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A brief survey on climate change effects on the Indian Monsoon

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Each year, Indian summer monsoon season begins in June and ends in September. Surface winds blow from the southwest during this season. The Indian summer monsoon typically covers large areas of India with western and central India receiving more than 90% of their total annual precipitation during this period, and southern and northwestern India receiving 50%-75% of their total annual rainfall. Overall, monthly totals average 200-300 mm over the country as a whole, with the largest values observed during the heart of the monsoon season in July and August. In all total, India receives about 870 mm of rainfall in a normal summer monsoon season.

This summary discusses the effects of climate change on the frequency, mean rainfall, duration and the variability of the Indian Monsoon. East Asian Monsoon in the southeastern part of Asia is not discussed in this summary. Changes in monsoon characteristics are mainly inferred from climate model simulations submitted to the Intergovernmental Panel on Climate Change (IPCC)'s Fourth Assessment Report (AR4). It should be cautioned that there is a large range in the results from these models. For instance, the range of mean monsoon precipitation as simulated by the AR4 models over India is from 500 mm to 900 mm for the present-day climate (Kirpalani et al. 2006).

Frequency
The Indian monsoon is a phenomenon that occurs each year. There is no evidence from climate modeling studies to show that this will change in the future.

Duration
The multi-model ensemble technique suggests a possible extension of the monsoon period (Kirpalani et al. 2006)

Annual mean monsoon rainfall
In general, modeling studies suggest increases in the mean monsoon rainfall over India with increases in greenhouse gas concentrations. The multi-model ensemble mean increase, relative to present-day, is about 10 % in year 2100 for the SRES A1B scenario (Ueda et al., 2006). Other studies reach a similar conclusion; rainfall might increase by 5-25 % (Annamalai et al., 2006), or by 8 % (Kirpalani et al., 2006). An analysis of climate change experiment using ECHAM4

model of Max Planck Institute shows an increase of 35 % (Hu et al., 2000; Ashrit et al. 2001).

The future change in the large-scale flow indicates a weakening of the monsoon circulation (Ueda et al., 2006). Enhanced moisture transport over the Asian summer monsoon region, associated with the increased moisture source from the warmer Indian Ocean, leads to a larger moisture flux convergence, which is responsible for the intensification of the mean rainfall. Increase in precipitable water of 12-16 % is projected over major parts of India (Kirpalani et al. 2006).

Year-to-year variability of monsoon rainfall

Extreme excess and deficient monsoons are projected to intensify (Meehl and Washington, 1993; Kirpalani et al., 2006). The study by Ashrit et al. (2001) using a single model (ECHAM4) shows an increase of 50 % in year-to-year variation in monsoon rainfall over India. However, a recent study using multiple models shows that the increase would be by about 5-10 % in a warm climate (Annamalai et al. 2006). These results imply more swings in the quantum of rainfall in a year; years with above-average rainfall could experience more flooding, and deficit years can result in severe droughts.

There is an inverse relationship between monsoon rainfall and El-Nino; the rainfall is less than normal when there is an El-Nino in the eastern tropical Pacific Ocean. The study by Annamalai et al. and another by Ashrit et al. (2001) show that this relationship will remain intact under climate change.

Intraseasonal variation

Monsoon rainfall is characterized by active/break spells. These spells constitute what is called the intraseasonal variation. The frequency and duration of these spells usually characterize an above/below normal monsoon season. The periodicities of these spells are about 3-7 days, 10-20 days and 30-60 days. Bhaskaran et al. (1995) did not notice any significant change in the intraseasonal variability with doubled CO_2 in the UK met office climate model. Changes in the number of active/break spells in rainfall and their duration with climate change in most of the models are small (Mandke et al. 2006). However, the reduction in precipitation during the break spells is statistically significant when CO_2 is quadrupled.

Daily precipitation statistics

Goswami et al. (2006) find statistically significant rise in the frequency and magnitude of extreme rain events and significant decreasing trend in the moderate rain events in central India for the period 1950-2000. They anticipate substantial hazards (landslides, crop damage and flash floods) related to heavy rain events in central India in the future. Most AR4 models show a modest increase in day-to-day variation in summer monsoon rainfall over central India in $2xCO_2$ climate, and stronger variation in $4xCO_2$ climate (Mandke et al. 2006).

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