NPG-2023-1519: Reply to comments from Referee #1

Below, you'll find our detailed responses addressing the reviewer's feedback. We truly appreciate the valuable input provided on our work. The initial comments are presented in bold font, followed by our responses in standard font.

1. The concept of potential was introduced at the end of section 2.2 and is only utilized in figure 2. However, this concept is not employed in the remainder of the paper. Could you please provide a more thorough explanation of the physical interpretation of this concept and how it relates to the other results?

We agree that a more detailed explanation of the potential is beneficial and will add it to the revised version.

2. The legends for figures 1 and 10 are very small and incomplete.

Thank you for pointing this out. We will fix that when we submit the revised version.

3. As a suggestion to improve the readability of the paper, I propose that section 2.3 be integrated into section 2.2 ("Impact of the choice of the stability function"). This consolidation would be beneficial since the results presented in section 2.2 involve randomized wind speeds. Alternatively, moving section 2.2 to section 2.3 would eliminate the need for readers to navigate back and forth in the manuscript.

We agree that the structure of the section 2 can be improved and will move section 2.2 to 2.3, as you suggested, to improve the readability. In addition, we will briefly introduce the randomizations (e.g. equation 3) in section 2.3 and give the current sections 2.3.1-2.3.3 more descriptive names.

We realize that we made a mistake in the description of figure 3. The additive noise model (equation 3, internal variability) has been used not the randomized wind speed model to create the histograms. We sincerely apologize and will correct the description of figure 3 in the revised version.

4. One curiosity: What is the computational cost of the method to randomize the stability function for application in NWP? Is it necessary to perform an ensemble of simulations or just a single simulation for the climate and weather models?

In principle, an ensemble of simulations is needed to see the multi-modality, as mentioned in the paper, in the output data and to get accurate regime occupation statistics. The answer to how many ensemble runs are required to achieve this depends on the goal and requires further research.

We expect large benefits from the inclusion of stochasticity, more in terms of sampling the variability, rather than improving the representation of the mean state. The usage of a randomized stability function potentially increases the variability of turbulent mixing, similar to what an increase in resolution would do by resolving more small-scale heterogeneity. Therefore, we hypothesize that a lower resolution may be required, but possibly a higher ensemble number would be needed. This hypothesis is, for example, supported by the research of Davini et.al. (2017) on evaluating the impact of stochastic physics parameterizations. They used multiplicative noise to represent model uncertainty due to the parameterization process in the EC-Earth global climate model. For their study, they ran a maximum of 10 ensemble members. The authors showed that the inclusion of stochasticity in the physics parameterizations can be as effective as resolution, and in some cases even more effective. In addition, they mention that with their setup the 16km resolution model can be run 9-10 times with the same amount of core hours as the 30km resolution one. Furthermore, the stochastic stability function we use is randomized in time. This might reduce the number of required ensemble members, as the time variability may act to sample appropriate statistics of mixing dynamics. Generally, the computational cost of a stochastic approach with higher ensemble number but lower resolution is potentially less than that of a high-resolution simulation, as the stochastic computations can be run independently and hence are highly parallelizable.

References:

Davini, P., and Coauthors, 2017: Climate SPHINX: evaluating the impact of resolution and stochastic physics parameterisations in the EC-Earth global climate model. Geoscientific Model Development, 10, 1383–1402, https://doi.org/10.5194/gmd-10-1383-2017.

5. line 120 - ODE is not defined.

Thank you for your comment. We will replace the abbreviation, ODE, with ordinary differential equation.

6. line 120 - "ΔT, between a reference height (Tr) and the surface temperature (Ts)" -> add "Temperature inversion".

We will add this to the revised version.

7. line 125 - ΔT is defined in line 125, and is no longer necessary.

Thanks for pointing this out. We will remove the duplicated definition of ΔT.

8. line 145, table 1 - units should not be in italics.

This will be fixed in the revised version.