Analysis Of Snow Cover Information Based On Weekly EOS-MODIS Data For The Gangotri Glacier Basin, Garhwal Himalaya

M. Tamil Selvan
Centre for the Study of Regional Development,
Jawaharlal Nehru University
New Delhi – 110 067

Abstract

The snow cover, which is an important component of the climatic system and a main indicator factor of the global change, will affect temperature, precipitation and other climatic factors. The MODIS/Terra Snow Cover 8-Day L3 Global 500m Grid (MOD10A2) data set contains data fields for maximum snow cover extent over an eight-day compositing period. A chronology of snow occurrence observations available in compressed Hierarchical Data Format-Earth Observing System (HDF-EOS) format, along with corresponding metadata. In this paper, the snow distribution information of Gangotri Basin of Garhwal Himalaya was extracted based on the weekly EOS-MODIS data for the year 2001-2002. Altitudinal Zone wise analysis also carried out to see the changes within the different elevation zones.

1. Introduction

The utility of Remote Sensing and GIS has revolutionised the studies in the field of glaciology. The satellite data provides synoptic, multi-spectral and repetitive coverage, which can be highly useful for inventory based studies of natural resources and evaluation of terrain. The Moderate Resolution Imaging Spectroradiometer (MODIS) snow cover data are based on a snow mapping algorithm that employs a Normalized Difference Snow Index (NDSI) and other criteria tests. The MODIS instrument acquires images in 36 spectral bands between 0.405 and 14.385mm have spatial resolutions of 250, 500 & 1000m. These bands designed especially to image the land surface. Highest resolution MODIS products are produced at a spatial resolution of 500m. MOD10A2 consists of 1200km by 1200km tiles of 500m resolution data gridded in a sinusoidal map projection. Most of the earth snow covered areas are imaged daily, with only snow cover at low altitude being imaged on other day.

The basis for all MODIS snow cover product is the MODIS snow-mapping algorithm. It is based on long lineage of snow detection algorithm and was developed using Landsat Thematic Mapper(TM) data as a MODIS surrogate. In the MODIS snow-mapping algorithm, snow is distinguished from other surface covers from other surface by two primary distinguishing features. The first is its high reflectance in the visible wavelengths (MODIS band 4 at 0.545 – 0.565mm) and second its low reflectance in the short wave infrared (MODIS band 6 at 1.628 –1.652mm). The snow detection algorithm for MODIS takes advantage of this unique spectral combination allowing for fully automated and computationally frugal approach to snow detection.

The study by Ningyu Zhang et al., (2008) shows that the remote sensing data of MODIS imagery has better applicability in monitoring the temporal and spatial variations of snow-covered conditions. Kumar (1991) also made sow cover mapping and modeling exercise using the different satellite data for the Beas basin gives better result, which can not be done using the conventional methods. An index developed by Negi et. al., 2007 for identifying accumulation and ablation zone is very important for any study of snow cover in Himalayan system.

2. Study Area

Gangotri glacier is one of the largest glacier of the Himalayas. This glacier is located in the Uttarkashi district of Uttaranchal state in the Garhwal Himalayan region. This is the sub-basin of the Bhagirathi River Basin. The total area of Gangotri glacier, which is a cluster of many glaciers is about 525km^2. The snout of the Gangotri glacier is known as Gomukh.

