SERVIR and Seasonal Climate Forecasts

The NASA/USAID SERVIR project is dedicated to developing and improving the capacity of several hub regions to incorporate unique NASA satellite and modeling resources into operational environmental monitoring and planning. Recent and currently served hub regions include Mesosamerica, East Africa (EA), and the Hindu Kush-Himalayan region.

The SERVIR Applied Science Team (AST) has recently been established with the goal of providing enhanced products for use in the hub regions. Currently awarded projects within the AST include (but not limited to) agricultural and hydrologic impact modeling, air quality and landslide assessments.

Another AST team is focused on the evaluation of climate model simulations and the development of downscaled scenarios to be used by AST projects focused on impact modeling. Results presented here focus on the initial development of downscaled seasonal forecasts from the NASA Global Modeling and Assimilation Office (GMAO) GEOS-5 model contribution to the U.S. National Multi-Model Ensemble (NMME) for use in agriculture and hydrologic modeling over East Africa.

Observed East Africa Rainfall Variability

Seasonal rainfall in East Africa (Fig. 1) is strongly tied to the annual march of the Intertropical Convergence Zone (ITCZ). The result is an annual maximum in rainfall in northern (southern) East Africa (Djibouti) and biannual maxima near equatorial East Africa (SS-SN) in MAM (“long rains”) and OND (“short rains”). The topographic influences on seasonal rainfall are pronounced with the largest seasonal rainfall occurring over the interior highlands (see Fig. 3 for elevation). Interannual variability of seasonal rainfall is locked strongly to the seasonal cycle.

Equatorial East Africa (EEA) rainfall variability can be examined through use of a standardized precipitation index (SPI) that quantifies the anomalous rainfall variability (annual SPI) relative to standard deviations of a normal distribution. Since 2000, EEA rainfall has shown significant interannual variability (Fig. 2) including excessive rainfall in late 2006 and the back-to-back failure of the short and long rains in 2010-2011.

Teleconnection maps for the short and long rainy seasons (Fig. 2) indicate significant relationships with both sea surface temperatures (SST) and precipitation variability. These have been identified in several studies with short rain interannual variability linked strongly to ENSO-induced alterations of tropical zonal circulation.

Precipitation over East Africa exhibits low skill at all but the shortest lead, while Niño 4/JAS regional sea surface temperatures show very high anomaly correlation out to many months. The ranked probability skill score (RPSS) at 0.5 month lead shows much improved skill prediction of ocean surface temperatures in many regions compared to climatological tercile probability use. Precipitation forecasts show only limited skill and is primarily limited to the central and western Pacific Ocean.

Forecasting to Impact Modeling Framework

Bridging the gap – “Downscaling”

Statistical downscaling makes use of large-scale model predictors together with observed climate variables to generate plausible high-resolution scenarios for assessing local-scale variability and/or driving end-user models. Spatial downscaling techniques vary widely including both linear and nonlinear (e.g. neural networks) methods. Techniques for generating sub-monthly variability include stochastic weather generators (univariate and multivariate) and analogue/resampling approaches.

GCM Seasonal Forecast – Raw Model Output

Coarse spatial resolution (~100 km)

Typically archived at monthly resolution

Systematic biases as a function of lead

Raw Model Skill and Bias Correction

Raw model simulated fields often contain systematic biases that vary as a function of lead. These can be corrected through methods such as quantile-quantile mapping that preserve rank correlation but provide improved amplitudes and spatial variability with respect to uncorrected model output. However, there can be large differences in the inherent skill of models as a function of variable, location and forecast lead time.

Raw model simulated precipitation over East Africa is currently shown to have limited inherent skill for direct forecasts of EA rainfall and must be spatially and temporally downscaled for use in impact modeling.

Matched filter regression (MFR) is a technique that can be used to identify predictability in large-scale variability that are significantly correlated with a predictand of interest. Hindcast simulations are used to identify significant correlations between the EA SPI and model fields (Fig. 5). Hindcasts of those regions exhibiting significant correlations are used to develop a multivariate vector (VMF) whose entries are scaled by the correlation strength at each location. The set of hindcast vectors are subjected to a principal component (PC) analysis. The 1-2 PC serves as a predictor for deriving a functional relationship with the MFR approach. This shows significant improvement over the direct model forecasts of EA rainfall (Fig. 6).

Summary Points

The NASA/USAID SERVIR Applied Science Team (AST) is currently supporting several projects that will make use of downscaled seasonal forecast scenarios in agricultural and hydrologic modeling over East Africa.

Interannual rainfall variability in equatorial East Africa is prominent, leading to floods and droughts. Variations in both the short and long rains are influenced by ocean-atmosphere teleconnections.

Seasonal forecasts from the GMAO model show limited inherent skill for direct forecasts of EA rainfall and must be spatially and temporally downscaled for use in impact modeling.

Matched filter regression, combined with bootstrap resampling of a high-resolution historical record (0.25°) is the approach to the development of refined scenarios for use within the SERVIR AST.