A MODIFIED DEEP LEARNING APPROACH FOR RECONSTRUCTION OF MODIS LST PRODUCT

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Abstract

This study aims to apply a modified deep learning model to reconstruct cloudy MODIS LST (Land surface Temperature) images. The proposed system was initially designed to colorize a grayscale image with a Convolutional Neural Network (CNN). We modified this approach by training our model using cloudless (clear-sky) MODIS LST data. In the application, 208 cloudless daily MODIS LST images were used. 90% of these images were utilized in the training step, the remaining 10% were used in the testing step. The average RMSE values of each image ranged from 1.76 ^{o}C to 4.41 ^{o}C. Results proved the significance of the proposed method in the reconstruction of cloudy MODIS LST pixels even with a small dataset.

Keywords: Remote Sensing, MODIS LST, Reconstruction, Deep Learning, CNN

INTRODUCTION

Land Surface Temperature (LST) is among the principal parameters influencing land-atmosphere interactions such as energy exchanges, heat fluxes, and surface energy balance (Sekertekin and Bonafoni 2020). Traditional LST measurements are obtained from ground-based stations. However, these measurements do not represent the spatial distribution of LST since they are point-based measurements (Becker and Li 1995). On the other hand, remotely sensed Thermal Infrared (TIR) data enable spatio-temporal LST analysis at various scales.

The Moderate Resolution Imaging Spectroradiometer (MODIS) sensor is one of the most commonly utilized sources of satellite-based LST data with high temporal resolution. Nevertheless, daily MODIS LST data often have missing pixels and outliers because of aerosols, sensor failure, and/or cloud coverage (Ghafarian Malamiri et al. 2018). To overcome this restriction, researchers have proposed various reconstruction algorithms based on multi-temporal information, geostatistical approach, Singular Spectrum Analysis (SSA), multitemporal classification and robust regression, spectral angle distance-weighting, and some machine learning methods (Ke et al. 2013; Shuai et al. 2014; Zeng et al. 2014; Ghafarian Malamiri et al. 2018; Kang et al. 2018; Tan et al. 2021; Xiao et al. 2021).

In this study, we modified a deep learning approach, which is initially designed for user-guided image colorization by Zhang et al. (2017), to reconstruct daily MODIS LST images.

METHODOLOGY

Zhang et al. (2017) introduced a study entitled “Real-Time User-Guided Image Colorization with Learned Deep Priors” that applies a deep learning approach for user-guided image colorization. The system colorizes a grayscale image considering several user-defined colored pixels with a Convolutional Neural Network (CNN). We have modified the corresponding study by training our model using cloudless (clear-sky) MODIS LST data. Fig.1 represents sample LST images used in the model to explain how the proposed system works. Apart from the original study, we do not have any grayscale image for colorization. Thus, firstly we create our gray-scale (reference or average) image (Fig 1.a) that will be colorized. The reason for this process is to obtain the temperature pattern of the study area according to the land cover characteristics. Additionally, we used the Cloud Filter Applied Data (Fig 1.b) to simulate the cloud presence causing missing LST pixels (blue pixels). In the end, the model learns how to construct a complete LST image (Fig 1.c) with minimum error using a few sample pixels (Fig 1.b) and the reference image (Fig 1.a). At the end of each iteration, the model validity is tested on the validation data set. A test dataset consisting of cloudless MODIS data is used in the testing phase.

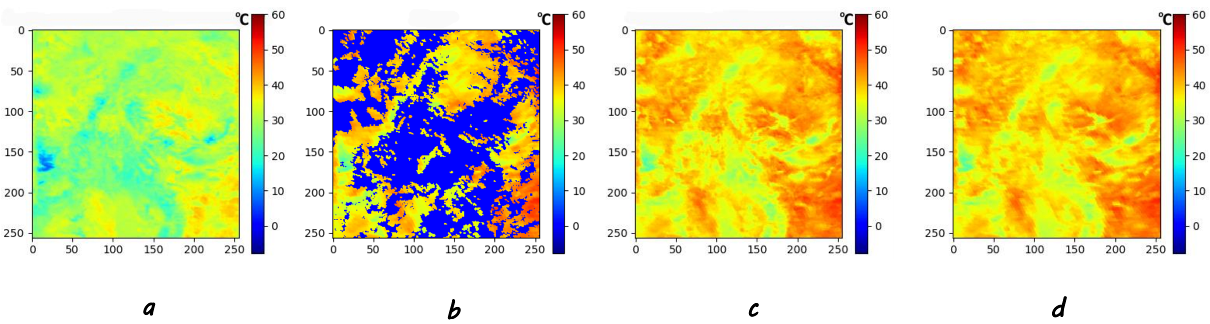

Fig. 1. a) Reference LST Data (created by averaging all the original images in the training dataset), **b)** Cloud Filter Applied Data (created by applying cloud filter to the original LST image shown in **d**), **c)** Predicted LST image, **d)** Original LST Data (any cloudless image from the training data set).

