Offline isotopic land surface simulations by Iso-MATSIRIO in tropical monsoon climate

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Institute of Industrial Science (IIS) in the University of Tokyo and Japanese National Institute of Agro-Environmental Sciences (NIAES) have monitored and modelled land surface hydro-bio-meteorological processes in tropical monsoon climate as a GAME-T (GEWEX Asian Monsoon Experiments in Tropics) activity since the late 1990s. One of the GAME-T flux sites is the Tak measurement site in northern Thailand (16°56’N, 99°25’E, Fig. 1) located in an area with mixed land use: tropical deciduous forest, grassland and paddy field. A variety of instruments, including an automatic weather station, have been installed at the station in a 120-m tower [1]. An example of the several interesting phenomena observed at the site was the large evapotranspiration (251.2 mm out of 783.6 mm/year) during dry season (November to May), in spite of dryness of soil and deciduous vegetation (see red line in Fig. 2a).

Offline runs using Iso-MATSIRIO [2] model, with stable water isotope physics embedded, were manipulated for year 2003 with in situ surface meteorological observations to reproduce the large evapotranspiration measured during dry season (November to May), in spite of dryness of soil and deciduous vegetation (see red line in Fig. 2a).

Of the time captured well the observed seasonal evolution of total evapotranspiration during both dry and wet seasons (Fig. 2a). However, during dry season ratios of soil evaporation and transpiration to total evapotranspiration were significantly different between the two parameterization runs. With VG80 parameterization transpiration dominated but with CH78 evaporation from soil surface was dominant (Fig. 2b).

Stable water isotope $^{2}H_{2}O$ and/or DHO, known as $\delta^{2}H$ and $\delta D$, respectively (see Footnote) measurements should help distinguish between evaporation and soil transpiration. The physical basis of this rather classic idea is very simple: evaporation is fractionated (less $^{2}H_{2}O$ and DHO concentrated relative to the source water, surface soil moisture) and transpiration non-fractionated (but actually fractionated near stomata) leading to a significant isotopic difference between evaporation and transpiration. Though both $^{2}H_{2}O$ and DHO fractionate similarly in a linear manner, the relationship between the two, known as d-excess ($\delta^{2}D-8x\delta^{18}O$), would change (not discussed here).

Verifications, however, have not been carried out very precisely. Therefore, we should first examine if the method is applicable to a complicated land surface system that includes both kinetic and equilibrium isotopic fractionation mechanisms. The Iso-MATSIRIO model suits this purpose as it includes fractionation of soil surface evaporation, vegetation transpiration,
canopy-intercepted evaporation as well as vertical transport and subsurface advective flow of water and stable water isotopes. Isotope ratios in precipitation and surface ambient vapor were not observed in situ, but monthly meteorological data was obtained from a global isotopic circulation model simulation [5].

During dry season, the monthly daytime (8 am to 4 pm) weighted average of δ18O in surface (0-5 cm) soil moisture differed significantly between two parameterization runs (Fig. 2c, two light blue lines, only for δ18O). The CH78 parameterization run estimated more evaporation from soil surface than VG80 run during dry season. It caused 5‰ higher surface soil moisture in δ18O, due to isotopic fractionation. Also, the δ18O difference of evaporation from soil surface and transpiration is large enough (more than 5‰) for the separation of the components. Furthermore, δ18O of soil evaporation is throughout the year constantly less than δ18O of surface soil moisture, and δ18O of transpiration is almost identical to that of root zone (0-75 cm) soil moisture.

In summary, the isotopic compositions of soil evaporation and transpiration can be approximated by the stable isotope ratio of soil water. Similarly, separation of evapotranspiration by adding stable water isotope observations should be successful, and subsequently, lead to detailed verification of land surface simulations and increase in understanding the land surface system. For further details on this work, please see [6].

 δ18O and δD indicate difference relative to H218O and HDO concentration of SMOW (standard mean ocean water), respectively, in units of parts per thousand (%). For example, both SMOW’s δ18O and δD are 0‰, and 0.99 of H218O concentration to that of SMOW is written as δ18O=-10‰.

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