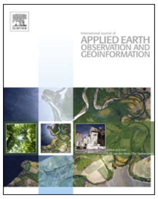
Int J Appl Earth Obs Geoinformation 73 (2018) 136–147

Contents lists available at ScienceDirect

Int J Appl Earth Obs Geoinformation

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



Downscaling of surface air temperature over the Tibetan Plateau based on DEM

Lirong Ding[a], Ji Zhou[a,*], Xiaodong Zhang[a], Shaomin Liu[b], Ruyin Cao[a]

[a] School of Resources and Environment, Center for Information Geoscience, University of Electronic Science and Technology of China, Chengdu, 611731, China
[b] Faculty of Geographical Science and State Key Laboratory of Earth Surface Processes and Resource Ecology, Beijing Normal University, Beijing, 100875, China

ARTICLE INFO

Keywords:
Surface air temperature (T_a)
Digital elevation model (DEM)
Downscaling
Tibetan Plateau

ABSTRACT

Surface air temperature (T_a) is critical to the studies of radiation balance, energy budget, and water cycle. It is a necessary input for associated models. Most of the current T_a datasets of reanalysis products have limitations at local scales due to their coarse spatial resolutions. For better modeling the radiation balance, energy budget, and water cycle over the Tibetan Plateau, this study proposes a practical method for T_a downscaling based on the digital elevation model. This method is applied to downscale T_a of the China regional surface meteorological feature dataset (CRSMFD) at 0.1° and the ERA-interim (ERAI) product at 0.125° to 0.01°. The daily mean T_a and the 3-hourly instantaneous T_a with a 0.01° are obtained. The downscaled T_a are evaluated from the perspectives of accuracy and image quality. Results show that the daily mean T_a downscaled from the CRSMFD product has a RMSE of 1.13 ± 1.0 K at 105 meteorological stations and RMSEs of 0.96 K to 2.34 K at three experimental stations; the instantaneous T_a downscaled from CRSMFD has RMSEs of 1.02 K to 4.0 K at the three experimental stations. T_a after downscaling has better agreement with the ground measured T_a than before downscaling, especially in mountain areas. By contrast, T_a downscaled from the ERAI product has unacceptable accuracy due to the great uncertainty of the ERAI T_a over the Tibetan Plateau. With the proposed method, a 0.01° T_a dataset from 2000 to 2015 over the Tibetan Plateau was generated to satisfy related studies and applications.

1. Introduction

Surface air temperature (T_a) is a key parameter for radiation balance, energy budget, and water cycle studies at regional and global scales. T_a data is an important input for the modeling of land surface processes (Sicart et al., 2008), such as surface evapotranspiration estimation (Kosa, 2009), agricultural fields monitoring (Juknys et al., 2011), and climate change analysis (Jones et al., 1999). The traditional way to obtain T_a is to measure it at ground stations. However, the point-measured T_a cannot reflect the temperature of a large area (Zhou et al., 2017). One possible way to extend T_a measured at spatially distributed ground stations to large areas is spatial interpolation, in which one frequently employed factor is the distance (Dodson and Marks, 1997). In addition to consider the spatial correlation of the T_a variation and the distance, scientific communities have further developed advanced interpolation methods by incorporating more factors, e.g. elevation, latitude, and longitude (Willmott and Matsuura, 1995). With the development of climatic models, long-term T_a products, e.g. National Centers for Environmental Prediction and National Center for Atmospheric Research (NCEP/NCAR) reanalysis dataset and ERA-interim reanalysis dataset (Kalnay et al., 1996; Onogi et al., 2007; Wang et al., 2015), have been generated and are available to users. Compared to the T_a maps interpolated based on ground measurements, these T_a products are usually global or regional and have spatial resolutions ranging from 0.0625° to 1° or even coarser.

