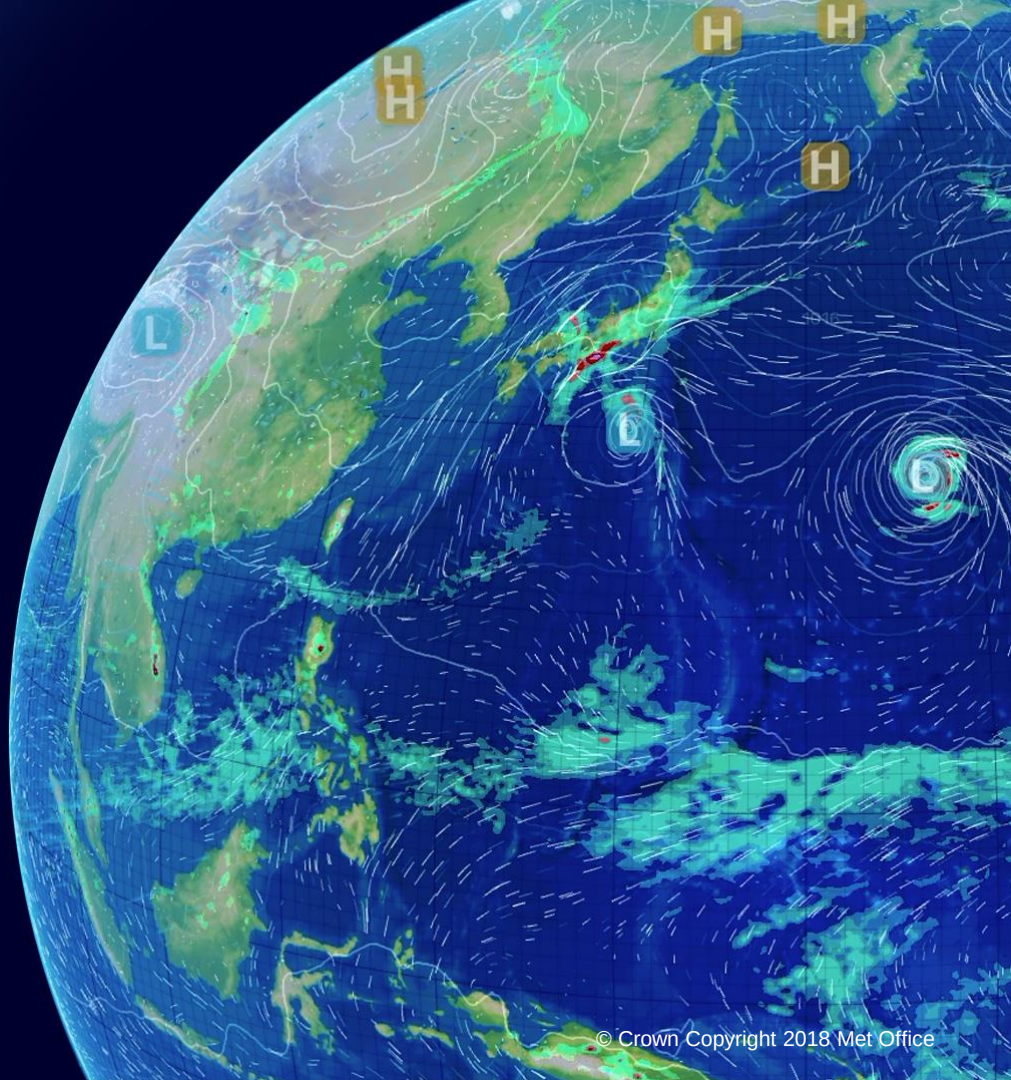
Downdraughts and cold pools



Gabriel Rooney

June 2018

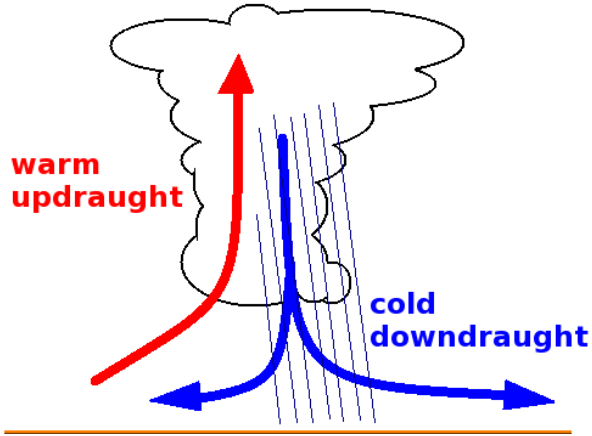
Motivation

Convection parametrisation at mid-range time and space scales may be missing some processes that provide “memory” in the system.

