Moisture Transport in Baroclinic Waves

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Motivation & Aims

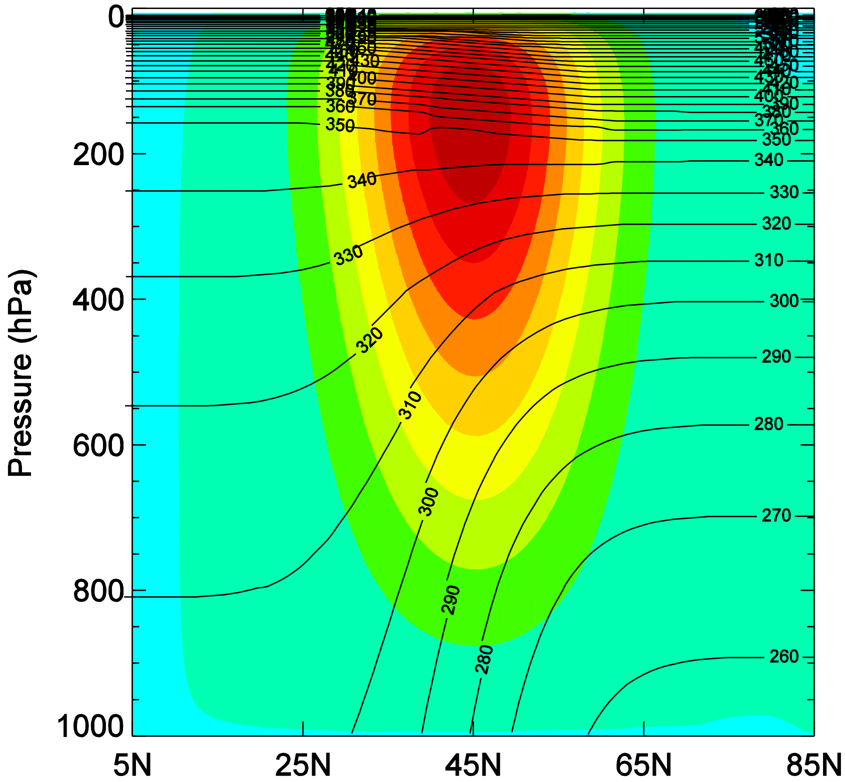
- Boundary layer couples the surface to the free troposphere – how does it link surface moisture fluxes to mid-level moisture?
- Cyclones bring heavy rain on their warm-conveyor belts – what is the source of this moisture?
- Cyclone waves are responsible for transporting moisture poleward on climatological timescales – how is this transport achieved at the scale of individual systems?

Model Setup

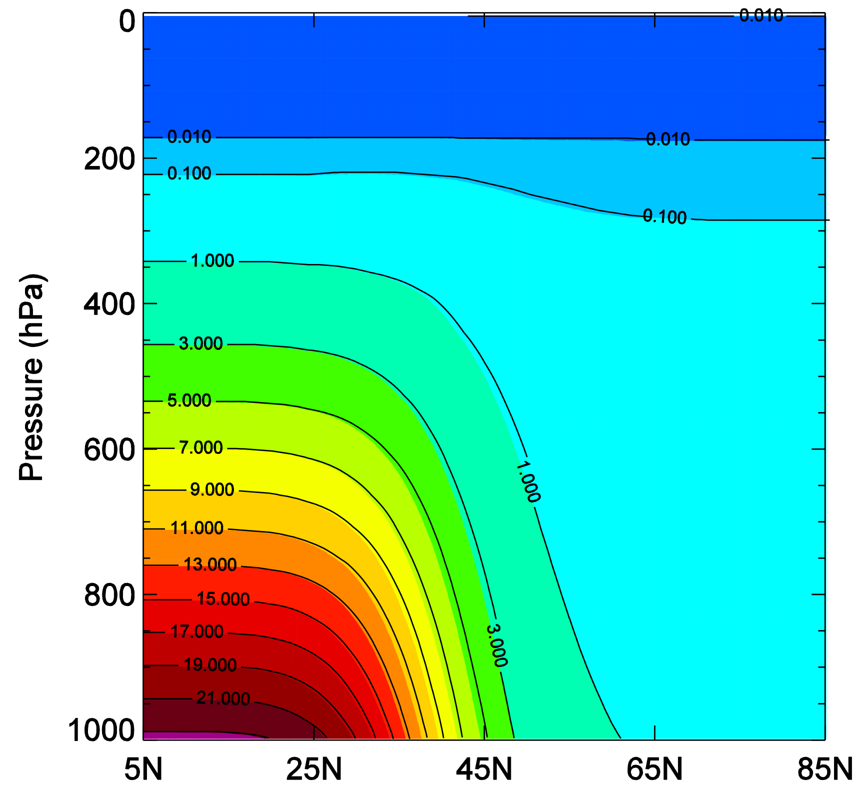
- Met Office Unified Model (MetUM) is used in Idealised mode
- 0.4° horizontal resolution (~44 km grid squares)
- 38 vertical levels with a well resolved boundary layer
- Boundary-layer scheme of Lock et al. with nonlocal mixing in CBL & cumulus/stratocumulus decoupling
- Mass-flux convection, mixed phase microphysics, large-scale cloud
- Sea-surface with fixed temperature

