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An idealised model of the Indian monsoon onset

Lucy Recchia[1], **Stephen Griffiths**[1], and Douglas Parker[2]
[1]School of Mathematics, University of Leeds, Leeds, UK (l.g.recchia1@leeds.ac.uk)
[2]School of Earth and Environment, University of Leeds, Leeds, UK

The Indian monsoon is a seasonal large-scale circulation system with complex dynamical and thermodynamical interactions, the physics of which is not fully understood. In particular, the advance of the monsoon over India, propagating against the mean mid-level wind field, cannot be explained by simple moisture flux arguments.

Here we introduce an idealised two-layer model of the moisture dynamics of monsoon onset, with simple and transparent physics, based on conservation laws applied to a vertical plane (which could represent a transect from northwest to southeast India). The model allows for moisture replenishment in the lower layer (corresponding to evaporation or a moist inflow), a flux of water vapour between the layers (corresponding to convection), and along-transect advection by prescribed upper and lower-layer flows. With idealised parameterisations of replenishment and convection, the model can be written as a pair of coupled partial differential equations, which permits both analytical and numerical solutions. When an equilibrium solution is perturbed by either a change in replenishment rate, convection strength, or winds, we observe the propagation of moisture fronts in both the upper and lower layers as the solution adjusts to a new equilibrium. When these moisture fronts propagate northwestwards against the upper-layer flow, they can be viewed as the monsoon onset. Taking advantage of the simplicity of the model, which allows a wide parameter regime to be investigated efficiently, we show how the onset speed depends on the assumed timescales of the parameterised convection and lower-layer replenishment, and that physically plausible parameterisations can lead to realistic onset speeds, even in this highly idealised model.