4.12 THE INFLUENCE OF THE MADDEN-JULIAN OSCILLATION (MJO) ON THE WEATHER OF ALASKA

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1. INTRODUCTION

The Madden-Julian Oscillation (MJO) is the primary mode of large-scale intraseasonal (30–90 day) variability in the tropics (Madden and Julian 1994). Previous (e.g., Mo and Higgins 1998) and ongoing (Bond and Vecchi 2003) work has explored the influences of the MJO on precipitation along the U.S. West Coast. These studies indicated that the atmospheric circulation anomalies associated with the MJO extend into the high latitudes of the Pacific Ocean and North America. The objective of the present study has been to determine whether the MJO has a statistically robust effect on important elements of the weather of Alaska and its environs.

2. DATA AND METHODS

We make use of two different data sets. For specification of the MJO, and for determining its relationship to the atmospheric circulation over Alaska, we use the NCEP/NCAR Reanalysis (Kalnay et al. 1996). The MJO is diagnosed based on time series of the principal components of the two leading EOF modes of the 850 mb zonal wind in the band from 5°S to 5°N following the technique of Shinoda et al. (1998). The input here is daily averages for the period of 1979 to 2001 (prior to 1979 satellite data were not consistently available to constrain the 850 mb wind fields in the tropics). The MJO is considered to be active when the square root of the sum of the squared amplitudes of the principal components of the two leading modes exceeds unity; by this definition it is active roughly 2/3 of the time during the boreal cool season. The phase of the MJO is determined by the arctangent of the ratio of the two principal components and is divided into eight parts of roughly 6 days each, on average. These phases are related to the longitude of the anomalous deep convection along the equator. Composites with respect to the MJO are constructed by averaging daily values for each of the eight phases. The flow over Alaska and its surroundings is characterized using mid-tropospheric geopotential height and specific humidity fields from the Reanalysis. The weather of Alaska is based on daily station data at a representative sample of locations from the National Climatic Data Center (NCDC). The seasons considered are the early (October–December) and late (January–March) parts of the cool season. The weather elements of special interest are surface air temperature and precipitation anomalies. For each of the data sets described above, monthly climatologies are constructed and then interpolated to daily values, which were then subtracted to form anomalies for each parameter.

3. RESULTS

The MJO has a statistically significant effect on the weather of Alaska in the cold season due to teleconnections between the tropics and higher latitudes. Examples of the consequences of these teleconnections on the tangible weather in Alaska are illustrated in Figs. 1 and 2. These plots indicate the average daily minimum temperature as a function of MJO phase in OND (top) and JFM (bottom) for Barrow and Nome, Alaska, respectively. Similar temperature signals were found for daily maximum and daily mean temperatures. Considering OND, note temperatures are about 4–6°F warmer than normal during MJO phases 2–3 (when the 850 mb westerlies and deep convection are enhanced over the Indian Ocean) and temperatures are 4–6°F colder than normal during MJO phases 6–7 (when the 850 mb westerlies and deep convection are enhanced over New Guinea and the tropical West Pacific warm pool). The MJO signal during

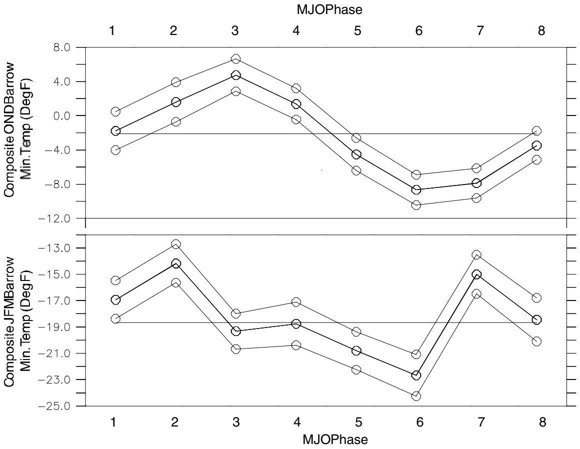

Figure 1. Minimum temperatures (°F) as a function of MJO phase at Barrow, Alaska during October through December (top) and January through March (bottom). The heavier line in the middle refers to the average temperature; the lines bracketing it refer to the 90% confidence limits based on a normal distribution. The horizontal line indicates the mean value for the period. See text for details regarding the MJO phase.

