Atmosphere-Ocean Coupling in the Korean Integrated Model

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1 Introduction

- The ocean plays an important role in controlling momentum, heat, and moisture fluxes at the air-sea interface. Although oceans are generally slow-responsive due to their large heat capacity, the upper ocean can change rapidly responding to high-frequency atmospheric forcing and re-affect the atmosphere. Thus the importance of **coupling between the atmosphere and ocean** has been emphasized for better predictability on time scales of hours to weeks.
- **Atmosphere-Ocean coupling** has been therefore developed **in the framework of the operational Korean Integrated Model (KIM)** to improve the extended-range predictability.
- This study examined the impact of ocean coupling on medium-range forecast and seasonal ensemble prediction through a comparison of the coupled and uncoupled forecasts against analysis datasets.

2 Coupling method of Atmosphere-Ocean

Atmosphere model

KIM[1] v3.7 ATM
[NE180/L91(Medium-range) or NE090/L91(Seasonal)]

Atmosphere → Ocean

Downward SW/LW radiative fluxes

Air temperature/ specific humidity/wind at the 1st layer height

Sea level pressure, Precipitation, Snow

MCT[3]-based Coupler

Sea surface temperature

SI[3](Sea-ice temperature/ Concentration/depth)

Ocean → Atmosphere

Hourly interacting

About 20% increase in wall clock time

NEMO[2] v4.0
[Tripolar grid ORCA025/L75]

Ocean model

1) Korean Integrated Model
2) Nucleus for European Modelling of the Ocean
3) Model Coupling Toolkit

3 Improvement of the coupling

Bulk formula

Refining to be consistent between the models by unifying C_m, C_h, C_q, and z_{0m}

$$\tau = \rho C_P \boldsymbol{C_m} U U_z \qquad H_0 = -\rho C_P \boldsymbol{C_t} U(\theta_s - \theta_z) \qquad E_0 = -\rho L \boldsymbol{C_q} U(q_s - q_z)$$

$$C_m = k^2 \left[ln\left(\frac{z}{\boldsymbol{z_{0m}}}\right) - \varphi_m \right]^{-2} \qquad C_t = k^2 \left[ln\left(\frac{z}{z_{0m}}\right) - \varphi_m \right]^{-1} \left[ln\left(\frac{z}{z_{0t}}\right) - \varphi_t \right]^{-1} \qquad C_q = k^2 \left[ln\left(\frac{z}{z_{0m}}\right) - \varphi_m \right]^{-1} \left[ln\left(\frac{z}{z_{0q}}\right) - \varphi_q \right]^{-1}$$

Thermal roughness length

Replacing with the parameterization dependent on the roughness length scale

COARE3.0: $z_{0t} = 5.5\text{x}10^{-5} Re^{-0.6}$ ⇒ **B-G:** $\boldsymbol{z_{0t}} = z_{0m} \exp(-2.67 Re^{0.25} + 2.57)$

Skin sea surface temperature (skin SST)

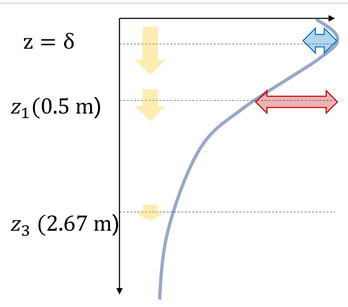
Including the schemes of cool-skin and warm layers to simulate skin SST (T_s)

1) Cool-skin layer: caused by non-solar heat flux

- A02 which includes the relaxation timescale as the function of the wind intensity

$$\Delta T_c = \frac{Q\delta}{k}, \quad \delta = \frac{\lambda \nu}{u_*},$$

$$\lambda = \frac{u_* k C}{\Upsilon \rho_w c_w h \nu}, \quad \Upsilon = \begin{cases} 0.2U + 0.5, & U \le 7.5\ ms^{-1} \\ 1.6U - 10, & 7.5\ ms^{-1} < U < 10\ ms^{-1} \\ 6, & 10\ ms^{-1} < U \end{cases}$$



