Ocean NGD

Luke Van Roekel, Steven Brus

On behalf of: Andrew Bradley, Peter Bosler, Andy Salinger, Andrew Roberts, Phil Jones, Matt Turner, Andrew Roberts, Kat Smith, Qing Li, Alice Barthel, LeAnn Conlon, Darren Engwirda, Xylar Asay-Davis Brodie Pearson, Scott Bachman

E3SM DOE BER Review: November 9-10

A new E3SM NGD project

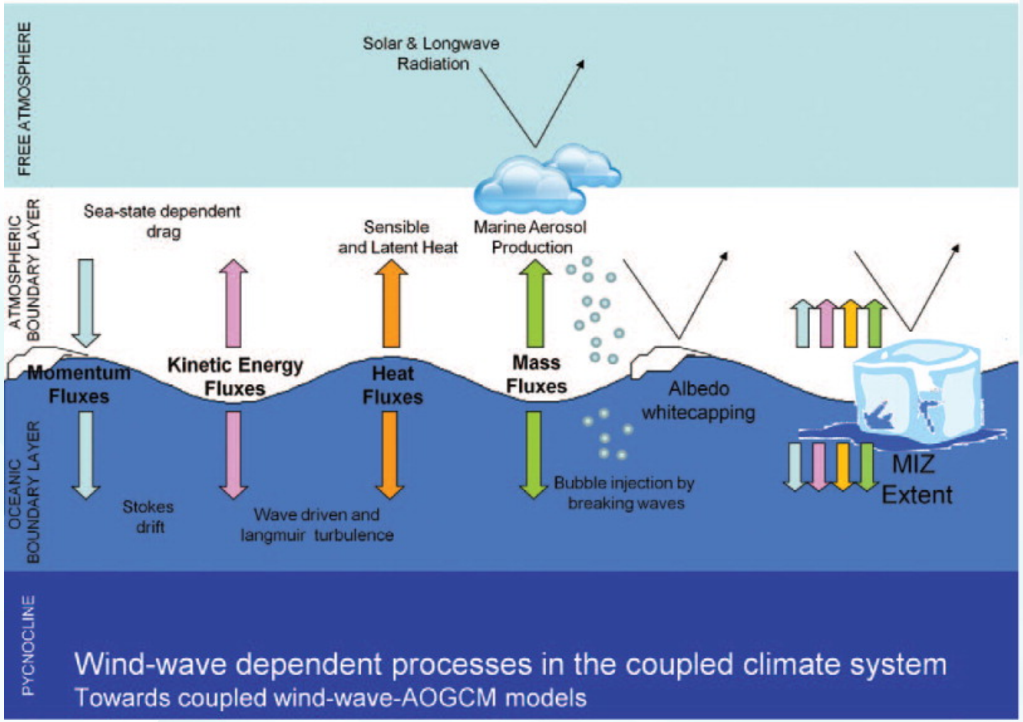
- Newly formed project so much of the presentation is forward looking

- Grown out of the Waves MiniNGD
  - Initial Goal: Implement WAVEWATCHIII as a component in E3SM

- Goals of the new ocean NGD
  - Firmly establish DOE as the leader in coastal ocean modeling and coastal ocean impacts
  - Pursue low hanging fruit to improve ocean/ice fidelity and performance

Where we are now

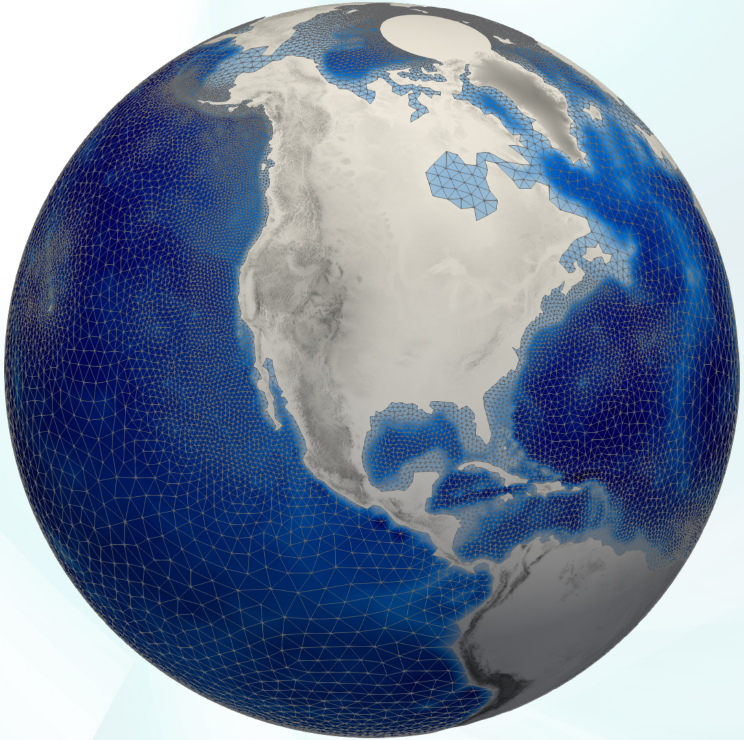
Why start with waves?



