Supplementary Materials for

Enhanced Tropical Cyclone Precipitation Prediction in the Northwest Pacific Using Deep Learning Models and Ensemble Techniques

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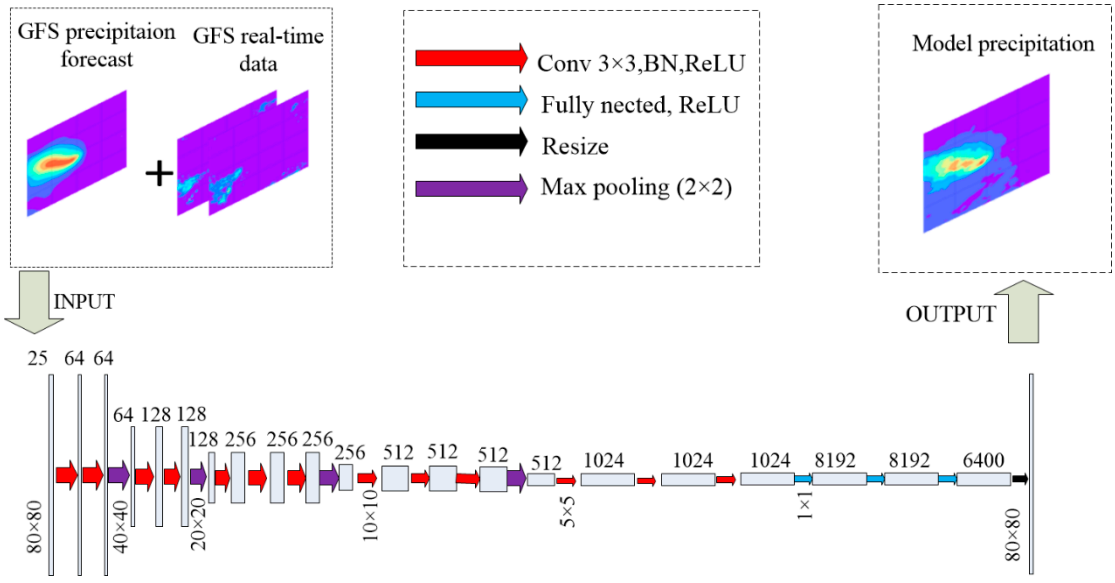

