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NMME Monthly/Seasonal Forecasts for NASA SERVIR Applications Science

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SERVIR

SERVIR and Seasonal Climate Forecasts

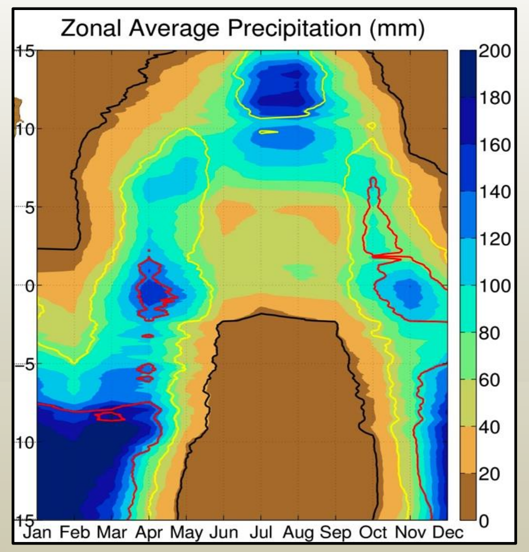
- SERVIR is a joint NASA and US Agency for International Development project to bring Earth observations and products into developmental decision making in SERVIR regions. Currently SERVIR Hubs serve East Africa (EA), Mesoamerica, and the Hindu Kush-Himalayan region.
- The SERVIR Applied Science Team (AST) has been established with the goal of providing enhanced products (e.g. agricultural and hydrologic modeling, air quality and landslide risk), outlooks and projections for use in the hub regions.

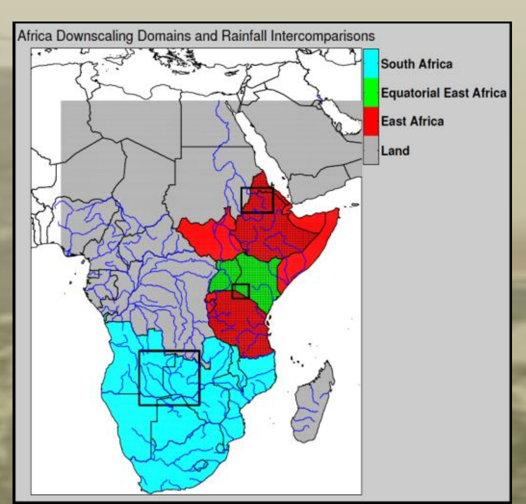
SERVIR Hub Regions and the Applications Science Team Investigations Served

This SERVIR project serves other AST teams by pursuing the following objectives:

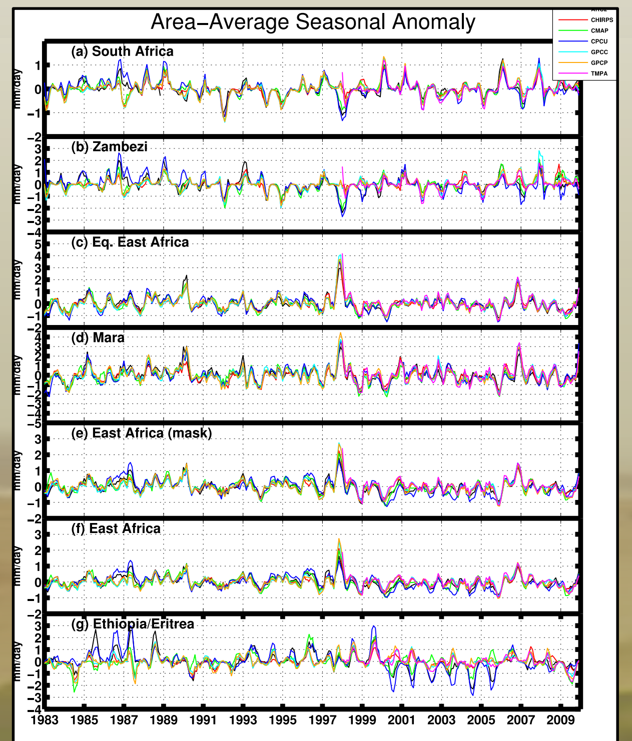
- *Critically assess and employ Phase I North American Multi-Model Ensemble (NMME) and other climate model projections of seasonal / interannual hydrometeorological climate variability affecting SERVIR Hub regions.*
- *Develop and refine scenarios through downscaling and stochastic modeling to enable AST Investigators to drive decision support system models of hydrologic processes, crop production and water availability on seasonal time horizons.*