Cavaleri et al. (2012)

- Wind-generated waves are an important interfacial process in the climate system
- Some cross-component interactions include:
  - Ocean vertical mixing
  - Sea-state dependent drag
  - White-capping albedo
  - Sea-ice floe size

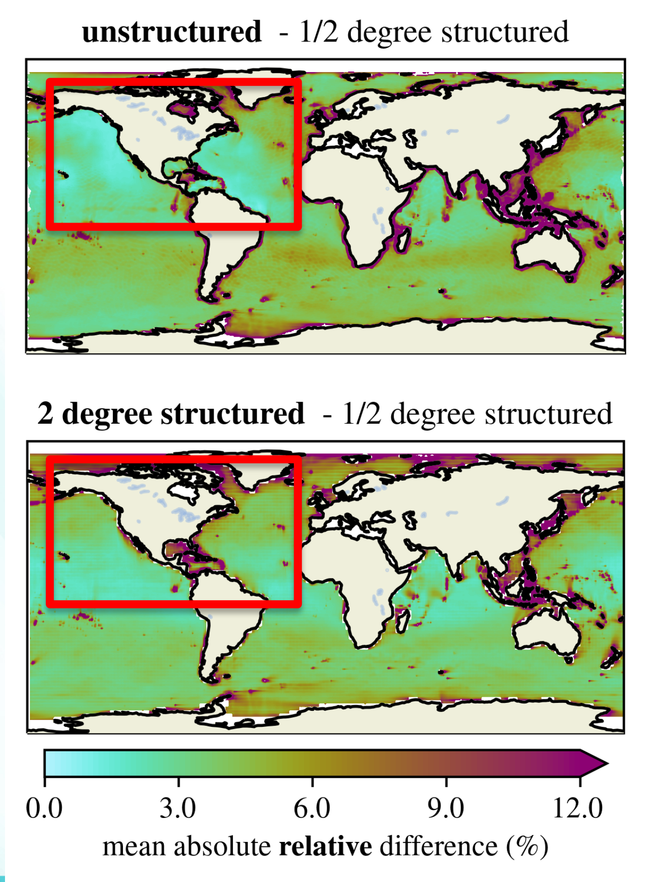
WAVEWATCHIII Progress

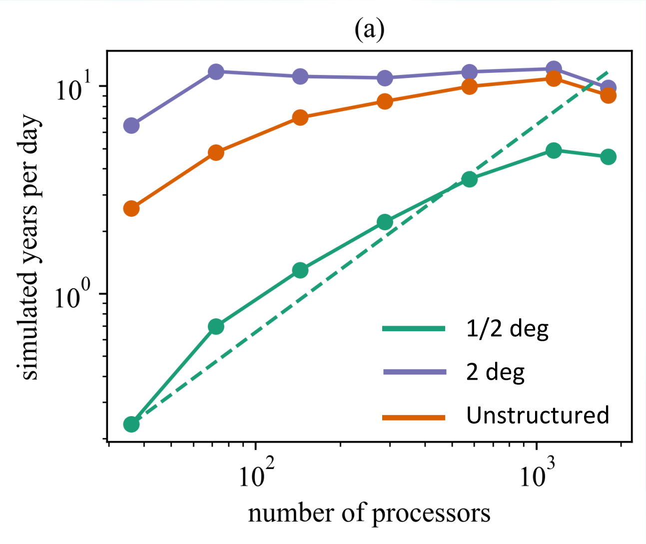


- WW3 implemented into E3SM as a separate component
- New unstructured capability successfully validated
    - 2 degree resolution globally
    - ½ degree resolution for depths < 4km in U.S. coastal regions
    - Unstructured mesh is compared to 2 degree and ½ resolution structured meshes

