Supplementary Material

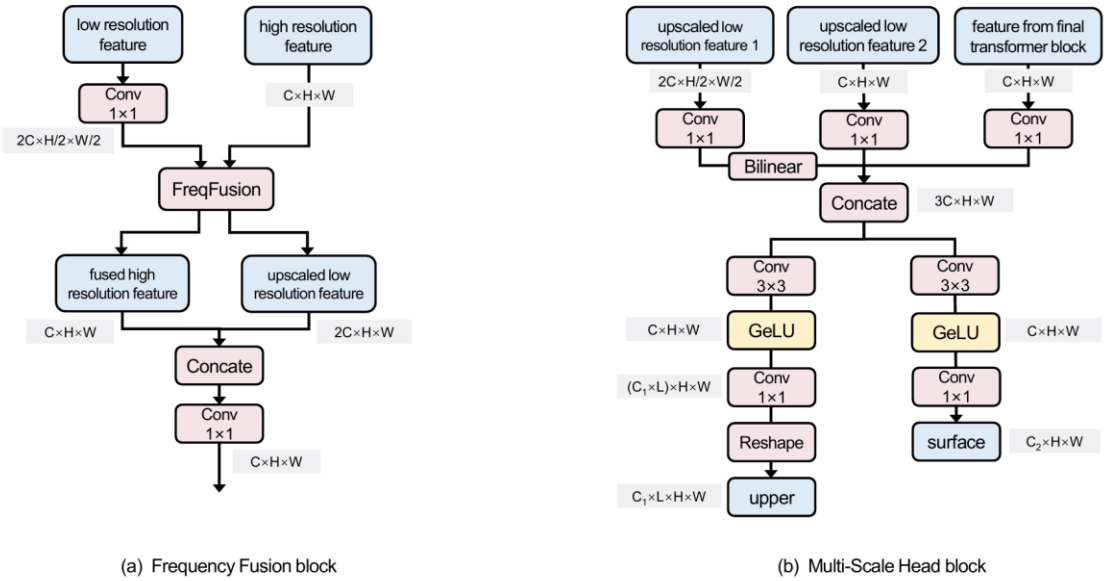

Figure S1. Schematic diagram of Frequency Fusion block (a), and Multi-Scale Head block (b). In subplot (a), low resolution feature in Frequency Fusion block comes from skip connections in Figure 1a. High resolution feature comes from Transformer block. In subplot (b), the two upscaled low resolution features are the corresponding features of the two Frequency Fusion blocks in Figure 1a. The dimensions of matrixes at each node are shown.

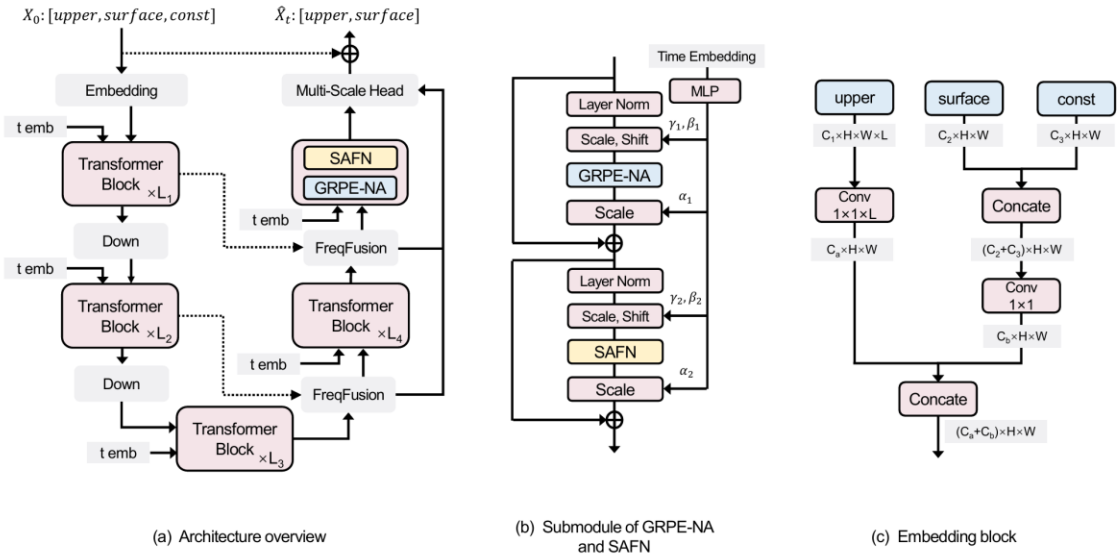

Figure S2. Schematic diagram of model architecture with time embedding inputs (a), submodule of GRPE-NA and SAFN (b), and Embedding block (c). The adaptive layer normalization is used in submodule of (b). The dimensions of matrixes at each node are shown.

