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DEVELOPING PHASE OF THE SOUTH PACIFIC CONVERGENCE ZONE AND THE CROSS-EQUATORIAL FLOW IN THE WESTERN TROPICAL PACIFIC

Zhang Suping[1] Liu Qinyu
Physical Oceanography Lab. & Ocean –Atmosphere Interaction and Climate Lab.
Ocean University of China, Qingdao, China

1. Introduction

The South Pacific Convergence Zone (SPCZ) contains one of the earth's most expansive and persistent cloud bands, and plays an important role in the global climatic systems. Though first depicted by Bergeron (1930), the overall imagery of the SPCZ was not fully appreciated until satellite data became available in the early 1960s. However, few studies have been concerned about the developing phase of the SPCZ, i.e. in boreal autumn. The problems the paper is going to discuss are: Why is the maximum precipitation associated with the SPCZ not consistent with the maximum SSTs but located to the south of the axis of maximum SSTs in boreal autumn (Fig.1) ? What could be the reasons for the deflection? How do SSTs or SST gradients affect the SPCZ in its developing phase? What should be the relationship between the SPCZ and its surrounding winds? Do the winds play a role in the intensifying episode of the SPCZ? If so, what is the relationship between winds and SSTs?

2. Datasets

Datasets used for this study are QuikSCAT scatterometer estimated 10m level winds, TRMM (Tropical Rainfall Measuring Mission) satellite microwave imager estimated SSTs, rain-rates and surface wind speeds, long-term SSTs, 1000hPa winds, 1000hPa air temperature as well as OLR that are from NCEP/NCAR, NCEP/NWS/NOAA and NOAA-CIRES.

3. The first sign of the developing phase of the SPCZ

In order to investigate the variations in winds in detail, the monthly wind vector increment (defined as wind vector of the present month minus that of the last or immediately preceding month: $V'=V_p-V_l$) are analyzed in the SPCZ regions (Fig.2). The increment winds are almost opposite to the dominating winds from August to November. Corresponding to the increment winds, wind speed is going to decrease and SPCZ is starting to develop in August (Fig.3, 4).

4. Origin of the northerly increment winds in August

Why are the increment winds not uniform and especially strong to the east of New Guinea in August (Fig.2)? Look back at Fig.1 carefully and notice that from boreal summer to autumn the

[1] Corresponding author: Prof. Suping Zhang, College of Physical and Environmental Oceanography, Ocean University of China, Qingdao, Shandong, 266003, P.R.China. Email: zsping@ouc.edu.cn, Tel. 86 0532 2032411

SST isotherms become to incline northwestward to the east of New Guinea, thus producing steep zonal SST gradients in this area (Table 1), which is very much consistent with the air temperature gradient at 1000hPa level because of the intense sensible and latent heat exchange between atmosphere and ocean in the tropics based on climatological data supplied by NOAA. The positive zonal temperature gradients could produce northerly thermal winds in the Southern Hemisphere according to the thermal wind equation:

$$V_T = \frac{R}{f}\left(\frac{\partial \overline{T}}{\partial x}\right)_p \ln \frac{P_1}{P_2}.$$

Thus, it is reasonable to link the stronger northerly increment winds appeared to the east of New Guinea with the contribution of the northerly thermal winds.

Table 1. Monthly SST zonal gradients

SST zonal gradients °Cm^{-1}×10E-6	JUL	AUG	SEP	OCT	NOV	DEC	JAN
	1.358	1.638	1.573	1.126	0.367	0.389	-0.086

5. Contribution of the cross-equatorial flow to the SPCZ

Observations of QuikSCAT reveal that the northwesterly winds in the southwestern tropical Pacific in boreal winter can be traced back to the cross-equatorial flow particularly between 135-145°E (Fig.1). The cross-equatorial flows deflect gradually eastward forced by the Coriolis effect when reaching 5°S or farther south. Influenced by the land topography in Pabua New Guinea with mean elevations greater than 1000m running in a northwest-southeast direction roughly in parallel with the air flows, a strong northwesterly wind jet forms over the Bismarck Sea, almost exactly east of Mt. Wilhelm (4,509m). Strong convergence occurs in the broad ocean when the jet encounters the southeasterly prevailing winds originally existed there, thus, triggering the intense convective activities and producing the substantial development of the SPCZ. A detailed analysis can be found from Fig.5, which shows that the date of the establishment of the cross-equatorial flows is around the first half of Oct. and the SPCZ comes to the robust periods about the second half of Oct..

