Quantification of non-hydrostatic effects and the role of vertical resolution in HOMME

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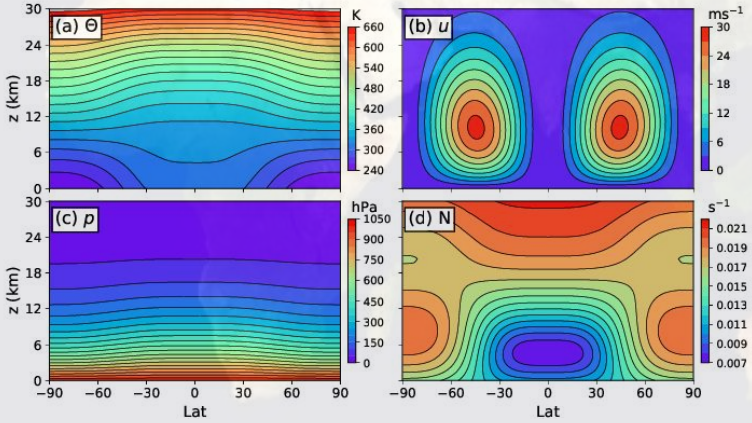
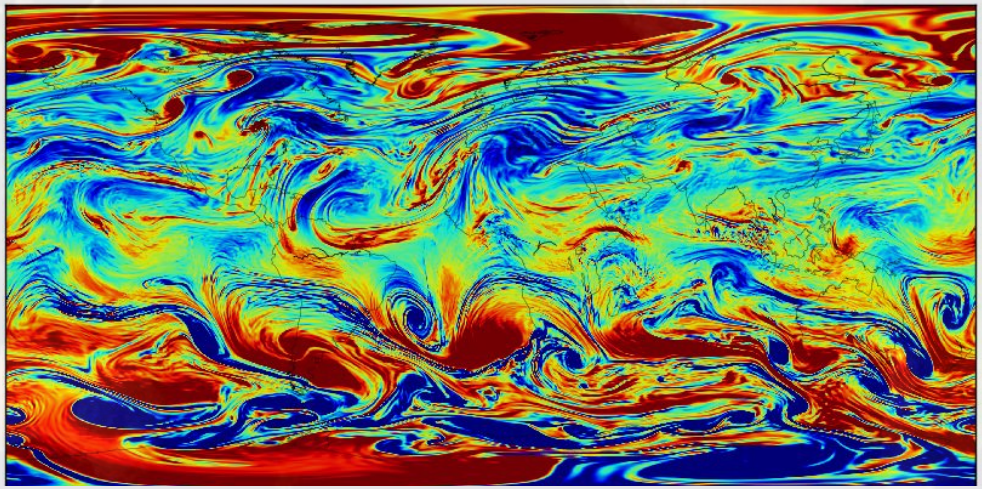
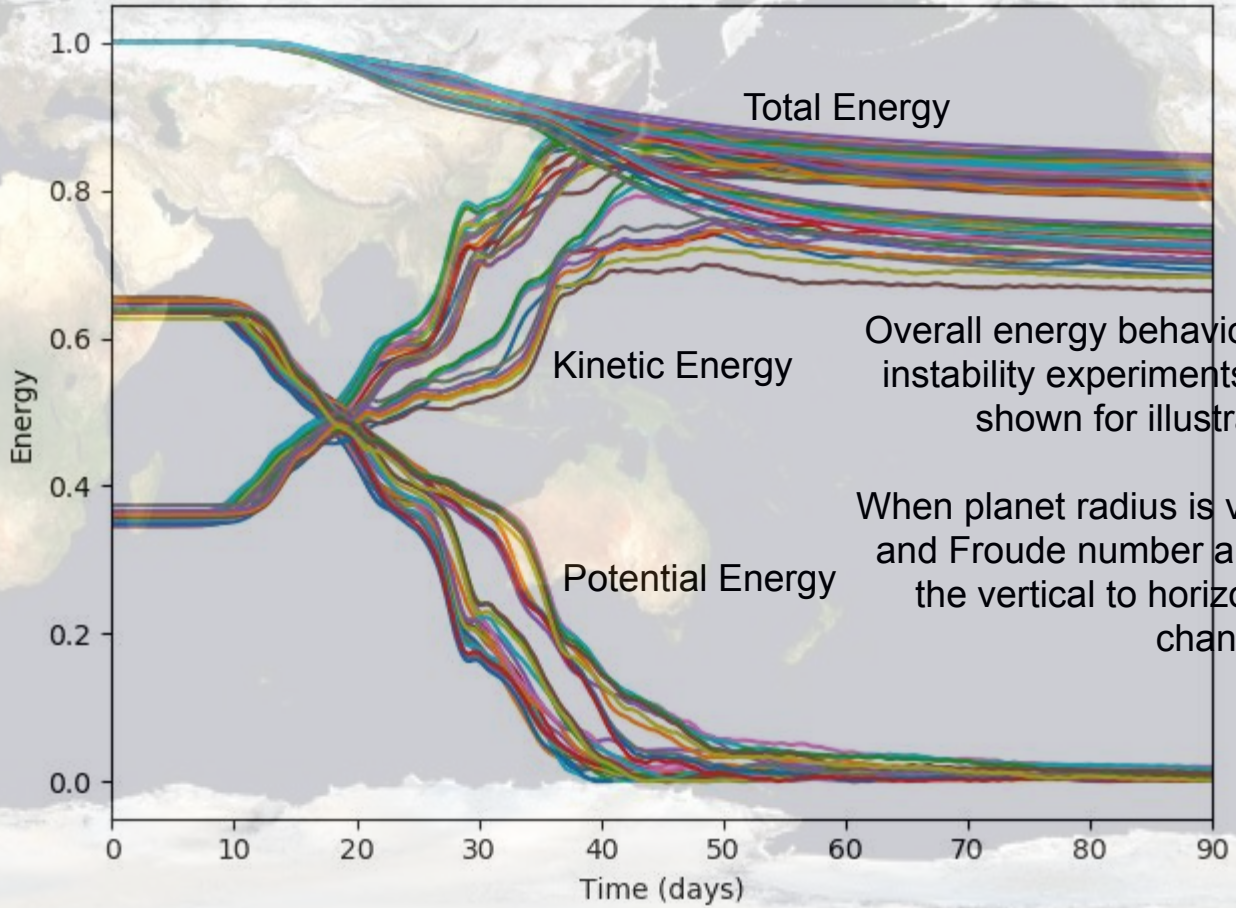
Nonlinear Evolution of Baroclinic Instability





