WGAN-GP application on radar reflectivity nowcasting

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Outline

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- Methodology
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Introduction

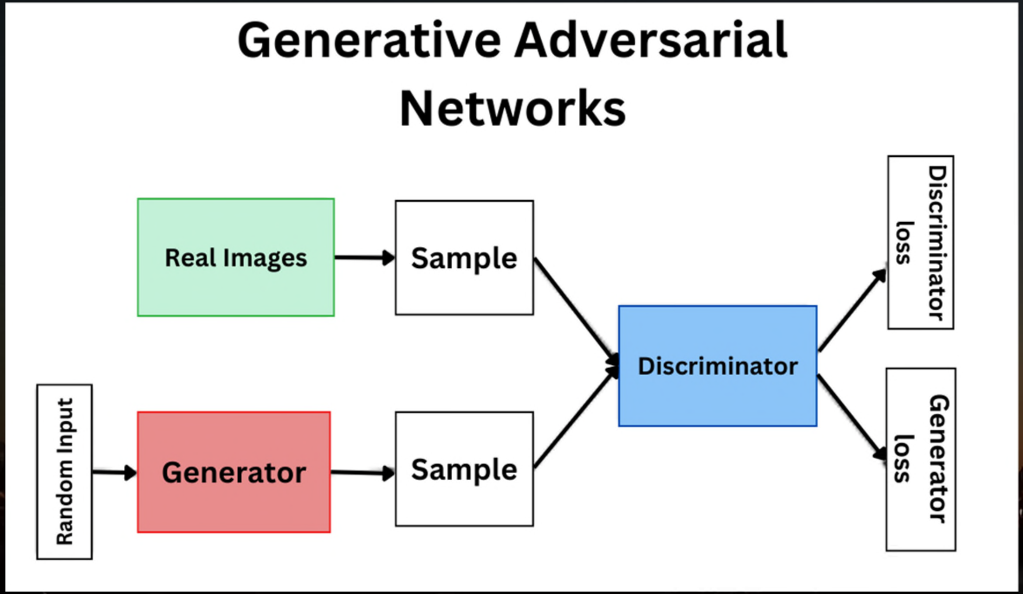
The issues of extrapolation nowcasting are

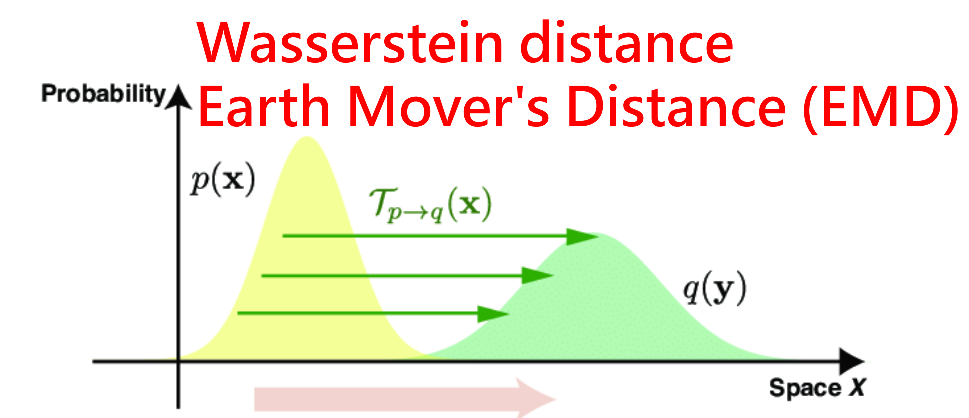
- ◈ Weather system may growth and decay
- ◈ Can we save more time after a system after it detected by radar?

→ Deep learning may be a solution

Methodology
WGAN

- GAN = Generative Adversarial Network
- Generator → generate “fake” radar images
- Discriminator → discriminate image is fake or true
- Wasserstein GAN (WGAN) solve the gradient vanish





https://medium.com/@sumit.kaul.87/what-is-generative-adversarial-networks-gans-32e747b03f46

