Mapping of Snow Melt in Chenab Basin using Microwave Remote Sensing

S.Surya Teja, D.L Sai Teja, Mehanaz Fathima J, Rajashree Vinod Bothale, D.S Chandra

***Abstract:** Snow is considered to be the largest source of fresh water in the world with almost seventy percent of it in the form of ice. Himalaya's are largest snow covered mountains and the source of ten major rivers in the Asian region. Chenab basin in Indian Himalayas is the area under analysis for our current study. For an effective coverage of the basin characteristics, remote sensing data is the key element. Passive microwave remote sensing which has its roots deep in the field of Cryospheric studies is being used in many applications, which involve snow study and the same is being used in this research. Advanced Microwave Scanning Radiometer (AMSR2) gives the global product of Brightness Temperature (Tb) in seven different band frequencies 6, 7, 10, 18, 23, 36, 89GHz. Frequencies of 18GHz and 36GHz are used in our study to determine the cross polarization gradient ratio (XPGR). XPGR gives us clear indication of where the melt is being observed in the region, by plotting a time series of XPGR values we can get a clear understanding of melting trend in the region and the results show that the melt has been mostly observed from end of April to mid July and in some regions extending up to August. The variations of melt depend upon the climatic conditions and also on the elevation of the region.*

***Keywords:** Glacial Hydrology, Remote sensing, Brightness Temperature, XPGR, GIS, AMSR2*

I. INTRODUCTION

Due to rapid changes in the global climatic conditions during the past three decades the entire concentration of the world has been shifted towards polar ice caps and their fresh water resources. Seventy percent of the fresh water available globally has been in the form of snow, so there is special concern about how these water resources must be efficiently used with out bringing any degrading effect on the subsequent flora and fauna in that region. Continuous observation of snow caps and snow covered area gives us the accurate estimation of water availability in the regions. Optical, Infrared and Microwave remote sensing are the most commonly used methods for large scale monitoring of snow. Due to limitations of the infrared and optical regions in electromagnetic spectrum to identify the properties of icepack microwave region is widely used. Microwave radiometers measure the emitted radiance from a surface. Active microwave radiometers measure the backscattering coefficient while passive microwave radiometers measure the brightness temperatures. In active microwave region as temperature increases the backscatter decreases, in the case of passive microwave it is quite opposite, so use of both active and passive sensors helps us giving more meaningful insight of the snow melt. Ice continuously undergoes metamorphosis under the influence of climatic conditions and topographic conditions [1][2]. Study of internal properties of such as moisture content, grain size distribution, underlying soil type, density, thickness of ice layer gives more insight of the snow packs and makes it easy for melt analysis [3][4]. Microwave radiations emitted by the snow packs consist of emission from both the snow volume and underlying ground [5].Study on snowpack's using microwave remote sensing started over three decade's long, continuous research and advancements in technology resulted in accurate identification of hotspot zones. India which is facing the challenge of water supply shortage in many of its provinces needs to find a continuous and abundant source of fresh water. Chenab River which is originating from the Himalayan region is one of the major basins in the Himalayan river system[6].The complexity of the terrain is one of the major reasons which create a lot of problems for hydraulic study on the Chenab basin. Seasonal climate change of the Himalayan regions is influenced by three major climatic systems like Indian summer monsoon, winter westerly disturbances, East Asian Summer Monsoon[7]. These climatic patterns are completely different from one another and they influence the hydrologic cycle in the Himalayas causing the dynamic shift in the snowpack properties. The study on Chenab basin is not only useful for water balance estimations but also helpful for the prediction of Snow Avalanches. Due to its complex topographical conditions Remote Sensing and Geographical Information System (GIS) are used to achieve our objectives.

