TheoryWaves in CESM3

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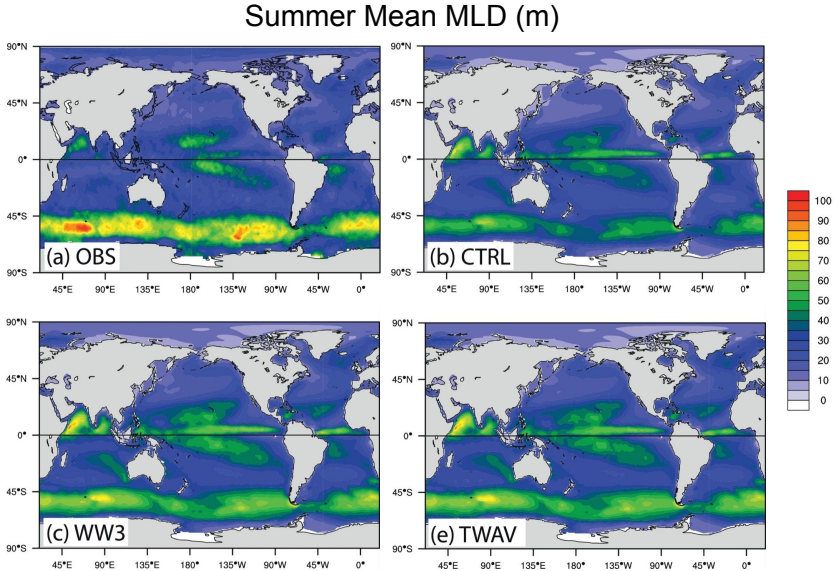
BROWN

Theory Waves

Theory Waves (Li et al, 2016, 2017)

- Approximation of Langmuir turbulence enhancement factor (ε) based on Stokes drift profile from an empirical wave spectrum
- Reproduces much of the effect of Langmuir mixing at a fraction of the computational cost of prognostic wave models
- Wind-sea only (no swell)
- Input: U_{10}, τ_a, and H_{BL}
- Output: ε, $u^s_{SL,}$ La_{SL}, v^s, k_{Phil}, h_{mo}, f_p, f_m



Li et al. (2017)

Li, Q., Fox-Kemper, B., Breivik, Ø., Webb, A., 2017. Statistical models of global Langmuir mixing. Ocean Model. 113, 95-114.

Theory Waves

$$u_0^S \approx 0.016 U_{10},$$
$$V^S \approx 2.67 \times 10^{-5} g U_{10}^3,$$
$$k_p \approx 0.176 \frac{u_0^S}{V^S},$$
$$k_p^* = 2.56 k_p,$$
$$H_{SL} = H_{BL}/5,$$
$$T_1(k,z) = e^{2kz},$$
$$T_2(k,z) = \sqrt{2\pi k|z|}\,\mathrm{erfc}\left(\sqrt{2k|z|}\right),$$

$$u_{SL}^S \approx u_0^S \Bigg\{ 0.715 + \left(\frac{0.151}{k_p H_{SL}} - 0.840\right)[1 - T_1(k_p, H_{SL})] - \left(0.840 + \frac{0.0591}{k_p H_{SL}}\right) T_2(k_p, H_{SL}) + \left(\frac{0.0632}{k_p^* H_{SL}} + 0.125\right)\left[1 - T_1(k_p^*, H_{SL})\right] + \left(0.125 + \frac{0.0946}{k_p^* H_{SL}}\right) T_2(k_p^*, H_{SL}) \Bigg\},$$

$$La_{SL} = \sqrt{\frac{u^*}{u_{SL}^S}},$$
$$\mathcal{E} = \sqrt{1 + (1.5 La_{SL})^{-2} + (5.4 La_{SL})^{-4}}.$$

Li, Q., Fox-Kemper, B., Breivik, Ø., Webb, A., 2017. Statistical models of global Langmuir mixing. Ocean Model. 113, 95-114.

