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Implementation of a high-resolution atmosphere-ocean coupled model with an ensemble Kalman filter

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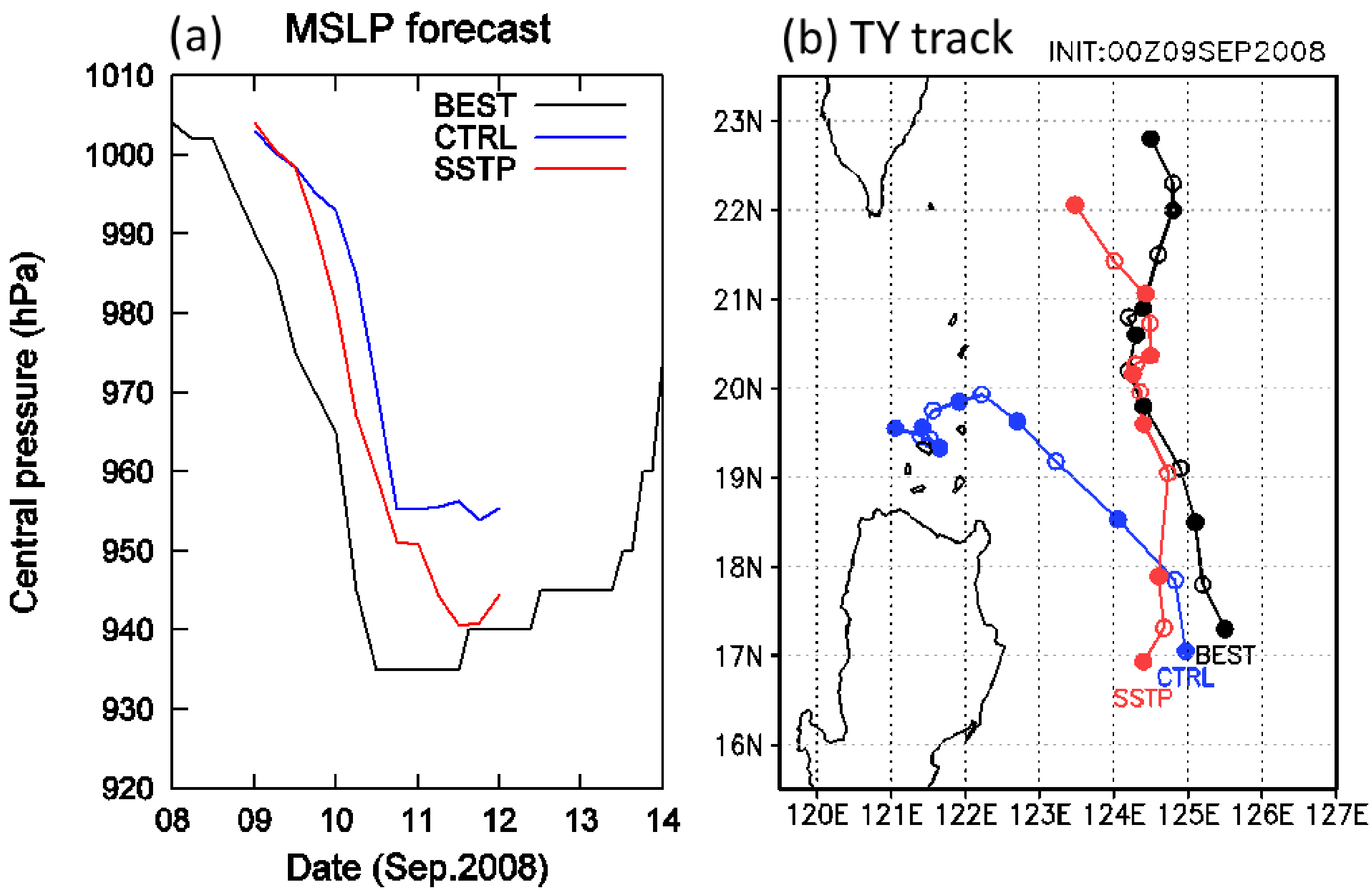
SST uncertainties in EnKF

- Considering SST uncertainties in EnKF cycles has positive impact for TC forecasts (Kunii and Miyoshi 2012).

