P1.9 SOUTHEAST US EXTREME PRECIPITATION EVENTS FOOTPRINT IN INTER-ANNUAL VARIABILITY

Steven C. Chan* and Vasubandhu Misra
Florida State University, Tallahassee, Florida, United States

1. INTRODUCTION

Floods and droughts have been historically one of the most important issues in climate variability. For North America, interest in Southeast US (SEUS) hydroclimate variability has been shied by the interest in the Great Plains and the Mississippi Basin.

Using daily 1° latitude x 1° longitude land-only CPC US-Mexico Merged Precipitation data set (Higgins et al. 2004), we plot the JJA mean and standard deviation of daily precipitation (Figure 1). The SEUS JJA daily precipitation mean and day-to-day standard deviation are observed to be as larger than the Great Plains and the Mississippi Basin.

2. INTER-ANNUAL VARIABILITY

NOAA's definition for SEUS is defined by political borders – Florida, Alabama, Georgia, North Carolina, South Carolina, Puerto Rico, and Virginia. One can use rotated EOFs (REOF) to determine a more reasonable definition (Figure 2). The leading three REOFs have overlapping loadings in Tennessee, Georgia, Florida, and Alabama, and this is represented by the box that is marked in Figure 1.

Wang et al. (2008) have shown increased SEUS precipitation variability from the last thirty year. The inter-annual variations of JJA box averaged precipitation are shown in Figure 3. We have identified the top three driest (1980, 1990, 2000) and wettest (1994, 2003, 2005) JJAs. Those six years also rank as historically among the top four (three) driest (wettest). The signature of those JJAs can also be seen in the principle components in Figure 2.

Why are those JJAs dry and wet? We chose those six years for an in-depth analysis of its sub-seasonal variability and moisture source.

3. DAILY AND SUBSEASONAL VARIABILITY

The daily variability of the precipitation is shown in Figure 4. Variability is mostly dominated by a large number of little rainfall days with a few wet periods that last 2-4 days – typical of synoptic time scales. A notable exception is 1994, where the first half of July is prolonged wet (about 8-10 mm/day, lasting about 10 days).

The distributions of the box averaged daily precipitation for the selected dry and wet JJAs, and climatology are shown in Figure 5. The most common case, not surprisingly, is the smallest bin (0-1 mm/day). The dry JJAs are characterized by increased number of little precipitation days, and reduced extreme (10+ mm) precipitation days. It is the opposite for the wet JJAs, where such 10+ mm days are six time more frequent. The climatology lies in between the two cases.

Another interesting distinction between the dry and wet JJAs is tropical cyclone activity. There is no one single SEUS tropical cyclone land fall during the wet JJAs. While the wet years all have SEUS land falls including the infamous 2005 Hurricane Katrina (Table 1). Tropical cyclones themselves lead to the extreme precipitation events.

4. MOISTURE TRAJECTORIES AND SOURCES

Is there an intensification or weakening of the existing climatological pattern during the wet JJAs? Or there are significant shifts of moisture transport pattern?

4.1 Trajectory Methodology

We employ the isentropic moisture tracing method by described in Dirmeyer and Brubaker (1999). The method traces air parcels from precipitating grid points backward in time (conserving potential temperature unless parcel "runs" into the ground; in that case potential temperature is set to equal to the surface potential temperature). During the trajectory, the initially saturated parcel "loses" water content via surface evaporation. The trajectory is stopped whenever the parcel loses 90% of its initial water content or time has exceeded 15 days, whichever comes first.

The trajectory itself is computed from an average of two trajectories: the backward trajectory from the initial location, and the forward trajectory from the end point of the backward trajectory. We use the NCEP-DOE Reanalysis II (Kanamitsu et al. 2002) for both the trajectory and surface evaporation. Hourly precipitation is calculated by interpolating the daily CPC observations to the Reanalysis II diurnal variability.

Outputs are the surface evaporation sources **S**(x,t) of precipitation from each grid point x for pentads t. Outputs are grouped into five days pentads that begins with January 1st to 5th being pentad 1 (JJA is covered by pentad 31-49). We define "wet" pentads whenever a day within that pentad has exceeded 10 mm/day, and "normal" pentads to whichever pentads that are not "wet". The list of wet pentads for the selected six years are shown in Table 2.

