Science and Technology Infusion Climate Bulletin
NOAA's National Weather Service
36th NOAA Annual Climate Diagnostics and Prediction Workshop
Fort Worth, TX, 3-6 October 2011

Spatial-Intensity Variations in Extreme Precipitation in the Contiguous United States and the Madden-Julian Oscillation

Charles Jones[1] and Leila M. V. Carvalho[1,2]

[1] *Earth Research Institute, University of California, Santa Barbara, California*

[2] *Department of Geography, University of California, Santa Barbara, California*

1. Introduction

The Madden–Julian Oscillation (MJO) is the most prominent mode of tropical intraseasonal variability in the climate system (Madden and Julian 1994; Lau and Waliser 2005; Zhang 2005; Jones and Carvalho 2006; Jones 2009; Jones and Carvalho 2011a). Important linkages have been found between the MJO and precipitation variability including occurrences of extreme events (Jones *et al.* 2004; Donald *et al.* 2006). Significant signals have been shown over the contiguous United States (CONUS) (Mo and Higgins 1998a, 1998b; Mo 1999; Higgins *et al.* 2000a; Jones 2000; Bond and Vecchi 2003; Becker *et al.* 2011; Ralph *et al.* 2011; Zhou *et al.* 2011).

The present study focuses on the MJO and occurrences of precipitation over the CONUS during boreal winter. This problem is investigated by considering two joint properties: intensity and spatial extent of extreme precipitation. The following questions are investigated: 1) What is the probability of extreme precipitation over the CONUS when the MJO is active? 2) Does the spatial-intensity probability of extreme precipitation associated with the MJO significantly vary with ENSO? 3) Do probabilities of spatial-intensity characteristics of extreme precipitation over the CONUS vary with MJO phases? 4) Are large amplitudes of the MJO associated with high probabilities of extreme precipitation over the CONUS?

2. Data

Daily gridded precipitation from the NOAA Climate Prediction Center (CPC) unified gauge (CPC-uni) (Higgins *et al.* 2000b; Chen et al. 2008) is used to investigate the variability of extreme events. Data with 0.5º in latitude by longitude are used for the period 1 January-31 December, 1979-2010. Figure 1 shows the mean daily precipitation over the CONUS during boreal winter seasons defined from 1 November to 31 March (1979-2010). In the western CONUS, mean precipitation exceeds 2 mm day^{-1} and shows large gradients associated with topographic features over the Coastal Ranges, Sierra Nevada and Rocky Mountains. In contrast, the mean winter precipitation in the eastern CONUS shows smooth horizontal gradients and maximizes over the southeastern States. To make the presentation manageable, the CONUS is divided into six sectors: southwest (SW), central-south (CS), southeast (SE), northwest (NW), central north (CN) and northeast (NE). The spatial-intensity characteristics

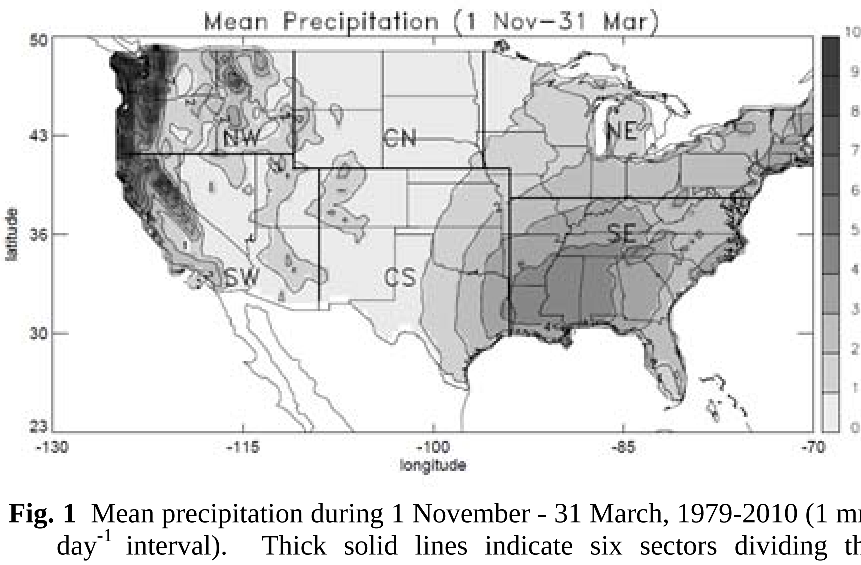

Fig. 1 Mean precipitation during 1 November - 31 March, 1979-2010 (1 mm day^{-1} interval). Thick solid lines indicate six sectors dividing the continuous United States (CONUS).