Initial Conditions

Winds and Temperature:

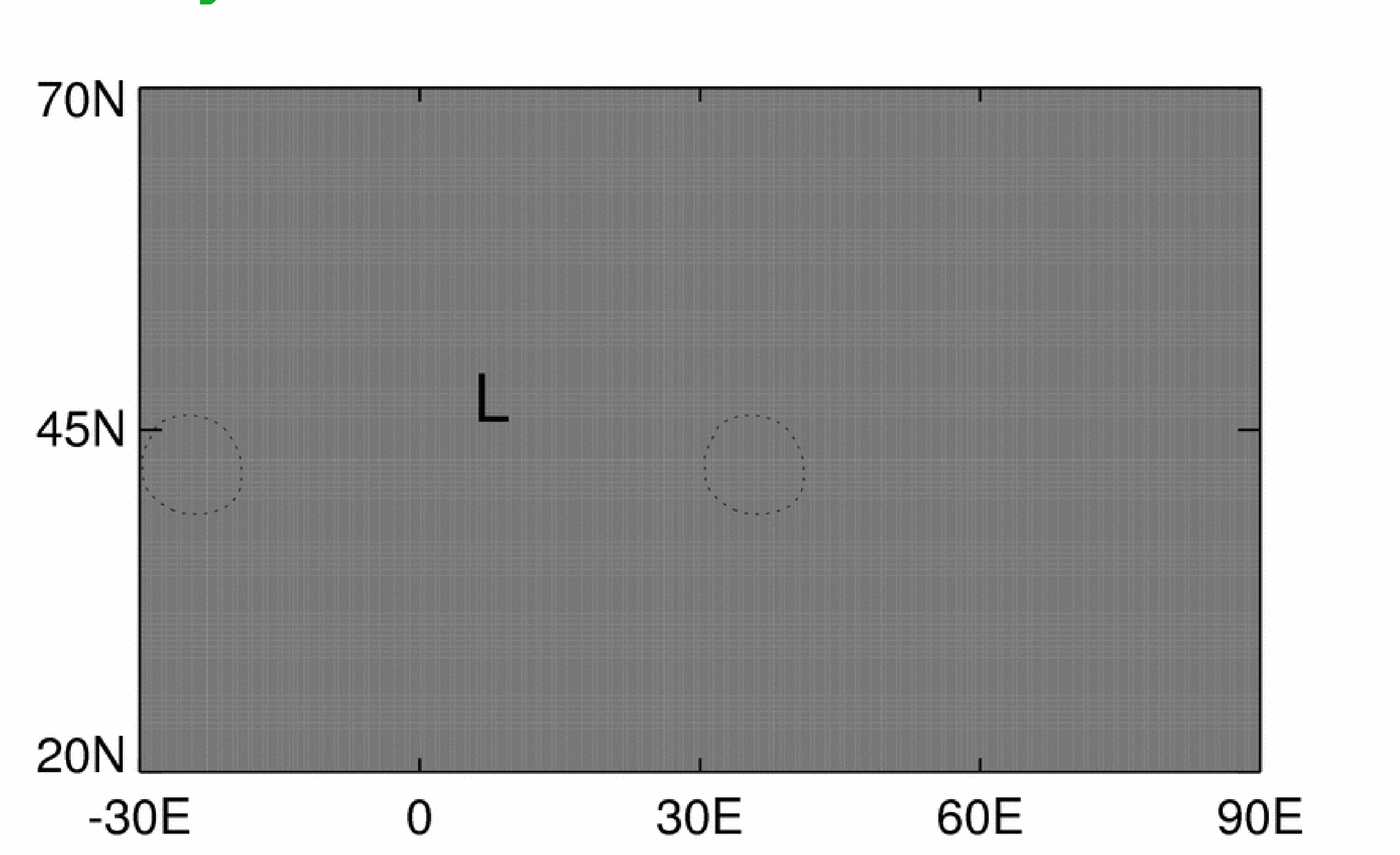


Specific Humidity:



Match closely climatological winter zonal-mean – perturb at wavenumber-6 to create LC1-type cyclone

Life cycle



Cloud Fraction and Rainrate over 14 days of the life cycle

Boundary-Layer Moisture Budget

$$\frac{\partial}{\partial t}\widehat{\rho q} = (\rho q)_h \frac{\partial h}{\partial t} - (\rho q)_h \mathbf{u.n} - \nabla_2 . \widehat{\rho q \mathbf{v}} - (\rho \overline{w'q'})_h + (\rho \overline{w'q'})_0 + \hat{S}$$

