

Research Application Summary

Validation of satellite derived rainfall estimates over Kenya

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Abstract

Precipitation is one of the major components of the earth's climate system. Many countries in the tropics depend on rainfall for the agricultural and hydrological activities which are dominant in their economies. Rainfall information is a crucial aspect not only for sustainable social-economic development of many countries but also for study of atmospheric circulations, climate analysis and global energy balance. Hence it is important to use reliable and accurate rainfall data in any planning. This study aims at validating satellite-derived rainfall estimates retrieved from TRMM's monthly rainfall retrieval algorithm, (3B-43 algorithm), over Kenya. The study analyzes eleven years of monthly rainfall estimates (1998-2008) produced by Tropical Rainfall Measuring Mission (TRMM)'s 3B-43 algorithm and compares them with gridded monthly rainfall totals from 26 synoptic and Agrometeorological stations in Kenya for the same period. Preliminary results suggest that satellite rainfall estimates can be modeled to represent areal rainfall in areas with inadequate ground based rainfall observations, especially over Northwestern, Northern, Northeastern and Southern Kenya.

Key words: Agrometeorology, rainfall data, remote sensing

Résumé

La précipitation est l'une des principales composantes du système climatique de la terre. De nombreux pays dans les régions tropicales sont tributaires des pluies pour les activités agricoles et hydrologiques qui sont dominantes dans leurs économies. L'information pluviométrique est un aspect crucial, non seulement pour le développement socio-économique durable de nombreux pays, mais aussi pour l'étude des circulations atmosphériques, l'analyse du climat et le bilan énergétique mondial. C'est pourquoi il est important d'utiliser les données pluviométriques précises et fiables dans toute la planification. Cette étude vise à valider les précipitations obtenues par satellite TRMM estimations extraites de l'algorithme de récupération de pluie par mois, (3B-43 algorithme), sur le Kenya. L'étude analyse les onze années d'estimations des précipitations mensuelles (1998-2008) produit par « Tropical Rainfall Measuring Mission » (Mission de Mesure de Précipitations Tropicales) (TRMM) 's 3B-43 algorithme et les compare avec

les totaux des précipitations mensuelles de 26 stations synoptiques et agro météorologiques au Kenya pour la même période. Les résultats préliminaires suggèrent que les estimations des précipitations par satellite peuvent être modélisées pour représenter les précipitations dans les zones à nombre des stations insuffisant pour observations des précipitations, en particulier au Nord-Ouest, Nord, Nord-Est et le sud du Kenya.

Mots clés: Agro-météorologie, les données des précipitations, la télédétection

Background

Most of rainfall data in Kenya is derived from rain gauge records. The rain gauge data only accurately indicate rainfall in a localized area (Ouma, 1988). Although improvements in satellite observations of precipitation are sought, it should be noted that gauge measurements provide the only long-term direct measure of precipitation and should not be overlooked (Gruber and Levizzani, 2008). Recently, more accurate automatic weather stations have been introduced but their network is too sparse due to their high cost.

In many parts of the world especially in the African continent the rain gauge network is too sparse to produce reliable areal rainfall estimates. In Kenya, the number of rain gauge stations is limited and the distribution of rain gauges is very uneven, with most stations located near main towns. As a result, these gauges may not represent the rainfall over the rural areas where the information is needed most. Even where data exist, there are other limitations including short historical time series, missing data and reading errors.

Many researchers are therefore focusing upon getting better and alternative methods of collecting areal rainfall data. One of the modern methods being used to acquire rainfall data is remote sensing. Remote sensing is the science and art of obtaining information about an object, area or phenomenon through the analysis of data acquired by a device that is not in contact with the object, area or phenomenon under investigation (Lillesand, 1979). Remote sensing methods of rainfall estimation use information received from radar and weather satellite based sensors. If the methods of estimating rainfall using data retrieved from satellites are close to the rain gauge observations, then satellites may be used to estimate precipitation in areas where rain gauge network is sparse.

Literature Summary

Currently, studies are being carried out in order to use microwave channels to estimate rainfall. This has been enhanced by the Tropical Rainfall Measuring Mission (TRMM). The passive microwave observations from radiometers on board low earth-orbiting platforms have better physical connection to precipitation processes as compared to the visible infrared sensors that can offer quasi-continuous coverage from space. The measurement by passive microwave radiometers is less sensitive to the presence of cirrus clouds, which is one of the major problems in infrared based rainfall estimation algorithms.

