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METEOROLOGICAL PARAMETERS OF NARADU GLACIER VALLEY, INDIA: AN ANALYSIS

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ABSTRACT

Keeping the importance of glaciers in mind it is necessary to measure different meteorological parameters as these factors play an important role in the survival of the glacier. An attempt has been taken to measure different meteorological parameters at the Naradu Glacier. The analysis is based on the records available for one year. Air temperature has been analysed on monthly and seasonal basis. Seasonal air temperature trend analysis shows negative trend in accumulation season while positive trend in ablation season. Both solar radiation and sunshine hour follow the seasonal trend i.e. highest in ablation season and lowest in accumulation season.

Keywords: meteorological parameters, solar radiation, air temperature, wind speed and wind direction.

1. INTRODUCTION

Many researchers claim that recent year have shown high growth of climate change and the reported reasons behind are natural as well as anthropogenic influences (M.F. Akorede *et al*., 2012). Principal causes are excessive emission of CO_2 and atmospheric aerosols etc., (O. Preining (a), 1992; O. Preining (b), 2000). Excessive melting of the glaciers is one of among many effects of warming. Glaciers are the main source of water for the surrounding lowlands, and melting of these glaciers may trigger several outburst floods (J.I. López-Moreno *et al*., 2014). Climate change is likely to change the snow cover area and alter the water availability in future making long term water management more challenging(D. Khadka *et al*., 2014). In short-term, as glaciers retreat and lose mass, they add to a temporary increase in runoff to which downstream users will quickly adapt, thereby raising serious sustainability concerns (M. Vuille *et al*., 2008). Forth Assessment Report by IPCC clearly mentioned that continued loss of ice has been noticed and according to IPCC report 2013 satellite records indicate that over the period 1967–2012 snow cover extent has decreased significantly in the Northern Hemisphere. The analysis of different meteorological parameters, which play an important role in the survival of any glacier, has been done.

2. STUDY AREA

The present study is undertaken on the Naradu glacier which is located in the upper reaches of Naradu Garang (valley) enclosed by high mountain peaks, namely Khimsung (5, 600 m), Khomsung (5, 700 m) and Khimloga (5, 400 m) in south and southeast of the valley (Koul and Ganjoo, 2010). It is situated in High Himalayan mountain system in Kinnaur district of Himachal Pradesh. The glacier is one among the 89 glaciers of Baspa basin which contributes its water to river Baspa a tributary of Satluj River. The glacier ranges between 78^o 22’ 38.49”- 78^o 25’ 57.02” E and 31^o 16’ 27.02” - 31^o 18’ 33.57” N. According to the recent study based on the field observation and satellite imagery (LISS-IV, 2011), Naradu glacier covers an area of 3.7sq km. Naradu glacier is being enclosed by mountains by its three sides and it is the north-east facing glacier. During the 2013 visit the equilibrium line was found at the height of approximately 5100m asl. The irregular outline ofsnout is covered with loose rock debris. The meteorological data of Naradu Garang is useful to assess seasonal and monthly changes, in mean maximum and minimum temperature of glacier basin. The glacier ranges in altitude from 4512 to 5600m asl. The location map of the glacier is shown through Figure-1.

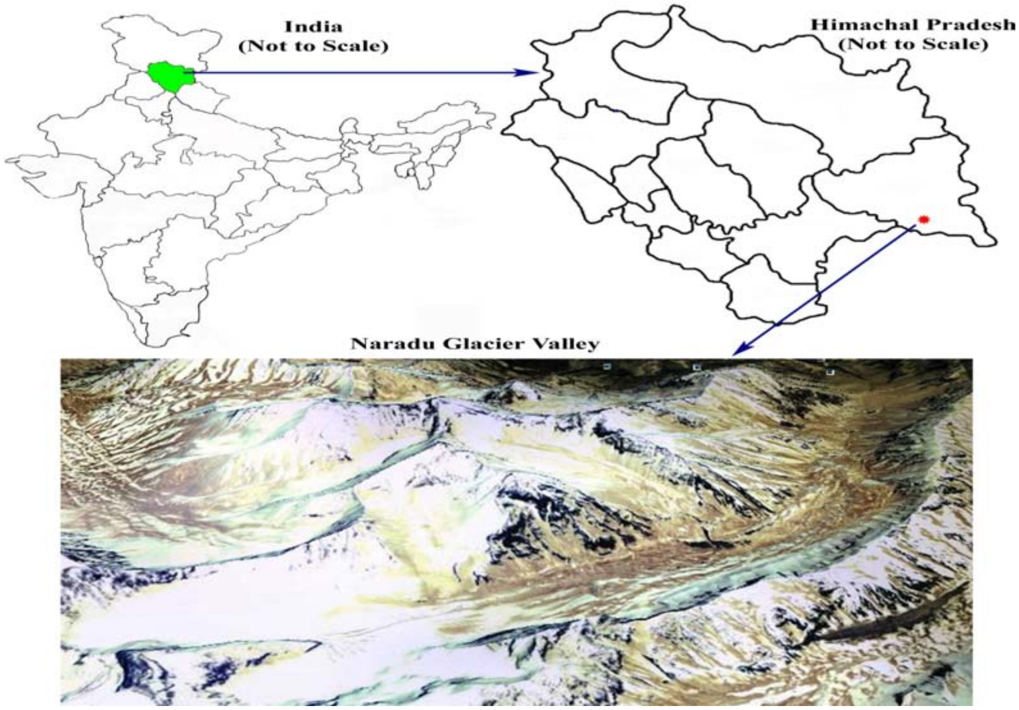

Figure-1. Location map of Naradu glacier, District Kinnaur, Himachal Pradesh (India).

