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Monsoon Wager

Climate Change and the Indian Monsoon

Contents

Executive summary

Across geographical, cultural, urban-rural and religious divides, the Indian monsoon binds all Indians together. From the marginal farmers of the arid plateaus of central India and the wheat farmers of Punjab, to the office-goers and schoolchildren of Mumbai, the monsoon is key to the lives of millions across the subcontinent. The Indian economy remains heavily dependent on the seasonal rains, and news of the monsoon's success or failure is keenly awaited every year. If the Indian monsoon failed, it would damage the country's economy and food security.

Will climate change affect the Indian monsoon? What the exact impacts are likely to be is still uncertain, but the science increasingly suggests that climate change is going to change the pattern of the Indian monsoon.

More than 60% of India's cropped area still depends entirely on monsoon rainfall. With political and economic power concentrated in urban India, it is easy to forget that agriculture still accounts for one third of India's GDP, supports 70% of India's working population and provides around 70% of Indian exports (by value). A rural population of 700 million is directly dependent on climate sensitive sectors and resources, and given the high levels of poverty in this section of the population, people's adaptive capacity is low.

The IPCC's 4th Assessment Report (Christensen et al. 2007) suggests that warming in India is likely to be above the average for South Asia, with an increase in summer precipitation and an increase in the frequency of intense precipitation in some parts. Other regional modelling exercises suggest that temperatures could rise by between 2.5° to 4°C and 3°C to 5°C by 2100, but that the warming would be more pronounced over northern India.

Climate modelling and an analysis of historical data suggest that climate change is likely to bring about significant changes in the monsoon. Rainfall will increase by some 20% overall in the summer monsoon, but the increase will not be evenly spread across the country. For example, the Western Ghats and north-eastern regions will get more than the average rainfall increase, with more extreme rainfall events predicted for the Western Ghats/west coast region.

The degree to which monsoonal patterns alter is likely to depend on changes occurring elsewhere on the planet. Climate change is likely to lead to a stronger but more variable monsoon until 2100. After this, a weakening is possible as the melting Greenland ice sheet begins to affect temperatures in the North Atlantic and, as a consequence, the pattern of the North Atlantic ocean circulation.

The hydrological cycle appears to be particularly vulnerable to any changes. Some river basins are likely to experience more frequent flooding events, and others more severe droughts due to a higher frequency and intensity of monsoon 'break' events.

Given the subcontinent's high population densities, limited agricultural lands and water resources, the summer monsoon rains are central to India's continued economic and cultural development. While the exact nature of monsoonal variations is still being modelled, it is clear that any future changes in monsoon intensity will be accompanied by enormous economic and societal consequences.

The planet is entering an era of dangerous climate change. To prevent runaway climate change, global greenhouse gas emissions need to peak by 2015, reaching as close to zero as possible to by 2050.

Historically, India has contributed little to the creation of the climate change problem. Conversely, India has a lot to lose from the effects of climate change. Given the difficult challenge humanity faces in trying to rein in the climate change monster, India cannot afford to be a silent spectator. We must continue to pressure the industrialised world to make deep and urgent emission cuts. At the same time, domestically, India must take whatever action possible to curtail CO2 emissions, by adopting mandatory, ambitious targets for energy efficiency and renewable energy, and creating fiscal incentives to help reach them, as outlined in the concluding pages of this report.

It is clear that India is going to suffer with the expected alterations in the monsoon due to climate change, and it would be foolish not to take whatever action we can to reduce the severity of those impacts.