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

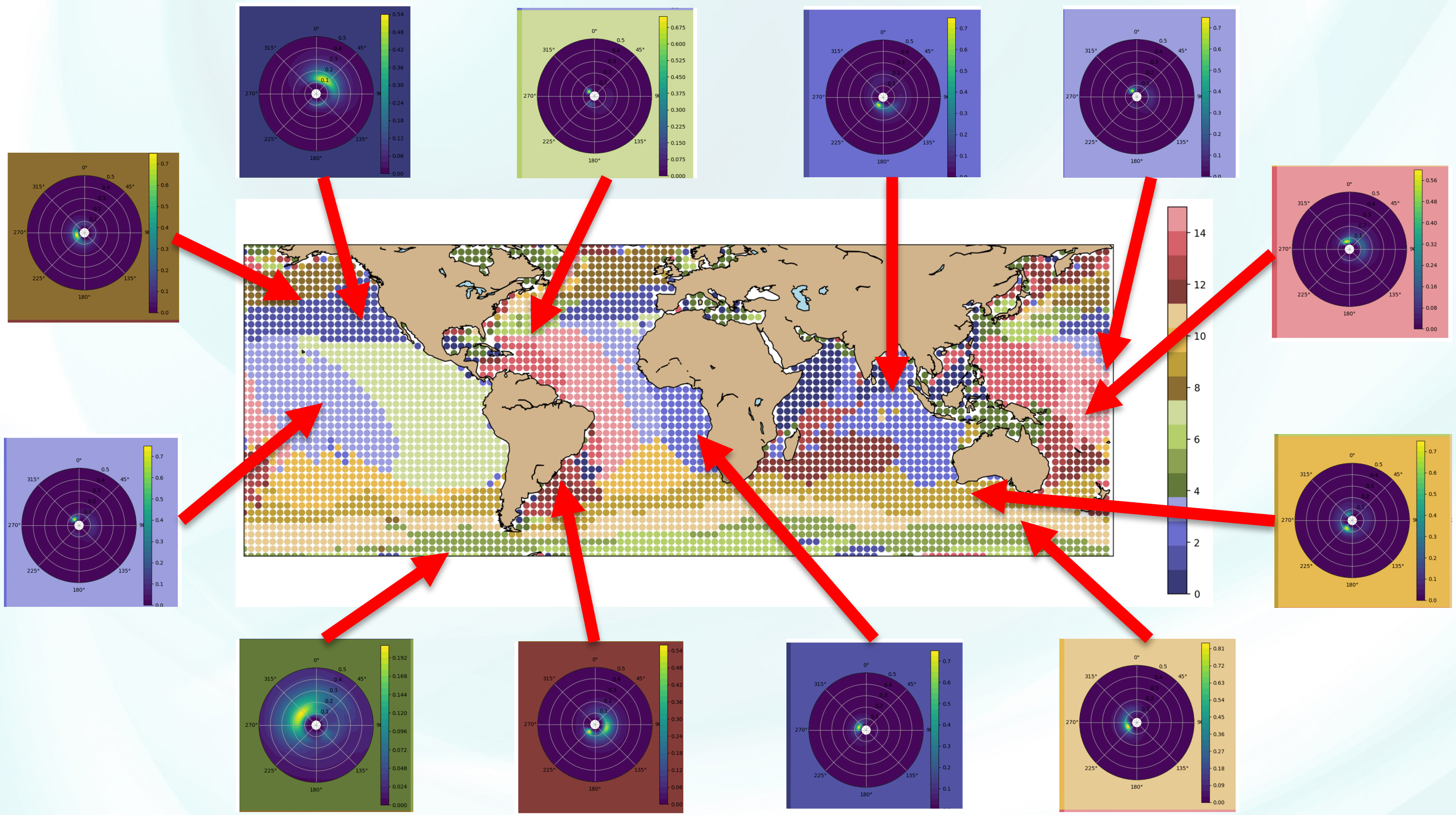
Unstructured Mesh Assessment





- Coarse regions of unstructured mesh are equivalent to 2 degree structured mesh
- Coastal refined regions of unstructured mesh are equivalent to ½ structured mesh
- Performance close to 2 degree mesh

