Removing long-term bias of operational oceanography forecasting system by adjusting the parameters using data assimilation method

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Abstract

For the operational oceanography forecast, the short-term forecast error is partly from the long-term systematic bias of numerical model, which can be counteracted by adjusting the physical parameters, to a certain degree. An optimization system for multi-parameters is implemented into South China Sea Operational oceanography Forecasting System (SCSOFS). Using data assimilation method, five physical parameters (coefficients of horizontal/vertical diffusion and viscosity and linear bottom drag) of ROMS have been adjusted, according to the Argo temperature profiles of 51 days in the model domain. The independent validations show that the RMSE of temperature of freerun can be decreased from 0.97 to 0.88 degree, and that of hindcast from 0.90 to 0.80, using the optimal values of parameters. Other variables also show improvements, accordingly.

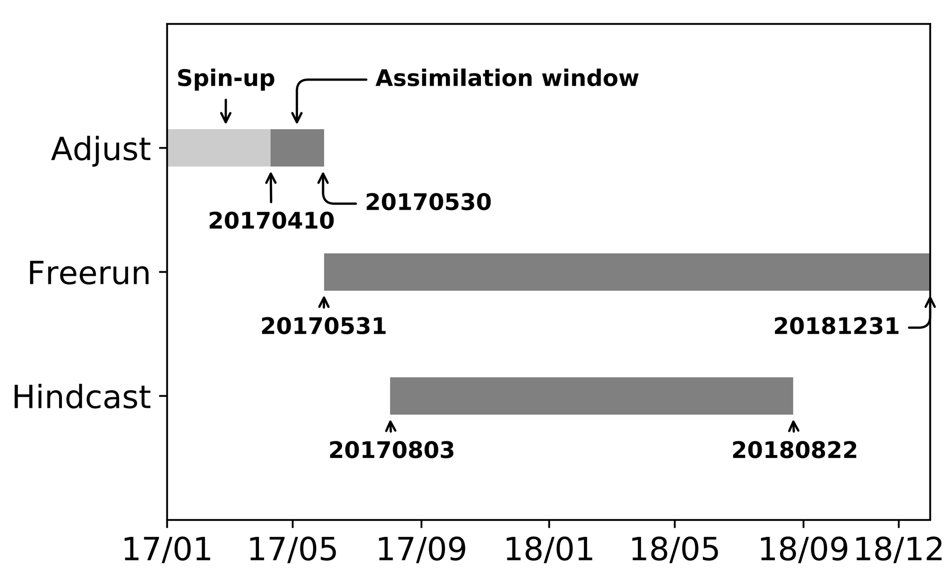
3 Methods and observations for optimization and validation

3.1 Strategy of optimization and validation

The model is initialized from 2017/01/01, and runs for 150 days, in which the first 99 days are spin-up period. The assimilation window covers 51 days, from 2017/04/10 to 2017/05/30. In the assimilation window, only the Argo T profiles are assimilated, to adjust the five parameter values.

