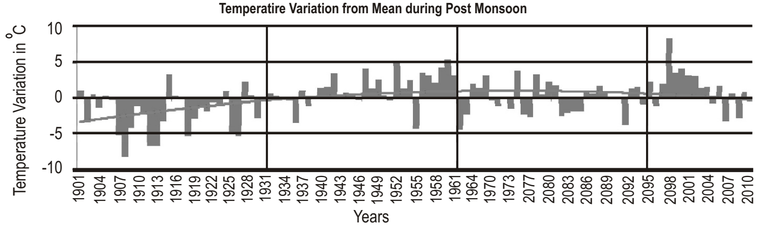
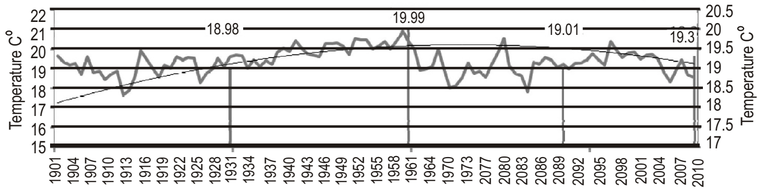
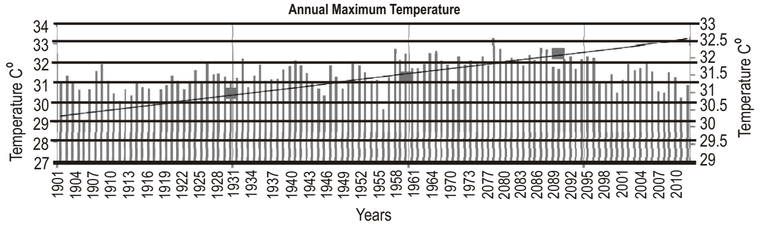


Minimum temperature shows significant rising trend of 0.012° C per year during post monsoon season and significant falling trend of 0.001° C per year during the monsoon season.(fig.4)

However minimum temperature shows insignificant increasing trend during winter and insignificant decreasing trend during summer season.

Fig 5 Average Minimum Temperature





Tri-decadal (30 years) comparison of maximum temperature over hundred years (period from 1901 to 2011) in Gorakhpur presents some interesting observations.(fig 6) Above Graph shows that annual maximum temperature for period from 1961 to 90 has maintained an overall higher trend compared to thirty years periods from 1901-1930 and 1931-1960 respectively. Similarly, tri-decadal annual average for minimum temperature during 1961 1990 has been found to maintain either lower or almost similar trend as that for annual minimum during 1930 1960 and 1901 1930. In other words, it could be said that summer is becoming more warm and winter more cooler in last thirty year i.e. from 1961-1990.

Cause of change in summer and winter temperatures may be of anthropogenic nature through building of greenhouse gases in upper atmosphere?? Interpretation of tri-decadal temperature with rainfall data shows increase in frequency of extreme rainfall events during same period i.e. 1961-1990. Extreme rainfall events repeat almost with consistency in every 4th or 5th year. It is further observed that extreme rainfall events are more consistent in later half of tri-decadal period after 1980. Therefore, corollary of temperature and rainfall events follow very much on expected lines and much to with heating on earth surface and atmosphere.

On decadal comparison basis, analysis of average maximum and minimum temperature shows almost an increase of 1° C. However comparison of average maximum temperature for periods 1961-90 and 1901-1960, temperature increase of almost 1.5°C is reported. Meaning thereby, much sharper increase in maximum temperature observed post 1960s. Similarly average winter temperature shows decline, however compared to maximum temperature, minimum temperature show gradual decline. It could be interpreted that there is overall warming of earth and atmosphere. (Fig.5 & 6) Increase or decrease in temperatures, however has not been accompanied by increase in quantity of precipitation, except for increase in frequency of extreme rain fall events. It is accompanied by reduced number of rainy days in Gorakhpur.

Interpretation of Climate data and Effects on Water Cycle Over Region

Analysis of temperature and rainfall trend in Gorakhpur finds corollary between two physical phenomenon of heating (temperature) and evaporation (rainfall). It is obvious that a general warming of atmosphere has factored into sporadic rainfall events. Temperature spikes in pre and post monsoon season have produced 'split effect' in monsoon circulation over region, leading to profound change in rainfall patterns and its consequent affect on general well-being of people. Over all, following results could be inferred from climate data analysis over Gorakhpur.