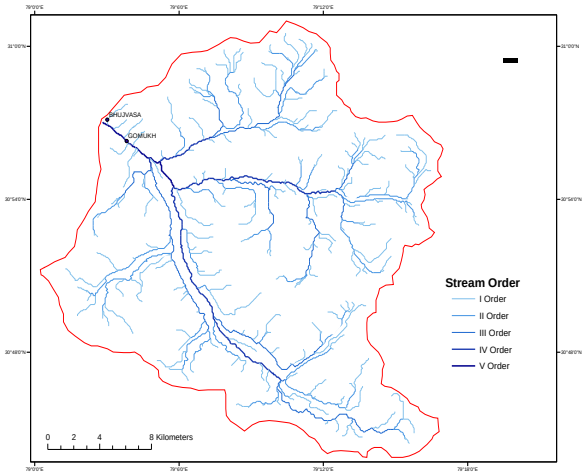


Figure 1: Base Map of the Gangotri basin, Garhwal Himalaya

3. Data Base

Shuttle Radar Topography Mission(SRTM) 30m interval data is used to generate the contour map of the basin. The MODIS products are spatial and/or temporal composite of individual snow observation from all MOD10_L2 products covering a particular area. These data are provided by National Snow and Ice Data Centre (NSIDC). Temporal composites of individual snow observation at 500m resolutions are composite for 8 day periods MODIS/Terra Snow Cover 8 day L3 Global 500m SIN Grid –MOD10A2. Observations in this 8 day snow cover products are provided for $10^0 \times 10^0$ regions and are distributed in Sinusoidal map projection developed by MODIS land discipline group. Snow cover by using standard MODIS snow cover maps was overlain by the basin boundary and snow extent in the basin was measured on pixel.

4. Methodology

Remote sensing technologies introduce a potential scientific basis for the extraction of snow cover information, which is the basis and key of snow cover study. The MODIS snow-mapping algorithm is used to map snow for individual 500m pixel within MODIS swath using the following inputs: calibrated radiances (MOD02HKM), the MODIS cloud mask and solar and satellite viewing geometries, as well as other ancillary information from MOD03 geolocation product. The resulting snow product is the MODIS/ Terra Snow Cover MOD10 A2 Swath 500m product. Finally, the snow cover information extraction model was established by Spatial Modeler Tool in ERDAS software as used in Zhiming Liu et al., 2008.

Based on the SRTM data, Digital Elevation Model(DEM) was generated. Using this DEM, the stream order information has been extracted using the GIS techniques. In view of the great elevation range, Gangotri basin was divided into four elevation zones and the snow coverage was evaluated separately for each elevation zone. Detailed study of the Gangotri basin has been done using these Four Altitudinal and Climatic Zone.

5. Result and Discussion

a. Continuous Snow Cover Study

The time series analysis of snow cover derived from MODIS for the year 2001-2002 is used to predict the snow cover extent in the basin. Figure 2 and 3 shows the continuous snow cover variations over the period of time.

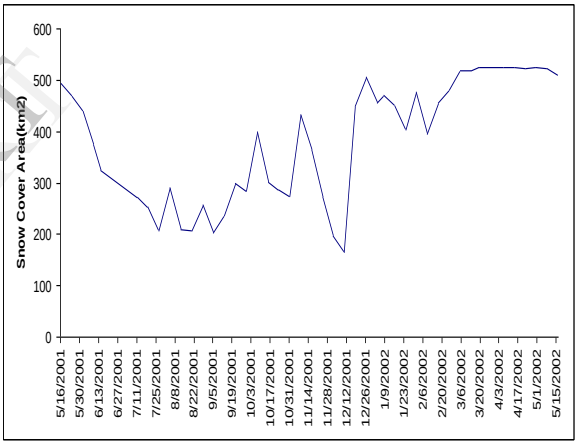


Figure 2: Weekly Snow Cover Area of the Gangotri Basin from May 2001 to May 2002

As the snow cover area from May 2001 to May 2002 has been extracted and plotted against its time series. So, we could able to get the continuous information of snow cover area and non-snow area for the whole year. Above graph clearly shows that melting process starts in the end of May and it goes continuously upto starting of the December. As it shows that the snow fall started very late compare to other years as it normally starts in the starting of November. Snow cover area increases with time till middle of March.

