CMFRI

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Impact of Climate Change on Indian Marine Fisheries

Lecture Notes

Part 1

Compiled and Edited by

E. Vivekanandan and **J. Jayasankar**

Central Marine Fisheries Research Institute (CMFRI),
(*Indian Council of Agricultural Research*)
P.B. No. 1603, Cochin - 682 018, Kerala

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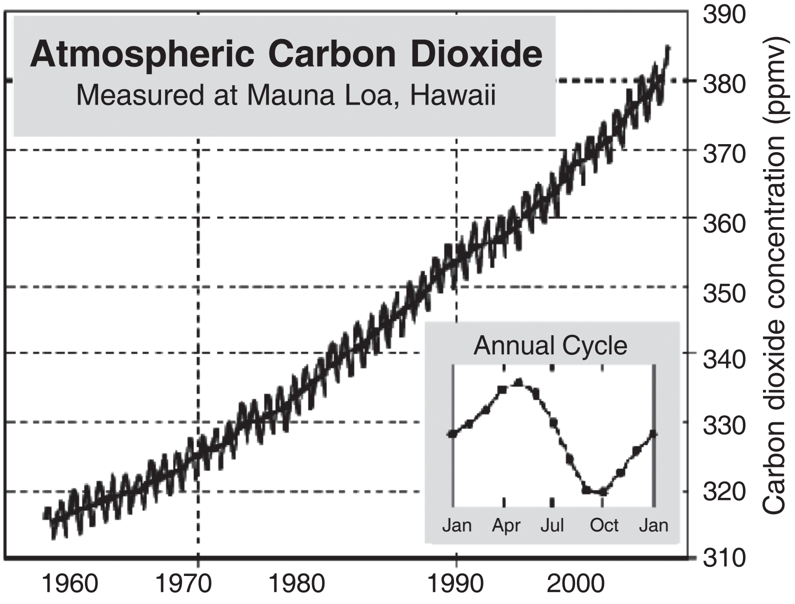
CLIMATE CHANGE AND MONSOON

M. R. Ramesh Kumar
Physical Oceanography Division
National Institute of Oceanography
Dona Paula, Goa 403 004

Introduction

Even though there has been a substantial increase in carbon dioxide concentration in the atmosphere during the recent decades (see figure 1), global temperatures (both air and water temperatures), have not increased to the extent as predicted by various models. The reason lies in the fact that not only the greenhouse gases, but there are other parameters, such as clouds, aerosols, and the ocean that influence the temperature. Since 1960s, scientists have developed models to understand the ocean's role in moderating the climate.



Yet, several questions remain unanswered. In which way, does the ocean help to keep the global temperatures under control and partially offset global warming? Or in the long term, will the ocean amplify and accelerate the warming trend? How will the changes in climate trend and climate variability affect life in the ocean and on land? How will the changes in physics and biology of the oceans and their interaction change the climate? How are the human activities contributing to the changes in the marine environment, and in turn, how will these changes affect the human beings?

Ocean – Atmosphere Interaction

The Ocean interacts with the atmosphere in two different ways. The first way is through the exchanges of heat (latent and sensible) and momentum. Oceans cover about 70% of the earth's surface and contain about 97% surface water. The oceans store enormous amounts of energy in the form of heat. Further, the ocean has a relatively large temperature inertia, or resistance to change.

Scientists were under the general impression that the oceans were sluggish in nature due slow circulation (as compared to the more dynamic atmosphere) and its low biological productivity. But, now we know that biological and physical functioning of the ocean system can change quickly over both small and large areas (*i.e*., during a cyclone or during an El Nino). Some scientists call the ocean as the "global heat engine".

Oceans play a very important role in the global climate system. They absorb most of the incoming shortwave solar radiation entering the earth atmosphere system and redistribute the heat and energy with oceanic environment by both horizontal and vertical oceanic movements. This energy is then further transported back into the atmosphere in the form of energy fluxes such as latent and sensible heat fluxes, and longwave radiation, which are the main sources of energy for atmospheric circulation. The tropical oceans are the regions of net radiation gain. This excess energy is transported to the higher latitudes through atmosphere and oceans to maintain the energy balance. Further, the tropical oceans are the regions where active air-sea interactions processes such as monsoons, El Nino and Southern Oscillations take place. Thus study of air-sea interaction parameters, fluxes and the hydrological cycle of the global oceans are quite important for our understanding of climate variability. Of the three major oceans, the Pacific Ocean has the largest longitudinal extension reaching over 140Ú. On the western part of the Pacific Ocean, there exists one of the warmest regions in the world, the so called " warm pool"; and in the eastern equatorial Pacific, a well developed cold tongue exists towards the west. This large thermal gradient and the resulting surface winds in turn drive ocean currents. These winds and water vapor dramatically alter the meteorological conditions, resulting in the formation of clouds or even rain clouds that are vital for life on land.

