Annex I: Abstracts of posters

An improved representation of the rain drop size distribution for single-moment microphysics schemes

S. J. Abel and I. A. Boutle

We analyse observations of the size distribution of rain drops from a variety of cloud types and precipitation rates. The measurements show a transition from large rain drops observed in convective showers and frontal rainbands to higher concentrations of much smaller drizzle drops observed in stratocumulus clouds. The observations are used to develop an improved parameterization of the rain drop size distribution that better captures the observed transition for use in single-moment microphysics schemes. Sensitivity tests are performed in both climate and Numerical Weather Prediction versions of the Met Office Unified Model to demonstrate that the new parameterization leads to improvements in various precipitation and cloud related metrics.

Reference

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Harmonisation of Cloud and Precipitation Concepts in the ALARO Physical Package

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ALARO is the name of one variant of the parameterisation system of the global IFS/ARPEGE system of Météo-France and of the parent LAM ALADIN/HARMONIE system. By extension it sometimes means one of the LAM operational-type configurations run on its basis, for instance in At, Be, Cz, Hr, Hu, No, Pt, Ro, Se, Si, Sk and Tk, under various roles. The present poster restricts itself to the physical package aspect. It also targets the topic of the ECMWF workshop, by focussing on cloud and precipitation aspects and by insisting on the ingredients supposed to favour a fully multi-scale use of ALARO.

Concerning the multi-scale side, there is a strong basic hypothesis in ALARO. One starts from the 'grey-zone' of deep convection (mesh-sizes around 4 km). Further, one tries and gets rid of the detrimental syndromes associated with the half-resolved vs. half-parameterised convection challenge. Finally one explores how far in each direction (larger and smaller scales) the resulting configuration behaves according to expectations. For lack of space, the poster does not show any result supporting this strategy, but they may for example be found in the paper Gerard et al. (2009).

The key to a successful solving of the grey-zone challenge in ALARO mainly resides in consistency of all formulations (under a 'cascade' system: locally sequential and globally parallel combinations of contributions to the prognostic variables' budgets) and on the 3MT approach. The latter (and its ongoing evolution for attacking the problem of the convective diurnal cycle, once considering the grey-zone convective problem as practically solved) are mentioned in the poster. More precisely, 3MT gets away from assumptions of a stationary cloud (neither in size nor in properties) and it fully takes into account the fact that microphysics has a rather long lag-time and is thus not only happening 'within the drafts'.

Basically, 3MT is a way to do 'as if' deep convection was resolved but without needing to go to the small mesh-sizes where this is true without any parameterisation of convective drafts. This possibility comes from (i) prognostic and diagnostic 'memory' of convection and (ii) a single micro-physical treatment beyond all sources of condensation. These choices strongly influence the structure of the physical time-step of ALARO, a target version of which (if all plans materialise) is given in the poster.

The drive towards a strong prognostic character is another trade-mark of ALARO, since it is considered here that ‘memory’ of physical processes is an essential ingredient for stabilising and keeping realistic the interactive combination of more and more complex algorithmic descriptions for basic local atmospheric phenomena. From this point of view ALARO is an interesting test-bed for studying the interactions between some stochastic forcing and more classical parameterisation outcomes. This is the topic of an ongoing attempt at combining a Cellular Automaton and the 3MT updraft’s closure assumption, with some first promising results, mentioned in the poster.

Trying and harmonising the thermodynamic behaviour of ALARO beyond the global conservation laws derived in Catry et al. (2007) is another important recent addition. It is hoped that a revisit of the entropy formulation and of its link with energy conversion aspects should allow a completely consistent picture of all the moist physics or at least of its non-precipitating part. This however calls for increased flexibility and modularity in the design of the moist turbulent diffusion scheme (TOUCANS). The ongoing work fortunately goes in the right direction for this, with coexistence within the same code structure of various options for (a) basic formulations (M-Y, QNSE, EFB), (b) choices for the length-scale determination, (c) inclusion or not of TOMs effects and (d) two methods for avoiding the collapse of turbulence beyond a ‘critical Richardson number’. The resulting algorithmic solution indeed favours a differentiation between the various sources/sinks of TKE, this allowing a quasi-transparent introduction of moist aspects in the SOMs + TOMs formalism. In such an attempt, the mass-flux aspects of EDMF-type schemes are in principle represented at the crossroad of total moisture budget’s handling and of TOMs considerations.