Photo : AFP

Chapter 1:

The monsoon phenomenon

An annual cycle of seasonal changes in the direction of prevailing winds is a phenomenon that occurs in various parts of the world and which extends over a large part of the tropics (25°S to 35°N and 30°W to 170°E). The Asian-Indian Ocean-Australian monsoon system, (Gadgil, 2003; Clift and Plumb, 2008) is considered to be the most intense of these phenomena. Despite being classified on a regional basis, however, monsoons are part of the circulation of the tropical atmosphere that takes place on a planetary scale, which both drives and is driven by these seasonal systems (see: Clift and Plumb, 2008; Wang, 2003). Many aspects of these seasonal processes remain poorly understood; indeed, there are competing hypotheses explaining the basic drivers of the Asian monsoon (see Gadgil 2003). Nonetheless, it is thought that the Asian monsoon was critical in shaping the evolution of human society. It is estimated that today, almost two thirds of humanity live within regions influenced by the Asian monsoon and depend on the water that it brings to support agriculture and to supply potable water.

The Indian subcontinent and the oceans surrounding it are located close to the centre of the monsoonal region and experience has shown seasonal changes in the prevailing wind directions and the weather systems that accompany these winds. One hypothesis suggests that these winds are driven by the relatively larger seasonal range of land temperatures as compared to ocean temperatures, originally suggested over a century ago. The concept of the monsoon as essentially a gigantic onshore/offshore breeze is undermined by the fact that, in general, India is much hotter in May before the monsoon begins than in July when it is fully active. Additionally, it has been noted that temperatures in years of poor rains are higher than those of more intense rains. An alternative theory proposes that the monsoon is attributable to the seasonal migration of the intertropical convergence zone. Gadgil (2003) notes that these theories have different implications with respect to the variability of the monsoon, and goes on to point out that satellite imagery supported by other observations and modelling exercises supports the ITCZ migration theory to a large extent. He concludes that key uncertainties in monsoon meteorology attach to the mechanistic understanding of influences on the ITCZ and that these hamper predictions of variability.

During what is known as the south-west monsoon in India, prevailing winds from the south-west between June and September, with their moisture-laden air, supply most of the rainfall (80% or so) to most of India in four months of massive convective thunderstorms. The most intense rainfall takes place along the western peninsular region (due to coastal geography) and in the north-east regions. These latter areas are known as the wettest on Earth. The exception to this seasonal pattern of rainfall due to the south-west monsoon is in the south-eastern part of peninsular India, where much

of the rainfall takes place between October and November and is supplied by the dry north-east (winter) monsoon winds picking up water as they blow across the Indian ocean. In general, the south-west monsoon rainfall is greater in southern than in northern India (see: IMD 2009).

Monsoon variations and their impacts on India

The seasonal monsoon rains are a critical factor in Indian agriculture to the extent that it has been stated that the Indian economy as a whole can be characterised as a gamble on the monsoon rains (see: Gadgil 2003). Agriculture is a key sector of the Indian economy, accounting for around a third of GDP, supporting some 70% of the working population and providing around 70% of the value of exports (Krishna Kumar et al. 2004). More than 60% of the cropped area in India still depends solely on monsoon rainfall, even though areas of land under irrigation have increased. Considered in this way, there are two components to this gamble that can impact on the success and yield of agricultural systems. The first component, inter-seasonal variation resulting in a particularly wet or particularly dry south-west monsoon, can impact significantly on yields, as can a late onset or early or late withdrawal of the monsoon. The second component comprises the more subtle intra-seasonal variation impacts, which may be exerted at critical stages of plant development or maturation. Given the potential impacts of monsoon variability on agricultural production, it is unsurprising that much effort has been directed at understanding and predicting these variations (see Gadgil 2003; Kulkarni et al. 2009; Ihara et al. 2009; Yadav, R.K. 2009; Krishna Kumar et al. 1999; Krishna Kumar et al.2006). While some of the drivers have been identified, much remains uncertain.

Chapter 2:

Climate change and the Indian monsoon

The considerable uncertainties and indeterminacies attached to understanding the Indian monsoon extend to prediction of the way(s) in which the monsoon is likely to change as a result of anthropogenically-forced climate change. As noted by Sathaye et al. (2006), a rural population of 700 million in India directly depends upon climate sensitive sectors and resources and adaptive capacity is generally low. A key problem in predicting the response of the south-west monsoon to anthropogenically-driven climate change is the application of Global Circulation Models (GCMs) at the regional-scale. Nonetheless, GCMs have been applied and have lead to some relatively consistent conclusions.