- Rate of change of total moisture in boundary layer
- Eulerian change in boundary-layer height
- Advection across boundary-layer top
- Horizontal divergence within the boundary layer
- Net vertical transport by boundary-layer turbulence
- Source and sink from microphysical processes

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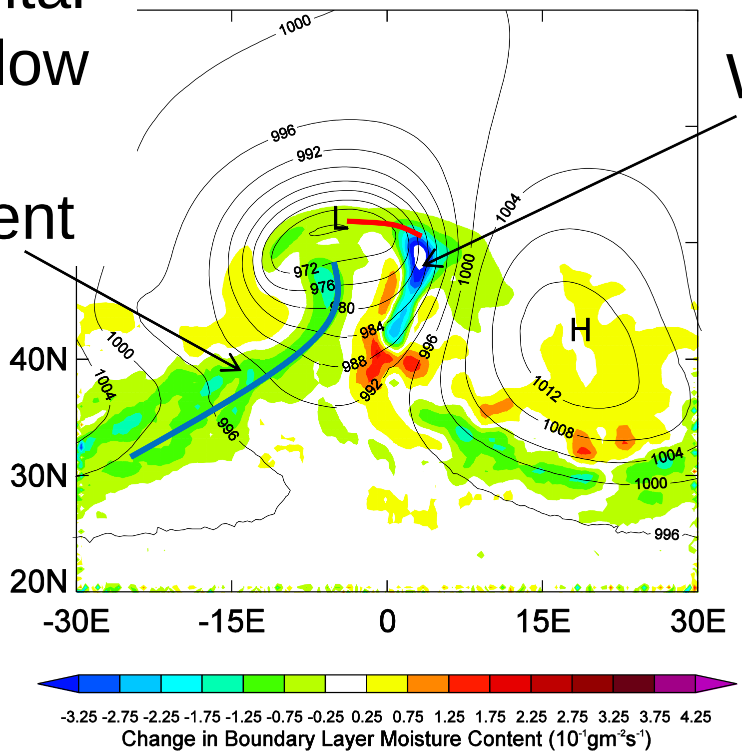
Flow across BL Top