2) Warm layer: caused by insolation

- T10 with a correction considering the shallowest level of the ocean model

$$\frac{\partial}{\partial t}(T_\delta - T_3) = \frac{(\nu+1)(Q + R(\delta) - R(z_3))}{d\nu\rho_w c_w} - \frac{(\nu+1)\kappa u_w * f(La)}{d\phi_t(\zeta)}(T_\delta - T_3)$$

$$\Delta T_w = T_\delta - T_1 = \begin{cases} (T_\delta - T_3) - (T_1 - T_3), & T_\delta - T_3 > T_1 - T_3 \\ 0., & T_\delta - T_3 \le T_1 - T_3 \end{cases}$$

$$\boldsymbol{T_s} = T_1 + \Delta T_c + \Delta T_w$$

** A02: Artale et al. 2002*
T10: Takaya et al. 2010

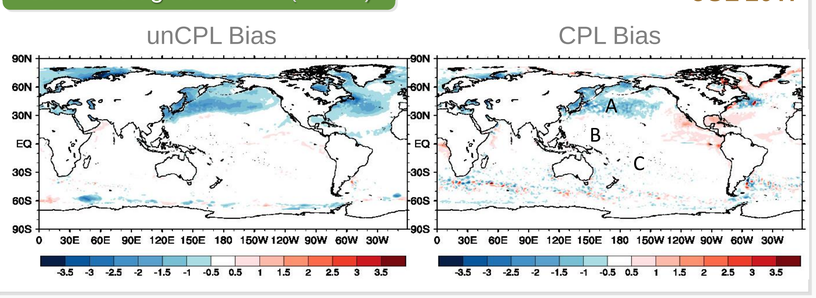
4 Results

Medium-range forecast

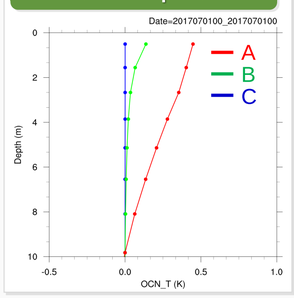
Reproducing the temperature profile of the upper ocean under the various atmospheric conditions by the coupled model

⇨ **Alleviation of the cold bias in the simulated SST** during the boreal summer

SST Bias aginst OSTIA (+240hr) — JUL 2017

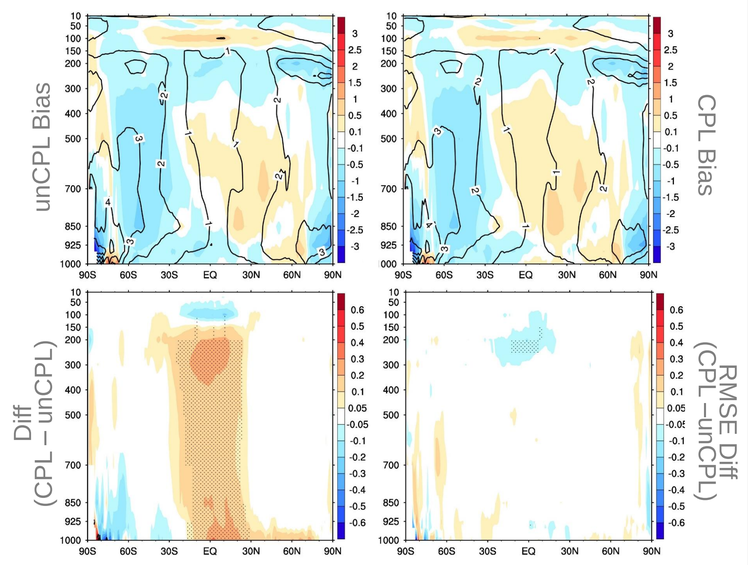


Ocean Temperature

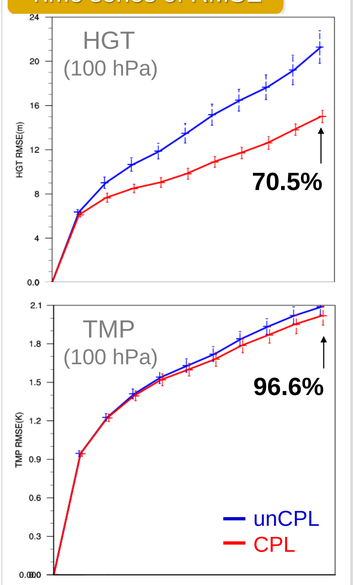


Improvement of simulated temperature in the tropical upper atmosphere

TMP Bias against IFS anal (+120hr)



