On the Northwestward Propagation of the Intraseasonal Oscillation in the Western North Pacific during Boreal Summer

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Abstract

This study investigates the nature of the northwestward propagation of the intraseasonal oscillation over the western North Pacific during boreal summer. It is found that ocean-atmosphere interaction play an important role to supply the energy to sustain the circulation and convection during the course of northwestward propagation. The circulation-convection interaction is the key factor to maintain the system's strength until it reaches the Asian landmass when the supply of moisture is cut off. The combination of ocean-atmosphere interaction and circulation-convection interaction lead to the northwestward propagation of the system.

1. Introduction

Eastward propagation of intraseasonal oscillation along the equator has been a widely explored phenomenon. Many mechanisms, mostly based on the equatorial wave dynamics, have been proposed. It is also known that the intraseasonal oscillation not only propagates eastward but also propagates poleward (Lau and Chan, 1985, 1986; Wang and Rui, 1990; Hsu, 1996). The latter is particularly evident in South and Southeast Asia during boreal summer. In addition, documented northwestward propagation of large-scale convection system is also observed in the western North Pacific (e.g., Lau and Chan, 1986; Kawamura et al., 1996). While there are many mechanisms proposed to explain the eastward propagation along the equator and the northward propagation in South Asia, little has been done to explain the northwestward propagation in the western North Pacific. In this study, we document the major characteristics of the northwestward propagation of the intraseasonal oscillation in the western North Pacific and propose a mechanism to explain the phenomenon.

2. Data and analysis procedure

Data used in this study include (1) European Centre for Medium Range Forecast (ECMWF) reanalysis (ERA), (2) outgoing longwave radiation (OLR) compiled by the Climate Diagnostic Center, and (3) optimal-interpolated sea surface temperature (SST) produced by the National Centers for Environmental Prediction. ERA and OLR are on a 2.5 by 2.5 degree grid, while SST is on a 1 by 1 degree grid.

All data are filtered by a 30-60 day band-pass filter to isolate the intraseasonal variability. A spatial smoother following Sardeshmukh and Hoskins (1984) was also applied to all data to remove smaller scale fluctuation. Our calculation indicates that several variables (e.g., OLR, vorticity) exhibit a maximum variance and a tendency to propagate northwestward in the Philippine Sea. An index, which is the OLR averaged over (0-25°N, 120°E-160°E), is defined to represent the convective activity in the Philippine Sea. Cross correlation and regression coefficients between the index and various variables at different time lags were then computed to investigate the temporal and spatial variation of the phenomenon.

3. Results

Figure 1 present the evolution of OLR and diabatic heating pattern from day –25 to day 10. A comparison indicates an overall consistency between OLR and diabatic heating pattern. The following discussion concerning figure 1 will focus on OLR, unless otherwise stated. At day –25, a positive region in the Philippine Sea indicates a weaker-than-normal convective activity in the area. At the same time, a negative region near the equator (indicating active convective activity) moves eastward from the Indian Ocean to the maritime continent. While the inactive convective region moves northwestward toward Taiwan in the next few pentads, the active convective region near the equator continues moving eastward. During this period, a weak negative region moves westward along 25°N and reach 160°E at day –10. This subtropical convective region from the east and the tropical convective region from the west start to merge at day –5 and form a strong convective region in the Philippine Sea. This newly formed convective region then moves northwestward from the Philippine Sea toward Taiwan.

In order to understand the mechanism responsible for the northwestward propagation of the feature, we examined the temporal and spatial relationship between the OLR and various variables such as vorticity, divergence, moisture flux, surface heat fluxes, and SST. The evolution of the phenomenon can be divided into three stages, which are presented in the schematic diagram shown in figure 2 and are summarized as follows.

