The impact of monsoon intraseasonal variability on renewable power generation in India

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The impact of intraseasonal variability (active/break phases) in the South Asian summer monsoon on the Indian power sector is investigated. Break phases are likely to be associated with both strong demand for power (associated with its use for cooling) and weaker-than-normal wind-power resources over much of India. This situation is reversed in active phases.

Monsoon variability therefore exacerbates the variability in demand-net-wind over India (i.e., the power that must be supplied by other generation resources). This has potentially profound consequences for power system operation, both for renewable-energy and conventional generation plant.

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Intraseasonal Monsoon Variability

The South Asian Monsoon varies significantly within the summer period. This variation results in "active" and "break" phases and has consequences for both the large-scale atmospheric circulation and the local surface climate.

Over India there are two preferred locations for convection during the monsoon season. Convection over the Indian subcontinent brings heavy rainfall over India (active phases) while convection over the equatorial Indian Ocean results in reduced precipitation across India (break phases), (see Annamalai and Sperber, JAS 2005, Lau *et al.*, Springer 2012).

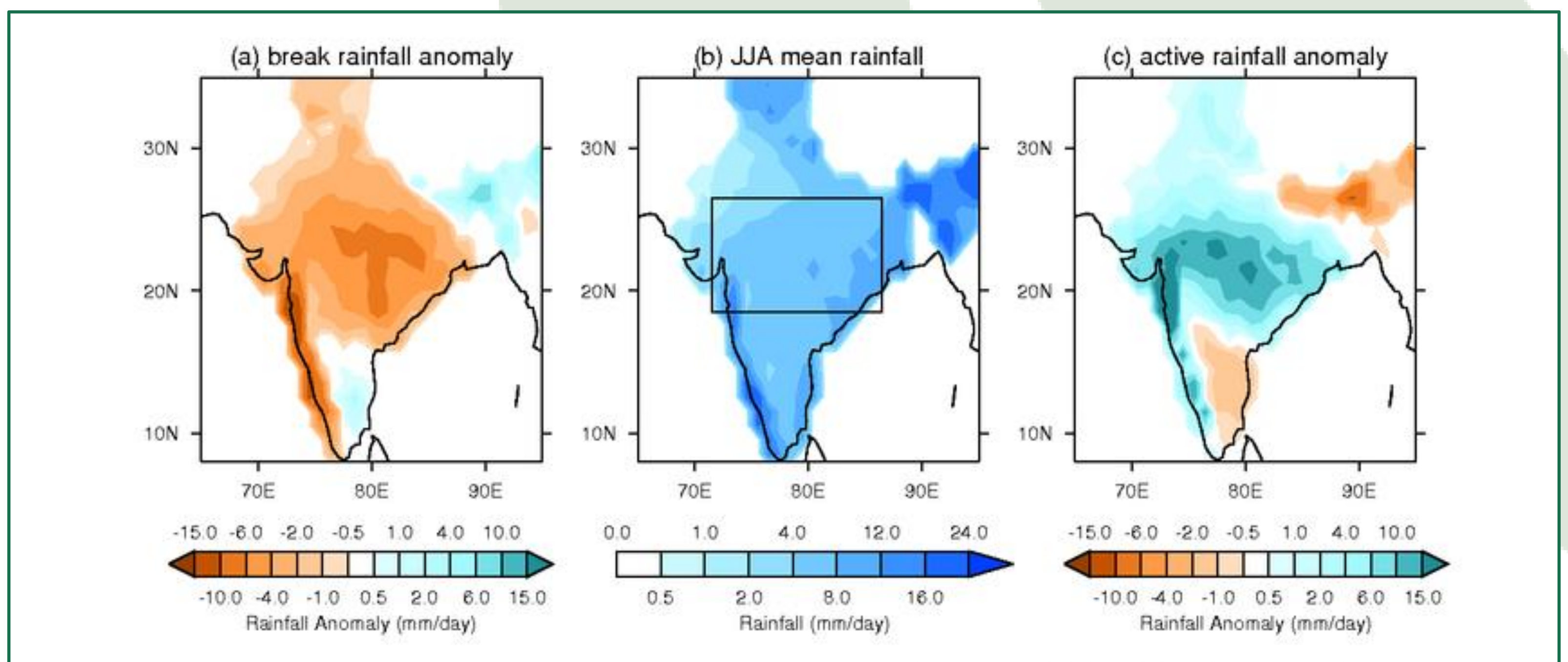

Fig 1: Precipitation distribution during the monsoon (JJA) over 1969-2004 (mm/day). Monsoon active and break phases were defined using rainfall over the core monsoon zone marked in (b). (a) and (c) show the precipitation anomaly in break and active phases respectively.