Next Steps: Global Wave Spectra ML Classification

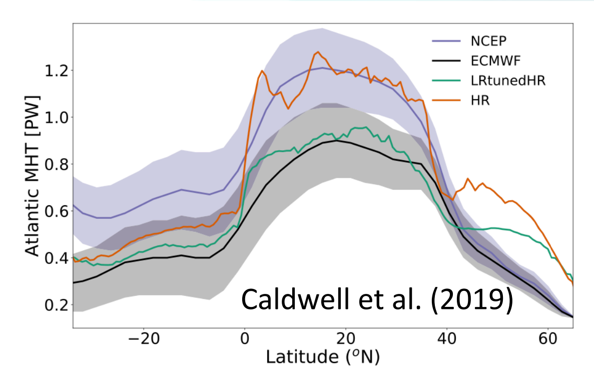


Where we are going

Improving ocean model fidelity

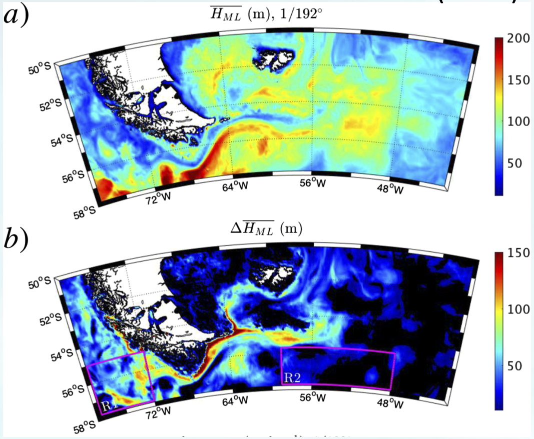
E3SM v3

- Part of phase 3 will focus on model biases and their impact on WC.
- Ocean biases can be reduced in 3 parameterizations (mesoscale eddies, submesoscale eddies, and vertical mixing)



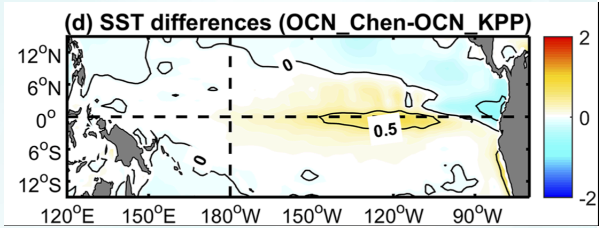
Mesoscale Eddies

Bachman et al (2017)



Submesoscale Eddies

Zhu and Zhang (2019)

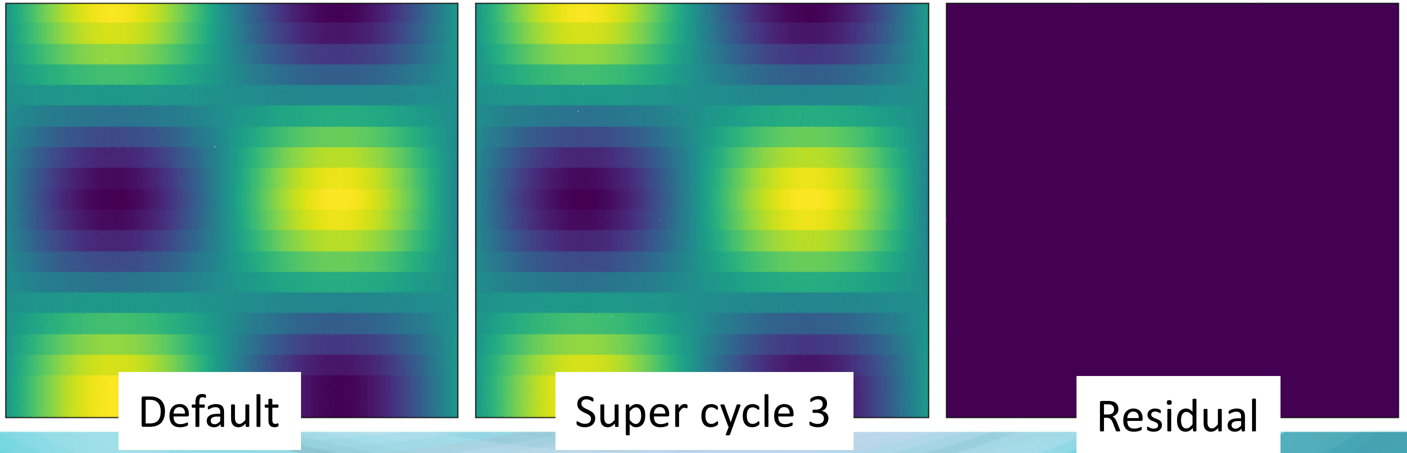


Vertical Mixing

Improving ocean model performance

E3SM v2/v3

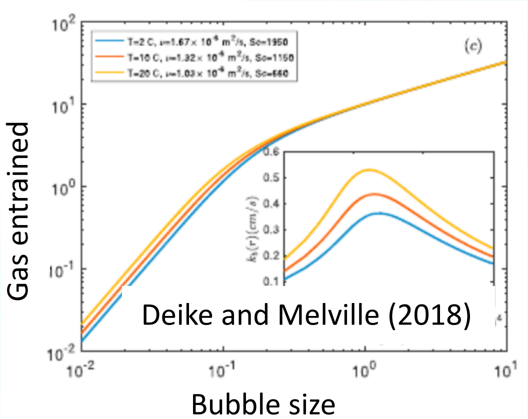
- Ocean passive tracer advection is very expensive.
- Does not need to advect passive tracer every ocean timestep (can super cycle)
- Great progress on this for v2.
  - Will benefit RRM BGC simulations
- Also exploring more efficient advection routines for active and passive tracers



