

Response to Referee #1

We would like to thank the three reviewers for their helpful comments and corrections. We propose a revised version of the paper in which we have taken into account their comments and suggestions. We hope that our revisions will address their expectations.

In the following document, the reviewer's comments are shown in **black** and our point-by-point responses are in **blue**.

The main adjustments proposed in the new version of the manuscript are described below:

- The section "Code and data availability" has been modified to add a brief description of the ICOLMDZ model.
- We have reorganized the figures and tables to improve the flow as reviewers suggested. The figure and table numbers have changed from the initial version of the manuscript:
 - Figure 5 has been removed to avoid repetition with Table 5.
 - Table 3, Table 4, Figure 3 and Figure 8 have been moved to the Supplementary Material.
 - Table 6 has been removed.
 - Figures S2 and S4 were moved from the Supplementary Material to the main text.
 - For each tendency, the results obtained during the first learning and those obtained with the second learning were separated to ease the flow of the presentation of the results. The results of the second learning are only shown when they are discussed (in Section 5 "Refined approach: integrating physical knowledge"). The revised figure numbering, for the zonal wind tendency, is as follows: Figure 4 has been split into Figure 3 and Figure 9, and Figure 6 becomes Figure 4 and Figure 10. We did the same for the five other tendencies in the Supplementary Material. We also separated the results from Table 5 into two tables.
- We propose a new colour scheme for vertical profiles according to the Coblis-Color Blindness:

	Initial training	Second training with laplacians
DNN	Green with solid lines	Blue with solid lines
U-Net	Orange with dashed lines	Red with dashed lines

- Section 6 "Discussion" has been merged with Section 7 "Conclusions". The results of this merger is Section 7 "Conclusions and discussion".

- As suggested by the reviewer 3, new results on the emulation of a realistic configuration have been added to the manuscript in Section 6 “Results for a realistic setup”. The data used for this realistic configuration are described in Section 2.1 “ICOLMDZ simulation data”. The terms “for the aquaplanet setup” have been added to the names of Sections 4 “Initial training performance for the aquaplanet setup” and 5 “Refined approach for the aquaplanet setup: integrating physical knowledge” to avoid confusion.

The manuscript "Contribution of physical latent knowledge to the emulation of an atmospheric physics model: a study based on the LMDZ Atmospheric General Circulation Model" studies emulators for all parameterizations of the ICOLMDZ in an idealised aquaplanet configuration. The authors develop four emulators: two FCNs and two UNets, with two sets of input variables: the vertical profile of six state variables and four auxiliary variables in the first set, that are complemented by the vertical laplacian of the state variables in the second set.

Both network architectures are established and have been used to emulate components of GCMs. The main addition by this manuscript is that the authors investigate whether including latent variables as predictors can improve the prediction of physical tendencies. This can be relevant for researchers looking to replace the physical parameterizations with machine-learning based emulators, as stability and accuracy are very important for successful online emulators.

The FCN with vertical laplacians performs similar to the UNet (without vertical laplacians). Considering that the UNet input layer is built up of convolutions that can connect neighboring vertical levels, I find it conceivable that the UNet learns something like a vertical laplacian on the go, without the need to incorporate these predictors explicitly. Incorporating the laplacians also helps with variance, which is underestimated by all emulators.

The methods are outlined clearly and the deep learning code is provided. I believe it would be possible to reproduce the findings, given access to ICOLMDZ and the training dataset. However, ICOLMDZ is not included in the submission.

We have added a link to a repository on the Harvard Dataverse that provides access to the ICOLMDZ model, along with the data shown in this manuscript. The section “Code and data availability” has been modified accordingly.

I would like to ask the authors to address the following points in a revised version of this manuscript:

1. The overall presentation could use some clarification. Due to the nature of the quantities that are evaluated, the figures are quite complex, and the main text discusses findings that are only presented in the supplementary material (S2,

S4). I think it would be beneficial to show the figures that are important for building the main narrative in the paper, and move less important subfigures to the supplemental material.

In the revised version, a few changes have been made to improve clarity.

We have moved Table 3, Table 4, Figure 3 and Figure 8 in the Supplementary Material.

Figures S2 and S4 were moved from the Supplementary Material to the main text.

2. Figures 4 and 5 already contain results that are based on the incorporation of the latent variables that is only introduced in a later section (5.2). I find this confusing, as a reader I was not able to interpret the figures while reading the manuscript front to back. I think it would be beneficial to show results once the underlying experiments have been discussed to keep the flow of information.

We have taken this comment into account. In the revised version, we have separated the results from the first learning and those from the second learning. Now, the results of the second learning are only shown when they are discussed. The revised figure numbering is as follows:

- For the zonal wind tendency:
 - Figure 4 becomes Figure 3 and Figure 9.
 - Figure 6 becomes Figure 4 and Figure 10.
- For the meridional wind tendency:
 - Figure S5 becomes Figure S6 and Figure S8.
 - Figure S6 becomes Figure S7 and Figure S9.
- For the temperature tendency:
 - Figure S7 becomes Figure S10 and Figure S12.
 - Figure S8 becomes Figure S11 and Figure S13.
- For the humidity tendency:
 - Figure S9 becomes Figure S14 and Figure S16.
 - Figure S10 becomes Figure S15 and Figure S17.
- For the liquid water tendency:
 - Figure S11 becomes Figure S18 and Figure S20.
 - Figure S12 becomes Figure S19 and Figure S21.
- For the ice water tendency:
 - Figure S13 becomes Figure S22 and Figure S24.
 - Figure S14 becomes Figure S23 and Figure S25.

We have removed Figure 5 as the same information is provided in Table 5.

We have separated the results from Table 5 into two tables, Table 3 and Table 5.

3. Figure 6 (c-f) contains results that are only introduced later in section 5.2. Again, I find it confusing to see the results early without having the necessary

context, and once the context was there in section 5.2 I had to search for the figure to understand the findings.

We have implemented the required changes to improve clarity, as mentioned just before (see our response to the previous comment).

4. It is obvious that the UNet outperforms the FCN. In the conclusion (Sect. 7), the authors state their interest in coupling both architectures to the dynamical core for an online evaluation. Maybe I am missing a point, but why would it be beneficial to continue working with the FCN if it is outperformed by the UNet? If it is useful to continue with FCN, I would appreciate a short explanation why it should be favored over UNet.

We have added the following sentences in Section 7 “Conclusions and discussion” to address the reviewer’s comment: “Even though the U-Net architecture outperforms the DNN during offline evaluation, it might not be the case when emulators are coupled with the dynamical core. That is why it would be interesting to assess the performance of both emulators. Moreover, the DNN might be faster to set up than the U-Net since it has six times fewer parameters to optimize”.

5. Please correct the grammar in the first sentence of section 4.2.

This has been corrected, we have removed the term “study”.