Convective cold pools, forced by downdraughts, are one possible process.

The Unified Model presently has some representation of downdraughts, and also plans to improve this.

A cold-pool scheme is now under development.



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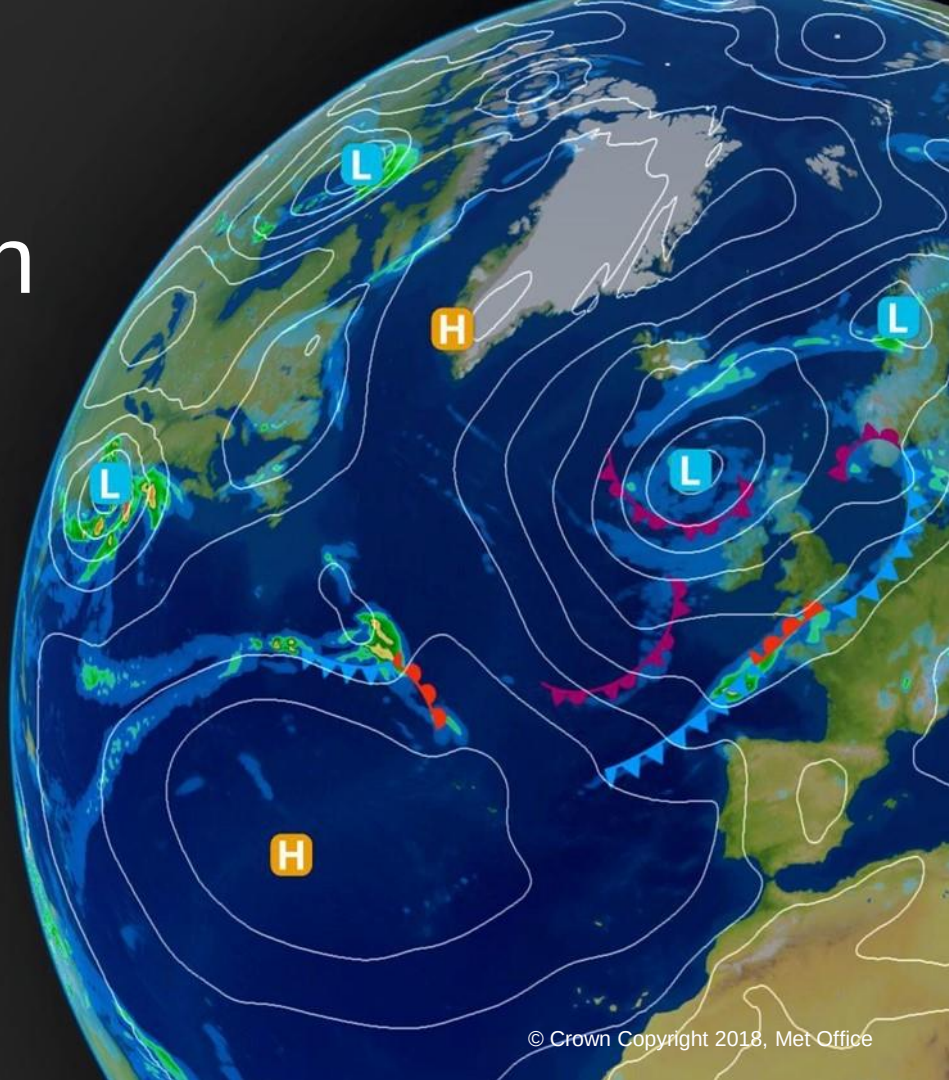
Contents

- Cold-pool propagation
- Spreading and interaction
- Application in the UM
- Related work

