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Research Article

Water Availability at Macro to Micro Level: Role of Climate Change

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Abstract

Moisture is the limiting factor for crop growth in tropical warm regions wherein most of the developing countries are located, which varies with the scale of study, such as macro to micro. Moisture availability varies with the climate change expressed by the natural variability in rainfall and snowfall. At all India level, the Annual and Southwest Monsoon Season rainfall presented 60-year cycle. Frequency of occurrence of high magnitude floods in the rivers of northwest India followed this cycle. At state level, for example Andhra Pradesh annual rainfall presented 132-year cycle. Water availability in Krishna River followed this cycle. The severe drought condition seen in rainfall during 1876/78 was reported for Bangalore in British Memoirs. Andhra Pradesh receives rainfall in both the Southwest Monsoon (SWM) and Northeast Monsoon (NEM) seasons along with from pre-monsoon sporadic cyclonic activity. The three met sub-divisions in Andhra Pradesh followed 56-year cycle in SWM and NEM rainfalls but in reverse order. Cyclonic activity in the Bay of Bengal followed the SWM rainfall pattern. At station level, Kurnool in Rayalaseema met Sub-division followed SWM rainfall, in which showed on an average drought proneness in 45% of the years; and during above and below the average cycle parts of 28 years they are respectively 30% and 70% of the years. In such scenarios, studies based on the truncated data sets lead to misleading inferences. Therefore, detailed rainfall/snowfall analyses are critical for water resources and agriculture assessments over different parts of the country at station level and region level. Climate System plays an important role in the modification at local/regional level. For example, the drought prone zones are confined to leeward side of the Western Ghats.

Keywords: Water Availability; Climate Change; Macro and Micro Levels; Rhythmic Variation; River Water; Dry-Land Agriculture

Introduction

Earth's climate is dynamic and it is always changing through the natural cycles. What we are experiencing now is part of this system. People of all walks of life make statements attributing weather aberrations to global warming forgetting the fact that "When was, the period, in human history in which some person, in some location or other, wasn't feeling that some recent day, month or season has been very unusual in some dry, wet, hot, or cold?" Several civilizations have gone in to the history. Most unfortunate thing is that people are shy of using the word "Global Warming" with narrow implications of emission related rise in temperature and instead use "Climate Change" as de-facto global warming, a word with broader implications [1]. Climate relates to all meteorological parameters while global warming relates to temperature only, though it is not global in nature. The temperatures and Carbon Dioxide in the atmosphere are lower in Southern Hemisphere compared to Northern Hemisphere following the land area distribution. Even within the hemisphere based on climate system [2] they varied. Nowadays everything has turned into unusual and try to attribute to something they don't have the comprehensive knowledge like a blind man using a light pole. Most unfortunate thing is that man on the street to editor of scientific magazine talk of climate change at the same wavelength, and thus science of climate change became a scapegoat. Here might is right.

Intergovernmental Panel on Climate Change (IPCC) in its 3rd Assessment Report defines "Climate change refers to a statistically significant variation in either the mean state of the climate or in its variability, persisting for an extended period [typically decades or longer]. Climate change may be due to natural internal processes or external forcing's or to persistent anthropogenic changes in the composition of the atmosphere or in land use". Note that the United Nations Framework Convention on Climate Change [UNFCCC], in its Article 1, defines "climate change as a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods". In fact in 1966 WMO presented manual on "climate change". World renowned meteorologists from meteorological departments prepared this report. Late Shri K. N. Rao from India Meteorological Department [DDGC, Pune] was a co-author (in fact I worked under him - my boss). This manual presented methods to separate natural variability [cyclic or rhythmic patterns] from man induced variations [trend] – WMO [1].

Natural variability in climate

The two important climatic parameters that are of importance are temperature and rainfall. There are two other parameters, namely global solar radiation and net radiation. They follow the sunspot cycle (10.5 ± 0.5 years and its multiples) [3]. Temperature is regulated by these two parameters under climate system [as defined by IPCC, Reddy [2] and local general circulation patterns. Let us see the natural variability in temperature and rainfall.

