The Characteristics and Statistics of Daily Extreme Precipitation Events over the United States

Yehui Chang and Siegfried Schubert: DAO, NASA/GSFC, Greenbelt, MD
E-mail: ychang@dao.gsfc.nasa.gov

1. Introduction

Extreme weather events (e.g. hurricanes or winter blizzards) can clearly have a major impact on our lives. Yet the link between such extreme events and climate variability and climate change is poorly understood. In this study we examine the regional and seasonal differences in the characteristics of extreme precipitation events over the United States. We present here some initial results of our analysis of both observations and model simulations in which we address the impact of El Nino on extreme events and how well AGCMs produce realistic extreme events and their statistics. The NASA/NCAR GCM is based on the finite-volume dynamical core developed at the DAO (Lin and Rood 1996), with physical parameterizations from the NCAR CCM-3. Three 20 year runs were made, forced with idealized a) cold, b) neutral and c) warm ENSO SST anomalies with 2x2.5 resolution and 32 levels. The simulated climate is described in Chang et al. (2001). We use NOAA daily precipitation observations over the United States for the period 1963-1998. Extreme precipitation is defined from the monthly and annual maximum daily precipitation. The relationships between extreme precipitation at selected grid points and atmospheric circulation are based on composites and regression of daily precipitation anomalies, 300mb height, 850mb wind and sea level pressure anomalies from the model and NCEP/NCAR reanalysis as described below.

2. Linear Regression Model

We consider the simple linear regression model in which a variable Y is regressed against the precipitation extremes X at a base point o. The regression model has the form

$$Y(j,k) = a\, X(o) + e.$$

Where j is the j-th grid point, k is the time lag in days and e is the error in the regression model. The regression links daily extreme precipitation for a particular point $X(o)$ with precipitation and related quantities at all other points Y. We show the average of Y over all times when $X(o)$ is an extreme event (the average conditions that occur when $X(o)$ is an extreme). We also show the regression coefficient a. These show the co-variability, or structure and time evolution of the extreme events.

3. Results

Figure 1 shows a composite of the precipitation (shading), 300mb heights (contours) and 850mb wind (vectors) during extreme precipitation events for each month at base grid point (77.5W, 40N). The left figure shows the results based on 36 years (1963-1998) of daily NOAA precipitation observations and reanalysis. The right figure shows the results based on 60 years of AGCM model simulations. The results show the expected large regional and seasonal changes in the structure and scales of the extreme precipitation events, with continental-scales and strong dynamical controls during the cold season, and highly localized events during the warm season. The AGCM does remarkably well in reproducing the basic structures of the extreme events, though there are some clear deficiencies such as excessive ridging during northwest events. Figure 2 shows the regression coefficient a relating the precipitation extremes at the base point (77.5W,40N) to precipitation at other grid points and at different time lags. The southwest-northeast orientation of the precipitation and its propagation are consistent with the northeastward motion of cyclones along the East Coast. The results indicate that our analysis method appears to work well in characterizing the structure and temporal evolution of extreme precipitation events over the US. Many of the structures are clearly identifiable with well-known intense synoptic systems.

Applying a standard extreme value analysis technique to the annual extreme precipitation, we estimate 10-, 20-, and 50-year return values of simulated and observed climate at every grid point. Extreme value analysis is performed in this study by fitting the generalized extreme value (GEV) distribution to the sample of annual extreme at each grid point using the method of L moments (Hosking 1990). GEV fits samples of extreme values to the distributions that provide more stable estimates of the wings. The T-year return value is estimated by inverting the fitted distribution function. We use a variant of the bootstrap method to estimate the uncertainty in our estimates (see Zwiers et al 1997). Our initial assessment of the impact of the warm and cold ENSO SST forcing indicates that the warm SSTs lead to a greater likelihood of more intense precipitation events in the Gulf States.

