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GLOBAL WARMING AND CLIMATIC SENSITIVITY- A CASE STUDY OF UTTARAKHAND STATE OF INDIAN HIMALAYA

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ABSTRACT

Average arctic temperatures have been increasing at almost twice the rate of the rest of the world in the past 100 years; however arctic temperatures are also highly variable. Although more greenhouse gases are emitted in the Northern than Southern Hemisphere, this does not contribute to the difference in warming because the major greenhouse gases persist long enough to mix between hemispheres. IPCC projected an increase in global mean surface air temperature (SAT) which will continue over the 21st century if the anthropogenic greenhouse gases keep on emitting with the current rate. Geographical patterns of projected surface air temperature warming show greatest temperature increases over land (roughly twice the global average temperature increase) and at high northern latitudes, and less warming over the southern oceans and North Atlantic, consistent with observations during the latter part of the 20th century. Scope of the present is to analysis the climate sensitivity in the hill regions of Uttarakhand.

KEYWORDS: *Climate Sensitivity, Global Worming, Green House effect.*

INTRODUCTION:

The remarkable economic growth achieved by the developed world since the industrial revolution fuelled by large scale consumption of fossil energy is mostly responsible for global warming and climate change. Accumulation of greenhouse gases (GHGs) such as carbon dioxide, methane, nitrous oxide, hydro-fluorocarbons and other halocarbons, per-fluorocarbons and sulfur hexafluoride from fossil fuel combustion, cement manufacture, deforestation and other anthropogenic activities responsible for global warming and the resulting climate change (IPCC, 2013). Climate change could be seen as rising temperatures, unpredictable monsoons, occurrence of extreme weather events such as prolonged hot periods, floods, droughts etc. Climate change has begun to seriously impact agriculture in every part of the planet (Rosenzweig, and Hillel, 1995; Rosenzweig, and Liverman, 1992; Richard et al., 1998) especially in tropical countries where rain-fed agriculture is widely prevalent.

Climate change became a major international issue towards the end of the 20th century. This is perhaps the most universally discussed developmental issue of the 21st century. Climate change is a product of human development, but this is now becoming a serious threat to development itself. Its impact will directly affect all sectors of life in every country and nobody can escape from the consequences of climate change (HDR, 2007/2008).

GREENHOUSE GASES (GHGS) AND GREENHOUSE EFFECT

The gases that contribute to the greenhouse effect by absorbing infrared radiation and cause warming of the earth's atmosphere are known as greenhouse gases. Carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), perfluorocarbons (PFCs), Hydrofluorocarbons (HFCs) and sulphur hexafluoride (SF6) are the main greenhouse gases. Water vapour is also considered as a greenhouse gas, but it stays in the atmosphere for only a short time. However, in humid tropics, a high concentration of CO_2 in the atmosphere can have a more powerful warming effect due to the prevailing high atmospheric humidity. Some species of the GHGs (CO_2, CH_4, N_2O and water vapour) have been naturally occurring; while the others (PFCs, HFCs and SF6) are produced purely as a result of industrial activities.

Life on earth depends on the energy which is received from the sun, the ultimate source of energy. About 30 percent of the sunlight that beams toward earth is reflected by the earth surface, clouds and aerosols and scattered back in to the space. The rest of the light reaches the earth surface and again reflected as a type of long wave radiation. Greenhouse gases present in the atmosphere absorb the infrared radiation leaving the planet and reflect it again back to the earth's surface and this causes the atmosphere to warm. This phenomenon is known as “greenhouse effect” and it plays a significant role in shaping the earth's climate. It produces the relatively warm and hospitable environment near the earth's surface where humans and other life-forms have been able to develop and prosper. With no GHGs present in the atmosphere, the mean temperature of earth would be around -18 ^{0}C (Le Treut et al., 2007), much below the current mean temperature of about 14 to 14.5 ^{0}C and unsuitable for human inhabitation. Greenhouse effect is one of a large number of physical, chemical and biological processes that determine the earth's climate

INCREASE IN ATMOSPHERIC GHG CONCENTRATION

David Keeling's continuous and accurate measurements of atmospheric CO_2 concentration since 1958 on Mauna Loa in Hawaii provide the best data on global carbon cycle. Observations on the atmospheric abundances of 13 CO_2 isotope (Francey and Farquhar, 1982) and molecular oxygen (O_2) (Keeling and Shertz, 1992; Keeling et al., 1993) indicated that as fossil fuel consumption increased, atmospheric concentration of CO_2 also went up. The ice core data also provided that the CO_2 concentration in the ice age periods was significantly lower than the industrial period. Thousands of years before industrial revolution, CO_2 concentration in the atmosphere stayed within the range 280±20 ppm (Indermuhle et al., 1999). During the industrial era, CO_2 concentration increased exponentially to 367 ppm in 1999 (Neftel et al., 1985; Etheridge et al., 1996) and to 379 ppm in 2005 (IPCC, 2007) and 395 ppm in 2013 (IPCC, 2013). Measurements of the atmospheric concentration of the two other major greenhouse gases, methane (CH4) and nitrous oxide (NO_2) since 1970 have also showed an increasing trend (Graedel and McRae, 1980). CH_4 concentration was relatively constant abundance of 700 ppb until the 19th century when a steady increase brought CH_4 abundances to 1,745 ppb in 1998 and 1,774 ppb in 2005. For NO_2 the increase over the period from 1998 to 2005 was only 5 ppb (314 ppb in 1998 and 319 ppb in 2005), but the changes from the glacial-interglacial cycles (180-260 ppb) was much higher (IPCC, 2007).