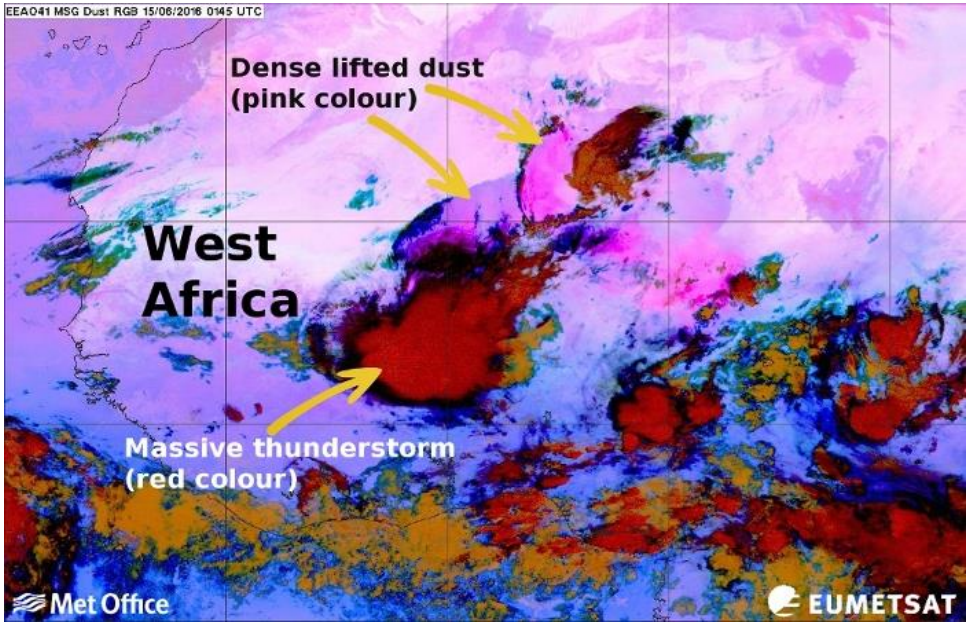
cold-pool propagation



Modelling gravity currents (a.k.a. density currents)

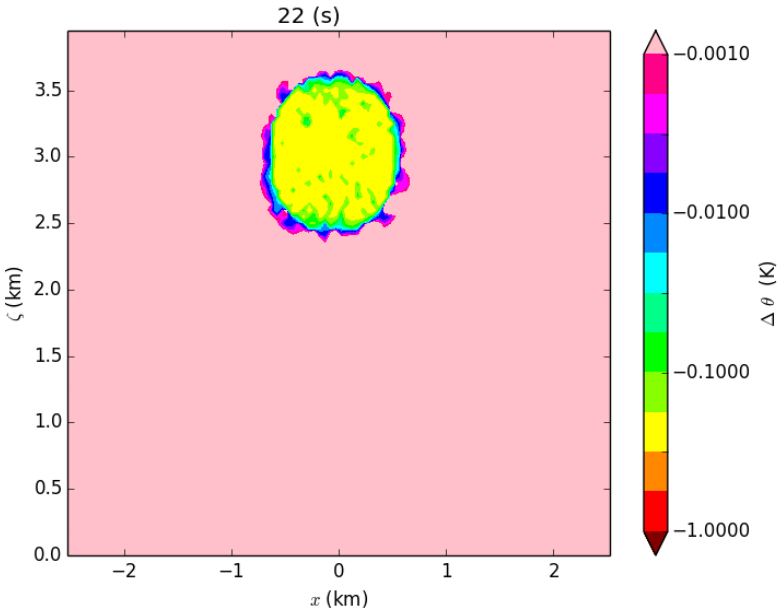
Lots of lab experiments in tanks

- Similarity models based on propagation distance and total buoyancy
- Shallow-water models
    - need front (and back) condition
    - not appropriate for radial spreading (Patterson et al. 2006)?
- Flow affected by the limited domain size



Cold pools in the lower atmosphere

- no problem with domain size (hills maybe...)
- radial spread and interaction
- propagation distance and total buoyancy?
  - NWP considerations / limitations



LEM idealised “cold thermal” simulations and similarity theory

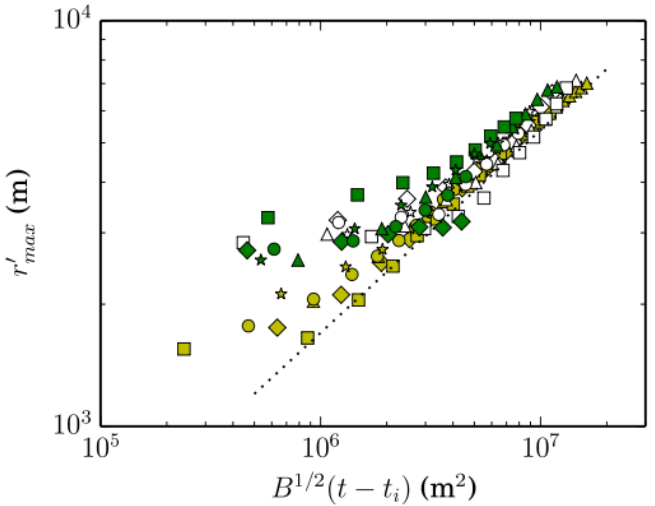
reduced gravity $g' = g\,\Delta\rho / \rho$

buoyancy $B = g'$ x volume

depth h

Fr = speed / $(g' h)^{1/2}$

cold-pool spreading



(Rooney JFM 2015)

Entrainment as a relative increase in volume

Evolution of g' and h on the ground depends on entrainment.

Hallworth et al. (1996) :
Relative proportion of entrainment $\Delta V / V$ is independent of g'.