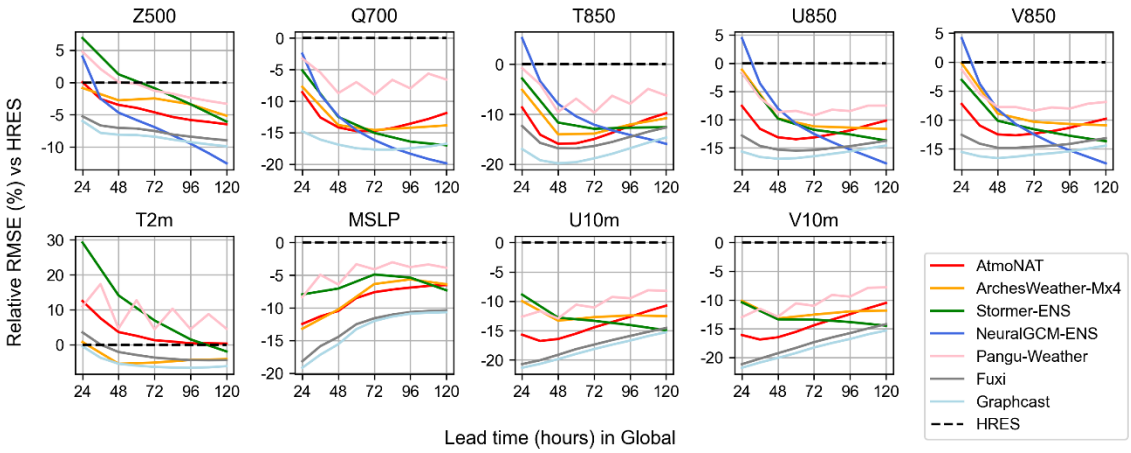

Figure S3. Relative RMSE of DWMs on key variables. Relative RMSE is calculated based on HRES performances. All the models including those trained on 0.25° resolution are shown.

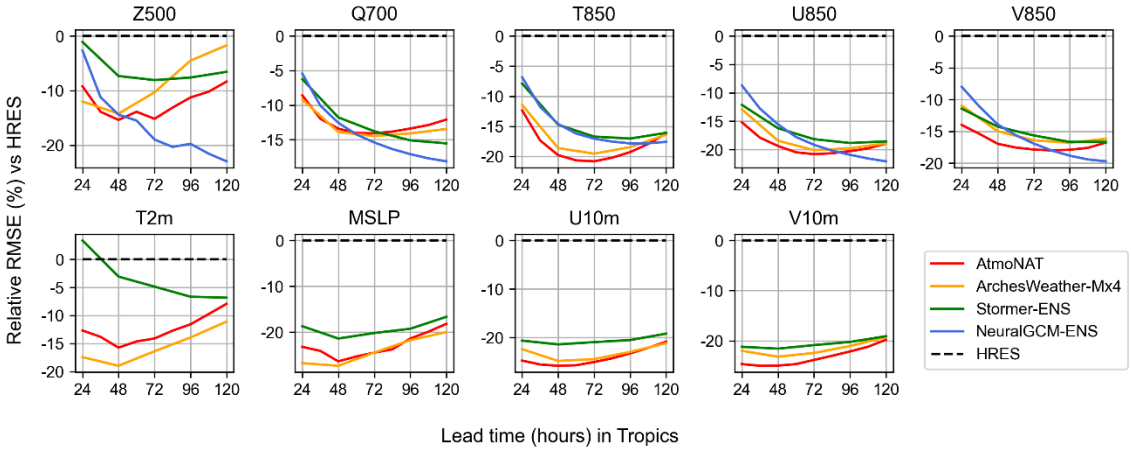

Figure S4. Relative RMSE of DWMs trained on coarse resolution on key variables. Relative RMSE is calculated based on HRES performances in the tropics.

