STUDY OF SURFACE TEMPERATURE LAPSE RATE IN HIMALAYAN REGION

A DISSERTATION

Submitted in partial fulfillment of the requirements for the award of the degree of

INTEGRATED MASTER OF TECHNOLOGY
in
GEOPHYSICAL TECHNOLOGY

By

SUPRIYA DUBE

DEPARTMENT OF EARTH SCIENCES
INDIAN INSTITUTE OF TECHNOLOGY ROORKEE
ROORKEE – 247 667 (INDIA)

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CANDIDATE'S DECLARATION

I, ***Supriya***, hereby declare that the work, which is being presented in this dissertation report, entitled, "***Study of Surface Temperature Lapse Rate in Himalayan Region***", in partial fulfillment of the requirements for the award of the degree of ***Integrated Master of Technology in Geophysical Technology***, submitted in the Department of Earth Sciences, Indian Institute of Technology, Roorkee. It is an authentic record of my own carried out under the guidance and supervision of ***Dr. Ajanta Goswami, Assistant Professor in the Department of Earth Sciences, IIT Roorkee***, during the period of May 2018 to May 2019.

The matter embodied in this report has not been submitted by me for the award of any other degree or diploma of this institute or any other university/institute.

I understand the action of plagiarism and that if at any stage the statement above made by me is found to be incorrect, I shall be fully responsible for my act(s).

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Place: Roorkee

(SUPRIYA DUBE)

This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

Dated: 16/05/2019

Place: Roorkee

Dr. Ajanta Goswami

Assistant Professor

Department of Earth Sciences, IIT Roorkee

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(SUPRIYA DUBE)

ABSTRACT

Study of temperature lapse rate (TLR) is of vital importance for understanding the hydrological process and its relation with climate change. TLR on the account of land surface temperature (LST) and air temperature was determined for Indus-Ganga-Brahmaputra (IGB) river basin. To assess the LST lapse rate, Moderate Resolution Imaging Spectrometer (MODIS) datasets provided LST over the IGB basin. The LST values were plotted for their corresponding elevation for each of the basin and TLR was calculated using linear regression analysis. The LST lapse rate differed from 6.5-7.2º C/Km for the entire basin area. Monthly air temperature was obtained from the IMD and MOSDAC meteorological stations from September 2011 to December 2018 and was correlated with elevation to obtain near-surface air TLRs for selected sub-basin of each of the 3 major basins. The average monthly TLR ranges between 4.6 ºC Km^{-1} and 8.39 ºC Km^{-1} from January 2011 to December 2016 for the Alkananda and Bhagirathi sub-basin in Ganga, whereas 4.1 – 8.1ºC Km^{-1} for the Sutlej-Beas sub-basin in Indus and 4.9 – 6.5 ºC Km^{-1} for the Teesta river sub-basin in Brahmaputra respectively. This study also includes the air temperature modeling using land surface temperature obtained from Landsat 8 data to analyze the air temperature in the Upper reaches of the Himalaya basin, where the field observations are limited. Multivariate linear regression method is used for the air temperature retrieval through remote sensing. This method is based on the empirical correlation between the air temperature and other variables. The estimated modeled air temperature is validated with the field observation obtained from the AWS data. It was observed that the modeled air temperature shows ± 0.5 º C error with the observation data and the obtained result was well correlated with the station data. The modeled method-based air temperature depends upon the accuracy, size of the study area and the remote sensing image resolution. It is important to determine the change in temperature with elevation to map the climate change and sustainable water resource management.

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INTRODUCTION

As indicated by IPCC (2013), the normal worldwide temperature has ascended by 0.85ºC from 1880 to 2012 (Stocker, 2014). The temperature encounters huge vacillation because of unsurprising repeating occasions (night and day, summer and winter) and difficult to-anticipate wind and precipitation designs (Carlowicz, 2010). The worldwide temperature relies upon the measure of vitality gets from and emanated once again into the environment. Notwithstanding, the changing temperature has not been uniform everywhere throughout the world in light of the fact that the net temperature change isn't exclusively influenced by the common climatic variety. Surely, it is the superposition of the anthropogenic exercises on the normally differing atmosphere (Stott, 2003). Human exercises, for example, consuming of petroleum products have expanded the greenhouse gases in the air, which thusly have intensified the regular nursery impact, causing the temperature of the Earth's environment, sea, and land surface to increase(Malhi et al., 2002). A dangerous atmospheric devation has made serious harm both physical just as organic conditions (Smith et al., 2009). The harm can be seen independently at both worldwide and local scales. Universally, the changing temperature cause direct effect on snow and ice sheet, fast ascent in the ocean level and increasingly extreme warmth waves (Aggarwal, 2008). While on a local dimension, individuals have seen an expansion in the recurrence of outrageous climate occasions like unseasonal precipitation, sudden floods and dry seasons (Masinde, 2014).

The expansion popular of water assets developing worry that the stream frameworks might be defenseless with regards to worldwide cautioning(Bates, 2009; Change, 2007; Shrestha et al., 2015). Later on, it will put weight on officially focused on water assets and environments

(Shrestha et al., 2015). Changes in Precipitation and increment in temperature will influence the sustenance generation and water accessibility over the South Asian nations because of variety in rainstorm beginning and term. It likewise added to outrageous occasions, for example, floods, dry seasons, Glacier Lake Outburst Flood (GLOF) which presenting genuine effect on the financial procedures of the IGB locale (Bolch et al., 2012; Hirabayashi et al., 2013, 2008; Lutz et al., 2014; Pechlivanidis et al., 2017; Viste and Sorteberg, 2015). In this manner, in open approach area, the top-notch temperature and precipitation change data is critical for anticipating future environmental change and its suggestion on hydrology of the IGB waterway bowl and sub-bowls (Figure 1).

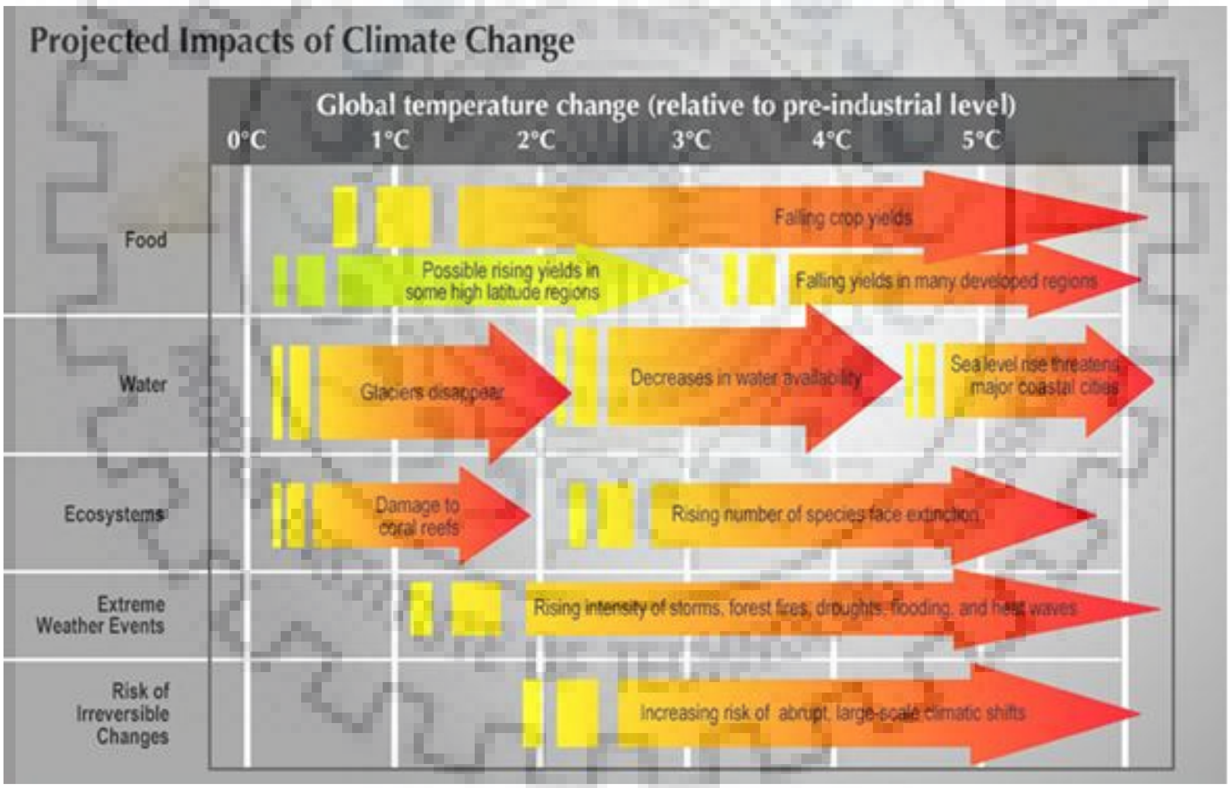

Figure 1: The future projected climate change and its implication on different domain *(Stern; 2006)*

To describe the impact of environmental change on territorial scale, the rate of progress of temperature with height need to get it. The surface and air temperature diminishes with increment in height (Liu et al., 2009). This lessening in temperature in with respect to the rise is

broadly known as the temperature pass rate. A few creator for example(Barry, 2001; Blandford et al., 2008; Gardner et al., 2009; Gouvas et al., 2011; Laughlin, 1982; Marshall et al., 2007; Pepin, 2001; Rolland, 2003; Tang and Fang, 2006; Thyer, 1985) detailed that the TLR changes with geology. It was seen that the size of TLR changes area to area as an element of vitality balance parts, for example, surface condition, rise, air dampness content, wind speed, darkness, radiative conditions, and separation from the ocean (Gill, 2016). Many creator underscored on the huge investigation of TLR for a few area, for example, glaciology, hydrology, and horticulture (Blandford et al., 2008; Chang, 2017; Lookingbill and Urban, 2003). Various examinations have been done on the yearly cycle of surface air TLR and its controlling components in numerous mountain locales (Joshi et al., 2018; Kattel et al., 2018, 2013).
A few investigations concluded that the Himalayan locale unequivocally influence by the beginning and the power of Asia's storm through unique and warm procedures (Flohn, 1957; Ichiyanagi et al., 2007; Shrestha et al., 2000; Shrestha and Aryal, 2011; Wu and Zhang, 1998; Ye and Gao, 1979) in light of its unpredictable landscape. Scarcely any examinations undertaken have concentrated on the upper Himalayan area because of an absence of meteorological record information. Nevertheless, efficient investigations were performed on the temperature slip by rates and their controlling components in the Himalayan locale are as yet deficient.

