JP5.13 INTRASEASONAL VARIABILITY OF SUBTROPICAL CYCLONE OCCURRENCE IN THE CENTRAL AND EASTERN PACIFIC OCEAN

Jason A. Otkin* and Jonathan E. Martin
University of Wisconsin, Madison, Wisconsin

1. INTRODUCTION

During the Northern Hemisphere cool season, cyclones frequently develop in the subtropical central and eastern Pacific (SCEP) Ocean. Although a number of studies have examined these cyclones from synoptic-climatological (e.g. Simpson 1952; Otkin and Martin 2003), case study (e.g. Ramage 1962; Businger et al. 1998; Morrison and Businger 1998; Martin and Otkin 2003) and hydrological perspectives (e.g. Kodama and Barnes 1997; Chu et al. 1993), no study has ever systematically examined the large-scale circulation that is present across the north Pacific basin during periods that are characterized by the frequent or infrequent occurrence of subtropical cyclones (deemed “active” and “inactive” periods, respectively). Therefore, in order to discern the underlying physical processes that produce these temporal variations in cyclone occurrence, we present an analysis of the large-scale circulation features associated with both active and inactive periods of subtropical cyclogenesis.

2. DATA ANALYSIS

Surface and upper-air analyses from the ECMWF TOGA data set and OLR analyses from the NOAA interpolated outgoing longwave radiation (OLR) data set for 10 boreal cool seasons (October-March) were used for this study. The ECMWF TOGA dataset consists of twice-daily sea level and standard pressure level analyses on a global domain with 2.5° latitude-longitude resolution. The NOAA OLR dataset consists of daily OLR analyses with global 2.5° latitude-longitude resolution.

For this study, a cyclone was defined to be a minimum in the sea level pressure field surrounded by at least one-closed isobar (analyzed at 2 hPa intervals). To qualify as a subtropical cyclone, the surface cyclone also had to initially develop within a portion of the SCEP (shown in Fig. 1) and then maintain at least one closed sea-level isobar for a minimum of 48 hours. The initial positions of the 101 cyclones that satisfied these requirements are shown in Fig. 1.

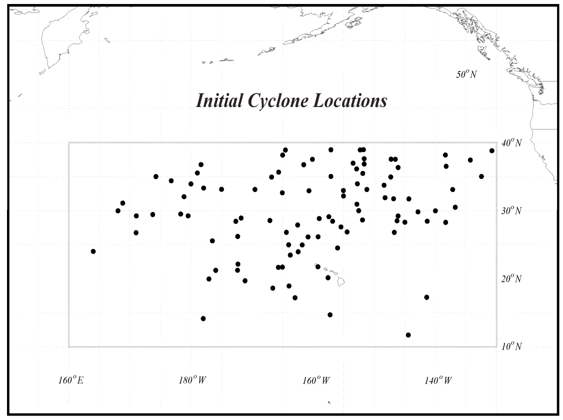

Figure 1. Black dots represent the initial locations of the subtropical cyclones considered in the analysis. Rectangular box is the SCEP domain referred to in the text.

Figure 2 is a daily time series of subtropical cyclone occurrence for each of the 10 cool seasons. It is evident that certain periods are characterized by a substantial number of cyclones while other periods are totally void of cyclones. In order to provide an objective measure of this cyclone variability, active periods were defined to be periods in which 2 or more cyclones sequentially developed with a maximum of 10 days separation between the final time of one cyclone and the initial time of another. Inactive periods were defined to be periods of at least 10 days duration, with a 5-day boundary at both the front and back ends of the period, in which no cyclones with a subtropical origin were present within the Pacific basin. Active and inactive periods defined in this manner are indicated by shading in Fig. 2.

3. COMPOSITE CORRECT AND INCORRECT ACTIVE PERIODS

Based on prior theoretical results (e.g. Hoskins and Karoly 1981), it was inferred that active periods might be associated with suppressed tropical convection in the central Pacific due to the generation of an anomalous subtropical trough by Rossby wave dispersion away from the anomalous convection. A detailed analysis of the outgoing longwave radiation anomalies (OLR) associated with each active period, however, revealed that only 55% of the periods were characterized by the theoretically-expected distribution of anomalous

*Corresponding author address: Jason A. Otkin, SSEC/CIMSS Univ. of Wisconsin–Madison, 1225 W. Dayton Street, Madison WI 53706-1695. email: jason.otkin@ssec.wisc.edu, phone: (608) 265-2476