3. AWS DETAILS

To assess the annual variation in different meteorological parameters and its impact on glacierdynamics of Naradu Garang, an automatic weather station (AWS) were set upat the height of approximately 4,661 metre above sea level. The study is based on one year (1 Sep, 2012 – 31 August, 2013) Naradu Glacier meteorological parameters. The AWS station provided monitors air temperature, relative humidity, wind speed and direction, solar radiation, atmospheric pressure. An automatic weather system with its sensor package operating on solar batteries, mounted on galvanized steel tower fitted with XLite9210 data logger and other accessories like battery and housed in weather proof enclosures was installed. The sensors comprise air temperature, relative humidity, speed and direction of wind, solar radiation, sunshine hours. Different sensors attached with the AWS have different resolution with different accuracy level.

4. METEOROLOGICAL OBSERVATIONS

Seasonal analysis depending on one year data has been done by dividing whole year into five categories i.e. post monsoon (September-November), winter (December-February), pre-monsoon (March-May), monsoon (June-August).

Temperature

Seasonal air temperature analysis: The mean monthly minimum post monsoon temperature for September, October and November was 2.84°C, -4.73°C, and -7.09°C, respectively and the mean monthly maximum temperature for the same period was recorded as 3.61°C, -3.81°C, and -6.16°C, respectively. The mean temperature record for the month of September, October and November varies from -2.7 to 8.5°C, -11.6 to 4.4°C and -15.7 to -1.7°C, respectively.

The mean monthly minimumwinter temperature for December, January, and February was -8.75°C, -11.96°C, and -11.45°C, respectively and the mean monthly maximum temperature for the same period was recorded as -7.70°C, -10.85°C, and -10.26°C, respectively. The mean temperature record for the month of December, January, and February varies from -17.4 to -0.7°C, -18.7 to -1.4°C and -17.7 to -1.7°C, respectively.

The mean monthly minimumpremonsoon temperature for March, April, and May was -6.95°C, -4.68°C, and -0.46°C respectively and the mean monthly maximum temperature for the same period was recorded as -5.43°C, -3.17°C, and -0.79°C, respectively. The mean temperature record for the month of March, April, and May varies from -12.8 to 2.1°C, -11.3 to 5.3°C and -7.2 to 10.4°C, respectively.

The mean monthly minimumpremonsoon temperature for June, July and August was 4.11°C, 7.24°C, and 5.57°C, respectively and the mean monthly maximum temperature for the same period was recorded as 5.35°C, 6.32°C, and 6.42°C, respectively. The mean temperature record for the month of June, July, and August varies from -3.1 to 14.1°C, 1.6 to 16.2°C and 1.7 to 11.6°C, respectively.

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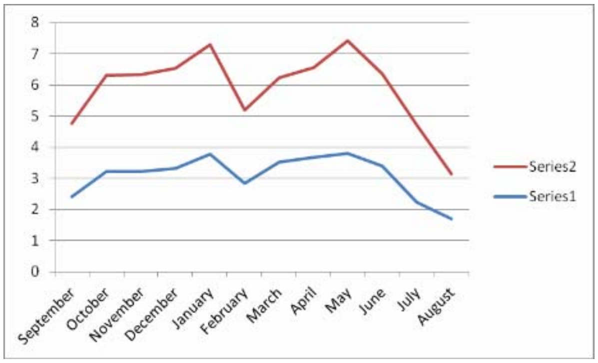

Figure-2. Maximum and Minimum temperature (standard deviation) from September, 2012 to August, 2013 of Naraduglacier.

Monthly Air Temperature Analysis: By Figure-2 it can be analyzed that month wise air temperature shows decreasing trend in almost every month of accumulation season (except April) which is helpful for more accumulation whereas Figure-3 reveals that the almost all months of ablation season shows the opposite behaviour which indicate more melting. In case of accumulation season the value of m which shows the slope of the line equation y = mx + c is highest negative in the month of November and highest positive in April while in case of ablation season the value of m is highest positive in May and highest negative in August.

