Supporting Information for

A Space-time Partial Differential Equation Based Physics-Guided Neural Networks for Sea Surface Temperature Prediction

TaikangYuan[a], Kaijun Ren[a]*, Junxing Zhu[a]*, Wuxin Wang[b], Jingze Lu[b], Xiang Wang[a], Xiaoyong Li[a]

[a]College of Meteorology and Oceanography, National University of Defense Technology, Changsha, Hunan, China

[b]College of Computer Science and Technology, National University of Defense Technology, Changsha, Hunan, China

* Corresponding author: {kaijunren@nudt.edu.cn } and {zhujunxing@nudt.edu.cn}

Contents of this file:

(1) Text S1 to S6
(2) Table S1 to S23
(3) Figure S1 to S57

Introduction

The supporting information provides detail of the design of the deep CNN neural network model, deep ConvLSTM neural network model, and deep Vision Transformer neural network model, the line chart for 1-10day ahead prediction of SST by different methods using various input samples (1-10year), the comparisons of our framework with various state-of-the-art models, and the histogram for 1-10day ahead prediction mechanisms of SST by different methods using various input samples (1-10year).

Text S1. Supporting information for “Sensitivity experiments performed for robustness”

Improved performance (mean ± std) of the empirical equation by three algorithms (compared with the finite difference method) in predicting the SST RMSE using different numbers of datasets (1-10years).

Models	1day	5day	10day
Number of smaple: 10 years			
STPDE-NET-1	18.56% ± 0.15%	13.15% ± 0.12%	10.52% ± 0.08%
STPDE-NET-2	14.99% ± 1.60%	13.69% ± 1.47%	20.01% ± 1.39%
STPDE-NET-3	3.36% ± 2.40%	5.07% ± 1.80%	4.44% ± 2.51%
Number of smaple: 9 years			
STPDE-NET-1	18.88% ± 0.85%	18.12% ± 0.28%	11.11% ± 0.14%
STPDE-NET-2	15.27% ± 3.04%	20.47% ± 1.78%	21.90% ± 2.40%
STPDE-NET-3	3.83% ± 1.25%	11.23% ± 0.46%	6.67% ± 1.30%
Number of smaple: 8 years			
STPDE-NET-1	18.42% ± 0.00%	13.47% ± 0.60%	10.60% ± 0.40%
STPDE-NET-2	9.26% ± 2.29%	10.97% ± 3.09%	15.91% ± 2.44%
STPDE-NET-3	5.21% ± 0.73%	6.00% ± 0.82%	7.34% ± 0.84%
Number of smaple: 7 years			
STPDE-NET-1	18.23% ± 0.19%	13.28% ± 0.00%	10.75% ± 0.00%
STPDE-NET-2	14.70% ± 0.84%	11.41% ± 0.85%	13.87% ± 2.74%
STPDE-NET-3	2.15% ± 2.19%	-10.4% ± 12.39%	3.15% ± 3.47%
Number of smaple: 6 years			
STPDE-NET-1	18.87% ± 1.27%	13.85% ± 0.30%	11.30% ± 0.35%
STPDE-NET-2	17.52% ± 1.44%	12.55% ± 1.80%	15.48% ± 2.92%
STPDE-NET-3	3.72% ± 2.92%	4.94% ± 1.01%	6.27% ± 2.36%
Number of smaple: 5 years			
STPDE-NET-1	18.78% ± 1.16%	14.55% ± 0.84%	12.20% ± 0.51%
STPDE-NET-2	16.41% ± 4.11%	12.39% ± 2.96%	10.31% ± 2.16%
STPDE-NET-3	3.76% ± 0.61%	5.36% ± 0.37%	6.13% ± 0.07%
Number of smaple: 4 years			
STPDE-NET-1	20.22% ± 1.18%	15.27% ± 0.69%	12.68% ± 0.49%
STPDE-NET-2	18.47% ± 1.44%	15.48% ± 0.61%	15.02% ± 3.08%
STPDE-NET-3	3.83% ± 2.89%	4.94% ± 0.70%	6.18% ± 0.62%
Number of smaple: 3 years			
STPDE-NET-1	20.54% ± 1.08%	14.98% ± 0.66%	12.58% ± 0.51%
STPDE-NET-2	21.46% ± 0.97%	16.80% ± 0.55%	13.85% ± 5.31%
STPDE-NET-3	4.87% ± 0.54%	4.82% ± 1.07%	6.43% ± 0.46%
Number of smaple: 2 years			
STPDE-NET-1	19.53% ± 0.19%	15.69% ± 0.13%	12.86% ± 0.00%
STPDE-NET-2	13.77% ± 7.79%	14.09% ± 2.86%	13.37% ± 3.81%

STPDE-NET-3	6.33% ± 1.59%	6.90% ± 0.66%	6.79% ± 0.11%
Number of smaple: 1 years			
STPDE-NET-1	17.88% ± 0.11%	11.93% ± 0.14%	9.06% ± 0.00%
STPDE-NET-2	13.97% ± 8.19%	9.48% ± 1.07%	6.26% ± 1.30%
STPDE-NET-3	1.31% ± 0.35%	2.29% ± 0.51%	3.47% ± 0.38%

Text S1. Design of the architecture of the deep CNN neural network model

The time window of all methods is fixed in 7 days for different horizontal SST prediction. First, we design the CNN models with different parameter settings. For each setting, we train the traditional date-driven deep learning model test the 1-day lead prediction performance. Here, four stages of experiments are conducted to determine the best parameters of the CNN model, including the number of epochs denote by e_{cnn}, the number of CNN layers denote by l_{cnn}, the number of hidden units of CNN denote by $hidden_cnn$, and the learning rate of CNN denote by lr_cnn.

To measure the prediction of CNN models with different parameter settings, five indexes are used, including the root mean square error (RMSE), mean square error (MSE), mean absolute error (MAE), mean absolute percentage error (MAPE) and correlation coefficient (r).

$$RMSE = \frac{1}{n}\sum_{i=1}^{n}\sqrt{(y_i - y_i^{'})^2} \qquad MSE = \frac{1}{n}\sum_{i=1}^{n}(y_i - y_i^{'})^2$$

$$MAE = \frac{1}{n}\sum_{i=1}^{n}|y_i - y_i^{'}| \qquad MAPE = \frac{1}{n}\sum_{i=1}^{n}\left|\frac{(y_i - y_i^{'})}{y_i}\right|$$

$$r = \frac{\sum_{i=1}^{n}(y_i - \bar{y_i})(y_i^{'} - \bar{y_i^{'}})}{\sqrt{\sum_{i=1}^{n}(y_i - \bar{y_i})^2}\sqrt{\sum_{i=1}^{n}(y_i^{'} - \bar{y_i^{'}})^2}} \qquad (1)$$

where, y_i represents the target SST values, $y_i^{'}$ means the predicted SST values, $\bar{y_i}$ denotes the average of the target SST values, and $\bar{y_i^{'}}$ is the means of the predicted SST values.

Stage 1: Determine e_{cnn}

To determine e_{cnn}, we first fix l_{cnn} as 3 according to the works of Ham *et al*, $hidden_cnn$ as 16 to 32 to 1, and lr_cnn as 0.001. Then we vary the value of e_{cnn} from the set {50,100,200,300,400}. The results are shown in Table S1. From Table S1, we can see that when $e_{cnn} = 300$, the models can obtain satisfactory results. Hence, we set $e_{cnn} = 300$.

Table S1

Prediction results (mean ± std) for 1-day ahead with different e_{cnn} settings.

Indexes / e_{cnn}	RMSE	MSE	MAE	MAPE	r
50	1.140 ± 0.109	3.921 ± 5.924	0.889 ± 0.096	0.034 ± 0004	0.699 ± 0.023
100	1.003 ± 0.110	1.017 ± 0.227	0.776 ± 0.079	0.029 ± 0.003	0.757 ± 0.028
200	1.026 ± 0.201	1.085 ± 0.444	0.810 ± 0.172	0.030 ± 0.007	0.754 ± 0.031
300	**0.916 ± 0.072**	**0.843 ± 0.134**	**0.713 ± 0.042**	**0.027 ± 0.002**	**0.771 ± 0.010**
400	0.970 ± 0.117	0.952 ± 0.089	0.759 ± 0.089	0.028 ± 0.004	0.768 ± 0.016

Stage 2: Determine l_{cnn}

To determine l_{cnn}, we first fix e_{cnn} as 300, $hidden_cnn$ as 16 to 32 to 1, and lr_cnn as 0.001. Then we vary the value of l_{cnn} from the set {1,2,3,4,5}. The results are shown in Table S2. From Table S2, we can see that when $l_{cnn} = 2$, the models can obtain satisfactory results. Hence, we set $l_{cnn} = 2$.

Table S2

Prediction results (mean ± std) for 1-day ahead with different l_{cnn} settings.

Indexes / l_{cnn}	RMSE	MSE	MAE	MAPE	r
1	1.034 ± 0.179	1.094 ± 0.395	0.828 ± 0.157	0.031 ± 0.006	0.802 ± 0.021
2	**0.881 ± 0.096**	**0.784 ± 0.173**	**0.692 ± 0.070**	**0.026 ± 0.003**	**0.809 ± 0.010**
3	0.916 ± 0.072	0.843 ± 0.134	0.713 ± 0.042	0.027 ± 0.002	0.771 ± 0.010
4	1.014 ± 0.076	1.032 ± 0.153	0.789 ± 0.049	0.030 ± 0.002	0.731 ± 0.013
5	1.080 ± 0.085	1.174 ± 0.186	0.842 ± 0.076	0.032 ± 0.003	0.735 ± 0.025

Stage 3: Determine $hidden_cnn$

To determine $hidden_cnn$, we first fix e_{cnn} as 300, l_{cnn} as 2, and lr_cnn as 0.001. Then we vary the value of $hidden_cnn$ from the set {4,8,16,32,64}. The results are shown in Table S3. From Table S3, we can see that when $hidden_cnn = 16$, the models can obtain satisfactory results. Hence, we set $hidden_cnn = 16$.

Table S3

Prediction results (mean ± std) for 1-day ahead with different $hidden_cnn$ settings.

Indexes / *hidden_cnn*	RMSE	MSE	MAE	MAPE	r
4	0.993 ± 0.162	1.007 ± 0.327	0.795 ± 0.144	0.030 ± 0.006	0.791 ± 0.012
8	0.961 ± 0.127	0.937 ± 0.264	0.756 ± 0.108	0.028 ± 0.004	0.793 ± 0.013
16	**0.881 ± 0.096**	**0.784 ± 0.173**	**0.692 ± 0.070**	**0.026 ± 0.003**	**0.809 ± 0.010**
32	0.931 ± 0.130	0.881 ± 0.244	0.732 ± 0.100	0.027 ± 0.004	0.799 ± 0.018
64	0.968 ± 0.042	0.939 ± 0.082	0.757 ± 0.030	0.028 ± 0.001	0.784 ± 0.007

Stage 4: Determine lr_cnn

To determine lr_cnn, we first fix e_{cnn} as 300, l_{cnn} as 2, and $hidden_cnn$ as 16. Then we vary the value of lr_cnn from the set {0.01, 0.005, 0.001, 0.0005, 0.0001}. The results are shown in Table S4. From Table S4, we can see that when $lr_cnn = 0.001$, the models can obtain satisfactory results. Hence, we set $lr_cnn = 0.001$.

Table S4

Prediction results (mean ± std) for 1-day ahead with different lr_cnn settings.

Indexes / lr_cnn	RMSE	MSE	MAE	MAPE	r
0.01	1.064 ± 0.096	1.139 ± 0.197	0.840 ± 0.087	0.032 ± 0.003	0.777 ± 0.035
0.005	1.038 ± 0.118	1.088 ± 0.234	0.820 ± 0.096	0.031 ± 0.004	0.790 ± 0.015
0.001	**0.881 ± 0.096**	**0.784 ± 0.173**	**0.692 ± 0.070**	**0.026 ± 0.003**	**0.809 ± 0.010**
0.0005	0.912 ± 0.123	0.881 ± 0.320	0.725 ± 0.125	0.027 ± 0.005	0.800 ± 0.014
0.0001	0.910 ± 0.017	0.829 ± 0.012	0.715 ± 0.012	0.027 ± 0.001	0.763 ± 0.008

Text S2. Design of the architecture of the deep ConvLSTM neural network model

The time window of all methods is fixed in 7 days for different horizontal SST prediction. First, we design the ConvLSTM models with different parameter settings. For each setting, we train the traditional date-driven deep learning model test the 1-day lead prediction performance. Here, four stages of experiments are conducted to determine the best parameters of the ConvLSTM model, including the number of epochs denote by e_{lstm}, the number of ConvLSTM layers denote by l_{lstm}, the number of hidden units of ConvLSTM denote by $hidden_lstm$, and the learning rate of ConvLSTM denote by lr_lstm.

Stage 1: Determine e_{lstm}

To determine e_{lstm}, we first fix l_{lstm} as 3 according to the works of Xiao *et al*, $hidden_lstm$ as 16, and lr_lstm as 0.001. Then we vary the value of e_{lstm} from the set $\{50,100,200,300,400\}$. The results are shown in Table S5. From Table S5, we can see that when $e_{lstm} = 200$, the models can obtain satisfactory results. Hence, we set $e_{lstm} = 200$.

Table S5

Prediction results (mean ± std) for 1-day ahead with different e_{lstm} settings.

Indexes / e_{lstm}	RMSE	MSE	MAE	MAPE	r
50	1.371 ± 0.013	1.879 ± 0.037	1.108 ± 0.021	0.041 ± 0.001	0.000 ± 0.000
100	0.714 ± 0.203	0.543 ± 0.275	0.558 ± 0.155	0.021 ± 0.006	0.858 ± 0.072
200	**0.440 ± 0.103**	**0.202 ± 0.099**	**0.351 ± 0.079**	**0.013 ± 0.003**	0.958 ± 0.030
300	0.494 ± 0.151	0.262 ± 0.161	0.403 ± 0.136	0.015 ± 0.005	**0.958 ± 0.026**
400	0.494 ± 0.151	0.262 ± 0.161	0.403 ± 0.136	0.015 ± 0.005	**0.958 ±0.026**

Stage 2: Determine l_{lstm}

To determine l_{lstm}, we first fix e_{lstm} as 200, $hidden_lstm$ as 16, and lr_lstm as 0.001. Then we vary the value of l_{lstm} from the set $\{2,3,4,5\}$. The results are shown in Table S6. From Table S6, we can see that when $l_{lstm} = 3$, the models can obtain satisfactory results. Hence, we set $l_{lstm} = 3$.

Table S6

Prediction results (mean ± std) for 1-day ahead with different l_{lstm} settings.

Indexes / l_{lstm}	RMSE	MSE	MAE	MAPE	r
2	0.515 ± 0.172	0.289 ± 0.142	0.410 ± 0.142	0.015 ± 0.005	0.946 ± 0.032
3	**0.440 ± 0.103**	**0.202 ± 0.099**	**0.351 ± 0.079**	**0.013 ± 0.003**	**0.958 ± 0.030**
4	0.685 ± 0.283	0.534 ± 0.456	0.546 ± 0.222	0.020 ± 0.008	0.847 ± 0.190
5	0.840 ± 0.211	0.741 ± 0.360	0.663 ± 0.168	0.025 ± 0.006	0.822 ± 0.143

Stage 3: Determine $hidden_lstm$

To determine $hidden_lstm$, we first fix e_{lstm} as 200, l_{lstm} as 3, and lr_lstm as 0.001. Then we vary the value of $hidden_lstm$ from the set {8,16,32,64,128}. The results are shown in Table S7. From Table S7, we can see that when $hidden_lstm = 16$, the models can obtain satisfactory results. Hence, we set $hidden_lstm = 16$.

Table S7

Prediction results (mean ± std) for 1-day ahead with different $hidden_lstm$ settings.

Indexes / $hidden_lstm$	RMSE	MSE	MAE	MAPE	r
8	0.532 ± 0.157	0.303 ± 0.160	0.432 ± 0.142	0.016 ± 0.005	0.947 ± 0.021
16	**0.440 ± 0.103**	**0.202 ± 0.099**	**0.351 ± 0.079**	**0.013 ± 0.003**	**0.958 ± 0.030**
32	0.475 ± 0.138	0.241 ± 0.148	0.378 ± 0.113	0.014 ± 0.004	0.946 ± 0.041
64	0.560 ± 0.162	0.335 ± 0.181	0.446 ± 0.134	0.017 ± 0.005	0.942 ± 0.032
128	0.599 ± 0.175	0.381 ± 0.206	0.477 ± 0.147	0.018 ± 0.006	0.928 ± 0.029

Stage 4: Determine lr_lstm

To determine lr_lstm, we first fix e_{lstm} as 200, l_{lstm} as 3 and hidden$_lstm$ as 16. Then we vary the value of lr_lstm from the set {0.01, 0.005, 0.001, 0.0005, 0.0001}. The results are shown in Table S8. From Table S8, we can see that when $lr_lstm = 0.001$, the models can obtain satisfactory results. Hence, we set $lr_lstm = 0.001$.

Table S8

Prediction results (mean ± std) for 1-day ahead with different lr_lstm settings.

Indexes / lr_lstm	RMSE	MSE	MAE	MAPE	r
0.01	0.532 ± 0.117	0.294 ± 0.126	0.419 ± 0.092	0.016 ± 0.003	0.933 ± 0.029
0.005	0.546 ± 0.155	0.317 ± 0.170	0.429 ± 0.117	0.016 ± 0.004	0.924 ± 0.044
0.001	**0.440 ± 0.103**	**0.202 ± 0.099**	**0.351 ± 0.079**	**0.013 ± 0.003**	**0.958 ± 0.030**
0.0005	0.585 ± 0.183	0.369 ± 0.195	0.472 ± 0.154	0.018 ± 0.006	0.929 ± 0.051
0.0001	2.982 ± 0.445	9.126 ± 3.026	2.725 ± 0.458	0.098 ± 0.017	0.000 ± 0.000

Text S3. Design of the architecture of the deep Vision Transformer (ViT) neural network model

The time window of all methods is fixed in 7 days for different horizontal SST prediction.

First, we design the ViT models with different parameter settings. For each setting, we train the traditional date-driven deep learning model test the 1-day lead prediction performance. Here, four stages of experiments are conducted to determine the best parameters of the ViT model, including the number of epochs denote by e_{ViT}, the number of ViT head denote by h_{ViT}, the number of ViT depth denote by d_{ViT}, and the learning rate of ViT denote by lr_ViT.

Stage 1: Determine e_{ViT}

To determine e_{ViT}, we first fix h_{ViT} as 8 and d_{ViT} as 12 according to the works of Dosovitskiy *et al*, and lr_ViT as 0.001. Then we vary the value of e_{ViT} from the set {50,100,200,300,400}. The results are shown in Table S9. From Table S9, we can see that when $e_{ViT} = 200$, the models can obtain satisfactory results. Hence, we set $e_{ViT} = 200$.

Table S9

Prediction results (mean ± std) for 1-day ahead with different e_{ViT} settings.

Indexes / e_{ViT}	RMSE	MSE	MAE	MAPE	r
50	1.316 ± 0.263	1.783 ± 0.674	1.154 ± 0.264	0.043 ± 0.010	0.863 ± 0.008
100	1.093 ± 0.374	1.300 ± 0.861	1.024 ± 0.446	0.035 ± 0.014	0.868 ± 0.012
200	**0.832 ± 0.270**	0.750 ± 0.524	**0.666 ± 0.282**	0.026 ± 0.009	**0.882 ± 0.008**
300	1.093 ± 0.374	1.300 ± 0.861	0.934 ± 0.374	0.035 ± 0.014	0.868 ± 0.012
400	0.835 ± 0.096	**0.748 ± 0.149**	0.687 ± 0.089	**0.022 ± 0.003**	0.879 ± 0.015

Stage 2: Determine h_{ViT}

To determine h_{ViT}, we first fix e_{ViT} as 200 and d_{ViT} as 12, and lr_ViT as 0.001. Then we vary the value of h_{ViT} from the set {4,8,12,16,20}. The results are shown in Table S10. From Table S10, we can see that when $h_{ViT} = 8$, the models can obtain satisfactory results. Hence, we set $h_{ViT} = 8$.

Table S10

Prediction results (mean ± std) for 1-day ahead with different h_{ViT} settings.

Indexes / h_{ViT}	RMSE	MSE	MAE	MAPE	r
4	1.029 ± 0.411	1.195 ± 0.967	0.870 ± 0.415	0.032 ± 0.015	0.863 ± 0.009
8	**0.832 ± 0.270**	**0.750 ± 0.524**	**0.666 ± 0.282**	**0.026 ± 0.009**	**0.882 ± 0.008**
12	1.086 ± 0.485	1.367 ± 1.144	0.936 ± 0.483	0.033 ± 0.015	0.873 ± 0.013
16	0.834 ± 0.176	0.720 ± 0.314	0.674 ± 0.165	0.025 ± 0.006	0.870 ± 0.020
20	1.163 ± 0.799	1.863 ± 2.709	1.005 ± 0.817	0.037 ± 0.030	0.858 ± 0.009

Stage 3: Determine d_{ViT}

To determine d_{ViT}, we first fix e_{ViT} as 200 and h_{ViT} as 8, and lr_ViT as 0.001. Then we vary the value of d_{ViT} from the set {4,8,12,16,20}. The results are shown in Table S11. From

Table S11, we can see that when $d_{ViT} = 8$, the models can obtain satisfactory results. Hence, we set $d_{ViT} = 8$.

Table S11

Prediction results (mean ± std) for 1-day ahead with different d_{ViT} settings.

Indexes / d_{ViT}	RMSE	MSE	MAE	MAPE	r
4	1.676 ± 0.383	2.926 ± 1.267	1.533 ± 0.414	0.056 ± 0.015	0.858 ± 0.016
8	**0.755 ± 0.043**	**0.571 ± 0.066**	**0.596 ± 0.041**	**0.022 ± 0.002**	0.878 ± 0.018
12	0.832 ± 0.270	0.750 ± 0.525	0.667 ± 0.282	0.026 ± 0.010	**0.882 ± 0.008**
16	0.908 ± 0.217	0.862 ± 0.400	0.749 ± 0.215	0.028 ± 0.008	0.872 ± 0.010
20	1.138 ± 0.432	1.876 ± 1.065	1.107 ± 0.749	0.035 ± 0.025	0.866 ± 0.008

Stage 4: Determine lr_ViT

To determine lr_ViT, we first fix e_{ViT} as 200 and h_{ViT} as 8, and d_{ViT} as 8. Then we vary the value of lr_ViT from the set {0.01,0.005,0.001,0.0005,0.0001}. The results are shown in Table S12. From Table S12, we can see that when $lr_ViT = 0.001$, the models can obtain satisfactory results. Hence, we set $lr_ViT = 0.001$.

Table S12

Prediction results (mean ± std) for 1-day ahead with different lr_ViT settings.

Indexes / lr_ViT	RMSE	MSE	MAE	MAPE	r
0.01	1.519 ± 0.463	2.481 ± 1.614	1.183 ± 0.304	0.044 ± 0.011	0.650 ± 0.077
0.005	1.634 ± 1.247	3.920 ± 6.138	1.096 ± 0.557	0.040 ± 0.020	0.695 ± 0.230
0.001	**0.755 ± 0.043**	**0.571 ± 0.066**	**0.596 ± 0.041**	**0.022 ± 0.002**	0.878 ± 0.018
0.0005	1.291 ± 0.322	1.749 ± 0.818	1.125 ± 0.333	0.042 ± 0.012	0.859 ± 0.018
0.0001	1.245 ± 0.429	1.363 ± 1.263	1.080 ± 0.437	0.039 ± 0.016	0.846 ± 0.018

Text S4. Line chart for 1-10day ahead prediction of SST by different methods using various input samples (1-9year)

Here, we plot the line chart of (observed SSTs, predicted SSTs for 1-10day ahead) for different models using various input samples (1-9years). We systematically compared the finite difference method in traditional numerical calculation, the classical data-driven deep learning methods, the classical physics-informed neural network methods, and our proposed methods. The comparisons are shown in Figure S1 to Figure S9. Data-driven methods have presented the most unstable prediction results, with the increase of prediction horizons, RMSE is on the rise as a whole. Among them, the ConvLSTM model performs best because they are good at processing time-series data. As the state-of-the-art model in the field of CV and NLP, it does not seem to achieve satisfactory results in this experiment. This because Transformer-based model has large model parameters, so it is more suitable for processing large-scale datasets. Transformer-based

model does not possess the inductive bias and translation invariance that are beneficial for smaller dataset, hence learning the relevant patterns directly from small data is insufficient. The PINN_based methods do not depend too much on the selected model, because their original intention is to solve the PDEs rather than optimize PDE to solve, so it is shown the most stable prediction results. Moreover, it can be seen, regardless of the number of input data and prediction horizons, our proposed method can always achieve the best prediction performance.

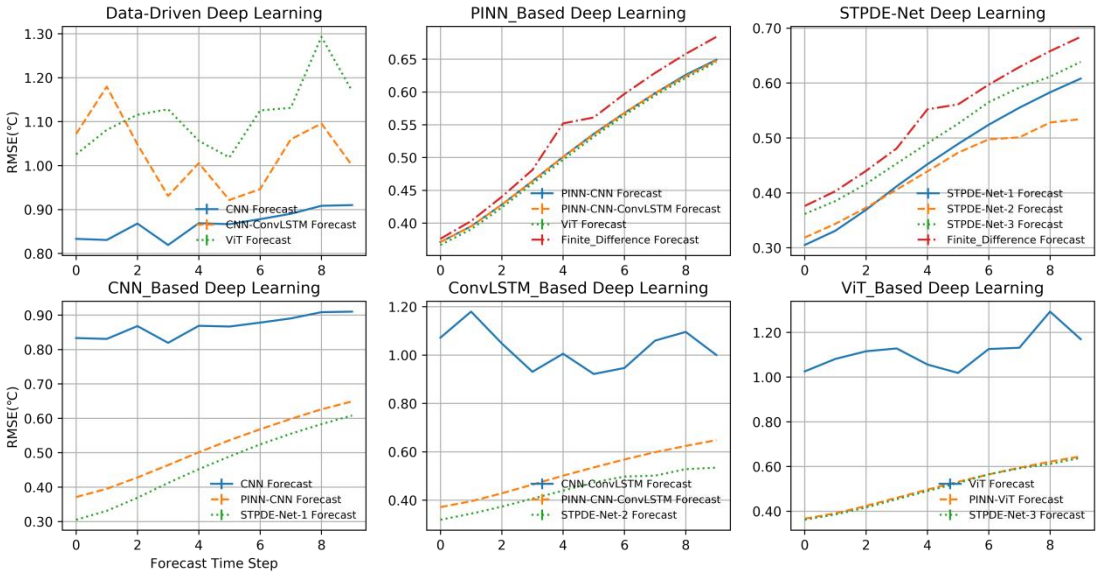


Figure S1. RMSE of the SST prediction using 9 years data and various methods for different prediction horizons (1-10days).

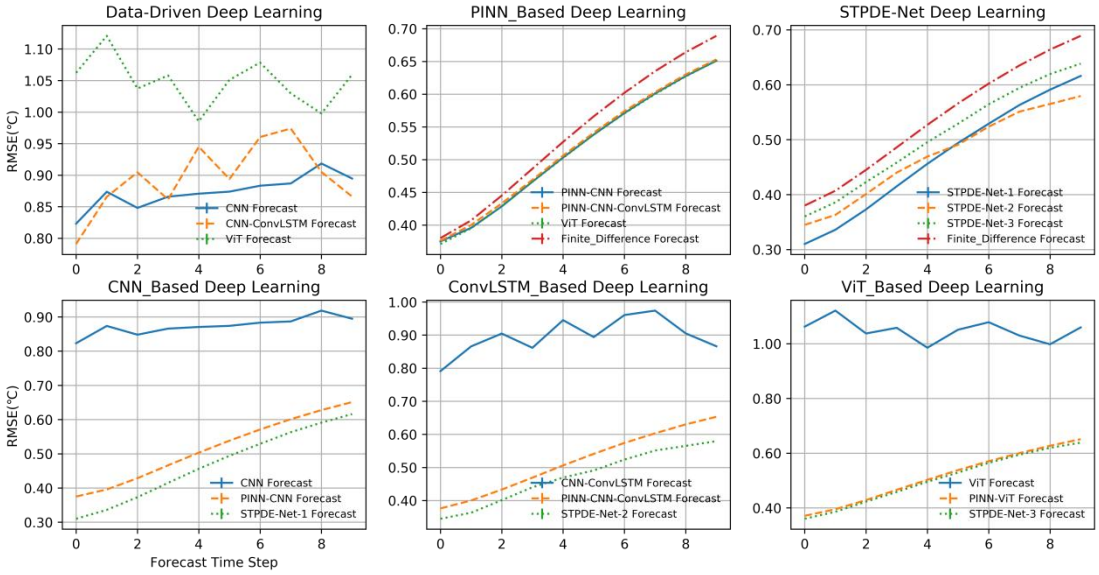


Figure S2. RMSE of the SST prediction using 8 years data and various methods for different

prediction horizons (1-10days).

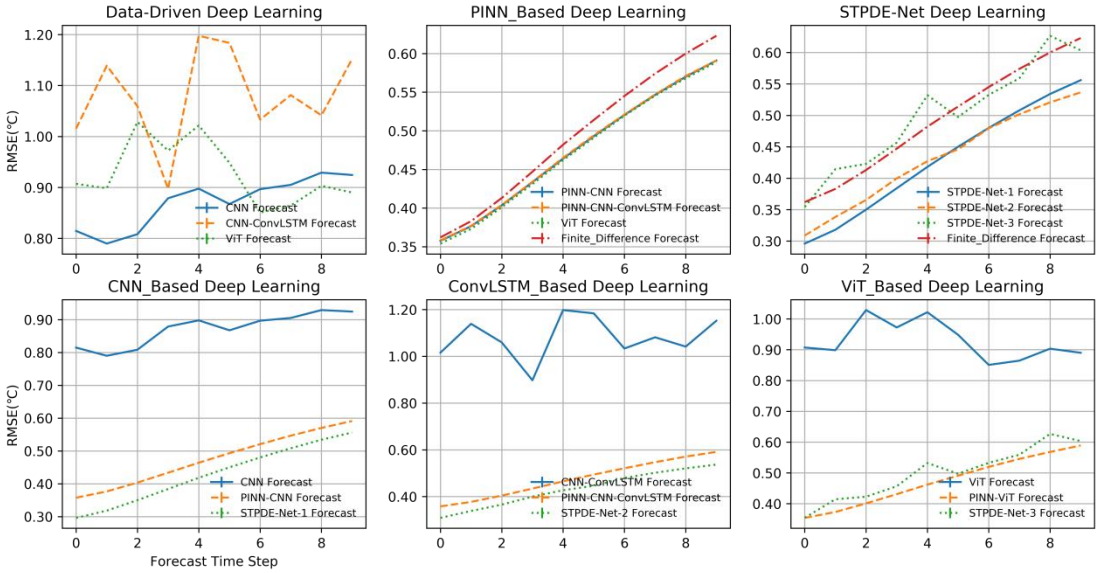


Figure S3. RMSE of the SST prediction using 7 years data and various methods for different prediction horizons (1-10days).

