Session: C13 Poster: T18A

Effects of the land-atmosphere interaction on the West African monsoon onset

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The West African monsoon onset, the abrupt latitudinal shift of maximum precipitation from the Guinean coast into the Sahel region in summer, is essential for the life in this region because it is strongly related to the water resource management. The monsoon onset in West Africa is also highlighted scientifically because the physical processes of the monsoon onset are thought to be controlled by the temporal and spatial variability of the land-atmosphere interaction. However, it is difficult to investigate the terrestrial effects on the West African monsoon onset due to the limitation of the existing climate model simulation capability of the land surface hydrological parameters such as soil moisture and surface fluxes. Therefore, this study applies an atmospheric meso-scale model coupled with a satellite based land area assimilation which can physically introduce heterogeneities of land surface conditions into models in order to investigate the effects of the land surface on the monsoon onset in West Africa. The inland tropospheric warming is found as a key driver of the monsoon onset because it makes a pressure gradient between the coastline and the inland area. The mechanism of this warming, especially the seasonal progress of it, is investigated. In early May, the model result shows two sources of heat of the atmosphere above the inland area. One is adiabatic heating due to a brunch of the subsidence of the Hadley circulation induced by the latent heat fluxes from the ocean surface. The other is diabatic heating due to the heat of condensation of moisture which is transported from Gulf of Guinea to Sahel by the shallow meridional circulation induced by strong sensible heating on the land area. However, this atmospheric structure abruptly changes at the end of May. The subsidence above the inland disappears, even the diabatic heating still exists. Then, the convections shift northward abruptly at the end of June. The present study also investigates the mechanism of the shallow surface circulation which plays an important role to transport moisture from the ocean to the inland area and to warm the troposphere in summer. This shallow surface circulation consists of the northward wind over the Gulf of Guinea and the updraft over the Sahel region. Soil moisture is a strong factor in determining the distribution of the surface albedo and land surface energy budget. And because of the distribution of soil moisture, the sensible heating maximum is placed on the Sahel region in spring. This strong sensible heating drives the shallow surface circulation and leads to the monsoon onset. In addition, the forest cover is not a key factor in determining the distribution of soil moisture compared with the amount of light rainfall in spring before the monsoon onset. In present study, the above processes are addressed by using the sensitivity analysis. Through several numerical experiments by changing the sensible heat flux on land or the vegetation type, this study clarifies the effects of the sensible heating and vegetation on a shallow circulation in this region. In conclusion, this study found the distribution of the albedo plays an essential role in the seasonal march of the monsoon onset.