J4.15 WEATHER-CLIMATE LINKAGE LEADING TO THE 24-29 JUNE 2006 EXCESSIVE EAST COAST RAINFALL

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1. Introduction

Torrential rainfall impacted the mid-Atlantic and Northeastern USA during the period of 24-29 June 2006. Twenty-four hour rainfall amounts of at least 3-5 inches were common, with total amounts in excess of a foot at several locations. This event caused widespread river and flash flooding, numerous fatalities, and disruption of services. The purpose of this presentation is to examine the interactions of slow dynamical processes with synoptic time scales which produced the excessive rainfall.

2. The Global Synoptic-Dynamic Model (GSDM)

An empirical Global Synoptic-Dynamic Model of subseasonal variability (GSDM; Weickmann and Berry 2006) (WB06) provides a framework to interpret the sequence of events leading to this high-impact weather situation. Only a brief summary of the GSDM is given here since a complete discussion can be found in WB06.

The GSDM (Fig. 1) considers the interactions of multiple time scales that have both stochastic and quasi-oscillatory behavior and consists of four stages based on the MJO time-scale. However, phenomena other than the MJO are incorporated. The dynamical framework of the GSDM is the earth-atmosphere angular momentum budget (AAM) (Peixoto and Oort 1992) for zonal mean variations, the response to tropical forcing for regional variations and the baroclinic life cycle for mobile, fast variations.

The streamfunction anomalies (isopleths and shading) are based on lag regressions onto the first two EOFs of 20-100 day filtered OLR data. Lags from –25 to +25 days were examined for each EOF where the red (blue) depict subtropical anticyclonic (cyclonic) anomalies of 200mb streamfunction (inter-hemispheric sign reversal understood) that accompany MJO tropical convection anomalies as they propagate east. Only a complete temporal evolution of anomalies for the MJO is shown.

The “Hs” and “Ls” for the other components are placed within a specific stage based on a “large AAM tendency” criterion. Specifically, the lighter gray “Hs” and “Ls” are for the MJO while the heavier ones illustrate a west Pacific wavetrain linked to the MJO at Stage 2. The brown “Hs” and “Ls” depict teleconnection patterns associated with a “mountain-frictional torque index cycle” and the green ones show synoptic-scale wavetrains.

3. The Rainfall Event

Berry and Weickmann discussed the synoptic/dynamic evolution of this excessive rain episode in their weather-climate discussion dated 18 August 2006. This report can be found on the ESRL/PSD MJO web site at

http://www.cdc.noaa.gov/MJO/Forecasts/climate_discussions.html

A review is given below.

A super-position of at least four time scales contributed to the circulation anomalies responsible for this event. These include: 1) persistent tropical convection across the western Pacific Ocean due to warm SSTs from global warming and ENSO variability (see Fig.2), 2) a ~50 day mountain-frictional torque index cycle having roughly a 6-day decay time scale and large amplitude around the latitude bands of major north-south mountain ranges with east-west slopes (e.g., 10-50N) (see Fig. 3), 3) 20-30 day tropical convective variations that induced jet stream fluctuations over the mid-latitude west and central Pacific, and 4) baroclinic life cycles and mobile wave packets. The MJO signal was weak.

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The circulation response to (1) was for twin subtropical anticyclones centered ~150E, with their amplitudes being modulated as they interacted with extratropical baroclinic wave packets. These anticyclones supported a western Pacific wave train favoring ridges across western North America with downstream troughs across the central and eastern USA during June. The trades increased across the subtropical North Atlantic Ocean basin by the middle of the month with anomalies ~ 5 m/s, as part of a strong positive global frictional torque due to (2). An intense tropical convective flare-up occurred across the central equatorial Indian Ocean by around 16 June linked to (3). The divergent outflow from this event interacted with a passing baroclinic wave packet, (4), moving through Asia on about 18 June, allowing rapid downstream amplification of already existing circulation anomalies at an energy propagation speed of ~36 m/s. By 24 June retrogression and amplification of the wave train occurred across North America, supporting an anomalous trough across the central USA with a large anticyclone just east of New England (a summertime version of Stage 2 of the GSDM). The 250-mb anticyclone, with daily mean vector wind anomalies in excess of 50 m/s at times, dynamically induced the moisture laden enhanced trades to spread northward across the eastern USA. With a stationary north-south front in place and the central states trough jet streak dynamics passing through, several days of tremendous rainfall occurred. Figure 4 presents a sequence of maps showing 250mb daily mean vector wind anomalies for the period of 28-30 June 2006, at about the height of this rainfall event. A transition to GSDM Stage 3 by early July broke down this synoptic pattern.

