

RESPONSE LETTER

We would like to thank the Topic editor and reviewers for the valuable suggestions on our manuscript once again. The suggestions made by the Topic editor and reviewers further improved our manuscript.

Comments from Topic editor:

Comment 1: *The authors emphasize that the new framework includes a module to intensify the spatiotemporal variations of the feature. However, the example they used did not justify this advantage. The example shown in Figure 8 exhibits decaying features during the last 30-min in the forecast. Although the GAN-argcPredNet V2.0 method alleviates the "attenuation" disadvantage shown in the results from other methods, it is unclear whether the decaying features are due to attenuation or well representation of the actual signals. I'd suggest the authors consider a different case (even better with multiple cases) to justify the advantage of the method, e.g. evident spatiotemporal variations with rapidly intensifying convection.*

Response: Thanks for your suggestion. We have added two prediction examples to more comprehensively demonstrate the advantages of our model. One example is the rapid growth of the storm, and the other example is the decay of the storm. Our model curbs echo attenuation in all examples and has the best performance (Page 15, Figure 10; Page 16, Figure 11).

Comment 2: *As pointed out by reviewer #1, the word "intensify" repeatedly appears. This word may need to be revised to describe the features the authors want to emphasize adequately. I'd suggest using other words, such as "enhance"?*

Response: Thanks for your suggestion. We have revised the description of "intensify" in the manuscript, taking into account your suggestions and those of reviewer #1 (Page 1, Line 18, Line 20; Page 3, Line 91-92; Page 4, Line 111; Page 5, Line 119-120; Page 18, Line 341-343; Page 19, Line 363-366). We have also changed the model name to " a Spatiotemporal Process Enhancement Network ".

Comment 3: *The authors did not explain why the strong echoes outside the center of the echo maps are not as well represented as the main features during the forecast. Please make some comments about this limitation in section 6.1.*

Response: Thanks for pointing it. We have added the relevant explanations in the manuscript (Page 19, Line 350-353). This phenomenon can be better explained by combining the previous descriptions (Page 3, Line 81-85).

Comment 4: For readers unfamiliar with the concept of generator and discriminator, these components should be briefly explained. Also, Figure 2 is provided with little explanation.

Response: Thanks for your advice. We have briefly explained the role of generator and discriminator (Page 3, Line 69-72). We have also added descriptions in the figure caption (Page 7, Figure 3).

Comment 5: Caption in Figure 1: " Fifteen radar echo images are used in the testing set" Please clarify this.

Response: Thanks for your advice. We have revised the sentence which was misleading (Page 6, Line 135-136).

Comments from Reviewer 1:

Comment 1: Page 1, line 20: "By intensifying ..." This wording is somewhat misleading. It is not proven in this manuscript whether the network always increases the "evolution." What is shown in this paper is that the new network implementation contributed to "suppress the blurring effect of rain distribution and reduce the negative bias (i.e., the Bias Score less than one)" by STIC Attention. Therefore, my suggestion is as follows:

"By suppressing the blurring effect of rain distribution and reducing the negative bias by STIC Attention, ..."

Throughout the manuscript, the authors emphasize that they "intensify" something. However, rain intensity grows or decays, following the lifecycle of precipitation systems. Therefore, the network should not intensify features regardless of environment. In addition, it is not explicitly proven whether the output of Attention blocks really increases the signals of hidden states or not. Scientific papers need to describe results objectively, not subjectively. Again, what can be read from the figures is that the network succeeded in suppressing the blurring effect and reducing the negative bias. You do not really need to introduce subjective interpretation on it.

Response: Thanks for your suggestion. We have revised the description of "intensify" in the manuscript (Page 1, Line 18, Line 20; Page 3, Line 91-92; Page 4, Line 111; Page 5, Line 119-120; Page 18, Line 341-343; Page 19, Line 363-366).

Comment 2: Page 3, line 89: " In sequence prediction, temporal information is also important, but these methods fail to intensify it. For radar echo extrapolation, it reflects as a lack of intensification to rainfall evolution information." As in the comment above, the use of word "intensification" is not adequate. What is needed is to avoid blurring or to maintain the intensity.

Response: Thanks for your advice. Since we have rewritten Section 1 and Section 2, this sentence has been removed. However, all other descriptions of "intensify" have been revised

(Page 1, Line 18, Line 20; Page 3, Line 91-92; Page 4, Line 111; Page 5, Line 119-120; Page 18, Line 341-343; Page 19, Line 363-366).

Comment 3: *Page 10, line 222: " To measure information loss, the paper also uses the Bias metric," The introduction of the Bias Score generally improved the discussion here. However, the Bias Score is a measure of bias. Bias does not necessarily reflect information loss. Therefore, I would suggest rephrasing the sentence as follows:*

"To measure the blurring effect, the paper also uses the Bias Score."

Usually, the amount of information is measured by the Shanon entropy of information.

Response: Thanks for pointing it. We have revised this sentence (Page 11, Line 232).

Comment 4: *Table S5-S8: These tables do not have information on padding. I still feel that information is not complete.*

Response: Thanks for pointing it. We have added the information on padding (Table S5-S8).

Comment 5: *Page 1, line 26: "Bias" This is not raw bias, but so-called "Bias Score."*

Response: Thanks for your advice. We have revised this description (Page 1, Line 25).

Comment 6: *Page 3, line 69: "The extrapolation accuracy is affected." This sentence is isolated and does not make sense. Please consider rephrasing.*

Response: Thanks for your advice. We have revised the sentence to make it more complete. (Page 2, Line 46).

Comment 7: *Page 3, line 77: "the natural variation motion" What does this mean? Please consider rephrasing.*

Response: Thanks for pointing it. We have revised the misrepresentation. (Page 2, Line 55).

