FLOODS AND DROUGHTS IN THE INDIAN MONSOON

Natural variability trumps human impact

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About the author

Madhav Khandekar is a former research scientist from Environment Canada and was an expert reviewer for the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Khandekar started his career at the India Meteorological Department in Pune more than 55 years ago, where his first job was to develop a statistical-empirical algorithm for forecasting summer monsoon rainfall over India. Khandekar is the lead author on the chapter on extreme weather in *Climate Change Reconsidered II*, published by the Non-Governmental International Panel on Climate Change in September 2013.

Executive summary

The floods and unfortunate deaths of several dozen people in the Kashmir region of India in September 2014 reignited the debate about increasing human emissions of carbon dioxide and their putative linkage to extreme weather events such as floods, droughts and heat waves. What is missing from many of the media reports and scientific publications on this subject is critical analysis of past weather extremes to determine if there has been an increase in recent years. In this brief report, past floods and droughts in the Indian monsoon are examined carefully and it is shown that such events have occurred throughout the excellent 200-year-long summer monsoon rainfall dataset. It is further documented that such floods and droughts are caused by natural variability of regional and global climate, and not by human carbon dioxide emissions. Improving our understanding of the inter-annual variability of the monsoon and the associated extremes may help reduce damage to infrastructure and loss of life in the future.

1 Introduction

The Indian summer monsoon and, by extension, the South Asian monsoon, impacts about 2.5 billion people of South Asia on an annual basis and is perhaps the most complex regional climate science issue of all. Most climate models have achieved only limited success in simulating and predicting the features of the monsoon, for example extreme rainfall events and the associated flooding or extended monsoon-season dry spells. As such, current climate models are of very little operational utility in providing timely warnings of extreme weather events during the monsoon season.

Attempts at developing seasonal forecasting of the Indian monsoon go back more than one hundred years, to when Gilbert Walker, the Meteorological Reporter to the Government of India in early 1900s, started his pioneering research on correlating worldwide weather to monsoon rainfall. The first operational forecast, based on statistical-empirical algorithms, was issued in 1906. Walker's work was extended subsequently by several others.[1]

The state of the summer monsoon is known to be closely linked to sea-surface temperatures in the equatorial Pacific – the so-called El Niño-Southern Oscillation (ENSO) phase – as well as to other natural climate fluctuations such as the Indian Ocean Dipole. The present operational prediction algorithm of India Meteorological Department uses parameters based on some of these key climate features, and has shown some skill and operational utility on seasonal timescales. However, much more research is needed to develop early warning systems with useful lead times (say of 12 to 24 hours) for the extreme weather events that are associated with the monsoonal passage.

2 Recent floods and droughts

In view of the current media concern about the question of extreme weather events and the monsoon, it is instructive to examine past monsoonal flood and drought events in India, in order to assess their inter-annual variability.

In the last six years the Indian summer monsoon encompassed two major droughts: in 2009 and 2012. The drought of 2009 was primarily due to the presence of an El Niño[2] in the equatorial Pacific.[3,4] El Niño events are generally associated with a weak Indian monsoon and the 2009 summer monsoon rains were 22% below normal (see Figure 1a).

There were no major floods anywhere in the country in 2009. The 2012 monsoon was also adversely impacted by a weak El Niño event and phase of the Indian Ocean Dipole that was unfavourable. In contrast, the monsoons for 2010 (Figure 1b) and 2013 were slightly above normal, mainly due to favourable conditions in the equatorial Pacific and the equatorial Indian Ocean.

It is of particular interest here to note that some recent monsoon floods that received extensive media coverage occurred when the overall monsoon was only slightly above normal. For example, the 2010 floods, which inundated about 20% of the land area in Pakistan and caused the unfortunate deaths of about 2000 people, occurred in early August and were caused by heavy localised rains in northwest India and Pakistan. A key element in producing the extensive flooding in Pakistan was a rapid transition of the ENSO phase from El Niño to La Niña – i.e. from warmer to colder sea surface temperatures in the equatorial eastern Pacific – which invigorated the 2010 summer monsoon by increasing convection and moisture transport from the Bay of Bengal to northwest India and Pakistan.[5]