Cooling Energy Demand

Monsoon break events lead to much higher temperatures and demand for cooling over India. The situation is reversed for active monsoon phases. Monsoon variability thus exacerbates the variability of power-demand.

During active phases vigorous convection across India and the associated precipitation acts to reduce the surface temperature, conversely during break phases suppressed convection results in higher temperatures (see Fig 2). Higher temperatures result in higher numbers of cooling degrees days, a proxy for cooling energy demand based on the deviation of the daily mean temperature above a certain threshold. Thus during break phases the demand for cooling energy is elevated, with the demand reduced during active phases.

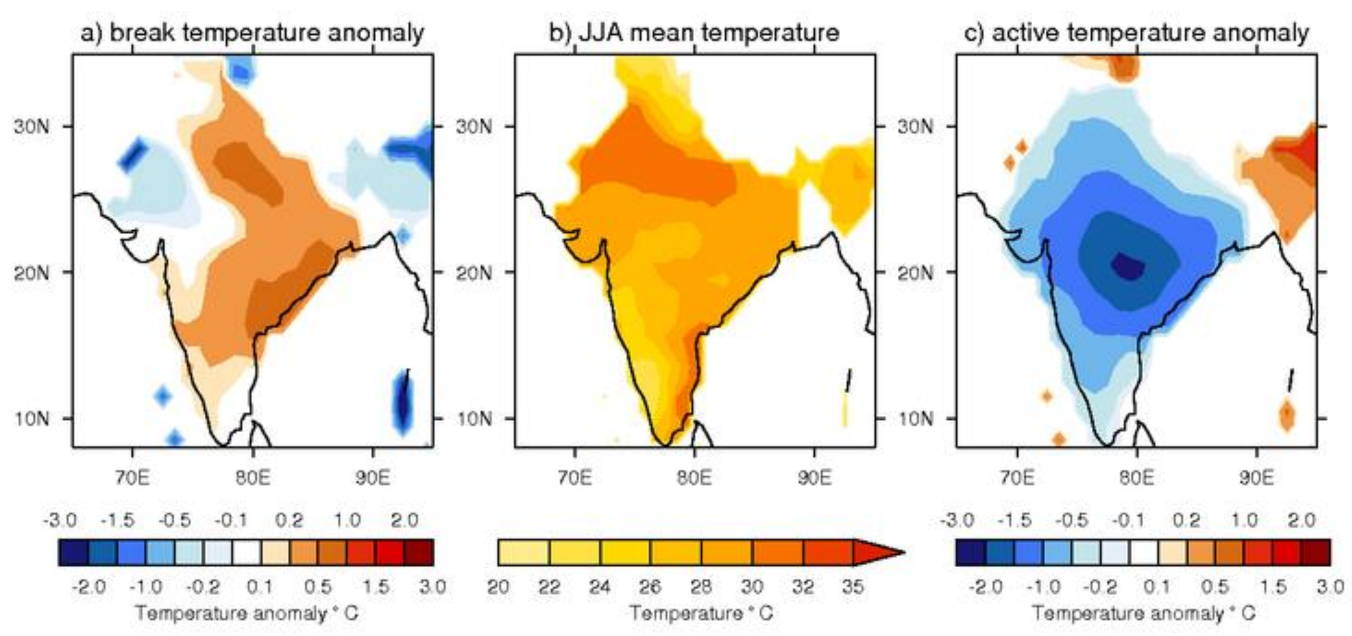

Fig 2: Surface mean temperature during JJA (b) and anomalies during active (c) and break (a) phases.

Wind power electricity generation

Active and break phases lead to significant changes in the near-surface wind patterns. For much of India, active phases tend to have anomalously strong wind-power resources whereas in break phases there is less wind-power. Monsoon variability thus exacerbates the variability of wind-power generation.

