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Evaluation of six land-surface diurnal temperature cycle models using clear-sky *in situ* and satellite data

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ABSTRACT

Land surface temperature (LST) and its diurnal variation are vital to the study of land-atmosphere interactions and climate change. In this study, *in situ* and MSG-SEVIRI-derived LSTs were used to evaluate the performance of six published diurnal temperature cycle (DTC) models, i.e. the GOT01, GOT01_0, VAN06, JNG06, INA08, and GOT09 models. Two time intervals were considered: one is the entire day (sunrise to sunrise: Period A), and the other is from 09:00 A.M. to 03:00 A.M. on the following day (local solar time) (Period B). The results of Period A indicated that the JNG06 and GOT09 models performed best with overall root mean square errors (RMSEs) of 0.5 K. The GOT01, VAN06, and INA08 models performed similarly with overall RMSEs of 0.8 K. The GOT01_0 model performed the worst with an overall RMSE of 1 K. The results of Period B demonstrated that, except for the GOT01_0 model, the other models produced similar results with overall RMSEs of 0.4 K. However, if the width over the half-period of the cosine term (ω) in the GOT01_0, GOT01, and INA08 models was treated as a free parameter in the model fit during Period A, the performance of the GOT01 and INA08 models was significantly improved and attained the same level of accuracy as the JNG06 and GOT09 models. Although the accuracy of the GOT01_0 model was also improved to an overall RMSE of 0.8 K, with five free parameters, this model cannot accurately describe the variations of the LSTs around sunrise and noon.

1. Introduction

Land surface temperature (LST) is one of the key parameters of land-atmosphere energy exchange, climate change, and the global hydrological cycle (Wan & Li, 1997). The diurnal variations of LST are closely related to solar insolation, wind, and land surface characteristics, e.g. vegetation type, soil moisture, and surface structure (Göttsche & Olesen, 2001). Satellite remote sensing is a unique way to measure the diurnal variations of LST over extended regions (Göttsche & Olesen, 2001; Inamdar et al., 2008). The diurnal temperature cycle (DTC) can be represented by a set of model parameters describing the thermal behavior of the land surface (Göttsche & Olesen, 2009). Some of the model parameters are closely related to the physical properties of the land surface. For instance, minimum temperature and temperature amplitude are important quantities for epidemiological studies and in agricultural research. The time of maximum temperature and attenuation coefficient are closely related to the thermal inertia and soil moisture (Price, 1985). The total optical thickness in the DTC model potentially benefits the determination of atmospheric dust loads over deserts (Göttsche & Olesen, 2009). Several applications of DTC models are identified. Schädlich et al. (2001) and Jiang et al. (2006) employed DTC models to interpolate atmospheric corrections for METEOSAT and MSG-SEVIRI data, respectively. van den Bergh et al. (2006) and Göttsche and Olesen (2001) filled in the missing data caused by brief periods of cloud cover using different DTC models. In addition, DTC models can be used to normalize a remotely sensed LST measured at a different time to the same time. There have been several attempts at temporal normalization in the published literature (Jiang, 2007). DTC models can also be applied to improve cloud-screening algorithms (Inamdar et al., 2008).

DTC can be modeled using various functions, such as a simple sine/cosine function or a combination of a cosine term with an exponential decay function. Parton and Logan (1981) first proposed a semi-empirical DTC model to describe the diurnal variations of soil and air temperatures. Their model introduced a sine function to predict the variations in daytime temperature and an exponential function to model night-time temperature changes. Based on the thermal diffusion equation, Schädlich et al. (2001) developed a simple physics-based DTC model to temporally interpolate atmospheric corrections for METEOSAT brightness temperature. Subsequently, this physics-based model was improved in several studies and successfully used in several cases, such as the interpolation of atmospheric corrections and filling in

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