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A practical approach for deriving all-weather soil moisture content using combined satellite and meteorological data

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ABSTRACT

Soil moisture has long been recognized as one of the essential variables in the water cycle and energy budget between Earth's surface and atmosphere. The present study develops a practical approach for deriving all-weather soil moisture using combined satellite images and gridded meteorological products. In this approach, soil moisture over the Moderate Resolution Imaging Spectroradiometer (MODIS) clear-sky pixels are estimated from the Vegetation Index/Temperature (VIT) trapezoid scheme in which theoretical dry and wet edges were determined pixel to pixel by China Meteorological Administration Land Data Assimilation System (CLDAS) meteorological products, including air temperature, solar radiation, wind speed and specific humidity. For cloudy pixels, soil moisture values are derived by the calculation of surface and aerodynamic resistances from wind speed. The approach is capable of filling the soil moisture gaps over remaining cloudy pixels by traditional optical/thermal infrared methods, allowing for a spatially complete soil moisture map over large areas. Evaluation over agricultural fields indicates that the proposed approach can produce an overall generally reasonable distribution of all-weather soil moisture. An acceptable accuracy between the estimated all-weather soil moisture and in-situ measurements at different depths could be found with an Root Mean Square Error (RMSE) varying from 0.067 m^3/m^3 to 0.079 m^3/m^3 and a slight bias ranging from 0.004 m^3/m^3 to −0.011 m^3/m^3. The proposed approach reveals significant potential to derive all-weather soil moisture using currently available satellite images and meteorological products at a regional or global scale in future developments.

1. Introduction

Due to the ability of controlling the partition of turbulent energy on the Earth's surface into sensible and latent fluxes and the allocation of rainfall into infiltration and runoff, soil moisture has long been recognized as one of the most important surface variables in terrestrial ecosystems, climate and water cycle (Jackson et al., 1996; Seneviratne et al., 2010; Rahimzadeh-Bajgiran et al., 2013; Leng et al., 2014; Hasan et al., 2014; Peng et al., 2016; Wang et al., 2016). Currently, rapid developments of satellite remote sensing technology allow a wealth of algorithms for deriving soil moisture from space data. In particular, at present, several microwave-based soil moisture products can be freely accessed for various applications. For an instance, the soil moisture Climate Change Initiative (CCI) project, led by the European Space Agency (ESA), was started in 2010 and has been dedicated to producing the most complete and most consistent global soil moisture data record based on active and passive microwave sensors (Dorigo et al., 2015). The latest released version (v03.2) of CCI products cover a period of 37 years from 1978 to 2015, which can significantly contribute to a number of studies, such as drought monitoring, precipitation and evapotranspiration over large regions or even at the global scale (Ghulam et al., 2007; Taylor et al., 2012; Li et al., 2013; Duan et al., 2014; Peng et al., 2015; Martínez-Fernández et al., 2016).

Although microwave emissions can penetrate clouds and rain and provide continuous soil moisture products at present, there are at least two critical issues involved in the currently available microwave-based soil moisture products with respect to generat-

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