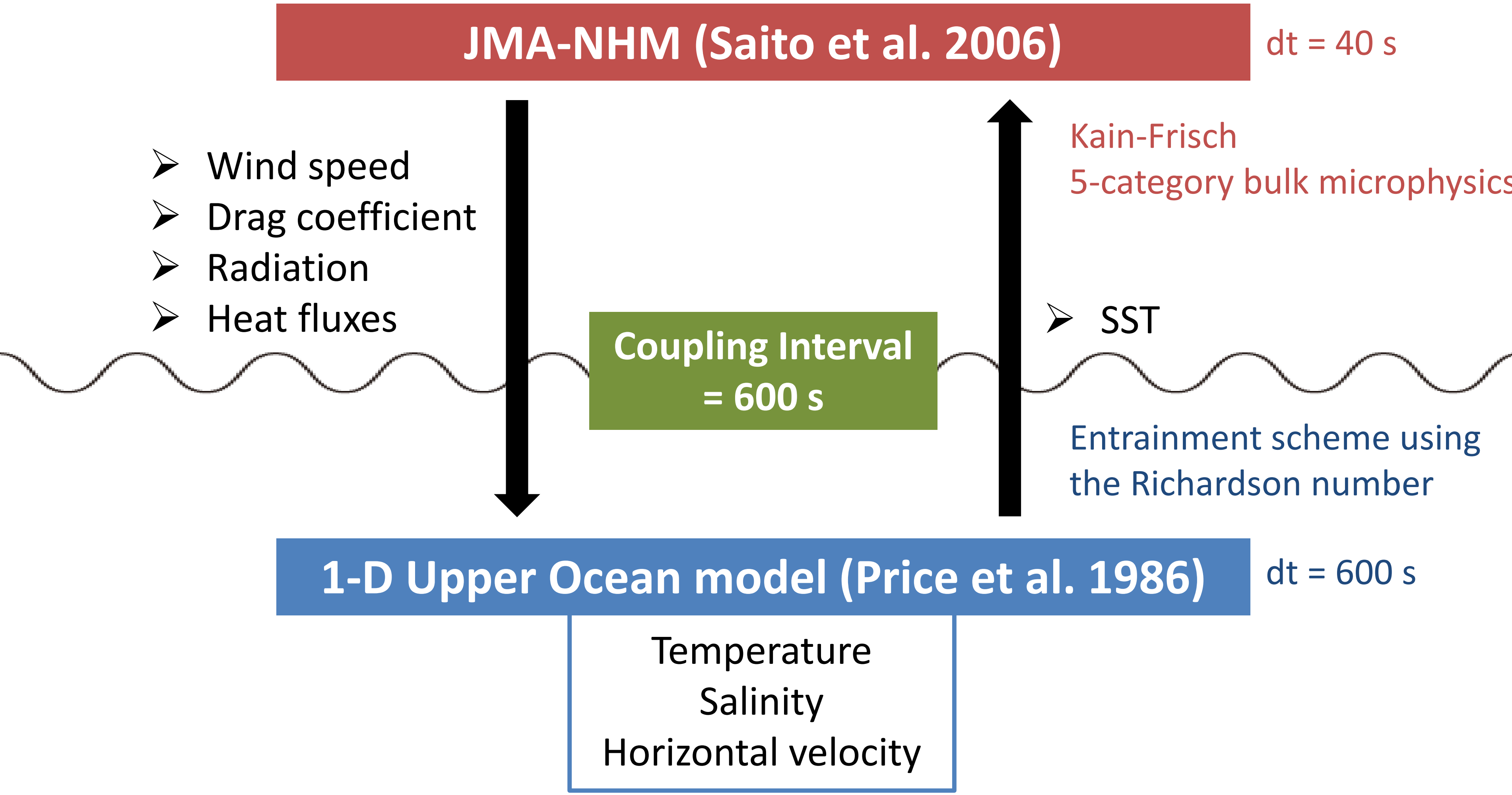


Motivation and objective

- Kunii and Miyoshi (2012) used fixed SST perturbations derived from random draws of SST analyses.
- For estimating time-dependent SST uncertainties, implementation of an atmosphere-ocean coupled model with an EnKF would be favorable.
- Here, atmosphere-ocean coupled model developed by Ito et al. (2014) is implemented with the NHM-LETKF (Kunii 2014), and the impact of the SST uncertainties on EnKF analyses is investigated.

Coupled mesoscale model

CMSM (Ito et al. 2014)

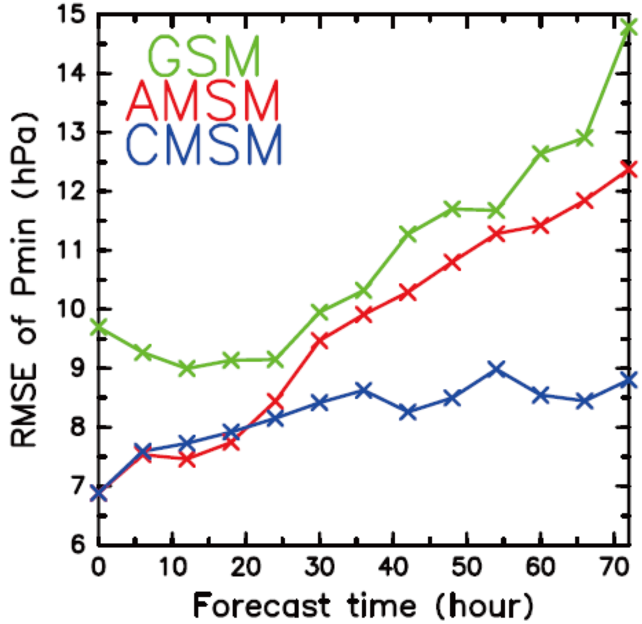


CMSM improves TC forecasts

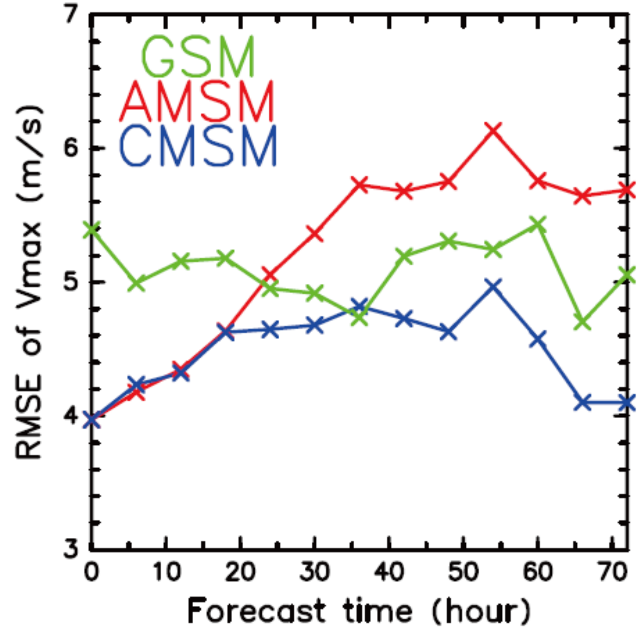
TC intensity forecast skills

- CMSM outperforms GSM and AMSM in the forecast of both Pmin and Vmax by 13-27% at FT=48 h.
- Benefits of CMSM become larger with increasing FT.