II. STUDY AREA

Chenab River is a confluence of two rivers Chandra and Bhaga which originate from the Himalayan valley of Barelacha pass. The catchment area of the Chenab basin up to international border is 29,050 Sq. Km. out of which an area of about 6,242 Sq. Km. is under perpetual snow. Large part of the basin lies in Himachal Pradesh. It is one of the

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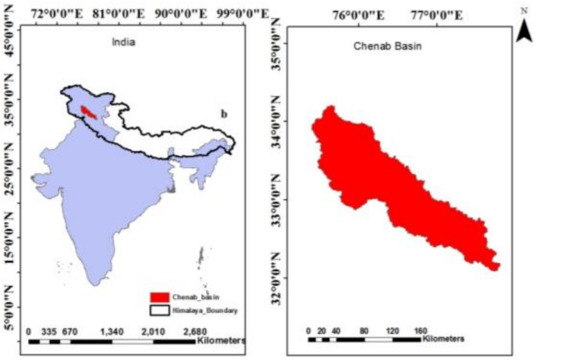

Figure1: Map of study area showing Chenab basin in Himalayas

five major rivers of Sindh region. The catchment area of the river Chenab is up to Akhnoor, the lower most gauge discharge site in India is 21,808 Sq. Km[8]. The extent of the study area is between 75º 0'0''East to 78˚ 0'0'' East longitude and 32º 0'0'' North to 35º 0'0'' North latitude and is shown in figure 1.

III. DATA USED

Advanced Microwave Scanning Radiometer (AMSR2) sensor on the GCOM-W satellite launched by Japan Aerospace Exploration Agency (JAXA) in collaboration with National Aeronautics and Space Administration (NASA) in 2012 which is a continuation of AMSR-E sensor. This is a passive microwave sensing sensor which records the Brightness Temperatures (T_b) emitted by the surfaces twice a day and its local passing time is 01:30. It has seven different frequency bands which are 6.93, 7.3, 10.65, 18.7, 23.8, 36.5, 89 GHz respectively. The spatial resolution depends upon the band the highest being given by 89GHz which is 5 × 3 km and lowest by 6.93 GHz which is 62 × 35 km[9]. This is the most advanced sensor which is used for glacial studies because of its continuous monitoring of the earth in all weather conditions and also the different available band combinations. Data from AMSR generation of sensors is available from 2002 and AMSR2 is the third generation. For study on Ice packs and dry snow 18 GHz and 37 GHz bands are widely used as they have ample penetration capability and less effect on snow scattering and its metamorphic changes[10][11].

IV. METHODOLOGY

Methodology adopted for mapping of snow melt is shown in figure 2.AMSR2 data is available on daily basis it gives the global product of brightness temperature values at 01:30 in both ascending and descending passes at 0.1 decimal degree resolution. Brightness values are extracted for 18GHz horizontal polarization band and 37GHz vertical polarization bands, the combination of bands is used to access the melt conditions more precisely and to avoid the erroneous results caused by wet snow condition as we know wet snow alters the brightness temperature values. Cross polarization gradient ratio (XPGR) is calculated by using the equation-1[12][13][14].

$$\text{XPGR} = \frac{(T_{18h} - T_{37v})}{(T_{18h} + T_{37v})} \qquad (1)$$

After calculating XPGR values from March 15th to july15th in 2017, melt statistics are compared with the IMD daily average temperature data.