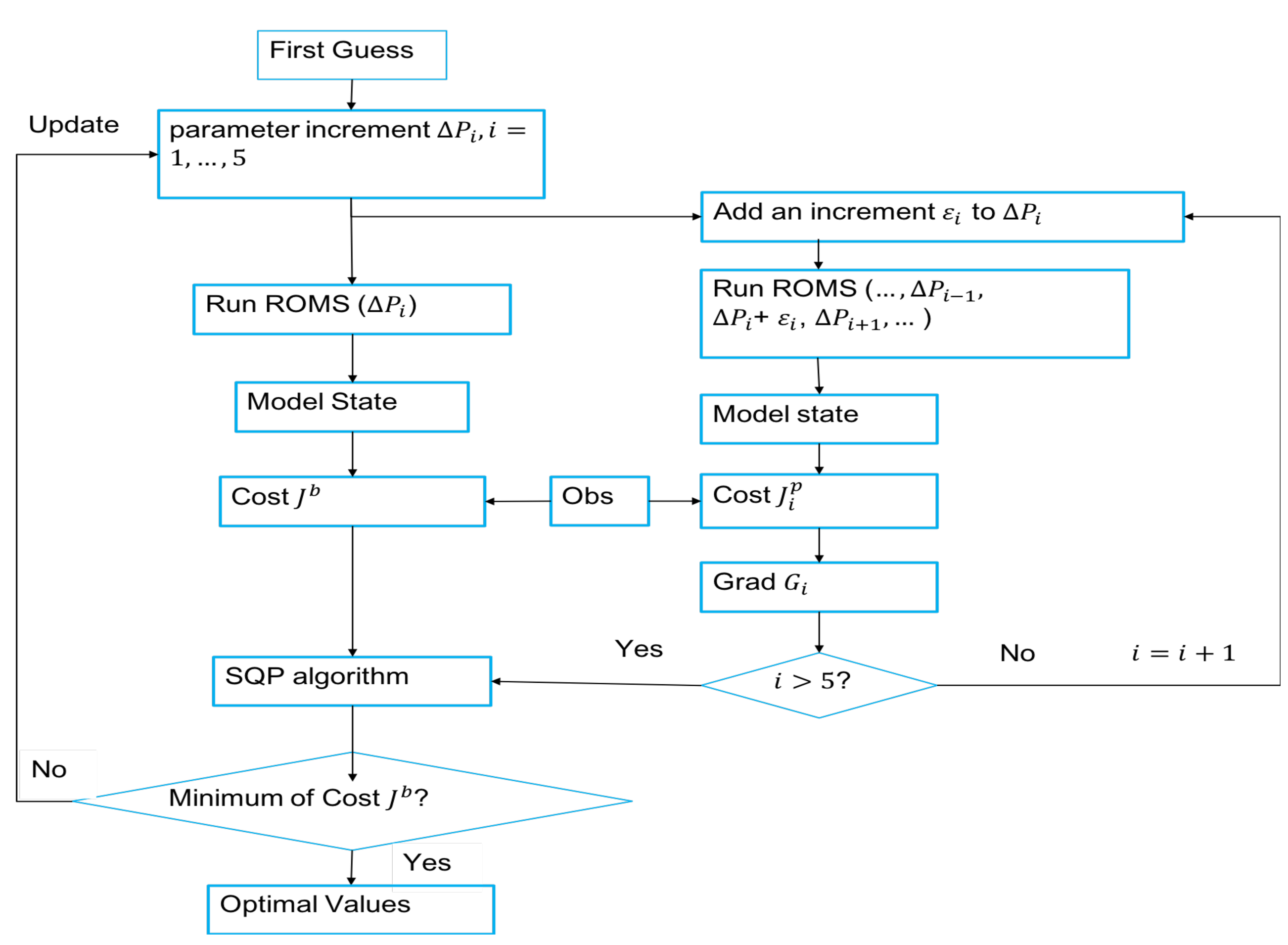
Independent validations of freerun (without DA for initial conditions) and hindcast (with DA) are conducted to compare the improvements using the original and optimal parameter values.

It should be noted that a relatively long spin-up, 99 days, is used, to make sure that the parameter perturbations can exert an influence on the model states.



3.2 Method of optimization

In the calculation of the optimal values for the five physical parameters, we used an adjoint-free method. In this routine below, the gradient of costfunction with respect to one parameter increment, is obtained by integrating the model one more time. That is, to calculate the five gradients, the model will be integrated six times. Indeed, the computation is relatively larger, with respect to the adjoint method, but still acceptable.