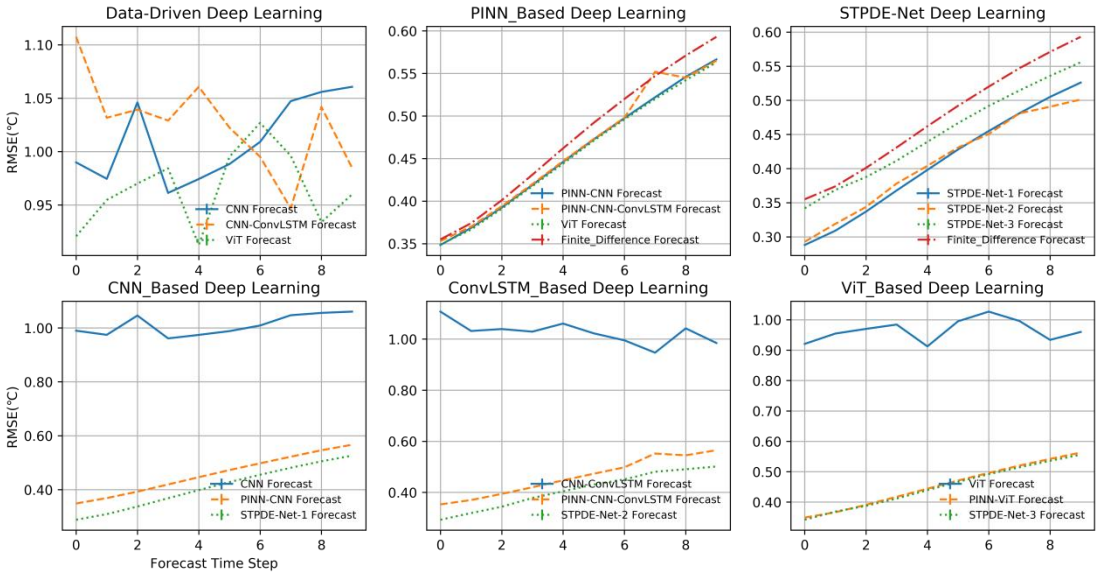


Figure S4. RMSE of the SST prediction using 6 years data and various methods for different prediction horizons (1-10days).

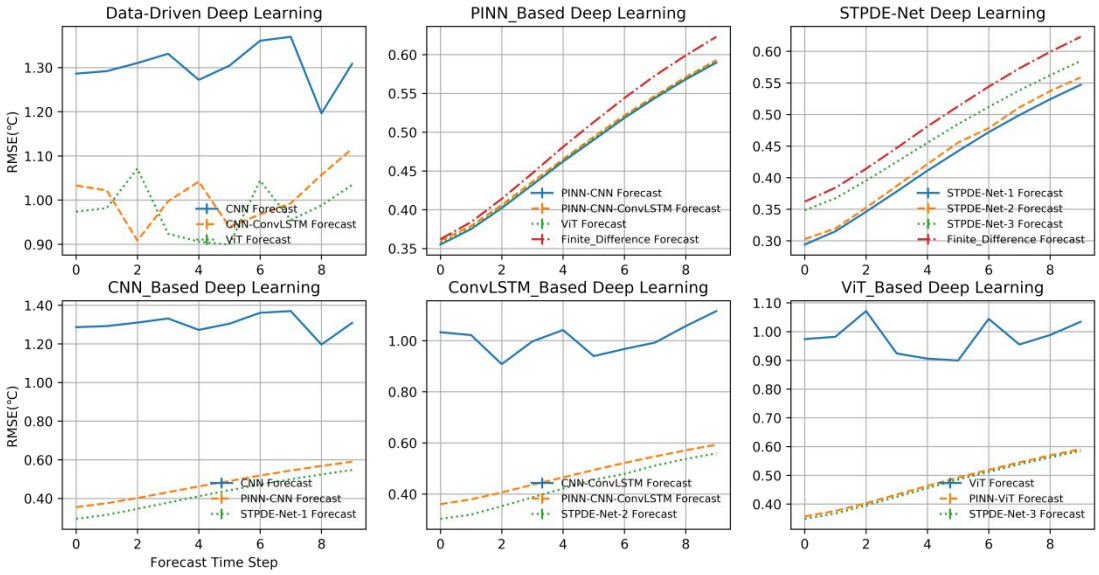


Figure S5. RMSE of the SST prediction using 5 years data and various methods for different prediction horizons (1-10days).

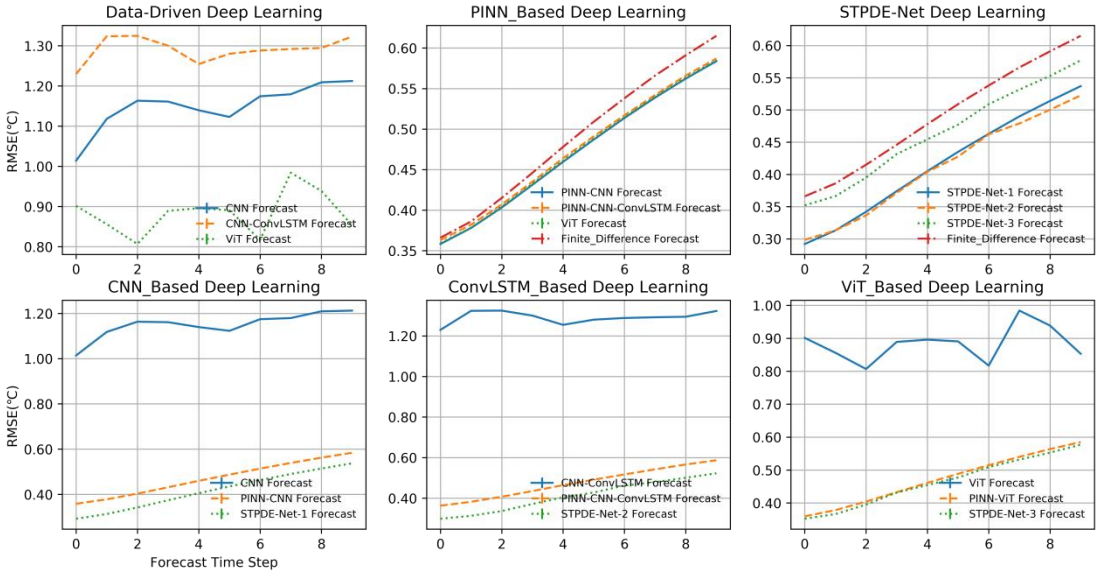


Figure S6. RMSE of the SST prediction using 4 years data and various methods for different prediction horizons (1-10days).

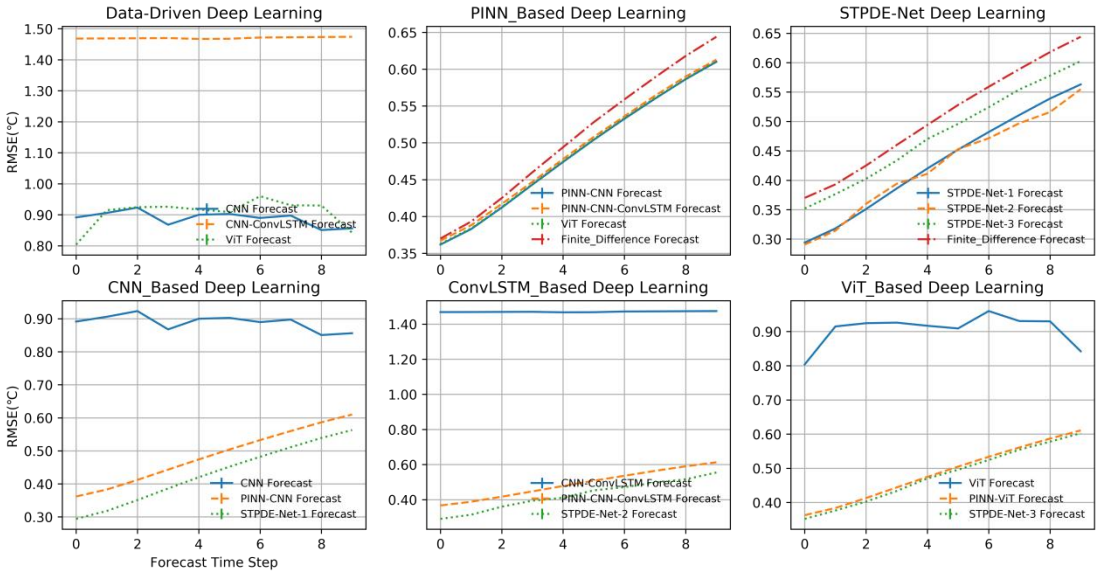


Figure S7. RMSE of the SST prediction using 3 years data and various methods for different prediction horizons (1-10days).

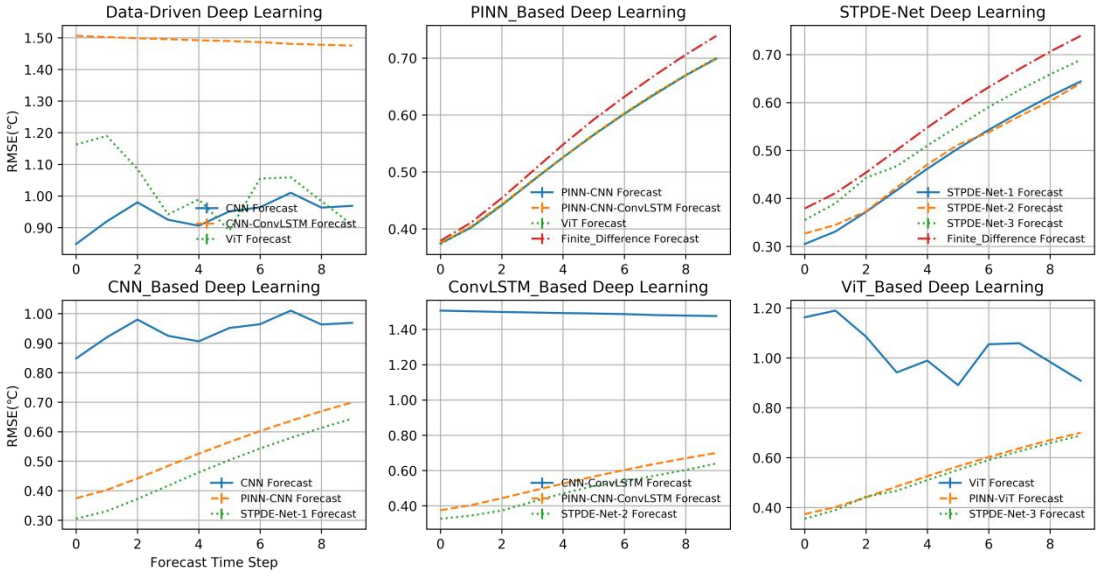


Figure S8. RMSE of the SST prediction using 2 years data and various methods for different prediction horizons (1-10days).

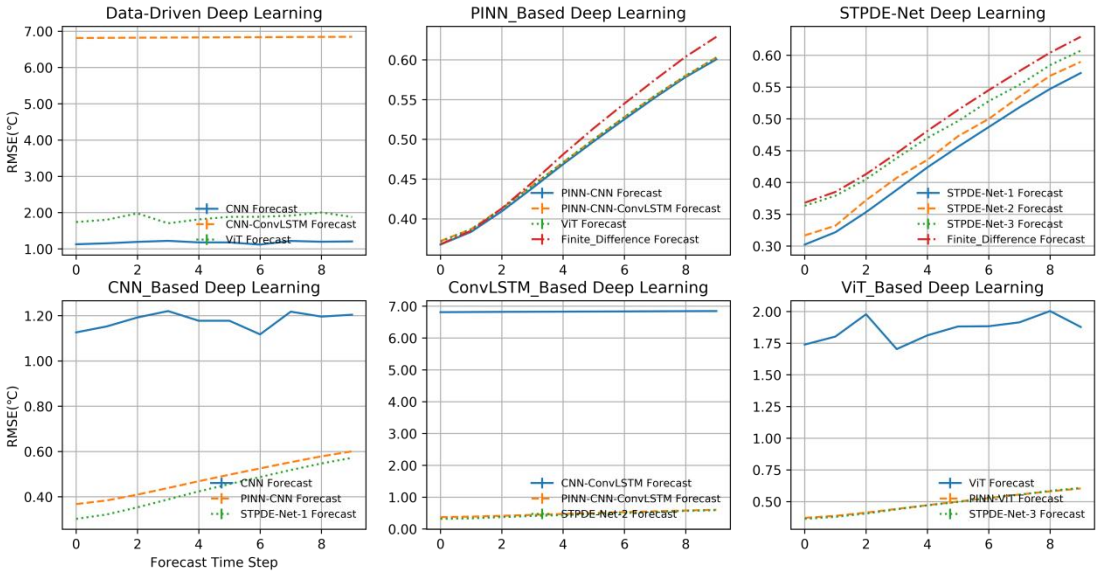


Figure S9. RMSE of the SST prediction using 1 year's data and various methods for different prediction horizons (1-10days).

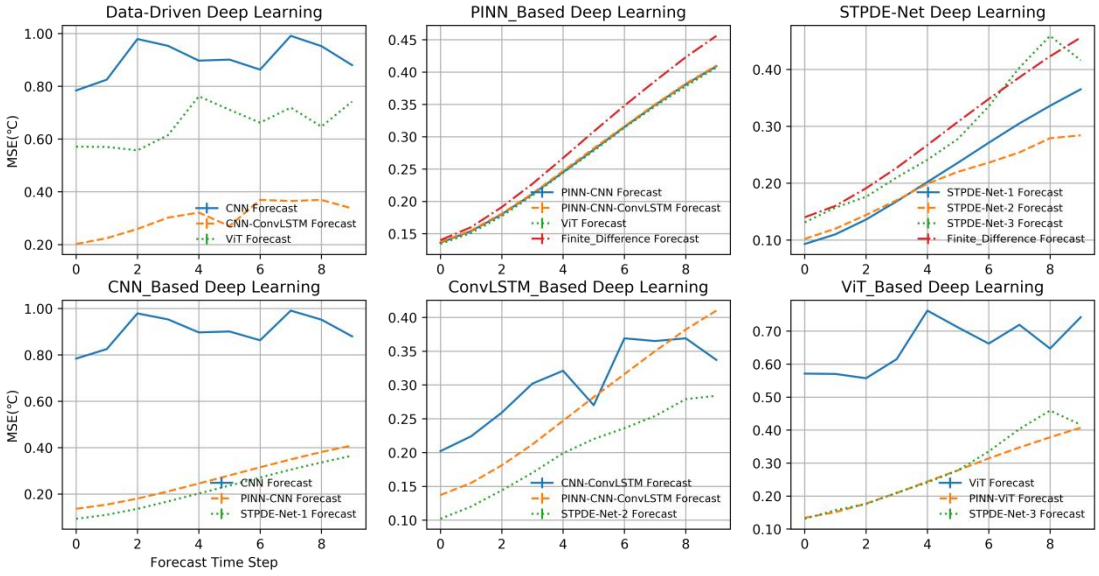


Figure S10. MSE of the SST prediction using 10 year's data and various methods for different prediction horizons (1-10days).

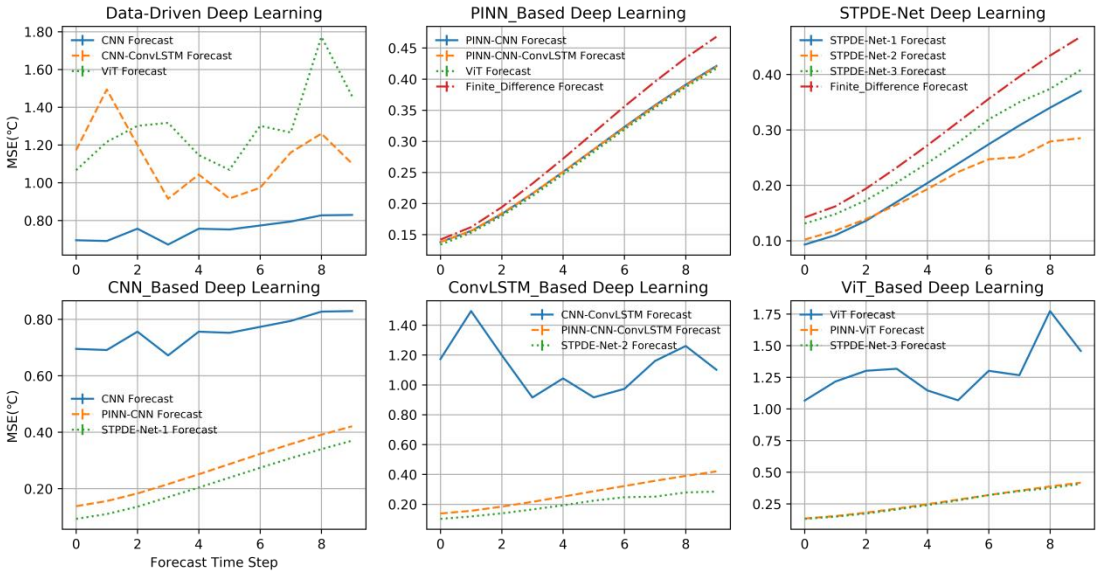


Figure S11. MSE of the SST prediction using 9 year's data and various methods for different prediction horizons (1-10days).

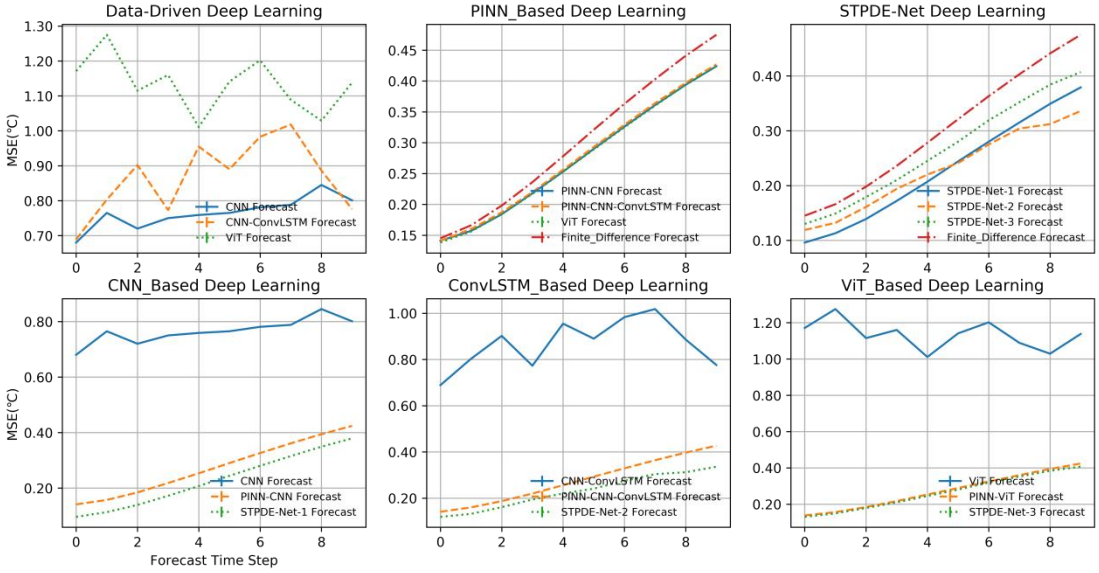


Figure S12. MSE of the SST prediction using 8 year's data and various methods for different prediction horizons (1-10days).

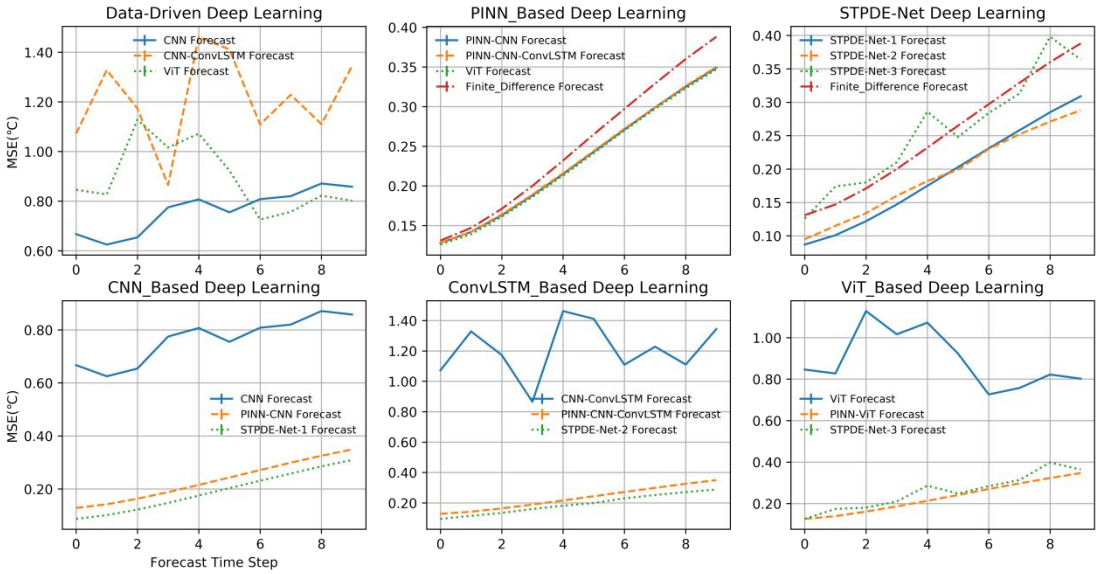


Figure S13. MSE of the SST prediction using 7 year's data and various methods for different prediction horizons (1-10days).

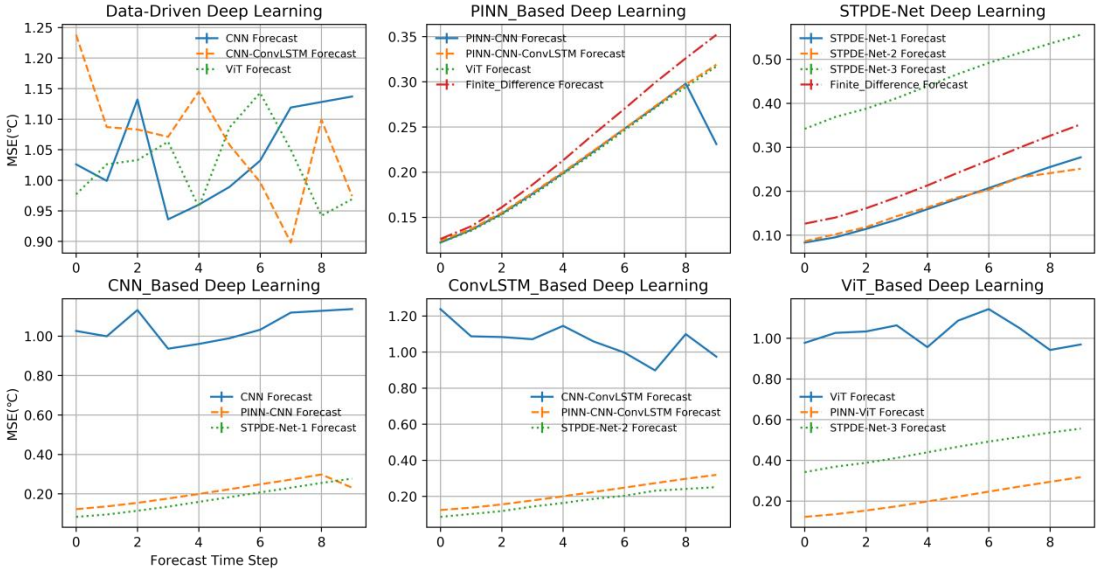


Figure S14. MSE of the SST prediction using 6 year's data and various methods for different prediction horizons (1-10days).

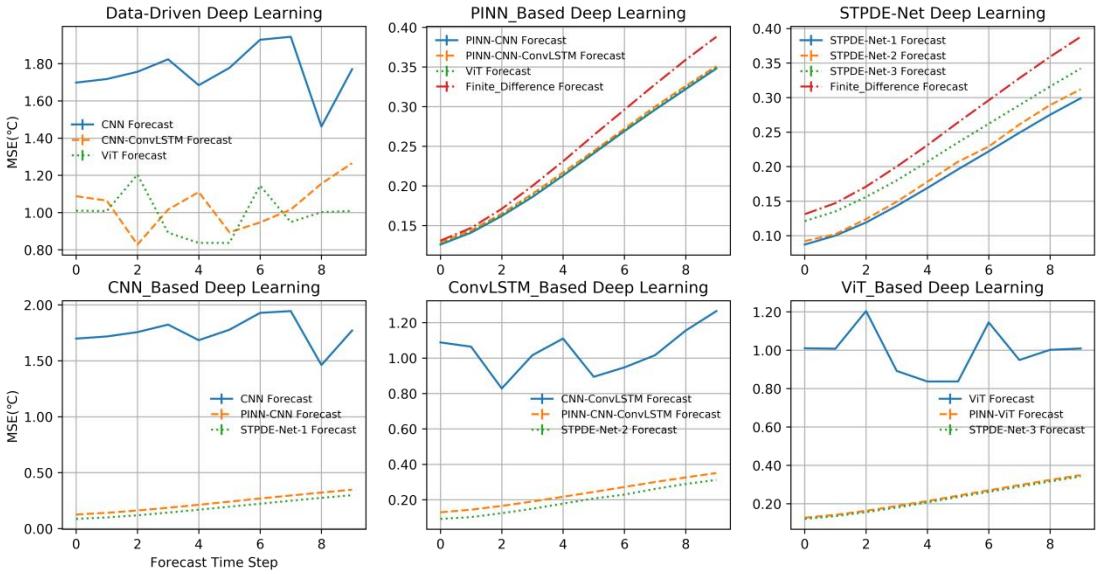


Figure S15. MSE of the SST prediction using 5 year's data and various methods for different prediction horizons (1-10days).

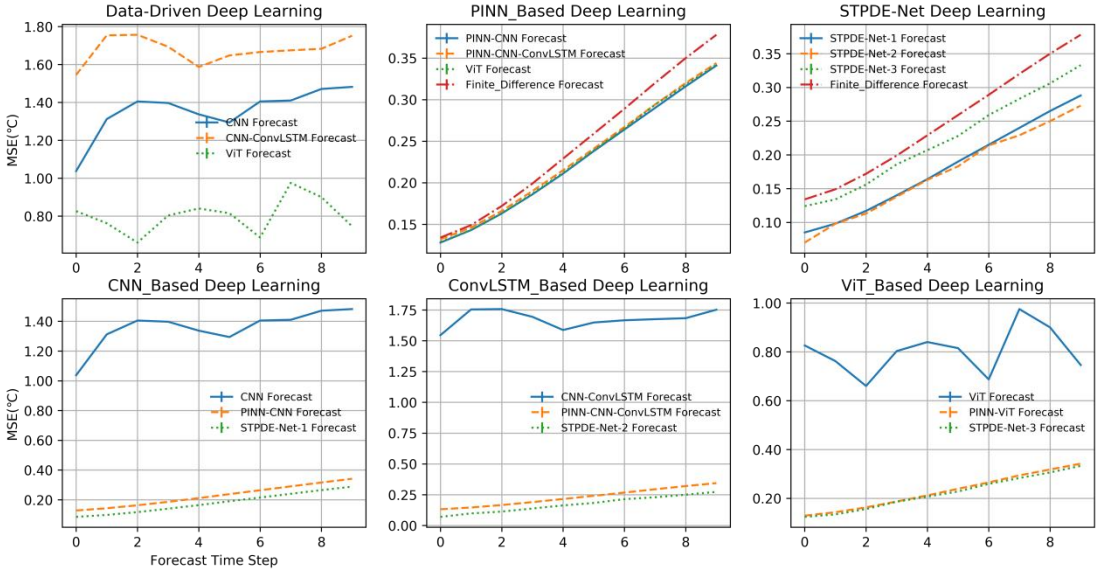


Figure S16. MSE of the SST prediction using 4 year's data and various methods for different prediction horizons (1-10days).

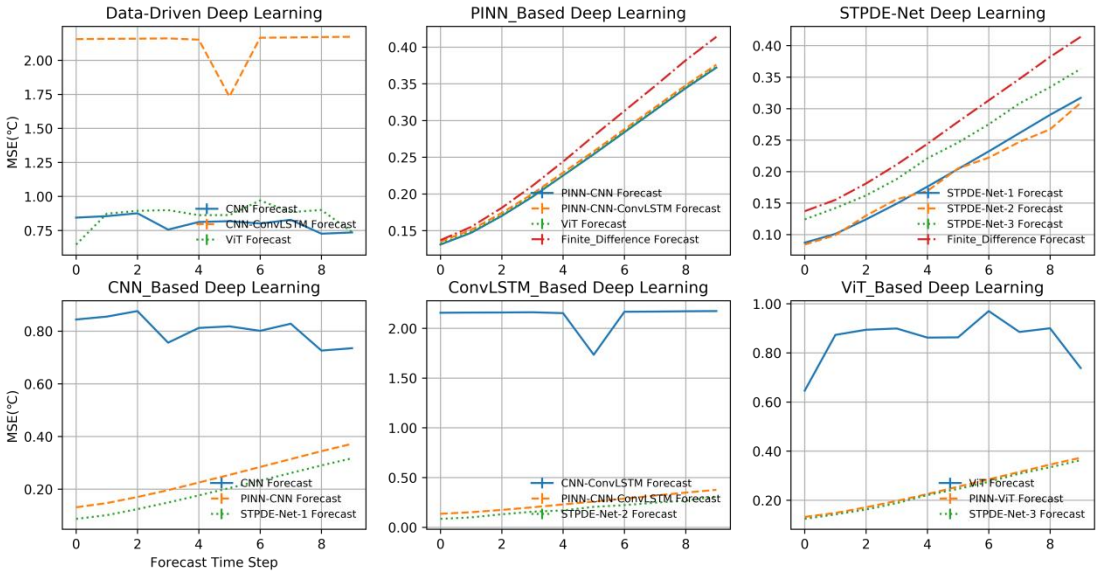


Figure S17. MSE of the SST prediction using 3 year's data and various methods for different prediction horizons (1-10days).

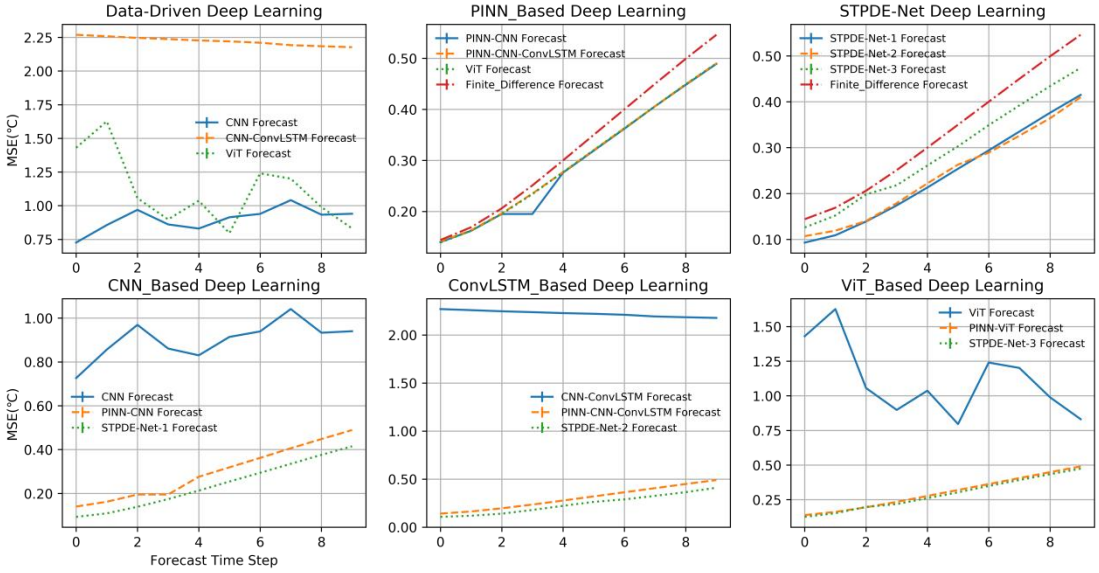


Figure S18. MSE of the SST prediction using 2 year's data and various methods for different prediction horizons (1-10days).

