ALGORITHM RESEARCH OF BUILDING MATERIALS EMISSIVITY EXTRACTING

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1. Problems

Heat flux estimation and modeling are needed for understanding urban energy consumption among which building materials are pivotal. For building materials, temperature and emissivity are key parameters in urban remote sensing. Emissivity can be used directly to classify and temperature can be used to evaluate the character of building. We know estimating temperature and emissivity from radiometric measurements belongs to the problem of solving N+1 parameters with N equations. Some approximations or assumptions must be taken to reduce the number of unknown parameters and make the equation complete.

This paper presents a theoretical study if the algorithm adapted for building materials emissivity extracting operating in thermal infrared in order to characterize surfaces from ground-based field measurements. The experimental data were obtained with a hyperspectral Fourier transform infrared (FTIR) spectroradiometer in emission (BOMEN M304) to illustrate the applicability of these algorithms.

2. Methodology

For lambertian surface, the thermal radiance received by the sensor can be expressed as

$$L_j = \varepsilon_j \tau_j B_j(T_s) + \tau_j (1-\varepsilon_j) L^{\downarrow}_{atm,j} + L^{\uparrow}_{atm,j} \tag{1}$$

$B_j(T_s)$ is the radiance emitted by a black body at the surface temperature T_s, ε_j is the surface emissivity, τ_j is the total atmosphere transmittance. $L^{\downarrow}_{atm,j}$ is the downward radiance emitted and diffused by the atmosphere, $L^{\uparrow}_{atm,j}$ is the radiance directed by the atmosphere towards the sensor. At ground level, $L^{\uparrow}_{atm,j}$ can be ignored, so the equation (1) can be written as:

$$L_j = \varepsilon_j \tau_j B_j(T_s) + \tau_j (1-\varepsilon_j) L^{\downarrow}_{atm,j} \tag{2}$$

Most of the emissivity extraction methods can be summarized as obtain the optimal surface temperature $T_{inverse}$, and then calculated the surface emissivity based on as follows:

$$\varepsilon_j = \frac{L_j - L^{\downarrow}_{atm,j}}{B_j(T_{inverse}) - L^{\downarrow}_{atm,j}} \tag{3}$$

2.1NEM algorithm

This method assumes that there is always a band in which the emissivity is maximum for all channels for hyperspectral remote sensing. The maximum of calculated temperatures is considered to be the surface temperature. This algorithm is simple and reasonable. The precision of it depends on the prior.

2.2 Iterative Spectrally Smooth Temperature-Emissivity Separation (ISSTES)

This method was first described by Borel. The algorithm's basis is the assumption that the surface emissivity is smoother than the atmospheric downward radiance. Given the definition of smoothness for emissivity curves, one can calculated the smoothness of the family of emissivity curves correspond to different temperature. The optimal surface temperature corresponds to the smoothest emissivity curve, in which the atmospheric absorption lines disappear.

2.3 Maximum-Minimum Difference (MMD)

MMD is defined as the difference of maximum emissivity and minimum emissivity. The scattering plots of MMD and mean emissivity show that MMD is minus relationship with mean emissivity. The first step of this algorithm is to obtain the initial value of emissivity from radiometric measurements, adjust the initial value of emissivity based on the empirical relationship, calculating the temperature with adjusted emissivity and radiometric measurements and take its mean value as the surface temperature. This process is repeated until the temperature difference of two adjacent times less than the given constant value.

2.4 Temperature and Emissivity Separation (TES)

The TES algorithm is the ASTER operational algorithm for temperature and emissivity recovery. In fact, this method is an iterative processing:

(1)The normalized emissivity method (NEM). This step is to prime estimate for object's emissivity.

(2) Using current emissivity to compute MMD:

$$MMD_j = \varepsilon_{\max,j} - \varepsilon_{\min,j}\text{, j is iterative times.} \tag{4}$$

(3) Using empirical formulation to compute the mean emissivity:

$$\overline{\varepsilon_{j+1}} = a + b * MMD_j \tag{5}$$

(4) Adjusting every band emissivity based on the mean emissivity

$$\varepsilon_{i,j+1} = \varepsilon_{i,j}\frac{\overline{\varepsilon}_{j+1}}{\overline{\varepsilon}_{j}}\text{, i is band number.} \tag{6}$$

(5) Compute the building material surface temperature using the new emissitivity and radiance.

(6) $j = j+1$, repeat the steps (2)~(5), until to $T_{sj+1} - T_{s,j} < NE\Delta T$, where $NE\Delta T$ is the noise level.

3. Central Conclusions

(1) In order to find derive building materials emissivity accurately, this paper examines several existed typical temperature emissivity methods, and assess the precision to hyperspectral data. We may conclude that the precision of ISSTES is higher than NEM, so the original NEM module has been replaced by ISSTES to acquire the accurate initial value of emissivity in TES.

(2) We present examples of building materials emissivity extraction using these methods mentioned above with ground-based measured hyperspectral data, which were measured by BOMEN M304 spectrometer. This data will verify the results of our algorithms.

(3) Analysis the relationship between the characters of building materials emissivity and heat transfer characteristic. This will be useful to evaluate the heat preservation of different building materials.

4. References

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