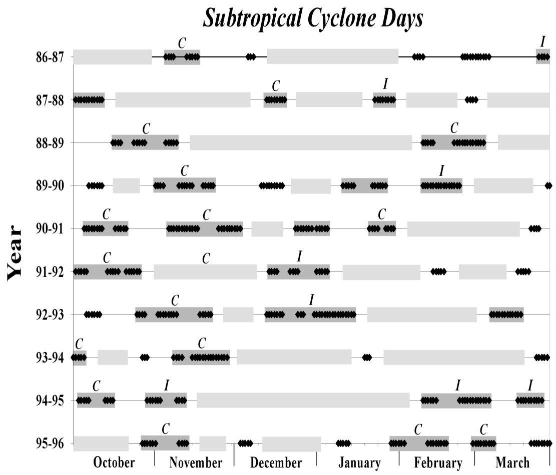

Figure 2. Daily time series of subtropical cyclone occurrence during cool seasons (October-March) from 1986-1996. Black diamonds represent days on which subtropical cyclones were found in the Pacific basin. Light (dark) shading identifies the inactive (active) periods defined in the text. The letters "C" and "I" correspond to the correct and incorrect active periods identified in the text.

tropical convection while nearly a third of the periods were actually characterized by the exact opposite distribution.

Given the lack of uniformity among the individual active periods with respect to the distribution of anomalous tropical convection, an additional composite grouping was adopted. We define "correct" active periods to be those with suppressed tropical convection in the central Pacific and enhanced convection in the western Pacific. Conversely, "incorrect" active periods are characterized by enhanced convection in the central Pacific and suppressed convection in the western Pacific. Correct active periods defined in this manner are identified by the label “C” in Fig 2. The anomalous OLR distributions associated with the correct and incorrect active periods are shown in Fig. 3.

The composite 300 hPa height and zonal wind anomalies for correct and incorrect active periods are shown in Fig. 4. Correct active periods are characterized by an anomalous subtropical trough in the central Pacific, an anomalous ridge across the north Pacific and an anomalous trough over central North America (Fig. 4a). These elements of the height anomaly pattern are indicative of the negative phase of the PNA pattern. The orientation of the height anomaly centers along a great circle route is strongly suggestive of Rossby wave dispersion emanating away from the central Pacific, which indicates that anomalous tropical convection near the dateline could be forcing an extratropical response that resembles the PNA pattern.

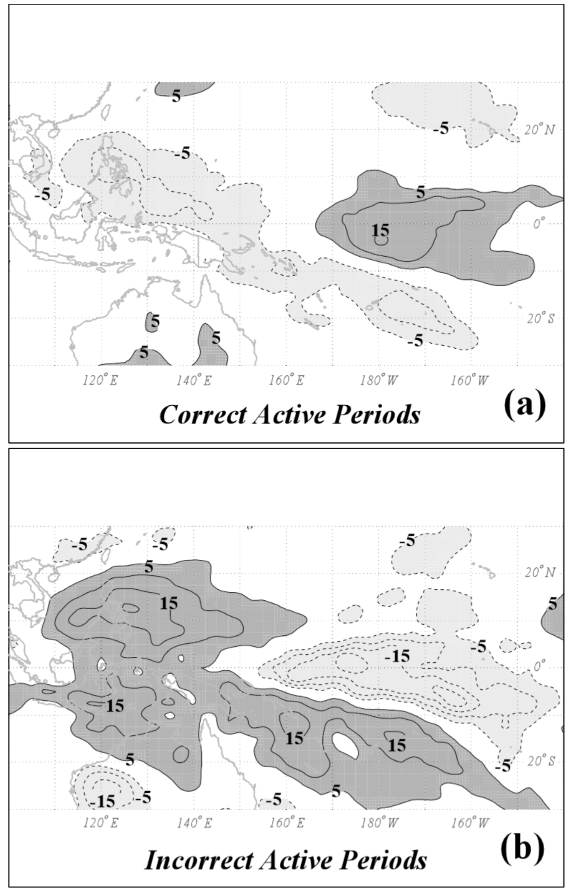

Figure 3. (a) OLR anomalies for correct active periods. Positive (negative) anomalies are labeled in W m^{-2}, indicated by dark (light) shading and contoured every 5 W m^{-2} beginning at 5 (-5) W m^{-2}. (b) As for Fig. 3a but for incorrect active periods.