Left: Initial Condition; Right: Nonlinear phase (relative vorticity)

Number of Vertical Levels and Planet Radius are Varied

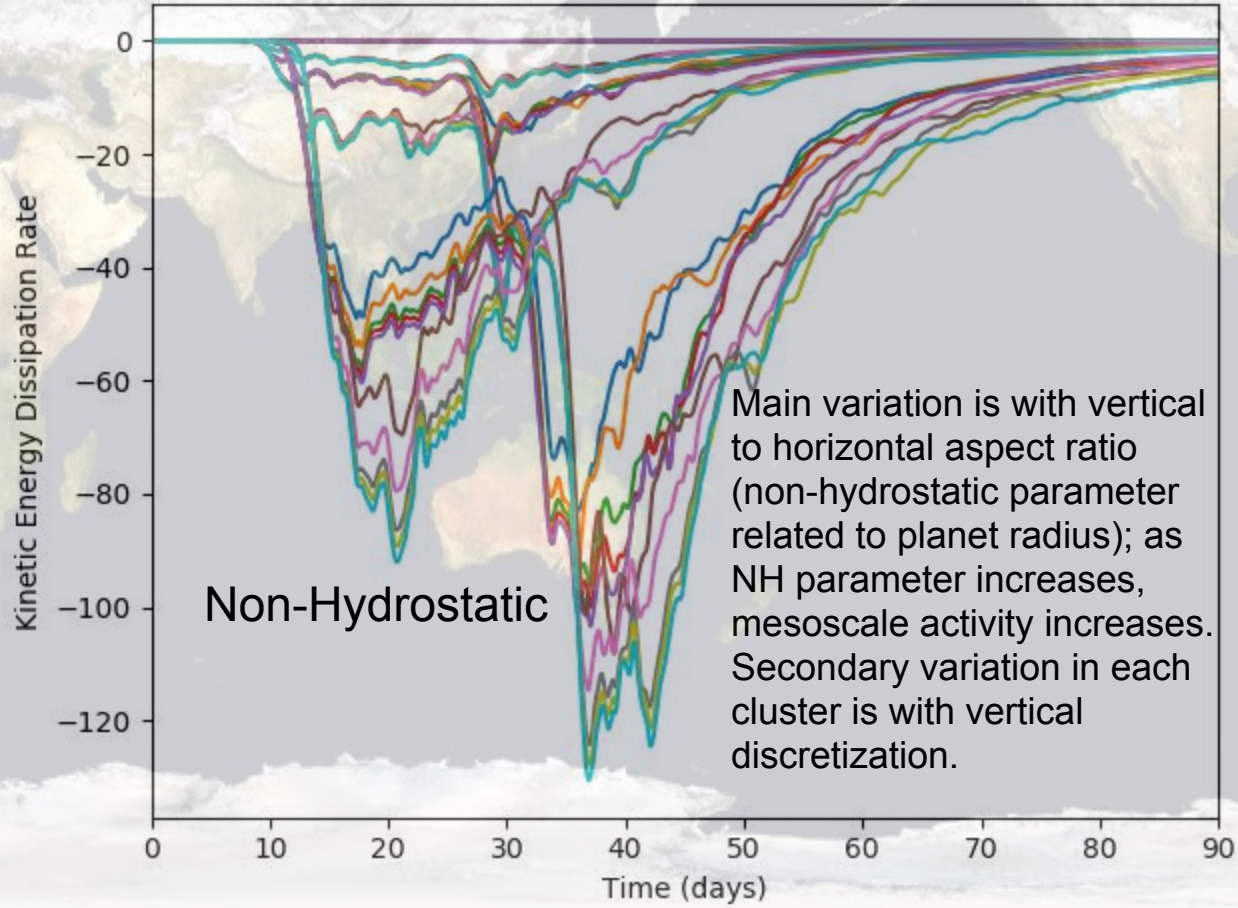


Overall energy behavior in a set of baroclinic instability experiments with HOMME-NH is shown for illustration purposes.

When planet radius is varied, Rossby number and Froude number are held constant; only the vertical to horizontal aspect ratio is changed.