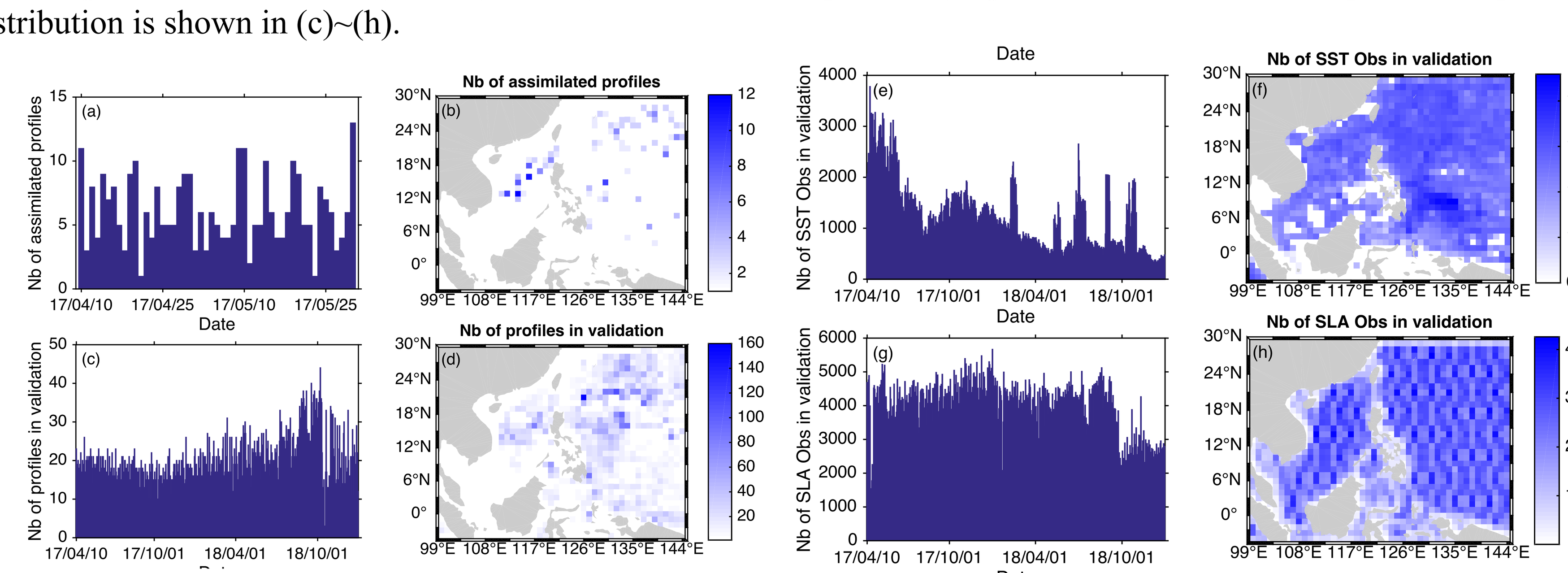


Costfunction: $J = \sqrt{\frac{1}{N}\sum_{i=1}^{N}[H(X) - y_i]^2}$, where y denotes the observation assimilated with a number of samples N, X the daily-mean simulated T and H the operator that interpolates the simulation to the position and time of observation.

3.3 Observations

During the optimization, the Argo T profiles are assimilated, of which temporal and spatial distribution is shown in (a) and (b).

During the validation, SST (Drifter), SLA (AVISO) and T/S profiles (Argo) are used, of which temporal and spatial distribution is shown in (c)~(h).

