Remote Sensing of Environment 140 (2014) 339–349

Contents lists available at ScienceDirect

Remote Sensing of Environment

journal homepage: www.elsevier.com/locate/rse

Generation of a time-consistent land surface temperature product from MODIS data

Si-Bo Duan [a,b,c], Zhao-Liang Li [d,c,*], Bo-Hui Tang [a], Hua Wu [a], Ronglin Tang [a]

[a] State Key Laboratory of Resources and Environment Information System, Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, Beijing 100101, China
[b] University of Chinese Academy of Sciences, Beijing 100049, China
[c] ICube, UdS, CNRS, 300 Bld Sebastien Brant, BP10413, 67412 Illkirch, France
[d] Key Laboratory of Agri-informatics, Ministry of Agriculture/Institute of Agricultural Resources and Regional Planning, Chinese Academy of Agricultural Sciences, Beijing 100081, China

ARTICLE INFO

Article history:
Received 26 July 2013
Received in revised form 6 September 2013
Accepted 7 September 2013
Available online xxxx

Keywords:
Land surface temperature
MODIS
MSG-SEVIRI
Time-consistent
Temporal normalization

ABSTRACT

Land surface temperature (LST) is crucial for a wide variety of land–atmosphere studies. A long-term and time-consistent LST product is highly desirable for use in global climate studies. In this study, we developed a method to normalize the Terra-MODIS LST during daytime to a consistent local solar time to generate a time-consistent LST product. A multiple linear regression model for the slope of LST versus the local solar time during the period 10:00–12:00 as a function of the normalized-difference vegetation index, solar zenith angle, and digital elevation model was established using MSG-SEVIRI data. The regression equation was then applied to normalize the Terra-MODIS LST during daytime to a consistent local solar time (i.e., 11:00 local solar time). The accuracy of the proposed method was evaluated using MSG-SEVIRI-derived LST data. The results indicate that the root mean square error of the differences between the LST before temporal normalization and the actual LST (derived from MSG-SEVIRI data) is approximately 1.5 K, whereas those between the LST after temporal normalization and the actual LST is approximately 0.5 K.

1. Introduction

Land surface temperature (LST), which is a key variable in the physical processes of land surface energy and water balance on regional and global scales, is widely used in a range of hydrological, meteorological, and climatological applications (Anderson et al., 2008; Karnieli et al., 2010; Li et al., 2009). Satellite remote sensing offers the only possibility to measure LST over extended regions with high temporal and spatial resolution (Li & Becker, 1993; Li, Tang, et al., 2013a). To date, one of the highest-quality LST products has been generated from the Moderate-Resolution Imaging Spectroradiometer (MODIS) onboard the Terra and Aqua platforms (Wan, 2008; Wan, Zhang, Zhang, & Li, 2002, 2004).

Two MODIS LST algorithms were developed to generate the MODIS LST products. One algorithm is the generalized split-window algorithm (Becker & Li, 1990; Wan & Dozier, 1996), which generates LST data at 1 km resolution. The other algorithm is the physics-based day/night algorithm (Wan & Li, 1997), which generates LST data at approximately 5 km (Collection 4) and 6 km (Collection 5) resolution. Two different methods were used to validate the MODIS LST products: a temperature-based method (Wan, 2008; Wan et al., 2002, 2004; Wang, Liang, & Meyers, 2008) and a radiance-based method (Coll, Wan, & Galve, 2009; Wan & Li, 2008). Comparisons between the MODIS LST products and in situ measurements indicate that the accuracy of the MODIS LST products is better than 1 K for a given observation time and angle. Therefore, the MODIS LST products have been widely used in various studies (Friedl et al., 2010; Tang & Li, 2008; Tang, Li, & Tang, 2010; Wang et al., 2005).

Due to the intrinsic scanning characteristics of the MODIS instrument onboard the polar-orbiting satellites, the differences in local solar time for pixels along a given scan line on the same day (see Fig. 1a) or for the same pixel on different days in one revisit period (see Fig. 1b) may reach up to 2 h. As LST changes with local solar time, it is therefore not possible to directly compare the LST of different pixels on the same day or of the same pixel on different days. Fig. 2 displays LST versus local solar time during the period 10:00–12:00 for in situ data and data from the Meteosat Second-Generation Spinning-Enhanced Visible and Infrared Imager (MSG-SEVIRI) for various land cover types. One hour of differences in local solar time during the period 10:00–12:00 corresponds to LST differences of approximately 3–5 K. Table 1 shows the detailed information and statistics for the data displayed in Fig. 2. To make the LST of different pixels on the same day or of the same pixel on different days comparable, it is therefore necessary to normalize LST to a consistent local solar time to generate a time-consistent LST product. A long-term and time-consistent LST dataset is highly desirable for use in global climate studies (Jin & Dickinson, 2002).

Various methods related to the temporal normalization of LST have been developed using the diurnal cycle of LST. If the diurnal cycle of LST is available, LST at any time can be derived in terms of a diurnal

* Corresponding author at: Key Laboratory of Agri-informatics, Ministry of Agriculture/Institute of Agricultural Resources and Regional Planning, Chinese Academy of Agricultural Sciences, Beijing 100081, China. Tel.: +86 1082105077.
E-mail address: lizhaoliang@caas.cn (Z.-L. Li).

0034-4257/$ – see front matter © 2013 Elsevier Inc. All rights reserved.
http://dx.doi.org/10.1016/j.rse.2013.09.003