Rooney (2015): - LEM data verify the findings of Hallworth et al.
- The relative increase in volume may be related to the relative increase in propagation distance.

This leads to an entrainment model in terms of radial distance r :

$$\Delta g' / g' \approx -\alpha \, \Delta r / r$$
$$\Delta h / h \approx (\alpha - 2) \, \Delta r / r$$

LEM data indicate $\alpha \approx 1$

Approximations based on similarity, for NWP application

Incremental changes over Δt :

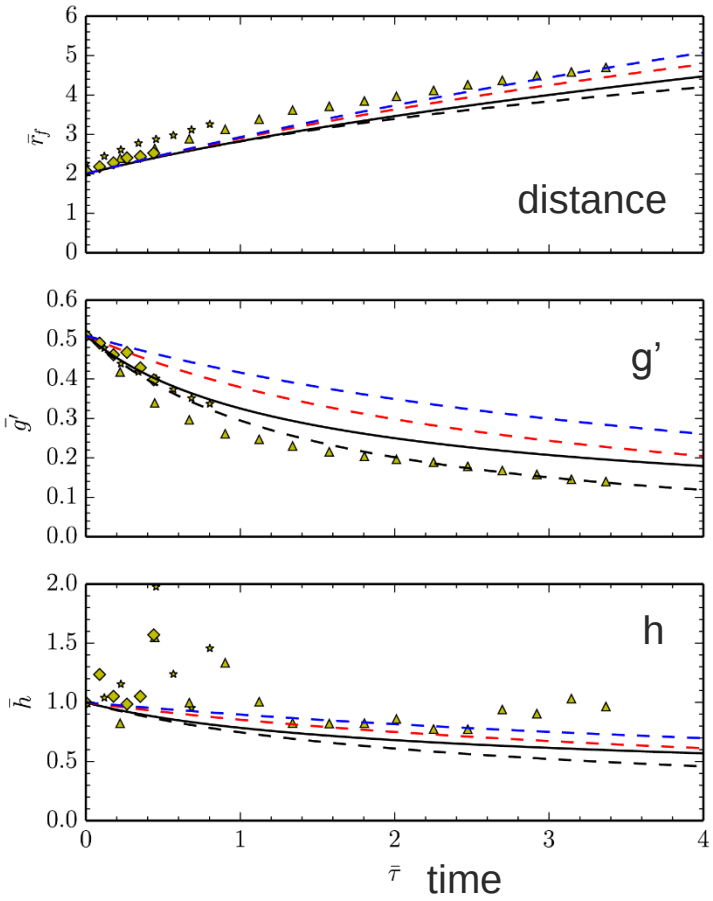
Speed set by $(g' h)^{1/2}$

Timestep Δt gives distance Δr .

Entrainment model gives

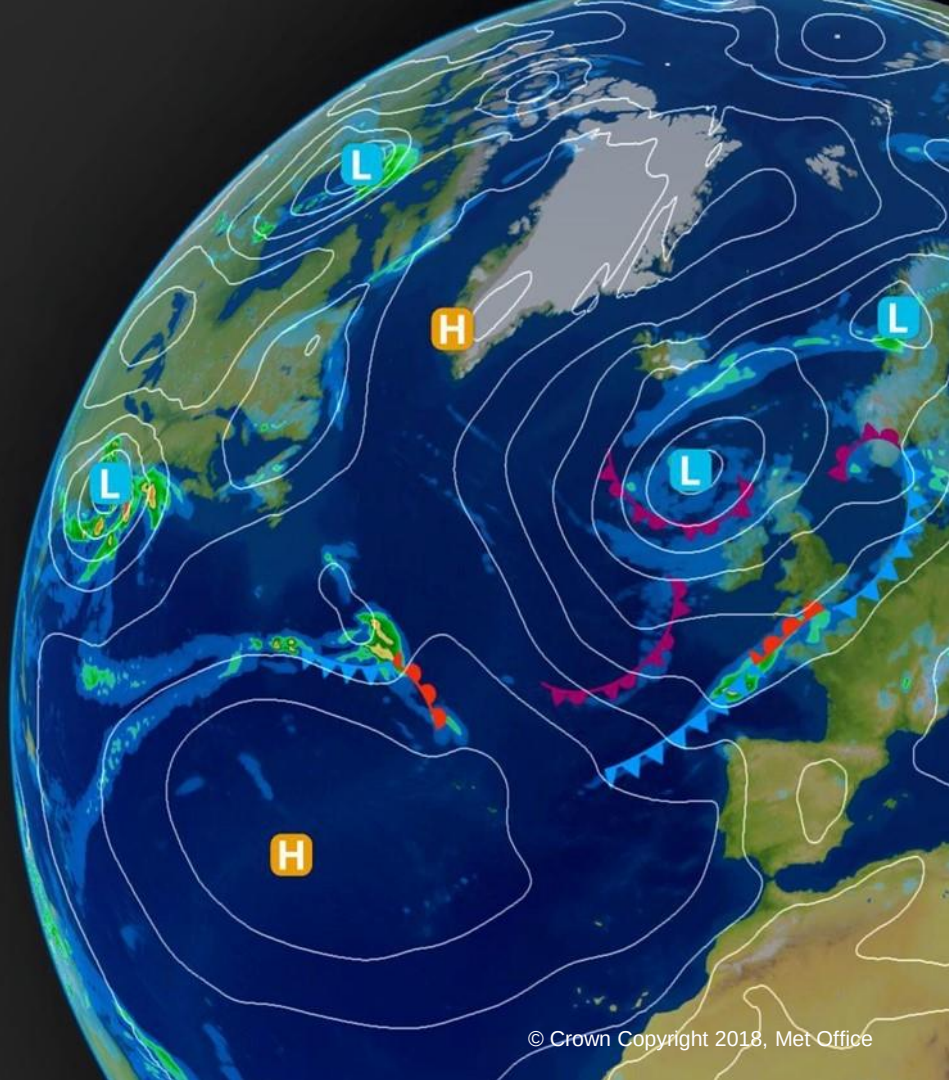
$\Delta g'$ and Δh across Δr .