Monsoon

The southwest monsoon or the summer monsoon, which gives about 80% of the mean annual rainfall for the subcontinent, is one of outstanding meteorological phenomena of the Indian Meteorology (Ananthakrishnan et al., 1983). A typical monsoon sets in over the Kerala coast by 1st June and covers the entire Indian subcontinent by 15th July. The quantum of monsoon rainfall also varies from year to year. The monsoon rainfall is not continuous within the life cycle of monsoon; there are several spells of active, weak and break in monsoon conditions. The summer monsoon months of June to September contribute 21%, 33%, 28% and 18% of the seasonal rainfall respectively. Thus it can be seen that the mid monsoon months July and August contribute about 61% of the mean seasonal rainfall. Hence, prolonged breaks in these mid monsoon months can create deficit monsoon or drought-like conditions as in the case of 2002, which incidentally had the longest break spell of 34 days according to Ramesh Kumar and Uma (2004).

Scientists have used the term "break" to refer the features such as convection and circulation over different regions. Further they have used different durations and also looked them during different months. By analyzing 80 years (1888 – 1967) rainfall data, Ramamurthy (1969) suggested various synoptic situations responsible for the break in monsoon conditions. They include a) migration of monsoon trough to the foothills of Himalayas, b) the absence of low level easterly winds over the northern India, and c) the increased rainfall activity in the foothills of Himalayas and decreased rainfall over the rest of the country. The criteria used by him were based on the surface pressure distribution and circulation. He looked for the breaks only for the period from 1st July to 31st August.

De et al. (1998) have further classified the breaks for 30 years (1968 – 1997) and found some more additional features during the break in monsoon conditions, which include a) weak pressure gradient over the west coast of India, b) presence of a trough in mid tropospheric westerlies over northern parts of the country, and c) strong westerlies in the northern part as compared to the westerlies over the peninsula. They looked for the breaks only for the period from 1st July to 30th September.

Krishnan *et al.* (2000) defined the breaks as days with large positive outgoing longwave radiation (OLR) anomalies for at least four consecutive days or more over a wide region covering northwest and central India. They also kept a objective criterion that the OLR anomaly averaged over the region (18° - 28° N; 73° - 82° E) should exceed 10 watts per m^2 during all the days of the break period. Further, they considered breaks only during the period from 15th June to 15th September.

Goswami and Ajaymohan (2001) define the breaks on the basis of the strength of the 850 hpa wind at a reference point just south of the “monsoon trough” (15° N; 90° E). They also found that the frequency of the occurrence of the “active” and “break” monsoon conditions were distinctly different during the excess and deficit monsoon years. Further, they found that the most frequent pattern associated with an excess (deficit) monsoon year is the ‘active’ (‘break’) condition with enhanced (decreased) cyclonic vorticity and convection over monsoon trough.

Gadgil and Jospeh (2003) have looked into the breaks over the Indian subcontinent using rainfall over the monsoon zone, which they feel is representative of the all India summer monsoon rainfall. They obtained a negative and significant correlation between monsoon zone rainfall and number of rain break days (r = -0.56). They also obtained a positive and significant correlation between active and monsoon zone rainfall (r= 0.47).

During the break in monsoon conditions, according to Joseph and Sijikumar (2004), the strong cross equatorial low level jet stream (LLJ) with its core around 850 hPa is oriented southeastwards and it flows east between Sri Lanka and equator. During active monsoon conditions, the LLJ axis passes from central Arabian Sea eastwards through peninsular India and it provides moisture for convection over the Bay of Bengal and for the formation of monsoon depressions over there.

Ramesh Kumar and Uma (2004) have used a new parameter, namely, the all India daily rainfall, which they felt is truly representative of the rainfall conditions over the entire Indian subcontinent and hence will be better parameter suited to identify the breaks rather than the traditional parameters such as increase in surface pressure or circulation features over the Indian subcontinent. They have also further showed that the breaks identified by this method are consistent with the breaks obtained by previous studies and the duration of the breaks so identified matches very well with that reported by Ramamurty (1969) and Gadgil and Joseph (2003).

