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Research Article

The Relationship of MODIS LST (Land Surface Temperature) and Terrain Attributes of Basins in Jammu and Kashmir, Western Himalaya, India

Saif A Khan and Sarfaraz Ahmad

[1]Department of Civil Engineering, KIET School of Engineering and Technology, Muradnagar, Ghaziabad, India

[2]Department of Geology, Aligarh Muslim University, Aligarh, India

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Abstract: Average Night and Day LST (Land surface Temperature) were extracted for various basins in J & K, North-Western Himalayas using MODIS – 11 LST products. The linear relationship between LST and mean altitude of the basins is good in case of Night LST and poor for the Day LST. It suggests that the Night time atmospheric turbulences are minimum in the atmosphere and hence shows good relation with altitude. The relationship between mean altitude and Day LST suggested that as season progresses from 241 Julian day to 337 Julian day the altitude and temperature linear relationship improves. However, temporal variation of linear relationship does not vary with season. Average LST in the western Himalayan basins is mostly controlled by the mean slope and altitude, while aspect and CTI plays lesser role. Long term mean Night LST can be used for long term time series analysis of the Satellite derived temperature.

Keywords: Land Surface Temperature, Western Himalaya, MODIS, Terra

INTRODUCTION

MODIS is a payload scientific instrument launched into Earth orbit by NASA in 1999 on board the Terra (EOS AM) Satellite, and in 2002 on board the Aqua (EOS PM) satellite. The instruments capture data in 36 spectral bands ranging in wavelength from 0.4 µm to 14.4 µm and at varying spatial resolutions (2 bands at 250 m, 5 bands at 500 m and 29 bands at 1 km). Together the instruments image the entire Earth every 1 to 2 days. They are designed to provide measurements in large-scale global dynamics including changes in Earth's cloud cover, radiation budget and processes occurring in the oceans, on land, and in the lower atmosphere. Land surface temperature (LST) is one of the key variables needed to describe land surface processes. It is required for a wide variety of climatic, hydrological, ecological, and biogeochemical studies. For example, the MODIS LST product can be used as input for models of the LST diurnal cycle, cloud and atmospheric vertical profiles, surface-emitted energy fluxes, and hydrological processes [1-3].

The MODIS LST product provides global day and night land surface temperature and emissivity at 1 and 5 km. spatial resolutions with a daily, eight-day and monthly temporal frequency. Acquiring the atmospheric/ land temperature in remote Himalayas is one of the challenges for on-going research in climate change and large scale hydrological modelling. Because of remoteness, logistic problems and highly variable environment the collection of ground based temperature information is tedious and difficult task. However, a remote sensing tool i.e., observation of temperature from satellite based on reflection or absorption of solar spectrum can be utilized. The time series of this information can utilize for early warning for climate change. Moreover, the calibration of this information can be designed with real time ground based observation and further utilize for hydrological modelling. In present study the average Day and Night time LST of various basins in parts of Jammu & Kashmir; North-Western Himalayas is extracted using MODIS – 11 and LST products. The relationship between mean altitude of the basin and MODIS derived composite LST is workout along with temporal variation. Terrain attributes of the basins and its relationship with average LST temperature is also attempted in present work [4-6.]

Modes Land Surface Temperature Algorithm: the Moderate Resolution Imaging Spectro-radiometer (MODIS) On board the first EOS platform (called Terra), which was successfully launched on 18 December 1999, provides a new opportunity for global studies of atmosphere, land and ocean processes and for satellite measurements of global LST. The strengths of MODIS include its global coverage, high radiometric resolution, appropriate dynamic ranges and accurate calibration in thermal infrared bands designed for retrievals of sea-surface temperature, LST and atmospheric properties.