RMSE of Pmin



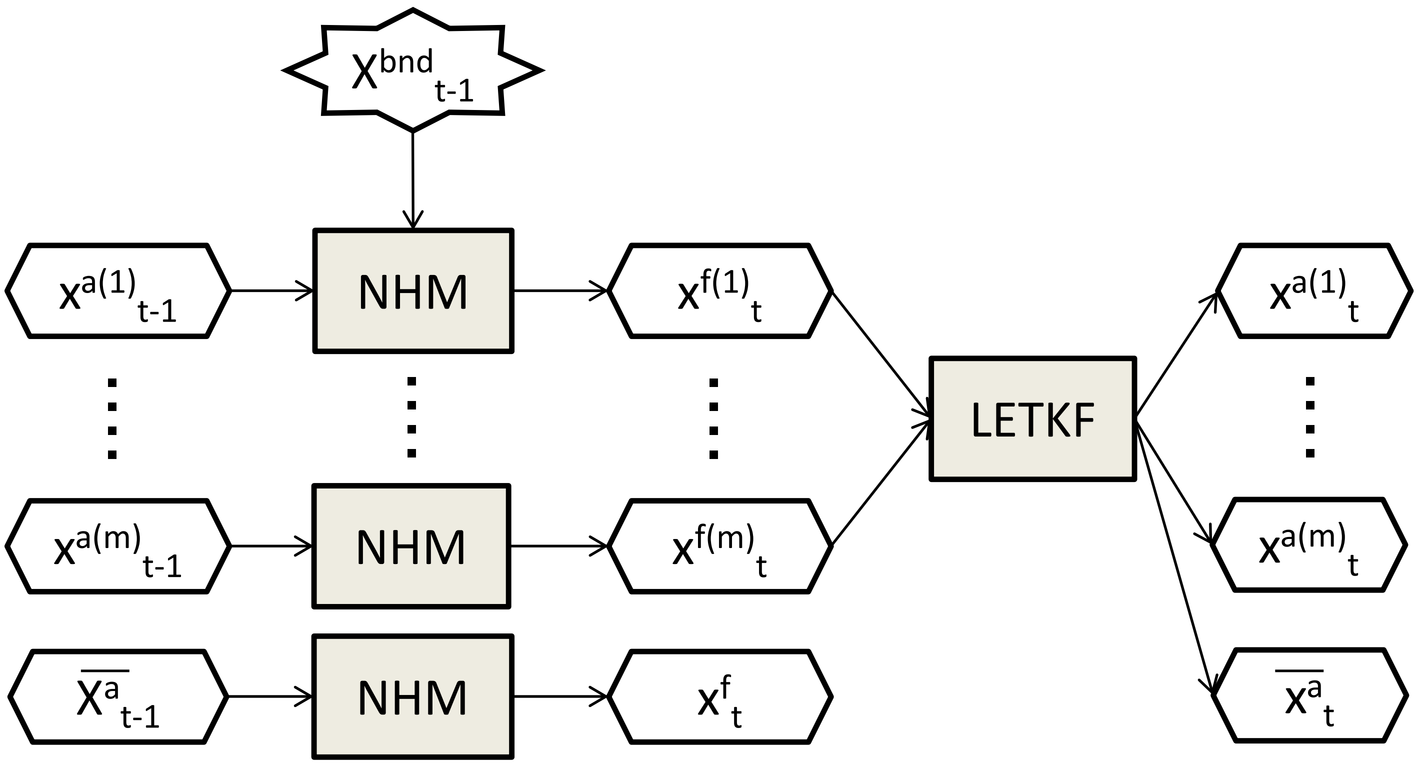
RMSE of Vmax



Ito et al. 2014

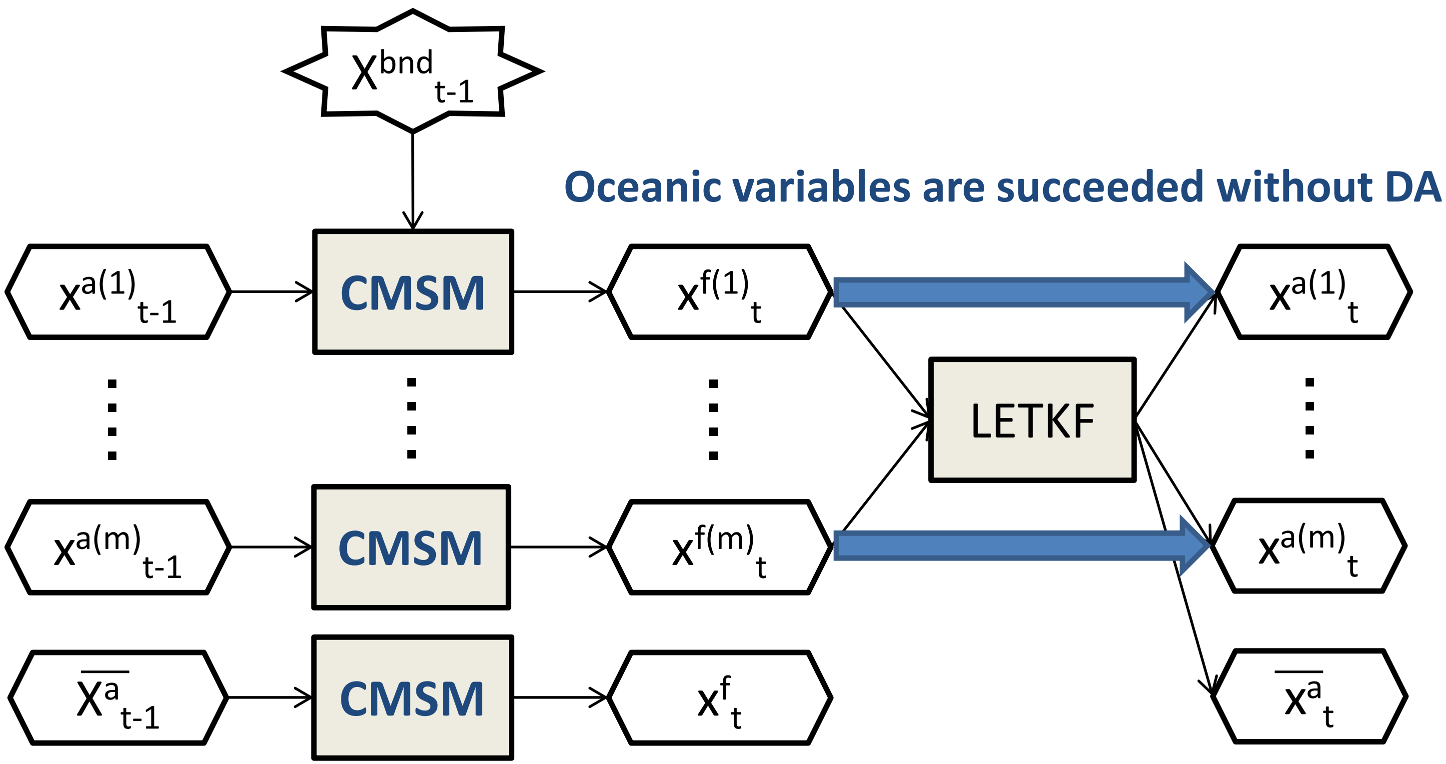
Data assimilation system

Flow-chart of the NHM-LETKF



Data assimilation system

Flow-chart of the CNHM-LETKF



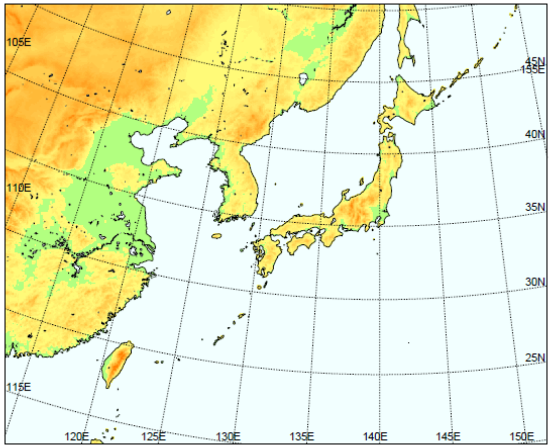
- Oceanic variables are initialized with climatological values (WOA 2001).
- Oceanic variables are not included in the control variables in the LETKF.

Experimental design

Experiment	SST uncertainties
CTRL	NOT considered
CPL	Atmospheric-ocean coupled model Restoration to the SST analysis with 1-day relaxzation time
SSTP	Random draws (Kunii and Miyoshi 2012)

