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Global Warming: An Impact Assessment on Cyclonic Disturbances over Monsoon Asia

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Abstract

The monsoon region of Asia is a very distinctive part of the world with peculiar physiographic setting. It embraces the territories of the countries on the mainland from West Pakistan to Manchuria together with the arc of off-shore Island stretching from Shrilanka to Japan. It has defined the region primarily in terms of its climate which is its basic differentiating feature as Russell and Kniffen have said "it include the maritime southern coasts of the continent, where monsoon influences either dominate climates or are rather strongly felt."A substantial achievement has been made in basic physical processes predictability and prediction since the MONEX of 1978-1979. For a country like India, where the economy of the country mainly depends on agriculture, the performance of monsoon both in space and time is very crucial and important providing regional climate, PRECIS is an atmospheric and land surface model of limited area and high resolution which can be configured for any part of the globe, pounding regional climate for impact studies a regional climate modeling system developed by Hadley center for climate prediction and research U.K is applied over the Indian domain to investigate the impact of global warming on the cyclonic disturbances such as depressions and storms. The Asian monsoon is characterized with a distinct seasonal reversal of wind and repaid alternation of dry and wet or rainy season in the annual cycle, which is concert with the seasonal reversal of the large-scale atmospheric heating and steady circulation features. The model simulation under the scenario of increasing greenhouse gas concentration and sulphate aerosols are analyzed to study the likely changes in the frequency intensity and tracks of cyclonic disturbances forming over Bay of Bengal, Arabian sea and the Indian landmass during monsoon season, the model overestimates the frequency of cyclonic disturbances over the Indian subcontinent in baseline simulations. The change is evaluated towards the end of present century with respect to the baseline climate. The present study indicates that the storm tracks simulated by model are southwards as compared to the observed tracks during the monsoon season especially for the two main monsoon months, viz. July and August. The analysis suggests that the frequency of cyclonic disturbances forming over north Indian Ocean is likely to reduce by 9% towards the end of the present century in response to the global warming. However the intensity of cyclonic disturbances is likely to increase by about 11% compared to the present.

Keywords: Climate change, global warming, cyclonic, satellite remote sensing, summer monsoon.

Introduction

The Asian monsoon is the most significant component of the global climate system. During recent two decades, a more and more efforts have been made to study the Asian monsoon. A substantial achievement has been made in basic physical processes predictability and prediction since the MONEX of 1978-1979[1]. The major advance in new understanding of the Asian summer monsoon has been highlighted in this. For a country like India, where the economy of the country mainly depends on agriculture, the performance of monsoon both in space and time is very crucial and important. Cyclonic Disturbances (cd) such as storms and depressions originating from the two adjacent oceans of Indian Landmass, viz. Arabian Sea and Bay of Bengal are recognized as the main synoptic weather systems over India during monsoon season[2]. As the southwest monsoon progress over India, the space time variation of rainfall often occurs in association with the genesis and movement of these synoptic scale systems.Many studies indicate the decreasing trend in the observed frequency of monsoon season cyclonic disturbances in recent decades over Indian Ocean have studied the variability and long term trends in the frequency of cyclonic storms over north India[3]. They have found the maximum decreasing trend in the frequencies of They have also seen the increase in the intensities of the system. The influence of greenhouse gas-induced warming on tropical cyclone activity, over different ocean basins, has been investigated by many studies in recent years[4] .Analysis of the Had RM2 simulations shows a decrease in the frequency of cyclonic storms over Indian region in due to global warming have shown that the number of tropical cyclone days have decreased in all ocean basins except the north Atlantic during the last 35 years, whereas the frequency of most intense cyclones is increasing studied the tropical cyclones in North Atlantic Ocean and found that the future changes of total tropical cyclone counts is statistically insignificant[5]. However, the spatial pattern of the frequency of tropical cyclone occurrence will show marked change in future.

The summer monsoon system over Asia cannot be just thought of as the eastward and northward extension of the Indian monsoon. Numerous studies have well documented that the huge Asian summer monsoon system can be divided into two subsystems: the Indian and the East Asian monsoon system which are to a greater extent independent of each other and at the same time, interact with each other[6]. In this context, the major findings made in recent two decades are summarized the earliest onset of the Asian summer monsoon occurs in most of eases in the central and southern Indochina peninsula. The onset is preceded by development of a (Bay of Bengal) cycle, the rapid acceleration of low-level Westerly's and significant increase of convective activity in both areal extent and intensity in the tropical East Indian Ocean and the Bay of Bengal[7]. Most of the studies in recent period have indicated the significant decrease in the frequency of cds over different ocean basin in the world. However there are only few studies dealing exclusively with Indian subcontinent. Therefore, it will be interning on the investigate the likely impact of global warming on the cyclogensis in the northern Indian Ocean especially in the monsoon season which is a prime rainy season in this part of the world.

