Ocean NGD

Ocean Model in E3SM for Global Applications (OMEGA) project

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On behalf of many – Steven Brus, Andrew Bradley, Kat Smith, Pete Boesler, Matt Turner, Xylar Asay-Davis, Darren Engwirda, Sara Calandrini, Mark Petersen, Chad Sockwell, Alice Barthel, LeAnn Conlon, Filipe Soares-Pereira, Anirban Sinha, Scott Bachman, Brodie Pearson, Jon Wolfe

History and Purpose

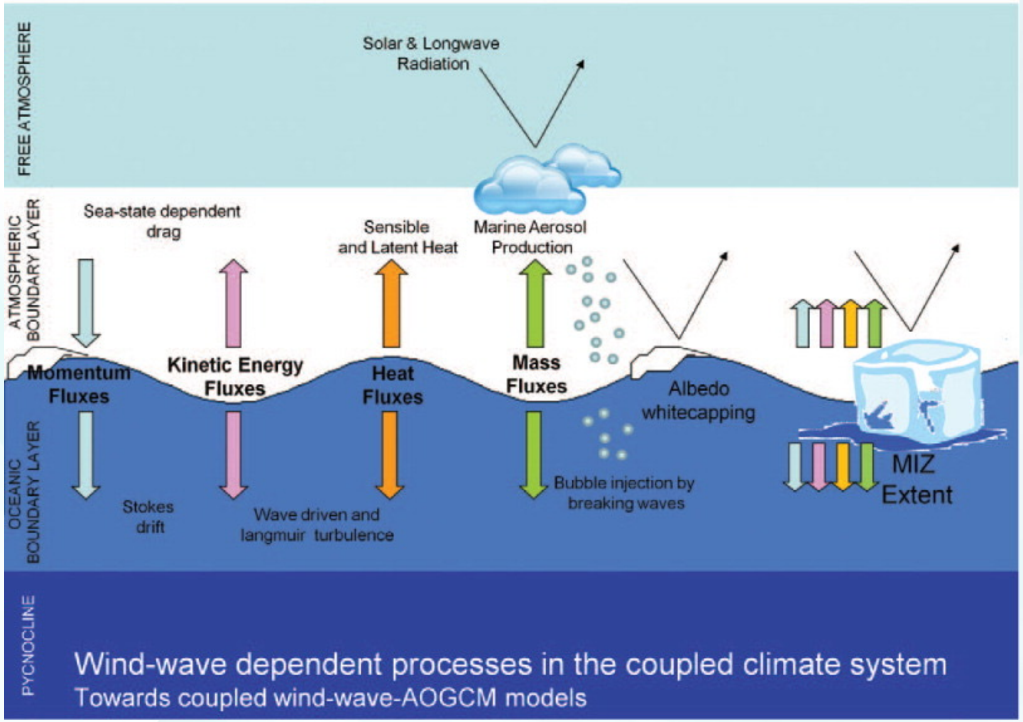
- Grown out of the Waves MiniNGD
  - Initial Goal: Implement WAVEWATCHIII as a component in E3SM ✅

- Goals of the new ocean NGD
  - Firmly establish DOE as the leader in coastal ocean modeling and coastal ocean impacts
  - Accelerate ocean model exascale readiness
  - Pursue low hanging fruit to improve ocean/ice fidelity and performance for v3/v4

Subgroup Focus Areas

- Physics parameterizations: Mesoscale Eddy, Submesoscale Eddy, vertical mixing
- Framework and Testing: New Framework, Increased testing coverage, improved testing infrastructure, Discretizations
- Waves: making wave model possible for climate simulations
- ML/Ai: Parameterization development, grid design

Why start with waves?



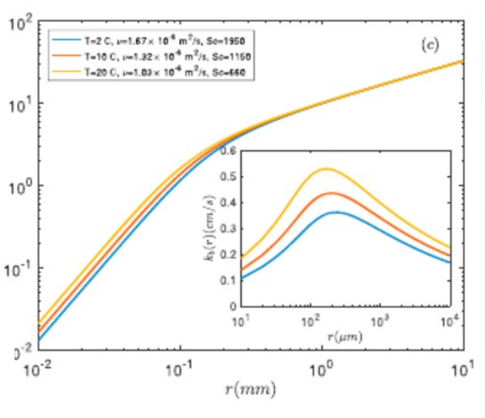
Cavaleri et al. (2012)