4.2 Evaporation Sources of Precipitation

The evaporation of the all of the rainfall within our box for sum of different pentads can be calculated as:

$$TS = \sum_x \sum_t S(x,t) \quad (1)$$

* Corresponding author address: Steven C. Chan, Florida State University, Center for Ocean-Atmospheric Prediction Studies, 200 RM Johnson Bldg., Tallahassee, Florida 32306, USA

TS has units of total evaporation (mm). TS for the JJA pentads (31-49) from the selected six years are shown in Figure 6. Wet JJAs are characterized by both enhanced moisture flux from the Gulf and local recycling.

TS can be calculated just for the selected wet and normal pentads (Table 2) to illustrate the difference between sub-seasonal dry and wet periods. Due to difference of numbers between pentads that are grouped as wet and normal, one can perform a time average to obtain evaporation per day (mm/day). That is shown in Figures 7 and 8.

The wet pentads for both wet and dry JJAs are characterized by increased non-local moisture sources. The wet pentads during wet JJAs are more "wet" (more rainfall) than the dry JJAs by about 20%. However, the number of such wet pentads itself is increased by ~five times during the wet JJAs (Table 2 and Figure 5).

There are no notable change of the sources of non-local moisture sources between wet and dry JJAs. The majority of non-local moisture comes from the Gulf of Mexico. Chan and Misra (2009) have shown that the wet JJAs are associated with enhanced southerly moisture flux.

The normal pentads for dry and wet JJAs are characterized by local recycling. During the dry JJAs, this local recycling attributes to 75% of the JJA precipitation. For the wet JJAs, the extreme pentads attributes to 60-70% of the seasonal precipitation.

5. CONCLUSIONS

A full detail discussion of the analysis can be found in Chan and Misra (2009). While sub-seasonal recycling and non-local fluxes are indeed enhanced during the wet JJAs, most important is the increase of number of extreme events during the wet JJAs. Our results imply that good dynamical model predictions of SEUS JJA precipitation anomalies will require a realistic representation of sub-seasonal variability.

We have not discussed about the issue of reanalysis evaporation – a known serious problem among reanalyses (Nigam and Ruiz-Barradas 2006). A more in-depth discussion of Reanalysis II evaporation is found in Chan and Misra (2009). It is found that NCEP DOE Reanalysis II evaporation rates appear to be comparable to the North American Regional Reanalysis (NARR, Mesinger et al. 2004). Both NARR and Reanalysis II land surface are forced by observed precipitation.

6. REFERENCES

Chan, S. C., and V. Misra, 2009: A diagnosis of 1979-2005 extreme rainfall events in the southeast US with isentropic moisture tracking. *Mon. Wea. Rev.,* accepted.

Dirmeyer, P. A., and K. L. Brubaker, 1999: Contrasting evaporative moisture sources during drought of 1988 and the flood of 1993. *J. Geophys. Res.,* **104(D16),** 19383-19397.

Higgins R. W., W. Shi, E. Yarosh, J. Shaake, and R. Joyuce, 2004: Improved US precipitation quality control system and analysis, NCEP/CPC Atlas 7, National Centers for Environmental Prediction. [Available online at http://www.cpc.ncep.noaa.gov/products/outreach/research_papers/ncep_cpc_atlas/7/]

Mesinger, F., and coauthors, 2006: North American Regional Reanalysis. *Bull. Amer. Meteor. Soc.,* **87,** 343-360.

Nigam, S., and A. Ruiz-Barradas, 2006: Seasonal hydroclimate variability over North America in global and regional reanalyses and AMIP simulations: varied representation. *J. Climate,* **19,** 815-837.

Kanamitsu, M., W. Ebisuzaki, J. Wollen, S-K. Yang, J. J. Hnilo, M. Fiorino, and G. L. Potter, 2002: NCEP-DOE AMIP-II Reanalysis (R-2). *Bull. Amer. Meteor. Soc.,* **83,** 1631-1643.

Wang, H., R. Fu, A. Kumar, and W. Li, 2009: Intensification of summer rainfall variability in the Southeastern United States during recent decades. *J. Hydrometor.,* submitted.

