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Impact of El-Nino Southern Oscillation Index on Monsoonal Rainfall

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ABSTRACT: This paper is described to investigate linkages between a large scale index, namely El-Nino southern oscillation and precipitation at several meteorological stations in India. The climate indices considered in this study include both phases of El-Nino southern Oscillation index. Linkages of both the phases of El-Nino southern oscillation with the precipitation data of several cities have been investigated in this project. Mean monthly temperature and rainfall data for several stations was obtained from India Meteorological Department (IMD), Pune. The data is available for the period 1901-2000. The NINO 3.4 index, that is the SST anomaly over the Nino3.4 region (1200 W–1700 W, 50 S– 50 N), was obtained from Climate Analysis Section, National Centre for Atmospheric Research, USA (<http://www.cgd.ucar.edu/>). An year is classified as an El-Nino year if the temperature anomaly in the Nino 3.4 region in the Pacific ocean for a particular year exceeds a threshold value of 0.40 C whereas a year with an anomaly less than 0.40 C is classified as a La-Nina year

KEYWORDS: El-Nino southern Oscillation index, India Meteorological Department, El-Nino year, La-Nina year

I. INTRODUCTION

Water is the most essential resource of all life on Earth. The spatial and temporal distribution of water is highly variable and is dependent upon the climatic factors that are beyond human control. Water resource systems are an important part of the infra-structure of every country, particularly the developing ones. In addition to the basic purpose of supporting life, water resource systems serve a multitude of water uses such as water supply, hydropower generation, recreation, irrigation, flood control, navigation and wild life maintenance. Due to tremendous population growth and extensive industrial and agricultural development, the demand on water resources is increasing everywhere in the world. In some parts, the characteristics of water supply and demand pose few problems for agricultural, domestic, and industrial users. In other areas, including much of the developing world, physical, social and political factors make effective water resource management vital. The situation is critical in developing countries as the gap between water demand and supply has been continuously widening. This has led to an increased emphasis on the optimal management of the available resources.

Rigorous planning and management of water resources is required for long term sustainable resource development. The need for optimal management of existing water resource systems as well as the optimal development of the new ones is now universally acknowledged. Currently, hydrological systems are designed, managed and operated on the assumption of stationarity of hydro-meteorological variables. It is well acknowledged that fluctuations in temperature and other meteorological variables are often the source of hydrologic variability in a basin. From an engineering perspective it is of utmost importance to understand and identify the changes that have taken place in the past in order to be able to consider their impact in future design and analysis activities. Therefore, the ability to identify trends of change in meteorological variables due to ongoing climate change is likely to enhance the capability of water resource managers to plan and design their systems with greater degree of efficiency and reliability.

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II. LITERATURE REVIEW

The review of literature was considered essential in order to put the work carried out in this project in context. One of the most important and immediate effects of global warming would be the changes in local and regional water availability (Jiang et al., 2007). Temperature changes are accompanied by changes in precipitation and runoff amounts. As a result, hydrological systems are anticipated to experience not only the changes in the average availability of water but also changes in the extremes (Jiang et al., 2007). Dracup and Vicuna (2005) reported that increase in temperature has impacted the timing of snowmelt in the California Sierra Nevada mountains leading to earlier system runoff. Other impacts of climate change that have been identified include changes in rainfall patterns, extreme weather events, and the quality of water availability.

Reservoir operations, crop production, erosion processes, runoff production and many other hydrological processes are likely to be impacted by climate change. Revelle and Waggoner, (1983) and Gleick (1987) have indicated that climate change can adversely affect the availability of water supply. Patterns of water demand will need to alter in response to changes in water supply. Some other impacts of climate change that have been identified includes changes in the quantity of runoff produced (Gleick, 1986; Lattenmaier and Gan, 1990), and changes in the timings of the hydrologic events.

Global climate is expected to change significantly due to the continuously increasing levels of carbon dioxide and other greenhouse gases. By the year 2056 the CO₂ concentration in the atmosphere is likely to double (Jenkins and Derwint, 1990). Globally, the 10 warmest years on record have occurred since 1990s (1989-98) with 1998 the warmest year in at least a millennium (Mann et al., 1999). Mean annual global increases of air temperature of 0.5^o C in the last century are evident, and the precipitation has increased over land in high latitudes in the Northern Hemisphere especially in the cold season (IPCC, 1996). The future projections of climate change indicate a global average warming of between 1.5^o to 4.5^o C, greater surface warming at high latitudes in winter, but less during the summer. An increase of 3 to 15 % in global precipitation is expected mainly due to globally increasing temperatures which causes greater evaporation from sea surface water. A year-round increase in precipitation in high-latitude regions is expected, whilst some tropical areas may experience small decreases.

