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Analyzing and leveraging self-similarity for variable resolution atmospheric models

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Variable resolution modeling techniques are rapidly becoming a popular strategy for achieving high resolution in a global atmospheric models without the computational cost of global high resolution. However, recent studies have demonstrated a variety of resolution-dependent, and seemingly artificial, features. We argue that the scaling properties of the atmosphere are key to understanding how the statistics of an atmospheric model should change with resolution. We provide two such examples.

In the first example we show that the scaling properties of the cloud number distribution define how the ratio of resolved to unresolved clouds should increase with resolution. We show that the loss of resolved clouds, in the high resolution region of variable resolution simulations, with the Community Atmosphere Model version 4 (CAM4) is an artifact of the model's treatment of condensed water (this artifact is significantly reduced in CAM5).

In the second example we show that the scaling properties of the horizontal velocity field, combined with the incompressibility assumption, necessarily result in an intensification of vertical mass flux as resolution increases. We show that such an increase is present in a wide variety of models, including CAM and the regional climate models of the ENSEMBLES intercomparision. We present theoretical arguments linking this increase to the intensification of precipitation with increasing resolution.