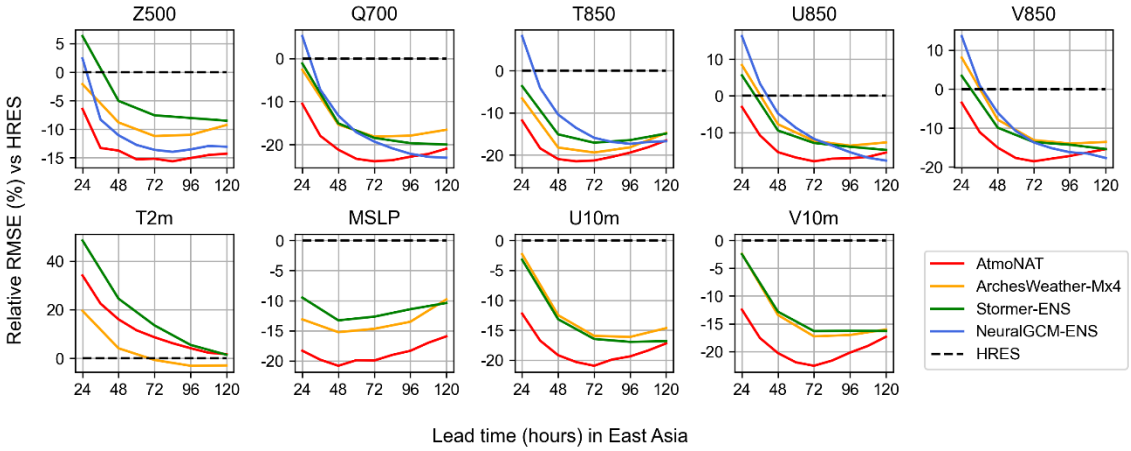

Figure S5. Relative RMSE of DWMs trained on coarse resolution on key variables. Relative RMSE is calculated based on HRES performances in East Asia.

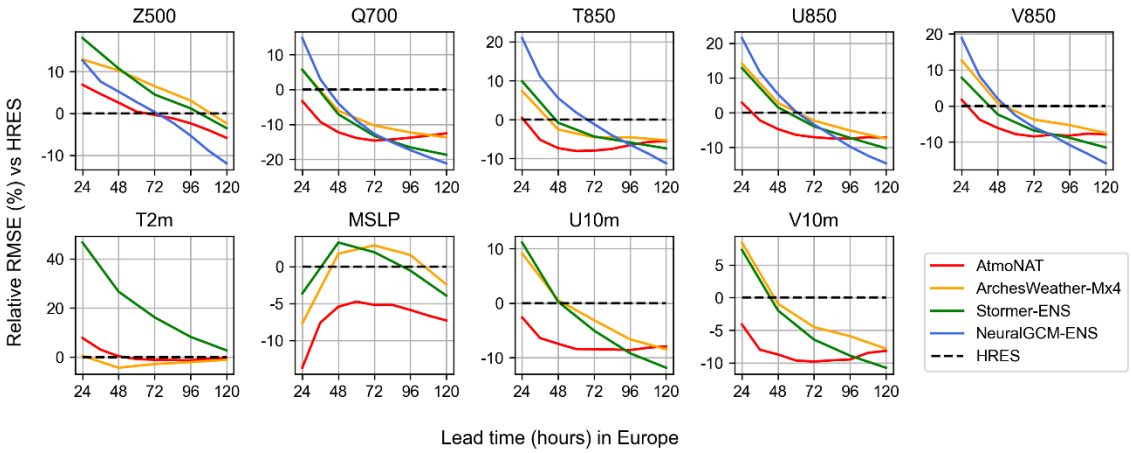

Figure S6. Relative RMSE of DWMs trained on coarse resolution on key variables. Relative RMSE is calculated based on HRES performances in Europe.

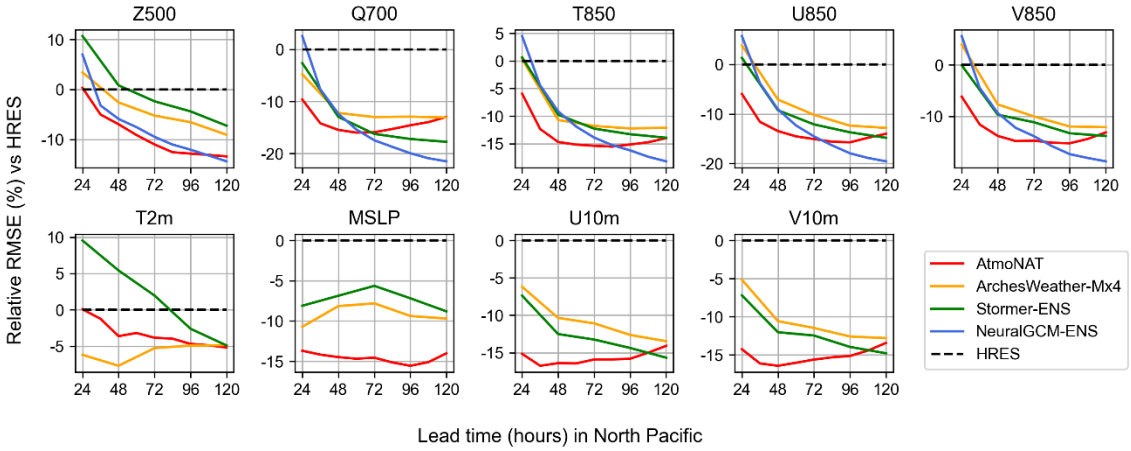

Figure S7. Relative RMSE of DWMs trained on coarse resolution on key variables. Relative RMSE is calculated based on HRES performances in North Pacific.

