

Review of manuscript titled “TemDeep: A Self-Supervised Framework for Temporal Downscaling of Atmospheric Fields at Arbitrary Time Resolutions” by Wang et al., submitted to GMD

General Comments

A deep learning model is used to show that 2 meter temperature, 850 hPa relative humidity and 850 hPa geopotential height re-analysis data can be downscaled from intervals of 2, 3, 4 and 5 hours to 1-hourly data. The results of this downscaling process are shown to be closer to 1-hourly re-analysis data than other methods.

Overall, the method appears clear, and the results are presented in a way that motivates why the presented model is useful, and outperforms other methods. Some things need clarification, as described in the specific comments. The conclusions are occasionally slightly too optimistic, but clear, useful, and substantiated conclusions can still be drawn from the presented results.

Specific Comments

Line 2: I disagree with the title, in that the downscaling is not to arbitrary time resolutions. It is to 1-hourly resolutions, and the manuscript does not demonstrate the ability to interpolate to finer resolutions.

Line 28: I am not sure what you mean by precise interpolation. The process of interpolation should inherently be precise by virtue of being a mathematical exercise, but with a limited accuracy inherent to the method. I suggest rewording to “accurate.”

Line 57: I think it would be more fair to say that reanalysis product temporal resolutions are mostly on the order of hours, not hours to days.

Line 126: I do not understand what you mean by “wind volume.” Please elaborate or rephrase.

Line 128: Is there any specific reason to not match the resolution of topography to that of the ERA5 data?

Line 131ff: That a region with transitions between climate zones is highly representative of climate change studies is a very strong statement. I believe that this statement does not belong into a figure caption, but should be postulated in the bulk text, discussed further, and above all substantiated with adequate references. In the absence of a thorough discussion, I am not sure what the statement means in detail, and it therefore seems rather dubious. A more thorough discussion would also justify section 2 being a separate section, as currently the section consists of only one paragraph, which could be moved to section 3, which in turn could be renamed to “data and methods.”

Line 136: Is there a specific reason to use x and y for horizontal and vertical dimensions? It might be more intuitive to use z for the vertical component, as that is more commonly used.

Line 148ff: I suggest removing the technical description from the figure caption, as this inflates the caption with substance that belongs in the bulk text.

Line 157ff: This is not easily understood by me. It appears that you are claiming that processes that can occur over long periods of time can also occur in short periods of time, which I do not agree with. Further, the entire paragraph is worded in a way that implies that it is entirely speculative, and

not substantiated. As a result, I cannot confidently agree with anything in this paragraph, and am led to disregard further argumentation that builds on it. I suggest rephrasing the paragraph for more clarity, and to substantiate the claims made therein.

Line 162ff: This paragraph states that changes in certain variables can signify changes in weather patterns. While I agree with that, I think it would be good to also incorporate at least a substantiated estimate of how often this is the case, e.g., how often a change in humidity actually triggers severe convection. Further, it is not clear to me why these events should be filtered out. This is especially the case due to the previous argumentation of an increase in temporal resolution being useful in capturing the timing of changes in weather patterns.

Line 211: I do not understand how a temperature gradient can be given in Kelvin, without any reference to physical space (K per meter) or time (K per second). It is unclear whether this gradient refers to a difference in temperature between adjacent grid point and adjacent time steps, or something different. Please rephrase for clarity. Further, the phrasing implies that t2m has vertical gradients, which seems odd to me.

Line 237: It might be useful to very briefly state what an encoder-decoder architecture is, and what it aims to achieve, at the beginning of this section, as is done for the section at line 263.

Line 301f: Table 1 does not show downscaling from 6-hourly to 1-hourly intervals, and it should be stated that rh and z are only downscaled from 2-hourly to 1-hourly intervals.

Line 303ff: This subsection describes the methods used to evaluate the performance of TemDeep, and therefore belongs in section 3.

Line 322ff: The table caption should contain a description of the structure of the table, not an interpretation of the results.

Line 324: Saying that TemDeep performance approaches performance of TemDeep* seems plausible, but using the word “closely” seems to be an optimistic stretch in some cases (e.g., t2m(2h → 1) and t2m(3h → 1)). It might be better to rephrase to not overstate the performance, or to argue why this qualifies as “closely approaching.”

Line 371ff: As diurnal variations are relevant to the evolution of the assessed fields, it would be good to state whether these times are in UTC or the local time within the region.

Line 376: The use of the word “exactly” makes this a very strong claim, and I therefore suggest replacing it with “closely,” unless the exactness of the alignment can be clearly demonstrated.

Line 381f: I think the conclusion is worded too strongly. It is only demonstrated that TemDeep can capture non-linear transitions in this specific case, and therefore the conclusion should be that TemDeep is not incapable of capturing these transitions. It cannot be concluded that it is guaranteed to capture all non-linear transitions, as the presented conclusion in the manuscript somewhat implies. I suggest rewording the conclusion to be more careful.

Line 401f: It might be good to state the temporal interval to which the downscaling was performed. This would clearly indicate to which temporal resolution the model is demonstrated to perform well, and above which this has not been demonstrated.

Line 403ff: As it has not been demonstrated that the model performs well when downscaling to resolutions finer than 1-hourly, this manuscript strongly motivates further research into assessing

how far re-analysis data can be meaningfully downscaled. This is especially the case, as the motivation presented in the beginning is that high-resolution data are very useful for certain applications. While I understand that the validation of finer resolutions is made difficult by the absence of re-analysis data to compare the downscaling results to, I still believe that mentioning this is of value.

Figures 4 and 5: The gradient should not be given in K, as the spatial and temporal dimensions are unclear.

Figure 9: It might be better to label the bottom colorbar as “Relative Humidity [%],” as this would immediately clarify which quantity is being shown. It is already clear from the unit itself that it is a percentage. Also, it might be useful to set the upper boundary at 100%, as relative humidity generally does not exceed 100% by much.

Technical Corrections

Line 15: “exhibits” should be changed to “exhibit,” as the word data is plural.

Line 41: “aids” should be changed to “aid,” as the word data is plural.

Line 66: “their potentials” refers to deep learning, and should therefore be “its potential.”

Line 72f: “exists significant demands” should either be “exist significant demands” or “exists significant demand.”

Line 121: “data [...] was downloaded” should be changed to “data [...] were downloaded,” as the word data is plural.

Line 312: “is the data” should be “are the data,” as the word data is plural.

Line 400: “utilizes” should be “utilize,” because the statement is “we [...] utilize existing consecutive fields[...].”

Line 413: “has” should be “have,” as the statement refers to multiple authors.