The 2013 monsoon began on time on 1 June 2013 at the southern tip of India and rapidly

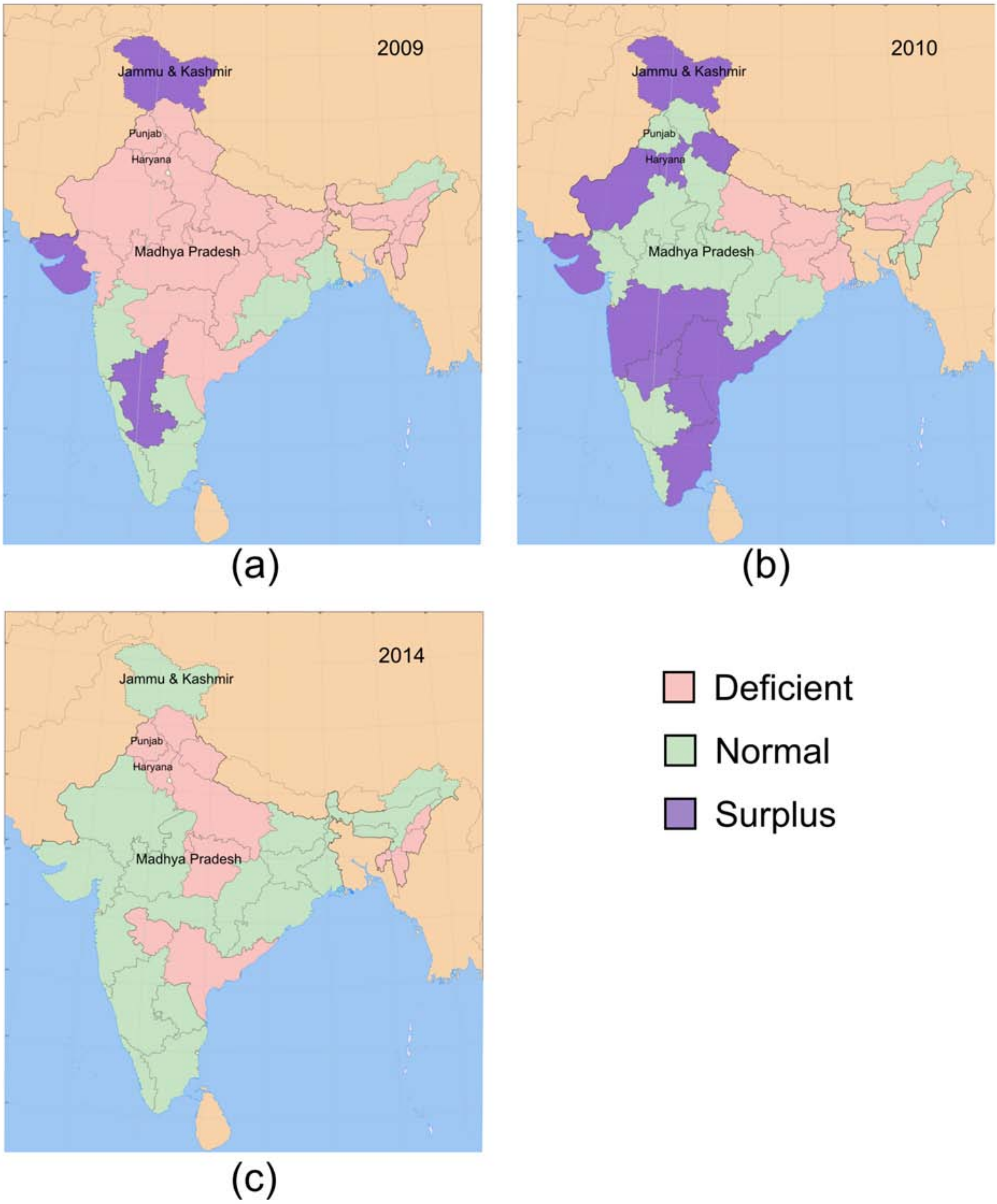

Figure 1: The Indian summer monsoons of 2009, 2010 and 2014

Deficient defined as more than 20% below average rainfall; surplus as more than 20% above average. Redrawn from IMD Hydromet Division data using Wikimedia map of India.

progressed northward. By mid-June, heavy rains were being reported in many parts of northwest India. On 17–18 June, heavy rains accompanied by localised cloudbursts (possibly linked to solar activity[6]) produced flooding and landslides in the state of Uttarkhand. Several hundred pilgrims on their way to the Kedarnath Shrine in the Himalayan foothills were tragically killed by landslides and a lack of adequate shelter.Ť

The latest flood event, in Kashmir during the first week of September 2014, was also due to heavy localised rains caused by the development of a low pressure system, with moisture transported from the Bay of Bengal.