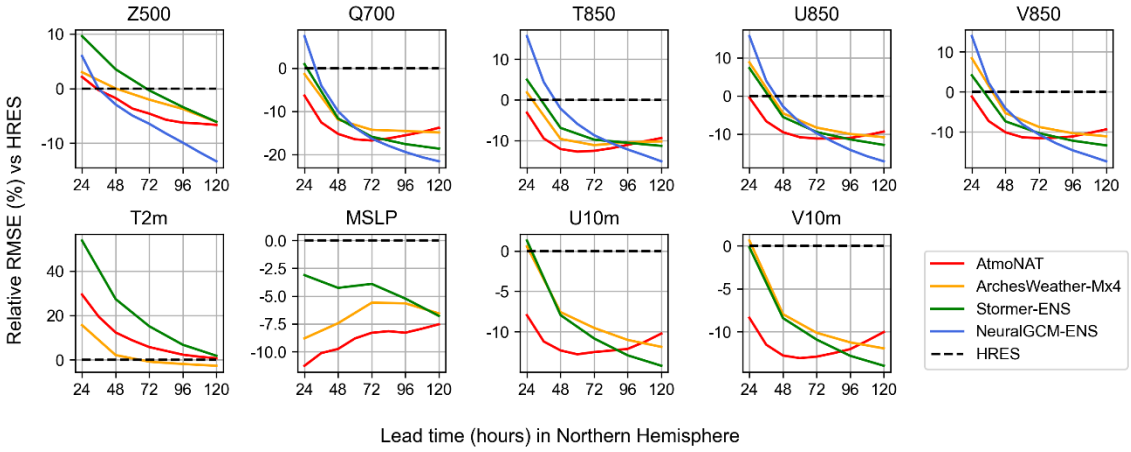

Figure S8. Relative RMSE of DWMs trained on coarse resolution on key variables. Relative RMSE is calculated based on HRES performances in Northern Hemisphere.

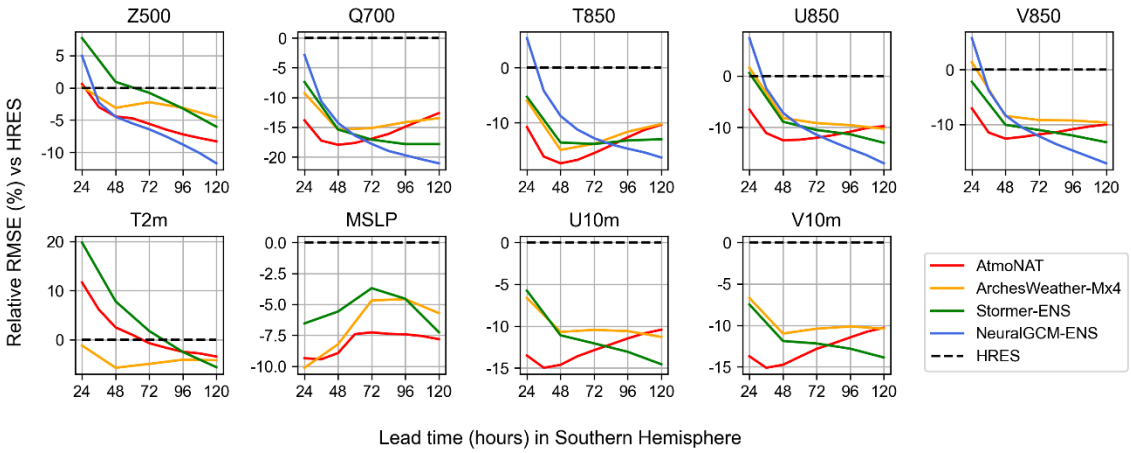

Figure S9. Relative RMSE of DWMs trained on coarse resolution on key variables. Relative RMSE is calculated based on HRES performances in Southern Hemisphere.