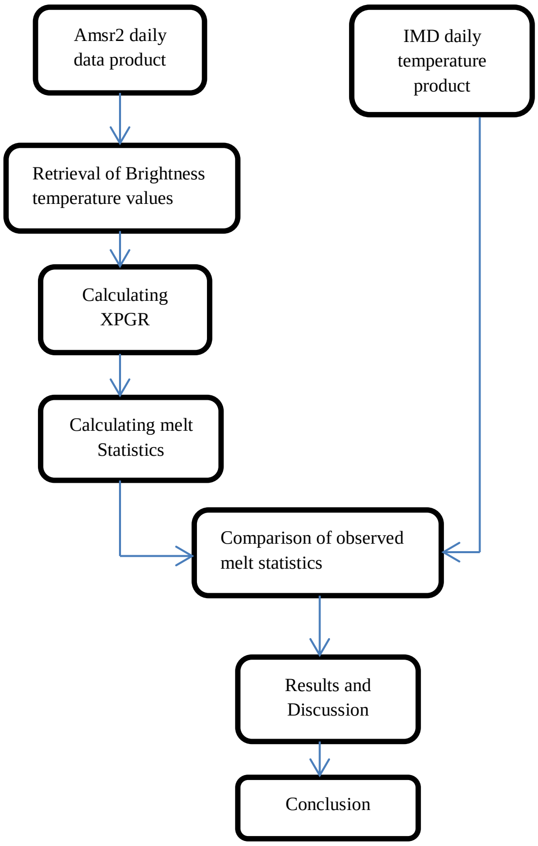

Figure 2: Flow chart showing methodology

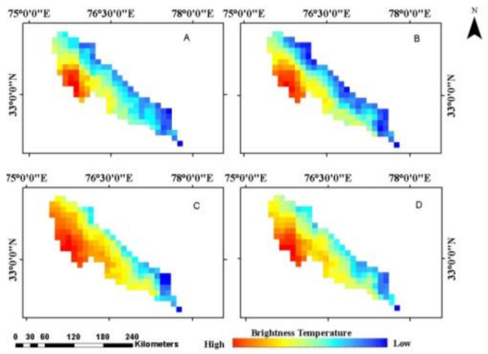

Figure 3: Brightness temperature values in the months of A) March, B) April, C) May and D) June

V. RESULTS AND DISCUSSIONS

Mapping of melt using the brightness temperature values have been very instrumental in observing how the melt progresses in the basin. Figure-3 shows the variations in the brightness temperatures in Chenab basin as the summer progresses, the images in figure 3(A, B, C, D) shows clear trend in increase of brightness temperature values. By observing the figure it is seen that onset of summer started from the western part of the basin and gradually moved towards eastern part of the basin. It is because of the lower elevation on western part of the basin as compared to the

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higher mountain ranges on the eastern side[15]. As the figure 3 shows the clear increase in brightness temperatures we couldn't possibly say the melt has been observed as brightness temperatures may be influenced by many other factors like underground soil conditions, density of snow packs, liquid water content and also atmospheric conditions. The cross polarization gradient ratio (XPGR) is used to calculate the melt statistics in the region and this method is used in various research works and has given good results. This XPGR relies on two band frequencies at two different polarizations which eliminate the possible limitations of using single band and single polarized data. 18.7 GHz horizontal polarization and 36.5 GHz vertical polarization datasets are used for computing the XPGR and the results are shown in the figure 4. Images shown in the figure 4(A, B, C, D) are the same days as depicted in figure 3, same days were used in the figures to provide a clear understanding of the technique used. By seeing the figure 4 we can understand that wherever higher brightness temperatures are recorded in some places there may not be any melt and wherever the lower brightness temperatures are recorded there has been melt. This clearly shows how the brightness temperatures alone cannot be used to judge the melting pattern in the area. Figure 4 also shows the