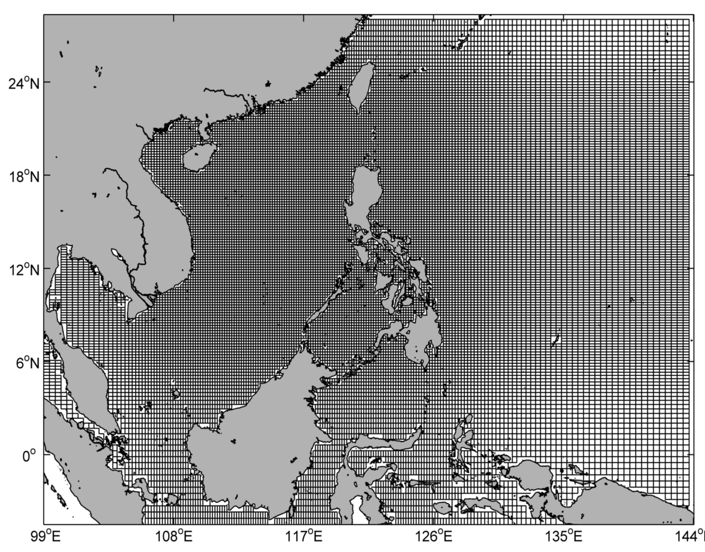


5 Summary & Conclusion

- For the operational forecast, there are systematic bias caused by model errors. These errors are superimposed on the forecast, which can not be removed by adjustment of initial conditions. In this study, the values of five parameters have been adjusted using a data assimilation method, to counteract the systematic bias.
- An adjoint-free method is used, which increases the computation, however, is still acceptable when the number of parameters is less than 10.
- During the assimilation window, the RMSE of T can be decreased by about 0.2 degree (not shown) using the optimal values. The improvement can be maintained in the freerun and hindcast experiment, with a RMSE decrease of about 0.1 degree. The hindcast of other variables, SLA/SST/S, also shows improvement. For example, the RMSE of SLA decreases from 8.4 cm to 7.8 cm.
- The results show that the short-term model errors can be counteracted by the adjustment of model parameters on a long-term time scale.

1 SCSOFS Introduction

- Based on ROMS **Version 3.7**
- **Domain**
  - ✓ -4.5°S~28.4°N, 99°~145°E
- **Horizontal Resolution**
  - ✓ 1/12°～1/30°, Grid NO.: 975×795
- **Vertical Resolution**
  - ✓ 50 Layers
- **Bathymetry data**
  - ✓ GEBCO（0.5′×0.5′）
  - ✓ ETOPO1（1′×1′）
- **Forcing**
  - ✓ **Surface**: CFSR 6-hourly
  - ✓ **Open Boundary**: SODA
  - ✓ **River**: Pearl, Mekong monthly
  - ✓ **Tides**:OTPS（10 constituents）
- **DA**
  - ✓ Qcorrection (SST)
  - ✓ EnOI (SST, SLA, Argo profile)
- **Time step**
  - ✓ External: 6s
  - ✓ Internal: 180s