The Generalized Split Window Lst Algorithm: The LST of clear-sky pixels in MODIS scenes is retrieved with the split-window algorithm in a general form

$$T_s = C + (A_1 + A_2 (1-\varepsilon)/\varepsilon + A_3 \Delta\varepsilon/\varepsilon^2)\, T_{31} + T_{32}/2$$

$$+ (B_1 + B_2 (1-\varepsilon)/\varepsilon + B_3 \Delta\varepsilon/\varepsilon^2)\, T_{31} - T_{32}/2$$

Where $\varepsilon = 0.5\,(\varepsilon 31 + \varepsilon 32)$ and $\Delta\varepsilon = \varepsilon 31 - \varepsilon 32$ are the mean and the difference of surface emissivity's in MODIS bands 31 and 32. T_{31} and T_{32} are brightness temperatures in the two split-window bands. The coefficients C, Ai and Bi, i = 1, 2, 3 are given by interpolation on a set of multi-dimensional look-up tables (LUT) [1, 2]. The LUTS were obtained by linear regression of the MODIS simulation data from radioactive transfer calculations over wide ranges of surface and atmospheric conditions. Improvements for the generalized split window LST algorithm incorporated in the establishment of the LUTS include: 1) view-angle dependence, 2) column water vapor dependence, and 3) dependence on the atmospheric lower boundary temperature. The view-angle dependence is kept in one dimension of LUTS for a set of viewing angles covering the whole MODIS swath so that LST can be retrieved at higher accuracies for pixels at both small and large viewing zenith angles.

The column water vapour dependence is kept in another dimension of LUTS for a set of overlapping intervals of column water vapour so that the water vapour provided in the MODIS atmospheric product is used as the most likely range of water vapour rather than its exact value because the uncertainties in the atmospheric water vapours may be large. Similarly, the atmospheric lower boundary temperature (T) provided in the MODIS atmospheric product is also used to improve the LST retrieval accuracy. The band emissivity's, also called classification-based emissivity's[3, 4] are estimated from land cover types in each MODIS pixel through TIR BRDF and emissivity modelling. In the at-launch MODIS LST processing, the University of Maryland IGBP-type land-cover based on AVHRR data in 90s is used to provide global land cover information at 1 km grids. Errors and uncertainties in the classification-based emissivity's may be large in semi-arid and arid regions because of the large temporal and spatial variations in surface ernissivities.

The Modis Day/Night Lst Algorithm: A physics-based day/night algorithm[5] was used to retrieve surface spectral emissivity and temperature at 5 km resolution from a pair of day time and night time MODIS data in seven TIR bands (bands 20, 22, 23, 29, and 31-33). The inputs to this algorithm include the MODIS calibrated radiance product, geo location product, atmospheric temperature and water vapour profile product and cloud mask product. In our knowledge, this day/night algorithm is the first LST algorithm that has a limited capability to adjust the uncertainties in atmospheric temperature and water vapour profiles for a better retrieval of the surface emissivity and temperature in the day/night algorithm. There are 14 unknown variables, 7 band emissivities, surface temperature, atmospheric temperature at the surface level, column water vapour for day time and night time respectively and an anisotropic factor of the solar beam BRDF at the surface.

MATERIALS AND METHODS

There are two important requirements needed to find out Land surface temperature, the first one is MODIS data and the second one is basin shape files of which the LST is to be find out. The Land surface temperature is determined by MODIS-11 data which was provided by NASA in the form of CD. The temperature is recorded in Kelvin and LST temperature is for the radiance recorded in last eight days. For converting the MODIS LST data into centigrade a 0.020 factor is required [6]. In CD there were number of granules in HDF files.

These HDF files were converted to pix files. The basin shape files of Himalaya region were downloaded from 1 km hydrological web page which again converted to vector pix files and were re-projected in ISIN- WS86.The average land surface temperature in various basins was extracted using MODIS-11 land surface temperature product for night and day temperature. The various basins in Himalaya have terrain attribute such as mean altitude, slope, cti (compound topographic index), aspect, standard deviation, slope etc.

Average day and night temperature in various basins in different part of the Himalaya were analysed. Average day and night temperature for the period of August – October 2000 and its relation with altitude were established.

Area of Study: The present study is conducted in the western Himalaya region. Kashmir Himalayas cover the state of Jammu & Kashmir, a state of Indian republic. In this study 42 basins of this region are selected, range in altitude from 400 msl to 6000 msl. Climate of the region is mostly control by the precipitation of snow in winter period and some shower by the monsoonal precipitation. Geologically this is one of the youngest regions on the earth; it is structurally and geologically active region. In the south of the Kashmir region the Siwalik Hills, while in North it is bounded by flat plateau of Tibet region.

