Implementation of the University of Miami Wave model (UMWM) into the NASA/GMAO Goddard Earth Observing System Model (GEOS)

GMAO
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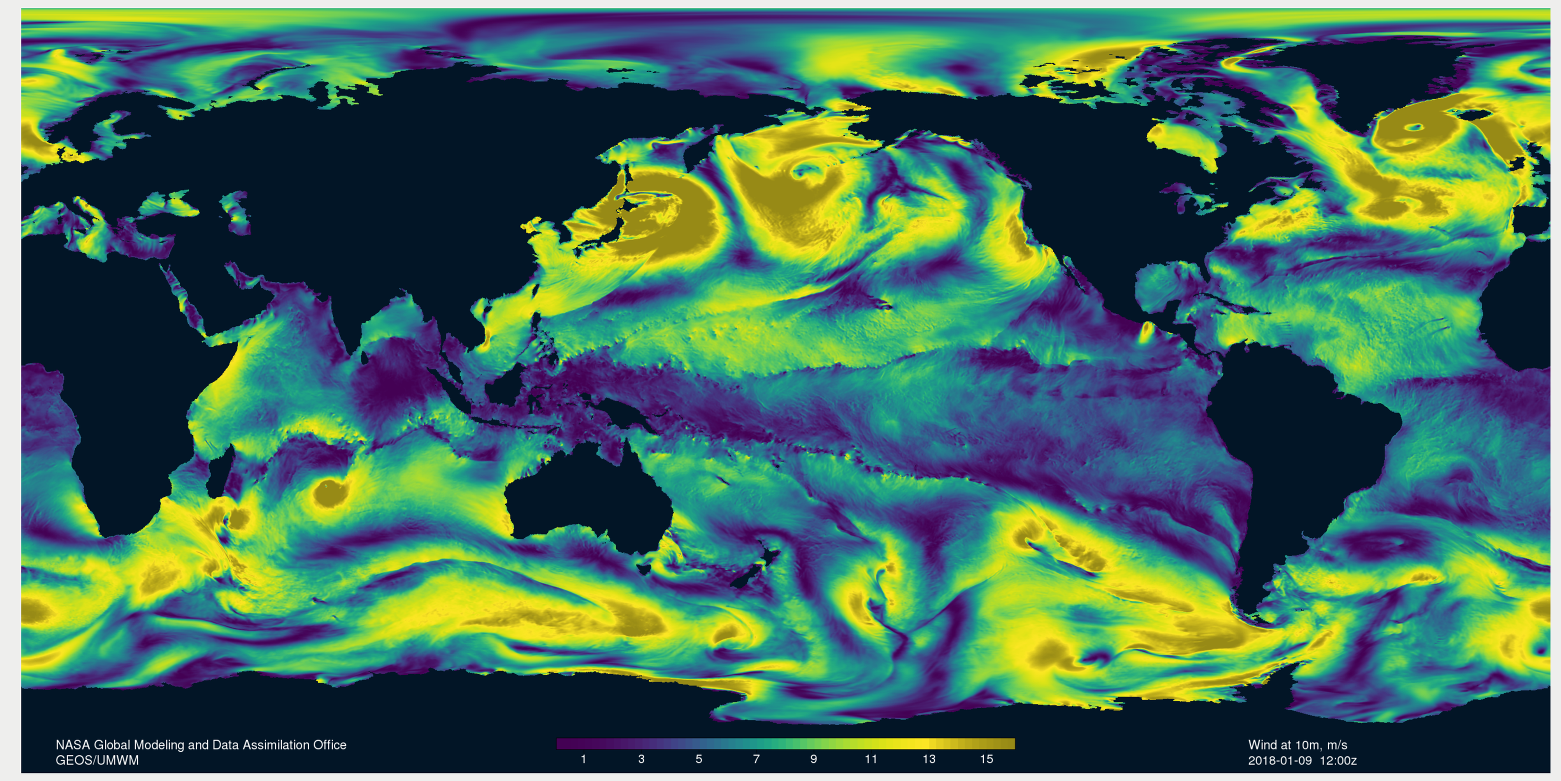
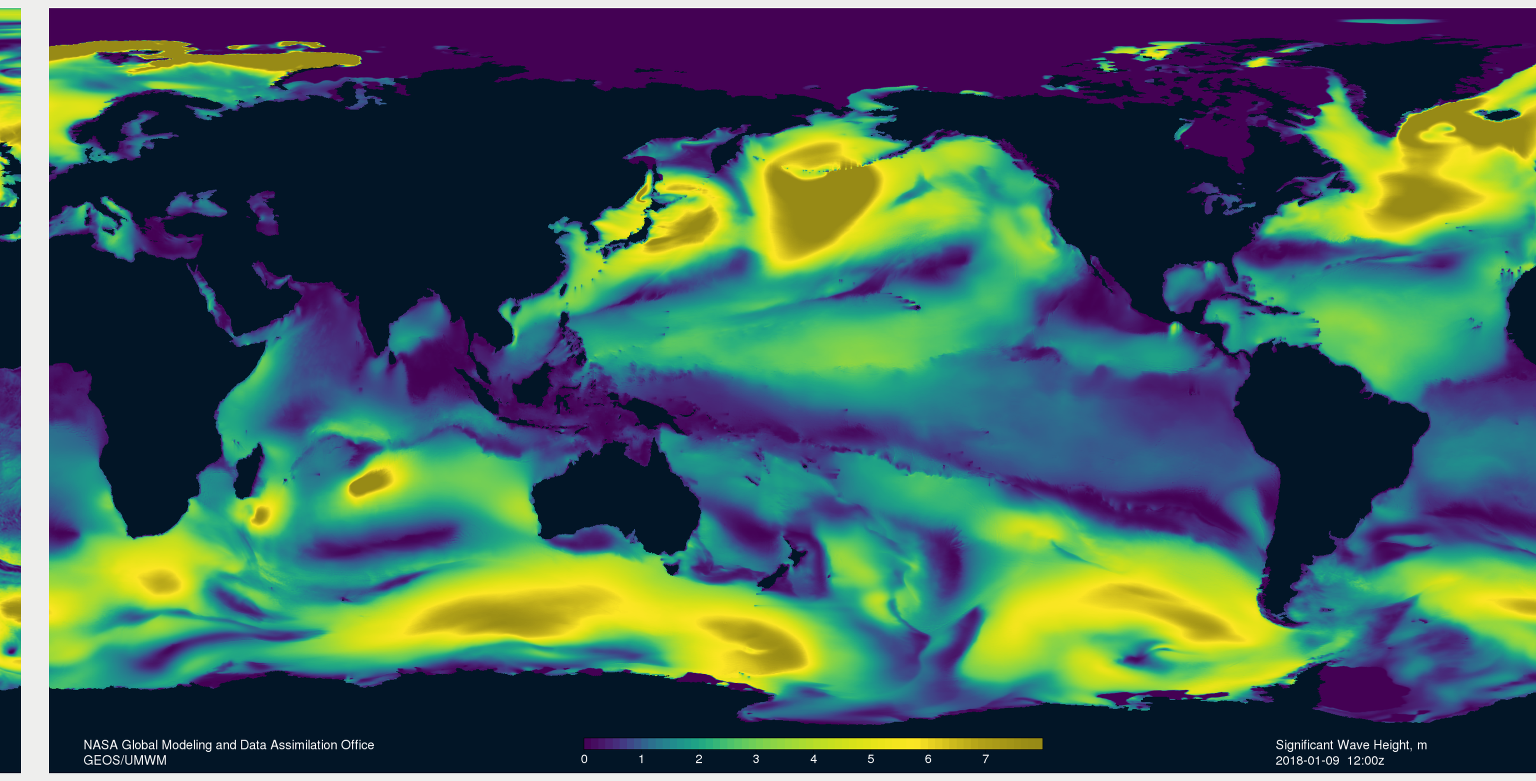
1. Abstract