TEMPERATURE RISE: GLOBAL CONTEXT

Global land surface temperature (LST) and sea surface temperature (SST) have been increasing at an increasing rate in recent decades and according to IPPC, this is unequivocal and anthropogenically induced (IPCC, 2007 & IPCC, 2013). The present global average surface temperature is much higher than that of the pre-industrial period. The current warming trend is very likely due to accumulation of human-induced greenhouse gases in the atmosphere and proceeding at a rate that is unprecedented in the past 1,300 years (IPCC, 2007).

Rate of global warming during 1910s-1940s was 0.35 0C per decade and from 1970s to the first decade of this millennium was 0.55 0C per decade (IPCC, 2007). Eleven of the 12 warmest years on record have occurred in the most recent 12 years. According to an assessment by NOAA, the year 2012 was one of the 10 warmest years since global average temperatures have been recorded and the planet has transformed by rising temperatures (Blunden and Arndt, 2013). Global average surface temperatures have increased by about 0.74 0C over the past 100 years since 1906.

Generally the temperature has been increasing in an increasing rate in the last one and half century (AR4 & AR5). The rate of increase for last 150 years was 0.045 ^{0}C per decade while the rate for the last 25 years was 0.177 ^{0}C per decade. Even as there was consistency between the land and ocean temperature changes, the latter increased more slowly than land temperatures because of the larger effective heat capacity of the oceans and the ocean loses more heat by evaporation (Sutton et al., 2007). Since the beginning of industrialization, the inter-hemispheric temperature difference has increased due to melting of sea ice and snow in the North (Fuelner, et al., 2013).

Average arctic temperatures have been increasing at almost twice the rate of the rest of the world in the past 100 years, however arctic temperatures are also highly variable (IPCC, 2007). Although more greenhouse gases are emitted in the Northern than Southern Hemisphere, this does not contribute to the difference in warming because the major greenhouse gases persist long enough to mix between hemispheres (TAR, 2001). IPCC projected an increase in global mean surface air temperature (SAT) which will continue over the 21st century if the anthropogenic greenhouse gases keep on emitting with the current rate. Geographical patterns of projected surface air temperature warming show greatest temperature increases over land (roughly twice the global average temperature increase) and at high northern latitudes, and less warming over the southern oceans and North Atlantic, consistent with observations during the latter part of the 20th century. The equilibrium global mean surface temperature warming for a doubling of atmospheric carbon dioxide is likely to lay in the range 2 ^{0}C to 4.5 ^{0}C, with a most likely value of about 3^{0}C. It is very likely that heat waves will be more intense, more frequent and longer lasting in a future warmer climate. Cold episodes are projected to decrease significantly in a future warmer climate. Almost everywhere, daily minimum temperatures are projected to increase faster than daily maximum temperatures, leading to a decrease in diurnal temperature range (see figure 1.1, 1.2, 1.3, & 1.4). Decreases in frost days are projected to occur almost everywhere in the middle and high latitudes, with a comparable increase in growing season length (AR 4, 2007 & AR 5, 2013, The Physical Science basis).

Figure 1.1: Estimated trend of observed global mean surface temperature.

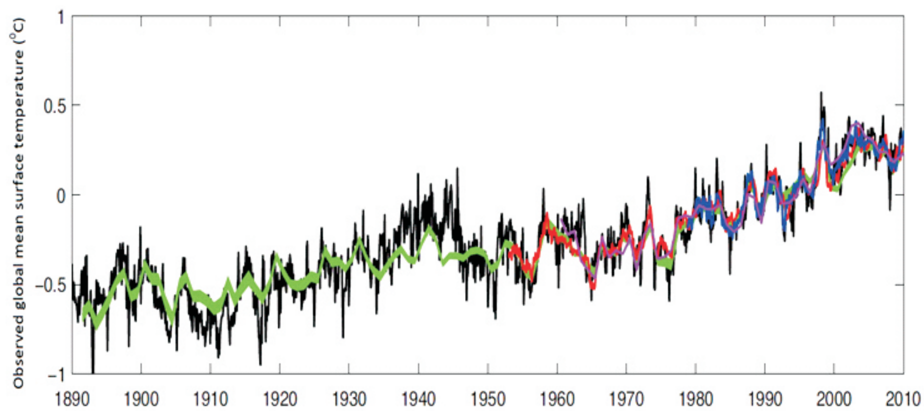


Figure 1.2: Estimated trend of contribution of volcanoes in global mean surface temperature

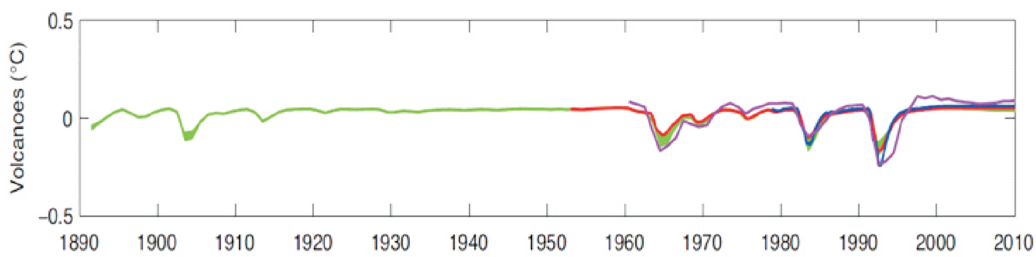


Figure 1.3: Estimated trend of contribution of solar in global mean surface temperature.

