Rainfall Variations of the Asian Summer Monsoon: Diurnal and Intraseasonal Oscillations

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1. Introduction

One of the major goals of the GAME is to enhance our understanding of the hydrological cycle of the Asian summer monsoon. However, it is also equally important for us to understand the role played by the Asian monsoon hydrological cycle in the global context. It was revealed from previous studies that the Asian summer monsoon undergoes diurnal and intraseasonal (12-24 day and 30-60 day) variations. As depicted by the potential function of water vapor flux (χ_Q), the global diurnal variation mode propagates westward, opposite to the Earth's rotation, and the global 12-24 day and 30-60 day modes propagate eastward. In view of propagation properties of these global hydrological modes, the following questions are raised:

(1) What is the contribution of the Asian monsoon to the global hydrological cycle?
(2) How does the Asian monsoon hydrological cycle respond/link to these global propagating modes?

The GAME hydrological data, several global precipitation datasets (TRMM, GPCP, GPI), and NCEP/NCAR reanalyses were analyzed to search for answers to these two questions.

2. Global Rainfall Variation

It was shown by our previous studies (Chen et al. 1995a, b) that intraseasonal rainfall variations of the Asian-monsoon (AA; 60°E-120°W) and extra-AA monsoon (EA; 120°W-60°E) hemispheres are out-of-phase. Let us represent the global, AA- and EA-hemisphere rainfall by P_G, P_{AA}, and P_{EA}, respectively. Departures of these three variables (ΔP_G, ΔP_{AA}, and ΔP_{EA}) at four synoptic times (00, 06, 12, 18UTC) from their daily mean values are shown in Figs. 1a and b. The daily variation of ΔP_G is almost in-phase with that of ΔP_{AA}, but out of phase with ΔP_{EA}. The diurnal variation signal ( )' dominates power spectra of all three variables (Figs. 1d-f). Variations of P'_G, P'_{AA}, and P'_{EA} behave the same way as those of ΔP_G, ΔP_{AA}, and ΔP_{EA}. Evidently, the Asian summer monsoon plays a crucial role in determining the diurnal variation of the global rainfall.

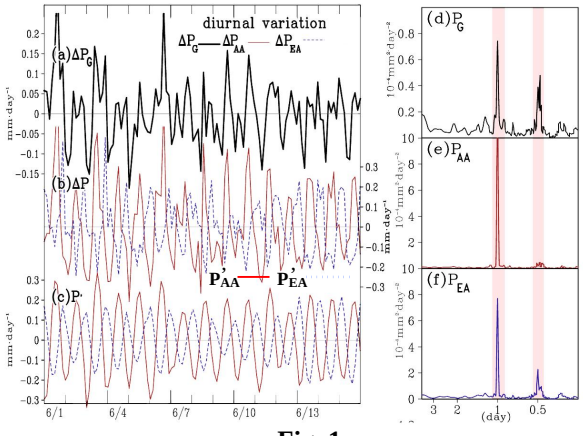

Fig. 1

Time series of 3-day mean P_G (thick-solid line), P_{AA} (thin-solid line), and P_{EA} (thin-dash line) are shown in Fig. 2a. Variations of P_{AA} and P_{EA} are more or less out-of-phase. However, variation of P_G almost follows that of P_{AA}. The 12-24 day (^) and 30-60 day (~) intraseasonal signals emerge from power spectra of these variables (Figs. 2d-f). Periods of 1979-1980 and 1989-2001 were analyzed, but time series of various variables in 1979 are shown in Fig. 2 as an example for illustration. Time series of ($\hat{P}_G$, $\hat{P}_{AA}$, and $\hat{P}_{EA}$) and ($\tilde{P}_G$, $\tilde{P}_{AA}$, and $\tilde{P}_{EA}$) are shown in Figs. 2d and c, respectively. In-phase variations exist between $\hat{P}_G$ and $\hat{P}_{AA}$ and between $\tilde{P}_G$ and $\tilde{P}_{AA}$, while out-of-phase variations appear between $\hat{P}_G$ and $\hat{P}_{EA}$ and between $\tilde{P}_G$ and $\tilde{P}_{EA}$. As diurnal variation, intraseasonal variations of the global rainfall are primarily determined by the Asian monsoon, through the AA-hemisphere rainfall.

