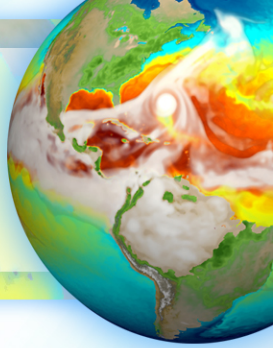
NGD Ocean



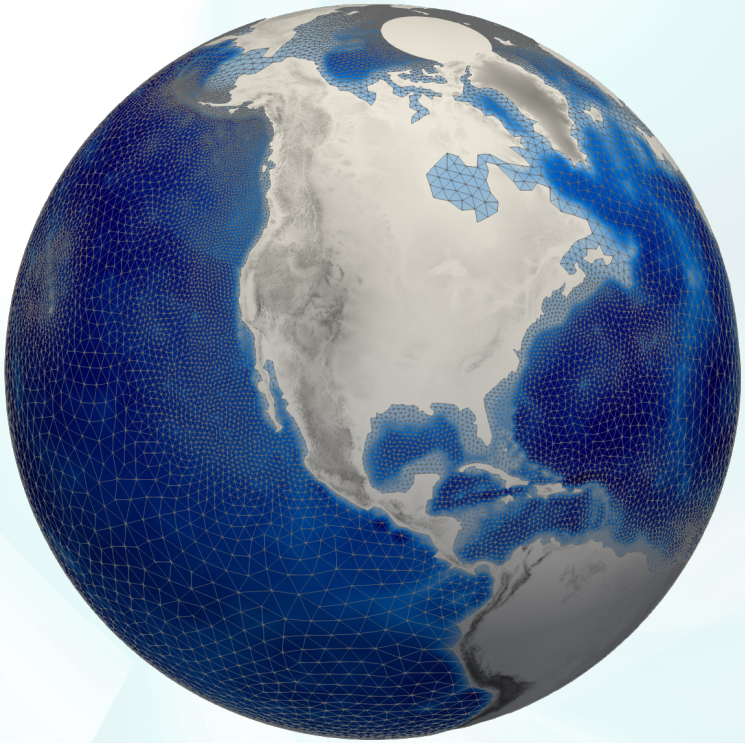
Luke Van Roekel, Steven Brus, Phillip Wolfram

DOE ESMD PI meeting, October 26, 2020

Advancing DOE Science through an Ocean NGD

- **GOAL**: Create the first Earth System Model that can accurately simulate waves from coastal to global oceans for decadal simulations
  - Needs: Create an exascale ready version of WW3, optimized unstructured mesh capability
- **GOAL** : Utilize the unique variable resolution capability in E3SM to improve climate projections of coastal impacts
  - Needs: Understand where high resolution is necessary, create an exacale ready MPAS-Ocean for ultra large ensembles
- **GOAL:** Examine the impact of uncertainty in unresolved ocean physics on fidelity of decadal projections
  - Needs: Improved and scale aware physics parmeterizations, create an exacale ready MPAS-Ocean for ultra large ensembles

Global unstructured WAVEWATCHIII mesh



- Mesh designed to demonstrate accuracy and efficiency of unstructured meshes for wave models