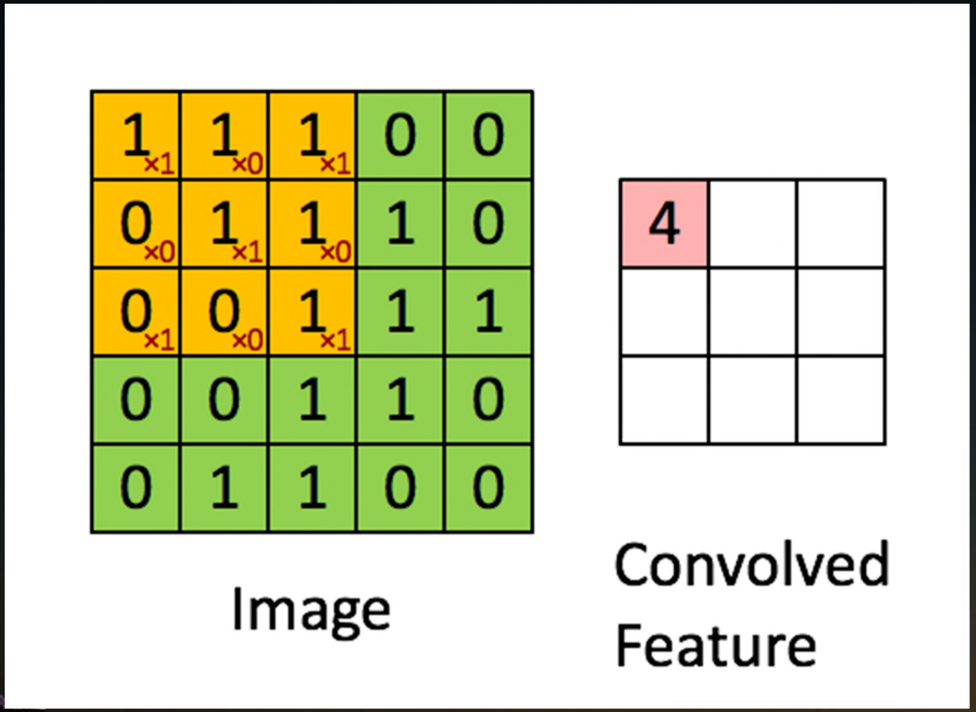
Methodology
WGAN

- Training discriminator every steps
- Training generator every 5 steps

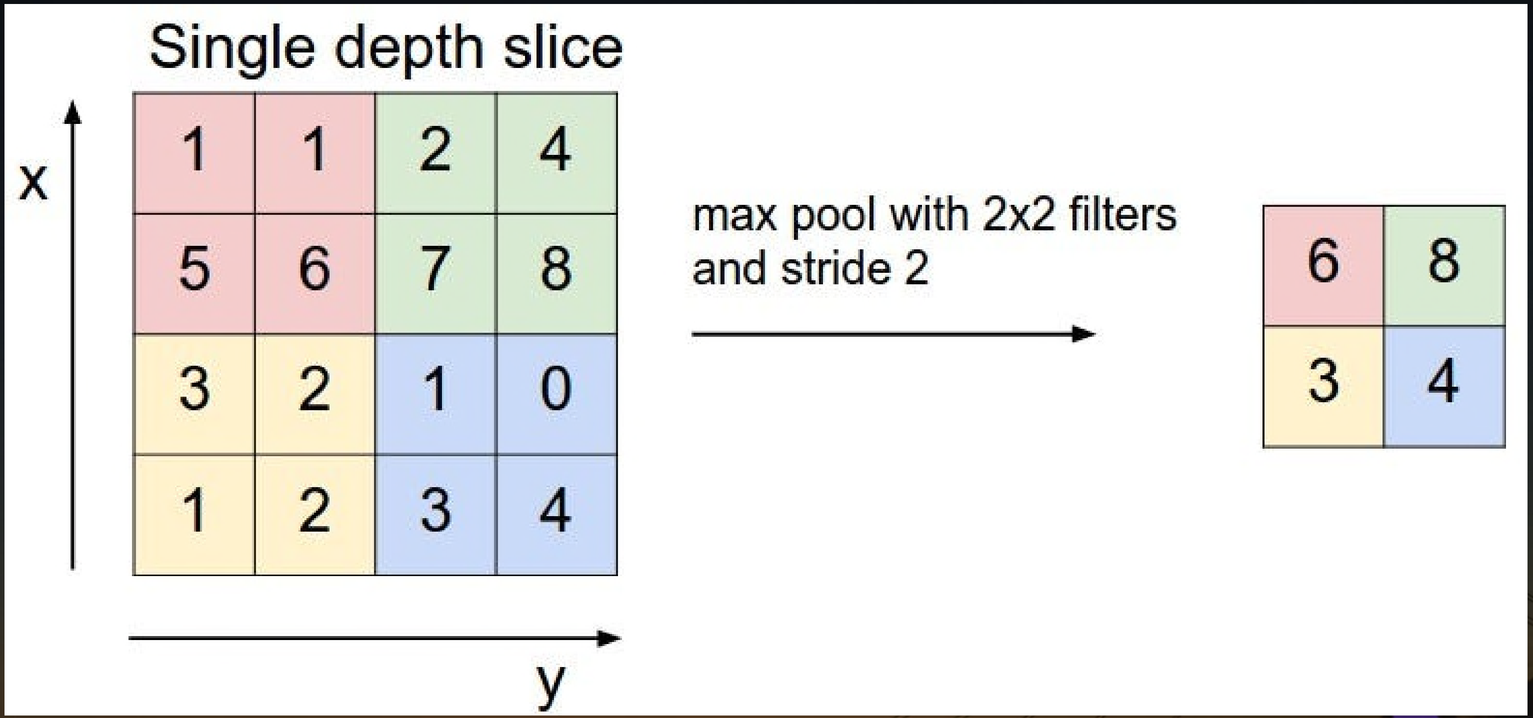
Methodology

Discriminator - Convolutional Neural Network (CNN)

Convolve



Max pooling



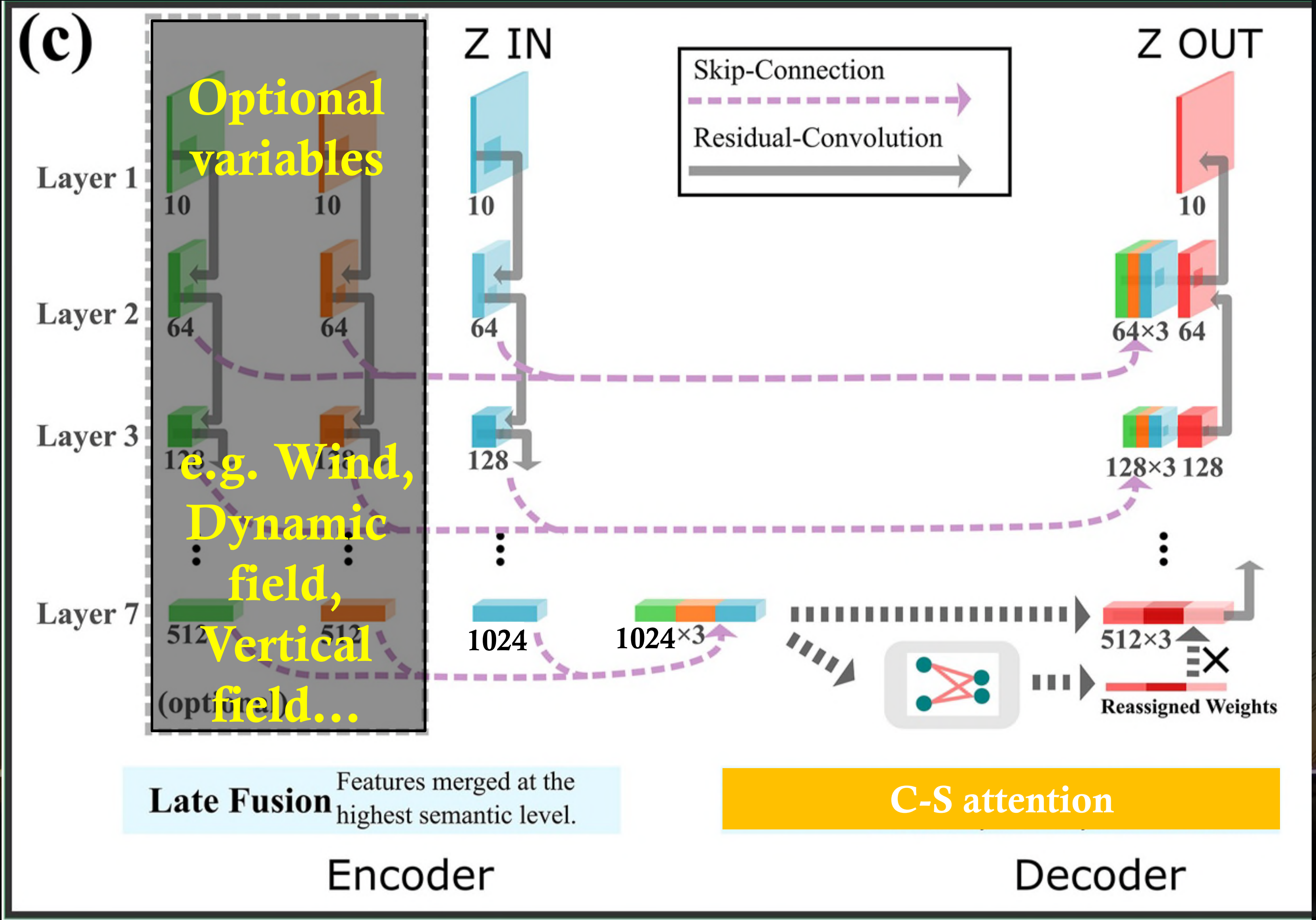
https://cinnamonaitaiwan.medium.com/深度學習-cnn原理-keras實現-432fd9ea4935

Methodology
Generator - U-Net

Pan, X., Lu, Y., Zhao, K., Huang, H., Wang, M., & Chen, H. (2021). Improving Nowcasting of convective development by incorporating polarimetric radar variables into a deep-learning model. *Geophysical Research Letters*, *48*(21), e2021GL095302.