The South Asian monsoon brings strong westerly winds across the Bay of Bengal, the north Arabian Sea, and across much of India (as seen in Fig 3b). During active phases vigorous convection across India brings stronger winds (as seen in Fig 3c), whereas reduced convection during break phases results in weaker winds (as seen in Fig 3a). During break phases, the monsoon trough moves north, resulting in the increase in wind speeds observed over northern India.

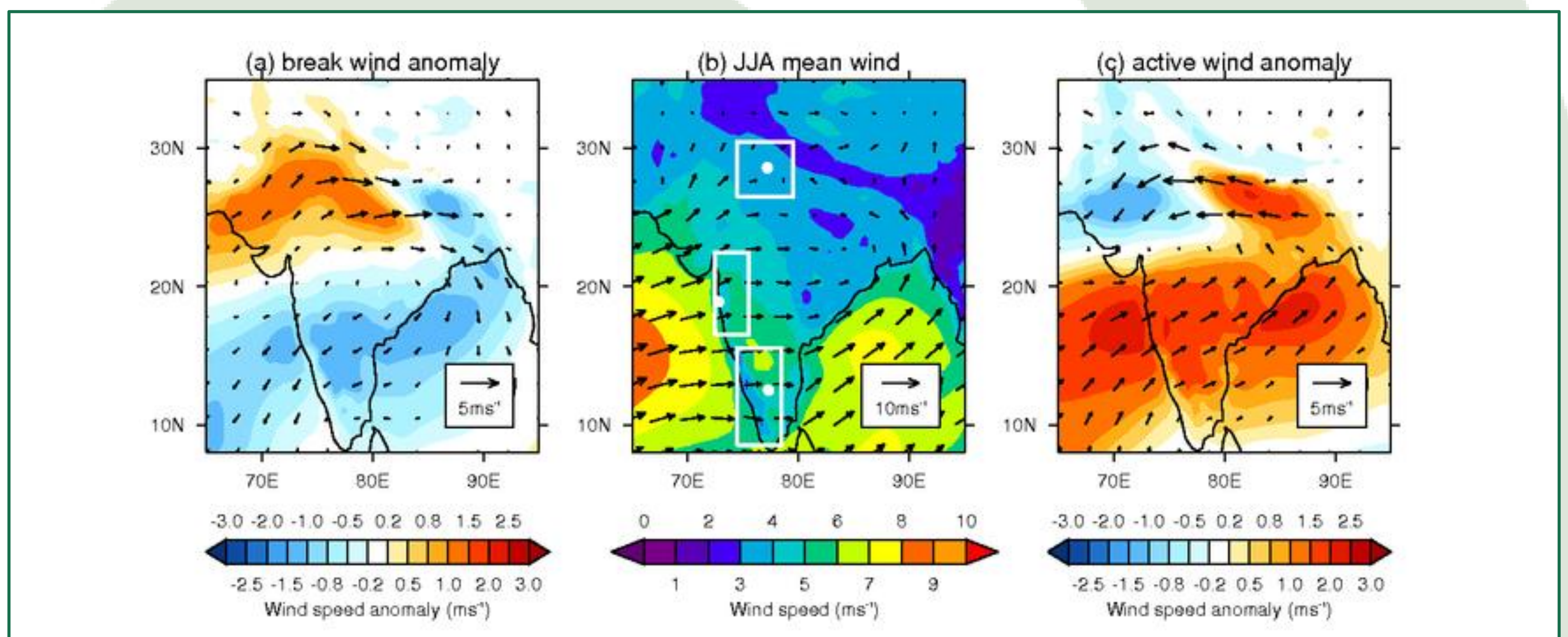

Fig 3: 50m wind speed and direction during JJA (b) and anomaly during break (a) and active (c).

A physically-based wind turbine model was used to convert the high-frequency wind-speed data (in m/s) into wind-power (MW). This was then time-averaged and normalised by the theoretical maximum turbine output to produce the so-called 'wind-power capacity factor' as shown in Fig 4. Despite the non-linear transformation from wind power to capacity factor, the same patterns are seen; wind-power capacity factor is higher over peninsular India and the surrounding oceans during active phases and lower during break phases. Part of the north Arabian Sea that experiences higher wind power during breaks.