The predictions made by the IPCC in the 4th Assessment Report suggest that warming is likely to be above the global average for South Asia, with an increase in summer precipitation and an increase in the frequency of intense precipitation in some parts. More extreme rainfall and winds may result from tropical cyclones. Other modelling exercises carried out using more regionally-focussed models (Rupa Kumar et al. 2006; see also DEFRA 2005) suggest that temperatures could rise relatively uniformly by between 2.5° to 4°C and 3°C to 5°C by 2100, depending upon the modelled scenario, but with more pronounced warming over northern India. The modelling also suggests that rainfall will increase by some 20% overall in the summer monsoon, albeit with very substantial spatial differences over the country as a whole. A rise is seen in all states except Punjab, Rajasthan and Tamil Nadu, in which slight decreases are predicted. These statistics, however, hide some important information. The rainfall increases are not uniformly distributed and may be as high as 30% over Western-central India and also higher than average over the north-eastern regions. More extreme rainfall events are predicted for the Western Ghat mountains running along the west peninsular coast and in some adjoining states. Some evidence that this trend may already have emerged is provided by research showing that the apparent stability of the Indian monsoon between 1951 and 2000 masks an increase in heavy precipitation events and a reduction in moderate ones (Goswami et al. 2006). In addition, based on palaeological evidence, monsoon wind strength appears to have increased over the last four centuries in parallel with northern hemisphere warming (Anderson et al 2002).

This raises the question of how intra-seasonal variation of monsoon activity may be impacted under climate change. As Gadgil (2003) points out, large intra-seasonal fluctuations between active and weak spells of rainfall in India have been known for over a century but, currently, prediction of these is hampered by the same raft of uncertainties that attach to prediction of overall monsoon strength/intensity i.e. poor understanding of some of the key mechanisms driving the monsoon. Nonetheless, modelling studies carried out (Turner and Slingo 2009) indicate that, in addition to generally wetter extremes of weather, break events during which rainfall is sparse (see: Wang 2006) are predicted to be more intense, although their duration and periodicity appears to remain unchanged. While this study used what is arguably the best model available at present (the HadCM3), the authors point to the need for the development of higher resolution GCMs that incorporate more sophisticated representations of ocean-atmosphere coupled processes. Attempts to analyse trends in historical break event data derived from rainfall gauges have given conflicting results to date.

In addition to the modelled predictions, which suggest an intensification of active and break monsoon events, other studies have suggested that climate change phenomena could interact to trigger abrupt transitions between two stable states. Zickfield et al. (2005) suggest that changes in planetary albedo or in insolation could act to cause a transition from a stable 'wet' monsoon to a stable 'dry' monsoon state, characterised by much lower levels of rainfall than are currently common. Initially driven by light-scattering sulphate aerosols and land-use changes, periodic abrupt switches between the two states might result if the suppressive effects of these aerosols are removed, allowing increased CO2 concentrations to drive an intensified 'wet' monsoon cycle. This phenomenon has been identified as one of a number of potential climate tipping points, defined as a threshold at which relatively small changes can trigger large changes at a continental or sub-continental scale (Lenton et al 2008).

The paleological studies which have suggested an increase in monsoon wind intensity over the past four centuries (Anderson et al. 2002) have also suggested a link between conditions in the North Atlantic Ocean and the Asian monsoon as well as linkages with extent of Eurasian snow cover. Cold conditions in the North Atlantic have been linked with weakened monsoons. This provides a further mechanism through which a weakened Asian monsoon could be triggered. It is possible that a weakening or collapse of the Gulf Stream could occur due to the impact of ice-melt derived freshwaters on the thermohaline circulation. A very much weakened monsoon could be the result (see Clift and Plumb 2008), a contention supported by data representing conditions 8000 years before present. Hence, while climate change is likely to lead to a stronger but perhaps more variable monsoon in the period to the end of the 21st century, the monsoon would be likely to weaken considerably after rapid melting of the Greenland ice sheet begins to affect the North Atlantic circulation, with significant inter-annual variation characterising the period immediately before the new weakened state becomes prevalent. In addition, large-scale changes to northern hemisphere temperatures can influence the position of the ITCZ, providing a theoretical basis for such influences on the monsoon.