East Africa: An Example of Rainfall Variability Challenges





- Seasonal rainfall in East Africa is strongly tied to the annual march of the Intertropical Convergence Zone resulting in bi-annual maxima near equatorial East Africa (5S-5N) in MAM ("long rains") and OND ("short rains"). Interannual variability of seasonal rainfall is locked strongly to the seasonal cycle.
- SERVIR AST regions of interest (black squares) span this large region affected by the ITCZ as well as extratropical variability in the south and interannual responses to SST change.
- A complicating factor in assessing interannual hydroclimate variability and verifying / modifying NMME forecasts is the uncertainty in rainfall data sets (below).



NMME Seasonal Climate Forecasts and Strategy for SERVIR Applications

NMME Phase-1 Raw Forecasts

- 9 CGCMs from 6 centers
- ~10 month forecasts
- 1°x1° , monthly averages
- Hindcasts 1981-2012 with t2m/sst/rain

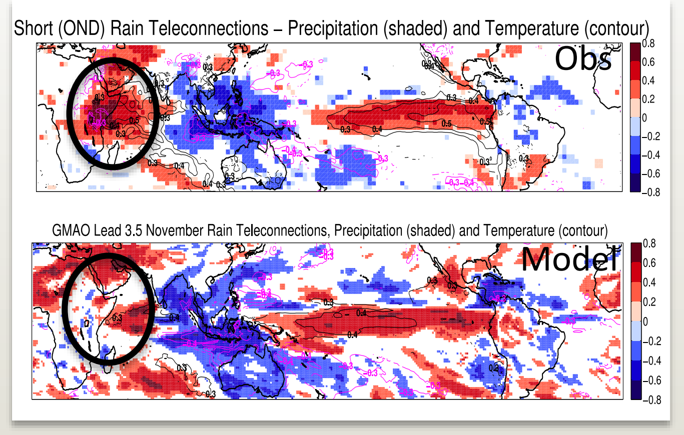
Two Fundamental Obstacles

- Biases in amplitude and spatial structure
- Not at a resolution useful for AST modeling

Solution

- Model output statistic skill-correction using hindcasts
- Spatial and temporal downscaling using tercile resampling of observations

Step 1: Skill Correction



Model evaluations

Ensemble model predictions of SST and precipitation may have reasonable global structure but the regional details are typically distorted. This underscores the need for MOS correction of precipitation and most likely other NMME archived quantities.

Model Output Statistics

- A number of multivariate statistical methods exist for analyzing the relations between two vector quantities (Tippet et al, 2008). Here, the NMME ***predictors*** of SST and precipitation are related to the ***predictand***, precipitation over the East Africa region.
- Among these methods are Canonical Correlation Analysis, CCA; Maximum Covariance Analysis, CCA and Redundancy Analysis, RDA. We adopt RDA which maximizes the explained variance in the predictand field.
- The regression relationships are derived by training on hindcasts using leave-one-out cross-validation for each calendar month & forecast lead.

Issues / Pitfalls

- *Small sample size (~30 years), non-stationarity of relationships.*
- *High-dimensional multivariate regressions can over-fit*