Theory Waves

Goal

Implement TheoryWaves as a component within CESM

- low-cost alternative to WaveWatchIII
- useful in cases where it is important to account for Langmuir mixing

Approach

Drop-in replacement for WaveWatchIII component in CESM

- built using dev/unified_0.0.13 tag of WW3
- To use, just point to ww3 submodule in CESM .gitmodule file to TW interface repo
- wind stress from coupler (Fwxx_taux and Fwxx_tauy)
- Fill values passed to coupler/history files if variable is not calculated
  - wave elevation spectrum, partitioned Stokes drift

Theory Waves

Test Case

CESM tag: cesm3_0_alpha06b

Compset (g):

2000_DATM%JRA-1p4-2018_SLND_CICE_MOM6_DROF%JRA-1p4-2018_SGLC_WW3_SESP

Grid: TL319_t232_wg37

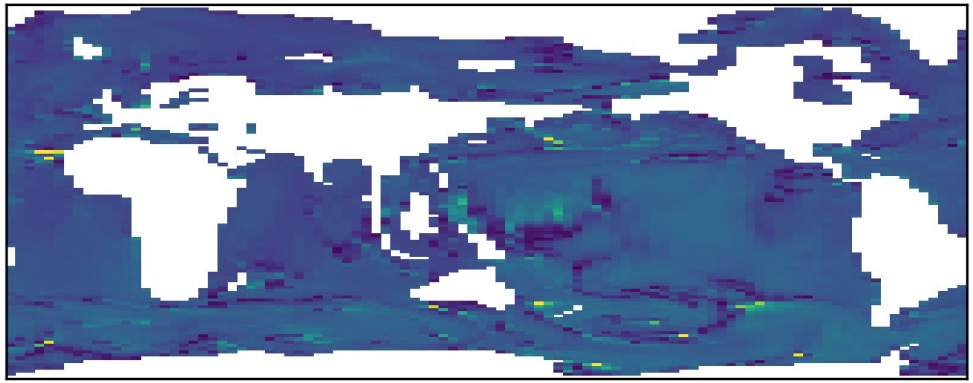
Wave Method: EFACTOR

Langmuir Turbulence VT2 Method: VR12 (van Roekel et al., 2012, Li et al., 2016)

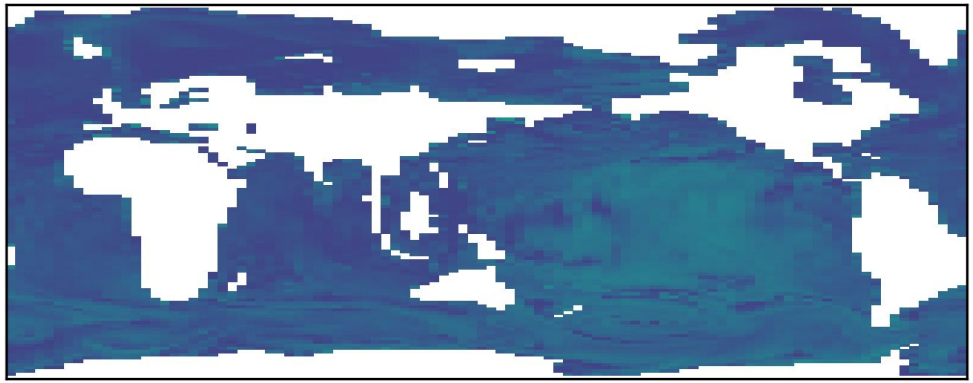
Duration: 20 years

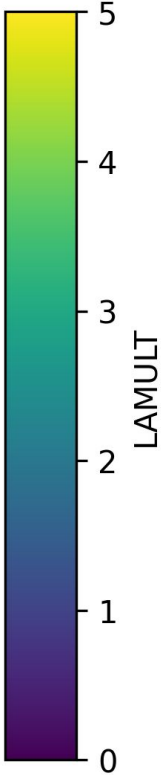
Langmuir Multiplier (LAMULT)