Stage 1:

A convective region propagates eastward along the equator from the Indian Ocean to the maritime continent, while another convective region propagates westward in the subtropics from the central North Pacific to the

Philippine Sea. The latter is located to the east of a positive vorticity anomaly and exhibits the characteristics of a Rossby wave, which tends to propagate westward. The nature of the former is not clear so far. The merging of two convective regions enhances the convection in the Philippine Sea, which in turn enhances the low-level cyclonic anomaly located to the northwest. At the same time, the convection near Philippine and Taiwan is relatively inactive and the SST anomaly is positive because of light wind and stronger incoming short wave radiation.

Stage 2:

The low-level cyclonic anomaly is now well developed and extracts more latent heat flux from the ocean at its southwestern and northeastern corners probably due to the land-sea contrast. The moisture is transported northeastward and southwestward from these two regions, respectively, and converges at the northwestern corner of the cyclonic anomaly, where is already relatively unstable due to the warmer SST and the release of sensible heat flux from the ocean.

Stage 3:

The system consequently propagates northwestward toward Taiwan and southern China and starts weakening when approach the landmass due to the lack of supply of latent heat flux and moisture.

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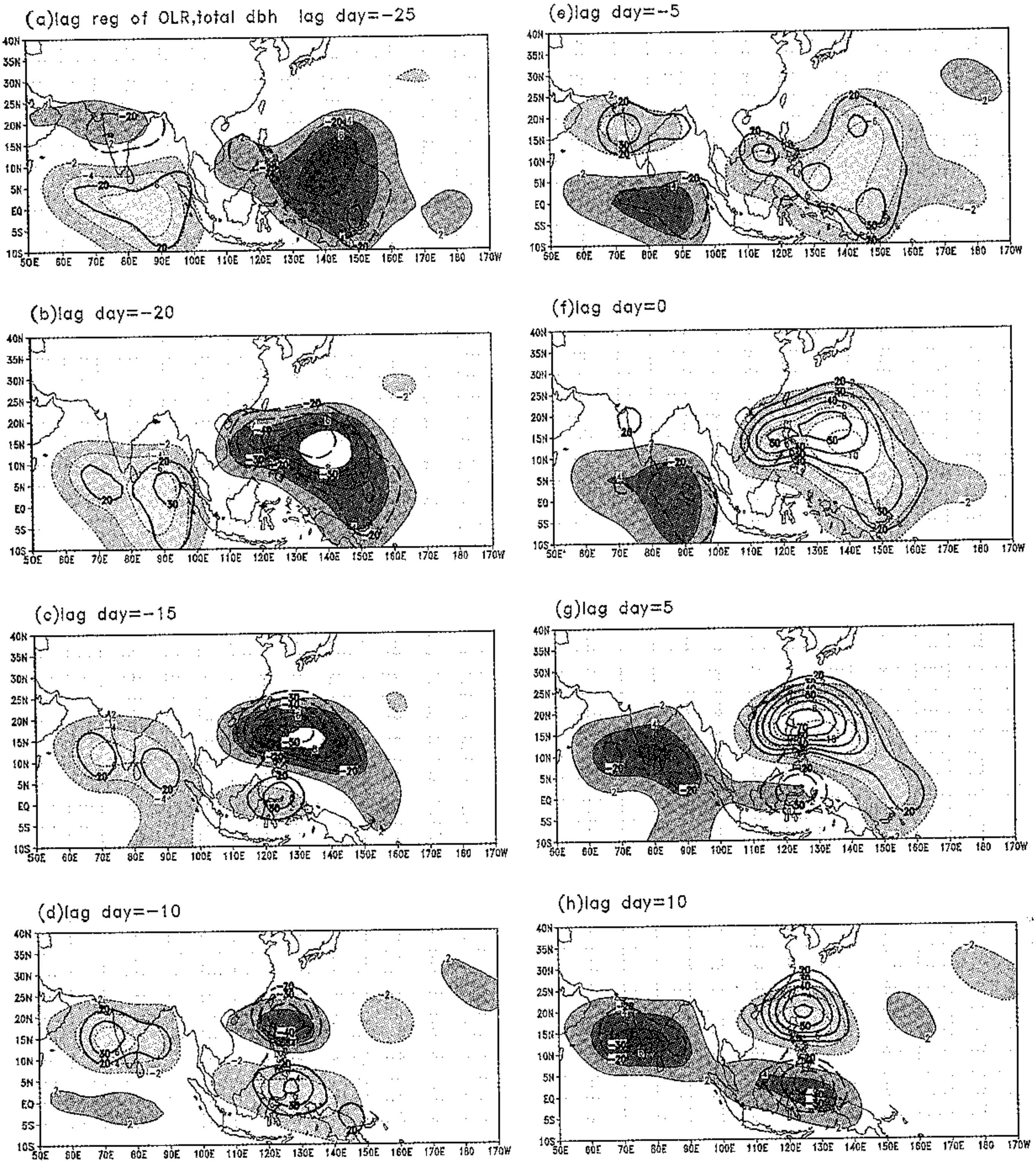