In conclusion, therefore, the results of climate modelling backed by analysis of historical data (including paleological data) suggest that climate change may bring about significant changes to the monsoon. While it is likely that temperature rises will produce more intense (but possibly more variable) monsoon rainfall over India in the period through to 2100, after this time the situation may possibly be driven by large-scale changes in the northern hemisphere temperature regime that, while ultimately weakening the monsoon, may be preceded by large inter-annual variation.

Overall, the impacts of climate change in India through to the end of the 21st century are likely to arise both from changes in the temperature regime and from hydrological changes exerted through a changed monsoon as described by Sathaye et al.(2006). The hydrological cycle appears to be particularly vulnerable, with some river basins likely to experience an increase in flooding events, while others are likely to experience more severe droughts (Gosain et al 2006). After 2100, the outlook becomes much less certain, given the high degree of connection between the North Atlantic temperature regime and the potential for large scale disturbance of ocean circulation patterns which determine this regime. Asia as a whole has high population densities, supported by limited agricultural lands and water resources to support agriculture. Clift & Plumb (2008) state that summer monsoon rains are central to continued economic and cultural development in Asia. Perhaps the only thing that is beyond doubt, therefore, is that any future changes in monsoon intensity will be accompanied by enormous societal consequences.

Cyclonic activity, Storm surges, Sea Level Rise and Climate Change

An increase in sea surface temperature also increases the risk of intensified cyclone activity and heightened storm surges. Coastal regions vulnerable to sea level rise are even more vulnerable to the impacts of such cyclonic activity and storm surges. In a recent policy research paper published by the World Bank Development Research Group Environment and Energy Team in April 2009, the findings show that severe impacts are likely to be experienced in some coastal countries, especially in some coastal cities.

Cyclones get their power from rising moisture which releases heat during condensation. As a result, cyclones depend on warm sea temperatures and the difference between temperatures at the ocean and in the upper atmosphere. If global warming increases temperatures at the earth's surface but not the upper atmosphere, it is likely to provide tropical cyclones with more power (Emmanuel et al. 2008).

In the South Asian region, India and Bangladesh are most vulnerable in absolute terms on coastal populations, GDP. Among the cities most under risk in India are Mumbai, Bhavnagar, Surat, Thane and Vadodara.

Chapter 3:
Conclusions and demands

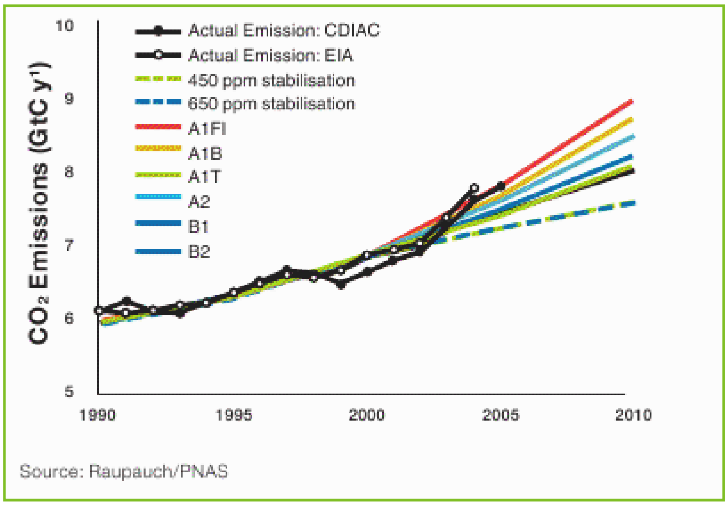

Figure 1: Actual global CO^2 emissions as compared to IPCC scenarios.

