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Evaluating the types of split window algorithms for calculating the land surface temperature to determine the best algorithm for MODIS sensor images

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Abstract

Background and Objective In recent years, the study of climate changes as well as their effects, has become a constant topic in the scientific fields of many countries. One of the main features of these changes is the increase in air temperature over the last 5 decades compared to the last 500 years. Statistics show an increase of one degree centigrade in air temperature over the last 5 decades. The land surface temperature means the radiant temperature of the earth's crust and the amount of pure energy that is balanced on the earth's surface under climatic conditions and depends on the reached the amount of energy, surface emissivity, humidity and atmospheric airflow. Land surface temperature is considered as one of the key variables in climate and environmental studies of the Earth’s surface. It is also one of the basic parameters in the physical features of the earth's surface at all scales from local to global. Currently, the most important sources of climatic data are meteorological stations, and these stations provide climatic statistics for certain points, while the temperature may alter at different intervals stations and decrease or increase compared to the desired station. Therefore, it is necessary to have a technology that can eliminate the shortcomings of meteorological stations in calculating the temperature at sampling intervals and in impassable places where it is not possible to build a meteorological station. In recent years, new sciences such as remote sensing have provided new ways to monitor the environment and acquire, evaluate, and analyze environmental data, and can provide a wide range of parameters relating to the environment. This technology is considered as an important and increasing source of information for studying climate change that has a direct impact on global warming. Over the past two decades, 18 algorithms have been developed to calculate the land surface temperature. These algorithms fall into four categories: emissivity-dependent models, two-factor models, complex models, and radio-based models. The results of the comparisons between different algorithms shows that different algorithms perform differently in different situations with different geographical climates. Therefore, the present study aims to compare the types of LST calculation algorithms for MODIS sensor images and determine the best algorithm for East Azarbaijan province.

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Materials and Methods Convert digital numbers (DN) to spectral radiation. The following equation was used to convert the numerical values to spectral radiation for thermal bands of MODIS sensor images.

$$L_\lambda = \frac{[(L_{max} - L_{min})]}{[(QCal_{max} - QCal_{min}) \times QCal] + L_{min}} \quad [1]$$

Planck's equation was used to convert spectural radation to spectral reflection when the radiant power of thermak data of MODIS sensor is considered to be a maximum of one.

$$TB = \frac{K_2}{l_n\left(\frac{K_1}{l_\lambda} + 1\right)} \quad [2]$$

In order to estimate the surface emissivity, the Normalized Difference Vegetation Index (NDVI) thresholding method is used. The radiant power is divided into three categories to determine the soil characteristics in each pixel and to calculate the emissivity rate and emissivity difference; 0.2>NDVI, it is considered as dry soil and its radiant power is considered to be equal to 0.978. 0.5 NDVI, it is related to pixels with higher vegetation density and its radiant power is considered 0.985. 0.5>NDVI<0.2, it is based on a combination of pixels relating to vegetation and soil and the radiant power for them can be calculated using the following equations.

$$\varepsilon = \varepsilon_{Veg} P_v + \varepsilon_{Soil}(1 - P_v) \quad [3]$$

In this equation; P_v is the vegetation ratio, that its value can be calculated using the following formula.

$$P_v = \left(\frac{NDVI - NDVI_{min}}{NDVI_{max} - NDVI_{min}}\right) \quad [4]$$

The value of each scientific finding depends on its accuracy. Thus equations 5 to 8 were used to compare the obtained results from the algorithms used to calculate the land surface temperature with the recorded temperature in meteorological station.

$$MAD = \frac{\sum_{t=1}^{n} |A_t - F_t|}{n} \quad [5]$$

$$MSE = \frac{\sum_{t=1}^{n} (A_t - F_t)^2}{n} \quad [6]$$

$$RMSE = \sqrt{\frac{\sum_{t=1}^{n} (A_t - F_t)^2}{n}} \quad [7]$$

$$MAPE = \frac{\sum_{t=1}^{n} \left|\frac{A_t - F_t}{A_t}\right|}{n} \times 100 \quad [8]$$

Results and Discussion The results of the present study show that among the 18 algorithms for the land surface temperature estimation for MODIS sensor images, the Sobrino algorithm with RMSE value of 1.79 has the highest accuracy, Cole Casillas and Prata algorithm with RMSE value of 2.85 is in the second position, and also the Salisbury and Sobrino algorithms with RMSE values of 2.39 have the third place for LST calculation among the other algorithms. The Qin algorithm with a RMSE value of 5.28 has the lowest accuracy for LST estimation.

Conclusion A review of the data obtained from comparing split-window algorithms shows the overall compliance of the calculated temperatures with the topographic conditions of the region, so that almost the lowest temperature values in all algorithms are related to the parts having more height (mountainous) and green cover of the region and also, temperature values have risen in low-lying areas lacking dense vegetation.

Keywords Land surface temperature (LST), Split window algorithms (SW), MODIS sensor, East Azarbaijan province