Validation of remotely-sensed evapotranspiration and NDWI using ground measurements at Riverlands, South Africa

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ABSTRACT

Quantification of the water cycle components is key to managing water resources. Remote sensing techniques and products have recently been developed for the estimation of water balance variables. The objective of this study was to test the reliability of LandSAF (Land Surface Analyses Satellite Applications Facility) evapotranspiration (ET) and SPOT-Vegetation Normalised Difference Water Index (NDWI) by comparison with ground-based measurements. Evapotranspiration (both daily and 30 min) was successfully estimated with LandSAF products in a flat area dominated by fynbos vegetation (Riverlands, Western Cape) that was representative of the satellite image pixel at 3 km resolution. Correlation coefficients were 0.85 and 0.91 and linear regressions produced R^2 of 0.72 and 0.75 for 30 min and daily ET, respectively. Ground-measurements of soil water content taken with capacitance sensors at 3 depths were related to NDWI obtained from 10-daily maximum value composites of SPOT-Vegetation images at a resolution of 1 km. Multiple regression models showed that NDWI relates well to soil water content after accounting for precipitation (adjusted R^2 were 0.71, 0.59 and 0.54 for 10, 40 and 80 cm soil depth, respectively). Changes in NDWI trends in different land covers were detected in 14-year time series using the breaks for additive seasonal and trend (BFAST) methodology. Appropriate usage, awareness of limitations and correct interpretation of remote sensing data can facilitate water management and planning operations.

Keywords: Fynbos, LandSAF ET, scintillometry, SPOT-Vegetation NDWI

INTRODUCTION

Accurate quantification of the water cycle is fundamental in assessment, planning, allocation and protection of water resources. Evapotranspiration (ET) and soil water content are the most critical variables in arid areas, where ET may reach nearly 100% of rainfall (Bugan et al., 2012). In addition, soil moisture and ET have a significant impact on the energy, carbon and water cycles. ET is unique in that it provides the link between the energy and water cycles at the land surface as well as between the water and carbon cycle through vegetation transpiration. Soil water plays an important role in partitioning rainfall into runoff and infiltration, two components that determine water supply to ET, and also has a direct impact on weather conditions and thus short-term weather forecasting (LeMone et al., 2007). By understanding how ET and soil water content vary in space and time, a critical component of the water cycle can be understood.

Optical remote sensing from aircraft and satellites involves the measurement of reflected electromagnetic energy using sensors to generate multi- or hyper-spectral digital images. These data can then be used to estimate spatial variables such as surface and cloud temperatures, surface reflectance and wetness, vegetation indices (e.g. the Normalised Difference Vegetation Index NDVI) that describe the vegetation activity and its energy status, etc. These methods were not available in the past at large scales and high frequency; however, with the latest technological advances, their spatial and temporal coverage and resolution have significantly improved. Broadly, remote sensing methods to link vegetation and ET are classified into empirical and physically-based methods. Empirical methods involve the use of statistical relationships between ET and vegetation indices (e.g. NDVI) (Nadler et al., 2005; Glenn et al., 2007), while the physical approaches are based on either solving the surface energy balance equation (Bastiaanssen et al., 1998a, b; Su, 2002; Mu et al., 2007; Allen et al., 2007a, b; Sinclair and Pegram, 2010) or the application of the combination Penman-Monteith type of equations (Monteith, 1977).

Nowadays, there is an increasing number of remote sensing and earth observation (EO) products obtained from satellite images that are available at continental or global scales for estimating water cycle-related variables such as ET, precipitation, soil moisture, vegetation indices, etc. Nevertheless there is not a similar effort in validating these large-scale products with global or continental coverage in different regions of the world. These products, once properly validated, will enable hydrologists to adopt new and significantly improved approaches for water resource assessment and to move beyond the current approach, which has remained little changed since the 1960s. The EO data can also be used as inputs into spatially distributed hydrological models for the prediction of water flow discharge and quality. Thus, the hydrological models can in turn be applied for catchment water management and used to support water management boards and similar institutions.

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