Geophysical Research Abstracts
Vol. 20, EGU2018-917, 2018
EGU General Assembly 2018

The land-atmosphere coupling and climate extremes in Africa

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Soil moisture is one of the most important variables of the climate system as it constrains evapotranspiration, affecting the water and energy balances at the surface, mainly over transition areas between humid and dry climates. An analysis of the energy and moisture balance, heat waves and droughts for the Africa Coordinated Regional Downscaling Experiment (Africa-CORDEX) is performed in present climate and used to evaluate heat and moisture projections for the future. Two different RCM sets from the Africa-CORDEX were exploited. One is driven by ERA-Interim reanalysis (1990-2008) and the other by Atmosphere-Ocean Global Circulation Models, from CMIP5 (RCP4.5 and RCP8.5 scenarios) and focused in two periods (1971-2000 and 2071-2100). Multi-Model ensembles means were produced, as it is the best estimative for present and future climate, as well as to assess the relationship between the fluxes partitioning, heat waves and droughts. Precipitation, Soil Moisture, Latent and Sensible Heat Fluxes, Mean, Maximum and Minimum Temperatures are also assessed and validated against observationally based databases (CRU, GPCC, FLUXNET and GLEAM) for seasonal and climatological time-scales. Overall, all models display a good agreement with observations, however the multi-model ensemble is found to perform better than individual models. The 10 days non-overlapping means correlations between latent and sensible heat fluxes and, between latent and maximum temperatures are used to assess the seasonal coupling strength. Also, the Bowen ratio and the Evaporative Fraction are computed to evaluate the climate evolution and coupling for each model. Overall, all models can represent the strong soil moisture-temperature coupling regions, where those areas coincide with transition zones identified on both Bowen ratio and Evaporative Fraction. These strong coupling regions also correspond to regions of more heat wave events in present climate. Nonetheless, in present climate, soil moisture-temperature feedback is found to not influence the duration of heat wave events, which seems to be controlled by the synoptic conditions. In future, more and longer heat waves are expected in Africa due to an increase of mean surface temperature, but also due to changes in the spatial distribution of strong coupling regions. Drought is assessed for both Hindcast and CMIP5 simulations with the SPEI index. In the future, for both scenarios, all models agree with longer and more intense droughts over Africa. To better asses the link between temperature and soil moisture or evapotranspiration, a new coupling metric for short time scales is proposed, the Latent Heat Flux-Temperature Coupling Magnitude (LETCM). This new metric is computed for a specific period, considering the positive temperature extremes and the negative latent heat flux extremes. Areas with positive magnitude values imply higher temperature anomaly, due to a negative latent heat flux anomaly. LECTM returns the areas where negative soil moisture anomalies influence the flux partitioning, leading to a surface increase of air temperatures, and on those regions, this metric is found to correlate well with lower mean SPEI values.

Acknowledgements. The authors wish to acknowledge SOLAR (PTDC/GEOMET/7078/2014) and FCT UID/GEO/50019/ 2013 (Instituto Dom Luiz) projects.