WaveWatchIII

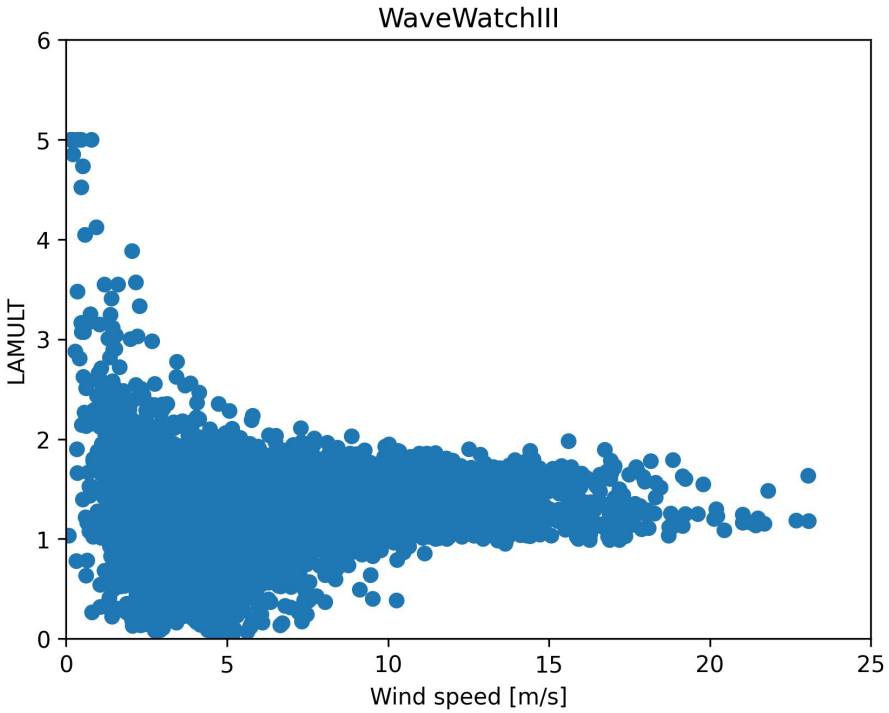


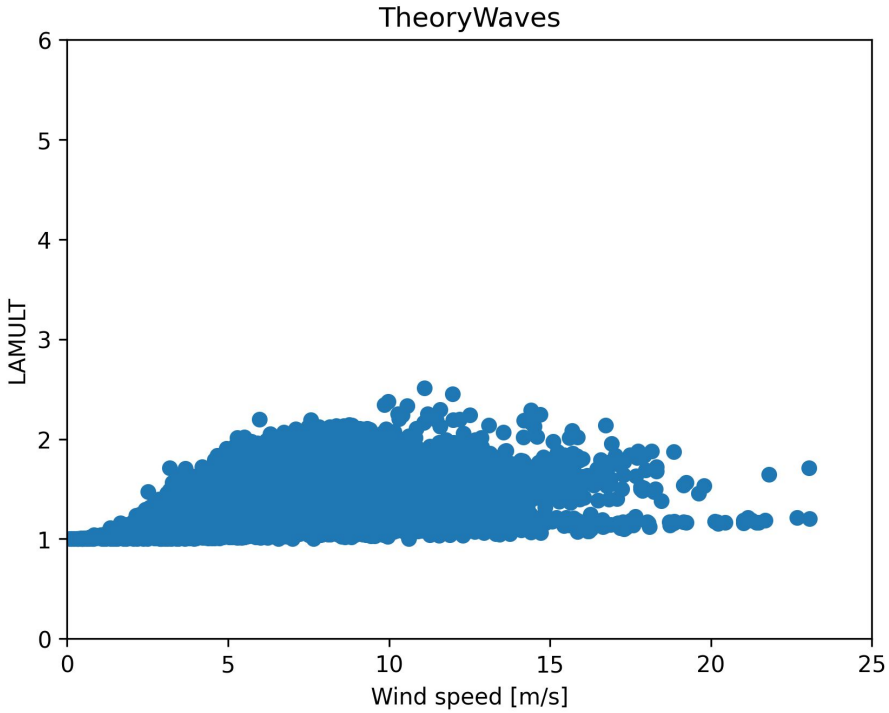
TheoryWaves





Langmuir Multiplier (LAMULT)





