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Geoscientific
Model Development
Discussions

Interactive comment on "Mass-flux subgrid-scale parameterization in analogy with multi-component flows: a formulation towards scale independence" *by* J.-I. Yano

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I much appreciate the anonymous referee's various insights on the paper.

General Comments

• The basic idea of mass–flux convection parameterization is to divide the grid–box domain into convection and the environment. For simplicity, let us assume only one type of convection is found within a given grid box. Let us also assume that convection occupies a fractional area, σ_c, within the grid box, then the environment occupies a fractional area, $1-\sigma_c$. As a result, for example, the vertical velocity, w, is divided into the

two parts, those coming from convection, w_c, and those coming from the environment, w_e. The total vertical velocity is recovered by taking a weighted sum of the two: $w = \sigma w_c + (1-\sigma_c)w_e$. Here, conversely, the environmental vertical velocity is given by

$$w_e = \frac{w - \sigma_c w_d}{1-\sigma_c} \qquad (R.1)$$

Under the standard approximation, we take $\sigma_c \ll 1$, thus Eq. (R.1) reduces to

$$w_e \simeq w - \sigma_c w_d \qquad (R.2)$$

However, when the fractional area satisfies $\sigma_c \sim 1$, Eq. (R.2) obviously underestimates the environmental subsidence compared to the exact equation (R.1).

This is just one simple example to demonstrate why the parameterization formulation must be re–written when $\sigma_c \ll 1$ is no longer satisfied. All the formulations must be re–written thoroughly for this reason as presented in this paper. Especially, as already emphasized in the original text, the grid–box mean for the thermodynamic variables can no longer equated with the environmental values as assumed in the standard formulation. Also for this very reason, the substantial re–formulation of the problem is required as discussed in details in the present manuscript.

• The final set of equations (3.12), (3.14), (3.15), (3.20) and (3.21) is essentially a primitive equation system but written for an individual subgrid–scale component indicated by an index j. The numerical cost is essentially N times of running a primitive equation system, but without subgrid–scale parameterizations of the physical processes included into this multiple–component analogue representation (notably convection and cloud schemes, but also some boundary–layer processes), when N subgrid–scale components are considered

• Yes, this is a very important point: the present formulation is so general that it can be applied to any geophysical and planetary fluid systems that are described by a primitive equation system. However, of course, we have to know what the subgrid–scale processes are in order to subscribe the entrainment–detrainment rates correctly.

Specific Comments

In the section 2.2, it will be explicitly stated in the revised text that the adaptation of the primitive equation system is based on the aim "for numerical weather prediction and climate change".

In the section 3.1, it will be explicitly stated in the revised text that the contour integral is in the counter–clockwise direction.

In the section 3.1, "w" of the left of Eq. (3.2b) should be read ω.

In the section 3.1, the schematics prepared as Fig. 1 here will be added in the revision in order to show a geometry of $\partial S_{ij}^{\pm}$. This schematic will also make it clear that there could be more than three components neighboring to a given particular component.

Here, the schematics show the definitions of the boundary segments for the j-th subgrid component. The boundary is first divided into the two parts: those associated with the outflow, ∂S_j^+, and those associated with the inflow, ∂S_j^-. In the figure, the outflow segment, ∂S_j^+, is shown by a thick curve. The inflow segment is, in the present case, further divided into the four subsegments, $\partial S_{ji_1}^-$, $\partial S_{ji_2}^-$, $\partial S_{ji_3}^-$, and $\partial S_{ji_4}^-$, adjacent to the subgrid components, i_1,i_2,i_3,i_4, respectively. Note that this schematics focused on a single contour contribution to the j-th component. In general, a j-th component is found everywhere over a grid box with similar subdivisions to the segment boundary.

The effect of the vertical wind–shear on subgrid–scale structures is difficult to estimate precisely, though a crude estimate can relatively be easily made in the following manner. Assume that a subgrid–scale structure with a vertical scale H is continuously tilted by a differential wind, ΔU. Clearly, the tilt becomes noticeable after a time, Δt, when the condition $H \sim \Delta U \Delta t$ is satisfied. When $H \sim 10$ km $\sim 10^4$ m and $\Delta U \sim 1$ m/sec are assumed, the tilt becomes noticeable after $\Delta t \sim 10^4$ sec ~ 3 hours. Of course, this

estimate is extreme, because no subgrid–scale structure would simply be tilted like a ridged body twisted by a torque. Furthermore, a typical subgrid–scale structure like a convective tower would typically has a life span less than 3 hours.

The present formulation allows a continuous description of the all subgrid–scale components, as long as it remains $\sigma_j > 0$, without any triggering condition to initiate them. However, once it reaches $\sigma_j = 0$, such a continuous description is no longer possible. This component must somehow be re–initiated back to $\sigma_j > 0$ by a certain "triggering condition" as remarked in the section 4.4.

Technical corrections

I much appreciate the the typographical errors pointed out by the present referee. All these errors will be corrected in the revised text.

Interactive comment on Geosci. Model Dev. Discuss., 4, 3127, 2011.

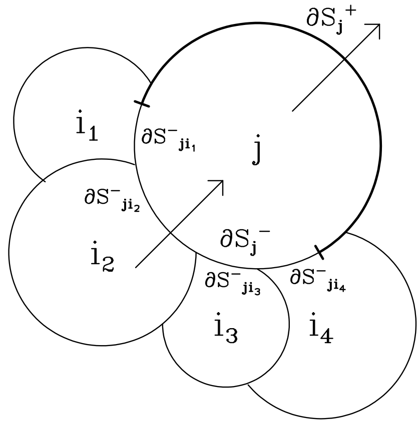

Fig. 1. Schematics for showing the definitions of the boundary segments for the j-th subgrid component.