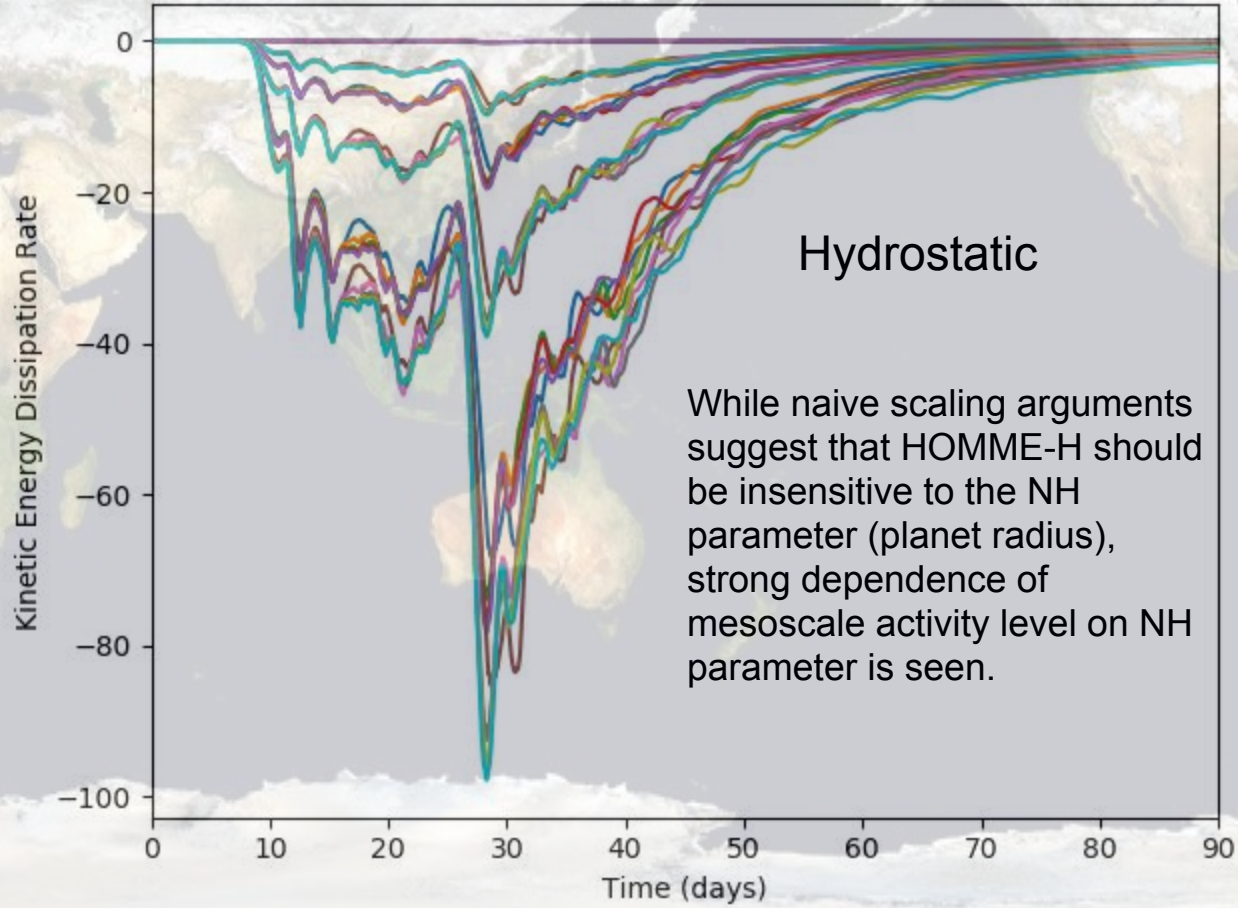
Even though BC is a large scale instability, resulting strain and deformation lead to frontogenesis and other smaller scale imbalanced instabilities (e.g., see Nadiga 2014). The latter leads to a forward cascade of kinetic energy that is dissipated by hyperviscosity in HOMME. We measure that dissipation and use it as a proxy for mesoscale activity.

