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Interactive Comment

Interactive comment on "The Met Office Unified Model Global Atmosphere 4.0 and JULES Global Land 4.0 configurations" *by* D. N. Walters et al.

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1 Reply to general comments

We thank the referee for their review and for their positive comments regarding the value of this paper. We also note their point about the difficulty of describing such diverse model components clearly. We respond to their individual comments below, which we hope will improve the clarity of the final document.

2 Structure of the paper

The order in which the parametrizations are described is designed to follow their order within the model timestep; i.e. they are split between "slow" and "fast" processes as described in section 2.9. In this framework, precipitation and cloud are treated as "slow" process (along with radiation and gravity wave drag) which act in parallel before advection. Boundary layer turbulence and convection are "fast" processes that occur after advection. Also, given that the results of the boundary layer scheme are a requirement for the diagnosis of convection, we would rather group these parametrizations together. To make this clearer, however, we will move section 2.9 (Structure of the atmospheric model timestep) to be directly after section 2.1 (Dynamical formulation and discretization) and explicitly state this reason for ordering the descriptions of the schemes in this way.

In response to the specific question on the distinction between large scale precipitation and large scale cloud, the cloud scheme (PC2) is responsible for the creation and evolution of prognostic cloud fields in response to increments from the model's dynamics and other parametrizations. The precip. scheme uses these cloud fields, in conjunction with other prognostics, to diagnose the creation of precipitation and the consequent increments to the prognostic cloud, moisture and heat variables. It is also responsible for modelling the fall of that precipitation (and any pre-existing prognostic precip.), applying associated changes in phase and distributing the resulting total between surface precipitation and precip. remaining in the column. In a proposed alteration to the paper, we can clarify that the inputs to the radiation and precip. schemes are the cloud fields from the end of the previous timestep and that the cloud scheme uses the increments from these (and other) schemes to calculate changes to the cloud prognostics.

3 Responses to specific questions

3.1 Questions about section 2.1

"There can't be 3 prognostic thermodynamic variables.": In Davies et al. (2005), the potential temperature θ, Exner pressure Π and density ρ are all described as being prognostic variables. As described in section 6 of that paper, θ and ρ are advected in a "predictor" step (along with the moist variables and winds), whilst Π is solved implicitly by formulating an elliptic equation for the change in Π from the predicted changes in these advected fields. The resulting Π is then back-substituted into the expressions for the advected fields in a "corrector" step to give the final advected fields. This is why Π in this predictor/corrector algorithm was described as a prognostic variable, but we agree that the precise definition of what is prognostic and what is not in an implicit scheme is not clear-cut. Ideally, we would like to keep our list of prognostics consistent with that in Davies et al. (2005), but will agree to change this if the referee insists.

"There is nothing said about typical time-steps for the different resolutions.": We agree that this is important in the context of the sub-stepping described later on. We have added a brief paragraph on this to the end of section 2.1.

3.2 Question about section 2.2

"Are some of the absorbing gases prognostic?": We have added the following to the text: "Of the major gasses considered, only H_2O is prognostic; O_3 uses a zonally symmetric climatology, whilst other gasses are prescribed using either fixed or time-varying mass mixing ratios and assumed to be well-mixed.".

"Are the calls to the radiation schemes always only once in 3h?": Yes, there is one full call of the radiation scheme every three hours and one update in the cloud-absorbing

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bands every hour, independent of the choice of model resolution or timestep.

3.3 Question about section 2.7

"Which thermodynamic variable is in fact mixed in the boundary layer scheme?": The thermodynamic variable mixed is the liquid/frozen water static energy, which is chosen as it is conserved under adiabatic ascent/descent through cloudy and cloud-free layers. This is discussed in the references from the paper, but we do propose expanding the sentence "It is a first-order turbulence closure mixing adiabatically conserved variables" to "…mixing adiabatically conserved heat and moisture variables, momentum and tracers".

3.4 Question about section 3.3

"To me it is not clear what the physical meaning of [*doing the iterations over columns or surfaces*] *should be and why it should give different results when doing the mentioned alteration."*: In the absence of sedimentation of hydrometeors moving down through the column, it is quite correct to say that the choice of column-based or surface-based substepping should have no impact. However when particles are allowed to sediment the order does matter (a better representation of the sedimentation and subsequent interaction is the primary motivation for substepping). As an example, one could imagine a situation where rain falls through a dry atmosphere to the surface. With a long timestep, substepping over the surface may result in all the rain evaporating at its origin, while substepping over the column may allow some of the rain to fall to lower levels before evaporating. Thus substepping over the column and allowing a parallel treatment of sedimentation would be the preferred method.

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