Advancing Coastal Ocean Modeling

Influence of Waves on the Ocean

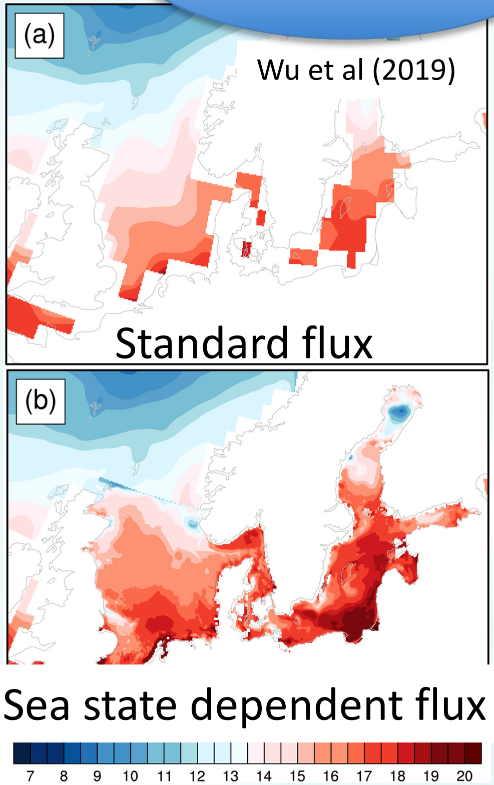
E3SM v3



Air-sea gas exchange

<u>NGD Targets</u>

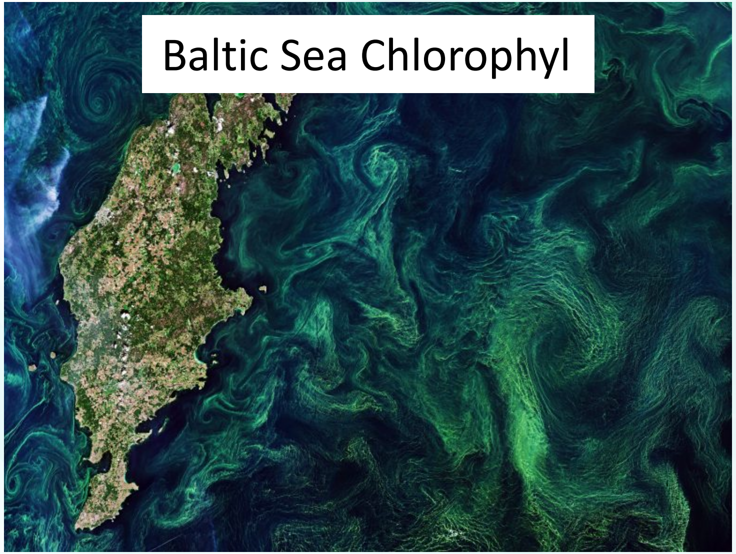
- Link sea state from WAVEWATCHIII to the coupler
- Implement sea spray and bubble parameterization