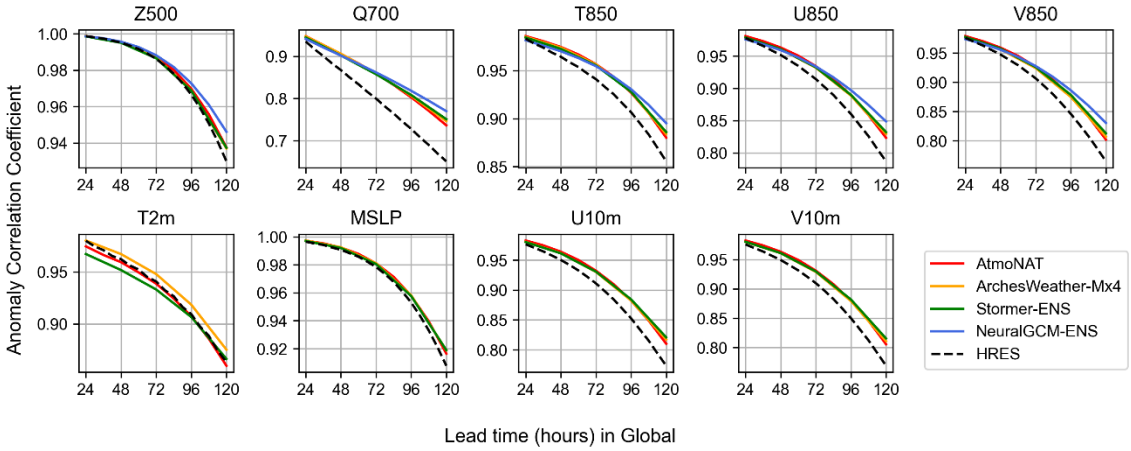

Figure S10. ACC of different DWMs trained on coarse resolution on key variables till 120-hour lead time.

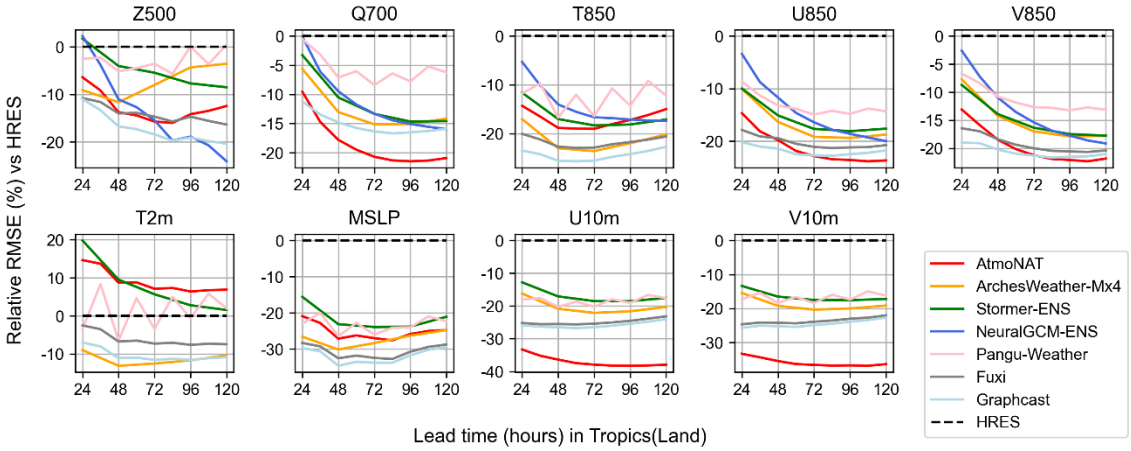

Figure S11. Relative RMSE of DWMs in land area of the tropics on key variables. Relative RMSE is calculated based on HRES performances.

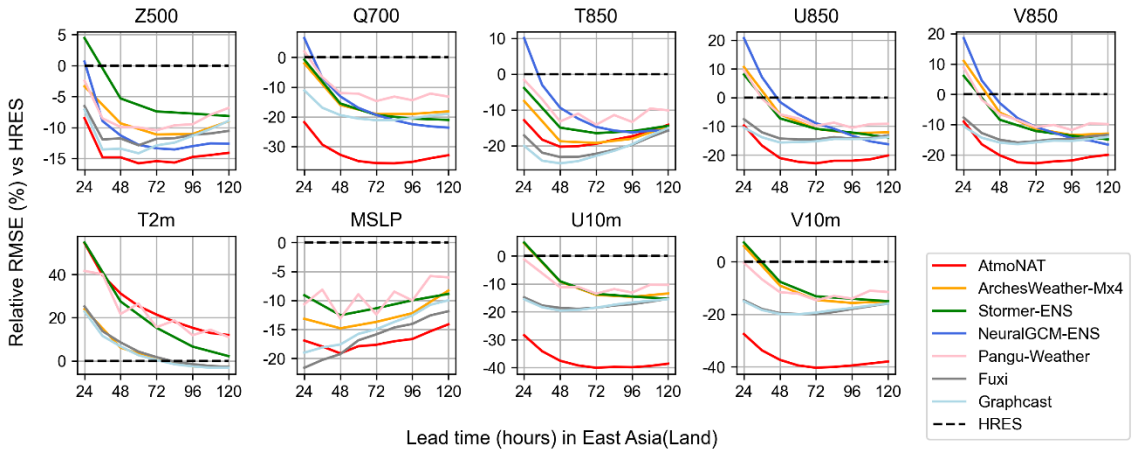

Figure S12. Relative RMSE of DWMs in land area of East Asia on key variables. Relative RMSE is calculated based on HRES performances.

