

**Supporting Information for Deep Learning Model for Sea Surface Salinity Forecast
in the Tropical Pacific Ocean during ENSO Events**

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Introduction

The supplementary file is mainly for the analysis of models forecast errors, mainly including the spatial RMSE and Bias and temporal RMSE and MAE. The bias between the filtered DNN and the CCI SSS is also analyzed, in addition to the bias of the specific DNN SSSA index.

Text S1.

Our DNN model with proposed CSE function significantly improves the spatial forecast results. From the spatial RMSE and Bias, it can be seen that the RMSE obtained using the CSE function (Figure S1.B) is better improved than the MSE function (Figure S1.A) in the north of the equator, and is suppressed from 0.10 to 0.15 to 0.03 to 0.08 pss. The same improvements are also seen on spatial bias, such as the more obvious bias of MSE function (Figure S1.C) at 140°W and 10°S was well reduced by the CSE function (Figure S1.D).

We calculated the RMSE, mean absolute error (MAE), and the bias of the models participating in the experiment to further demonstrate the performance of DNN. For all samples during the test period, the RMSE and Bias of the spatial distribution are calculated grid-by-grid (see Figure S3). The global RMSE of the DNN, ConvLSTM, and ConvGRU is 0.07, 0.10, and 0.12 pss, respectively. The global bias is 0.01, 0.03, and 0.06 pss. We adjusted the forecast data sequence to a day-by-day time series; the RMSE and MAE of the three models over time trends are calculated on a sample-by-sample basis during the test period (see Figure S4). The RMSE of the three models mentioned above varies between 0.03 and 0.11 pss, 0.09 and 0.11 pss, and 0.11 and 0.13 pss, respectively. The MAE values vary from 0.02 to 0.08 pss, 0.07 to 0.09 pss, and 0.08 to 0.10 pss. The global error statistics are shown in Table S1; the metrics are calculated as (2), (3). The forecast accuracy demonstrated a substantial relationship with SSS seasonal variations, according to the errors over time trends.

$$RMSE = \sqrt{\frac{1}{n} \sum_{i=1}^n (SSS_{result} - SSS_{GT})^2} \quad (2)$$

$$MAE = \frac{1}{n} \sum_{i=1}^n \text{mean}(|SSS_{result} - SSS_{GT}|) \quad (3)$$

Where n is the total number of samples, SSS_{result} is the SSS forecast result by the DNN, and SSS_{GT} is the CCI SSS (satellite SSS) at the same time step of the test dataset.

The spatial distribution of SSS fields forecasted by three model iterations over three subsequent time steps is supplemented by Figure S5. Bias in Figure S8 is CCI SSS minus the forecast SSS.