- 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

Advancing Coastal Ocean Modeling

Influence of Waves on the Ocean

E3SM v3

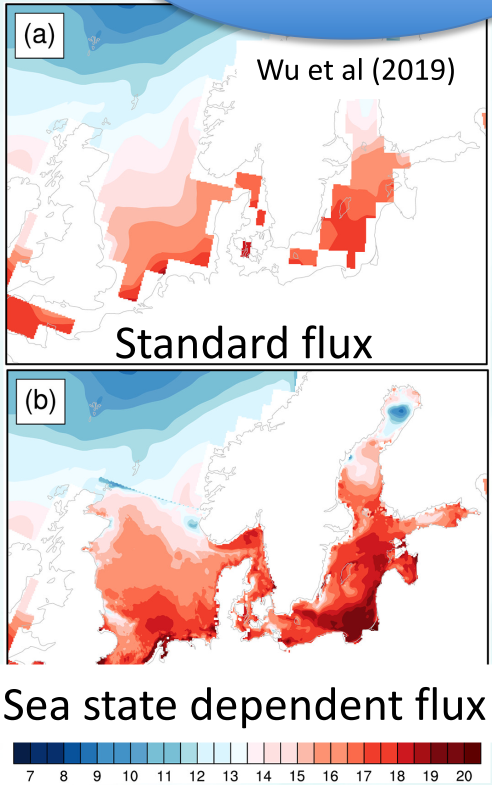


Gas entrained

Baltic Sea Chlorophyl

<u>NGD Targets</u>

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

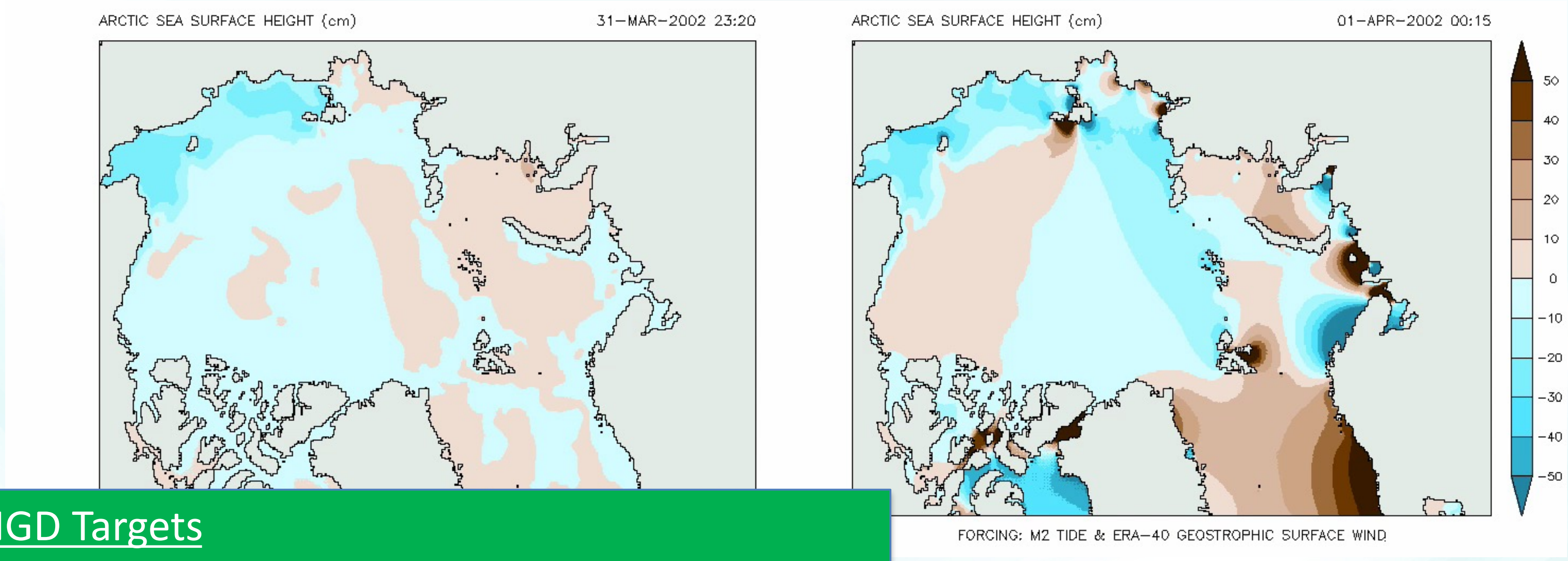


Temperature and momentum fluxes

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