(a)lag reg of OLR,total dbh lag day=-25

(b)lag day=-20

(c)lag day=-15

(d)lag day=-10

(e)lag day=-5

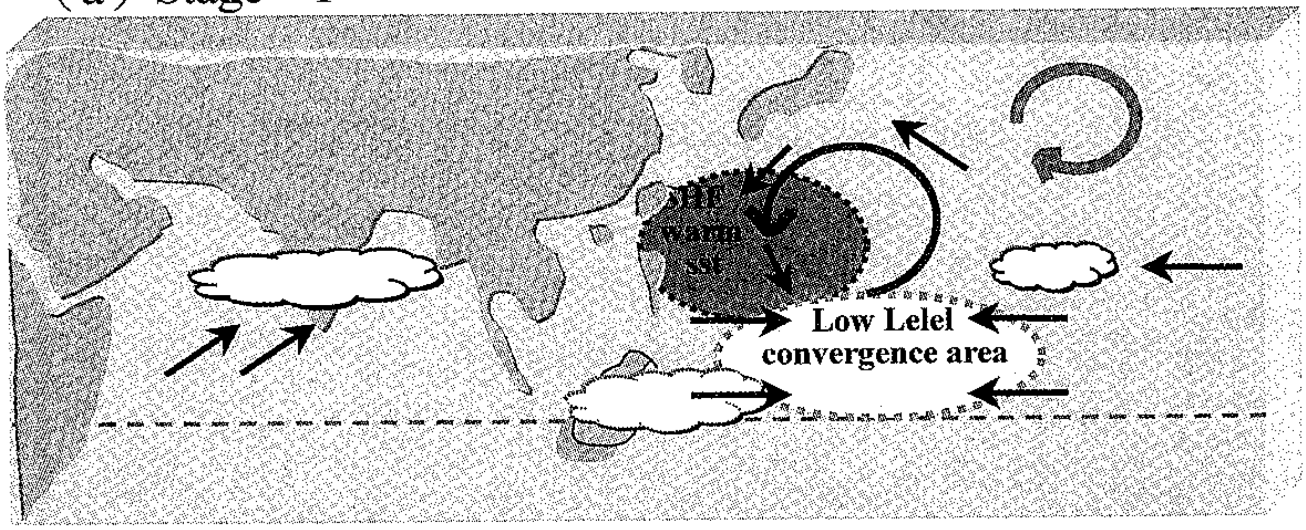
(f)lag day=0

(g)lag day=5

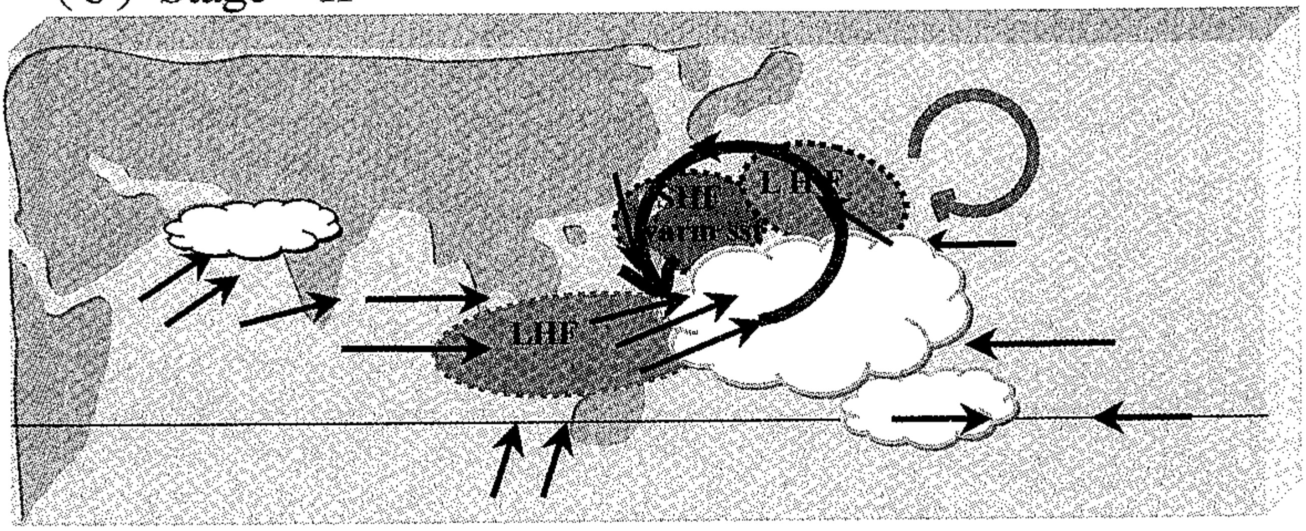