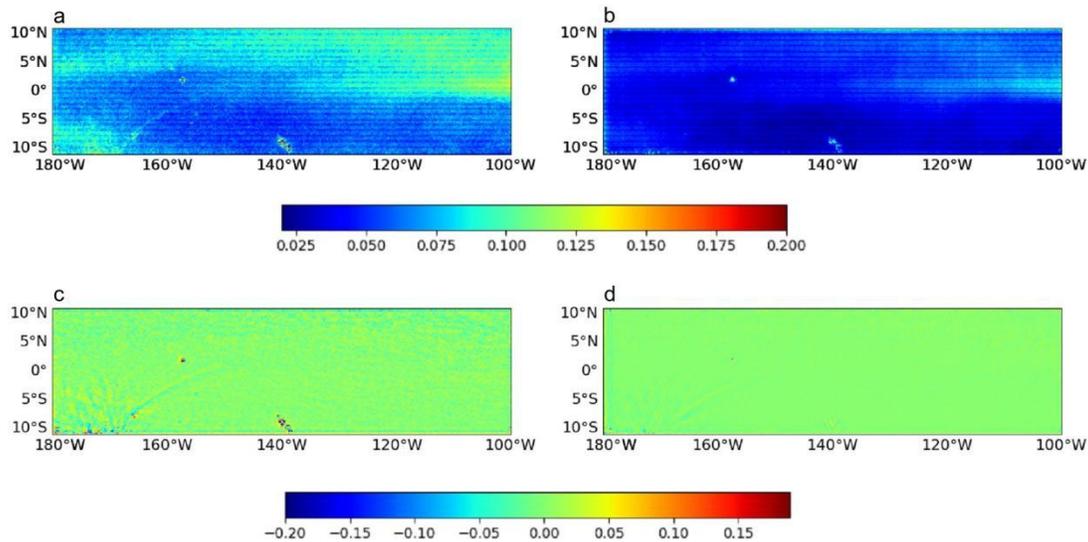


Figure S1. RMSE and Bias distribution of DNN forecast SSS, using different loss functions during the testing period: (a, c) MSE function, (b, d) CSE function.

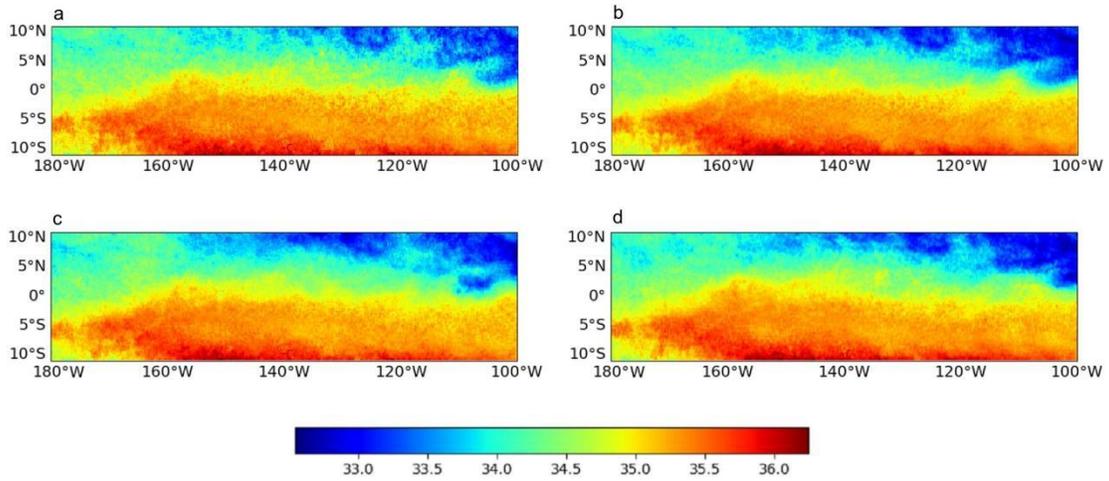


Figure S2. Comparison of forecast SSS fields on July 12, 2015. (a) CCI SSS fields, the SSS fields forecast by the DNN model (b), ConvLSTM model (c), and ConvGRU model (d)

