

Responses to comments on egusphere-2026-2293: ‘A mountain-generated mesoscale test case from DCMIP-2025: Gap flow and vortex shedding variants’

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1 General Response

Thank you for taking the time to review the paper. Below (in red) are our responses to the reviewer comments.

2 Reviewer 1

While the proposed mountain-generated flow test case is potentially useful and the manuscript provides a detailed description of the test case, I do not believe the manuscript, in its current form, meets the scientific standard expected for publication in GMD. The paper is presented primarily as a numerical benchmark for evaluating atmospheric dynamical cores, yet the analysis remains largely qualitative and descriptive. Differences among the participating models are almost exclusively assessed through visual inspection of contour plots, with little quantitative evaluation using objective error metrics, convergence studies, conservation diagnostics, or a converged reference solutions. A DCMIP benchmark should ideally provide objective measures with which the behaviour of different numerical formulations can be quantitatively assessed.

We have added more quantitative discussion and comparison of the simulations. We firstly note that there is no analytical solution of this test case, hence we do not provide a global error metric (such as an L2 error). Instead, we quantify key features of the gap flow and vortex shedding test that can be compared between models, or for different configurations of the same model. To highlight the qualitative measures, we have explicitly added new ‘Diagnosed fields and metrics’ subsections in the gap flow and vortex shedding sections (sections 4.2 and 5.2, respectively).

The new metrics we have included are:

- An equatorial asymmetry measure for the gap flow test, as described in lines 387–394 and equation (23). Equatorial asymmetries for the dynamical cores are quoted in Table 5. We also quote the change in equatorial asymmetry for FV3 and MPAS in the diffusion studies of Section 6.
- Positions of the lee vortices in the gap flow test with rotation, identified through the maximum temperature perturbation in each hemisphere. This reflects the transport of the vortices during the simulation. Lee vortex positions for the dynamical cores are quoted in Table 4. We use this metric to quantify differences in the vortex transport between the models (the vortices are transported further in SE and MPAS compared to FV3 and GungHo). This diagnostic also highlights asymmetry in MPAS simulations, with different lee vortex locations and maximum temperatures between the northern and southern hemispheres. We use this metric in the MPAS diffusion study (section 6.3).
- Positions and strengths of leading vortices in the vortex shedding tests (with and without rotation). For the case without rotation, both the leading positive and negative vortices are identified, whilst just the leading positive vortex is quoted in the case with rotation. We use this metric to quantify the weakening of the leading positive vortex with increased diffusion in SE and FV3 (sections 6.1, 6.2 and Figures 17 and 19). It also quantifies that the vortex street without rotation for MPAS is curved equatorwards (Figure 13).

To provide an indication of spatial convergence, we have run the tests with SE and FV3 at a finer, approximately quarter-degree, resolution. Comparisons of the half-degree and quarter degree simulations are provided in the supplementary material (Figures S.1–S.12). We mention these higher resolution runs in the manuscript in lines 266–267.

For the gap flow, we also provide another analysis method of plotting zonal velocities along the equator (Figure 7). This highlights the two regions of accelerated flow in the case without rotation, and the single accelerated region for the case with rotation. We mention that vertical cross sections along the equator are also insightful, and provide examples of this in the supplementary material (Figures S.13, S.14).

We also note that a key purpose of this manuscript is providing a framework for further exploration of mountain-generated dynamics, through modifications of the orography and flow parameters. This is described in the introduction (lines 93–98).

Consequently, many of the interpretations regarding the influence of diffusion, grid staggering, or discretization remain speculative rather than being rigorously demonstrated. This is particularly important because the manuscript itself recognizes that the vortex-shedding behavior is sensitive to the effective numerical diffusion and therefore to the different explicit and implicit dissipation mechanisms employed by the dynamical cores. Nevertheless, the manuscript does not establish numerical convergence or demonstrate that the observed differences reflect intrinsic properties of the numerical methods rather than resolution- or diffusion-dependent effects. Also, statements attributing differences in smoothness, vortex strength, symmetry, or

propagation to particular properties of the dynamical cores remain largely speculative. For example, differences are frequently attributed to diffusion, grid staggering, or the D-grid/C-grid formulation, but these effects are not isolated experimentally, making such conclusions difficult to substantiate and establish causality.

