

Geosci. Model Dev. Discuss., author comment AC2  
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## Reply on RC3

Matthias Göbel et al.

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Author comment on "Numerically consistent budgets of potential temperature, momentum, and moisture in Cartesian coordinates: application to the WRF model" by Matthias Göbel et al., Geosci. Model Dev. Discuss., <https://doi.org/10.5194/gmd-2021-171-AC2>, 2021

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We are grateful to the reviewer for her/his insightful and constructive comments.

As we included a new equation and a new figure, the equation numbers and figure numbers have changed. Line, equation, and figure numbers in our replies refer to the revised manuscript.

- **As I understood it, the current implementation of WRFlux needs it to run online with WRF. I wonder if there is a way to provide an offline version without significant changes to the WRF code, which will be much easier to use for most people.**

Budget analysis on WRF simulations requires two steps: (1) Sending individual tendency terms to the WRF output stream; (2) Recursively averaging all relevant quantities over time to enable an estimation of the explicitly resolved turbulent fluxes. WRFlux implements the necessary code changes for both operations. Doing the same analysis entirely offline is not impossible in principle, but would not be efficient. As an alternative to step (1), one could develop code to compute budget terms from regular model output, mimicking exactly what WRF does; but this would imply rewriting large parts of WRF's dynamical core and parameterizations. As an alternative to step (2), one could output every single time step during the model integration and then do the averaging offline; but this would require immense storage space, besides being computationally inefficient in comparison to recursion. We believe our solution is an optimal compromise between the complexity of the task and the usability of the tool. The GitHub page (<https://github.com/matzegoebel/WRFlux/>) includes an extensive manual and we are open to help users getting the tool to run.

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**Section 2.1, Equation 11: I think it would be helpful to readers if a reference is made to the fact that all the WRF prognostic variables are so-called "coupled" (multiplied by the mass inside the grid cube per unit area) as explained in the technical notes?**

We added this in line 96.

- **Line 195: "The fluxes and all budget components except for advection are averaged in time during model integration". I don't know what "fluxes" refer to here. Surface fluxes?**

"Fluxes" refers to the subgrid-scale and resolved fluxes of the five prognostic model variables in the whole domain, not only at the surface. We changed this in line 212. The "except for advection" only refers to the budget components.

- **Line 280: "The only difference between the total tendencies in the terrain-following and the Cartesian formulation is the second term on the left-hand side in Eq. 11, which accounts for the height of the vertical levels being time-dependent". I wonder if the averaging contributes to the difference as well. For the first term in Eq. 11, the averaging is done after dividing by  $z_{\eta}$ .**

The coupled tendency is first calculated with the time-averaged flux in Eq. 10 and then divided by  $\langle \rho z_{\eta} \rangle$ . This was not stated clearly in the original manuscript, so we corrected the caption of Fig. 3.

- **The equation numbers are probably wrong in the figure/table labels, shouldn't they be Eqs. 13, 14 and 15 rather than 14, 15 and 16?**

Yes, indeed - thank you for spotting this. However, since we included an additional equation (Eq. 12) in the revised manuscript, the labels are correct now.

- **Line 313: "To quantify the differences, we plot the sum of all forcing terms for each budget calculation method against the actual model tendency ..." By that sentence do you mean plotting the LHS and RHS of Eqs. 13, Eqs. 13 with 2nd-order advection, 14 and 15 respectively? If so, It would be clearer to say that explicitly.**

Yes. We modified lines 347-348 and the caption of Fig. 6 accordingly.