Abstract

Precipitation enhancement is one of the possible measures to improve on the available fresh water in East Africa (EA). The existing gap in knowledge not only on suitable conditions but also Aerosol-Cloud-Precipitation (ACP) interactions limits the success of precipitation enhancement through weather modification. This study aimed at modelling the effects of aerosols on clouds and precipitation for weather modification in EA. Aerosol and cloud data were retrieved from Moderate Resolution Imaging Spectroradiometer (MODIS). It comprised of Aerosol Optical Depth (AOD), Fine Mode Fraction (FMF), Cloud Top Pressure (CTP), Cloud Top Temperature (CTT) and Cloud Optical Depth (COD). Precipitation data comprised of 3B42 product sourced from Tropical Rainfall Measuring Mission (TRMM), and comprised of 3B42 product. The Weather Research and Forecasting model (WRF) initial and boundary conditions utilized the National Centers for Environmental Prediction Final (NCEP FNL) data. The daily datasets from MODIS and TRMM spanned the period 2001-2012 (12 years). The spatial and temporal analysis utilized the time series and Principal Component Analysis (PCA). The relationship between aerosol, clouds and precipitation were based Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) and Multiple Linear Regression (MLR) analysis. Suitable weather modification conditions were identified using Greater Horn of Africa (GHA) consensus forecast, CAPE and COD and CTP. Evaluation of WRF to simulations of Deep Convective Clouds (DCCs) was based on updrafts/downdrafts and precipitation. Aerosols effects on precipitation modification were simulated based on microphysical properties, precipitation, and convective strength under low, intermediate, and high Cloud Condensation Nuclei (CCN) and Cloud Droplet Number Concentration (CDNC) scenarios. In EA, time series (trend and seasonality), Hovmoller and PCA analysis of aerosol, clouds, and precipitation showed a high spatial and temporal variability. The PCA analysis yielded 13, 20, 11, 9 and 16 Principal Components (PCs) during MAM for AOD, FMF, CTT, OLR and TRMM 3B42 respectively. Similarly, PCA analysis yielded 14, 18, 10, 10 and 17 PCs during OND for AOD, FMF, CTT, OLR and TRMM 3B42 respectively. The explained variance during both MAM and OND were all greater than 57%. The MLR analysis showed that all aerosol and cloud variables with strong factor loading in EA had a positive relationship with rainfall. The backward trajectory indicated differences in origins of transported particles in the atmosphere with strong vertical mixing inland with mixed aerosols due to mountain blocking systems. GHA consensus forecast verification indicated less reliability due to lower Critical Success Index (CSI) and Heidke Skill score (HSS). However, verified consensus forecast for MAM 2012 indicated a likelihood of Near Normal (NN) to Below Normal (BN) rainfall and thus suitable for precipitation enhancement. Areas located centrally to EA exhibited optimal seedable temperatures of -5 oC to -25oC. DCCs dominated pentad 29 (CTP > 440MB, COD>23 and meridional/zonal transition in CAPE >1000J/kg) over Mt. Kenya catchment. Therefore, Mt. Kenya catchment was selected as representative of seedable conditions in EA. Evaluation of the efficiency of WRF microphysics shows that Morrison scheme simulated the initiation of downdraft cumulus core almost at the same time as observed. The initiation of several updrafts and its associated downdrafts with strong downdrafts below the updraft cores were comparable to the observed. Accumulated precipitation based on TRMM 3B42 and WRF model output for Mt. Kenya Region were also found to be comparable to the 24h simulation. Observed and model simulated the initiation of downdraft Cores was comparable. Microphysical properties (vertical profiles of mass

concentrations of five hydrometeors of cloud water, rainwater, ice-crystal snow and graupel) showed the complex relationship under three aerosol scenarios. Precipitation increased with increase in CDNC and CCN from maritime/clean to continental/polluted conditions and reduced/suppressed at highly polluted conditions (CDNC>1600cm-3 , CCN>2000cm-3). Accumulated total precipitation exhibited a complex variation (non-linear relationship) under CDNC and CCN scenarios. The mean of core updraft and maximal vertical velocity increased under intermediate and low CCN scenarios and decreased under high CCN scenarios. The response of precipitation to increase in aerosol concentration (CDNC and CCN) was non-monotonic. The study indicates the possibility of enhancing precipitation in locations with similar conditions to Mt. Kenya catchment. Increasing the available fresh water in EA will spur sustainable development. However, critical issues remain yet to be solved and require stronger scientific evidence/support. These include improvement of the predictability of seasonal rainfall and development of cloud-resolving models for the region. Further, It will be necessary to develop relevant policies to address the benefits, risks, and ethical issues related to weather modification.