The Physiographic Setting: The monsoon region has very varied physiographic setting; no other part of the world, in fact, can show such great physical contrasts. The region exhibits a highly complex pattern of differing landforms –high, rugged fold mountains, and string of volcanoes, dissected plateaus, enclosed basins, broken hill lands, and spacious river plains[8]. The overall impression presented by the relief map, however, is that the region is essentially a very hilly one. The physical pattern is made even more complicated by the intermingling of land and sea for the continental margin is broken by many bays and gulfs, while offshore are numerous islands, large and small in size[9]. Professor E.H. Dobby has said the broken continental margin and the massive rampart of the Tibetan Highlands are the two dominating physical features of monsoon Asia.

Study of good atlas relief maps, such as those in The Times Atlas, helps one to appreciate the topographic complexity and topographic variety of the monsoon lands[10]. This outward complexity is the visible result of an equally complex and as yet not precisely understood, structural and geological history plus prolonged and very active sub-aerial erosion. Professor D.L .Linton's map of the structure of the world in the Oxford Atlas shown the broad structural components of the region[11].

July average temperatures may be around 27^0C, yet January averages may be below 0^0C. North of the Tsinling Shan in china there is a define tendency towards extreme conditions and the inner Asian borders of the monsoon region suffer emphatic extremes. Sian, in northern China, may be taken as a reasonably good illustration (figure 1). The mean annual temperature is $I6{\cdot}I^0$ C; July temperatures average around 30^0C and January temperatures average just above freezing point[12]. The mean temperature range is 29^0C. Thus the temperate monsoon areas, though frequently experiencing summer conditions not greatly different from those in tropical latitudes, are distinguished by their cold winters.

Professor J. E. Spencer, in an attempt to simplify the physical intricacies of the region, has divided it up into four units which make up 'the physical geometry of the oriental world'. His imaginative set of figures provide a superficial but useful skeletal framework upon which one may discuss the geomorphology and surface features of several broad regions[13]. Spencer's geometrical units, illustrated in (figure 2), are: i. the Indian Triangle, embracing the Tibetan plateau, the Indian sub-continent and Shrilanka ii. the Burmo-Malayan fan which comprises peninsular South-east Asia; iii. the Chinese Checkerboard stretching from southern China to northern Manchuria; and iv. the Island arcs off the coast swinging from Sumatra in the south to the Kuriles and Sakhalin in the north[14].

Pre-human climate variations: Earth has experienced warming and cooling many times in the past. The recent Antarctic EPICA ice core spans 800,000 years, including eight glacial cycles timed by orbital variations with interglacial warm periods comparable to present temperatures. A rapid buildup of greenhouse gases amplified warming in the early Jurassic period (about 180 million years ago), with average temperatures rising by 5^oc. Research by the Open University indicates that the warming caused the rate of rock weathering locks away carbon in calcite and dolomite, CO_2 levels dropped back to normal over roughly the next 150,000 years[15].

Sudden releases of methane from clathrate compound (the clathrate gun hypothesis) have been hypothesized as both a cause for and an effect of other warming events in the distant past, including the Permian-Triassic extinction event (about251million years ago) and the, Paleocene-Eocene thermal Maximum (about55million years ago).

Climate models: Scientists have studied global warming with compute models of the climate. These models are based on physical principles including fluid dynamics and radioactive transfer and are designed to be simplifications of the actual climate system. All modern climate models include treatments of chemical and biological processes. These models project a warmer climate due to increasing levels of greenhouse gases. Although a large amount of the variation in model outcomes depends on the greenhouse gas emissions used as inputs, the temperature effect of a specific greenhouse gas concentration (climate sensitivity) varies depending on the model used[16].

Global climate model projections of future climate depend on estimates of greenhouse gas emissions, most often those from the IPCC Special report on emissions Scenarios (SRES). In addition to unman-caused emissions, some models also include a simulation of the carbon cycle; this generally shows a positive feedback, though this response us uncertain. Some observational studies also show a positive feedback[17]. The representation of clouds is one of the main sources of clouds is one of the main sours of uncertainty in present-generation models, though progress is being mode on this problem. Including uncertainties in future greenhouse gas concentrations and climate sensitivity, the IPCC anticipates a warming of 1.1°c to 6.4°c by the end of the 21st century, relative to 1980-1999. A 2008 paper predicts that the global temperature will not increase during the next decade because of short-term natural climate cycles.