Local Features

Global Features

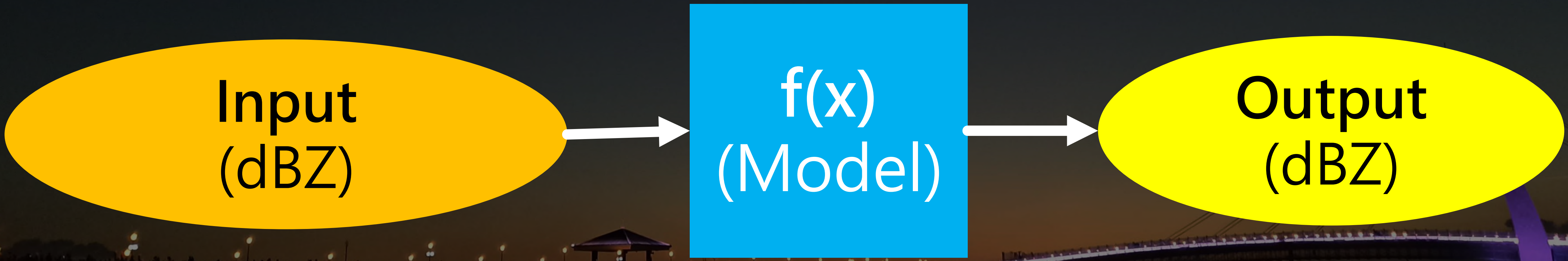


Local Features

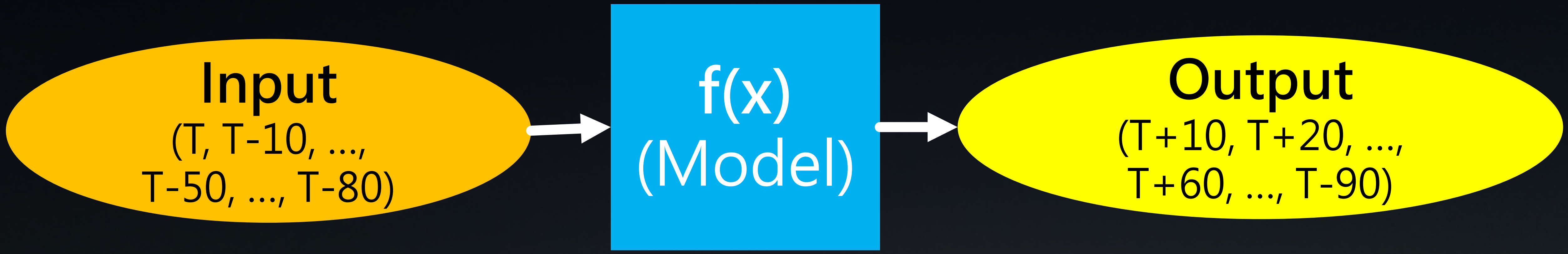
Global Features

Methodology
Data & Hyperparameter

- Source: CWA QPESUMS radar composite reflectivity (dBZ)
- Training & validation: 2021 OND ~ 2022 JFM each 10 minutes
- Evaluation: 2022 OND ~ 2023 JFM each 10 minutes
- Learning rate (size of steps in gradient descent): 10^{-3}



Methodology
Data & Hyperparameter



- 10 minutes gap between each input and output
- Input 6 or 9 radar images (T, T–10, ⋯, T–50, ⋯, T–80)
- Output 6 or 9 radar images (T+10, T+20, ⋯, T+60, ⋯, T–90)

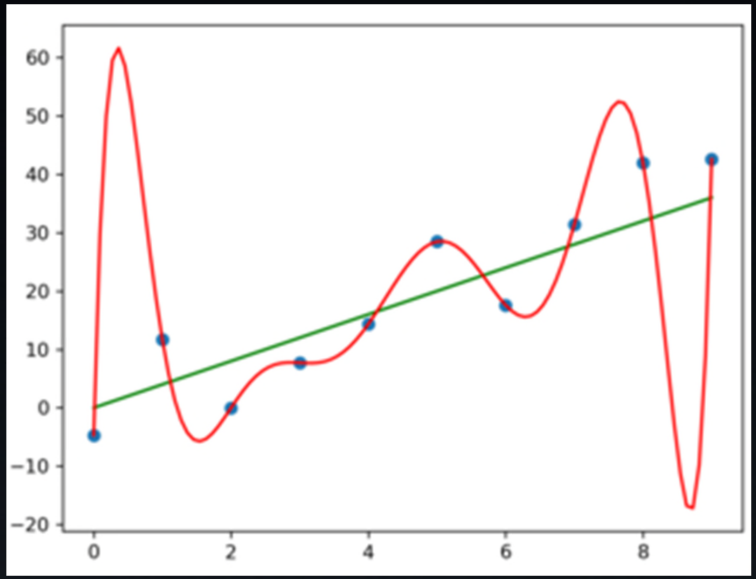
Methodology
Clear sky threshold

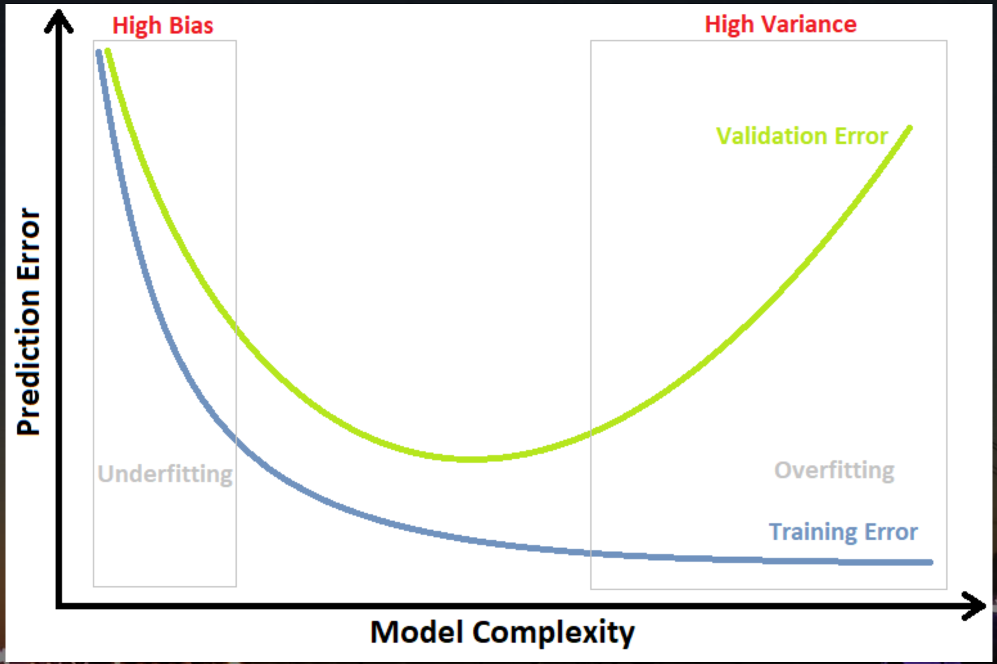
- Too much clear sky in the training set will cause unbalance and bias (Lin et al. 2024)
- Use percentage of 15 dBZ area filter out clear sky data
- All models train 45 epochs

15 dBZ area threshold	Number of orininal data	Number of filtered data
10 %	25829	2903
15 %	25829	1884
20 %	25829	1244

