Hail occurrence: relationship to the intraseasonal oscillation

Brittany N. Henley, Bradford S. Barrett
Oceanography Department, United States Naval Academy

Introduction

- Large-scale meteorological patterns (LSMPs) are known to be associated with local extreme weather events.
- LSMPs favorable for hail activity in the central U.S. include the presence of a mid- and upper-tropospheric trough, low static stability, high precipitable water content, and high CAPE values (Hailstorms; Knight and Knight 1984).
- The leading cause of atmospheric variability on an intraseasonal (30-60 day) timescale is the Madden-Julian Oscillation (MJO; Madden and Julian 1972).
- MJO modulates many synoptic-scale weather phenomena: precipitation, air temperature, cloud cover and circulation (MJO; Madden and Julian 1972).
- If links between MJO and extreme weather events such as hail can be established and explained, intraseasonal prediction of hail activity may be possible (Barrett and Gensini 2013).

Methods

- Create MJO phase composites using the Wheeler-Hendon Real-time Multi-variate MJO Index (Fig. 1; Wheeler and Hendon 2004).
- Divide the MJO into 8 phases that roughly follow the original description of Madden and Julian (Fig. 2; 1972); define an active phase as one with the square root of the sum of squares of both empirical orthogonal functions larger than 1.
- Use the following data sets: (1) U.S. storm reports (maintained by SPC WCM); (2) North American Regional Reanalysis (NARR); and (3) Wheeler-Hendon Real-time Multivariate MJO Index (RMM).
- Create a gridded hail-day dataset, defining a hail day at a 1 degree x 1 degree resolution as one in which at least one hail report occurs in the respective CONUS grid box.
- Create composites of hail anomalies for the months of April and May (months with the most hail), daily values of precipitable water (PW) content for the entire atmosphere, daily values of convective available potential energy (CAPE), 3 hour values of geopotential height at 500 mb (GPH), and calculate anomalies for each of the 8 MJO phases for each of the above variables.

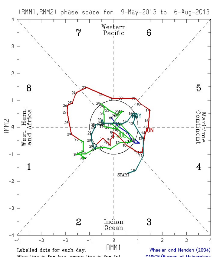

Figure 1: Example of Wheeler Hendon RMM progression.

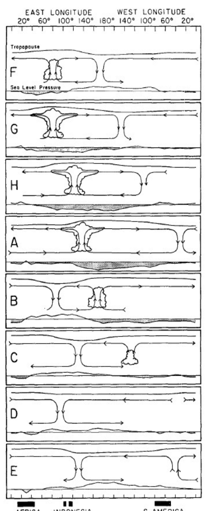

Fig. 2: Phases of MJO (Madden and Julian 1972).

Purpose

- Examine the relationship between the leading mode of atmospheric intraseasonal variability, the Madden-Julian Oscillation, and hail events in the continental U.S.
- Stratify April and May U.S. hail activity by phase of the Wheeler-Hendon RMM Index. Connect observed trends in hail activity with variability, by MJO phase, of geopotential height, CAPE, and precipitable water content in the months of April and May.
- Determine if there is a relationship between hail and MJO by studying hail and MJO data in the United States during the months of April and May from 1990-2012.

Results: hail variability by MJO phase

Mean values of daily hail frequency (left) and CAPE, PW, and GPH at 2100 UTC (below) for April.

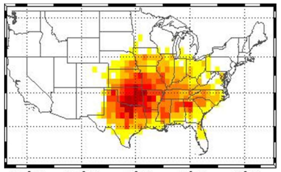

Fig. 3: Mean April daily hail frequency

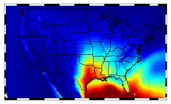

Fig. 4: Mean April CAPE

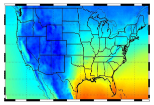

Fig. 5: Mean April PW

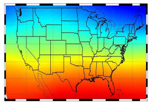

Fig. 6: Mean April GPH

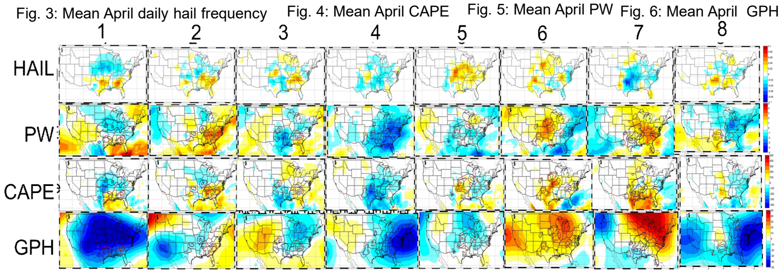

Fig. 7: Composite anomalies of hail frequency (2100 UTC mean values), precipitable water (2100 UTC mean values) in mm, CAPE (2100 UTC mean values) in J/kg, and geopotential height (2100 UTC mean values) in m for the month of April.