In this study, the surface and air temperature was examined at daily, monthly and annually scale from 2001-2016 for the India major river basin (Indus-Ganga-Brahmaputra (IGB)). This study also includes the air temperature modeling using Land surface temperature obtained from Landsat 8 data to analyses the air temperature in the Upper reaches of the Himalaya basin where the field observation are limited. Therefore, this study played a vital importance for understanding the hydrological process and its relation with climate changeof study is vital for displaying hydrological forms (Noilhan and Planton, 1989; Wang et al., 2001) and observing agrarian (Sow et al., 2013; Wan et al., 2004; Zhang et al., 2015) and natural frameworks ashore.

Research Questions:

- Has the spatio-transient temperature circulation changed in the course of recent years?
- If changes existed, are these progressions speaking to momentary vacillations or mirroring a long haul pattern?
- How to manage the constrained air temperature perception station?

Objective:

- Quantify the slip by rate of close surface air (Ta) and land surface temperature (LST) to comprehend the yearly example of temperature in connection with height
- Assessing the effect of landscape superficially slip by rate and their fluctuation
- Modeling and approval of close air temperature dependent on the Land Surface Temperature (LST) and other vitality balance segments

LITERATURE REVIEW

2.1. INTRODUCTION TO TLR

The temperature lapse rate decreases with increase in elevation. This happens because of less retention of approaching sunlight-based radiations by the barometrical gases when contrasted with the ground (Stone and Carlson, 1979). The ground assimilates the greater part of the sun powered radiation falling on it and mirrors the rest. This outcome in warming of the ground, which thusly by methods of conduction and convection, warms the air above it. Subsequently, the temperature close to the surface is higher and it diminishes as we leave starting from the earliest stage. This rate of progress of temperature with change in rise is called temperature slip by rate (TLR). TLR is taken as positive when the temperature diminishes with elevation, negative when the temperature diminishes with height and is taken as zero when the temperature does not change with the height.

2.2. RECENT STUDIES

In the previous decade, a few authors distinguish free-air (vertical) and close surface (incline) temperature for slip by rate examination (Blandford et al., 2008; Harlow et al., 2004; Pepin and Losleben, 2002). This predominantly happens due to vast pollution brought about by the geography (Kattel et al., 2013; Pepin and Losleben, 2002) and progressively factor of close surface TLRs (Blandford et al., 2008; Harlow et al., 2004). Close surface TLR changes with respect to the reality (Bolstad et al., 1998; Chung et al., 2006; Jain et al., 2008; Rolland, 2003). A few research recommended that the size of temperature slip by rate fluctuation for the most part relies upon the climate conditions, for example, wind speed, air dampness content, precipitation, relative mugginess, darkness and surface qualities, vegetation examples and separation from the ocean (Blandford et al., 2008; Bolstad et al., 1998; Chung et al., 2006; Gardner et al., 2009; Kattel et al., 2013; Laughlin, 1982; Lookingbill and Urban, 2003; Marshall et al., 2007; Pepin, 2001; Rolland, 2003; Stone and Carlson, 1979; Tang and Fang, 2006).

A few examination were done over the TLR at occasional scale for the sloping areas in everywhere throughout the world (Blandford et al., 2008; Diaz and Bradley, 1997; Gouvas et al., 2011; Harlow et al., 2004; Mahrt, 2006; Minder et al., 2010; Pepin and Losleben, 2002; Rolland, 2003; Tang and Fang, 2006). From this examination, it was reasoned that an unmistakable occasional fluctuation pattern of the TLR for example Soak in the late spring season and Shallow in the winter season. A few creator revealed the significance of the TLR in numerous fields for example glaciology, hydrology, nature, ranger service and farming in rugged areas (Blandford et al., 2008; de Scally, 1997; Diaz and Bradley, 1997; Kattel et al., 2013; Marshall et al., 2007; Minder et al., 2010; Rolland, 2003). Numerous investigations over the Himalayan and Tibetan level recommended the beginning and force of Asia's rainstorm through powerful and warm procedures (Flohn, 1957; Kitoh, 1997; Ye and Gao, 1979). As The Himalayan region, have the mind-boggling landscape and barometrical connection with Cryospheric, hydrological, geographical and ecological procedures. Consequently, a climatology changes potential effect on the atmosphere and ecological change at neighborhood, provincial and even worldwide scales (Yao et al., 2012, 2012; Yeh and Gao, 1979).

STUDY AREA

The Indus-Ganga-Brahmaputra basins form an integral part of the Himalayan foreland basin. They are the major contributors to one of the world's largest sediment routing systems. All in all, they cover a total catchment area of ~2,520,000 sq. kms. (source: Indus-Ganga-Brahmaputra Plains:). Their collective annual discharge amounts to nearly 38,510 m^3/s and annual sediment load to approximately 1490 million tonnes per year. These basins are fed by 3 main rivers of Indus, Ganga and Brahmaputra, and therefore, can be divided into Indus basin, Ganga basin and Brahmaputra basin respectively.

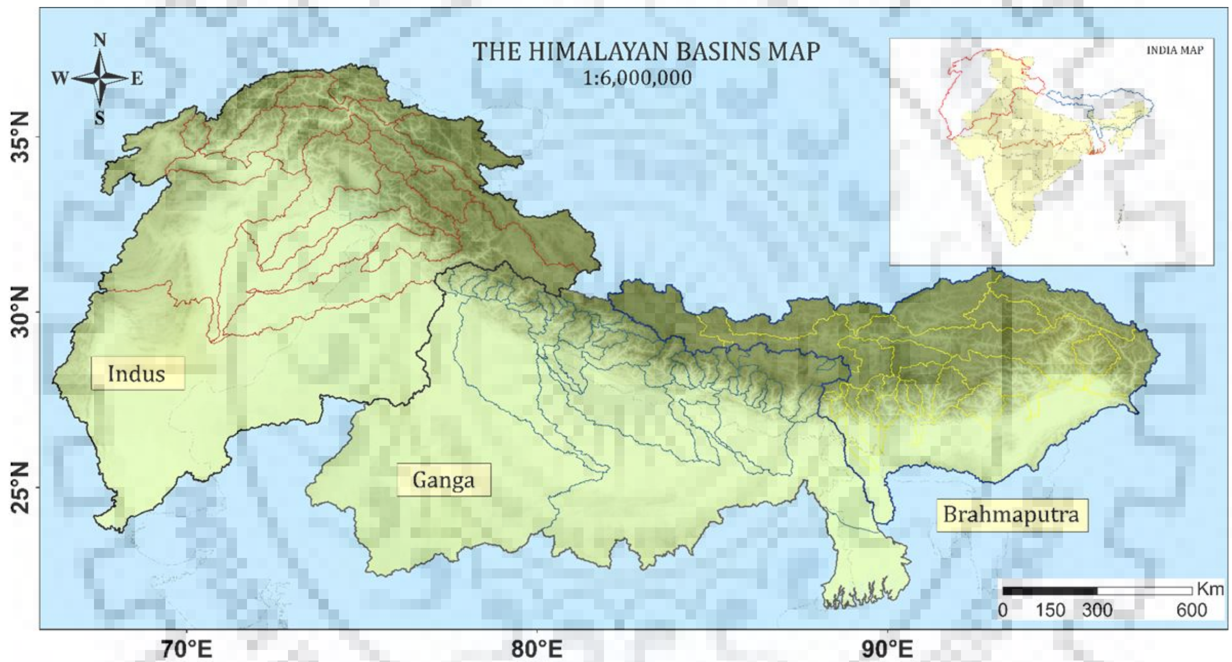

Figure 2: The study area of the proposed work

Indus river basin : The Indus basin lies in the east of the Indus-Ganga-Brahmaputra stream framework and is spread in parts of Tibet, India, Pakistan and Afghanistan over an absolute zone of 11,65,500 sq. kms(India-WRIS, 2012). The bowl lies between 72°28' to 79°39' E longitudes and 29°8' to 36°59' N scopes inside India and feeds more than 300 million individuals (Shrestha et al., 2015).The bowl is limited by the Himalayas on the east, Sulaiman and Kirthar extends on the west, Karakoram and Haramosh goes on the north and Arabian Sea on the south. The Indus River has a complete length of 3180 km, beginning from it purpose of start in Tibet to its end in the Arabian Sea. The waterway goes about as a noteworthy wellspring of water for agribusiness, businesses and human utilization and has Jhelum, the Ravi, the Chenab, the Satluj and the Beas as its foremost tributaries.