Temperature

Temperature presents high seasonal and annual variations. WMO [1] presented methods to separate trend from cyclic variations. Moving average technique is one such method. In the case of global average temperature anomaly BRS and USNAS [4] studied 10-, 30- and 60- year moving averages. The 60-year moving average eliminated natural variability and presented trend. Reddy (2008) studied this using 1880 to 2010 data series and found the 60-year cycle "sign curve" varied between -0.3 and + 0.3°C. The trend showed 0.6°C per century.

Literature is flooded with climate change as de-facto global warming and many people used climate change as an adjective to get hype to their poor quality works. According to IPCC, (i) 1951 is the starting year of global warming, and (ii) the trend comprises of anthropogenic greenhouse component (more than half) and non-greenhouse component associated with land use and cover changes that includes urban-heat-island and rural-cold-island effects (less than half). The anthropogenic greenhouse component comprises of global warming component and volcanic aerosols, etc. component. If we assume that the global warming component alone is 50% in more than half then it is 0.6°C x 0.5 = 0.3°C per century. From 1951 to 2100 [in 150 years], it is 0.45°C.

There are several versions of global average temperature anomalies – adjusted data sets, which include measurements on the ground and from the space using satellites. Also, there are several versions of model estimates. As there is no clarity on the climate sensitivity factor, model estimates showed wide variations. IPCC monotonically started reducing the climate sensitivity factor in carbon dioxide forcing from SER to AR5 [in AR4 it is1.95 and in AR5 it is1.55]. From this it is clear that the trend may not be linear but may be non-linear [Reddy, 1995] as the energy from the Sun is not increasing with the time but it is constant with natural variability superposed on it. The average global temperature anomaly from 1880 to 2010 is not raw data series but adjusted data series. The met network increased with time sharply from few to thousands. With the satellite era again the met stations gradually falling. With all these limitations, global warming component by 2100 is far less than 0.45°C, which is insignificant to cause the so-called impacts of global warming.

Table 1 presents the temperature parameters for Hyderabad [January to June] and Table 2 presents the highest temperature for few selected stations. In these tables also presented relative humidity, the highest rainfall and average wind speeds for Hyderabad and relative humidity for the selected stations to understand impact on heat. It is clear from Table 2 that station-wise extremes in temperature varied with climate system, particularly soil type in Kadapa, Kurnool and Anantapur, Humidity plays critical role in human comfort factor in Visakhapatnam compared to Mumbai. These are the temperatures that impact agriculture and not the 0.45°C raise [if any]. Based on the temperature ranges in different seasons, crops are selected. As Tw reaches 28°C, humans experience severe human comfort problems. This is seen in Bihar and surrounding regions. Western disturbances [5] create unusual extreme heat wave conditions in northern parts of Telangana wherein the temperature go around 50°C.

Month Temperature (°C)										
	Tw	Tmax	Tmin	Thm	Tim	Th	T1	Rho %	Rh mm	W km/h
Jan.	18.0	28.6	14.6	31.9	10.7	35.0	06.1	36	093.2	08.1
Feb.	18.9	31.2	16.7	35.3	12.9	37.2	8.9	35	042.9	08.9
Mar.	20.1	34.8	20.0	38.5	16.5	42.2	13.2	30	103.1	09.6
Apr.	21.8	36.9	23.7	40.8	20.0	43.3	16.1	31	060.7	10.9
May	23.1	38.7	26.2	42.4	22.5	44.4	19.4	33	065.0	12.4
Jun.	23.7	34.1	24.1	39.9	21.2	43.9	17.8	54	122.7	23.8
Highest	23.7	38.7	26.2	42.4	22.5	44.4	19.4			
Lowest	17.2	27.8	13.4	30.6	09.9	33.3	06.1			
Range	06.5	10.9	12.8	11.8	12.6	11.1	13.3			

Table 1: Hyderabad climate [January to June].