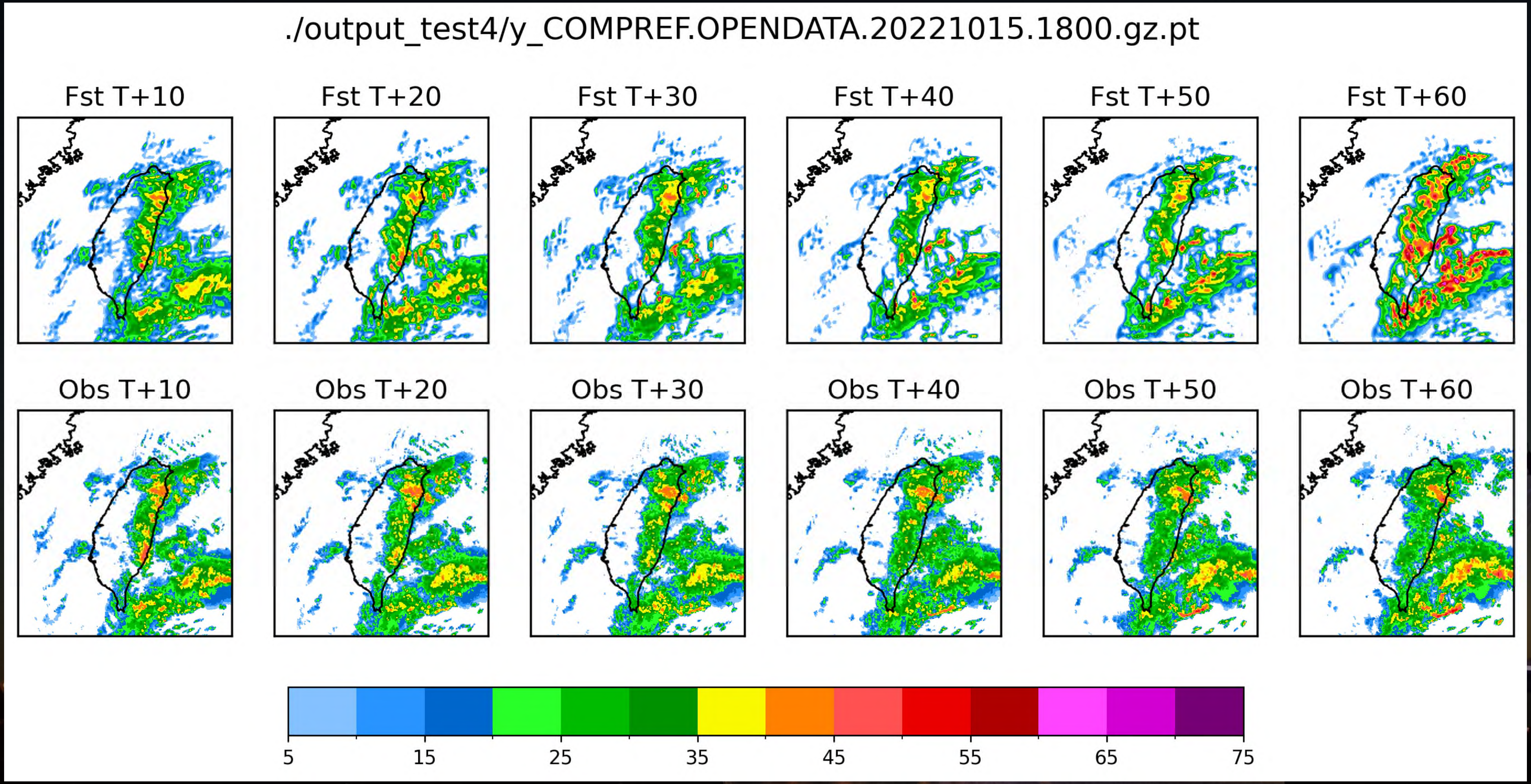
Methodology
Cross-validation

- Overfitting: model fit too closely to training data
  → Good on training data but not other data
- Cross-validation: Randomly split 70% data into "training-set" and 30% into "validation-set".
  Use "validation loss" to determine when stop training
- If validation loss stop improve over 20 epochs, stop training