(h)lag day=10

Fig1 Lag regression coefficient of OLR(shaded) and total diabatic heating(contoured).

(a) Stage I



(b) Stage II



(c) Stage III

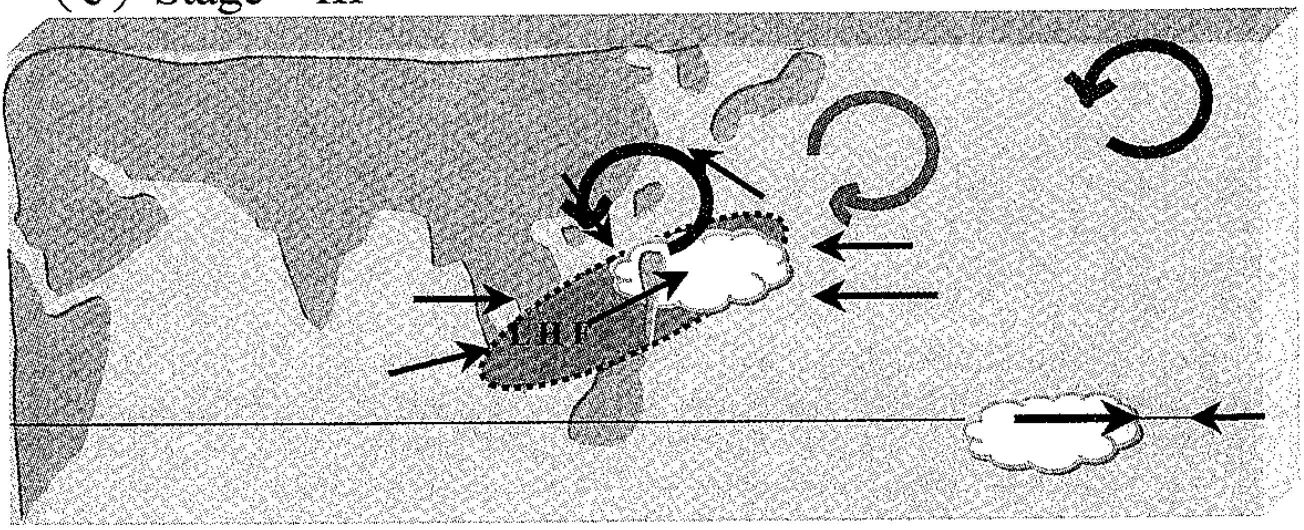


Fig 2 Schematic diagram