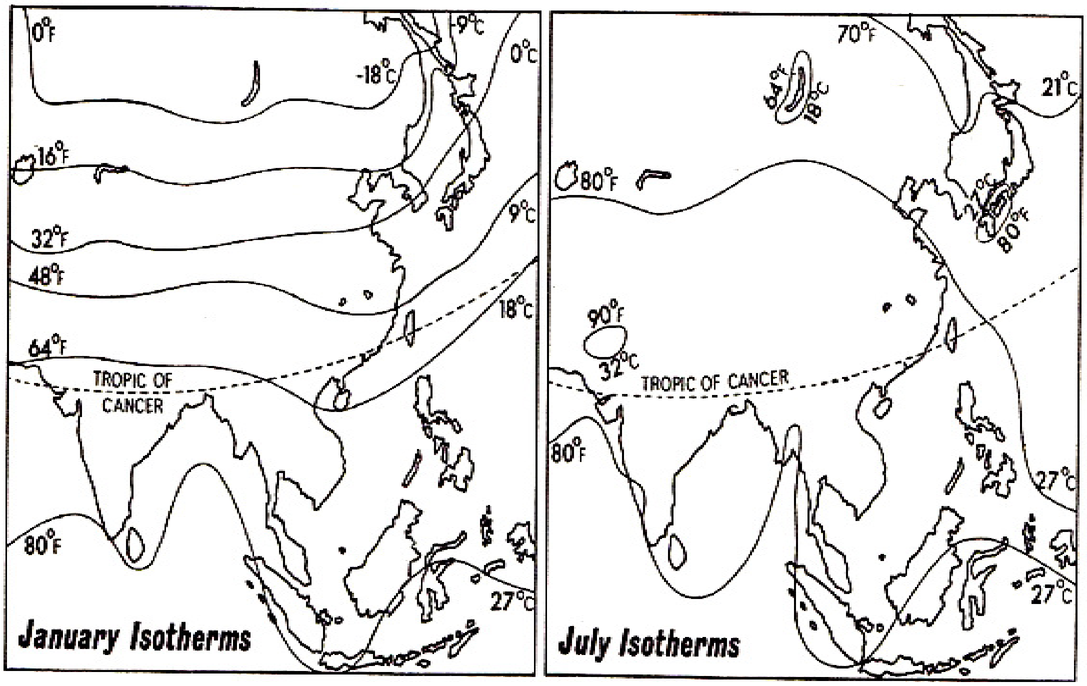

Figure-1
Temperatures: January and July

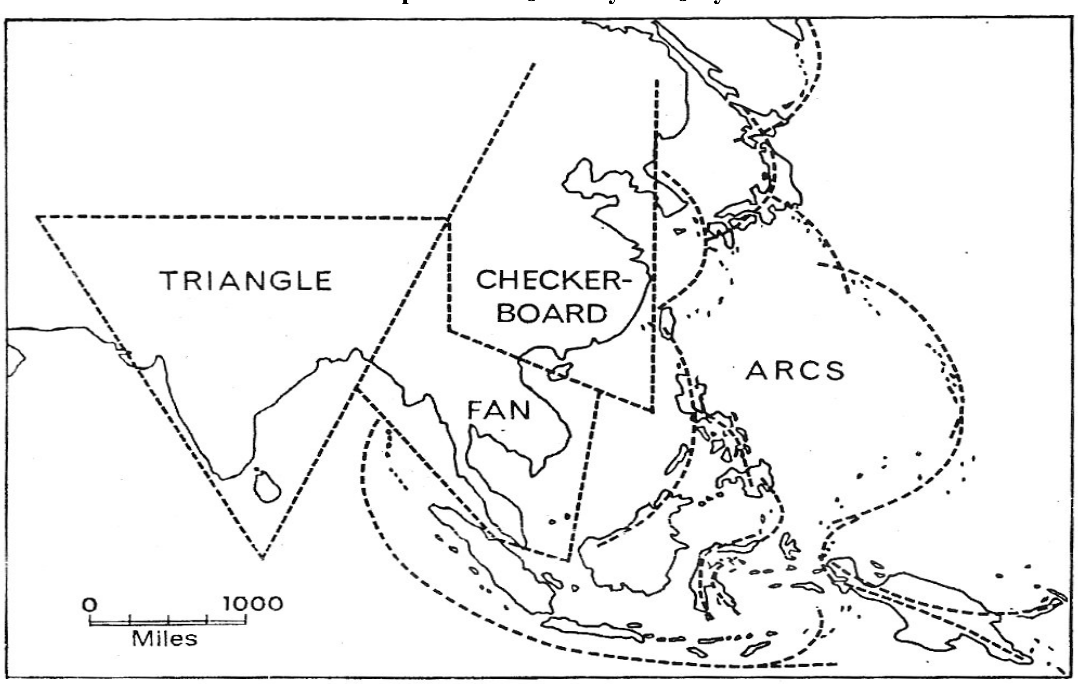

Figure-2
The physical geometry of Asia, Spencer uses an imaginative set of geometrical figures to indicate the four major physical units into which the main structural and landscape features of Monsoon Asia fall