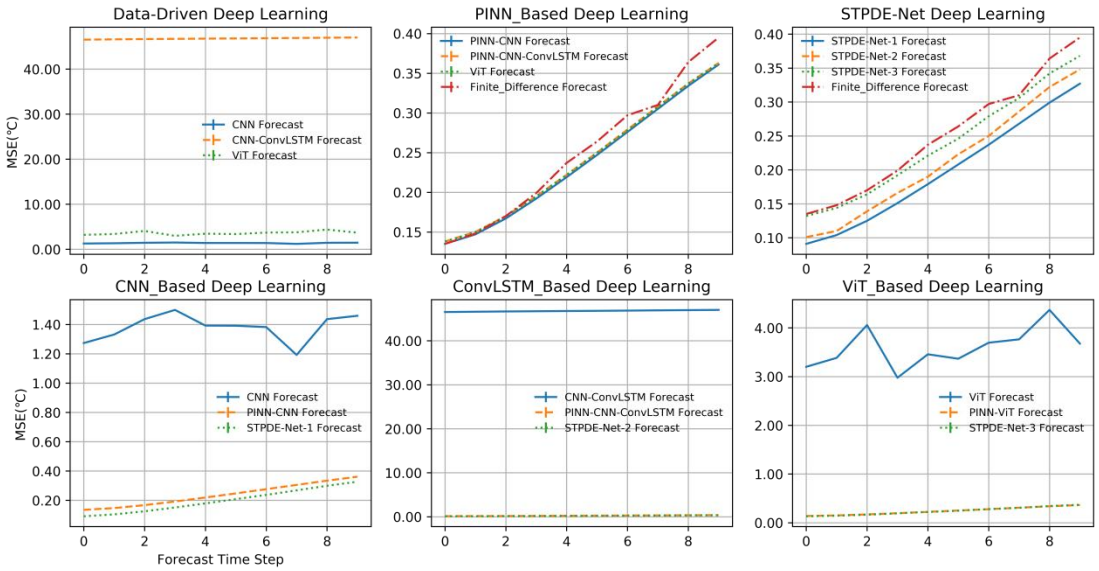


Figure S19. MSE of the SST prediction using 1 year's data and various methods for different prediction horizons (1-10days).

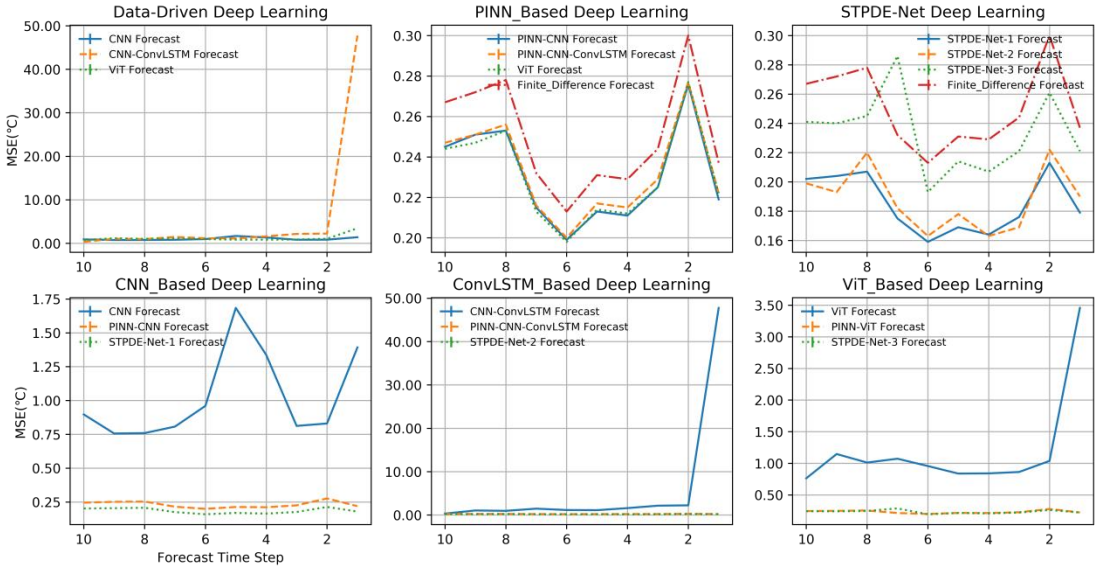


Figure S20. 5-day lead MSE for SST prediction(2010-2019).

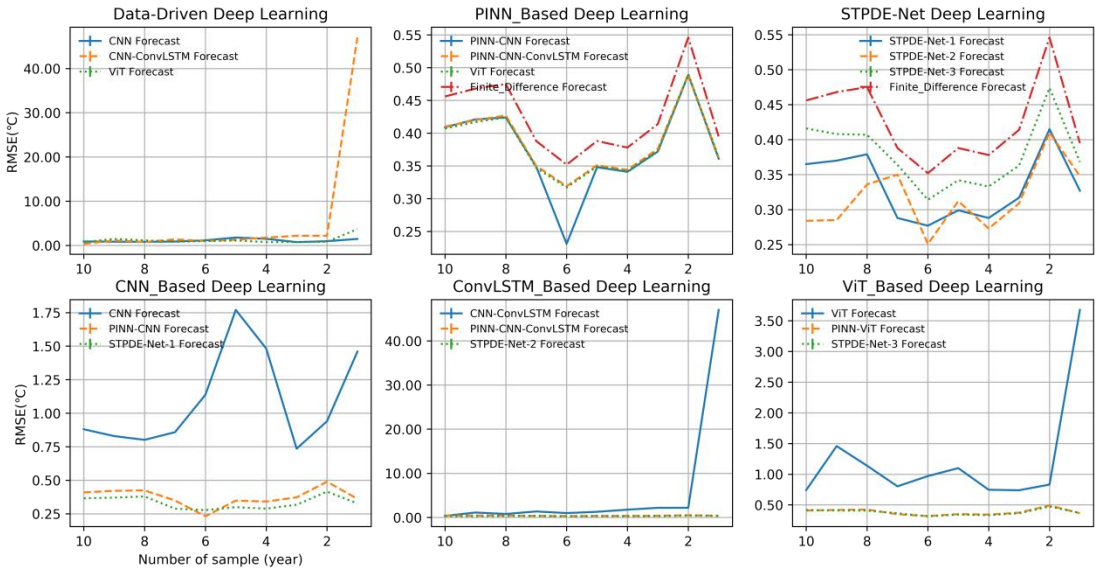


Figure S21. 10-day lead MSE for SST prediction(2010-2019).

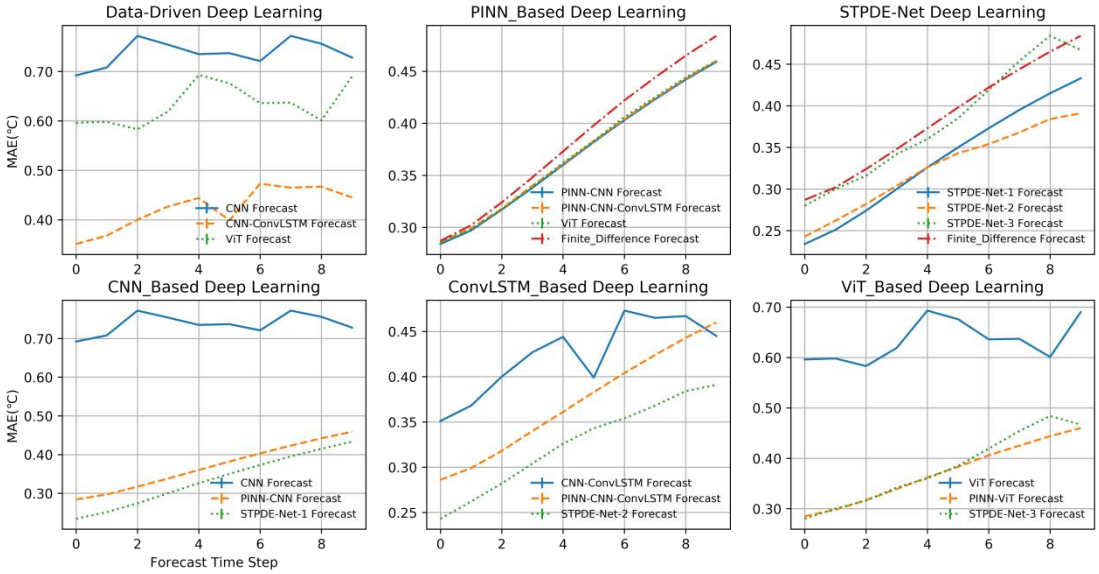


Figure S22. MAE of the SST prediction using 10 year's data and various methods for different prediction horizons (1-10days).

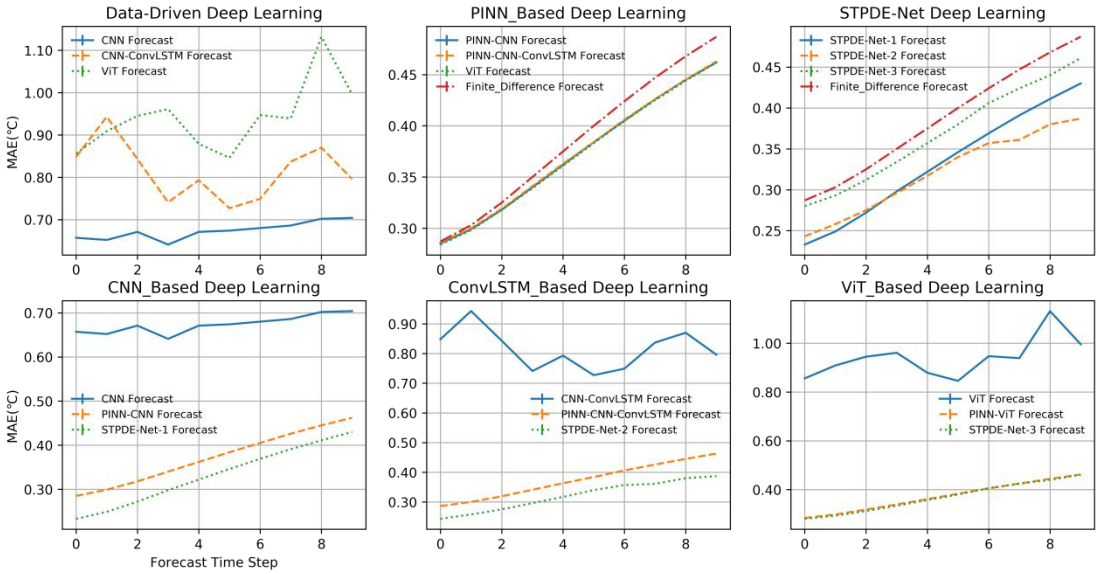


Figure S23. MAE of the SST prediction using 9 year's data and various methods for different prediction horizons (1-10days).

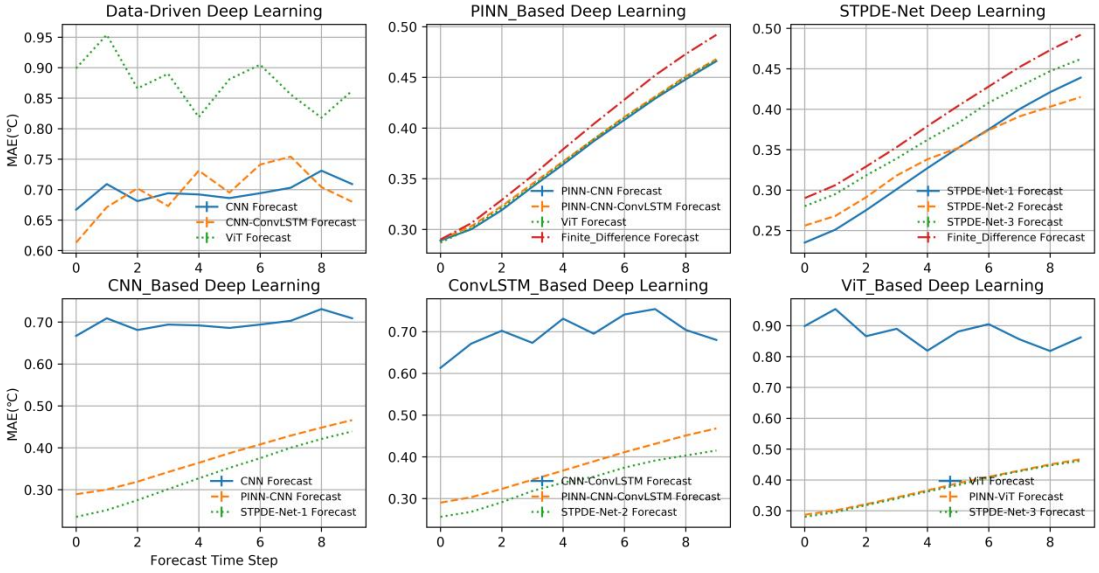


Figure S24. MAE of the SST prediction using 8 year's data and various methods for different prediction horizons (1-10days).

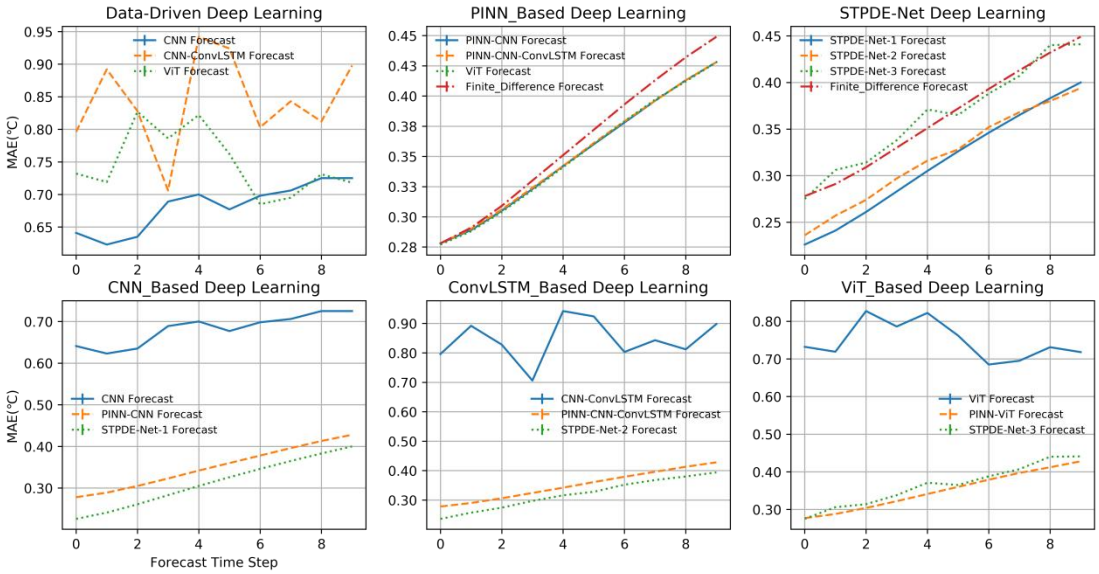


Figure S25. MAE of the SST prediction using 7 year's data and various methods for different prediction horizons (1-10days).

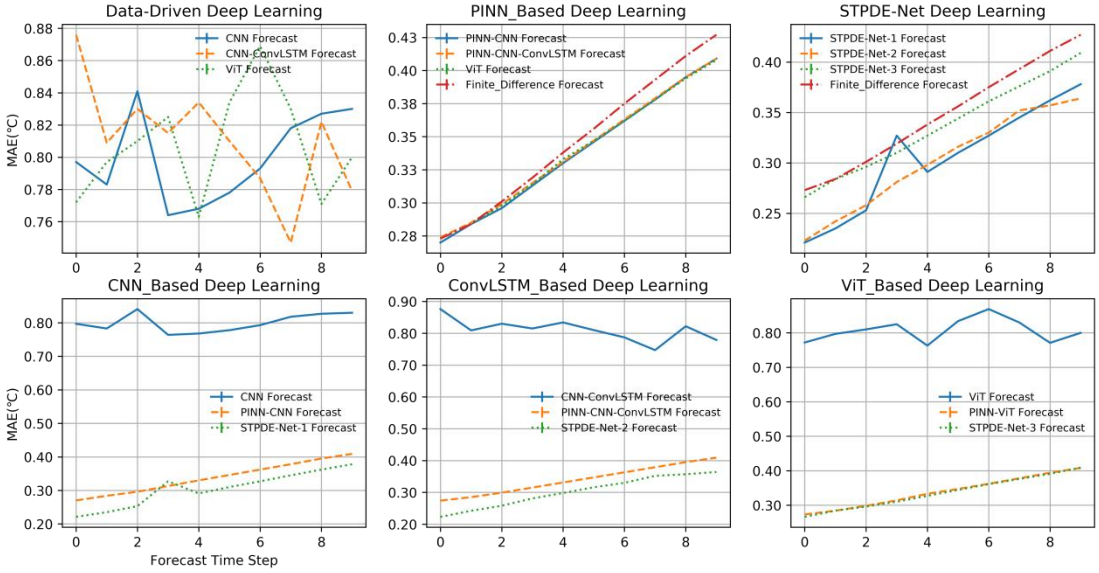


Figure S26. MAE of the SST prediction using 6 year's data and various methods for different prediction horizons (1-10days).

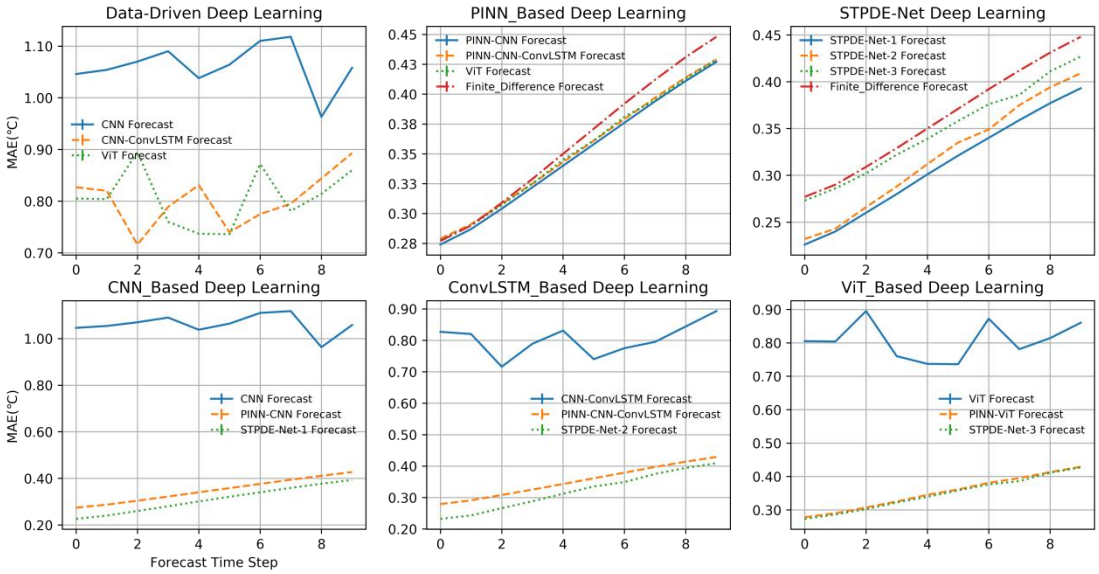


Figure S27. MAE of the SST prediction using 5 year's data and various methods for different prediction horizons (1-10days).

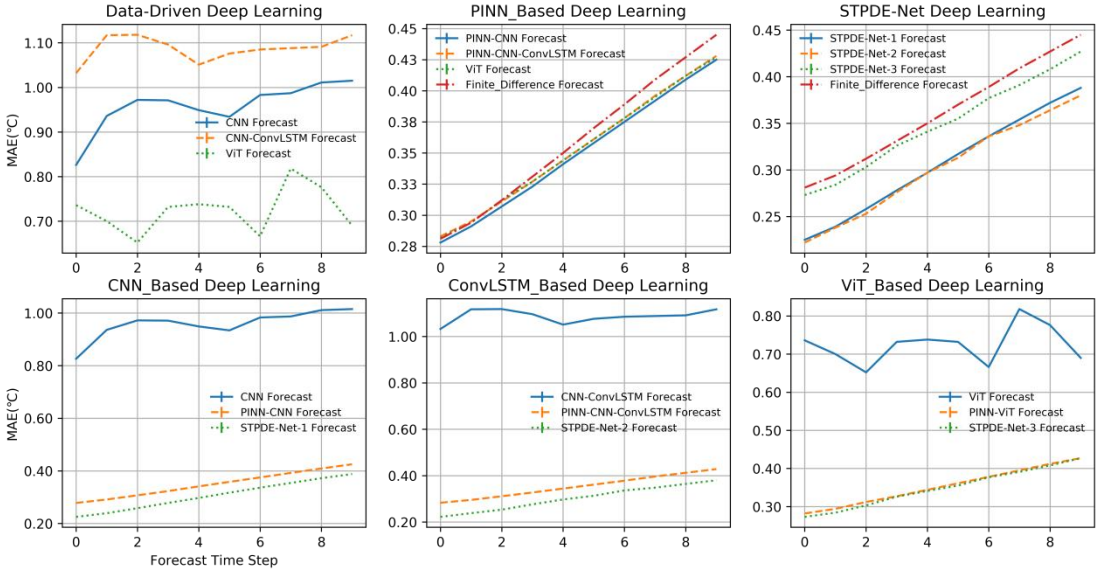


Figure S28. MAE of the SST prediction using 4 year's data and various methods for different prediction horizons (1-10days).

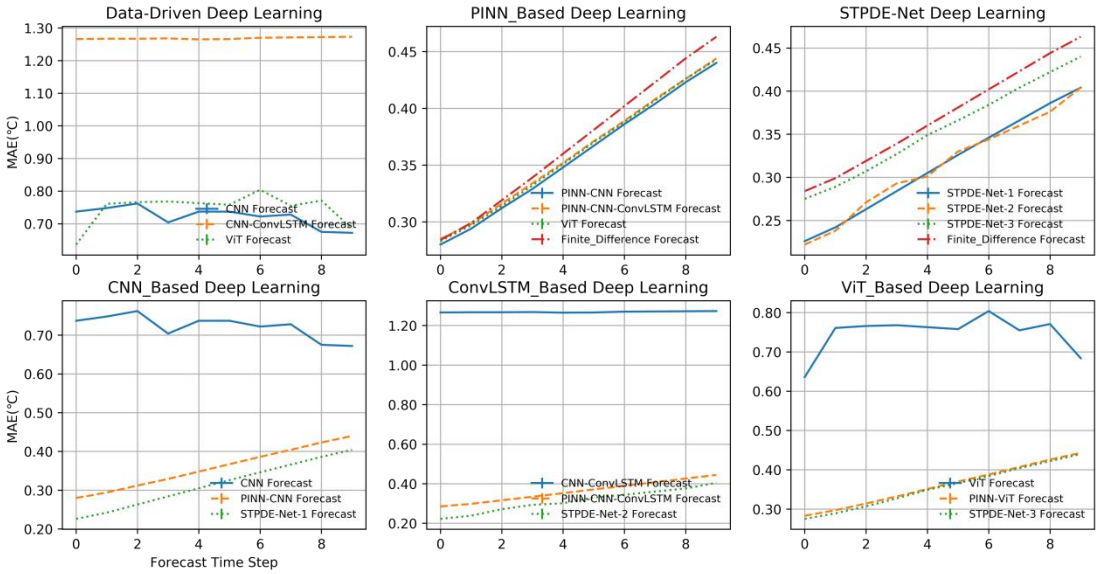


Figure S29. MAE of the SST prediction using 3 year's data and various methods for different prediction horizons (1-10days).

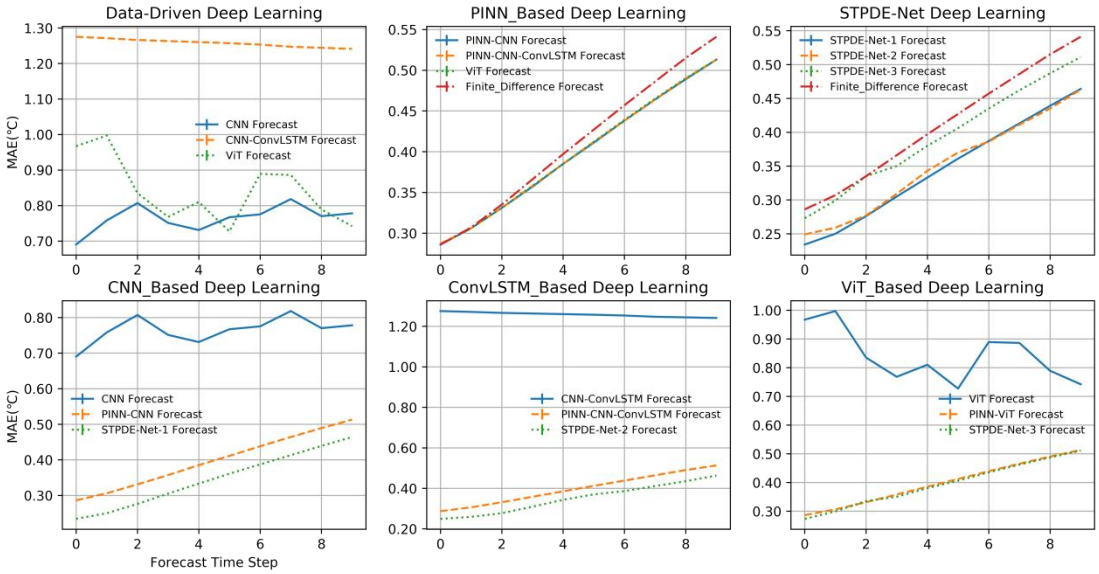


Figure S30. MAE of the SST prediction using 2 year's data and various methods for different prediction horizons (1-10days).

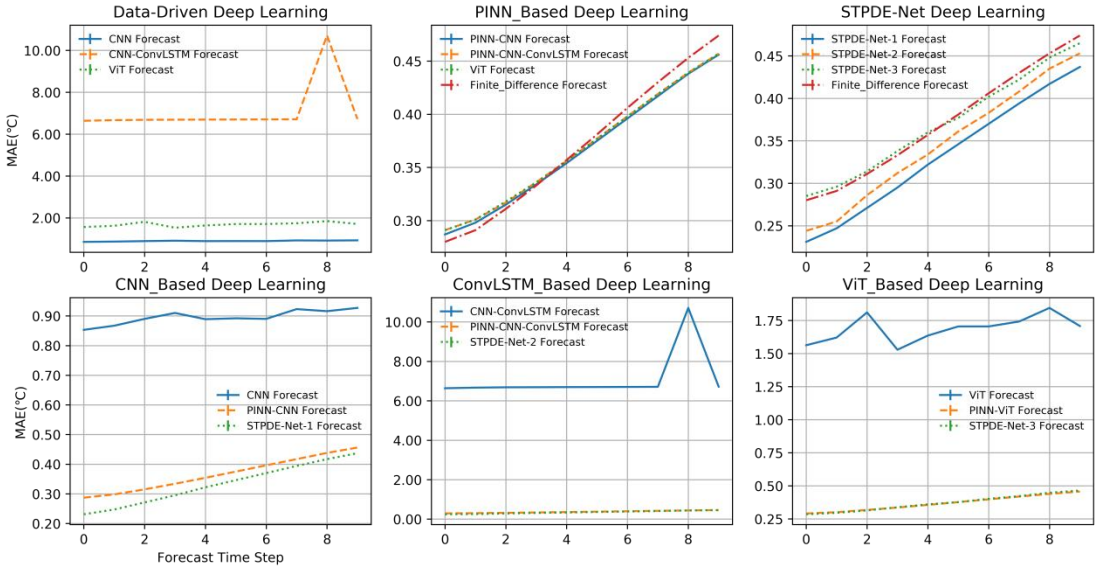


Figure S31. MAE of the SST prediction using 1 year's data and various methods for different prediction horizons (1-10days).

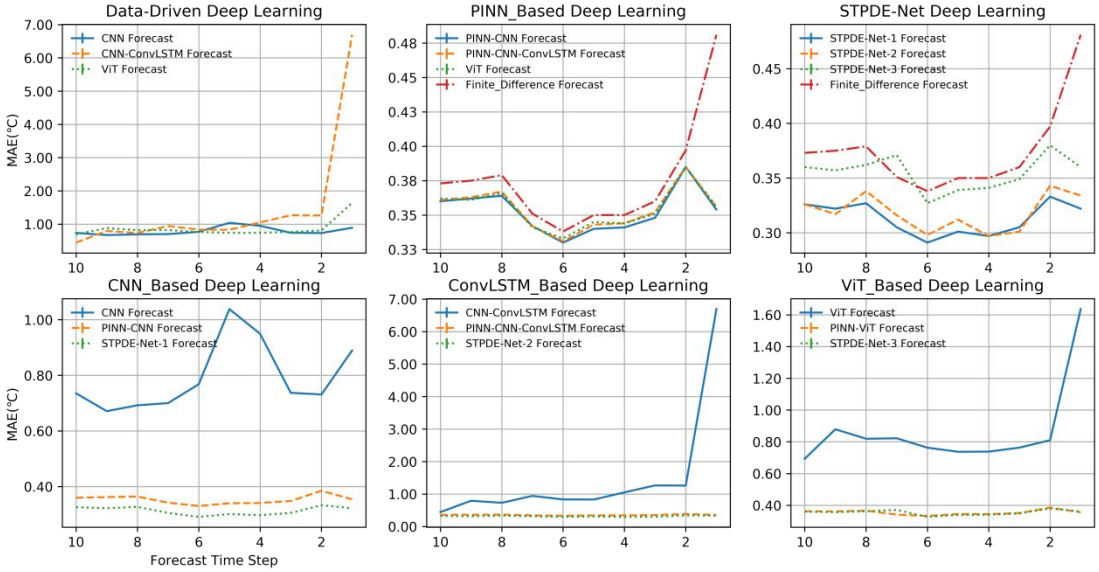


Figure S32. 5-day lead MAE for SST prediction(2010-2019).

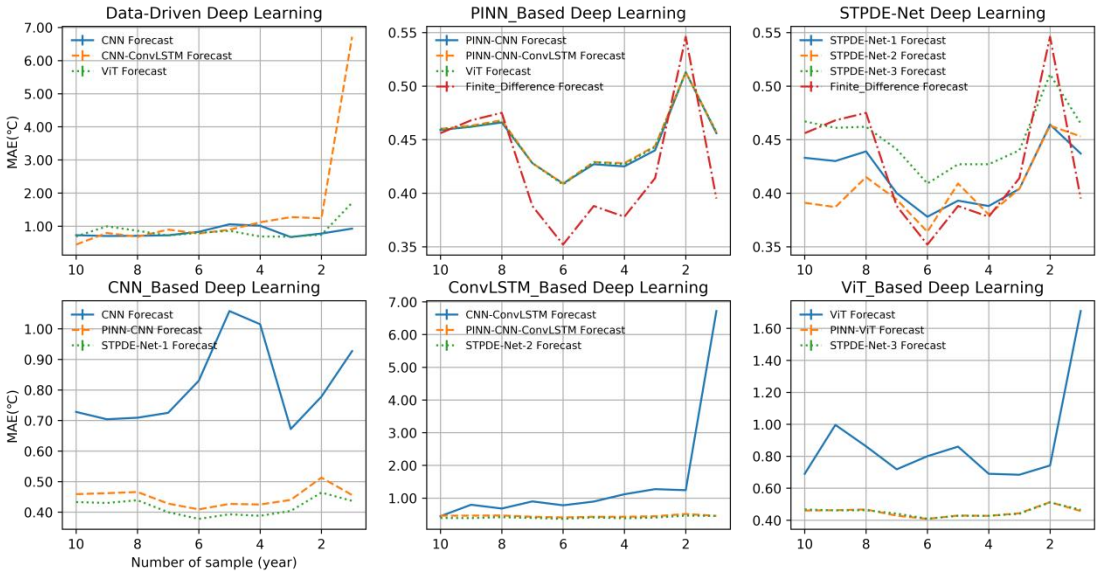


Figure S33. 10-day lead MAE for SST prediction(2010-2019).