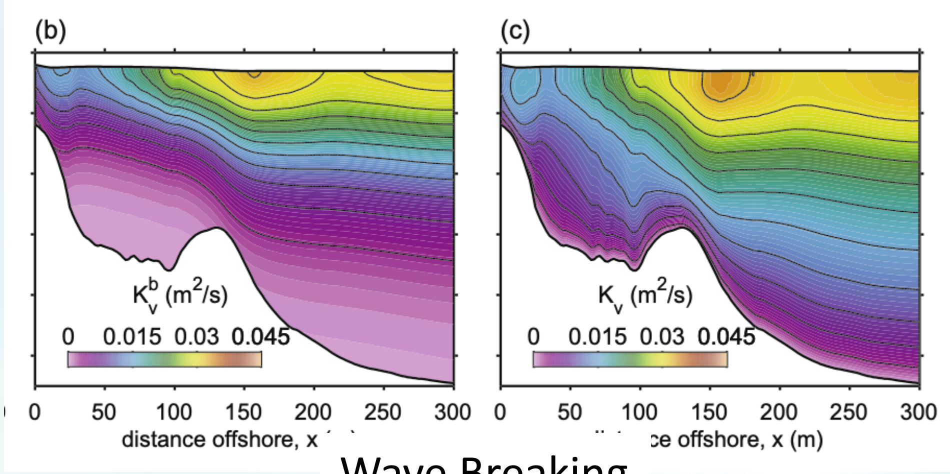


Temperature and momentum fluxes

Influence of Waves on Coastal BGC

E3SM v3





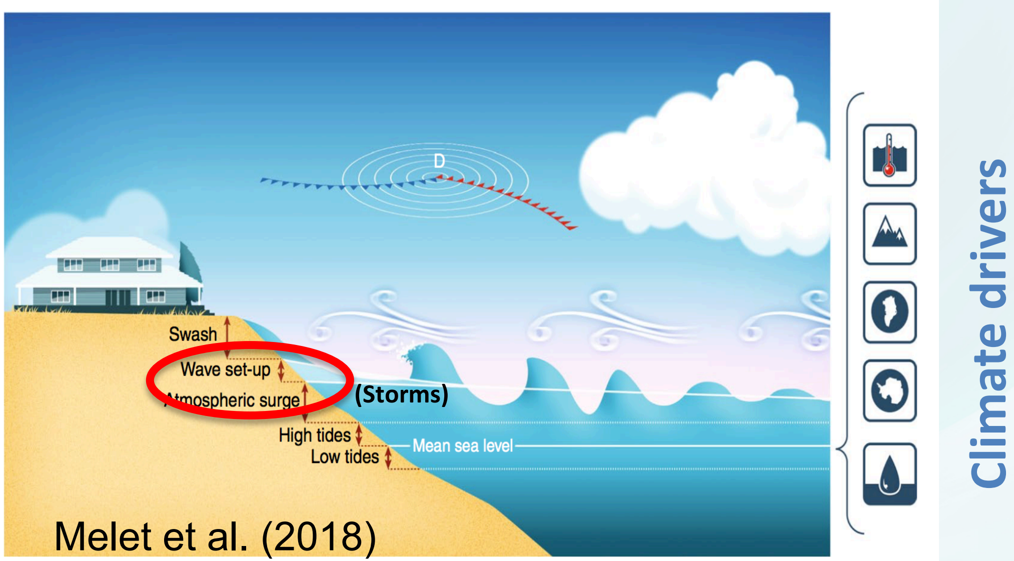
Wave Breaking

NGD Targets

- Couple Stokes drift to the ocean
- Add wave driven mixing to vertical mixing closure

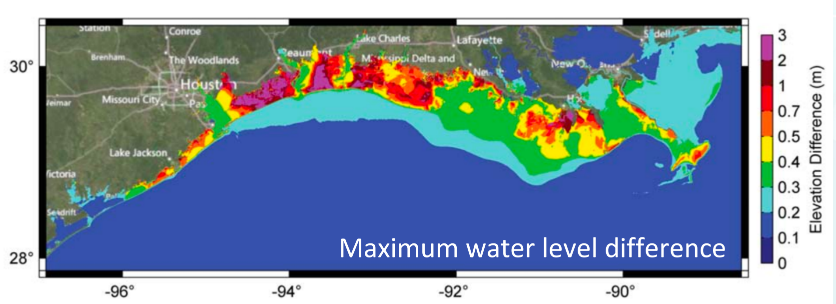
Coastal Inundation

E3SM v4



Melet et al. (2018)

Wave contribution to water levels during Hurricane Ike



Kerr et al. (2013)

