The "nitty gritty" of convection scheme development

aka "Parameterisation-aholics anonymous"

(a "bring and share" of technical and numerical problems faced by all of us trying to implement convection schemes / ideas in practice).

Aim to learn from each other's practical experience of how to actually get models to work!

Global model mass-flux schemes:

Peter Bechtold
Akira Shimikobe
Eimear Dunne
Mike Whitall
Romain Roehrig

Grey-zone mass-flux schemes:

Danahe Paquin-Ricard
Jian-Wen Bao
Luc Gerard
Bob Plant

Multi-fluid modelling:

Jon Thuburn
Hilary Weller
Daniel Shipley
Yair Cohen

Common themes…

a) **How to couple a mass-flux convection scheme to the “large-scale” microphysics scheme in the grey-zone?**

Luc and Mike’s mass-flux schemes both detrain condensate and allow LS microphysics to do the rain-out, accretion etc.

But messy to ensure consistency (e.g. appropriate sub-grid fraction for the rain-shaft, double-counting autoconversion for convective cloud, different treatment of mixed-phase cloud in parcel and large-scale).
c.f. Kengo’s talk.

Coupling to double-moment microphysics; what to do if convection scheme predicts only the mass of detrained condensate and not the number?

Coupling issues sometimes only manifest unexpectedly when the model resolution is changed!

Best solution: use same microphysics in parcel and environment!

b) How to couple convective cloud (and detrained cloud) to the "large-scale" cloud scheme?

e.g. diagnostic cloud schemes fail to account for large variance / skewness of moisture where convection detrains cloudy air into a dry layer, and spuriously remove all the cloud.

TKE-based cloud-schemes assume variance is small because free troposphere is not turbulent.

Even if prognostic moisture variance is accounted for, can't get a sensible answer without skewness as well.

What is the right split between "convective" vs "large-scale" cloud? How should it be controlled? Vs what really controls it?

Practical solutions:

i) 3MT (include convective cloud within the LS cloud scheme's framework)
ii) Separate variables for diagnosed convective cloud, added on for clouds passed to radiation.

c) How to ensure sensible behaviour of convective fraction sigma (consistent with convective w / mass-flux).

Both mass-flux schemes and multi-fluid models have problems with this!

Especially difficult in prognostic approaches such as multi-fluid, since errors can amplify over successive timesteps.

Questionable whether sigma is a good choice of variable (partitioning is arbitrary).

Solutions can be messy; e.g. “capping”…

d) Physics improvements often degrade NWP performance due to very fine tuning of operational systems with compensating errors.

e.g. improvements to energy conservation in convection scheme make the scores worse (Martin Willet and JMA convection group both found this!)

EC IFS model biases are now only ~0.1K, so a conservative approach to model and DA changes is the only way to avoid degrading the biases.

Statistical / machine-learning approach to model tuning?

Collaborate with developers of other schemes in the model to use their practical knowledge of how to tune those schemes effectively?

University researchers can get help overcoming this by collaborating more closely with operational centres.

e) Interactions with Data Assimilation.

Improved model parameterisations can make the NWP scores worse:

- Model becomes inconsistent with the Tangent Linear Model in DA.

- More realistic convective organisation can give finer-scale storm structures in not exactly the right locations => double-penalty effect, and violates linearity assumption in 4-D VAR.

- DA system often fine-tuned / hacked to optimise NWP scores with the existing model physics, so DA trials are biased against new physics schemes.

Parameterisation developers and DA developers need to work together more closely!

Take lessons from convective-scale DA? Shorter cycling periods / assimilate radar. For global, use GPM etc?

DA system needs more intelligent / non-local penalty function rather than point-based RMSE.

Use outputs from DA / Analysis increments to diagnose errors in parameterisations.

f) How to represent sub-grid perturbation pressure gradient terms?

Neglected in mass-flux approach (except where represented as drag on thermals). But at updraft base it plays a strong role in overcoming CIN.

Difficult choice of assumptions / numerical methods to solve for the pressure in the multi-fluid system.

Multi-fluid framework probably the best current solution on the table. More process-based research needed to constrain and validate the pressure terms in both mass-flux and multi-fluid frameworks.

g) Shortcomings of numerical methods in models

e.g.:
- Semi-Lagrangian “eternal fountain” problem.
- Intermittency / noisy behaviour / biases due to numerical overshoot of explicit time-integration schemes.

Need to use implicit methods wherever the process being modelled is “fast” compared to the timestep!
Parameterisation developers need to be more aware and carefully check for these numerical issues.