Tw = mean afternoon wet bulb, Tmax = mean maximum, Tmin = mean minimum, Thm = highest mean, Tlm = mean lowest, Th = highest in a day, Tl = lowest in a day, RHa = afternoon mean relative humidity, Rh = highest rainfall in 24 hours, w = mean wind speed

Months	Station-wise highest temperature, °C					
	1	2	3	4	5	6
January	37.8	36.1	34.1	35.0(36)*	35.0(63)*	33.1(78)*
February	40.6	38.9	37.9	37.2(35)	38.3(62)	36.7(73)
March	43.3	41.7	40.6	42.2(30)	39.7(63)	38.3(71)
April	45.0	44.4	42.2	43.3(31)	40.6(66)	40.5(80)
May	46.1	45.6	42.2	44.4(33)	36.2(68)	43.3(83)
June	45.0	44.4	41.7	43.9(54)	37.2(78)	44.4(83)

Table 2: The highest temperatures at few met stations

1- Kadapa, 2 – Kurnool, 3 – Anantapur, 4 – Hyderabad, 5 – Mumbai and 6 – Visakhapatnam

- Data in brockets - Relative Humidity in % -- afternoon

Rainfall

In rainfall there is no trend except abrupt shifts due to modifications in the local terrain/land use. Rainfall presents clear cut rhythmic variations. They varied with latitude, coast to inland, etc. [6,7]. However, they vary with national, regional and local level with the climate system and general circulation patterns. Recently a report [8] says "NASA Study: Human Influence on Global Droughts Goes back 100 years, May 3, 2019, by Jessica Murzdorf, NASA Goddard Space Flight [GISS] in New York". The report states that human generated greenhouse gases and atmospheric particles were affecting global drought risk as back as the early 20th century. This is a false theory.

National Level

IITM compiled met sub-division-wise monthly, seasonal and annual rainfall series from 1871 to 1994 [9]. Using this data series for all-India Southwest Monsoon Rainfall Reddy [10] found 60-year cycle in line with Telugu Calendar 60-years [lagging by three years to Chinese 60-year Calendar]. CWC used all India rainfall data series supplied by IMD for 1984-85 to 2014-15 [June to May] for the estimation of water availability in Indian Rivers – estimated at 0.25 degrees grid interval using the satellite and ground data. Figure 1 presents the annual march of all-India rainfall [June to May] from 1871-72 to 2014-15. The frequency of occurrence of high magnitude floods in few northwest Indian Rivers followed the same 60-

year cycle pattern. Table 3 presents these results. This data was published by MoEF in 2009. This shows that floods and droughts are part of natural variations in rainfall. However, they vary with space.

Frequency of high magnitude floods*			
River	**Period**	**Frequency**	**Climatic cycle**
Chenab	1962-1990	1 in 9 years	(a) below the average cycle
	1990-1998	1 in 3 years	(b) above the average cycle
Ravi	1963-1990	1 in 14 years	(a)
	1990-1998	1 in 3 years	(b)
Beas	1941-1990	1 in 8 years	(a)
	1990-1995	1 in 2 years	(b)

Table 3: Frequency of occurrence of high magnitude floods in few northwest Indian Rivers.

*State of Environment Report, India – 2009, MoEF/GoI: The frequency of floods in India is largely due to deforestation in the catchment area, destruction of surface vegetation, changes in land use, increased urbanization and other developmental activities – this is a false statement but it is more in association of cyclic variation in rainfall.

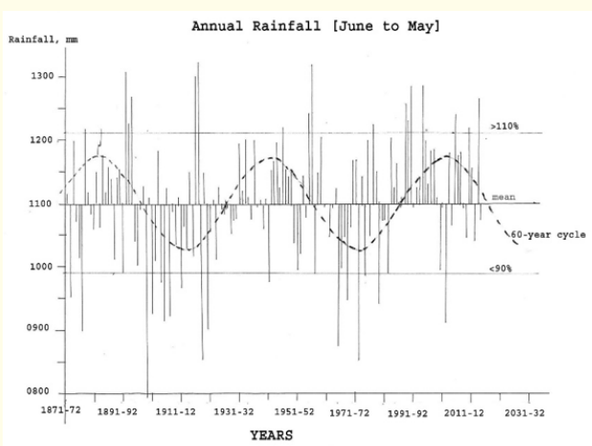


Figure 1: All India Annual Rainfall
[Observed, vertical lines and Predicted, dotted curve].