During the last decade, the concentration of carbon dioxide and other greenhouse gases in Delhi has considerably increased mainly due to the vehicular pollution, excessive use of air conditioner units, rapid industrialization and changing land-use patterns. The interactions between increase in concentration of greenhouse gases and the weather systems are complex but a broad consensus exists among scientists that water availability, erosion processes, and runoff production are likely to experience significant impacts due to climate change. An alarming fact is that the rate of increase in greenhouse gas emissions in Delhi is likely to continue in the near term that is anticipated to result in several serious impacts on magnitude and timings of water availability in the city.

In developing countries like India, climate change represents an additional stress on ecological and socioeconomic systems that are already facing tremendous pressures due to rapid urbanization, industrialization and economic development. With its huge and growing population, a 7500-km long densely populated and low-lying coastline, and an economy that is closely tied to its natural resource base, India is considerably vulnerable to the impacts of climate change. A major impact of climate change is on the occurrence of extreme precipitation events leading to increase in the frequency and magnitude of extreme events such as floods and droughts. There are several indications that climate change is indeed taking place in India. The recent droughts in northern India and unprecedented floods in parts of Southern India are seen as a manifestation of ongoing climate change in India. Cheerapunji is the rainiest place on the globe but recently it saw a drought-like situation. Badhmer in Rajasthan, on the other hand, has been the driest place in India but recently there was large amount of rainfall in the region. People have not seen that kind of rainfall in the region during the last several decades. The year 2005 was the hottest year in the recorded history, and 10 out of the last 12 years have been the hottest. Recent drought in northern India is an indication of what changes in the patterns of monsoon could do to the country's agriculture in the coming years.

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III.NEED TO STUDIES IMPACT OF EL-NINO SOUTHERN OSCILLATION INDEX

From an engineering perspective it is of utmost importance to understand and identify the changes that have taken place in the past in order to be able to consider their impact in future planning and design activities. Meteorological variables, in particular temperature and precipitation, act as input to the hydrological cycle and impact the spatial and temporal distribution of rainfall. In the present world, the study of urban climates is attracting significant attention. Rapid urbanization that is taking place in cities is likely to have significant effects on climate in the cities. In recent years erratic patterns have been observed in monsoonal rainfall in India. Many modelling and empirical studies have revealed that summer monsoonal precipitation is significantly affected by El-Nino Southern Oscillation as well as by sea surface temperatures in the Arabian Sea, Bay of Bengal and Indian Ocean. Large scale climate indices are believed to impact the rainfall and temperature characteristics of different regions. Evaluating the impact of large scale indices on rainfall in India is, therefore, a subject of great practical significance. In an agriculture-dominated country like India where rainfall is critical to the large agricultural economy, the subject assumes great importance.

One of the major climate indices is El-Nino southern oscillation index. It is a quasi- periodic climate pattern that occurs in the tropical Pacific Ocean on average every 4-5 years. It is characterized by variations in the temperature of the surface of the tropical eastern Pacific Ocean- warm or cooling known as El Nino and La Nino respectively – and air surface pressure in the tropical western Pacific. Developing countries dependent upon agriculture and fishing, particularly those bordering the Pacific Oceans, are the most affected. El Nino is defined by prolonged differences in Pacific Ocean surface temperature when compared with the average value. The accepted definition is a warming and cooling of at least 0.4 C averaged over the east central tropical Pacific Ocean. ENSO causes extreme weather such as Floods, droughts and other weather disturbance in many region of the world. Therefore, it is important to analyse the meteorological data to understand the linkages between large scale climate indices and meteorological data.

Weather agencies worldwide are attempting to determine if systematic disturbances in climate, such as the El Niño-southern oscillation (ENSO), can be detected far enough in advance so that decisions can be altered to better accommodate these disturbances. If climate forecasters were able to disseminate information on upcoming ENSO-induced weather patterns with sufficient lead time, farmers could adjust by altering a variety of crop decisions, such as growing less (or more) water consumptive crops, planting drought resistant varieties, or altering planting times. This could have a positive impact on crop production, enhancing food security, farmers' incomes, and social welfare.

IV.PHENOMENON OF CLIMATE CHANGE

The earth's climate has been evolving continuously over millennia but the last two centuries have witnessed the development of the greenhouse problem, which threatens to change climate in an unprecedented manner. The greenhouse problem is created due to excessive accumulation of greenhouse gases in the atmosphere. The main greenhouse gases are carbon dioxide, methane, nitrous oxide, ozone and chlorofluorocarbons (CFCs). Except for CFCs the rest of the gases occur naturally together making up less than 1% of the atmosphere. The naturally occurring greenhouse gases allow incoming ultraviolet solar radiation to pass through relatively unimpeded, but partially absorb and re-emit outgoing infrared terrestrial radiation. This natural process changes the earth's average temperature from - 18 °C to +15 °C, and is hence, vital for life on earth.

Since the industrial revolution the anthropogenic activities such as energy generation from fossil fuels and deforestation activities have been increasing. Consequently, the atmospheric concentrations of greenhouse gases have increased beyond their natural levels, resulting in an enhanced greenhouse effect. This has caused an increase in global temperatures, a phenomenon known as global warming. This warming can be amplified through positive feedback, such as increases in water vapour, or reduced through negative feedback, such as increases in stratospheric aerosols.