1. *Mean maximum temperature of Gorakhpur has increased by 0.88°C from 1901-2011.*
2. *Mean minimum temperature has decreased.*
3. *Changes in maximum and minimum temperature are more significant in post 1960 period.*
4. *Rate of decrease in mean minimum temperature is not commensurate with increase in mean maximum temperature. It leads to overall warming of atmosphere.*
5. *There is no significant change in over all quantity of precipitation. However, there is depreciating trend in total quantity of rainfall since 1970s.*
6. *Extreme rainfall events are more pronounced and frequent post 1960s. It means more rainfall in lesser number of days in the region.*
7. *Precipitation during monsoon season has shown unusual split. Rainfall is more common in late summer now i.e. during late June and in September. July and August months receive deficient rainfall.*

Conclusions

In last hundred years, Gorakhpur climate has undergone profound changes with consequent affects on life and property of people. Climate change is more significant and bothersome in later half of twentieth century. Growing extreme rainfall events have drastically affected livelihoods of people and if trend continues further, Gorakhpur city will receive more number of rural migrants in city. Increased population will cause increased demand on water, sanitation and other civic services in city.

City will face increased problem of water logging and flooding. It will affect people living in low lying areas of city further worsening water, sanitation, drainage systems. Since rice crop is the important Kharif crop (May- Oct) in this region. The decrease trend of rainfall during the July may delay/ affect the transplanting/ vegetative phase of crop.

Recommendation

1. *City must improve drainage and sanitation and water supply system*
2. *Housing construction should not be allowed in river basin and on flood plains or close of river system.*
3. *Water bodies and wetland need to be conserved to collect sporadic rainwater.*
4. *Urban development authority should review existing construction bylaws and issue new guidelines in view of climate change.*
5. *Construction bylaws should be reviewed in wake of water logging problem in Gorakhpur*
6. *Pilot projects to conserve green areas in city.*
7. *Mass communication and broadcasting of early-warning of extreme events, rainfall and temperature to general public.*
8. *Establishment and strengthening of community institutions to manage drinking water and sanitation systems.*

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Gorakhpur Environmental Action Group
Post Box # 60, Gorakhpur-273001 (U.P.)
Phone # 91 551 2230004, Fax # 91 551 2230005
E-mail : geag2@sancharnet.in, geag_india@yahoo.com
Website : www.geagindia.org

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PROGNOSTIC STUDY
of Climate Behavior in Gorakhpur

K. C. Pandey and M. Ghoshal
Gorakhpur Environmental Action Group
E-mail : geag.weather@gmail.com, ucei@geagindia.org

Biotic and abiotic constituents of an ecosystem have intricate and inalienable relations to sustain life on earth. Imbalance in this relation of any kind could prove to be catastrophic for continuance of life. Increased human activity and competing individual and national interests all over is unfortunately fast eroding this harmonious relation with consequent changes in climate profile. Impact of climate change is manifested differently and differentially in loss of life, damage to property, poor health or failing economy etc.

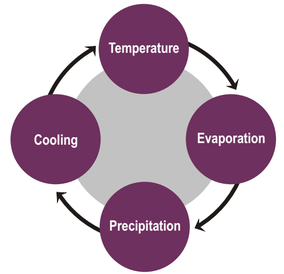
A growing concern over changing nature of climate has caught imagination of global audience. People and governments strive to find effective measures to fix the problem and build resilience. Phenomenon of climate change, however complicated may be to understand is increasingly felt by people and cities across the world. Gorakhpur too is not spared; and common experience of people with climate will tell a similar tale. So, coming back to answer the moot question, is climate change a rhetoric or reality, it was thought to have a critical review of basic elements of climate over Gorakhpur city.

***Key words** : Climate change, Precipitation, Hydrological cycle, Temperature, evaporation*

Thermo Hydrological Cycle and Climate An Introduction

Although there is much to know and learn about climate and complexities of relationships between ever changing factors, core of climate is generally understood or felt by commoners in terms of changes in temperature and precipitation. Physical phenomenon of heating, evaporation, precipitation and cooling forms the fulcrum to climate and hydrology with intermittent factors viz. wind, pressure, wind break, flora, fauna and natural phenomenon render garnishing effects to complicated science of climatology. (Fig.1)

Fig 1 Thermo Hydrological Cycle



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Delicate and dynamic balance between constituting factors is naturally influenced, it is precariously dented by anthropogenic phenomenon borne out of human needs and behavior. Food and energy securities of nation are two key dependants and determinants clamoring for growth on a constrained water budget. Rainfall received in region is important in determining quantum of water available to meet various demands, such as agricultural, industrial, domestic water supply. Global and local climate change may influence long-term rainfall patterns impacting availability of water, along with danger of increasing occurrences of droughts and floods. The South West Monsoon which brings about 78% of the total precipitation over the region is critical for the availability of fresh water for drinking and irrigation. Changes in climate over East Uttar Pradesh, particularly the South West Monsoon would have a significant impact of agricultural production, water resource management and livelihoods of millions of poor households. Present article would only make exhaustive analysis of two variables which are critical for regional hydrology i.e. rainfall & temperature.

