Contribution ID: **7** Type: **not specified**

Temperature discretizations for the IFS, horizontal to vertical resolution aspect ratio and their importance for accurate global weather predictions

Wednesday, 16 September 2020 09:45 (45 minutes)

In a continuous effort to increase the horizontal resolution of NWP models, vertical resolution increases often lag behind. This results in an inconsistent horizontal-to-vertical resolution aspect ratio, which has detrimental consequences for ECMWF-IFS employing vertical finite element vertical discretization. In particular, global-mean temperature in the stratosphere unphysically cools when the horizontal resolution is increased without a concomitant increase in the vertical resolution. Such horizontal resolution sensitivity is undesirable for model development and/or for 4d-Var, where each minimization loop is performed at a different horizontal resolution. The unphysical cooling arises because at higher horizontal resolution smaller scale gravity waves are generated not only in the horizontal direction but also in the vertical. If the vertical resolution is not adequate, these gravity waves alias into a vertical grid-scale mode in the temperature field, leading to spurious thermal sources. Apart from an increase in the vertical resolution, alternative solutions to the unphysical global-mean cooling are presented.

Another source of discretization errors in the thermodynamic formulation of ECMWF-IFS is the use of temperature as a prognostic variable instead of potential temperature. In the potential temperature formulation, the thermodynamic variable is materially conserved whereas it is not in the temperature formulation. In the second part of this talk, a semi-implicit system using potential temperature as a prognostic variable is derived and the performance of ECMWF-IFS is compared to the temperature formulation. It is shown that the two formulations behave comparably under several scenarios.

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