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INFLUENCE ON NORTHERN PACIFIC STORM TRACK OF EQUATORIAL CENTRAL AND EASTERN PACIFIC SSTA DURING WINTER

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ABSTRACT: Singular value decomposition (SVD) is conducted of 15 winter tropical Pacific SST with 500 hPa filtered potential height variance over the northern Pacific storm track. It is shown that the first coupled mode obtained depicts the effect on the track of SSTA over equatorial central and eastern Pacific. Further composite analysis indicates that the SSTA over there during winter can give rise to or invigorate PNA teleconnection response pattern in 500 hPa height field which, in turn, exerts crucial influence on the interannual variability in vigor and east-west displacement of the Pacific storm track, especially over its central and eastern part.

Key words: storm track; interannual variability; SVD analysis; teleconnection pattern

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1 INTRODUCTION

A storm track is an area in which the transient disturbance is the most active on the scale of 2.5 ~ 6 days. For the Northern Hemisphere there are two such significant areas, locating in two oceans in mid latitudes, respectively. Since the discovery, with the aid of filtered data, of its existence in the end of the 1970's (Blackmon, 1976; Blackmon, Wallace and Lau, 1977; Lau, 1979), research in the aspect has become an important branch in the field of 3-D transient wave dynamics. Progresses have been made in probing the mechanisms for maintaining the storm track and internal dynamics (Hoskins and Valdes, 1990; Cai and Mak, 1990; Chang and Orlanski, 1993; Zhu and Sun, 1998; Sun and Zhu, 1998), though with little understanding so far of its interannual anomalies. As the condensation heating anomalies resulted from transient disturbance within the track region pose important effect on global circulation of the atmosphere (and the heating itself directly brings forth changes in weather and climate), studying the anomalies and physical mechanism responsible for them is of essential implication for weather forecasting and short-term climate prediction. As is shown in some previous work, the vorticity flux caused by mid-latitude transient disturbance during ENSO plays a vital role in maintaining the pattern of general circulation over north Pacific and North America, which is triggered by the sea surface temperature anomaly (SSTA) over the equatorial region; the distribution of the flux itself is also subject to SSTA in equatorial Pacific (Held, Lyons and Nigam, 1989; Hoerling and Ting, 1994; Straus and Shukla, 1997). It is the aim of the current work to use observed data to have thorough discussions of the interannual anomalies and their possible physical mechanisms of the storm track in north Pacific in winter, from the point of external heating sources.

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2 DATA AND METHODS

The current work uses reanalyzed grid data for a global 2.5°×2.5° size in 1979 ~ 1994 from NCEP/NCAR and the global 1°×1° SST grid data in 1979 ~ 1994 compiled by the British Met. Office.

A 31-bit digital band-pass filter, as introduced in Deng and Sun (1994), is first used here so that the transient vortex on a 2.5 ~ 6 day span is directly filtered out from day-to-day original datasets. Then, the filtered data are divided into a section per winter month for which relevant variance is computed, and from which monthly mean band-pass filter variance is thus derived. When conducting SVD analysis of the storm track (a filter variance for the 500-hPa height) and the SST field, the length of every time series of grid data is set at 15 years, with the focus on standardized mean over the wintertime (from 1979/1980 to 1993/1994). Specifically, the winter mean refers to one over the five months from November and December of the preceding year down to January, February and March of the year that follows and represents the mean state of a given field in a given year. For the selection of spatial domain, the value is sought between 100°E ~ 100 °W and 20°N ~ 70°N for the storm track in north Pacific and between 105.5°E ~ 78.5 °W and 28.5°S ~ 27.5°N for the SST in tropical Pacific.

The SVD method is widely used in meteorology. Being one of best methods for decomposing coupling patterns for any two fields, it renders easy and illustrative usage, requiring no custom setting of parameters and hardly attaching any systematic error. Following Bertherton, Smith and Wallace (1992) and Wallace, Smith and Bretherton (1992), we have studied the heterogeneous correlation patterns between different species.

