An idealised model of of the Indian monsoon onset

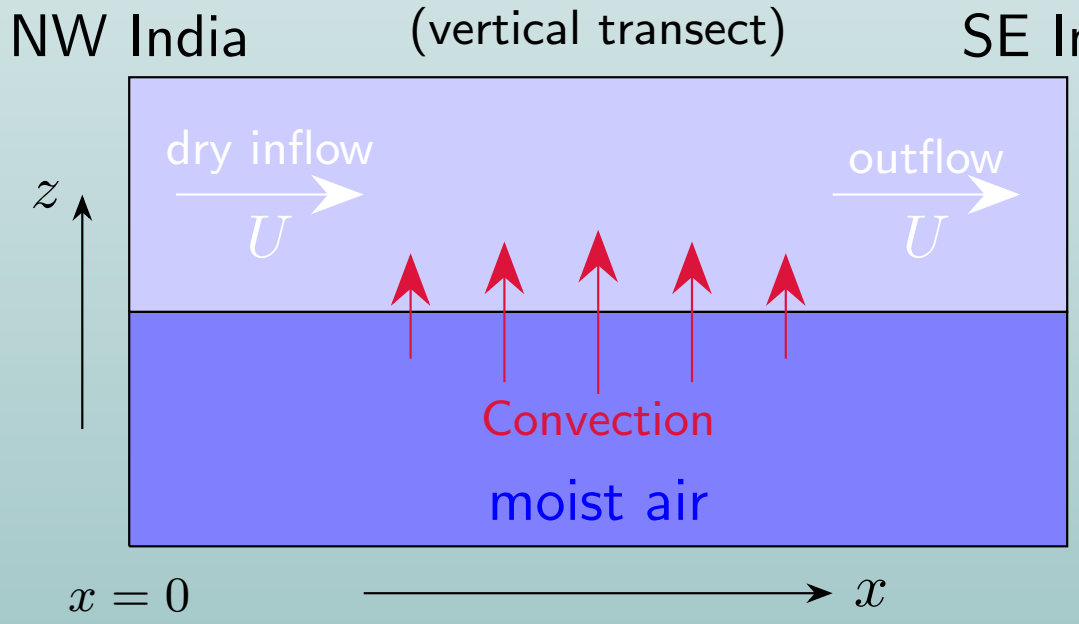
Lucy Recchia[1], Stephen Griffiths[1], Doug Parker[2]

[1] School of Mathematics, University of Leeds

[2] School of Earth and Environment, University of Leeds

L.G.Recchia1@leeds.ac.uk

A simplified model of moisture transport



Upper-level water $q_2(x,t)$ (column-integrated):

$$\frac{\partial q_2}{\partial t} + U\frac{\partial q_2}{\partial x} = +F$$

Lower-level water $q_1(x,t)$ (column-integrated):

$$\frac{\partial q_1}{\partial t} = -F + R.$$

- Convective flux $F = \frac{q_1 - q_2}{T_c}$: mixes q_1 and q_2 on timescale T_c.
- Replenishment (evaporation, moist inflow) $R = -\frac{q_1 - q_*(x)}{T_r}$ adjusts $q_1(x,t)$ towards $q_*(x)$ on timescale T_r . Here take $q_*(x) = 0$ (dry) for $x < 0$ and $q_*(x) = 1$ for $x > 0$, i.e., no imposed lengthscale.
- Yields linear PDEs in (x,t), with $q_2(x,0) = 0$ (dry inflow).

Monsoon onset as a transition

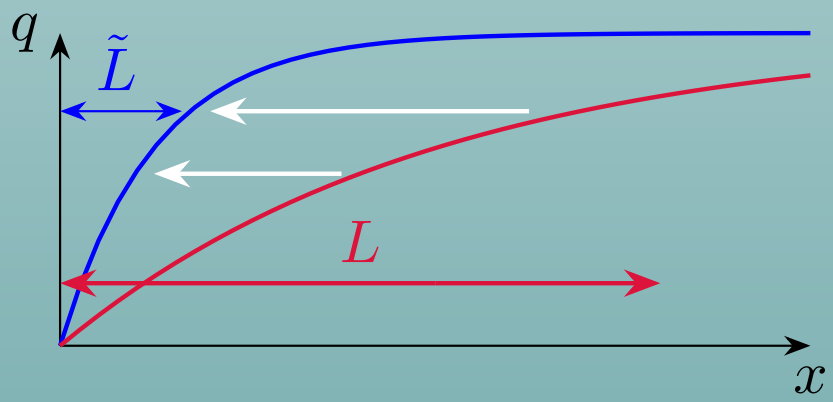
There is a steady state solution in terms of $L = U(T_c + T_r)$:

$$q_1(x) = 1 - \frac{T_r}{T_c + T_r} \exp(-x/L), \quad q_2(x) = 1 - \exp(-x/L).$$

We call L the monsoon lengthscale: it is the distance over which the flow transitions from dry (in the NW) to moist (in the SE). For example, $U = 10\,\mathrm{m\,s^{-1}}$, $T_c = T_r = 1\,\mathrm{day} \implies L = 1700\,\mathrm{km}$.