Time series of RMSE

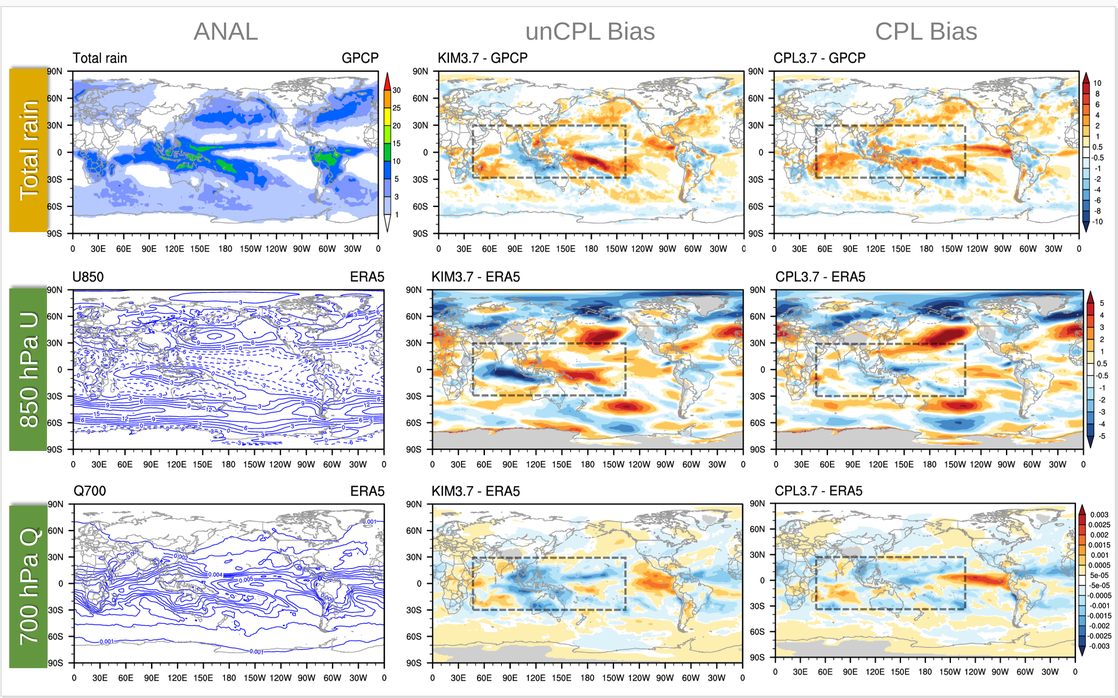


Seasonal prediction

Simulating moisture convergence near the maritime continents

⇨ **Alleviation of the cold bias in the simulated SST**

DJF 2016



5 Conclusions

- **The ocean model, NEMO, was successfully coupled to the operational KIM by means of MCT-based coupler.**
- **To elaborate the coupling technique and improve the physical processes, some modifications were applied**; 1) Ensuring the consistency of the bulk formula, 2) Modifying the parameterization of a thermal roughness length scale and 3) Appling the parameterizations of the cool-skin and warm layers for skin SST.
- For the medium-range forecast, **the coupled model decreased the cold bias in the tropical upper atmosphere layers**, compared to the uncoupled model, by reproducing a thermal structure of the upper ocean.
- For the seasonal prediction, **the model alleviated the bias of precipitation** by simulating the **moisture convergence near the maritime continent** in the western Pacific, the detailed mechanism will be investigated as a further study.

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