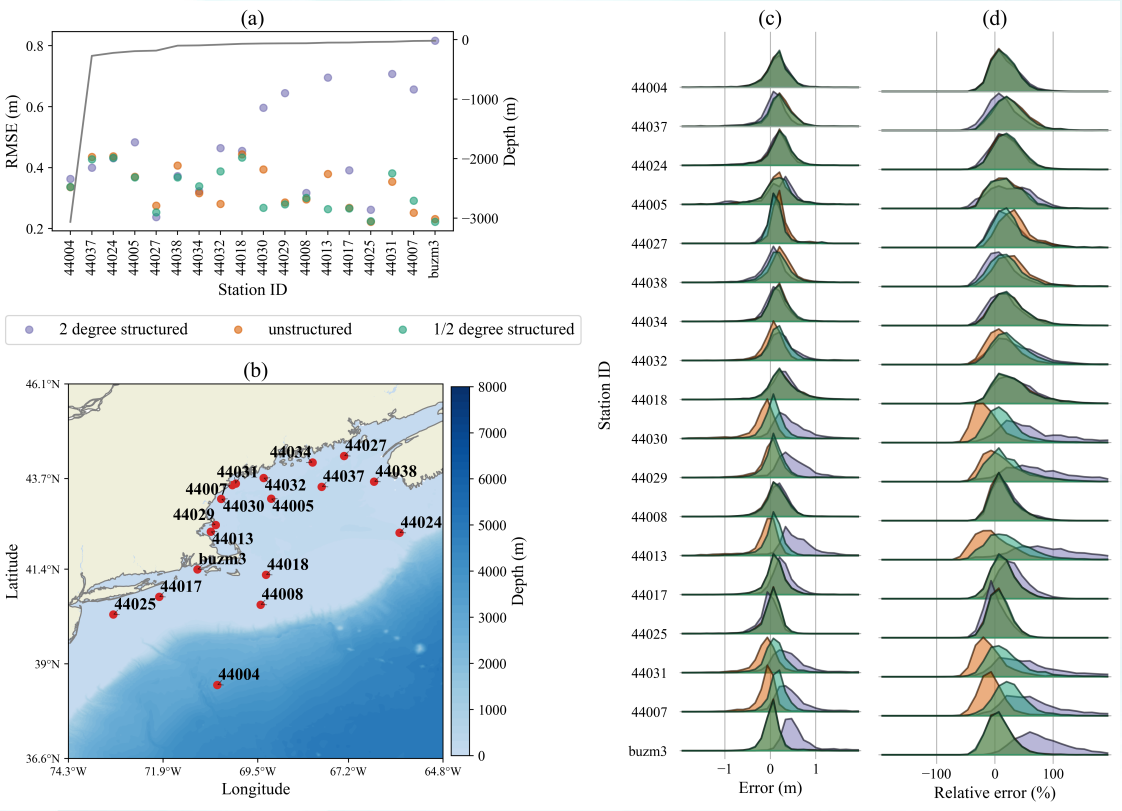
- 2 degree resolution globally
- ½ degree resolution for depths < 4km in U.S. coastal regions

- Unstructured mesh is compared to 2 degree and ½ resolution structured meshes

Mesh	Size
2 degree structured	9,841 cells
Unstructured	16,160 nodes
½ degree structured	160,808 cells

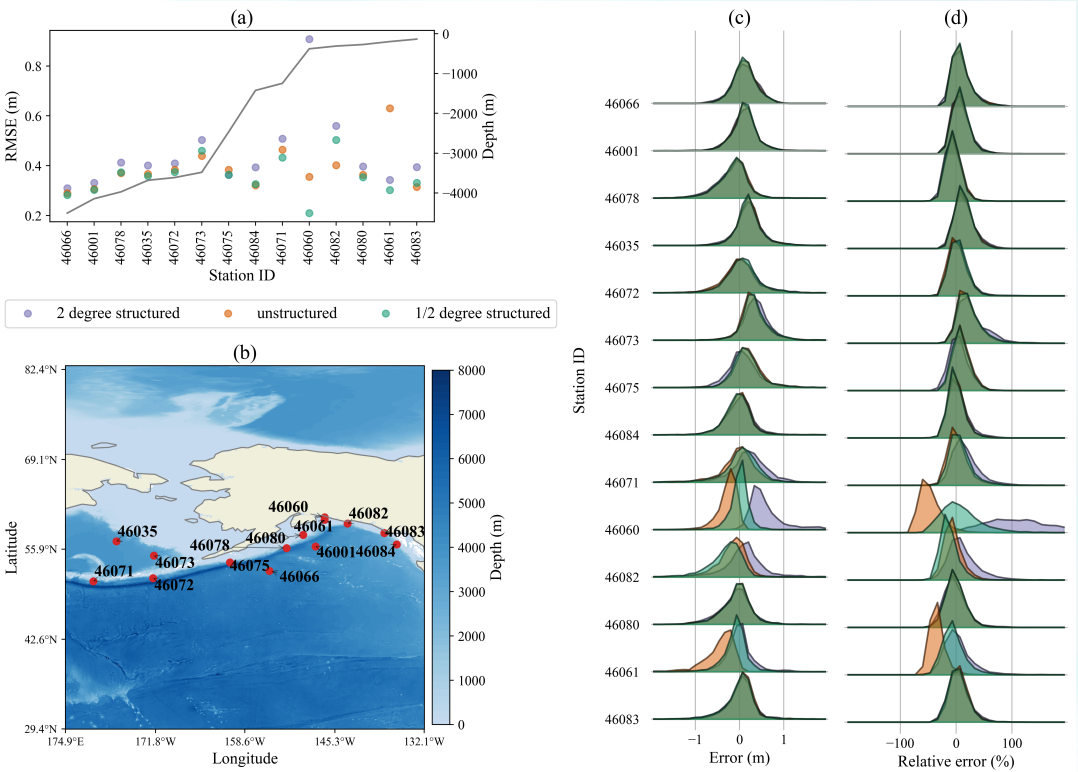
Brus, S.R., Wofram, P.J., Van Roekel, L.P, Meixner, J.D., GMD, Submitted.