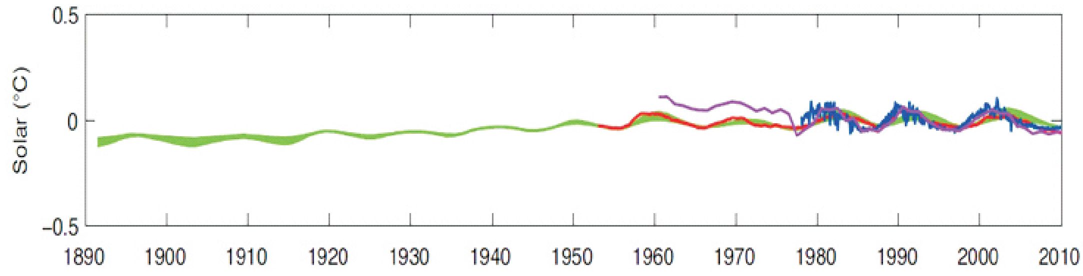
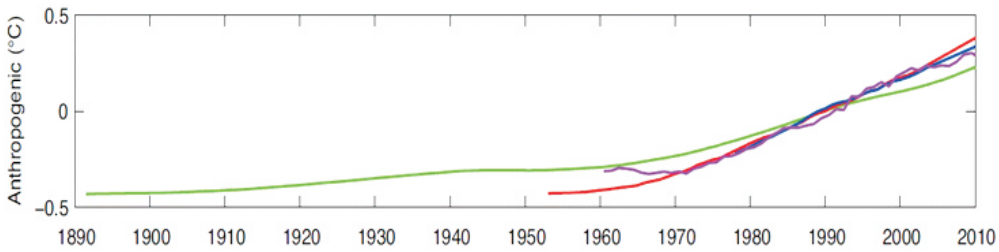


Figure 1.4: Estimated contributions of anthropogenic in global mean surface temperature.



Source: AR 5, Climate change 2013, The Physical Science basis

Note: Trends have been estimated on specific data/studies/methods as Hadley Centre/ Climatic Research Unit gridded surface temperature data set version 3 (black line) and the best multivariate fits using the method of Lean and Rtnd (2009) (red line), Lockwood (2008) (violet line), Folland et al. (2013) (green line) and Kaufmann et al. (2011) (blue line).

Anthropogenic influence (GHG responsible for global warming while aerosol for global cooling) on climate has been robustly detected on the global scale, but for many applications an estimate of the anthropogenic contribution to recent temperature trends over a particular region is more useful. However, detection and attribution of climate change at continental and smaller scales is more difficult than on the global scale for several reasons. In the last five to six decades global temperature as well as Asian continent temperature is increasing at its critical limit, moreover anthropogenic forces are the major contributor (see figure 2.1).

• Evidences from Indian Subcontinent

Indian subcontinent is also not an exception for the changes in surface temperature due to climate change. Temperature variability across the country was studied by Kumar and Hingane (1988); Pant and Hingane (1988); Kumar and Parikh (1998); showed a significant warming trend of 0.57 °C per 100 years in India for 1881–1997, seasonally and annually. The magnitude of warming was higher in the post- monsoon and winter seasons. The monsoon temperature did not show a significant trend in any major parts of the country, except for a significant negative trend over northwest India. Mean annual temperature was found to be increasing in all India level, in the west coast, interior peninsula, north central and north-eastern regions during the period 1901-1982 (Hingane et. al., 1985).

Trend analyses of maximum and minimum temperature data at 121 stations in India for 1901-1987 by Rupa Kumar et al. (1994) showed increasing maximum temperature, minimum temperature did not show any pattern, resulting in rise in mean and diurnal range of temperature. For the last 100 years, there was an increase of 0.42 °C in the annual mean temperature, 0.92 °C in the mean maximum temperature and 0.09 °C in the mean minimum temperature. There was a rise of 1.1 °C in mean winter temperature, 0.94 °C in mean post- monsoon temperature, and a decline of 0.40 °C in mean pre-monsoon temperature for the last century in India (Arora et al., 2005). Frequency of occurrence of hot days and hot nights showed an increasing trend, whereas cold days and cold nights showed a decreasing trend during the period 1970–2005 in India as a whole and seven homogeneous regions. For the last 100 years in India, the annual mean, maximum and minimum temperatures showed significant warming trends of 0.51 °C, 0.72 °C and 0.27 °C, respectively. Indian mean annual and seasonal temperatures also showed a significant warming trend in all seasons (Kothawale et al., 2010).

• Temperature Trend in Uttarakhand

The climate of Uttarakhand is temperate, marked by seasonal variations in temperature but also affected by tropical monsoons. January is the coldest month, with daily high temperatures averaging below freezing in the north and near 70 °F (21 °C) in the southeast. In the north, July is the hottest month, with temperatures typically rising from the mid -40s F (about 7 °C) to about 70 °F daily. In the southeast, May is the warmest month, with daily temperatures normally reaching the low 100s F (about 38 °C) from a low around 80 °F (27 °C). Most of the states roughly 60 inches (1,500 mm) of annual precipitation are brought by the southwest monsoon, which blows from July through September. Floods and landslides are problems during the rainy season in the lower stretches of the valleys. In the northern parts of the state, 10 to 15 feet (3 to 5 meters) of snowfall is common between December and March (Sati & Kumar, 2013).

