The Relationship between the intra-seasonal variation of $\delta^{18}O$ in precipitation and MJO/BSISO over the Asian equatorial and monsoon regions

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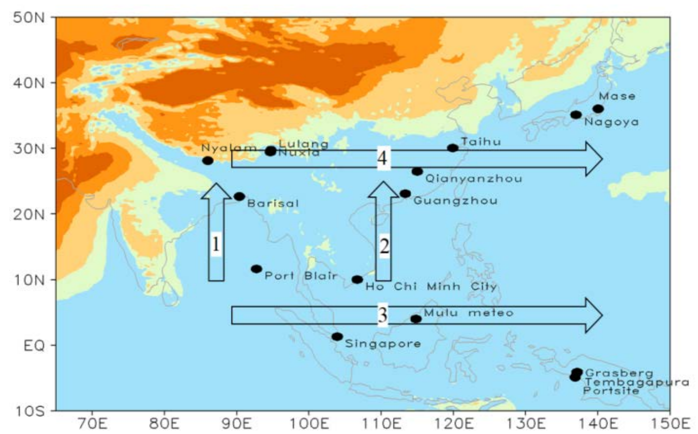
1. Introduction

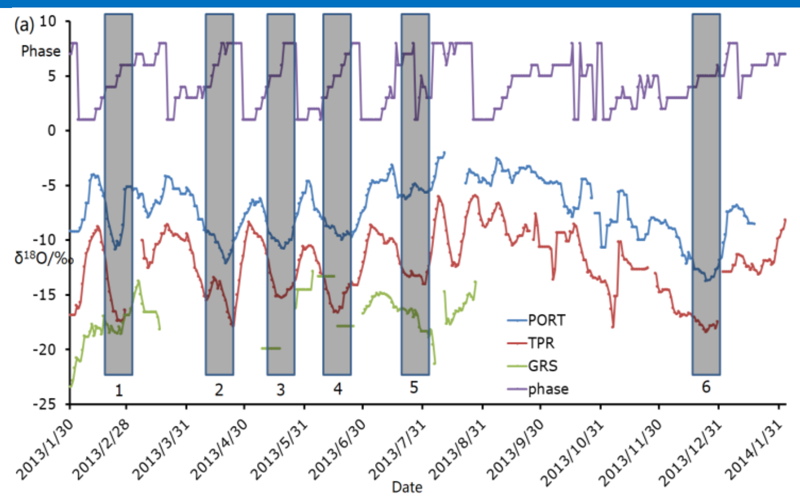


The intraseasonal oscillation has the widest coverage and largest amplitude between Asia and Australia, which is easy to have a wide influence on stable isotopes in vapor/ precipitation (Hoyos, 2007; Li Chongyin, 1993) by severe convective activity spreading eastward and poleward.

In the monsoon and equatorial regions of Asia, the variation of water stable isotopes in intraseasonal scale is obvious during summer and the amplitude of variation is equal to the seasonal amplitude. The excessive intraseasonal variation of precipitation isotopes will affect the dating of ice core, stalagmite, tree ring isotopes, and the explanation of interannual variation (Sengupta, S, et al, 2020; Goswami, 2003)

FIG.1 The 30-year mean of precipitation from ERA5 (shaded, mm), The influence of BSISO propagation along four paths on precipitation/vapor isotope are discussed (marked by numbers). The geographical stations are also show as dots.