When closely examined, the flood events of August 2010, June 2012 and September 2014 are an inherent part of the natural variability of the Indian monsoon, and are associated with heavy rainfall in many other regions of India. This issue is discussed further below.

It is instructive to note that despite media hype about 'increasing floods', the summer monsoon rains have in fact, diminished recently, with droughts becoming more frequent in the last 20 years. Since the new millennium, there have been several years – 2002, 2004, 2009 and 2012 – with a deficient summer monsoon, and 2014 has added a fifth year to this sequence, with the monsoon at 12% below normal (see Figure 1c).

A 2005 paper by Sontakke et al. painstakingly compiled rainfall data over the Indian region going back to 1813.[7] This study showed that after the summer monsoon of 1994, during which rainfall was 12% above normal, there was not a single year with 'excess' rain. An interesting 2012 article from the well-known newspaper *The Hindu*, entitled 'The Missing Monsoon', discussed the decline in the summer monsoon since the late 1990s. The article stated that:

> Overall there has been a downward trend in monsoon rainfall since late 1990s. It is important to note that the monsoon has cycles of high and low rainfall and it could be that we are in the middle of a 'low rainfall cycle'. Even so, the severity of the last few droughts is unusual.

The diminishing intensity of the global monsoon since 1950 was also discussed in a comprehensive paper by Chase et al. in 2003.[8] The authors analysed monsoonal circulations for 1950–1998 over four major tropical regions and documented significantly diminished monsoonal circulations. They concluded: 'We find no support for the increasing hydrological cycle or increasing extremes as hypothesized by greenhouse warming scenarios'.

What has caused monsoon rains to diminish in recent years? Several recent studies have attempted to examine if there is a link to increasing pollution – 'aerosols' – and in particular to the 'Asian brown haze' (ABH), which has been frequently referred to in media reports and in the scientific literature. The rise in ABH is caused by burning of biomass, which is a cheap household energy source in rural India.

Among several recent studies on the impact of aerosols and the ABH on the monsoon and the climate is a noteworthy paper by Ramanthan et al.[9] These authors suggest that the intensity of the ABH has a significant impact on climate and on the monsoon in particular, and this possibility is being investigated by many others. However, the recent floods in India and other south Asian countries with monsoonal climates, for example Thailand and Vietnam in October 2010, strongly suggest that natural variability trumps any possible diminishment by the ABH.

In view of the strong evidential support for a diminishing monsoon in the last 25 years or so, we have a paradoxical situation: floods are on the rise locally while the overall monsoon has been diminishing in intensity. In fact, several recent heavy floods have afflicted some lo-

Table 1: The Indian summer monsoon

	Year	mm
Mean rainfall		906
Highest rainfall	1961	1089
Lowest rainfall	1877	609

Figures are for June–September rainfall

cales, while the rest of India has experienced a deficient monsoon. A recent example was the 2002 summer monsoon, which produced extreme drought over most of India, while lashing the northeast region of the country with heavy rains, leading to flooding of the Brahmaputra River and several hundred deaths. Such oddities in the Indian monsoon are all too common.

3 Severe rainfall zones over India

In a 1993 paper, Dhar and Nandargi used data for the period 1880–1990 to document a total of 97 extreme localised rainfall events around India, defined as 200 mm or more over a two-day period.[10] The largest number of such extreme events (15 in all) was recorded in Madhya Pradesh, in central India. In one case during 1926, totals of 25 cm (approximately 10 inches) and higher were recorded over an area of 2500 km^2 in a three-day period. Similar extreme rainfall events and the associated floods have been recorded in other regions of India during heavy monsoon years, in particular in 1917, 1933, 1936, 1942 and 1961. What is of interest in the context of the global warming debate is that some of the heavy monsoon years were recorded during the 1910–1945 period, when the Earth's mean temperature was rising steeply, while during the recent warming of the climate, from 1977 to 1998, the monsoon diminished in intensity, producing more droughts.

