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Asian Monsoon Climate Stabilities and its Onset Processes: Dynamics and AsiaPEX Field Campaigns

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Abstract: We identified the process of Asian monsoon onset using new diagnostic method based on the mass amount of high moist and dry static energy airmass. In 2017, Asian monsoon onset process is driven by convective heating over the sector of Bay of Bengal and Bengal Plain. Estimation of convective heating has large uncertainty in ERA5 reanalysis dataset. We discuss the stability of Asian monsoon circulation and uncertainties in state-of-the-art analysis. We propose to develop new observational platform under the AsiaPEX project under the GEWEX climate research framework.

Keywords: ***Asian monsoon, Onset, Heating process.***

Introduction

Asian summer monsoon circulation is a global atmospheric circulation driven by the diabatic heating due to vigorous convective activities over the Asian monsoon region centered at around the southern rim of the Tibetan Plateau. It is characterized by a non-linear abrupt onset, at which the Asian monsoon circulation including the strong lower tropospheric monsoon southwesterly over the Indian Ocean connected with the cross equatorial Somali Jet are established (Boos and Emanuel, 2009).

The Asian summer monsoon onset has been traditionally recognized as abrupt commencement of rainy seasons. However, this empirical understanding is sometimes inconsistent with each other (Stiller-Reeve et al., 2015). Especially in Northeastern Indian subcontinent, pre-monsoon storms develop from March, that is well before the monsoon onset (Matsumoto, 1997). Different definitions of the monsoon onset have been proposed and are still under debate.

Asian monsoon has been changing in geological time scales under the glacier and inter-glacier climate cycle. An interesting feature of this climate cycle is the exceptional stability of climate in the Holocene, the most recent geological period. Some discussed about the inherent instability in the Asian monsoon process, which can be a Tipping Element in the current climate system. The role of the Asian monsoon dynamics in the

stabilizing process of the recent Earth's climate is interesting topic.

A case study of the 2017 Asian monsoon onset revealed key uncertainties in ERA5 reanalysis regarding the onset process. The Asian Precipitation Experiment (AsiaPEX) will address these issues through the Asian Monsoon Years-II field campaign in the 2020s and by establishing a sub-regional observational platform along the southern rim of the Tibetan Plateau.

Asian monsoon onset in 2017

We propose new analysis method based on lower tropospheric High Moist Static Energy Airmass (HMSEA) and upper tropospheric High Dry Static Energy Airmass (HDSEA) which are represented by the mass amount of airmass in a layer with certain ranges of equivalent potential temperatures and potential temperatures.

We analyzed the diabatic processes during May, the onset phase of Asian summer monsoon in 2017 using the non-conservative residual term of mass continuity equation for HDSEA using hourly ERA5 reanalysis. Figure 1 shows the upper tropospheric accumulation of HDSEA. This corresponds to HDSEA source (Figure 2) that should be accounted for by the convective heating and radiative cooling. The highest contribution for the accumulation of HDSEA, which is linked with the Asian monsoon onset, comes from the convection developing over the sector of the Bay of Bengal and the Bengal Plain. Thus, rather small regions can play key role in the onset process, indicating local conditions may have impact on monsoon stability.

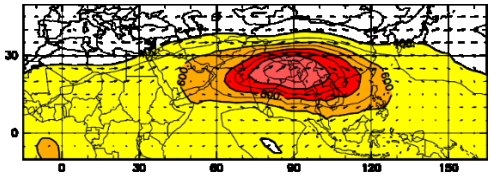

Figure 1, Amount of HDSEA averaged for the latter half of May 2017. The unit is kgm^{-2}. Contour intervals are 100 kgm^{-2}. Values larger than 400 kgm^{-2} are shaded.

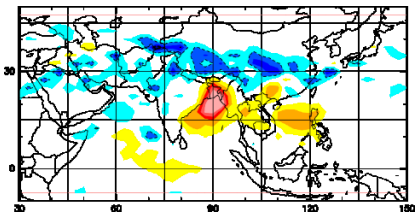

Figure 2, Source of HDSEA averaged for the latter half of May 2017. The unit is kgm-2s-1. Values larger than 1.0x 10-3 kgm-2s-1 and smaller than -0.5x10-3 kgm-2s-1 are shaded in warm and cool colors, respectively.

Our analysis revealed unexplained extra heating just below the tropopause over the convective region, suggesting that the reanalysis convective heating scheme underestimates upper-tropospheric heating during the Asian monsoon onset. This highlights challenges in representing land–atmosphere interactions and convection coupling.

Development of observational platform

We are promoting the AsiaPEX project, a coordinated international field campaign focusing on terrestrial precipitation in the Asian monsoon region (Terao et al., 2023). As an official Regional Hydroclimatological Project under the Global Energy and Water Exchanges (GEWEX) framework, AsiaPEX aims to address uncertainties in current atmospheric analyses. By improving our understanding of land–atmosphere interactions and their coupling with convective cloud systems—key targets of AsiaPEX—we present recent observational results and discuss effective sub-regional observational platforms along the southern rim of the Tibetan Plateau to clarify the production processes of HDSEA in this region.

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