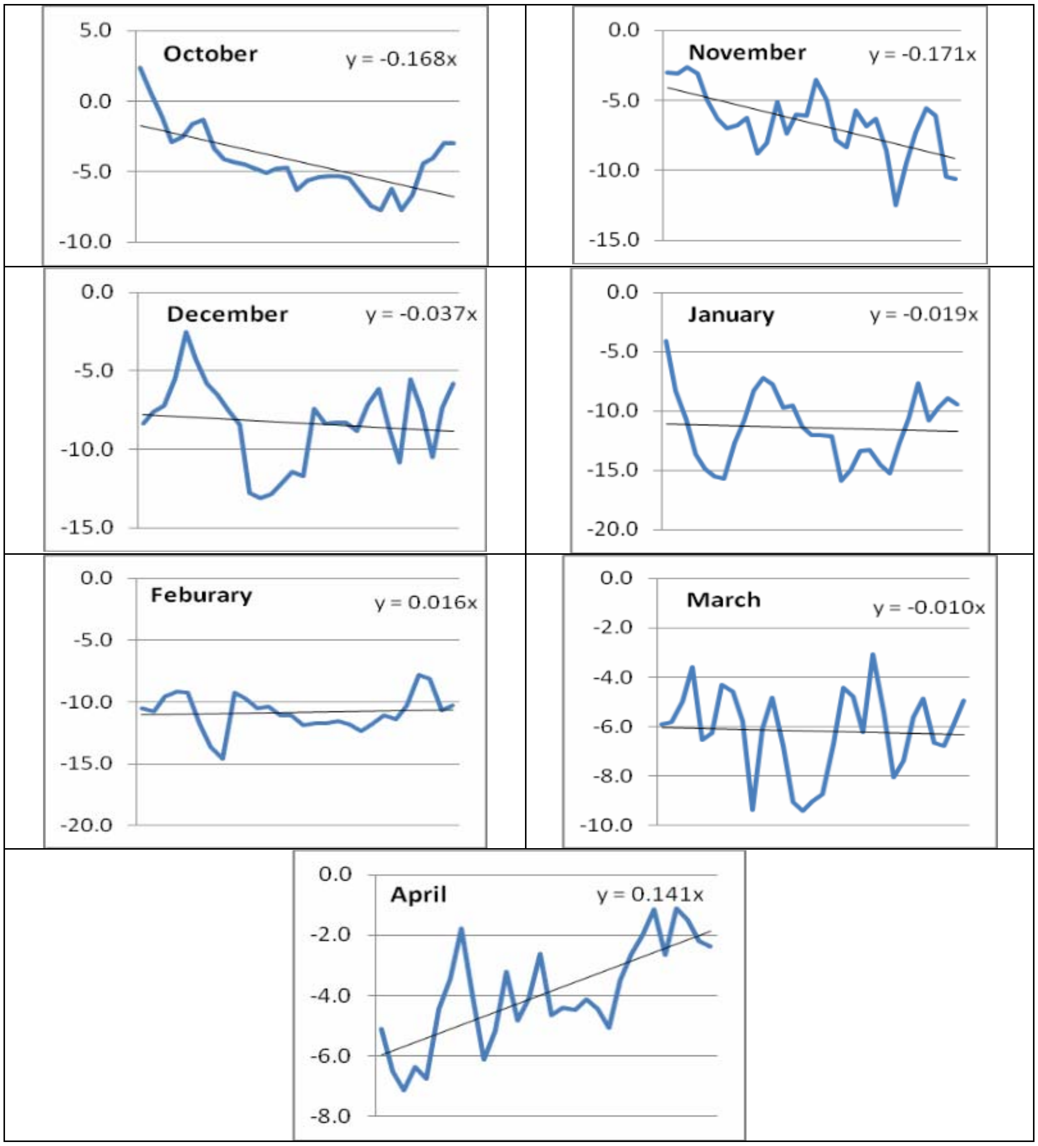

Figure-3. Month wise daily temperature of Accumulation Season.

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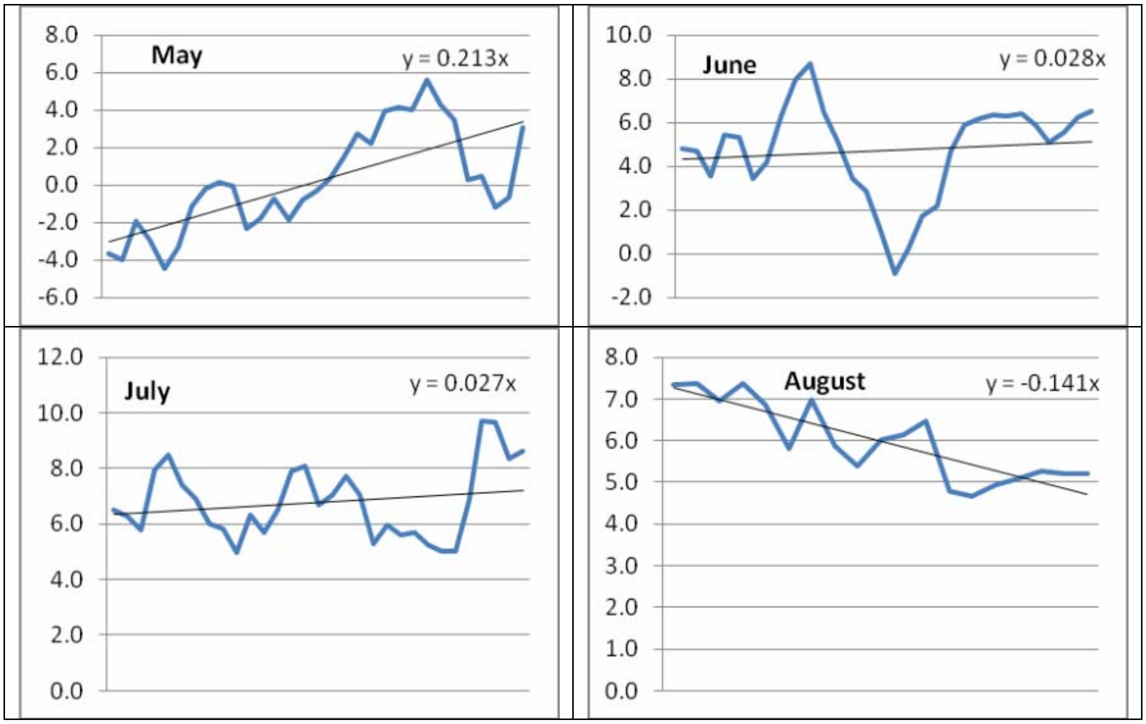

Figure-4. Month wise daily temperature of Ablation Season.