State Level

At regional level the natural variability may or may not be the same as that of national level. For example, let us see the Andhra Pradesh Rainfall [total of Coastal Andhra, Rayalaseema and Telangana Met sub-divisions]:

Figure 2(a) presents the annual rainfall pattern [1871 to 1994 from IITM data set and after that the deficits and surplus rainfall as presented year-wise by the government. This presents a 132 year cycle. Before 1935, the 66 years part is below the average part of the cycle in which 24 years were drought years and 12 years were flood years; and from 1935 to 2000, the 66 years part is above the average part of the cycle in which 12 years were drought years and 24 years were flood years. From 2001, the below the average part of 66 years started and so far majority of the years [including the last three years] presented deficit rainfall [2002 and 2009 were drought years at all India level and showed a temperature raise of 0.7°C and 0.9°C, respectively].

Figure 2(b) presents the water availability in Krishna River – the data was taken from Bachawat (1894 to 1971) and Brijesh Kumar (1961 to 2007-08) Tribunals' reports. With the repairs to Prakasham Barrage the data was derived indirectly for 1951-1960 by the tribunal. This data series also followed the 132 year cycle pattern. It follows the rainfall pattern. Water reached Srisailam dam during 2009-10 to 2018-19 in tmc ft are: 1222, 1028, 736, 197, 848, 614, 59, 345, 489, 562. This presents the character of low rainfall after 2001 [Figure 2(a)]. 1876 presented deficit rainfall less than 50% and on either side also presented less than average rainfall. British Memoirs showed severe drought in Bangalore during 1876/78 [Figure 3].

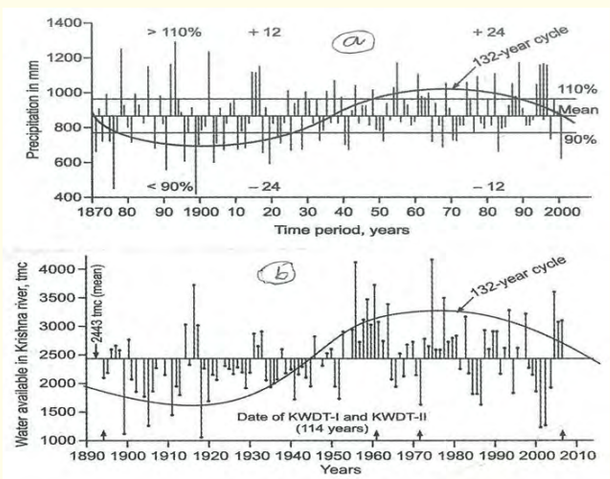


Figure 2: (a) Annual Rainfall of AP and (b) Water Availability in Krishna River.

Figure 3: 1876-78 severe drought impacts on Bangalore.

Andhra Pradesh receives rainfall during Southwest Monsoon Season [June to September] (SWM) and Northeast Monsoon Season [October to December] (NEM). This region is influenced by sporadic cyclonic activity during the pre-monsoon season and severe cyclonic activity during the post-monsoon season, other-wise known as NEM season. Reddy [10] observed in the SWM season rainfall a 56-year cycle and same was also observed in NEM season rainfall but they are in opposite phase. Cyclonic activity in Bay of Bengal followed SWM season rainfall pattern. Table 4 presents some of these statistics.

It is clear from Table 4 that during below the average cyclones part of the 56 year cycle, SWM rainfall presents a deficit (less than 90% of the average) rainfall in majority of the years. Table 5 presents Depressions (D), cyclonic storms (CS) and severe cyclonic storms (SCS) in Bay of Bengal and Arabian Sea during pre-monsoon season (April and May), monsoon season (June to September) and post-monsoon season (October to December) during 1891 to 1990 [Reddy, 2008 – pages 66-67].

