A Physical-Based Framework for Estimating the Hourly All-Weather Land Surface Temperature by Synchronizing Geostationary Satellite Observations and Land Surface Model Simulations

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***Abstract*— The high-frequency all-weather land surface temperature (LST) product generated from the thermal-infrared (TIR) observations of the geostationary meteorological satellite is of great significance to study the diurnal variations in the LST and the land surface energy balance. However, the TIR sensor cannot penetrate the clouds and obtain the desired LST under cloudy conditions. In this study, we developed a physical-based framework for generating high-frequency (hourly) all-weather LST data by synchronizing geostationary satellite TIR observations and simulations of the land surface model (LSM). There are three parts to the developed framework. First, the clear-sky LST was retrieved from the Advanced Himawari Imager (AHI) onboard the geostationary satellite Himawari-8 using our newly developed temperature and emissivity separation algorithm. Second, the Advanced Microwave Scanning Radiometer 2 (AMSR2) observations were assimilated into the Noah land surface model with multiple parameterization (Noah-MP) options' model to generate the all-weather LST. Finally, the retrieved clear-sky AHI LST and Noah-MP assimilated LST were fused using the ensemble Kalman filter (EnKF) algorithm. In situ measurements from three networks were collected to evaluate the Noah-MP assimilated LST and EnKF fused LST. The bias/RMSE of the Noah-MP assimilated LST and EnKF fused LST were –0.16/3.01 K and 0.15/2.68 K, respectively, under all-weather conditions. Compared to the Noah-MP free-run LST, the absolute values of the bias were reduced by 0.64 K and 0.68 K for the Noah-MP assimilated LST and EnKF fused LST, while the RMSEs were reduced by 0.33 K and 0.65 K, respectively. In addition, the spatial distribution of EnKF fused LST was in good agreement with the retrieved clear-sky AHI LST. The proposed framework in this study was demonstrated to be capable of obtaining accurate high-frequency (hourly) all-weather LST data.**

***Index Terms*— Advanced Himawari imager (AHI), data assimilation, ensemble Kalman filter (EnKF), land surface temperature (LST), Noah land surface model with multiple parameterization (Noah-MP), passive microwave (PMW).**

I. Introduction

As ONE of the essential climate variables, the land surface temperature (LST) plays an important role in the surface–atmosphere interactions and energy exchange processes, which is of great significance in many research fields, including drought monitoring, crop yield estimation, urban heat island effect, weather forecasting, and energy balance research [1], [2], [3], [4], [5], [6]. To obtain evapotranspiration data with an accuracy of better than 10% and to better support research and application in agriculture, forestry, meteorology, hydrology, and other fields, the accuracy of the LST products must be better than 1 K [7], [8], [9].

Ground measurements are the most accurate method of obtaining the LST, but ground measurements cannot provide spatially consistent and temporally continuous LST measurements over large areas. Satellite remote sensing provides a more effective and efficient method of estimating the LST at regional and global scales [10]. Polar orbit satellites only provide limited high spatial resolution sampling per day for one location, whereas the instruments onboard geostationary meteorological satellites provide an adequate sampling of the LST during the diurnal cycle. The high-frequency observations of geostationary satellites make up for the deficiency of polar-orbiting satellites in terms of retrieving the diurnal variations in the key atmosphere–surface parameters. Hence, the generation of high-frequency all-weather LST products from geostationary meteorological satellite observations is of great significance for regional drought monitoring, meteorological forecasting, evapotranspiration research, surface energy balance (SEB) research, and disaster monitoring [11], [12].

Currently, various algorithms, such as the classical single-channel algorithm [13], the split-window algorithm [14],

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