Figure 3: Weekly Snow Cover Area of the Gangotri Basin from May 2001 to May 2002

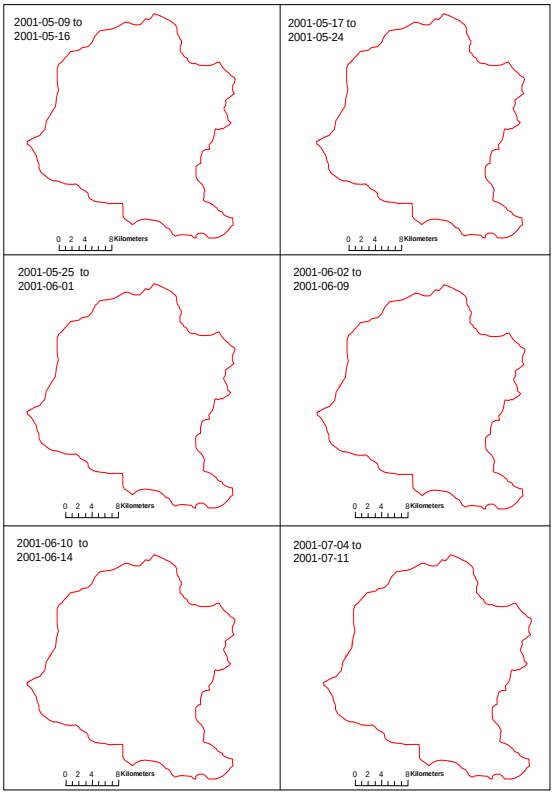


Figure 3: Weekly Snow Cover Area of the Gangotri Basin from May 2001 to May 2002 cont…

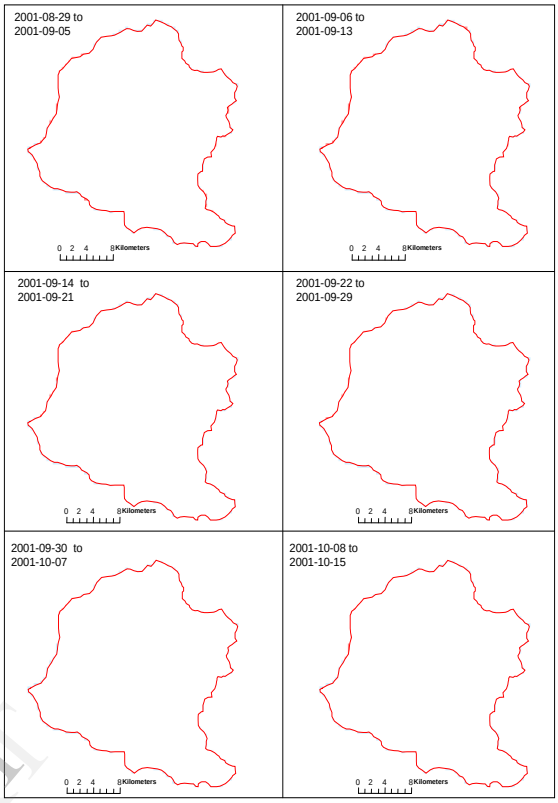


Figure 3: Weekly Snow Cover Area of the Gangotri Basin from May 2001 to May 2002 cont…

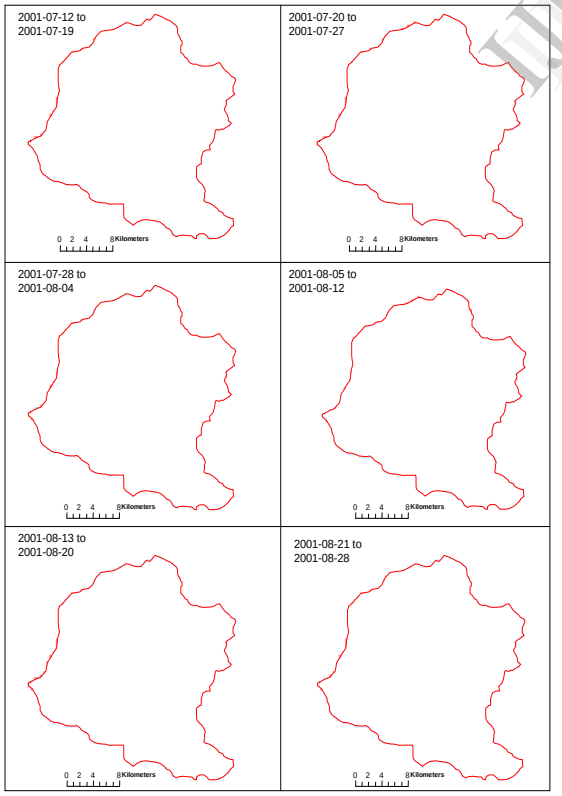


Figure 3: Weekly Snow Cover Area of the Gangotri Basin from May 2001 to May 2002 cont…

