Part 1:

Comparing Ocean Boundary Vertical Mixing Schemes with Langmuir Turbulence

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Key Points:

\begin{itemize}
\item Six Langmuir turbulence parameterization schemes (and their non-Langmuir counterparts) are compared in a common single column modeling framework.
\item A suite of test cases of various scenarios are used, including typical global ocean conditions in JRA55-do.
\item Significant discrepancies among schemes are found, and sorted by locations, seasons and forcing regimes.
\end{itemize}
Take Advantage of CVMix & GOTM

- GOTM has time-stepping ability
- CVMix is called through GOTM (versus of CESM/MOM/POP)
- In this way, all GOTM & CVMix parameterizations can be compared in 1D mode without numerical discrepancies.
- JRA55-do and CORE II are used, WaveWatch for waves
- KPP-ROMS, ePBL, OSMOSIS, and Harcourt (2015) scheme ported to GOTM or CVMix for the purpose.
- Furthermore, *actual code* from GCMs & coastal models is the code used, which has identified bugs and missing diagnostic capabilities.
Global JRASS initial profiles from Argo

Following Regime diagnostic approaches from Belcher et al. (2012)

No TRUTH!

Limited LES as truth!
Langmuir, Convection, and their combination are the dominant regimes.

Mixing
w/o
Entrain
Li et al.
2016
(CESM2)

Mixing
&
Refined
Entrain.
Li & FK ’17
(CESM2.3)

Obs.

Control
No
Lang.
(~CESM1)

Early
Entrain
Guess.
Boundary Layer Turbulence:
Regardless of forcing becomes isotropic 3D forward cascade on small enough scales.

Wind-Only

What do Large Eddy Simulations of Wave-Averaged Equations Show?

Langmuir
(Wind & Waves)

Why is entrainment hard?

Hor. Velocity  RMS W  $\langle w_b \rangle$

Depends a lot on shear profile—resolved & unresolved.

Li & F-K (2017) adjust unresolved shear to arrive at LES-consistent entrainment


Present CESM2
Li et al. (2016)

Potential CESM2.3
Li & BFK (2017)

GFDL Scheme
Reichl & Li (2019)

January

Percentage change from non-Langmuir to Langmuir Partner

January

July
Change of MLD vs. non-Langmuir multi-scheme avg.

Observations provide truth, but only if 3D effects included...
So use deviations from KPP-CVMix as control

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LES provides truth, but Extant LES don’t cover everything...

KPP-LF17 (CESM2.3) & ePBL-LT (CMIP6) are the best versus LES tested.
Time-step and vertical resolution sensitivity

Building on recent diagnostic approaches from Van Roekel et al. (2018) and Reichl & Halberg (2018)
Conclusions

- A parameterization inter-comparison approach, similar to CORE/MIP with unified numerics & idealized to realistic forcing.

- Not all schemes are in all GCMs, thus we emphasize calling-model independent results.

- Li & F-K (2017) and ePBL-LT (Reichl & Li, 2019) are closest to LES & often agree. Li & F-K (2017) is NOT in CESM yet.

- In general, Langmuir schemes are deeper than their non-Langmuir partners.

- JRA55-do vs. CORE II differences are greater than inter-scheme differences.

- Langmuir schemes have greater inter-scheme spread than non-Langmuir.

- All code will be shared, including all parameterizations, test cases, GOTM & CVMix stable versions (upgrades elsewhere not to affect), so that later revisits can occur easily.
Part 2: Infrastructure for Waves in CESM—WaveWatch, NUOPC, Waves in Sea Ice

- Waves in climate beyond Langmuir needs more than just Stokes drift

- Wave-sea ice interactions in Marginal Ice Zone
  - Floe Size Distribution affects Waves
  - Waves fracture flows, affect Floe Size Distribution

- Ice-free and wavy Arctic

- Wave model on same grid (non Lat-Lon, polar cap) matching the ocean model

Sponsors: NSF (OCE 1350795, PHY-1748958: KITP), ONR (N00014-17-1-2963)
Part 2: Infrastructure for Waves in CESM—WaveWatch, NUOPC, Waves in Sea Ice

- Software Improvements:
  - NUOPC (WaveWatch & CESM)

- Speed
  - Slower if wave resolution = ocean, but good for science if not production
  - Can be sped up by coarsening in ice-free regions or total ice (wave-free) regions

- People
  - Helen Kershaw, Chris Horvat & BFK (Brown)
  - C.C. Bitz & Lettie Roach (UW)
  - Mariana Vertenstein (NCAR)
  - Jessica Meixner (NOAA NCEP)
  - Qing Li & L. Van Roekel (LANL)
  - Adrean Webb (Kyoto)

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The relative deepening due to Langmuir, and relative differences among schemes is fairly robust whichever dataset is used.

However, the differences in mean MLD between JRA55-do and CORE-II exceed the interscheme differences.
Comparing all of the KPP-based Langmuir parameterizations.

Enhancement Factor vs. Langmuir Number
Distribution of absolute MLD

Δ

Non-Langmuir
Non-Langmuir
Non-Langmuir
Non-Langmuir

JRA55-do, CORE-II

R

Non-Langmuir
Non-Langmuir
Non-Langmuir
Non-Langmuir

JRA55-do, CORE-II

Distribution of absolute MLD

Non-Langmuir
Non-Langmuir
Non-Langmuir
Non-Langmuir

JRA55-do, CORE-II