

Evaluation of Satellite Rainfall Estimates and Gridded Gauge Products over the Upper Nile Region

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Abstract

A dense station network over the Ethiopian highlands is used to perform an extensive validation and inter-comparisons of eleven satellite rainfall products and five gridded gauge products. The satellite products include Global Precipitation Climatology (GPCP), National Oceanographic and Atmospheric Administration-Climate Prediction Centre (NOAA-CPC) Merged Analysis (CMAP), the Tropical Rainfall Measuring Mission (TRMM) combined ‘TRMM and Other Sources’ (3B43), NOAA-CPC African Rainfall Estimation Algorithm (RFE), NOAA-CPC African Rainfall Climatology (ARC), GPCP one-degree daily (1DD), the ‘TRMM and Other Satellites’ product (3B42), Tropical Applications of Meteorology using Satellite and other data (TAMSAT) product, the CPC morphing technique (CMORPH), Precipitation Estimation from Remotely Sensed Information using Artificial Neural Network, (PERSIANN), and the Naval Research Laboratory’s blended product(NRL). These products are evaluated in three groups. The first group has low spatial (2.5°) and temporal (monthly) resolutions, and includes, GPCP, CMAP and 3B43. The second category (RFE, ARC, 1DD, 3B42, TAMSAT and CMORPH) are validated at 10-daily accumulations and spatial resolutions of 1.0° . The third group (RFE, 3B42, CMORPH, PERSIANN and NRL) are evaluated at daily accumulation and 0.25° spatial resolution. The first and second group of products exhibited reasonably good performance. The results are not so good for comparisons at daily accumulations. Though the products performed reasonably well in detecting the occurrence of rainfall, they performed poorly in estimating the amount of rainfall in each pixel.

The five gridded monthly rainfall products include the Global Precipitation Climatology Center (GPCC), NOAA Climate Prediction Center (NOAA-CPC), and the Climate Research Unit at the University of East Anglia (UEA-CRU). There are three different products from GPCC at multiple spatial resolutions (0.5°, 1° and 2.5°). The NOAA-CPC product has a spatial resolution of 2.5° while that of UEA-CRU is 0.5°. The GPCC and UEA-CRU products are compared at spatial resolutions of 0.5°, 1° and 2.5°, while NOAA-CPC is compared with the other products only at 2.5° resolution. A satellite product, from the Global Precipitation Climatology Project (GPCP), has also been included for comparison. There is a very good agreement between the global products and the reference data. Correlation coefficients are about 0.95 at 2.5° resolution, while the mean absolute error (MAE) is between 15 and 21 mm. Multiplicative bias is between 1.0 and 1.04 for the gridded products and 0.96 for GPCP. At 1.0° resolution correlation coefficients are about 0.92 while MAE is between 21 and 28 mm. Correlation coefficients are about 0.90 at 0.5° spatial resolution, and the MAE ranges from 27 to 32 mm. Bias remains very low at all resolutions. The performance of these products is highest during the wettest season (Jun to August), while it is relatively poor during the dry months (December, January, February). The seasonal differences are more prominent at high resolution and for the satellite product. These results are very encouraging, particularly considering the complex terrain of the validation site.

CHARACTERISTICS OF MONTHLY AND ANNUAL RAINFALL OF THE BLUE NILE RIVER BASIN

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ABSTRAT

The Blue Nile Basin is relatively wet with mean annual rainfall of 1423 mm (1960-2002) with standard deviation of 125 mm. The rainfall statistics is based on 36 rainfall stations with varying length of record. This mean rainfall is similar to a mean annual rainfall reported for a longer period of record (1900-1998). The annual rainfall has a normal probability distribution. The year-to-year rainfall variation is relatively small with a coefficient of variation of 0.09. The 100-year-drought basin annual rainfall is 1101 mm and the 100-year-wet basin annual rainfall is 1745 mm. The dry season is from November through April. The wet season runs from June through September with 74 percent of the annual rainfall and with low variation and skewness. October and May are transitional months. Monthly rainfall probability distribution varies from month to month fitting to Gamma-2, Normal, Weibull and Lognormal distributions. Monthly and annual rainfalls for return periods 2, 5, 10, 25, 50 and 100-year dry and wet patterns are presented.