Concerning the degree of sophistication needed in the description of other basic physical processes (radiation and microphysics), the ALARO choices are rather specific. More attention is paid to the search for efficient algorithms and to a consistent introduction of all relevant geometrical aspects of clouds and precipitation than to intrinsic complex details of the local processes. Said differently, the idea is here to give more importance to the spatial than to the spectral distribution of radiative and microphysical impacts.

One ingredient missing in the poster (again for lack of space) is the algorithmic description of the thermodynamic adjustment. We shall try to briefly repair this miss here. Modifying a bit the Xu-Randall (1996) formula and combining it with obvious definitions allow obtaining a closed intrinsic system for diagnosing stratiform cloud-cover N as well as a related condensate amount. However, when convective condensate is assumed to be present after advection from the previous time-step, one must take care of avoiding an exaggerated re-evaporation rate in case of a subsiding too dry environment. Fortunately, assuming equality of the intensive amounts of condensate in both convective and stratiform parts of the grid-box leads to a single appearance of the convective cloud cover Ncv in the resulting Xu-Randall-type algorithm, so that the solving for N* (the relative stratiform cloudiness within the ‘non-protected’ part of the grid-box) remains basically unchanged.

ALARO is currently (end of 2012) undergoing a transition from its first version (ALARO-0) to a major upgrade (ALARO-1). From the items presented on the poster, those concerning cloud radiative impacts, geometry of microphysics, 3MT architecture and the convective diurnal cycle will be part of the final frozen ALARO-0 set-up. Those on CA and on the moist thermodynamics, the latter as part of the TOUCANS package for moist turbulence and diffusion, are available for testing but not yet in (pre-)operational shape. The upper-left flow-diagram of the poster encompasses all items corresponding to ‘already’ and ‘soon’ in the enumeration about prognostic aspects. Extensions linked to CSU and TTE are not (yet) present there.

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Understanding Grid-Scaling Behavior Using the Separate Physics and Dynamics Experiment (SPADE)

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The Separate Physics and Dynamics Experiment (SPADE) can be used to understand the behavior of specific physics parameterizations at different grid spacings. This is of particular importance when developing parameterizations for multi-resolution grids, such as those becoming available in new atmospheric model dynamical cores, e.g., the Model for Prediction Across Scales (MPAS). Physics parameterizations are needed that behave accurately at all resolutions used within the model domain and not just at specific resolutions. The SPADE framework separates the physics and dynamics portions of the atmospheric model, allowing each of them to operate on independent grids with different resolutions. This allows one to hold the model behavior constant at a given resolution for all processes except for those being tested at an alternate resolution. By spanning a range of resolutions for the tested process, one can identify changes in parameterization behavior. This has the advantage that it reveals the resolution dependence of the selected processes without interactions from other processes that can have their own resolution dependence.

This poster will present the SPADE framework and show results for cloud microphysics as an example of how the technique can be used. A comparison is made between resolution behavior of microphysics from a regional model (a typical configuration from the Weather Research and Forecasting model) versus a global model (physics from the Community Atmosphere Model v5.1). This provides an interesting comparison because the grid spacings used by the communities is converging, and assumptions built into the schemes differ in terms of how macrophysics affects the results. The resolution dependence of the entire model system is stronger when using the "mesoscale" physics suite compared to the "global" physics suite. And, when tested in isolation, the "mesoscale" microphysics also shows stronger resolution dependence than the "global" microphysics.

Assimilation of radar and lidar observations over the UK in MetOffice convective-scale models

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Convective-scale forecasts of precipitation and cloud can benefit from the inclusion of novel types of high-resolution observations in the data assimilation system. Met Office radar and ceilometer networks have good spatial coverage of the UK and the instruments report measurements frequently, every 5 minutes for radar and 30 seconds for ceilometers. We discuss our current research at the Met Office on the assimilation of radar reflectivity and atmospheric backscatter from ceilometers.