Repeat as required.

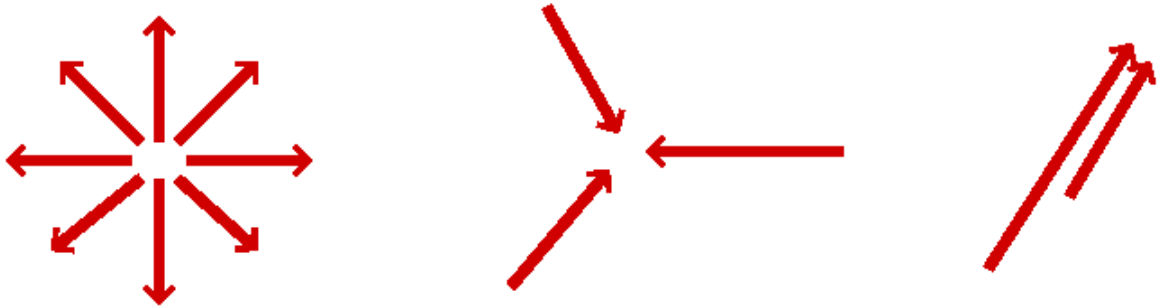


Data as in Rooney (2015)
Solid line : similarity
Dotted lines : approximations
Everything is non-dimensionalised

Spreading and interaction



Sources, collisions, isotropic and directed propagation



Not a lot is known about g.c. interactions (but see later).

But, a parametrisation can be written anyway…

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Model cold-pool evolution as a physically-based cellular automaton

- Downdraught input gives initial *g'* and *h* values (*g' h* ~ "potential")
- *g'* and *h* evolve according to the entrainment model.
- For front "arrivals" at any point:
  - accumulate the max values of *g'* and *h*
  - accumulate velocities (Σ vector) and speeds (Σ scalar)
- The relative magnitudes of the vector and scalar sums

  indicates how to split the potential between
  isotropic or directed propagation.

