Ensemble-based Statistical Prediction of Ethiopian Monthly-to-Seasonal Kiremt Rainfall

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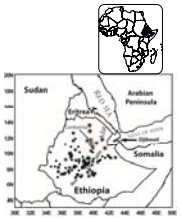
1. Introduction

This study employs an ensemble-based multiple linear regression technique to assess Ethiopian monthly and seasonal rainfall predictability on both national and regional/local scales. Up to 471 orthogonalized linear and nonlinear regional atmospheric and global SST predictors are prescreened and used to individually initialize models in a forward stepwise model-fitting procedure. In a cross validation strategy, predictor selection and model development processes utilize data for all of 1970-2002 except for single years from 1990-2002 that are withheld for verification.

2. Data

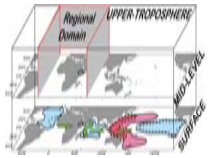
Rainfall

- 100 rain gauge stations for 1970-99 for all-Ethiopian seasonal prediction
- 52 stations for 2000-2002
- 11 stations for regional prediction
- Combolcha for local prediction



Predictors

- Regional: U, V, W, T, P, H, q
- Global: sea surface temperature
- Time: March, April (pre-monsoon)
- Space: 2.5° lat. x 2.5° lon., 12 levels
- Challenge: Too many (> 4000) predictors

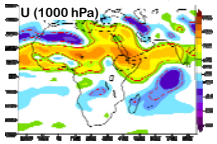


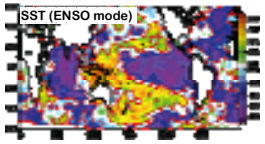
Problem of multicollinearity (interrelated predictors)

To reduce the number of predictors and handle multicollinearity issues, apply Principal Component Analysis (PCA)

3. Monsoon Rainfall Correlations

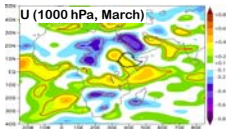
Concurrent (June-September) Correlations

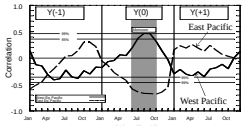




Increased lower tropospheric zonal wind is associated with enhanced monsoon rainfall over Ethiopia, and ENSO time-scale warming over both the Indian Ocean and the eastern Pacific Ocean tends to reduce monsoon rainfall over Ethiopia

Time-Lagged Correlations





Atmospheric and SST correlations are low prior to the onset of monsoon over Ethiopia

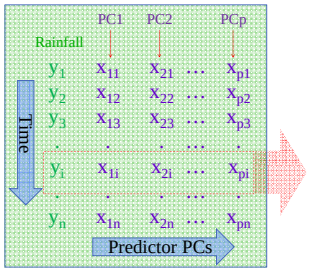
Conclusions

Both regional circulations and global SSTs are required for skillful Ethiopian June-September rainfall (Kiremt) predictions

Ensemble-based statistical prediction technique provides high-quality local and regional forecasts for Ethiopian Kiremt one to two months in advance of onset month

Leave-one-out (and also retroactive) prediction technique identified observed all-Ethiopian seasonal anomalies

4. Prediction Design



For a leave-one-out prediction strategy, any PC with at least 0.2 correlation magnitude with rainfall (excluding data for predicted year) is used as a potential predictor provided that the correlation is stable (i.e., remain fairly the same) for any 9/10 data-pair segments of the training data

Leave-One-Out strategy

Ensures no information of the future state is leaked into the prediction

Procedure

Exclude year i of time series & develop a MLRE from the remaining data by initializing with PC1 => Model M_{1i}, Prediction Y_{1i}

Repeat the model fitting by initializing the model with PC2 => M_{2i}, Y_{2i}

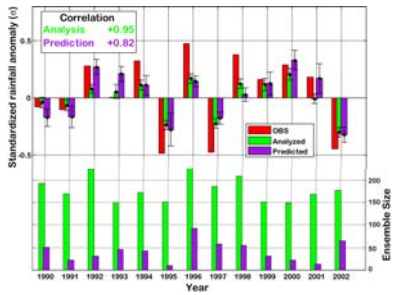
Continue until each PC initializes the model, yielding a set of *p* models and *p* prediction values for year i => M_{1i}, M_{2i}, …, M_{pi}, and Y_{1i},Y_{2i}, …,Y_{pi}

The final prediction for year i is then the average of predicted values of the best models, which are selected based on several criteria that largely involve intra/inter-model correlation strength and significance levels

The above model-fitting procedure is repeated for all years to be predicted

Reference:
Segele, Z. T., P. J. Lamb, and L. M. Leslie, 2009: Seasonal-to-interannual variability of Ethiopian/Horn of Africa monsoon. Part I: Associations of wavelet-filtered large-scale atmospheric circulation and global sea surface temperature. *J. Climate*, **22**, 3396–3421

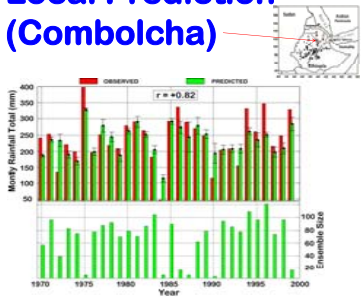
5. National Prediction



For the Prediction, only fitted model statistics were used to select ensemble members

For all (most) years, the ensemble prediction correctly identified the sign (magnitude) of the observed All-Ethiopian standardized June-September rainfall anomalies

6. Local Prediction (Combolcha)



High correlation predictions for Combolcha (northeastern Ethiopia) based on the state of the ocean-atmosphere system observed in April

Deviations from the observations are large for excessively wet (e.g., 1975) or excessively dry (e.g., 1984) years

The interannual variability of monthly rainfall is well captured

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