2. The influence of MJO on $\delta^{18}O$ in precipitation at the stations of equatorial Asia



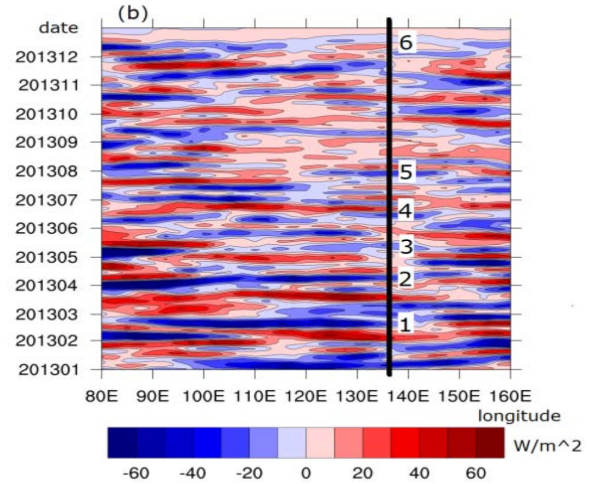


FIG.2 9 days moving average $\delta^{18}O$ in three stations, Portsite (PORT), Tembagapura (TPR), Grasberg (GRS) and the phase of MJO during 2013 in Papua Province, Indonesia (a), average OLR anomaly value from 10°S to 0°S, processed by 10-80 days Band-pass filtering (Hovmöller diagram), W/m^2, the vertical black line represents the longitude of the three stations (b).

FIG.2a shows that the intraseasonal oscillations of $\delta^{18}O$ are associated with phase cycle of MJO and the low $\delta^{18}O$ period occur in phase 4, 5 and 6 of MJO. During this time, the central convective region is moving from Maritime Continent (Indonesia archipelago) to the Western Pacific. From FIG.2b we can know that the low $\delta^{18}O$ periods is corresponding with the coming low value of OLR from 1 to 6 marked. The amplitude of $\delta^{18}O$ in precipitation during the active phase of the MJO is about 8‰, the fluctuation is uniform.

3. The characteristic of $\delta^{18}O$ variations in precipitation/vapor affected by the propagation of BSISO at the Asian monsoon stations

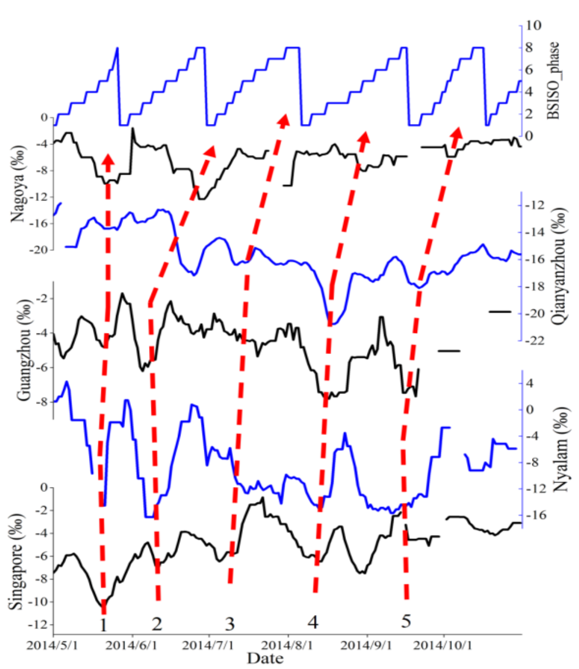


FIG.3 The 9 days moving average $\delta^{18}O$ in precipitation of Singapore, Nyalam, Guangzhou, Nagoya, and $\delta^{18}O$ in the vapor of Qianyanzhou and the phase of BSISO from May to October in 2014, the number from 1 to 5 are Low-value phases of precipitation $\delta^{18}O$ at stations in the southern Asian monsoon region caused by five BSISO propagations.

FIG.3 shows that due to the wide spatial distribution of stations, in the propagation process of BSISO, precipitation/vapor isotope oscillations of different stations will have phase differences, the amplitude of $\delta^{18}O$ fluctuation varies from 4‰ to 12‰ at different stations with different BSISO periods. The convective band of BSISO is characterized by spreading from southwest to northeast in the Asian monsoon region. The low phase of $\delta^{18}O$ is delayed from Singapore to Nagoya.

