Geophysical Research Abstracts
Vol. 15, EGU2013-3281, 2013
EGU General Assembly 2013

Vegetation-climate feedback causes reduced precipitation in CMIP5 regional Earth system model simulation over Africa

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Terrestrial ecosystems have been demonstrated to play a significant role within the climate system, amplifying or dampening climate change via biogeophysical and biogeochemical exchange with the atmosphere and vice versa (Cox et al. 2000; Betts et al. 2004). Africa is particularly vulnerable to climate change and studies of vegetation-climate feedback mechanisms on Africa are still limited. Our study is the first application of A coupled Earth system model at regional scale and resolution over Africa. We applied a coupled regional climate-vegetation model, RCA-GUESS (Smith et al. 2011), over the CORDEX Africa domain, forced by boundary conditions from a CanESM2 CMIP5 simulation under the RCP8.5 future climate scenario. The simulations were from 1961 to 2100 and covered the African continent at a horizontal grid spacing of 0.44°. RCA-GUESS simulates changes in the phenology, productivity, relative cover and population structure of up to eight plant function types (PFTs) in response to forcing from the climate part of the model. These vegetation changes feedback to simulated climate through dynamic adjustments in surface energy fluxes and surface properties. Changes in the net ecosystem-atmosphere carbon flux and its components net primary production (NPP), heterotrophic respiration and emissions from biomass burning were also simulated but do not feedback to climate in our model. Constant land cover was assumed. We compared simulations with and without vegetation feedback switched "on" to assess the influence of vegetation-climate feedback on simulated climate, vegetation and ecosystem carbon cycling. Both positive and negative warming feedbacks were identified in different parts of Africa. In the Sahel savannah zone near 15°N, reduced vegetation cover and productivity, and mortality caused by a deterioration of soil water conditions led to a positive warming feedback mediated by decreased evapotranspiration and increased sensible heat flux between vegetation and the atmosphere. In the equatorial rainforest stronghold region of central Africa, a feedback syndrome characterised by reduced plant production and LAI, a dominance shift from tropical trees to grasses, reduced soil water and reduced rainfall was identified. The likely underlying mechanism was a decline in evaporative water recycling associated with sparser vegetation cover, reminiscent of Earth system model studies in which a similar feedback mechanism was simulated to force dieback of tropical rainforest and reduced precipitation over the Amazon Basin (Cox et al. 2000; Betts et al. 2004; Malhi et al. 2009). Opposite effects are seen in southern Senegal, southern Mali, northern Guinea and Guinea-Bissau, positive evapotranspiration feedback enhancing the cover of trees in forest and savannah, mitigating warming and promoting local moisture recycling as rainfall. We reveal that LAI-driven evapotranspiration feedback may reduced rainfall in parts of Africa, vegetation-climate feedbacks may significantly impact the magnitude and character of simulated changes in climate as well as vegetation and ecosystems in future scenario studies of this region. They should be accounted for in future studies of climate change and its impacts on Africa.

Keywords: vegetation-climate feedback, regional climate model, evapotranspiration, CORDEX.

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