Analysis of temperature data of Mountainous regions of Uttarakhand showed that the surface maximum temperature over the region has significantly increased annually and seasonally during the last five to six decades. If see the pattern of temperature of last three to four decades in the region it is found that annual mean maximum temperature of Mukhim ($T_{M\_Mmax\_Annual}$) and Mukteshwar ($T_{R\_Mmax\_Annual}$) weather station, and highest annual maximum temperature of Mukhim ($T_{M\_Hmax\_Annual}$) and Mukteshwar ($T_{R\_Hmax\_Annual}$) is increasing. Annual mean minimum temperature and lowest minimum temperature of both weather stations are having opposite trend; annul mean minimum temperature (TM_Mmin_Annual) and annual lowest minimum temperature ($T_{M\_Lmin\_Annual}$) of Mukhim weather station is getting decreased on the contrary annual mean minimum temperature ($T_{R\_Mmin\_Annual}$) and annual lowest minimum temperature ($T_{R\_Lmin\_Annual}$) of Mukteshwar weather station is getting increased (see figure 2.2 and 2.3).

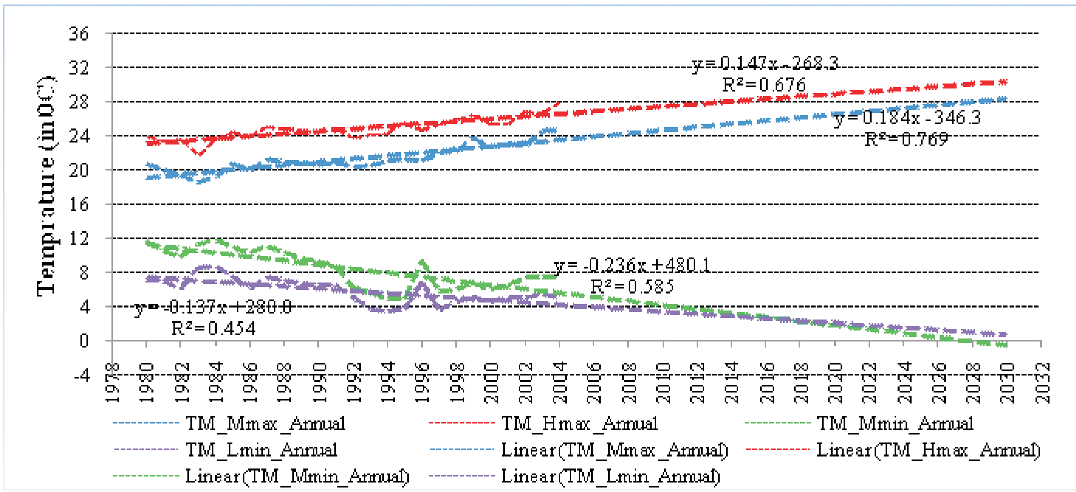


Figure 2.2: Trends of following indicators of climate;

Annual trend of mean maximum temperature of Mukhim weather station ($T_{M\_Mmax\_Annual}$), Annual trend of highest maximum temperature of Mukhim station ($T_{M\_Hmax\_Annual}$), Annual trend of mean minimum temperature of Mukhim weather station ($T_{M\_Mmin\_Annual}$), and Annual trend of lowest minimum temperature of Mukhim weather station ($T_{M\_Lmin\_Annual}$)

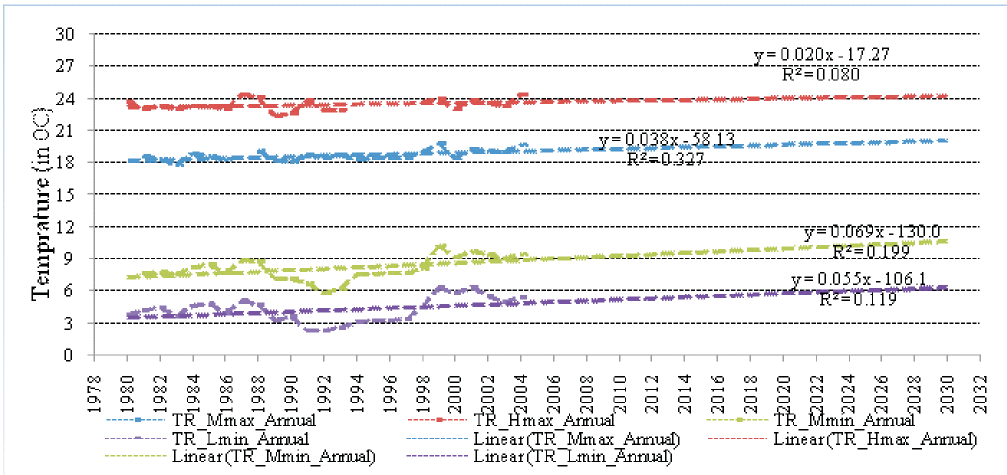


Figure 2.3: Trends of following indicators of climate;

Annual trend of mean maximum temperature of Mukteshwar weather station ($T_{R\_Mmax\_Annual}$), Annual trend of highest maximum temperature of Mukteshwar weather station ($T_{R\_Hmax\_Annual}$), Mean minimum temperature trend of Mukteshwar weather station ($T_{R\_Mmin\_Annual}$), and Lowest minimum temperature trend of Mukteshwar weather station ($T_{R\_Lmin\_Annual}$).