Figure S1. VGG model structure

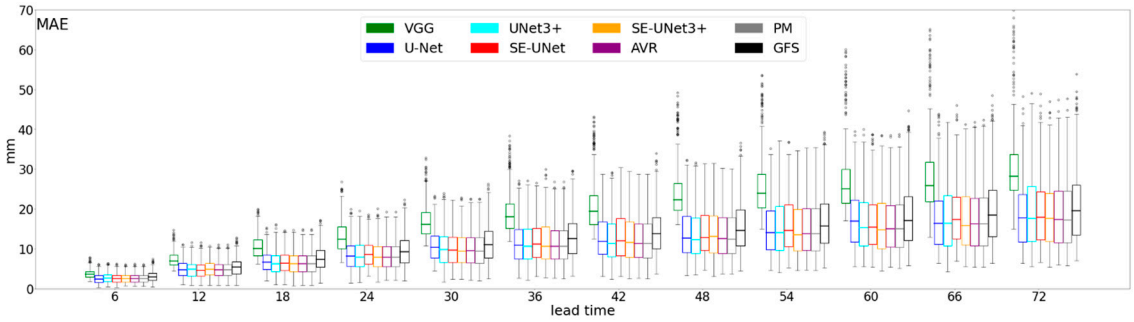

Figure S2. Boxplots of MAE for different models with various lead times

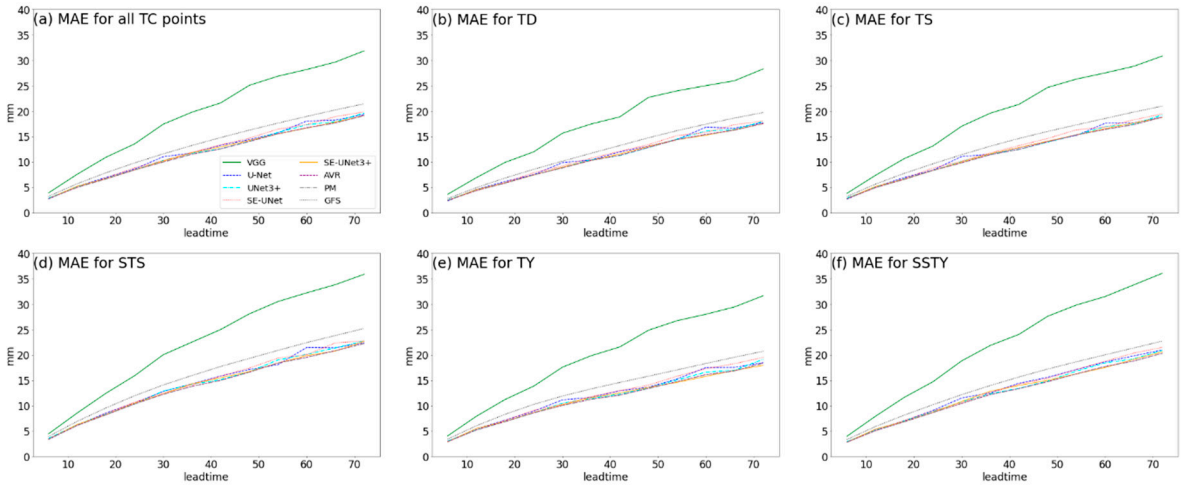

Figure S3. MAEs of different models for various TC levels: (a) All TC points, (b) TD, (c) TS, (d) STS, (e) TY, and (f) SSTY

The MAE is also calculated for all models to assess their performance. Figures S2 and S3 show the MAEs for different models at various lead times, as well as the mean MAEs for different models to forecast precipitation induced by TC points with varying intensities. Similar to the RMSE analysis results, the VGG model produced the highest average MAEs across all TC levels, followed by the GFS model. The results indicate that UNet-based models outperform GFS models in reducing the MAE, as all UNet-based models exhibit lower MAEs than GFS models. Figure S3a shows the mean MAEs of all TC points, with GFS models having mean MAEs of 9.79 mm, 16.24 mm and 21.43 mm at lead times 24h, 48h and 72h, respectively. In contrast, UNet-based models demonstrate lower mean MAEs at the same lead times. U-Net, UNet3+, SE-UNet, SE-UNet3+, AVR, and PM models have lower MAEs than the GFS model, with reductions of 9.6%, 11.3%, 9.0%, 12.0%, 12.8%, and 13.0%, respectively. The PM models have the lowest average MAE compared with the other models, which is consistent with the RMSE calculation results.

Figure S4 displays the MAE spatial distribution for the PM and GFS models at various lead times. The average MAEs for the PM models at lead times of 24 h, 48 h, and 72 h are 8.39 mm, 13.99 mm, and 19.08 mm, respectively. These values are lower than the average MAEs for the GFS models at lead times of 24 h, 48 h, and 72 h, which are 9.79 mm, 16.24 mm, and 21.43 mm, respectively. Figures S4g, h, and i depict the differences between the average MAE for the PM models and the average MAE for the GFS models. In most regions, the average MAE for the PM models is lower than that of the GFS models, with average differences of 1.4 mm, 2.25 mm, and 2.35 mm at 24 h, 48 h, and 72 h, respectively. The difference in MAE between the PM model and the GFS model is greater near the TC centre, as shown in Figure S4 g,h,I, suggesting that the PM

model primarily reduces MAE in precipitation prediction near the TC centre.

