New Climate Models:

The ICON Hydrostatic Atmospheric Model on Triangular Grids

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ICOHAM

As a member of the ICON model system (cf. poster W25B of Giorgetta et al.) and based on the work of Bonaventura and Ringler (2005), the Icosahedral Hydrostatic Atmospheric Model (ICOHAM) is developed as an intermediate step towards the fully compressible nonhydrostatic model system. The triangular version of the new model (Wan, 2009) is tested with a series of idealized experiments, and compared against the ECHAM model (Roeckner et al. 2006) to evaluate the performance of the mimetic finite difference schemes on icosahedral grids.

Model Configuration

Dynamical core:

- Icosahedral grids with triangular control volume in the horizontal, hybrid *p*-*σ* coordinate in the vertical, both with C-grid staggering.
- Mass conservation; no spurious energy source/sink due to advection.
- Several choices of time stepping schemes: leapfrog with semi-implicit correction, two time level semi-implicit scheme, four-stage Runge-Kutta, and strong stability preserving Runge-Kutta scheme.

Large-scale tracer transport:

- Flux-form semi-Lagrangian algorithm with various options for sub-grid distribution reconstruction.
- Consistent with the continuity equation when a two-time-level integration scheme is used for the dynamical core.

Diabatic physics: same as the ECHAM model.