We have sought to address this concern primarily through the addition of new metrics, as discussed in the previous reply. We suggest that there is not enough space in this manuscript to properly delve into the numerical aspects that cause each noted behaviour; such analyses would require a separate manuscript to properly investigate the specific causes. We discuss that this would be fruitful future work in the conclusions (lines 571–572).

As discussed in the response to the first paragraph, the new metrics provide evidence for the more quantitative claims in the paper. Statements around vortex strength in the vortex shedding case are now based off the relative vorticity peaks for the leading positive and negative vortices. Comments around symmetry are justified through the new equatorial asymmetry metric. Transport differences are quantified by the location of the lee vortices in the gap flow with rotation, and the leading vortices in the vortex shedding tests.

In its current form, the work documents that different models produce different solutions, but it does not provide the level of numerical analysis required by a journal publication to explain, quantify, or evaluate those differences. Addressing these shortcomings would require substantial new numerical experiments and analyses and potentially restructuring of the manuscript rather than revisions to this version alone. For these reasons, I cannot recommend publication in its current form and recommend rejection, while encouraging the authors to substantially strengthen the numerical evaluation and resubmit a revised manuscript in the future.

We wish to point out that there are a number of published papers whose purpose is to outline a new test and document differences between dynamical cores. These include dynamical core test cases previously published in GMD, including the DCMIP supercell test case (Zarzycki et al. 2019) and the DCMIP tropical cyclone test (Wilson et al. 2024), and the baroclinic wave test case with orography (Hughes and Jablonowski, 2023). Our paper aims to continue in the vein of these previous works.

3 Reviewer 2

The manuscript addresses a need for test cases when evaluating dynamical cores of numerical models on smaller (local, regional) scales when no analytic solutions exist. Two new cases are presented, a gap glow and vortex shedding. The authors use a reduced-radius sphere to test dynamical cores of global models, and four dynamical cores are compared for both cases. Special attention is given to the impact of numerical diffusion on the flow evolution. The manuscript is concise, with sound reasoning for the experiment setup choices, and enough details for readers to attempt to replicate the test cases when testing their dynamical cores.

Minor comments

1) For the gap flow case:, computing of field extrema did not account for the gap itself (L376: exclusion of the region between 170 and 190 degrees). Low-level gap flow maxima can actually occur within the gap, especially for the non-dimensional mountain height 2.73 presented in the paper.

For the gap flow, field extrema are now computed for the entire domain, excluding locations that are inside the orography or one cell away from the orography. This is described in lines 386–387. The modified metric now captures any extrema located within the gap.

2) Vertical cross-sections for the gap flow would be beneficial too, especially if the inverse Froude number is lowered to around 1-1.5.

We have made such visualisations for CAM-SE and CAM-FV3 and have placed them in the supplementary material for the sake of paper length (Figures S13, S14 for the standard test, and Figures S19, S20 for a reduced inverse Froude number of 1.37). We discuss such vertical cross-sections in the gap flow test in lines 383–385.

3) For the lower inverse Froude number (1-1.5), the pressure perturbation induced by the lee mountain wave plays an important role in the gap flow acceleration. I wonder how the chosen hydrostatic dynamical cores would resolve that? It would be useful to know what to expect from the same global NWP model dynamical cores as the horizontal grid spacing gets finer, and more regional features and their topographic forcing become important.

We have run a simulation with a lower inverse Froude number of 1.37, which is achieved by increasing the maximum zonal wind speed in the initial condition from 10 m s^{-1} to 20 m s^{-1} . We have run this simulation with the CAM-SE and CAM-FV3 dynamical cores and provide the results in the supplementary material (Figures S15–S20). We reference these modified simulations in the manuscript at lines 373–375.

4) Temperature perturbations are hard to visualize in all figures. Maybe use the same blue-white-red color map?

We have changed colour map for the temperature perturbation plots to a blue-yellow-red map.

5) I like the proposed modifications to the test case design described in the summary. I wish there were some examples for at least one dynamical core (e.g., gap width, length, inverse Froude number).

As per comment 3, we have run gap flow simulations at a lower inverse Froude number for CAM-SE and CAM-FV3. These are provided in the supplementary material (Figures S15–S20).