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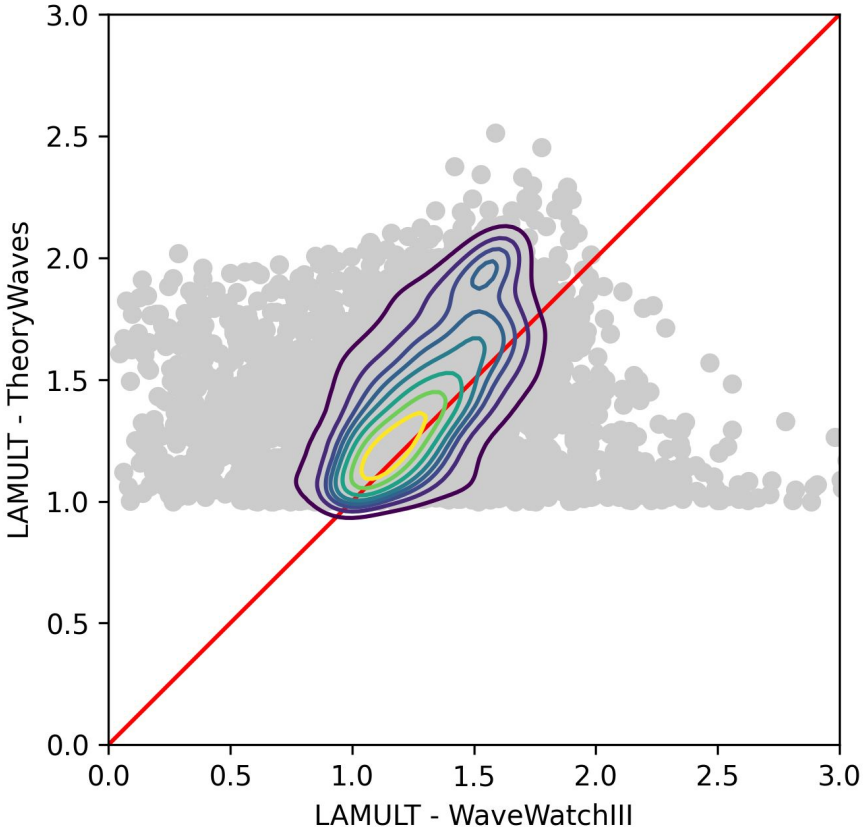
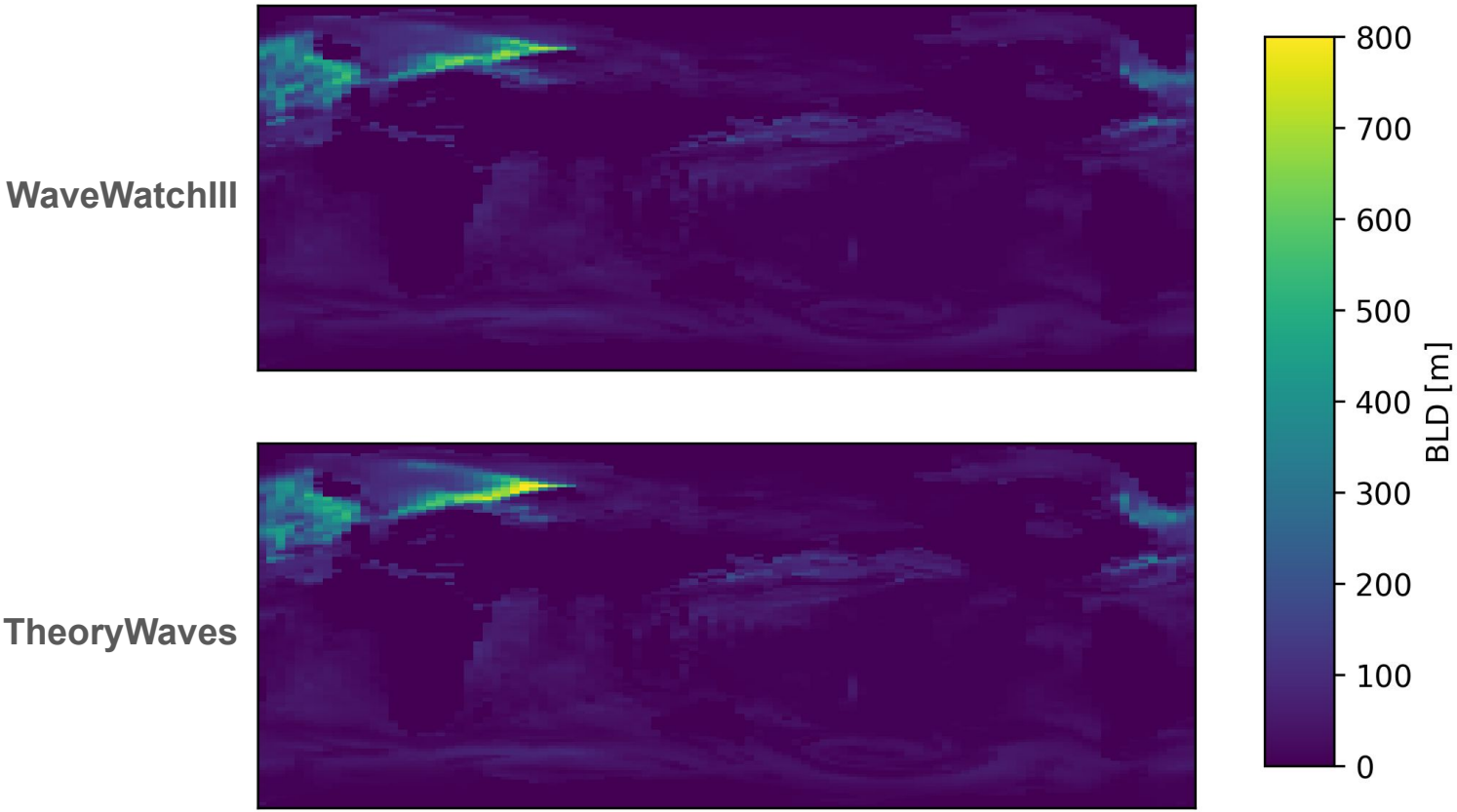