NHM-LETKF specifications

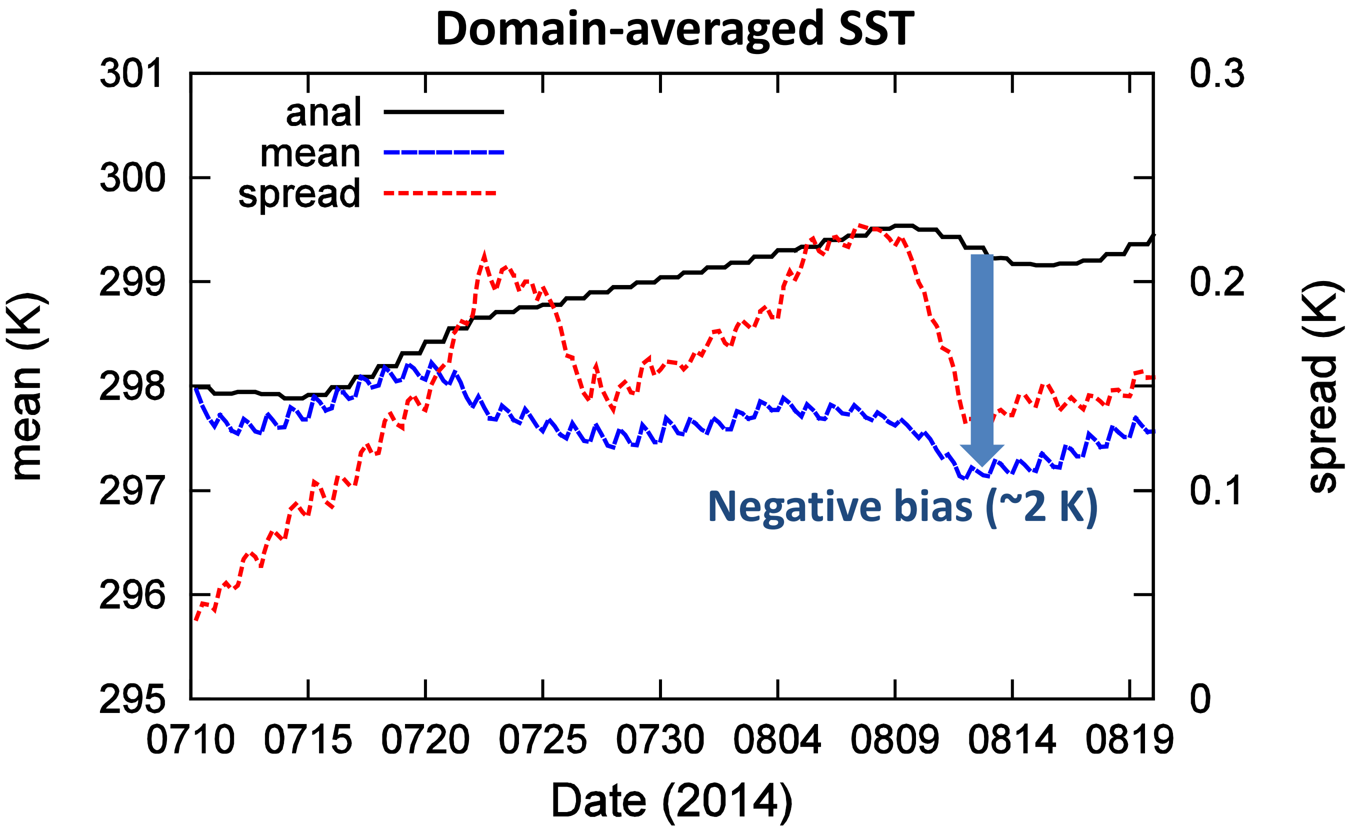
Ensemble size	50
Grid size	273 x 221 x 50 (Δx = 15 km)
Covariance inflation	Adaptive multiplicative (Miyoshi 2011)
Covariance localization	200 km, 0.2 ln p
Analyzed variables	u, v, w, t, p, qv, qc, qr, qci, qs, qg
Observation data	MA CDA4 (u, v, t, rh, ps, tpw)
Extended forecast	817 x 661 x 50 (Δx = 5 km), up to 48 hr Use the uncouple model with the MGDSST



Domain for the DA experiment

Negative bias of SST

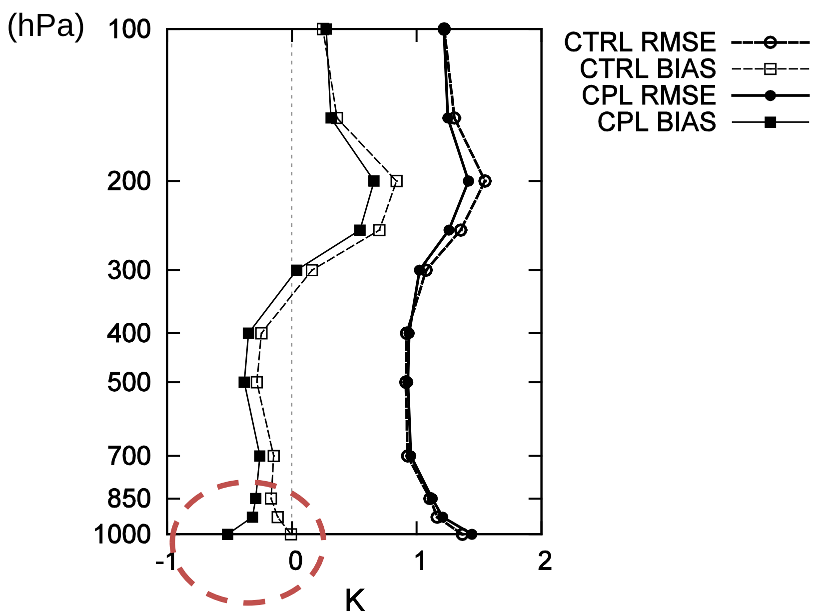
- With the coupled model, the ensemble spread of SST increases gradually, and fluctuates around 0.17.
- After a 10-day DA cycle, the negative bias of SST becomes obvious.



Negative bias for precipitation

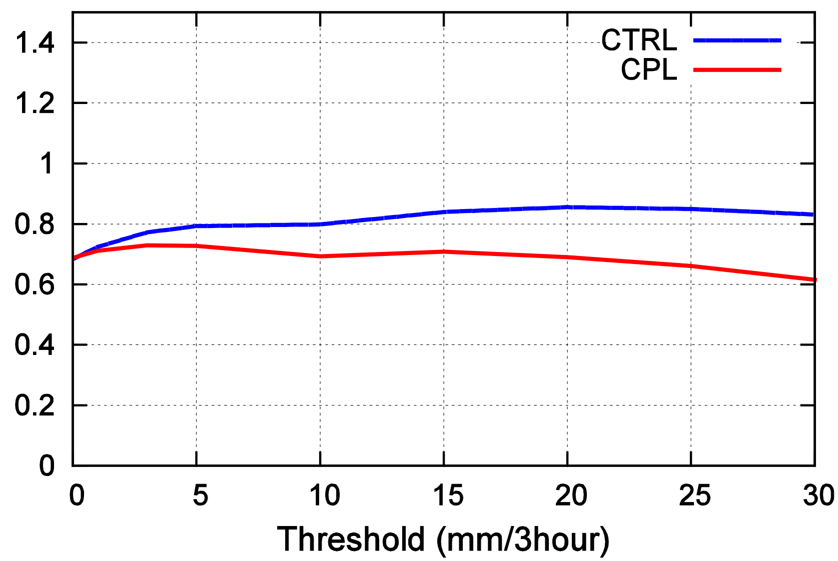
- Statistical verifications (LEFT for DA cycles, RIGHT for extended forecasts) show that the negative bias of SST leads to the negative bias for precipitation forecasts, especially in the early stage.

