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Coupled Model Intercomparison Project Phase 5 (CMIP5) projected twenty-first century warming over Southern Africa: Role of Local Feedbacks

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The warming rates projected by an ensemble of the Coupled Model Intercomparion Project Phase 5 (CMIP5) global climate models (GCMs) over southern Africa (south of 10 degrees latitude) are investigated. The low resolution GCMs forced by four representative concentration pathways (RCPs) have been interpolated to a common resolution using a bilinear interpolation scheme. Warming is defined in terms of absolute differences in annual-mean near-surface air temperatures between two twenty-year time slices (2046-2065 and 2081-2100) and the historical period 1986-2005.

In all RCPs, CMIP5 models project a higher warming rate over the southwestern parts centred around the arid Kalahari and Namib deserts and extending towards northern South Africa, eastern Namibia, western Botswana and southern Angola. The higher warming rates over these areas outpace global warming by up to a factor 2 in some GCMs. The projected warming is associated with an increase in heat waves. There is notable consensus across the models with little intermodel spread, suggesting a strong robustness of the projections. The spatial pattern and magnitude of the projected temperature increase relative to global warming is quite similar across the two selected time slices in the twenty-first century.

Mechanisms underlying the enhanced warming are investigated. A positive soil moisture-temperature feedback is suggested to contribute to the accelerated temperature increase. A decrease in soil moisture is projected by the GCMs over the area of highest warming. The reduction in soil wetness reduces evapotranspiration rates over the area where evaporation is dependent on available soil moisture. The reduction is evapotranspiration affects the partitioning of turbulent energy fluxes from the soil surface into the atmosphere and translates into an increase of the Bowen ratio featuring an increase in sensible relative to latent heat flux. An increase in sensible heat flux leads to an increase in near-surface temperature. The increase in temperature leads to a higher vapour pressure deficit and evaporative demand and evapotranspiration from the dry soils, possibly leading to a further decrease in soil moisture.

A precipitation-soil moisture feedback is also suggested. A decrease in mean precipitation and an increase in drought conditions are projected over the area of enhanced warming. The reduced precipitation results in drier soils. The drier soil translates to reduced evapotranspiration for cloud and rainfall formation. However, the role played by the soil moisture-precipitation feedback loop is still inconclusive and characterized by some degree of uncertainty given that the strength of the local moisture recycling has not been explicitly quantified. An alternative mechanism involving the impact of soil moisture anomalies on boundary-layer stability and precipitation formation will be investigated.