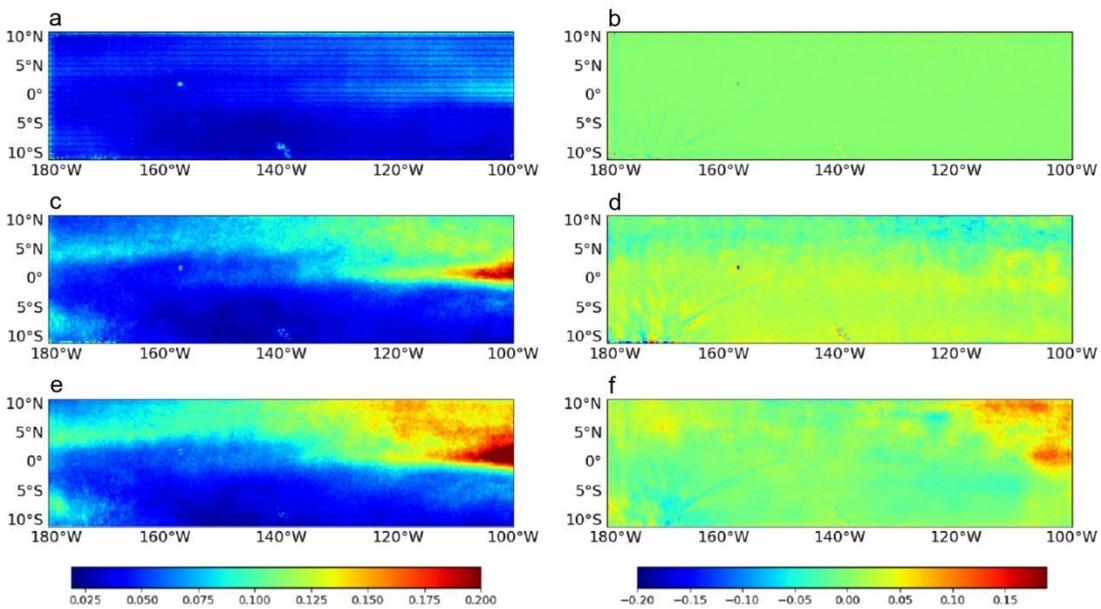


Figure. S3. Spatial distribution of errors during the testing period. (a) RMSE of the DNN model, (c) RMSE of the ConvLSTM model, (e) RMSE of the ConvGRU model, (b) bias of the DNN model, (d) bias of the ConvLSTM model, and (f) bias of the ConvGRU model.

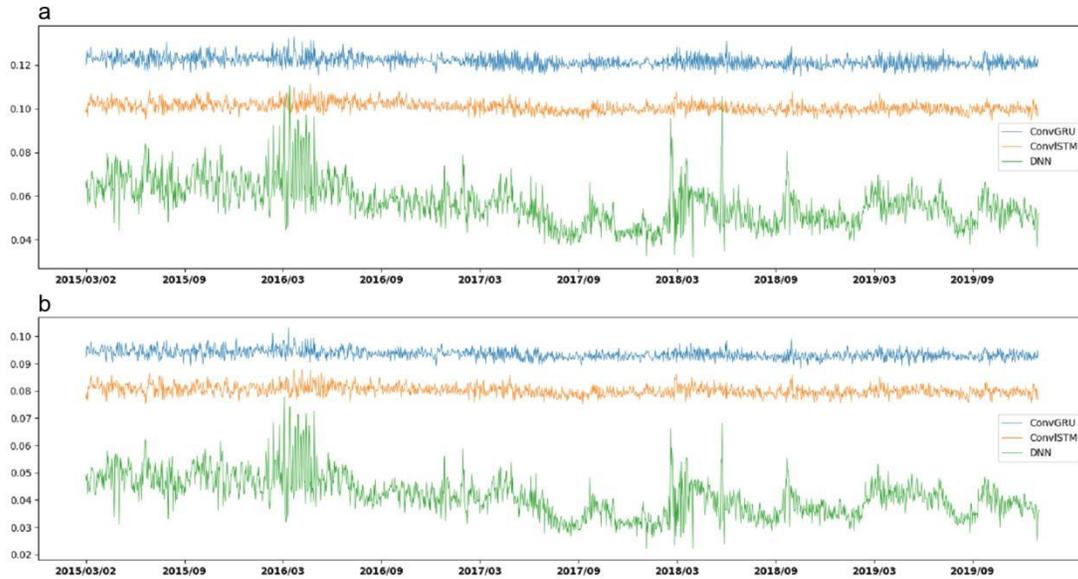


Figure S4. The time trends of errors during the testing period. (a) RMSE comparison of three deep learning models and (b) MAE comparison of three deep learning models.