The world has entered an era of dangerous and destructive climate change, and this change is increasing exponentially through lack of action to tackle the problem. Whether or not we can step back from the brink and change course will depend heavily on the level of cuts in greenhouse gas emissions the world is prepared to make over the next few years.

This report points to the linkages between the monsoons, which are a combination of a multitude of complex weather systems, and the effects that human induced climate change will cause to this phenomenon. Currently, while the exact response of the monsoons to climate change is still unclear, enough is known to indicate that the monsoons are likely to become more unpredictable and result in more frequent, more intense spells of rain that can lead to flooding. The frequency and intensity of weather events such as cyclones is likely to increase as well. It is also clear that India depends heavily on a 'normal' monsoon to maintain healthy economic growth, good agricultural output and the livelihoods of its farmers. The possibility of flooding from intense rain spells and increased cyclonic activity will place an even greater load on the country's disaster management systems than already exists. In all cases, it is the poor of the country who will be the worst hit.

In reality, climate change impacts are outstripping the IPCC projections, which are increasingly recognised as conservative. The dramatic melting of the Arctic summer sea-ice in 2007 and 2008 is probably the most visible example and has forced a significant re-evaluation of how close the world may be to runaway climate change. It is now clear that ice in the Arctic is melting substantially faster than the IPCC predicted only two years ago and there are concerns that the Arctic could be ice-free in summer within the next ten years. Changes in the real world make it clear that even the current level of global warming is too much. The Earth's capacity to deal with the effect of a continuously growing concentration of greenhouse gases in the atmosphere has already been exceeded.

James E. Hansen, who directs NASA's Goddard Institute of Space Studies, has pointed out that the extent of increase in the Earth's average temperature would "imply changes that constitute practically a different planet. It's not something you can adapt to". In a recent interview, Hansen said, "We can't let it go on another 10 years like this. We've got to do something".

There is still a window of opportunity to prevent the worst impacts of climate change, and we are the last generation that has an opportunity to avert a catastrophe. But the longer we continue with 'business as usual', the smaller this window becomes and the larger the task ahead of us. Upholding the precautionary principle and that of intergenerational equity, it becomes our responsibility to mitigate the climate threat without further delay.

Greenhouse gas emissions are growing fast; atmospheric concentrations already beyond projections.

The actual growth rate of greenhouse gas emissions since 2000 is at the top or beyond any of the projected scenarios used by the IPCC in either their 3rd or 4th Assessment Reports as shown in Figure 1. In 2007, the atmospheric CO2 concentration reached 383 parts per million (ppm), The annual increase rate of 2.2 ppm was up from the average 2.0 ppm over the prior seven years, according to the Global Carbon project's report, Carbon Budget 2007. Since 2000, human induced CO2 emissions have been growing four times faster than over the previous decade.

At the current rate of emissions, we may be heading for a temperature rise of 4°C or more by 2100. A 4° temperature rise would have catastrophic consequences including implications on the monsoons that the country depends upon.

Greenpeace's Demands

The need of the hour is to reduce emissions urgently and at the greatest rate possible due to the uncertainties and unpredictability of the climate system. To prevent runaway climate change, it is clear that global greenhouse gas emissions need to peak by 2015, reaching as close to zero as possible to by 2050.

In order to achieve this, Greenpeace is calling for:

A binding international agreement that ensures global greenhouse gas emissions will peak by 2015;

Strong leadership by the industrialised countries, as a group, towards achieving this peak in emissions by rapidly reducing their greenhouse gas emissions by at least 40% by 2020, compared to 1990 levels. At least three-quarters of this reduction needs to be met by domestic action;

On top of this 40% reduction, industrialised countries should provide financial and technological support to developing countries in order to assist them to achieve a reduction of between 15% and 30% of their greenhouse gas emissions as compared to a business-as-usual projection;

Developing countries to achieve, as a group and by 2020, with financial and technological support from industrialised countries, a 15% to 30% deviation from business-as-usual growth. Developing countries would unilaterally implement those negative and zero-cost ('no regret') measures that can be achieved without external assistance.