Ramesh Kumar and Uma (2004) classified a day as a break day if the all India monsoon rainfall was less than 9 mm/day and it persisted for a minimum of three days and it occurred in the mid monsoon months of July and August. They confined their study only to mid monsoon months for the following three important reasons:

1. A delayed onset or an early withdrawal of the monsoon can create an artificial break if we consider the months of June and September.
2. The monsoon months of July and August together contribute 61% of the seasonal total, hence a prolonged break in these months can have effect on the seasonal rainfall total.
3. There are large interannual variabilities with the monsoon covering the entire Indian subcontinent in 26 days in the year 26 days in 1980 and it took 76 days in the year 2002.

The percentage of days during July and August for different rainfall regimes is given in Table 1. In order to obtain a further insight into monsoon activity during these months, these days have been further classified as normal days (rainfall less than 9 mm/day), normal days (rainfall between 9 mm/day and 15 mm/day) and active days (rainfall greater than 15 mm/day). From the table it can be seen that about 34% of the days have rainfall less than 9 mm/day in July, while in the case of August, 53% of the days have rainfall less than 9 mm/day. Using this threshold, breaks were identified by Ramesh Kumar and Uma (2004) for the study period (1901-2002) and they were consistent with breaks identified by previous studies (Ramamurty, 1969; De et al., 1998; Gadgil and Joseph, 2003). The frequency of breaks of different durations is given in Table 2. From the table it can be seen that 45% of the breaks are of 3-4 days duration. The percentage of duration of breaks compared reasonably well with previous studies.

A comparison of the monsoon activity for two contrasting years, 1908 (which incidentally had only few break days) and 2002 (which incidentally had only few active days) is given in Figure 1a and 1b. The contrasts can be clearly seen in the daily rainfall activity for the months of July and August.

The breaks for different ten-day periods of July and August have been catalogued in Table 3. Further, three different types have been classified depending upon their duration a) Type I (short duration, breaks d" 7 days), b) Type II (medium duration, breaks > 7 days and d" 15 days), and c) Type III (long duration, breaks >15 days). The decadal distribution these types are given in Table 4.

In order to look at the role of the convective activity over the Indian Ocean on the break monsoon conditions of different durations, linear correlation was tried between the break day rainfall over the Indian subcontinent and the OLR over the tropical Indian Ocean. Correlation was found between the convective activity over the eastern equatorial Indian Ocean and type III breaks over the Indian subcontinent.

The low pressure systems (LPS) and low pressure system days (Jadhav and Munot, 2004) play an important role in the monsoon rainfall distribution. Majority of the low pressure systems, which form in the Bay of Bengal travel in the northwesterly direction and give copious amounts of rainfall to large parts of the Indian subcontinent. The LPS days also showed an increasing trend during the first epoch of the study period (Fig. 2). Interestingly, the LPS days also show a decreasing trend in the recent decades in tune with the decreasing monsoon rainfall.

Increasing convective activity (shown by negative trend) over the central and eastern equatorial Indian Ocean during 1979 – 2004 clearly indicates the recurrence of prolonged breaks over the Indian subcontinent. Thus we clearly see that the equatorial Indian Ocean, especially the eastern equatorial Indian Ocean has more influence on the monsoon activity over the Indian subcontinent during the recent decades. Thus the increase in the number of prolonged breaks and decrease in seasonal rainfall during the recent decades, could be a part of the 'climate change' induced by the global warming.

Conclusions

There is a major shift in the monsoon rainfall pattern and there is a decrease in rainfall in the month of July and increase in rainfall in the months of August and September. The number of breaks and break days in July has increased by 30%, whilst the breaks in August have decreased in the second half of the last century as compared to the first half. This major shift in the monsoon rainfall pattern could be attributed to the climate change.