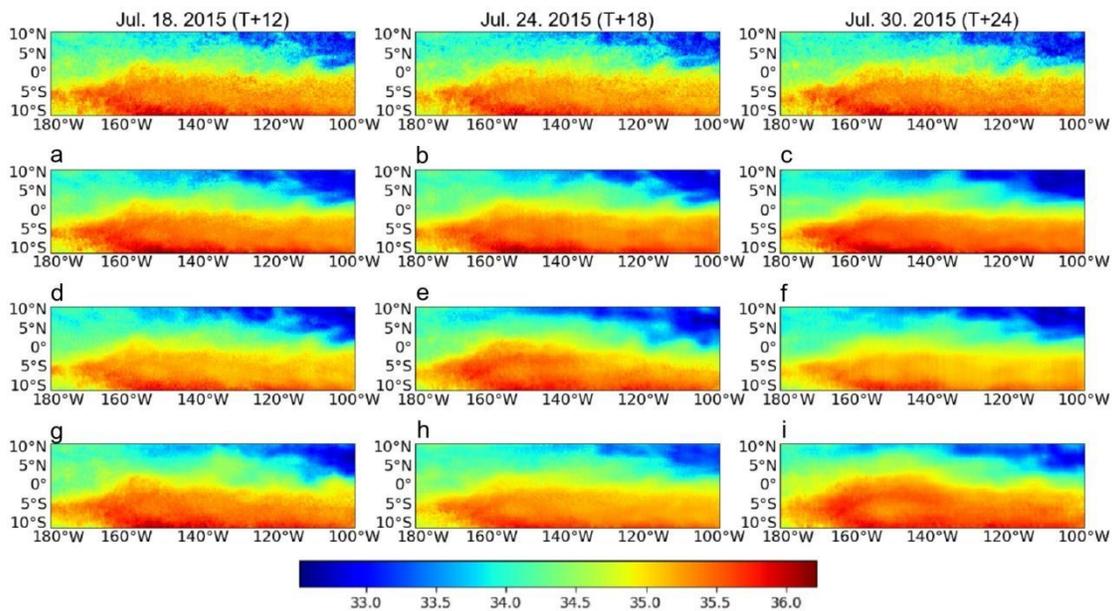


Figure S5. Spatial distributions of the CCI and forecast SSS fields at three subsequent time steps (July 18, 2015, July 24, 2015, and July 30, 2015). CCI SSS fields at the 3 steps and those forecast by the DNN model ((a to c), ConvLSTM model (d to f), and ConvGRU model (g to i).

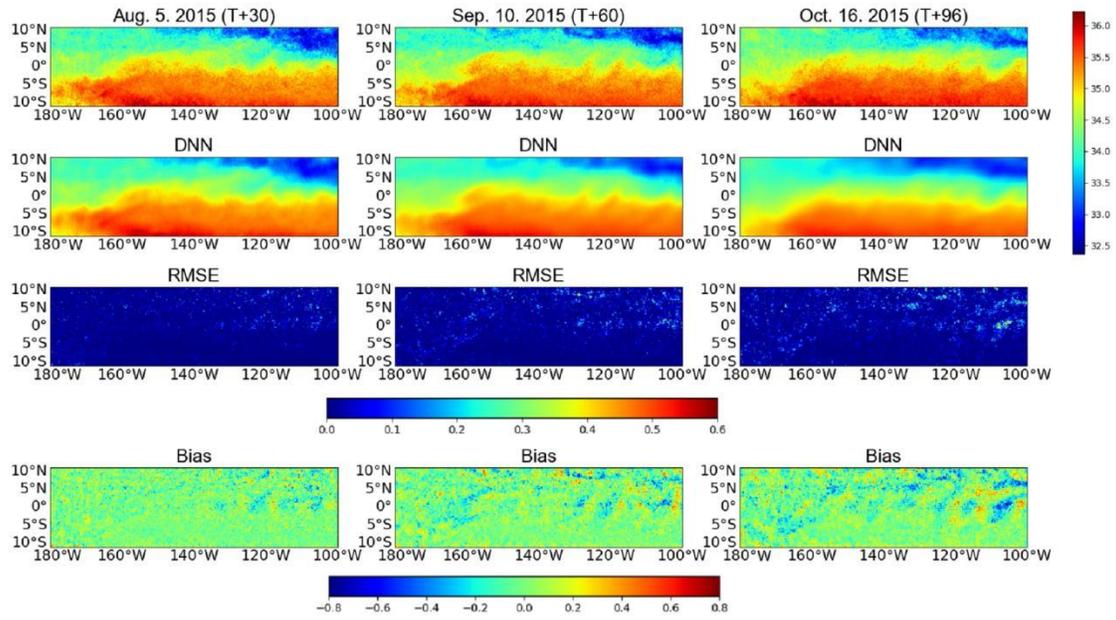


Figure S6. Comparison of SSS fields spatial distribution, the RMSE, and the bias at the 5th, 10th, and 16th, forecast of the DNN model with the CCI SSS on August 6, 2015, September 10, 2015, and October 16, 2015.

