ENSO 對太平洋冬季航路之可能影響

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Abstract

Possible influences of El Niño/Southern Oscillation (ENSO) on winter (December-February) shipping in the North Pacific (NP) and associated large-scale regulatory processes are investigated for the period 1983-2008 using marine observations compiled by the International Comprehensive Ocean-Atmosphere Data Set (ICOADS). The impacts of ENSO on winter shipping are systematic and evident in the western and northern NP. During El Niño (La Niña) events, weakened (intensified) ocean waves provide conditions that facilitate (hinder) shipping efficiency, resulting in increased (decreased) shipping frequency in the SCS. In the northern NP, shipping during El Niño events tends to avoid the dangerous mid-latitude 300-500N regions and stick to the major 540N Aleutian-Islands route to cross the NP. During La Niña events, there is an increase in the frequency of shipping detouring southward along the wave-weakened 300-400N zone and a decrease in shipping frequency along the wave-intensified 540N route. Shipping frequency along the major routes across the NP generally increases in El Niño events but decreases during La Niña events.

1. Introduction

Earth's climate system is considered to primarily result from ocean-atmosphere interactions. In contrast to the large amounts of observed atmospheric data, oceanic data are considerably rare. To improve this situation, tremendous efforts have been made to compile surface meteorological observations from voluntary observing ships, fixed and drifting buoys, and ocean stations. The resultant data are referred to as the International Comprehensive Ocean-Atmosphere Data Set (ICOADS; e.g., Parker et al. 2004; Woodruff et al. 2005; Worley et al. 2005). For the ICOADS data, the most reliable information ought to come from spatial location and the number of reports. The spatial distribution of ship-report numbers should provide reliable information for delineating shipping frequency and the major routes used. In general, shipping frequency and routes should vary in accordance with marine conditions. This suggests that significant climate variability should noticeably impact these features of shipping.

On an interannual time scale, the most striking variability feature in the Pacific is El Niño-Southern Oscillation (ENSO). At low latitudes, strong El Niño events cause a low-level anomalous anticyclone anchored in the Philippine Sea-South China Sea (SCS) region (e.g., Wang et al. 2000; Wang and Zhang 2002). It induces anomalous southwesterly flows to suppress prevailing winter northeasterly monsoon flows over the SCS and East Asia, leading to a weakened winter EA monsoon (e.g., Zhang et al. 1996; Zhang et al. 1997; Wu et al. 2006). In the extratropics, the Aleutian low tends to be deepened with an eastward displacement during El Niño winters as it is modulated by the Pacific/North American (PNA) teleconnection pattern (e.g., Horel and Wallace 1981; Wallace and Gutzler 1981; Shukla and Wallace 1983).

The above studies reveal that ENSO can evoke noticeable surface circulation anomalies in the NP during winter. These circulation anomalies should further induce changes in surface winds and ocean waves by which shipping frequency and routes in the NP may vary accordingly to exhibit certain dynamic relationships with ENSO. Efforts are thus made in this study to investigate the possible influences of ENSO on the interannual variability of NP shipping during winter.

2. Data

Two data sets are analyzed in this study. The first is the National Centers for Environmental Prediction-National Center for Atmospheric Research (NCEP-NCAR) monthly reanalysis data (Kalnay et al. 1996). This data set is hereafter referred to as the reanalysis data. The second data set includes ICOADS observations, which contain reports from ships, buoys, and ocean stations. To reduce uncertainty problems regarding data quality, analyses in this study span the recent period of 1983-2008 winters, where 1983 winter begins in December of 1982 through to January and February of 1983. Ocean wave and surface wind are important factors affecting shipping efficiency and safety. Thus, only records with both wave (represented by wind sea parameter) and wind observations are included in the analysis. To have a uniform spatial distribution, the winter-mean gridded values are obtained by averaging individual parameters within 2^0 x 2^0 box-spaces.

3. ENSO-related circulation variability in the NP

The ENSO events are categorized by the Niño-3.4 (170^0W-120^0W, 5^0S-5^0N) SST index compiled by the Climate Prediction Center (http://www.cpc.ncep.noaa.gov). A year in which the winter Niño-3.4 SST anomaly is higher (lower) than 0.5^0C (-0.5^0C) is classified as an El Niño (a La Niña) case. This classification results in nine El Niño and seven La Niña events as listed in Table 1. The reanalysis SLP anomalies associated with El Niño (La Niña) events exhibit an anomalous high (low) in the tropical western Pacific to the west of the divergent (convergent) center around the 150^0E, while an anomalous low (high) appears in the northeastern NP. The above circulation variability indicates that the Aleutian low tends to be intensified during El Niño but weakened during La Niña. For the ICOADS data, composite SLP anomalies exhibit coherent patterns with the reanalysis anomalies in terms of spatial structures and magnitudes of the major anomaly features in the western and northeastern NP.