Radar Reflectivity

Across the UK, the Met Office has access to 18 C-band radars that are being renewed and upgraded to Doppler and dual-polarization capability. Operational Met Office convective-scale models assimilate Doppler radial winds directly and radar-derived surface rainrates via latent heat nudging.

Two methods for the assimilation of radar reflectivity scans have been developed: indirect 1D-VAR+3D-VAR and direct assimilation in 4D-VAR. The indirect method uses a 1D variational retrieval to derive psuedo temperature and humidity profiles from reflectivity scans which can be assimilated in 3D-VAR. Met Office 4D-VAR is incremental. The Unified Model (UM) provides a background and the simplified linear perturbation forecast (PF) model is iterated during the minimization to update values of model guess fields in the assimilation window. The adjoint of the PF model runs backwards through time after each PF model run to calculate gradients for the minimization. Model variables are transformed into control variables which should be uncorrelated. Met Office 4D-VAR uses velocity potential, stream function, unbalanced pressure and a humidity variable representing total water.

An observation operator has been designed to forward model radar reflectivity from rainrate and its adjoint calculates gradients. PF model 3D rainrate increments are diagnosed from cloud water increments.

We have demonstrated our capability to directly assimilate radar reflectivity superobs. In a case study from 5 April 2011, the direct assimilation of reflectivity worked to intensify and suppress rainfall forecasts in the correct regions.

Current research involves the specification of observation error, use of observations at multiple times, the optimisation of the length of assimilation window and the use of 4D-VAR multiple outerloops.

Ceilometer Backscatter

The Met Office operates a network of more than 100 infrared ceilometers to observe cloud base and total cloud amount. A subset of these stations is currently reporting vertical profiles of raw attenuated atmospheric backscatter. There is the potential for more ceilometers to send this data which would provide even denser coverage over the UK.

Our research question is: Can these raw backscatter profiles be directly assimilated into the high-resolution UM to improve the forecast? To answer this question we have designed a forward model to convert Unified Model (UM), UKV 1.5 km, diagnostic output into a vertical profile of attenuated backscatter. The operator has been created to work in concert with the current assumptions valid in the UM aerosol code for NWP and with those in the UM microphysical schemes.

Currently, our forward model for producing synthetic backscatter has been designed for clear-sky and non-precipitating, liquid cloud cases. Initial case studies at Middle Wallop site, near Chilbolton, for both clear-sky (3 June 2011) and cloudy (5 November 2011) days show qualitatively that the attenuated backscatter in the boundary layer can be simulated well by our forward model.

This forward model for atmospheric backscatter created for use in data assimilation could also be used to evaluate the UKV (1.5km) model's representation of aerosol and non-precipitating, liquid cloud. Forward model design needs to be expanded to cope with precipitating cloud and potentially ice cloud as well.

Our next step is to produce infrastructure to monitor statistics of observed minus modelled (O-B) backscatter profiles over several weeks and multiple sites. Analysis of these error statistics will determine whether we proceed with the direct assimilation in 4D-VAR of the vertical profiles of atmospheric backscatter.

The new microphysic cloud scheme implemented in RegCM4

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The Regional Climate Model RegCM4 presently lacks a detailed treatment of cloud microphysics. We therefore show preliminary results from a new cloud scheme currently under development. The approach is based on an implicit numerical framework that recently developed and implemented into the ECMWF operational forecasting model. This is used to solve a network of parameterizations that describe the sources and sinks of prognostic cloud variables of ice, liquid water, snow and rain. Results from the implementation of the initial scheme in the REGCM regional climate model will be shown. A novel aspect of the scheme that is currently under development is the attempt to implement the microphysics scheme in the mass flux convection scheme in a fully self-consistent way accounting for convective-scale as well as large-scale vertical velocity, which implies that the cloud properties and consequently the model climate will be insensitive to future increasing resolution as convection becomes increasingly resolved.