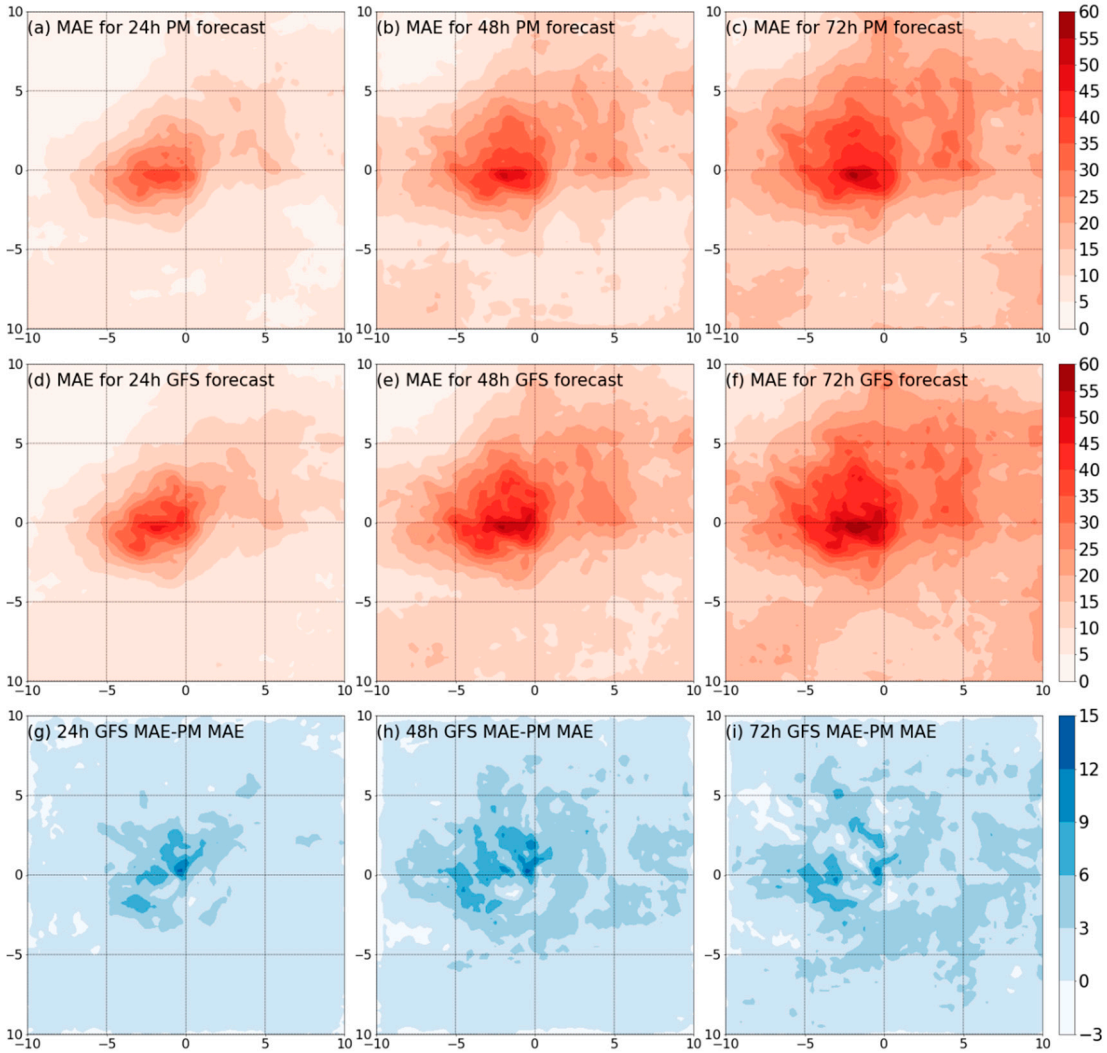

Figure S4. The spatial distribution of precipitation prediction MAE (mm) by PM and GFS models with different lead times: (a) PM with 24 h, (b) PM with 48 h, (c) PM with 72 h, (d) GFS with 24 h, (e) GFS with 48 h, (f) GFS with 72 h. The spatial distribution of the MAE (mm) difference in precipitation prediction between GFS model and PM model with different lead times: (g) 24 h, (h) 48 h, and (i) 72 h.