Correspondence to: Charles Jones, Earth Research Institute, University of California, Santa Barbara, CA 93106.
Email: cjones@eri.ucsb.edu

of extreme precipitation, their probabilities of occurrence and the importance of the MJO are aggregated in each sector over the CONUS.

To identify MJO events, daily averages of zonal wind components at 850-hPa (U850) and 200-hPa (U200) from the National Centers for Environmental Prediction/National Center for Atmospheric Research (NCEP/NCAR) reanalysis (Kalnay et al. 1996) are used (1 January-31 December 1979-2010). MJO events are identified according to the method discussed in Jones (2009) and Jones and Carvalho (2011b).

The spatial-intensity variability of extreme precipitation in the CONUS is analyzed by first identifying extreme events in daily gridded precipitation. Two thresholds of daily precipitation intensity are used: exceeding the 75th and 90th percentiles. In additional, the spatial extent of extreme precipitation is analyzed by considering the frequency distribution of areas. Regions of spatially connected gridpoints in which precipitation exceeds the 75th or 90th percentiles are identified. In summary, two types of *contiguous regions of extreme precipitation* (hereafter CREP) are analyzed. Type I: intensity of precipitation and size exceeds the 75th percentiles of frequency distributions. Type II: intensity and size exceed the 90th percentiles of the frequency distributions.

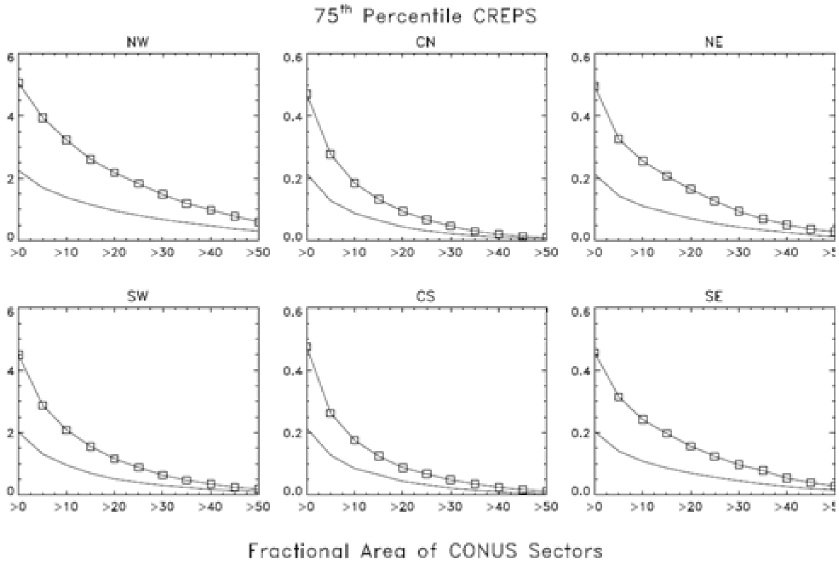

Fig. 2 Joint Probabilities of 75th percentile CREP during active and inactive MJO days. Panels are for each sector in the CONUS. Solid lines with squares show joint probabilities that the fractional area of the sector due to 75th percentile CREPs exceeds a given threshold (horizontal axis; percentages) and the NJO being active (in any phase). Solid lines show joint probabilities that the fractional area of the sector due to 75th percentitle CREP exceeds a given threshold and the MJO being inactive.

3. The MJO and probabilities of CREPs

This section presents a quantitative analysis of probabilities of CREP occurrences and relationships with the MJO. To make the presentation more manageable, the results are aggregated for each CONUS sector. We define fractional area as the area of the sector covered by CREPs divided by the total area of the sector. The calculation for each sector considers the area of the CREP contained within the sector. Likewise, intensity is defined as the total precipitation associated with CREPs falling in each sector.