Ganga River basin: The Ganga basin frames the focal piece of the Indus-Ganga-Brahmaputra waterway framework and spreads over nations of India, Nepal, Tibet and Bangladesh covering an all out zone of 10,86,000 sq. kms(India-WRIS, 2012). Geologically, the bowl lies between 73°2' to 89°5' E longitudes and 21°6' to 31°21' N scopes inside India and feeds in excess of 500 million individuals. The Brahmaputra and the Aravalli mark the eastern and western limits of the bowl, while the Himalayas, Vindhayas, and Chhotanagpur Plateau mark the northern and southern limits of the bowl. The Ganga sustained bowl reaches out over a length of 2150 kms, beginning from Gangotri ice sheet in Uttarakhand and completing at the Bay of Bengal. The fields are further sub-separated into the Northern Mountains, the Gangetic Plains and the Central Highlands. The foremost tributaries joining the waterway are the Yamuna, the Ramganga, the Kosi, the Ghaghra, the Gandak, the BurhiGandak, the Sone and the Mahananda(Shrestha et al., 2015).

Brahmaputra basin: The Brahmaputra river basin shapes the western piece of the Indus-Ganga-Brahmaputra stream framework and stretches out over pieces of Tibet, India, Bhutan and Bangladesh depleting a region of 5,80,000 Sq.km. Topographically, the bowl lies between 88°11' to 96°57' E longitudes and 24°44' to 30°3' N scopes inside India and feed individuals. It is limited by the Himalayas on the north, the Assam goes on the south, Patkari runs on the east and the edge isolating it from Ganga bowl on the west. The Brahmaputra bolstered bowl begins from Kailsah goes in Himalayas and reaches out over a length of 2900 km. The primary tributaries of the stream are the Dibang, the Lohit, the Jiabharali, the Subansiri the DhansiritheTorsa, , the Manas, the Sankosh, the Teesta while the Burhidihing, the Desang, the Dikhow, the Dhansiri and the Kopili goes along with it from left (Shrestha et al., 2015).

The detailed description of the hydrological processes of the 3 basins has been shown in the table below.

Table 1: The detailed description of the IGB river basins

Basin Parameters	**Indus**	**Ganga**	**Brahmaputra**
Latitude	29 ° 8 ’ - 36 ° 59 ’ N	21 ° 6 ' to 31 ° 21' N	24 ° 44' to 30° 3' N
Longitude	72 ° 28 ’ - 79 ° 39 ’ E	73 ° 2 ' to 89 ° 5 ' E	88 ° 11 ' to 96° 57' E
Catchment Area (km^2)	960,000	980,000	580,000

Catchment Area Distribution (country-wise %)	Pakistan : 47% India : 39 % China : 8 % Afghanistan : 6 %	China : 3% Nepal : 14% India : 79% Bangladesh :4%	India : 36% China : 50% Bangladesh : 7% Bhutan : 7%
River length (km)	3180	2150	2880
Annual Discharge(m3/s)	7610	11,600	19,300
Contribution of Snowmelt (%)	50	22	25
Major tributaries	Shyok, Shigar, Hunza, Gilgit Jhelum, Chenab, Ravi, Beas and Satluj	Yamuna, Ramganga, Gandak, Ganghara, Kamali, Koshi, Chambal, Sindh, Ken, Betwa, Son and Punpun	Dibang, Lohit, Jiadhal,Ranganadi,Puthimari,Pagladiy,Subansiri,JiaBharali , Manas,BurhiDihing, Dhansiri, Dikhow, Kopili, Kulsi and Krishnai
Major geological features	-Structural depression -Evolution of plains is largely governed by western & eastern Himalayan syntaxis -Geologic units: Thrust sheets, Indus suture zone, Kohistan arc	-WNW-ESE oriented elongated depression -Bounded by Himalayan thrust sheets in north &Bundelkhand craton & constituents in south -variable basement depth. Bundelkhand complex, Banded Gnessic complex.	-Structural depression -Evolution of plains is largely governed by western & eastern Himalayan syntaxis -Geologic units: a.NE-SW trending Himalayan thrust sheets b.NW-SE trending Mishimi Thrust Belt c.NE-SW trending Naga-Haflong-Dibang Thrust Belt
Climate	Arid to semi-arid	Sub-tropical	Sub-tropical
Mean monthly temperature(degcelcius	-0.3-14 (winter) 18-30 (summer)	6.4-21.1 (winter) 21.5-30.3 (summer)	-0.3-9.2 (winter) 18.3-19.6 (summer)
Annual precipitation (in mm)	100 – 500 (in lowlands) ~ 3000 (mountain slopes)	760-1020 (Upper Ganges Plain) 1020-1520 (Middle Ganges Plain) 1520-2540 (Delta)	~2216 (lower brahmaputra) ~750 (upper Brahmaputra)
Precipitation dominant seasons	Winter and spring	Monsoon:70% Pre-monsoon:20%	Monsoon:70% Pre-monsoon:20%
Population (million)	300	>500	

DATA USED

To understand the temperature structure of a region, it is important to have a continuous database in space and time. In this study, both remotely sensed datasets and data from ground-based stations have been used. The details of the following datasets are given below:

Table 2: The data required in this proposed work and their purpose

S.No.	Data type	Data used	Purpose
1.	Land Surface Temperature	Terra(MOD10A2)	Daily Land Surface temperature changes with respect to elevation
		Aqua(MYD10A2)	
2.	Air Temperature	AWS: MOSDAC; IMD	Calculation of temperature lapse rate and validation of modelled air temperature data
3.	Digital Elevation Model	SRTM	For elevation information
4.	Multispectral Satellite Data	Landsat OLI	Modelling of air temperature based on surface temperature estimation from LANDSAT OLI data

4.1. LAND SURFACE TEMPERATURE (LST)

The land surface temperature (LST) information was acquired from the Moderate Resolution Imaging Spectrometer (MODIS). The MODIS instrument which locally available on Terra and Aqua satellite. These satellites use the information to watch the Earth's whole surface in 1-2 days. The Terra satellite crosses the equator in the first part of the day at 10:30 AM in a sliding mode (from north to south) while the Aqua crosses the equator toward the evening at 1:30 PM in a rising mode (from south to north). The information got will be utilized for understanding the earth procedures and communication of air Land-Oceans.

In this investigation, daily MODIS Terra (MOD11A2) and AQUA (MYD11A2) were acquired at 1Km spatial resolution from NASA earth information. A tile of MOD11A2 contains 1200 X 1200 tiles with 1200 lines and 1200 columns. MOD11A2 information contains daytime LST and evening time LST, perception times, quality evaluation, clear sky day and night, see edges.

4.2. AIR TEMPERATURE (Ta)

Automatic climate station (AWS) information for the IGB stream bowl were download from ISRO's Meteorological and Oceanographic Satellite Data Archival Center (MOSDAC). The site likewise incorporates the AWS area information acquired by IMD. The air temperature information were acquired over a time of 1998-2016. The AWS information is recovered an hour transient goals. The AWS area record additionally contains weight, precipitation, wind, mugginess and daylight conditions for investigating the day by day variety in driving variables.