4. Predictability

Examination of week-two mean precipitation forecasts from the ESRL/PSD reforecast ensemble showed this model had very little skill for the prediction of this event from initial conditions such as 13-15 June 2006. However, predictability did improve especially when the period of this event became week 1. Apparently as the initial conditions from the multiple time scale interactions discussed in Section 3 became better sampled, forecast skill improved. However, speculation in regard to the dependence of model performance on the interactions of multiple time scale processes needs to be quantified with many models (understanding well known regime dependency).

5. Conclusions

The historic excessive east coast rainfall event from 24-29 June 2006 occurred as the result of a unique set of complex interactions ranging from ENSO/global warming to individual synoptic-scale systems. Real-time weather-climate linkage monitoring with the GSDM framework did allow identification of some of the physical forcing-response behaviors such as that due to tropical convective flare-ups which were responsible. The information gained from this monitoring did allow (at the minimum) value to be added to the numerical forecasts specifically for this rain event. It is felt that a complete forecast process needs to involve modeling, diagnostics, attribution and monitoring making use of the GSDM. As shown in a few of the weather-climate discussions (see link above) and WB06, there are forecasts of opportunity when monitoring within the GSDM framework can provide statistically useful predictive information through at least week 2 before the models “catch on”.

Future work will involve further development and experience with the GSDM. That may help provide earlier warning of extreme weather events like this rainfall episode and abrupt circulation changes that at this time appear unpredictable. The GSDM is being applied to the NOAA Climate Prediction Center (CPC) Global Tropical and USA Hazards Assessments.

6. References

Peixoto, J., and A. Oort, 1992: *Physics of Climate*, American Institute of Physics, 520pp.

Weickmann, K.M., 2003: Mountains, the global frictional torque, and the circulation over the Pacific-North American Region. *Mon. Wea. Rev.*, **131**, 2608-2622.

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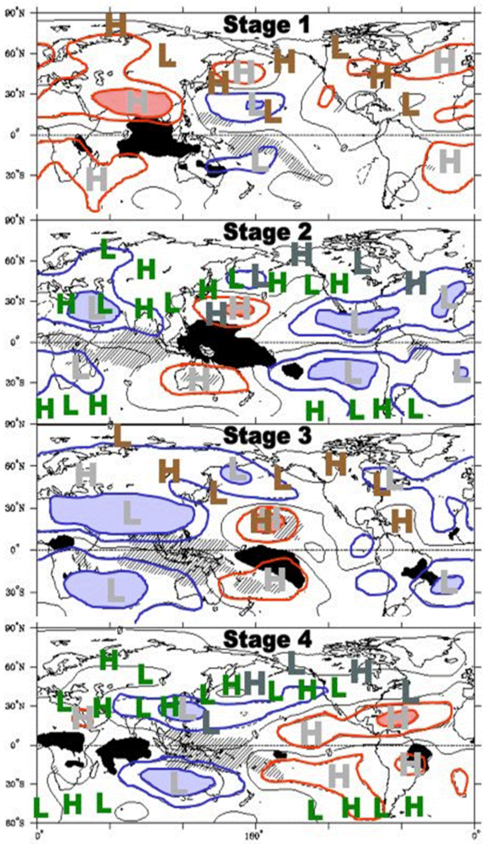

Fig. 1. The GSDM. See Text.

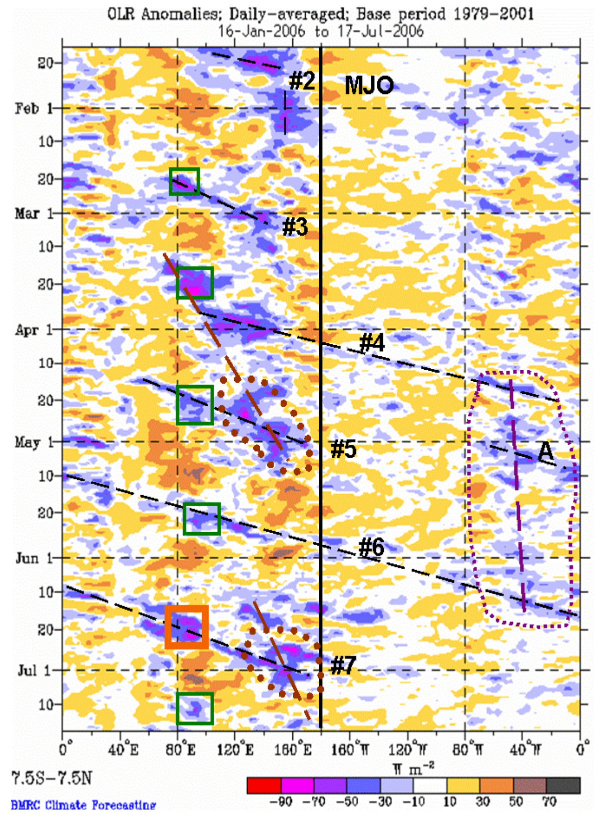

Fig 2. Hovmoller of anomalies of outgoing longwave radiation (OLRA; a proxy for deep moist tropical convection). Blues and purples (yellows and oranges) denote enhanced (suppressed) rainfall. See scale at the bottom. This plot is Fig. 3 of the 18 August 2006 weather-climate discussion.