6. Relationships between SSTs and wind speeds

a. Analysis of time series

Look closely at the Fig.6 and observe that wind speeds taper off successively from the beginning of August, SSTs ascend stably around the mid August, and the SPCZ indexes climb dramatically after the mid August. The lags in phases between wind velocities, SSTs and the SPCZ indexes give rise to a picture that the drop in winds contributes to the rising in SSTs which leads to the developing SPCZ in August. The increase in SST fuels the convection as well as the SPCZ, which, in turn, causes the flows of air to converge and the winds to weaken further. We refer to this interaction between ocean and atmosphere as the wind-evaporation-SST-SPCZ feedback mechanism.

b. Correlative analysis

Simultaneous correlation coefficients between wind speeds and SSTs are computered for the four seasons respectively using TMI data. Each season holds 52 samples (weeks) for the period of

4 years. Somewhat surprisingly, among the four seasons, only boreal autumn occupies the significant negative correlation exceeding 0.001 level and the area marked by the high confidence covers almost the domain of the SPCZ (Fig.7). The lag correlation coefficients between the winds and SSTs are also as important (over 0.001 significant level) when SSTs are one week lagged, while the correlations are obviously weaker when SSTs are one week ahead. These results support the scenario we assume above: decreased (increased) wind speeds, being able to impose less (more) evaporation on the sea surface, could lead to the rise (fall) in SSTs, which, in turn, helps intensify the SPCZ, and the more convective activities could further calm the horizontal winds.

7. Conclusions

The whole developing phase of the SPCZ can be divided into two stages. The first sign for the intensifying episode is the emergence of the northerly increment winds, which come into view in August and are likely connected to the thermal-wind caused by the steep zonal SST gradients east of New Guinea. The second stage is marked by the interaction between the Northern Hemisphere and the Southern Hemisphere combined with the land orographic effect in Pabua New Guinea.

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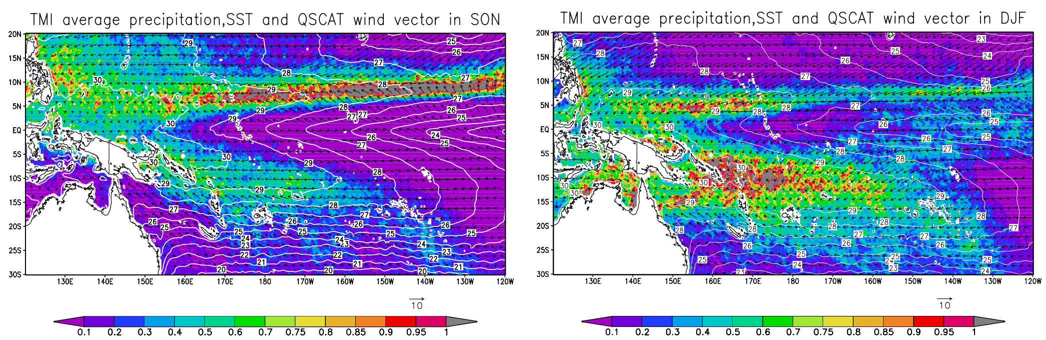

Fig.1 Seasonal average rain rate (colored area), SST (white solid line) and wind vector. left: SON, right: DJF.

