Convection Working Group

"Future Avenues"

Discussion of possible ways forward with understanding biases.

Overarching Comments on ways forward

a. Developing a robust understanding of issues/biases
b. Addressing underlying causes is key, rather than symptoms
c. Developing insightful evaluation techniques/evaluation framework which can be applied easily to subsequent model versions for comparison
d. Comparing different model resolutions
e. Understanding impact of driving model
f. Improving theory (e.g. for squall lines)
g. Balance of real time analysis (O2R), case studies (selected hindcasts), long period simulations (free running or multi-forecast)

1. Timing Biases

1.1. Summary of issues

Precipitation is seen to initiate too early in convection-permitting (CP) Met Office Unified Model (MetUM), especially in the tropics. Once initiated, precipitation rates grow too rapidly. Given that the finite grid renders such models unable to represent the very small initial plumes, the expectation is for initiation to be late. Consistent with this, generally any model change that makes the fields less smooth (increasing resolution, reducing diffusion or applying perturbations) causes the model to initiate earlier. Reasons for the early initiation are not clear, but some suggestions include too strong stochastic perturbations (where these are used), insufficient CIN in the pre-convective profiles, and incorrect (too strong) model response to the profiles. Another key issue is the coupling of the atmosphere model to the surface model, where soil moisture has been shown to affect initiation. Much of the above is based on comparisons between model and observations for surface rainfall. It is possible that updrafts or clouds may compare better to observations and that the issue is related to rain production in the model.

1.2. Suggested ways forward

(a) Run (semi-)idealised simulations initialised with an observed profile in both LEM and high-resolution MetUM to investigate the ability of the model to respond correctly to a given thermodynamic profile. Has this already been done? Related to the following suggestion, the model may rain at the wrong time despite a correct representation of the updrafts and clouds.

(b) Perform model evaluation for quantities other than the surface rain rate, e.g. clouds and updrafts which are generating clouds. Clouds can be elucidated with radar (3D scans or 3D composites from radar networks). Updrafts are harder to observe, but could be investigated with research radars. We should be able to say something about the clouds v rain question from existing work (Keats et al SA, Kirsty Hanley, DYMECS). Kirsty says that she doesn't have any `clean' cases without clouds before the convection initiates. Thorwald suggested working with cloud radars and ceiliometers (e.g. with Chris Westbrook in Chilbolton context).

(c) Understand how profiles evolve in observations vs. model in real cases and compare regional model to global model. Carry out analysis in terms of CAPE and CIN. Difficult in practice due to lack of observational soundings. Another issue is a consistent calculation of CAPE and CIN amongst all cases. In cases where some rain may not be convective, it is important to determine when the convective rain does occurs, so as to correctly identify and analyse the pre-convective environment.

(d) Trajectory analysis of initial precipitating updrafts to understand how the model initiates these updrafts.

(e) Budget analysis, e.g. vertical momentum.

(f) Investigate effect of land surface (in particular soil moisture) on initiation. Can we perturb the soil moisture in a realistic way in some case(s) to investigate this?

(g) Analysis of climate runs inc. UKCP 2.2km ensemble, 2.2km over Europe and 4.5km over Africa. Event composites for different weather regimes. Analyse profiles of events and rainfall distributions in a statistically robust way.

(h) Define the pre-convective period and develop an objective method to pick out pre-convective environments. Study CAPE and CIN changes before and after rainfall is triggered (probably in combination with (g)).

(i) Test sensitivity to stochastic perturbations in the model (including Clark Halliwell scheme).

2. Rain amount biases

2.1. Summary of issues

A number of biases in the overall rain amount have been reported. Historically CP models tended to produce too much rain overall, but it is likely that this is now a less consistent bias since the introduction of conservation schemes. Various biases have been reported relating to land/sea contrast in rainfall amounts, but it is unclear if there is a consistent signal. Wet biases have also been identified where orography and/or local convergence is associated with convective initiation. Understanding how any rainfall overestimation varies in future climate is a key issue for CP climate modelling (i.e. how does the overestimation scale with temperature?)

A consistent bias has been identified in the rain rate distribution, which exhibits too much heavy rain and not enough light rain. This bias is understandable given the inability to resolve detrainment from convective updrafts (and does improve as resolution increases towards 100m), although it has also been addressed in terms of microphysics changes.

2.2. Suggested ways forward

(a) More work to pool observational data and better stratify cases to identify robust errors. Need to consider stratification issues such as land surface state and land/sea contrast.

(b) Case study work to identify reasons for biases in particular cases. Similar to 1(b) above, there is a need to trace the origin of the errors (e.g. if there is too much rain, is there too much precipitable water in the clouds? If so, is this a result of too much moisture, or because the vertical velocities are too great?)