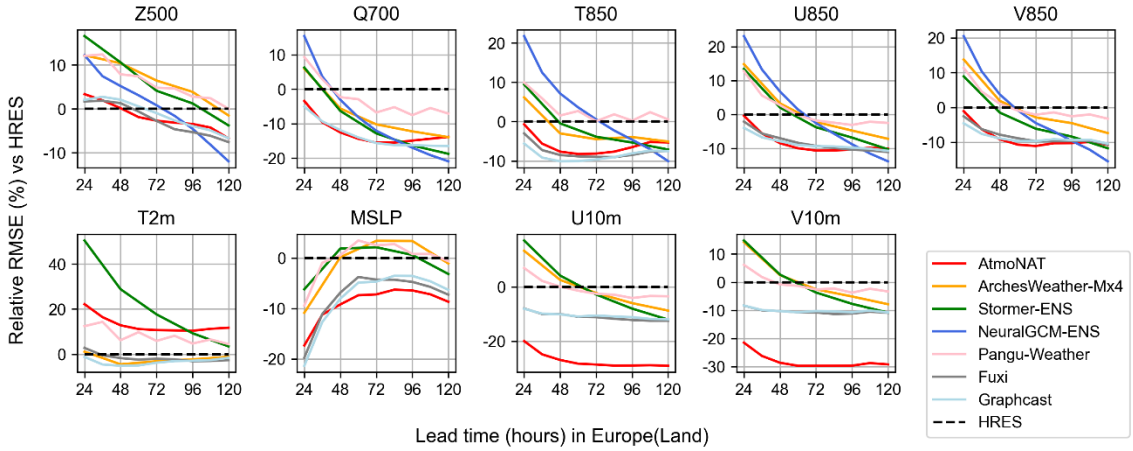

Figure S13. Relative RMSE of DWMs in land area of Europe on key variables. Relative RMSE is calculated based on HRES performances.

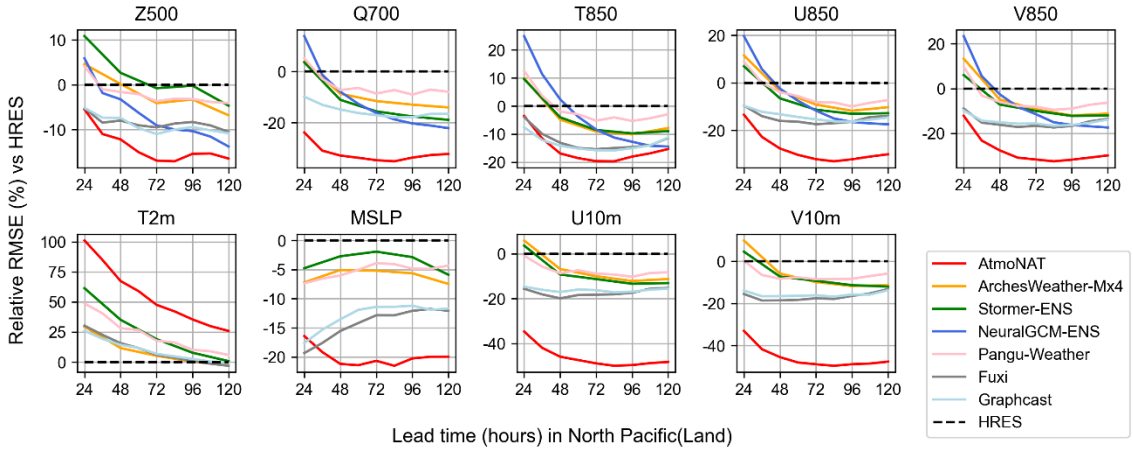

Figure S14. Relative RMSE of DWMs in land area of North Pacific on key variables. Relative RMSE is calculated based on HRES performances.

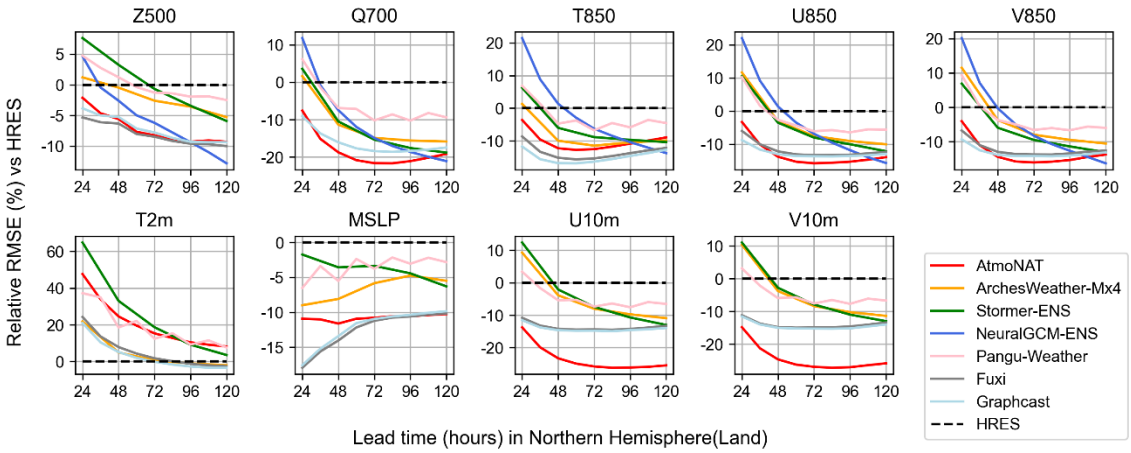

Figure S15. Relative RMSE of DWMs in land area of Northern Heimisphere on key variables. Relative RMSE is calculated based on HRES performances.