Radiosonde verification scores for T



Negative bias near the surface

Bias scores for 3-h precipitation (FT=6)



Restoring to the analyzed SST

- For alleviating the negative bias of SST, SST in CMSM is restored to the MGDSST in every time step in each ensemble member.

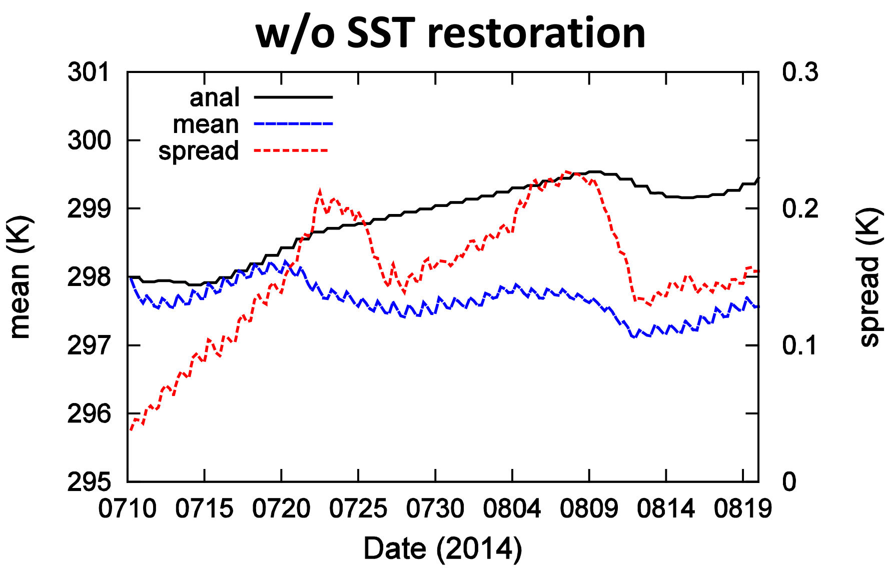
$$SST^{rest} = SST^{fcst} + \frac{dt}{T}\left(SST^{anal} - SST^{fcst}\right)$$

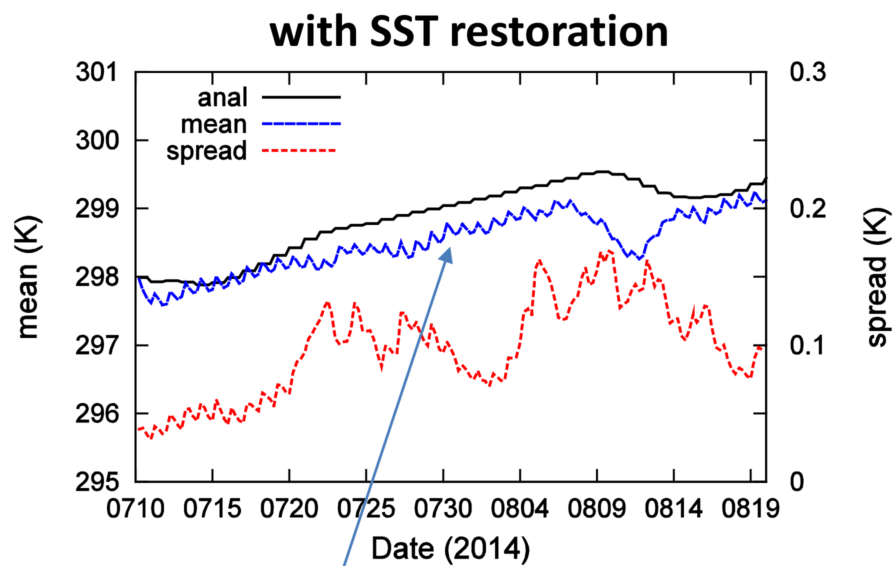
- The short relaxation time will reduce the bias, but can excessively inhibit the growth of ensemble spread of SST.

- The relaxation time T is set to 1-day in the following CPL experiment.

Impact of SST restoration

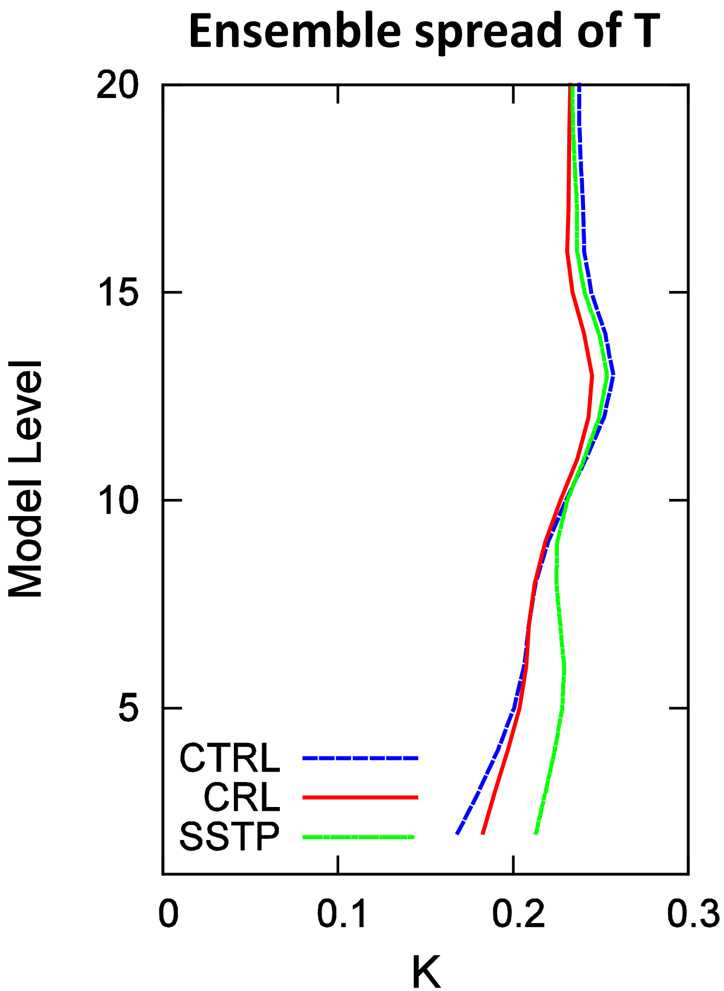
- With SST restoration, the negative bias is significantly reduced.
- The ensemble spread of SST becomes smaller, but acceptable.