Period	Rainfall [% years with < 90% of average]						Cyclones in Bay of Bengal
	SWM			NEM			[May to November] $ number
	CA	R	T	CA	R	T	
1861-1888*	72	61	72	33	28	66	<10
1889-1916	53	43	46	60	71	71	>10
1917-1944	75	78	68	46	50	60	<10
1945-1972	43	43	32	64	60	46	>10 [10-16]
1973-2000**	54	54	54	41	45	41	<10 [0-8]
2001-2027							>10

Table 4: SWM & NEM and Cyclonic activity in Bay of Bengal Statistics

* 1871-1888; ** 1973-1994, average cyclones 10; SWM = south-west monsoon; NEM = northeast monsoon; CA = Coastal Andhra, R = Rayalaseema, & T = Telangana met sub-divisions

$: Joint Typhoon Warning Centre – Bay of Bengal Region Cyclones per year during 1945-2000 (May-November) – Reddy (2008) page. 160.

Month	Number of cyclonic disturbances during 1891-1990								
	Bay of Bengal			Arabian Sea			Total		
	D	CS	SCS	D	CS	SCS	D	CS	SCS
April	08	11	10	02	0-1	08	10	15	18
May	32	15	35	11	15	31	43	30	66
Monsoon [June to September]	514	119	29	57	15	03	571	134	32
Post-Monsoon Season									
October	104	44	34	28	12	12	132	56	46
November	55	42	53	32	06	20	87	48	73
December	37	23	19	08	04	02	45	27	21
Annual	767	260	185	143	47	68	910	176	224

Table 5: D, CS and SCS during pre-monsoon, monsoon and post-monsoon seasons

D = depressions, CS = cyclonic storms, SCS = severe cyclonic storms

Station Level

For agriculture planning in real time, we need to study the time variation in rainfall and agro-climatic parameters. Figure 4 presents one such an example for Kurnool in AP state. S and G in the figure refer to week of commencement time of planting rains and G is the available effective rainy period from S. This figure presents the pattern of 56-year cycle in which the drought risk is 45% of the years on an average. During below the average 28 year period, drought risk is 70% and during above the average 28 year period is 30%. Figure 5a presents the average drought risk in the semi-arid tropics in India and using the same procedure Akumunchi Anand., *et al*. [11] presented for Maharashtra [Figure 5b].