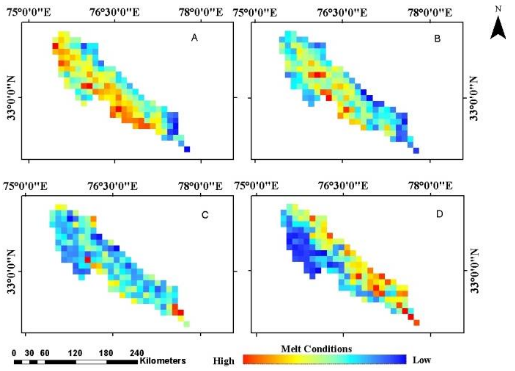


Figure 4:XPGR values in the months of A) March, B) April, C) May and D) June

Same pattern of melt as we have seen in the case of brightness temperature values. The melt has started from western part of the basin and gradually increased towards east as the summer progressed this is because of the same reason as we have mentioned earlier i.e. due to elevation profile of the region. Onset of summer is first experienced in the low elevation region compared to that of higher elevation regions. In order to further check the accuracy of our results we have used daily average temperatures of the region provided by the Indian meteorological department (IMD). The values are given in gridded raster format and we have extracted the values for Chenab basin and cross checked with our model. Figure 5(A, B, C, D) shows the IMD temperature values for the Chenab basin for the same days as shown in figure 3,4. Images from the figure 5 clearly indicate the calculated melt statistics (XPGR values) are in relation with the IMD temperature data.

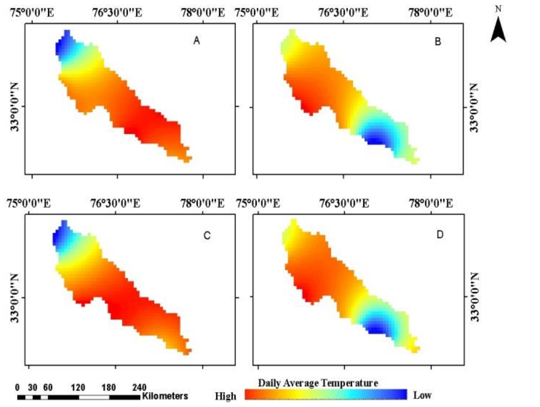
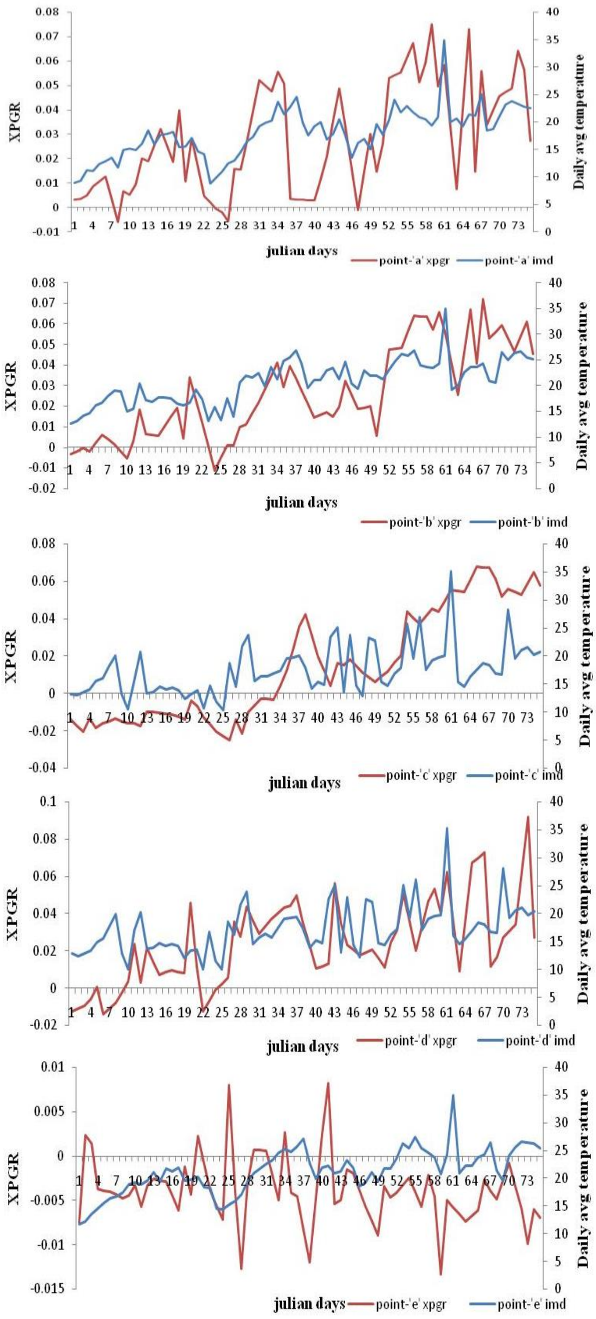