(c) Idealised modelling.

3. Spatial structure of convection (Blobbiness)

3.1. Summary of issues

So called ‘blobbiness’ is the tendency of CP MetUM to produce focused, largely circular cells, often with too intense rainfall rates and lacking in regions of lighter rainfall, in particular when the cells are under-resolved. Larger cells are seen to break up into a number of small ones in situations where they are well-resolved. This issue also manifests itself in sub-km models where the cells are, incorrectly, seen to get smaller and smaller as the grid length is reduced. Blobbiness has been attributed to the behaviour of the dynamical core (in particular semi-Langrangian advection) in under-resolved flows, parametrisation of sub-grid turbulent mixing, sensitivity to microphysics and the cloud scheme. Historically PC2 was originally included in the tropical configurations because it appeared to help with the spatial structure of convection, although this is no longer clear in recent sensitivity studies. Work in W Africa (Amma2050, unpublished) raises questions about response to shear (model updrafts and OLR respond to shear as observed, but rain much less so). Comparisons of very high-resolution MetUM with MONC has shown that MetUM performs well at ~100m. At coarser resolutions, and particularly in the grey zone around 400/200m, small storms and grid-scale structures are seen which can cause moisture conservation issues. Simulations also have a high sensitivity to microphysics, in particular the raindrop size distribution, which is affected by the amount of evaporation of small rain drops as they fall. Care needs to be taken when comparing LEM and MetUM that consistent microphysics and other aspects of the configuration are used. More details from about two years ago can be seen in the report from the MO blobbiness working group at https://code.metoffice.gov.uk/trac/rmed/wiki/pegs/blobbiness/KDreport_Sept17. More comparisons of the MetUM and MONC have recently been carried out by Carol Halliwell.

3.2. Suggested ways forward

(a) Further idealised simulations and comparisons with MONC to determine how much of this is MetUM specific.

(b) Investigate microphysics sensitivities. For example, compare the model's reflectivity diagnostic with radar at various heights to investigate impact of evaporation of rainfall on surface rainfall diagnostic.

(c) Perform experiments comparing model performance with the PC2 and Smith cloud schemes

(d) Develop metrics of organisation of convection.

3.3. Other structure issues

There are other issues related to the structure of convection, such as the unwillingness of the model to form squall lines as often observed over the western Maritime Continent.

4. Elevated Convection

4.1. Summary of issues

Elevated convection is thought to be poorly represented in CP MetUM. Elevated convection occurs above stable layers and is defined as convection for which the inflow originates from a layer not in contact with the surface close to the storm (Markowski and Richardson, 2010). Steve Willington concludes that elevated convection can be defined as ‘convection where the inflow layer or parcel is derived from above the PBL’. Note that elevated convection refers to the source of the air in the plume, rather than the actual height of the cloud. Steve also argues that the term ‘mid-level convection’ is therefore unhelpful and should not be used.

Elevated convection can incorporate a wide range of configurations. For example, there CAPE maximum may occur above the PBL, there may still be some CAPE in the PBL, and the a stable layer may exist below the source air which may be shallow or deep , of if there is a deep layer(s), whether downdrafts can reach the surface – and so whether systems are cold-pool based or bore/wave based).

In the UK, elevated convection is most common during ‘Spanish Plume’ cases, where hot dry air from the Iberian Peninsula advects northwards and interacts with colder air from the west to produce convective storms which move north over the Channel from the continent (Bennett et al., 2006). It has been noted that the UKV often fails to capture such convection. White et al. (2016) showed for a CSIP case that the fine layering required was not captured in the boundary conditions in the UKV. Problems including poor organisation/upscaling, poor maintenance and unreliable triggering. Elevated convection has also been identified as a problem in CP MetUM configurations run for the Hazardous Weather Testbed. It is assumed that the models do poorly in these situations because it is hard to correctly capture moisture variations in elevated layers not in contact with the ground (Weckworth et al., 2019). This also suggests a lack of predictability.

4.2. Suggested ways forward

(a) Detailed case(s) study analysis of poor cases over the UK or elsewhere to elucidate reasons for model issues.

(b) Look at case(s) in (a) above in an ensemble context to investigate predictability. Does the ensemble spread encompass the observations or are ensemble solutions clustered around the wrong solution?

(c) Work with people involved in the PECAN (Plains Elevated Convection At Night) project in the US to understand the model issues in that case. Run some MetUM cases to compare with their observational data and model runs.

(d) LES/idealised MetUM modelling. For example, RCE (Radiative Convective Equilibrium) experiments to identify any other reasons for poor performance (e.g. whether model response to correct profiles is lacking in elevated cases).

References

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