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Spatio-Temporal Analysis of Land Surface Temperature of Sikkim, India

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Abstract: Spatio-temporal variability of Land surface temperature is calculated with help of remote sensing and GIS tools. LST is very important phenomenon of research now a day because as a global temperature is increasing due to global warming and it directly affects the land surface and surface temperature increases. TIRS band of Landsat 8 is used for estimation of Brightness temperature. NDVI is highly co-related with emissivity and it give more accuracy in estimation of land surface temperature. Sikkim is mostly covered with vegetation cover and glacier so LST variation in last 25 years is very minimal. It shows that Sikkim is unaffected by anthropogenic activities and global warming.
Keywords: LST; Remote Sensing; Landsat 5; Landsat 8; LSE; Brightness temperature; Sikkim

I. INTRODUCTION

Land Surface Temperature or LST can be defined as "the radiative skin temperature of the land surface, measured in the direction of the sensor". LST is "surface radiometric temperature" in terms of remote sensing. It depends on the temperature and emissivity within a pixel and spectral channel of measurement.

The evaluation of LST can be done from top of atmosphere brightness temperature with the help of infrared spectral channel. The temperature of the black body that emit the same intensity as measured is brightness temperature. LST can also be evaluated by albedo, vegetation covers and soil moisture. It is controlled by solar radiation and land atmosphere heat exchange [3], [4].

Factor that scales blackbody radiance to predict emitted radiance and the efficiency of transmitting thermal energy across the surface into the atmosphere is termed as Land Surface emissivity (LSE) [5]. It is the intrinsic property of the natural materials. The value of the emissivity varies from 0 (shiny mirror) to 1 (blackbody).

There are various methods to calculate LSE. Here, NBEM (NDVI-based emissivity method) has been used to calculate LSE. NDVI is calculated with the help of reflectance measured in the near infrared and in the red wave band. For the estimation of LSE at pixel scale directly from space NBEM is proved as a powerful tool as one can get NDVI easily from the refl-ectance easily from the reflectance in VNIR bands, relationship is dependent on the study area and the coefficient 'a' and 'b' are different for different sites.

Remote sensing is basically the collection of information or data remotely i.e. not being in physical contact with the object. The detection of electromagnetic radiation by sensor is the basic need for remote sensing.

To analyse spectral response, different objects emits different EMR. Thermal Infrared is the wavelength mostly used for LST. Here for Landsat 5 and Landsat 8 wavelength of thermal infrared band is 10.40-12.50 and 10.60-11.19 micrometre respectively. To measure LST, number of remote sensing satellites are available with multiple sensors in the TIR spectrum. One of the best advantages of remote sensing is its global coverage [2].

The objective of our study is to estimate the variation of Land Surface Temperature for period of 1994 – 2018 in Indian state Sikkim.

II. STUDY AREA AND DATA USED

Sikkim is located in northeast India. Sikkim is a land of dramatic contours. Rugged mountains, deep valleys and dense forests consort with raging rivers, lakes and waterfalls to create a visual feast. It has three side international borders and one national borders. Tibet in the north and northeast, Bhutan in the east, Nepal in the west, and West Bengal in the south. Among 28 states of India, Sikkim is least populated state and second smallest state.

A part of the Eastern Himalaya, Sikkim is known for its biodiversity, including alpine and subtropical climates, and being a host to Kanchenjunga, the highest peak in India and third highest on Earth.

Khangchendzonga National Park covers 35% of the state. Sikkim is characterised by mountainous terrain. Entire state is covered with hills, with an elevation ranging from 280 metres to 8,586 metres. Most of the part of Sikkim is unsuitable for agriculture because of rocky terrain and high slope area.

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III. METHODOLOGY AND DATA USED

Land surface temperature retrieval includes calculation of following factors.