- April: For central U.S. (Kansas, Nebraska, Missouri), hail days were more likely in phases 5 and 6 and less likely in phases 1 and 7 (Fig 7, row 1).

Mean values of daily hail frequency (left) and CAPE, PW, and GPH at 2100 UTC (below) for May.

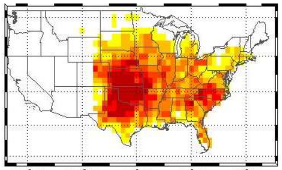

Fig. 8: Mean May daily hail frequency

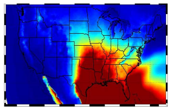

Fig. 9: Mean May CAPE

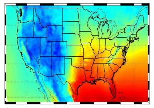

Fig. 10: Mean May PW

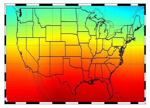

Fig. 11: Mean May GPH

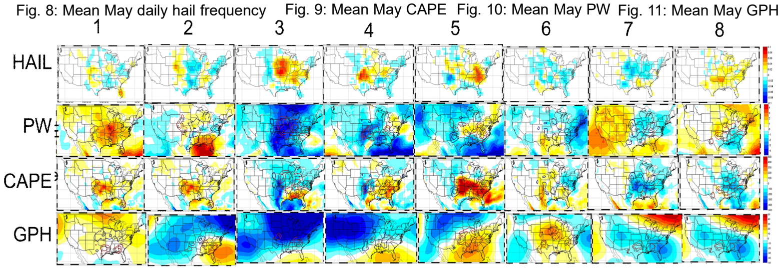

Fig. 12: Composite anomalies of hail frequency (2100 UTC mean values), precipitable water (2100 UTC mean values) in mm, CAPE (2100 UTC mean values) in J /kg, and geopotential height (2100 UTC mean values) in m for the month of May.

- May: For central U.S. (Kansas, Nebraska, Missouri), hail days were more likely in phases 3 and 4 and less likely in phases 6 and 7 (Fig 12, row 1).

Results: hail variability by MJO phase

Table 1: Comparison of anomalies of hail, CAPE, precipitable water, and geopotential height for April.

	1	2	3	4	5	6	7	8
HAIL	-	-	-	-	+	+	-	-
PW	-	+	-	-	-	+	+	-
CAPE	-	0	-	-	+	+	+	+
GPH	-	-	0	-	-	+	+	+

- For phase 6 in April, positive anomalies of CAPE, precipitable water, and geopotential height supported a positive hail anomaly (Table 1).
- For phase 1 in April, negative anomalies of CAPE, precipitable water, and geopotential height supported a negative hail anomaly (Table 1).

Table 2: Comparison of anomalies of hail, CAPE, precipitable water, and geopotential height for May.

	1	2	3	4	5	6	7	8
HAIL	+	-	+	+	+	-	-	+
PW	+	-	+	+	0	-	+	+
CAPE	+	+	-	-	+	+	-	-
GPH	+	-	-	-	+	+	+	-

- For phase 1 in May, positive anomalies of CAPE, precipitable water, and geopotential height supported a positive hail anomaly (Table 2).
- Hail and atmospheric anomalies did not always agree: for example, regions of positive CAPE, PW, and negative GPH were not always associated with above-normal hail frequencies.
- And for phase 4, negative anomalies of PW, CAPE, and GPH resulted in above-normal hail frequencies (Table 2).

Conclusions and future work

- Hail frequency varied by MJO phase across the continental United States in the months of April and May.
- Hail variability by MJO phase was largely supported by anomalies of CAPE, precipitable water, and geopotential height for April and May.
- Positive anomalies of CAPE and precipitable water content, and negative anomalies of geopotential height, were generally associated with above normal hail activity for April and May.
- Negative anomalies of CAPE and precipitable water content, and positive anomalies of geopotential height, were generally associated with below normal hail activity for April and May
- Study the relationship between storm helicity and vertical wind shear and hail activity.
- Collect the above data and perform the same research for the month of June as well as April and May.

References

Barrett, B., and V.A. Gensini, 2013: *Variability of central United States April-May tornado day likelihood by phase of the Madden Julian Oscillation.* Geophysical Research Letters, 40, 2790-2795.

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.* American Meteorological Society, 17.

Knight, C.A., and N.C. Knight, 1984: *Hailstorms.* National Center for Atmospheric Research, 223-247.

Madden, R.A., and P.R. Julian, 1972: *Description of Global-Scale Circulation Cells in the Tropics with a 40-50 day period.* Journal of the Atmospheric Sciences, 29, 1109-1123.

Wheeler, M.C., and H.H. Hendon, 2004: *An All-Season Real-Time Multivariate MJO Index: Development of an Index for Monitoring and Prediction.* Monthly Weather Review, 132, 1917-1932.