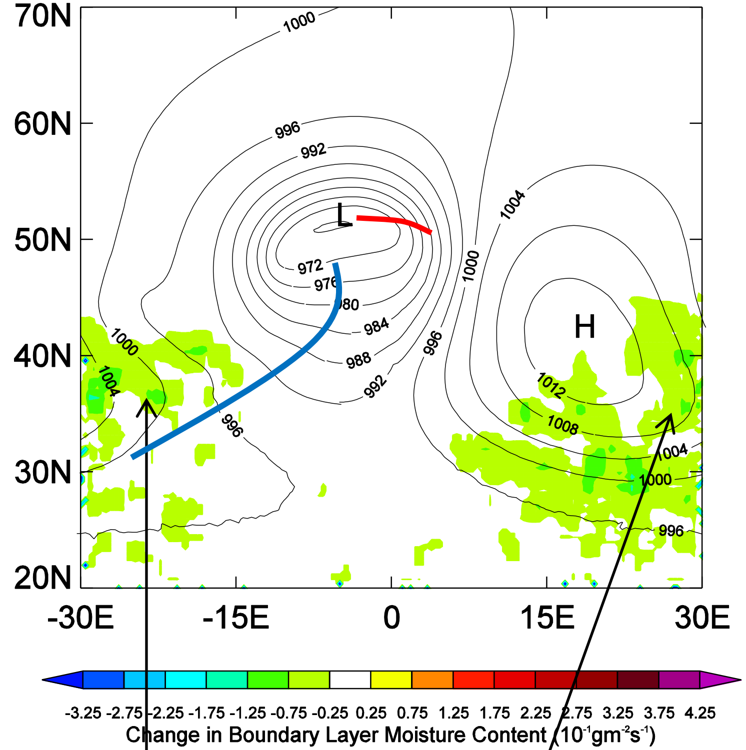
Large scale advection:

Frontal outflow and ascent

WCB



Cumulus Convection:

