Estimating Hourly All-Sky Surface Longwave Upward Radiation Using the New Generation of Chinese Geostationary Weather Satellites Fengyun-4A/AGRI

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***Abstract*— Surface longwave upward radiation (SLUR) is a key parameter in studying hydrological and climate models. This study develops a framework for estimating the all-sky SLUR from the Advanced Geostationary Radiation Imager (AGRI) onboard the Chinese geostationary weather satellite FengYun-4A (FY-4A). The framework is composed of a hybrid method for estimating clear-sky SLUR and a machine learning (ML) method for estimating cloudy-sky SLUR. According to the in situ validation, the R^2/bias/root mean square error (RMSE) of the developed hybrid method is 0.95/0.59/18.41 W/m^2, which is clearly superior to the AGRI official SLUR and ERA5 SLUR with an R^2/bias/RMSE of 0.95/−7.79/19.04 and 0.92/-4.94/23.2 W/m^2, respectively. The developed hybrid method performs better than the classical land surface temperature-broadband emissivity (LST-BBE) method. The R^2/bias/RMSE of the developed cloudy-sky SLUR estimate light gradient boosting machine (LightGBM) model is 0.85/0.56/21.16 W/m^2, which is also better than the accuracy of the LST-BBE method and comparable to the accuracy of the ERA5 SLUR. The R^2, bias, and RMES of the all-sky SLUR are 0.93, 0.57, and 19.58 W/m^2, respectively. The developed framework is employed to determine hourly all-sky SLUR from AGRI data. This study provides a promising solution to obtain hourly all-sky SLUR from geostationary satellites (GOESs).**

***Index Terms*— FY-4A/Advanced Geostationary Radiation Imager (AGRI), hybrid method, light gradient boosting machine (LightGBM), machine learning (ML), surface longwave upward radiation (SLUR), surface radiation budget (SRB).**

I. Introduction

THE Earth's surface absorbs radiation from the Sun, which heats the surface and causes it to emit surface longwave (LW) radiation. This energy is then redistributed by the atmosphere and ocean and radiated back into space at the predominantly infrared part of the electromagnetic spectrum, with wavelengths ranging from approximately 4 to 100 μm [1], [2], [3], [4]. Surface longwave upward radiation (SLUR) is one of the four components of the surface radiation budget (SRB), which is an essential parameter of hydrological and climate models and is closely linked with variables such as evapotranspiration, soil moisture, and topography. Consequently, it is necessary and scientifically imperative to accurately estimate SLUR and understand its spatiotemporal dynamics in favor of characterizing the Earth's surface hydrological, ecological, and biogeochemical processes.

SLUR is expressed as the sum of surface-emitted thermal radiation and the surface-reflected component of the surface longwave downward radiation (SLDR). Two categories of methods are available for SLUR estimation using remote sensing technology: the land surface temperature-broadband emissivity (LST-BBE)-based method and the hybrid method. The LST-BBE algorithm is straightforward and has been widely employed to estimate the SLUR and needs knowledge of the land surface temperature (LST), broadband emissivity (BBE), and SLDR [5]. Due to the errors arising from the uncertainties in the retrieved LST, BBE, and SLDR, the accuracy of the estimated SLUR is not ideal. Considering that the clear-sky top-of-atmosphere (TOA) radiance contains information on LST, BBE, and SLDR, the hybrid method directly links the SLUR and clear-sky TOA radiance using a linear or nonlinear model based on extensive radiative transfer simulations, bypassing the uncertainties in separating LST and emissivity [6]. Hence, accurate estimation of the clear-sky SLUR can be achieved in many cases.

Currently, four all-sky global satellite SLUR products are publicly available: the International Satellite Cloud Climatology Project-Flux Data (ISCCP-FD, ∼280 km) [7], [8], the Global Energy and Water Cycle Experiment-Surface Radiation Budget (GEWEX-SRB, ∼100 km) [9], [10], the Clouds and Earth Radiant Energy System-Gridded Radiative Fluxes and Clouds (CERES FSW, ∼100 km) [11], [12], [13], and the Essential thermaL Infrared remoTe sEnsing (ELITE) surface LW radiation product (1 km) [14], [15], [16]. The ISCCP-FD, GEWEX-SRB, and CERES FSW SLUR products share coarse spatial resolution. Their validation accuracy is sometimes not

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