The magnitude of surface wind anomalies is compared in terms of WSP between the reanalysis and ICOADS data. For El Niño cases, significant WSP features of the reanalysis data include northwest-southeasterly oriented positive anomalies in the northern NP (160^0E-150^0W, 30^0-50^0N) and negative anomalies in the western Pacific (15^0-25^0N). These two features correspond to, respectively, the intensification of mid-latitude westerlies at the southern flank of the Aleutian low and the weakening of northeasterly monsoon flows and trade winds in the SCS and tropical western Pacific. The WSP anomalies of La Niña cases exhibit a pattern more or less opposite to that of El Niño cases. WSP variability features for the mid-latitude westerlies and the subtropical northeasterly monsoon flows and trade winds depicted by the ICOADS data are consistent with that depicted by the reanalysis data with respect to spatial structure and anomaly magnitude. The above SLP and surface wind analyses clarify that the ICOADS observed data can adequately delineate the influence of ENSO on surface circulations in the northern and western NP. Thus, the ICOADS data are suitable for delineating interannual variability features.

4. Interannual variability of shipping frequency

Composite wave patterns for El Niño cases (Fig. 1a) exhibit positive anomalies across the 30^0-50^0N zone of the NP in concurrence with enhanced mid-latitude westerlies in the southern sections of the Aleutian low, while negative anomalies appear in the SCS-Philippine Sea region in association with suppressed northeasterly monsoon flows. Composite wave anomalies of La Niña cases (Fig. 1b) exhibit features largely opposite to that of El Niño cases in the SCS-Philippine Sea region. In the northern NP, the anomalous anticyclonic circulation associated with the weakened Aleutian low results in intensified (weakened) wave anomalies to the north (south) of 40^0N. The intensified and weakened wave anomalies are separated by the latitude of 40^0N in La Niña cases but by 50^0N in El Niño cases. In general, the major wave anomalies are highly coherent with variability patterns of surface winds.

Composite anomaly patterns of shipping frequency for El Niño cases exhibit two salient features (Fig. 1c). First, positive frequency anomalies appear in the SCS, Taiwan Strait, the vicinity of Japan, the Kuril Islands northeast of Japan, the Aleutian Islands, and the western coasts of North America. These anomalies suggest an increase in shipping frequency along the conventional great-circle routes. Second, negative anomalies appear in the 32^0-50^0N zone of the NP, while positive anomalies exist to the south of 32^0N. These large-scale frequency anomalies indicate the systematic influences of El Niño on NP shipping. The intensified and eastward-displaced Aleutian low result in strengthened mid-latitude westerly winds and ocean waves in the 30^0-50^0N zone of the NP. Strong winds and high waves are dangerous to shipping. The NP cross-shipping may detour either northward or southward to avoid the dangerous 32^0-50^0N zone, yielding negative frequency anomalies in the central NP and two tracks of positive frequency anomalies in the northern and southern NP. Specifically, shipping tends to stay with the conventional great-circle route along the Aleutian Islands near 54^0N or move along a southern course in the safe subtropical regions within the 20^0-30^0N zone. In the SCS, positive frequency anomalies are concurrent with weakened northeasterly flows and suppressed waves. Weak winds and low waves provide a safer marine environment and better navigational efficiency, allowing shipping to stay on courses more readily. Increased shipping frequency thus occurs in the SCS.

For La Niña cases (Fig. 1d), negative frequency anomalies appear throughout the major great-circle routes across the Pacific rim, exhibiting a pattern largely reverse to that of El Niño cases. As mentioned previously, La Niña events induce an anomalous anticyclonic circulation over the NP with weakened waves in the regions south of 40^0N but intensified waves to the north of 40^0N. Shipping tends to detour from the conventional 54^0N Aleutian-Islands routes along two alternative courses, as indicated by two zonal tracks of positive anomaly. One alternative course takes shipping further northward in the 56^0-58^0N zone, while the other takes it southward along the 30^0-36^0N zone. The former alternative course intends to avoid the strongly intensified waves in the 170^0-140^0W, 45^0-55^0N regions, while the latter course simply sails toward the regions with weakened waves. In the SCS, the occurrence of anomalous cyclonic circulation results in enhanced northeasterly monsoon flows and high waves. The worsened marine environments slow down shipping efficiency, resulting in negative frequency anomalies in the SCS.

