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Research papers

Soil moisture estimation based on the microwave scattering mechanism during different crop phenological periods in a winter wheat-producing region

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ABSTRACT

In this research, a novel microwave scattering model-based semiempirical method for estimating the soil moisture of areas covered with winter wheat was proposed. In the proposed soil moisture estimation method, the crop and soil microwave scattering mechanisms during different crop phenological periods were considered to remove the influences of the wheat crop canopy on soil backscattering. Using RADARSAT-2 images and field-measured sample data, the validity and feasibility of the proposed soil moisture estimation method were verified in the study region of Hengshui City in the North China Plain. Among the winter wheat jointing stage, heading stage and maturity stage, the R^2, adjusted R^2 and *RMSE* values between the estimated soil moisture value and field-measured value were 0.762, 0.762 and 2.36%, respectively. The results indicate that high-accuracy soil moisture estimations could be obtained, and the proposed method had good performance in regional applications in the study region at key growth stages of winter wheat.

1. Introduction

Soil moisture is crucial for Earth's ecosystems functioning, as it plays important roles in the regulation of water migration, the carbon cycle and evapotranspiration from the land surface (Srivastava et al., 2009; Legates et al., 2011; Kornelsen and Coulibaly, 2013; Sharma et al., 2018). Soil moisture is also an essential parameter in hydrological, meteorological and agricultural applications and is vital for crop growth, yield estimation, and drought monitoring (Stoyanova and Georgiev, 2013; Xing et al., 2019). Affected by vegetation factors, soil moisture varies greatly at different temporal and spatial scales (Wagner et al., 2008; Vereecken et al., 2014). Traditional soil moisture measurements are carried out at the point scale, which has a poor spatiotemporal resolution (Huete et al., 2002; Petropoulos et al., 2015). With the recent development of remote sensing technology, traditional finite point measurements of soil moisture have transitioned to the acquisition of spatial surfaces, thus providing an effective means for the rapid, large-area, real-time and dynamic monitoring of soil moisture (Balenzano, et al., 2010; Gherboudj et al., 2011; Lievens and Verhoest, 2011; Deng et al., 2017; Stoyanova, et al., 2019). Among the many available remote sensing approaches, synthetic aperture radar (SAR) is widely used to monitor and estimate the soil moisture due to its ability to provide observations at all times and under all weather conditions and its high sensitivity to soil moisture.

SAR mainly captures the scattering characteristics of ground objects by transmitting pulses and receiving the microwave backscattering coefficients (BCs) reflected by those objects (Chen et al., 2009; Lee, and Pottier, 2009; Huang et al., 2017). The BC of the bare ground is mainly determined by the soil dielectric constant, ground roughness and ground texture; among these factors, the soil dielectric constant is especially correlated with the soil moisture (Martinez-Agirre et al., 2017). Therefore, the soil moisture of bare ground can be directly estimated by microwave BCs. To date, many scholars have conducted in-depth research on estimating the soil moisture of bare ground. The existing empirical and semiempirical models mainly include the Oh model (Oh et al., 1992), Dubois model (Dubois et al., 1995) and Shi model (Shi et al., 1997). Alternatively, the existing theoretical models are mainly based on the integral equation model (IEM) (Chen et al., 1995), two-scale model (TSM) (Iodice et al., 2011) and advanced integral equation model (AIEM) (Chen et al., 2003).

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