Data collected from Mukhim weather station is showing incline of 0.19 ^{0}C year^{-1}, 0.15 ^{0}C year^{-1}, -0.24 ^{0}C year^{-1}, and -0.14 ^{0}C year^{-1} in annual mean maximum temperature ($T_{M\_Mmax\_Annual}$), annual highest maximum temperature ($T_{M\_Hmax\_Annual}$), annual mean minimum temperature ($T_{M\_Mmin\_Annual}$), and annual lowest minimum temperature (TM_Lmin_Annual), respectively, on the contrary data collected from Mukteshwar weather station is showing incline of 0.04 ^{0}C year^{-1}, 0.02 ^{0}C year^{-1}, 0.07 ^{0}C year^{-1}, and 0.06 ^{0}C year^{-1} for annual mean maximum temperature ($T_{R_Mmax_Annua}$l), annual highest maximum temperature ($T_{R\_Hmax\_Annual}$), annual mean minimum temperature ($T_{R\_Mmin\_Annual}$), and annual lowest minimum temperature ($T_{R\_Lmin\_Annual}$) respectively. Result of Mann-Kendall trend test regarding agricultural land use pattern is facilitated in the table 2.2.

Table 2.2: Sen's estimator of slope for various heads of temperature in Uttarakhand

Particulars	Kendall's tau	S	ρ -value	Sen's estimator	Confidence interval
$T_{M\_Mmax\_Annual}$	+0.725	217	< 0.0001	+0.18*	0.175 to 0.194
$T_{M\_Mmin\_Annual}$	-0.513	-154	0	-0.23*	-0.254 to -0.211
$T_{R\_Mmax\_Annual}$	+0.364	109	0.012	+0.03*	0.023 to 0.027
$T_{R\_Mmin\_Annual}$	+0.297	82	0.044	+0.07*	0.067 to 0.079

(*) Values are significant at 95percent confidence level.

As the computed ρ-value is lower than the significance level a = 0.05, Therefore, Null Hypothesis (H_0: there is no trend in the series) is rejected, i.e., Alternative Hypothesis (H_A: there is a trend in the series) is selected.

• Seasonal Trend: Winter Cropping Season

Winter is longest season of Uttarakhand. In most parts of the hilly region, winter sets in during the end of November and continues until in the end of March with increase in the day temperature. Temperature goes lowest during winter in hills, especially in upper tracts of Uttarakhand. A thick blanket of snow covers the ground for three to four months during this season in higher reaches. Snowfall occurs usually over the elevation of 2,200 m. Frost is experienced in the valleys and terai and bhabhar tracts. Avalanches and snowstorms are common above the snow line in the winter season (Tripathi, S.K. & Chintamanie, B., 2010).

If see the winter season pattern of temperature of last three to four decades in the region it is found that mean maximum temperature during winter season of Mukhim ($T_{M\_Mmax\_winter}$) and Mukteshwar ($T_{R\_Mmax\_winter}$) weather station, and highest maximum temperature during winter season of Mukhim ($T_{M\_Hmax\_winter}$) and Mukteshwar ($T_{R\_Hmax\_winter}$) is increasing. Mean minimum temperature and lowest minimum temperature of winter season of both weather stations are having opposite trend; mean minimum temperature ($T_{M\_Mmin\_winter}$) and lowest minimum temperature ($T_{M\_Lmin\_winter}$) during winter season of Mukhim weather station is getting decreased on the contrary mean minimum temperature ($T_{R\_Mmin\_winter}$) and lowest minimum temperature ($T_{R\_Lmin\_winter}$) during winter season of Mukteshwar weather station is getting increased (see figure 2.4 and 2.5).

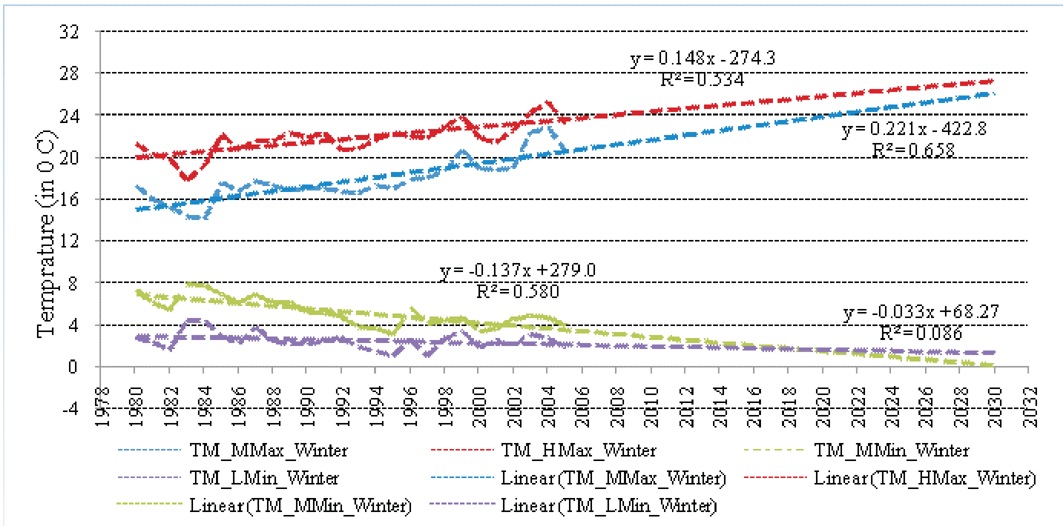


Figure 2.4: Trends of following indicators of climate;

Mean maximum temperature of Mukhim weather station during winter season ($T_{M\_MMax\_Winter}$), highest maximum temperature of Mukhim weather station during winter season ($T_{M\_HMax\_Winter}$), Mean minimum temperature of Mukhim weather station during winter season ($T_{M\_MMin\_Winter}$), and Lowest mean temperature of Mukhim weather station during winter season ($T_{M\_LMin\_Winter}$).