Although T_a generated through spatial interpolation and derived from the reanalysis products have succeeded in many applications, they have limitations in some applications. On the one hand, the spatial interpolation is not applicable in areas with insufficient ground stations, e.g. the Tibetan Plateau. On the other hand, T_a provided by the climatic models have exhibited good performance at macro-scales (e.g. continental or global scales), but their coarse resolutions are not suitable for applications at local scales (Hofer et al., 2015). Coarse spatial resolution cannot satisfy the descriptions of spatial variation of T_a at local scales, especially in mountain areas with drastic changes of terrain (Pan et al., 2012).

In order to satisfy the applications in local areas, scientific communities have focused on how to obtain the T_a data with medium to high spatial resolutions. Statistical downscaling has been proven to be an efficient tool to enhance the spatial resolution of T_a. For example,

---

* Corresponding author at: No.2006, Xiyuan Ave, West Hi-Tech Zone, Chengdu, 611731, Sichuan, China.
E-mail addresses: dlryouxiang@163.com (L. Ding), jzhou233@uestc.edu.cn (J. Zhou), bobtennis@sina.com (X. Zhang), smliu@bnu.edu.cn (S. Liu), cao.ruyin@uestc.edu.cn (R. Cao).

https://doi.org/10.1016/j.jag.2018.05.017
Received 14 March 2018; Received in revised form 16 May 2018; Accepted 29 May 2018
0303-2434/

Schoof and Pryor (2001) examined the performance of the regression model and neural network model in T_a downscaling; T_a downscaled through these two models were found to yield similar results. By selecting the central and western Europe as the study area, Huth (2002) developed a statistical method to downscale the daily T_a measured by a network of stations, guiding many scientists to start to focus on obtaining T_a with medium spatial resolutions through downscaling. Pan et al. (2012) used the Weather Research and Forecasting (WRF) model to generate a 5 km/1 h T_a dataset to drive the hydrological model in the Heihe River Basin, China. Hofer et al. (2015) used a statistical downscaling method to obtain the daily T_a in a data-sparse glaciated mountain environment. Jha et al. (2015) proposed a geostatistical framework for T_a downscaling. In addition to the statistical downscaling, machine learning methods can also perform well in T_a downscaling (Coulibaly et al., 2005). Additional to the downscaling methods, it has been found that the factors describing T_a variation are also important (Rong et al., 2011). For example, Holden et al., (2011) fully considered the influence of the terrain on the nocturnal T_a in the downscaling of the daily minimum T_a; Kettle and Thompson (2004) used the ground measured T_a and the elevation to downscale the reanalysis T_a data in European mountain areas.

The Tibetan Plateau, which is known as "the roof of the world" and "the third pole" on the Earth, is a focus region of the climate change. T_a is a necessary parameter in the examination of the surface radiation balance and energy budget as well as the water cycle of the Tibetan Plateau. However, the acquisition of T_a over the Tibetan Plateau faces great challenges due to insufficient ground stations and complex terrain. Although there are some T_a datasets provided by reanalysis products, T_a with medium to high resolutions are still rare. Under this context, the objective of this study is to develop a practical method to downscale T_a provided by the current reanalysis products and to reconstruct a long-term daily mean/3-hourly instantaneous T_a dataset with a 0.01°spatial resolution. This T_a dataset can contribute to better modeling the radiation balance, energy budget, and water cycle over the Tibetan Plateau.

2. Study area and datasets

2.1. Study area

The study area is the Tibetan Plateau (73 °E–106 °E, 40 °N–23 °N). As the highest plateau in the world, it has the largest glaciers except the Arctic and Antarctic; thus, it is the birthplace of many rivers in Asia and the source of water for billions of people. The Tibetan Plateau has many mountain areas with steep terrain and varied topography. Its elevation varies from 60 m to over 8000 m, and the average elevation is much higher than the other areas at the same latitude. The digital elevation model (DEM) of the Tibetan Plateau is shown in Fig. 1. Due to complex environment, the Tibetan Plateau has significant impacts on climate change of the surrounding areas and even the whole world. Because of its special location and terrain, the examination of the radiation balance and energy budget and water cycle of the Tibetan Plateau are particularly important. Thus, the scientific communities require the long-term T_a datasets with acceptable accuracy and medium to high spatial resolutions.