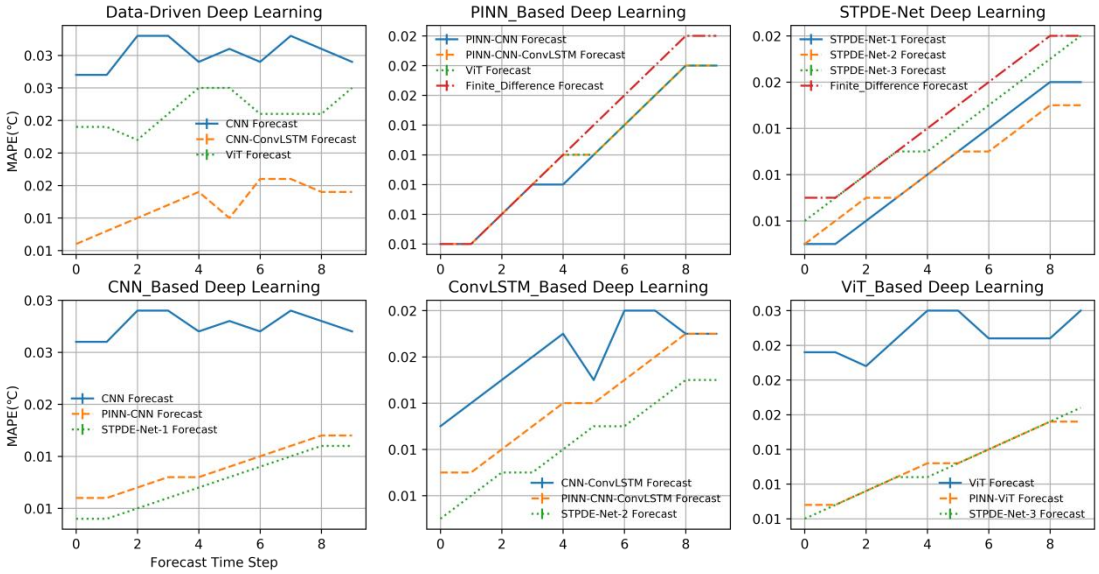


Figure S34. MAPE of the SST prediction using 10 year's data and various methods for different prediction horizons (1-10days).

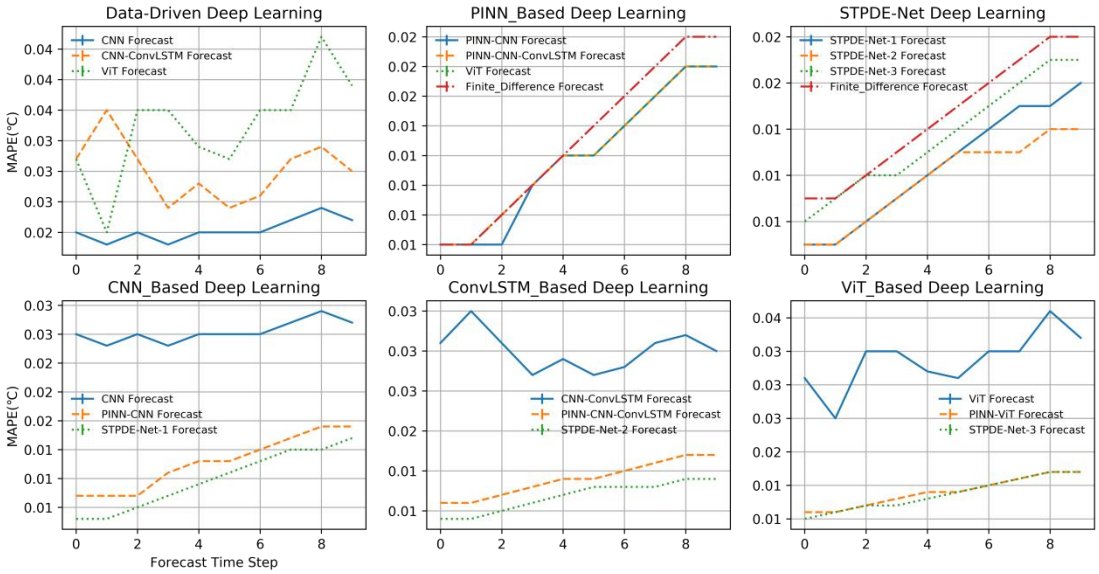


Figure S35. MAPE of the SST prediction using 9 year's data and various methods for different prediction horizons (1-10days).

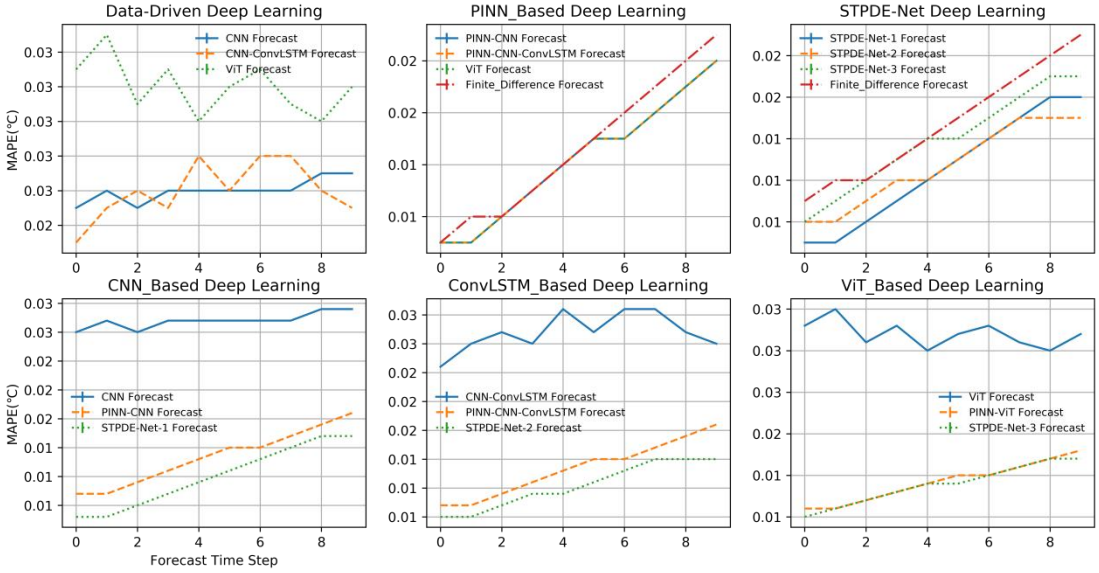


Figure S36. MAPE of the SST prediction using 8 year's data and various methods for different prediction horizons (1-10days).

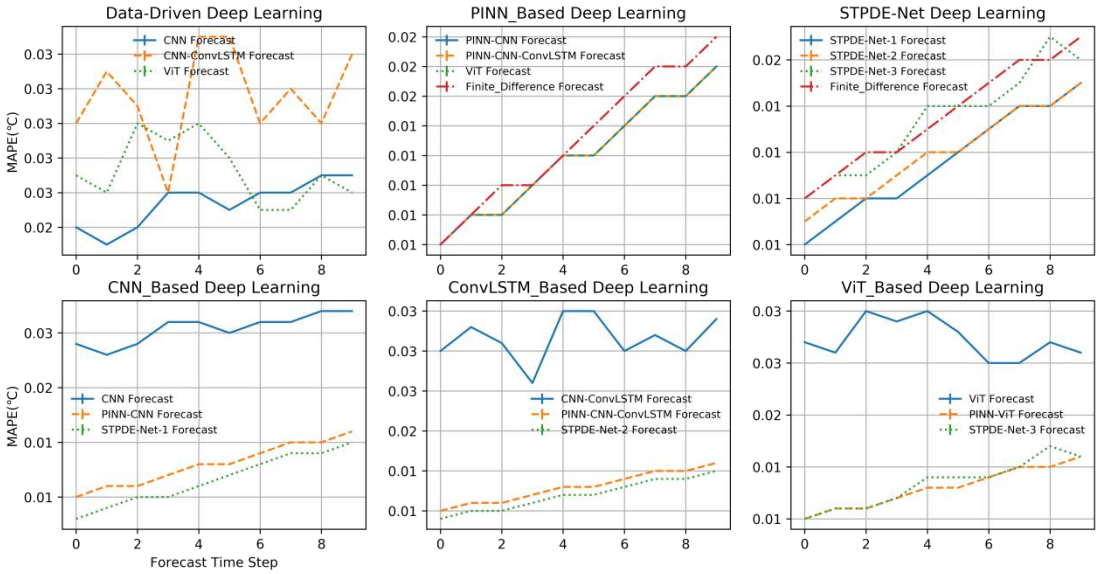


Figure S37. MAPE of the SST prediction using 7 year's data and various methods for different prediction horizons (1-10days).

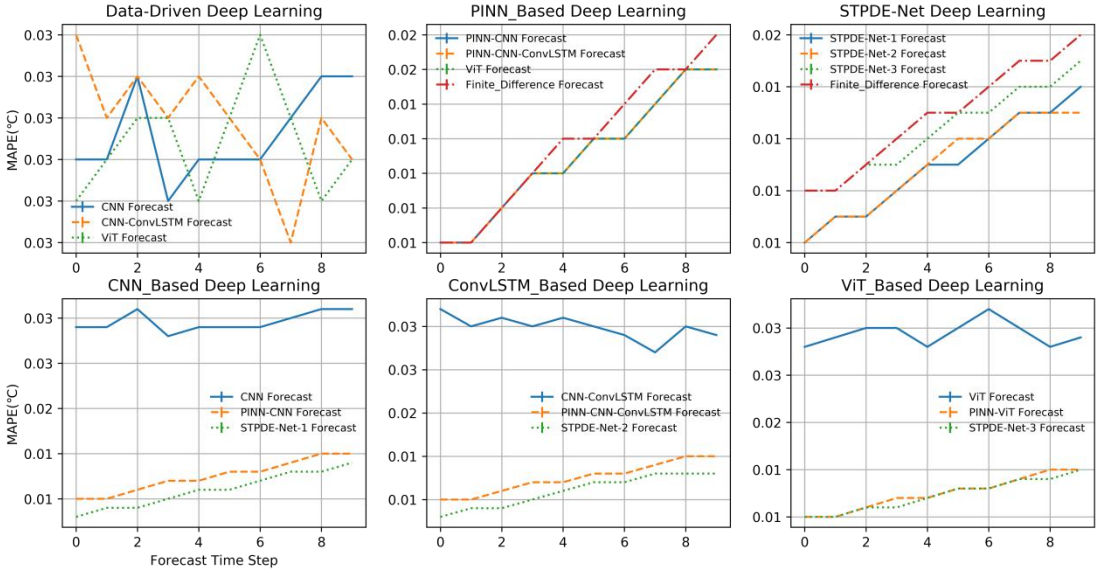


Figure S38. MAPE of the SST prediction using 6 year's data and various methods for different prediction horizons (1-10days).

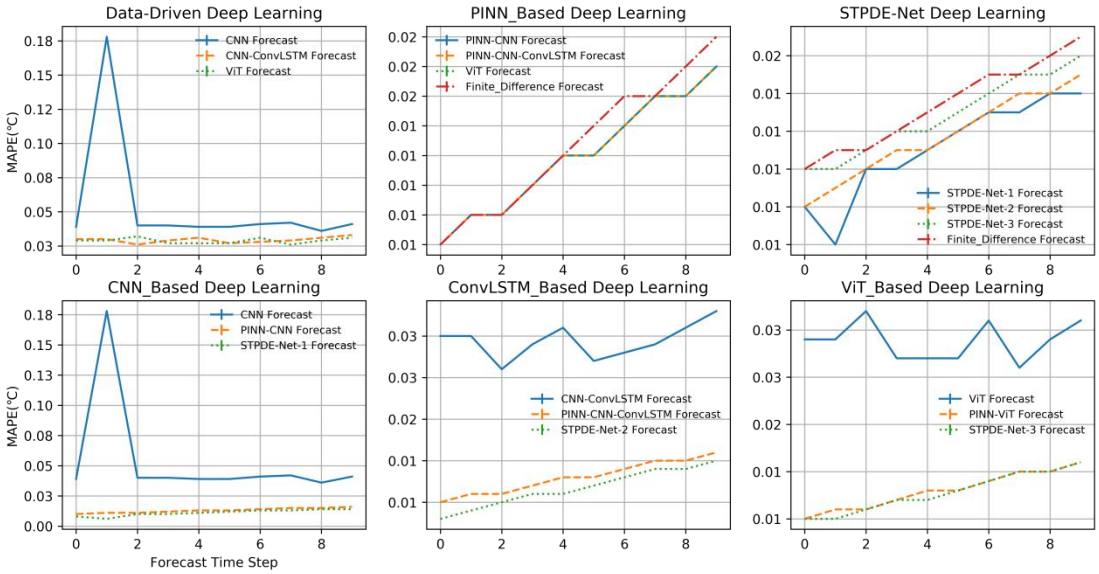


Figure S39. MAPE of the SST prediction using 5 year's data and various methods for different prediction horizons (1-10days).

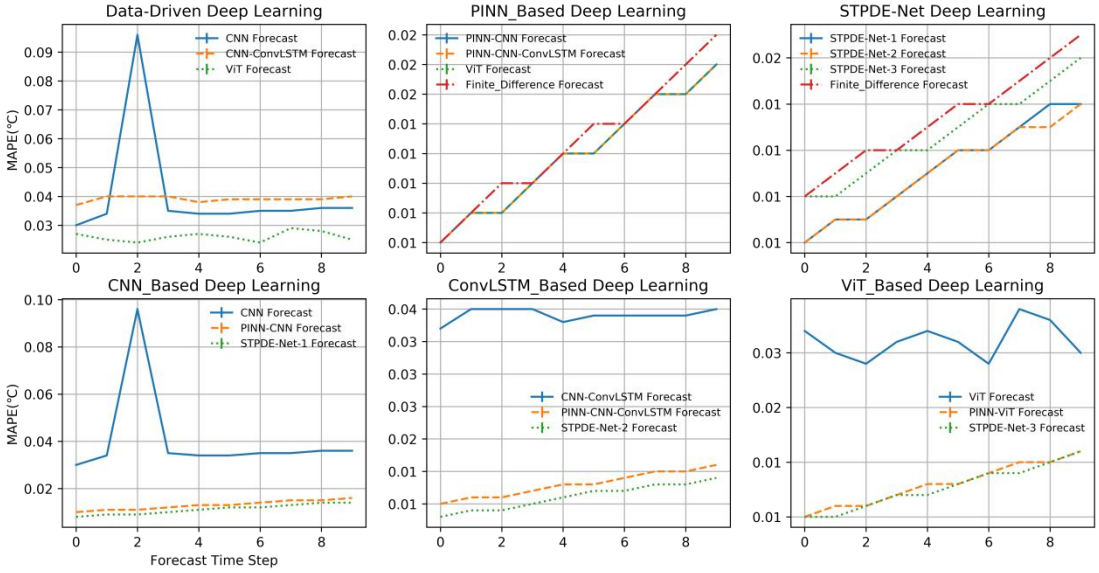


Figure S40. MAPE of the SST prediction using 4 year's data and various methods for different prediction horizons (1-10days).

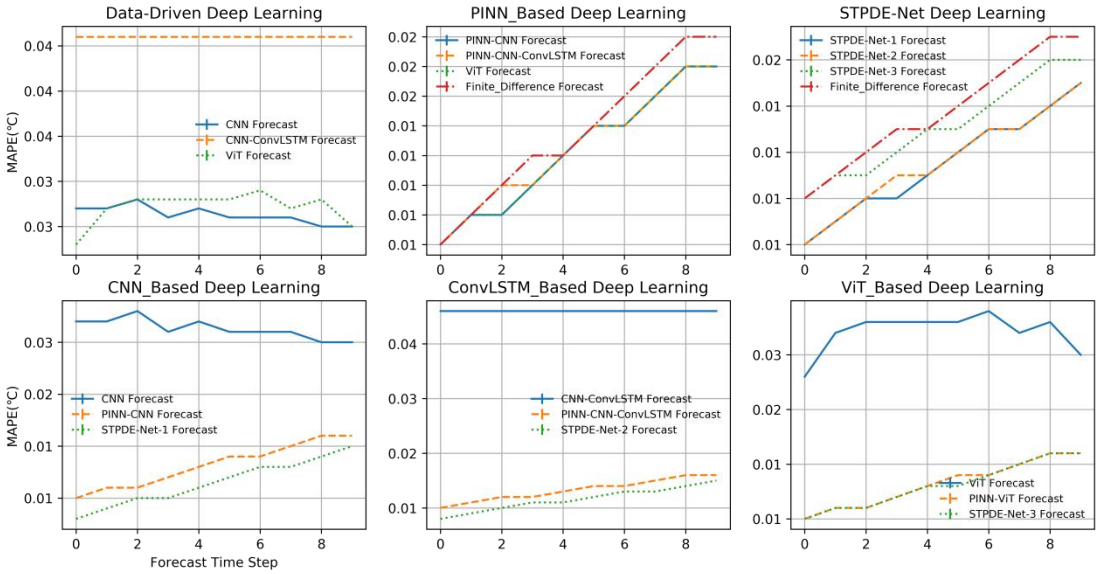


Figure S41. MAPE of the SST prediction using 3 year's data and various methods for different prediction horizons (1-10days).

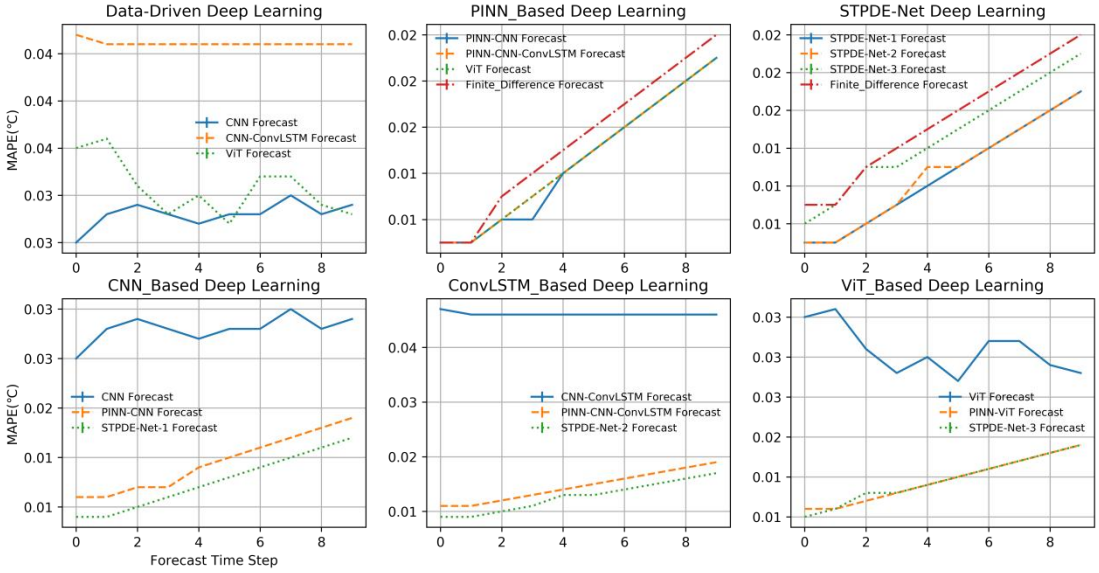


Figure S42. MAPE of the SST prediction using 2 year's data and various methods for different prediction horizons (1-10days).

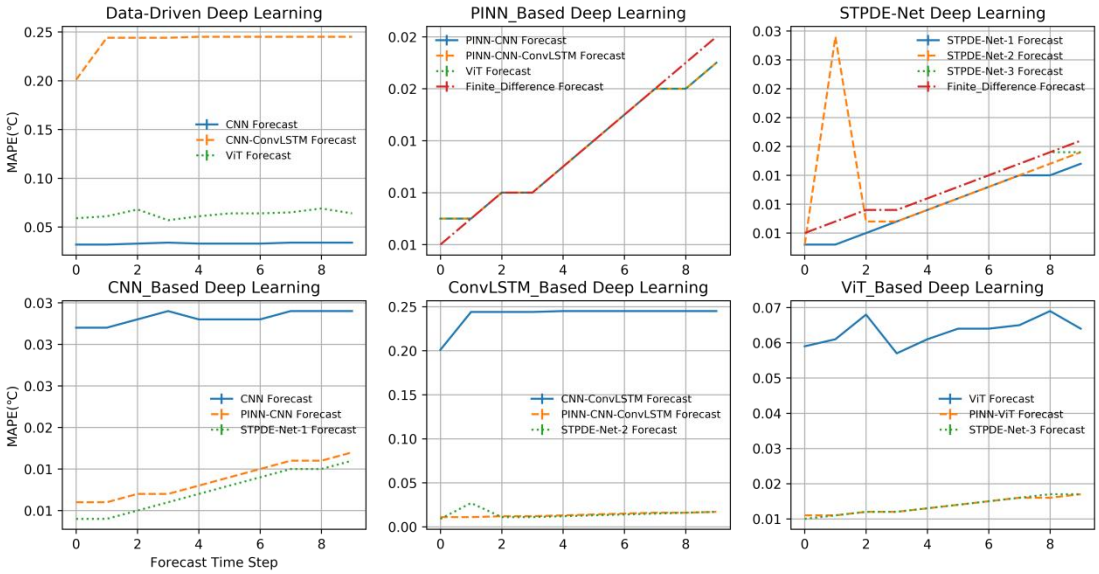


Figure S43. MAPE of the SST prediction using 1 year's data and various methods for different prediction horizons (1-10days).

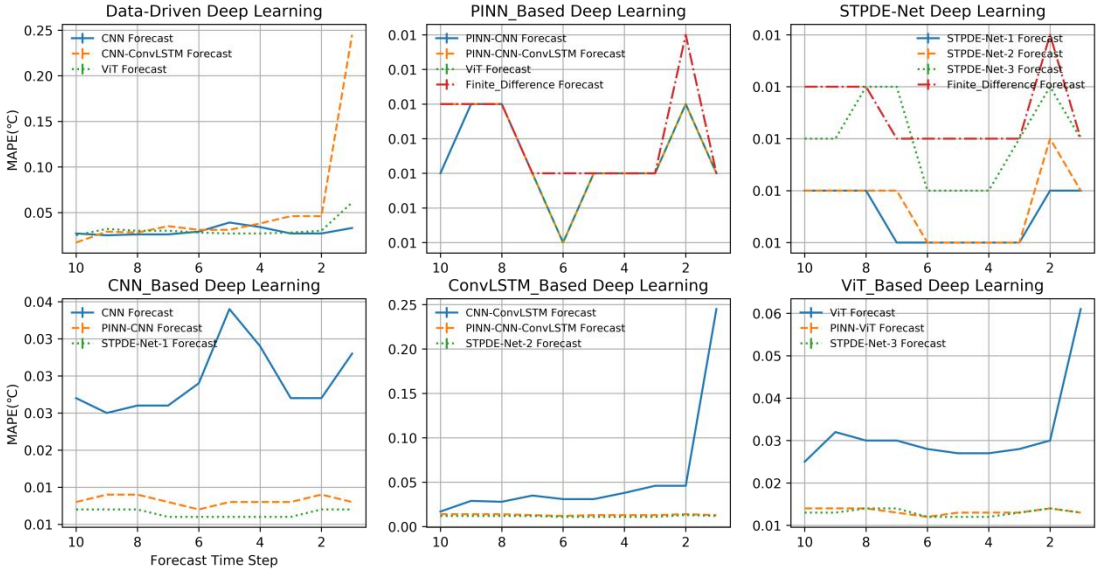


Figure S44. 5-day lead MAPE for SST prediction(2010-2019).

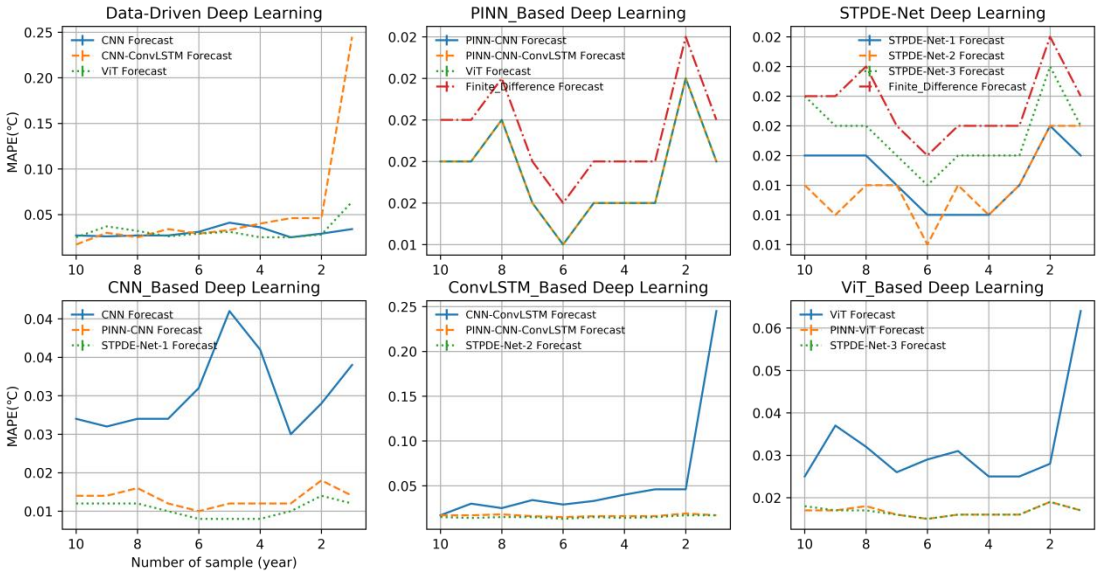


Figure S45. 10-day lead MAPE for SST prediction(2010-2019).

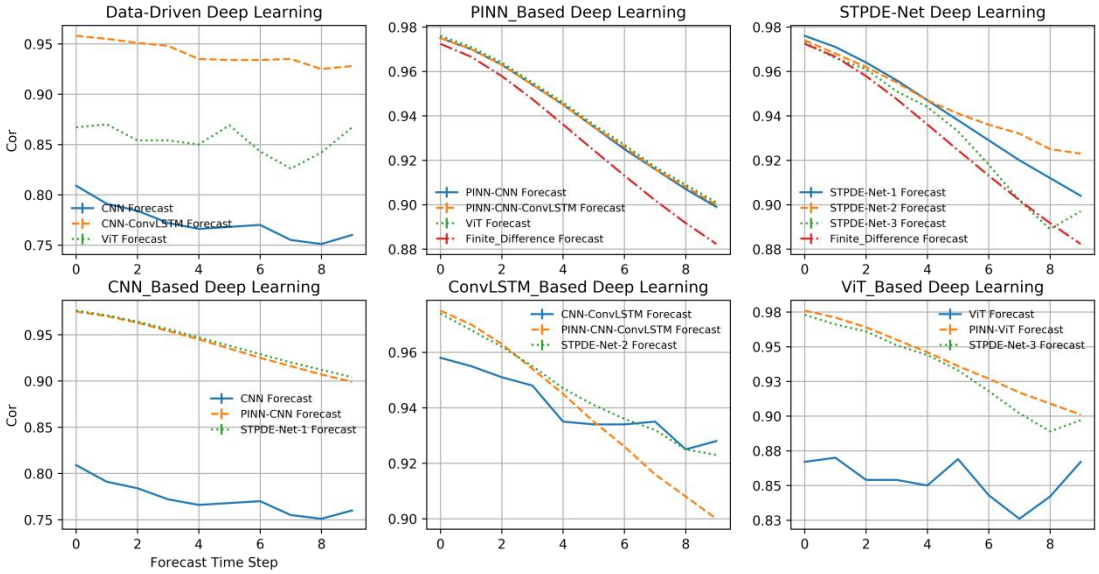


Figure S46. Correlation coefficient of the SST prediction using 10 year's data and various methods for different prediction horizons (1-10days).

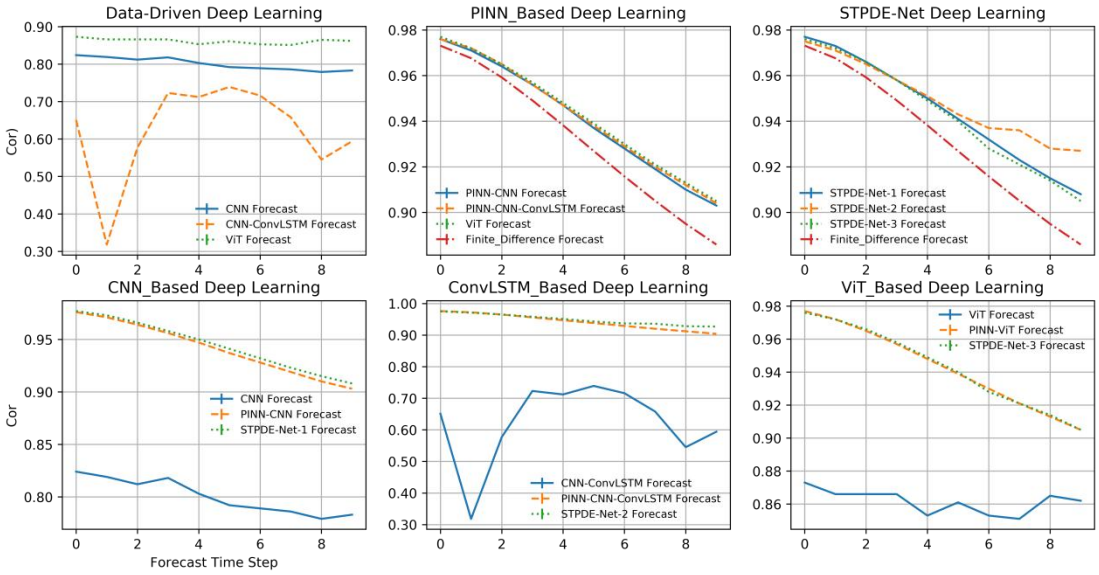


Figure S47. Correlation coefficient of the SST prediction using 9 year's data and various methods for different prediction horizons (1-10days).

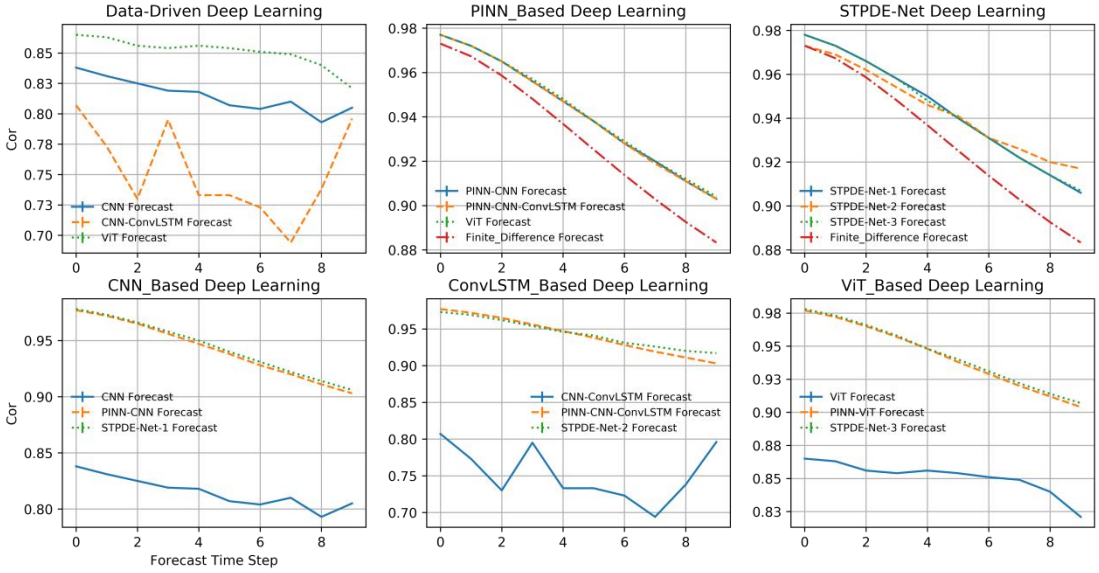


Figure S48. Correlation coefficient of the SST prediction using 8 year's data and various methods for different prediction horizons (1-10days).