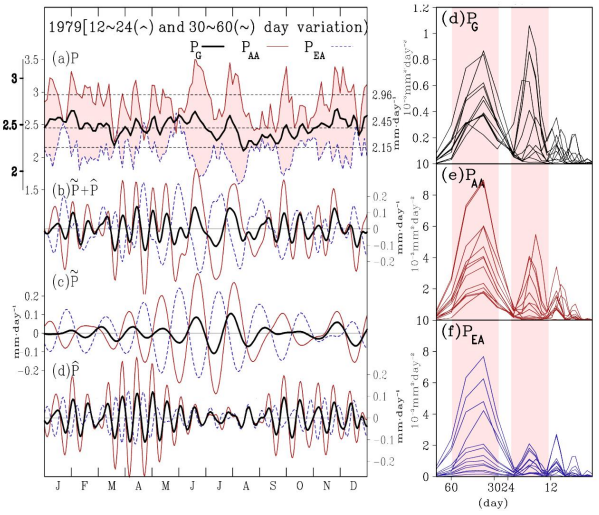

Fig.2

3. Variation of Asian monsoon rainfall

The global diurnal (Chen et al. 2004) and intraseasonal [12-24 day (Chen et al. 1995a) and 30-60 day (Chen et al. 1995b)] modes of streamfunction and potential function of water vapor flux, ψ_Q and χ_Q, exhibit relatively regular westward and eastward propagations, respectively. On the other hand, the Asian-monsoon hydrological cycle responds to the global propagating modes in complicated ways:

a. Diurnal Variation: Diurnal components of χ_Q and rainfall [blue (positive) and pink (negative) areas], χ'_Q and P', undergo a clockwise rotation around the Asian continent in response to the westward propagation of the global χ'_Q mode, as shown in Fig. 3.

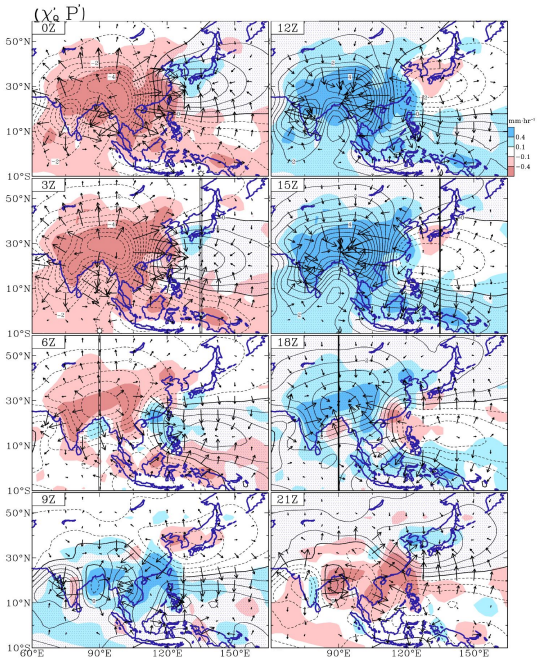

Fig. 3

b. 12-24 day Variation: The 12-24 day monsoon mode propagates northwestward along the Southeast Asia-western tropical Pacific monsoon trough to East China. The eastward propagation of cold fronts before the East Asian summer monsoon break (not shown) is regulated by this intraseasonal mode, while the tropical cyclone (TC)/tropical depression (TD) activity (indicated by red dots in Fig. 4) in East/Southeast Asia is modulated by this intraseasonal mode (depicted by composites $\hat{\psi}_Q$ of six phases) after the East Asian monsoon break (shown in Fig. 4). Because fronts and TCs/TDs are major rainfall producers, the East/Southeast Asian summer monsoon rainfall is h this

