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Review

Disaggregation of remotely sensed land surface temperature: Literature survey, taxonomy, issues, and caveats

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A B S T R A C T

Land surface temperature (LST) is an important parameter highly responsive to surface energy fluxes and has become valuable to many disciplines. Prior to the advent of satellites, it was difficult to obtain LSTs over extensive areas. Even today, as a result of the resolution tradeoffs involved in using satellite data, it is difficult, and sometimes impossible, to acquire satellite LSTs with high spatial and temporal resolutions. This low resolution results in a thermal mixture effect, where the resolution cells are larger than the thermal elements. The disaggregation of remotely sensed land surface temperature (DLST), a research field that focuses on decomposing pixel-based temperatures, has been critical in related fields such as the surface flux downscaling, forest fire detection, and urban heat island monitoring and it is now growing rapidly as one of the thriving subbranches of thermal remote sensing. Various methods have been independently proposed for DLST in recent decades. However, this field is suffering a disorderly development. We thus critically investigate the interdisciplinary literature on DLST and identify the terms used to denote DLST in different disciplines. Two subtopics of DLST, thermal sharpening (TSP) and temperature unmixing (TUM), are identified as a dual pair of DLST because of their parallel areas of interest. Previous studies are classified into different categories in chronological and taxonomic order. We formulate definitions of TSP, TUM, and DLST, and we then examine how TSP and TUM are connected to related fields in remote sensing. Based on the literature, we present the key issues related to DLST, the recommended DLST methods in different applications, and the caveats that must be considered in future work, including (1) four predetermined assumptions (i.e., *additivity*, *separability*, *connectivity*, and *convertibility*), (2) the utilization of diurnal thermal observations, and (3) the complication of aggregation. This overview will provide a generalization of TSP and TUM, promote the understanding of DLST, and guide future research.

Contents

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1. Introduction

Widely used in many disciplines, land surface temperature (LST) is an important parameter that modulates surface energy fluxes. Common applications of LST involve soil moisture estimation (Merlin et al., 2010; Sandholt et al., 2002), forest fire detection (Eckmann et al., 2008), surface urban heat island monitoring (Voogt & Oke, 2003; Zhou et al., 2011), studies of hydrological processes (Crow & Wood, 2003), and climate studies (Kustas & Anderson, 2009).

Obtaining LSTs over extensive terrains was impractical until the advent of satellite thermal sensors. However, acquiring satellite images with high temporal, spatial, and spectral resolutions remains extremely difficult due to tradeoffs among these resolutions. Within thermal bands, there are fewer thermal sensors than optical sensors, and the associated spatial resolutions are much lower, resulting in a mixture effect that is more prevalent in thermal pixels. The thermal mixture effect is defined as a blending of multiple thermal signals from components within a larger thermal pixel, where the resolution cell is larger than thermal elements. Although several satellite launch missions, such as the MIcro Satellite for Thermal Infrared GRound surface Imaging (MISTIGRI) (spatial resolution: 50 m; 1- or 2-day interval) (Tintó Garcia-Moreno et al., 2009) and the Hyperspectral Infrared Imager (HyspIRI) (spatial resolution: 60 m; 5-day interval) (Chien et al., 2009; Kustas & Anderson, 2011), may provide higher spatial and temporal resolutions, the mixture effect is inevitable. The consequences of this effect are an increasingly urgent demand for the disaggregation of LSTs (DLST).

DLST provides a better dataset of LST with finer temporal and spatial resolutions and thus it is widely regarded as an effective tool to detect subpixel wildfire temperatures (Dennison et al., 2006), to downscale surface energy fluxes (Anderson et al., 2012), to map urban surface temperature (Nichol, 2009) and analyze the urban heat island (Stathopoulou & Cartalis, 2009; Zakšek & Oštir, 2012), to recover stream temperatures (Gustavson et al., 2003), and even to map the thermo-physical features of planetary surfaces (Hughes & Ramsey, 2010). In fact, DLST can contribute to any application that utilizes satellite-observed LSTs and that relates to the surface energy balance (SEB). Great success has been achieved in recent decades to perform DLST (Fig.1). This is confirmed by the abundant literature related to DLST from different journals and conference proceedings (Table 1). However, (1) DLST is still developing in a disorderly fashion, which has made algorithm improvements less effective; (2) many previous studies did not recognize and cite the classical works related to DLST (see Figs. 4 and 7), fairly as a result of the interdisciplinary utility of LST and partly because some newly developed studies, e.g., Kustas et al. (2003) and Agam et al. (2007a, 2007b), have been evolving independently from those classical works, e.g., Tom et al. (1985) and Inamura (1988, 1993). This situation has raised the necessity to trace the evolution process of DLST in different aspects from a chronological perspective; and (3) as the literature related to DLST rapidly increases (Fig. 1a), it is urgent to survey the current literature to better inform future research because to our knowledge there is no thorough review on DLST and because there are increasing satellite data available to assist DSLT.

Our review not only surveys the developments and interdisciplinary status of DLST over recent decades, but it also presents the key issues and caveats facing future studies. We also intend to follow the methodology of Strahler et al. (1986), generalizing DLST into two subtopics: thermal sharpening (TSP) and temperature unmixing (TUM). We adopt a *review-and-generalization* style at *L*-resolution