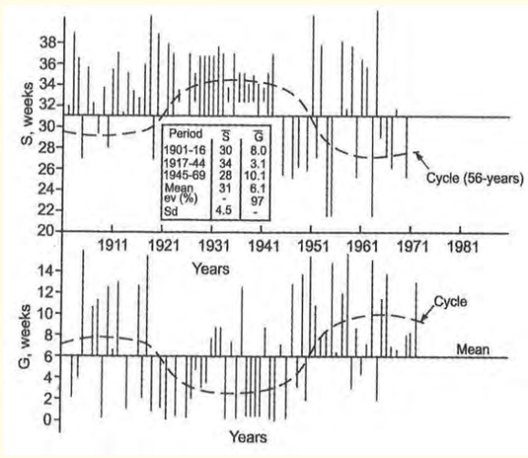
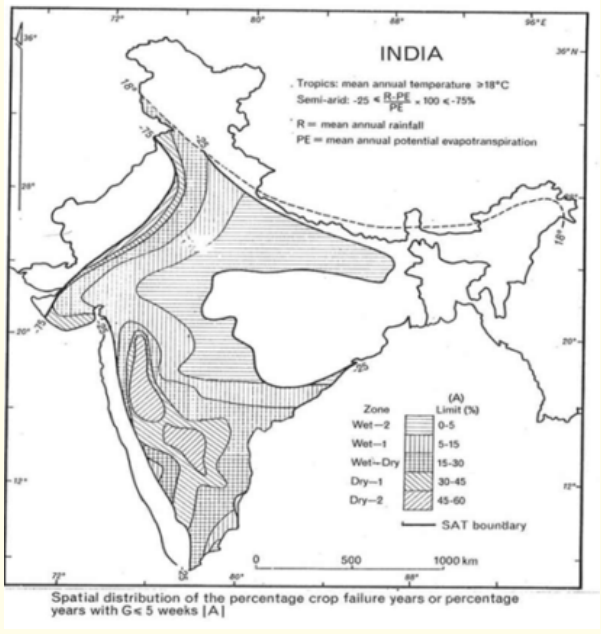
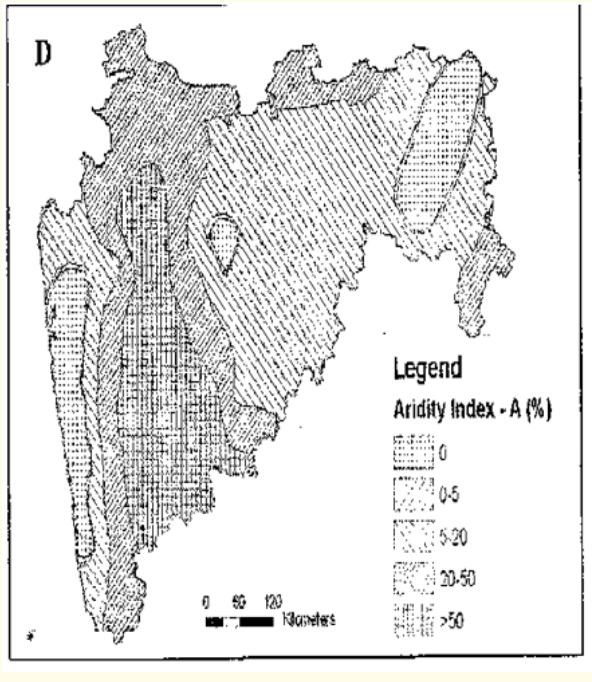


Figure 4: Annual march of agroclimatic variables: G & S.



Spatial distribution of the percentage crop failure years or percentage years with G≤ 5 weeks [A]



(a) India by Reddy [1993]

(b) Maharashtra by Akumunchi Anand., *et al*. [2009].

Figure 5: Drought Risk (a) India and (b) Maharashtra.

Discussion

Climate is dynamic; climate change was there in the past and people adapted to them; and climate change will be there in future needs develop adaptive measures. Climate change varies with space and time. Climate change is modified at local and regional levels by "climate system and general circulation patterns". However, too generalisation is too dangerous. Scientific institutions must change from copycat mode to real science mode. Traditional agriculture was based on natural variability in rainfall and accordingly water resources storage methods were invented. Some of these are there still to date.

Truncated data series

In the above section presented the natural variability in rainfall data series at national, state and station level. It is common to researchers and planners use truncated data set of a natural variability series. This type of selection leads to misleading conclusions or lead to biased inferences. For example, let me present few cases in this direction wherein the data series present rhythmic variations:

On India rainfall a question was asked in the parliament

IMD/IITM prepared an answer and submitted to the concerned minister to respond. The reply states that Indian rainfall is decreasing. To get such bad answer, they used the data set of 2nd cycle in Figure 1. Here the first 30-year part is above the average and the second 30 year part is below the average. Naturally this shows a decreasing trend. If they would have chosen the 30 year below the average part (2nd below the average peak in Figure 1) and then the 30 year above the average part (3rd above the average peak in Figure 1), then this shows an increasing trend.

Water availability estimates in Krishna river by tribunals

Bachawat Tribunal used 78 years data series that were available to him at that time (1894-1971) to estimate water availability in Krishna River under different probability levels and thus to distribute water to three riparian states. Brijesh Kumar Tribunal used 47 years [1961-62 to 2007-08] data series though 114 years data series were available to him at that time. Brijesh Kumar used high rainfall period and thus estimates of water availability are at higher side that affect the lower riparian states.