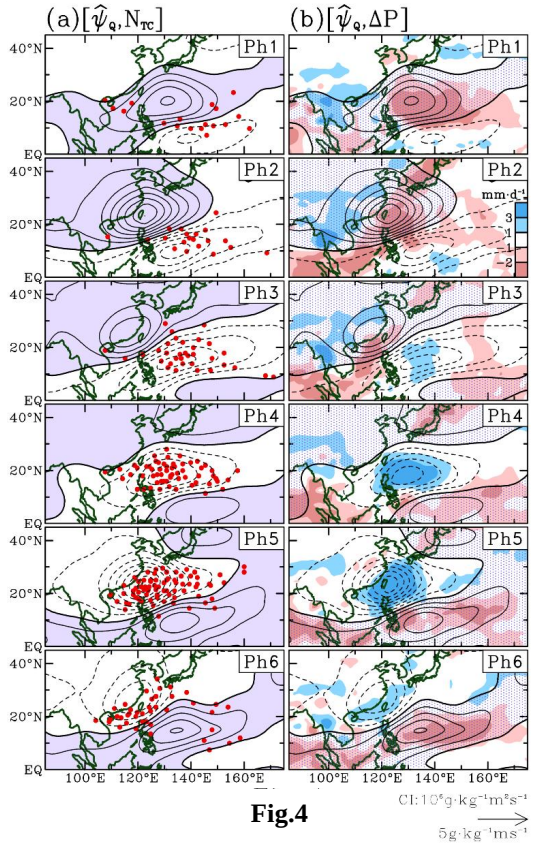

Fig.4

c. 30-60 day Variation: The East Asian monsoon life cycle (onset-active-break-revival) is basically established by the northward migration of the 30-60 day monsoon trough/ridge (inferred from composite $\tilde{\psi}_Q$ of eight phases in Fig. 5) from the Equator (Chen et al. 2000) in response to the global 30-60 day mode as shown in Fig. 5b. Monsoon rain is primarily generated by fronts [blue (positive) and pink (negative) areas in Fig. 5b] along the Meiyu-Baiu rainbelt before the monsoon break, and by TCs/TDs (red dots in Fig. 5a) after the break. The modulation of the global 30-60 day mode on the East/Southeast Asian monsoon rainfall is accomplished through the effect of the 30-60 day monsoon mode on the frontal and TC/TD activities (Fig. 5a).

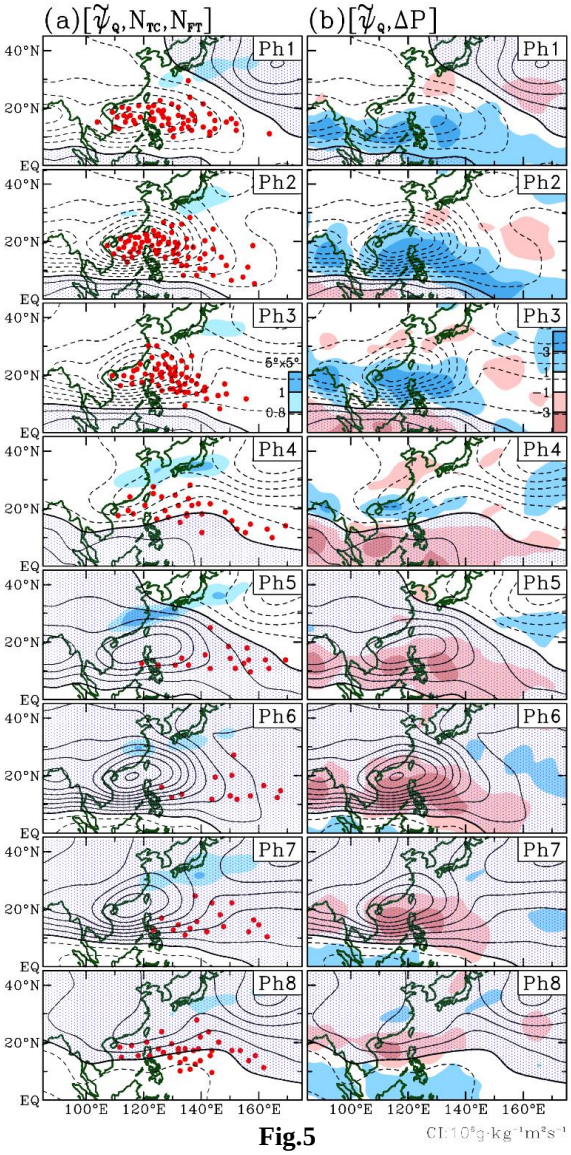

Fig.5

4. Remarks

Impacts of the global diurnal and intraseasonal modes on the Asian monsoon rainfall are established through the downscale processes described in Section 3. On the other hand, the contribution of the Asian monsoon to the global hydrological cycle is reflected by the coherent variations between the global and monsoon-hemispheric precipitation, and the variation in the water vapor flux exchange between the monsoon- and extra-monsoon hemispheres.

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