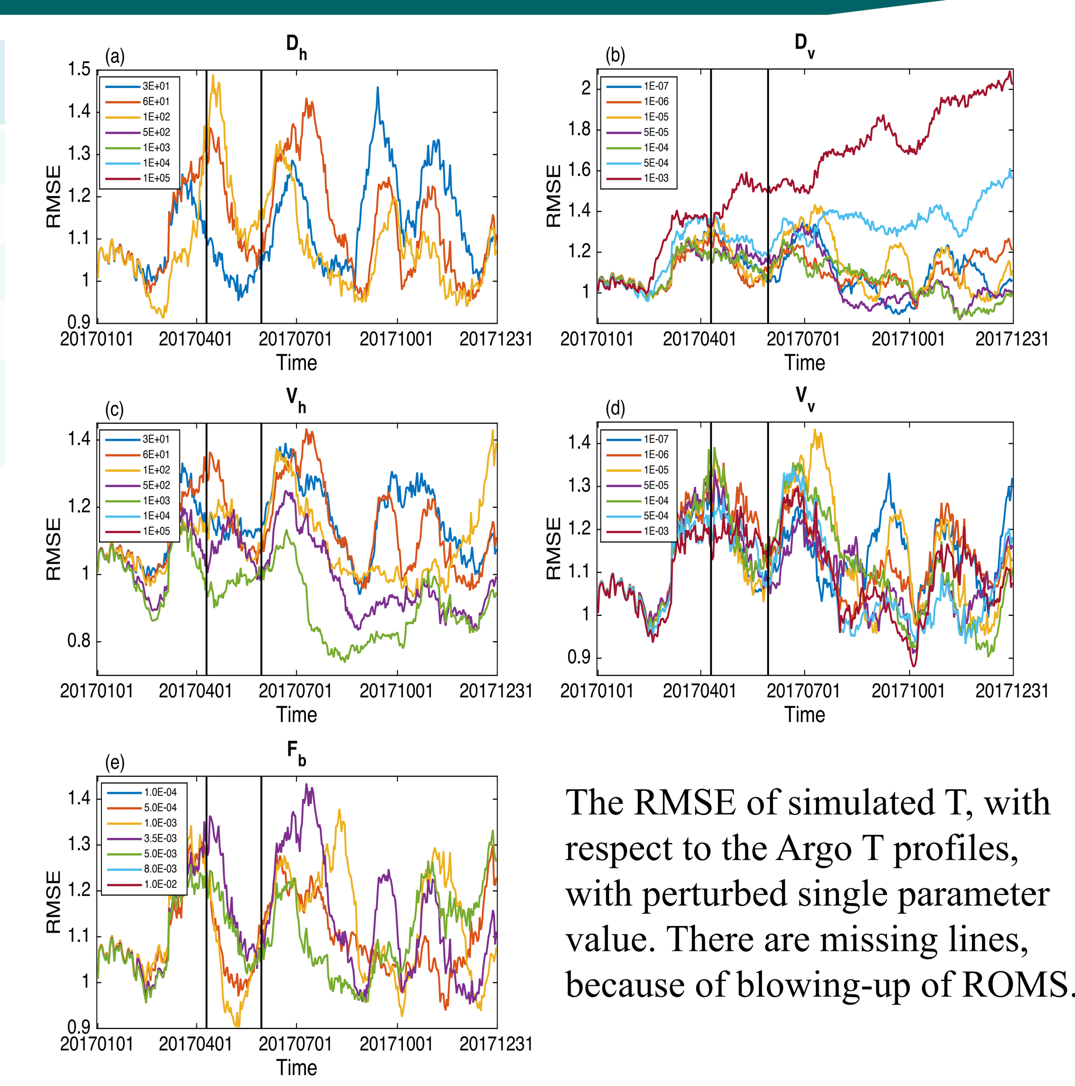


2 Sensitivity of five physical parameters

Parameters	Bounds to test the sensitivity and to avoid blowing-up	Bounds for searching the optimal values
Coefficient of horizontal diffusion [m2/s]: Dh	[3.0E+1, 1.0E+5]	[3.0E+1, 1.0E+2]
Coefficient of vertical diffusion [m2/s]: Dv	[1.0E-7, 1.0E-3]	[1.0E-7, 1.0E-3]
Coefficient of horizontal viscosity [m2/s]: Vh	[3.0E+1, 1.0E+5]	[3.0E+1, 1.0E+3]
Coefficient of vertical viscosity [m2/s]: Vv	[1.0E-7, 1.0E-3]	[1.0E-7, 1.0E-5]
Coefficient of linear bottom drag [non-dimensional]: Fb	[1.0E-2, 1.0E-4]	[5.0E-4, 5.0E-3]

It should be confirmed that the model state is sensitive to the variations of parameter values. Therefore, five experiments have been conducted. In each experiment, the parameter is perturbed in a large interval (the middle column in the upper table), and the RMSEs of simulated T are shown in right figures.

In some cases, ROMS will blowing-up when parameter takes inappropriate values. To avoid blowing-up, a new bounds is given (the right column in the upper table) to search the optimal values.



The RMSE of simulated T, with respect to the Argo T profiles, with perturbed single parameter value. There are missing lines, because of blowing-up of ROMS.