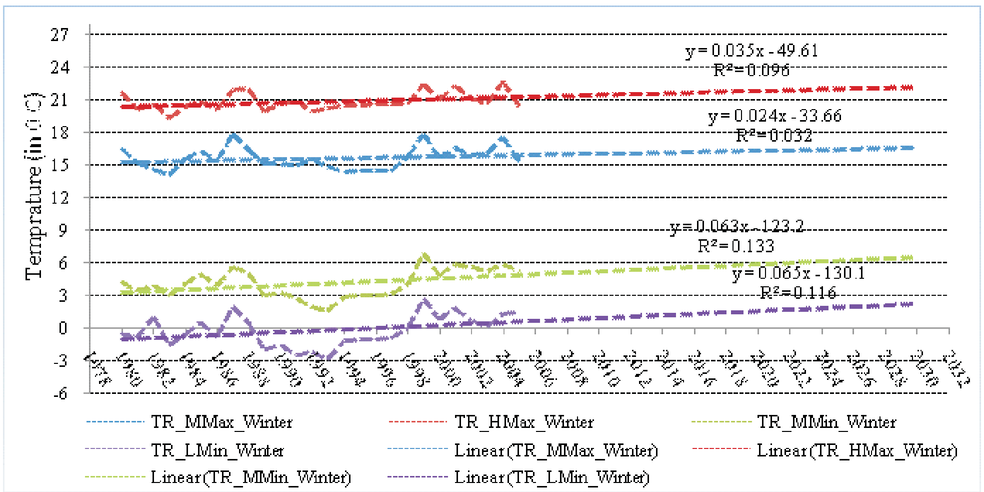


Figure 2.5: Trends of following indicators of climate;

Mean maximum temperature of Mukteshwar weather station during winter season ($T_{R\_MMax\_Winter}$), highest maximum temperature of Mukteshwar weather station during winter season ($T_{R\_HMax\_Winter}$), Mean minimum temperature of Mukteshwar weather station during winter season ($T_{R\_MMin\_Winter}$), and Lowest mean temperature of

Mukteshwar weather station during winter season ($T_{R\_LMin\_Winter}$).

Data collected from Mukhim weather station is showing incline of 0.22 ^{0}C year-1, 0.15 ^{0}C year^{-1}, -0.14 ^{0}C year^{-1}, and -0.03 ^{0}C year^{-1} in mean maximum temperature ($T_{M\_Mmax\_winter}$), highest maximum temperature ($T_{M\_Hmax\_winter}$), mean minimum temperature ($T_{M\_Mmin\_winter}$), and lowest minimum temperature ($T_{M\_Lmin\_winter}$) of winter season, respectively, on the contrary data collected from Mukteshwar weather station is showing incline of 0.03 ^{0}C year^{-1}, 0.04 ^{0}C year^{-1}, 0.06 ^{0}C year^{-1}, and 0.07 ^{0}C year^{-1} for mean maximum temperature ($T_{R\_Mmax\_winter}$), highest maximum temperature ($T_{R\_Hmax\_winter}$), mean minimum temperature ($T_{R\_Mmin\_winter}$), and lowest minimum temperature ($T_{R\_Lmin\_winter}$) of winter season, respectively.

• Seasonal trend: Summer Cropping Season

If see the summer season pattern of temperature of last three to four decades in the region it is found that mean maximum temperature during summer season of Mukhim ($T_{M\_Mmax\_summer}$) and Mukteshwar ($T_{R\_Mmax\_summer}$) weather station, and highest maximum temperature during summer season of Mukhim ($T_{M\_Hmax\_summer}$) and Mukteshwar ($T_{R\_Hmax\_summer}$) is increasing. Mean minimum temperature and lowest minimum temperature of summer season of both weather stations are having opposite trend; mean minimum temperature ($T_{M\_Mmin\_summer}$) and lowest minimum temperature ($T_{M\_Lmin\_summer}$) during summer season of Mukhim weather station is getting decreased on the contrary mean minimum temperature ($T_{R\_Mmin\_summer}$) and lowest minimum temperature ($T_{R\_Lmin\_summer}$) during summer season of Mukteshwar weather station is getting increased (see image 2.6 and 2.7).

Data collected from Mukhim weather station is showing incline of 0.13 ^{0}C year-1, 0.12 ^{0}C year-1, -0.29 ^{0}C year^{-1}, and -0.23 ^{0}C year^{-1} in mean maximum temperature ($T_{M\_Mmax\_summer}$), highest maximum temperature ($T_{M\_Hmax\_summer}$), mean minimum temperature ($T_{M\_Mmin\_summer}$), and lowest minimum temperature ($T_{M\_Lmin\_summer}$) of winter season, respectively, on the contrary data collected from Mukteshwar weather station is showing incline of 0.01 ^{0}C year^{-1}, 0.01 ^{0}C year^{-1}, 0.07 ^{0}C year^{-1}, and 0.06 ^{0}C year^{-1} for mean maximum temperature ($T_{R\_Mmax\_summer}$), highest maximum temperature ($T_{R\_Hmax\_summer}$), mean minimum temperature ($T_{R\_Mmin\_summer}$), and lowest minimum temperature ($T_{R\_Lmin\_summer}$) of winter season, respectively.