Analysis of temporal temperature change

Annual, seasonal and monthly trends in Naradu glacier has been investigated from 1994 to 2003 and 2012-13. The temperature record of 11 years have been analysed by putting the trend line. In case of mean minimum temperature of accumulation season (Figure-4) shows increasing trend and the same trend have also been followed by the month of August of ablation season (Figure-5). The air temperature for the month of June and July experience cooling in comparison to the previous years.

An optimistic sign was noticed while analysing the maximum air temperature for all the months of both the seasons (Figure-6 and Figure7), which shows negative trend for all the months.

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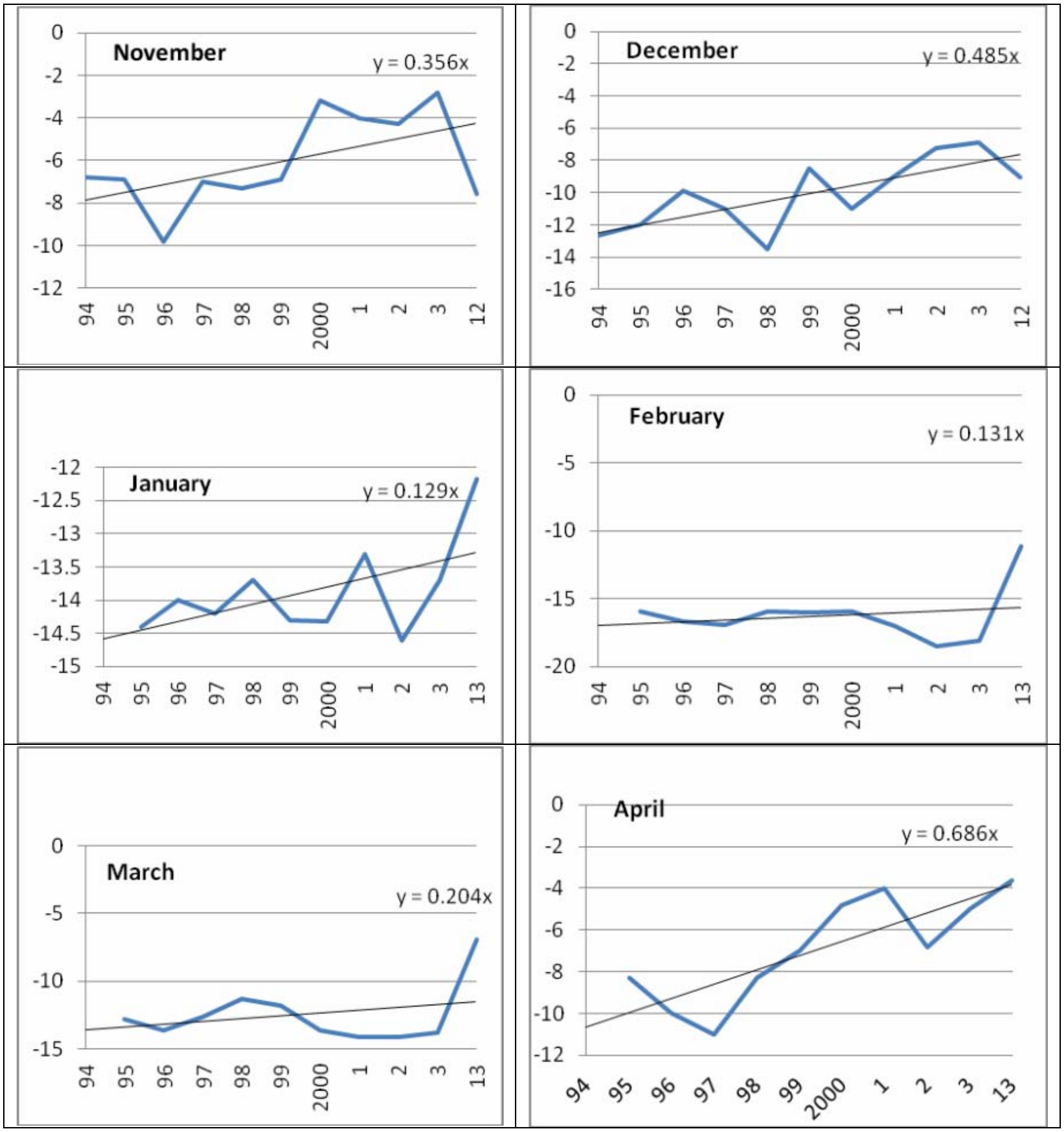

Figure-5. Mean monthly minimum temperature of accumulation season at snout of Naradu glacier between 1994 to 2003 and 2012-13.

