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Assessment of regional climatic changes in the Eastern Himalayan region: a study using multi -satellite remote sensing data sets

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1. Introduction

Regional air pollution, glacial retreat and climate change are three large-scale environmental issues which have captured the attention of scientists and policymakers all around the world. To study changes of regional climate and their impacts on the cryospheric component of Earth system there is a need to assess the climatology and landscape of any region for at least 30 years. Due to the inaccessibility, unavailability of long term on-field data and availability of satellite data, changes in Eastern Himalaya of Sikkim have been studied using satellite data.

Study Area

Eastern Himalaya is situated between Central Nepal in the west and Myanmar in the east, occupying southeast Tibet in China, Sikkim, North Bengal, Bhutan and North-East India. Here the focus is on the Himalaya of Sikkim. Sikkim is a small state with area of ~7,455 square km and population of 54,0851. It has a relief ranging from 235 – 8556 m a.s.l..

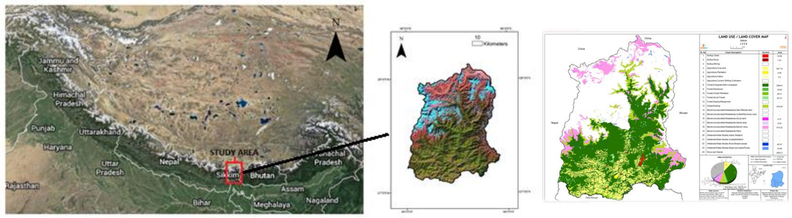

Figure 1: Inset of Sikkim (red box) located in High Asia (left). Land Use Land Cover map of Sikkim (Source: http://bhuvan-noeda.nrsc.gov.in/theme/thematic/tools/document/LULC/MAP/11.jpg, right).

2. Datasets

Different datasets like water balance data from Hydrological Information System (HIS) of India, Landsat images from Earth Explorer, Atmospheric Infrared Sounder data (carbon dioxide, methane, CO and ozone), Modern Era Retrospective-Analysis for Research and Applications (MERRA 2D) data sets (albedo, temperature at 500 hPa, absorbed longwave at the surface; latent heat flux over land and sensible heat flux over land), Aerosol Optical Depth (AOD) from Terra, Black carbon column optical depth (550 nm) from Giovanni web portal and Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO) have been used. The details of the data are given in the table below:

Landsat data				
Date	Sensor	Mission	Resolution (m)	Path/ Row
30.11.1976	MSS	Landsat 2	60	149/41
12.13.2001	ETM+	Landsat 7	30	139/41
27.08.2011	TM	Landsat 5	30	139/41
21.11.2013	OLI	Landsat 8	30	139/41
IMD data				
Time Period	Type of data	Data archived from station		Type of data
1971-2005	Water Balance	IMD grid data (downloaded from Hydrological Information System)		Sub-catchment level
1966-2000	Temperature	Gangtok		Monthly average
CALIPSO data				
01-08-2013	VFM nighttime image	North-East India		
From Giovanni portal				
Time Period	Type of data	Longname of the data downloaded		Resolution
1979-2011	Albedo, Temperature Shortwave, Longwave, Latent heat and Sensible heat fluxes	Surface albedo, Temperature at 500 hPa , Net downward shortwave flux over land, Net downward longwave flux over land, Latent heat flux from land, Sensible heat flux (positive upward)		2/3° × 1/2°
2001-2011	AOD	Aerosol Optical Thickness at 0.55 microns for both Ocean (best) and Land (corrected): Mean of Daily Mean		0.5° × 0.5°
2003-2011	CH_4 Vmr, CO, O_3	CH_4 volume mixing ratio ascending, Total column CO, Total column O_3		1° × 1°
2003-2011	CO_2 mole fraction	Mole fraction of carbon dioxide in free troposphere		2.5° × 2°

Table 1: Details of the data used.

3. Methodology

A. Analysis of climatological data

Different statistical tests like Mann-Kendall, Theil and Sen's slope estimator, Buishand's U and Pettitt-Mann-Whitney tests are used for trend, slope of trend, shift and year of shift detection respectively.

B. Change in glacierised area

East Rathong watershed consists of 36 glaciers. The glacierised area of the 36 glaciers of East Rathong basin for the years 1976 and 2013 is estimated individually using unsupervised and supervised classification. Difference in the sum of the glacierised areas computed for all the glaciers together for 1976 and 2013 gave the change in the glacierised area (area I) of the basin from 1976 and 2013. The change in glacierised area of the East Rathong basin (area II) is again estimated using change detection method (image differencing approach). Hence, error involved in the change in the glacierised area estimated using image differencing approach is as follows:

$$Correction\ factor\ (E) = Area\ II / Area\ I$$

The actual change in the glacierised area (dC) becomes:

$$dC = dC_i / E$$

where dC_i = change estimated using image differencing approach

Change in glacierised area of Sikkim is estimated using change detection method. Change estimated is divided with E to estimate the actual change in the glacierised area.

