A Neural Network Technique for Separating Land Surface Emissivity and Temperature From ASTER Imagery

Kebiao Mao, Jiancheng Shi, *Senior Member, IEEE*, Huajun Tang, Zhao-Liang Li, Xiufeng Wang, and Kun-Shan Chen, *Fellow, IEEE*

***Abstract*—Four radiative transfer equations for Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) bands 11, 12, 13, and 14 are built involving six unknowns (average atmospheric temperature, land surface temperature, and four band emissivities), which is a typical ill-posed problem. The extra equations can be built by using linear or nonlinear relationship between neighbor band emissivities because the emissivity of every land surface type is almost constant for bands 11, 12, 13, and 14. The neural network (NN) can make full use of potential information between band emissivities through training data because the NN simultaneously owns function approximation, classification, optimization computation, and self-study ability. The training database can be built through simulation by MODTRAN4 or can be obtained from the reliable measured data. The average accuracy of the land surface temperature is about 0.24 K, and the average accuracy of emissivity in bands 11, 12, 13, and 14 is under 0.005 for test data. The retrieval result by the NN is, on average, higher by about 0.7 K than the ASTER standard product (AST08), and the application and comparison indicated that the retrieval result is better than the ASTER standard data product. To further evaluate self-study of the NN, the ASTER standard products are assumed as measured data. After using AST09, AST08, and AST05 (ASTER Standard Data Product) as the compensating training data, the average relative error of the land surface temperature is under 0.1 K relative to the AST08 product, and the average relative error of the emissivity in bands 11, 12, 13, and 14 is under 0.001 relative to AST05, which indicates that the NN owns a powerful self-study ability and is capable of suiting more conditions if more reliable and high-accuracy ASTER standard products can be compensated.**

***Index Terms*—Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) data, emissivity, land surface temperature (LST).**

Manuscript received January 2, 2007; revised May 23, 2007. The work was supported in part by the National Science Foundation of China under Grants 90302008 and 40571101, by the Central Scientific Research Institution for Public Welfare through the Special Fund for Basic Research Work, by the project 863 of China under Grants 2006AA10Z241, and by the Ministry of Agriculture through the Open Fund of the Key Laboratory of Resource Remote Sensing and Digital Agriculture.

K. Mao was with the State Key Laboratory of Remote Sensing Science, jointly sponsored by the Institute of Remote Sensing Applications of the Chinese Academy of Sciences and Beijing Normal University, Beijing 100101, China, and also with the Graduate School of the Chinese Academy of Sciences, Beijing 100049, China. He is now with the Key Laboratory of Resources Remote Sensing and Digital Agriculture, Ministry of Agriculture, Hulunber Grassland Ecosystem Observation and Research Station, Institute of Agricultural Resources and Regional Planning, Chinese Academy of Agricultural Sciences, Beijing 100081, China (e-mail: kebiaomao2004@hotmail.com).

J. Shi is with the Institute for Computational Earth System Science, University of California at Santa Barbara, Santa Barbara, CA 93106 USA.

H. Tang is with the Key Laboratory of Resources Remote Sensing and Digital Agriculture, Ministry of Agriculture, Hulunber Grassland Ecosystem Observation and Research Station, Institute of Agricultural Resources and Regional Planning, Chinese Academy of Agricultural Sciences, Beijing 100081, China.

Z.-L. Li is with the Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, Beijing 100101, China, and also with the Laboratoire des Sciences de l'Image, de l'Informatique et de la Teledetection (UMR7005), 67412 Illkirch, France.

X. Wang is with the Graduate School of Agriculture, Hokkaido University, Sapporo 060-8589, Japan.

K.-S. Chen is with Center for Space and Remote Sensing Research, National Central University, Chungli 320, Taiwan, R.O.C.

Color versions of one or more of the figures in this paper are available online at http://ieeexplore.ieee.org.

Digital Object Identifier 10.1109/TGRS.2007.907333

I. Introduction

The Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) is an imaging instrument aboard the Terra satellite, which was launched in December 1999 as part of the National Aeronautics and Space Administration's (NASA's) Earth Observing System (EOS). ASTER has 15 bands, which cover the visible, near-infrared, short-wave infrared, and thermal infrared regions, and the spatial resolution is from 15 to 90 m. It is mainly used to obtain detailed maps of land surface temperature (LST), emissivity, reflectance, and elevation [1].

Many methods have been developed to retrieve the sea surface temperature and the LST from the National Oceanic and Atmospheric Administration (NOAA)/Advanced Very High Resolution Radiometer (AVHRR) and Moderate Resolution Imaging Spectroradiometer (MODIS) data [2]–[17]. The study of algorithms for retrieving the LST and emissivity from high-resolution thermal images (like ASTER) is not too much [1], [18]–[21] because it is difficult to obtain the atmospheric parameters (like water vapor content).

The retrieval of land surface emissivity and temperature is a typical ill-posed problem in geophysical parameter retrieval because the number of unknown parameters is always at least one more than the number of simultaneous equations that are available for solution. It is very difficult to exactly separate land surface emissivity and temperature from thermal radiance measurement if we do not utilize some prior knowledge. Many people [1], [10], [13], [16], [18], [20]–[29] made a lot of research for the separation of land surface emissivity and temperature. The detailed introduction for different LST/emissivity separation algorithms has been well discussed by Li and Becker [10] and Gillespie *et al.* [1]. Three algorithms of them [1], [10], [13] are widely used in application. Li and Becker [10] and