YEAR 1 ANNUAL PROGRESS REPORT

Investigating the Dynamical Control of the Pacific Storm Track on the Occurrence of Extreme Hydrological Events in the western United States Using NASA Observations and Models

NASA Award Number - NNX09AJ36G

PI: Yi Deng, Georgia Institute of Technology, 311 Ferst Drive, Atlanta GA 30332-0340

Since May 2009, this grant has provided one month of summer salary for both the PI (Yi Deng) and the Co-PI (Robert Black), and supported a graduate research assistant (Tianyu Jiang) at the School of Earth and Atmospheric Sciences, Georgia Institute of Technology. The research activity organized around the central theme of this project has led to three journal papers (one published, two submitted) and four workshop/conference presentations.

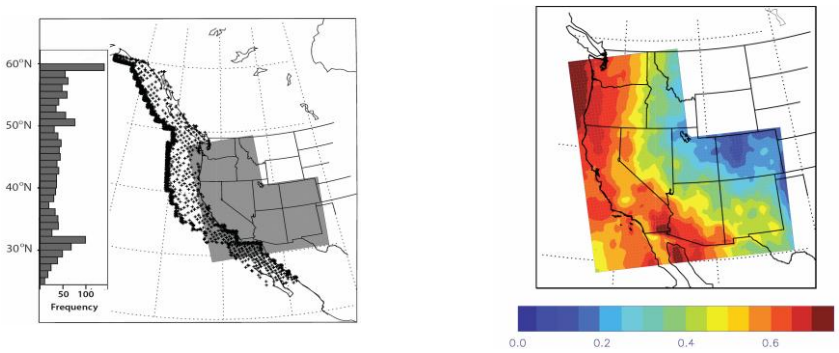
The main objective of the project is to understand how the Pacific storm track controls the hydro-climate variability, in particular, the occurrence of hydrological extremes, over its downstream region (i.e., western North America). The first goal of the investigation is to construct a database for the cyclonic activity over the North Pacific during the past three decades. This was achieved by applying a "feature-tracking" algorithm to daily geopotential height, pressure and vorticity fields in global reanalysis products (e.g., the NASA MERRA and the NCEP-NCAR reanalysis) to derive track information (e.g., position and intensity) of cyclones/anticyclones on a global domain. By October 2009, this goal had been accomplished. Based on the database constructed, we completed three additional research tasks with the main findings summarized below.

Task 1: Interannual modulation of the characteristics of the western U.S. winter precipitation by the coastal cyclonic activity

Climatologically, coastal cyclonic activity in the western U.S. peaks at three latitudes: 30°N, 50°N and 60°N (Fig. 1a). Cyclone-induced precipitation accounts for more than 60% of the total winter precipitation in most coastal areas with the maximum ratio being about 74% (Fig. 1b). Defining a cyclonic activity function (CAF) that measures the accumulated intensity of cyclones (e.g., geostrophic relative vorticity) in each 1° latitude interval in a winter, we quantified the dominant modes of interannual variability in the CAF through Empirical Orthogonal Function (EOF) analysis. EOF1 of the CAF (Fig. 2a) was found to be responsible for the EOF1 of the winter precipitation in the western U.S., which is a monopole mode centered over the Pacific Northwest and northern California. EOF2 of the CAF (Fig. 2b) contributes significantly to the EOF2 of the precipitation, which indicates that above-normal precipitation in the Pacific Northwest and its immediate inland regions tends to be accompanied by below-normal precipitation in California and the Southwest and vice versa. While EOF2s of the CAF and precipitation are linked to the ENSO signal on interannual timescales, EOF3 of the CAF (figure not shown) shows robust relationship with the North Pacific Oscillation (NPO) and hemispheric-scale variability such as the Arctic Oscillation (AO). A composite analysis revealed that the leading CAF modes increase (reduce) the winter total precipitation by increasing (reducing) both the number of rainy days per winter and the extremeness of precipitation (Fig. 3). The relationship between ENSO and EOF2 of the CAF indicates that the tropical Pacific SST anomalies modulate the winter precipitation in the western U.S. by inducing equatorward and eastward (poleward and westward) shift of the Pacific storm track in an El Niño (La Niña) winter, thereby moving the preferred cyclone track locations southward (northward) and leading to more (less) precipitation in the Southwest.