Material and Methods

PRECIS is an atmospheric and land surface model of limited area and high resolution which can be configured for any part of the globe. Dynamical flow, the atmospheric sulphur cycle, clouds and precipitation, radioactive processes the land surface and the deep soil are all formulated in the model and boundary conditions are required to be specified at the limits of the models domain information about every aspect can be diagnosed from the model for the present study has been configured for a domain extending from about 1.5^0-38^0 N and 56^0-103^0 E with a horizontal resolution of $0{\cdot}44^0$ in Latitude and $0{\cdot}44^0$ in Longitude.

Lateran boundary conditions namely surface pressure winds temperature and humidity provide the necessary dynamical atmospheric information at the latitudinal and longitudinal edges of the model domain. PRECIS is forced at its lateral boundaries by a Global Climate Model (GCM) of 150 km horizontal resolution called Had AM3H in so-called time slice experiments. Had AM3H is an atmospheric component of HadCM3 the Hadley Center’s state of the art coupled model which has horizontal resolution of 3.75^0 long.X 2.5^0 lat. HadAM3H has been favored over HadCM3 for driving the RCMs since it has a higher resolution and exhibits an improved control climate especially with respect to the positioning of the storm tracks of the Northern Hemisphere.

Simulations using the model have been performed to generate the climate for the present and a future period for two different SRES scenarios both characterized by regionally focused development but with priority to economic issuers in one (E1 scenario) and to environmental issues in the other (E2 scenario) The IPCC published a new set of scenarios in 2000 for use in the Third Assessment Report (Special Report on Emissions Scenarios- SRES) The SRES scenarios were constructed to explore future developments in the global environment with special reference to the production of greenhouse gases and aerosol precursor emissions. The RCMs have shown reasonable skill in depicting the surface climate over the Indian region. Rainfall maximum over the west coast of India and the rain-shadow region in the southeastern peninsula is well simulated by the model the seasonal precipitation patterns in the baseline simulation are quitesimilar to those observed indicating that the baseline simulations provide and adequate representation of present day conditions however there exists some quantitative biases in the spatial patterns. A conspicuous bias is considerably higher than the observed monsoon precipitation over cost central India in the baseline simulation.

The cds are identified using the MONEX, PRECIS derived parameters viz. daily surface winds and daily mean sea level pressure. The criteria used for the identification of the system are as follows.

The centre of cd is a grid point at which the sea level pressure over the region of cyclogenesis is minimum. The centre of cd is a grid point at which the sea level pressure departure from the daily mean should be less than -5 hPa. Maximum wind speed at 10 m level near the center of the disturbance should be more than 17 knots. The onset and the seasonal march of the Asian monsoon observation. Intraseasonal variability (ISV) and Interannual variability observations.

Table 1 Monthly frequencies of cyclonic disturbances (per year) formed over north Indian Ocean and Indian landmass as simulated by PRECIS. The values in the parenthesis indicate the mean maximum intensity (knots).

Table-1

	June	**July**	**August**	**Sept.**	**Monsoon**
Observed	1.5(27)	1.4(23)	2.1(24)	2(29)	7(26)
Baseline	1.6(34)	2.2(32)	1.7(29)	2.7(31)	8.2(31)
E2 Scenario	1.7(37)	1.7(34)	1.4(30)	2.6(34)	7.4(34)

The storms are identified for baseline as well as E2 scenario using the above criteria. It gives the model simulated mean sea level pressure pattern associated with typical cyclonic storm simulated by PRECIS in baseline simulation. The systems form over Bay of Bengal region (near 89.9^0 E, 17.4^0 N locations) Next day it intensifies while moving in the northwesterly direction into the Indian landmass. During its movement it further intensifies thethird and subsequently weakens as seen from (figure 3). The cds are also simulated well in E1 scenario. The model captures the cyclogenesis in the north Indian Ocean quite realistically due to its high horizontal resolution. Bengtsson have also expressed the need to increase the resolution in climate modeling studies to capture the correct structure of tropical cyclone upto at least 50 km or equivalent. The storms thus identified are analised to see the likely changes in their frequency intensity and the tracks under the influence of increased GHG concentration.

