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Indian monsoon inter-annual variability and climate change

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The Indian monsoon and by extension the South Asian monsoon impacts close to three billion people of South Asia on an annual basis. Timely arrival of monsoon and its steady progress over the summer (June-September) months is critical for agriculturally dominated countries of South Asia. A moderate to severe drought significantly reduces grain yields and poses acute problem of lack of potable water for billions. A moderate to heavy monsoon can produce extensive flooding in low-lying areas, while alleviating water shortage problems. In this study, inter-annual variability of floods and droughts in summer monsoon has been analyzed using an excellent data set of over 200 years. It is found that floods and droughts in the Indian/South Asian monsoon have occurred irregularly throughout the 200-year data set, with No linkage to recent warming of the earth's climate or climate changes in the past. The droughts and floods are found to be linked to large-scale atmosphere-ocean features like the ENSO (El-Nino/Southern Oscillation) phase and the Equatorial Indian Ocean Dipole that dominate the equatorial Indian Ocean during the summer months. Additionally, several cases of back-to-back drought and flood have been identified as

seen in the enclosed table. An empirical model based on large-scale atmospheric and oceanic features is developed which provides a useful guideline for forecasting floods and droughts, few weeks to few months ahead of the monsoon season.

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	1886
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.

Biography

Madhav Khandekar is a former research scientist from Environment Canada and was an Expert Reviewer for the IPCC (Intergovernmental Panel on Climate Change, a UN Climate Panel) 2007 Climate Change Documents. Khandekar holds M.Sc in Statistics from Pune University, India and M.S and PH.D. in Meteorology from the Florida State University USA. He has published over 150 papers, reports, book reviews and scientific commentaries. While at Environment Canada, Khandekar published a book 'Operational Analysis & Prediction of Ocean Wind Waves' (Springer-Verlag) published in December 1989. Khandekar is a Lead Author of a Chapter on *Extreme Weather* in a report 'Climate Change Reconsidered-II' published in 2013 by the NIPPC-Nongovernmental International Panel on Climate Change.

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