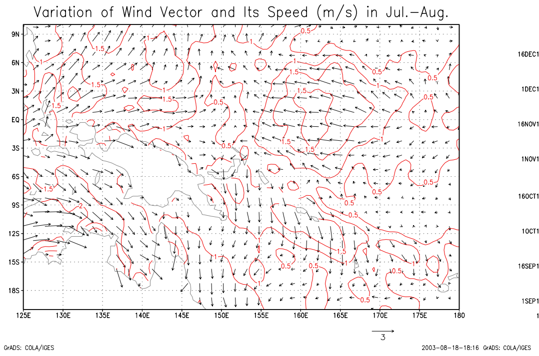

Fig.2 Monthly increment winds (Aug.-Jul) . Solid lines: the isotaches.

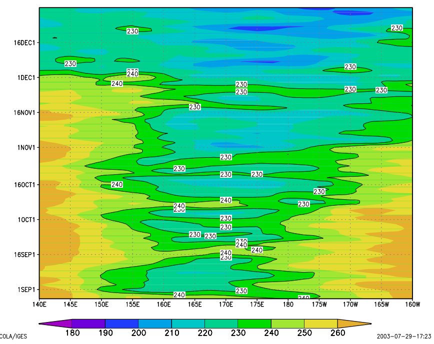

Fig.3 OLR time-longitude profile along 10ºS

Fig.4 Divergence time-longitude profile along 10ºS

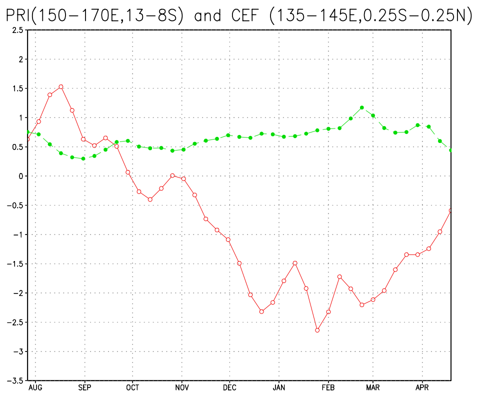

Fig.5 Time series of the cross equatorial flow (red) and SPCZ index (green) of three years average.

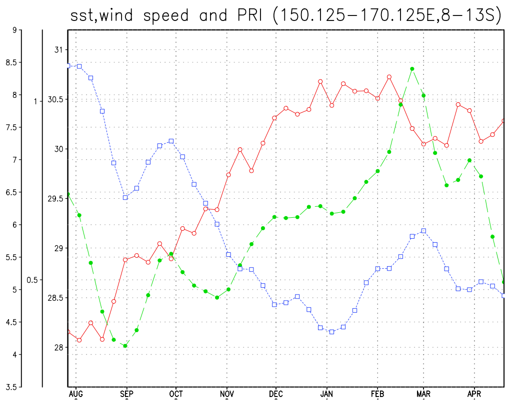

Fig. 6 Time series of SST (red), wind speed (blue) and PRI (green) of three years average. The Y-axes represents wind speed (m/s), PRI (mm/day) , and SST (ºC) respectively from left to right.

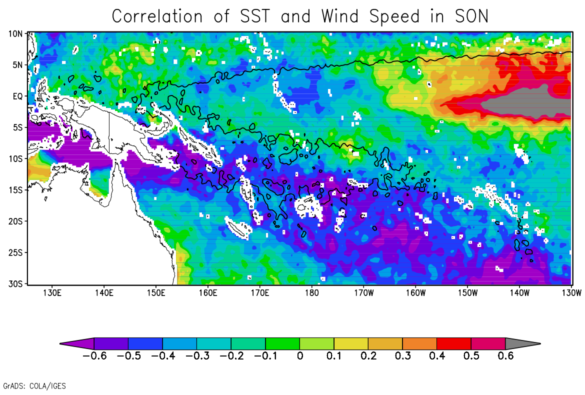

Fig.7. Correlation coefficients between wind speeds and SSTs in boreal autumn from TMI.