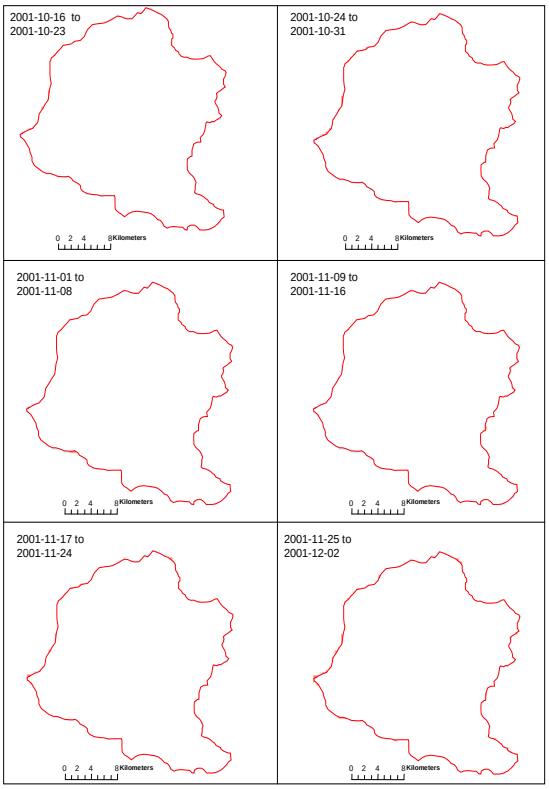


Figure 3: Weekly Snow Cover Area of the Gangotri Basin from May 2001 to May 2002 cont…

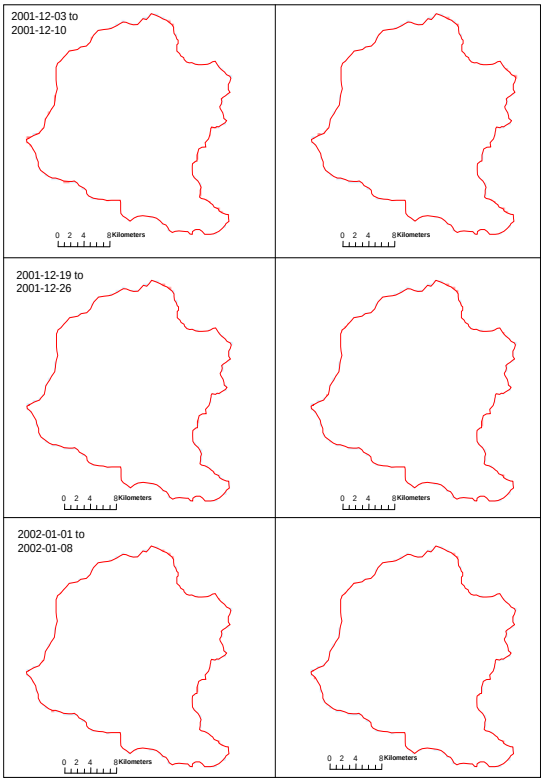


Figure 3: Weekly Snow Cover Area of the Gangotri Basin from May 2001 to May 2002 cont…

