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Comments from RC1 (Anonymous Referee 1, 17 Jun 2026):

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Dear editor,

Thank you for the opportunity to review the manuscript. I would like to recommend the article titled "Subtropical Extreme Heatwave Dynamics in the Intermediate-Complexity Atmospheric Model Aeolus 2.0" for publication after minor revision.

The authors employ the intermediate-complexity multilayer moist-convective Thermal Rotating Shallow Water (mcTRSW) (Aeolus 2.0 framework) to investigate the dynamics of localized buoyancy anomaly driven extreme heatwaves in the subtropical atmosphere. The study systematically conducts idealized numerical simulations across a multi-dimensional parameter space, including dry/moist convection, barotropic/baroclinic configurations, and weak/strong anomaly amplitudes. The results present a range of dynamical phenomena, including the initial adjustment process, the propagation of inertia–gravity waves, the simultaneous generation of cyclonic and anticyclonic circulations, and the evolution of precipitation structures, while also reproduce several canonical observational signatures, including comma-shaped water vapor patterns, spiral rainbands, and mesoscale vortices. Overall, the topic is of scientific interest, and the manuscript is generally well organized. But I have several comments about the paper.

Author response:

Dear Reviewer,

We appreciate the time and effort you have dedicated to providing feedback on our manuscript, and we are grateful for your insightful comments and valuable suggestions for improving our paper. We will carefully review all of the concerns raised and incorporate the necessary changes into the revised manuscript.

Comments:

1. The authors do not report the functional form (f-plane or β-plane) or the numerical values of the Coriolis parameter used in the model and numerical simulations.

Author response:

The numerical value for the meridional gradient of the Coriolis parameter (β) at the Equator is 2.2793 10^{-11} m^{-1} s^{-1}. This value is presented in the **`config.py`** (https://zenodo.org/records/18065000 > Aeolus2.0_model/config.py > line 75) under the name **`beta_eq`**.

The model uses the barotropic equatorial Rossby deformation radius (L_d) (lines 113-116 on the Manuscript) for nondimensionalization, applied to simplify the system dynamics. The β-plane effects are introduced in the L_d term.

Additionally, the thermogeostrophic balance described in **Equations (2a–b)** accounts for the Coriolis parameter within the Rossby number calculation under an adiabatic setting (lines 147–153 of the manuscript).

2. The authors explicitly state in the Conclusions Section that "*Compared to studies based on earlier versions of our model, adding certain real-world characteristics, such as topography and background wind velocity effects, in a novel development that improves the fidelity of the experiments*". However, upon careful examination of the full manuscript, no mathematical formulation, numerical implementation, or diagnostic analysis of topographic effects is provided anywhere in the text. If topography was indeed implemented, the authors should provide its mathematical formulation, implementation details, and a sensitivity analysis demonstrating its impact. If not, the reference to topography should be removed from the novelty statements and, if appropriate, moved to the future work section.

Author response:

The topography formulation is described in the Model Description section (lines 125–129 of the manuscript):

"To define the structure of the pressure gradient terms in the governing equations, we specify the relevant velocity and pressure-related quantities for each model layer. In this formulation, $\langle \nabla p_i \rangle = \nabla \tilde{p}_i - \tilde{h}_i \nabla b_i$ represents the vertically-averaged horizontal gradient of the pressure field. For the 2 layers schema, the lower layer gradient is $\langle \nabla p_1 \rangle = (1/2) h_1 \nabla b_1 + b_1 \nabla (h_b + h_1 + h_2)$, and in the upper layer $\langle \nabla p_2 \rangle = \nabla (h_1 b_1) + (1/2) h_2 \nabla b_2 + b_2 \nabla (h_b + h_2)$, where h_b is a bottom topography height, $\tilde{p}_1 = (h_b + h_1 + h_2) b_1$, $\tilde{p}_2 = h_1 b_1 + (h_b + h_2) b_2$, $\tilde{h}_1 = h_b + (1/2) h_1 + h_2$, and $\tilde{h}_2 = h_b + (1/2) h_2$."

The gradient of the pressure term ($\langle \nabla p_i \rangle$) carries the bottom topography effects, calculated for the two layers schema using the bottom topography height (h_b) in the formulation, to represent its contribution into the governing equations **- Equations (1a-b)** and **(3a-b)**.

In addition to the dynamic equations, the thermodynamic terms $\mathcal{C}$ (condensed liquid water) and $\mathcal{D}$ (downward convective flux) were also parametrized in this version to account for the influence of topography.

The explicit implementation of topography within the model equations can be found in the **`aeolus2main.py`** (https://zenodo.org/records/18065000 > Aeolus2.0_model/aeolus2main.py > lines 1460-1464) under the variable name **`Dh10`**.

In the previous study conducted by Rostami et al. (2023; DOI: 10.1002/asl.1188) introducing the Aeolus framework, the conceptual experiments were performed in an atmosphere initially at rest, without the inclusion of background flow or topography. In contrast, the present work incorporates these factors, allowing us to evaluate how topography interacts with the background zonal flow and vertical wind shear to distort the developing pressure systems. Consequently, the upper-level anticyclonic ridges and surface low-pressure anomalies develop non-uniform, elongated geometries similar to real-world atmospheric blocking configurations. Furthermore, the background velocity field interacts dynamically with the imposed buoyancy anomalies, generating more realistic, comma-shaped water vapor signatures and complex spiral rainbands. This highlights how a localized thermal anomaly propagates through a moving atmosphere, shedding inertia-gravity waves that redistribute heat and momentum far from the initial heatwave center; by comparison, the configurations in Rostami et al. (2023) present a more stable, centered evolution.

A comprehensive sensitivity analysis comparing model runs with and without topography under the present buoyancy anomaly configuration will be pursued in a future study.

I have found some minor issues in the manuscript.

1. Page 10 line 225: Additional zonal and meridional divergence temporal evolution--->Additional zonal and meridional divergence temporal evolutions

2. Page 11 line 274: extremes scenarios--->extreme scenarios

3. Page 12 line 279: the strong cases shows--->the strong cases show.

I recommend acceptance of the manuscript after minor revision.

Author response:

The comments are accepted with thanks. We updated the text in the manuscript with corrections to be submitted.

We are going to make the points clearer in the text following the suggestions. A table of parameter values is planned to be added in Appendices.

Sincerely,

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