(Key words: Blue Nile River, rainfall, probability distribution)

Rainfall Estimation Using Satellite Remote Sensing and ground truth for Hydrologic Modeling Over the Upper Blue Nile Region

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Abstract

A major source of uncertainty in hydrologic modelling is the inaccurate specification of rainfall as a meteorological forcing term. Rainfall often shows high spatial and temporal variability and capturing such aspects over a given area of interest is of great difficulty. Ground-based rainfall observations as obtained from radar and rain gauges are reported to have major limitations in terms of cost, areal coverage and accuracy. Since the early 1960s, efforts have been made to estimate rainfall from remote sensing data which provides large spatial coverage. However, applicability of the satellite image-based estimates for hydrologic modeling purposes is not yet effective. In this study, the objective is to identify and retrieve image-based information relevant for rainfall estimation and evaluate the accuracy of the existing rainfall products. The study area is situated in the Upper Blue Nile region, Ethiopia. In this study, the accuracy of two instantaneous rainfall products of the Tropical Rainfall Measuring Mission (TRMM), the Microwave Imager (TMI) and the Precipitation Radar (PR) are evaluated as well as the Infrared (IR) and water vapor (WV) channels of Meteosat Second Generation (MSG). From IR-10.8 μm & WV-6.2 μm , three primary indices namely: minimum Brightness Temperature (TBmin), Cold Cloud Duration (CCD) and Brightness Temperature Difference (BTD) of the IR and WV channels are identified. CCD is determined as the duration of clouds with brightness temperature lower than a predefined temperature threshold. The effectiveness of variable temperature threshold values is also assessed. For validation, reliable datasets are obtained from 10 automatic rain gauges over the Upper Blue Nile region (Gilgel Abay Subcatchment). A space and time collocation has been

made between the image-based estimates and products and ground-based observations and such research is unprecedented for the study area. A comparison between TRMM products and gauge observation over a spatial domain of 20x20 km showed better accuracy than resolutions of 5x5, 10x10 or 15x15 km. However, the overall estimate from TMI and PR products is unsatisfactory. Both overestimate the gauge measurements except at some high elevations (>3000m) where effects of orography are evident. Within the catchment, the CCD showed different performance when used at individual stations. Clusters from the TBmin vs rainfall plots are identified based on $CCD < 0.1$. The procedure indicates that the rainfall estimation procedure requires a spatially variable brightness temperature threshold. Scatter plots of both BTD and TBmin versus ground truth indicate some trend and a regression equation is derived. A retrieval procedure based a regression equation that utilizes multiple indices is found superior as compared to utilizing single indices. Results from this study indicate that, even though rainfall can be estimated through satellite remote sensing in the Upper Blue Nile area, caution is needed for application of rainfall estimations to hydrological modeling. However, it must be realized that assessments in this study focused on estimating rainfall from single events that are highly dynamic and non-linear.

Key words: Rainfall Estimation, TRMM, MSG, CCD, Brightness Temperature, Upper Blue Nile