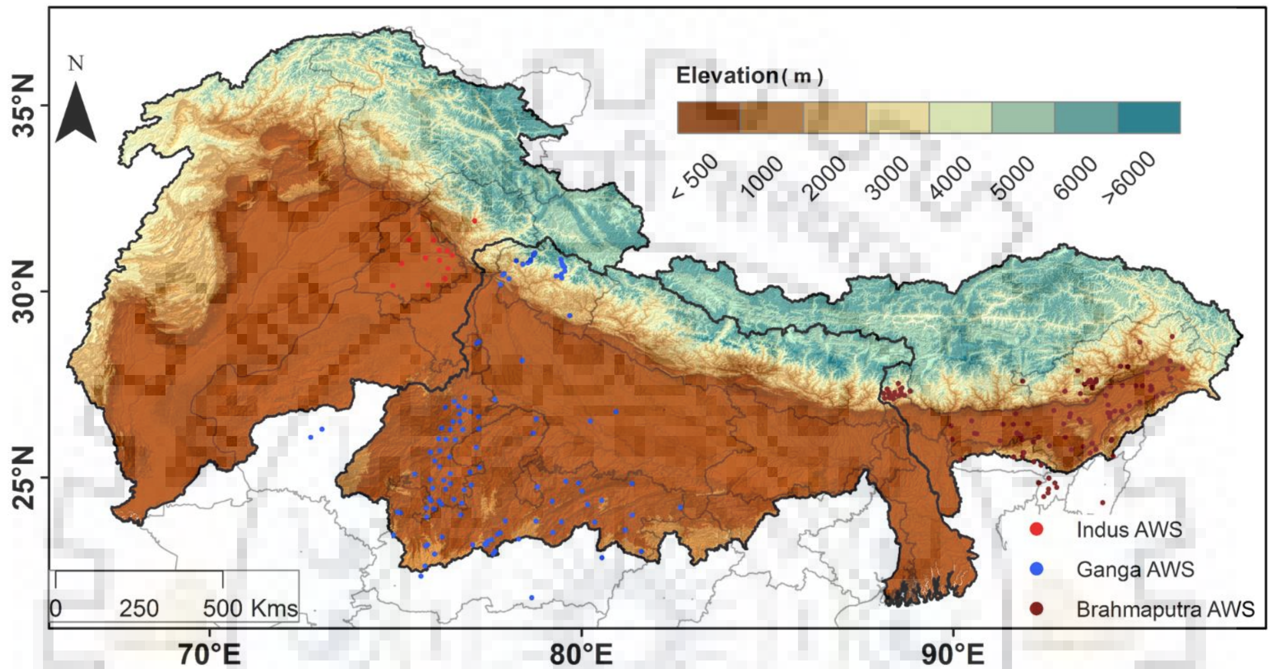

Figure 3: The location map of the AWS data

4.3. DIGITAL ELEVATION MODEL (DEM)

The void filled Shuttle Radar Topography Mission (3-circular segment SRTM) Digital Elevation Model (DEM) information with 90 m spatial goals is utilized for topographic (rise, viewpoint, and incline) data. The goals of unique DEM was re-examined with a 500m by utilizing the closest neighbor introduction technique to coordinate the spatial goals of snow secured information. Huang et al. (2011) revealed that the vertical precision of the SRTM DEM was under 16m. It is unreservedly downloadable from the United States Geological Survey (USGS) site (http://gdex.cr.usgs.gov/gdex/).

4.4. LANDSAT 8 OLI

The Landsat 8 OLI multispectral information were utilized for displayed the air temperature dependent on Land surface temperature. The Landsat 8 satellite was propelled effectively by a community venture among NASA and the U.S. Land Survey (USGS) on February 11, 2013. Its payload comprises of two science instruments—the Operational Land Imager (OLI) and the Thermal Infrared Sensor (TIRS). These two sensors give regular inclusion of the worldwide Landmass with a spatial goals of 30 meters (unmistakable, NIR, SWIR); 100 meters (warm); and 15 meters (panchromatic). Earth Resources Observation and Science (EROS) focus play out the information adjustment, satellite activities, information item age and information filing. The sans cloud symbolism is downloaded from the US Geological Survey (USGS). Landsat 8 was propelled in 11 February 2013 and has been in administration since 30 May 2013. In any case, in our investigation, we have used the dataset on 23 September 2013.

METHODOLOGY

The overall methodology adopted for monitoring and modeling of temperature rate is given below (Figure 4):

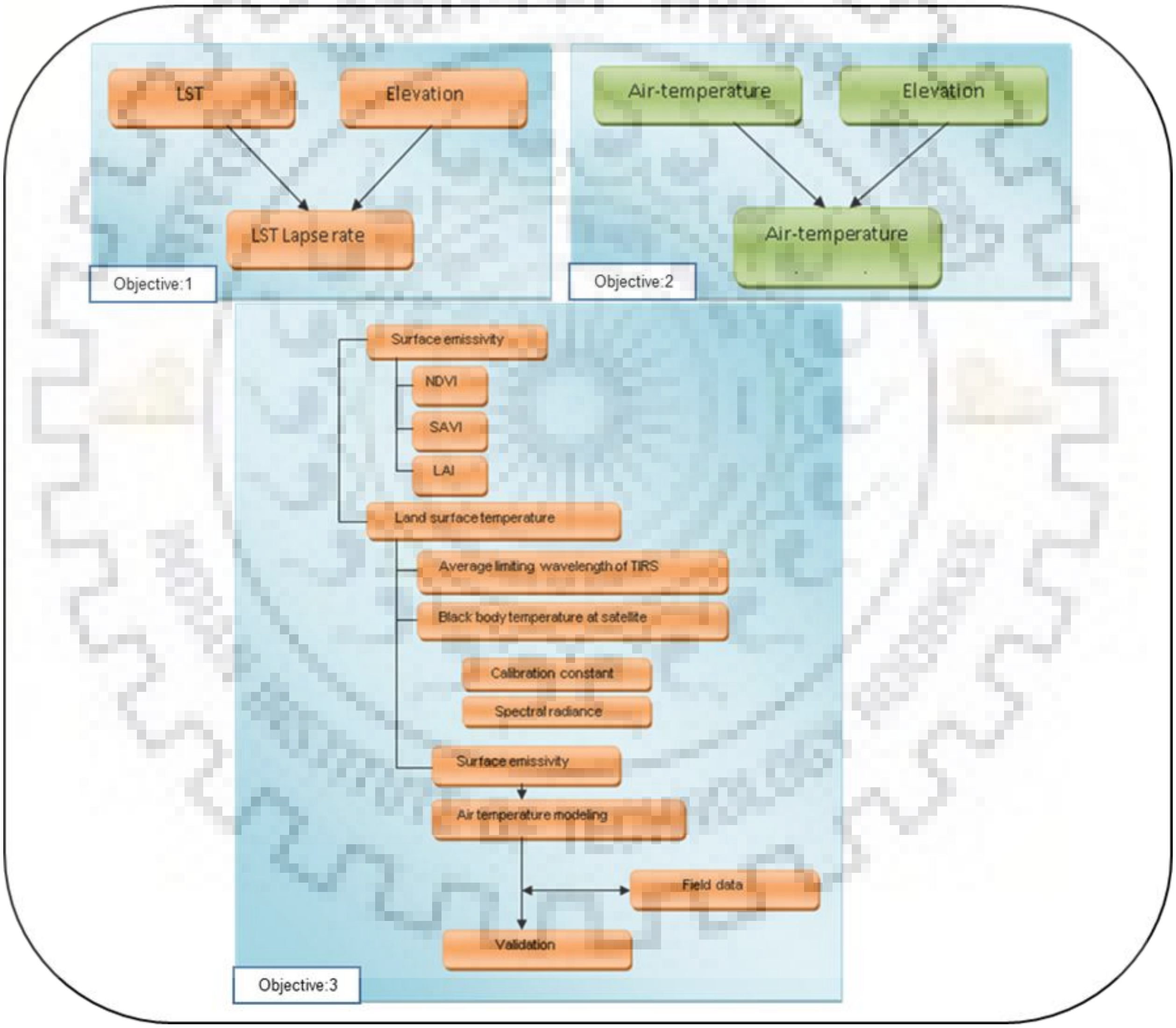

Figure 4: The overall proposed methodology

5.1. ESTIMATION OF LST LAPSE RATE

In this study, MOD11A2 version-6 provided us with an 8-day average, day and night land surface temperature per pixel of grid in a 1200 X 1200 km, for a period of 17 years, from 26 February in 2000 to 21 September in 2016. The data was extracted for the Indus-Ganga-Brahmaputra basins and was in the form spatially distributed temperature maps/image. Each pixel in the image corresponds to LST at that location. Elevation for the locations was obtained from the Digital Elevation Model (DEM) for the Indus-Ganga-Brahmaputra basins, where also each pixel in the image contained information corresponding to the elevation of that location. Linear regression analysis was used to calculate temperature lapse rate.

The linear regression method can be formally expressed as:

$$y_i = a_0 + a_1 x_i + b_i, i = 1, \dots, n \qquad \text{…. (1)}$$

where a_0, a_1 and b_i are regression coefficients, y_i is given by the dependent variable i.e. temperature and x_i is given by the independent variable i.e. elevation in this case.

The regression coefficients were calculated for each sub-basin, for each day and night. Seasonal and annual variations in LST were observed by plotting the slope (a_1) against time.

5.2. ESTIMATION OF AIR TEMPERATURE LAPSE RATE

Meteorological stations were established in the three basins to monitor the meteorological variables. Air temperature data were taken from MOSDAC and IMD for these stations for 7 years, starting from 08 September in 2011 to 31 December in 2018. Continuous hourly data was collected each for a few hours. This hourly data was averaged to calculate the mean daily temperature. Monthly and yearly data was calculated in a similar manner by averaging the daily and monthly temperatures respectively. Elevation of the respective meteorological stations was determined from the GPS data. Temperature lapse rate is given by the temperature difference divided by the height difference. For a small region, TLR was calculated by using the temperature and elevation values for 2 different weather stations in that region,

$$\text{TLR} = \frac{(T_1 - T_2)}{(h_2 - h_1)} \qquad \text{…. (2)}$$

where T_1, T_2 and h_1, h_2 are the temperatures and elevations for two weather stations , such that station 2 is at higher altitude than station 1. In this manner, monthly and yearly TLRs were calculated for each of the 3 basins.

5.3. MODELING AIR TEMPERATURE FROM LST

The multivariate linear regression method accounts for not only LST but also at least two other variables that impact Ta. Land surface variables such as NDVI (Prihodko and Goward, 1997), albedo (Cristóbal et al., 2008), elevation (Lin et al., 2012), and solar zenith angle (Cresswell et al., 1999) are used as proxies for reflecting Ta. In general, the multivariate linear regression method

can be acquired through multiple regressions:

$$T_a = b_0 + b_1 \times X_1 + b_2 \times X_2 + \cdots + b_n \times X_n \quad .....(3)$$

where $b_0, b_1, \ldots, b_n$ are regression coefficients and $X_1, X_2 \ldots, X_n$ are variables used to simulate T_a.