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Figure-6. Mean monthly minimum temperature of ablation season at snout of Naradu glacier between 1994 to 2003 and 2012-13.

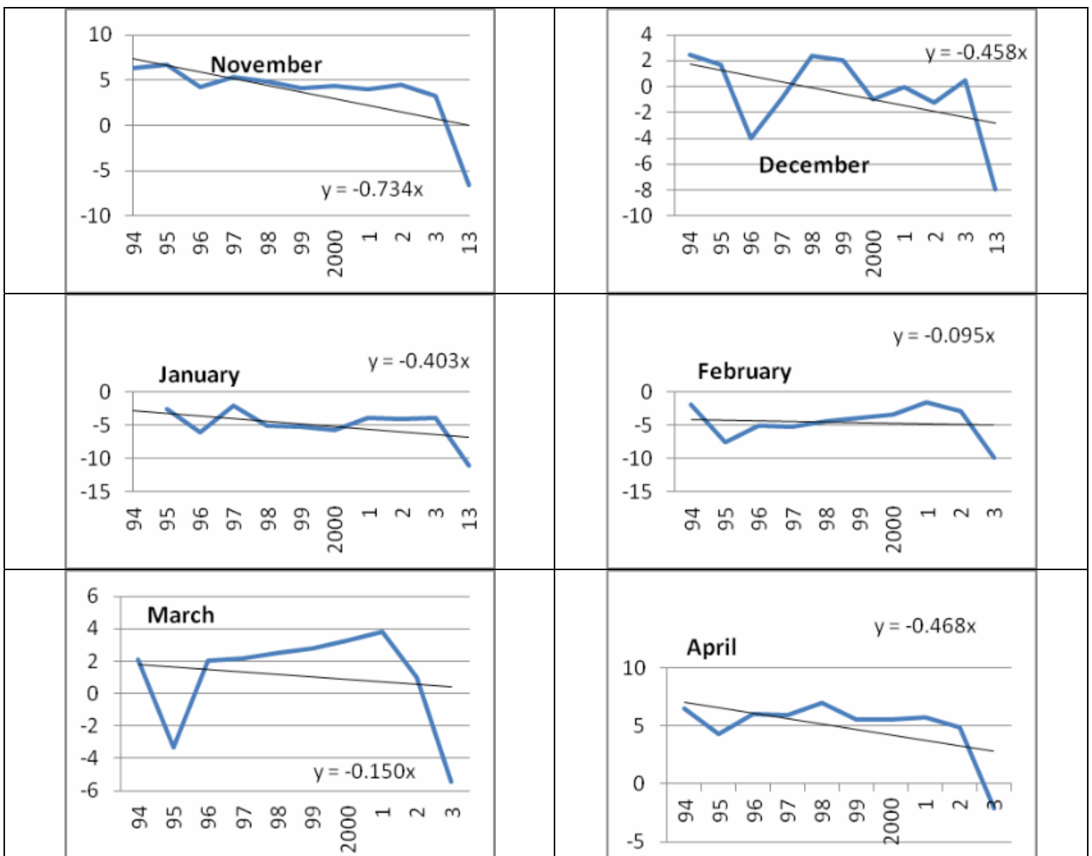

Figure-7. Mean monthly maximum temperature of accumulation season at snout of Naradu glacier between
1994 to 2003 and 2012-13.

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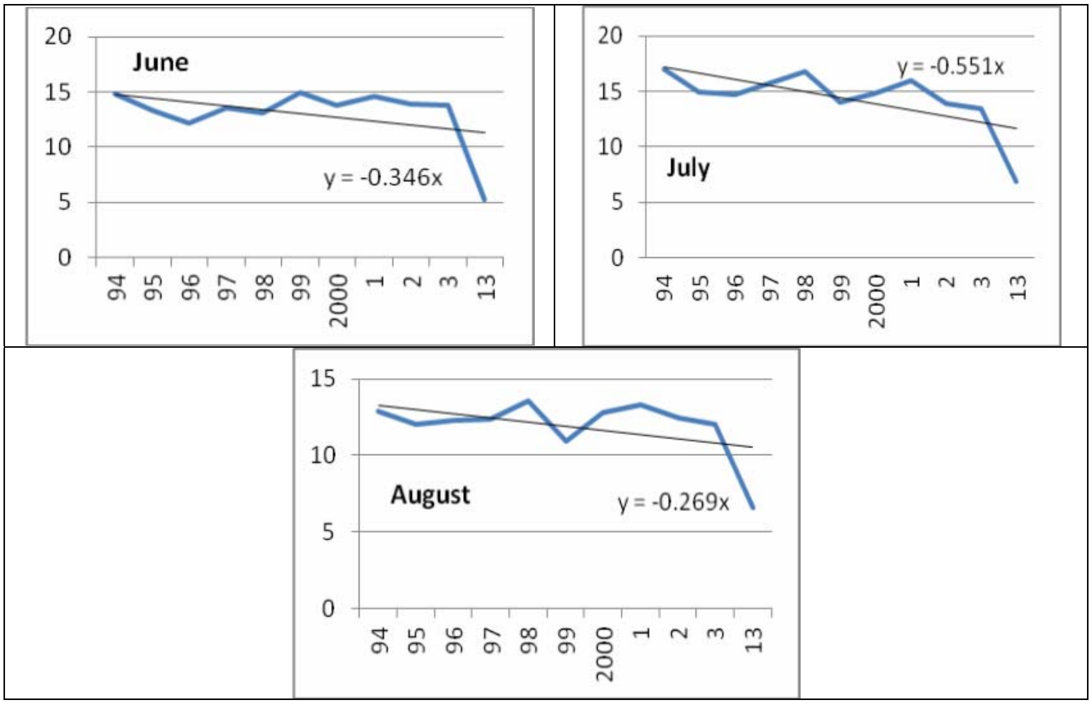

Figure-8. Mean monthly minimum temperature of ablation season at snout of Naradu glacier between 1994 to 2003 and 2012-13 (Yadav *et al*. 2004).