3 ANALYSIS OF RESULTS

3.1 *SVD results*

The position and intensity of a storm track can be expressed using the filter variance of 500-hPa height. SVD analysis has been done for 500-hPa height filter variance field and tropical Pacific SST field over 15 winters so that not only the typical spatial distribution of the interannual difference for the storm track but the patterns of concurrent correlation between the variation of its coupling and tropical Pacific SST are obtained (Fig.1). We will discuss the first pair of typical spatial distribution.

Fig.1 gives this distribution with SVD analyzing the storm track and SST field (to be called Pattern SVD1) and corresponding curve of temporal coefficients. As is described in Section 2, the given typical spatial distribution is represented by the correlation chart of different species. For the filter variance of the 500-hPa height (Fig.1a), Pattern SVD1 depicts how the storm track varies out of phase in terms of intensity in areas north and south of 45°N in mid-latitude central and eastern Pacific, which is associated with north-south displacement of its own. Following the treatment introduced in Section 2, such pattern of variation is believed to reflect the interannual difference. For the tropical Pacific SST (Fig.1b), Pattern SVD1 shows the relationship of out-of-phase variation of concurrent SST between the equatorial central and eastern Pacific, the South China Sea and northwestern Pacific and the remainder. The distribution bears high similarity to the transverse "V" pattern of SSTA during a typical ENSO episode. As a matter of fact, the three El Niño years (1982/1983, 1986/1987 and 1991/1992) and two La Niña years (1984/1985 and 1988/1989) in the period, as indicated by the dashed curves of the temporal variation of the coefficients corresponding to Pattern SVD1, have opposite signs of temporal coefficients, all in respective maximal values. It is an indication that the SSTA in ENSO years has the largest contribution to such distribution

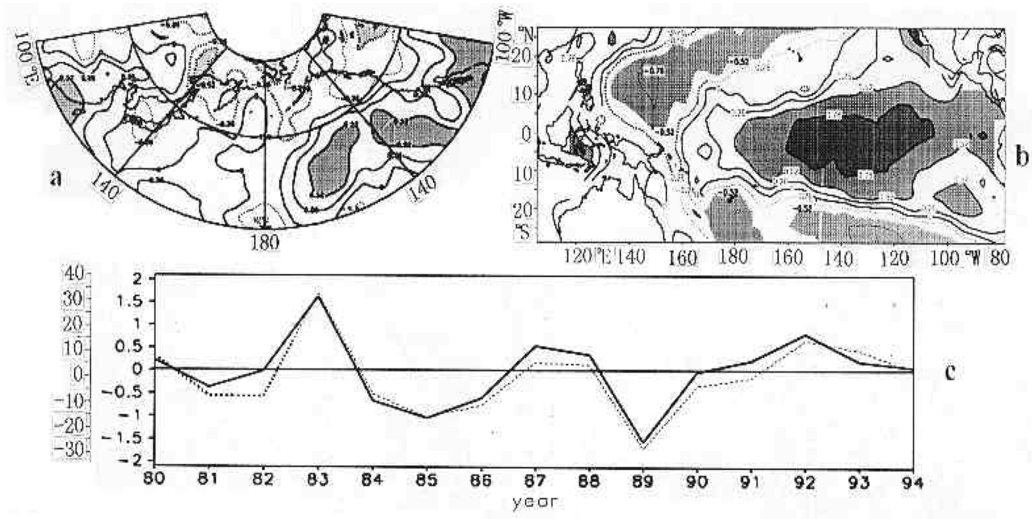

Fig.1 Heterogneous correlation patterns for the first SVD mode of the winter 500-hPa geopotential height variance in the Pacific storm track (a) and SST over the tropical Pacific (b). The squared covariance fraction explained by this mode is 41.2% and the temporal correlation coefficient between the expansion coefficient of this two fields for the same mode is 0.92. Given in (c) is the temporal coefficients related to the SST field (dashed) and the SSTA series averaged over the Niño 3+4 area (full line, in unit of °C). Regions with correlation values above +0.52 and below –0.52 are shaded.

pattern. The percentage of covariance square that is interpreted by this pair of typical distribution pattern is 41.2% and the correlation coefficient is 0.92 between two corresponding temporal coefficients, suggesting a high correlation in the pair. It is then clear that the interannual variation pattern of intensity and displacement in the middle and eastern sections of storm track over north Pacific in wintertime bears a close relation to the concurrent pattern of SST varying out-of-phase between the equatorial central and eastern Pacific, South China Sea and northwestern Pacific and the rest of the world oceans.

