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# Linear retrieval of microwave Land Surface Emissivity in Taklimakan Desert

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**ABSTRACT:** Land Surface Emissivity is an inherent property of land surface, an important condition for retrieving surface and atmospheric parameters, and a key element in land surface data assimilation system. In order to obtain more accurate and physically meaningful microwave Land Surface Emissivity, the linear retrieval model is constructed for estimating the microwave Land Surface Emissivity in the Taklimakan Desert. Firstly, the function relationship between the microwave Land Surface Emissivity and two factors is deduced by using a Taylor expansion of a multivariate function. Secondly, according to the optimal control theory and the principle of atmospheric radiation transfer, a cost function is established by combining the observational brightness temperature with simulated brightness temperature. At last, the optimal solution is obtained with the Newton iteration method. The result shows that the optimal microwave Land Surface Emissivity improves the simulated value of brightness temperature. In addition, an independent test of the retrieval model in different area demonstrates the effectiveness and feasibility of this proposed model. The optimal control principle and Newton iteration method can be applied to the linear retrieval of LSE.

**Keywords:** Optimal control theory; Linear retrieval; Newton iteration method; microwave Land Surface Emissivity

## 1. Introduction

With the development of the Feng-Yun (FY) series satellites and the maturity of the theory and method of Satellite Meteorological remote sensing, the satellite-borne remote sensor plays an irreplaceable role in numerical weather prediction, climate monitoring and prediction, tropical cyclone and so on [1]. The radiation that the remote sensing receives includes the contribution of atmospheric radiation and surface radiation. Surface radiation is mainly affected by the microwave Land Surface Emissivity (LSE), so it is crucial to obtain accurate LSE.

LSE is a variable related to many factors. The LSE of bare soil generally decreases with the increase of surface temperature and soil moisture content, but increases with the increase of surface roughness. In addition, the LSE of bare soil is also affected by detection frequency and polarization mode, with the low-frequency LSE being more sensitive to the change of soil moisture content [2]. The LSE of vegetation-covered land surface is higher than that of bare soil [3], the LSE of vertical polarization increases with the incident angle, while that of horizontal polarization shows obvious seasonal variation [4]. At present, there are two main common algorithms for the calculation of LSE, namely, the statistical method and the inversion calculation method based on the satellite data. The statistical method includes genetic algorithm, Monte Carlo method, simulated annealing method, neural network method, etc. Aires et al. [5] used neural network method to calculate LSE in day time, and found that the convergence speed of the method is very slow, the calculation is complex and it is very difficult to obtain some surface parameters. The inversion calculation method based on the satellite data usually needs lots of input data such as observational brightness temperature， surface temperature， the upward and downward radiation， the atmospheric transmittance，channel frequency, soil humidity, vegetation coverage percentage and so on. Although the physics of the inversion calculation method is clear, there are too many parameters for inputting. Moreover, the uncertainty of parameters will also affect the precision of derived LSE. Therefore, it is imperative to develop a new retrieval method of LSE.

The optimal control theory and method is about how to find the optimal and the best scheme among many schemes by minimizing a prescribed cost function. Due to the continuous expansion of computer application, the optimization control theory is widely used in various fields, such as economics, engineering, and especially in meteorology in recent years[6-8].In order to derive a more accurate LSE with physical meaning, and improve the utilization rate of microwave Radiation Imager (MWRI) data on FY-3C satellite, we will take the optimal control theory for the calculation of LSE in Taklimakan Desert area. The linear retrieval model of LSE is constructed by considering the influence of surface temperature and specific humidity, then the formulas of calculating LSE is obtained.

This paper is organized as follows. Preliminaries are briefly described in the next section. The construction of the Linear retrieval model and the numerical result analysis are provided in Sect. 3. The model test is implemented in Sect. 4. Summary and discussion are given in the final section.

## 2. Preliminaries

In this section, we introduce the research area and the algorithm principle of Community Radiative Transfer Model (CRTM),

### 2.1. Research area

Desert accounts for 15% of the earth's land area, which, with scarce vegetation, relatively flat surface and small roughness. Due to the special geographical environment in desert area, the LSE retrieval from satellite observations is always different from other surface types in space and time [9-11]. In addition, since its associated frequent sandstorms and other disastrous weather seriously affect the surrounding areas, it is of great meteorological significance to monitor and study LSE in the desert area. In this study, we choose the Taklimakan desert (37°~41°N, 78°~88°E) for investigation. Figure 1 shows the observational brightness temperature in the Taklimakan Desert on November 3, 2014. The blue box is selected retrieval area (38$^{o}$ ~40 $^{o}$ N, 81$^{o}$ ~85$^{o}$ E), containing 998 scanning points.

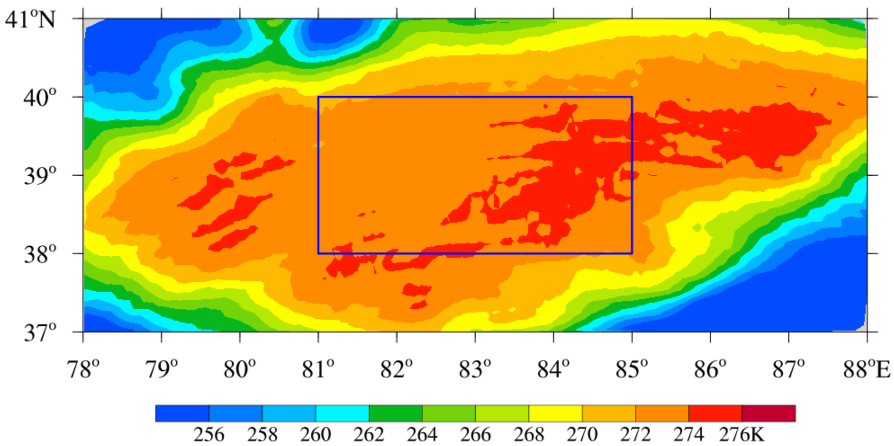


Figure 1. The observational brightness temperature in the Taklimakan Desert on November 3, 2014. (The blue box is retrieval area(38$^{o}$ ~40$^{o}$ N, 81$^{o}$ ~85$^{o}$ E))

### 2.2. Model

CRTM is a fast radiation transmission model for satellite visible light, infrared, ultraviolet or microwave channel radiation transmission [12], developed by the United States Satellite Data Assimilation Joint Center. CRTM also computes radiance sensitivities such as the radiance derivatives (Jacobians) with respect to the state variables. We input T639 model forecast data, ERA-Interim reanalysis data, and Satellite (FY-3C, Microwave Radiation Imager (MWRI), FY-3C/MWRI) observation data into CRTM model to obtain the simulated brightness temperature of MWRI. Here we introduce the principle of CRTM simulation of bright temperature.

Assuming a vertically-stratified, plane-parallel and non-polarized atmosphere, the monochromatic radiative transfer equation will be written as