Reference:

Myoung, B., and Y. Deng, 2009: Interannual variability of the cyclonic activity along the U.S. Pacific coast: influences on the characteristics of winter precipitation in the western United States. *Journal of Climate*, **22**, 5732–5747.



(a) **(b)**

Fig. 1. (a) Distribution of the locations of the coastal cyclones ("+") and the histogram of their frequency across latitudes in 27 winters (DJF, 1979/80-2005/06). (b) Ratio of the cyclone-induced precipitation amount to the total winter precipitation in the western U.S. Contour interval is 0.05.

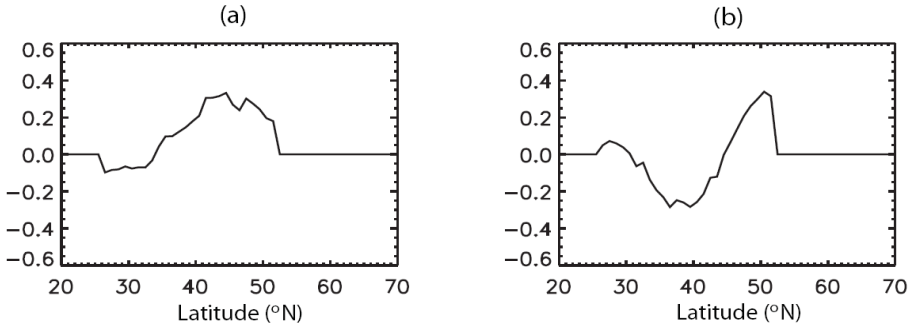


Fig. 2. EOF1 (a) and EOF2 (b) of the cyclone activity function (CAF).

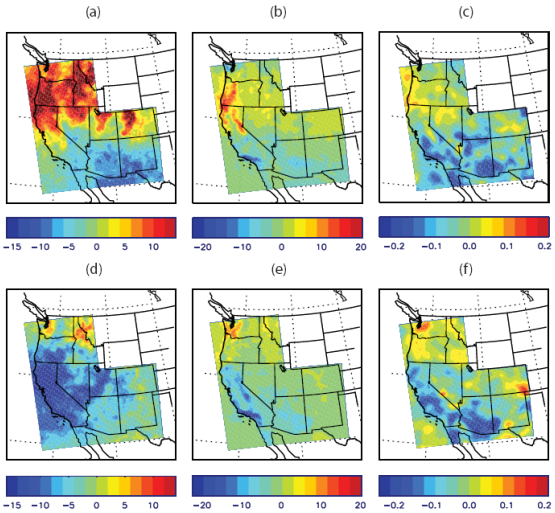


Fig. 3. Differences of the number of rainy days per winter (a), the 95th percentile of the daily rain rate (unit: mm/day) (b) and the number probability (c) between PC1+ and PC1- winters (Please refer to Myoung and Deng (2009) for the definitions). (d)-(f) are the same as (a)-(c) except for the differences between PC2+ and PC2- winters.

Task 2: Cyclonic forcing for winter droughts over the U.S. Southern Great Plains (SGP) and its connection to modes of low-frequency variability over the western North Pacific

This task is part of a collaborative effort with Dr. Xiquan Dong within the NEWS Drought and Flood Extremes Working Group. The investigation is motivated by the fact that the Hydrological Year 2006

