Emissivity and land surface temperature mapping from HyTES thermal hyperspectral images using TES and ARTEMISS algorithms

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Extended abstract

Land Surface Temperature (LST) and Emissivity are two significant physical features of the Earth's surface and atmosphere. The calculation of land surface temperaturehas a great significance in environmental studies, meteorology, evapotranspiration study, interactions between land surface and the atmosphere, detection of earthquake- related thermal anomalies, monitoring the drought, fire and energy balance models on the surface of the earth on a regional and global scale.The use of remote sensing technology and types of satellite images as one of the most important sources of data collection to study and monitor the land and environmental resources has attracted the attention of many experts and specialists of various sciences including environment, meteorology, hydrology, etc. in recent years.In recent years, hyperspectralthermal images have become a powerful tool for estimation of the land surface temperature due to the large number of thermal bands. The main purpose of this research is to obtain land surface temperature and emissivity using two distinct methods of TES (Temperature/Emissivity Separation Algorithm) and ARTEMISS (Automatic Retrieval of Temperature and emissivity using Spectral Smoothness) from the HyTES thermal hyperspectral images. The HyTES (Hyperspectral Thermal Emission Spectrometer) is an airborne thermal hyperspectral sensor with 256 spectral channels within the range of 7.5 and 12 micrometers in the range of thermal infrared of the electromagnetic spectrum designed by NASA.

The scope of this study was to retrieve land surface temperature, emissivity and atmospheric parameters from the HyTES sensor in two different methods: ARTEMISS and TES. We used the ISAC method that estimates the transmission and upwelling radiance of the atmosphere. In ISAC method, it is necessary to fit a straightforward line to optimize upper boundary of data. We used the smoothness of the spectral emissivity in the ARTEMISS algorithm in order to retrieve temperature and emissivity. Atmospheric parameters that were obtained from ISAC were used in ARTEMISS and TES. In the next step, the TES algorithm was applied to derive surface emissivity and LST. This method is designed to reduce systematic errors in LST and LSE and also to limit errors in the amplitude and shape of emissivity spectra. This algorithm first estimates the normalized emissivity and then, calculates emissivity band ratios. Next, anempirical relationship predicts the minimum emissivity from the spectral contrast (MMD) of the normalized values, permits recovery of the emissivity spectrum with improved accuracy by using an empirical relationship between emissivity contrast and minimum emissivity, the nondeterministic problem of TES was solved. The basic problemof TES is, as indicated by Realmuto 1990 that we obtain N spectral measurements of radiance and need to find $N + 1$ unknowns (N emissivities and one temperature). This is a nondeterministic problem, so at least one additional constraint must be considered. Several methods have been developed to resolve these problems such as Normalized Emissivity Method (NEM), RATIO and Minimum-Maximum emissivity Difference (MMD). In the NEM module of TES, we guessed preliminary values of temperature and LSE assuming a value for the maximum local emissivity (for blackbodies$\varepsilon_{max} = 0.99$). Then, in RATIO module, we estimated emissivity normalized spectrum (β). In order to scale the β spectrum to actual emissivity values, we used the MMD module of TES. After applying NEM, RATION and MMD module, TES estimates and reports pixel-by-pixel precisions for LST and LSE. Finally, we compared the results of LST and LSEs derived from these algorithms with products of HyTES. The results shown in this study prove the feasibility of retrieving accurate estimates of atmospheric parameters, surface temperature and emissivity with HyTES data.It should be noted that the noise and water vapor absorption bands of HyTEShyperspectral image were removed, therefore, 202 optimal bands were selected. Then, TES algorithm consists of modules NEM, MMD and RATIO was applied. ARTEMISS method is based on (1) in-scene atmospheric transmission estimation, (2) matching of the transmission to a database and (3) retrieving a spectrally smooth emissivity by an iterative method used on hyperspectral data. The ARTEMISS algorithm was applied. The final outputs of these two algorithms include thermal and emissivity images. In order to evaluate these two methods and quality assessment, we used the satellite products that have been prepared by NASA. The results of the quality assessment show that temperature RMSE for TES and ARTEMISS methods are 0.6 and 1.2 kelvin respectively, and also emissivity RMSE for band 171 are 0.01 and 0.02 respectively. Therefore, TES algorithm is a more accurate method than ARTEMISS which was implemented for the first time on this type of data.The obtained results show that the thermal hyperspectral data are suitable for accurate retrieval of emissivity and land surface temperature in any kind of land cover.

Keywords: LST, Emissivity, TES, ARTEMISS, HyTES, Thermal Hyperspectral Scanner.