Measurement records suggest that the world has already warmed by 0.3 to 0.6 °C since 1860 and the last two decades have been the warmest. Evidence is getting stronger that the warming being experienced at present is anthropogenic ally induced. The IPCC (Intergovernmental Panel on Climate Change) has recently completed its Third Assessment

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Report, which incorporates new results from the last 5 years of climate change research. The global average surface temperature is projected to increase by 1.4 °C to 5.8 °C over the period 1990 to 2100. This projected warming will be greater than that experienced over the last 10,000 years. It is also higher than the projected increase in the IPCC Second Assessment Report, which was 1.0 °C to 3.5 °C. Moreover, the global mean sea level is projected to rise by 9 cm to 88 cm over the same period, as a result of the thermal expansion of the oceans, and the melting of glaciers and polar ice sheets. The real concern here is, however, the rate of change in temperature. Such a rapid rate of change will leave ecosystems less time to adapt making them more vulnerable to the phenomenon of climate change.

Recognizing this problem, the United Nations Framework Convention on Climate Change (UNFCCC) aims at "stabilization of CO₂ concentrations at a level that will prevent dangerous anthropogenic interference with the climate system, within a timeframe sufficient for allowing ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner." The UNFCCC was opened for signature at the Rio Earth summit and came into force on 21 March 1994. Today 186 governments are party to the convention.

Climate change is primarily influenced by the total stock of GHGs in the atmosphere and not by annual GHG emissions. Historically, developed countries and economies in transition have been responsible for about 75% of the total global stock of GHGs. In terms of annual contributions too, the level of emissions across different countries shows considerable variations in terms of absolute amounts and per capita emissions. India figures among the top ten contributors to greenhouse gas emissions. However, current per capita gross emissions in India are only one-sixth of the world's average. India is highly vulnerable to climate change as its economy is heavily reliant on climate-sensitive sectors like agriculture and forestry, and its low-lying densely populated coastline is threatened by a potential rise in sea level.

India's strategy in contributing to global efforts to reduce the risk of climate change has been to develop the institutional capacity to formulate, assess, and implement economic and technical responses to climate change issues; focus on the transfer and adaptation of technology; and integrate sustainable development with national development programmes. India is party to the UNFCCC (United Nations Framework Convention on Climate Change). It signed this multilateral treaty on 10 June 1992 and was the 38th country to ratify it on 1 November 1993. India acceded to the Kyoto Protocol on 26 August 2002.

In 1997, the Kyoto Protocol created three cooperative mechanisms – Emissions Trading, Joint Implementation, and Clean Development Mechanism – allowing member countries some flexibility in meeting their commitments with respect to reduction in emissions. The Clean Development Mechanism is important for India as it allows developed countries to use certified emissions reduction credits from project activities in developing countries, and also assists developing countries in achieving sustainable development objectives.

IMPACTS ON AGRICULTURE

Agriculture and allied activities constitute the single largest component of India's economy, contributing nearly 27% of the total Gross Domestic Product (GDP) in the year 1999-2000. Agriculture exports accounts for 13 to 18% of total annual exports of the country. However, given that 62% of the cropped area is still dependent on rainfall; Indian agriculture continues to be fundamentally dependent on the weather.

In a study supported by the Government of Norway, TERI is working on a project, "Vulnerability of Indian agriculture to climate change and globalization". The macro level vulnerability is assessed at a district level using GIS-based techniques. This involves the development of a climate change vulnerability map and a globalization vulnerability map. Based on an overlay of these two maps, regions across India that are doubly exposed to both climate change and globalization are identified. To study the micro-level implications of vulnerability, detailed case studies are being conducted. The case studies aim to see how economic factors within the context of domestic policies have either

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enhanced or reduced the capacity of farmers to cope with climate change. The pilot case study was undertaken in district Jhalawar of Rajasthan.

IMPACTS ON FORESTRY

In addition to their crucial ecological role, forests make a considerable contribution to the Indian economy. Forests contribute 1.7% to the GDP of the country. Moreover, non-timber forest products provide about 40% of total official forest revenues and 55% of forest-based employment. Nearly 55 million people living in and around forests in India depend upon non-timber forest products as a critical component for their sustenance.

Climate is an important determinant of the geographical distribution, composition and productivity of forests. Therefore, changes in climate could alter the configuration and productivity of forest ecosystems. These changes in turn, could have profound implications for traditional livelihood, industry, biodiversity, soil and water resources, and hence, agricultural productivity. Moreover, these climate change induced effects would aggravate the existing stresses due to non-climate factors, such as land use changes and the unsustainable exploitation of natural resources.