drought over the SGP region is characterized by large rainfall deficits in winter months, and the SGP winter precipitation is typically associated with the passage of extratropical cyclones. We examined the 300mb cyclonic activity in 26 winters (Nov-Feb, 1979/80-2005/06) in the NASA MERRA and found that the winter rainfall deficit over the SGP is linked to significantly-suppressed cyclonic activity over the southwestern states (Fig. 4a). This signal is also clearly present during the extreme dry period of Nov. 2005-Feb. 2006 (Fig. 4b). In addition, correlations between the winter 500mb geopotential height and an index measuring the cyclonic activity over the southwestern states resemble the loading pattern of the Western Pacific teleconnection (WP), a primary low-frequency mode over the North Pacific (Fig. 5a). The correlation between the index of the cyclonic activity and the WP index is 0.57 and statistically significant at the 99% level (Fig. 5c). The index of cyclonic activity is also moderately correlated with the PNA index on monthly timescales (Fig. 5b). Given the relationship between the index of cyclonic activity (therefore, the SGP precipitation) and the WP and PNA index on respectively seasonal and monthly timescales, improved understanding and simulation of the WP and PNA variability have strong implications for future studies that explore the predictability of the SGP hydrological extremes.

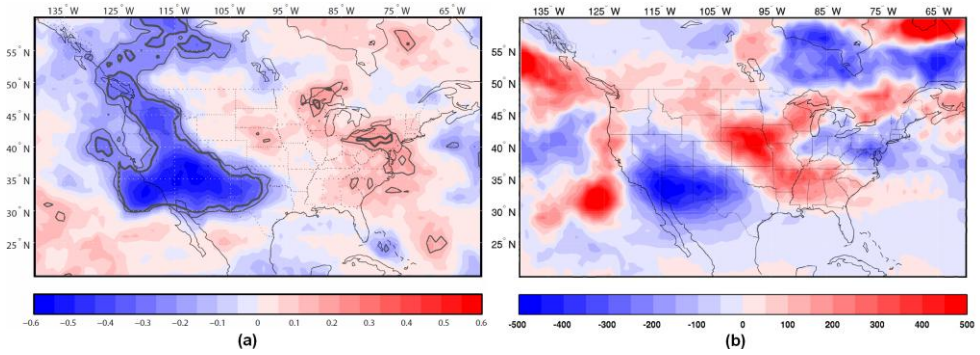


Fig. 4. (a) Correlation between the monthly cyclonic activity over the United States and the total precipitation over the SGP in Nov-Feb, 1979/80-2005/06 (sign of the precipitation is reversed to reflect the drought condition), (b) Anomalies of the cyclonic activity during the extreme dry period (Nov. 2005- Feb. 2006) relative to the 1979/80-2005/06 climatology (color shadings in m per day). Thick (thin) contours in (a) correspond to the 99% (95%) level of statistical significance.

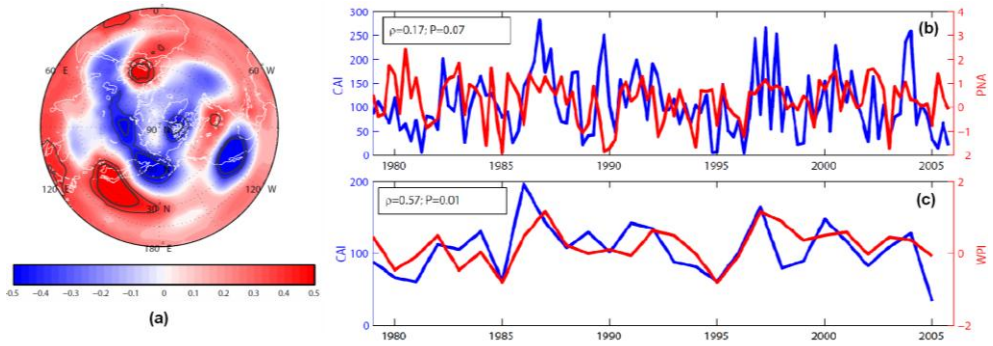


Fig. 5. (a) Correlation between the Nov-Feb averaged 500mb geopotential height and the cyclonic activity index (CAI), (b) Monthly CAI (blue line) and the corresponding NOAA PNA index (red line) in Nov-Feb, 1979/80-2005/06, (c) Nov-Feb averaged CAI and the corresponding NOAA WP index in Nov-Feb, 1979/80-2005/06. Thick (thin) contours in (a) correspond to the 99% (95%) level of statistical significance. Source of the PNA and WP index: http://www.cpc.noaa.gov/data/teledoc/telecontents.