Wind generated waves are integral element in air-sea interactions and affect exchange of momentum, heat, water, gases and production of marine aerosol. Motivated by the need to resolve the air-sea interface we have implemented the University of Miami Wave model (UMWM) into the NASA/GMAO Goddard Earth Observing System Model (GEOS). The implementation of the wave model in GEOS aimed to facilitate coupling with the atmosphere and ocean model components with minimal changes to the existing system, while at the same time ensure correctness of the predicted wave energy spectrum and wave diagnostics. Here we describe the implementation of the GEOS/UMWM system and show results from model experiments and verifications. This work is a step toward development of a coupled atmosphere-wave-ocean GEOS system.

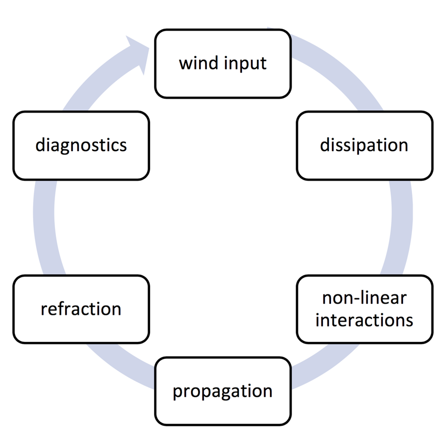




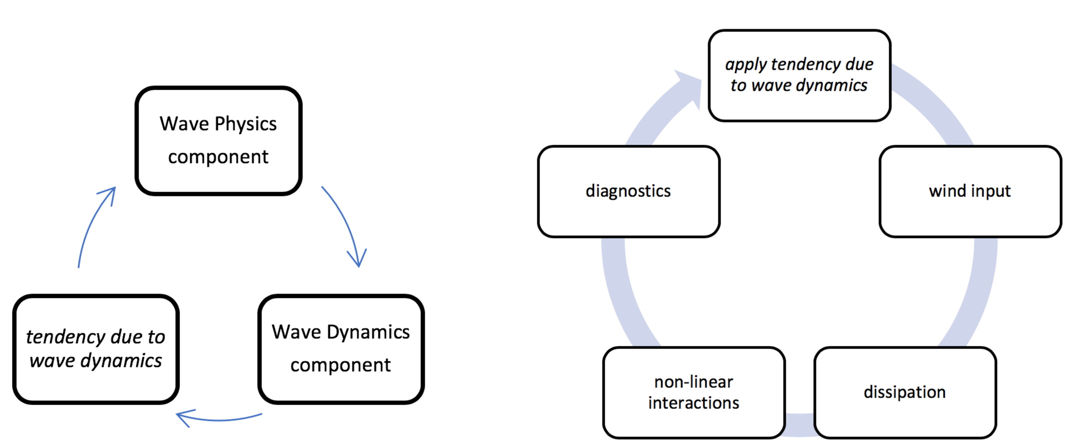
High resolution (13km, C720) global wind-wave simulations with the newly developed GEOS/UMWM system.

2. Implementation of the UMWM wave model in GEOS

The wave model physics (wind input, wave dissipation and non-linear wave interactions) was wrapped into an ESMF gridded component that operates over salt-water tiles and contains the wave model state. The wave model dynamics (propagation and refraction of waves) was wrapped into an ESMF gridded component that operates on the ocean grid. This approach allows the wave model to run on different types of grids and effectively enables 2D decomposition of the global domain and should scale better than the 1D decomposition used in the stand-alone UMWM.



Schematic of the process sequence in the stand-alone wave model.