Klepp *et al.* (2003) used rainfall estimates derived from the Special Sensor Microwave Imager (SSM/I) on board National Oceanic and Atmospheric Administration (NOAA) National Environmental Satellites to study rainfall processes associated with frontal and cyclonic systems over North Atlantic. A multi satellite method was applied for complete coverage of North Atlantic twice a day. Different special sensor microwave imager precipitation algorithms were tested for individual cyclones and compared to the Global Precipitation Project datasets. An independent rainfall pattern and intensity validation method was presented using voluntary observing ship datasets and AVHRR images. The results showed that mesoscale backside rainfall events contributed up to 25% of the total amount of rainfall in North Atlantic cyclones.

Furuzawa and Nakamura (2005) used Tropical Rainfall Measuring Mission precipitation radar (PR) and TRMM Microwave Imager, to investigate the performance of TMI rainfall estimates. The results showed that TMI underestimates rainfall with low cloud height and overestimate rainfall with high cloud height. Combination of microwave imager and precipitation radar improved rainfall estimates.

Tapiador *et al.* (2004) evaluated an operational procedure to produce half-hourly rainfall estimates at a 0.1 spatial resolution which combined rainfall estimated by a Neural Network (NN) approach utilizing passive microwave and infrared satellite measurements. Half hourly rain gauge data over Andalusia, Spain, were used for validation purposes. Results showed fused methodologies improved the performance of estimations.

Study Description

The quality of rain gauge records was assessed before they were included in this study. These monthly rain gauge records were then gridded using Kriging method to a grid scale of 0.25 ° by 0.25 ° to match with the TRMM satellite's rainfall estimates.

The two gridded data sets were then compared by plotting scatter diagrams for a dry season (January to February), a wet season (March to May) and for the whole period of study. Simple correlation analysis was also carried out to determine the relationship between the two variables.

Principal component analysis was performed in both spatial and temporal modes to investigate the underlying physical processes which gave rise to the two data sets. The first principal components were presented on spatial maps for both Kriged rainfall and satellite rainfall estimates, respectively. A pair of maps with similar patterns, one for each variable, were obtained for the wet season, dry season and for the whole period of study. Time series of the first and the second principal components of the Kriged rainfall and TRMM satellite's rainfall estimates were also plotted.

The accuracy of TRMM satellite rainfall estimates was also determined using the mean absolute percentage errors (MAPE), Mean errors (Bias), Mean absolute errors (MAE) and Root mean squared errors (RMSE). From these results, temporal mode was found to generate larger errors than the spatial mode. In spatial mode more than half of the country was found to have errors within the acceptable range. The TRMM's 3B43 algorithm overestimated rainfall during the wet season.

Canonical correlation analysis (CCA) was done to determine a linear combination of each of the two sets of variables such that the correlation between two functions was maximized. The CCA which is equivalent to multiple regression was also used to develop models for estimation of areal rainfall using satellite derived rainfall estimates. The results from CCA reveal high correlation coefficients between Kriged rainfall and TRMM rainfall estimates. For the overall period of study eight out of ten Eigen vectors analyzed had CCA coefficients greater than 0.5.

Research Application

Spatial maps of the loadings of the first Principal Component, drawn in order to compare the two variables had similar patterns. PCA was also done in temporal mode and time series of the first Principal components of the two data sets were plotted and the resulting graphs had similar trend.

Results from scatter plots showed that the two variables were compactly arranged with few outliers. Results from simple and canonical correlations showed large correlation coefficients.

The results obtained from error analysis indicated that the temporal mode method generated larger errors than the spatial mode method, while wet regions had larger errors than dry regions. Also dry season had smaller errors than the wet season.

Finally spatial and temporal Canonical Correlation (CCA) models were developed using the significant Principal components (PCA) to estimate rainfall in areas with sparse rain gauge network over Kenya. The study found that no one mode was similar to the other. July was found to have largest CCA loadings while January had the smallest.

Recommendation

Based on these results it is suggested that satellite derived rainfall estimates may be used in areas with inadequate rain gauge observations.

Acknowledgement

This study was supported with funding from the Kenya government and the Regional Universities Forum for Capacity Building in Agriculture (RUFORUM). The authors are grateful to University of Nairobi and Kenya Meteorological Department for the support.

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