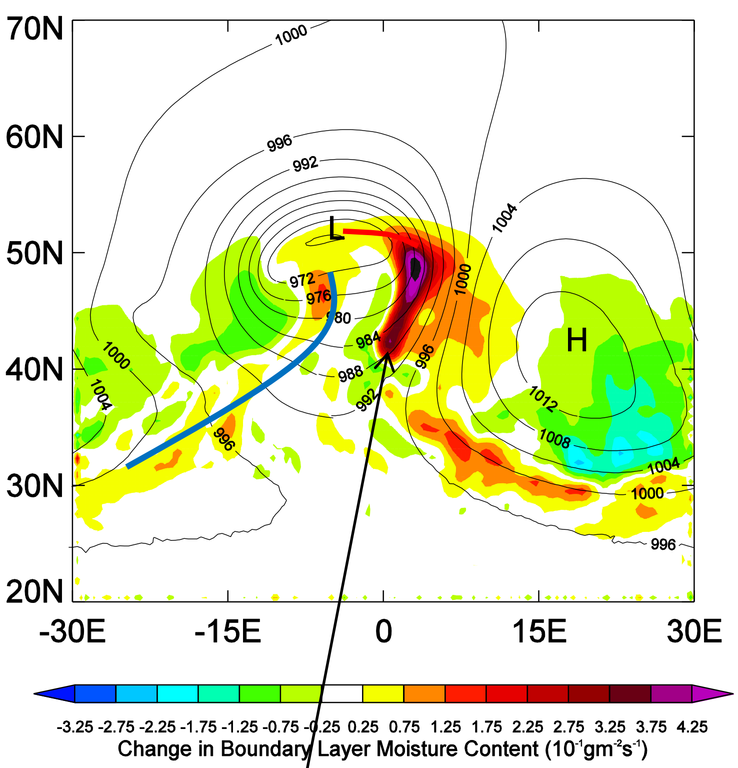


Large amount of ventilation

www.met.rdg.ac.uk/~swr06iab

Movement and sources

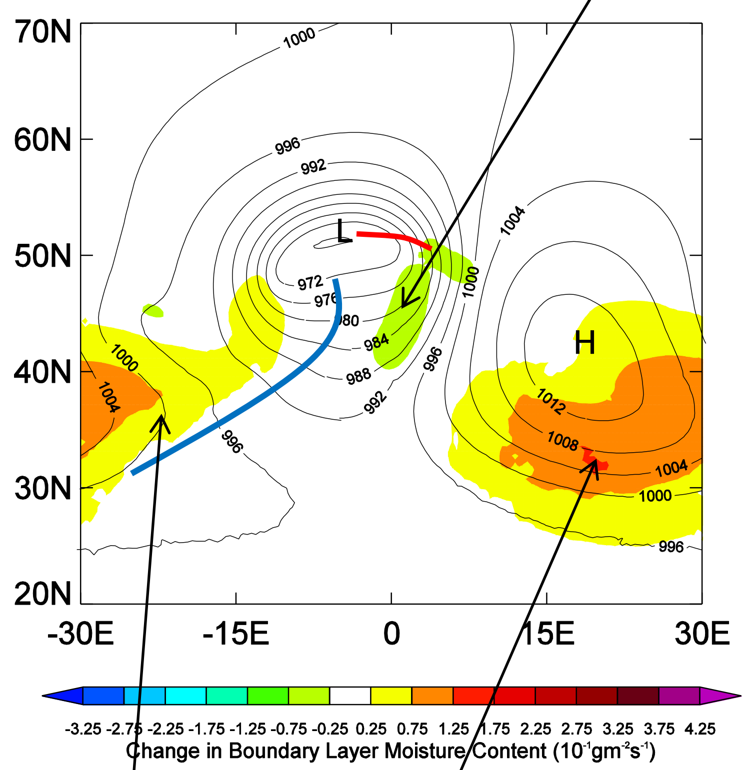
Divergence in BL:



WCB source

Turbulent Flux:

Negative λE



Evaporation is main input

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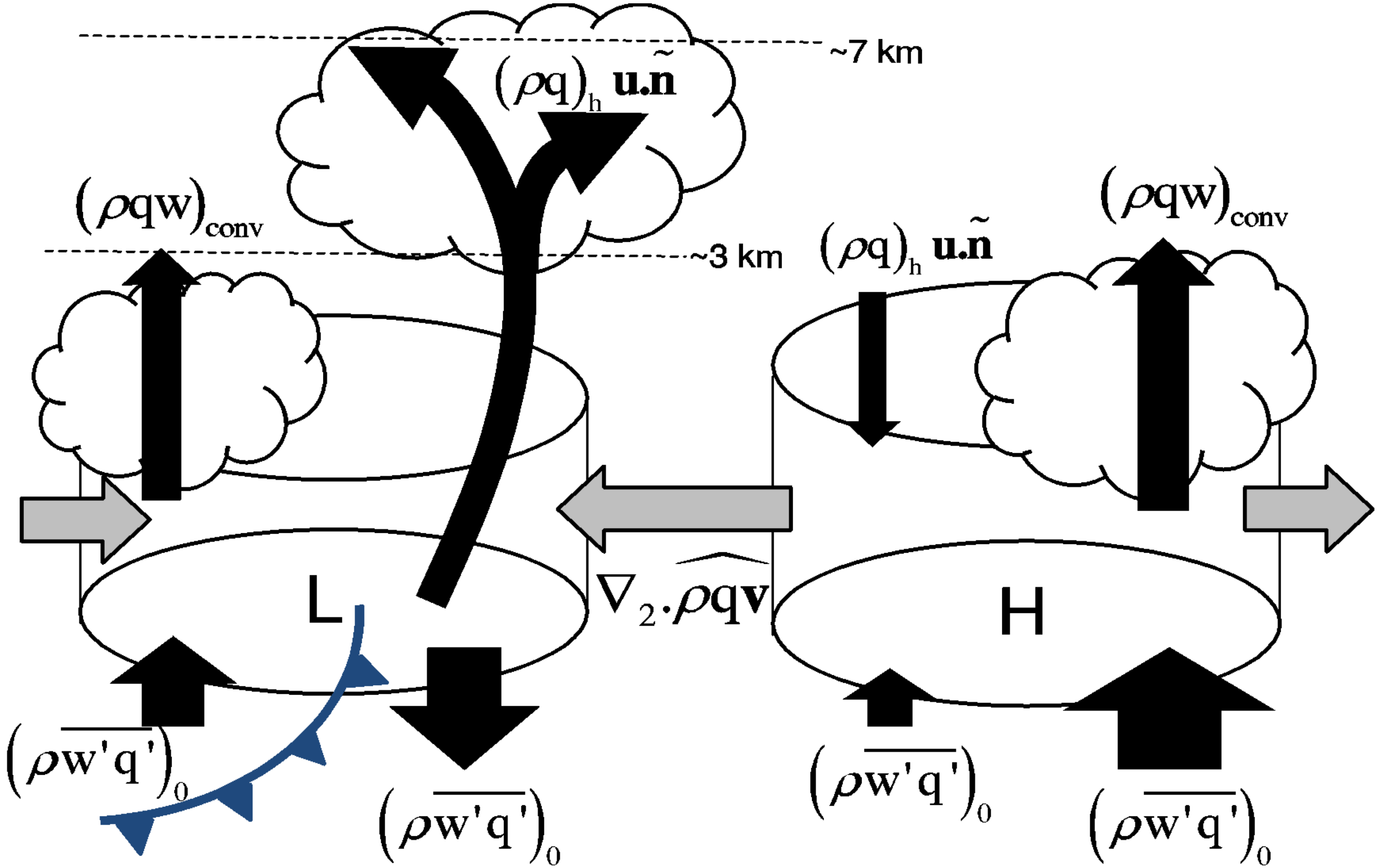
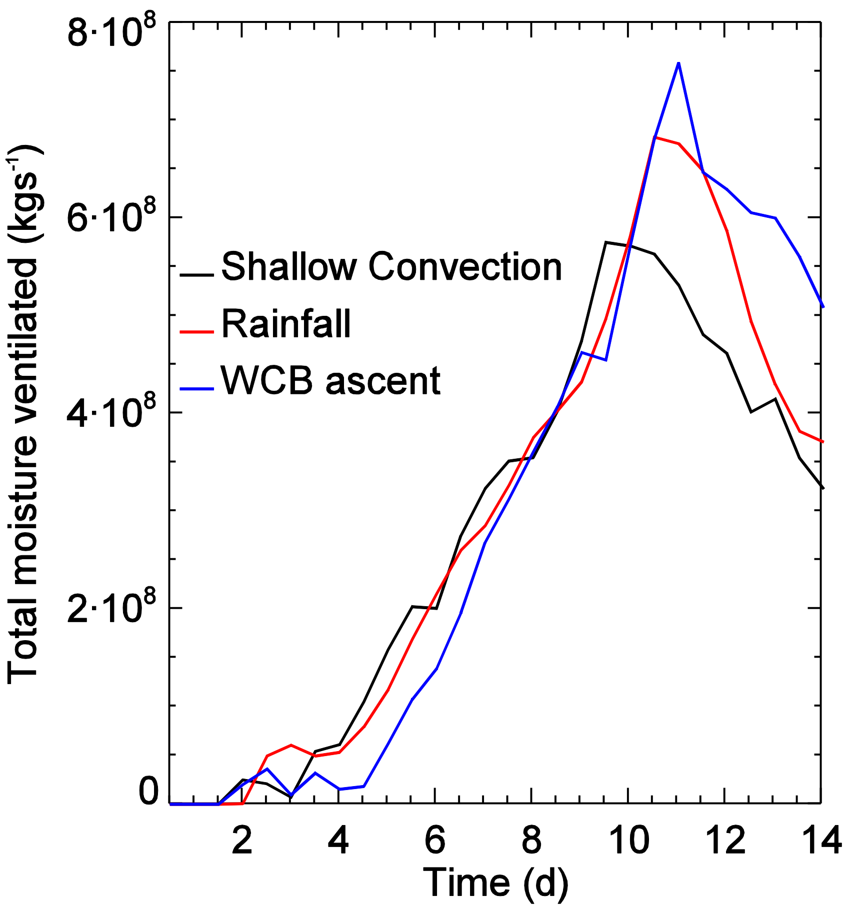
Conceptual Model



