Indian summer monsoon*

Will the onset of the Indian summer monsoon change due to increased concentration of anthropogenic aerosols? What should be an ideal definition of the onset of monsoon? How will the onset of the Indian monsoon change in the future? These were some of the key questions that were discussed in a workshop held recently.

In the inaugural lecture, P. V. Joseph (Cochin University of Science and Technology) discussed variations in the onset of monsoon over Kerala in the atmosphere and oceans. He showed how moisture content of the atmosphere has to build up to 40 kg/m^2 before the onset of monsoon. He also showed how the date of pre-monsoon rain peak over Kerala can be used to forecast the date of monsoon onset in that state. He argued that the long-term variations of onset date over Kerala are associated with the north–south gradient of sea surface temperature (SST) in the Pacific and Indian Oceans.

The significance of thermodynamic pre-conditioning of the atmosphere for onset of summer monsoon was highlighted by Arindam Chakraborty (Indian Institute of Science (IISc), Bengaluru). He showed through numerical simulations that onset occurs only after moist static energy of the lower troposphere crosses a certain threshold. Using the past seven decades of observations, he argued that higher than normal pressure over western Asia during April–May delays the onset of monsoon over central India. This is because of the decrease in low-level winds and moisture transport that essentially decreases surface moist static energy. Based on this theory, a model for real-time prediction of the onset of summer monsoon over Kerala was constructed that predicted correctly the 7-day delay in the onset of monsoon in 2019.

V. Krishnamurthy (George Mason University, USA) depicted the results from coupled model simulations to forecast the onset of Indian summer monsoon. He used two models: one with 54 km and another with 16 km resolution for the atmosphere. Although the climatology and annual cycle of rainfall in the models were reasonably good, both predicted earlier than observed onset of monsoon over Kerala. SST was found to be warmer in the models before the onset. The key conclusion made from this study was that the higher resolution model (16 km) did not show improvement over the lower resolution model (54 km).

The local onset and demise (withdrawal) dates of monsoon were presented by Vasu Misra (Florida State University, USA). He showed that knowledge of climatological daily time series of rainfall and daily evolution of rainfall for a particular year, will help construct the onset and demise dates of monsoon locally. This method also helps to construct maps of progress of onset isochrones during the early phase of summer monsoon. Interannual variations of the local onset dates were then explained through two known modes of intraseasonal oscillations of monsoon: the low-frequency and high-frequency intraseasonal oscillations.

R. S. Ajayamohan (New York University, Abu Dhabi, UAE) showed that synoptic-scale disturbances which are generated mostly over the Bay of Bengal are changing their seasonal characteristics. He showed that in future climate scenario simulated by coupled climate models, the onset of monsoon is delayed due to weakening of vertical shear of zonal wind.

At present there are several criteria used to define onset of the Indian summer monsoon. Subimal Ghosh (Indian Institute of Technology (IIT)-Bombay, Mumbai) showed that many of those criteria are well correlated to each other and thus can be used interchangeably. Using observations, he showed that during the late 1970s, the onset of summer monsoon over Kerala went through an abrupt delay due to changes in SST of the Pacific Ocean.

Raghu Murtugudde (University of Maryland, USA) illustrated the different roles played by the western and eastern equatorial Indian Ocean in the onset of the summer monsoon over Kerala. He showed that air–sea interaction along the equator and over the Bay of Bengal plays a crucial role during the onset of monsoon. He hypothesized that some of the interannual variations of onset dates could be related to the phase of monsoon intraseasonal oscillation.

Performance of a dynamical model in predicting the onset of monsoon was illustrated by A. K. Sahai (Indian Institute of Tropical Meteorology (IITM), Pune). He showed that date of onset defined using dynamic criteria is more or less similar in different reanalysis datasets. The extended range prediction model currently used by the India Meteorological Department (IMD) captures the changes in onset dates reasonably well.

P. Mukhopadhyay (IITM, Pune) described the fidelity of the high-resolution (12 km) Global Forecast System model in predicting the onset of summer monsoon. He showed that this model captured the observed antecedents of onset of summer monsoon during 2019, including the cyclonic vortex in the Arabian Sea during the first week of June.

D. S. Pai (IMD, Pune) described in detail the methodology used to forecast the onset of monsoon over Kerala. He showed that the root mean square error of this statistical model used for real-time forecast of onset was about four days this is less than the interannual standard deviation of onset dates, which is about seven days.

The second day of the workshop started with a presentation by Dilip Ganguly (IIT Delhi). He used climate model simulations to quantify the role of greenhouse gases (GHGs) and aerosols in altering the onset of Indian summer monsoon. He showed that while GHG forcing does not have any significant impact on the onset over central India, anthropogenic aerosols delay the onset by a few days. A combination of GHGs and

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anthropogenic aerosols delays the onset further.

Pankaj Kumar (Indian Institute of Science Education and Research, Bhopal) presented his research on understanding thermodynamic features of the onset of monsoon in a regional coupled model. Based on the thermodynamic criteria used, the model could capture the observed earlier onset of monsoon after 2000 compared to the previous two decades.

The observed relationship between monsoon rainfall over the equatorial Indian Ocean and that over the Indian land was illustrated by Sulochana Gadgil (IISc). She showed that a combined index based on convection over the equatorial Pacific Ocean and that over the equatorial Indian Ocean could explain a large amount of interannual variations of Indian summer monsoon. She further illustrated the link between convection over the northwest Pacific Ocean and the Indian region in June.

P. A. Francis (India National Centre for Ocean Information Services, Hyderabad) discussed the role of western equatorial Indian Ocean during the onset phase of monsoon. He showed how air–sea coupling can be important in determining rainfall and the progress of onset.

Charu Singh (Indian Institute of Remote Sensing, Dehradun) presented the role of remote dust aerosols during early phase of Indian summer monsoon. When there were no dust aerosols in the numerical simulations, the onset of monsoon over central India was delayed.

The skill of the coupled model used by the National Centre for Medium Range Weather Forecasting (NCMRWF) was described by D. Rajan (NCMRWF, Noida). He showed that this model could forecast accurately the climatological date of onset of monsoon over the Bay of Bengal, Kerala and northwestern parts of India.

The concluding session debated whether the onset of monsoon should be defined primarily based on rainfall, or should we redefine it considering changes in large-scale thermodynamic and dynamic parameters. Participants also debated on advantages and disadvantages of probabilistic definition of onset dates. The workshop ended with a note that stronger collaboration between various academic and research institutions is necessary for advancement of our understanding of the onset of Indian summer monsoon.

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