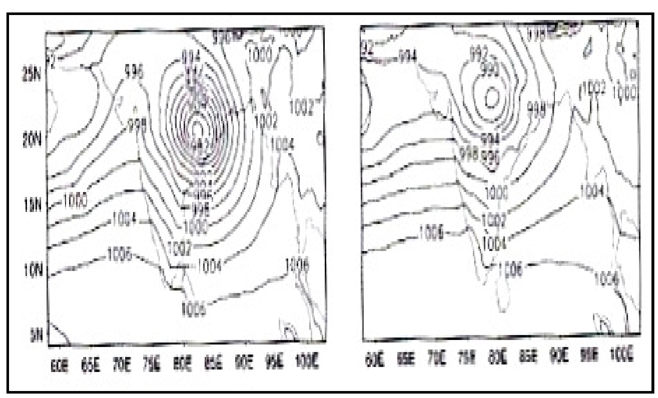

Figure-3
Mean Sea Level pressure pattern of the simulated cyclonic storm

The results obtained for E1 and E2 scenarioare quite similar, though they differ slightly in magnitude. Hence in the present study the climate change impacts are assessed and presented with respect to E1 scenario only[18].

Results and Discussion

The frequency and the intensity of the cyclonic disturbances forming over north Indian Ocean and the Indian Landmass during individual monsoon months and the season as a whole are shown in table 1. It can be seen from the table that the model overestimates the frequency of disturbances viz. 8.2 disturbances per season as compared to the observed frequency of 7 disturbances per season. There is no significant change under E1 scenario though slight decrease in the frequency is seen towards the end of 21st century towards 2080 due to the increase in GHG concentrations .This change is within the limits of natural variability .The decrease in monsoon cds is mainly due to reduction in July and August systems as can be seen from table 1. The intensity of the synoptic system is the maximum intensity of the wind associated with the system .The values in parenthesis in the table are the mean maximum winds associated with the system. The model has positive bias in the intensity of cyclonic disturbances in the baseline simulations (31 Knots) as compared to the observed intensity of 26 knots for season as a whole. The positive bias in the intensity of cds is seen in all the four monsoon months. The model indicates intense cds in the future in monsoon months with 11% increase in the intensity towards the end of present century as compared to baseline. Few scholars have studied the possible changes in tropical cyclones using high resolution, global atmospheric model. They have indicated the reduction of tropical cyclones in north Indian Ocean in future with the possibility of higher risks of more devastating systems.

Models are also used to help investigate the causes of recent climate change by comparing the observed changes to those that the models project from natural and human-derived causes. Although these models do not unambiguously attribute the warming that occurred from approximately 1910 to 1945 to either natural variation or human effects, they do suggest that the warming since 1975 is dominated by man-made greenhouse gas emissions[19].

Current climate models produce a good match to observations of global temperature changes over the last century, but do not simulate all aspects of climate. Comparing model predictions with current climate is a good way to test the predictive power of models. While a 2007 study by David Douglass and colleagues found that the models did not accurately predict observed changes in the tropical troposphere, a 2008 paper published by a17- members team led by Ben Scanter noted errors in the Douglass study, and found instead the models and observations were not statistically different.

The cds simulated by the model are analyzed to investigate the possible changes in the frequency and intensity of depressions and the cyclonic storms separately. The analysis shows that the frequency of depressions may decrease by 28% in the period futureas compared to that in the past. Also the average intensity of the depressions (cyclonic storms) may increase by 2.4% in future indicating the more intense cds in future. The cds forming over warm regions of Bay of Bengal follow northwesterly track along the monsoon trough region to give ample rainfall on the way. The storm tracks are therefore analysed to see the possible changes in their pattern.

Active minus break composite of intrseasonal anomalies (10-90-day filtered) of precipitaion and 850hpa winds averaged for the summer (from June 1 to September 30 of 1979-2002) Positive (negative) anomialies are represented by full (dashed) isolines (Goswarmi 2004) and (b) tracks of LPS for the period of 1954-1983 during active (SO phase (top panel) and break phase (bottom panel) Dark dots represent the genisis point and the lines their tracks (figure 4). Large number of LPS durinig active phase are strongly clustered to be along the monsoon trough. The few LPS that form during breaks clearly avoid the monsoon trough region and form either near the foothills of Himalyas or off the western coast and move westward.

In baseline (left) and E1 scenario (right) along with their normal observed tracks for monsoon months. Upper panels show the cds forming in the Bay of Bengal have short tracks. In the baseline simulations as compared to the tracks for E1 scenarios (Upper panels). The systems in baseline simulations do not reach west central India, to the west of 80 E as they do in E1 Scenario The northerly track after passing 80 E as seen from normal tracks is missing in PRECIS simulations The cds forming in the month of July and August are to the south of normal tracks in baseline as well as E1 scenario (figure 5) Model simulated cds in the month of July and August do not 80 E in both the simulations.