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Table 1. Percentage of days in July and August with rainfall (mm/day) in different range

Range	July	August
0-9	33.7	52.9
9-15	50.0	40.9
15-33	16.3	6.1

Table 2. Comparison of the percentage of duration of the breaks with earlier studies

Duration (days)	Ramesh Kumar and Uma (2004)	Gadgil and Joseph (2003)	Ramamurty (1969)
3-4	45.4	44.8	49.5
5-6	23.2	22.8	19.8
7-8	11.7	14.3	16.2
9-10	6.1	6.7	6.3
11-12	3.6	4.8	4.5
13-14	3.4	3.8	1.0
> 15	2.2	2.8	2.7

Table 3. Distribution of breaks (number of break days) for 10 day periods for July and August for different decades

Period	July			August		
	01-10	11-20	21-31	01-10	11-20	21-31
1951-1960	41	32	**58**	24	18	57
1961-1970	42	50	53	32	36	**60**
1971-1980	31	22	**57**	30	40	46
1981-1990	**54**	50	34	27	34	53
1991-2000	**63**	25	31	30	53	56

Table 4. Number of days of break (Short Duration Breaks (SDB), Long Duration Breaks (LDB) and Very Long Duration Breaks (VLDB) for two different epochs.

Period	SDB	LDB	VLDB
1951-1976	77	26	02
1977-2002	69	27	04

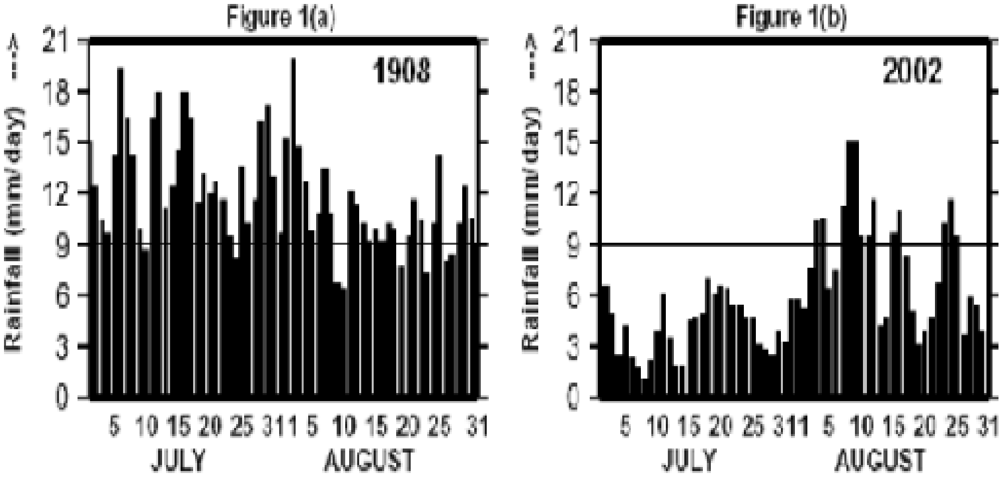

Figure 1(a)

Figure 1(b)

Fig. 1. Daily all India monsoon rainfall for two contrasting monsoon years 1908 and 2002 for the months of July and August

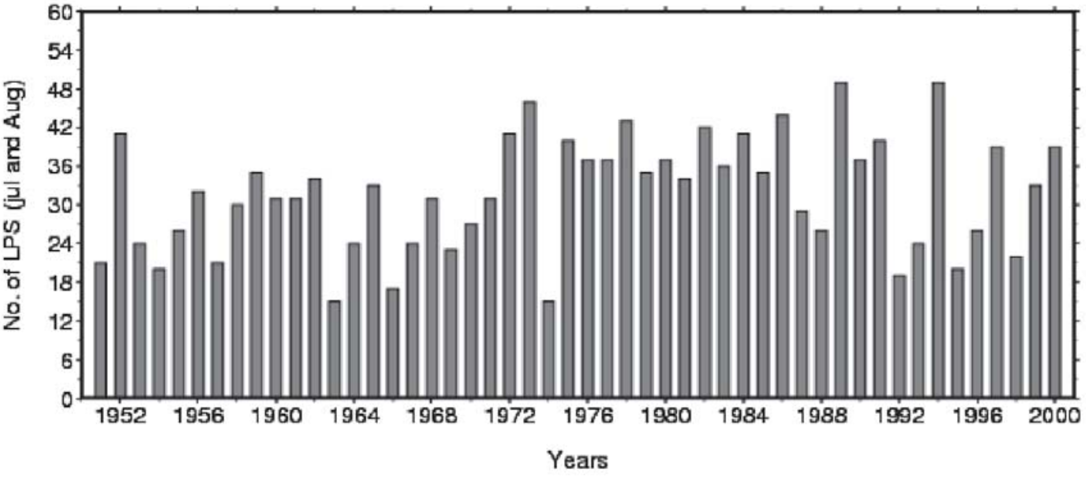

Fig. 2. Number of low pressure system days during July and August from 1951 to 2003