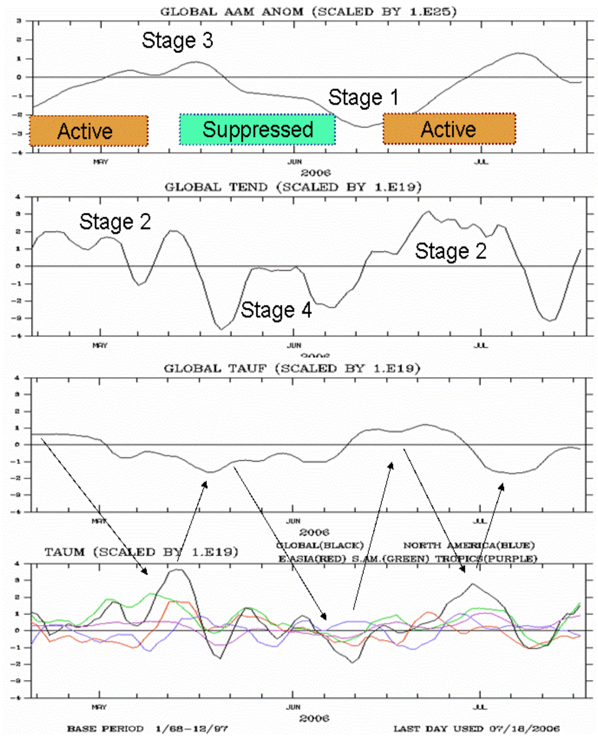

Fig. 3. From top to bottom, panels of tropospheric global relative atmospheric angular momentum (AAM) (10^{25} kg/m^2 sec), relative AAM tendency, frictional torque and mountain torque (units of 10^{19} kg/m^{2}s^2 for last 3 panels). The orange-green-orange boxes on top panel denote the periods of active-suppressed-active tropical convection across the west central Pacific.

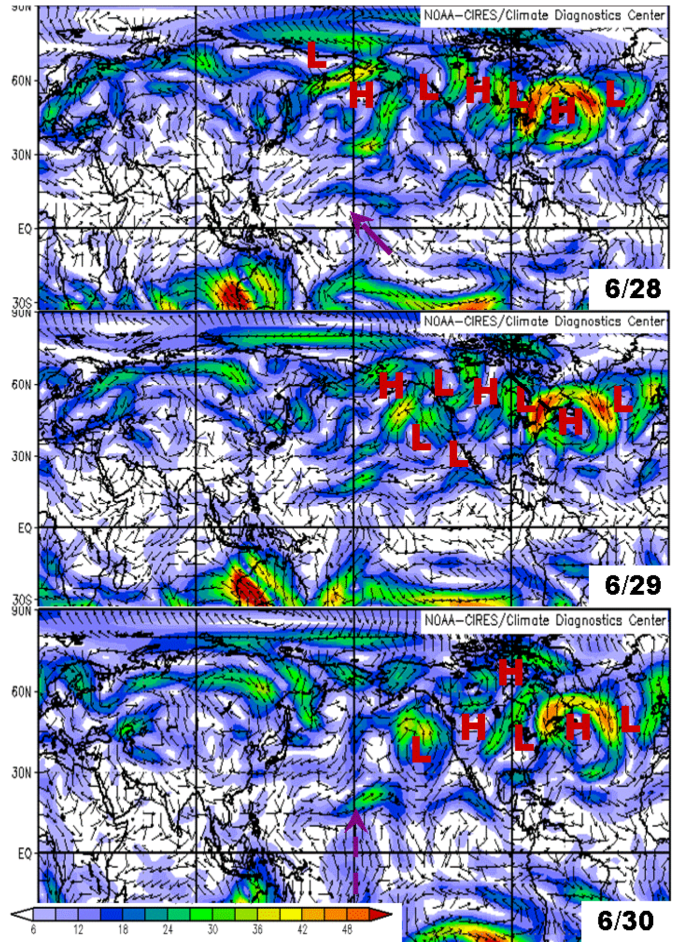

Fig. 4. This is a sequence of 250mb daily mean vector wind anomalies during roughly the peak of the rain event from 28-30 June 2006. "H"s and "L"s denote anticyclonic and cyclonic circulation anomalies with the scale given in the lower left (also taken from 18 August 2006 weather-climate discussion, Fig. 8).