2.2. Reanalysis datasets

Two T_a datasets are selected as the basis of downscaling in this study. The first one is the China Regional Surface Meteorological Feature Dataset (CRSMFD) (Chen et al., 2011; Yang et al., 2010), which is based on the existing Princeton reanalysis data, Global Land Surface Data Assimilation System (GLDAS) data, NASA GEWEX Surface Radiation Budget (GEWEX-SRB) radiation data, and Tropical Rainfall Measuring Mission (TRMM) precipitation data. The 6-hourly instantaneous T_a at some meteorological stations operated by China Meteorological Administration (CMA) are also fused in CRSMFD. In addition to T_a, CRSMFD provides atmospheric variables including the near-surface pressure, near-surface air-specific humidity, near-surface wind speed, downward shortwave radiation, downward longwave radiation, and surface precipitation. Here, the T_a dataset is used. CRSMFD has a spatial resolution of 0.1° and a temporal resolution of 3 h. It was downloaded from the Third Pole Environment Database (http://en.tpedatabase.cn/portal/index.jsp).

The second dataset is the global ERA-interim (ERAI) of the European Centre for Medium-Range Weather Forecasts (ECMWF). The original spatial resolution is a reduce Gaussian grid (N128) with an approximately uniform spacing of 79 km (Dee et al., 2011; Gao et al., 2017; Uppala et al., 2008). Using interpolation techniques, the ERAI of original spatial resolution is interpolated to a variety of lon/lat grids from 0.125° to 2.5°. The ERAI used here has a spatial resolution of 0.125° and a temporal resolution of 3 h. It was downloaded from ECMWF (https://www.ecmwf.int/). To satisfy the modeling of surface radiation balance and energy budget of the Tibetan Plateau from 2000 to 2015, the CRSMFD and ERAI datasets during this period were collected.

2.3. Auxiliary datasets

The DEM acquired by the Shuttle Radar Topography Mission was collected to present the terrain of the study area, as shown in Fig. 1. It has a spatial resolution of 90 m. The Normalized Difference Vegetation

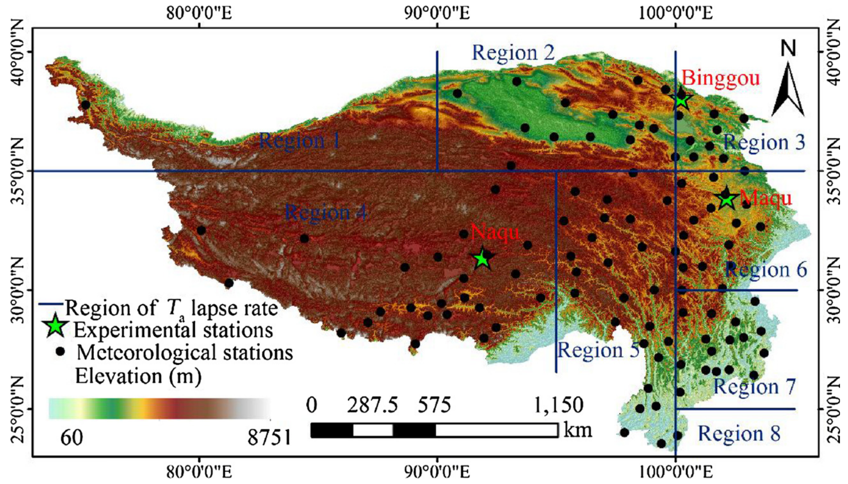


Fig. 1. Digital elevation model (DEM) of the Tibetan Plateau. The meteorological and experimental stations providing the measured T_a are also shown.