C. Analysis of water balance data

For water balance analysis of the state precipitation, evapotranspiration (ET), groundwater, water yield and soil water data for time period 1971–2005 are downloaded for all the sub-catchments of the state. The data was downloaded under virgin scenario, i.e. the unprocessed conditions or the scenario under which the data was collected. The data is statistically analyzed to detect the presence of trends and shifts at the sub-catchment level.

D. Estimation of built-up and vegetated area

Following Zha et al. (2003), two classes are made, barren land and built-up area as one class and vegetated area (woodland and farmland) as one class. The area is estimated for both the classes for years 2001 and 2011.

3. Results

Changes in the landscape of Sikkim

Average rate of loss of the glacierised area from 1976 to 2013 has been estimated to be ~2.21 square km/year.

It has been found that from 2001 to 2011 class A (built-up and barren area) has decreased by 36 % and class B (wood-land and grassland area) has increased by ~6.5 %. Changes in class A and class B are almost the same in terms of area.

Changes in the water balance

Parameter	Time-period (years)	Change	Slope of trend	Significant Trend	% change over mean
Water Yield	35	-28.25 %	-28.48	-ve	-46.77
Precipitation	35	-22.42%	-26.81	-ve	-34.63
Evapotranspiration	35	5.91%	2.7	+ve	17.82
Soil Water	35	2.79%	2.07	Absent	9.5
Ground Water	35	-15.36%	-5.33	-ve	-27.64

Table 2: Summary of hydrological parameters assessed to study the change in the regional climate of Sikkim for the time period 1971-2005.

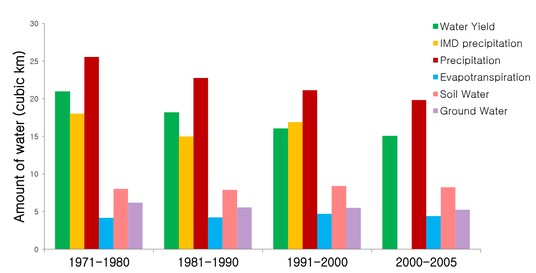

Figure 2:Details of water balance of Sikkim from 1971-2005.

Changes in the climatological variables

Parameter	Time-period (years)	Change	Statistically significant Trend	Slope of trend	Magnitude of change	Significant Shift	Change in mean before and after the shift
T500	40	0.7±0.46 ºC	+ve	0.02	0.24	1997	0.413
IMD Gangtok station temp	40		Absent			1976	-0.83
absorbed longwave radiation	30	6±2.41 W/ m^2	+ve	0.21	2.33		
Heat fluxes	33	2±0.97 W/ m^2	+ve	0.05	1.41		
Albedo	30		Absent			1997	-0.002
CO_2	10	4.42%	+ve	2.09	4.92	CO_2	10
Methane	10	0.61%	+ve	0.001	0.7	Methane	10
Ozone	10	0.67%	+ve	0.23	0.8	Ozone	10
BC optical depth	10	7.19%	+ve	1.8×10^{-5}	0.5	BC optical depth	10
CO	10	-2.61%	Absent	0.006	-3.11	CO	10
AOD	10	19.16%	+ve	0.005	14.42	AOD	10

Table 3: Summary of climatological parameters assessed to study the change in the regional climate of Sikkim for the time period 1971-2011.

5. Conclusions

With the help of satellite data, this study has captured regional changes in the landscape, hydrological cycle, atmospheric chemistry and radiation budget of Sikkim during the past 46 years. From the analyses, the following conclusions have been drawn:

- Urban sprawl, increasing energy demands and increasing air pollution are causing rapid environmental degradation of Sikkim.
- An increase in temperature at an altitude of 5.5 km and the suppression of precipitation caused by increasing aerosol concentration have led to rapid retreat of Sikkim Himalayan glaciers. Eastern Himalayan glaciers are found at the altitude at which generally the aerosol layers are found. Hence, increasing AOD and concentration of aerosols have made Eastern Himalayan glaciers highly vulnerable to the impacts of climate change.
- This study is another proof of the fact that mountainous regions are vulnerable to elevation-dependent warming.
- The technique of change detection can be effectively used to estimate change in a glacierised area.

Acknowledgement

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References

1. Goddard Earth Sciences data and Information Services Center (GES DISC), viewed on 17 June 2013 (http://disc.sci.gsfc.nasa.gov).
2. Hydrological Information System, IIT Delhi, viewed 15 February 2012, http://gisserver.civil.iitd.ac.in/natcom/.
3. Zha, A., Gao, J., & Ni, S. (2003). Use of normalized difference built-up index in automatically mapping urban areas from TM imagery. International Journal of Remote Sensing, 24, 583–594.