CWC water availability estimates at all India level:

Central Water Commission (CWC) used 30 years (1984-85 to 2014-15) data series that represent the 3rd above the average peak in Figure 1. Method adapted by CWC in estimating water availability in Indian rivers present overestimation by around 20-30%; and the 30 years period selected for such estimates refer to high rainfall period. Thus, using such data series in the inter-linking of rivers and distribution of water among riparian states is highly biased and misleading.

Hundreds and thousands of papers published relating to climate change/global warming impact assessments are made using

truncated data series only. Such studies wherein the truncated data set is part of natural variability are highly dangerous [12-15].

Projection of droughts and floods

International media highlighted the recent droughts and floods in Southern Africa [Cape Town in South Africa and Beira in Mozambique] and attributed them to global warming by international Institutes and as well by the media. It is not so [16]. Durban rainfall in South Africa presented 66 year cycle with sub-multiple of 22 years; and Beira rainfall in Mozambique presented 54 year cycle with the sub-multiple of 18 years. The integrated patterns followed W & M pattern. W means below the average part and M means above the average part of the respective cycles. In W & M at the middle few years presented opposite pattern. The projections are shown in Table 6.

It is clear from Table 6 that the droughts and floods are not uniform over different parts of Mozambique as the natural variability changes with coast to inland and with the latitude.

Station	**Average Rainfall (mm)**	**Cycle 1**	**Cycle 2**	**Cycle 3**
Catuane	low rainfall (620)	1943-1996	1997-2050	2051-2104
Maputo	medium rainfall (900)	1925-1978	1979-2032	2033-2086
Beira	high rainfall (1480)	1931-1984	1985-2038*	2039-2092
Cycle 2 of Beira:				
W =	1985-1995(-)	1996-2000(+)	2001-2011(-)	
M =	**2012-2022(+)**	2023-2027(-)	2028-2038(+)	
Durban medium (1050)	1876-1942	1943-2009	2010-2075*	
Cycle 3 of Durban:				
W =	2010-2023(-)	2024-2028(+)	2029-2042(-)	
M =	2043-2056(+)	2057-2061(-)	2062-2075(+)	

Table 6: Catuane, Maputo, Beira and Durban information.

+ above the average & - below the average

The cyclone Idai caused severe blow to Sofala-Beira reaching Zimbabwe and Malawi on 14th March 2019 killing around 300 people. The Idai cyclone is associated with Beira. Recent flood period as projected in my 1986 publication is clearly seen in Beira, a high rainfall zone in Mozambique. That is, in 2012 to 2038 of M, 11-5-11 years presented wet-dry-wet years in 27 year period. Here wet means above the average rainfall of 1480 mm and dry means below the average of 1480 mm. The 1st wet 11 year period is 2012-2022 is above the average rainfall [1480 mm] period coinciding with the present floods is associated with the cyclonic activity. The recent droughts in southern South Africa are clearly seen in Durban cyclic pattern in rainfall. 2010 to 2076 of 66 years, the 1st part is W and the second part is M. That is, in 2010 to 2042 of W, 14-5-14 years present dry-wet-dry years in 33 year period. Here wet means more than 1050 mm of average rainfall and dry means, less than 1050 mm of rainfall. The present drought is associated with the dry period. These projections clearly suggest that they are associated with natural variability part of climate change and global warming (if any) has not played any role.

Conclusions

- Making claims from the air is a bad science. Unfortunately majority of people make statements from air to serve their vested interests. The media and as well institutes biased towards global warming are the fore-runners in this direction. These groups are using children/students to achieve their goals.
- In fact the word climate change is used as de-facto "global warming and carbon credits" to get a share in green fund. Many a time climate change is used as an adjective and media uses to get hype.
- Scientific Institutions have no time even to read fully the reports of Intergovernmental Panel on Climate Change [IPCC] on climate change. In agriculture and water resources climate change in terms of natural variability in

rainfall is playing vital role but this is missing in practice. However, they vary with nation to state to station as there are several localized factors that control or modify rainfall.

- Climate Change/Global Warming impact studies made using truncated data series of a natural variability are highly dangerous.

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