4 Validation

The original and optimal values for the five parameters

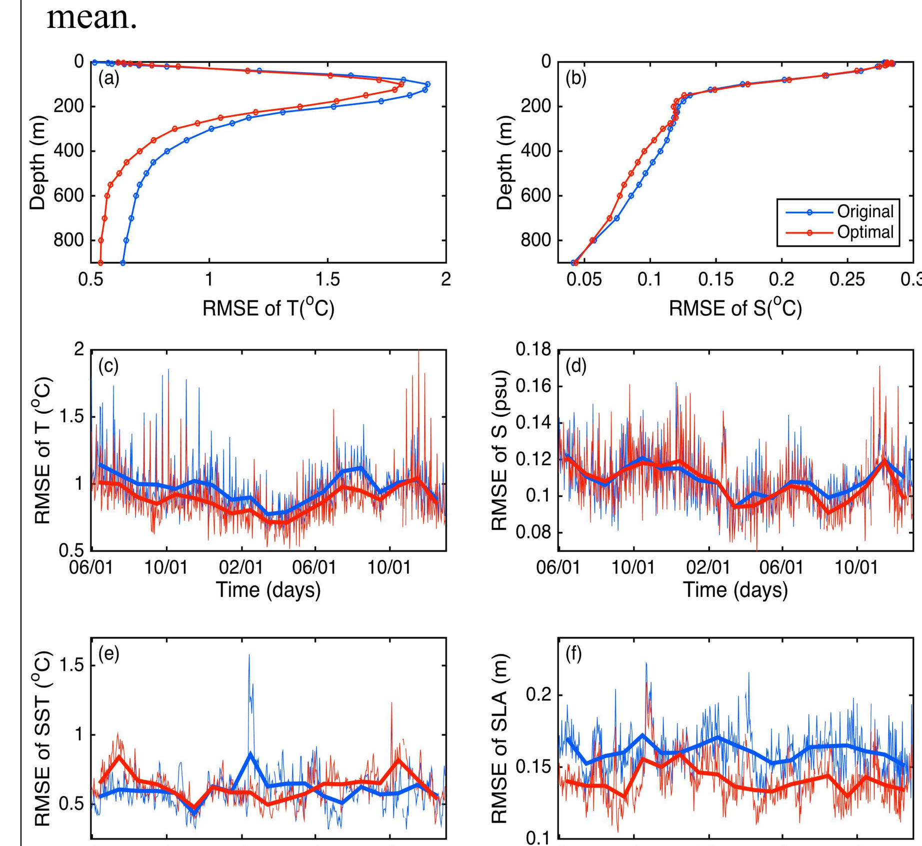
	Original value	Optimal value
D_h	6.0E+1	3.0E+1
D_v	1.0E-5	1.0E-7
V_h	6.0E+1	1.0E+3
V_v	1.0E-5	1.0E-5
F_b	3.5E-3	5.0E-4

The total RMSEs of freerun and hindcast using original and optimal values

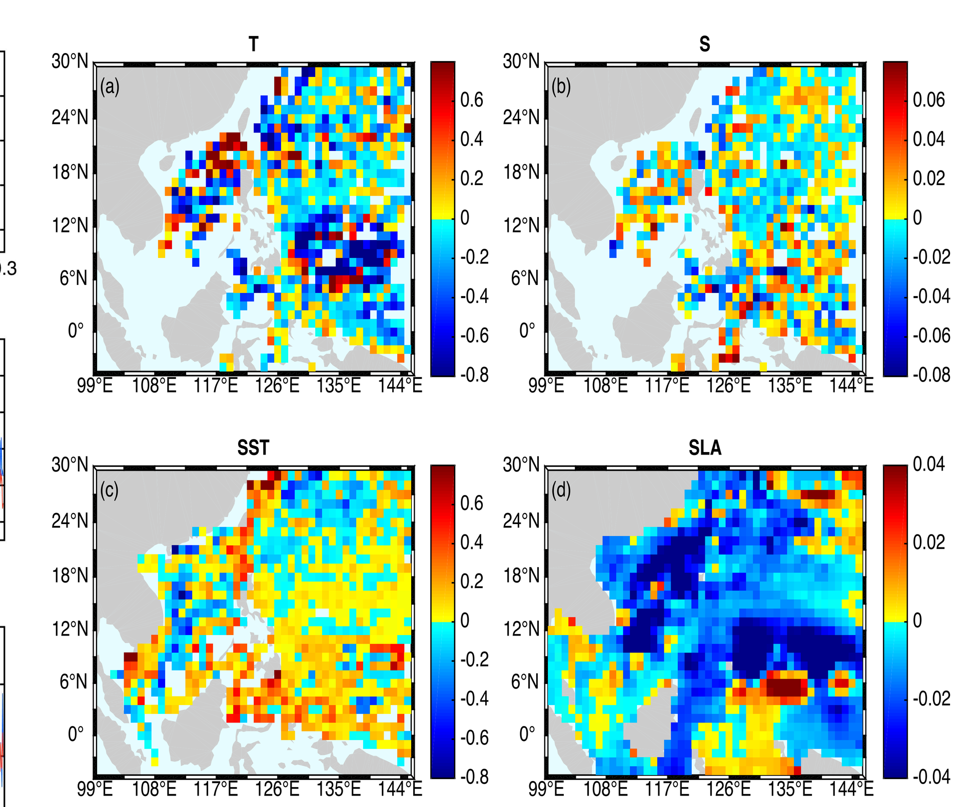
	Freerun		Hindcast	
	Original	Optimal	Original	Optimal
T	0.9712	0.8849	0.8985	0.7998
S	0.1091	0.1073	0.0973	0.0935
SST	0.5999	0.6274	0.4926	0.4745
SLA	0.1613	0.1406	0.0836	0.0779