However, with enhanced convection near the dateline during incorrect active periods (Fig. 3b), the same general height anomaly pattern still develops across the central Pacific and North America with even larger height anomalies in the jet exit region (Fig. 4c) than during correct active periods. This height anomaly pattern is still indicative of the negative phase of the PNA pattern, yet is precisely opposite of what might be expected to develop when enhanced tropical convection occurs in the central Pacific. In fact, considering that Rossby wave dispersion theory links enhanced convection in the central Pacific to the development of an anomalous subtropical ridge and extratropical trough, the magnitude of these anomalies is even more impressive. Therefore, we conclude that a fully-developed PNA pattern can exist for periods of a week or longer regardless of whether enhanced or suppressed tropical convection occurs in the central Pacific.

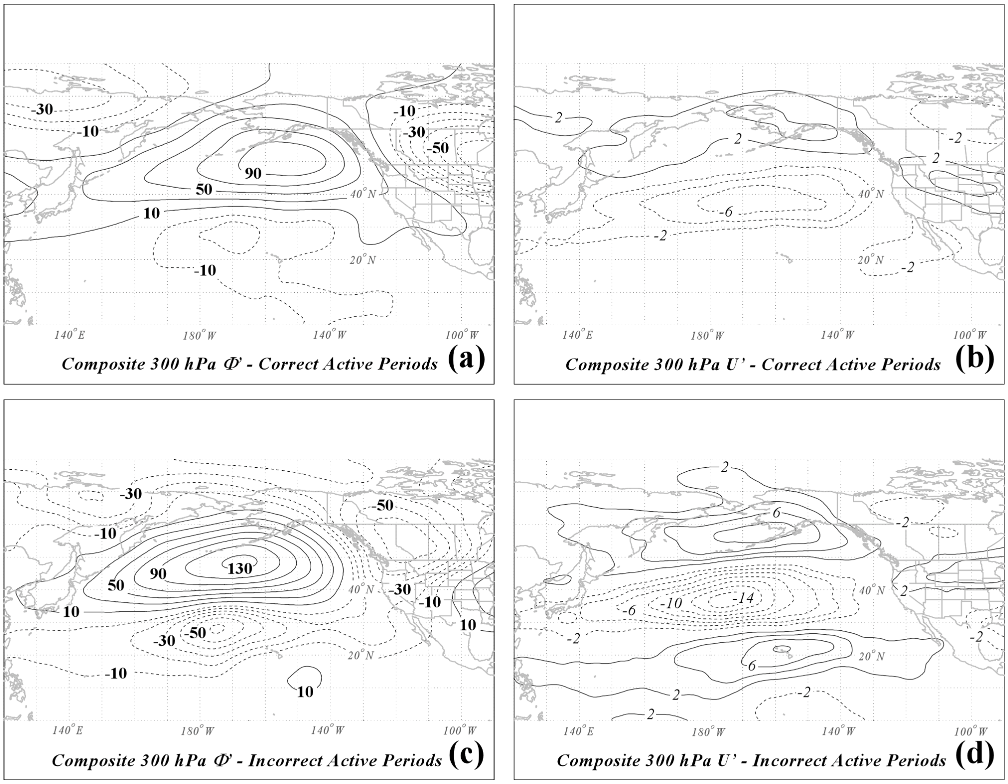

Figure 4. (a) Composite 300 hPa geopotential height anomalies (m) for correct active periods. (b) Composite 300 hPa zonal wind anomalies for correct active periods. (c) As for Fig. 4a but for composite incorrect active periods. (d) As for Fig. 4b but for composite incorrect active periods.

The development of anomalous height patterns in the central Pacific is also accompanied by significant changes in the strength and location of the Asian jet. Although both correct (Fig. 4b) and incorrect (Fig. 4d) active periods are characterized by diminished westerlies across the central Pacific, much larger zonal wind anomalies occur during incorrect active periods. The development of a “tripole” pattern in the wind anomaly field during incorrect active periods, characterized by enhanced westerlies over Alaska and the subtropical Pacific and greatly diminished westerlies in the jet exit region represents a dramatic broadening of the Asian jet. Hoskins and Karoly (1981) have indicated that a broadened jet can result from barotropic energy conversions in the exit region of the jet, which suggests that barotropic energy conversions may provide an important source of energy for cyclone development during these periods.

4. CONCLUSIONS

Outgoing longwave radiation data were used to explore the potential link between anomalous convection in the tropical Pacific and the occurrence of active periods of subtropical cyclogenesis. It was suggested that Rossby wave dispersion away from anomalous tropical convection during correct active periods was associated with an extratropical response resembling the negative phase of the PNA pattern. However, a well-developed negative PNA pattern also occurred during incorrect active periods, even though these periods were characterized by enhanced tropical convection in the central Pacific. This suggests that viewing the PNA pattern primarily as an extratropical response to anomalous tropical convection in the central Pacific is an oversimplification.

5. ACKNOWLEDGEMENTS

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