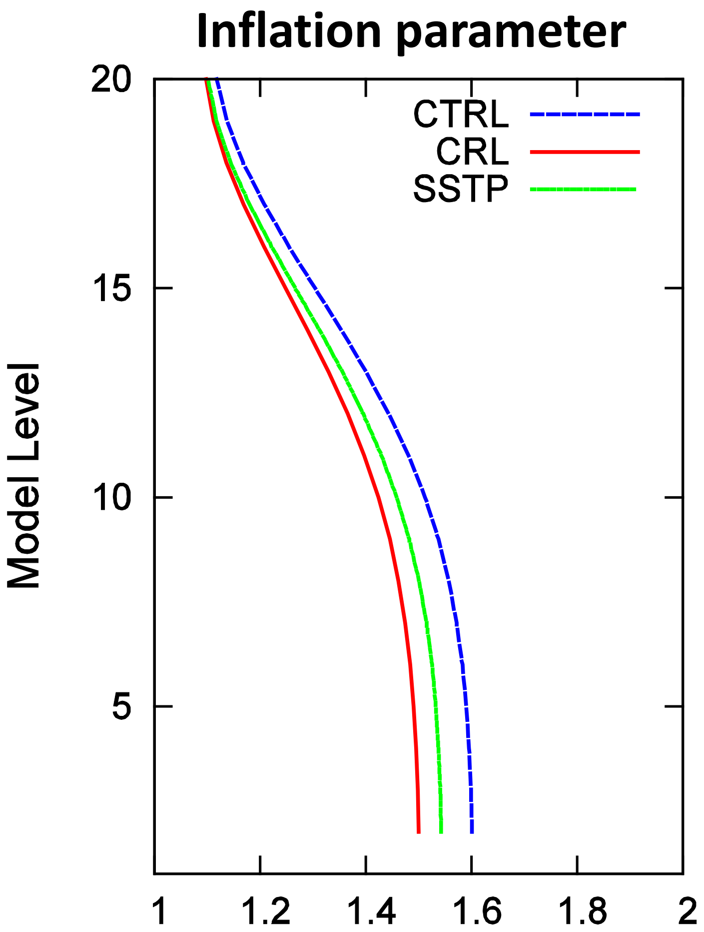




The negative bias of SST is significantly reduced

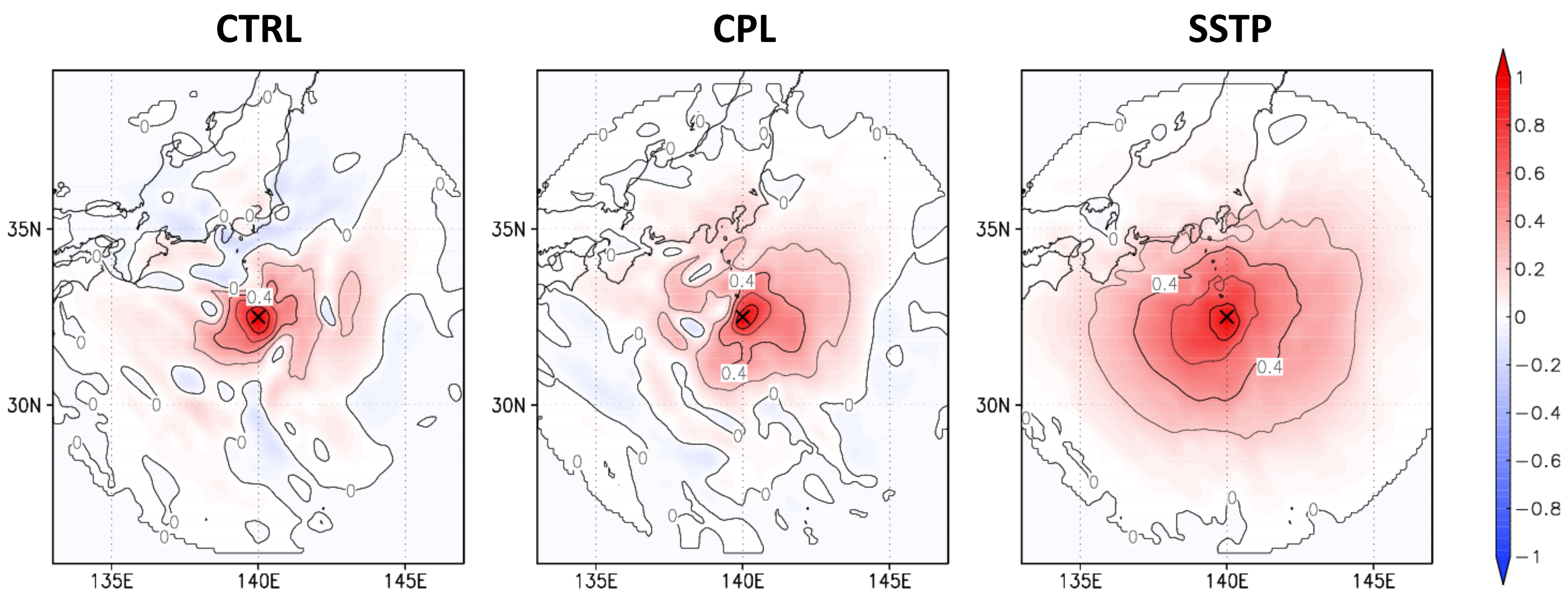
Vertical profiles in DA cycles





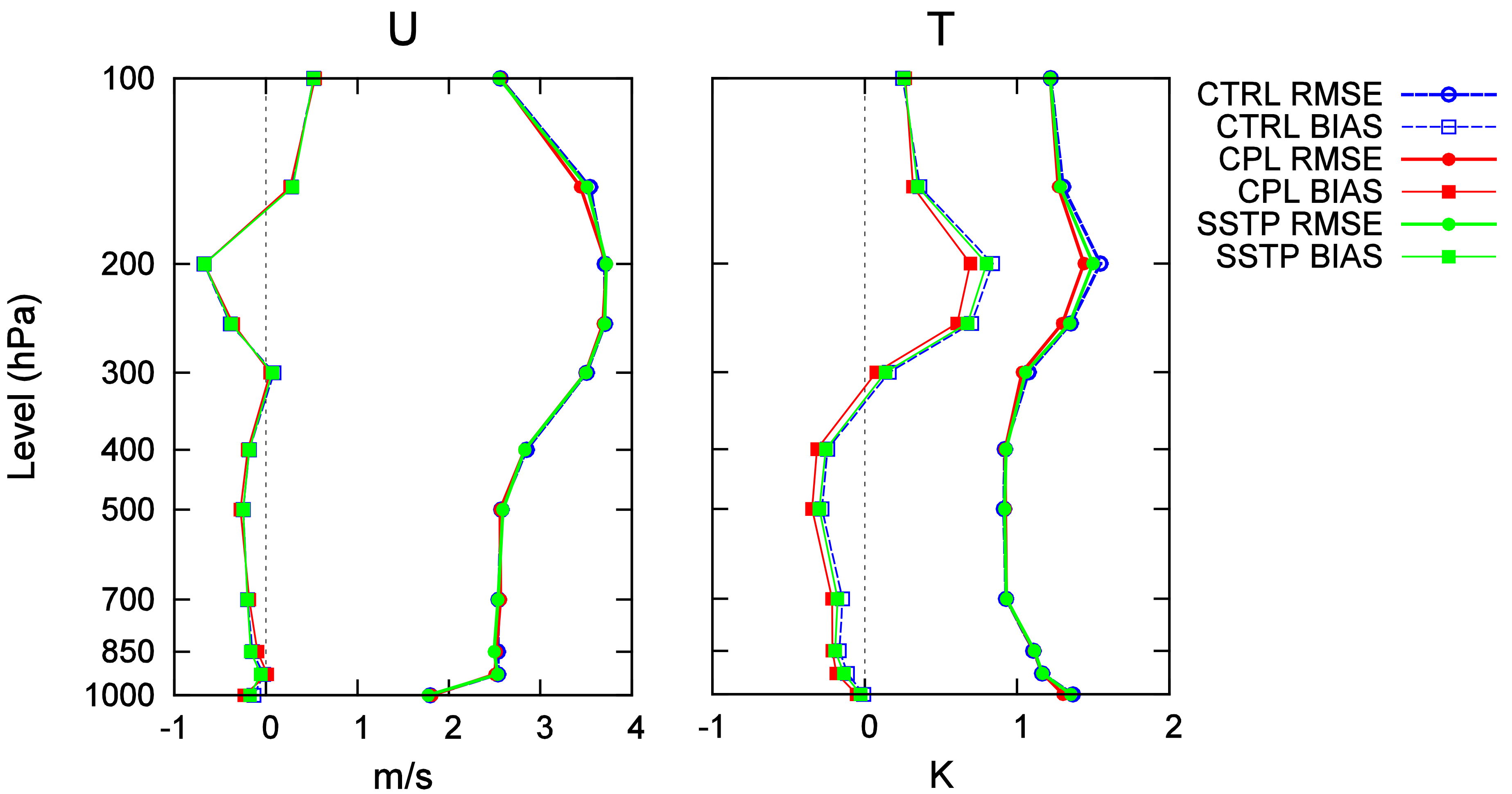
Error covariance structure

Error covariance structure for low-level temperature (T975)



- The CTRL and CPL experiments show similar structures of error correlations.
- In SSTP, the estimated error correlations have significantly broader structures due to the spatially and temporally larger correlation scales of the SST perturbation fields.

Verifications of the first guess



Summary

- The impact of time-dependent SST uncertainties was evaluated by developing the EnKF with the atmosphere-ocean coupled model.
- Brute application of the coupled model in the EnKF caused negative bias of the SST estimates, implying the limitation of the 1-D upper ocean model.
- Error covariance in the CTRL and CPL experiments showed similar structures, whereas the perturbations in SSTP broadened the error correlations.
- The impact on extended forecasts is now being evaluated.