Mesoscale Activity in HOMME-NH as measured by KE Dissipation Rate



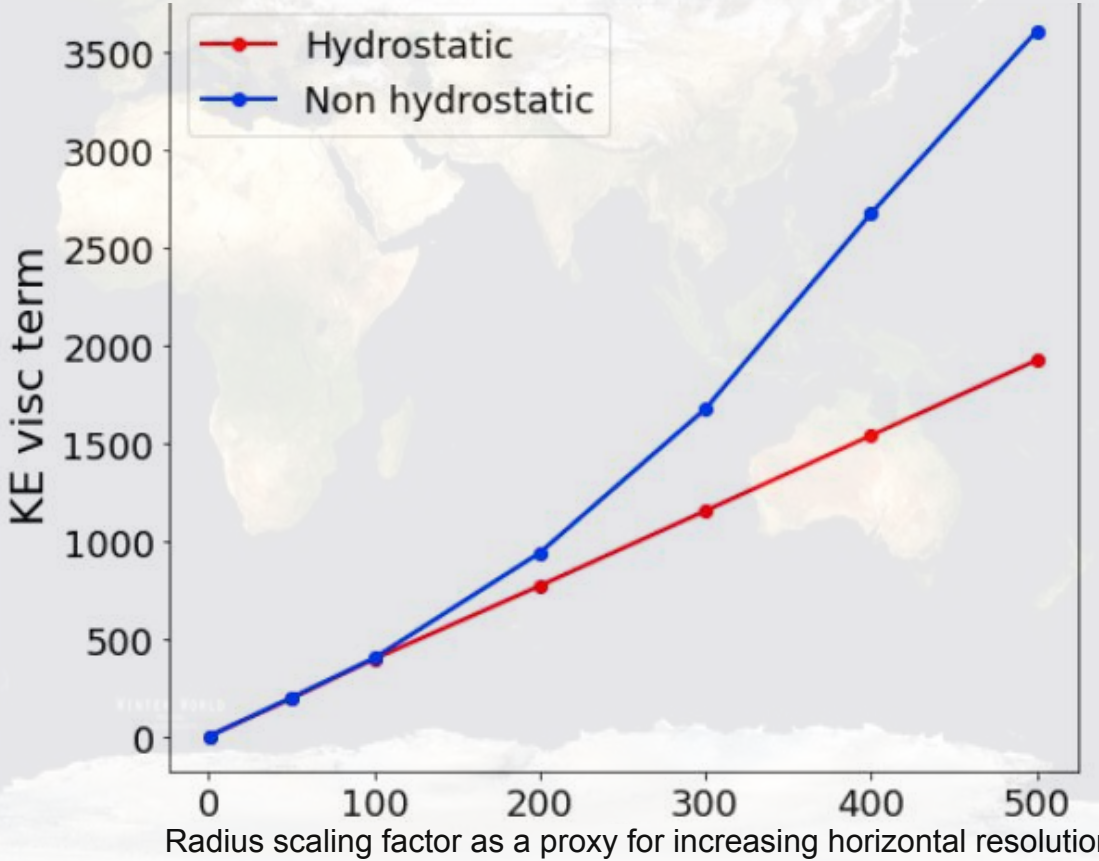
Main variation is with vertical to horizontal aspect ratio (non-hydrostatic parameter related to planet radius); as NH parameter increases, mesoscale activity increases. Secondary variation in each cluster is with vertical discretization.

Mesoscale Activity in HOMME-H as measured by KE Dissipation Rate



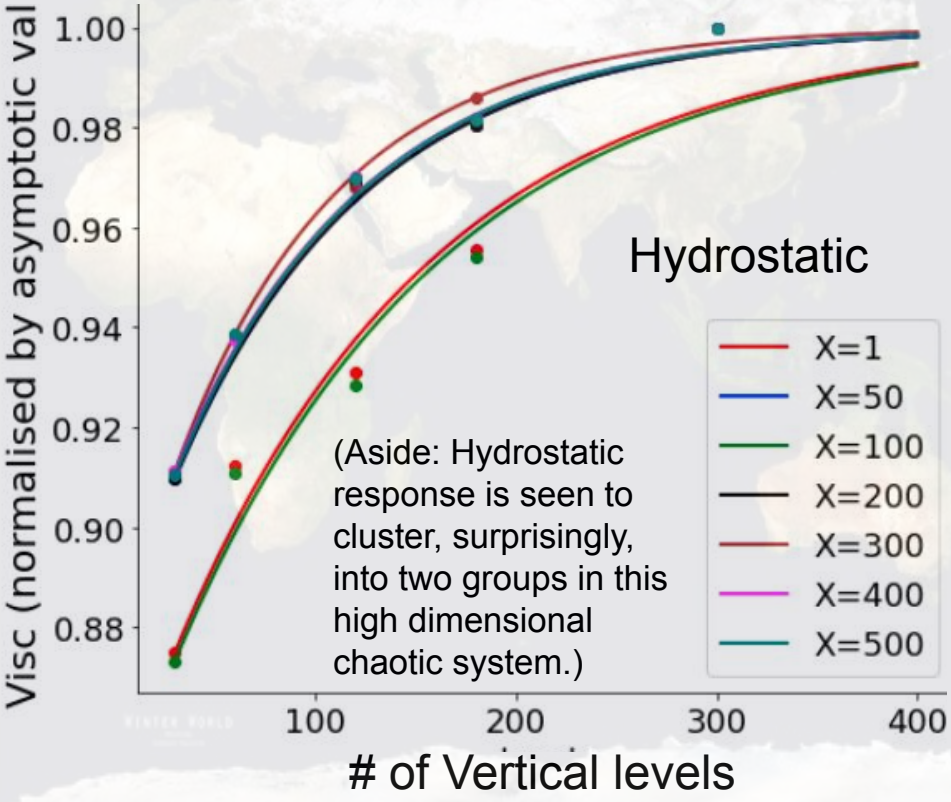
While naive scaling arguments suggest that HOMME-H should be insensitive to the NH parameter (planet radius), strong dependence of mesoscale activity level on NH parameter is seen.