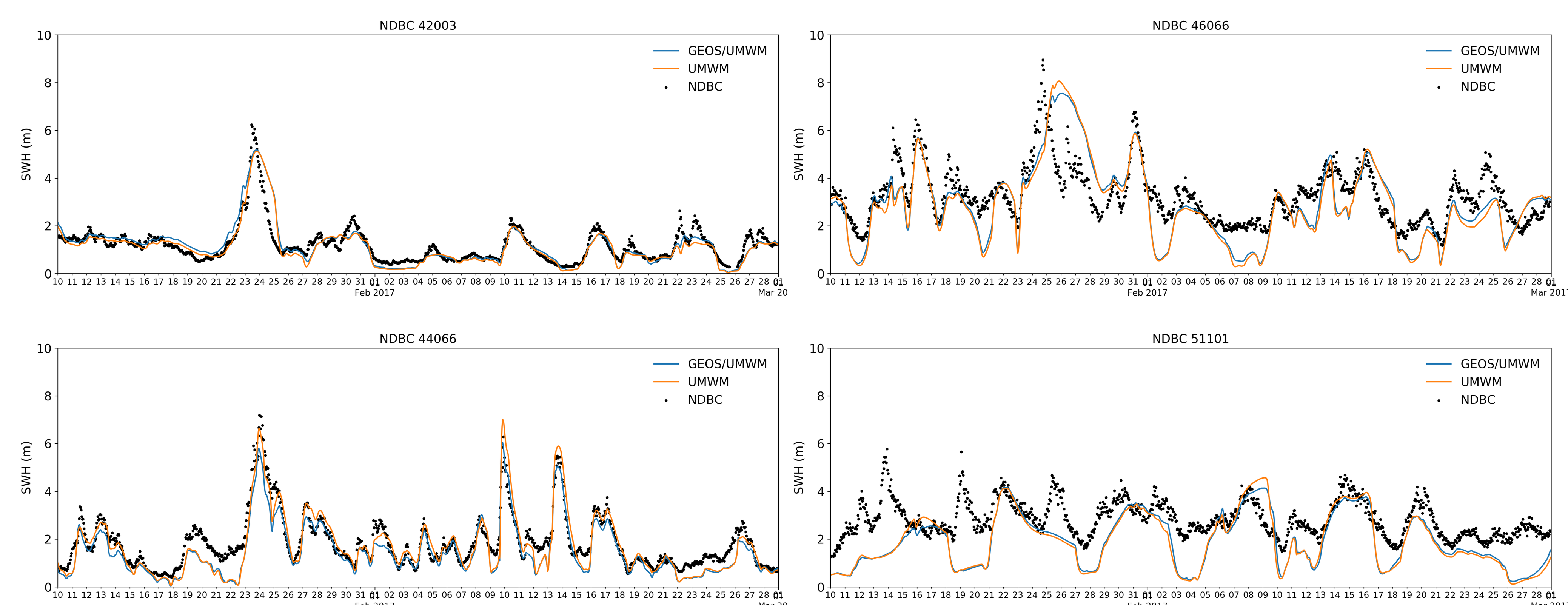


Schematic showing the component and process sequence in the online implementation of the UMWM wave model.

3. Development of a coupled atmosphere-waves-ocean system

- The wave model can be run in as a one-way or two-way coupled component in GEOS.
- Dynamic 2-way coupling between wind and waves follows the quasi-linear theory and approach of Janssen (1991).
- Preliminary results suggest that in the two-way coupled configuration near-surface winds increase globally by 0.3-0.4 m/s and significant wave height increase by 0.25 m when compared to results from the one-way system.
- We have also implemented and tested two sea-state based parameterizations of sea-salt emissions and coupled them with the GOCART aerosol model in GEOS enabling higher order interactions between the waves and atmospheric aerosols and clouds.