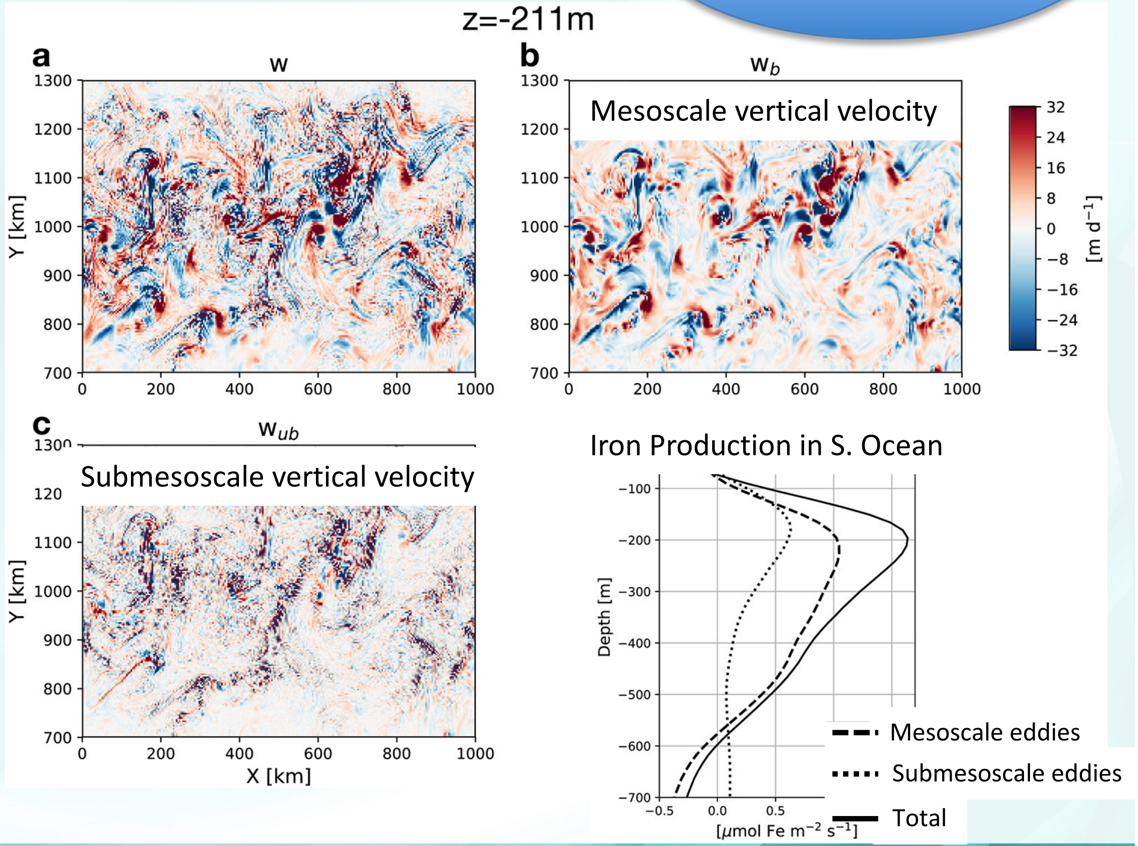
<u>NGD Targets</u>

- 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



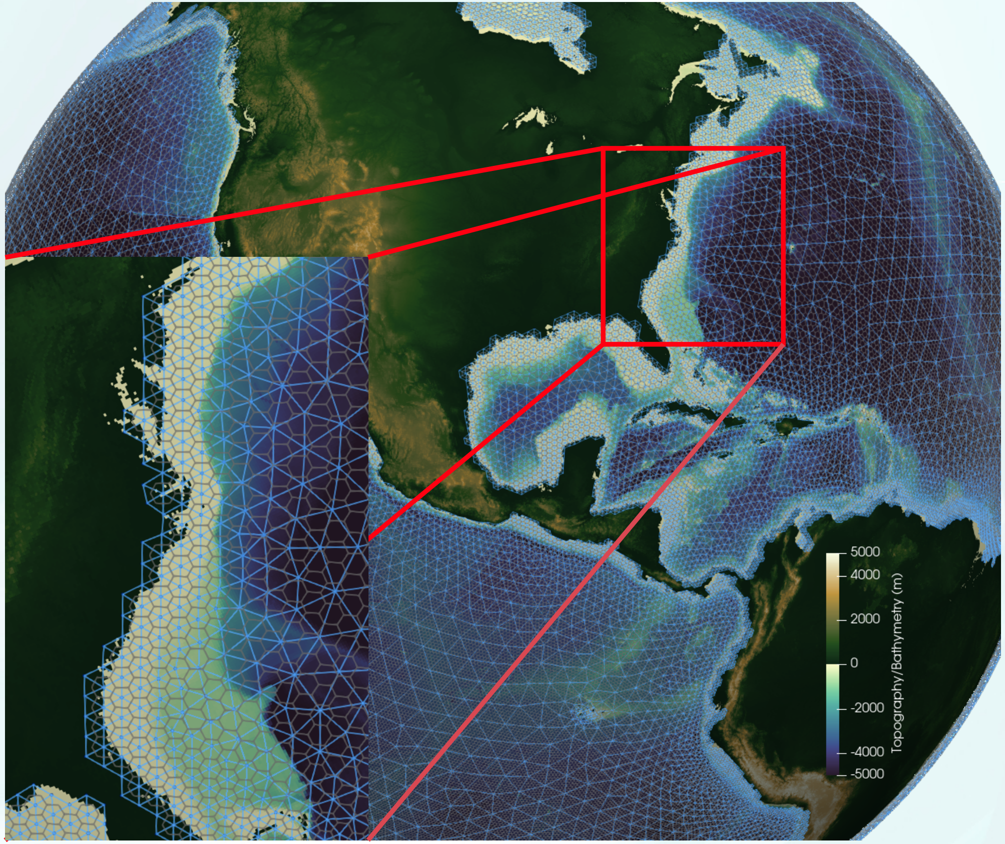
NGD Targets

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

Recent Progress

Waves

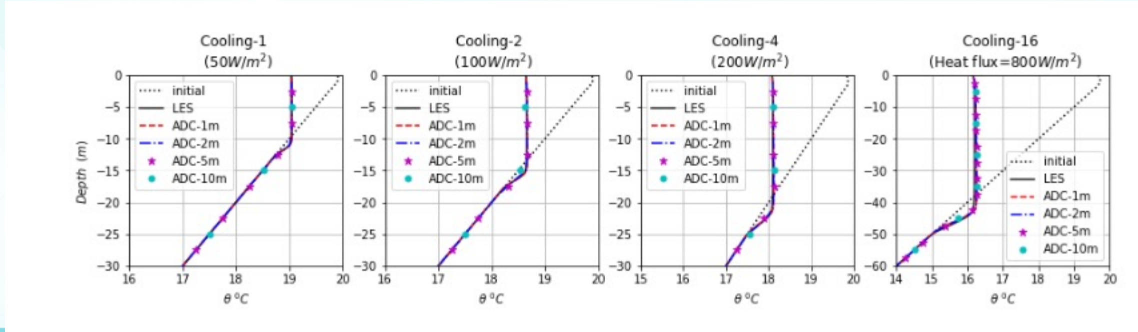
- Great progress – method developed to allow wave model to see same coastline as MPAS
  - Initial paper published at GMD
- Rotated Pole