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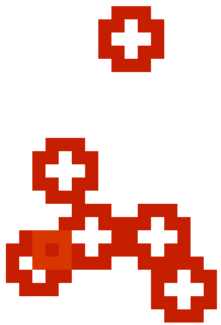
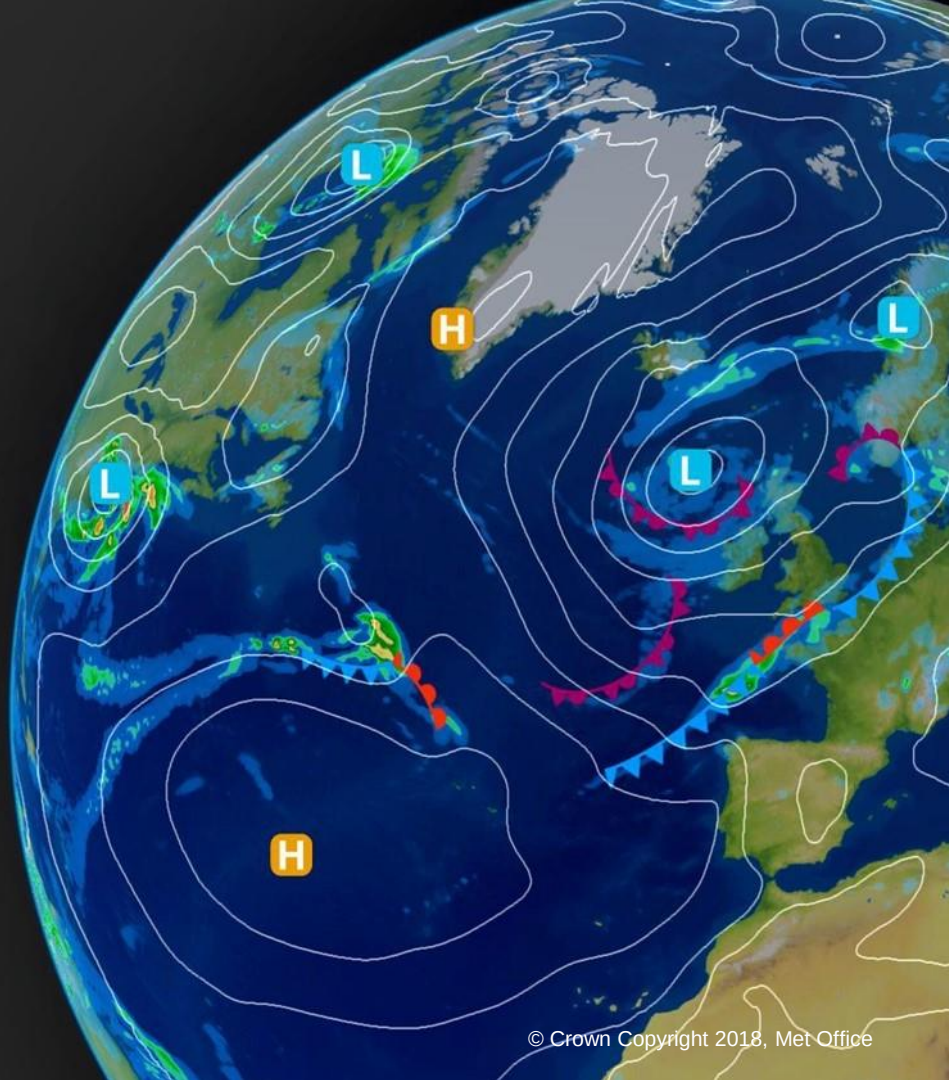
Toy model : moving sources



Application in the Unified Model



Cold-pool scheme in the Unified Model

Done

- Simple forcing from downdraughts
- Buoyancy, depth, velocity prognostics
- “Interactive ancillary” approach
  - can be generalised for multiple sources of convective triggering
- Velocity scale addition to BL KE for triggering of convection

In progress

- code progress onto UM trunk
- Better forcing / downdraughts : COMORPH etc.
  - M. Whitall, Met Office ; E. Kruger, Cambridge

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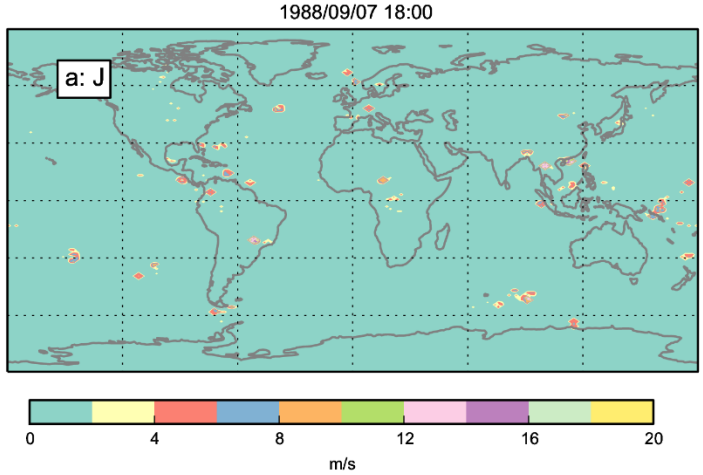
early test example

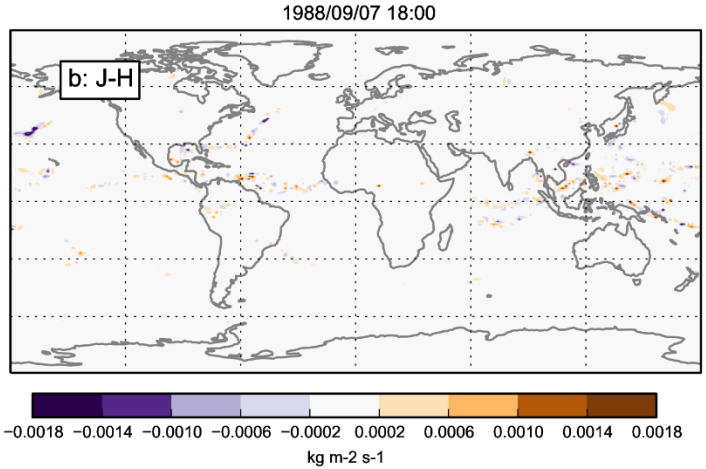
(6A convection scheme)