To achieve this, strong and rapid emission reductions to very low levels will be required from virtually all sectors, including the energy, forests and agriculture sectors, as well as from all greenhouse gases, including f-gases and other non-CO2 gases. We will need technological innovations and changes in lifestyle, consumption and trade patterns.

In India we demand that the Indian government

Immediately make public its 8 national mission plans under the National Action Plan on Climate Change that was unveiled in June 2008. This should be followed by a period of public consultation around the mission plans as in the case of any important policy measure.

Lay an emphasis on energy efficiency and enact policy measures for energy efficiency that includes:

Progressive and mandatory efficiency standards with clear timelines for implementation across all energy applications in the country - especially fuel efficiency in vehicles and efficiency standards of appliances.

Implements reforms in the banking sector to ensure that energy efficiency projects are made financially viable.

Provides substantive government investment to promote efficiency, especially in enabling the small and medium enterprises (SME) sector to change over from energy inefficient production and products to efficient ones.

Implements an accelerated depreciation for energy efficient equipment in the first year to help its deployment.

Introduces regulatory systems to implement and monitor efficiency.

Provides tax incentives for promotion of energy efficiency including differential taxation on appliances that are certified as energy efficient.

Mandates specific energy consumption decreases in large energy consuming industries with a framework to certify energy savings in excess of mandated savings. The certified excess savings will then be traded amongst companies to meet their mandated compliance requirements.

Enacts a Renewable Energy law with time bound legal targets for renewable energy uptake both at the grid and stand alone level, in every state as well as nationally. The RE uptake targets should not be less than

o 10% by 2010

o 20% by 2020

o 60% by 2050

Ensures that the law provides incentives for investment in RE technologies such as offering preferential tariffs, open transmission as well as incentives for buying green energy.

- An immediate shift in subsidies from fossil fuels to renewable energy.

- National feed-in-tariffs for renewable energy, without a cap.

- Incentives for rooftop solar photo-voltaics, the feed-in-tariff is made applicable even for small quantum of excess supply to the grid from the buildings.

- A national trading scheme wherein States are encouraged to promote generation of renewable energy in excess of the State standards, for which certificate are issued and which may be tradable amongst other states which fail to meet their renewable standard obligations.

Ensures a massive increase in the Research and Development expenditure to Solar by a factor of 8 at the very least.

Enacts legislation that completely phases out coolants in air conditioning and refrigerating products consisting of Hydro-fluoro-Carbons (HFCs) and Hydro-Chloro-Fluoro Carbons (HCFCs) by 2009 and substituted with safer Hydro–Carbon coolants. Phasing out high potential greenhouse gases is essential and extremely urgent.

Photo : AFP

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Greenpeace is a global campaigning organisation that acts to change attitudes and behaviour, to protect and conserve the environment and to promote peace by:

Catalysing an energy revolution to address the number one threat facing our planet: climate change.

Defending our oceans by challenging wasteful and destructive fishing, and creating a global network of marine reserves.

Protecting the world's remaining ancient forest and the animal, plants and people that depend on them.

Working for disarmament and peace by reducing dependence on finite resources and calling for the elimination of all nuclear weapons.

Creating a toxic free future with safer alternatives to hazardous chemicals in today's products and manufacturing.

Supporting sustainable agriculture by encouraging socially and ecologically responsible farming practices.

Greenpeace exists because this fragile earth deserves a voice. It needs solutions. It needs change. It needs action. At Greenpeace, we believe in the power of the many. The future of the environment rests with the millions of people around the world who share our beliefs.Together we can tackle environmental problems and promote solutions.