IMPACTS ON WATER RESOURCES

India is considered rich in terms of annual rainfall and total water resources available at the national level. However, these resources are unevenly distributed and result in spatial and temporal shortages, hence limiting availability across regions. Increased demand has further increased the pressure on the resource. The demand for water has increased tremendously over the years due to an increasing population, expanding agriculture, and rapid industrialization. However, the amount of water available on earth that can actually be beneficially utilized is limited. Fulfilling demands has led to considerable imbalances in the quantity and quality of water resources.

Climate change and variability are likely to worsen the existing situation by further limiting water availability. Under a changed climatic regime for any given region, the combined effect of lower rainfall and more evaporation would have dire consequences. Both these would lead to less runoff, substantially changing the availability of freshwater in the watersheds. Also, potential changes in temperature and precipitation might have a dramatic impact on the soil moisture and aridity level of hydrological zones. With changes in the flows, annual runoff, and ground water recharge, water available for usage will further be decreased.

An assessment of the implications of climate change for hydrological regimes and water resources using scenarios developed from Hadley Centre Model Simulations indicates that by the year 2050, the average annual runoff in the river Brahmaputra will decline by 14 %. Studies have indicated that the impact of snow melting in the high Himalayas will lead to flood disasters in Himalayan catchments. Impacts will be observed more in the western Himalayas as the contribution of snow to the runoff of major rivers on the western side is about 60 % compared to 10 % on the eastern side (IPCC. 2001).

CLIMATE CHANGE IMPACT STUDIES IN SOUTH ASIA

Recognizing the critical concern of global warming in south Asia, various studies have been conducted in the region to analyze trends in hydro-meteorological variables at regional and basin level (Hingane et al., 1985; Sinha et al., 1997; Arora et al. 2005; Singh et al., 2008), Bangladesh (Ahmad and Warrick, 1996), and Nepal (Shrestha et al., 1999)). Hingane et al. (1985) analyzed long-term mean annual temperature records from 1901 to 1982 over India and detected an increasing trend in mean surface air temperatures. It was observed that about 0.4°C warming has taken place over India during the last eight decades mainly due to rise in maximum temperatures. Sinha et al. (1997), however, showed that the changes in mean annual temperatures are partly due to the rise in the minimum temperature caused by rapid urbanization. Pant and Kumar (1997) have reported an increase in mean annual temperatures in India at the rate of 0.57°C per 100 years. Arora et al. (2005) investigated temperature trend all over India using Mann-Kendall non parametric technique and linear regression method. The results showed that mean temperature has increased by 0.94°C per 100 years for the post monsoon season and 1.1°C per 100 years for the winter season.

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Marco et al. (2003) analyzed the temperature data of 160 climate stations in China using Mann-Kendall and inverse distance methods. An increasing temperature trend was detected all over the country; however negative trend was detected in high latitude regions during summer. Winter period showed a warming trend with 95% significant level in southwest of Xinjiang and southwest of Tibet region. Fowler and Archer (2005) examined temperature data of seven climate stations in the Karakoram and Hindu Kush mountains of the upper region of UIRB for seasonal and annual trends using regression techniques. Mean and maximum winter temperatures showed significant increase while mean and minimum summer temperatures showed consistent decline. Zhang et al. (2005) analyzed monthly temperature and precipitation data for 51 climate stations and three hydrometric stations in the Yangtze basin, China. Significant positive and negative trends at 90, 95 and 99% significant level were detected using Mann-Kendall test. The middle and lower regions of the Yangtze basin showed downward temperature trend and an upward precipitation trend. The authors concluded that the middle and lower regions of the basin are likely to face more serious flood disasters in the future.

Several precipitation trend studies have also been carried out in the south Asia region. Marco et al. (2003) showed that there is an increasing precipitation trend throughout the year in southwest of Xinjiang which is an area adjacent to Northern part of Pakistan, and in Jammu- Kashmir which is southwest of Tibet. Archer and Fowler (2004) analyzed precipitation data of various stations in Upper Indus River Basin (UIRB) using linear regression with different record lengths. A significant increasing trend of precipitation in winter and summer during the period 1961-1999 was detected in upper region of UIRB. Zhang et al. (2005) detected an upward precipitation trend in middle and lower part of Yangtze basin, China. On the contrary, Raziei et al. (2005) concluded that precipitation in Iran has a decreasing trend. Kezer and Matsuyama (2006) investigated runoff trends for Ili and East rivers in central Asia. Regression and difference integral curve techniques were used for long term hydro-meteorological analysis. No statistically significant change was observed except for runoff. Arora et al. (2005) detected an increasing trend in mean annual temperature in industrialized cities of India including Mumbai where the increase was reported as 0.84°C per 100 years. Warming trend has also been found for Bangladesh. Ahmad and Warrick (1996) reported that the broad region encompassing Bangladesh has warmed at the rate of 0.5°C per 100 years. Shrestha et al. (1999) reported increases of 0.61°C, 0.90°C and 1.24°C per decade in winter maximum temperatures for Nepal, Himalayan and trans-Himalayan climate stations respectively. CICERO (2000) estimated a temperature rise of 0.9°C for Pakistan by 2020 and predicted that the temperature rise could double by 2050.

