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INCOMPASS SPECIAL COLLECTION

Preface to the INCOMPASS Special Collection

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The South Asian summer monsoon provides 80% of annual precipitation to over a billion people. Among other users of water resources, the monsoon is particularly important for agriculture and power generation, itself in support of food security and employment. Accurate prediction of the amount and timing of monsoon rainfall is vital to society across many time-scales, from daily weather forecasting up to multi-decadal changes in the mean state. While much research continues into monsoon modelling and prediction, large model biases prevail. A key opportunity lies in better measurement and understanding of processes operating at small space and time scales, particularly interactions between the surface, boundary layer and cloud dynamics which profoundly influence monsoon convection. These processes are often parametrized in models.

It is against this background that the Earth System Science Organization (ESSO) of the Ministry of Earth Sciences (MoES), Govt. India, in collaboration with the Natural Environment Research Council (NERC), United Kingdom, funded the *Drivers of variability in the South Asian monsoon* programme. For NERC, this was part of a larger NERC action on "Drivers of variability in atmospheric circulation", while for ESSO-MoES, this activity fell under its Monsoon Mission to improve prediction of the monsoon on short-range to interannual time-scales.

This funding avenue provided the unique opportunity for the Indo-UK scientific community to collaborate on a joint observational mission to India (described in Turner *et al.*, 2020), including the first deployment of a foreign atmospheric research aircraft to the country. The INCOMPASS aircraft mission, from bases in Lucknow and Bengaluru, took place between May and July 2016 using the Facility for Airborne Atmospheric Measurements (FAAM) BAe-146 aircraft, run jointly by NERC and the Met Office. This is a four-engine jet aircraft, capable of carrying a large suite of instruments and up to 19 scientists on missions lasting up to 5 hours. Use of the aircraft was shared with the sister project SWAAMI (South West Asian Aerosol–Monsoon Interactions: see, for example, Brooks *et al.*, 2019).

As described in the lead article of this Special Collection (Turner *et al.*, 2020), the INCOMPASS field campaign is designed to better understand how an air parcel is modified as it travels towards India, crossing coastlines, mountains and a variety of land surface types and soil moisture patterns. Work motivated by INCOMPASS and published in this Special Collection has already suggested a new paradigm for the monsoon onset (Parker *et al.*, 2016), as a tug-of-war between advancing tropical flow and a retreating dry intrusion emanating northwest of India. The erosion of this dry intrusion has been shown in modelling work to be aided by the detrainment of moisture from shallow convection (Menon *et al.*, 2018), while the role of the extratropics has been further highlighted (Volonté *et al.*, 2020), showing that monsoon progression is a jerky process.

While other monsoon processes such as ocean–atmosphere interaction have been heavily studied in the past, the role of the land surface is often overlooked. In particular, how the land surface feeds back on the progression of the monsoon through its seasonal cycle, or during monsoon variability, is ripe for study since there is a distinct lack of observations particularly related to the land surface and its role in driving convection over India. For this reason, INCOMPASS set out to plug the gap by installing a series of flux towers across the country (early results described in Bhat *et al.*, 2020). By bringing together their outputs (e.g. latent-heat flux) with traditional meteorological instrumentation, profiles and transects of the atmosphere overhead taken from the flight missions, INCOMPASS aims to interrogate the land–atmosphere interactions during monsoon convection.

This INCOMPASS Special Collection covers the first observational and modelling results of INCOMPASS. The process understanding developed through this work and ongoing analysis of the INCOMPASS observations will highlight the need for improved parametrizations to be developed and more observations to be assimilated in forecast models. Other work published so far in the Special Collection includes a description of the modelling and forecast tools employed in guiding the flight missions (Martin *et al.*, 2020) and an evaluation of convective-scale model performance in comparison to flight observations (Jayakumar *et al.*, 2020). There is a proof-of-concept of the importance of mesoscale soil moisture gradients over northern India in initiating convection, based on flight observations and modelling (Barton *et al.*, 2020), and the new identification of distinct regimes of onshore and offshore convection around the Western Ghats, based on flight and flux-tower measurements (Fletcher *et al.*, 2020) which could lead to new insights in forecasting.

As reported in Turner *et al.* (2020), INCOMPASS has highlighted the need to fully characterize the convective life cycle over India and how it changes under different conditions, whether by meteorological forcing at the large scale or by underlying surface conditions. Given the findings of strong land–atmosphere coupling in action during the monsoon, INCOMPASS has led new hypotheses to be tested on how irrigation affects the progression of the monsoon and its day-to-day variability. The INCOMPASS field campaign observations will serve as a starting point that, in combination with further observations and long-term data from remote-sensing and reanalysis products, will enable progress to be made in parametrization development and improving model biases.

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