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Tropical cyclone genesis over the south China sea

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Abstract

The South China Sea (SCS) is among areas in the Northwest Pacific most frequented by tropical cyclones (TCs) with intensity reaching a tropical storm or stronger. It is also an area of significant TC genesis. In this study, TC genesis in SCS and its monsoonal variability for 1948–2003 are analyzed. Altogether, in May–September (southwest monsoon period) 157 TC geneses have occurred north of 12°N in SCS, while in October–December (northeast monsoon period) 64 out of 65 TC geneses have happened south of 18°N. It is found that the monsoonal characteristics of the SCS basically determine the region of TC genesis in each monsoon season. Winter TC genesis in the SCS happens over the region where the marine environment satisfies the four criterions on, respectively, the sea surface temperature (SST), mid-troposphere relative humidity, vertical shear of the horizontal winds and low-level atmospheric vorticity. During the summer, as the two criterions on SST and the mid-troposphere relative humidity are satisfied for the whole SCS, TC genesis occurs in the region where both the low-level vorticity and the vertical shear satisfy the criterion. In addition, there is likely more TC genesis in the winter during the onset of La Nina, and more TC genesis in the summer following the onset of El Nino.

Keywords: Tropical cyclones; Genesis; Monsoon; Air–sea interaction; South China Sea

1. Introduction

The South China Sea (SCS), the largest semi-enclosed marginal sea in the Northwest Pacific with an area about 3.5×10^6 km^2 (Fig. 1), is under the influence of the East Asia Monsoon (Liang, 1991). Onset of the mild southwesterly summer winds over the SCS usually occurs suddenly around mid-May in its southern and central part and soon expands to the entire SCS in June. In contrast, the strong northeast winter monsoon is established progressively over the SCS, first appearing over its northern part in September, reaching its central in October and covering the entire SCS in November. The winter monsoon gradually diminishes in April. Most of the oceanic characteristics of the SCS are influenced by the monsoon.

As in many research works, here we define the tropical cyclone (TC) as a tropical mesoscale cyclonic weather system with its strength of a tropical storm or stronger (i.e., typhoon). Globally, the Northwest Pacific, including the SCS, has the most TCs. Based on data spanning over 1968–1988 (Neumann, 1993), the annual average numbers of TC and typhoon generated in the

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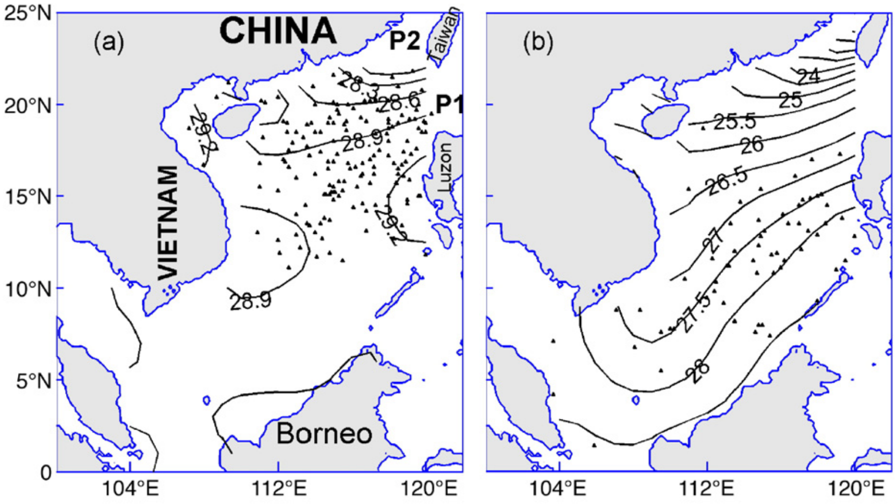

Fig. 1. SST climatology (in °C) and the initial positions of TCs (solid triangle) over the SCS for 1948–2003 (P1: Luzon Strait; P2: Taiwan Strait.). a: Southwest monsoon period; b: northeast monsoon period.

Northwest Pacific are 25.7 and 16.0, respectively. SCS is among the areas in the Northwest Pacific most often frequented by TCs. In addition, SCS itself is also an area of significant TC genesis. Our TC dataset shows that, among the annual average of 10.3 TCs passing through the SCS, 3.5 originated within the SCS. For typhoons, the corresponding numbers are 6.0 and 1.3, respectively.

TC is a tropical mesoscale weather system operating on the feedback between the enthalpy fluxes and winds at the ocean surface (Emanuel, 2003). It may be regarded as a heat engine with heat-intake over the ocean, a nearly adiabatic work-output in the eyewall and heat-loss near the stratosphere (Lighthill, 1998). In this system, TC genesis depends critically on the conditions at the air–sea surface and on the surrounding atmospheric environment. As summarized by Emanuel (2003), there are 6 necessary, or conducive, oceanic and atmospheric environmental conditions for TC genesis, namely,

(1) High sea surface temperature (SST): an ocean with SST at least 26 °C to provide sufficient latent-heat input to fuel the winds of a TC (Lighthill, 1998). However, Chen (1981) has found that an SST above 27 °C is a pre-requisite for TC genesis over the SCS. This will be the value we shall adopt for this study;
(2) Sufficiently large depths of the ocean mixed layer;
(3) An atmospheric environment characterized by large values of mid-troposphere relative humidity: necessary for sustained development of a TC. Otherwise, the extremely dense cloud eyewall of the TC will be dried out by upflow of the entrained dry ambient air (Lighthill, 1998). If the relative humidity at 500 mb (RH) is lower than 40%, formation of TCs will be inhibited (Gray, 1968);
(4) Small vertical shear of the horizontal winds: important for the TC development for allowing the heat released by condensation to concentrate in a vertical column (Fink and Speth, 1998). Gray (1968) proposed to characterize the vertical shear with $|V_z|$, the magnitude of the horizontal wind difference between the upper and lower troposphere, i.e., 200 mb and 850 mb, respectively. Local $|V_z|$ greater than 8 ms^{-1} is generally unfavorable for TC development (e.g., Goldenberg et al., 2001);
(5) An atmospheric background with relatively large cyclonic low-level vorticity: producing initially a frictionally forced low-level convergence of mass and water vapor, and consequently leading to an upward vertical motion in favor of TC genesis (Gray, 1968); and
(6) A non-negligible Coriolis force, usually at latitudes beyond 5° from the equator, to maintain the cyclonic circulation.

The first 3 are thermodynamic conditions, while the last 3 are dynamical ones. In addition, an external disturbance is also needed to trigger the TC genesis.

Previous studies have shown that TC genesis over the SCS happens predominantly at its northern basin in summer (Liang, 1991), while in winter it favors the southern SCS (Liang et al., 1998). Liang (1991) suggested that many external disturbances from atmosphere circulation over the SCS are responsible for the TC genesis.