In this study, we first selected variables including LST, NDVI, albedo, and humidity, which are associated with surface air temperature, and then we determined coefficients of inputted variables based on stepwise linear regression. Based on the stepwise linear regression results, the selected variables and their regression coefficients are acquired given below:

$$T_a = -1.1 + 0.68 \times LST + 1.67 \times NDVI + 0.39 \times e_a - 2.6 \times \alpha \quad .....(4)$$

where e_a (hPa) is the actual water vapor pressure, α is the albedo, and Ta and LST are also in units of degrees.

RESULTS AND DISCUSSION

6.1. AIR TEMPERATURE LAPSE RATE

The sub-basin from each major river basin (IGB) were analyzed for point based air temperature. For this purpose, Alkananda –Bhagirathi (AB) sub-basin from Ganga basin,Sutlej-Beas(SB) basin from Indus and Teesta(T) basin from Brahmaputra basin were selected (as shown in figure 5).

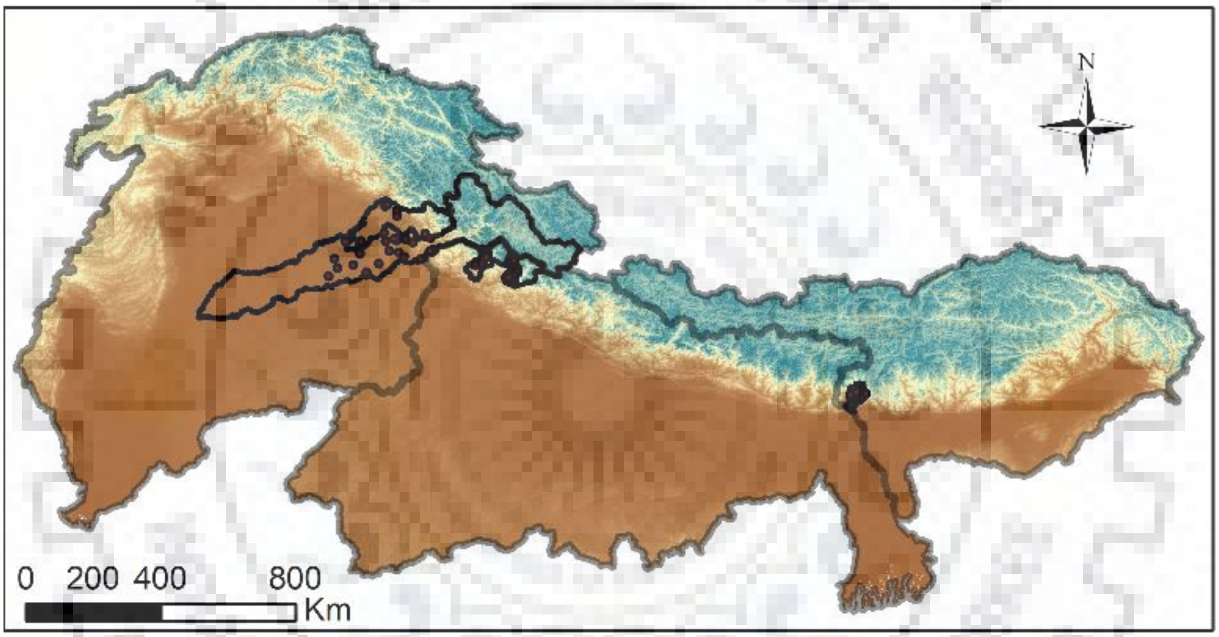

Figure 5: The number of AWS observation come inside the sub-basin

The average monthly temperature lapse rate ranges between 4.6 ºC Km^{-1} and 8.39 ºC Km^{-1} from January 2011 to December 2016 for the Alkananda and Bhagirathi river basin whereas 4.1 – 8.1ºC Km^{-1} for the Sutlej-Beasbasin and 4.9 – 6.5 ºC Km^{-1} for the Teesta river basin respectively. The average air temperature lapse rate for each of the basin is shown below (Table 3).

Table 3: Average air temperature lapse rate for the IGB sub-basin

Year	Month	AB	SB	T
2011-2016	Jan	5.20	5.2	5.5
	Feb	6.08	5.9	5.1
	Mar	6.8	7.4	4.9
	Apr	4.6	8.1	5.6

	May	5.4	7	6
	Jun	6.60	4.4	5.9
	Jul	4.98	4.1	6.5
	Aug	5.7	5	6.4
	Sep	8.39	6.4	5.4
	Oct	7.94	6.8	5
	Nov	5.58	6.3	5.5
	Dec	5.50	5.3	6

6.2. SURFACE TEMPERATURE LAPSE RATE

The MODIS extraction day and night Land surface temperature was extracted for the Indus-Ganga and Brahmaputra basin. The LST value of their corresponding elevation is plotted for each of the basin. Linear regression analysis was used to calculate temperature lapse rate. The computed temperature lapse rate for IGB river basin for daily scale is given in the table 4, 5 and 6.

Table 4: The Brahmaputra basin linear regression analysis from 2000 -2001

Date	Slope	Intercept	R^2
2000.02.26 Day	0.002096627	6.310513523	0.255146799
2000.02.26 Night	0.001226273	0.191289589	0.144040272
2000.03.05 Day	-0.000330138	12.79462845	-0.05757996
2000.03.05 Night	0.002969176	-5.25641446	0.206081005
2000.03.13 Day	-0.000596734	18.24959191	-0.106213593
2000.03.13 Night	-0.002025932	8.80893826	-0.140195181
2000.03.21 Day	0.000296846	17.83614612	0.037676824
2000.03.21 Night	0.00063583	8.516201168	0.106103489
2000.03.29 Day	-0.001919843	23.66767095	-0.244363582
2000.03.29 Night	-0.004856081	19.30833277	-0.427880283
2000.04.06 Day	0.001329264	14.51790497	0.120553727
2000.04.06 Night	0.000259734	9.946197374	0.031285884
2000.04.14 Day	-0.000645656	22.73677413	-0.080497365
2000.04.14 Night	0.001086386	7.131608485	0.11152826
2000.04.22 Day	-0.03773471	99.41814659	-0.65196961
2000.04.22 Night	-0.004296253	21.43206067	-0.462353105
2000.04.30 Day	-0.006918844	33.69754773	-0.491269165
2000.04.30 Night	0.000572672	10.81583036	0.081273312
2000.05.08 Day	0.001439894	18.47771715	0.141059186
2000.05.08 Night	-0.00032333	15.76857589	-0.06114
2000.05.16 Day	-0.001093562	24.63895179	-0.102621998
2000.05.16 Night	0.000763784	7.313607788	0.047348597
2000.05.24 Day	0.002039851	16.34370741	0.108257603
2000.05.24 Night	0.002781773	0.595033906	0.228794739
2000.06.01 Day	0.000629356	17.29510244	0.036045971
2000.06.01 Night	-0.003763489	21.78738093	-0.395709545
2000.06.09 Day	-0.002374863	24.87755231	-0.156326359

2000.06.09 Night	0.00272431	4.953597784	0.252999832
2000.06.17 Day	0.000549162	21.79172428	0.035038886
2000.06.17 Night	-0.005153704	22.95594952	-0.448338762
2000.06.25 Day	-0.004352407	22.6376319	-0.434380024
2000.06.25 Night	0.00078892	9.313755703	0.096644396
2000.07.03 Day	-0.007108565	32.91236066	-0.400152454
2000.07.03 Night	-0.002349077	10.81323219	-0.230140727
2000.07.11 Day	0.002243574	17.44197244	0.199244468
2000.07.11 Night	-0.001070419	17.85710779	-0.197024889
2000.07.19 Day	0.000847116	15.85756213	0.05440835
2000.07.19 Night	-0.003670048	21.19001741	-0.351023883
2000.07.27 Day	-0.01023168	42.0032279	-0.538907669
2000.07.27 Night	0.001493734	1.784299157	0.192461268
2000.08.04 Day	-0.000563234	6.855654344	-0.240202021
2000.08.04 Night	-0.006100241	24.16343985	-0.666777733
2000.08.20 Day	-0.000779306	23.10823742	-0.076007535
2000.08.20 Night	0.00110439	8.747124266	0.129815636
2000.08.28 Day	-0.001901464	29.37251891	-0.212095398
2000.08.28 Night	-0.00052853	10.86977941	-0.039243465
2000.09.05 Day	0.00125565	9.069045496	0.083261614
2000.09.05 Night	-0.004278343	22.1888836	-0.410206671
2000.09.13 Day	-0.001516563	22.35989511	-0.09612803
2000.09.13 Night	0.000830657	10.69606546	0.100628706
2000.09.21 Day	0.000584647	15.69723681	0.053076744
2000.09.21 Night	0.000912898	9.86071261	0.105417461
2000.09.29 Day	0.000811501	18.65254577	0.077225173
2000.09.29 Night	0.000539833	12.46509274	0.08133253
2000.10.07 Day	0.000450705	17.31661814	0.055848837
2000.10.07 Night	0.000721049	11.89223491	0.104138532
2000.10.15 Day	0.000329268	20.7163883	0.056148171
2000.10.15 Night	0.000406947	12.43824207	0.063706019
2000.10.23 Day	0.001276737	15.05459302	0.162962362
2000.10.23 Night	0.001372241	8.263756987	0.195241891
2000.10.31 Day	0.000505687	15.94371021	0.070675359
2000.10.31 Night	0.000619615	9.10175975	0.10202413
2000.11.08 Day	0.000339241	14.60789675	0.060319757
2000.11.08 Night	0.000846212	7.898384777	0.134136952
2000.11.16 Day	0.000707405	13.58013843	0.114425062
2000.11.16 Night	0.000543928	6.871677444	0.081951592
2000.11.24 Day	-4.76721E-05	14.6627721	-0.007263031
2000.11.24 Night	0.000531491	6.655860429	0.077966876
2000.12.02 Day	0.000711214	11.11383135	0.113366494
2000.12.02 Night	0.000932779	3.875434273	0.15012861
2000.12.10 Day	0.000548961	11.15276122	0.095194184
2000.12.10 Night	0.000982419	3.897149011	0.163856838
2000.12.18 Day	0.000301836	13.57920819	0.068379522
2000.12.18 Night	0.000546097	6.390945019	0.101563635
2000.12.26 Day	0.000551691	11.46051601	0.101332825