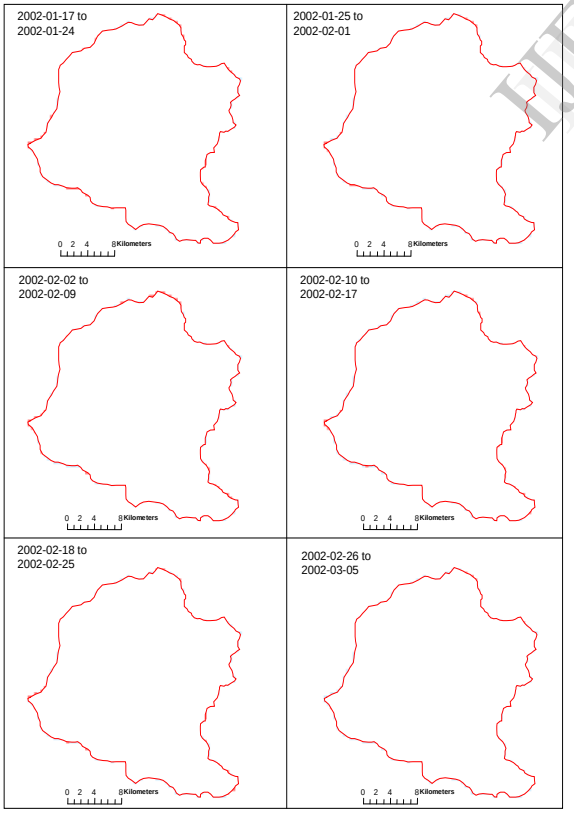
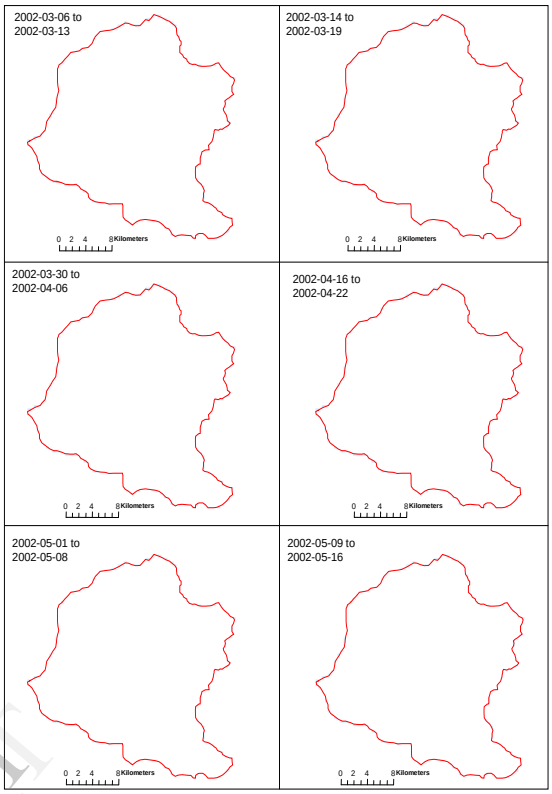


Figure 3: Weekly Snow Cover Area of the Gangotri Basin from May 2001 to May 2002 cont…



b. Altitudinal Zone wise Analysis

It is important to analyse the variations in the snow cover area by the changes of its elevation. So, the entire Gangotri basin have divided into four elevation zones. Zone I ranges from 3800-4500m, Zone II ranges from 4500-5000m, Zone III ranges from 5000-6000m and Zone IV ranges above 6000m elevation of amsl. The derived weekly snow cover information of the entire basin has been used to extract the each zone wise snow cover information on weekly basis. The zone boundary map of the basin is shown in Figure 4.

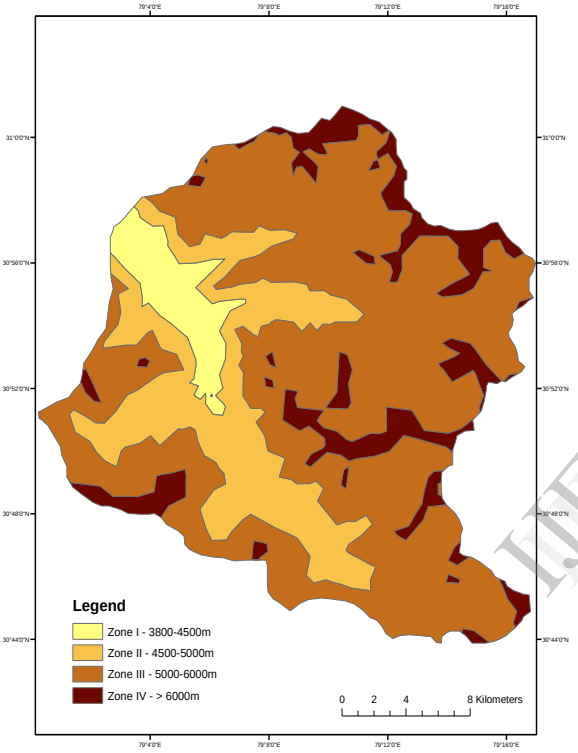


Figure 4: Altitudinal Zone wise classification of Gangotri Glacier

It indicates that a high elevation change in lower region corresponding to area vacated by glacier at elevation ranges of less than 4500m amsl, the glacier surface is covered by heavy debris, which inhibit the melting and depletion is observed less than 20m. At elevation range between 4500 – 5000m amsl, the depletion is observed more than 20-30m, this area is covered by thin debris covers, which enhance the melting processes. However, at elevation more than 5000m amsl, the change is zero or increase in thickness can be related with snow line. The average elevation changes of 26m is observed for the main Gangotri glacier, which can be consider as thinning of glaciers.

