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Systematic errors in the simulation of the Asian summer monsoon: the role of rainfall variability on a range of time and space scales

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Despite considerable efforts worldwide to improve model simulations of the Asian summer monsoon, significant biases still remain in climatological seasonal mean rainfall distribution, timing of the onset, and northward and eastward extent of the monsoon domain (Sperber et al., 2013). Many modelling studies have shown sensitivity to convection and boundary layer parameterization, cloud microphysics and land surface properties, as well as model resolution. Here we examine the problems in representing short-timescale rainfall variability (related to convection parameterization), problems in representing synoptic-scale systems such as monsoon depressions (related to model resolution), and the relationship of each of these with longer-term systematic biases.

Analysis of the spatial distribution of rainfall intensity on a range of timescales ranging from ~30 minutes to daily, in the MetUM and in observations (where available), highlights how rainfall biases in the South Asian monsoon region on different timescales in different regions can be achieved in models through a combination of the incorrect frequency and/or intensity of rainfall. Over the Indian land area, the typical dry bias is related to sub-daily rainfall events being too infrequent, despite being too intense when they occur. In contrast, the wet bias regions over the equatorial Indian Ocean are mainly related to too frequent occurrence of lower-than-observed 3-hourly rainfall accumulations which result in too frequent occurrence of higher-than-observed daily rainfall accumulations. This analysis sheds light on the model deficiencies behind the climatological seasonal mean rainfall biases that many models exhibit in this region. Changing physical parameterizations alters this behaviour, with associated adjustments in the climatological rainfall distribution, although the latter is not always improved (Bush et al., 2014). This suggests a more complex interaction between the diabatic heating and the large-scale circulation than is indicated by the intensity and frequency of rainfall alone.

Monsoon depressions and low pressure systems are important contributors to monsoon rainfall over central and northern India, areas where MetUM climate simulations typically show deficient monsoon rainfall. Analysis of MetUM climate simulations at resolutions ranging from N96 (~135km) to N512 (~25km) suggests that at lower resolution the numbers and intensities of monsoon depressions and low pressure systems and their associated rainfall are very low compared with re-analyses/observations. We show that there are substantial increases with horizontal resolution, but resolution is not the only factor. Idealised simulations, either using nudged atmospheric winds or initialised coupled hindcasts, which improve (strengthen) the mean state monsoon and cyclonic circulation over the Indian peninsula, also result in a substantial increase in monsoon depressions and associated rainfall. This suggests that a more realistic representation of monsoon depressions is possible even at lower resolution if the larger-scale systematic error pattern in the monsoon is improved.