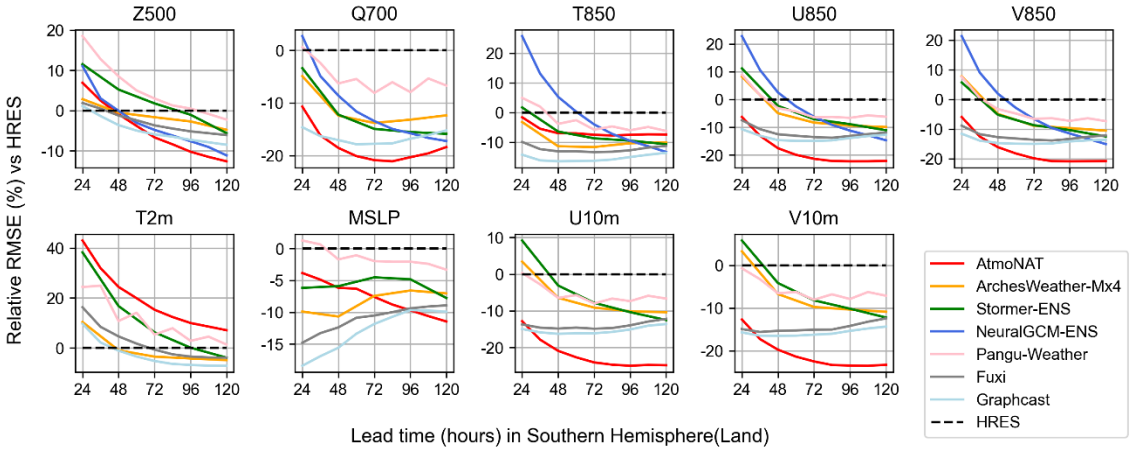

Figure S16. Relative RMSE of DWMs in land area of Southern Hemisphere on key variables. Relative RMSE is calculated based on HRES performances.