Chen et al. (2007) investigated temporal trends of annual and seasonal precipitation from 1951 to 2003 in the Hanjiang basin in China using Mann-Kendall and the linear regression methods. Results indicated that precipitation has no significant trend but a significant increasing trend for temperature was seen in most parts of the basin. Further, decreasing trend was seen in mean annual, spring, and winter runoffs in the Danjiangkou reservoir basin. Singh et al. (2008) have carried out an extensive analysis of basin-wide temperature trends in northeast and central India. A warming trend was observed in seven of the nine river basins studied. The other two basins showed a cooling trend. Results of several studies have confirmed that the south Asia region is indeed warming and the trend of warming is broadly consistent with the global warming trend. As a consequence, many aspects of the natural environment, including water resources, are anticipated to experience potentially serious climatic impacts in the South Asia region. Recent IPCC report (IPCC, 2007c) clearly indicates likelihood of considerable warming over sub-regions of south Asia with greater warming in winter than in summer. Results of multimodel GCM runs under Special Report on Emission Scenarios (SRES) scenarios B1 and A1F1 project an increase in average temperature over whole of South Asia with greatest increase being projected for winter months. The projected rise in temperature for winter months is particularly alarming as it exceeds the limit of global mean surface temperature rise of 1.8 o C to 4o C reported by IPCC (IPCC, 2007 a).

EL-NINO

For India's population, climate is a deciding factor in the subsistence of everyday life. Because the economy is so reliant on agricultural success, even slight setbacks in agricultural production due to unforeseen climate anomalies have dire economic and social consequences. Inter-annual variability of Indian monsoon rainfall has profound influence on

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agriculture and national economy. The monsoon rains, which usually occur from June to September, have a crucial impact on crop abundance. Because of this dependence, it is essential to be able to predict monsoons in a timely and accurate manner to prepare for and possibly mitigate the detrimental effects of these climate anomalies. More accurate prediction gives the law makers the ability to structure monetary and welfare policy changes in accordance with the upcoming agricultural situation. In addition, a better understanding of these anomalous occurrences will allow for the development of infrastructure to protect the economic and social livelihoods of the people, and mitigate the harsh potential effects of these weather patterns. Therefore, a better understanding of sources of correlation and/or causation between ENSO and the monsoon cycle will surely prove invaluable because it will allow them to predict and prepare.

El Niño is an oscillation of the ocean-atmosphere system in the tropical Pacific having important consequences for weather around the globe (NOAA, 2006). The prediction of Indian Summer Monsoon Rainfall (ISMR) is vital for Indian economic policy and a challenge for meteorologists. It needs various predictors among which El Niño is the most important. It has been established by various researchers that ENSO and ISMR relationship is weakening in recent years. It has been also argued that changes in ENSO-ISMR relationship may be due to decadal fluctuations, or it may be the indicative of longer-term trends related to anthropogenic-induced climate changes. If the 5-month means of SST anomalies in the NINO 3.4 region (5°S–5°N and 120°W–170°W) are higher than +0.5 °C, for at least six consecutive months, it is accepted that el Niño event has occurred (Trenberth, 1997). This is one of the definitions of El-Niño event, and using this definition El-Niño has occurred on 1982/83, 1987/88, 1991/1992, and 1997/1998, and La-Niña on 1988/89 and 1998/99 among other years. During four months (JJAS) the monsoon provides 80% of the total annual rainfall over India (Selvaraju, R., 2003). ENSO plays a significant role in the success or failure of Indian monsoon development. The year-to-year variability in monsoon rainfall could cause severe droughts and floods (Kulkarni, et al., 2003). Extreme hydrological events, such as floods and droughts, may result in reduction of agricultural output, affecting both population and national economy of India (Kripalani et al. 2003). Inter-annual variations in the anomalies of Indian food-grain production, from 25 to 30%, are related to the SST (sea surface temperature) of the region in the Pacific where El-Niño occurs. Repercussions of ENSO over India's climate depend on the region, season, and strength and spatial distribution of the SST anomalies. Understanding the relationship between ENSO and Indian monsoon rainfall is imperative to reduce negative impacts or to take advantage of favourable conditions (Selvaraju 2003).

Even though there is no long term trend, occurrence of droughts and floods associated with the inter-annual variability of Indian monsoon affects the agriculture, water resources and financial sectors. In many seasonal forecast tools, Indian monsoon rains are predicted to vary in direct proportion to the strength of the El Niño Southern Oscillation (ENSO) phenomenon in the tropical Pacific, measured, for example, by the standardized NINO 3.4 index. Years with moderate to extreme cold states have had abundant monsoon rains without exception. On the other hand, years of moderate to extreme warm states have not been reliably dry. Most of severe droughts in India have been associated with the El Niño events. However, El Niño years have not always produced severe droughts.