Figure 5: Daily average temperature values in month of A) March, B) April, C) May and D) June



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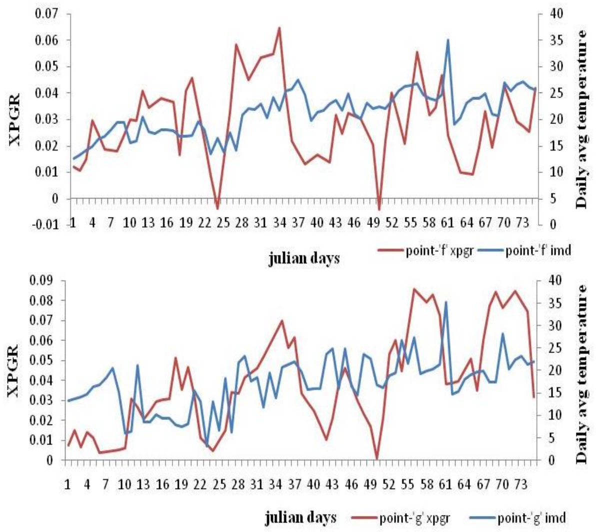

Figure 6: Time series graphs for the locations shown in figure 7

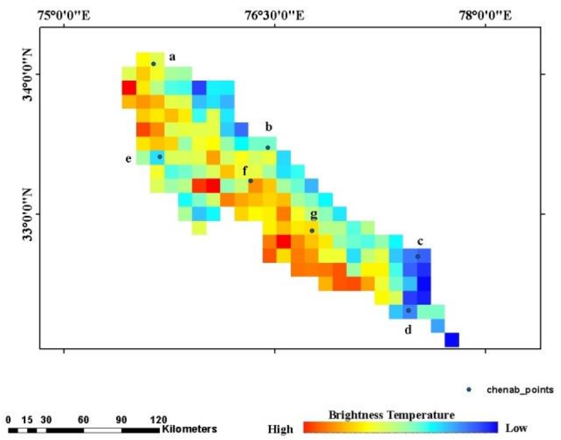

Figure 7: points a, b, c, d, e, f, g indicates the locations used for time series data analysis.

There may not be exact match between the images of melt statistics and daily average values but the graphical analysis shows there has been a good relation between those two datasets. To further understand the modeled data we plotted the time series graphs for the values of XPGR and daily average temperatures for the selected locations in the Chenab basin. Figure 7 shows the locations of the places used for time series graphs. The chosen locations are spatially well distributed in the region. As we can see in figure 6 the time series plots for the locations 'a', 'b'& 'c' are located in the higher elevation region and on the eastern side of the basin the observed XPGR and the daily average temperature values are much in agreement with what we have observed from the figures 3, 4, 5. Location 'd' is on the southernmost part of the basin and located on the higher elevation it experiences late summer when compared to locations 'e', 'f' & 'g', when we observe the XPGR and daily average temperature values at this location for the first forty days are in agreement and satisfactory from there onwards. Location 'e' which is in lower elevation and western region of the basin experiences early summer and early melt condition for this location also it is observed that the two factors are in good correlation and after that there has been a negative correlation. Locations 'f', 'g' which are located in middle of basin has mixed type of characteristics and the correlation between XPGR and daily average temperatures changes from month to month as they exhibit mixed characteristics of terrain and locations.

VI. CONCLUSION

From this study we came to know the melting trends are varying in Chenab basin. Melting conditions not only depends upon the temperature but also on the location and elevation profile of the region. By observing the melt at the basin level we can estimate the hydrological balance in the region and also there is good scope for employing better watershed management techniques. This study also shows that passive microwave sensors can be used to monitor the glacial melting patterns. There are some drawbacks using passive microwave sensors as they have very coarse resolutions.

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