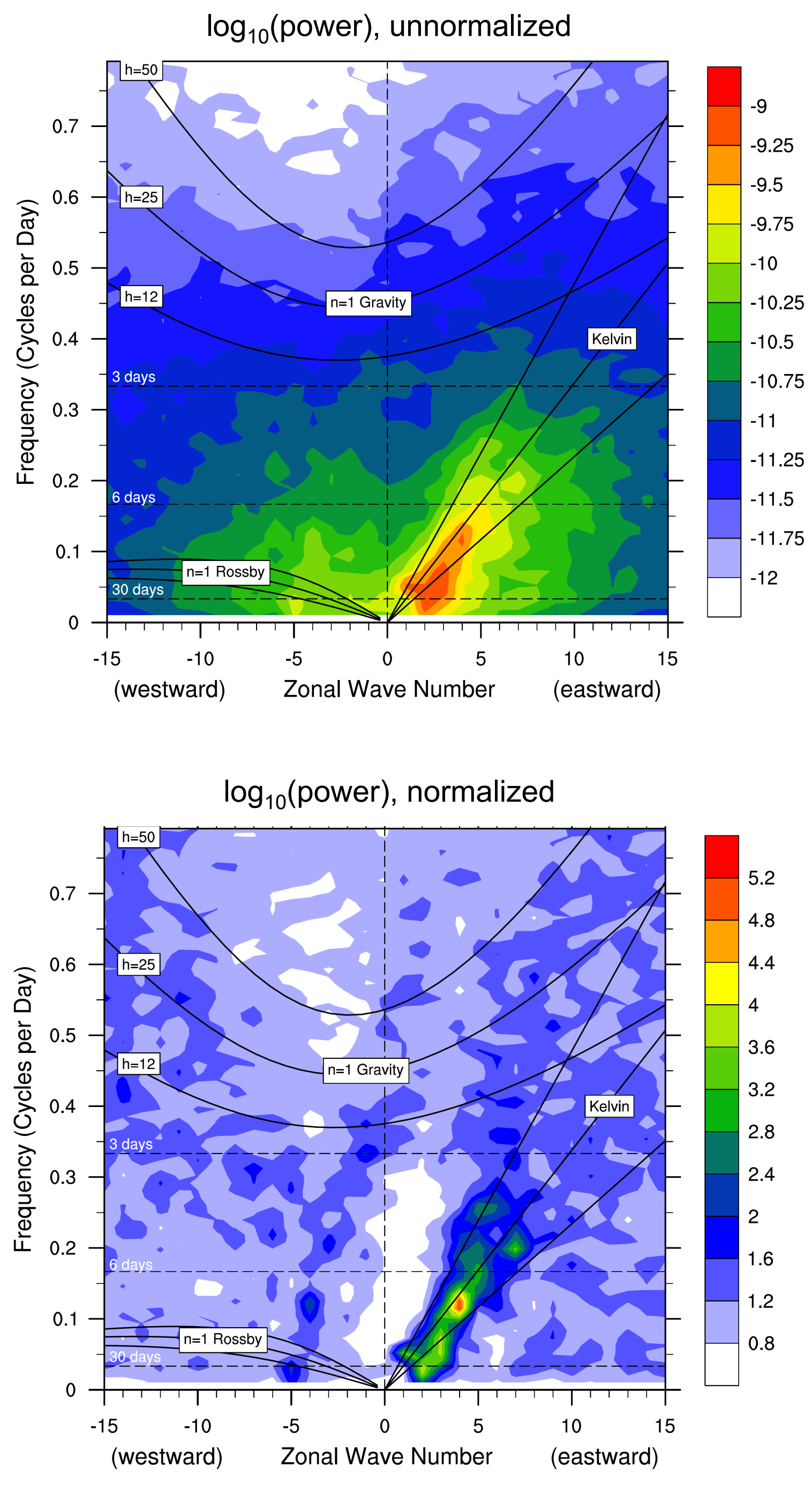

Fig. 4: Aqua-planet simulation (Neale and Hoskins, 2000) performed with ICOHAM at R2B4 resolution (140 km) forced by the “control” sea surface temperature profile. The model produces a single ITCZ at the equator (not shown). Panels on the left are wavenumber-frequency diagrams showing the symmetric component of the power spectra of equatorial (10ºS-10ºN) precipitation, diagnosed using the methodology of Wheeler and Kiladis (1999). The upper and lower panels display the unnormalized and normalized spectra, respectively, plotted as base-10 logarithm of the power.