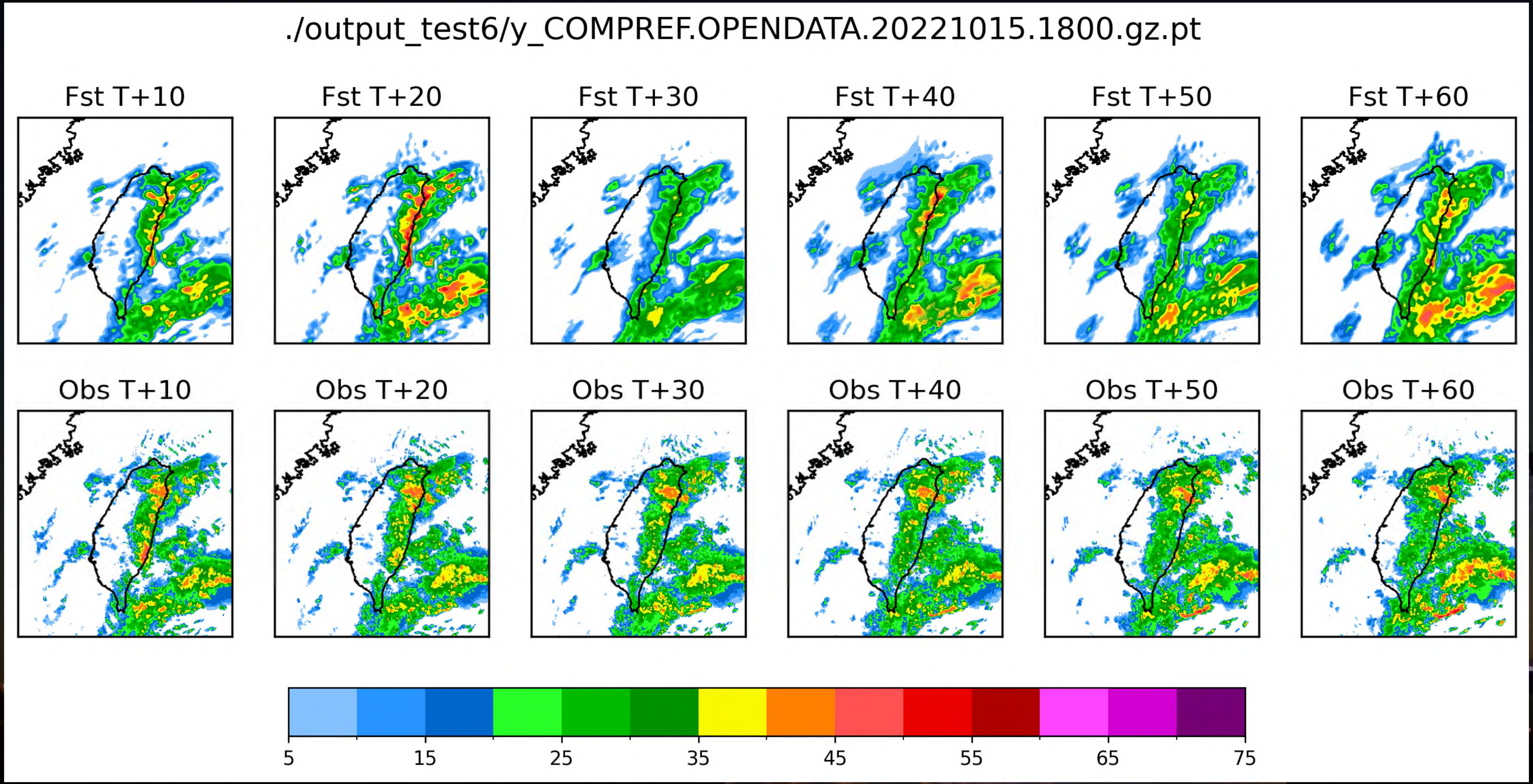




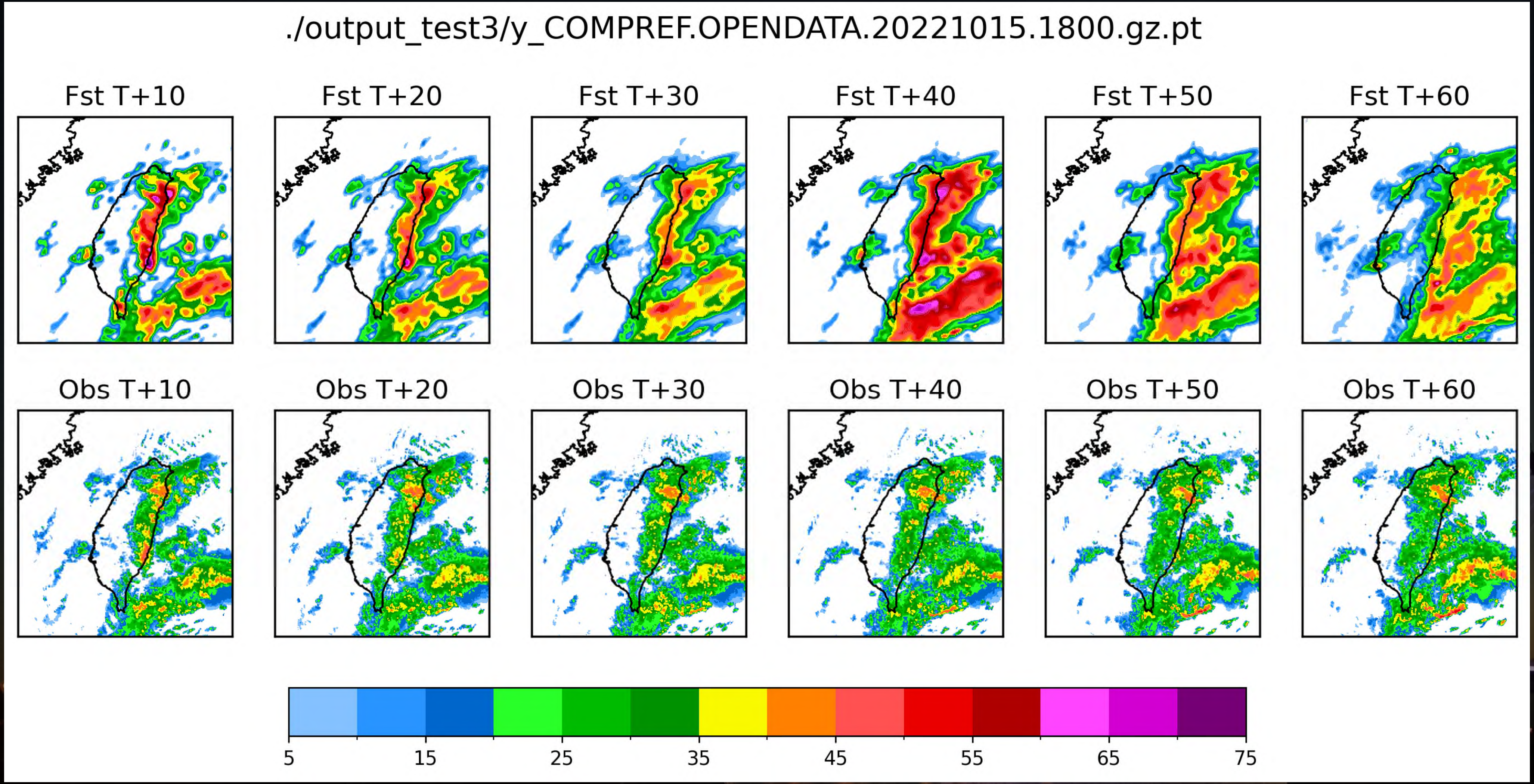
Results – Different clear sky threshold 10% area of 15 dBZ



Results – Different clear sky threshold 15% area of 15 dBZ

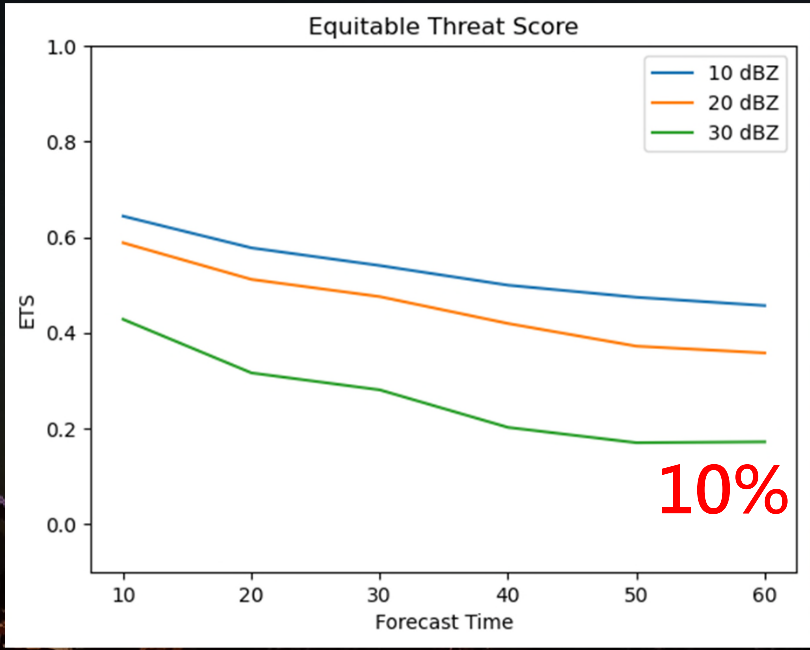


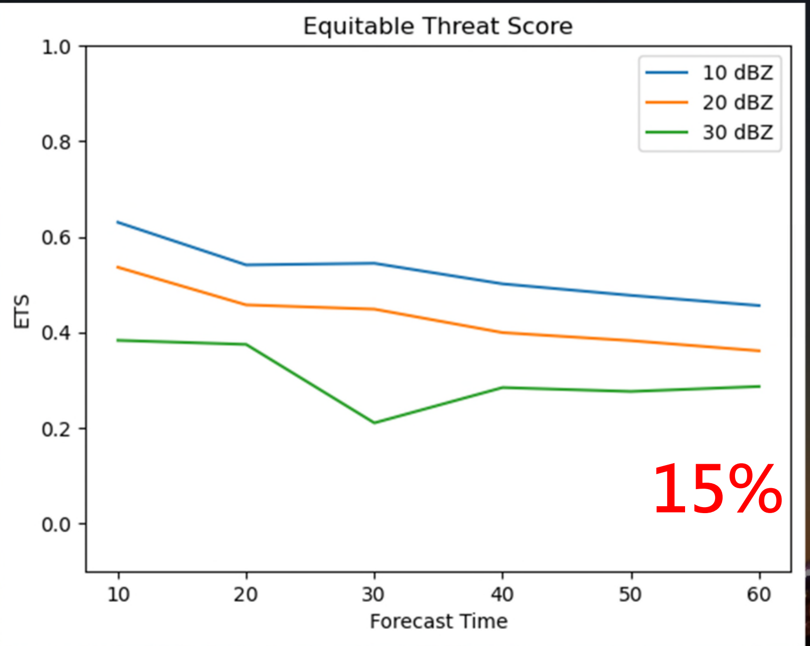
Results – Different clear sky threshold 20% area of 15 dBZ