- Langmuir turbulence mixing nearly complete



Physics

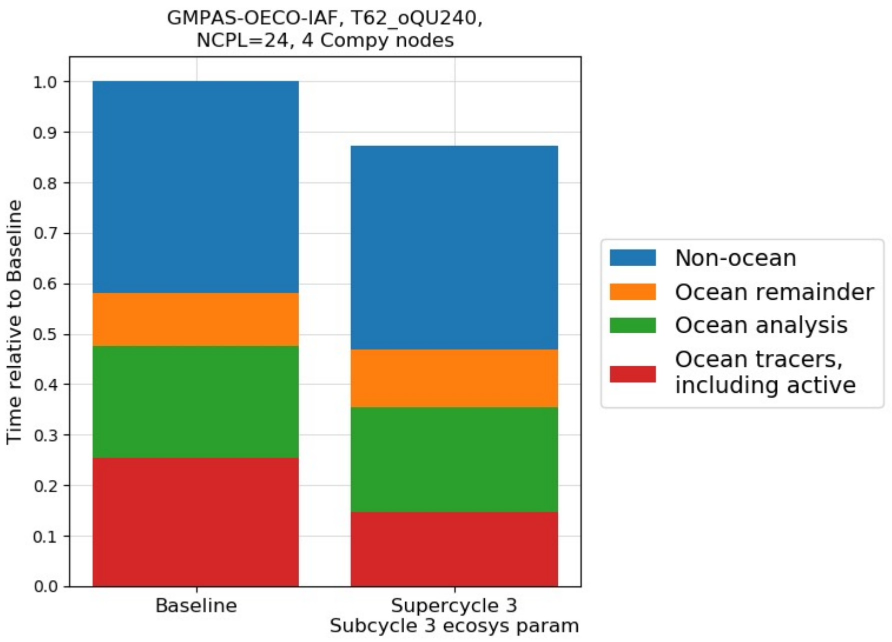
- Mesoscale Eddies
  - New configuration developed for testing (top right)
  - Conducting high res G-case for baseline
- Submesoscale eddies
  - Configuring MLI cases in LES code (right)
- Vertical mixing
  - Initial buoyant convection simulations nearly complete (below) – paper nearing completion
  - Langmuir turbulence implementation next