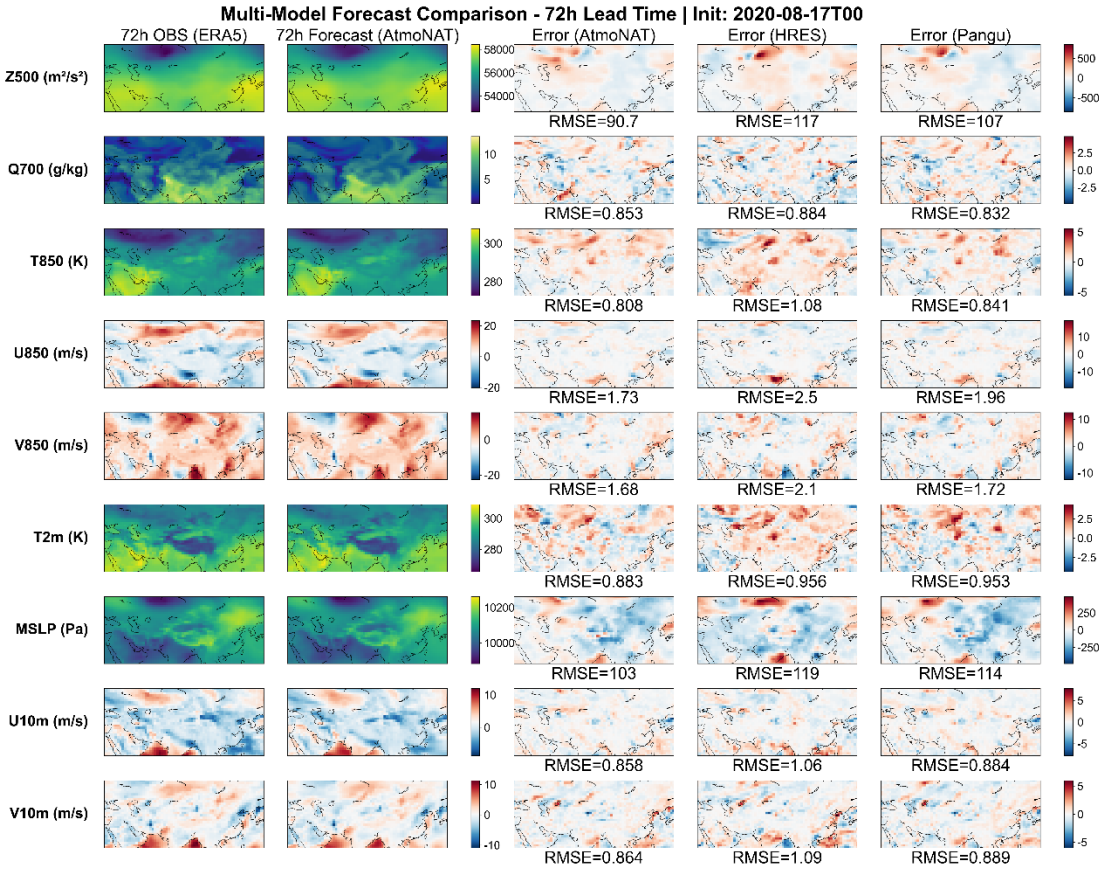

Figure S17. Forecast comparisons between AtmoNAT, HRES, and Pangu-Weather on Eurasia at 72-hour lead time initialized at UTC 2020-08-17 00:00. From left to right columns are ground truth data from ERA5, predicted fields from AtmoNAT, error fields from AtmoNAT, HRES, and Pangu-Weather. RMSE of each error field is located at the bottom of each subplot.

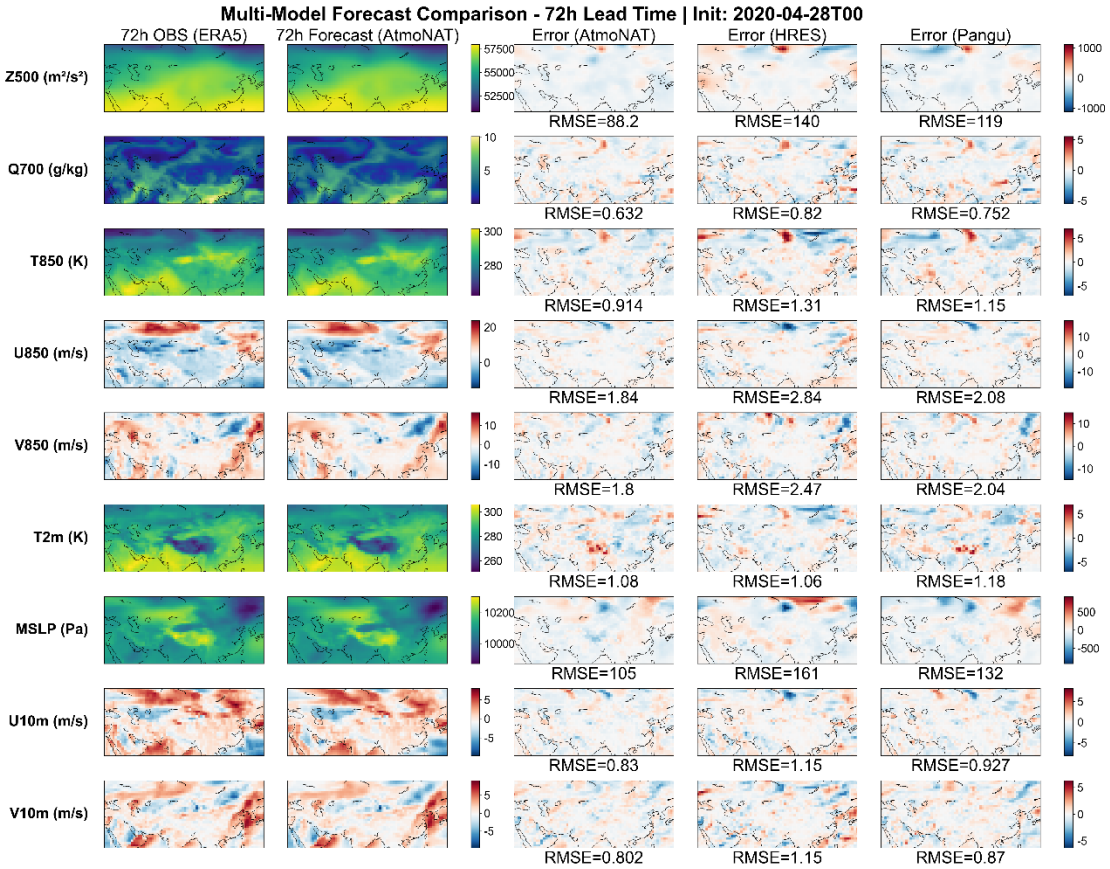

Figure S18. Forecast comparisons between AtmoNAT, HRES, and Pangu-Weather on Eurasia at 72-hour lead time initialized at UTC 2020-04-28 00:00. From left to right columns are ground truth data from ERA5, predicted fields from AtmoNAT, error fields from AtmoNAT, HRES, and Pangu-Weather. RMSE of each error field is located at the bottom of each subplot.