The important point being made here is this: monsoon interannual variability has produced severe droughts and floods in an irregular fashion with no apparent link to manmade carbon dioxide emissions (see Tables 1 and 2 and Box 1). Linking recent floods (and droughts) to manmade warming of the climate is therefore highly questionable.

4 Impacts of floods and droughts

Television footage of floods in the Kashmir region and elsewhere often portrays widespread damage to infrastructure, together with regrettable loss of life. However, such floods are also beneficial for Indian agriculture, which today accounts for about 10% of India's Gross National Product, at about US$200 billion dollars.

It is therefore true that a good-to-heavy monsoon has a beneficial impact on India's economy, despite the unfortunate loss of lives and property damage. For example, the 2013 summer monsoon produced extensive flooding in the northern States, with several hundred related deaths occurring in June alone; there was also flooding in several other areas. However, overall the monsoon rains were beneficial over the peninsular region of India, where the major rice crop is grown. Moreover, in the northern states of Punjab and Haryana, good rains also helped to produce enhanced yields of corn, beans, lentils etc. So despite heavy flooding, 2013 saw India's best grain yield ever: about 260 million tonnes.

Table 2: Variability of the Indian summer monsoon

Drought	Floods	Back-to-back drought and flood	Back-to-back good monsoon	Back-to-back weak monsoon
1843	1818	1860	1892	1823
1844	1861	1861	1893	1824
1848	1892	1917	1894	1986
1861	1894	1918	1916	1987
1877	1917	1941	1917	
1899	1933	1942		
1918	1942	1971		
1941	1988	1972		
1982	1994	1987		
1987		1988		
2002				
2009				
2014				

Drought is defined as monsoon more than 10% below normal; flood as 10% above normal.

The summer monsoon of 2014 was poor in some of the most important agricultural regions of the Punjab and Haryana, with rains about 40–50% below normal, and this shortfall is expected to have a negative impact on the harvest. However, in the peninsular region a late revival of monsoon rains in the first two weeks of September helped boost the rice yield estimate to about 106.5 million tonnes, which is two percentage points more than last year.

Box 1 Examples of monsoons of the past

1. Drought of 1918

The monsoon of 1918 was exceptionally feeble and rainfall was seriously deficient over the whole of India, with the exception of northeast India. The river discharges of the Godavari and Krishna basins (in the peninsular India) were 60% below average. The crops consequently failed. The drought of 1918 was more widespread and severe than the country had experienced in the previous two centuries.

2. Flood of 1961

ŞMany States experienced heavy floods during the monsoon of 1961 including several peninsular states like Kerala, Tamil Nadu, Karnataka, that are not normally appreciably affected. Many rivers recorded their highest ever levels and protective dams burst. The suffering and losses were so alarmingly high that the economics of flood control measures had to be reviewed by various government agencies.

Source: Bhalme & Mooley 1980: *Monthly Weather Review* 1980; 108: 1197–1211.

In general, a deficient monsoon can be more harmful than a very wet one from the socio-economic perspective. This is because a weak monsoon results in depleted reservoirs and rivers, which in turn necessitates the restricted use of water for domestic purposes. A weak monsoon also impacts the agricultural sector, with reduced yields of grain, vegetables, fruits and other crops. As an example, the deficient 2002 summer monsoon had a significant negative impact on India's economy.[11] A severe drought is more stressful to India's socio-economic fabric than a surplus monsoon, as water and grain shortages cannot be easily replenished. A surplus monsoon, even with accompanying regional flooding, can be beneficial in the long run, especially if the damage from floods can be reduced by the development of an adequate early warning system.