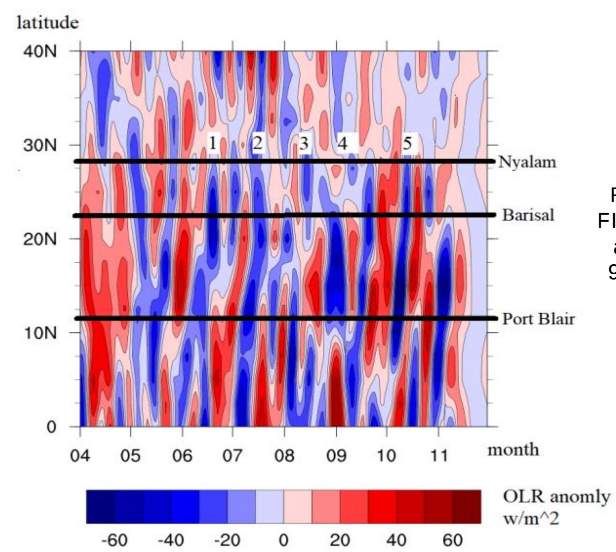
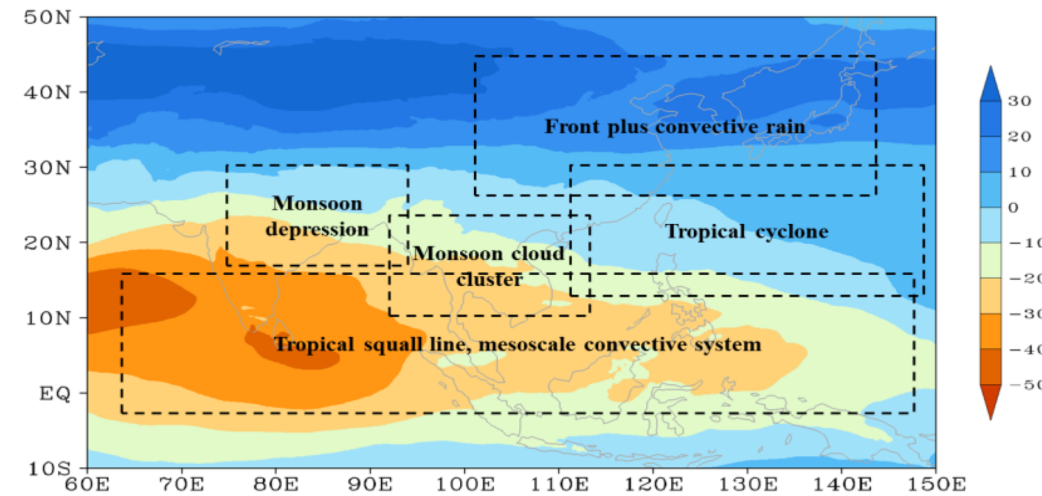


FIG.4 The same as FIG.2b but Longitude averaged (80°E to 95°E) during 2014.

4. Weather system analysis during BSISO propagation



When the convective phase of MJO arrives, it creates a large-scale meteorological environment good for convection, which will conducive to the MCS (mesoscale convective systems) such as squall line in the equatorial area and the monsoon cloud cluster in the monsoon area, what's more, which also have a catalytic effect for the generation of monsoon low in the Bay of Bengal and the formation of a tropical cyclone in the Western Pacific Ocean. After formation, they will propagate eastward and northward, so the values of stable isotopes in precipitation/vapor will dramatically decrease at the propogating path during the precipitation process due to the depletion within the convective system.

FIG.5 Averaged vertical wind shear in July 2014 (shaded, wind vector difference of 200 hPa minus 850 hPa, m/s), dotted box represented the general scope of different weather scale systems triggered by BSISO during propagation.