Cold-pool prognostic

(just to show areas of activity)



Difference in rain rate



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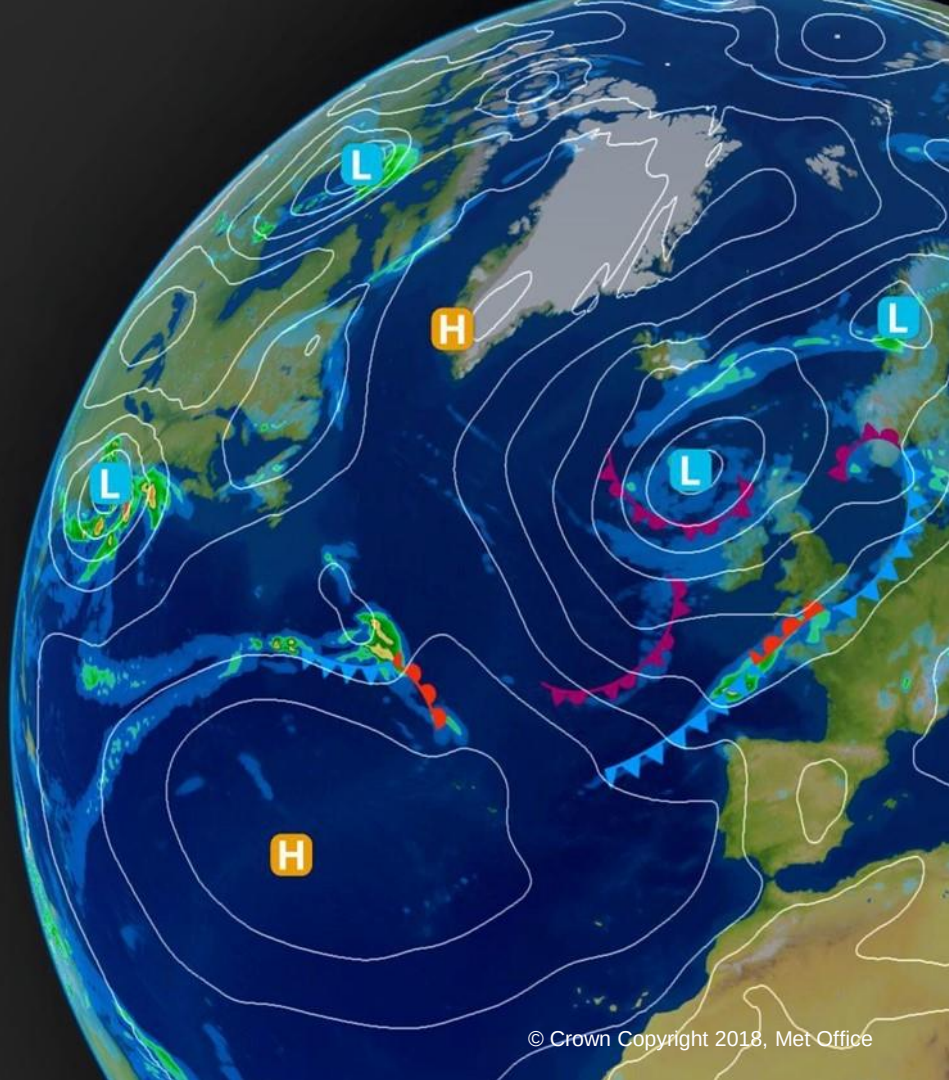
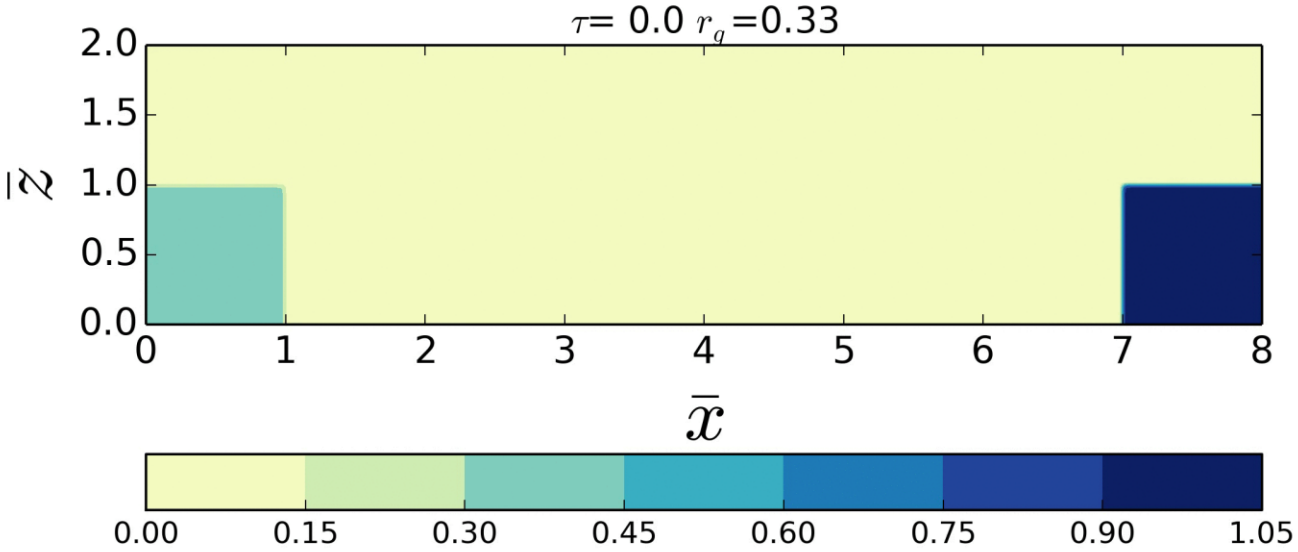