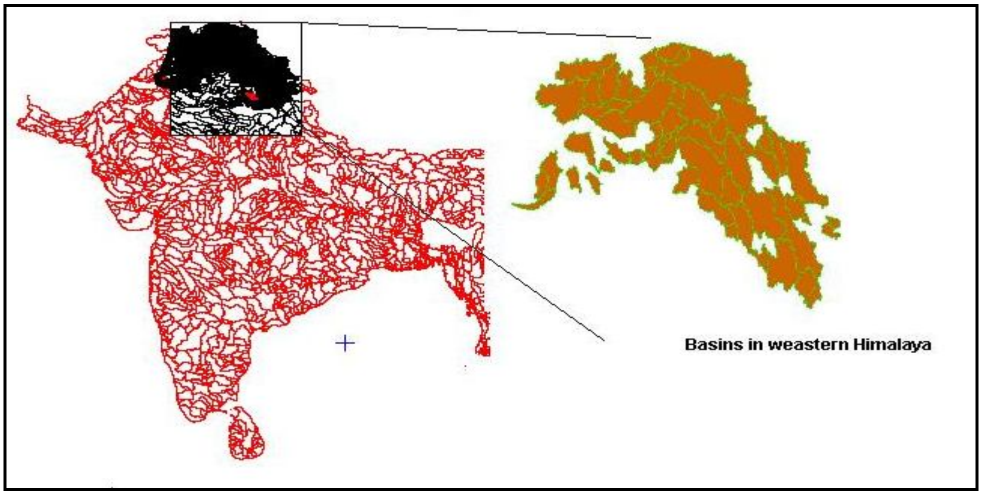

Figure 1: Location map of the study area

RESULT AND DISCUSSION

The average Land Surface Temperature is extracted for Day and Night in various basins for the 241-290 Julian and 337 Julian days in the year 2000. These values are average LST observed in last eight days and hence called as composite average LST.

LST for the day and night are discussed separately. The relationship between mean altitude of the basins and day composite average LST for the Julian day (241 – 337) are given in **Table 1**.

The R^2 and relationship between altitude and LST suggested that as the season progress from 241 Julian day to 337 Julian day the altitude and temperature relationship improves. It also suggests that in moderate winter the altitude and average Day LST temperature relationship is good due to the clear sky and stable climatic conditions. The relationship between mean altitude of the basins and Night LST for the 241 to 337 Julian days is given in **Table 2**.

The temporal variation of R^2 with Julian day suggests good relationship between altitude and average Night LST in all season. However, the relationship between LST and mean altitude of the basins is not good in case of Day LST and mean altitude of the basins. It suggests that the Night time atmospheric turbulences are minimum in the atmosphere and hence this relation is good with altitude.

Table- 1: The relationship between Average Day LST and mean altitude of the basins

Julian day	Gradient of temperature and altitude	R2
241	y = 0.4079x + 13648	0.1035
249	y = 0.0553x + 14664	0.0038
257	y = -0.185x + 15384	0.0809
265	y = -0.6988x + 15676	0.3266
273	y = -0.6975x + 15109	0.2383
281	y = -1.0466x + 16278	0.5239
289	y = -0.5757x + 15767	0.4244
337	y = -2.4195x + 16859	0.659
Average		0.29505

Table- 2: The relationship between Average Night time LST and mean altitude of the basins

Julian day	Gradient of temperature and altitude	R2
241	y = -0.0863x + 14486	0.0585
249	y = -0.294x + 14979	0.9196
257	y = -0.2925x + 14988	0.9455
265	y = -0.3798x + 14870	0.8909
273	y = -0.3498x + 14792	0.9132
281	y = -0.7574x + 15327	0.7137
289	y = -0.7965x + 15346	0.7032
337	y = -0.368x + 14296	0.9217
Average		0.758288

The average Night and Day LST of the various basin were analyzed in relation to basins terrain attributes such as mean altitude Standard deviation of the altitude, mean slope, standard deviation of slope, mean aspect, standard deviation of aspect and compound topographic index. The relationship of these terrain attributes and average Day LST (241—337 Julian day) for the year 2000 are summaries in **Table 3**.