A. TOA Spectral Radiance (L_λ)

$L_\lambda = M_L . Q_{Cal} + A_L$

Where,

L_λ = TOA spectral radiance

M_L = Band-specific multiplicative rescaling factor from the metadata

A_L = Band-specific additive rescaling factor from the metadata

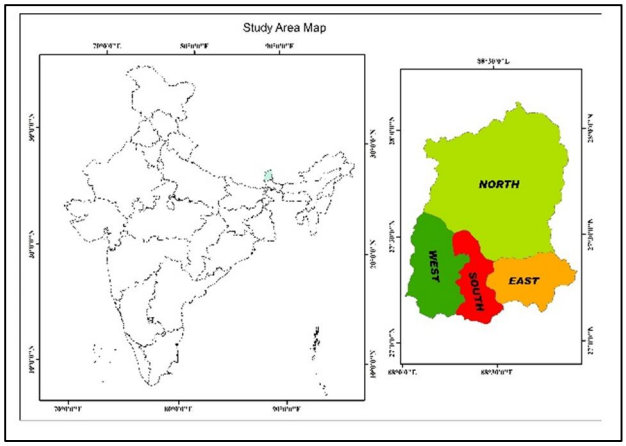

Figure 1: Study Area (Sikkim) Map

Q_{Cal} = Quantized and calibrated standard product pixel values

B. Brightness Temperature

$$BT = \frac{K_2}{\ln(\frac{K_1}{L_\lambda}+1)} \text{.....(i)}$$

Where,

BT = At-satellite brightness temperature (K)

L_λ = TOA spectral radiance

K_1 = Band-specific thermal conversion constant from the metadata

K_2 = Band-specific thermal conversion constant from the metadata

C. Normalized Difference Vegetation Index (NDVI)

$$NDVI = \frac{(NIR-Red)}{(NIR+Red)} \text{..... (ii)}$$

D. Land Surface Emissivity (ε)

$\varepsilon = a + b \ln NDVI$ [6].....(iii)

Where,

ε = Spectral Surface Emissivity

a = Constant derived from regression analysis

b = Constant derived from regression analysis

E. Land Surface Temperature (LST)

$$LST = \frac{BT}{\{1+[\frac{\lambda . BT}{\rho} . \ln \varepsilon]\}} \text{.....(iv)}$$

Where,

LST = Land Surface Temperature (K)

λ = wavelength of emitted radiance (μm)

$\rho = hc/\sigma$

For estimation of Land surface temperature, NDVI, LSE and BT are used. NDVI is a vegetation index which shows the vegetation health. From NDVI, LSE were estimated, and value of LSE varies from 0.05 W/m^2 to 0.99 W/m^2 according to emissivity. Since if the NDVI value is higher the emissivity is also going to near 0.99 W/m^2. Brightness temperature were calculated by top of Atmospheric spectral radiance using constant provided in metadata.

Table 1: Data used for Land Surface Temperature variation studies

Scene Id	and Used
T05_L1TP_139041_19941218_20170111_01_T1	Band 5
T05_L1TP_139041_19981229_20161221_01_T1	Band 5
T05_L1TP_139041_20010119_20161212_01_T1	Band 5
T05_L1TP_139041_20031227_20161203_01_T1	Band 5
T05_L1TP_139041_20061219_20161117_01_T1	Band 5
T05_L1TP_139041_20101230_20161011_01_T1	Band 5
C08_L1TP_139041_20131206_20170428_01_T1	Band 10
C08_L1TP_139041_20151228_20180524_01_T1	Band 10
C08_L1TP_139041_20180102_20180104_01_T1	Band 10

IV. RESULT AND DISCUSSION

Land surface temperature were analysed for last 25 years with a difference of 3 to 4 years from 1994 to 2018. Least temperature in last 25 years is around -39.5°C and highest temperature is around 36°C. Above map of 25 Years Land surface temperature it is observed that the trend of temperature is increasing in Sikkim. Its Northern part is mostly covered with snow and as per result of different years it shows that glacier temperature also increased i.e., melting increases and glacial cover decreases. In year 1994, Maximum region in the northern part is covered with glacier and its temperature is -35° - 0°C and Southern Sikkim have temperature about 10°-20°C. In year 1998, In northern Sikkim glaciers area temperature is increased i.e., Glacier melting increases and in the southern part of Sikkim land surface temperature has increased. In year 2001, 2003, 2006, 2010 Northern Sikkim temperature increased, and Southern part of the Sikkim is also increased. In year 2013, Northern Sikkim temperature have decreased, and Southern Sikkim Temperature has increased. In year 2015, Northern and Southern Sikkim temperature has been increased. In year 2018, Northern Sikkim temperature has been decreased and Southern Sikkim temperature has been increased.