RESULTS

In the application, 208 cloudless daily MODIS LST images acquired between 01 January 2017 and 01 October 2020 were used. 90% of these images (188 images) were utilized in the training step, while the remaining 10% (20 images) were used in the testing step. In addition, one mask pattern as shown in Fig.1b was considered for the application of the reconstruction. Fig.2 shows the testing results of the proposed method. As it is clear from Fig.2, the spatial patterns of the predicted LST images are very close to the real LST images. Concerning the statistical results, the average Root Mean Square Error (RMSE) for each image was calculated comparing the reconstructed and real (MODIS) maps of the testing step. The average RMSE values range from 1.76 ^{o}C to 4.41 ^{o}C; for the whole dataset, the average RMSE is 2.89 ^{o}C, which shows the efficiency of the proposed method even with a small dataset.

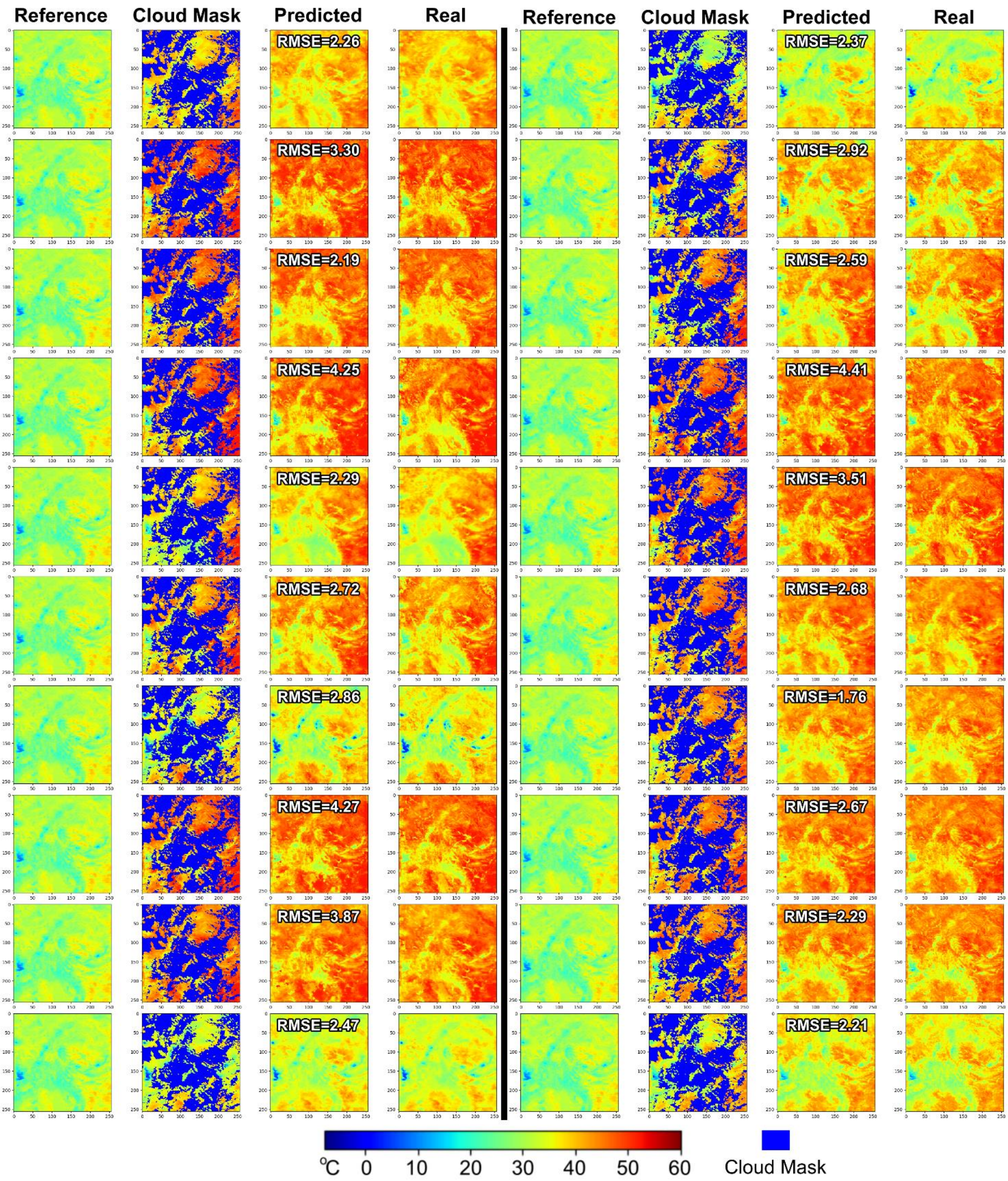

Fig.2. Testing results of the proposed method for LST reconstruction over cloud pixels. RMSE values are in °C.

CONCLUSION

TIR-based LST images are frequently affected by cloud coverage, and this phenomenon leads to restrictions on the use of LST images in environmental studies. Thus, it is essential to investigate effective methods for the reconstruction of missing pixels in LST images. In this study, a CNN-based deep learning model, initially proposed for user-guided image colorization, was modified and applied to reconstruct the cloudy MODIS LST images. The number of the training and testing data were set as 90% and 10%, respectively, since the application was performed with a limited number of data. The performance of the model was evaluated using the RMSE that was calculated from the observed and predicted images. The obtained results proved the efficiency of the proposed model, providing the average RMSE equal to 2.89 ºC for the whole testing data. Although a small dataset was performed in this study, the proposed model provided satisfactory results showing its ability to be used in the reconstruction of cloudy LST pixels. As a future work, it is planned to compare the proposed model with other state of the art methods and to present comprehensive analysis.

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