Buoy comparisons



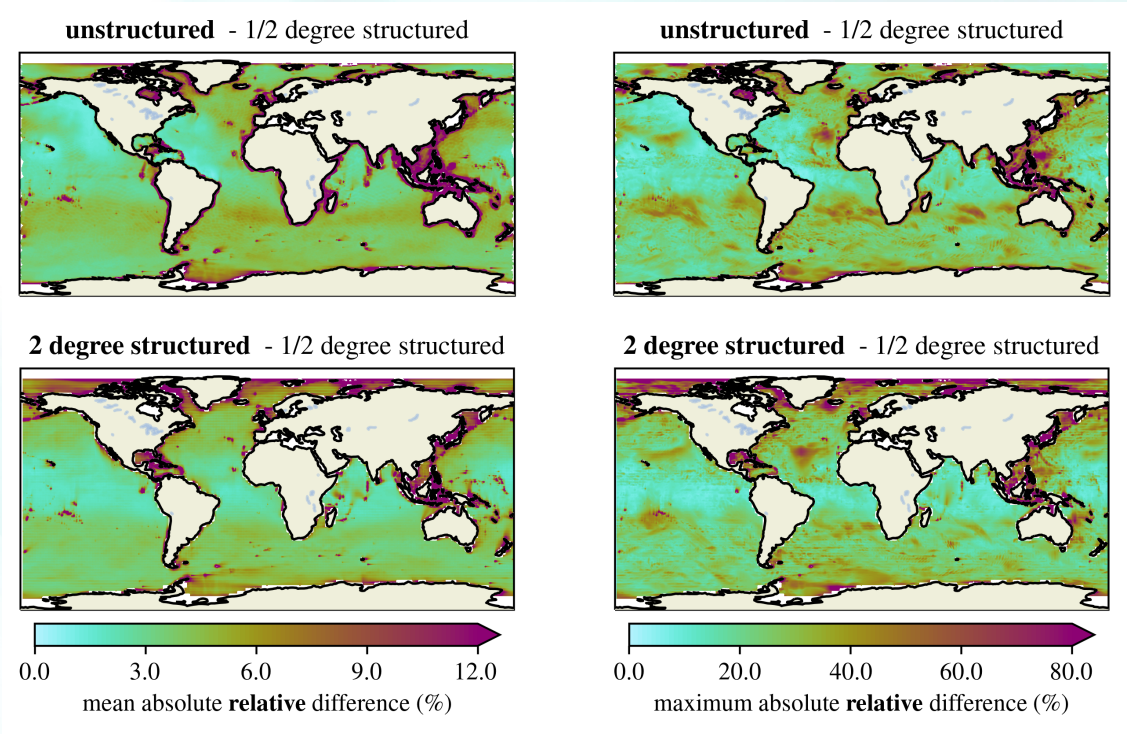
- Significant wave height comparisons to observations