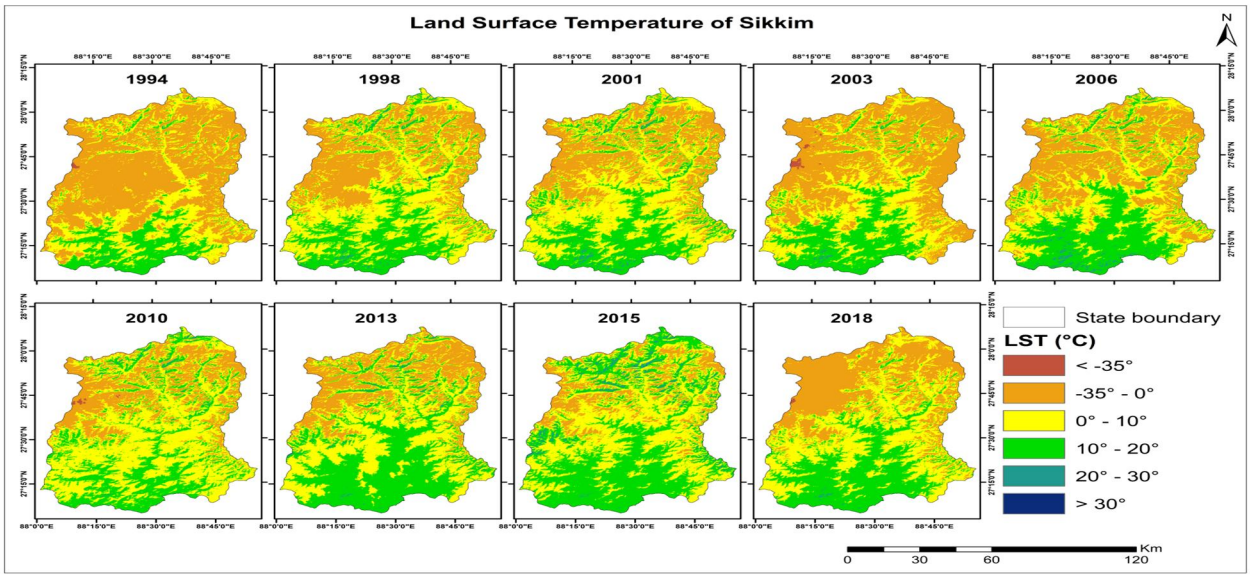

Figure 2: Land Surface Temperature map of Sikkim

Also, in the southern half of the Sikkim, there is continuous increase in land surface temperature from 1994 to 2006 after that sharp decrease in LST have been observed after then also there is continuous increase in LST till now (2018).

Table 2: Area change for different temperature change for Sikkim state

Area (km^2)									
Temperature/Year	1994	1998	2001	2003	2006	2010	2013	2015	2018
< -35° C	6.8	0.1	1.0	28.1	0.1	11.3	0.0	0.0	4.7
-35°C - 0° C	3982.5	2326.7	2109.7	3238.4	2595.3	1685.8	1757.7	944.9	2350.0
0°C - 10°C	2024.7	2912.4	3008.3	2279.8	2338.7	3520.9	2664.0	2961.2	2717.4
10°C - 20°C	1114.2	1830.0	1906.9	1559.9	2089.6	1873.9	2632.3	3021.5	2047.0
20°C - 30°C	4.6	63.0	106.9	26.6	109.1	40.9	78.8	204.8	13.8
30°C - 40°C	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.4	0.0

From table 2 it is observed that area is decreasing in temperature less than 35°C and there is continuous increase in the area of the higher temperature pattern and continuous decrease in the area of lower temperature pattern. There is exception in the result of 2018, there is much increase of area in 2018 at temperature range between -35°C to 0°C and rest all decrease in an area in temperature range between 0°C - 10°C, 10°C - 20°C, 20°C - 30°C.