2000.12.26 Night	0.001104958	3.122590251	0.182658299
2001.01.01 Day	0.000820955	8.560619546	0.125073039
2001.01.01 Night	0.00106215	1.913146908	0.154351011
2001.01.09 Day	0.000689937	8.902967262	0.115217759
2001.01.09 Night	0.00063549	3.132313476	0.103623652
2001.01.25 Day	0.000348345	10.78659619	0.055585511
2001.01.25 Night	0.000894579	2.447182187	0.101440558
2001.02.02 Day	0.000561511	11.60482147	0.083918326
2001.02.02 Night	0.001180219	2.832620834	0.18052332
2001.02.10 Day	0.000910328	13.05157733	0.1148303
2001.02.10 Night	0.001043488	6.108894367	0.163893255
2001.02.18 Day	0.000869118	11.86501051	0.112936524
2001.02.18 Night	0.000564593	4.230927127	0.081187453
2001.02.26 Day	0.000106736	13.44871169	0.012287625
2001.02.26 Night	0.001030729	4.264231186	0.120107116
2001.03.06 Day	0.000438861	15.62109774	0.058866366
2001.03.06 Night	0.000711957	7.059574715	0.113220536
2001.03.14 Day	0.000569874	15.04195066	0.062255814
2001.03.14 Night	0.001067852	6.192641093	0.157621261
2001.03.22 Day	0.000617814	15.81683399	0.081037835
2001.03.22 Night	-0.000170054	9.522189205	-0.026412208
2001.03.30 Day	0.000798828	14.6133053	0.089823221
2001.03.30 Night	0.000267202	8.914268247	0.037989761
2001.04.07 Day	-0.00149099	22.21319048	-0.160120259
2001.04.07 Night	0.000452105	10.19278176	0.050758331
2001.04.15 Day	-0.007006458	34.41546968	-0.591790034
2001.04.15 Night	0.000711229	6.977645587	0.066745647
2001.04.23 Day	-0.00061767	22.12267524	-0.102580319
2001.04.23 Night	0.000534488	9.99270517	0.066592411
2001.05.01 Day	0.000445591	21.55717515	0.050160865
2001.05.01 Night	0.000740609	10.19272704	0.118658187
2001.05.09 Day	7.17527E-05	23.17831936	0.009576586
2001.05.09 Night	-0.000650148	14.98479167	-0.091225048
2001.05.17 Day	0.000450225	23.84788192	0.082692485
2001.05.17 Night	0.001358574	6.443683246	0.116392278
2001.05.25 Day	0.001404471	17.38078053	0.142063156
2001.05.25 Night	0.001892308	5.355656096	0.11451246
2001.06.02 Day	0.001102287	18.83081666	0.074775857
2001.06.02 Night	-0.001240048	14.91101968	-0.116621001
2001.06.10 Day	0.0012805	18.63284391	0.116901565
2001.06.10 Night	0.00070406	13.04707603	0.083814906

Table 5: The Ganga river basin linear regression analysis from 2000 -2001

Date	Slope	Intercept	R^2
2000.02.26 Day	-0.00765	29.675	-0.93393
2000.02.26 Night	-0.00829	21.56157	-0.96022
2000.03.05 Day	-0.0078	31.02974	-0.92808
2000.03.05 Night	-0.00887	22.8441	-0.95556

2000.03.13 Day	-0.00759	31.21973	-0.93375
2000.03.13 Night	-0.00893	22.95538	-0.95766
2000.03.21 Day	-0.00878	38.56147	-0.95382
2000.03.21 Night	-0.00926	28.10321	-0.96317
2000.03.29 Day	-0.00863	42.55524	-0.94294
2000.03.29 Night	-0.00868	30.10423	-0.96985
2000.04.06 Day	-0.00883	46.21966	-0.93365
2000.04.06 Night	-0.00871	30.14674	-0.96882
2000.04.14 Day	-0.00726	40.45794	-0.90407
2000.04.14 Night	-0.00746	27.03374	-0.95997
2000.04.22 Day	-0.00675	36.48527	-0.87744
2000.04.22 Night	-0.00763	27.66676	-0.9533
2000.04.30 Day	-0.00775	46.57977	-0.88956
2000.04.30 Night	-0.00773	30.77897	-0.96328
2000.05.08 Day	-0.00509	35.18197	-0.72115
2000.05.08 Night	-0.00625	27.52897	-0.95409
2000.05.16 Day	-0.00477	34.35578	-0.68585
2000.05.16 Night	-0.00562	25.27173	-0.94449
2000.05.24 Day	-0.00361	30.90963	-0.53885
2000.05.24 Night	-0.00569	25.6692	-0.93954
2000.06.01 Day	-0.00307	28.17318	-0.46247
2000.06.01 Night	-0.00593	25.07886	-0.89269
2000.06.09 Day	-0.00526	34.63841	-0.78801
2000.06.09 Night	-0.00545	25.54636	-0.94679
2000.06.17 Day	-0.00302	25.42778	-0.43768
2000.06.17 Night	-0.00426	19.77175	-0.86948
2000.06.25 Day	-0.00274	23.97312	-0.40004
2000.06.25 Night	-0.00443	21.3589	-0.88484
2000.07.03 Day	-0.00183	22.13195	-0.27166
2000.07.03 Night	-0.004	18.8824	-0.82633
2000.07.11 Day	-0.00225	23.32697	-0.28898
2000.07.11 Night	-0.00295	12.48248	-0.56784
2000.07.19 Day	-0.00157	18.34045	-0.20333
2000.07.19 Night	-0.00199	7.67534	-0.45597
2000.07.27 Day	-0.00276	22.71741	-0.46567
2000.07.27 Night	-0.00349	14.02984	-0.7615
2000.08.04 Day	-0.00246	28.58227	-0.42496
2000.08.04 Night	-0.00436	22.78343	-0.91403
2000.08.12 Day	-0.00445	27.70228	-0.25682
2000.08.12 Night	-0.0048	25.4748	-0.92908
2000.08.20 Day	-0.0032	23.40946	-0.49435
2000.08.20 Night	-0.00389	16.65833	-0.76871
2000.08.28 Day	-0.00252	23.01084	-0.42709
2000.08.28 Night	-0.00286	13.32601	-0.75022
2000.09.05 Day	-0.0035	27.61495	-0.58485
2000.09.05 Night	-0.00414	17.8448	-0.85873
2000.09.13 Day	-0.00212	23.77195	-0.35431
2000.09.13 Night	-0.00449	21.00925	-0.91103
2000.09.21 Day	-0.00341	25.53233	-0.61465
2000.09.21 Night	-0.00618	24.76371	-0.95201
2000.09.29 Day	-0.00333	27.64635	-0.56487
2000.09.29 Night	-0.00653	27.15168	-0.96245

2000.10.07 Day	-0.00394	29.91575	-0.68655
2000.10.07 Night	-0.00728	27.85867	-0.95598
2000.10.15 Day	-0.00429	32.53186	-0.70037
2000.10.15 Night	-0.00675	26.73989	-0.96688
2000.10.23 Day	-0.00383	29.25226	-0.67903
2000.10.23 Night	-0.0068	25.62136	-0.96631
2000.10.31 Day	-0.00335	25.85668	-0.63789
2000.10.31 Night	-0.0065	23.82719	-0.96645
2000.11.08 Day	-0.00502	30.0025	-0.7878
2000.11.08 Night	-0.00738	24.78886	-0.96308
2000.11.16 Day	-0.00692	32.60327	-0.82818
2000.11.16 Night	-0.00794	24.04107	-0.96081
2000.11.24 Day	-0.0086	33.26664	-0.90747
2000.11.24 Night	-0.00847	22.61428	-0.96097
2000.12.02 Day	-0.00781	31.99172	-0.89983
2000.12.02 Night	-0.00806	22.70731	-0.96468
2000.12.10 Day	-0.00695	29.39041	-0.86391
2000.12.10 Night	-0.00748	21.42672	-0.96383
2000.12.18 Day	-0.00785	34.87966	-0.88301
2000.12.18 Night	-0.0083	25.67035	-0.96378
2000.12.26 Day	-0.00677	29.81488	-0.84492
2000.12.26 Night	-0.00788	21.72776	-0.96219
2001.01.01 Day	-0.00786	26.834	-0.90697
2001.01.01 Night	-0.00859	20.71802	-0.96382
2001.01.09 Day	-0.00818	30.62579	-0.88388
2001.01.09 Night	-0.00807	20.27927	-0.96518
2001.01.25 Day	-0.00713	31.57751	-0.88009
2001.01.25 Night	-0.00763	21.49046	-0.96116
2001.02.02 Day	-0.0072	31.881	-0.87503
2001.02.02 Night	-0.00785	21.62431	-0.96487
2001.02.10 Day	-0.00725	33.9405	-0.86983
2001.02.10 Night	-0.00838	22.61535	-0.96157
2001.02.18 Day	-0.00914	36.43148	-0.94742
2001.02.18 Night	-0.0087	23.18571	-0.9538
2001.02.26 Day	-0.00926	35.51541	-0.94205
2001.02.26 Night	-0.00903	23.74633	-0.96398
2001.03.06 Day	-0.00862	36.87341	-0.93473
2001.03.06 Night	-0.00903	25.62063	-0.96825
2001.03.14 Day	-0.00905	39.5692	-0.93314
2001.03.14 Night	-0.00886	26.27194	-0.96171
2001.03.22 Day	-0.00818	36.35819	-0.94999
2001.03.22 Night	-0.00912	27.45155	-0.96741
2001.03.30 Day	-0.00795	34.72443	-0.95274
2001.03.30 Night	-0.00916	27.72838	-0.96885
2001.04.07 Day	-0.0086	41.8501	-0.95424
2001.04.07 Night	-0.0081	26.94546	-0.96306
2001.04.15 Day	-0.00758	37.4201	-0.92767
2001.04.15 Night	-0.00799	26.91655	-0.96266

