A COMBINATION METHOD COUPLING SEBAL AND GG MODELS FOR EXTENDING REMOTELY SENSED EVAPOTRANSPIRATION TO DAYS WITHOUT IMAGES AT WATERSHED SCALES

Di Long, Ph.D. student, Department of Biological & Agriculture Engineering Texas A&M University, College Station, TX 77843, descartes66@tamu.edu; Vijay P. Singh, Professor, Department of Biological & Agriculture Engineering & Department of Civil & Environmental Engineering, Texas A&M University, College Station, TX 77843, vsingh@tamu.edu

Abstract The lack of good quality remote sensing images due to cloud obstruction particularly in rainy season or to long revisit time severely deteriorates predictions of time series of evapotranspiration (ET) from energy balance-based surface flux estimation models at watershed scales. This significantly hinders practical applications of satellite imagery-based operational ET estimation to the computation of water consumption by crops, irrigation water supply scheduling, reliable estimation of water budget for a watershed for water supply allocation, management and planning, and atmospheric and hydrological modeling. In the present work, we coupled the feedback GG model built on energy budget and aerodynamic principles simply using relatively less routine meteorological data with SEBAL that simulates surface fluxes from satellite images, with the intent of producing time series of ET with reasonable spatial and temporal distributions and reliable magnitudes at watershed scales. It is expected that the feedback GG model would inherit the characteristics of reasonable ET distribution from remote sensing-based model and successfully convey remotely sensed information to days without good quality images, greatly benefitting the applicability and simplicity for operational time series of ET estimation. The combination method would also be applicable to other watersheds and climatic zones and generally ameliorate the performance of the feedback method at large spatial scales.

First, we made the best of the ET outputs from SEBAL of a selected watershed to calibrate the empirical relationship between the relative drying power of the air *D* and the relative evaporation *G* in the GG model. The days with the best quality Moderate Resolution Imaging Spectroradiometer (MODIS) data products in each month in the year 2007 were selected to perform the calibration. The modified GG model with its reestablished relationships between *D* and *G* was applied to other cloud free days in each month. Comparison of outputs from the modified GG model versus SEBAL-based daily ET for those days was performed in order to test the utility of the newly calibrated relationships in the GG model.

Second, the modified GG model was then used to provide the times series of ET of the study watershed simply using less routine meteorological data and MODIS albedo and Leaf Area Index (LAI) data products. In addition, utility of the evaporative fraction method and the crop coefficient method to extrapolate time series of ET from the days with good quality remote sensing images are investigated. Comparison of outputs from the evaporative fraction method, the crop coefficient method and the proposed combination method against independently estimated annual ET from the water balance equation for two watersheds is performed in order to evaluate their accuracy and performance.

Results suggest that the modified GG model that has combined remote sensing information and shown to be able to provide consistent estimates relative to the outputs from SEBAL can make reliable predictions. The GG model with its newly reestablished relationships between *D* and *G* can successfully yield reasonable ET distributions compared to the original GG model.

There are totally 28 cloud free days in the year 2007 selected to estimate watershed evaporative fractions and the crop coefficients. It is found that the applicability and reliability of the evaporative fraction method depends largely on the number of good quality remote sensing images available, their intervals and corresponding soil and vegetation statues, and energy availability. Therefore uncertainties in the evaporative fraction method would introduce gross errors to time series of ET estimation. Limited satellite images merely covers a fraction of the crop coefficient cycle during a year; the crop coefficient method cannot provide a realistic and continuous crop coefficient curve primarily due to insufficient satellite images available, particularly during periods of rapid development of vegetation and crops. Underestimation of FAO56 reference ET in September and October over this watershed is another reason responsible for overestimation of the crop coefficient in the two months, causing erroneous ET estimates during this period. There is a gap between the desired quantity, quality and frequency of remote sensing images and practical applications for constructing reliable evaporative fraction and crop coefficient curves. The time series of daily actual ET from the combination method for the days with daily net radiation larger than 100 W m^{-2} and corresponding observations of pan ET clearly show a kind of asymmetric complementary relationship, which lends new support to the complementary relationship between daily pan ET and actual ET at the watershed scale. This finding, in turn, gives confidence to the utility of the newly proposed combination method because of its reasonable temporal distribution in a year. Validation performed using hydrologic budget calculations indicate that the proposed combination method has the highest accuracy of annual ET estimates for both watersheds.

Exponentially increasing satellite images nowadays give new opportunities to study hydrology, meteorology, agronomy, forestry and environmental issues-related disciplines. How to adequately utilize the increasing remotely observed information at different spatial and temporal scales has long been a focus for several decades. The remote sensing information available, however, has its inherent limitation regarding its quantity and quality qualified to be utilized. It seems that some conventional methods would be thriving again after incorporating the strengths of remote sensing methods and bypassing their drawbacks in the context of new developments in theoretical and experimental methods and information extraction techniques. From this standpoint, observations of surface and the lower atmosphere variables with relevant conventional techniques built on them should also be continuously utilized instead of only depending on satellite techniques. This, on the one hand, may obviate the inherent limitation in satellite remote sensing, and, on the other hand, provide surface references for comparing and evaluating predictions from satellite-based techniques.