area shown in Fig. 1. The analysis value is shown by the yellow diamond.*

Ensemble Member Analysis

• Construct individual ensemble members of two "wet" members and two "dry" members. Similar to the correlation analysis, "wet" members have a slightly weaker upper level trough across the United States. Additionally, the trough has a positive tilt in the "wet" members and more of a neutral tilt in the "dry" members (Fig. 6).

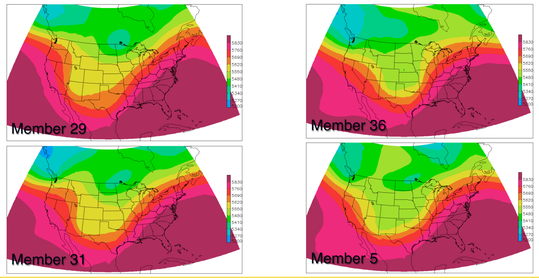

***Fig. 6**: 500-hPa height 0000 UTC 3 May 2010 (forecast hour 84). Individual ensemble members of the two "wet" members (left column) and the two "dry" members (right column).*

Ensemble Member Analysis, continued

• The stronger 850-hPa cyclone found in the "dry" members is associated with the warm front moving much farther north, which in turn spread the precipitation over a larger area rather than being concentrated over Tennessee and Kentucky (Fig. 7).

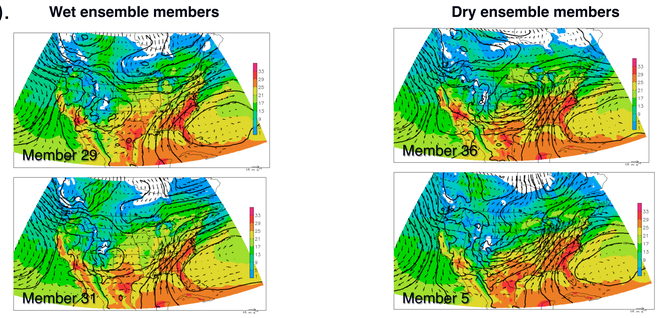

***Fig. 7**: 850-hPa temperature, height, and wind 0000 UTC 3 May 2010 (forecast hour 84).*

• In the "wet" members, the high values of total column water were centralized over Tennessee and Kentucky rather than being transported farther north (Fig. 8).

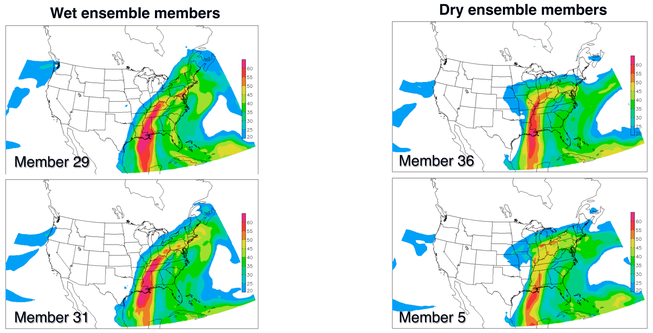

***Fig. 8**: Total column water 0000 UTC 3 May 2010 (forecast hour 84).*

Conclusions

• **Data from the TIGGE archive are useful both for forecast evaluation and diagnosis of weather systems.**

• **The strength of the upper level trough and associated low pressure system across the United States was closely tied to the development of the heavy rainfall. A weaker upper level trough and a weaker 850-hPa cyclone caused the moisture to concentrate in Tennessee and Kentucky producing heavy localized precipitation.**

•**Such a strong sensitivity to small-scale differences in the initial conditions highlights the importance of using ensembles for predicting the development of precipitation systems over both land and ocean.**

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