5. Concluding remarks

An attempt is made in this study to examine possible influences of ENSO on interannual variability of winter (December-February) shipping in the NP revealed by the ICOADS data. Shipping frequency is interpreted from the winter-accumulated number of ship reports for each 2^0 x 2^0 box-spaces in the study regions. Composite analyses reveal that impacts of ENSO on surface marine environments and shipping frequency in winter are systematic and notable in the western and northern NP. The El Niño events evoke an anomalous anticyclone in the western NP and an eastward-displaced and intensified Aleutian low in the northern NP. The former induces anomalous southwesterly flows to suppress prevailing northeasterly monsoon flows and trade winds. Weakened winds and waves in the SCS facilitate shipping efficiency, resulting in increased shipping frequency. The latter intensifies mid-latitude westerlies and ocean waves in the 30^0-50^0N zone. Shipping tends to detour from this dangerous region and stays on the conventional great-circle routes north of the Aleutian Islands. As such, shipping frequency decreases in the 30^0-50^0N zone but increases in the 54^0N route. During La Niña events, shipping frequency decreases in the SCS due to intensified winds and waves induced by an anomalous cyclonic circulation. In the northern NP, a weakened Aleutian low causes winds and waves to reduce in the regions south of 40^0N but to enhance north of 40^0N. Shipping frequency thus decreases in the 54^0N Aleutian-Islands route but increases in the 30^0-36^0N zone. Our analyses illustrate that interannual variability in shipping frequency and marine environments (surface wind, ocean wave) associated with ENSO exhibits robust large-scale patterns and dynamically-coherent relationships in the western and northern NP. These results demonstrate the existing reliability of the ICOADS data in studying interannual variability features in the NP, including visually-estimated wave parameters.

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Table 1: El Niño and La Niña winters defined by the Niño 3.4 SST index.

El Niño	1983, 1987, 1988, 1992, 1995, 1998, 2003, 2005, 2007
La Niña	1985, 1989, 1996, 1999, 2000, 2001, 2008

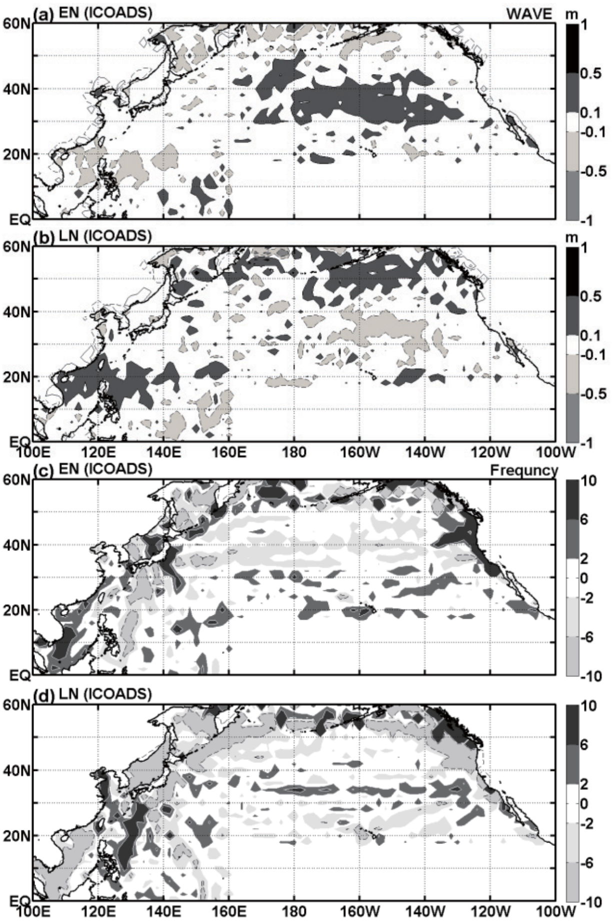

Fig 1: Composite anomalies of El Niño/La Niña cases of the ICOADS (a)/(b) waves and (c)/(d) shipping frequency.