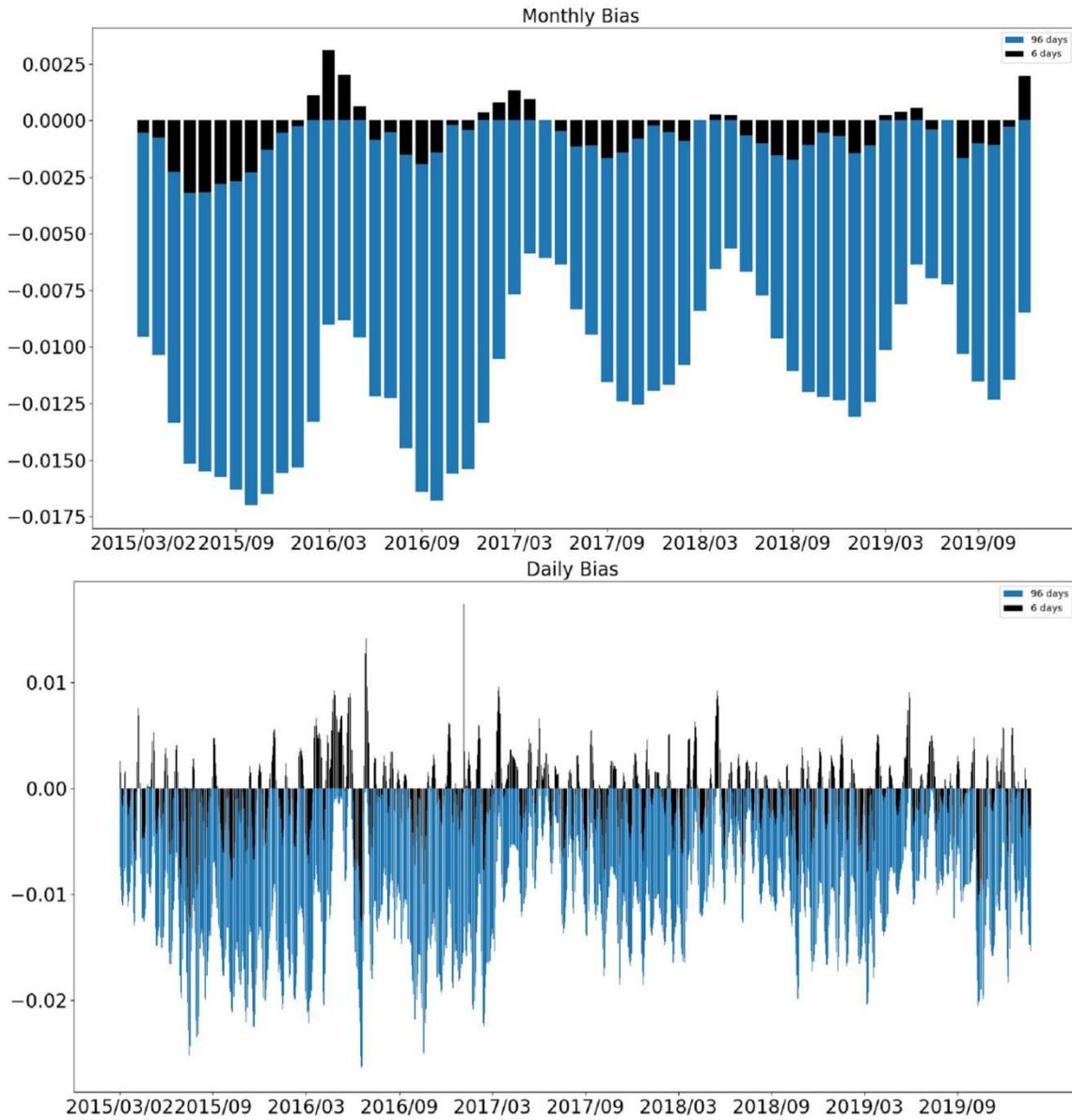


Figure S7. The comparison of bias for monthly and daily time series of DNN forecast SSS anomalies with 6-day (black) and 96-day (blue).