The Snow Cover Arera(SCA) in each zone was plotted against the time. Then the depletion curves for the basin were developed by joining the points in a smooth curve(Figure 5).

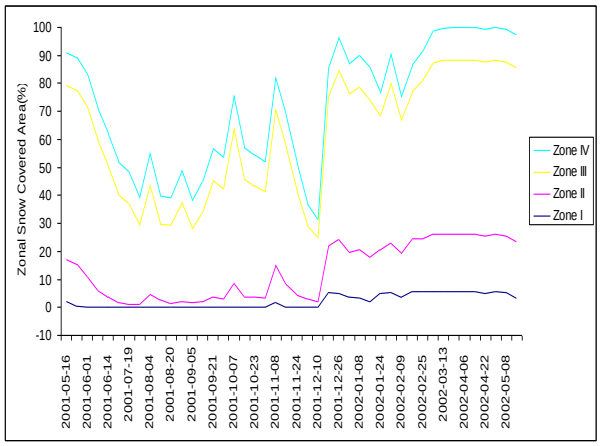


Figure 5: Snow Cover Depletion Curve of the Gangotri Basin from May 2001-May 2002

The graph indicates the estimated snow covered area in weekly basis from May 2001- May 2002 by altitudinal zone wise. This graph differs from the usual depletion curves of the snow coverage in which temporary increases of snow covered areas due to occasional summer snowfalls are eliminated(Hall and Martinec, 1985). The available data did not allow to recognize satellite images with short-lived snow cover from new snow and to interpolate between values referring to the seasonal snow cover.

6. Conclusion

The overall observation shows that the snowfall and snowmelt is not constant and it varies in time and altitude. Also indicates that the combination of MODIS data and spatial modeling method is economical and efficient to extract the information of snow cover. In order to study the impact of climate change on the streamflow, the long-term hydrological response should be simulated for different climate change scenarios and compared with base case (present climate conditions). This study strongly suggests that there is need to collect continuous hydro-meteorological data in the high altitude regions to study the changes in the meteorology and hydrology of the high altitude regions. This continuous data will be very much useful to develop or apply any snowmelt runoff models in this basin. It is also an important input to climatic and hydrological models, avalanche study, hydropower generation and flood forecasting.

Reference

Hall, D. K. and Martinec, J., Remote Sensing of ice and snow, Chapman Hall, New York, 1985.

S. Kumar, Satellite snow cover mapping and snowmelt runoff modelling in Beas basin. Snow, Hydrology and Forests in High Alpine Areas, *Proceedings of the Vienna Symposium*, August 1991. IAHS Publ. no. 205. pp. 101-109.

MODIS data: http://nsidc.org/data/docs/daac/modis_v5/mod10a2_modis_terra_snow_8-day_global_500m_grid.gd.html

H.S. Negi, N.K. Thakurand and V.D. Mishra, Estimation and Validation of Snow Surface Temperature Using MODIS Data for Snow avalanche Studies in NW-Himalaya. *Journal of the Indian Society of Remote Sensing*, 2007, Vol. 35, No. 4, pp. 287-299.

Ningyu Zhang, Quanyuan Wu and Ling Zhang. Extraction of Snow-Covered Information from Remote Sensing Data of CBERS-02 Imagery. In: *Proceedings of the 2008 Congress on Image and Signal Processing*, held at Sanya, China. May 27-30, 2008. Vol. 2, pp. 739-742. ISBN: 978-0-7695-3119-9.

Zhiming Liu, Chunxiao Zhan, Jianxia Sun and Ye Wei., The Extraction of Snow Cover Information Based on MODIS Data and Spatial Modeler Tool. In: *International Workshop on Geoscience and Remote Sensing* held at Shanghai, China during December 21 & 22, 2008. ISBN: 978-0-7695-3563-0.