The composite analysis of mean sea level pressure (MSLP) and rainfall also hints the increase in the intensity of cd. Fig.05 gives the composite of the MSLP that was attained at the maximum intensity of the baseline is 990 hPa whereas it further reduces to 988 hPa in the future indicating the intensification of the system under warmer climate. The central pressure associated with the system drops by around 2.5 hPa in warming scenario as shown in figure. Pisharoty and Asnani (1957) have shown that the heaviest precipitation occurs in the southwest sector of the depression. The model is able to capture this rainfall maximum associated with the cd. The increased rainfall along the monsoon trough region during the passage of cdis well captured in baseline simulations. The rainfall composites during the cd forming over the Bay of Bengal region also suggests that the rainfall associated with the cd is likely to be more in future compared to the baseline due to the intensification of the systems right panel gives the difference of rainfall composite which indicates .the rise in rainfall in warming scenario The rise in rainfall may be maximum near Orissa coast and over the state of Orissa and may decrease towards central India have also indicated increase in the near storm rainfall rate in future in response to global warming.

The location of inception of cd is analysed for the Bay of Bengal region to assess the impact of global warming on the inception of cd, gives the location of inception for baseline and for E1 scenario The maximum frequency of inception can be around 18N for baseline and it is likely to be shifted northwards slightly, i.e. towards 19 N by the end of the present century. The formation of cd may be concentrated close to 88 E in future with respect to baseline. The favorable inception location may shift westwards near Orissa coast in 2080 as compared to 1970.The model does not show much change in the landfall position in warming scenario towards the end of the present century.