Other aspects…

Gravity-current collisions

Idealised 2D simulations of baroclinic vorticity evolution using the Hydra model (courtesy of D.Dritschel).



- Ratio of buoyancies, r_g
- Collision height
- Collision angle

Cafaro & Rooney (2018, in press)

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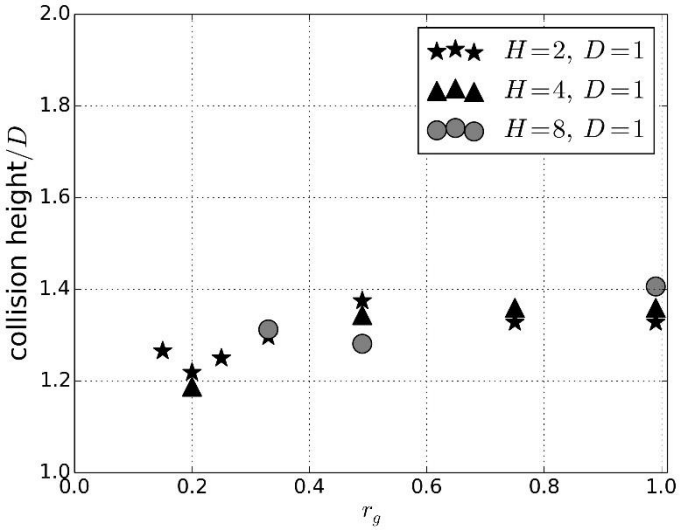
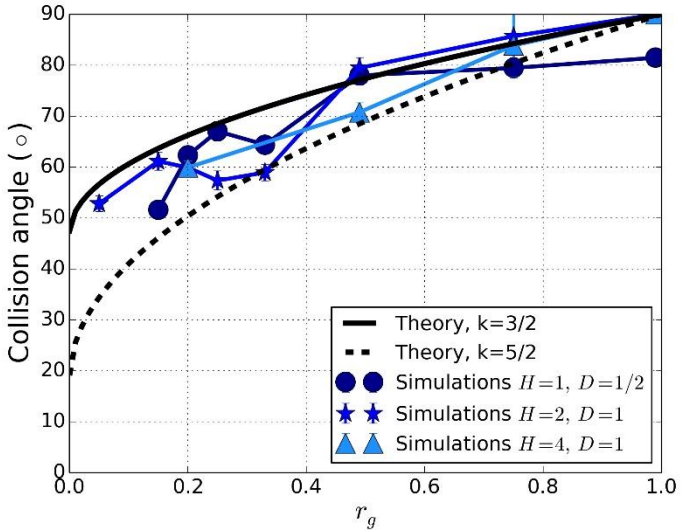
maximum collision height



interface angle-to-horizontal



Haboobs, dust spouts etc. (Rooney 2017)

- There is some evidence of cold pools giving rise to tornadoes.

Conclusions

- Cold-pool scheme is being developed for the UM
  - nearly finished!
  - cold-pool propagation / interaction
  - convective triggering
- Better representation of downdraughts is required
  - this is also under development
- Various processes are not yet fully understood
  - better understanding could help refine the model

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Questions and answers