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An observationally-based modelling framework to study the sensitivity of the diurnal cycle over land

Amanda Gounou, Françoise Guichard, and Fleur Couvreux
CNRM-GAME (CNRS & Météo-France), Toulouse, France (francoise.guichard@meteo.fr)

Over land in the Tropics, atmospheric processes display strong diurnal fluctuations, with, in particular the daytime growth of a convective boundary layer and the development of convective clouds. This widespread phenomenon is currently not well simulated by parametrized models. For instance, deep convection often occurs too early in models compared to observations in the wet Tropics.

More broadly, the strong couplings taking place between surface, convective and cloud processes within a diurnal cycle appear difficult to simulate and this issue is likely to affect the mean state obtained with such models. See more discussion on this issue in Guichard et al. EGU 2011, Session AS1.16, African Monsoon Multidisciplinary Analysis (AMMA).

The aim of the present study is to provide a simple framework in order to explore the modelling of the diurnal cycle of physical processes and its sensitivity to contrasted environmental conditions encountered over land. In particular, we want to assess whether bias in the diurnal cycle are associated with bias in the mean state and how these features vary according to the environment.

The approach takes advantage of observations collected over West Africa during the AMMA field campaign. Different climatic environments were sampled with high-frequency soundings, surface and cloud data. In addition, a special AMMA re-analysis was carried out at the ECMWF and provides information on larger scale circulations.

On this basis, an ensemble of four 10-day simulations have been designed, which can be run either with a single column model (SCM, 1D) or explicitly with a cloud-resolving model (CRM). They encompass colder to warmer tropical and subtropical environments.

As a first step, 1D simulations have been carried out with the MesoNH model coupled to the ISBA land-surface model. The results show that the simulations are able to qualitatively capture the contrasts in diurnal cycles and convective processes between climatic zones.

However, a dry bias develop in the four simulations (with lower specific humidity). It is associated with a warm bias in the warmer environment and with a cold bias in the colder environment. These distinct temperature biases appear to involve errors in the cloud-radiative forcing which feed-back on surface and boundary layer processes. The cloud cover it too low (resp. too high) under the warmer (resp. colder) conditions. For the warm case, the dry bias tends to suppress moist convective processes, precipitation and surface evapotranspiration. For the colder case, the cold bias leads to a decrease of the specific humidity at saturation, the amount of water vapour, bounded by saturation, becomes too low and the low cloud amount is enhanced. Thus, biases in specific humidity cannot be simply related to biases in cloud amount and convection.

Overall, these results underline modelling issues which go beyond a problem of timing of deep convection over land. They further point to the need of a more accurate simulation of clouds. Indeed, even if the cloud cover is generally less over land than over ocean in the Tropics, its impact on the low atmospheric layers and convection occurs on much smaller time scales, during daytime, via distinct couplings with surface processes.