V. CONCLUSION

From above work it is observed that land surface temperature has not increased much in Sikkim because mainly Sikkim is covered with a forest range and northern part of Sikkim is covered with snow. Most changes in last 25 years is seen on glacier region Land surface temperature has increased much more. Area also changed a lot in the Sikkim with difference in the temperature ranges. Temperature ranges between -35°C to 0°C area changed much more. In future work these works should be validated in the field.

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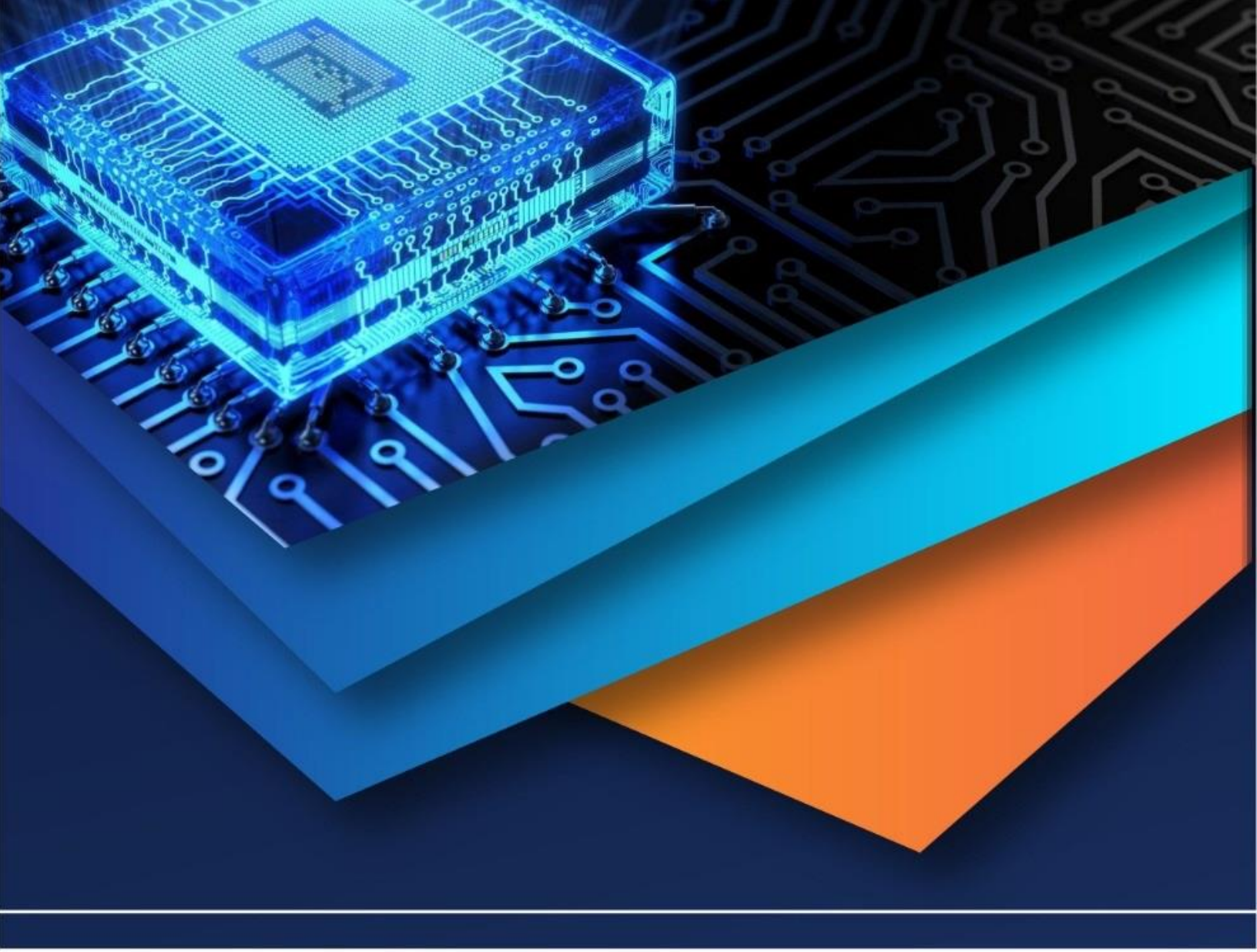

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