7. TABLES

	1994	2003	2005
SEUS TCs	Alberto (38) Beryl (46)	Bill (37) TD07 (41)	Cindy (38) Dennis (39) Katrina (49)

Table 1: Active JJA SEUS tropical cyclones during wet JJAs, and the pentad of its landfall.

Year	1980	1990	2000	1994	2003	2005
Type	Dry	Dry	Dry	Wet	Wet	Wet
Wet Ps	35 36	39	34	32 33 36 37 38 42 46 47	31 32 33 34 37 41	31 33 38 39 49

Table 2: The pentads that are defined to be wet (Wet Ps).

8. FIGURES

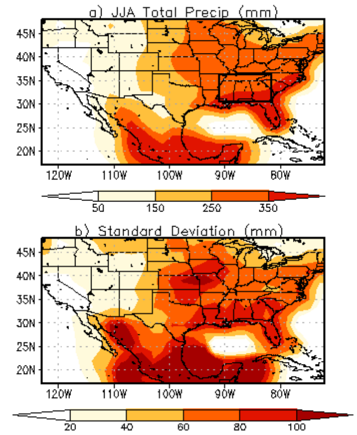

Figure 1: The 1950-2005 JJA total precipitation (mm) climatology from the Higgins et al. (2000) US-Mexico precipitation data set and its standard deviation (mm) are shown in panels (a) and (b) respectively.

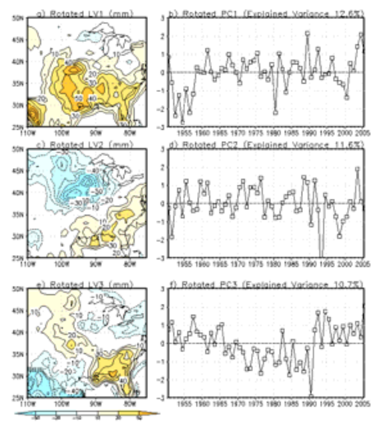

Figure 2: The three leading Varimax-rotated EOFs of 1950-2005 JJA precipitation (mm, left panels) and its non-dimensional principal components (right panels) are shown above.

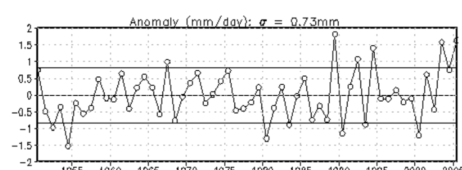

Figure 3: The 1950-2005 box (see Figure 1) averaged JJA precipitation anomaly (mm/day) are shown. The zero and ±1 standard deviation are delineated.

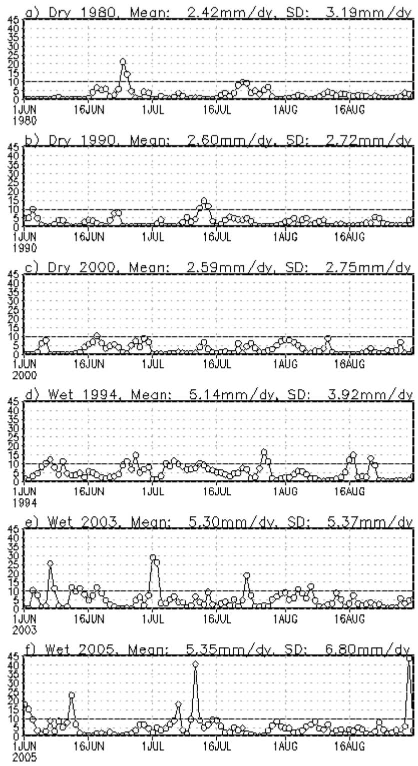

Figure 4: The spatially averaged daily rainfall (mm) during JJA for the three recent (1980-2005) driest (1980, 1990, and 2000) and wettest (1994, 2003, 2005) JJAs are shown.