4.1 Temporal and Spatial distribution of RMSE of freerun

The vertical and temporal distribution of RMSE using the original and optimal values. The smoothed lines in (c)~(f) denotes the monthly mean.

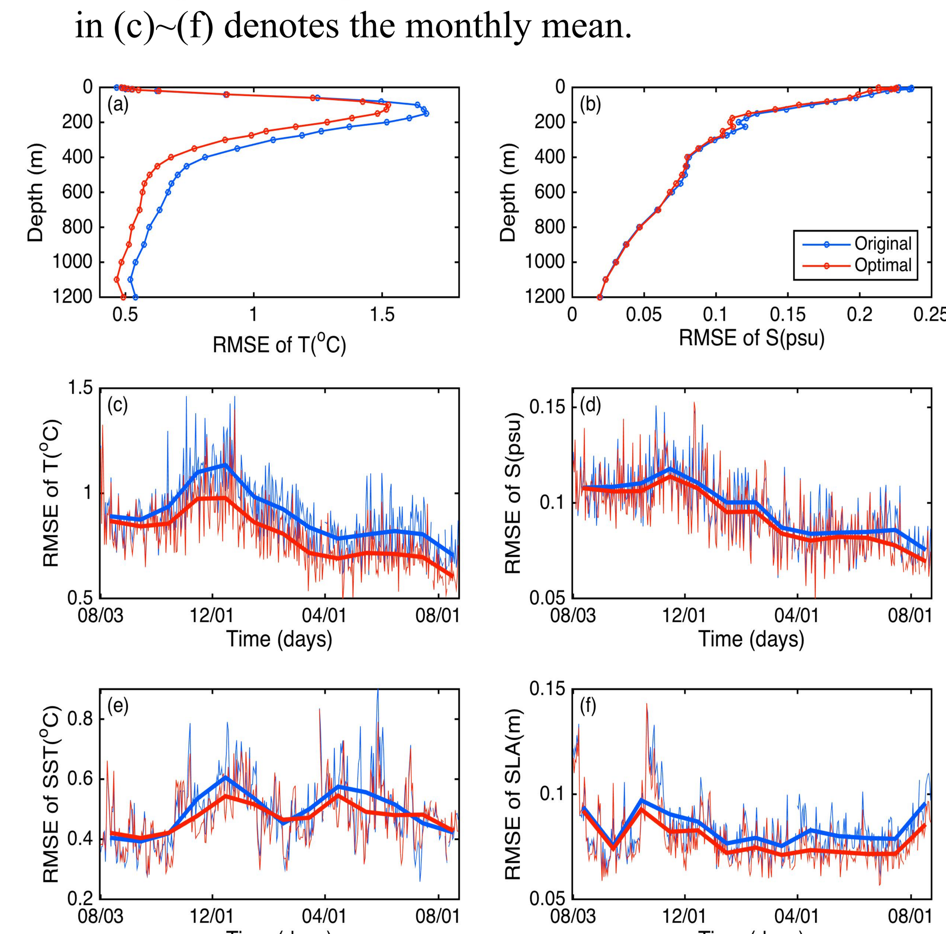


The RMSE difference between the cases using optimal and original values, where blue dots indicate the decrease of RMSE using the optimal values.



4.2 Temporal and spatial distribution of RMSE of hindcast

The vertical and temporal distribution of RMSE using the original and optimal values. The smoothed lines in (c)~(f) denotes the monthly mean.



The RMSE difference between the cases using optimal and original values, where blue dots indicate the decrease of RMSE using the optimal values.