2001.04.23 Day	-0.00845	44.68692	-0.93412
2001.04.23 Night	-0.00827	31.75465	-0.96802
2001.05.01 Day	-0.00681	40.79414	-0.87178
2001.05.01 Night	-0.00737	29.83013	-0.95671
2001.05.09 Day	-0.00702	44.97532	-0.85658
2001.05.09 Night	-0.0069	30.78584	-0.96307
2001.05.17 Day	-0.00529	33.67364	-0.75294
2001.05.17 Night	-0.00628	25.21419	-0.939
2001.05.25 Day	-0.00499	34.90929	-0.72941
2001.05.25 Night	-0.00595	26.07136	-0.95446
2001.06.02 Day	-0.00369	29.34494	-0.56576
2001.06.02 Night	-0.00545	23.83807	-0.92636
2001.06.10 Day	-0.00374	30.01545	-0.60315
2001.06.10 Night	-0.00578	27.04951	-0.92745
2001.07.04 Day	-0.00388	30.38908	-0.54811
2001.07.04 Night	-0.00344	16.3098	-0.75904
2001.07.12 Day	-0.00257	22.68919	-0.36067
2001.07.12 Night	-0.00166	7.198465	-0.50652
2001.07.20 Day	-0.00077	14.39089	-0.13443
2001.07.20 Night	-0.00191	8.377646	-0.4855
2001.07.28 Day	-0.00153	22.02632	-0.25717
2001.07.28 Night	-0.00316	15.14994	-0.76988
2001.08.05 Day	-0.00262	23.15923	-0.39281
2001.08.05 Night	-0.00241	12.40369	-0.73593
2001.08.13 Day	-0.00149	18.98637	-0.2455
2001.08.13 Night	-0.00254	12.18772	-0.55353
2001.08.21 Day	-0.00174	21.39177	-0.2866
2001.08.21 Night	-0.00353	17.12346	-0.81022
2001.08.29 Day	-0.00178	22.77855	-0.31611
2001.08.29 Night	-0.00414	20.00848	-0.89943
2001.09.06 Day	-0.00225	25.99155	-0.40102
2001.09.06 Night	-0.00494	22.57869	-0.92459
2001.09.14 Day	-0.00312	28.13057	-0.54825
2001.09.14 Night	-0.00605	26.56282	-0.95916
2001.09.22 Day	-0.00326	29.41156	-0.57042
2001.09.22 Night	-0.00621	27.22739	-0.96269
2001.09.30 Day	-0.00324	27.42406	-0.59238
2001.09.30 Night	-0.00643	27.39313	-0.96166
2001.10.08 Day	-0.0035	28.27109	-0.64866
2001.10.08 Night	-0.00665	26.17472	-0.96333
2001.10.16 Day	-0.00372	27.64337	-0.66803
2001.10.16 Night	-0.00647	24.71931	-0.96418
2001.10.24 Day	-0.00383	28.21609	-0.68749
2001.10.24 Night	-0.00658	24.77864	-0.96616
2001.11.01 Day	-0.00465	28.21159	-0.75067
2001.11.01 Night	-0.00756	24.83465	-0.96304
2001.11.09 Day	-0.00588	32.5708	-0.81489
2001.11.09 Night	-0.0074	25.50478	-0.96542

2001.11.17 Day	-0.00499	29.34456	-0.76913
2001.11.17 Night	-0.00688	23.64673	-0.96562
2001.11.25 Day	-0.00532	28.73147	-0.79364
2001.11.25 Night	-0.00733	22.48542	-0.96929
2001.12.03 Day	-0.00566	28.53901	-0.84013
2001.12.03 Night	-0.00691	19.96757	-0.96138
2001.12.11 Day	-0.00725	27.16474	-0.88303
2001.12.11 Night	-0.00778	19.66964	-0.95226
2001.12.19 Day	-0.00848	31.88446	-0.93368
2001.12.19 Night	-0.00854	23.6985	-0.96408
2001.12.27 Day	-0.00918	32.9201	-0.92097
2001.12.27 Night	-0.00906	23.52337	-0.96573

Table 6: The Indus river basin linear regression analysis from 2000 -2001

Date	Slope	Intercept	R^2
2000.02.26 Day	-0.00822	28.35416	-0.81635
2000.02.26 Night	-0.00816	17.8482	-0.8213
2000.03.05 Day	-0.00804	27.29636	-0.82797
2000.03.05 Night	-0.00933	19.83175	-0.8281
2000.03.13 Day	-0.00806	29.41275	-0.81498
2000.03.13 Night	-0.00999	22.59601	-0.82594
2000.03.21 Day	-0.00856	35.61354	-0.8174
2000.03.21 Night	-0.00894	25.84107	-0.83704
2000.03.29 Day	-0.00855	38.83492	-0.81889
2000.03.29 Night	-0.00869	26.00086	-0.83674
2000.04.06 Day	-0.0096	45.54997	-0.82547
2000.04.06 Night	-0.00842	27.14011	-0.84055
2000.04.14 Day	-0.00907	44.53081	-0.82237
2000.04.14 Night	-0.00821	27.8057	-0.83492
2000.04.22 Day	-0.00859	40.98655	-0.81764
2000.04.22 Night	-0.00783	26.15608	-0.82581
2000.04.30 Day	-0.00876	46.23065	-0.80939
2000.04.30 Night	-0.00768	29.0094	-0.83384
2000.05.08 Day	-0.00571	34.30023	-0.68987
2000.05.08 Night	-0.00646	26.79263	-0.83313
2000.05.16 Day	-0.00582	36.29031	-0.71817
2000.05.16 Night	-0.00641	27.46113	-0.83498
2000.05.24 Day	-0.00596	37.59612	-0.73639
2000.05.24 Night	-0.00672	27.69242	-0.832
2000.06.01 Day	-0.00516	34.44196	-0.70928
2000.06.01 Night	-0.00765	29.87283	-0.82335
2000.06.09 Day	-0.00549	33.23683	-0.7109
2000.06.09 Night	-0.00624	26.48492	-0.82605
2000.06.17 Day	-0.00426	27.74201	-0.57371
2000.06.17 Night	-0.00527	23.02811	-0.78775
2000.06.25 Day	-0.00452	28.10631	-0.60455
2000.06.25 Night	-0.00489	22.49051	-0.78755
2000.07.03 Day	-0.00367	25.38329	-0.5558