3.2 *Concurrent links to 500-hPa field in Northern Hemisphere*

Obtaining the correlation (Fig.2) between the temporal coefficient for the SST field of Pattern SVD1 and concurrent 500-hPa geopotential height in the Northern Hemisphere, we have examined links between the pattern of variation in coupling SST in wintertime tropical Pacific and storm track in the Pacific Ocean and the geopotential height field at 500 hPa in the hemisphere. As what is shown in the figure, this distribution of correlation reflects the typical pattern of teleconnected wavetrain over the Pacific and North America, suggesting close links between Pattern SVD1 and the PNA pattern (Pacific and North America) at 500 hPa. Comparing Fig.1 and Fig.2, we also discover that the center of storm track variation in wintertime north Pacific for Pattern SVD1 is right among the three centers of variation in the PNA pattern. It is then concluded that the anomalous SST in the tropical Pacific region in winter is closely related with concurrent changes in 500-hPa geopotential field and the storm track over the northern Pacific.

Studying the SSTA distribution given in SVD1 pattern for the wintertime tropical Pacific and its variation curves of temporal coefficients (Fig.1 b & c), we know that the equatorial central and eastern Pacific may turn out to be a signal zone. To confirm this presumption, we have highlighted the year-to-year curve of SSTA variation in Zone Niño 3+4 (160.5°E ~ 90.5°W, 5.5°S ~ 5.5°N, as

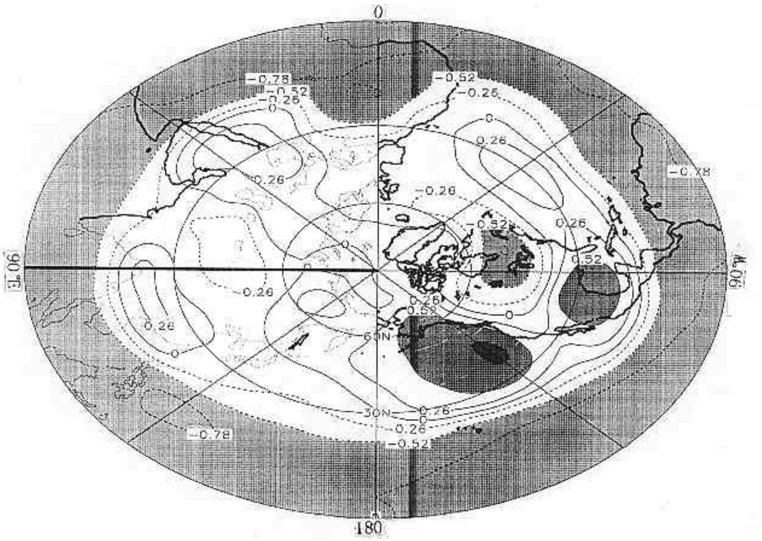

Fig.2 Distributions of the correlation coefficients between the temporal coefficients of the first leading SST eigenvector and the monthly averaged 500 hPa height values at individual grid points. Regions with correlation values above +0.52 and below –0.52 are shaded.

indicated by the solid line in Fig.1c). The figure presents a curve of SSTA variation over the zone that is very similar to that of the temporal coefficient for Pattern SVD1. Fig.3 further gives the distribution of simultaneous correlation of SSTA with (1) the filtered variance of 500-hPa geopotential height and (2) the height field itself. Fig.3a tells that in wintertime Niño 3+4 the SSTA correlates with concurrent filtered variance of the 500-hPa geopotential height by the most significant manner in the middle and eastern regions of the Pacific storm track. Positive correlation is found south of 45°N and negative correlation north of it, being very close to the typical pattern of correlation distribution as given by Pattern SVD1 (Fig.1a). In addition, the same SSTA is also in correlative distribution with the 500-hPa-geopotential-height field (Fig.3b), belonging to the PNA teleconnection pattern almost identical to Fig.2. From the analysis above, we know that results by Pattern SVD1 are reflecting the relationship between anomalous SST over that particular oceanic region in the equatorial central and eastern Pacific in winter and concurrent anomalies of north Pacific storm track and anomalous 500-hPa height.