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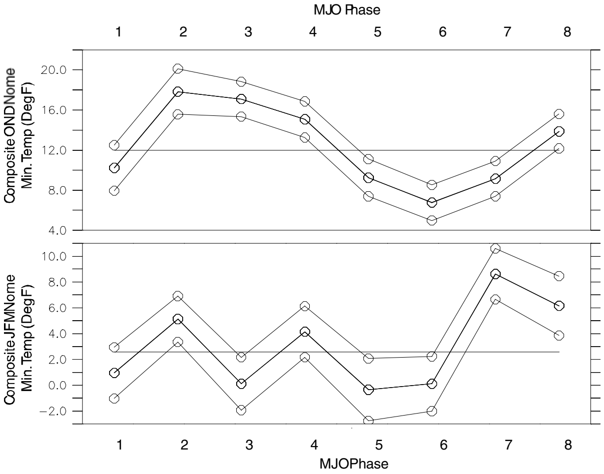

Figure 2. As in Fig.1, but for Nome, Alaska.

JFM is weaker, but still statistically significant. It is interesting that the warmest temperatures in JFM occurred during phase 7, which was a phase of anomalous cold in OND.

The differences between the response to the MJO in OND versus JFM appear to be due to differences in the mean atmospheric flow of the Northern Hemisphere. The polar jet and its associated storm track tends to be farther south, and extend farther east across the North Pacific, in JFM than in OND. It is this feature that probably acts as the agent by which tropical convection (heating) and wind anomalies impact higher latitudes. In other words, the anomalous wave train emanating from the tropical Pacific in association with the MJO has a different character in OND than in JFM. As for the Alaska temperatures illustrated here, a difference in the nature of the response to the MJO between OND and JFM was found for Pacific Northwest precipitation (Bond and Vecchi 2003). Our scrutiny of the anomalous tropospheric flow over Alaska accompanying each phase of the MJO (not shown) indicates that for much of Alaska it is the anomalous advection that is controlling surface temperatures. Not surprisingly, for example, relatively warm temperatures tend to be associated with anomalous ridging over and to the east of Alaska, and hence anomalous southerly flow. There are notable exceptions to these relationships in the interior of Alaska (e.g., Fairbanks). This region has a different shape for the temperature signal with respect to MJO phase (not shown). Our preliminary analysis of these differences suggests it is because the surface temperatures in these regions are more determined by local downward longwave radiative fluxes (the "effective sky temperature"), than by large-scale patterns of tropospheric temperature advection.

4. FINAL REMARKS

While our results appear to be robust, two caveats bear mentioning. The periods of analysis (1979 to 2001) included a tendency for more warm El Niño-Southern Oscillation (ENSO) conditions than cold ENSO conditions, and for the Pacific Decadal Oscillation or PDO (Mantua et al. 1997) to be in a positive state. It is unknown whether these decadal-scale background conditions influence the response of the atmospheric circulation over the North Pacific and Alaska to the MJO, and hence represent an important context for the results found here. Second, our analysis has had the benefit of hindsight in specification of the MJO. In order to make predictions based on the MJO, the MJO itself needs to be forecast.

Our investigation into the MJO's modulation of Alaska weather takes into account the seasonal cycle; the differences we see between early and late winter may be attributable to the difference in the mean atmospheric circulation during those times. In our ongoing research on this matter, we are also considering the state of climate modes such as the Arctic Oscillation (Thompson and Wallace 1998), since these factors also help determine the mean flow and hence the high latitude response to the MJO.

5. REFERENCES

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