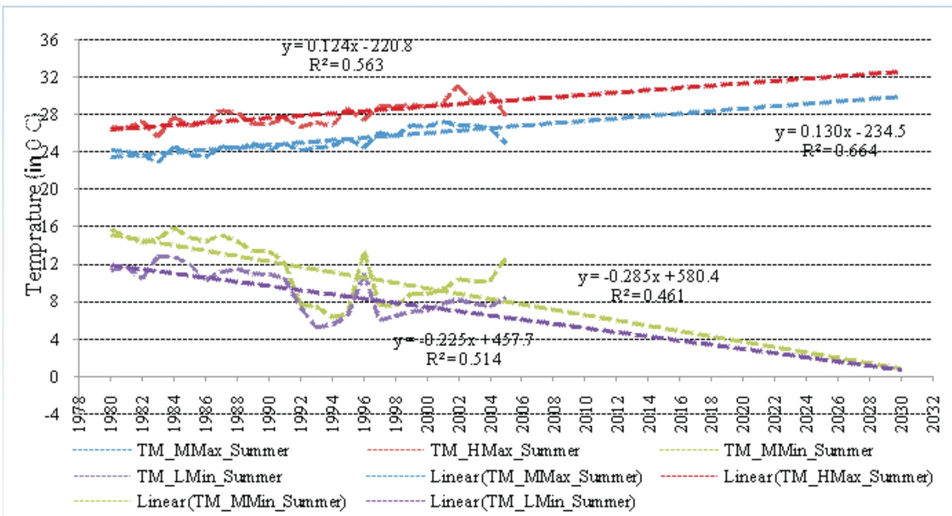


Figure 2.6: Trends of following indicators of climate;

Mean maximum temperature of Mukhim weather station during summer season ($T_{M\_MMax\_Summer}$), highest maximum temperature of Mukhim weather station during summer season ($T_{M\_HMax\_Summer}$), Mean minimum temperature of Mukhim weather station during summer season ($T_{M\_MMin\_Summer}$), and Lowest mean temperature of Mukhim weather station during summer season ($T_{M\_LMin\_Summer}$).

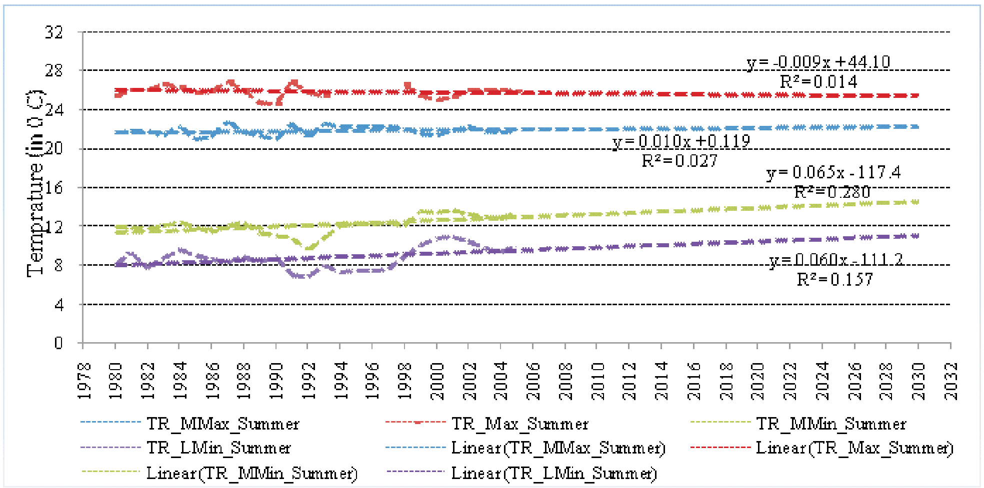


Figure 2.7: Trends of following indicators of climate;

Mean maximum temperature of Mukteshwar weather station during summer season ($T_{R\_MMax\_Summer}$) highest maximum temperature of Mukteshwar weather station during summer season ($T_{R\_HMax\_Summer}$), Mean minimum temperature of Mukteshwar weather station during summer season ($T_{R\_MMin\_Summer}$), and Lowest mean temperature of Mukteshwar weather station during summer season ($T_{R\_LMin\_Summer}$).

CONCLUSION

Accumulation of greenhouse gases in the atmosphere since the beginning of industrial revolution is largely responsible for the current warming and changes to global climate that are witnessing today. Global as well as regional evidences are showing that global climate has got changed and the mean temperature of the planet has gone up and it continues to go up at an increasing rate. Mountainous evidences of rapid climate change have now throwing drastic impact over the entire globe. This can have unprecedented effects on agriculture, food supply, biodiversity and human health of outreach population of Mountains. It can be seen that global warming is the byproduct of human development which has been and still largely driven by fossil energy. But, the economic costs of environmental damage are being paid by the cultivators of high altitude agriculture zones. Unprecedented change in the climatic phenomenon as, rising temperature, erratic precipitation, and increasing hazardous events are responsible factors which causing decreasing rain-fed agriculture in the high altitude agriculture zone in the region.

REFERENCE

1.Arora, M., Goel, N. K. and Singh, P. (2005).Evaluation of temperature trends over India. Hydrological Sciences Journal. 50 (1): 81–93.

2.Blunden, J. and Arndt, D. S. (Eds). (2013). State of the Climate in 2012. Bulletin of American. Meteorological Society. 94 (8): S1–S238.

3.Etheridge, D. M., Steele, L. P., Langenfelds, R. L., Francey, R. J., Barnola, J.M. and Morgan, V. I. (1996). Natural and anthropogenic changes in atmospheric CO2 over the last 1000 years from air in Antarctic ice and firn. Journal of Geophysical Research. 101(D2): 4115–4128.