5 Floods and droughts elsewhere

It is instructive to consider some of the recent floods and droughts in other regions of world in the context of monsoon floods in India. As mentioned earlier, an El Niño event in the equatorial Pacific is generally associated with a weak summer monsoon over India, while a La Niña event tends to invigorate it. The Indian monsoon, and by extension the South Asian monsoon in general, evolve in tandem, although there are significant regional and local differences. For example, the 1997-98 El Niño was perhaps the strongest such event in the last fifty years. However, its impact on the Indian summer monsoon of 1997 was only marginal. But over south Asia, and in particular over most of Indonesia, the 1997 El Nino produced one of the severest droughts in 50 years and exacerbated the pre-existing smoke problem there, which had been caused by deforestation in the Kalimantan region of Indonesia.[12] The 1997 El Niño also produced a severe drought over Malaysia and other islands in the vicinity.

Among more recent floods and droughts are those associated with the La Niña event of 2010, which produced heavy rains in Australia, Indonesia and Thailand. For northern Australia, the May–October 2010 period was the wettest on record, with rainfall at 152% of normal. The year 2010 also saw floods around the world: regions from west Africa (Benin, Niger and western Sahel) to central Europe to Romania, Ukraine, Moldova and parts of Turkey were all affected. Germany had its wettest August on record. In South America, November 2010 saw regional and localised floods from Columbia to Brazil to Argentina.

The Canadian prairies, meanwhile, are very drought prone, most notably during the dust-bowl years of the 1920s and 1930s, and more recently in the late 1990s and during the early years of the new millennium. But since 2005, droughts have been replaced by floods, with 2010 and 2014 ranking among the wettest summers on record.[13]

A careful analysis of these droughts and floods worldwide suggests a possible linkage to the ENSO and other large-scale atmosphere-ocean circulation patterns and changes. Any 'human imprint' is hard to find in the face of this dominant natural, regional climatic variability.

6 Summary and conclusions

The Indian summer monsoon is a robust regional climate event and is governed by large-scale atmosphere–ocean features such as the ENSO cycle. There are major occurrences of flood and drought throughout the excellent 200-year-long record of monsoon rainfall. Such events, either nationwide or localised, are governed by natural interannual variability and do not appear to be impacted by the feeble forcing of manmade global warming and associated changes in the climate.

It is noteworthy that many recent floods have been local, running counter to an overall decline in monsoon rains. In a recent news item from the *Times of India* the head of the Long-Range Forecast Division at the Pune Meteorological Office was quoted as saying that the drop in monsoon rainfall was due to natural variability.[14] Such low and high rainfall phases in the summer monsoon have also been identified by others.[15]

The Indian/South Asian monsoon is perhaps the most complex annual and regional climatic event in the world. It is therefore not surprising that it has eluded skilful simulation and prediction by climate modellers. There is an urgent need to develop more skilful algorithms for the short-term prediction of regional and localised floods and droughts. Such algorithms could be used to help develop an early-warning system, which in turn would help reduce loss of life and damage to infrastructure. Reducing greenhouse gas emissions (to reduce floods or other extreme weather events in future) is a meaningless exercise and will do nothing to influence future climate extremes. A case in point is the landfall of the powerful tropical cyclone ‘ŚHudhud’Š on the southeast coast of India on 11 October 2014. Use of an advance warning system by the India Meteorological Department, together with extensive collaboration with the Indian army and navy, enabled over a quarter of million people to be evacuated from the affected areas, thus reducing the number of fatalities to just under a dozen, according to preliminary estimates.

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The Global Warming Policy Foundation is an all-party and non-party think tank and a registered educational charity which, while openminded on the contested science of global warming, is deeply concerned about the costs and other implications of many of the policies currently being advocated.

Our main focus is to analyse global warming policies and their economic and other implications. Our aim is to provide the most robust and reliable economic analysis and advice. Above all we seek to inform the media, politicians and the public, in a newsworthy way, on the subject in general and on the misinformation to which they are all too frequently being subjected at the present time.

The key to the success of the GWPF is the trust and credibility that we have earned in the eyes of a growing number of policy makers, journalists and the interested public. The GWPF is funded overwhelmingly by voluntary donations from a number of private individuals and charitable trusts. In order to make clear its complete independence, it does not accept gifts from either energy companies or anyone with a significant interest in an energy company.

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