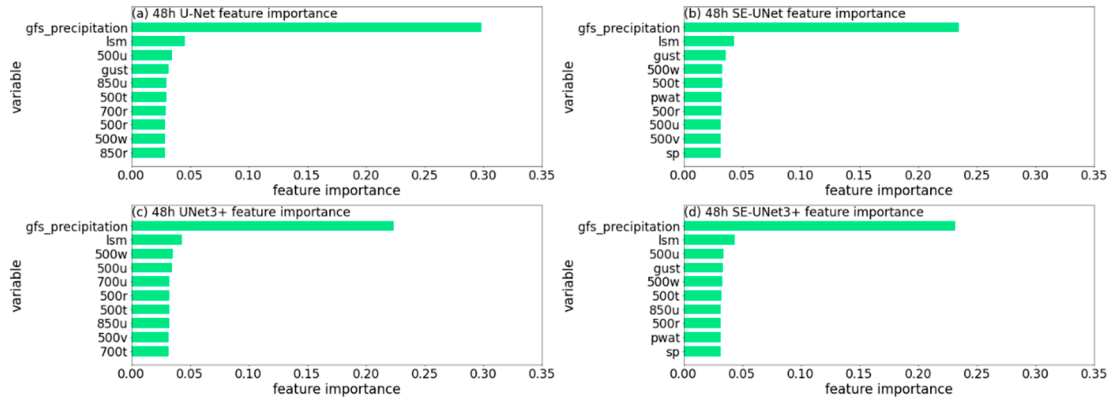

Figure S5. The first 10 significant features for 48-hour accumulated precipitation prediction by the

models of (a) U-Net, (b) SE-UNet, (c) UNet3+, and (d) SE-UNet3+.

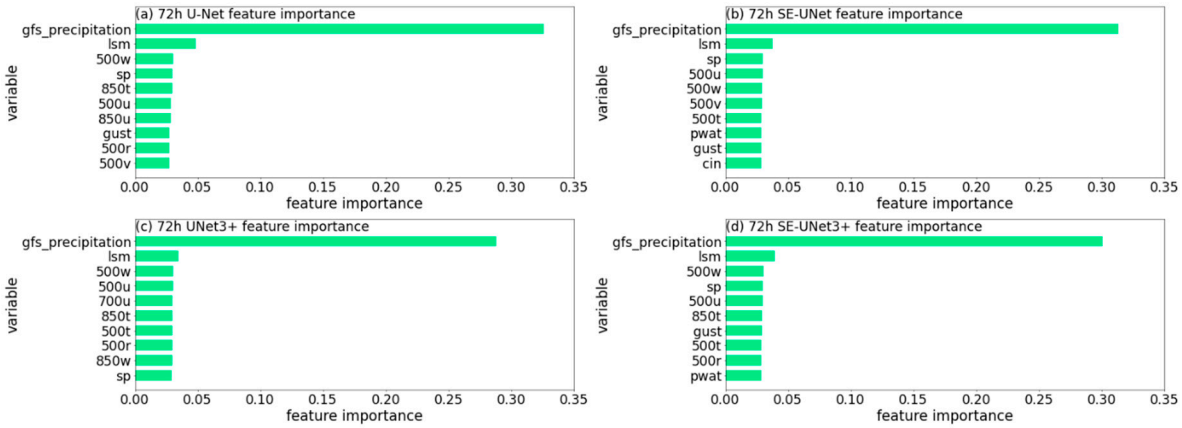

Figure S6. The first 10 significant features for 72-hour accumulated precipitation prediction by the models of (a) U-Net, (b) SE-UNet, (c) UNet3+, and (d) SE-UNet3+.