Boundary Layer Depth (BLD)



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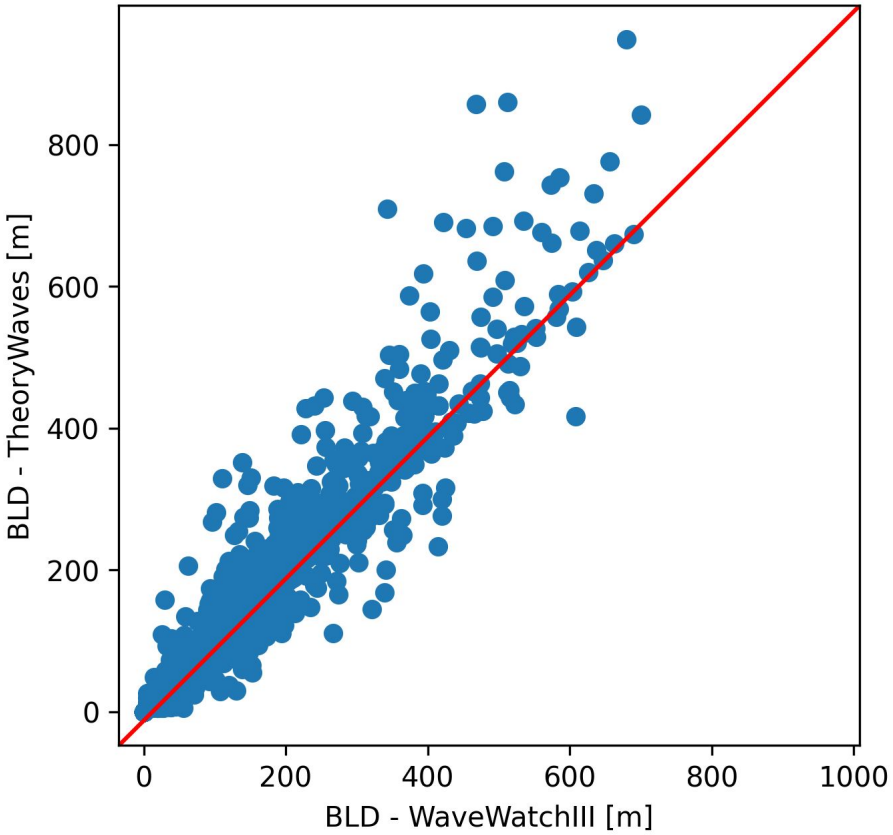
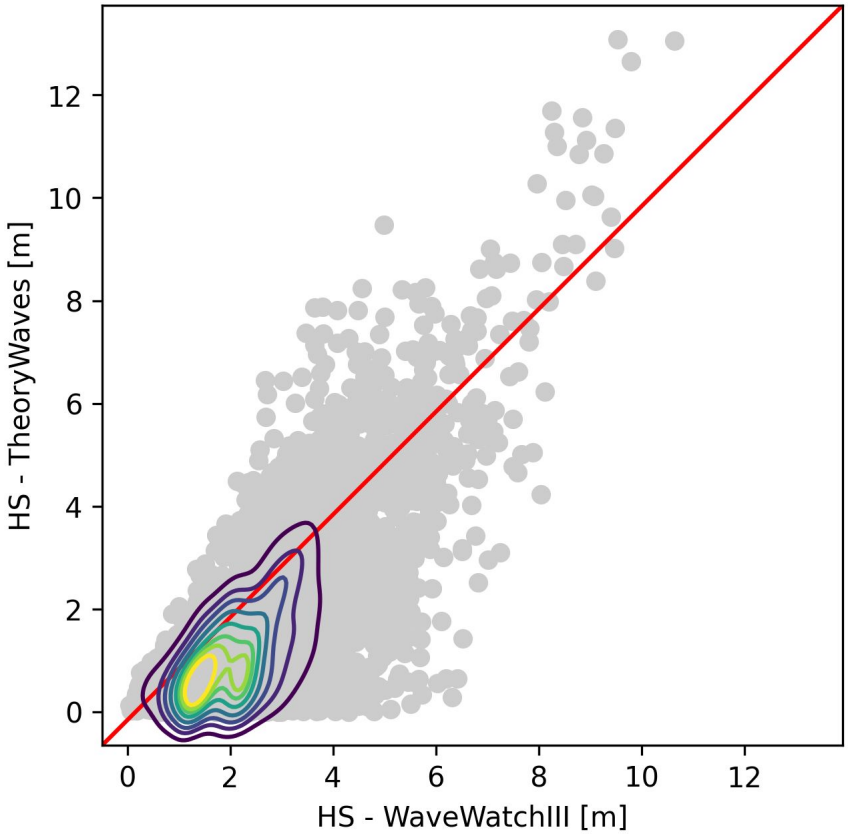


Significant Wave Height (HS)



Theory Waves

Conclusions

TheoryWaves reproduces the general patterns of LAMULT, BLD seen with WaveWatchIII

TheoryWaves provides faster performance than WaveWatchIII

- Test case: 41% decrease in wave component run time (4727 s vs. 2750 s)
- Anticipate further significant improvements with refactoring

Future: interchangeability with PiCLES, WaveWatchIII, TheoryWaves in CESM

Questions

How best to make TheoryWaves available within CESM?

- URL for wave component in .gitmodule? Completely separate component?