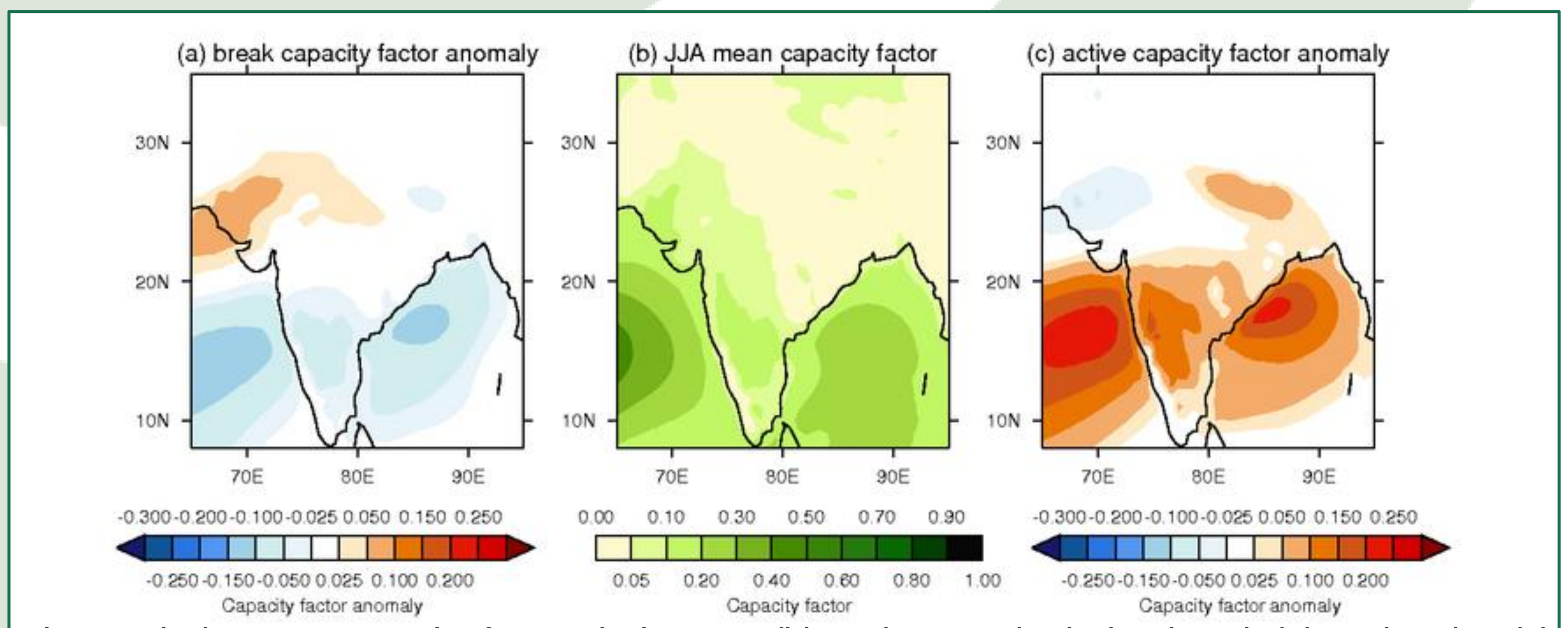

Fig 4: Wind power capacity factor during JJA (b) and anomaly during break (a) and active (c).

Consequences for Indian Power Systems

Intraseasonal monsoon variability (active/break phases) therefore tends to exacerbate fluctuations in demand-net-wind (i.e., the amount of power demanded from non-wind sources). This has potentially profound implications for investment, planning and operation of the power system.

Break phases, which are characterised by suppressed precipitation due to the movement of the main convection centres, result in higher temperatures and higher cooling demand coincident with lower wind power output across much of India. Hence during break phases a significant amount of generation by schedulable plants is likely to be necessary. This plant may be required much less often during active phases when convection over India brings lower temperatures and strong winds hence high wind power output and reduced demand for cooling energy. This additional weather-related volatility for schedulable generation plants may have consequences for the planning of future power plants.