5. Synchronicity and elevation effect of intra-seasonal oscillation amplitude of $\delta^{18}O$ in precipitation

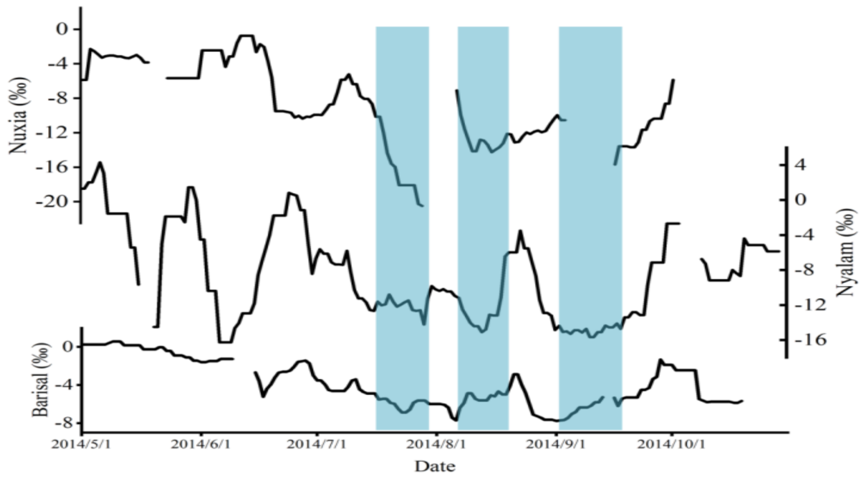


FIG.6 The 9-day moving average variation of $\delta^{18}O$ in precipitation from Barisal (7m a.s.l.), Nyalam (3747m a.s.l.), and Nuxia (2920m a.s.l.) during 2014, the light blue band are represented low-value phases of $\delta^{18}O$.

The first effect is the synchronicitym of oscillation amplitude, due to the variable intensity of convective activity, the fluctuation amplitude of $\delta^{18}O$ in precipitation at stations along the route of each propagating northward is somewhat different. This amplitude fluctuation is consistent in the whole research area, that is, the collective amplitude of the whole area becomes larger or smaller together, as shown in FIG.3.

The second effect is the elevation effect of oscillation amplitude, From the stations along the first path (FIG.1 and FIG.4) with huge height variations for this stations. FIG.6 shows that from July to September 2014, three times of intra-seasonal fluctuations of $\delta^{18}O$ in precipitation at Barisal is about 4‰, but the fluctuations of Nyalam and Nuxia are above 8‰. What's more, from part 2 we can also draw a similar conclusion that the amplitude of $\delta^{18}O$ from mountainous stations (TPR and GRS) larger than the plain station (PORT) in FIG.2a. We can believe that under the influence of the same BSISO convective phase, the intra-seasonal variation of $\delta^{18}O$ in precipitation at high altitude stations is significantly higher than that at low altitude stations.

6. Conclusions and prospects

- MJO and BSISO, two modes of intra-seasonal oscillation of tropical atmosphere, which can both created the background environment favorable or unfavorable to the formation of various convective weather systems, lead to significant intra-seasonal oscillation of $\delta^{18}O$ in precipitation cover equatorial and monsoon regions of Asia. Through the propagation process, the $\delta^{18}O$ amplitude of equatorial region is about 8‰, but in the monsoon region, the fluctuation range is about 4‰ to 12‰.
- The intensity of $\delta^{18}O$ intra-seasonal oscillation caused by each cycle of MJO or BSISO is related to the low OLR intensity and the altitude of the station. The lower the OLR anomaly and the higher the elevation of the station, the $\delta^{18}O$ intra-seasonal oscillation have bigger amplitude.
- Due to the lack of data, the north boundary of the intra-seasonal oscillation of precipitation/water vapor isotopes in Asia has not been defined and explained in detail, which needs to be further enriched and studied. Besides, the newfound phenomenon, the height effect of intra-seasonal variation of stable water isotopologues in precipitation need be further and systematic studied. The last is that we should specifically analyze the intra-seasonal oscillation of stable isotopes in precipitation and water vapor respectively in future studies.

7. Reference

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