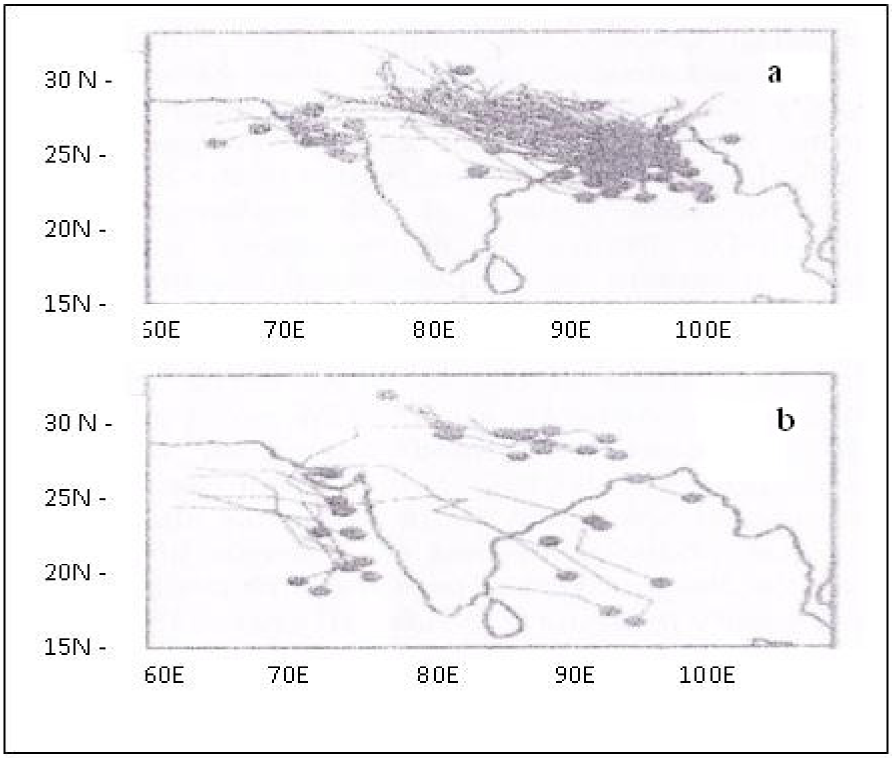

Figure-4
(a) Intra seasonal anomalies (b) Tracks of LPS active and break phase

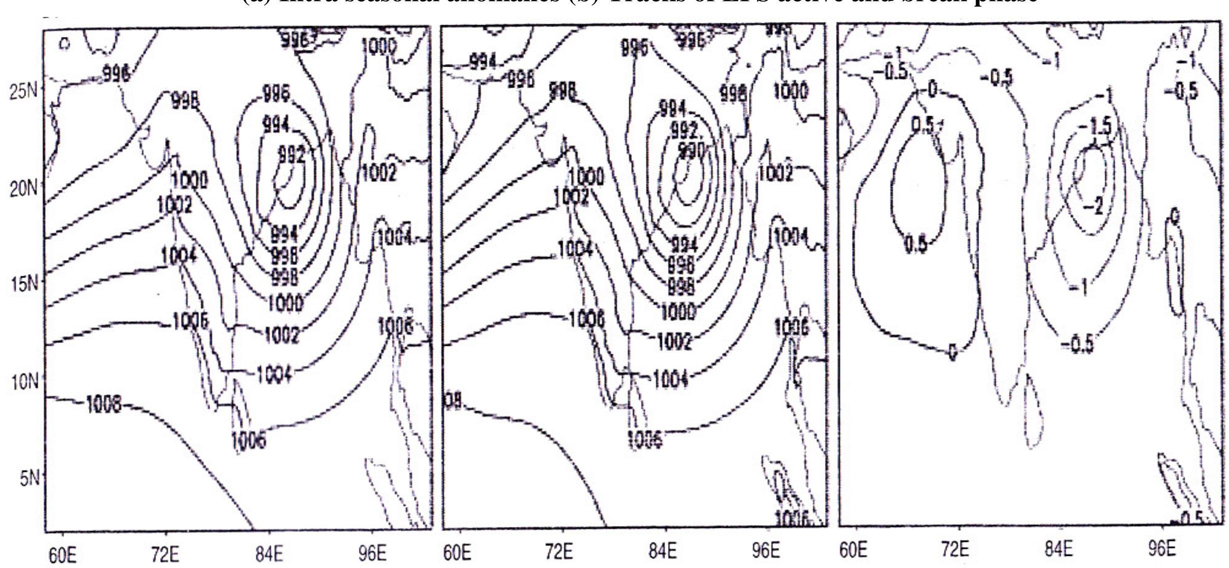

Figure-5
Composite of Sea Level pressure (hPa) attained at the maximum intensity of the cyclones disturbances for baseline (Left), E2 scenario (middle) and the difference between minimum pressures attained (right)

As seen from figure 6 summer air masses in southern Asia, even though the cd and cd days are seen to be less in warming scenario no change is seen in the duration of the cds in future when compared with model baseline simulations. The spatial pattern of frequency of cd occurring over Bay of Bengal is analysed to assess the likely changes in spatial distribution of frequency It can be seen from figure 6 that the frequencies of cd are likely to reduce over southwest Bay of Bengal (23%) and northeast Bay of Bengal (15%) whereas 12% increase in the frequency may be seen over northwestern Bay of Bengal. There may not be significant changes over southeastern sector of Bay of Bengal .where comparatively less number of cds are formed. This change in the spatial pattern of frequency is also projected over North Atlantic Ocean. Figure 7, climatic graphs represents different climatic regimes within Monsoon Asia[20].