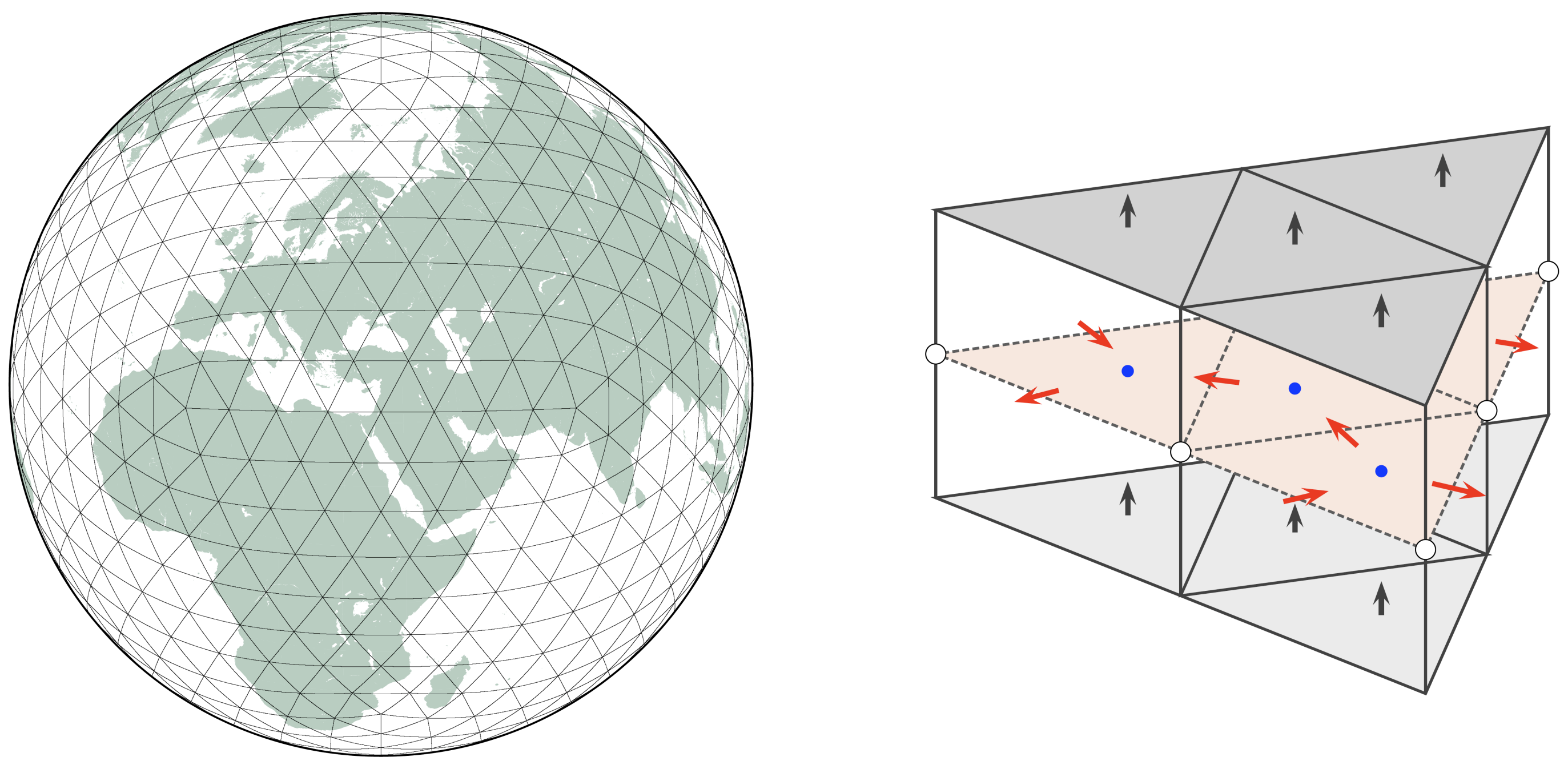

Fig. 1: Left: A triangular mesh on the sphere obtained by projecting and sub-dividing an icosahedron; Right: A piece of the 3D grid used by the dynamical core of ICOHAM. The air mass, temperature and tracer concentration are predicted at the center of each prism-shaped control volume (the blue point in sketch). The horizontal and vertical velocities (red and black arrows) are computed at the interface between cells.

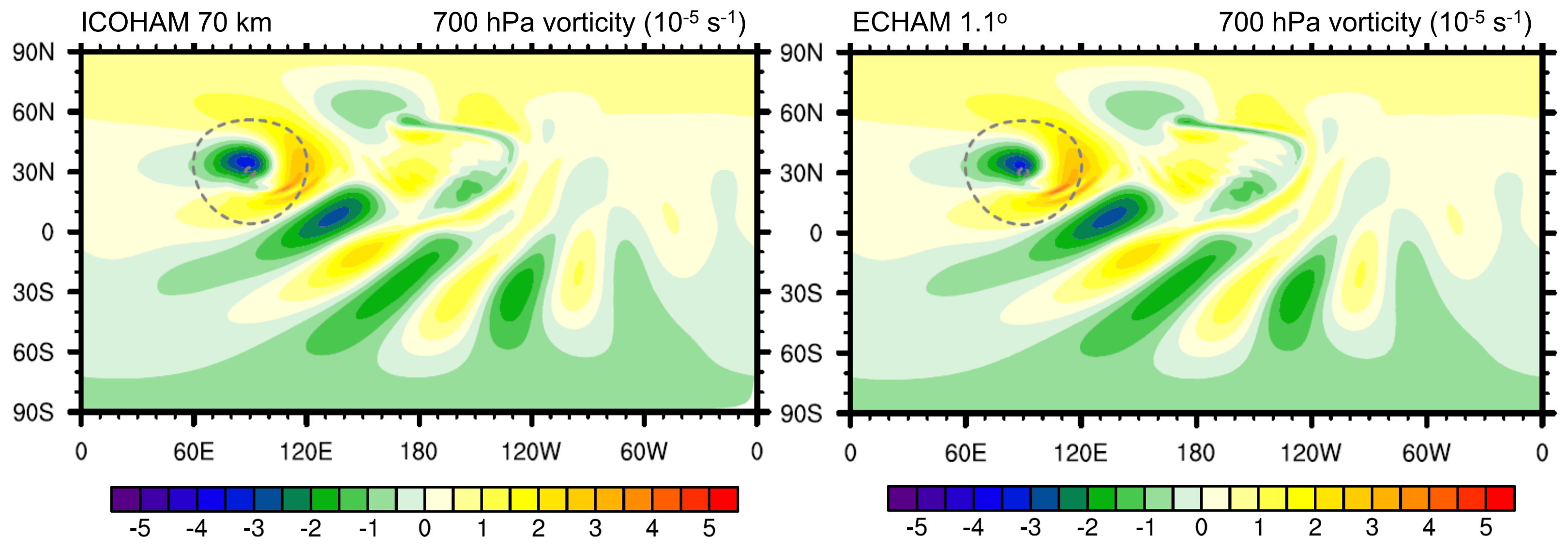

Fig. 2: A dry dynamical core test in which a planet-scale wave pattern (color shading) is generated when westerly flow impinges on a mountain (indicated by the dashed line). The 700 hPa vorticity field (unit: 10^{-5} s^{-1}) simulated by the new model with 70 km grid size shows very good agreement with the reference solution given by the spectral core at 1.1º resolution.