Figure 2 shows joint probabilities that the fractional area in each sector associated with 75th percentile CREPs exceeds specific thresholds (horizontal axis) and the MJO is active (in any phase). Similarly, joint probabilities for fractional area exceedance and inactive MJO days are plotted. Over the NW CONUS, for instance, the probability that the MJO is active and the sector is covered by more than 10% with 75th percentile CREPs is about 0.33. In contrast, the joint probability for the NW sector being covered by more than 10% CREPs during inactive MJO days is ~0.14. As the thresholds of fractional area increase, the joint probabilities decrease. The joint probabilities are significantly higher when the MJO is active than in inactive days. Joint probabilities decrease slower over the NW, NE and SE sectors relative to the CN and CS sectors, probably because precipitation over the central CONUS is not too intense during winter and weather systems quickly move eastward over those regions.

Joint probabilities of precipitation intensity and active (inactive) MJO days associated with 75th extremes are shown in Fig. 3. The joint probabilities are at least twice higher when the MJO is active than during inactive days. The results above demonstrate quantitatively that the MJO has a substantial influence on both the spatial and intensity characteristics of extreme precipitation over the CONUS during winter.

4. Conclusions

Jones and Carvalho (2011b) investigated the spatial-intensity variability of extreme precipitation over the CONUS during boreal winter and relationships with the MJO. Daily gridded precipitation is used to define two types of contiguous regions of extreme precipitation (CREPs): intensity and spatial extent exceeding the 75th and 90th percentiles of frequency distributions. Extreme precipitation occurs twice more frequent when the MJO is active than inactive. Joint probabilities of fractional area of CONUS sectors when the MJO is active are 2.0-2.5 higher than probabilities during inactive days for both 75th and 90th percentiles CREPs (similarly for intensity of CREPs). Probabilities of fractional area of 75th percentile CREPs when the MJO is active in neutral ENSO are higher than during warm or cold ENSO. Joint probabilities of fractional area during MJO and warm ENSO are higher than MJO and cold ENSO and statistically significant over southern sectors. Results are similar for joint probabilities of intensity exceedance and MJO activity in warm and cold ENSO phases. Proportions of 75th and 90th percentile CREPs for each sector and phase of the MJO are predominantly large when MJO convective signals are over the central Indian Ocean or western Pacific. Probabilities of fractional area of 90th percentile CREPS conditioned on MJO phases, however, do not show clear predominance. This indicates that the MJO is not the sole player in the occurrences of CREPs. Lastly, this study concludes that probabilities of fractional area and intensity of 75th and 90th percentile CREPs in the CONUS do not depend on the amplitude of the MJO.

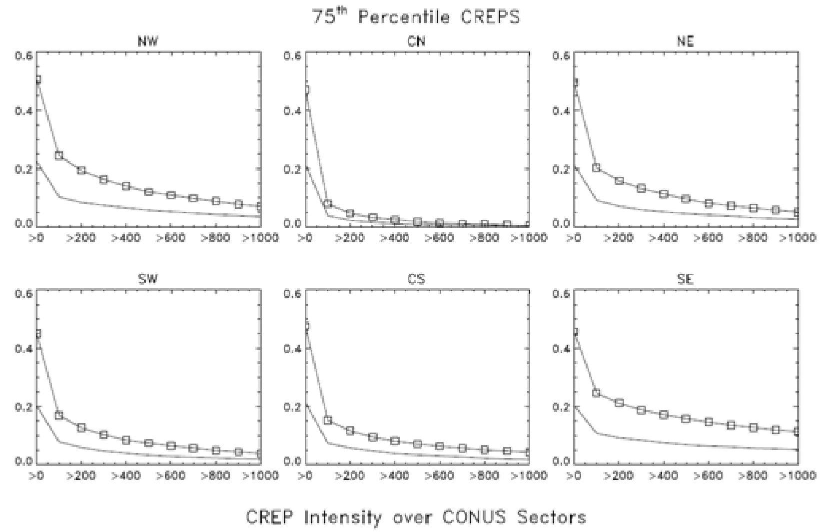

Fig. 3 Joint Probabilities of 75th percentile CREP during active and inactive MJO days. Panels are for each sector in the CONUS. Solid lines with squares show joint probabilities that the precipitation intensity in the sector due to 75th percentile CREPs exceeds a given threshold (horizontal axis; mm day^{-1}) and the MJO being active (in any phase). Solid lines show joint probabilities that the precipitation intensity in the sector exceeds a given threshold and the MJO being inactive.