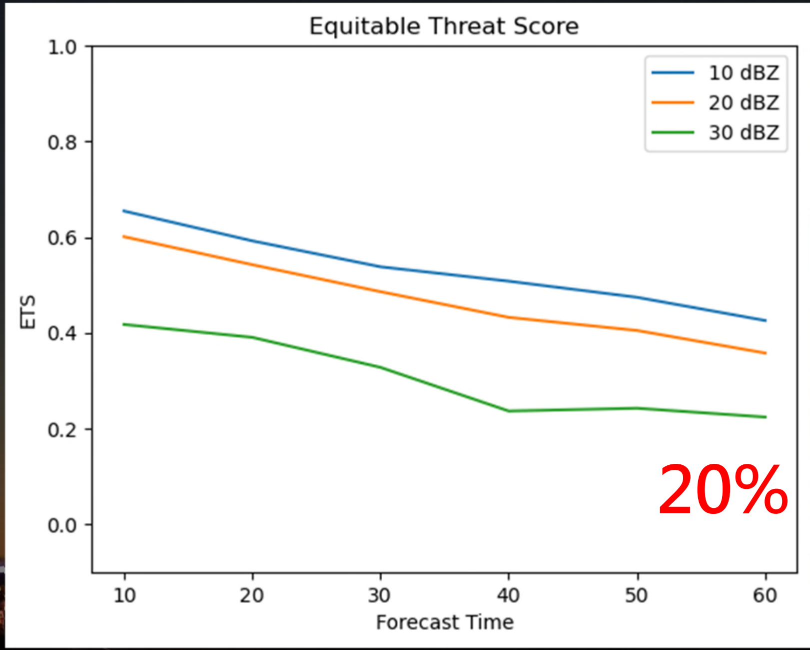


Results – Different clear sky threshold ETS

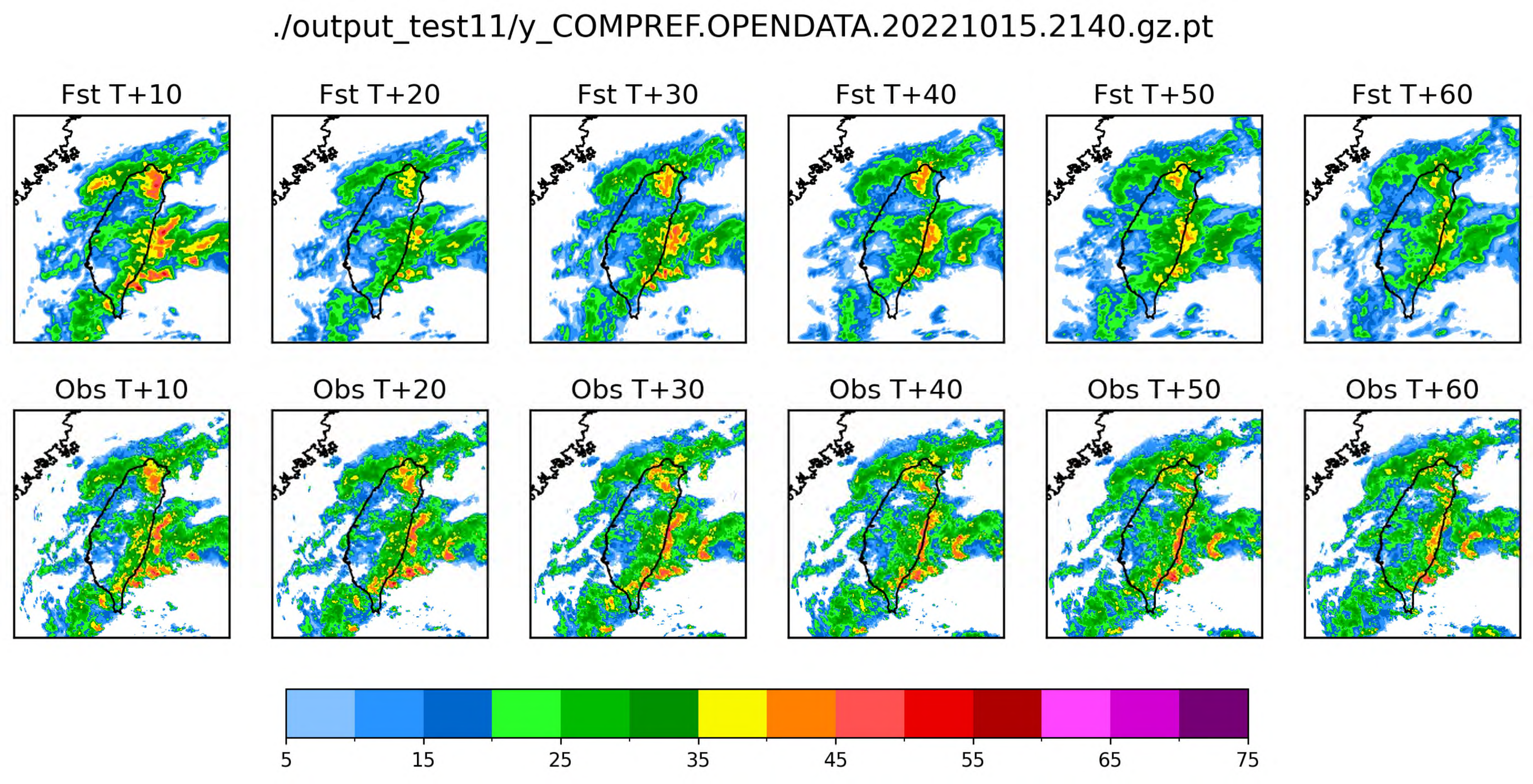
- 10% and 20% obviously poor in heavy rain