Buoy comparisons



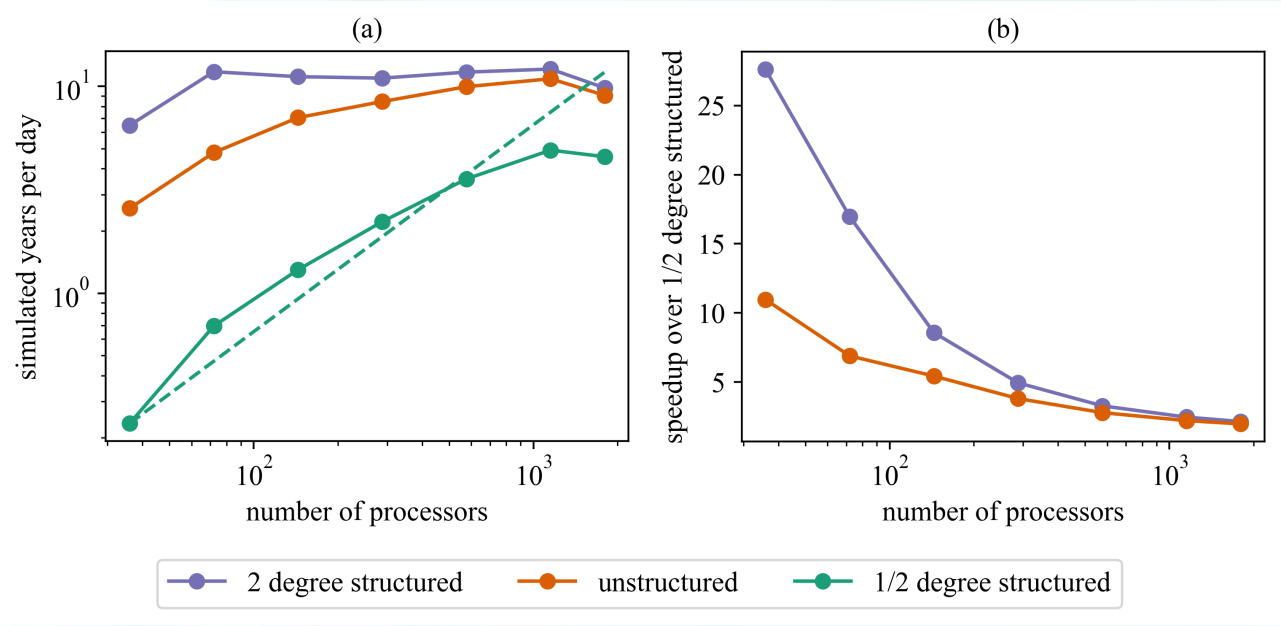
- In deep stations, the unstructured mesh is comparable to both structured meshes.
- At shallow stations, the unstructured mesh performs similarly to the ½ structured mesh.

Resolution Differences



- Mean and maximum relative differences in significant wave height compared to ½ structured mesh
- Coarse regions of unstructured mesh are equivalent to 2 degree structured mesh
- Coastal refined regions of unstructured mesh are equivalent to ½ structured mesh

Model Performance



- Unstructured mesh is between 2-11 times faster than ½ structured mesh, depending on core count
- Unstructured mesh achieves nearly the same throughput as the 2 degree mesh at high core counts

Waves Next Steps

- Unstructured Mesh
  - Explore use of ML to understand how much resolution is enough and where
- Port wave action source terms on GPU
- Wave sea ice interactions coming from ecosystem project
- Coupled with other developments, wave-setup and coastal flooding becomes possible in E3SM.
- Wave state based flux to improve fluxes of momentum, active tracers
- Sea spray aerosols

Supporting v4 Science Questions

- Possible v4 Science Questions for each campaign **require** ocean and sea-ice developments
- Water Cycle – target Exascale
  - supporting large ensembles
  - Regional refinement
- Cryosphere
  - Improvements for sea level rise
- BGC
  - Improved exchanges between atmosphere and ocean/sea ice

MPAS Infrastructure + Dynamical Core

- De-obfuscate MPAS
  - Linked lists, pointer retrievals and structures make optimization difficult
- Data layout
  - Use of single column models (mixing, BGC) cannot expose parallelism
- Model structure
  - Small kernels (modules) and small subdomains are not enough work for GPU
- Minimize communication
  - Reduce halo updates through careful accounting and larger halos.
- Passive tracers do not need to advect every timestep
  - Super cycling / SL transport
- Explore new programming models (Kokkos, FLeCSI, OpenMP, …)

Unresolved Physics

- Mesoscale eddy parameterization
  - Current implementation – highly simplified form of Eden and Greatbatch (2008)
  - Goal – Prognostic Eddy energetics based scheme
  - **Community Collaboration —** Eddy Energy CPT
- Submesoscale eddy parameterization
  - Fox-Kemper et al. (2011)
  - Needed to enable Langmuir mixing
  - **Community Collaboration –** S-MODE
- Vertical Mixing
- Will explore scale aware capabilities for both parameterizations

Questions?