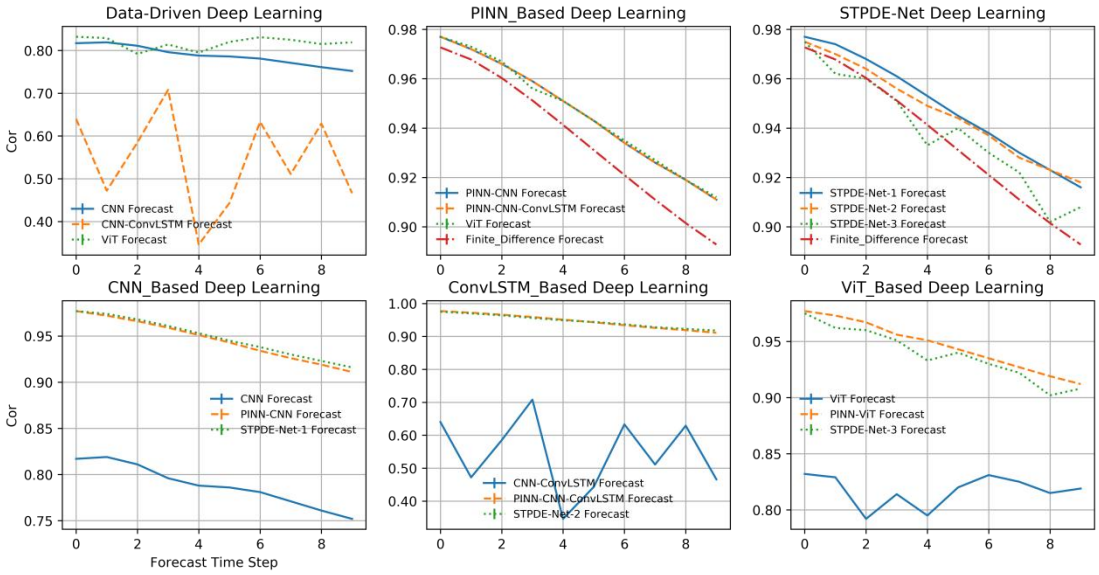


Figure S49. Correlation coefficient of the SST prediction using 7 year's data and various methods for different prediction horizons (1-10days).

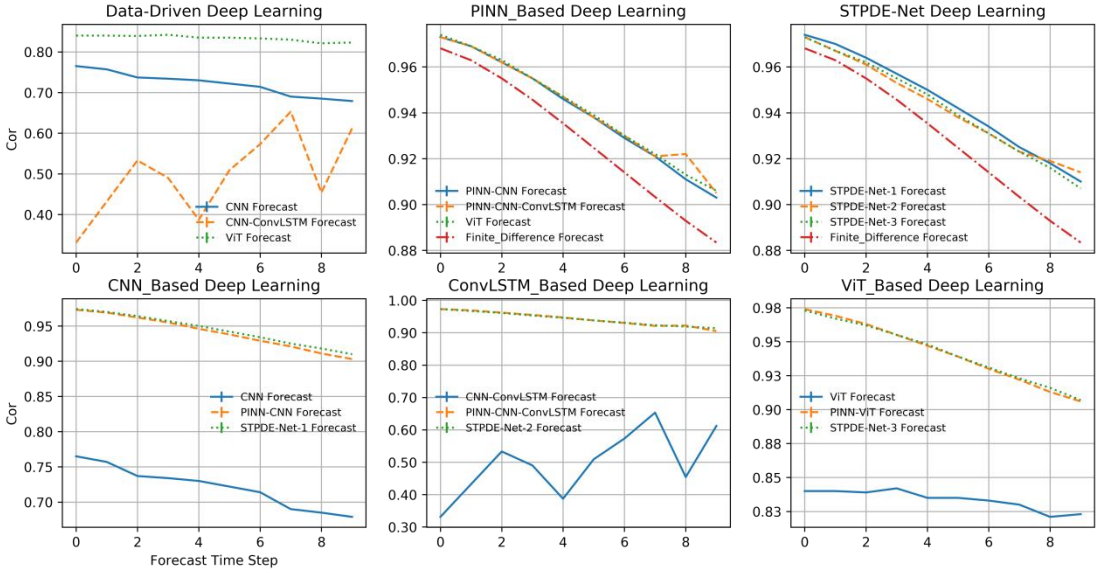


Figure S50. Correlation coefficient of the SST prediction using 6 year's data and various methods for different prediction horizons (1-10days).

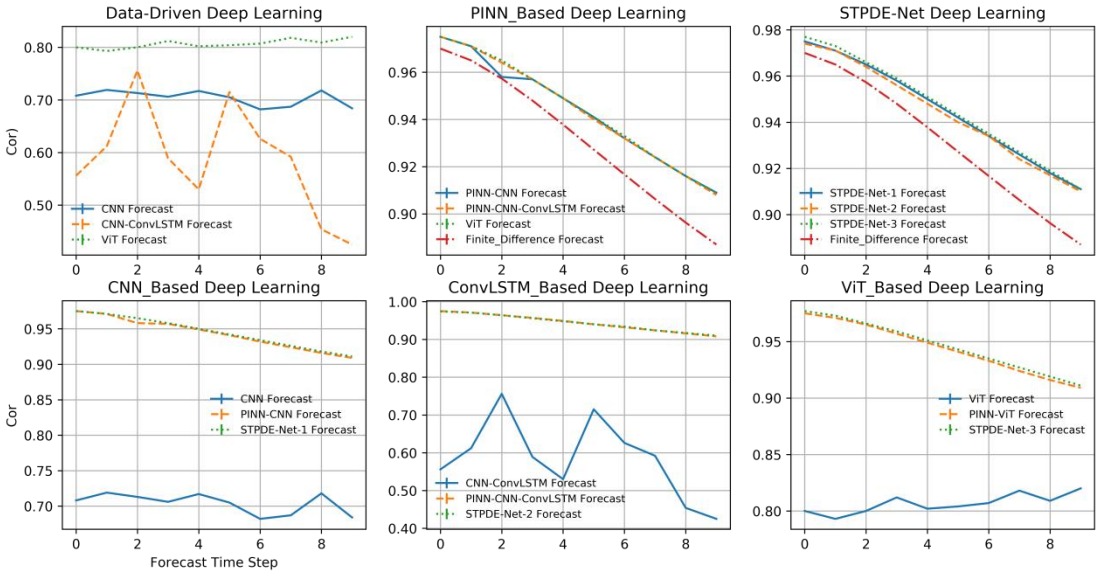


Figure S51. Correlation coefficient of the SST prediction using 5 year's data and various methods for different prediction horizons (1-10days).

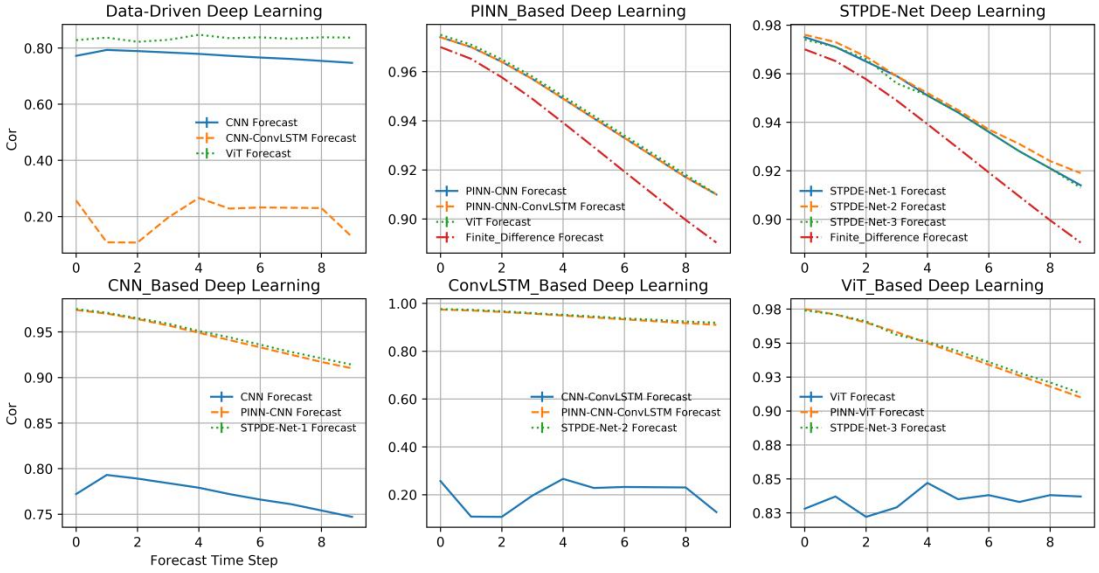


Figure S52. Correlation coefficient of the SST prediction using 4 year's data and various methods for different prediction horizons (1-10days).

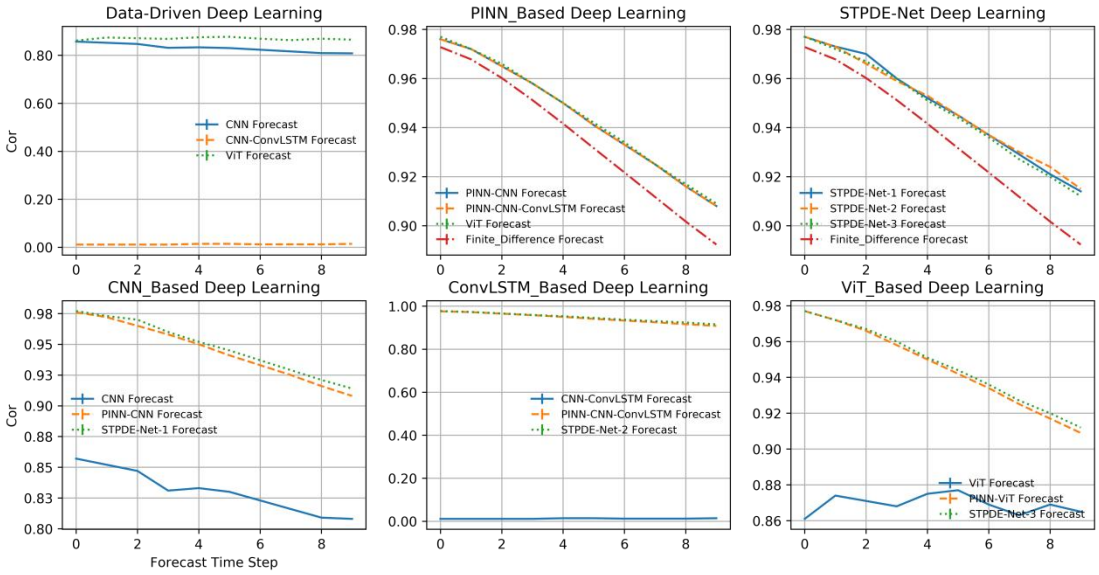


Figure S53. Correlation coefficient of the SST prediction using 3 year's data and various methods for different prediction horizons (1-10days).

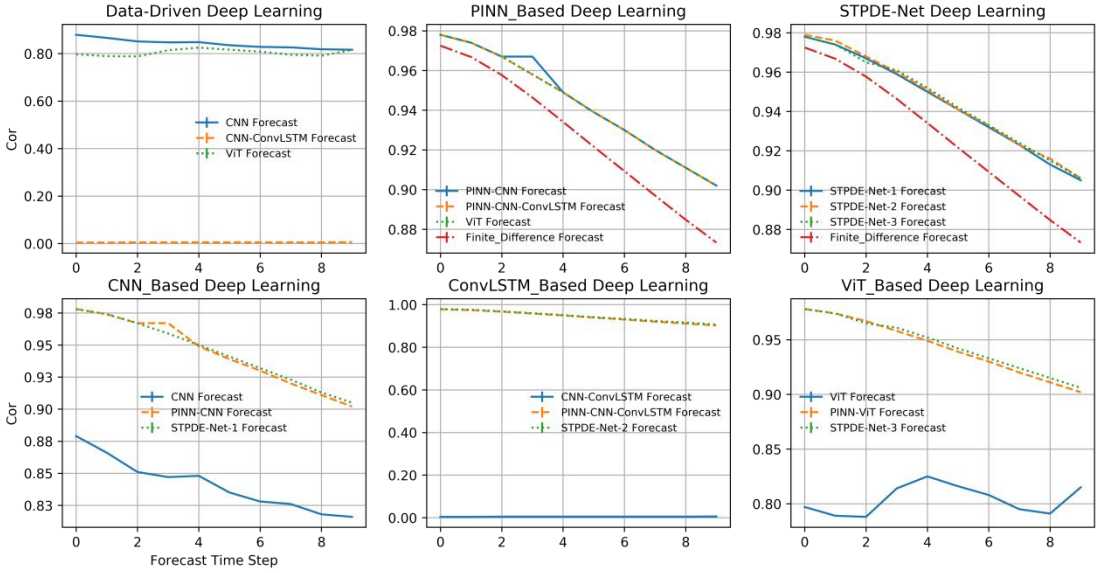


Figure S54. Correlation coefficient of the SST prediction using 2 year's data and various methods for different prediction horizons (1-10days).

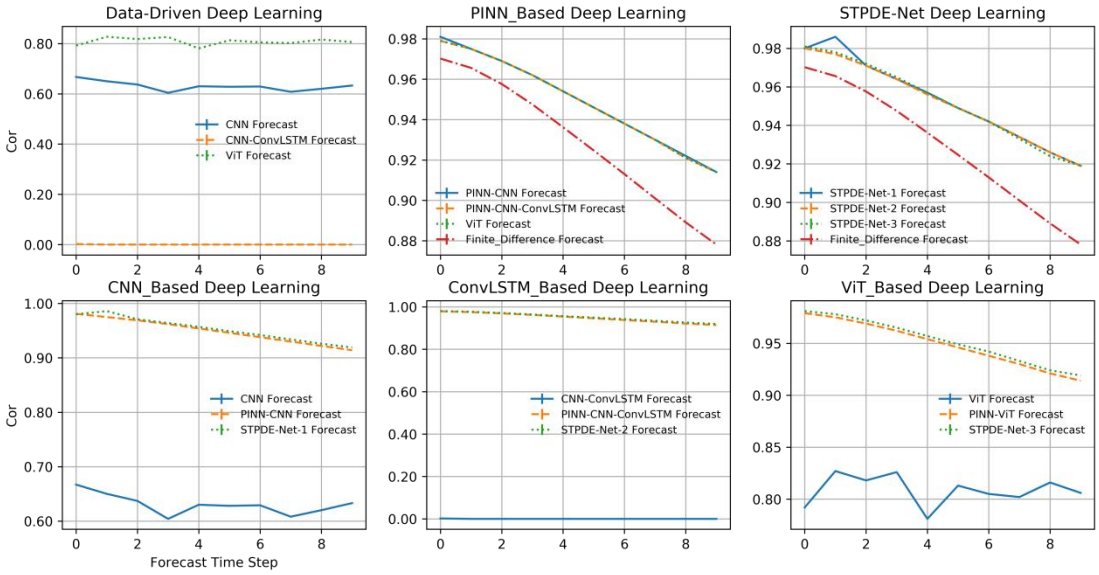


Figure S55. Correlation coefficient of the SST prediction using 1 year's data and various methods for different prediction horizons (1-10days).

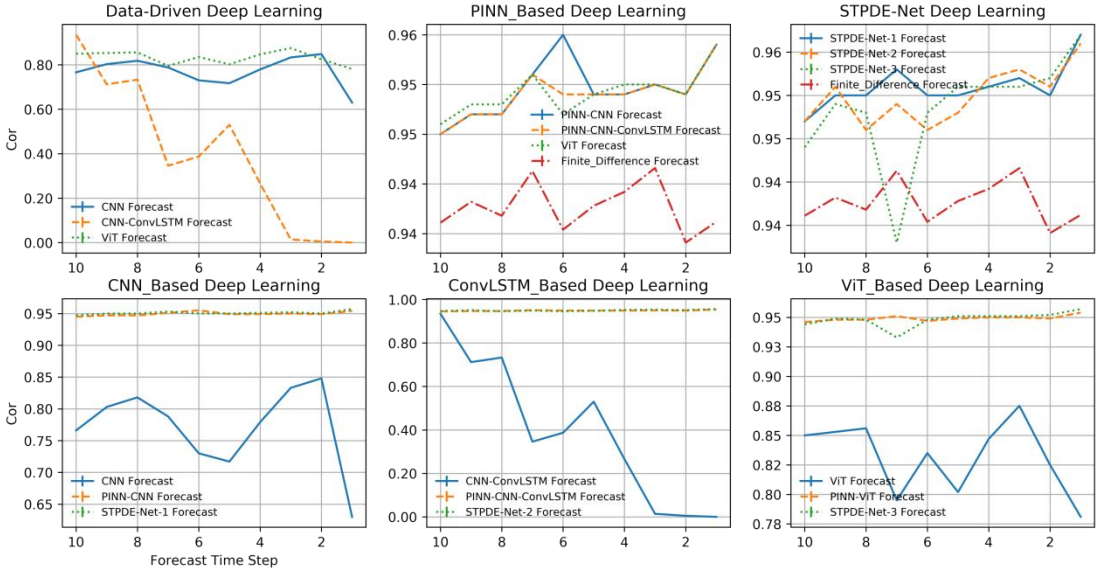


Figure S56. 5-day lead Correlation coefficient for SST prediction(2010-2019).

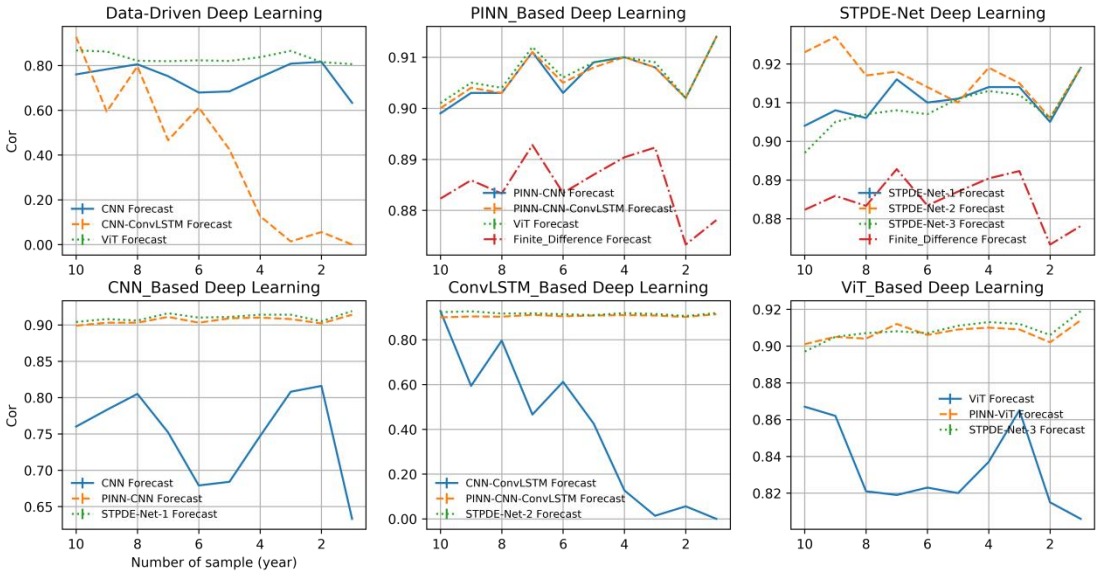


Figure S57. 10-day lead Correlation coefficient for SST prediction(2010-2019).

Text S5. MSE, MAE, MAPE, and r of the SST prediction comparisons of our framework with various state-of-the-art models

Here, to fully demonstrate the effectiveness and stability of our proposed method, we discussed the experimental results from the perspective of multiple indicators, including MSE, MAE, MAPE, and r, as follow:

Table S13

MAE, MSE, MAPE, and r (mean ± std) of the SST prediction using 10 years data and various methods for different prediction horizons (1-10days).

Indexes / *methods*	ahead day	MAE	MSE	MAPE	r
CNN	1	0.692 ± 0.070	0.784 ± 0.173	0.026 ± 0.003	0.809 ± 0.010
	2	0.708 ± 0.061	0.825 ± 0.157	0.026 ± 0.002	0.791 ± 0.023
	3	0.772 ± 0.072	0.979 ± 0.74	0.029 ± 0.003	0.784 ± 0.006
	4	0.754 ± 0.078	0.953 ± 0.193	0.029 ± 0.003	0.772 ± 0.021
	5	0.735 ± 0.036	0.897 ± 0.105	0.027 ± 0.002	0.766 ± 0.012
	6	0.737 ± 0.071	0.901 ± 0.177	0.028 ± 0.003	0.768 ± 0.012
	7	0.721 ± 0.026	0.863 ± 0.070	0.027 ± 0.001	0.770 ± 0.005
	8	0.772 ± 0.078	0.991 ± 0.195	0.029 ± 0.003	0.755 ± 0.009
	9	0.756 ± 0.035	0.952 ± 0.091	0.028 ± 0.001	0.751 ± 0.016
	10	0.728 ± 0.033	0.880 ± 0.091	0.027 ± 0.001	0.760 ± 0.005
PINN-CNN	1	0.284 ± 0.000	0.136 ± 0.000	0.011 ± 0.000	0.975 ± 0.000
	2	0.297 ± 0.000	0.154 ± 0.000	0.011 ± 0.000	0.970 ± 0.000
	3	0.317 ± 0.000	0.180 ± 0.000	0.012 ± 0.000	0.963 ± 0.000
	4	0.338 ± 0.000	0.211 ± 0.001	0.013 ± 0.000	0.954 ± 0.000
	5	0.360 ± 0.001	0.245 ± 0.000	0.013 ± 0.000	0.945 ± 0.001
	6	0.382 ± 0.000	0.280 ± 0.000	0.014 ± 0.000	0.935 ± 0.000
	7	0.403 ± 0.000	0.315 ± 0.000	0.015 ± 0.000	0.925 ± 0.000
	8	0.423 ± 0.000	0.349 ± 0.000	0.016 ± 0.000	0.916 ± 0.002
	9	0.442 ± 0.000	0.381 ± 0.002	0.017 ± 0.000	0.907 ± 0.000
	10	0.459 ± 0.001	0.409 ± 0.001	0.017 ± 0.000	0.899 ± 0.004
STPDE-Net-1	1	0.234 ± 0.001	0.093 ± 0.001	0.009 ± 0.000	0.976 ± 0.000
	2	0.251 ± 0.001	0.110 ± 0.000	0.009 ± 0.000	0.971 ± 0.000
	3	0.274 ± 0.001	0.136 ± 0.000	0.010 ± 0.000	0.964 ± 0.001
	4	0.300 ± 0.001	0.168 ± 0.000	0.011 ± 0.000	0.956 ± 0.000
	5	0.326 ± 0.001	0.202 ± 0.001	0.012 ± 0.000	0.947 ± 0.002
	6	0.350 ± 0.001	0.236 ± 0.000	0.013 ± 0.000	0.938 ± 0.000
	7	0.373 ± 0.001	0.271 ± 0.001	0.014 ± 0.000	0.929 ± 0.001
	8	0.395 ± 0.001	0.305 ± 0.002	0.015 ± 0.000	0.920 ± 0.000
	9	0.415 ± 0.001	0.336 ± 0.001	0.016 ± 0.000	0.912 ± 0.000
	10	0.433 ± 0.001	0.365 ± 0.000	0.016 ± 0.000	0.904 ± 0.001
CNN-ConvLSTM	1	0.351 ± 0.079	0.202 ± 0.099	0.013 ± 0.003	0.958 ± 0.030
	2	0.368 ± 0.075	0.224 ± 0.089	0.014 ± 0.003	0.955 ± 0.015
	3	0.400 ± 0.050	0.259 ± 0.058	0.015 ± 0.002	0.951 ± 0.007
	4	0.427 ± 0.117	0.302 ± 0.146	0.016 ± 0.005	0.948 ± 0.007
	5	0.444 ± 0.075	0.321 ± 0.093	0.017 ± 0.003	0.935 ± 0.011
	6	0.399 ± 0.039	0.270 ± 0.054	0.015 ± 0.001	0.934 ± 0.014
	7	0.473 ± 0.124	0.369 ± 0.169	0.018 ± 0.005	0.934 ± 0.006
	8	0.465 ± 0.133	0.365 ± 0.189	0.018 ± 0.005	0.935 ± 0.005
	9	0.467 ± 0.144	0.369 ± 0.213	0.017 ±0.005	0.925 ± 0.007
	10	0.445 ± 0.109	0.337 ± 0.149	0.017 ± 0.004	0.928 ± 0.005
PINN-CNN-ConvLSTM	1	0.286 ± 0.000	0.137 ± 0.000	0.011 ± 0.000	0.975 ± 0.000
	2	0.299 ± 0.000	0.155 ± 0.000	0.011 ± 0.000	0.970 ± 0.000
	3	0.318 ± 0.001	0.181 ± 0.000	0.012 ± 0.000	0.963 ± 0.000
	4	0.340 ± 0.000	0.212 ± 0.000	0.013 ± 0.000	0.954 ± 0.000
	5	0.361 ± 0.000	0.247 ± 0.000	0.014 ± 0.000	0.945 ± 0.000
	6	0.383 ± 0.000	0.282 ± 0.000	0.014 ± 0.000	0.935 ± 0.000
	7	0.404 ± 0.000	0.316 ± 0.000	0.015 ± 0.000	0.926 ± 0.000
	8	0.424 ± 0.000	0.350 ± 0.000	0.016 ± 0.000	0.916 ±0.000
	9	0.443 ± 0.000	0.382 ± 0.000	0.017 ± 0.000	0.908 ± 0.000
	10	0.460 ± 0.000	0.410 ± 0.000	0.017 ± 0.000	0.900 ± 0.000

STPDE-Net-2	1	0.243 ± 0.004	0.102 ± 0.004	0.009 ± 0.000	0.974 ± 0.001
	2	0.262 ± 0.002	0.120 ± 0.002	0.010 ± 0.000	0.968 ± 0.006
	3	0.282 ± 0.007	0.144 ± 0.007	0.011 ± 0.001	0.962 ± 0.002
	4	0.304 ± 0.004	0.170 ± 0.005	0.011 ± 0.000	0.955 ± 0.002
	5	0.326 ± 0.006	0.199 ± 0.007	0.012 ± 0.000	0.947 ± 0.002
	6	0.343 ± 0.003	0.220 ± 0.005	0.013 ±0.000	0.941 ± 0.002
	7	0.354 ± 0.003	0.236 ± 0.005	0.013 ±0.000	0.936 ± 0.001
	8	0.368 ± 0.008	0.254 ±0.011	0.014 ± 0.001	0.932 ± 0.003
	9	0.384 ± 0.012	0.279 ± 0.019	0.015 ± 0.001	0.925 ± 0.005
	10	0.391 ± 0.009	0.284 ± 0.013	0.015 ± 0.001	0.923 ± 0.003
ViT	1	0.596 ± 0.041	0.571 ± 0.066	0.022 ± 0.002	0.868 ± 0.018
	2	0.598 ± 0.071	0.570 ± 0.113	0.022 ±0.002	0.870 ± 0.011
	3	0.583 ±0.043	0.557 ± 0.088	0.021 ± 0.002	0.854 ± 0.025
	4	0.619 ± 0.071	0.615 ± 0.140	0.023 ± 0.003	0.854 ± 0.025
	5	0.693 ± 0.112	0.762 ± 0.194	0.025 ± 0.004	0.850 ± 0.028
	6	0.676 ± 0.131	0.711 ± 0.215	0.025 ± 0.005	0.869 ± 0.023
	7	0.636 ± 0.074	0.662 ± 0.169	0.023 ± 0.003	0.843 ± 0.054
	8	0.637 ± 0.111	0.719 ± 0.331	0.023 ± 0.004	0.826 ± 0.068
	9	0.601 ± 0.025	0.647 ± 0.037	0.023 ± 0.001	0.842 ± 0.020
	10	0.690 ± 0.111	0.742 ± 0.186	0.025 ± 0.004	0.867 ± 0.061
PINN-ViT	1	0.285 ± 0.001	0.134 ± 0.001	0.011 ± 0.000	0.976 ± 0.001
	2	0.298 ± 0.001	0.151 ± 0.001	0.011 ± 0.000	0.971 ± 0.000
	3	0.317 ± 0.000	0.177 ± 0.000	0.012 ± 0.000	0.964 ± 0.000
	4	0.339 ± 0.000	0.209 ± 0.000	0.013 ± 0.000	0.955 ± 0.000
	5	0.362 ± 0.001	0.244 ± 0.001	0.014 ± 0.001	0.946 ± 0.001
	6	0.383 ± 0.001	0.278 ± 0.001	0.014 ± 0.000	0.936 ± 0.000
	7	0.406 ± 0.001	0.314 ± 0.001	0.015 ± 0.000	0.927 ± 0.001
	8	0.425 ± 0.000	0.347 ± 0.000	0.016 ± 0.000	0.917 ± 0.000
	9	0.444 ± 0.001	0.378 ± 0.000	0.017 ± 0.000	0.909 ± 0.000
	10	0.460 ± 0.000	0.407 ± 0.000	0.017 ± 0.000	0.901 ± 0.000
STPDE-Net-3	1	0.280 ± 0.007	0.131 ± 0.007	0.010 ± 0.001	0.973 ± 0.002
	2	0.300 ± 0.008	0.157 ± 0.010	0.011 ± 0.001	0.966 ± 0.003
	3	0.316 ± 0.007	0.176 ± 0.009	0.012 ± 0.001	0.961 ± 0.003
	4	0.342 ± 0.011	0.210 ± 0.010	0.013 ± 0.001	0.951 ± 0.004
	5	0.360 ± 0.007	0.241 ± 0.009	0.013 ± 0.001	0.944 ± 0.004
	6	0.385 ± 0.011	0.278 ± 0.013	0.014 ± 0.000	0.933 ± 0.004
	7	0.419 ± 0.020	0.335 ± 0.037	0.016 ± 0.001	0.918 ± 0.010
	8	0.454 ± 0.024	0.403 ± 0.062	0.017 ± 0.001	0.902 ± 0.014
	9	0.484 ± 0.017	0.459 ± 0.046	0.018 ± 0.001	0.889 ± 0.011
	10	0.467 ± 0.012	0.416 ± 0.023	0.018 ± 0.001	0.897 ± 0.009

Table S14

MAE, MSE, MAPE, and r (mean ± std) of the SST prediction using 9 years data and various methods for different prediction horizons (1-10days).