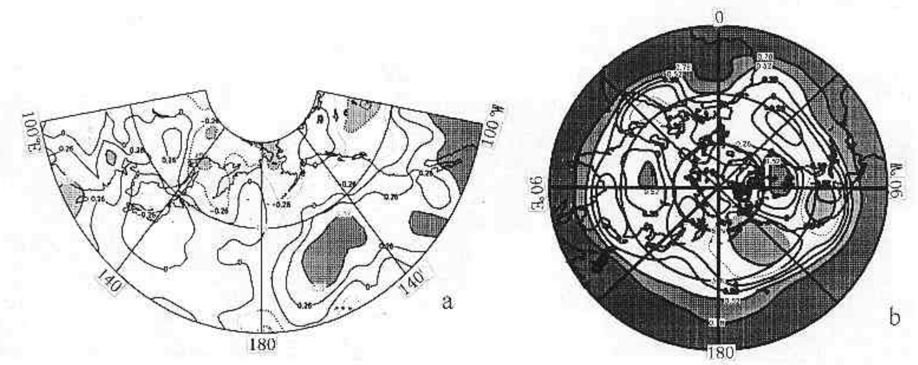

Fig.3 Distribution of the correlation coefficients between the mean SSTA series over Niño 3+4 Region and the 500-hPa geopotential height variance (a) and monthly averaged height values (b) at individual grid points. Areas with correlation values above +0.52 and below –0.52 are shaded.

3.3 *Results of composite analyse*

It is noted that the results above are only of correlation rather than of causality. On the other hand, both theoretic analysis and numerical simulation (Huang, 1991) have pointed to the possibility that the east Pacific SSTA may trigger or strengthen the PNA teleconnection pattern on the 500-hPa geopotential field so as to influence the changes in atmospheric circulation. It is therefore reasonable to argue that the interannual variation of the storm track may be caused by such tele-response of the atmosphere to the ocean — the wintertime SST anomaly in the equatorial central and eastern Pacific first influences the 500-hPa geopotential field and then produces important effects on concurrent interannual anomalies of the storm track in north Pacific.

In view of the consideration above, the months with absolute value of the SSTA $\geq$ 0.5°C are selected from the zone Niño 3+4 to composite the Tab.1 for further study of the effects of both positive and negative SSTA there on concurrent storm track for northern Pacific. Fig.4 gives the distribution of the filter variance and difference of 500-hPa geopotential height in response to positive and negative anomalies of SSTA in Niño 3+4. To add to the conclusion more degree of reliability, we have conducted the *t*-test of difference significance for the mean of two samples. Regions with the confidence level larger than $a = 0.05$ are shaded. From Fig.4, we know that for the equatorial central and eastern Pacific in winter, the north Pacific storm track is situated around 42°N with the bulk body extended towards southeast and the contour of 32 dagpm^2 shifted near 150°W when SSTA is positive; the central position of the storm track remains little changed with the contour still west of 170°W when SSTA is negative. Relatively speaking, however, the intensity of disturbance on the synoptic scale is much larger in the middle and eastern part of the storm track in times of positive than negative SSTA, and the disturbance intensifies (weakens) south