El Niño (La Niña) is associated with lower (higher) than normal rainfall (Maity and Kumar, 2006). Rasmusson and Carpenter (1983) observed that El Niño years are associated with negative pressure anomalies in the southeast Pacific, positive anomalies over the Indian Ocean region (low Southern Oscillation Index, SOI), weaker southwest monsoon over the Arabian Sea, and below normal rainfall over India.

Krishnan and Sugi (2003) analysed data from 306 rain gauge stations from 1871 to 2002. They identified that the warm (cool) phase of the Pacific Decadal Oscillation (PDO) is linked to a decrease (increase) in India summer monsoon rainfall index. The main conclusion of this study was that the PDO could amplify Indian climate signals related to ENSO. Indian monsoon rainfall is not exclusively affected by El Niño. There is consistent evidence that El-Niño has a major influence on monsoon development (Kripalani et al., 2003, Parsons et al. 2006) but, in spite of the intensive research on this subject there is no absolute agreement in the precise connection between monsoon rainfall and El Niño. Some authors have suggested a change in the relationship between these two phenomena (Kripalani and Kulkarni, 1997, Kumar, et al., 1999). However, this propose is not generally accepted and needs more evidence to be considered (Sahai et al. 2003).

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V. CONCLUSIONS

The linkages between El-Nino southern oscillation (ENSO) and precipitation have been a major theme in climatology for many regions across the world. In India, the monsoonal rainfall is believed to be significantly impacted by ENSO. But due to large spatial and temporal variability of monsoon rains, it becomes difficult to establish any single uniform relationship between the ENSO and Indian monsoonal rainfall that holds good over different subdivisions of India although the general type of relationship between all India monsoon rainfall and ENSO exists since long. Singh (2001) reported that while the ENSO signal could be found throughout India, the relationship is strongest in the northwestern and southern regions of the country. Therefore, the objective of the present project was to investigate linkages between large scale climate indices with the precipitation data at several stations in India, particularly northern India. The intent behind choosing mostly north Indian stations is that the agricultural production in this region is significant with major contribution coming from Punjab – the bread basket of India. Additionally, it is not possible to establish a general relationship between ENSO and different subdivisions in India. In this project, precipitation data for ten north Indian stations was obtained from India Meteorological department, Pune. The sea surface temperature data over the Nino 3.4 region (1200 W–1700 W, 50 S– 50 N, was obtained from Climate Analysis Section, National Center for Atmospheric Research, USA (<http://www.cgd.ucar.edu>). For the purpose of classification of El-Nino years, the sea surface temperature anomalies were computed for the June to September period. A year is then classified as El-Nino year if the anomaly for a particular year exceeds a threshold value of 0.40 C whereas a year with anomaly lesser than - 0.40 C is classified as a La-Nina year. Years not falling in either of these two categories are not classified as normal years. Results of analysis carried out in this project clearly reveal the tendency for reduced precipitation during El-Nino years whereas increase in precipitation was observed for the La-Nina years. It is clear from the analysis conducted herein that warm anomalies in the central Pacific are associated with weak Indian monsoons. An important practical advantage of the analysis carried out in this project is that the incorporation of SST anomalies information in the statistical forecasting models has the potential to improve monsoon forecast skills in India.

FUTURE WORK

Every year during the last week of May India Meteorological Department issues long range forecast for all India rainfall during June to September. But due to large spatial and temporal variability of monsoon rains there is a need for the prediction of monsoon rainfall over smaller regions and also for shorter durations. Meteorologically India has been divided into thirty five meteorological subdivisions and the efforts shall be made to identify relationships between precipitation and large scale climate indices for each of the meteorological divisions. Suitable predictors are to be identified for the development of statistical methods for the long range prediction of monsoon rainfall over each meteorological subdivision of India. An important predictor of monsoonal rainfall could be an index based on ENSO. In this project, linkages of monsoonal rainfall with El-Nino southern oscillation have been investigated. Any future work shall investigate linkages of monsoonal precipitation with pacific decadal oscillation, north Atlantic oscillation and other indices. While monsoonal precipitation throughout India is related to ENSO, the rainfall is also related to the sea surface temperatures of the Indian Ocean, Arabian Sea, and Bay of Bengal. Relationship of rainfall with the sea surface temperatures of the Indian Ocean, Arabian Sea, and Bay of Bengal shall also be investigated in future.