methods \ Indexes	ahead day	MAE	MSE	MAPE	r
CNN	1	0.657 ± 0.018	0.695 ± 0.039	0.025 ± 0.001	0.824 ± 0.015
	2	0.652 ± 0.025	0.691 ± 0.063	0.024 ± 0.001	0.819 ± 0.009
	3	0.671 ± 0.040	0.756 ± 0.109	0.025 ± 0.002	0.812 ± 0.010
	4	0.641 ± 0.030	0.672 ± 0.053	0.024 ± 0.001	0.818 ± 0.012
	5	0.671 ± 0.035	0.756 ± 0.079	0.025 ± 0.012	0.803 ± 0.014
	6	0.674 ± 0.016	0.752 ±0.046	0.025 ± 0.001	0.792 ± 0.011
	7	0.680 ± 0.029	0.773 ± 0.087	0.025 ± 0.001	0.789 ± 0.015
	8	0.686 ± 0.029	0.794 ± 0.087	0.026 ±0.002	0.786 ± 0.013
	9	0.702 ± 0.021	0.827 ± 0.078	0.027 ± 0.001	0.779 ± 0.009
	10	0.704 ± 0.027	0.829 ± 0.086	0.026 ± 0.001	0.783 ± 0.008
PINN-CNN	1	0.285 ± 0.000	0.138 ± 0.000	0.011 ± 0.000	0.976 ± 0.000
	2	0.299 ± 0.000	0.156 ± 0.000	0.011 ± 0.000	0.971 ± 0.000
	3	0.318 ± 0.001	0.183 ± 0.000	0.011 ± 0.000	0.964 ± 0.001
	4	0.340 ± 0.000	0.216 ± 0.000	0.013 ± 0.000	0.956 ± 0.000
	5	0.362 ± 0.000	0.251 ± 0.000	0.014 ± 0.000	0.947 ± 0.000

	6	0.384 ± 0.000	0.287 ± 0.000	0.014 ± 0.000	0.937 ± 0.000
	7	0.405 ± 0.002	0.323 ± 0.001	0.015 ± 0.000	0.928 ± 0.001
	8	0.426 ± 0.000	0.358 ± 0.000	0.016 ± 0.000	0.919 ± 0.000
	9	0.445 ± 0.001	0.391 ± 0.001	0.017 ± 0.000	0.910 ± 0.000
	10	0.462 ± 0.000	0.421 ± 0.000	0.017 ± 0.000	0.903 ± 0.000
STPDE-Net-1	1	0.233 ± 0.002	0.093 ± 0.004	0.009 ± 0.000	0.977 ± 0.003
	2	0.249 ± 0.003	0.110 ± 0.001	0.009 ± 0.000	0.973 ± 0.001
	3	0.272 ± 0.001	0.136 ± 0.002	0.010 ± 0.000	0.966 ± 0.001
	4	0.298 ± 0.002	0.170 ± 0.003	0.011 ± 0.000	0.958 ± 0.002
	5	0.322 ± 0.002	0.204 ± 0.001	0.012 ± 0.000	0.950 ± 0.003
	6	0.346 ± 0.000	0.239 ± 0.000	0.013 ± 0.000	0.941 ± 0.001
	7	0.369 ± 0.002	0.274 ± 0.001	0.014 ± 0.000	0.932 ± 0.000
	8	0.391 ± 0.004	0.308 ± 0.003	0.015 ± 0.000	0.923 ± 0.002
	9	0.411 ± 0.003	0.340 ± 0.003	0.015 ± 0.000	0.915 ± 0.002
	10	0.430 ± 0.001	0.370 ± 0.002	0.016 ± 0.000	0.908 ± 0.003
CNN-ConvLSTM	1	0.848 ± 0.137	1.172 ± 0.332	0.031 ± 0.005	0.651 ± 0.109
	2	0.943 ± 0.289	1.494 ± 0.712	0.035 ± 0.011	0.318 ± 0.421
	3	0.843 ± 0.289	1.199 ± 0.635	0.031 ± 0.011	0.577 ± 0.345
	4	0.741 ± 0.198	0.915 ± 0.474	0.027 ± 0.007	0.723 ± 0.155
	5	0.793 ± 0.164	1.043 ± 0.375	0.029 ± 0.006	0.712 ± 0.127
	6	0.727 ± 0.234	0.916 ± 0.496	0.027 ± 0.009	0.739 ± 0.152
	7	0.749 ± 0.250	0.973 ± 0.552	0.028 ± 0.009	0.716 ± 0.173
	8	0.837 ± 0.176	1.160 ± 0.399	0.031 ± 0.006	0.658 ± 0.129
	9	0.870 ± 0.222	1.260 ± 0.546	0.032 ± 0.008	0.545 ± 0.324
	10	0.796 ± 0.437	1.101 ± 0.686	0.030 ± 0.011	0.594 ± 0.363
PINN-CNN-ConvLSTM	1	0.286 ± 0.000	0.138 ± 0.000	0.011 ± 0.000	0.976 ± 0.000
	2	0.300 ± 0.000	0.156 ± 0.000	0.011 ± 0.000	0.972 ± 0.000
	3	0.319 ± 0.000	0.184 ± 0.000	0.012 ± 0.000	0.965 ± 0.000
	4	0.341 ± 0.000	0.216 ± 0.000	0.013 ± 0.000	0.956 ± 0.000
	5	0.363 ± 0.000	0.251 ± 0.000	0.014 ± 0.000	0.947 ± 0.000
	6	0.384 ± 0.000	0.287 ± 0.000	0.014 ± 0.000	0.938 ± 0.000
	7	0.406 ± 0.000	0.322 ± 0.000	0.015 ± 0.000	0.929 ± 0.000
	8	0.426 ± 0.000	0.357 ± 0.000	0.016 ± 0.000	0.920 ± 0.000
	9	0.445 ± 0.000	0.390 ± 0.000	0.017 ± 0.000	0.912 ±0.000
	10	0.463 ± 0.000	0.420 ± 0.000	0.017 ± 0.000	0.904 ± 0.000
STPDE-Net-2	1	0.243 ± 0.009	0.102 ± 0.008	0.009 ± 0.000	0.975 ± 0.002
	2	0.258 ± 0.011	0.118 ± 0.009	0.009 ± 0.001	0.971 ± 0.001
	3	0.275 ± 0.007	0.139 ± 0.007	0.010 ± 0.000	0.965 ± 0.002
	4	0.296 ± 0.004	0.165 ± 0.006	0.011 ± 0.000	0.958 ± 0.001
	5	0.317 ± 0.005	0.193 ± 0.008	0.012 ± 0.000	0.951 ± 0.002
	6	0.340 ± 0.004	0.224 ± 0.007	0.013 ± 0.000	0.943 ± 0.002
	7	0.357 ± 0.009	0.247 ± 0.015	0.013 ± 0.001	0.937 ± 0.003
	8	0.361 ± 0.016	0.251 ± 0.027	0.013 ± 0.001	0.936 ± 0.007
	9	0.380 ± 0.011	0.279 ± 0.019	0.014 ± 0.001	0.928 ± 0.005
	10	0.387 ± 0.011	0.285 ± 0.017	0.014 ± 0.001	0.927 ± 0.004
ViT	1	0.856 ± 0.140	1.066 ± 0.266	0.031 ± 0.005	0.873 ± 0.006
	2	0.909 ± 0.243	1.216 ± 0.560	0.025 ± 0.012	0.866 ± 0.007
	3	0.945 ± 0.272	1.301 ± 0.601	0.035 ± 0.010	0.866 ± 0.008
	4	0.961 ± 0.234	1.317 ± 0.551	0.035 ± 0.009	0.866 ± 0.006
	5	0.879 ± 0.198	1.146 ± 0.426	0.032 ± 0.007	0.853 ± 0.030
	6	0.846 ± 0.196	1.068 ± 0.421	0.031 ± 0.007	0.861 ± 0.020
	7	0.947 ± 0.206	1.301 ± 0.449	0.035 ± 0.007	0.853 ± 0.021
	8	0.939 ± 0.185	1.266 ± 0.408	0.035 ± 0.007	0.851 ± 0.024
	9	1.132 ± 0.359	1.773 ± 0.913	0.041 ± 0.013	0.865 ± 0.010
	10	0.996 ± 0.341	1.458 ± 0.836	0.037 ± 0.013	0.862 ± 0.009
PINN-ViT	1	0.284 ± 0.001	0.134 ± 0.000	0.011 ± 0.000	0.977 ± 0.000
	2	0.298 ± 0.001	0.153 ± 0.001	0.011 ± 0.000	0.972 ± 0.000
	3	0.318 ± 0.000	0.180 ± 0.001	0.012 ± 0.000	0.965 ± 0.000
	4	0.339 ± 0.000	0.212 ±0.001	0.013 ± 0.000	0.957 ± 0.000
	5	0.361 ± 0.000	0.247 ± 0.001	0.014 ± 0.001	0.948 ± 0.000
	6	0.383 ± 0.000	0.283 ± 0.001	0.014 ± 0.000	0.939 ± 0.000
	7	0.405 ± 0.001	0.319 ± 0.001	0.015 ± 0.000	0.930 ± 0.000
	8	0.425 ± 0.000	0.354 ± 0.001	0.016 ± 0.000	0.921 ± 0.000
	9	0.444 ± 0.000	0.387 ± 0.001	0.017 ± 0.000	0.913 ± 0.001
	10	0.462 ± 0.000	0.417 ± 0.001	0.017 ± 0.000	0.905 ± 0.000
	1	0.280 ± 0.004	0.131 ± 0.003	0.010 ± 0.000	0.976 ± 0.001

STPDE-Net-3	2	0.293 ± 0.002	0.148 ± 0.003	0.011 ± 0.000	0.972 ± 0.001
	3	0.312 ± 0.001	0.173 ± 0.002	0.012 ± 0.000	0.966 ± 0.000
	4	0.334 ± 0.001	0.205 ± 0.001	0.012 ± 0.000	0.958 ± 0.000
	5	0.357 ± 0.001	0.240 ± 0.003	0.013 ± 0.000	0.949 ± 0.001
	6	0.380 ± 0.001	0.277 ± 0.002	0.014 ± 0.000	0.940 ± 0.000
	7	0.406 ± 0.006	0.319 ± 0.013	0.015 ± 0.000	0.928 ± 0.003
	8	0.424 ± 0.003	0.350 ± 0.005	0.016 ± 0.000	0.921 ± 0.001
	9	0.440 ± 0.003	0.374 ± 0.007	0.017 ± 0.001	0.914 ± 0.002
	10	0.461 ± 0.008	0.408 ± 0.011	0.017 ± 0.000	0.905 ± 0.003

Table S15

MAE, MSE, MAPE, and r (mean ± std) of the SST prediction using 8 years data and various methods for different prediction horizons (1-10days).

methods \ Indexes	ahead day	MAE	MSE	MAPE	r
CNN	1	0.667 ± 0.060	0.680 ± 0.101	0.025 ± 0.002	0.838 ± 0.015
	2	0.709 ± 0.060	0.765 ± 0.089	0.026 ± 0.002	0.831 ± 0.015
	3	0.681 ± 0.041	0.720 ± 0.062	0.025 ± 0.002	0.825 ± 0.012
	4	0.694 ± 0.037	0.750 ± 0.050	0.026 ± 0.001	0.819 ± 0.008
	5	0.692 ± 0.023	0.759 ± 0.052	0.026 ± 0.001	0.818 ± 0.007
	6	0.686 ± 0.038	0.765 ± 0.070	0.026 ± 0.002	0.807 ± 0.014
	7	0.694 ± 0.023	0.781 ± 0.057	0.026 ± 0.001	0.804 ± 0.012
	8	0.703 ± 0.033	0.788 ± 0.063	0.026 ± 0.001	0.810 ± 0.010
	9	0.731 ± 0.037	0.845 ± 0.091	0.027 ± 0.001	0.793 ± 0.025
	10	0.709 ± 0.038	0.801 ± 0.064	0.027 ± 0.001	0.805 ± 0.009
PINN-CNN	1	0.289 ± 0.001	0.141 ± 0.001	0.011 ± 0.000	0.977 ± 0.000
	2	0.300 ± 0.004	0.157 ± 0.003	0.011 ± 0.000	0.972 ± 0.000
	3	0.319 ± 0.003	0.184 ± 0.003	0.012 ± 0.000	0.965 ± 0.000
	4	0.342 ± 0.003	0.218 ± 0.003	0.013 ± 0.000	0.956 ± 0.000
	5	0.364 ± 0.003	0.253 ± 0.003	0.014 ± 0.000	0.947 ± 0.000
	6	0.387 ± 0.003	0.290 ± 0.003	0.015 ± 0.001	0.938 ± 0.000
	7	0.408 ± 0.003	0.326 ± 0.003	0.015 ± 0.000	0.928 ± 0.000
	8	0.429 ± 0.002	0.361 ± 0.003	0.016 ± 0.000	0.920 ± 0.000
	9	0.448 ± 0.002	0.394 ± 0.003	0.017 ± 0.000	0.911 ± 0.000
	10	0.466 ± 0.003	0.424 ± 0.003	0.018 ± 0.001	0.903 ± 0.000
STPDE-Net-1	1	0.235 ± 0.001	0.096 ± 0.000	0.009 ± 0.000	0.978 ± 0.000
	2	0.251 ± 0.002	0.113 ± 0.001	0.009 ± 0.000	0.973 ± 0.000
	3	0.275 ± 0.002	0.139 ± 0.001	0.010 ± 0.000	0.966 ± 0.000
	4	0.301 ± 0.001	0.172 ± 0.002	0.011 ± 0.000	0.958 ± 0.000
	5	0.327 ± 0.002	0.207 ± 0.002	0.012 ± 0.000	0.950 ± 0.000
	6	0.352 ± 0.001	0.244 ±0.000	0.013 ± 0.000	0.940 ± 0.001
	7	0.375 ± 0.003	0.280 ± 0.003	0.014 ± 0.000	0.931 ± 0.000
	8	0.400 ± 0.002	0.315 ± 0.002	0.015 ± 0.000	0.922 ± 0.000
	9	0.421 ± 0.002	0.349 ± 0.001	0.016 ± 0.000	0.914 ± 0.000
	10	0.439 ± 0.001	0.379 ± 0.003	0.016 ± 0.000	0.906 ± 0.000
CNN-ConvLSTM	1	0.613 ± 0.214	0.689 ± 0.479	0.023 ± 0.008	0.807 ± 0.146
	2	0.671 ± 0.192	0.803 ± 0.470	0.025 ± 0.008	0.773 ± 0.143
	3	0.702 ± 0.253	0.902 ± 0.635	0.026 ± 0.010	0.730 ± 0.221
	4	0.673 ± 0.150	0.773 ± 0.355	0.025 ± 0.006	0.795 ± 0.096
	5	0.731 ± 0.216	0.955 ± 0.525	0.028 ± 0.008	0.733 ± 0.175
	6	0.695 ± 0.264	0.890 ± 0.649	0.026 ± 0.010	0.733 ± 0.227
	7	0.741 ± 0.205	0.983 ± 0.496	0.028 ± 0.008	0.723 ± 0.151
	8	0.754 ± 0.227	1.018 ± 0.578	0.028 ± 0.009	0.694 ± 0.204
	9	0.704 ± 0.236	0.886 ± 0.574	0.026 ± 0.009	0.738 ± 0.212
	10	0.680 ± 0.131	0.776 ± 0.344	0.025 ± 0.005	0.796 ± 0.106
PINN-CNN-ConvLSTM	1	0.290 ± 0.000	0.141 ± 0.000	0.011 ± 0.000	0.977 ± 0.000
	2	0.303 ± 0.000	0.160 ± 0.000	0.011 ± 0.000	0.972 ± 0.000
	3	0.323 ± 0.000	0.187 ± 0.001	0.012 ± 0.000	0.965 ± 0.000
	4	0.345 ± 0.000	0.220 ± 0.000	0.013 ± 0.000	0.956 ± 0.000
	5	0.367 ± 0.001	0.256 ± 0.001	0.014 ± 0.000	0.947 ± 0.000
	6	0.389 ± 0.000	0.293 ± 0.000	0.015 ± 0.000	0.938 ± 0.000
	7	0.411 ± 0.000	0.329 ± 0.000	0.015 ± 0.000	0.928 ± 0.000
	8	0.431 ± 0.000	0.364 ± 0.000	0.016 ± 0.000	0.919 ± 0.000

	9	0.451 ± 0.000	0.397 ± 0.000	0.017 ± 0.000	0.911 ± 0.000
	10	0.468 ± 0.001	0.427 ± 0.001	0.018 ± 0.000	0.903 ± 0.000
STPDE-Net-2	1	0.256 ± 0.005	0.119 ± 0.006	0.010 ± 0.000	0.973 ± 0.002
	2	0.268 ± 0.008	0.132 ± 0.010	0.010 ± 0.000	0.969 ± 0.002
	3	0.291 ± 0.009	0.161 ± 0.010	0.011 ± 0.000	0.962 ± 0.001
	4	0.318 ± 0.011	0.194 ± 0.014	0.012 ± 0.001	0.954 ± 0.002
	5	0.338 ± 0.009	0.220 ± 0.015	0.012 ± 0.001	0.946 ± 0.003
	6	0.352 ± 0.010	0.241 ± 0.017	0.013 ± 0.000	0.941 ± 0.003
	7	0.374 ± 0.010	0.275 ± 0.017	0.014 ± 0.000	0.931 ± 0.003
	8	0.391 ± 0.017	0.304 ± 0.030	0.015 ± 0.001	0.926 ± 0.006
	9	0.403 ± 0.012	0.312 ± 0.020	0.015 ± 0.001	0.920 ± 0.006
	10	0.415 ± 0.010	0.336 ± 0.020	0.015 ± 0.001	0.917 ± 0.004
ViT	1	0.899 ± 0.226	1.171 ± 0.491	0.033 ± 0.008	0.865 ± 0.005
	2	0.954 ± 0.161	1.275 ± 0.348	0.035 ± 0.006	0.863 ± 0.011
	3	0.866 ± 0.220	1.115 ± 0.475	0.031 ± 0.008	0.856 ± 0.004
	4	0.890 ± 0.224	1.160 ± 0.509	0.033 ± 0.008	0.854 ± 0.012
	5	0.819 ± 0.223	1.011 ± 0.473	0.030 ± 0.008	0.856 ± 0.008
	6	0.881 ± 0.208	1.141 ± 0.429	0.032 ± 0.007	0.854 ± 0.007
	7	0.905 ± 0.209	1.202 ± 0.437	0.033 ± 0.007	0.851 ± 0.011
	8	0.856 ± 0.185	1.089 ± 0.388	0.031 ± 0.007	0.849 ± 0.012
	9	0.818 ± 0.136	1.029 ± 0.257	0.030 ± 0.005	0.840 ± 0.013
	10	0.862 ± 0.128	1.138 ± 0.286	0.032 ± 0.004	0.821 ± 0.046
PINN-ViT	1	0.287 ± 0.000	0.138 ± 0.001	0.011 ± 0.000	0.977 ± 0.000
	2	0.301 ± 0.000	0.156 ± 0.000	0.011 ± 0.000	0.972 ± 0.001
	3	0.321 ± 0.000	0.184 ± 0.001	0.012 ± 0.000	0.965 ± 0.000
	4	0.343 ± 0.000	0.217 ± 0.001	0.013 ± 0.000	0.957 ± 0.000
	5	0.366 ± 0.001	0.253 ± 0.001	0.014 ± 0.000	0.948 ± 0.000
	6	0.389 ± 0.001	0.289 ± 0.000	0.015 ± 0.000	0.938 ± 0.000
	7	0.410 ± 0.000	0.325 ± 0.000	0.015 ± 0.000	0.929 ± 0.000
	8	0.430 ± 0.000	0.360 ± 0.000	0.016 ± 0.000	0.920 ± 0.000
	9	0.450 ± 0.001	0.394 ± 0.001	0.017 ± 0.000	0.912 ± 0.000
	10	0.467 ± 0.000	0.424 ± 0.001	0.018 ± 0.000	0.904 ± 0.000
STPDE-Net-3	1	0.280 ± 0.002	0.130 ± 0.002	0.010 ± 0.000	0.978 ± 0.000
	2	0.295 ± 0.001	0.149 ± 0.001	0.011 ± 0.000	0.973 ± 0.000
	3	0.318 ± 0.005	0.179 ± 0.006	0.012 ± 0.000	0.966 ± 0.002
	4	0.339 ± 0.001	0.210 ± 0.001	0.013 ± 0.000	0.958 ± 0.001
	5	0.362 ± 0.003	0.245 ± 0.004	0.014 ± 0.001	0.948 ± 0.001
	6	0.383 ± 0.003	0.280 ± 0.005	0.014 ± 0.000	0.940 ± 0.001
	7	0.408 ± 0.002	0.319 ± 0.003	0.015 ± 0.000	0.931 ± 0.001
	8	0.428 ± 0.002	0.352 ± 0.002	0.016 ± 0.000	0.922 ± 0.001
	9	0.447 ± 0.001	0.384 ± 0.003	0.017 ± 0.000	0.914 ± 0.000
	10	0.462 ± 0.006	0.407 ±0.007	0.017 ± 0.000	0.907 ± 0.001

Table S16

MAE, MSE, MAPE, and r (mean ± std) of the SST prediction using 7 years data and various methods for different prediction horizons (1-10days).

methods \ Indexes	ahead day	MAE	MSE	MAPE	r
CNN	1	0.641 ± 0.052	0.667 ± 0.114	0.024 ± 0.002	0.817 ± 0.015
	2	0.623 ± 0.024	0.625 ± 0.049	0.023 ± 0.001	0.819 ± 0.008
	3	0.635 ± 0.030	0.654 ± 0.062	0.024 ± 0.001	0.811 ± 0.014
	4	0.689 ± 0.047	0.775 ± 0.108	0.026 ± 0.002	0.796 ± 0.009
	5	0.700 ± 0.034	0.807 ± 0.079	0.026 ± 0.001	0.788 ± 0.009
	6	0.677 ± 0.039	0.755 ± 0.090	0.025 ± 0.002	0.786 ± 0.019
	7	0.698 ± 0.049	0.808 ± 0.121	0.026 ± 0.002	0.781 ± 0.016
	8	0.706 ± 0.027	0.820 ± 0.072	0.026 ± 0.001	0.771 ± 0.017
	9	0.725 ± 0.064	0.871 ± 0.181	0.027 ± 0.002	0.761 ± 0.017
	10	0.725 ± 0.047	0.858 ± 0.121	0.027 ± 0.002	0.752 ± 0.031
PINN-CNN	1	0.278 ± 0.001	0.128 ± 0.000	0.010 ± 0.000	0.977 ± 0.000
	2	0.289 ± 0.000	0.142 ± 0.001	0.011 ± 0.000	0.972 ± 0.000
	3	0.305 ± 0.000	0.163 ± 0.000	0.011 ± 0.000	0.966 ± 0.000
	4	0.323 ± 0.000	0.188 ± 0.000	0.012 ± 0.000	0.959 ± 0.000
	5	0.342 ± 0.001	0.215 ± 0.000	0.013 ± 0.000	0.951 ± 0.000
	6	0.360 ± 0.000	0.243 ± 0.000	0.013 ± 0.000	0.943 ± 0.000

	7	0.378 ± 0.000	0.271 ± 0.000	0.014 ± 0.000	0.934 ± 0.000
	8	0.396 ± 0.000	0.299 ± 0.001	0.015 ± 0.000	0.926 ± 0.000
	9	0.413 ± 0.000	0.325 ± 0.000	0.015 ± 0.000	0.919 ± 0.000
	10	0.428 ± 0.000	0.349 ± 0.000	0.016 ± 0.000	0.911 ± 0.000
STPDE-Net-1	1	0.226 ± 0.001	0.087 ± 0.003	0.008 ± 0.000	0.977 ± 0.000
	2	0.241 ± 0.002	0.101 ± 0.002	0.009 ± 0.000	0.974 ± 0.000
	3	0.261 ± 0.003	0.122 ± 0.002	0.010 ± 0.000	0.968 ± 0.001
	4	0.283 ± 0.002	0.147 ± 0.002	0.010 ± 0.000	0.961 ± 0.000
	5	0.305 ± 0.003	0.175 ± 0.001	0.011 ± 0.000	0.953 ± 0.001
	6	0.326 ± 0.002	0.203 ± 0.001	0.012 ± 0.000	0.945 ± 0.000
	7	0.346 ± 0.003	0.231 ± 0.002	0.013 ± 0.000	0.938 ± 0.000
	8	0.365 ± 0.002	0.258 ± 0.001	0.014 ± 0.000	0.930 ± 0.000
	9	0.383 ± 0.002	0.285 ± 0.002	0.014 ± 0.000	0.923 ± 0.001
	10	0.400 ± 0.003	0.309 ± 0.003	0.015 ± 0.000	0.916 ± 0.000
CNN-ConvLSTM	1	0.796 ± 0.179	1.072 ± 0.446	0.030 ± 0.007	0.640 ± 0.185
	2	0.892 ± 0.158	1.328 ± 0.430	0.033 ± 0.006	0.472 ± 0.301
	3	0.828 ± 0.200	1.173 ± 0.475	0.031 ± 0.008	0.585 ± 0.207
	4	0.706 ± 0.218	0.865 ± 0.520	0.026 ± 0.008	0.708 ± 0.216
	5	0.942 ± 0.143	1.462 ± 0.415	0.035 ± 0.006	0.346 ± 0.325
	6	0.924 ± 0.096	1.411 ± 0.273	0.035 ± 0.004	0.443 ± 0.260
	7	0.803 ± 0.179	1.109 ± 0.420	0.030 ± 0.007	0.633 ± 0.173
	8	0.843 ± 0.210	1.228 ± 0.530	0.032 ± 0.008	0.511 ± 0.329
	9	0.812 ± 0.136	1.110 ± 0.353	0.030 ± 0.005	0.629 ± 0.161
	10	0.898 ± 0.122	1.344 ± 0.335	0.034 ± 0.005	0.466 ± 0.280
PINN-CNN-ConvLSTM	1	0.278 ± 0.000	0.128 ± 0.000	0.010 ± 0.000	0.977 ± 0.000
	2	0.290 ± 0.000	0.142 ± 0.000	0.011 ± 0.000	0.972 ± 0.000
	3	0.306 ± 0.001	0.164 ± 0.000	0.011 ± 0.000	0.966 ± 0.000
	4	0.324 ± 0.001	0.189 ± 0.001	0.012 ± 0.000	0.959 ± 0.000
	5	0.342 ± 0.001	0.216 ± 0.001	0.013 ± 0.000	0.951 ± 0.001
	6	0.361 ± 0.000	0.244 ± 0.001	0.013 ± 0.000	0.943 ± 0.000
	7	0.379 ± 0.001	0.272 ± 0.000	0.014 ± 0.000	0.934 ± 0.000
	8	0.396 ± 0.000	0.299 ± 0.000	0.015 ± 0.000	0.926 ± 0.001
	9	0.413 ± 0.000	0.326 ± 0.000	0.015 ± 0.000	0.919 ± 0.000
	10	0.428 ± 0.001	0.350 ± 0.001	0.016 ± 0.000	0.911 ± 0.000
STPDE-Net-2	1	0.236 ± 0.002	0.095 ± 0.002	0.009 ± 0.000	0.975 ± 0.001
	2	0.257 ± 0.011	0.115 ± 0.009	0.027 ± 0.040	0.970 ± 0.001
	3	0.274 ± 0.007	0.134 ± 0.006	0.010 ± 0.000	0.964 ± 0.002
	4	0.297 ± 0.002	0.160 ± 0.003	0.011 ± 0.000	0.956 ± 0.001
	5	0.316 ± 0.004	0.182 ± 0.003	0.012 ± 0.000	0.949 ± 0.001
	6	0.328 ± 0.012	0.199 ± 0.014	0.012 ± 0.000	0.944 ± 0.003
	7	0.352 ± 0.018	0.230 ± 0.022	0.013 ± 0.001	0.937 ± 0.006
	8	0.368 ± 0.013	0.252 ± 0.018	0.014 ± 0.001	0.928 ± 0.005
	9	0.380 ± 0.013	0.271 ± 0.019	0.014 ± 0.000	0.923 ± 0.006
	10	0.394 ± 0.012	0.288 ± 0.018	0.015 ± 0.001	0.918 ± 0.006
ViT	1	0.732 ± 0.142	0.846 ± 0.323	0.027 ± 0.005	0.832 ± 0.025
	2	0.719 ± 0.133	0.827 ± 0.298	0.026 ± 0.005	0.829 ± 0.025
	3	0.827 ± 0.251	1.128 ± 0.633	0.030 ± 0.009	0.792 ± 0.046
	4	0.786 ± 0.252	1.016 ± 0.642	0.029 ± 0.009	0.814 ± 0.036
	5	0.822 ± 0.146	1.072 ± 0.383	0.030 ± 0.005	0.795 ± 0.039
	6	0.762 ± 0.140	0.923 ± 0.325	0.028 ± 0.005	0.820 ± 0.029
	7	0.685 ± 0.044	0.726 ± 0.088	0.025 ± 0.001	0.831 ± 0.012
	8	0.695 ± 0.090	0.757 ± 0.183	0.025 ± 0.003	0.825 ± 0.033
	9	0.731 ± 0.076	0.822 ± 0.156	0.027 ± 0.003	0.815 ± 0.035
	10	0.718 ± 0.094	0.802 ± 0.195	0.026 ± 0.003	0.819 ± 0.023
PINN-ViT	1	0.277 ± 0.001	0.126 ± 0.001	0.010 ± 0.000	0.977 ± 0.000
	2	0.288 ± 0.000	0.139 ± 0.000	0.011 ± 0.000	0.973 ± 0.000
	3	0.304 ± 0.001	0.161 ± 0.001	0.011 ± 0.000	0.967 ± 0.000
	4	0.322 ± 0.002	0.186 ± 0.001	0.012 ± 0.000	0.956 ± 0.002
	5	0.341 ± 0.001	0.213 ± 0.001	0.013 ± 0.000	0.951 ± 0.001
	6	0.360 ± 0.002	0.241 ± 0.002	0.013 ± 0.000	0.943 ± 0.001
	7	0.379 ± 0.003	0.270 ± 0.002	0.014 ± 0.000	0.935 ± 0.000
	8	0.397 ± 0.003	0.297 ± 0.003	0.015 ± 0.000	0.927 ± 0.001
	9	0.412 ± 0.001	0.323 ± 0.001	0.015 ± 0.000	0.919 ± 0.000
	10	0.428 ± 0.000	0.347 ± 0.001	0.016 ± 0.000	0.912 ± 0.000
	1	0.275 ± 0.005	0.126 ± 0.006	0.010 ± 0.000	0.975 ± 0.002
	2	0.306 ± 0.022	0.174 ± 0.048	0.011 ± 0.001	0.962 ± 0.012

STPDE-Net-3	3	0.314 ± 0.012	0.180 ± 0.029	0.011 ± 0.001	0.960 ± 0.007
	4	0.338 ± 0.022	0.210 ± 0.038	0.012 ± 0.001	0.951 ± 0.010
	5	0.371 ± 0.018	0.286 ± 0.065	0.014 ± 0.001	0.933 ± 0.016
	6	0.365 ± 0.019	0.248 ± 0.028	0.014 ± 0.001	0.940 ± 0.007
	7	0.388 ± 0.011	0.284 ± 0.017	0.014 ± 0.001	0.930 ± 0.005
	8	0.407 ± 0.012	0.313 ± 0.022	0.015 ± 0.000	0.922 ± 0.006
	9	0.440 ± 0.031	0.398 ± 0.110	0.017 ± 0.001	0.902 ± 0.026
	10	0.441 ± 0.013	0.364 ± 0.027	0.016 ± 0.001	0.908 ± 0.007

Table S17

MAE, MSE, MAPE, and r (mean ± std) of the SST prediction using 6 years data and various methods for different prediction horizons (1-10days).

