Estimation and Comparison of Evapotranspiration from MODIS & AATSR Sensors over the Savannah Volta Basin in West Africa

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Background

This Ph.D. research is aimed principally at evapotranspiration (*ET*) measurements from NASA's Moderate Resolution Imaging Spectroradiometer (MODIS) and ESA's Along-Track Scanning Radiometer (AATSR) data. The purpose is to understand the sensitivity of *ET* and related surface fluxes to savannah landcover and climate change, which have direct impacts on flow regimes upstream the Lake Volta (Fig. 1). Surface flows into the lake is of massive economic value in terms of hydropower generation downstream at the Akosombo dam.

Innovation

Distributed hydrological modelling is a useful approach to better understand the relationships between land surface characteristics, energy balance and flow regime change (e.g. Anderson & Burt, 1985; Beven, 2000). However, for large basins, this is of limited value because of a lack of information on the spatial distribution of rainfall, atmospheric-surface energy fluxes and flow characteristics (e.g. Kalma & Sivapalan, 1995; Beven, 2001). Currently, remote sensing has capabilities to provide measurements of energy fluxes and land cover dynamics (Donoghue, 2000). The paucity of spatial/temporal measurements and the difficulty of up-scaling the few direct measurements that do exist in West Africa are critical issues that MODIS & AATSR data attempt to address in this research.

Fig 1. Study area: northern Ghana savannah (The Volta Lake and river system is shown in deep blue). Study area shown as Fig2 = 5300 km^2)

Data Sources

The availability of fully calibrated, multi-temporal satellite data such as MODIS & AATSR for the first time, has enabled distributed modelling of water/energy balance components over wide areas in savannah West Africa. In this case, high resolution data, e.g. Landsat ETM+, minimum fieldwork and local scintillometer measurements (courtesy: ZEF-Bonn based GLOWA-Volta project) provided useful hydrological and environmental data to help validate the current output.

Methodology

The starting point of this research was (1) field data analysis based on the Penman-Monteith formula and (2) landcover classification. Following this, NDVI (veg. index) was derived (Fig. 2). Spatial models were then defined based on the example in (Fig. 3). The capabilities of the Surface Energy Balance Algorithm for Land (SEBAL) was thereafter utilized. SEBAL solves the radiation and energy balance on per pixel basis, incorporating NDVI to measure sensitivity of surface fluxes on landcover changes in space and time. This is feasible using MATLAB programming (Fig. 4). Sensor results were analysed and compared with field data using statistics and regression models.

Fig 2. Volta land cover

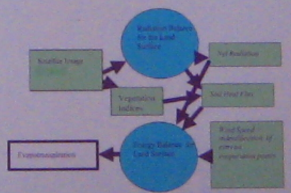

Fig 3. *ET* modelling based on SEBAL scheme. (After Morse *et al.* (2000)

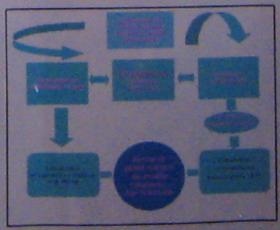

Fig 4. SEBAL integration with MATLAB program

Results

Figure 5 shows instantaneous energy flux results, whose range fall closely within GLOWA's scintillometer measurements, i.e. net radiation, sensible, latent and soil heat fluxes = 400-450, 280-320, 110-150, 30-55 W m^-2, respectively.

Following up-scaling methods by Bastiannssen *et al.* (1998a, b) Fig. 6 compares *ET* from MODIS and AATSR which is validated using Landsat ETM+ and Penman-Monteith results (3.70-3.90 mm day^-1 for Tamale metropolis – north-western part of image).

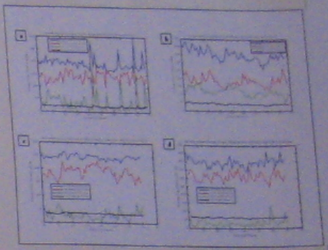

Fig 5. Instantaneous surface fluxes (transect of 1x1kmx78 pixels)
(a)& (b) =MODIS two winter dates
(c) & (d) =AATSR same dates

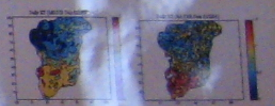

Fig 6. ET measured by MODIS & AATSR, evaluated by Landsat ETM+ (top-bottom)

Discussion & Conclusion

The scintillometer, Landsat and Penman-Monteith results are in close agreement with MODIS *ET* (see Fig. 7). Why AATSR flux measurements are consistently lower are probably due to over estimation of surface temperature and NDVI (not shown here) as a result of poor target response to atmospheric correction and less widely validated radiances over land compared to the sea.

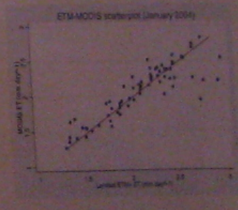

Fig 7. Correlation between MODIS & Landsat ET (y=0.77X+0.44; R^2=0.77; RMSE=0.16mm/day)

Acknowledgement

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