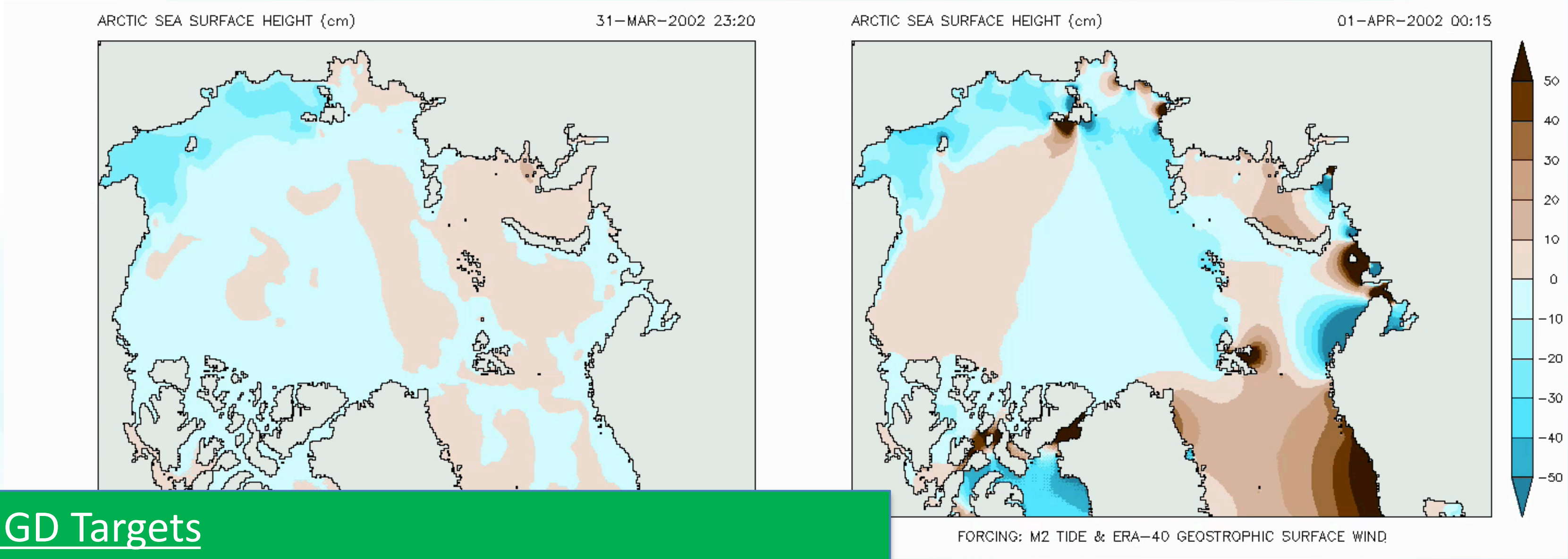
NGD Targets

- Coupling of radiation stress to ocean model and tides
- Ocean wetting and drying
- Improved vertical mixing

Influence of Sea-ice on Arctic Coast

E3SM v4

- Tides and associated mixing are essential to sea-ice in the Arctic
- Pattern of sea-ice loss impacts CONUS



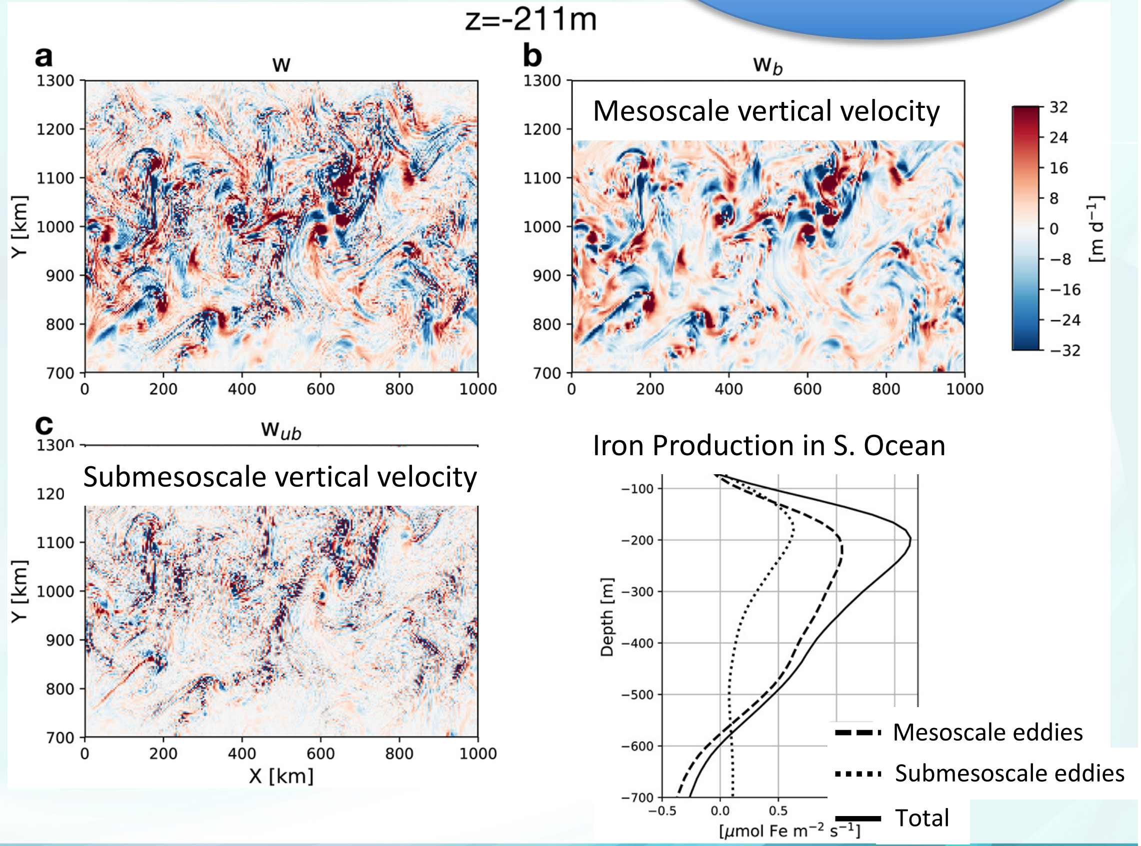
<u>NGD Targets</u>

- Embed sea-ice model into ocean model
- Improve sea ice physics (new ridging scheme)

Influence of ocean eddies on BGC

E3SM v4+

- Mesoscale and submesoscale eddies impact BGC
- Global impact and future changes unknown
- E3SM uniquely positioned with RRM capability



<u>NGD Targets</u>

- Scale aware physics
  - Scale interaction with vertical mixing
- Performance!