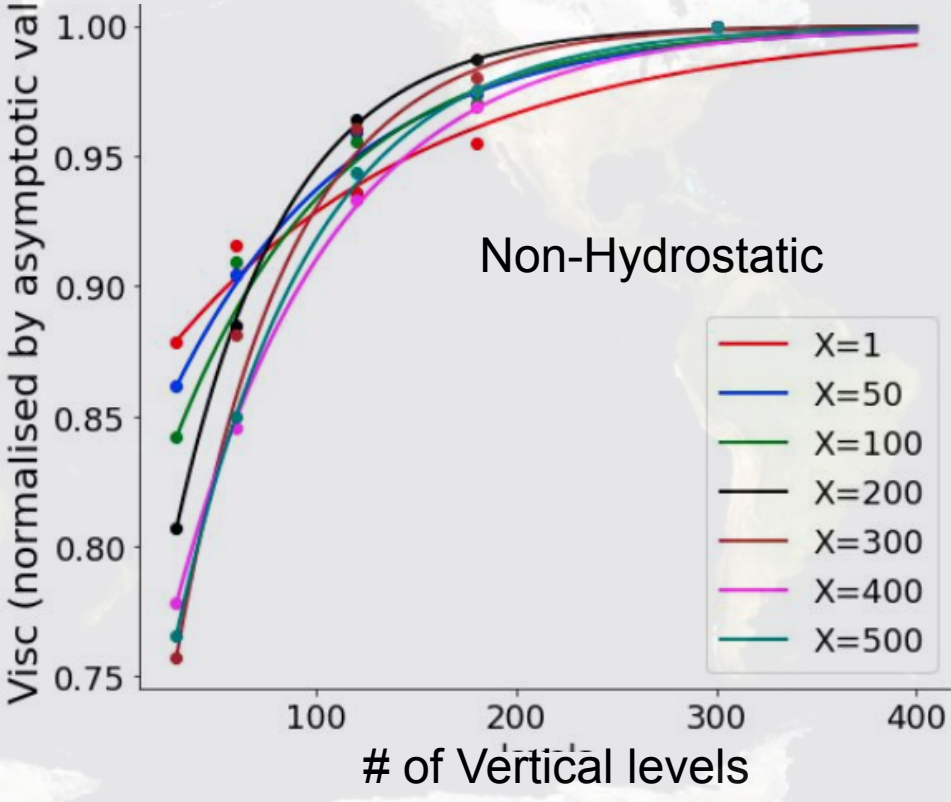
Representation of Mesoscale Processes in the Hydrostatic Approx. is Incomplete, sometimes Incorrect



The hydrostatic approximation permits only an incomplete representation of the full complement of imbalanced processes available under the full NH equations. Further detailed analysis of mesoscale processes show shortcomings and how interactions with numerics begin to be important

Mesoscale activity is under-represented in both hydrostatic and NH settings at vertical resolutions that are typical (lower end of x-axis)





Convergence of the considered measure of mesoscale activity is seen with increasing number of vertical levels

Summary and Conclusions

- Contrary to naive scaling arguments that suggest that the **hydrostatic** equations should be insensitive to the NH parameter (we use reducing planet radius as a proxy for increasing horizontal resolution), a strong dependence of mesoscale activity level on NH parameter is seen
- The hydrostatic approximation permits only an incomplete representation of the full complement of imbalanced processes available under the full NH equations
- Typically used vertical resolutions (30 to 72 levels) lead to an under-representation of mesoscale activity in both hydrostatic (by about 10%) and NH settings (up to as much as 25%)