REFERENCES

1. Ahmad Q.K, Warrick R.A. (1996). "The implications of climate and sea level change for Bangladesh". Kluwer Academic Publisher, Dordrecht, The Netherlands
2. Archer, D. R. and Fowler, H. J. (2004) Spatial and temporal variations in precipitation in the Upper Indus Basin, global teleconnections and hydrological implications, Hydrol. Earth Syst. Sci., 8, 47–61, doi:10.5194/hess-8-47-2004.
3. Arora M, Goel N.K, Singh .R. (2005). "Evaluation of temperature trends over India". Hydrol Sci J 50(1): 81-93
4. Chen, H., Guo, S., Chong,yu.Xu., Singh, V.P. (2007). "Historical temporal trends of hydro-climatic variables and runoff response to climate variability and their relevance in water resource management in the Hanjiang basin". Journal of Hydrology, 344, 171– 184.
5. CICERO. (2000) "Centre for International Climate and Environmental Research P.O. Box 1129 Blindern N-0318 Oslo, Norway".
6. Douglas AV, Englehart PJ (1981) On a statistical relationship between autumn rainfall in the central equatorial Pacific and subsequent winter precipitation in Florida. Mon Wea Rev 190:2377–2382

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

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7. Dracup, J. A., and S. Vicuña. (2005). "An Overview of Hydrology and Water Resources Studies on Climate Change: the California Experience". Paper presented at the Environmental & Water Resources Institute Congress conference, American Society of Civil Engineers, Anchorage, Alaska, May 15-19.
8. Fowler HJ, Archer, D.R. (2005). "Conflicting signals of climate change in the Upper Indus Basin". J Clim 19: 4276-4293.
9. Gleick, P.H. (1986). "Methods for evaluating the regional hydrologic impacts of global climatic changes." Journal of Hydrology. Vol. 88, pp. 97-116.
10. Gleick, P.H. (1987). "The development and testing of a water-balance model for climate impact assessment: Modeling the Sacramento Basin." Water Resources Research. Vol. 23, No. 6, pp. 1049-1061.
11. Hingane, L. S., Rup Kumar, K. & Ramanamurthy, B. V. (1985). "Long term needs of surface air temperature in India". Int.J.Climatol. 5, 521-528.
12. Hodgkins, G.A., Dudley, R.W., Huntington, T.G. (2003). "Changes in the timings of
13. IPCC. (1996). "Climate Change 1995: The Science of Climate Change. Cambridge University Press, 584 pp.
14. IPCC. (2007a). Impacts, Adaptation and Vulnerability. Asia Climate Change 2007 (eds Parry ML, Canziani OF, Palutikof JP, van der Linden PJ, Hanson CE) Cambridge University Press, Cambridge, UK, 469-506
15. Jenkins, G. J. & Derwint, R. G. (1990). Climate consequences of emissions. In Climate Change. The IPCC scientific assessment (ed. by J. T. Houghton, G. J. Jenkins & J. J. Ephraums). WMO, UNEP, Cambridge University Press, UK.
16. Jiang T, Chen YD, XU, C YU, Chen Xi, Singh V.P. (2007). "Comparison of hydrological impacts of climate change simulated by six hydrological models in the Dongjiang basin, south China". J Hydrol 336: 316-333
17. Kezer K, Matsuyama H. (2006). "Decrease of river runoff in the Lake Balkhash basin in Central Asia". Hydrological Processes Vol. 20 (6) pp 1407-1423;
18. Kundzewicz, Z.W., Robson, A.J. (2004). "Change detection in hydrological records-a review of the methodology". Hydrological Sciences, 49 (1), 7-19
19. Lettenmaier, D.P. and Gan, T.Y. (1990). Hydrologic sensitivities of the Sacramento-San Joaquin River Basin, California, to global warming, Water Resour. Res. 26, 69-86
20. Mann, H.B. (1945). Non-parametric tests against trend, Econometrica 13: 245-259.
21. Mann, M. E., R. S. Bradley, and M. K. Hughes, (1999). Northern Hemisphere temperatures during the past millennium: Inferences, uncertainties, and limitations, Geophys. Res. Lett., 26, 759-762,
22. Marco G, Stefan B, Tong. J. (2003). Detection and Visualization of Climate Trends in China. No. 15, Giessen, Nanjing Institute of Geography and Limnology, Chinese Academy of Science (CAS), 210008 Nanjing, PR China.
23. Pant, G.B.K. Rupa Kumar. (1997). Climate of South Asia. John Wiley & Sons. Chichester, UK. 320 pp.
24. Pant GB, Parthasarathy B (1981) Some aspects of an association between the Southern Oscillation and Indian summer monsoon. Arch Meteorol Geophys Bioklim 29:245-251
25. Ropelewski CF, Halpert MS (1987) Global and regional scale precipitation patterns associated with ENSO. Mon Wea Rev 115:1606-1626
26. Raziqi T, Arasteh PD, Saghfian B. (2005). Annual Rainfall Trend in Arid and Semi-arid Regions of Iran. ICID 21st European Regional Conference 15-19 May, 2005 Frankfurt (Oder) and Slubice-Germany and Poland.
27. Revelle, R. and Waggoner, P.E. (1983). Effects of a carbon dioxide-induced climate change on water supplies in the western United States, in: Changing Climate, Report of the Carbon Dioxide Assessment Committee, National Academy Press, Washington, D.C.
28. Shrestha A.B, Wake C, Mayewski P.A, Dibb J.E. (1999). "Maximum temperature trends in the Himalaya and its vicinity. An analysis based on temperature records from Nepal for the period 1971-1994". J Climate 12: 2775-2786.
29. Singh OP (2001) Multivariate ENSO index and Indian monsoon rainfall: relationships on monthly and subdivisional scales. Meteorol Atmos Phys 78:1-9
30. Singh, P., Kumar, V., Thomas, T., and Arora, M. (2008). "Basin-wide assessment of temperature trends in northwest and central India". Hydrological Science Journal, 53(2), 421-433
31. Sinha Ray, K.C., Mukhopadhyay, R.K. and Chowdhary, S.K. (1997). "Trend in maximum and minimum temperature and sea level pressure over India". INTROMET 1997 IIT Delhi, Hauz Khas, New Delhi
32. Zhang, Q., Jiang, T., Gemmer, M., Becker, S. (2005). "Precipitation, temperature and runoff analysis from 1950 to 2002 in the Yangtze basin, China". Hydrol Sci J 50(1): 65-79
33. Ashrit, R. G., K. R. Kumar, Kumar, K. K. (2001), "ENSO-Monsoon relationship in a greenhouse warming scenario." Geophys. Res. Lett. 28 (9):1727-1730.
34. Kripalani, R. H. and A. Kulkarni, (1997), "Climate impact of El Niño-La Niña on the Indian monsoon: A new perspective." Weather. 52:39-46.
35. R. H. Kripalani, A. Kulkarni, and S. S. Sabade (2003) "Indian Monsoon Variability in a Global Warming Scenario," pp. 189-206.
36. Krishnan R. and M. Sugi, (2003), "Pacific decadal oscillation and variability of the Indian summer monsoon rainfall." Clim. Dyn. 21:233-242.
37. Krishnamurthy V, Goswami BN (2000) Indian monsoon-ENSO relationship on interdecadal timescale. J Clim 13: 579-595
38. Kumar, K. K., B. Rajagopalan, et al, (1999), "On the Weakening Relationship Between the Indian Monsoon and ENSO." Science. 284:2156-2159.
39. Krishna Kumar, K., B. Rajagopalan, M. Hoerling, G. Bates and M. Cane, 2006, Science. Unraveling the Mystery of Indian Monsoon Failure during El Niño, doi:10.1126/science.1131152
40. T. D. Parsons, J. M. Self, L. H. Schaad, B. R. Gragg, G. E. Ryschkewitsch, A. Blumenthal, P. Bissinger, H. Schmidbaur, T. Imamoto, T. Hikosaka, H. Braunschweig, M. Colling, M. Wagner, N. J. R. V. E. Hommes, H. No, K. E. Laidig, A. Streitwieser, R. L. Harlow, M. Kline, A. Sundermann, M. Reither, W. W. Schoeller, A. L. McCloskey, L. L. Petterson, H. Steinberg, H. A. Ali, M. Srebnik, D. E. Kaufmann, A. Jockisch, H. Schmidbaur, B. L. Scott, R. T. Baker, R. Krafczyk, R.
41. Gadgil, S., P. N. Vinayachandran, P. A. Francis, and S. Gadgil (2004), Extremes of the Indian summer monsoon rainfall, ENSO and equatorial Indian Ocean oscillation, Geophys. Res. Lett., 31, L12213, doi:10.1029/2004GL019733.