Step 2: Spatial and Temporal Downscaling

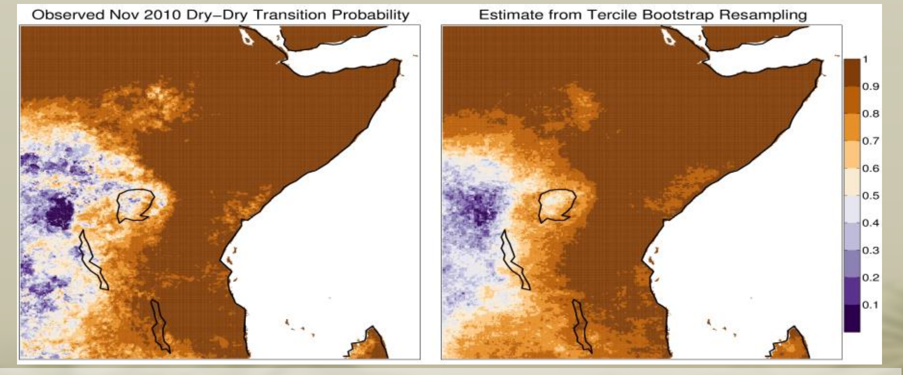
Requirements

- Fine resolution (0.05°), Daily
- Maintain weather covariability
- Access to required variables for impact models including those not available from CGCMs

Downscaling via Resampling

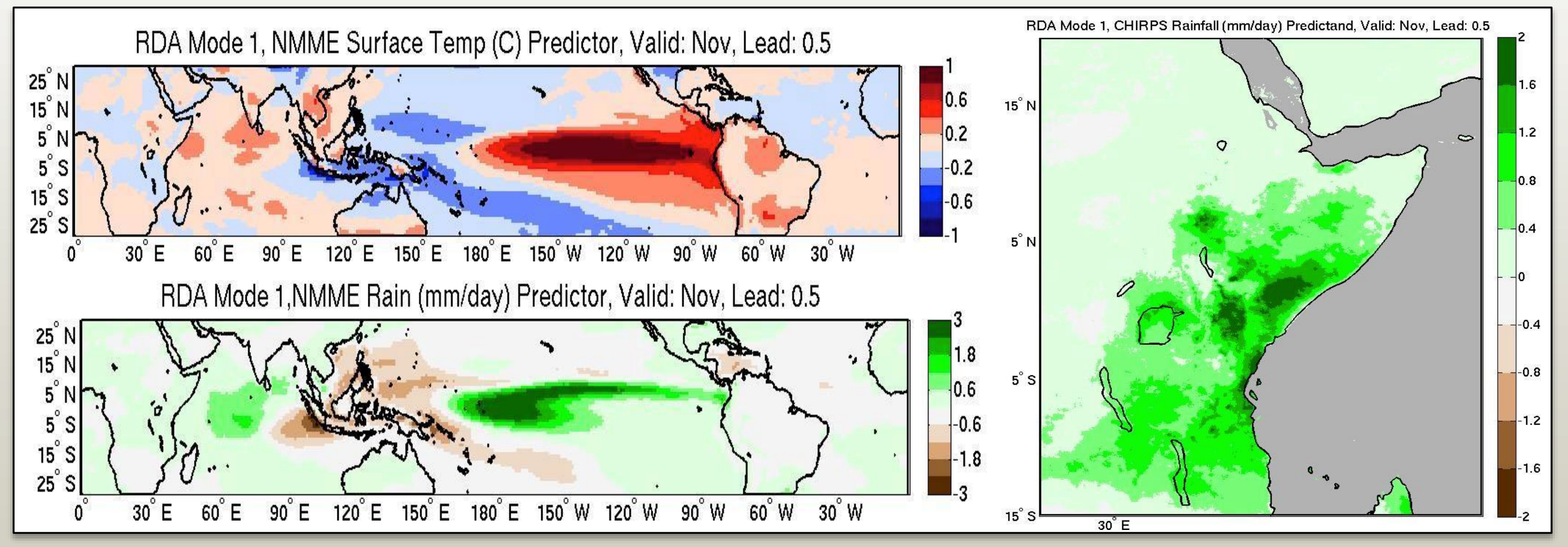
- Using NMME-predicted ***monthly*** EA SPI, the ensemble forecasts are used to identify the relative probabilities of falling into an observed tercile: below-, near-, or above- normal.
- These probabilities are used to bootstrap-resample into a historical dataset to generate plausible scenarios capturing coherent spatial and temporal variability (right).
- Multiple ***daily*** scenarios with same probabilistic ratio as NMME-forecasts are then generated.

Here we use the daily,1981-2013 Climate Hazards Group IR Precipitation with Stations (CHIRPS;Funk et al. 2013) dataset at (0.05°). For other hydromet data we use the Princeton Surface Forcing for Tmin/Tmax/Wind (1° interpolated to 0.05°).



