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Linking Equatorial African precipitation to Kelvin wave processes in the CP4-Africa convection-permitting regional climate simulation

Godwin Ayesiga[1,2], Christopher Holloway[1], Charles Williams[3], Gui-Ying Yang[4], Rachel Stratton[5], and Malcolm Roberts[5]

[1]University of Reading, Meteorology, Reading, United Kingdom of Great Britain – England, Scotland, Wales (g.ayesiga@pgr.reading.ac.uk)

[2]Uganda National Meteorological Authority, Uganda (godwinayesiga@unma.go.ug)

[3]School of Geographical Sciences,University of Bristol, Bristol, UK (c.j.r.williams@reading.ac.uk)

[4]National Centre for Atmospheric Scienceand Department of Meteorology,University of Reading, Reading, UK (g.y.yang@reading.ac.uk)

[5]Met Office, Exter, United Kingdom (rachel.stratton@metoffice.gov.uk)

Synoptic timescale forecasts over Equatorial Africa are important for averting weather-and climate-related disasters and the resulting agricultural losses. Observational studies have shown that rainfall anomalies often propagate eastward across Equatorial Africa, and that there is a linkage between synoptic-scale eastward-propagating precipitation and Convectively Coupled Kelvin Waves (CCKWs) over this region. We explore the mechanisms in which CCKWs modulate the propagation of precipitation from West to East over Equatorial Africa. We examine the first Africa-wide climate simulation from a convection permitting model (CP4A) along with its global driving-model simulation (G25) and evaluate both against observations (TRMM) and ERA-Interim (ERA-I), with a focus on precipitation and Kelvin wave activity.

Lagged composites show that both simulations capture the eastward propagating precipitation signal seen in observational studies, though G25 has a weaker signal. Composite analysis on high-amplitude Kelvin waves further shows that both simulations capture the connection between the eastward propagating precipitation anomalies and Kelvin waves. In comparison to TRMM, however, the precipitation signal is weaker in G25, while CP4A is more realistic. As the Kelvin wave activity is also well represented in both simulations when compared to ERA-I, the weak precipitation signal in G25 may be partly associated with the weak coupling between the precipitation and Kelvin waves. We show that CCKWs modulate the eastward propagation of convection and precipitation across Equatorial Africa through at least two related physical processes. Firstly, an enhancement of the low-level westerlies leads to increased low-level convergence; secondly, westerly moisture flux anomalies amplify lower-to-mid-tropospheric specific humidity. Results show that both CP4A and G25 generally simulate the key horizontal features of CCKWs, with anomalous low-level westerlies in phase with positive precipitation anomalies. However, both models show a weakness in capturing the vertical profile of anomalous specific humidity, and the zonal-vertical circulation is too weak in G25 and incoherent in CP4A compared to ERA-I.

In both ERA-I and the simulations, Kelvin wave-induced convergence and the westward tilt with height of anomalous zonal winds and specific humidity tends to weaken to the east of the East African highlands. It appears that these highlands impede the coherent eastward propagation of the wave-precipitation coupled structure.