Ventilation of Moisture

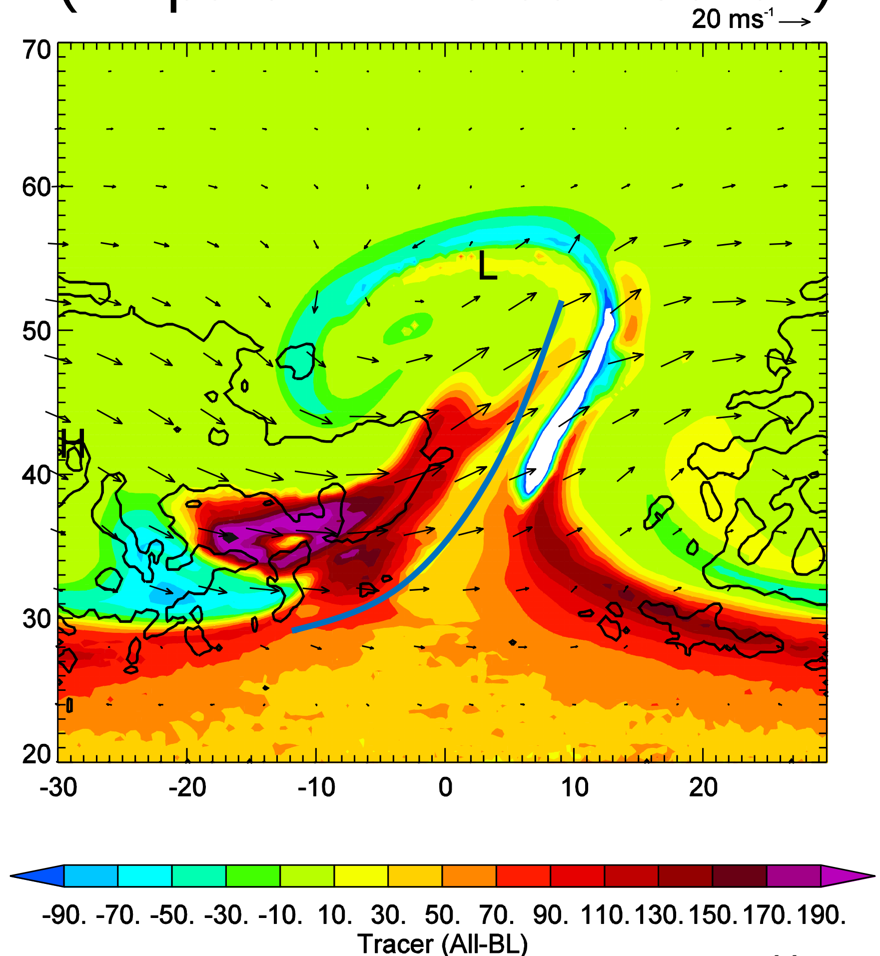
- Warm-conveyor belt and shallow convection can ventilate similar amounts of moisture from the boundary layer
- Rainfall rate closely matches warm-conveyor belt ventilation – moisture is precipitated out quickly and efficiently



Transport in Troposphere

- 2 tracers emitted at surface and passed through different parameterisations.
- Tracer passed through Convection scheme gets advected with background flow towards cyclone cold front and poleward

Tracer difference at 3km – (All param – no convection)



Conclusions

- Moisture source for warm-conveyor belt precipitation lies well away from the cyclone
- Shallow convection adds a new pathway for ventilation and transport from regions with large surface evaporation
- Shallow convection equally important for ventilation and contributes to poleward moisture transport – consequences for climate models since this transport is done in a parameterisation!