The Impact of Including a Wave Model in the Seasonal Forecast System

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Purpose

- Seasonal climate variability impacts people
- Agriculture, snow sports, tourism, and the availability of freshwater[1] all impacted by seasonal variability
- Forecasts of drought, precipitation variability, hurricane seasons, and climate patterns are crucial for decision makers

Background

- The Seasonal Forecast System (SFS) model is currently being developed by the Environmental Modeling Center (EMC)
- The SFS replaces the ~13-year-old Climate Forecast System version 2 (CFSv2)
- Unlike the CFSv2, the SFS could include a fully coupled wave model
- The SFS also hopes to improve on several CFSv2 biases

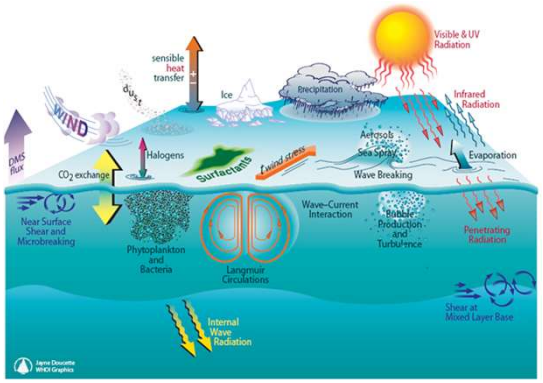


Fig. 1: Some of the interactions occurring between the ocean and atmosphere[2].

- The atmosphere and ocean interact through ocean waves
- Waves influence momentum, mass, and heat transfers[3]
- These interactions are important for both atmospheric and oceanic modeling[4,5]
- Including a coupled wave model has improved the European Center for Medium Range Weather Forecasts (ECMWF) 10-day forecasts[4] and the Rossby Center Regional Climate Model (RCA) 4-year climate simulations[5]
- The wave-atmosphere combination provides useful forecasts to industries and interests impacted by both[4,6]

References and Additional Figures:

Methodology

To test the value of coupling WAVEWATCH III we ran simulations on a developmental version of the SFS:

- With WAVEWATCH III ("waves") and without ("no waves")
- Version without waves parametrizes wave effects
- Ran 11 members for each of 3 initial conditions dates- November 1st of 1997, 2015, and 2020, all El Niño years
- 90-day forecasts
- Output at a 1-degree spatial resolution

Then performed data analysis in Python

- Calculated 11-member ensemble mean
- Plotted monthly comparisons of sea surface temperatures (SSTs), mixed layer depth, and other variables
- Plotted SST biases compared with the OSTIA[7] truth data set

Results

Monthly Sea Surface Temperatures

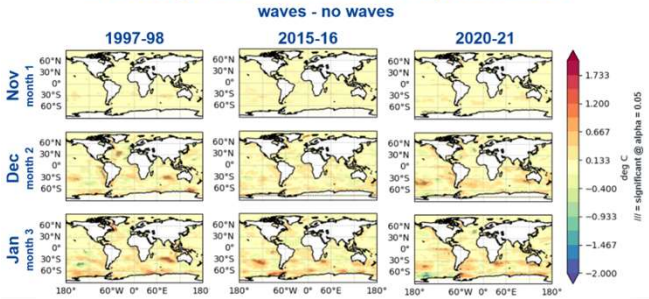


Fig. 2: The difference in monthly SSTs (waves – no waves) for each month (rows) of the three initial condition dates (columns). Statistically significant areas at α = 0.05 are hatched.

Monthly SSTs Compared with OSTIA, 2020

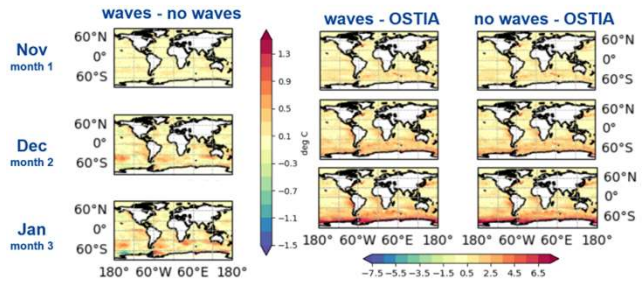


Fig. 3: The difference in monthly SSTs for 2020-21 tests (left) compared to the difference between the wave including run and truth (middle) in 2020-21 and the waveless model and truth (right) in 2020-21.

Results cont'd.

Monthly Ocean Mixed Layer Depth

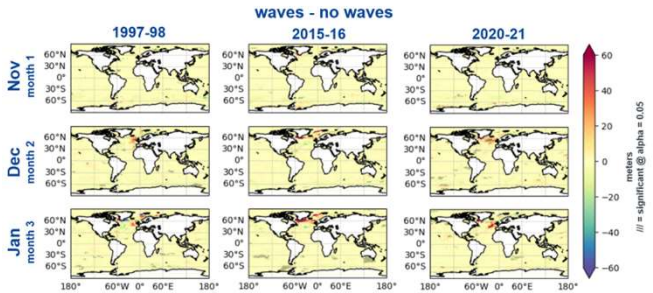


Fig. 4: The difference in ocean mixed layer depth (waves – no waves) for each month (rows) of the three initial condition dates (columns). Statistically significant areas at α = 0.05 are hatched.

- Little variation in SSTs, with some notable significant areas in the ENSO region, east of Australia, and around Antarctica
- Neither configuration performed better compared with OSTIA
- Persistent differences in mixed layer depth in the far North Atlantic- interactions between the ocean and ice models?
- Minimal difference in computational cost:

Configuration	Processors	Runtime (s)
With Waves	434	14,033
Without Waves	414	13,981

Conclusions and Future Work

- Project was a noteworthy step for the NWS- one of the first 90-day ensemble model runs- and faced a lot of unique challenges
- The SFS coupled with WAVEWATCH III did not notably outperform the SFS without the wave model
- Including a wave model came at a small computational cost
- Results possibly consistent with previous ECMWF findings[5] that resolution impacts the value of a coupled wave model
- Further testing should include:
  1. Higher resolution runs, for example at 0.5-degree
  2. More test cases outside of Northern hemisphere winter and El Niño
  3. Comparison with more truth data sets, especially for ocean mixed layer depth

Acknowledgments

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