methods \ Indexes	ahead day	MAE	MSE	MAPE	r
CNN	1	0.797 ± 0.219	1.026 ± 0.528	0.029 ± 0.008	0.765 ± 0.022
	2	0.783 ± 0.226	0.999 ± 0.549	0.029 ± 0.008	0.757 ± 0.017
	3	0.841 ± 0.195	1.132 ± 0.481	0.031 ± 0.007	0.737 ± 0.014
	4	0.764 ± 0.101	0.936 ± 0.248	0.028 ± 0.004	0.734 ± 0.017
	5	0.768 ± 0.092	0.960 ± 0.223	0.029 ± 0.003	0.730 ± 0.022
	6	0.778 ± 0.106	0.989 ± 0.259	0.029 ± 0.004	0.722 ± 0.021
	7	0.793 ± 0.108	1.032 ± 0.268	0.029 ± 0.004	0.714 ± 0.021
	8	0.818 ± 0.132	1.119 ± 0.359	0.030 ± 0.005	0.690 ± 0.035
	9	0.827 ± 0.106	1.128 ± 0.263	0.031 ± 0.004	0.685 ± 0.035
	10	0.830 ± 0.100	1.137 ± 0.247	0.031 ± 0.004	0.679 ± 0.044
PINN-CNN	1	0.270 ± 0.004	0.122 ± 0.003	0.010 ± 0.000	0.973 ± 0.000
	2	0.284 ± 0.001	0.136 ± 0.001	0.010 ± 0.000	0.969 ± 0.002
	3	0.296 ± 0.002	0.154 ± 0.000	0.011 ± 0.000	0.962 ± 0.003
	4	0.313 ± 0.003	0.176 ± 0.002	0.012 ± 0.001	0.955 ± 0.000
	5	0.330 ± 0.002	0.199 ± 0.001	0.012 ± 0.000	0.946 ± 0.000
	6	0.346 ± 0.003	0.223 ± 0.002	0.013 ± 0.000	0.938 ± 0.000
	7	0.362 ± 0.002	0.248 ± 0.002	0.013 ± 0.000	0.929 ± 0.001
	8	0.378 ± 0.000	0.272 ± 0.002	0.014 ± 0.000	0.921 ± 0.001
	9	0.395 ± 0.001	0.298 ± 0.002	0.015 ± 0.000	0.911 ± 0.001
	10	0.409 ± 0.003	0.231 ± 0.004	0.015 ± 0.000	0.903 ± 0.001
STPDE-Net-1	1	0.221 ± 0.003	0.083 ± 0.002	0.008 ± 0.000	0.974 ± 0.000
	2	0.235 ± 0.002	0.095 ± 0.002	0.009 ± 0.000	0.970 ± 0.000
	3	0.253 ± 0.004	0.114 ± 0.001	0.009 ± 0.000	0.964 ± 0.000
	4	0.327 ± 0.013	0.135 ± 0.004	0.010 ± 0.000	0.957 ± 0.001
	5	0.291 ± 0.002	0.159 ± 0.001	0.011 ± 0.000	0.950 ± 0.000
	6	0.310 ± 0.002	0.183 ± 0.004	0.011 ± 0.000	0.942 ± 0.001
	7	0.327 ± 0.001	0.207 ± 0.003	0.012 ± 0.000	0.934 ± 0.001
	8	0.345 ± 0.002	0.231 ± 0.002	0.013 ± 0.000	0.925 ± 0.000
	9	0.362 ± 0.003	0.255 ± 0.002	0.013 ± 0.000	0.918 ± 0.000
	10	0.378 ± 0.002	0.277 ± 0.002	0.014 ± 0.000	0.910 ± 0.001
CNN-ConvLSTM	1	0.876 ± 0.107	1.238 ± 0.265	0.032 ± 0.004	0.331 ± 0.272
	2	0.809 ± 0.141	1.087 ± 0.354	0.030 ± 0.005	0.432 ± 0.344
	3	0.830 ± 0.052	1.083 ± 0.120	0.031 ± 0.002	0.533 ± 0.099
	4	0.815 ± 0.101	1.071 ± 0.260	0.030 ± 0.004	0.490 ± 0.271
	5	0.834 ± 0.137	1.145 ± 0.336	0.031 ± 0.005	0.387 ± 0.318
	6	0.810 ± 0.103	1.058 ± 0.270	0.030 ± 0.004	0.509 ± 0.279
	7	0.787 ± 0.085	0.997 ± 0.184	0.029 ± 0.003	0.573 ± 0.128
	8	0.747 ± 0.048	0.898 ± 0.095	0.027 ± 0.002	0.653 ± 0.056
	9	0.822 ± 0.114	1.099 ± 0.274	0.030 ± 0.004	0.454 ± 0.261
	10	0.779 ± 0.072	0.974 ± 0.153	0.029 ± 0.003	0.612 ± 0.103
PINN-CNN-ConvLSTM	1	0.274 ± 0.001	0.124 ± 0.000	0.010 ± 0.000	0.973 ± 0.000
	2	0.285 ± 0.000	0.137 ± 0.001	0.010 ± 0.000	0.969 ± 0.000
	3	0.299 ± 0.000	0.155 ± 0.001	0.011 ± 0.000	0.962 ± 0.000
	4	0.315 ± 0.000	0.177 ± 0.000	0.012 ± 0.000	0.955 ± 0.000
	5	0.331 ± 0.000	0.200 ± 0.000	0.012 ± 0.000	0.947 ± 0.000
	6	0.347 ± 0.000	0.224 ± 0.001	0.013 ± 0.000	0.938 ± 0.000
	7	0.363 ± 0.000	0.248 ± 0.000	0.013 ± 0.000	0.930 ± 0.000
	8	0.379 ± 0.000	0.273 ± 0.001	0.014 ± 0.000	0.921 ± 0.000

	9	0.395 ± 0.001	0.297 ± 0.000	0.015 ± 0.000	0.922 ± 0.000
	10	0.409 ± 0.000	0.319 ± 0.000	0.015 ± 0.000	0.905 ± 0.000
STPDE-Net-2	1	0.223 ± 0.004	0.086 ± 0.003	0.008 ± 0.000	0.973 ± 0.001
	2	0.242 ± 0.006	0.102 ± 0.006	0.009 ± 0.000	0.967 ± 0.001
	3	0.258 ± 0.005	0.118 ± 0.004	0.009 ± 0.000	0.961 ± 0.001
	4	0.281 ± 0.006	0.143 ± 0.005	0.010 ± 0.000	0.953 ± 0.001
	5	0.298 ± 0.006	0.163 ± 0.007	0.011 ± 0.000	0.946 ± 0.003
	6	0.316 ± 0.013	0.186 ± 0.017	0.012 ± 0.001	0.938 ± 0.005
	7	0.330 ± 0.007	0.203 ± 0.009	0.012 ± 0.000	0.931 ± 0.004
	8	0.352 ± 0.012	0.231 ± 0.016	0.013 ± 0.000	0.923 ± 0.004
	9	0.357 ± 0.010	0.241 ± 0.015	0.013 ± 0.000	0.919 ± 0.003
	10	0.364 ± 0.014	0.251 ± 0.017	0.013 ± 0.001	0.914 ± 0.007
ViT	1	0.772 ± 0.390	0.977 ± 0.934	0.028 ± 0.014	0.840 ± 0.019
	2	0.797 ± 0.369	1.026 ± 0.888	0.029 ± 0.014	0.840 ± 0.022
	3	0.810 ± 0.327	1.033 ± 0.756	0.030 ± 0.012	0.839 ± 0.020
	4	0.825 ± 0.331	1.063 ± 0.804	0.030 ± 0.012	0.842 ± 0.022
	5	0.763 ± 0.373	0.956 ± 0.877	0.028 ± 0.014	0.835 ± 0.018
	6	0.834 ± 0.332	1.086 ± 0.785	0.030 ± 0.012	0.835 ± 0.020
	7	0.869 ± 0.321	1.143 ± 0.717	0.032 ± 0.011	0.833 ± 0.020
	8	0.830 ± 0.256	1.050 ± 0.599	0.030 ± 0.010	0.830 ± 0.021
	9	0.771 ± 0.281	0.942 ± 0.659	0.028 ± 0.010	0.821 ± 0.009
	10	0.800 ± 0.240	0.969 ± 0.491	0.029 ± 0.008	0.823 ± 0.020
PINN-ViT	1	0.273 ± 0.000	0.122 ± 0.001	0.010 ± 0.000	0.974 ± 0.000
	2	0.284 ± 0.003	0.135 ± 0.002	0.010 ± 0.000	0.969 ± 0.000
	3	0.298 ± 0.001	0.153 ± 0.001	0.011 ± 0.000	0.963 ± 0.000
	4	0.314 ± 0.001	0.174 ± 0.001	0.012 ± 0.000	0.955 ± 0.000
	5	0.333 ± 0.002	0.198 ± 0.002	0.012 ± 0.000	0.947 ± 0.000
	6	0.347 ± 0.002	0.221 ± 0.001	0.013 ± 0.000	0.939 ± 0.000
	7	0.362 ± 0.001	0.246 ± 0.000	0.013 ± 0.000	0.930 ± 0.000
	8	0.378 ± 0.000	0.271 ± 0.002	0.014 ± 0.000	0.922 ± 0.001
	9	0.394 ± 0.001	0.294 ± 0.001	0.015 ± 0.000	0.913 ± 0.000
	10	0.408 ± 0.001	0.317 ± 0.001	0.015 ± 0.000	0.906 ± 0.001
STPDE-Net-3	1	0.266 ± 0.008	0.117 ± 0.007	0.010 ± 0.001	0.973 ± 0.002
	2	0.284 ± 0.003	0.136 ± 0.003	0.010 ± 0.000	0.967 ± 0.001
	3	0.296 ± 0.004	0.150 ± 0.004	0.011 ± 0.000	0.962 ± 0.002
	4	0.310 ± 0.001	0.197 ± 0.002	0.011 ± 0.000	0.955 ± 0.001
	5	0.327 ± 0.003	0.193 ± 0.004	0.012 ± 0.000	0.948 ± 0.001
	6	0.344 ± 0.004	0.217 ± 0.005	0.013 ± 0.000	0.939 ± 0.002
	7	0.361 ± 0.002	0.242 ± 0.003	0.013 ± 0.000	0.931 ± 0.001
	8	0.376 ± 0.002	0.265 ± 0.005	0.014 ± 0.000	0.923 ± 0.002
	9	0.391 ± 0.002	0.287 ± 0.003	0.014 ± 0.000	0.916 ± 0.001
	10	0.409 ± 0.006	0.314 ± 0.008	0.015 ± 0.000	0.907 ± 0.002

Table S18

MAE, MSE, MAPE, and r (mean ± std) of the SST prediction using 5 years data and various methods for different prediction horizons (1-10days).

methods \ Indexes	ahead day	MAE	MSE	MAPE	r
CNN	1	1.046 ± 0.210	1.698 ± 0.558	0.039 ± 0.008	0.708 ± 0.032
	2	1.054 ± 0.226	1.717 ± 0.611	0.178 ± 0.189	0.719 ± 0.037
	3	1.070 ± 0.217	1.756 ± 0.583	0.040 ± 0.008	0.713 ± 0.037
	4	1.090 ± 0.234	1.823 ± 0.645	0.040 ± 0.009	0.706 ± 0.411
	5	1.038 ± 0.258	1.684 ± 0.739	0.039 ± 0.010	0.717 ± 0.061
	6	1.064 ± 0.281	1.777 ± 0.811	0.039 ± 0.011	0.705 ± 0.060
	7	1.110 ± 0.278	1.928 ± 0.798	0.041 ± 0.010	0.682 ± 0.055
	8	1.118 ± 0.266	1.944 ± 0.776	0.042 ± 0.010	0.687 ± 0.053
	9	0.963 ± 0.179	1.462 ± 0.473	0.036 ± 0.007	0.718 ± 0.012
	10	1.058 ± 0.238	1.770 ± 0.701	0.041 ± 0.009	0.684 ± 0.054
PINN-CNN	1	0.274 ± 0.004	0.126 ± 0.003	0.010 ± 0.000	0.975 ± 0.000
	2	0.287 ± 0.004	0.141 ± 0.003	0.011 ± 0.001	0.971 ± 0.000
	3	0.304 ± 0.004	0.162 ± 0.003	0.011 ± 0.000	0.958 ± 0.012
	4	0.322 ± 0.003	0.186 ± 0.004	0.012 ± 0.000	0.957 ± 0.000
	5	0.340 ± 0.003	0.213 ± 0.004	0.013 ± 0.001	0.949 ± 0.000
	6	0.358 ± 0.003	0.241 ± 0.003	0.013 ± 0.000	0.941 ± 0.000

	7	0.376 ± 0.003	0.269 ± 0.005	0.014 ± 0.000	0.932 ± 0.001
	8	0.394 ± 0.003	0.296 ± 0.004	0.015 ± 0.001	0.924 ± 0.000
	9	0.411 ± 0.003	0.322 ± 0.004	0.015 ± 0.000	0.916 ± 0.000
	10	0.427 ± 0.003	0.348 ± 0.004	0.016 ± 0.000	0.909 ± 0.000
STPDE-Net-1	1	0.226 ± 0.001	0.087 ± 0.002	0.008 ± 0.000	0.975 ± 0.000
	2	0.240 ± 0.000	0.100 ± 0.001	0.006 ± 0.000	0.971 ±0.000
	3	0.260 ± 0.002	0.119 ± 0.002	0.010 ± 0.000	0.965 ±0.000
	4	0.280 ± 0.001	0.143 ± 0.001	0.010 ± 0.000	0.958 ± 0.001
	5	0.301 ± 0.003	0.169 ± 0.004	0.011 ± 0.001	0.950 ± 0.001
	6	0.321 ± 0.004	0.196 ± 0.002	0.012 ± 0.001	0.972 ± 0.000
	7	0.340 ± 0.002	0.222 ± 0.003	0.013 ± 0.000	0.934 ± 0.000
	8	0.359 ± 0.002	0.249 ± 0.002	0.013 ± 0.000	0.926 ± 0.001
	9	0.377 ± 0.003	0.275 ± 0.001	0.014 ± 0.001	0.918 ± 0.001
	10	0.393 ± 0.002	0.299 ± 0.002	0.014 ± 0.000	0.911 ± 0.001
CNN-ConvLSTM	1	0.827 ± 0.132	1.088 ± 0.342	0.030 ± 0.005	0.556 ± 0.314
	2	0.820 ± 0.141	1.064 ± 0.316	0.030 ± 0.005	0.612 ± 0.164
	3	0.716 ± 0.052	0.828 ± 0.114	0.026 ± 0.002	0.756 ± 0.047
	4	0.789 ± 0.142	1.016 ± 0.362	0.029 ± 0.005	0.589 ± 0.319
	5	0.831 ± 0.160	1.110 ± 0.380	0.031 ± 0.006	0.530 ± 0.318
	6	0.740 ± 0.096	0.894 ± 0.226	0.027 ± 0.004	0.715 ± 0.104
	7	0.775 ± 0.106	0.947 ± 0.234	0.028 ± 0.004	0.626 ± 0.179
	8	0.795 ± 0.180	1.016 ± 0.421	0.029 ± 0.007	0.592 ± 0.334
	9	0.844 ± 0.184	1.155 ± 0.467	0.031 ± 0.007	0.454 ± 0.407
	10	0.893 ± 0.235	1.265 ± 0.364	0.033 ± 0.005	0.425 ± 0.367
PINN-CNN-ConvLSTM	1	0.279 ± 0.001	0.129 ± 0.002	0.010 ± 0.000	0.975 ± 0.000
	2	0.291 ± 0.001	0.144 ± 0.001	0.011 ± 0.000	0.971 ± 0.000
	3	0.308 ± 0.003	0.165 ± 0.003	0.011 ± 0.000	0.964 ± 0.001
	4	0.325 ± 0.002	0.190 ± 0.002	0.012 ± 0.000	0.957 ± 0.000
	5	0.343 ± 0.002	0.217 ± 0.001	0.013 ± 0.000	0.949 ± 0.001
	6	0.361 ± 0.004	0.244 ± 0.001	0.013 ± 0.000	0.940 ± 0.001
	7	0.379 ± 0.001	0.272 ± 0.002	0.014 ± 0.000	0.932 ± 0.000
	8	0.397 ± 0.002	0.300 ± 0.001	0.015 ± 0.000	0.924 ± 0.000
	9	0.414 ± 0.002	0.326 ± 0.002	0.015 ± 0.000	0.916 ± 0.001
	10	0.429 ± 0.003	0.351 ± 0.002	0.016 ± 0.000	0.908 ± 0.001
STPDE-Net-2	1	0.232 ± 0.011	0.092 ± 0.009	0.008 ± 0.000	0.974 ± 0.001
	2	0.243 ± 0.004	0.102 ± 0.002	0.009 ± 0.000	0.971 ± 0.001
	3	0.266 ± 0.007	0.124 ± 0.007	0.010 ± 0.000	0.964 ± 0.002
	4	0.288 ± 0.007	0.149 ± 0.009	0.011 ± 0.001	0.956 ± 0.002
	5	0.312 ± 0.012	0.178 ± 0.012	0.011 ± 0.001	0.948 ± 0.003
	6	0.335 ± 0.003	0.207 ± 0.004	0.012 ± 0.000	0.940 ± 0.001
	7	0.349 ± 0.011	0.229 ± 0.016	0.013 ± 0.000	0.934 ± 0.003
	8	0.375 ± 0.009	0.261 ± 0.010	0.014 ± 0.000	0.924 ± 0.001
	9	0.394 ± 0.019	0.289 ± 0.024	0.014 ± 0.001	0.917 ± 0.005
	10	0.409 ± 0.013	0.312 ± 0.015	0.015 ± 0.000	0.910 ± 0.002
ViT	1	0.805 ± 0.253	1.010 ± 0.564	0.029 ± 0.009	0.800 ± 0.034
	2	0.804 ± 0.214	1.008 ± 0.478	0.029 ± 0.008	0.793 ± 0.037
	3	0.895 ± 0.244	1.204 ± 0.565	0.032 ± 0.009	0.800 ± 0.029
	4	0.760 ± 0.211	0.892 ± 0.445	0.027 ± 0.008	0.812 ± 0.025
	5	0.737 ± 0.133	0.837 ± 0.265	0.027 ± 0.005	0.802 ± 0.022
	6	0.736 ± 0.171	0.837 ± 0.349	0.027 ± 0.006	0.804 ± 0.021
	7	0.872 ± 0.242	1.145 ± 0.527	0.031 ± 0.008	0.807 ± 0.026
	8	0.781 ± 0.201	0.949 ± 0.432	0.026 ± 0.006	0.818 ± 0.027
	9	0.814 ± 0.170	1.002 ± 0.379	0.029 ± 0.006	0.809 ± 0.022
	10	0.860 ± 0.181	1.099 ± 0.393	0.031 ± 0.006	0.820 ± 0.019
PINN-ViT	1	0.278 ± 0.001	0.127 ± 0.002	0.010 ± 0.000	0.975 ± 0.000
	2	0.290 ± 0.002	0.142 ± 0.003	0.011 ± 0.000	0.971 ± 0.000
	3	0.307 ± 0.001	0.163 ± 0.001	0.011 ± 0.000	0.965 ± 0.000
	4	0.325 ± 0.005	0.188 ± 0.003	0.012 ± 0.000	0.957 ± 0.002
	5	0.345 ± 0.004	0.214 ± 0.002	0.013 ± 0.000	0.949 ± 0.000
	6	0.361 ± 0.002	0.242 ± 0.004	0.013 ± 0.000	0.941 ± 0.001
	7	0.381 ± 0.001	0.270 ± 0.003	0.014 ± 0.000	0.933 ± 0.000
	8	0.395 ± 0.003	0.297 ± 0.001	0.015 ± 0.000	0.924 ± 0.000
	9	0.413 ± 0.001	0.324 ± 0.002	0.015 ± 0.000	0.916 ± 0.001
	10	0.429 ± 0.002	0.349 ± 0.004	0.016 ± 0.000	0.909 ± 0.002
	1	0.273 ± 0.001	0.121 ± 0.002	0.010 ± 0.000	0.977 ± 0.001
	2	0.286 ± 0.001	0.135 ± 0.000	0.010 ± 0.000	0.973 ± 0.000

STPDE-Net-3	3	0.302 ± 0.003	0.156 ± 0.002	0.011 ± 0.000	0.966 ± 0.001
	4	0.322 ± 0.001	0.180 ± 0.001	0.012 ± 0.000	0.959 ± 0.000
	5	0.339 ± 0.001	0.207 ± 0.001	0.012 ± 0.000	0.951 ± 0.001
	6	0.358 ± 0.001	0.235 ± 0.001	0.013 ± 0.000	0.943 ± 0.000
	7	0.376 ± 0.001	0.262 ± 0.001	0.014 ± 0.000	0.935 ± 0.000
	8	0.386 ± 0.015	0.289 ± 0.002	0.015 ± 0.000	0.927 ± 0.000
	9	0.411 ± 0.002	0.316 ± 0.003	0.015 ± 0.000	0.919 ± 0.000
	10	0.427 ± 0.000	0.342 ± 0.001	0.016 ± 0.000	0.911 ± 0.000

Table S19

MAE, MSE, MAPE, and r (mean ± std) of the SST prediction using 4 years data and various methods for different prediction horizons (1-10days).

methods \ Indexes	ahead day	MAE	MSE	MAPE	r
CNN	1	0.826 ± 0.093	1.037 ± 0.203	0.030 ± 0.003	0.772 ± 0.040
	2	0.936 ± 0.277	1.312 ± 0.699	0.034 ± 0.010	0.793 ± 0.002
	3	0.972 ± 0.258	1.405 ± 0.653	0.096 ± 0.137	0.789 ± 0.002
	4	0.971 ± 0.250	1.397 ± 0.624	0.035 ± 0.009	0.784 ± 0.002
	5	0.949 ± 0.224	1.337 ± 0.547	0.034 ± 0.008	0.779 ± 0.003
	6	0.934 ± 0.207	1.294 ± 0.500	0.034 ± 0.008	0.772 ± 0.003
	7	0.983 ± 0.176	1.405 ± 0.448	0.035 ± 0.006	0.766 ± 0.004
	8	0.987 ± 0.153	1.410 ± 0.385	0.035 ± 0.005	0.761 ± 0.009
	9	1.011 ± 0.118	1.471 ± 0.282	0.036 ± 0.004	0.754 ± 0.014
	10	1.015 ± 0.126	1.482 ± 0.307	0.036 ± 0.005	0.747 ± 0.018
PINN-CNN	1	0.278 ± 0.004	0.128 ± 0.003	0.010 ± 0.000	0.974 ± 0.000
	2	0.291 ± 0.004	0.143 ± 0.003	0.011 ± 0.001	0.970 ± 0.000
	3	0.307 ± 0.003	0.163 ± 0.003	0.011 ± 0.000	0.964 ± 0.000
	4	0.323 ± 0.003	0.186 ± 0.003	0.012 ± 0.000	0.957 ± 0.000
	5	0.341 ± 0.003	0.211 ± 0.003	0.013 ± 0.001	0.949 ± 0.000
	6	0.358 ± 0.003	0.238 ± 0.003	0.013 ± 0.000	0.941 ± 0.000
	7	0.375 ± 0.003	0.264 ± 0.003	0.014 ± 0.000	0.933 ± 0.000
	8	0.392 ± 0.002	0.290 ± 0.003	0.015 ± 0.001	0.925 ± 0.000
	9	0.409 ± 0.003	0.316 ± 0.003	0.015 ± 0.000	0.917 ± 0.000
	10	0.425 ± 0.002	0.341 ± 0.003	0.016 ± 0.000	0.910 ± 0.000
STPDE-Net-1	1	0.225 ± 0.002	0.085 ± 0.001	0.008 ± 0.000	0.975 ± 0.000
	2	0.239 ± 0.004	0.098 ± 0.001	0.009 ± 0.000	0.971 ± 0.000
	3	0.258 ± 0.003	0.117 ± 0.001	0.009 ± 0.000	0.965 ± 0.001
	4	0.278 ± 0.002	0.140 ± 0.003	0.010 ± 0.000	0.959 ± 0.001
	5	0.297 ± 0.003	0.164 ± 0.002	0.011 ± 0.000	0.951 ± 0.000
	6	0.317 ± 0.002	0.190 ± 0.003	0.012 ± 0.000	0.944 ± 0.001
	7	0.336 ± 0.004	0.215 ± 0.002	0.012 ± 0.000	0.936 ± 0.001
	8	0.354 ± 0.002	0.240 ± 0.001	0.013 ± 0.000	0.928 ± 0.002
	9	0.372 ± 0.007	0.265 ± 0.003	0.014 ± 0.001	0.921 ± 0.000
	10	0.388 ± 0.005	0.288 ± 0.002	0.014 ± 0.000	0.914 ± 0.001
CNN-ConvLSTM	1	1.032 ± 0.184	1.545 ± 0.455	0.037 ± 0.007	0.257 ± 0.341
	2	1.117 ± 0.048	1.754 ± 0.139	0.040 ± 0.002	0.108 ± 0.185
	3	1.118 ± 0.048	1.757 ± 0.139	0.040 ± 0.002	0.107 ± 0.185
	4	1.096 ± 0.063	1.694 ± 0.181	0.040 ± 0.002	0.196 ± 0.237
	5	1.051 ± 0.152	1.587 ± 0.388	0.038 ± 0.005	0.266 ± 0.358
	6	1.076 ± 0.101	1.648 ± 0.270	0.039 ± 0.004	0.228 ± 0.305
	7	1.085 ± 0.086	1.666 ± 0.239	0.039 ± 0.003	0.232 ± 0.295
	8	1.088 ± 0.083	1.675 ± 0.228	0.039 ± 0.003	0.231 ± 0.293
	9	1.091 ± 0.078	1.683 ± 0.219	0.039 ± 0.003	0.230 ± 0.291
	10	1.117 ± 0.048	1.752 ± 0.139	0.040 ± 0.002	0.127 ± 0.206
PINN-CNN-ConvLSTM	1	0.283 ± 0.000	0.132 ± 0.000	0.010 ± 0.000	0.974 ± 0.000
	2	0.295 ± 0.001	0.146 ± 0.000	0.011 ± 0.000	0.970 ± 0.000
	3	0.311 ± 0.000	0.166 ± 0.002	0.011 ± 0.000	0.964 ± 0.000
	4	0.327 ± 0.002	0.190 ± 0.001	0.012 ± 0.000	0.957 ± 0.000
	5	0.344 ± 0.001	0.215 ± 0.000	0.013 ± 0.000	0.949 ± 0.000
	6	0.361 ± 0.002	0.241 ± 0.001	0.013 ± 0.000	0.941 ± 0.001
	7	0.378 ± 0.001	0.267 ± 0.000	0.014 ± 0.000	0.933 ± 0.000
	8	0.396 ± 0.000	0.294 ± 0.001	0.015 ± 0.000	0.925 ± 0.000

	9	0.412 ± 0.000	0.320 ± 0.001	0.015 ± 0.000	0.917 ± 0.000
	10	0.428 ± 0.000	0.344 ± 0.000	0.016 ± 0.000	0.910 ± 0.001
STPDE-Net-2	1	0.222 ± 0.003	0.070 ± 0.004	0.008 ± 0.000	0.976 ± 0.001
	2	0.238 ± 0.010	0.098 ± 0.008	0.009 ± 0.000	0.973 ± 0.001
	3	0.253 ± 0.001	0.113 ± 0.002	0.009 ± 0.000	0.967 ± 0.001
	4	0.276 ± 0.001	0.138 ± 0.002	0.010 ± 0.000	0.959 ± 0.001
	5	0.297 ± 0.003	0.163 ± 0.002	0.011 ± 0.000	0.952 ± 0.001
	6	0.313 ± 0.005	0.183 ± 0.007	0.012 ± 0.000	0.945 ± 0.003
	7	0.336 ± 0.006	0.214 ± 0.007	0.012 ± 0.000	0.937 ± 0.004
	8	0.348 ± 0.003	0.229 ± 0.003	0.013 ± 0.000	0.931 ± 0.001
	9	0.364 ± 0.002	0.250 ± 0.007	0.013 ± 0.000	0.924 ± 0.002
	10	0.380 ± 0.009	0.273 ± 0.020	0.014 ± 0.000	0.919 ± 0.004
ViT	1	0.736 ± 0.121	0.826 ± 0.231	0.027 ± 0.005	0.828 ± 0.018
	2	0.700 ± 0.177	0.762 ± 0.358	0.025 ± 0.006	0.837 ± 0.017
	3	0.652 ± 0.101	0.660 ± 0.184	0.024 ± 0.004	0.822 ± 0.032
	4	0.732 ± 0.119	0.803 ± 0.217	0.026 ± 0.004	0.829 ± 0.035
	5	0.738 ± 0.204	0.840 ± 0.405	0.027 ± 0.007	0.847 ± 0.012
	6	0.732 ± 0.148	0.815 ± 0.283	0.026 ± 0.005	0.835 ± 0.016
	7	0.666 ± 0.141	0.687 ± 0.261	0.024 ± 0.005	0.838 ± 0.018
	8	0.818 ± 0.091	0.975 ± 0.170	0.029 ± 0.003	0.833 ± 0.021
	9	0.776 ± 0.145	0.900 ± 0.285	0.028 ± 0.005	0.838 ± 0.023
	10	0.690 ± 0.143	0.746 ± 0.026	0.025 ± 0.005	0.837 ± 0.028
PINN-ViT	1	0.282 ± 0.001	0.129 ± 0.000	0.010 ± 0.000	0.975 ± 0.000
	2	0.294 ± 0.000	0.143 ± 0.000	0.011 ± 0.000	0.971 ± 0.000
	3	0.312 ± 0.001	0.163 ± 0.001	0.011 ± 0.000	0.965 ± 0.000
	4	0.327 ± 0.001	0.187 ± 0.001	0.012 ± 0.000	0.958 ± 0.001
	5	0.344 ± 0.001	0.212 ± 0.001	0.013 ± 0.000	0.950 ± 0.000
	6	0.361 ± 0.001	0.239 ± 0.001	0.013 ± 0.000	0.942 ± 0.000
	7	0.378 ± 0.001	0.265 ± 0.000	0.014 ± 0.000	0.934 ± 0.000
	8	0.395 ± 0.000	0.294 ± 0.001	0.015 ± 0.000	0.926 ± 0.000
	9	0.412 ± 0.000	0.318 ± 0.001	0.015 ± 0.000	0.918 ± 0.000
	10	0.427 ± 0.001	0.342 ± 0.000	0.016 ± 0.000	0.910 ± 0.000
STPDE-Net-3	1	0.273 ± 0.006	0.124 ± 0.007	0.010 ± 0.000	0.974 ± 0.002
	2	0.284 ± 0.003	0.134 ± 0.003	0.010 ± 0.000	0.971 ± 0.001
	3	0.303 ± 0.004	0.156 ± 0.005	0.011 ± 0.000	0.966 ± 0.001
	4	0.326 ± 0.006	0.186 ± 0.012	0.012 ± 0.000	0.956 ± 0.004
	5	0.341 ± 0.003	0.207 ± 0.003	0.012 ± 0.000	0.951 ± 0.002
	6	0.355 ± 0.003	0.228 ± 0.004	0.013 ± 0.000	0.944 ± 0.001
	7	0.377 ± 0.003	0.259 ± 0.005	0.014 ± 0.000	0.936 ± 0.002
	8	0.391 ± 0.002	0.283 ± 0.002	0.014 ± 0.000	0.928 ± 0.001
	9	0.408 ± 0.004	0.306 ± 0.008	0.015 ± 0.000	0.921 ± 0.001
	10	0.427 ± 0.004	0.333 ± 0.005	0.016 ± 0.000	0.913 ± 0.001

Table S20

MAE, MSE, MAPE, and r (mean ± std) of the SST prediction using 3 years data and various methods for different prediction horizons (1-10days).