Acknowledgements. This research was supported by NOAA's Climate Program Office, Climate Test Bed program (NA08OAR4310698) and Climate and Large-scale Dynamics Program from the National Science Foundation (AGS-1053294). NCEP/NCAR Reanalysis and OLR data provided by the NOAA/OAR/ESRL PSD, Boulder, Colorado, USA (www.esrl.noaa.gov).

References

Becker, E. J., E. H. Berbery, and R. W. Higgins, 2011: Modulation of Cold-Season U.S. Daily Precipitation by the Madden–Julian Oscillation. *J. Climate*, **24**, 5157-5166.

Bond, N. A., and G. A. Vecchi, 2003: The influence of the Madden-Julian oscillation on precipitation in Oregon and Washington. *Weather and Forecasting*, **18**, 600-613.

Chen, M. Y., W. Shi, P. P. Xie, V. B. S. Silva, V. E. Kousky, R. W. Higgins, and J. E. Janowiak, 2008: Assessing objective techniques for gauge-based analyses of global daily precipitation. *J Geophys Res-Atmos*, **113**, D04110, 04111-04113.

Donald, A., and Coauthors, 2006: Near-global impact of the Madden-Julian Oscillation on rainfall. *Geophysical Research Letters*, **33**, L09704, doi:10.1029/2005GL025155.

Higgins, R. W., J. K. E. Schemm, W. Shi, and A. Leetmaa, 2000a: Extreme precipitation events in the western United States related to tropical forcing. *J. Climate*, **13**, 793-820.

Higgins, R. W., W. Shi, E. Yarosh, and R. Joyce, 2000b: Improved United States precipitation quality control system and analysis. *NCEP/Climate Prediction Center ATLAS No. 7,* National Oceanic and Atmospheric Administration, 40 pp.

Jones, C., 2000: Occurrence of extreme precipitation events in California and relationships with the Madden-Julian oscillation. *J. Climate*, **13**, 3576-3587.

——, 2009: A homogeneous stochastic model of the Madden-Julian Oscillation. *J. Climate*, **22**, 3270-3288.

Jones, C., and L. M. V. Carvalho, 2006: Changes in the activity of the Madden-Julian oscillation during 1958-2004. *J. Climate*, **19**, 6353-6370.

——, 2011a: Stochastic simulations of the Madden-Julian Oscillation activity. *Climate Dynamics*, **36**, 229-246, doi:210.1007/s00382-00009-00660-00382.

——, 2011b: Spatiotemporal variations in extreme precipitation in the contiguous United States and the Madden-Julian Oscillation. *J. Climate (in revision)*.

Jones, C., D. E. Waliser, K. M. Lau, and W. Stern, 2004: Global occurrences of extreme precipitation and the Madden-Julian oscillation: Observations and predictability. *J. Climate*, **17**, 4575-4589.

Kalnay, E., and Coauthors, 1996: The NCEP-NCAR 40 Year Reanalysis Project. *Bulletin of the American Meteorological Society*, **77**, 437-471.

Lau, W. K. M., and D. E. Waliser, 2005: *Intraseasonal Variability in the Atmosphere-Ocean Climate System.* Springer, Chichester, UK, 436 pp.

Madden, R. A., and P. R. Julian, 1994: Observations of the 40-50-Day Tropical Oscillation-A Review. *Mon.Wea. Rev.*, **122**, 814-837.

Mo, K. C., 1999: Alternating wet and dry episodes over California and intraseasonal oscillations. *Monthly Weather Review*, **127**, 2759-2776.

Mo, K. C., and R. W. Higgins, 1998a: Tropical influences on California precipitation. *J. Climate*, **11,** 412-430.

——, 1998b: Tropical convection and precipitation regimes in the western United States. *J. Climate*, **11,** 2404-2423.

Ralph, F. M., P. J. Neiman, G. N. Kiladis, K. Weickmann, and D. W. Reynolds, 2011: A Multiscale Observational Case Study of a Pacific Atmospheric River Exhibiting Tropical–Extratropical Connections and a Mesoscale Frontal Wave. *Monthly Weather Review*, **139,** 1169-1189.

Zhang, C. D., 2005: Madden-Julian oscillation. *Reviews of Geophysics*, **43,** 1-36.

Zhou, S., M. L'Heureux, S. Weaver, and A. Kumar, 2011: A composite study of the MJO influence on the surface air temperature and precipitation over the Continental United States. *Climate Dynamics***,** 1-13.