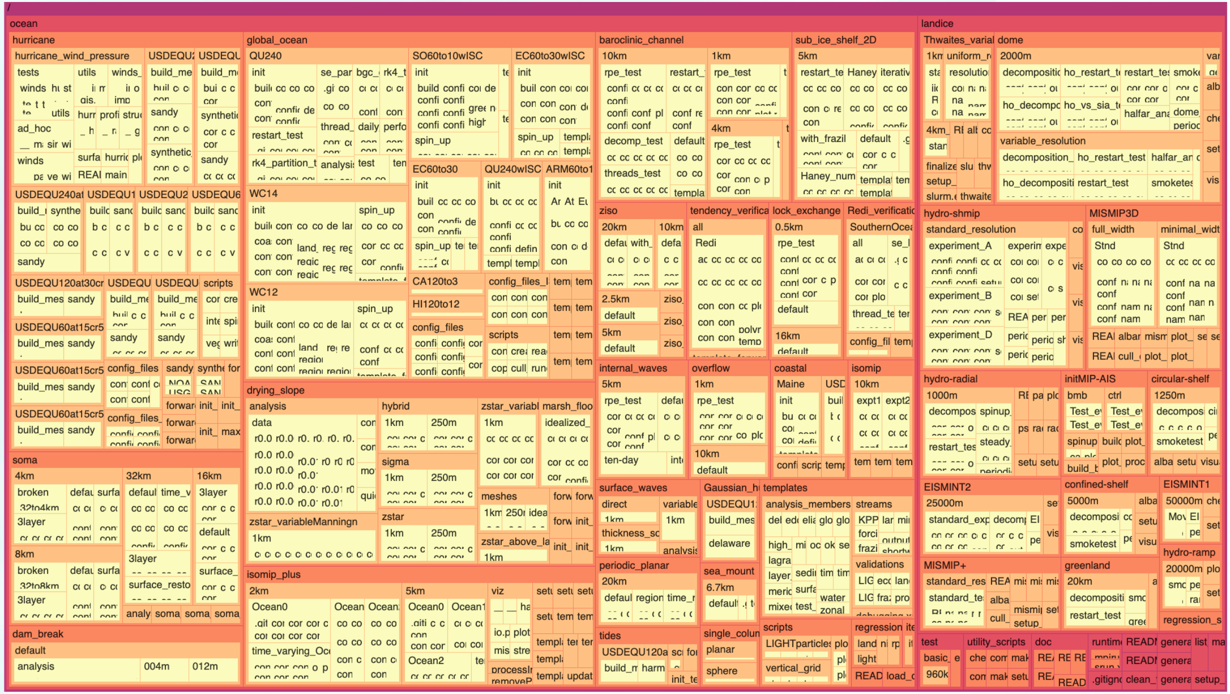
How do we get there?

E3SM v4+

- To achieve the extreme RRM simulation a more fundamental re-examination and MPAS framework and data structures is required
  – Examination starts now!
- New time stepping
  – Spatially variable time stepping (ICoM)
- Explore new data layouts
  – Use of single column models (mixing, BGC) cannot expose parallelism
- Explore new programming models
  – Kokkos, FLeCSI, OpenMP, …
- Explore alternate model structures
  – Current modular design of ocean models makes it difficult to expose enough work for GPU

Testing

- Verification testing will be central to the Ocean NGD.
- Primary testing infrastructure will be COMPASS
  - Infrastructure in place
  - Fully automated
  - Contains numerous established test cases
- Needs to be reconfigured to improve ease of use
  - Important for external users



Current COMPASS Directory Tree

Collaborations

- InteRFACE
  - Wave Sea-ice interactions
- ICoM
  - Tidal driven mixing
  - Spatially variable time stepping
- SciDAC ProSPect
  - Non-Boussinesq ocean
- SciDAC COMPOSE
  - Semi-Lagrangian passive tracer transport, super cycling
- SciDAC CANGA
  - Alternate programming models
- Eddy Energy CPT
  - Mesoscale Eddy Parameterization
- DOE Academic Project (Ju and Gunzburger)
  - Alternate timestepping for tracer advection

Summary

- Waves MiniNGD was successfully completed
  - WAVEWATCHIII integrated to E3SM
- New NGD formed to firmly establish DOE as the leader in coastal ocean modeling
- Requirements
  - New physics: Submesoscale and Mesoscale eddies, vertical mixing
    - Scale aware physics
  - Better performance: fundamental reexamination of MPAS framework and data structures

Questions?