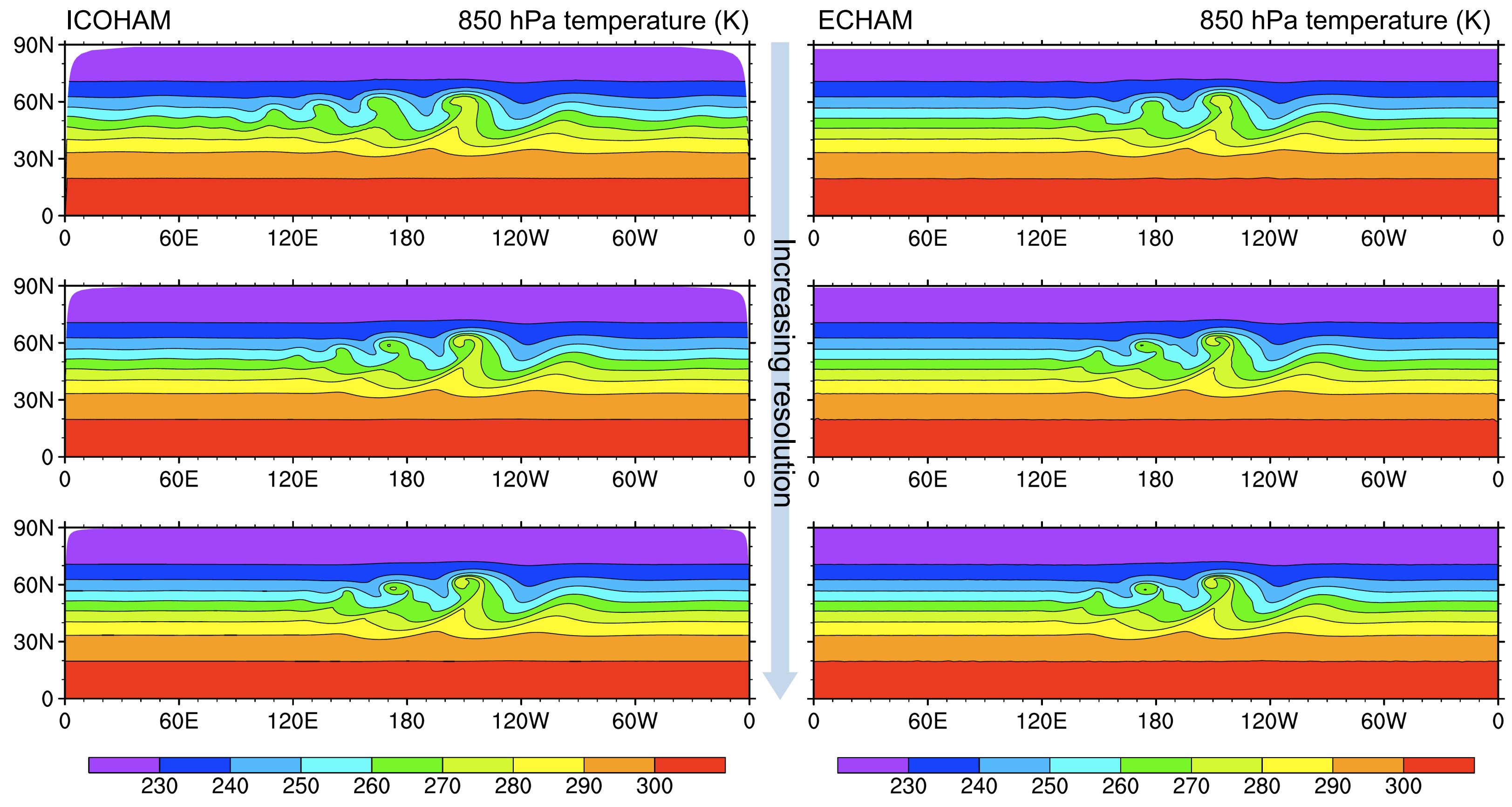

Fig. 3: 850 hPa temperature (unit: K) associated with cyclones simulated in a baroclinic instability test case (Jablonowski and Williamson, 2006) for the dry dynamical core. ICOHAM simulations closely resemble the reference results from a spectral model. Convergence of the numerical solution with respect to horizontal resolution can be seen clearly.

References

Bonaventura and Ringler (2005): Mon Wea Rev, 133, 2351-2373
Jablonowski and Williamson (2006): Q J Roy Meteor Soc, 132, 2943-2975
Neale and Hoskins (2000): Atmos Sci Lett, 1, 101-107
Roeckner et al. (2006): J Clim, 19, 3771-3791
Wan (2009): Reports on Earth System Science, 65, 152pp
Wheeler and Kiladis(1999): J Atmos Sci, 56, 374-399

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