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Seasonal Forecast of Two-Meter Temperature and Precipitation in Tanzania: A Hybrid Cluster and Point-by-Point Machine Learning Approach

Abstract

Seasonal climate forecasting is crucial for many socio-economic sectors, particularly agriculture. In Tanzania, agriculture accounts for about 25% of GDP and employs nearly three-quarters of the workforce, making reliable seasonal forecasts of temperature and precipitation an important challenge. Traditional dynamic models are widely used but require high computational resources and often lack regional-scale accuracy. Recently, statistical and machine learning approaches have emerged as promising alternatives. This study introduces **finres_S2S**, a hybrid approach designed to forecast monthly mean 2-meter temperature (2T) and total precipitation (TP) up to six months ahead. The model combines the advantages of both **gridpoint-based** and **cluster-based** methods, preserving geographical detail while reducing computational costs. Forecasting was carried out using a **Quantile Random Forest Regressor (QRF)**, which allows probabilistic predictions and avoids overfitting in small-sample conditions. Results show that finres_S2S outperforms ECMWF forecasts across Tanzania, with correlation improvements of up to 20–25% and MAAPE reductions of up to a factor of two, particularly over coastal and highland regions. This study demonstrates that machine learning-based hybrid approaches can complement dynamic models by providing accurate, low-cost, and geographically detailed seasonal forecasts.

Keywords

Hybrid Cluster, Quantile Random Forest (QRF)

Reference

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