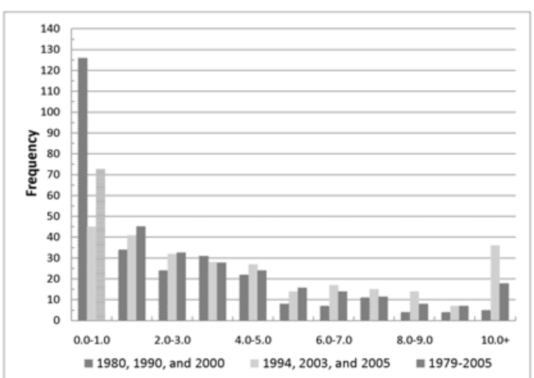

Figure 5: The daily precipitation (mm) distributions divided into eleven bins for the dry JJAs (1980, 1990, and 2000), wet JJAs (1994, 2003, and 2005), and climatological JJAs (1979-2005) are shown. Climatology is normalized to appear have the same number of samples as the other two cases.

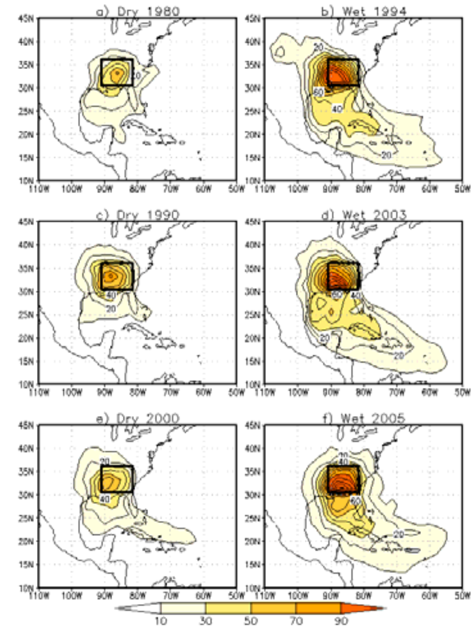

Figure 6: The total evaporative sources (mm) between pentads 31-49 (May 31st to September 2nd) are shown. The left panels are for (a) 1980, (c) 1990, and (e) 2000, and the right panels are for (b) 1994, (d) 2003, and (f) 2005.

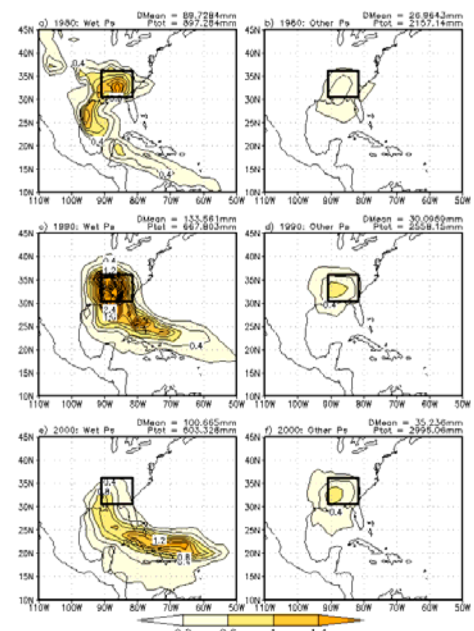

Figure 7: Similar to Figure 6, but only the pentads in the dry JJAs (1980, 1990, and 2000) that are wet (left panels) and normal (right panels) are used (see Table 2). Unlike Figure 6, the evaporative source is daily averaged. The box total precipitation (Ptot) and daily means (DMean) for the wet and normal pentads are shown above each panel.

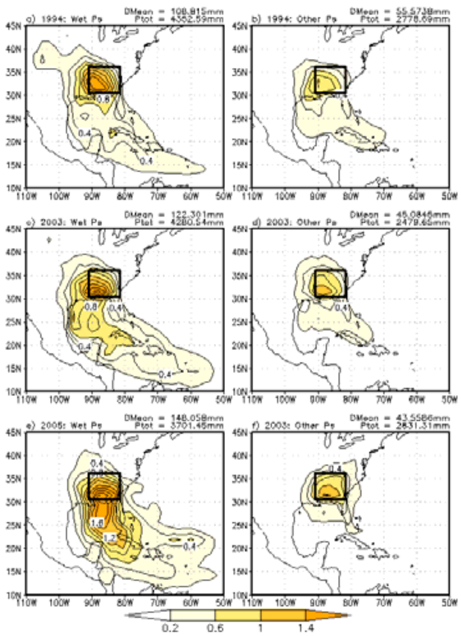

Figure 8: Similar to Figure 7, but it is for the wet JJAs (1994, 2003, 2005).