Assessing the Influence of Surface Wind Waves to the Global Climate by Incorporating WAVEWATCH III in CESM

Qing Li[1] (qing_li_1@brown.edu), Baylor Fox-Kemper[1], Todd Arbetter[1], Adrean Webb[2]
1.Brown University, USA; 2. Tokyo University of Marine Science and Technology, Japan

Introduction

Surface wind waves influence the climate through variety of processes at the interface between ocean and atmosphere. Langmuir Mixing is one important process but currently not included in almost all climate models. This work focuses on the effects of its roles in deepening the mixed layer depth (MLD), as a first stage toward including the surface wind wave effects in CESM and exploring their influences to the global climate.

Methods

- WAVEWATCH III (WW3) running as a component of CESM.
- Ocean and wave only with Large and Yeager Normal Year forcing.
- Surface Stokes drift $u_s(0)$ and turbulent Langmuir number La_t are directly calculated in WW3.

$$La_t^2 = |u_*| / |u_s(0)| \qquad (1)$$

- La_t is then passed back to the ocean model to update K-Profile Parameterization (KPP) using different schemes.
- Experiments for comparison:
  - **CTRL**: No Langmuir Mixing effects included.
  - **MS2K**: KPP updated according to McWilliams and Sullivan (2000) by applying an enhancement factor to the turbulent velocity scale.

$$W = \frac{k u_*}{\Phi} \epsilon \qquad (2)$$

$$\epsilon = \sqrt{(1 + 0.08\, La_t^{-4})} \qquad (3)$$

  - **VR12a**: The misalignment of wind and waves is considered according to Von Roekel et al. (2012).

$$La_{proj}^2 = \frac{|u_*| \cos\alpha}{|u_s(0)| \cos(\theta_{ww} - \alpha)} \qquad (4)$$

$$\alpha \approx \tan^{-1}\left[\frac{\sin\theta_{ww}}{\frac{u_*}{u_s(0)\kappa}\ln(|H_{ML}/z_1|) + \cos\theta_{ww}}\right] \qquad (5)$$

$$\epsilon = |\cos\alpha| \sqrt{(1 + (3.1\, La_{proj})^{-2} + (5.4\, La_{proj})^{-4})} \qquad (6)$$

where α is the angle between wind and LC direction and θ_{ww} is the angle between wind and Stokes drift. Here the mixed layer depth H_{ML} is simply taken as a constant of the global mean value (65 m) and z_1 is taken as four times the significant wave height. The aligned case ($\theta_{ww} = 0$) is tested first.

  - **OBS**: IFREMER Mixed Layer Depth climatology (de Boyer Montégut et al., 2004).
- gx3v7 resolution for the ocean and a 4 x 3.6 deg resolution for the wave. The average over the last 10 years of 40-year run for each case are analyzed.