Diurnal temperature

The monthly diurnal temperature range during accumulation (Figure-8a) season show an increasing trend while ablation (Figure-8b) season shows decreasing trend of diurnal temperature range. The average diurnal range of ablation season is 15.1°C and of accumulation is 17.2°C. The highest diurnal range is in December (18.3°C) and in May (18.1°C).

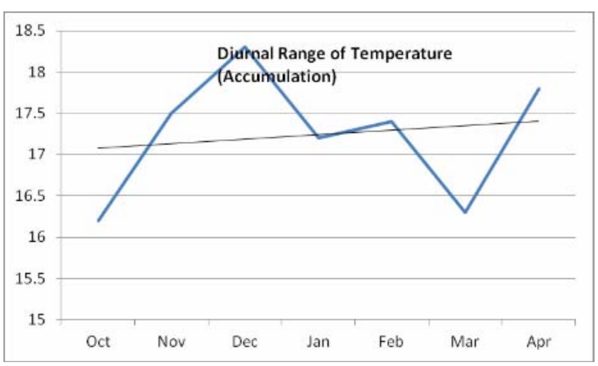

Figure-9. Diurnal range of temperature (accumulation).

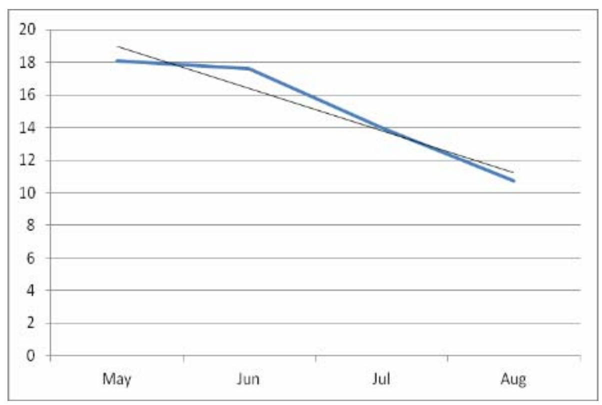

Figure-10. Diurnal range oftemperature (ablation).

Temperature anomaly

Figure-11 shows % anomaly of Naradu Glacier from September 2012 to August 2013. Anomaly was highest in the month of June and reported 60% while it was lowest in the month of October and found in approximately 38.7% of time.

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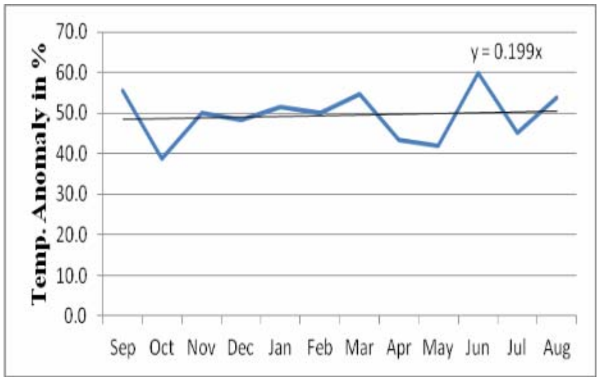

Figure-11. Percentage anomaly of temperature.

Solar radiation

Mean monthly solar radiation measured by automatic weather station follows the seasonal trend. In summer season it highest during May 717.32 W/m^2 and followed by June 645 W/m^2, July 522.48 W/m^2 and August 387.19 W/m^2. In winter season the highest mean monthly solar radiation was in the month of April 662.60 W/m^2 and followed by March 658.05 W/m^2, October 581.82 W/m^2, November 546.36 W/m^2, January 512.79 W/m^2, February 505.96 W/m^2 and it was lowest during the month of December 440.96W/m^2. The highest maximum total solar radiation is received during the month of June (1454W/m^2) followed by May (1441W/m^2), July (1400W/m^2), August (1385 W/m^2) in the case of summer and in winter the highest solar radiation during the month of April (1355W/m^2) followed by March (1168), October (1129W/m^2), February (1046W/m^2), January (962W/m^2), November (871W/m^2) and December (779W/m^2). According to the study conducted by Koul and Ganjoo on the same glacier during 2000-2003 the highest maximum solar radiation is received during the month of July and August which was 952 W/m^2 which is much less than the solar radiation received during the winter season of 2012-13.