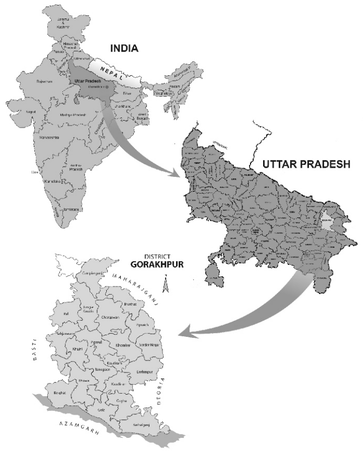
Scope of Study

Study is designed based on review of climate data for almost 111 years starting from year 1901 to 2011. Sample number of years is kept fairly large for making relevant assessment of climate health and to avoid inferring on data variations borne out of relatively small data samples. Analysis is done for only two physical parameters of climate i.e. temperature and rainfall. Except for generic fallout of impacts on livelihoods, study did not make any special attempt to establish cause and effects of climate change on loss of life or decline in economy of any particular region, district or city. Study however has drawn broad inferences from significant data deviations and trends.

Location and Physical Geography of District

Gorakhpur is one the most populated district of Eastern Uttar Pradesh situated. It is situated between 26°13′N and 27°29′N latitude and 83°05′ E and 83°56′ E longitude having long stretches of fertile alluvial plains split apart by perennial flow of gangetic[1] river system. District Gorakhpur shares common boundary with district Azamgarh on south, Basti on west and district Deoria on east. It shares international border with Nepal on north. (Fig.2)

| Fig 2 | Gorakhpur District



Perched close to Himalayan mountain range[2] and 1.65 per cent land under forest cover[3], beside large number of lakes and water bodies, Gorakhpur district finds itself nestled in unique microcosm of ecosystem. Three major seasons relay in succession of each other render range to agro-climatic conditions and to agriculture production and food economy[4] of country.

Geographical location of district and climate variability in region has close interrelations and may affect primary source[5] of livelihood for hundreds and thousands of families.

Gorakhpur City

Gorakhpur is head quarter of district and is also main center of commerce and trade in district. Population of Gorakhpur city is 692,519[6] and is rapidly increasing. Percentage of urban population to total population of district is 18.78[7] and changing fast with large floating population come and go every day in search of job in city. Pace of urbanization is fast eroding natural ecosystem in peri-urban areas and wetland[8] within city. It exacerbates micro-climate of city/region due to heat-island, increasing aerosol and changes in natural drainage line of river.

Gorakhpur city is situated 78 meter above mean sea level, which is not very high from level[9] of river bed. It does not allow low lying areas of city to drain properly, causing water to stand for 2-3 months in a year. Location, physical geography of district, perennial flow of river systems, plentiful of forest cover, low relief and large number of water bodies render a unique micro-climate to city. Rapid pace of urban expansion however is gradually rasping natural ecosystem around city by either filling low-lying areas with solid waste or building constructions on it. It perhaps is giving birth to some new ecosystem and building climate risks in city.

Climate-scan of Gorakhpur City

Gorakhrpur city always used to have moderate climatic condition which was neither extremely hot in summer nor very cold during winter months. Rainy days were fairly long, consistent and evenly spread during season. City records annual mean rainfall of 1238.9 mm with standard deviation of 304.4 mm. Annual mean temperature of city is 25.30 °C Annual mean maximum temperature of city is 31.45 °C and annual mean minimum temperature is 19.34 °C.[10] Thus climate behavior and extremes in Gorakhpur are said to be fairly normal and livable.

In summer average[11] maximum temperature however soars as high as to 37.5 °C and winter average minimum is 10.2 °C. Comparing annual mean maximum and minimum with summer and winter peaks for Gorakhpur, a general increase and decrease of 6.1° C and 9.1° C in summer and winter is found. On cursory basis, it could be summed that city is not very hot in summer but definitely cold during winter months.

Maximum temperature ever recorded for Gorakhpur is 49.4° C on 15 May 1962 and minimum temperature is- 1.0° C on 09 Jan 2013. While ever recorded rainfall in 24 hrs for Gorakhpur is 342.9 mm on 29 June 2013.

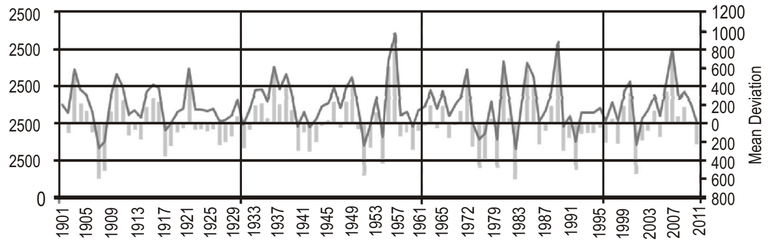
General climate scan of city gives empirical ideas about climate scenario in Gorakhpur. But growing encounters with extreme events and experience of climate change by commoners however draws attention and need for deeper analysis and understanding of climate change phenomenon. It is for this purpose critical analysis of three seasons is conceived to be more prudent method to situate issue of climate change in Gorakhpur. For each three seasons, 110 years data is analyzed and inferences are drawn accordingly.