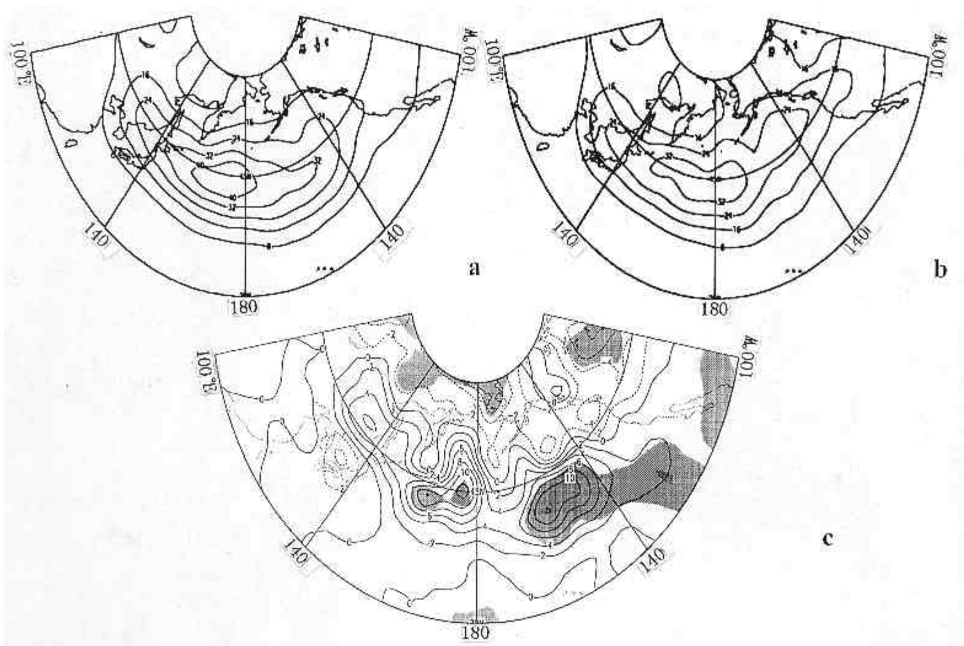

Fig.4 Northern 500-hPa geopotential height variance composites for winter positive (a), negative (b) SSTA over Niño 3+4 area and their difference (c) with contour interval of 8.0 (a, b) and 2.0 (c) dagpm^2, respectively. Shaded areas in (c) indicate that passing *t*-test at $a = 0.05$ confidence level.

Tab.1 Winter months related to the SSTA above and below 0.5°C over Niño 3+4 region

+SSTA	Nov.'82	Dec.'82	Jan.'83	Feb.'83	Mar.'83	Nov.'86	Jan.'87	Feb.'87
–SSTA	Feb.'81	Nov.'83	Dec.'83	Jan.'84	Dec.'84	Jan.'85	Feb.'85	Mar.'85
+SSTA	Mar.'87	Nov.'87	Dec.'87	Nov.'91	Dec.'91	Jan.'92	Feb.'92	Mar.'92
–SSTA	Dec.'85	Jan.'86	Feb.'86	Nov.'88	Dec.'88	Jan.'89	Feb.'89	Mar.'89

(north) of 45°N with the significance of difference reaching the level of $a = 0.05$. Studying Fig.1a and Fig.4c in parallel, we find that the distribution of difference is much similar to the pattern of SVD1 for the filter variance at 500 hPa geopotential height.

The results show that the positive SST in the equatorial central and eastern Pacific has important contribution to the eastward extension and consequent increase of the north Pacific storm track in the middle and eastern sections while the negative SST causes a largely opposite situation. The result agrees with the conclusion drawn in discussions of the role of ENSO events in maintaining the track (Zhu and Sun, 1998). In addition, Hu and Huang (1997) reported that the eastward extension of the storm track shows an obvious linear strengthening trend since the 1980's. It may, in our viewpoint, relate to higher frequency of ENSO outbreaks after the time.

4 CONCLUDING REMARKS

a. The SVD1 pattern obtained from SVD analysis describes how the north Pacific storm track varies out-of-phase in regions south and north of 40°N in mid-latitude central and eastern Pacific and how correlation is distributed by showing the concurrent SSTA in the equatorial central and eastern Pacific strengthens (decreases) but decreases (strengthens) in other waters of the tropics.

b. The SVD1 pattern is closely linked with the PNA pattern for the Pacific and North America on the 500-hPa geopotential field in northern winter. The linkage suggests that the SST anmalies in the equatorial central and eastern Pacific can have important influence on the interannual anomalies of the concurrent north Pacific storm track through the effect on the 500-hPa geopotential height field.

c. More composite study shows that the anomalous SST in the equatorial central and eastern Pacific have important contribution to the east-west oscillation of the storm track in the wintertime north Pacific and the changes in intensity in the middle and eastern section of its own.

Apart from the external heat forcing chosen for the current work — SSTA in tropical Pacific in winter, there are other factors that the interannual variations of the storm track in north Pacific in winter are subject to. More study needs to be done to reveal their effects.

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