2000.07.03 Night	-0.0049	23.95756	-0.78548
2000.07.11 Day	-0.00686	31.73192	-0.76471
2000.07.11 Night	-0.00517	22.49793	-0.68984
2000.07.19 Day	-0.00485	27.55708	-0.59309
2000.07.19 Night	-0.00226	10.12484	-0.45333
2000.07.27 Day	-0.00452	25.56787	-0.54381
2000.07.27 Night	-0.00419	16.88019	-0.70279
2000.08.04 Day	-0.00349	27.56556	-0.57982
2000.08.04 Night	-0.0047	24.32634	-0.80377
2000.08.12 Day	-0.0029	26.55519	-0.50182
2000.08.12 Night	-0.00511	26.1917	-0.76611
2000.08.20 Day	-0.00168	19.9083	-0.31154
2000.08.20 Night	-0.00469	22.53277	-0.76282
2000.08.28 Day	-0.00332	26.22118	-0.56139
2000.08.28 Night	-0.00434	20.6688	-0.76814
2000.09.05 Day	-0.00324	27.15127	-0.62596
2000.09.05 Night	-0.00512	21.74115	-0.80389
2000.09.13 Day	-0.00331	28.09734	-0.61235
2000.09.13 Night	-0.00486	22.61449	-0.7982
2000.09.21 Day	-0.00443	27.0951	-0.6518
2000.09.21 Night	-0.00623	23.49652	-0.80496
2000.09.29 Day	-0.00443	30.39626	-0.66491
2000.09.29 Night	-0.00612	25.14367	-0.81478
2000.10.07 Day	-0.00456	30.67551	-0.68841
2000.10.07 Night	-0.00606	22.72918	-0.81579
2000.10.15 Day	-0.00492	33.92247	-0.70956
2000.10.15 Night	-0.00599	23.70875	-0.81349
2000.10.23 Day	-0.00413	29.96746	-0.66794
2000.10.23 Night	-0.00594	22.22582	-0.82043
2000.10.31 Day	-0.00376	26.51321	-0.6458
2000.10.31 Night	-0.00582	20.633	-0.81688
2000.11.08 Day	-0.00532	28.66086	-0.71896
2000.11.08 Night	-0.00684	20.13282	-0.79608
2000.11.16 Day	-0.00795	30.6557	-0.81132
2000.11.16 Night	-0.00846	22.23776	-0.77642
2000.11.24 Day	-0.00968	31.7581	-0.86056
2000.11.24 Night	-0.00924	21.10152	-0.81898
2000.12.02 Day	-0.00928	33.407	-0.84334
2000.12.02 Night	-0.00864	21.62498	-0.82302
2000.12.10 Day	-0.00885	32.96213	-0.82198
2000.12.10 Night	-0.00817	20.92449	-0.82991
2000.12.18 Day	-0.00916	35.27378	-0.82879
2000.12.18 Night	-0.00881	24.29437	-0.83746
2000.12.26 Day	-0.00853	31.34517	-0.79719
2000.12.26 Night	-0.00893	22.55376	-0.8397
2001.01.01 Day	-0.00914	30.45599	-0.81901
2001.01.01 Night	-0.00878	19.02576	-0.83475
2001.01.09 Day	-0.00921	32.59116	-0.81847

2001.01.09 Night	-0.00885	20.31241	-0.84154
2001.01.25 Day	-0.00851	31.00336	-0.82046
2001.01.25 Night	-0.00844	20.65453	-0.8361
2001.02.02 Day	-0.00892	33.77689	-0.79847
2001.02.02 Night	-0.00851	20.59147	-0.83771
2001.02.10 Day	-0.0091	36.06766	-0.8083
2001.02.10 Night	-0.00845	20.18722	-0.83085
2001.02.18 Day	-0.00991	36.50776	-0.85161
2001.02.18 Night	-0.00942	21.50958	-0.8262
2001.02.26 Day	-0.00915	32.08035	-0.83726
2001.02.26 Night	-0.00956	22.35397	-0.84244
2001.03.06 Day	-0.0092	37.24187	-0.82942
2001.03.06 Night	-0.00931	24.94747	-0.83811
2001.03.14 Day	-0.009	35.24201	-0.82904
2001.03.14 Night	-0.00918	24.85645	-0.83259
2001.03.22 Day	-0.0084	35.05236	-0.82491
2001.03.22 Night	-0.00908	25.39193	-0.8387
2001.03.30 Day	-0.00825	35.74384	-0.82475
2001.03.30 Night	-0.00881	25.4633	-0.838
2001.04.07 Day	-0.00886	41.91384	-0.80518
2001.04.07 Night	-0.00814	25.17148	-0.83025
2001.04.15 Day	-0.00775	35.28842	-0.81234
2001.04.15 Night	-0.00845	25.90278	-0.82891
2001.04.23 Day	-0.00904	43.97548	-0.80742
2001.04.23 Night	-0.00819	28.9587	-0.82839
2001.05.01 Day	-0.00837	44.50161	-0.80671
2001.05.01 Night	-0.00741	28.59154	-0.83432
2001.05.09 Day	-0.00838	47.08434	-0.79077
2001.05.09 Night	-0.00717	30.18153	-0.82049
2001.05.17 Day	-0.00583	34.34198	-0.71891
2001.05.17 Night	-0.00657	24.34513	-0.81322
2001.05.25 Day	-0.00638	37.8071	-0.73881
2001.05.25 Night	-0.00636	26.67665	-0.82555
2001.06.02 Day	-0.00449	29.84465	-0.62307
2001.06.02 Night	-0.00623	25.72476	-0.82533
2001.06.10 Day	-0.00486	30.83987	-0.62996
2001.06.10 Night	-0.00558	26.73049	-0.78713

6.3. AIR TEMPERATURE LAPSE RATE MODELING FROM LST

The pilot was performed for the Bhaga basin using the Landsat 8 satellite. The Satellite was used to estimate the Land surface temperature, emissivity, NDVI and albedo over the large area. The air temperature can be modeled using the Land Surface, albedo, NDVI and other constant variable. The estimated modeled air temperature ranged from -5.44 to 25.63 ºC. The modeled output is validated with the field observation obtained from the AWS data. It was observed that the modeled air temperature shows ± 0.5 º C error with the observation data. The obtained result well correlated with the station data. This modeled output overcomes the AWS location limitation.

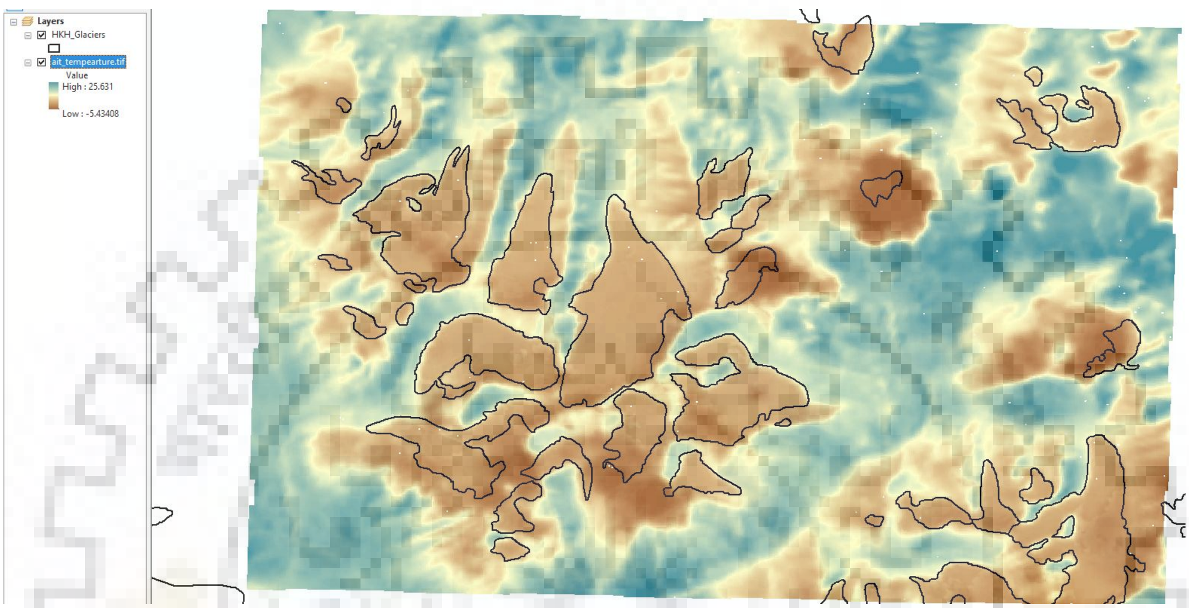

Figure 6: Modeled air temperature for the Bhaga basin

CONCLUSION

The present work provides a vision into the behavior of local near surface and air temperature lapse rate in the major river basin (IGB). The slope lapse rate of air temperature in the alpine zone of the Himalayan catchment show distinct variation with the valley scale slope lapse rate. This suggests that the snow/glacier melt runoff and mass balance model by temperature index method may preferably use the lapse rate observed in the alpine zone.Yearly varieties in the slip by rate in the snow capped catchment were extremely high. This likely came about because of the varieties in snow spread degree and its thickness in the high zone and closeness of the stations to the snowline. Valley scale slip by rate show decreased pass rate amid the storm months (June, July and August) when contrasted with the remainder of the removal months proposing airflow under soaked adiabatic conditions and arrival of idle warmth amid buildup. Anyway, slip by rate of elevated zone dosen't show such a pattern. Future slip by rate checking for glaciological considers in the Himalayas should be centered on the snow capped zone of the catchment instead of utilizing slip rate estimations of lower rises or valley scale pass rates. For several investigations, air temperature is a significant segment. In complex and roughed terrain, for example, the Himalayas, meteorological stations gathering air temperature information are scantily found and the perceptions, being point information, are not delegate of the entire landscape. In such conditions, LST maps arranged from satellite pictures are an alluring option. LST maps give a ceaseless dataset. They are set up from satellite information, which naturally measure brilliance esteems, making them free from human blunder gave an exact radiometric adjustment of the sensor stations is accomplished. In this examination, LST was estimated for the IGB river basin during the 2001-2017. The TLR on account of LST differed from 6.5-7.2º C/Km. The scope of slip by rate got from the present investigation can be utilized with trust in snowmelt overflow and different examinations. The surface air temperature was significantly modeled on regional scale based on the energy balance characterizations underlying the surface and atmosphere. The multivariate linear regression method is used for the air temperature retrieval through remote sensing. This method is based on the empirical correlation between the air temperature and other variables. The obtained is tested with the field observation and regressive analysis generating histograms, and overlying with different surfaces. The modeled method based air temperature depends upon the accuracy, size of the study area and the remote sensing image resolution. It is important to determine the change in temperature with elevation to map the climate change and sustainable water resource management.

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