Sunshine hours

Sunshine hours plays important role while assessing the melting of the glacier. The average monthly sunshine hour ranges between 6.99 and 10.70 h/day for the months September, 2012 to August, 2013. The average sunshine hours are longest in May (10.70 h/day) followed by July (10.20 h/day), June (10.18 h/day), August (9.33 h/day). The mean sunshine hour during the winter season was highest during April (9.86 h/day) followed by March (9.31 h/day), October (8.28 h/day), February (7.94 h/day), November (7.70h/day), December (7.06 h/day) and January (6.99 h/day).

Wind

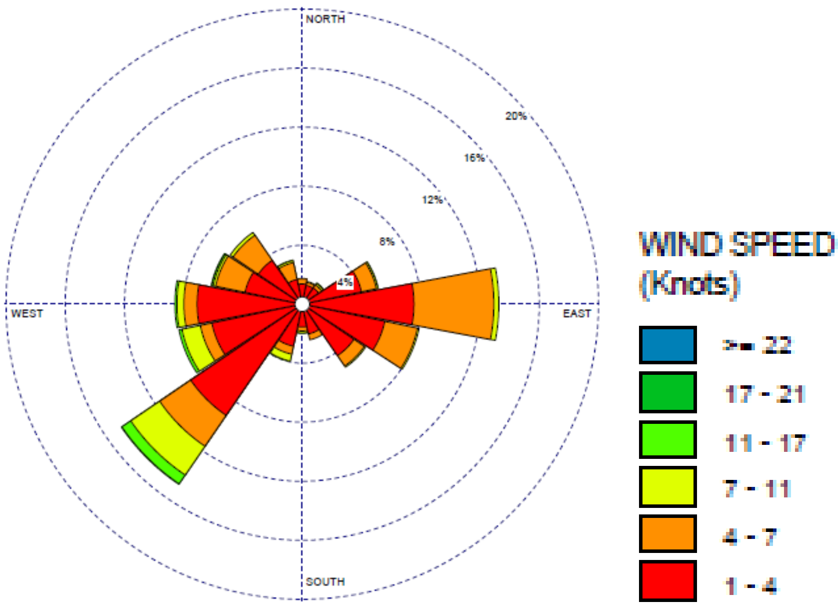

Figure-12 (a). Wind rose diagram of ablation period.

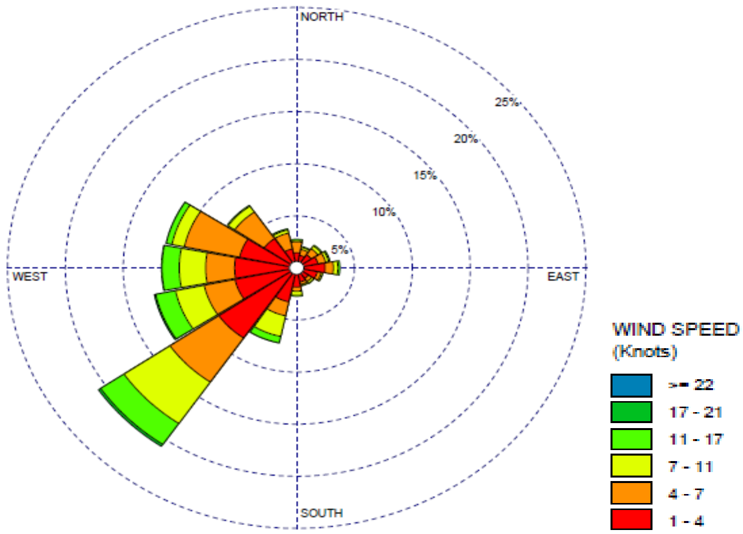

Figure-12 (b). Wind rose diagram of accumulation period.

Hourly wind speed and direction data has been analysed for ablation (May to August) and accumulation (October to April). Average wind speed is 3.22 knots and 5.02 knots for ablation and accumulation season respectively. No. of Calms in percentage to the total is 7.82% for ablation season and for accumulation season it is 2.28%. During both the seasons the highest wind speed was observed in south-west direction.

RESULT AND DISCUSSIONS

This paper is an attempt in the Naradu glacier region to understand the change in different meteorological parameters. The analysis based on long term data series obviously gives the better results but the limitation of the data in the higher Himalayas cannot be ruled out. For analysis we took hourly data for each meteorological parameter from 1st Sep, 2012 to 31st Aug, 2013. All types of data were subjected to analysis for both accumulation and ablation season. The present study deals with an examination of variability in seasonal as well as monthly temperature variables for the subjected glacier area. The results found during the analysis of monthly mean temperature fluctuation has been showed in Table-1.

Months/Seasons	Mean temperature in degree C
September, 2012	-2.7 to 8.5
October, 2012	-11.6 to 4.4
November, 2012	-15.7 to -1.7
December, 2012	-17.4 to -0.7
January, 2013	-18.7 to -1.4
February, 2013	-17.7 to -1.7
March, 2013	-12.8 to 2.1
April, 2013	-11.3 to 5.3
May, 2013	-7.2 to 10.4
June, 2013	-3.1 to 14.1
July, 2013	1.6 to 16.2
August, 2013	1.7 to 11.6

The analysis showed that the temperature fluctuation was maximum during the month of May followed by January, June, December, April, February and October, March, July, November, September and August. Air temperature trend analysis shows negative trend in accumulation season while positive trend in ablation season which increase snow fall in accumulation season and also more melting during ablation season.