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42. Maity, R. and D. N. Kumar, (2006), "Bayesian dynamic modelling for monthly Indian summer monsoon rainfall using El Niño–Southern Oscillation (ENSO) and Equatorial Indian Ocean Oscillation (EQUINOO)." J. Geophys. Res.111:D07104.
43. NOAA-National Oceanic and Atmospheric Administration, (2006) http://www.pmel.noaa.gov/tao/el_nino/el_nino_story.html
44. Rasmusson, E. M., and T. H. Carpenter, (1983), "The relationship between eastern equatorial Pacific sea surface temperature and rainfall over India and Sri Lanka." Mon. Weather Rev. 111:517–528.
45. Roy, S. S., G. B. Goodrich et al. (2003), "Influence of El Niño/southern oscillation, Pacific decadal oscillation, and local sea-surface temperature anomalies on peak season monsoon precipitation in India. Clim. Res. 25: 171–178.
46. A.K. Sahai, D. R. Pattanaik, V. Satyan, and A. M. Grimm, "Teleconnections in recent time and prediction of Indian summer monsoon rainfall," Meteorology and Atmospheric Physics, vol. 84, no. 3–4, pp. 217–227, Oct. 2003.
47. R. Selvaraju, "Impact of El Nino-southern oscillation on Indian foodgrain production," International Journal of Climatology, vol. 23, no. 2, pp. 187–206, Feb. 2003.
48. Trenberth, K.E. (1997), "The definition of El Niño." B. Am. Meteorol. Soc. 78(12): 2771– 2777.