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Monitoring surface soil moisture status based on remotely sensed surface temperature and vegetation index information

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ABSTRACT

Surface soil moisture is a key variable for describing water and energy exchanges at the surface/atmosphere interface. The triangle or trapezoid method is appropriate for monitoring the regional surface soil moisture status. In this study, an advanced temperature vegetation dryness index (ATVDI) is used to monitor soil moisture status using an improved surface temperature and a vegetation index space that is formed by the theoretical dry edge determined by the surface energy balance principle and the wet edge extracted from water surface temperature. The ATVDI was validated by in situ soil moisture measurements from the Southern Great Plains (SGP) and is compared with a simple temperature vegetation dryness index (STVDI) estimated from the observed dry edge. The results indicate that the theoretical dry edge forms a trapezoid shape during the period of data coverage whereas the observed dry edge does not. Across all points, the R^2 of the ATVDI (0.35) is greater than that for the STVDI (0.28). For almost all of the sites, the R^2 between the ATVDI and soil moisture apparently improved. We also examined the spatial variation, and the value range of the ATVDI is closer than the STVDI to the real soil moisture conditions. The temporal variation of the ATVDI is closer to soil moisture than that of the STVDI, and the ATVDI is more sensitive to rainfall. This study demonstrates that a theoretical dry edge, determined by the energy balance principle, sets a standard for different days and that the ATVDI could monitor soil moisture conditions better than the STVDI could.

1. Introduction

Surface soil moisture, an important hydrological variable, strongly controls soil energy partitioning between the sensible and latent heat flux and influences the crop water stress conditions and the interactions between the land surface and atmospheric processes. However, conventional point measurements are complex, expensive and available only at a limited number of stations.

The remote sensing technology provides an effective and convenient method to detect surface soil moisture information at the regional or global scale. The microwave bands could monitor soil moisture under all weather conditions. However, passive microwave sensors have a coarse spatial resolution (approximately 25 km). Therefore, they can only estimate soil moisture over a large area. Although active microwave sensors have better spatial resolution, they have smaller repeat intervals of about 16–25 days.

Optical-thermal sensors, such as MODIS and NOAA-AVHRR, have moderate resolution and frequent repeat intervals. Satellite-based vegetation indexes (VIs) extracted from the optical bands, such as the vegetation condition index (VCI) (Kogan, 1995), normalized difference vegetation index (NDVI), and enhanced vegetation index (EVI) (Huete et al., 2002), have proven useful for monitoring soil moisture (Farrar et al., 1994; Wang et al., 2007). However, VIs are not very sensitive to short-term soil moisture variations (Fensholt and Sandholt, 2003). The method of using the land surface temperature (T_s), extracted from the thermal infrared band, to monitor canopy water stress was originally proposed by Jackson et al. (1977), who developed the crop water stress index (CWSI). Many studies (Carlson et al., 1995; Moran et al., 1994; Nemani et al., 1993; Price, 1990) have suggested that the combination of T_s and VI can provide better information on the surface soil moisture conditions. There is generally a strong negative correlation between T_s and VI. The T_s–VI slope is related to the stomatal resistance, evapotranspiration (Nemani and Running, 1989; Price, 1990) and soil moisture conditions (Gillies et al., 1997; Nemani et al., 1993). The relationship of T_s–VI has also been used to estimate the air temperature (Boegh et al., 1999; Nieto et al., 2011; Prihodko and Goward, 1997; Stisen et al., 2007).

The T_s–VI triangle space emerges when the study area is large enough, because variability in the surface moisture and vegetation

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