Table- 3: Linear Relationship between Average Day LST and terrain attribute of the basin during 241 – 337 Julian day in 2000

The Terrain attribute and their relationship with Average Day LST in the region		R2
Mean altitude of the basin vs. Avg. Day LST	y = -0.3927x + 15225	0.1629
Mean Slope of the basins vs. Avg. Day LST	y = -114.81x + 15237	0.3025
Mean aspect of the basin vs. Avg. Day LST	y = -13.473x + 16791	0.077
CTI (Compound topographic index) of the basin vs. Avg. Day LST	y = 237.15x + 13480	0.0723

These relations suggest that Average Day LST in the western Himalayan basins is mostly controlled by the mean slope and altitude, while aspect and cti have lesser role for controlling the LST. This relationship is based on linear relationship between average Day LST and mean terrain attribute. However, if we uses the 2 degree of polynomial method to establish the relationship between terrain attribute of the basins and average Day LST, the result improve drastically as shown in Table 4

Table- 4: Polynomial 2 degree Relationship between Average Day LST and terrain attribute of the basin during 241 – 337 Julian day in 2000

The Terrain attribute and their relationship with Average Day LST in the region		R2	Improvement factor
Mean altitude of the basin vs. Avg. Day LST	y = -0.0006x2 + 2.2452x + 13108	0.7523	78.3464
Mean Slope of the basins vs. Avg. Day LST	y = -25.895x2 + 349.57x + 14015	0.5772	47.5918
Mean aspect of the basin vs. Avg. Day LST	y = -0.239x2 + 69.547x + 9706.7	0.1147	32.8684
CTI (Compound topographic index) of the basin vs. Avg. Day LST	y = -423.46x2 + 3963.1x + 5965.7	0.5292	86.3379

The linear relationship of terrain attributes and average Night LST (241—337 Julian day) for the year 2000 are summaries in **Table 5.**

Table- 5: Linear Relationship between Average Night LST and terrain attribute of the basin during 241 – 337 Julian day in 2000

The Terrain attribute and their relationship with Average Night LST in the region		R^2
Mean altitude of the basin vs. Avg. Night LST	y = -0.3402x + 14757	0.8184
Mean Slope of the basins vs. Avg. Night LST	y = -69.141x + 14565	0.7344
Mean aspect of the basin vs. Avg. Night LST	y = -9.9701x + 15057	0.0805
CTI (Compound topographic index) of the basin vs. Avg. Night LST	y = 241.16x + 13095	0.5007

The linear model of the average Night LST and their relationship between terrain attributes of basin suggest good relation as compare to average Day LST due to less atmospheric turbulence and stable climatic condition during night time in the basins.

The polynomial of the average Night LST shows good relation with terrain attributes of basin as shown in **Table 6.**

Table- 6: Polynomial 2 degrees Relationship between Average Night LST and terrain attribute of the basin during 241 – 337 Julian day in 2000.

The Terrain attribute and their relationship with Average Night LST in the region		R^2	Improvement factor
Mean altitude of the basin vs. Avg. Night LST	y = -0.0001x2 + 0.1421x + 14370	0.9503	13.87983
Mean Slope of the basins vs. Avg. Night LST	y = -5.7649x2 + 34.243x + 14293	0.8256	11.04651
Mean aspect of the basin vs. Avg. Night LST	y = 0.4689x2 - 97.252x + 19046	0.1351	40.41451
CTI (Compound topographic index) of the basin vs. Avg. Night LST	y = -109.75x2 + 1206.8x + 11148	0.7062	29.09941

But the improvement is larger in case of Day LST linear and polynomial mathematical model than the average Night LST.

CONCLUSIONS

The MODIS LST product can be used as good substitute for obtaining atmospheric temperature in the remote area and in absence of local meteorological station. The mean Day LST of the basins in the western Himalayas is affected by the local and day time atmospheric turbulence. This turbulence decreases as the season progresses towards winter. The mean Night LST of the basins show the better relationship with mean basin altitude and other basin terrain attributes than the mean Day LST.

Here we recommended that the long term mean Night LST can be used for long term time series analysis of the Satellite derived temperature. The mean Night LST can be used for detecting any long term change in atmospheric temperature such as global warming or regional climate change.

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***Corresponding Author: Saif A Khan;** Department of Civil Engineering, KIET School of Engineering and Technology, Muradnagar, Ghaziabad, India