Monthly percentage of anomaly shows an increasing trend. Analysis shows highest anomaly in the month of June and lowest in the month of October.

Mean monthly solar radiation was highest during the month of May and lowest during the month of December which follows the seasonal trend. The same seasonal pattern has been revised in the case of monthly total radiation received during the analyzed period. Sunshine hour also follows the seasonal pattern. Sunshine hour is highest during the month of May (10.70h/day) and it is lowest for the month of January (6.99h/day).

The highest wind speed was observed in south-west direction for accumulation as well as for ablation season. Wind speed was high during the month of accumulation season and it was low during ablation season.

5. CONCLUSIONS

Annual meteorological data for Naradu glacier region of High Himalayan Mountain range of Himachal Pradesh has been analysed in detail to demonstrate the observed changes in maximum, minimum, and mean air temperatures. Emphasis was placed on the quantification

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of temperature change on the monthly and seasonal basis. The conclusions drawn from the study are listed below:

- The monthly mean temperature has shown an increasing trend during ablation season and decreasing trend during accumulation season.
- The temperature anomaly shows an increasing trend with highest value in June and lowest in October.
- The seasonal air temperature shows that Monsoon was the period with highest temperature followed by post-monsoon, premonsoon and winter.
- Solar radiation and sunshine hour follows the seasonal trend.

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REFERENCES

M.F. Akorede, H. Hizam, M.Z.A. Ab Kadir, I. Aris and S.D. Buba. 2012. Mitigating the anthropogenic global warming in the electric power industry. Renewable and Sustainable Energy Reviews. 16(5): 2747-2761.

O. Preining (a). 1992. Global warming: greenhouse gases versus aerosols. Science of the Total Environment. 126(1-2): 199-204.

O. Preining (b). 2000. Aerosols - Short history of a shy science. Journal of Aerosol Science. Vol. 31, Supplement 1, pp. 578-579.

J.I. López-Moreno, S. Fontaneda, J. Bazo, J. Revuelto, C. Azorin-Molina, B. Valero-Garcés, E. Morán-Tejeda, S.M. Vicente-Serrano, R. Zubieta and J. Alejo-Cochachín. 2014. Recent glacier retreat and climate trends in Cordillera Huaytapallana, Peru, Global and Planetary Change. 112: 1-11.

Dibesh Khadka, Mukand S. Babel, Sangam Shrestha and Nitin K. Tripathi. 2014. Climate change impact on glacier and snow melt and runoff in Tamakoshi basin in the Hindu Kush Himalayan (HKH) region. Journal of Hydrology. 511: 49-60.

Mathias Vuille, Bernard Francou, Patrick Wagnon, Irmgard Juend, Georg Kaserd, Bryan G. Marke and Raymond S. Bradley. 2008. Climate change and tropical Andean glaciers: Past, present and future, Earth-Science Reviews. 89(3-4): 79-96.

Forth Assessment Report IPCC, 2007.

Fifth Assessment Report IPCC, 2013.

Koul M. N. and Ganjoo R. K. 2010. Impact of inter- and intra-annual variation in weather parameters on mass balance and equilibrium line altitude of Naradu Glacier (Himachal Pradesh), NW Himalaya, India. Climatic Change. 99: 119-139.

Dobhal D.P. 2009. Mass balance studies of Dokriani and Chorabari Glaciers, Garhwal Himalaya. In: Annual report, Wadia Institute of Himalayan Geology. Dehradun, Wadia Institute of Himalayan Geology. pp. 36-37.

Dobhal D.P., J.T. Gergan and R.J. Thayyen. 2008. Mass balance studies of the Dokriani Glacier from 1992 to 2000, Garhwal Himalaya, India. Bull. Glacier Res. 25: 9-17.

Etienne Berthier, Yves Arnaud, Rajesh Kumar, Sarfaraz Ahmad, Patrick Wagnon and Pierre Chevallier. 2007. Remote sensing estimates of glacier mass balances in the Himachal Pradesh (Western Himalaya, India). Remote Sensing of Environment. 108(3): 327-338.

Wagnon P. *et al*. 2007. Four years of mass balance on Chhota Shigri glacier, Himachal Pradesh, India, a new benchmark glacier in the Western Himalaya. J. Glaciol. 53(183): 603-611.
Koul M. N. and Ganjoo R. K. 2010. Impact of inter- and intra-annual variation in weather parameters on mass balance and equilibrium line altitude of Naradu Glacier (Himachal Pradesh), NW Himalaya, India. Climatic Change. 99: 119-139.
Kulkarni AK, Rathore BP, Mahajan S, Mathur P. 2005. Alarming retreat of Parbati glacier, BeasBasin, Himachal Pradesh. Current Science. 88(11):1844-1850.

Dobhal DP, Gergan JT and Thayyen RJ. 2004. Recession and morphometrical changes of Dokrianiglacier (1962-1995) Garhwal Himalaya, India. Current Science. 86(5): 692-696.

Srivastava D, Sangewar CV, Koul MK and Jamwal KS. 2001. Mass balance of Rulung glacier-a transHimalayan glacier, Indus basin, Ladakh. GSI Special Publication. 53: 41-46.

Yadav RR, Park W-K, Singh J and Dubey B. 2004. Do the western Himalayas defy global warming? Geophysics Research Letter. 31: L17201.