Results

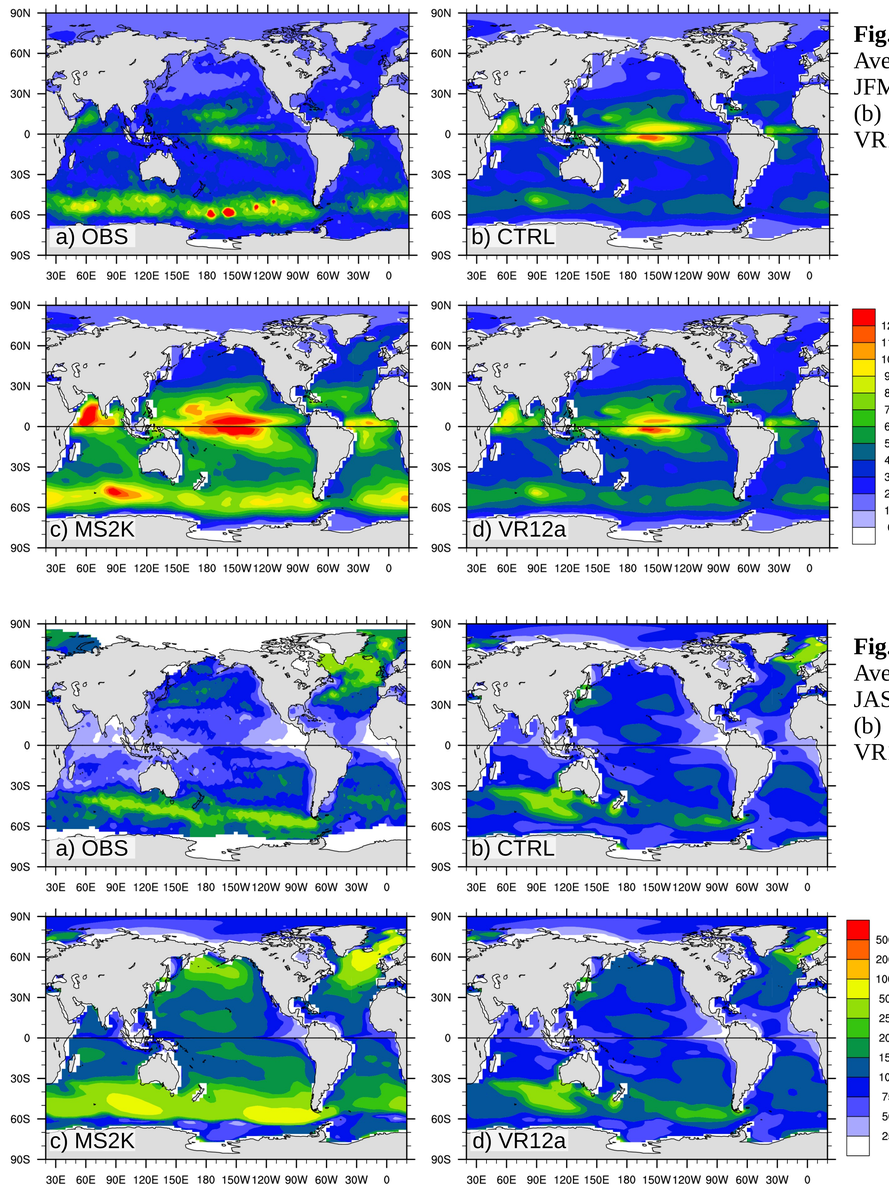

Fig. 1. Summer mean MLD (m; Averaged over JAS for NH and JFM for SH) for cases (a) OBS, (b) CTRL, (c) MS2K and (d) VR12a.

RMSE (m)	Global	90°S-30°S
CTRL	14.94	20.53
MS2K	25.95	20.56
VR12a	14.92	16.67

Fig. 2. Winter mean MLD (m; Averaged over JFM for NH and JAS for SH) for cases (a) OBS, (b) CTRL, (c) MS2K and (d) VR12a.

RMSE (m)	Global	90°S-30°S
CTRL	59.57	63.46
MS2K	135.55	184.87
VR12a	54.86	53.93

References

Belcher, S. E. and Coauthors, 2012: A global perspective on Langmuir turbulence in the ocean surface boundary layer. Geophys. Res. Lett., 39, L18605.
de Boyer Montégut, C., 2004: Mixed layer depth over the global ocean: An examination of profile data and a profile-based climatology. J. Geophys. Res., 109, C12003.
Large, W. G., J. C. McWilliams, and S. C. Doney, 1994: Oceanic vertical mixing: A review and a model with a nonlocal boundary layer parameterization. Rev. Geophys., 32, 363–403.
McWilliams, J. C., and P. P. Sullivan, 2000: Vertical mixing by Langmuir Circulations. Spill Sci. Technol. Bull., 6, 225–237.
Van Roekel, L. P., P. P. Sullivan, P. E. Hamlington, and S. R. Haney, 2012: The form and orientation of Langmuir cells for misaligned winds and waves. J. Geophys. Res., 117, C05001.