Comment 8: *Figure 7: There is no information about the forecast time. Did you use all the time steps to compute the scores? If so, please describe it in the caption.*

Response: Thanks for your suggestion. We have described it in the caption. (Page 13, Line 272-273).

Comments from Reviewer 3:

Comment 1: *Please re-write and re-arrange sections 1 and 2: both sections introduced and reviewed the previous studies of nowcasting systems. The title of section 2 is "related work", which made me think it is a section of "methodology", but it seems that authors only did*

literature review in section 2.1 for traditional echo extrapolation. Besides, although these traditional methods do not utilize amounts of historical images, it is capable of performing the nowcasting at least up to 1-hour. Some nowcasting systems combined different information and further improved the ability of nowcasting. I suggest authors to include those works in the literature review.

References:

- 1. Pulkkinen, S., Chandrasekar, V. and Niemi, T. (2021) Lagrangian integro-difference equation model for precipitation nowcasting. Journal of Atmospheric and Oceanic Technology, 38, 2125– 2145.*
- 2. Chung, K.-S., and I. Yao, 2020: Improving radar echo Lagrangian extrapolation nowcasting by blending numerical model wind information: Statistical performance of 16 typhoon cases. Mon. Wea. Rev., 148, 1099–1120,*
- 3. Nerini, D., Foresti, L., Leuenberger, D., Robert, S. and Germann, U. (2019) A reduced-space ensemble Kalman filter approach for flow-dependent integration of radar extrapolation nowcasts and NWP precipitation ensembles. Monthly Weather Review, 147, 987– 1006.*

Response: Thanks for your suggestion. We have rewritten Sections 1 and Section 2 based on the section formatting of the references you provided. The literature review is now all in Sections 1. We have also added the references you provided (Section 1; Page 2, Line 40-46).

Comment 2: Lines 39-40, please clarify the meaning of "generating high-quality echo images".

Response: Thanks for pointing it. High quality represents that the image is more realistic and structurally similar to the real image. We have clarified the meaning in the manuscript (Page 3, Line 68-69).

Comment 3: Since this is a independent article, I suggest to briefly introduce the GAN-argcPredNet v1.0 in section 3.

Response: Thanks for your advice. We have added the introduction of GAN-argcPredNet v1.0 (Section 2.1).

Comment 4: Overall, the captions in the figures are not formal (by using "This is"). In addition, the information is not clear enough in the captions.

Response: Thanks for your suggestion. We have revised the description of the captions and added relevant information (Page 4, Figure 1; Page 6, Figure 2; Page 7, Figure 3; Page 8, Figure 4 and 5; Page 9, Figure 6; Page 10, Figure 7; Page 11, Table 1; Page 13, Figure 8; Page 14, Figure 9; Page 15, Figure 10; Page 16, Figure 11; Page 16, Table 2; Page 17, Table 3; Page 18, Figure 12; Page 19, Figure 13).

Comment 5: Authors introduced the quality control of radar data used in this study. Since it included 11 weather radar, I am curious that do authors encounter a problem of random interference in any weather radar? How to deal with this problem.

Response: Thanks for your question. Our data have been professionally processed. We also verified the quality of the data before the experiment. You can find the descriptions in Page 10, Line 209-213.

Comment 6: Line 208: "... with the height of 1km" please confirm that the "CAPPI" radar is used in this study.

Response: Thanks for pointing it. We have added the description of "CAPPI" (Page 10, Line 218).

Comment 7: Z-R relationship has lots of uncertainties, do the coefficients of a and b obtain and determine in Guangzhou province? In addition, what kind of ground truth rainfall is used in this study? It is necessary to introduce it.

Response: Thanks for your question. Our experiment is in cooperation with Guangdong Meteorological Observatory, and they have confirmed the experiment details. The kind of ground truth rainfall has been introduced in the manuscript (Page 6, Line 136).

Comment 8: Current study only compared the new systems to other deep-learning nowcasting systems. How is the performance compared to traditional radar echo extrapolations as mentioned in section 2.1?

Response: Thanks for your advice. We have added a comparison experiment with the optical flow method (Page 12, Line 249-250; Page 12, Line 260-262; Page 13, Figure 8; Page 13, Line 276, Line 281, Line 284; Page 14, Line 286; Page 14, Figure 9; Page 15, Figure 10; Page 16, Figure 11; Page 16, Line 303; Page 18, Line 329-332).

Comment 9: The new nowcasting system is able to alleviate the echo attenuation compared to other deep-learning nowcasting models. However, can you say that GAN-argcPredNet v2.0 is able to capture the evolution (growth and decay) of the weather systems? The cases demonstrated in current study all focused on the growth of weather system, how about the decay of the weather system?

Response: Thanks for your question. Based on the comments from the Topic Editor and Reviewer #1, we have revised the description of "intensify" (Page 1, Line 18, Line 20; Page 3, Line 91-92; Page 4, Line 111; Page 5, Line 119-120; Page 18, Line 341-343; Page 19, Line 363-366). We have also added an example of storm decay (Page 16, Figure 11). Our model still outperforms others.

Comment 10: Fig. 10 try to explain the reason of false predictions in Fig. 8. If you change the frequency or number of images as inputs, is it able to solve the issue?

Response: Thanks for your question. The evolution process of rainfall is complex and variable, influenced by multiple factors. However, the rainfall evolution process reflected in the samples is limited. Our model performs better by maintaining the intensity, but due to the limitations of the samples, it cannot fully learn all the evolving features. As a result, deviations between the predicted trends and the real trends are inevitable, leading to false predictions. Even with an increase in the number of input images, it is still difficult to avoid false predictions.