Scan of Seasonal Trends in Precipitation

Analysis of rainfall for period from 1901 to 2011 year shows declining but not significant trends in annual rainfall. However, 0.12 mm. per year increase in rainfall is observed in pre-monsoon period i.e. in summer months, particularly in the month of June. Similar increase in rainfall trend is observed in post monsoon period. Pre and post monsoon increases are however reversed by insignificant decrease of rainfall in monsoon. Data for period 1901-30 however show decreasing trend of rainfall during rainy seasons, particularly in month of July. Over all, significant decline of 3.2 mm per day rain is reported during rainy season. No specific trend in winter rainfall has been noticed for period 1901 -2011 except for marginal decline of rainfall in December. However 0.4 mm increase per year in rainfall from period 1971-2000 is reported in January.

Declining trend of rainfall is not encouraging sign and beacon loss in food grain and agriculture production in district. Decline of rainfall in December is particularly alarming for sowing of Wheat, which constitutes main winter crop of region. (Fig.3)

| Fig 3 | Annual Rainfall and its variation from Mean



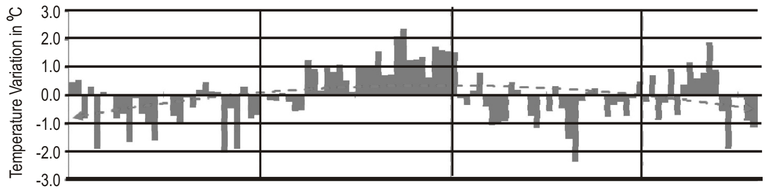
Scan of Seasonal Trends in Temperature

Among two important climate variables, temperature is one of the key variables usually experienced by common people as climate change. Temperature variations have deep impact over hydrological cycle and climate of any region. Analysis and interpretation of temperature variability therefore constitutes important component of study.

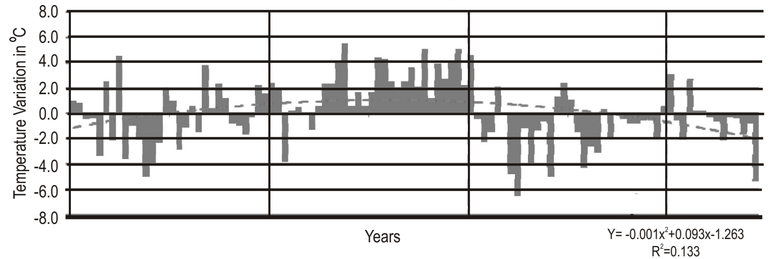
Like rainfall, temperature trend too is largely fluctuating with marginal increase over Gorakhpur. Temperature data analysis for period from 1901 to 2011 shows overall increasing trend for maximum temperature by 0.008°C (per year). Rise in maximum temperature is most significant during monsoon season (0.008 ° C per year) and 0.014 ° C (per year) during post monsoon season. No significant trend is found in maximum temperatures in summer and winter seasons.(Fig 4)

| Fig 4 | Seasonal Variation of Mean Temperature (1901-2011)

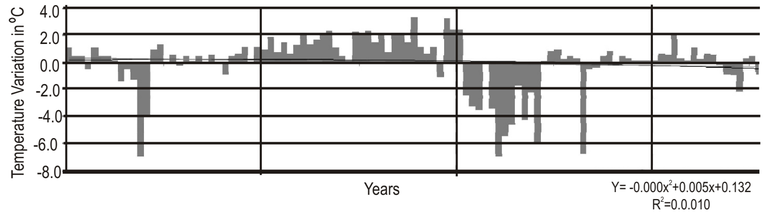
Temperature Variation from Mean in Winter Season



Temperatire Variation from Mean during Pre Monsoon



Temperatire Variation from Mean during Monsoon



1 Rapti, Rohin and Chhoti Gandak river
2 Lower Himalayan mountain range is approx 150 km.
3 www. mofe.nic.in
4 651719 metric tons of food grain production in Gorakhpur district
5 66% HHs depended on agriculture
6 Census of India 2011 (www.censusofindia.gov.in last access on 17.9.13)
7 Census of India 2011 (www.censusofindia.gov.in last access on 17.9a nbvvhnh.13)
8 Ramgarh Tal lak is 18 kms.
9 Wajih, 2010
10 Average of 110 years climate data from IMD and IITM
11 Average maximum and minimum of 110 years climate data