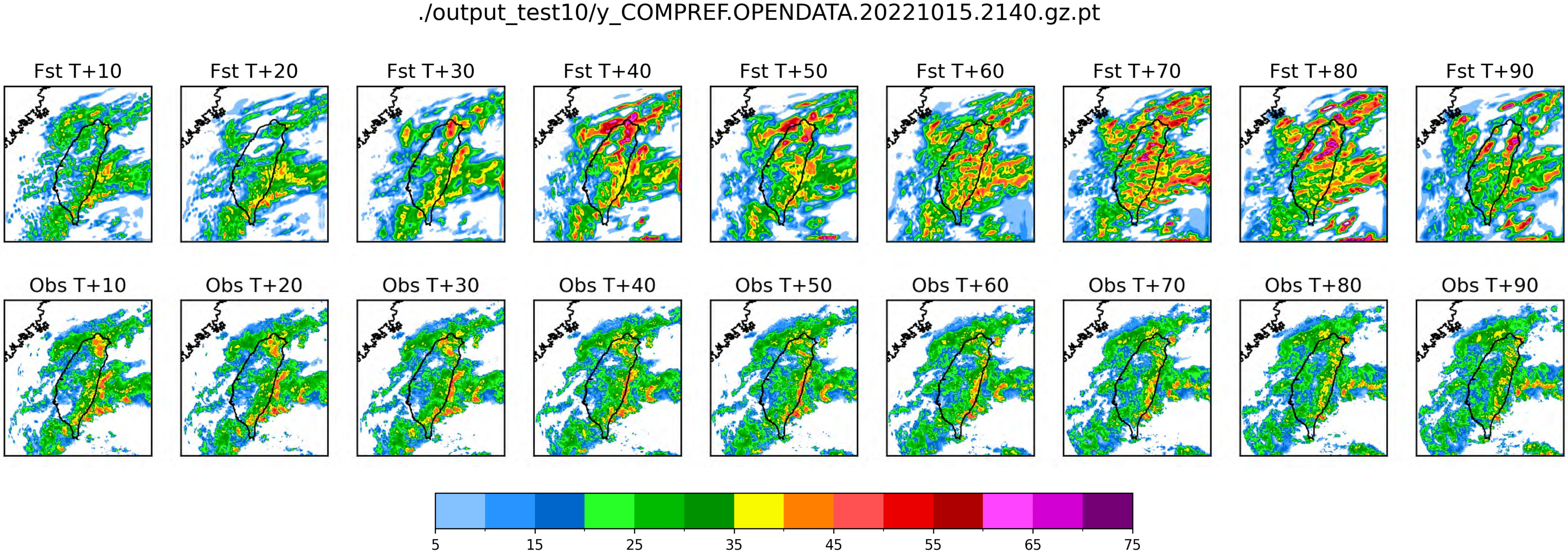




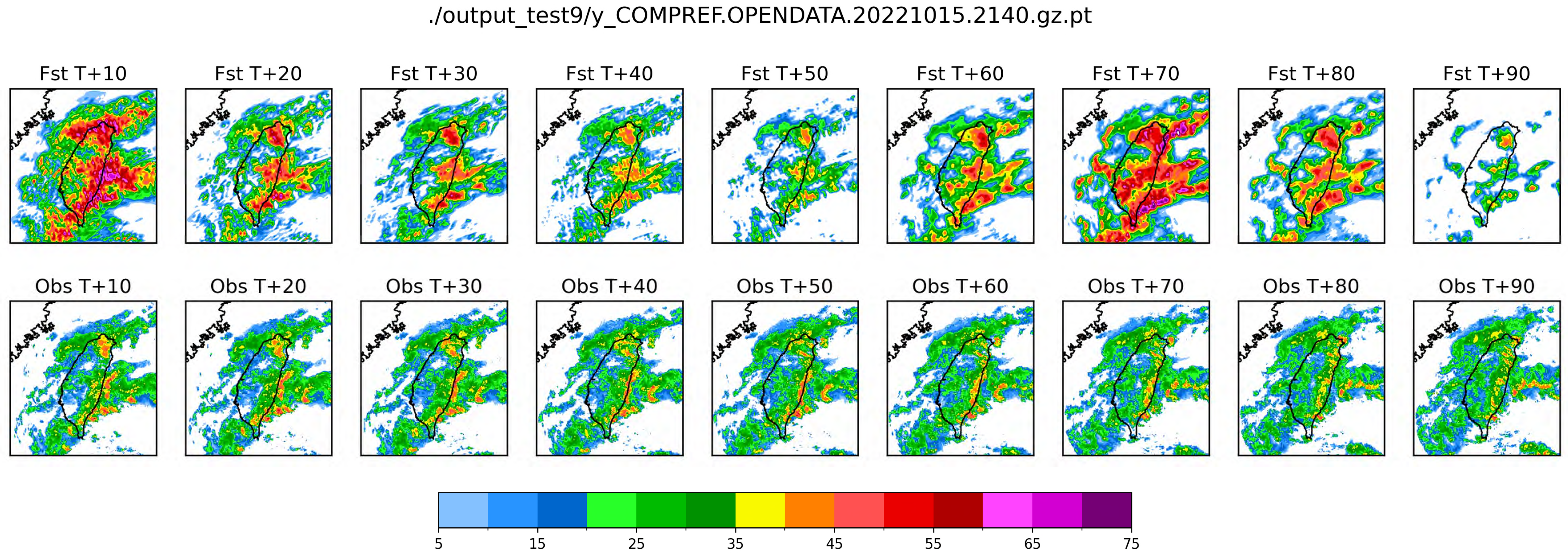
Results – Different input and output length
6 Obs, (60 min) → 6 Fst. (60 min)



Results – Different input and output length 6 Obs, (60 min) → 9 Fst. (90 min)

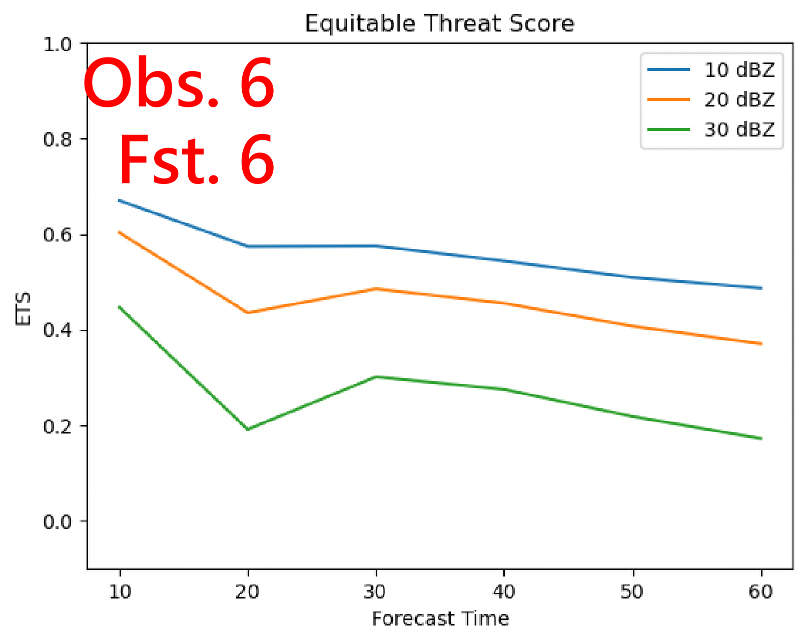


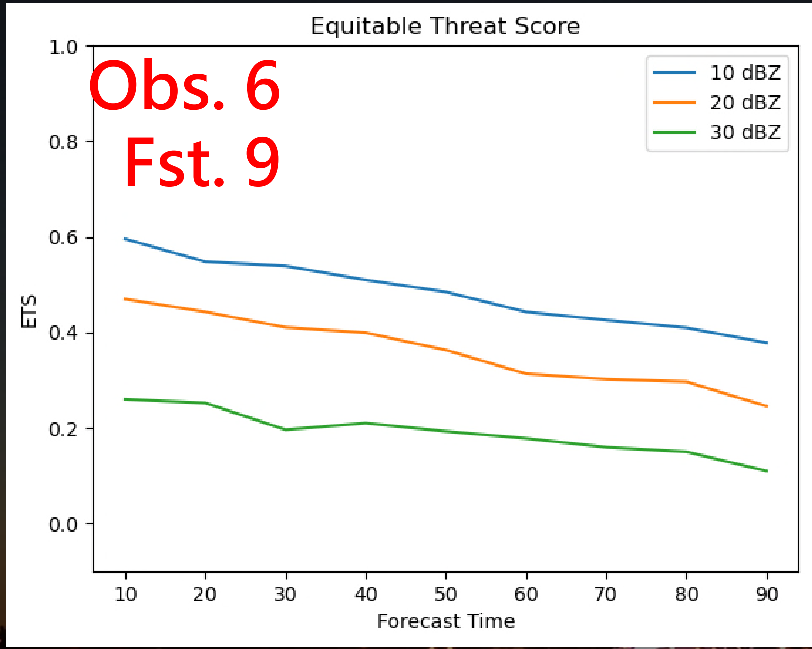
Results – Different input and output length
9 Obs, (90 min) → 9 Fst. (90 min)