4.Folland, C. K., et al., (2013). High predictive skill of global surface temperature a year ahead. Geophys. Res. Lett., 40, 761–767.

5.Feulner G., Rahmstorf S., Levermann A., Volkwardt S. (2013). On the origin of the surface air temperature difference between the hemispheres in earth's present-day climate, Journal of Climate, 26(18): 7136-7150. doi:10.1175/JCLI-D-12-00636.1

6.Francey, R. J. and Farquhar, G. D. (1982). An explanation of 13C/12C variations in tree rings. Nature. 297: 28 – 31.

7.Graedel, T. E. and McRae, J. E. (1980). On the possible increase of the atmospheric methane and carbon monoxide concentrations during the last decade. Geophysical Research Letters. 7(11): 977-979.
8.HDR (Human Development Report). (2007/2008). Fighting climate change: Human solidarity in a divided world. Published for United Nations Development Programme by Palgrave Macmillan, New York.
9.Hingane, L.S., Kumar, K.R. and Murthy, B.V.R. (1985). Long term trends of surface air temperature in India. Journal of Climatology. 5: 521-528.
10.Indermühle, A., Stocker, T. F., Joos, F., Fischer, H., Smith, H. J., Wahlen, M., Deck, B., Mastroianni, D., Tschumi, J., Blunier, T., Meyer, R. and Stauffer, B. (1999). Holocene carbon-cycle dynamics based on CO2 trapped in ice at Taylor Dome, Antarctica. Nature. 398: 121 – 126.
11.IPCC, (2013) Fifth Assessment Report (AR5). Climate Change 2013: The Physical Science basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
12.IPCC, (2007). Fourth Assessment Report (AR4). Climate Change 2007: Impacts Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. vander Linden and C.E. Hanson (eds). Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
13.Kaufmann, R.K., Kauppi, H., Mann, M.L. and Stock, J.H. (2011). Reconciling anthropogenic climate change with observed temperature 1998–2008. Proc. Natl. Acad. Sci. U.S.A., 108, 11790–11793.
14.Keeling, R.F. and Shertz, S.R. (1992). Seasonal and interannual variations in atmospheric oxygen and implications for the global carbon cycle. Nature. 358:723-727.
15.Keeling, R.F., Najjar, R.P., Bender, M.L. and Tans, P.P. (1993). What atmospheric oxygen measurements can tell us about the global carbon cycle, Global Biogeochemical Cycles. 7(1): 37-67.
16.Kumar, K.S.K and Parikh, J. (1998). Climate change impacts on India agriculture. The Ricardian approach. In: Measuring the impacts of Climate Change on Indian Agriculture, Technical paper No.402.World Bank, Washington, D.C.
17.Kumar, K.R. and Hingane, L.S .(1988). Long term variations of surface air temperature at major industrial cities of India. Climatic change. 13: 287-307.
18.Kothawale, D. R., Munot, A. A. and Kumar, K.K. (2010). Surface air temperature variability over India during 1901–2007, and its association with ENSO. Climate Research. 42: 89–104.
19.Le Treut, H., Somerville, R., Cubasch, U., Ding, Y., Mauritzen, C., Mokssit, A., Peterson, T. and Prather, M. (2007). Historical Overview of Climate Change. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
20.Lean, J.L., and Rind, D.H. (2009). How will Earth's surface temperature change in future decades? Geophys. Res. Lett., 36, L15708.
21.Lockwood, M., and Frohlich, C. (2008). Recent oppositely directed trends in solar climate forcings and the global mean surface air temperature: II. Different reconstructions of the total solar irradiance variation and dependence on response time scale. Proc. R. Soc. London A, 464, 1367–1385.
22.Neftel, A., Moor, E., Oeschger, H. and Stauffer, B. (1985). Evidence from polar ice cores for the increase in atmospheric CO2 in the past two centuries. Nature. 315:45-47.
23.Pant, G. B. and Kumar, K.R. (1997). Climates of South Asia, John Wiley & Sons Ltd.,West Sussex, UK. 320 pp.
24.Richard, M. A., Brian, H. H., Stephanie, L. and Neil, L. (1998). Effects of global climate change on agriculture: an interpretative review. Climate Research. 11: 19–30.
25.Rosenzweig, C. and Hillel, D. (1995). Potential Impacts of Climate Change on Agriculture and World Food Supply. Consequences (Summer):24–32.
26.Rosenzweig, C. and Liverman, D. (1992). Predicted effects of climate change on agriculture: A comparison of temperate and tropical regions. In Global climate change: Implications, challenges, and mitigation measures, ed. S. K. Majumdar, 342-61. PA: The Pennsylvania Academy of Sciences.

27.Sati M.C. and Kumar, Prashant (2013). Climate Change and Hill Agriculture: A case study of Uttarakhand state of Indian Himalaya. In J. Sundaresan et al. (Ed.), Climate Change and Himalaya. Scientific Publisher, India.
28.Sutton, R. T., Dong, B. and Gregory, J.M. (2007). Land/sea warming ratio in response to climate change: IPCC AR4 model results and comparison with observations. Geophysical Research Letters. 34(2): L02701, doi:10.1029/2006GL028164.
29.Tripathi, S.K. & Chintamanie, B. (2010). Climate Change and Agriculture over Uttarakhand. In GSLHVPrasad Rao, GGSN Rao and VUM Rao (Ed.). Climate Change and Agriculture Over India (pp. 259-268), Eastern Economy Edition, PHI Learning Private Limited, New Delhi.

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