6. References

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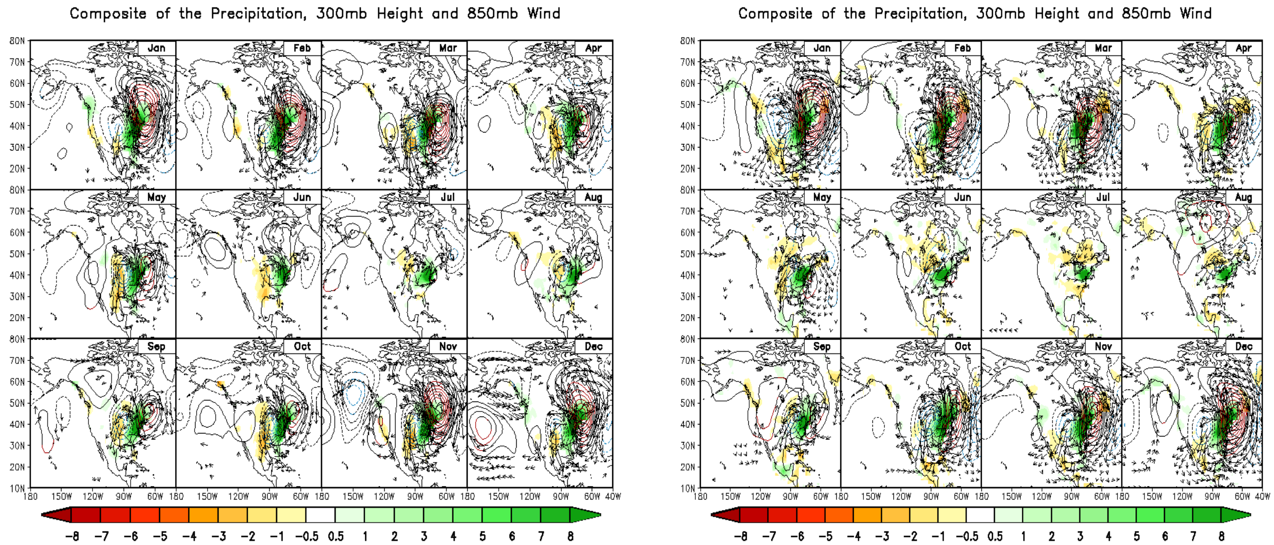

Figure 1. A composite of the precipitation (shading), 300mb heights (contours) and 850mb wind (vectors) during extreme precipitation events for each month at base grid point (77.5W, 40N). Left figure: The results based on 36 years (1963-1998) of daily NOAA precipitation observations and NCEP/NCAR reanalysis. Right figure: The results based on 60 years of NASA/NCAR model simulations. Precipitation has units of mm/day. Height contours are 20m. Colored contours are significant at the 5% level.

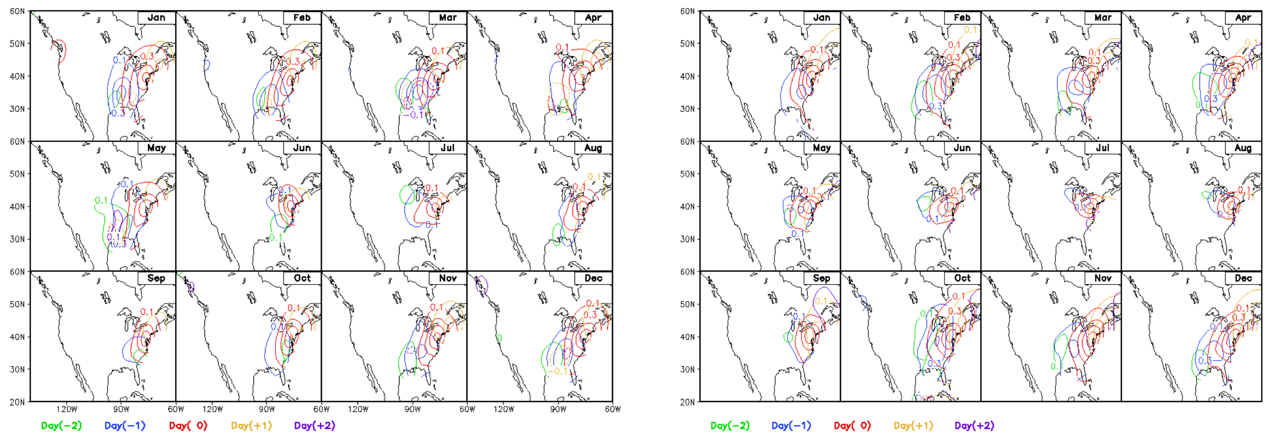

Figure 2. The regression coefficient ***a*** relating the precipitation extremes at the base point (77.5W, 40N) to precipitation at other grid points and at different time lags. Left panel is for the observation, and right panel is for the model. The colors indicate the lag in days. The southwest-northeast orientation of the precipitation and its propagation are consistent with the northeastward motion of cyclones along the East Coast.