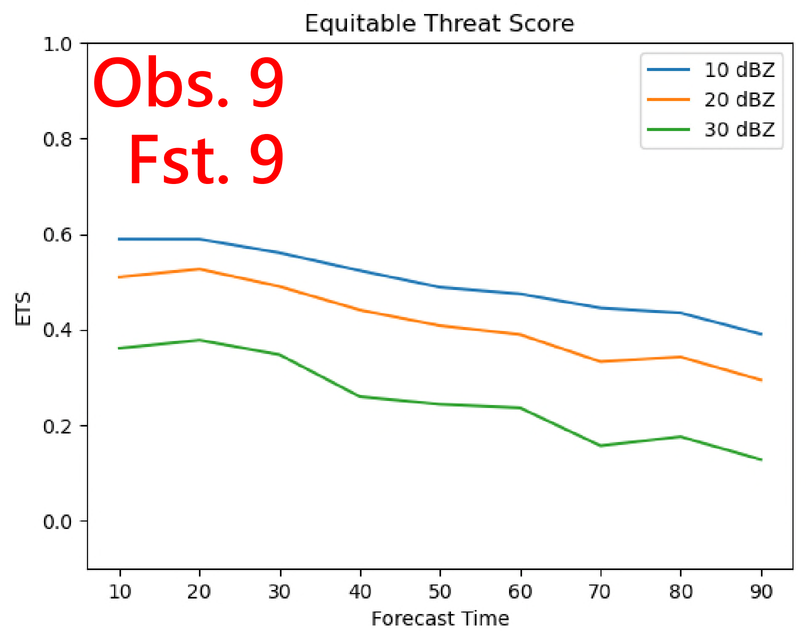


Results – Different input and output length ETS

◈ 6-to-6 get highest ETS





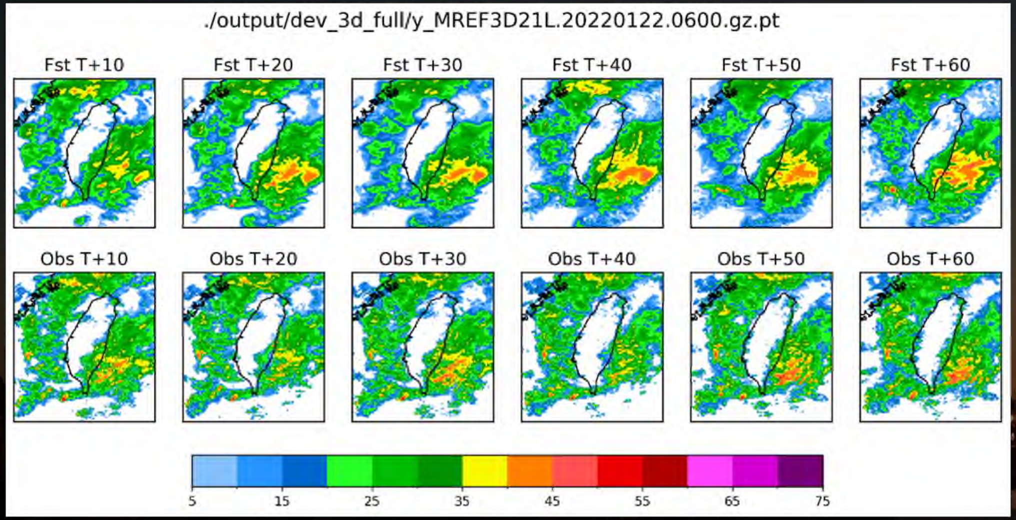


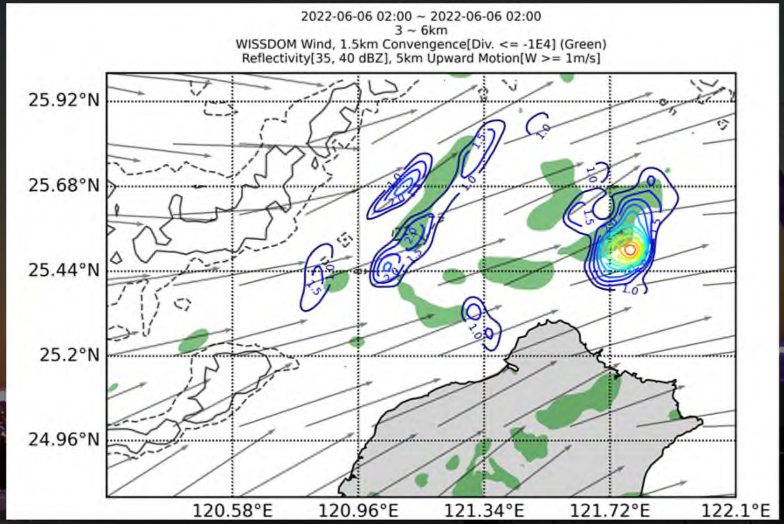
Summary

1. 15% area of 15dBZ is a suitable clear sky threshold in winter.
2. Higher clear sky threshold may cause insufficient training data; lower threshold may cause under-forecast.
3. Input 60 min. observed, and output 60 min. forecast is the best choice. This may be caused by only reflectivity cannot provide sufficient growth and decay information.

Future work

1. Test clear sky threshold in different season
2. More training data (many years)
3. 3D reflectivity input
4. Process-based (wind, vorticity, divergence…)

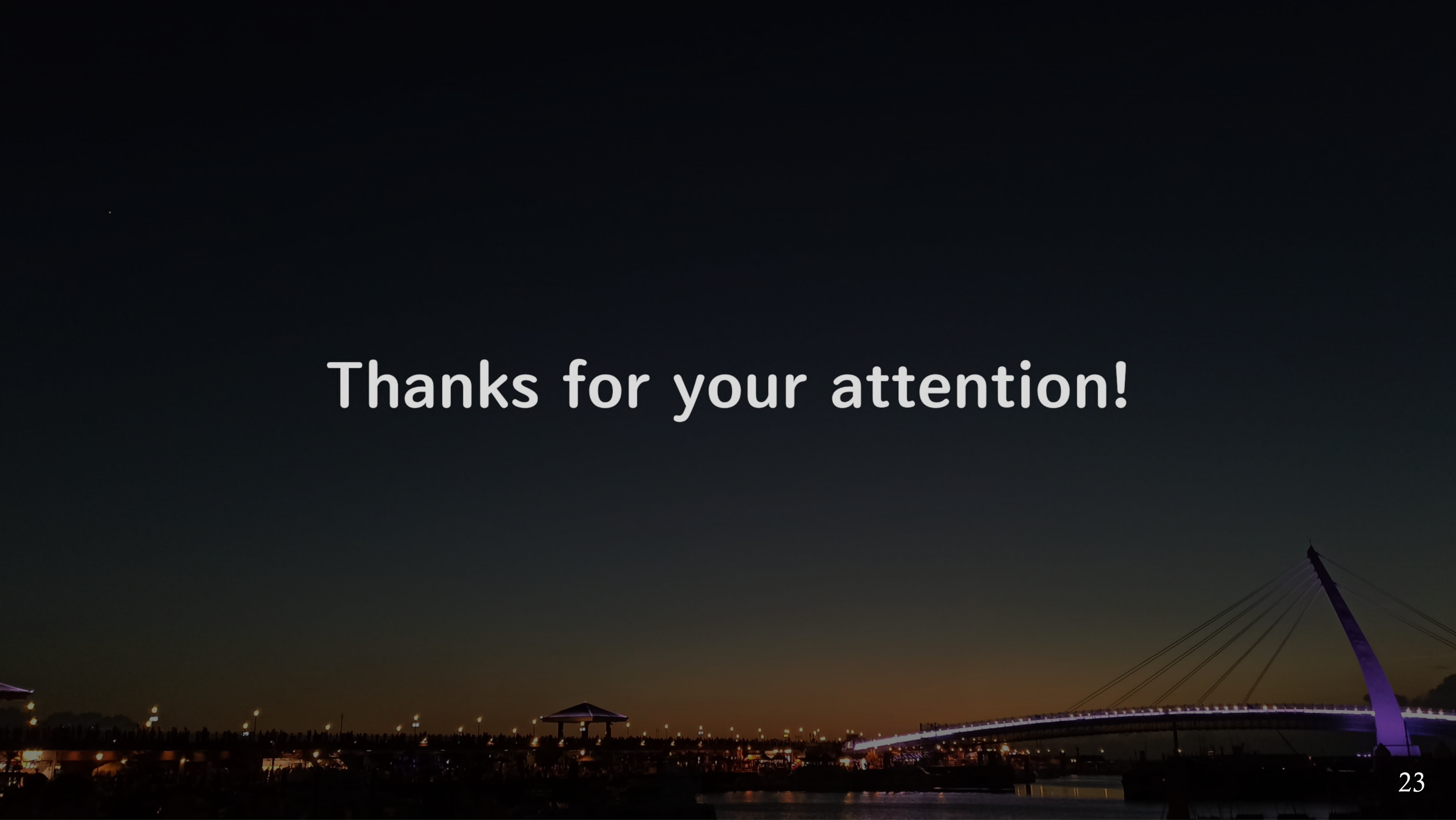




Reference

Pan, X., Y. Lu, K. Zhao, H. Huang, M. Wang, and H. Chen, 2021: Improving Nowcasting of Convective Development by Incorporating Polarimetric Radar Variables Into a Deep-Learning Model. *Geophysical Research Letters*, 48, e2021GL095302, https://doi.org/10.1029/2021GL095302.

Lin, K.-C., W.-T. Chen, P.-L. Chang, Z.-Y. Ye, and C.-C. Tsai, 2024: Enhancing the Rainfall Forecasting Accuracy of Ensemble Numerical Prediction Systems via Convolutional Neural Networks. *Artificial Intelligence for the Earth Systems*, 3, 230105, https://doi.org/10.1175/AIES-D-23-0105.1.


Thanks for your attention!