Weakening upper-level flow (reducing $U > 0$), increasing convection (reducing T_c), or increasing low-level replenishment (reducing T_r) implies a new equilibrium with smaller $L = \tilde{L}$.

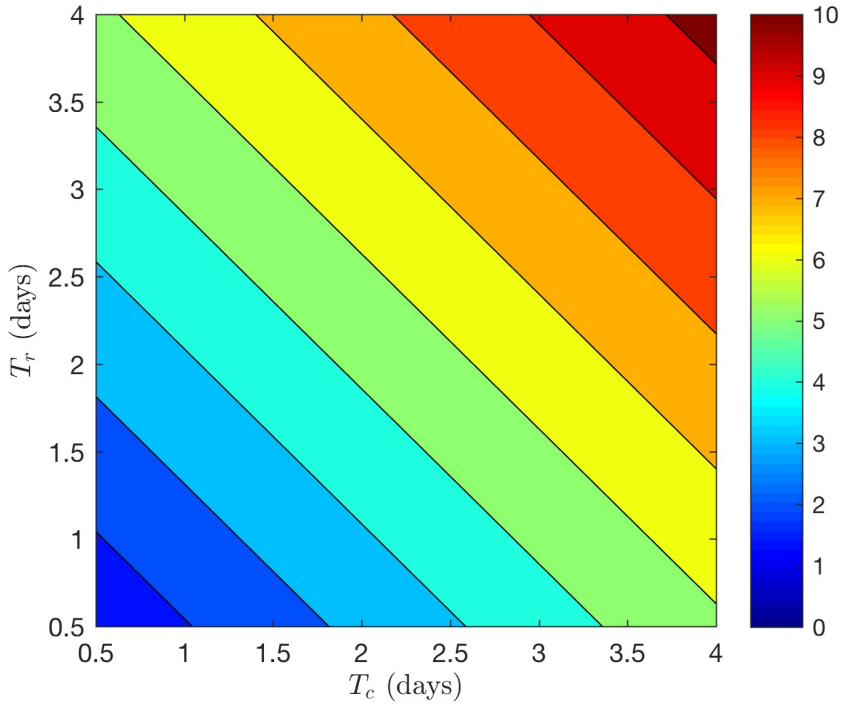
Solution transitions to a new equilibrium. Moisture front moves left (NW) against the upper-level flow. This can be viewed as the monsoon onset.



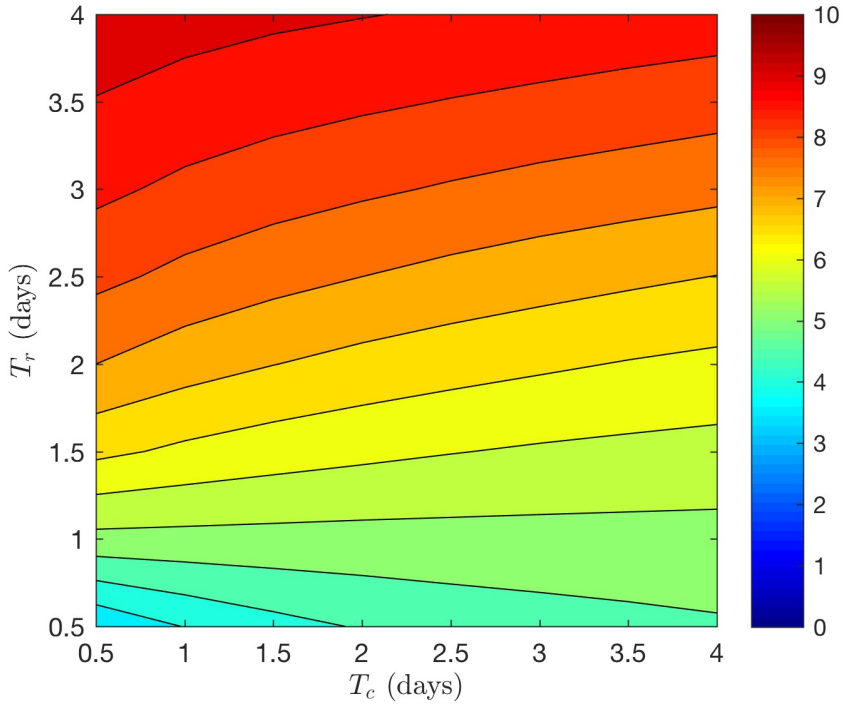
Monsoon advance and timescales

Sample numerical experiments: U changing from $10 \to 5\,\mathrm{m\,s^{-1}}$, and T_c and T_r each halving. So $L \to \tilde{L} = L/4$.

Advance: $L - \tilde{L}$ ($\times 10^3$ km)



Adjustment time (days)



At small T_c and larger T_r, find monsoon advances over $\approx 3000\,\mathrm{km}$ that take in excess of a week, similar to those on W coast of India.