methods \ Indexes	ahead day	MAE	MSE	MAPE	r
CNN	1	0.737 ± 0.245	0.844 ± 0.497	0.027 ± 0.009	0.857 ± 0.004
	2	0.748 ± 0.204	0.855 ± 0.413	0.027 ± 0.007	0.852 ± 0.003
	3	0.762 ± 0.170	0.876 ± 0.340	0.028 ± 0.006	0.847 ± 0.002
	4	0.704 ± 0.060	0.756 ± 0.107	0.026 ± 0.002	0.831 ± 0.017
	5	0.737 ± 0.052	0.812 ± 0.091	0.027 ± 0.002	0.833 ± 0.007
	6	0.737 ± 0.062	0.818 ± 0.112	0.026 ± 0.002	0.830 ± 0.007
	7	0.722 ± 0.115	0.801 ± 0.195	0.026 ± 0.004	0.823 ± 0.007
	8	0.728 ± 0.170	0.828 ± 0.336	0.026 ± 0.006	0.816 ± 0.009
	9	0.675 ± 0.054	0.726 ± 0.091	0.025 ± 0.002	0.809 ± 0.011
	10	0.672 ± 0.046	0.735 ± 0.091	0.025 ± 0.002	0.808 ± 0.007
PINN-CNN	1	0.280 ± 0.004	0.131 ± 0.003	0.010 ± 0.000	0.976 ± 0.000
	2	0.294 ± 0.003	0.147 ± 0.003	0.011 ± 0.000	0.972 ± 0.000
	3	0.312 ± 0.003	0.170 ± 0.003	0.011 ± 0.000	0.965 ± 0.000
	4	0.329 ± 0.003	0.196 ± 0.003	0.012 ± 0.000	0.958 ± 0.003
	5	0.348 ± 0.003	0.225 ± 0.003	0.013 ± 0.000	0.950 ± 0.000
	6	0.367 ± 0.003	0.254 ± 0.003	0.014 ± 0.001	0.941 ± 0.000

	7	0.386 ± 0.002	0.284 ± 0.003	0.014 ± 0.000	0.933 ± 0.001
	8	0.404 ± 0.002	0.314 ± 0.003	0.015 ± 0.000	0.925 ± 0.001
	9	0.423 ± 0.002	0.344 ± 0.004	0.016 ± 0.000	0.916 ± 0.001
	10	0.440 ± 0.002	0.372 ± 0.004	0.016 ± 0.000	0.908 ± 0.001
STPDE-Net-1	1	0.226 ± 0.001	0.087 ± 0.003	0.008 ± 0.000	0.977 ± 0.002
	2	0.242 ± 0.005	0.101 ± 0.005	0.009 ± 0.000	0.973 ± 0.001
	3	0.263 ± 0.003	0.124 ± 0.005	0.010 ± 0.000	0.970 ± 0.003
	4	0.284 ± 0.003	0.149 ± 0.002	0.010 ± 0.000	0.960 ± 0.000
	5	0.305 ± 0.002	0.176 ± 0.004	0.011 ± 0.000	0.952 ± 0.002
	6	0.326 ± 0.009	0.204 ± 0.001	0.012 ± 0.000	0.945 ± 0.002
	7	0.346 ± 0.003	0.232 ± 0.004	0.013 ± 0.000	0.937 ± 0.003
	8	0.366 ± 0.011	0.261 ± 0.002	0.013 ± 0.001	0.929 ± 0.002
	9	0.386 ± 0.001	0.290 ± 0.002	0.014 ± 0.000	0.921 ± 0.001
	10	0.404 ± 0.006	0.317 ± 0.003	0.015 ± 0.000	0.914 ± 0.002
CNN-ConvLSTM	1	1.266 ± 0.009	2.156 ± 0.024	0.046 ± 0.001	0.011 ± 0.005
	2	1.267 ± 0.009	2.158 ± 0.024	0.046 ± 0.000	0.011 ± 0.005
	3	1.267 ± 0.009	2.159 ± 0.024	0.046 ± 0.000	0.011 ± 0.005
	4	1.268 ± 0.009	2.161 ± 0.024	0.046 ± 0.000	0.011 ± 0.005
	5	1.265 ± 0.004	2.152 ± 0.011	0.046 ± 0.000	0.014 ± 0.006
	6	1.266 ± 0.004	1.734 ± 0.944	0.040 ± 0.014	0.014 ± 0.006
	7	1.270 ± 0.009	2.166 ± 0.024	0.046 ± 0.000	0.012 ± 0.006
	8	1.271 ± 0.009	2.168 ± 0.024	0.046 ± 0.000	0.012 ± 0.006
	9	1.272 ± 0.009	2.171 ± 0.024	0.046 ± 0.000	0.012 ± 0.006
	10	1.273 ± 0.009	2.173 ± 0.024	0.046 ± 0.000	0.014 ± 0.005
PINN-CNN-ConvLSTM	1	0.285 ± 0.001	0.135 ± 0.000	0.010 ± 0.000	0.976 ± 0.000
	2	0.298 ± 0.000	0.151 ± 0.001	0.011 ± 0.000	0.972 ± 0.001
	3	0.316 ± 0.000	0.174 ± 0.000	0.012 ± 0.000	0.965 ± 0.000
	4	0.334 ± 0.001	0.200 ± 0.000	0.012 ± 0.000	0.958 ± 0.000
	5	0.352 ± 0.001	0.229 ± 0.000	0.013 ± 0.000	0.950 ± 0.000
	6	0.371 ± 0.000	0.258 ± 0.001	0.014 ± 0.000	0.941 ± 0.000
	7	0.389 ± 0.001	0.288 ± 0.000	0.014 ± 0.000	0.933 ± 0.001
	8	0.408 ± 0.002	0.318 ± 0.000	0.015 ± 0.000	0.925 ± 0.001
	9	0.426 ± 0.000	0.348 ± 0.000	0.016 ± 0.000	0.916 ± 0.000
	10	0.444 ± 0.000	0.376 ± 0.001	0.016 ± 0.000	0.908 ± 0.000
STPDE-Net-2	1	0.222 ± 0.003	0.084 ± 0.002	0.008 ± 0.000	0.977 ± 0.001
	2	0.238 ± 0.004	0.099 ± 0.004	0.009 ± 0.000	0.973 ± 0.002
	3	0.271 ± 0.013	0.130 ± 0.012	0.010 ± 0.000	0.966 ± 0.002
	4	0.293 ± 0.024	0.156 ± 0.025	0.011 ± 0.001	0.959 ± 0.002
	5	0.301 ± 0.002	0.169 ± 0.002	0.011 ± 0.000	0.953 ± 0.001
	6	0.330 ± 0.016	0.205 ± 0.019	0.012 ± 0.000	0.945 ± 0.002
	7	0.344 ± 0.007	0.222 ± 0.008	0.013 ± 0.001	0.937 ± 0.003
	8	0.360 ± 0.001	0.247 ± 0.006	0.013 ± 0.000	0.930 ± 0.003
	9	0.376 ± 0.013	0.267 ± 0.021	0.014 ± 0.001	0.924 ± 0.006
	10	0.404 ± 0.023	0.309 ± 0.039	0.015 ± 0.001	0.915 ± 0.000
ViT	1	0.636 ± 0.067	0.646 ± 0.137	0.023 ± 0.002	0.861 ± 0.021
	2	0.761 ± 0.204	0.873 ± 0.408	0.027 ± 0.007	0.874 ± 0.008
	3	0.766 ± 0.211	0.894 ± 0.401	0.028 ± 0.007	0.871 ± 0.022
	4	0.768 ± 0.218	0.899 ± 0.419	0.028 ± 0.007	0.868 ± 0.021
	5	0.763 ± 0.151	0.862 ± 0.282	0.028 ± 0.005	0.875 ± 0.010
	6	0.758 ± 0.204	0.863 ± 0.393	0.028 ± 0.007	0.877 ± 0.008
	7	0.804 ± 0.231	0.970 ± 0.454	0.029 ± 0.008	0.869 ± 0.006
	8	0.755 ± 0.141	0.885 ± 0.275	0.027 ± 0.005	0.863 ± 0.016
	9	0.771 ± 0.202	0.900 ± 0.381	0.028 ± 0.007	0.869 ± 0.009
	10	0.684 ± 0.192	0.738 ± 0.376	0.025 ± 0.007	0.865 ± 0.012
PINN-ViT	1	0.283 ± 0.001	0.132 ± 0.001	0.010 ± 0.000	0.977 ± 0.000
	2	0.297 ± 0.001	0.148 ± 0.001	0.011 ± 0.000	0.972 ± 0.000
	3	0.314 ± 0.001	0.171 ± 0.001	0.011 ± 0.001	0.966 ± 0.000
	4	0.332 ± 0.001	0.197 ± 0.001	0.012 ± 0.000	0.958 ± 0.000
	5	0.351 ± 0.000	0.225 ± 0.001	0.013 ± 0.000	0.950 ± 0.000
	6	0.370 ± 0.001	0.255 ± 0.001	0.014 ± 0.000	0.942 ± 0.000
	7	0.388 ± 0.000	0.285 ± 0.001	0.014 ± 0.000	0.934 ± 0.000
	8	0.407 ± 0.000	0.315 ± 0.001	0.015 ± 0.000	0.925 ± 0.000
	9	0.426 ± 0.001	0.345 ± 0.001	0.016 ± 0.000	0.917 ± 0.000
	10	0.443 ± 0.000	0.373 ± 0.001	0.016 ± 0.000	0.909 ± 0.000
	1	0.275 ± 0.002	0.124 ± 0.001	0.010 ± 0.000	0.977 ± 0.000
	2	0.289 ± 0.003	0.142 ±0.005	0.011 ± 0.000	0.972 ± 0.001

STPDE-Net-3	3	0.307 ± 0.002	0.162 ± 0.003	0.011 ± 0.000	0.967 ± 0.001
	4	0.327 ± 0.002	0.188 ± 0.001	0.012 ± 0.000	0.960 ± 0.000
	5	0.349 ± 0.003	0.221 ± 0.005	0.013 ± 0.000	0.951 ± 0.001
	6	0.366 ± 0.001	0.246 ± 0.003	0.013 ± 0.000	0.944 ± 0.001
	7	0.384 ± 0.002	0.275 ± 0.004	0.014 ± 0.000	0.936 ± 0.001
	8	0.404 ± 0.001	0.308 ± 0.002	0.015 ± 0.000	0.927 ± 0.001
	9	0.422 ± 0.003	0.334 ± 0.004	0.016 ± 0.000	0.920 ± 0.001
	10	0.440 ± 0.001	0.363 ± 0.003	0.016 ± 0.000	0.912 ± 0.001

Table S21

MAE, MSE, MAPE, and r (mean ± std) of the SST prediction using 2 years data and various methods for different prediction horizons (1-10days).

methods \ Indexes	ahead day	MAE	MSE	MAPE	r
CNN	1	0.690 ± 0.074	0.726 ± 0.147	0.025 ± 0.003	0.879 ± 0.008
	2	0.758 ± 0.101	0.856 ± 0.211	0.028 ± 0.004	0.866 ± 0.016
	3	0.807 ± 0.096	0.969 ± 0.204	0.029 ± 0.003	0.851 ± 0.020
	4	0.751 ± 0.073	0.861 ± 0.150	0.028 ± 0.003	0.847 ± 0.021
	5	0.731 ± 0.092	0.830 ± 0.194	0.027 ± 0.003	0.848 ± 0.016
	6	0.767 ± 0.088	0.914 ± 0.198	0.028 ± 0.003	0.835 ± 0.021
	7	0.775 ± 0.089	0.939 ± 0.203	0.028 ± 0.003	0.828 ± 0.021
	8	0.818 ± 0.148	1.041 ± 0.337	0.030 ± 0.006	0.826 ± 0.026
	9	0.770 ± 0.058	0.933 ± 0.148	0.028 ± 0.002	0.818 ± 0.023
	10	0.778 ± 0.038	0.940 ± 0.098	0.029 ± 0.002	0.816 ± 0.020
PINN-CNN	1	0.286 ± 0.001	0.140 ± 0.000	0.011 ± 0.000	0.978 ± 0.001
	2	0.306 ± 0.003	0.162 ± 0.001	0.011 ± 0.000	0.974 ± 0.000
	3	0.331 ± 0.003	0.195 ± 0.000	0.012 ± 0.000	0.967 ± 0.001
	4	0.357 ± 0.001	0.195 ± 0.001	0.012 ± 0.000	0.967 ± 0.000
	5	0.385 ± 0.002	0.276 ± 0.001	0.014 ± 0.000	0.949 ± 0.002
	6	0.411 ± 0.002	0.319 ± 0.004	0.015 ± 0.000	0.939 ± 0.000
	7	0.438 ± 0.000	0.362 ± 0.002	0.016 ± 0.000	0.930 ± 0.001
	8	0.464 ± 0.002	0.406 ± 0.002	0.017 ± 0.001	0.920 ± 0.001
	9	0.489 ± 0.001	0.448 ± 0.003	0.018 ± 0.000	0.911 ± 0.000
	10	0.513 ± 0.002	0.489 ± 0.001	0.019 ± 0.000	0.902 ± 0.001
STPDE-Net-1	1	0.234 ± 0.001	0.093 ± 0.001	0.009 ± 0.000	0.978 ± 0.001
	2	0.250 ± 0.001	0.109 ± 0.001	0.009 ± 0.001	0.974 ± 0.000
	3	0.276 ± 0.001	0.139 ± 0.001	0.010 ± 0.000	0.967 ± 0.002
	4	0.305 ± 0.001	0.174 ± 0.000	0.011 ± 0.000	0.959 ± 0.000
	5	0.333 ± 0.002	0.213 ± 0.001	0.012 ± 0.000	0.950 ± 0.001
	6	0.361 ± 0.001	0.254 ± 0.000	0.013 ± 0.000	0.941 ± 0.001
	7	0.387 ± 0.000	0.294 ± 0.001	0.014 ± 0.000	0.932 ± 0.001
	8	0.413 ± 0.002	0.335 ± 0.001	0.015 ± 0.000	0.923 ± 0.002
	9	0.439 ± 0.000	0.376 ± 0.000	0.016 ± 0.000	0.913 ± 0.001
	10	0.464 ± 0.001	0.415 ± 0.000	0.017 ± 0.000	0.905 ± 0.000
CNN-ConvLSTM	1	1.275 ± 0.028	2.269 ± 0.084	0.047 ± 0.001	0.004 ± 0.005
	2	1.271 ± 0.028	2.258 ± 0.081	0.046 ± 0.001	0.004 ± 0.005
	3	1.266 ± 0.028	2.246 ± 0.080	0.046 ± 0.001	0.005 ± 0.005
	4	1.263 ± 0.027	2.237 ± 0.078	0.046 ± 0.001	0.005 ± 0.005
	5	1.260 ± 0.027	2.227 ± 0.076	0.046 ± 0.001	0.005 ± 0.005
	6	1.257 ± 0.026	2.220 ± 0.073	0.046 ± 0.001	0.005 ± 0.005
	7	1.253 ± 0.026	2.210 ± 0.071	0.046 ± 0.000	0.005 ± 0.005
	8	1.247 ± 0.018	2.192 ± 0.046	0.046 ± 0.000	0.005 ± 0.005
	9	1.244 ± 0.017	2.184 ± 0.044	0.046 ± 0.001	0.005 ± 0.005
	10	1.241 ± 0.017	2.177 ± 0.043	0.046 ± 0.001	0.056 ± 0.005
PINN-CNN-ConvLSTM	1	0.287 ± 0.000	0.141 ± 0.000	0.011 ± 0.000	0.978 ± 0.000
	2	0.306 ± 0.000	0.163 ± 0.000	0.011 ± 0.000	0.974 ± 0.000
	3	0.331 ± 0.000	0.196 ± 0.000	0.012 ± 0.000	0.967 ± 0.000
	4	0.358 ± 0.000	0.235 ± 0.000	0.013 ± 0.000	0.958 ± 0.000
	5	0.385 ± 0.000	0.277 ± 0.000	0.014 ± 0.000	0.949 ± 0.000
	6	0.412 ± 0.000	0.320 ± 0.000	0.015 ± 0.000	0.939 ± 0.000
	7	0.438 ± 0.000	0.363 ± 0.000	0.016 ± 0.000	0.930 ± 0.000
	8	0.464 ± 0.000	0.406 ± 0.000	0.017 ± 0.000	0.920 ± 0.000
	9	0.490 ± 0.000	0.449 ± 0.000	0.018 ± 0.000	0.911 ± 0.000

	10	0.513 ± 0.000	0.490 ± 0.000	0.019 ± 0.000	0.902 ± 0.000
STPDE-Net-2	1	0.249 ± 0.023	0.107 ± 0.020	0.009 ± 0.001	0.979 ± 0.001
	2	0.259 ± 0.015	0.119 ± 0.013	0.009 ± 0.001	0.976 ± 0.000
	3	0.277 ± 0.002	0.140 ± 0.002	0.010 ± 0.000	0.968 ± 0.001
	4	0.309 ± 0.007	0.179 ± 0.007	0.011 ± 0.001	0.960 ± 0.001
	5	0.343 ± 0.012	0.222 ± 0.015	0.013 ± 0.000	0.951 ± 0.002
	6	0.370 ± 0.024	0.263 ± 0.030	0.013 ± 0.001	0.941 ± 0.001
	7	0.386 ± 0.009	0.289 ± 0.015	0.014 ± 0.000	0.933 ± 0.002
	8	0.411 ± 0.004	0.326 ± 0.005	0.015 ± 0.000	0.923 ± 0.001
	9	0.435 ± 0.008	0.364 ± 0.017	0.016 ± 0.000	0.916 ± 0.003
	10	0.463 ± 0.021	0.410 ± 0.037	0.017 ± 0.001	0.906 ± 0.003
ViT	1	0.967 ± 0.289	1.430 ± 0.783	0.035 ± 0.010	0.797 ± 0.022
	2	0.997 ± 0.457	1.626 ± 1.544	0.036 ± 0.016	0.789 ± 0.047
	3	0.835 ± 0.109	1.056 ± 0.354	0.031 ± 0.004	0.788 ± 0.027
	4	0.768 ± 0.093	0.898 ± 0.215	0.028 ± 0.004	0.814 ± 0.023
	5	0.810 ± 0.229	1.037 ± 0.588	0.030 ± 0.009	0.825 ± 0.029
	6	0.727 ± 0.043	0.796 ± 0.103	0.027 ± 0.002	0.816 ± 0.020
	7	0.889 ± 0.383	1.240 ± 1.046	0.032 ± 0.013	0.808 ± 0.024
	8	0.886 ± 0.299	1.201 ± 0.787	0.032 ± 0.011	0.795 ± 0.024
	9	0.789 ± 0.107	0.989 ± 0.332	0.029 ± 0.004	0.791 ± 0.029
	10	0.742 ± 0.059	0.831 ± 0.157	0.028 ± 0.003	0.815 ± 0.038
PINN-ViT	1	0.286 ± 0.001	0.139 ± 0.001	0.011 ± 0.000	0.978 ± 0.001
	2	0.306 ± 0.001	0.162 ± 0.001	0.011 ± 0.000	0.974 ± 0.000
	3	0.331 ± 0.000	0.195 ± 0.001	0.012 ± 0.000	0.967 ± 0.000
	4	0.358 ± 0.001	0.234 ± 0.002	0.013 ± 0.000	0.958 ± 0.000
	5	0.385 ± 0.001	0.277 ± 0.002	0.014 ± 0.000	0.949 ± 0.000
	6	0.412 ± 0.001	0.320 ± 0.002	0.015 ± 0.000	0.939 ± 0.000
	7	0.439 ± 0.001	0.363 ± 0.001	0.016 ± 0.000	0.930 ± 0.000
	8	0.465 ± 0.001	0.406 ± 0.001	0.017 ± 0.000	0.920 ± 0.000
	9	0.490 ± 0.000	0.449 ± 0.001	0.018 ± 0.000	0.911 ± 0.000
	10	0.513 ± 0.001	0.490 ± 0.001	0.019 ± 0.000	0.902 ± 0.000
STPDE-Net-3	1	0.273 ± 0.005	0.126 ± 0.004	0.010 ± 0.000	0.978 ± 0.001
	2	0.299 ± 0.007	0.152 ± 0.008	0.011 ± 0.000	0.974 ± 0.002
	3	0.335 ± 0.032	0.198 ± 0.042	0.013 ± 0.001	0.965 ± 0.010
	4	0.350 ± 0.003	0.218 ± 0.003	0.013 ± 0.000	0.961 ± 0.001
	5	0.380 ± 0.002	0.261 ± 0.004	0.014 ± 0.000	0.952 ± 0.001
	6	0.406 ± 0.003	0.303 ± 0.003	0.015 ± 0.000	0.942 ± 0.001
	7	0.435 ± 0.000	0.349 ± 0.001	0.016 ± 0.000	0.933 ± 0.001
	8	0.462 ± 0.001	0.392 ± 0.002	0.017 ± 0.000	0.924 ± 0.001
	9	0.487 ± 0.000	0.434 ± 0.001	0.018 ± 0.000	0.915 ± 0.000
	10	0.511 ± 0.001	0.474 ± 0.001	0.019 ± 0.000	0.906 ± 0.000

Table S22

MAE, MSE, MAPE, and r (mean ± std) of the SST prediction using 1 year's data and various methods for different prediction horizons (1-10days).

Indexes / *methods*	ahead day	MAE	MSE	MAPE	r
CNN	1	0.853 ± 0.042	1.273 ± 0.178	0.032 ± 0.002	0.667 ±0.050
	2	0.867 ± 0.040	1.331 ± 0.143	0.032 ± 0.002	0.650 ± 0.040
	3	0.890 ± 0.084	1.436 ± 0.340	0.033 ± 0.004	0.637 ± 0.062
	4	0.910 ± 0.070	1.499 ± 0.291	0.034 ± 0.003	0.604 ± 0.055
	5	0.889 ± 0.059	1.392 ± 0.203	0.033 ± 0.002	0.630 ± 0.048
	6	0.892 ± 0.053	1.391 ± 0.185	0.033 ± 0.022	0.628 ± 0.047
	7	0.890 ± 0.056	1.382 ± 0.194	0.033 ± 0.002	0.629 ± 0.053
	8	0.923 ± 0.062	1.192 ± 0.263	0.034 ± 0.002	0.608 ± 0.070
	9	0.916 ± 0.053	1.436 ± 0.201	0.034 ± 0.002	0.620 ± 0.049
	10	0.927 ± 0.081	1.459 ± 0.253	0.034 ± 0.003	0.633 ± 0.082
PINN-CNN	1	0.287 ± 0.005	0.135 ± 0.003	0.011 ± 0.001	0.981 ±0.004
	2	0.298 ± 0.004	0.147 ± 0.003	0.011 ± 0.000	0.975 ± 0.000
	3	0.315 ± 0.004	0.167 ± 0.003	0.012 ± 0.000	0.969 ± 0.000
	4	0.334 ± 0.004	0.192 ± 0.003	0.012 ± 0.000	0.962 ± 0.000
	5	0.354 ± 0.003	0.219 ± 0.003	0.013 ± 0.000	0.954 ± 0.000
	6	0.375 ± 0.003	0.247 ± 0.003	0.014 ± 0.000	0.946 ± 0.000

	7	0.396 ± 0.003	0.276 ± 0.003	0.015 ± 0.00	0.938 ± 0.000
	8	0.417 ± 0.002	0.305 ± 0.003	0.016 ± 0.001	0.930 ± 0.000
	9	0.438 ± 0.002	0.334 ± 0.003	0.016 ± 0.000	0.922 ± 0.000
	10	0.456 ± 0.002	0.361 ± 0.003	0.017 ± 0.000	0.914 ± 0.000
STPDE-Net-1	1	0.231 ± 0.001	0.091 ± 0.000	0.009 ± 0.000	0.980 ±0.000
	2	0.247 ± 0.000	0.104 ± 0.001	0.009 ± 0.000	0.986 ± 0.000
	3	0.271 ± 0.000	0.125 ± 0.000	0.010 ± 0.000	0.971 ± 0.000
	4	0.295 ± 0.003	0.151 ± 0.000	0.011 ± 0.000	0.964 ± 0.000
	5	0.322 ± 0.000	0.179 ± 0.000	0.012 ± 0.000	0.957 ± 0.000
	6	0.346 ± 0.000	0.208 ± 0.000	0.013 ± 0.000	0.949 ± 0.000
	7	0.370 ± 0.000	0.237 ± 0.000	0.014 ± 0.000	0.942 ± 0.000
	8	0.394 ± 0.000	0.268 ± 0.000	0.015 ± 0.000	0.934 ± 0.000
	9	0.417 ± 0.000	0.299 ± 0.000	0.015 ± 0.000	0.926 ± 0.000
	10	0.437 ± 0.000	0.327 ± 0.000	0.016 ± 0.000	0.919 ± 0.000
CNN-ConvLSTM	1	6.673 ± 0.425	46.53 ± 5.814	0.201 ± 0.100	0.002 ± 0.003
	2	6.677 ± 0.421	46.60 ± 5.819	0.244 ± 0.016	0.000 ± 0.001
	3	6.684 ± 0.425	46.66 ± 5.824	0.244 ± 0.016	0.000 ± 0.001
	4	6.689 ± 0.425	46.71 ± 5.829	0.244 ± 0.016	0.000 ± 0.000
	5	6.694 ± 0.425	46.76 ± 5.831	0.245 ± 0.015	0.000 ± 0.000
	6	6.698 ± 0.425	46.80 ± 5.834	0.245 ± 0.015	0.000 ± 0.000
	7	6.703 ± 0.425	46.85 ± 5.838	0.245 ± 0.016	0.000 ± 0.000
	8	6.708 ± 0.425	46.91 ± 5.842	0.245 ± 0.016	0.000 ± 0.000
	9	10.71 ± 8.700	46.96 ± 5.845	0.245 ± 0.016	0.000 ± 0.000
	10	6.717 ± 0.425	47.01 ± 5.849	0.245 ± 0.016	0.000 ± 0.000
PINN-CNN-ConvLSTM	1	0.291 ± 0.000	0.138 ± 0.000	0.011 ± 0.000	0.979 ± 0.000
	2	0.301 ± 0.000	0.150 ± 0.000	0.011 ± 0.000	0.975 ± 0.000
	3	0.317 ± 0.000	0.170 ± 0.000	0.012 ± 0.000	0.969 ± 0.000
	4	0.336 ± 0.000	0.195 ± 0.000	0.012 ± 0.000	0.962 ± 0.000
	5	0.356 ± 0.000	0.222 ± 0.000	0.013 ± 0.000	0.954 ± 0.000
	6	0.377 ± 0.000	0.250 ± 0.000	0.014 ± 0.000	0.946 ± 0.000
	7	0.398 ± 0.000	0.279 ± 0.000	0.015 ± 0.000	0.938 ± 0.000
	8	0.419 ± 0.000	0.308 ± 0.000	0.016 ± 0.000	0.930 ± 0.000
	9	0.439 ± 0.000	0.337 ± 0.000	0.016 ± 0.000	0.921 ± 0.000
	10	0.457 ± 0.000	0.363 ± 0.000	0.017 ± 0.000	0.914 ± 0.000
STPDE-Net-2	1	0.244 ± 0.025	0.101 ± 0.020	0.009 ± 0.001	0.980 ± 0.000
	2	0.255 ± 0.006	0.110 ± 0.006	0.027 ± 0.040	0.977 ± 0.000
	3	0.286 ± 0.018	0.139 ± 0.018	0.011 ± 0.001	0.971 ± 0.001
	4	0.312 ± 0.014	0.166 ± 0.017	0.011 ± 0.001	0.964 ± 0.001
	5	0.334 ± 0.006	0.190 ± 0.005	0.012 ± 0.001	0.956 ± 0.001
	6	0.361 ± 0.009	0.223 ± 0.015	0.013 ± 0.000	0.949 ± 0.001
	7	0.383 ± 0.003	0.250 ± 0.004	0.014 ± 0.000	0.942 ± 0.001
	8	0.408 ± 0.007	0.286 ± 0.012	0.015 ± 0.000	0.934 ± 0.002
	9	0.435 ± 0.009	0.322 ± 0.014	0.016 ± 0.000	0.926 ± 0.002
	10	0.453 ± 0.004	0.348 ± 0.010	0.017 ± 0.000	0.919 ± 0.003
ViT	1	1.563 ± 0.487	3.200 ± 1.634	0.059 ± 0.019	0.792 ± 0.071
	2	1.621 ± 0.462	3.384 ± 1.523	0.061 ± 0.017	0.827 ± 0.046
	3	1.811 ± 0.474	4.057 ± 1.658	0.068 ± 0.018	0.818 ± 0.053
	4	1.529 ± 0.327	2.976 ± 1.051	0.057 ± 0.012	0.826 ± 0.056
	5	1.636 ± 0.511	3.457 ± 1.626	0.061 ± 0.019	0.781 ± 0.090
	6	1.705 ± 0.459	3.366 ± 2.141	0.064 ± 0.017	0.813 ± 0.051
	7	1.705 ± 0.458	3.695 ± 1.540	0.064 ± 0.017	0.805 ± 0.046
	8	1.742 ± 0.380	3.764 ± 1.338	0.065 ± 0.014	0.802 ± 0.055
	9	1.845 ± 0.705	4.368 ± 2.772	0.069 ± 0.026	0.816 ± 0.022
	10	1.708 ± 0.460	3.677 ± 1.679	0.064 ± 0.017	0.806 ± 0.036
PINN-ViT	1	0.291 ± 0.000	0.138 ± 0.000	0.011 ± 0.000	0.979 ± 0.000
	2	0.301 ± 0.000	0.150 ± 0.000	0.011 ± 0.000	0.975 ± 0.000
	3	0.318 ± 0.001	0.170 ± 0.000	0.012 ± 0.000	0.969 ± 0.000
	4	0.336 ± 0.000	0.195 ± 0.000	0.012 ± 0.000	0.962 ± 0.000
	5	0.356 ± 0.000	0.222 ± 0.000	0.013 ± 0.000	0.954 ± 0.000
	6	0.377 ± 0.000	0.250 ± 0.000	0.014 ± 0.000	0.946 ± 0.000
	7	0.398 ± 0.001	0.278 ± 0.001	0.015 ± 0.000	0.938 ± 0.000
	8	0.419 ± 0.000	0.308 ± 0.000	0.016 ± 0.000	0.930 ± 0.000
	9	0.439 ± 0.000	0.337 ± 0.000	0.016 ± 0.000	0.921 ± 0.000
	10	0.457 ± 0.000	0.363 ± 0.001	0.017 ± 0.000	0.914 ± 0.000
	1	0.285 ± 0.001	0.132 ± 0.001	0.010 ± 0.000	0.981 ± 0.000
	2	0.296 ± 0.002	0.144 ± 0.001	0.011 ± 0.000	0.978 ± 0.000

STPDE-Net-3	3	0.314 ± 0.006	0.164 ± 0.004	0.012 ± 0.000	0.972 ± 0.001
	4	0.338 ± 0.003	0.192 ± 0.003	0.012 ± 0.001	0.965 ± 0.001
	5	0.360 ± 0.001	0.221 ± 0.002	0.013 ± 0.000	0.957 ± 0.001
	6	0.377 ± 0.005	0.246 ± 0.005	0.014 ± 0.000	0.949 ± 0.002
	7	0.402 ± 0.002	0.279 ± 0.003	0.015 ± 0.000	0.942 ± 0.001
	8	0.422 ± 0.004	0.306 ± 0.004	0.016 ± 0.000	0.933 ± 0.002
	9	0.448 ± 0.007	0.342 ± 0.008	0.017 ± 0.001	0.924 ± 0.003
	10	0.465 ± 0.002	0.368 ± 0.002	0.017 ± 0.000	0.919 ± 0.002