SIMPLE MODEL AND REMOTE SENSING METHODS FOR EVAPORATION ESTIMATION OF RIFT VALLEY LAKES IN ETHIOPIA

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ABSTRACT

In most arid regions of the world, evapotranspiration (ET) is a major component of the water budget. Accurate estimation of ET has been a challenge for hydrologist mainly because of the spatiotemporal variability and also most available models rely on intensive metrological information for ET estimation. Such data are not available at a desired spatial scale in less developed parts of the world. Measurement and estimation methods of ET usually provide different results as is the case for the Rift Valley Lakes of Ethiopia. Such limitations have necessitated the development of simple models that are less data intensive and also the use of remote sensing that can be applied to large areas where metrological data are not available. In areas like the Rift Valley regions of Ethiopia, the applicability of the Simple Method of lake evaporation estimation and surface energy balance approach using remote sensing was studied. The Simple Method of potential ET, lake evaporation and wetland ET estimation from a single parameter, solar radiation, has been successfully applied in South Florida. The Simple Method and a remote sensing evaporation estimates for Rift Valley Lakes were compared to the Penman, Energy balance, Pan, Radiation and CRLE methods. Results indicate a good correspondence of the model outputs to that of the Penman, Energy balance, CRLE and Radiation methods. Comparison of the 1986 and 2000 monthly ET from the Landsat images to the Simple and Penman Methods show that the remote sensing and surface energy balance approach is promising.

(Key words: Simple model, remote sensing, evaporation, Rift valley)

Spatio-temporal Dynamics of Landscape Evapotranspiration and its Implication on Food Security in the Nile Basin Rainfed Ecosystems

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Abstract

Evapotranspiration (ET) is an important component of the hydrologic budget because it relates to exchanges of mass and energy between the soil-water-vegetation system and the atmosphere. The prevailing weather conditions influence potential or reference ET through variables such as radiation, temperature, wind and relative humidity. In addition to these weather variables, actual ET (ETa) is also affected by land cover type and condition and soil moisture. ETa's dependence on land cover and soil moisture and its direct relationship with carbon dioxide assimilation in plants makes it an important parameter to estimate of crop yield and biomass for decision makers interested in food security and carbon sequestration. A new modeling approach in VegET, developed at USGS/EROS, has shown that the spatio-temporal dynamics of landscape ETa can be captured in an operational manner through the use of land surface phenology (LSP) derived using remotely sensed data. VegET is a simple agro-hydrological model for estimating landscape ETa in rainfed crop and grassland ecosystems. It uses global forcing data including satellite-based rainfall estimate (RFE) and reference ET calculated using Global Data Assimilation System (GDAS) weather parameters. Water holding capacity was derived from FAO's digital soils map of the world. Land surface phenology (LSP) was derived from the Advanced Very High Resolution Radiometer (AVHRR) dataset. We apply the VegET model to produce daily and seasonal landscape ETa for 10 years from 1998 to 2007 at a spatial resolution of 5 km for the entire Nile Basin which includes countries with food insecurity due to high rainfall variability in the region. The resulting seasonal ETa values were summarized by local administrative boundaries. Preliminary validation based on FAO and USGS/FEWS NET field reports indicated that the seasonal ETa maps correctly identified the spatial and temporal patterns of drought and bumper harvests seasons in the riparian countries. In an operational use, the resulting ETa maps are also useful for identifying areas that require or benefit from supplemental irrigation. Since ET flux towers are absent in the region, we plan to validate the relative magnitude and variability of ETa using indirect methods such as country crop statistics in the region.

Keywords: evapotranspiration, food security, Nile, land surface phenology,

**Rainfall Intensity –Duration-Frequency Relationship for Selected Stations in Eastern
Ethiopia**

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Abstract

The rainfall Intensity-Duration-Frequency (IDF) relationship is a very useful site specific tool needed in the design and development of water resource systems. The information, however, has not been available due to absence of recording rain gauges in Ethiopia until very recently. In this study, rainfall Intensity-Duration-Frequency (IDF) relationships have been developed for six weather stations in eastern Ethiopia. The annual maximum rainfall data of varying duration were extracted from rainfall charts and fitted to theoretical frequency distribution and then extrapolation of values for larger return periods were made. The log Pearson type III distribution was applied to the annual maximum rainfall data sets generated in the six rainfall stations to estimate the parameters of general IDF mathematical forms for the study area. The chi-square test confirmed the appropriateness of the selected distribution. Log Pearson graphical plots and the computed confidence limits also showed that the log Pearson type III distribution fits the empirical distribution well. The IDF equations of the generalized mathematical form and families of curves have been generated for the station. The parameters of the equation were tested and found that they adequately describe the observed data showing that the method is reliable. The IDF relationship generated could be used for estimating peak runoff rates in water resource systems design and development.