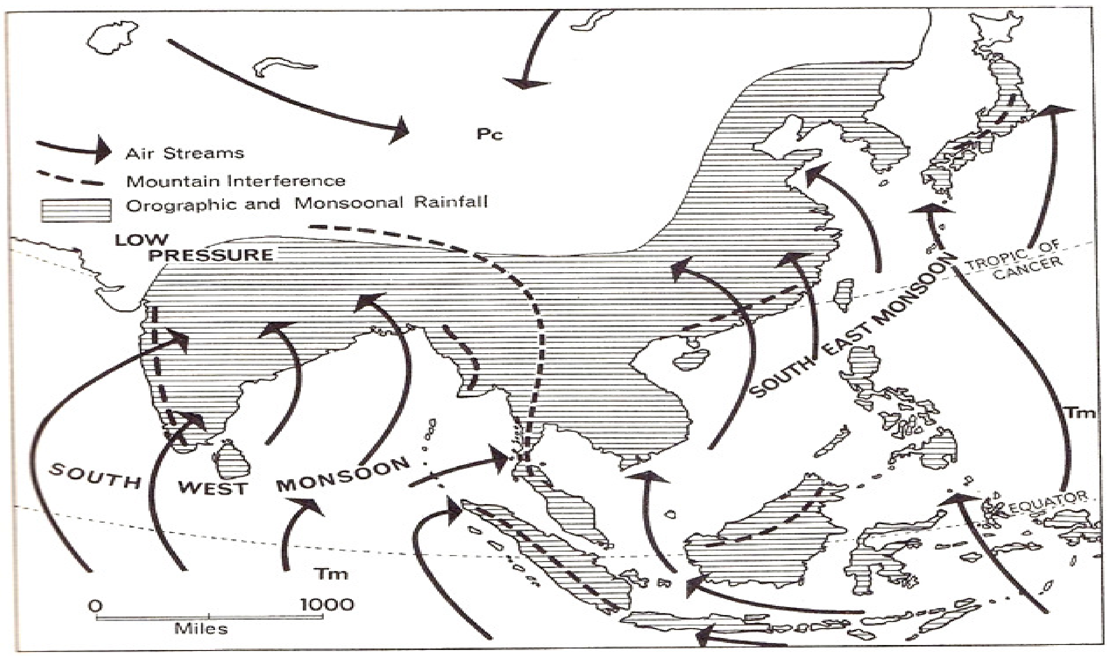

Figure-6
Air Masses: Summer

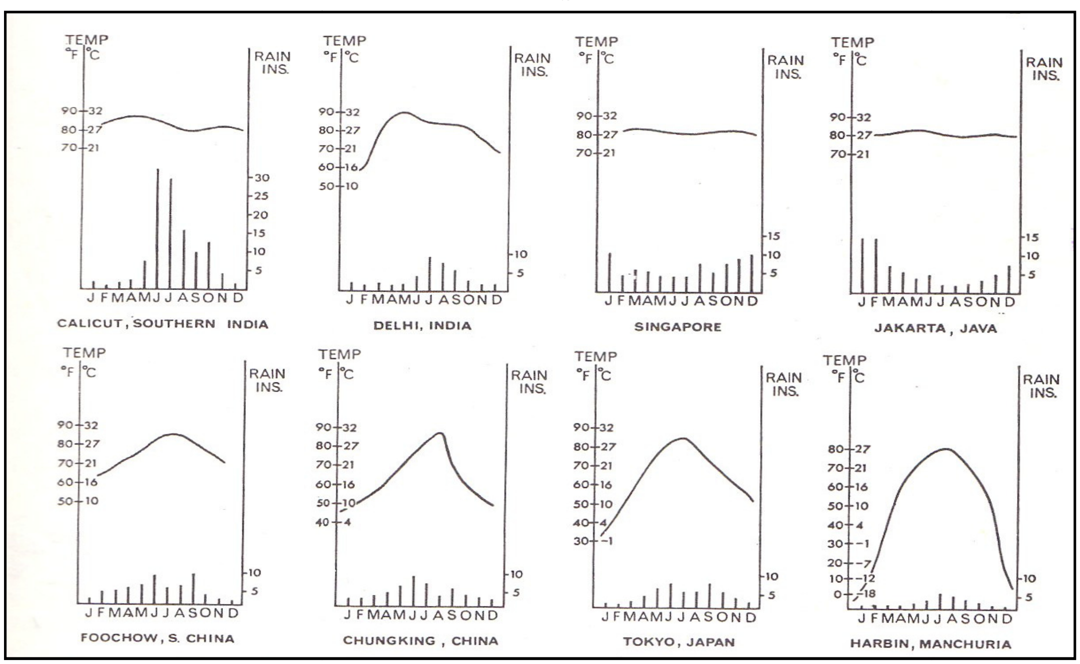

Figure-7
Climatic graph, Representative graphs illustrating different climatic regimes within Monsoon Asia

Conclusion

The curliest onset of the Asian summer monsoon occurs in most of cases in the central and southern Indochina Peninsula. The onset is preceded by development of a BOB(Bay of Bengal) cyclone the rapid acceleration of low-level westerilies and significant increase of convective activity in both areal extent and intensity in the tropical East Indian Ocean and the Bay of Bengal.

Climate change is now universally recognized as a significant global environmental challenge. It is now well established that the warming climate will definitely have an impact on the monsoonal climate over India[21]. Cyclonic disturbances play a major role in the performance and quantum of mean seasonal rainfall. In this view, the impact of global warming on the cyclogenesis over north Indian Ocean and the Indian landmass is assessed using high resolution regional climate models. The model simulations are evaluated to study the impact on frequency, intensity and tracks of the cyclonic disturbances, with its high horizontal resolution is able to capture the synoptic systems realistically. Though the analysis indicates slight decrease in the number of cds there may not be significant change in the frequency of systems forming over Indian subcontinent during monsoon season[22]. The analysis also indicates the possibility of intense systems in future under the effect of increased GHG concentrations. The composite analysis of rainfall as well as mean sea level pressure also confirm the increase in the intentracks in model simulations are towards the southern latitude as compared to the normal observed tracks there in no significant change in the tracks towards the end of present century as compared to the model baseline simulation of the regional climate model the results may be used only qualitatively, with caution. More simulations are required to reduce the uncertainty in the results. Further study is required to assess the different factors responsible for the changes in the cyclogenesis. However, the internal variability of the atmospheric circulation is also very important in particular the blocking highs in mid-and high latitudes of Eurasian continents and the subtropical high over the western North Pacific play a more important role which is quite different from the condition for the South Asian monsoon. The later is of tropical monsoon nature while the former is of hybrid nature of tropical and subtropical monsoon with intense impact from mid-and high latitudes.

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