ABSTRACT

This paper describes the dynamics of evapotranspiration (ET) in South Africa using MOD16 ET satellite-derived data, and analyses the interdependency of variables used in the ET algorithm of Mu et al. (2011). Annual evapotranspiration is strongly dependent on rainfall and potential evapotranspiration (PET) in 4 climatically different regions of South Africa. Average ET in South Africa (2000–2012) was estimated to be 303 mm·a⁻¹ or 481.4 x 10⁻³ m³·a⁻¹ (14% of PET and 67% of rainfall), mainly in the form of plant transpiration (T, 53%) and soil evaporation (Soil E, 39%). Evapotranspiration (ET) showed a slight tendency to decrease over the period 2000–2012 in all climatic regions, except in the south of the country (winter rainfall areas), although annual variations in ET resulted in the 13-year trends not being statistically significant. Evapotranspiration (ET) is spatially dependent on PET, T and vapour pressure deficit (VPD), in particular in winter rainfall and arid to semi-arid climatic regions. Assuming an average rainfall of 450 mm·a⁻¹, and considering current best estimates of runoff (9% of rainfall), groundwater recharge (5%) and water withdrawal (2%), MOD16 ET estimates were about 15% short of the water balance closure in South Africa. The ET algorithm can be refined and tested for applications in restricted areas that are spatially heterogeneous and by accounting for soil water supply limiting conditions.

Keywords: MOD16, potential evapotranspiration, soil evaporation, transpiration, water balance

INTRODUCTION

Sustainable management of water resources requires careful planning, monitoring and management, as water is a finite resource in quality and quantity. Environmental change driven by anthropogenic global warming imposes additional constraints, for example, increase in extreme weather occurrences (droughts and floods), increase in temperature and potential evaporation, changes in rainfall amounts and distribution, etc. The quantification of the water cycle components is a fundamental requirement in the assessment and management of water resources, in particular, under the impacts of human-induced land-use and climate change.

Evapotranspiration (ET) is a key process within the hydrological cycle and arguably the most difficult component to determine, especially in arid and semi-arid areas where a large proportion of low and sporadic precipitation is returned to the atmosphere via ET. In these areas, vegetation is often subject to water stress and plant species adapt in different ways to prolonged drought conditions (Jovanovic and Israel, 2012). Evapotranspiration (ET) is estimated to be >60% of rainfall on a global scale (Korzoun et al., 1978; L’vovich and White, 1990) and can reach nearly 100% of rainfall in arid regions (Bugan et al., 2012). In addition, ET varies depending on the heterogeneity of the landscape and topography, climate, type of vegetation and soil properties (Mu et al., 2007a). This makes the process of ET very dynamic over time and variable in space. By understanding how this parameter varies in space and time, we will improve our understanding of a critical component of the water cycle.

Besides the FLUXNET network (Baldocchi et al., 2001), measurements of ET are scarce and localised. However, our ability to use information from satellite sensors to estimate ET is developing rapidly and offers the opportunity to understand how ET varies across space and time, reduce uncertainty levels, increase spatial details and scale-up to large areas. The accuracy and uncertainty of satellite-based estimates of ET were evaluated in specific studies for different algorithms and products, e.g., SEBAL (Bastiaanssen et al., 1998a and b), METRIC (Allen et al., 2007a and b), SEBS (Su, 2002), and MODIS ET (Mu et al., 2007a), as well as for components of ET calculation such as MODIS fraction of absorbed photosynthetically active radiation (FPAR) and leaf area index (LAI) (Myneni et al., 2002). This was generally done by comparison between remote sensing–based estimates of ET and ground-based measurements of ET or other variables. Mueller et al. (2011) and Jimenez et al. (2011) also compared global ET datasets and surface fluxes obtained with satellite-based products and land surface models for large river basins of the world.

The Council for Scientific and Industrial Research (CSIR) has recently initiated research aimed at evaluating, validating and improving the MOD16 ET product, one of the free satellite-based ET products with readily available ET data for the past 13 years. These time series were seldom applied to estimate ET in Africa, especially in arid and semi-arid regions. The MOD16 ET product estimates global ET from ground-based meteorological observations and remote-sensing data from the Moderate Resolution Imaging Spectroradiometer (MODIS) located on NASA’s Terra and Aqua satellites (Justice et al., 2002). The MODIS sensor works on a spatial resolution of approximately 1 km, making it potentially suitable for applications in water resource management. The images contain 36 spectral bands in the wavelength range of 0.4 to 14.4 µm. The MOD16 ET algorithm was developed by Mu et al. (2007a) from the original model of Cleugh et al. (2007), and later improved by Mu et al.