4. GEOS/UMWM modeling experiments



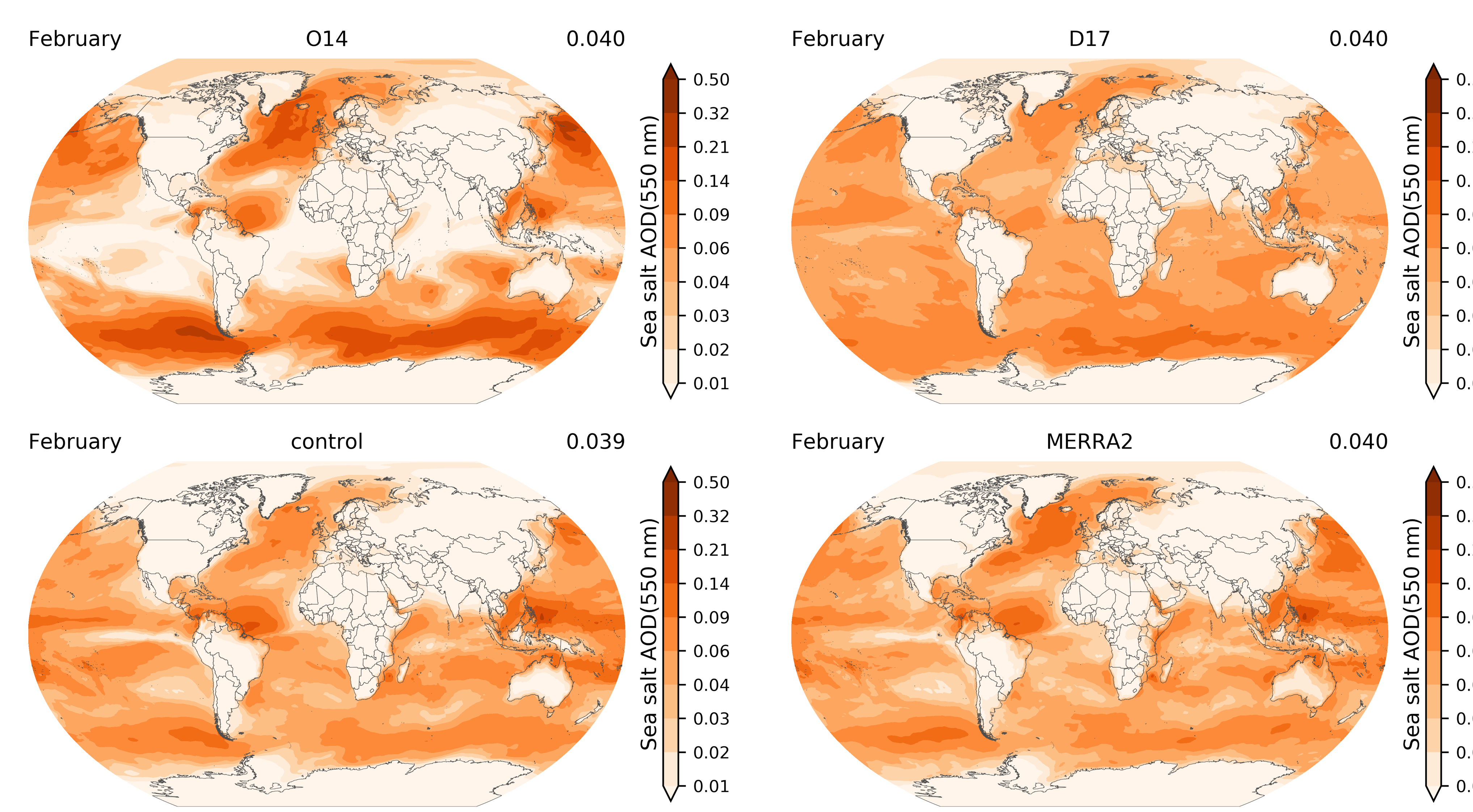
The GEOS/UMWM was run at horizontal resolutions from 50km up to 13km, and with 36 directional bins and 37 wave frequency bins (0.0313Hz - 2Hz). Significant wave height (SWH) in hindcast experiments was found to be in a good agreement with observations from the National Data Buoy Center (NDBC).

Significant wave height at fixed buoy locations from the NDBC network. Shown are SWH from the GEOS/UMWM system, standalone UMWM forced with MERRA2 winds, and reported NDBC values.

The implementation of a wave model in GEOS enables the use of physically based parameterizations of marine aerosol emissions and gas exchange between atmosphere and ocean. We have implemented two sea-state based emissions of sea salt particles:

1. *O14 emission scheme* - based on Ovadnevaite et al. (2014) and Partanen et al. (2014)
2. *D17 emission scheme* - based on Deike et al. (2017) and Anguelova and Hwang (2012, 2016)

Monthly sea salt aerosol optical depth (AOD) in February, 2017 simulated with GOCART using the default/nominal (control) emission scheme in GEOS and the O14 and D17 sea-state based emissions. Also shown is sea salt AOD from the MERRA2 reanalysis.



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