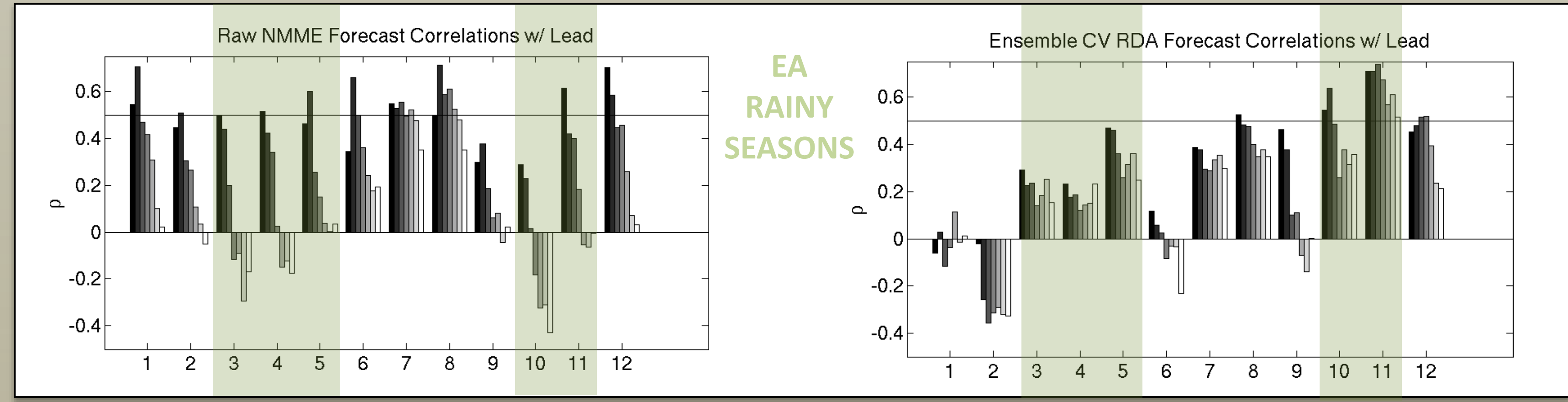
Transition probabilities for dry to dry days in November 2010 are shown over EA from observations (left) and those derived using a cross-validated bootstrap resampling of the most likely tercile as forecast by the 0.5 month Lead forecast. Note the similar spatial structure and amplitude captured by the downscaled scenarios.

An Analysis of NMME Downscaling over East Africa



1st Coupled Modes for NMME SST (upper left), tropical rainfall (lower left) and EA rainfall produced by RDA for the month of NOV and lead 0.5 month. Note that the global NMME rainfall pattern agrees closely with that of the single GMAO model (see center panel) in terms of biased EA rainfall compared to observations. Data used spans 1981-2012. Additional modes could be used to increase explained variance of but over-fitting was exacerbated.

Raw NMME and RDA Predicted vs CHIRPS Obs Rainfall



- Except for NOV, the raw NMME skill in first two months of lead surpasses RDA. This is likely due to the importance of initial conditions for NMME as well as overfitting of the RDA.
- Greatest RDA improvement is in the two rainy seasons, but especially in the "Short Rains" of ON. For the small sample size (~30) the few, but high amplitude, ENSO events skew the RDA (or any multivariate) corrections. When predictability related to ENSO falls, so does the RDA skill correction. Inclusion of additional modes with regularization may be needed.
- RDA maintains skill better at longer lags; however the skill is quite low.

Summary Points

- Several investigations from the NASA SERVIR Applied Science Team (AST) require use of downscaled seasonal forecast scenarios in agricultural and hydrologic modeling outlooks for East Africa, Southern Asia and Mesoamerica.
- Multivariate statistical approaches combined with bootstrap re-sampling of a high-resolution historical record has been implemented as a first approach to the development of refined scenarios for use within the SERVIR AST.
- Initial assessment of direct model seasonal forecasts shows limited "seasonal windows" of RDA skill enhancement in forecasts of EA rainfall in the current configuration. We are examining the utility of additional modes.
- Extensions to other NMME model fields now available (e.g. 850 winds or soil moisture) and Phase II data will be pursued.