Reference:

Dong, X., B. Xi, A. Kennedy, Z. Feng, J. K. Entin, P. R. Houser, R. A. Schiffer, T. L'Ecuyer, W. S. Olson, K. Hsu, T. Liu, B. Lin, Y. Deng and T. Jiang, 2010: Investigation of the 2006 drought and 2007 flood extremes at the Southern Great Plains through an integrative analysis of observations. *Journal of Geophysical Research-Atmosphere*, submitted.

Task 3: Intraseasonal modulation of the Pacific storm track by tropical convection in boreal winter and implications for the subseasonal rainfall regimes over western North America

The purpose of this investigation is to identify key tropical and extratropical variability that affects the Pacific storm track on intraseasonal timescales. The results will set up observational basis for future diagnosis of the AMIP-type simulations of the GISS ModelE and GSFC GEOS5 and provide guidelines for the design of the seasonal forecasting experiments using these two models. Case compositing for the synoptic eddy kinetic energy (SEKE) anomalies indicate that the storm track response to the intraseasonal variation in tropical convection can be described as a northeastward-propagating, amplitude-varying tri-pole anomaly in the SEKE field. A diagnosis of the local SEKE budget shows that the three main energy conversion terms (convergence of energy flux, baroclinic conversion and barotropic conversion) are nearly equally important in terms of contributing to the SEKE anomalies observed during the course of a typical Madden-Julian-Oscillation (MJO) event. Associated with the SEKE anomalies identified here, a three-band ("dry-wet-dry") precipitation anomaly forms and propagates poleward over the eastern Pacific near western North America (Fig. 6). The region between 25 ℃N and 45 ℃N makes a transition from a dry to a wet regime around day 0 (i.e., when the center of anomalous tropical convection reaches 150 ℃E), with each regime lasting approximately 20 days. South of 20 ℃N, two transitions occur respectively at day -15 and day 5 (Fig. 6).

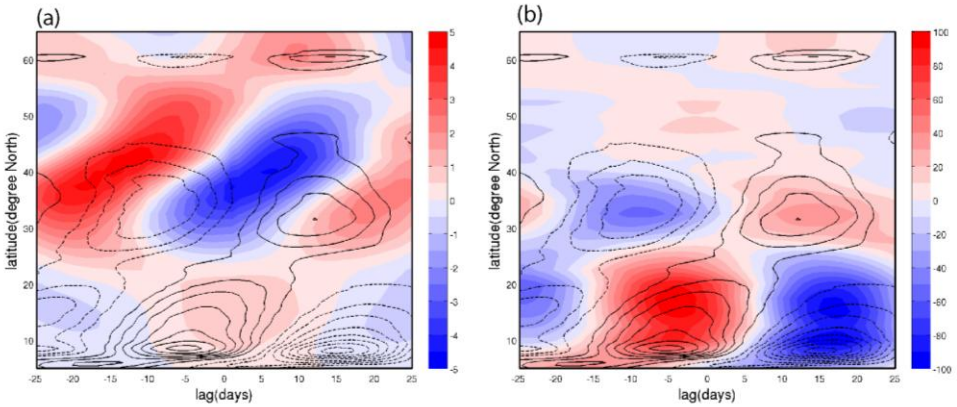


Fig. 6. (a) Time-latitude plot of the composite intraseasonal anomalies of the precipitation (contour) and the composite intraseasonal SEKE anomalies (color shading) averaged over 160 ℃W-130 ℃W. (b) is the same as (a) except for the color shading now corresponding to the composite intraseasonal anomalies of the 2-8 day band-pass filtered OLR variance. Contour interval is $2\times10^{-6} mmday^{-1}$ in (a) and (b). Unit for the color shading is m^2s^{-2} in (a) and w^2m^{-4} in (b). Solid (dashed) contours correspond to positive (negative) values and the zero contours are omitted.

Reference:

Deng, Y., and T. Jiang, 2010: Intraseasonal modulation of the North Pacific storm track by tropical convection in boreal winter. *Journal of Climate*, submitted.