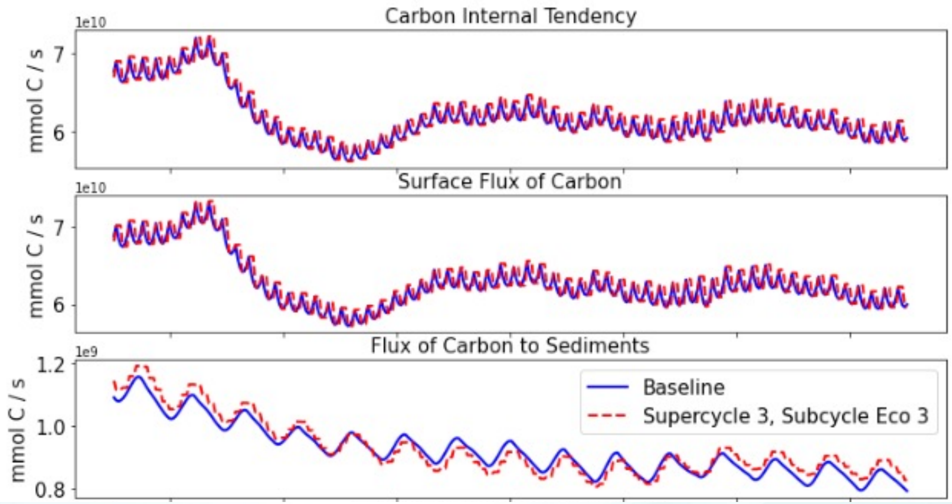
NEED MESOSCALE FIG



Passive Tracer Supercycling

- Supercycling
  - Implementation essentially complete, awaiting MARBL integration which is in progress



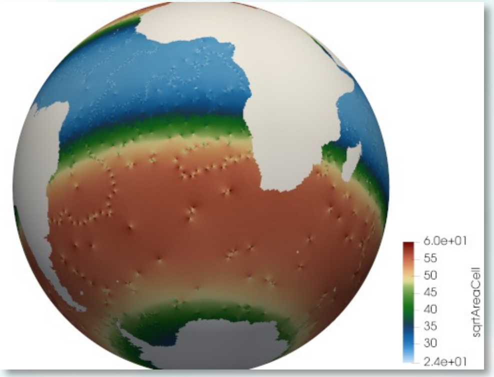


compass - Configuration Of MPAS Setups

What is it?

- Python package
- Realistic and idealized test cases
- Regression testing
- Meshes and ICs for E3SM
- MPAS-Ocean, MALI and OMEGA*

* soon

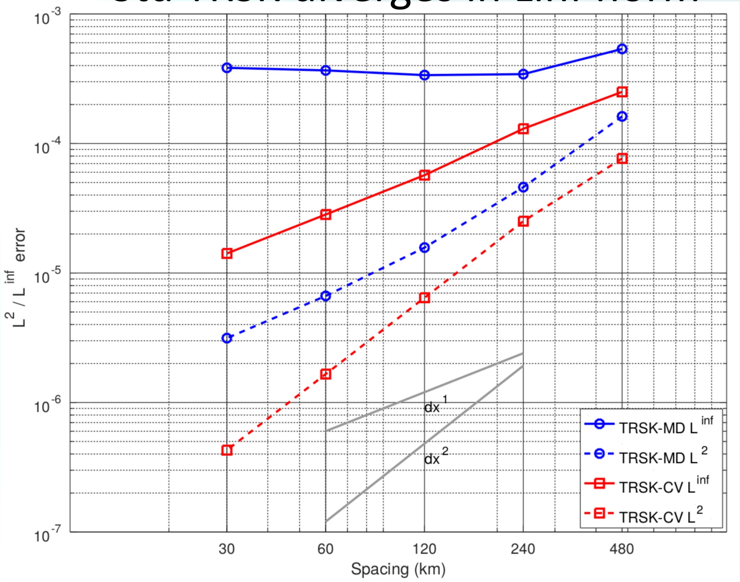


Recent Progress

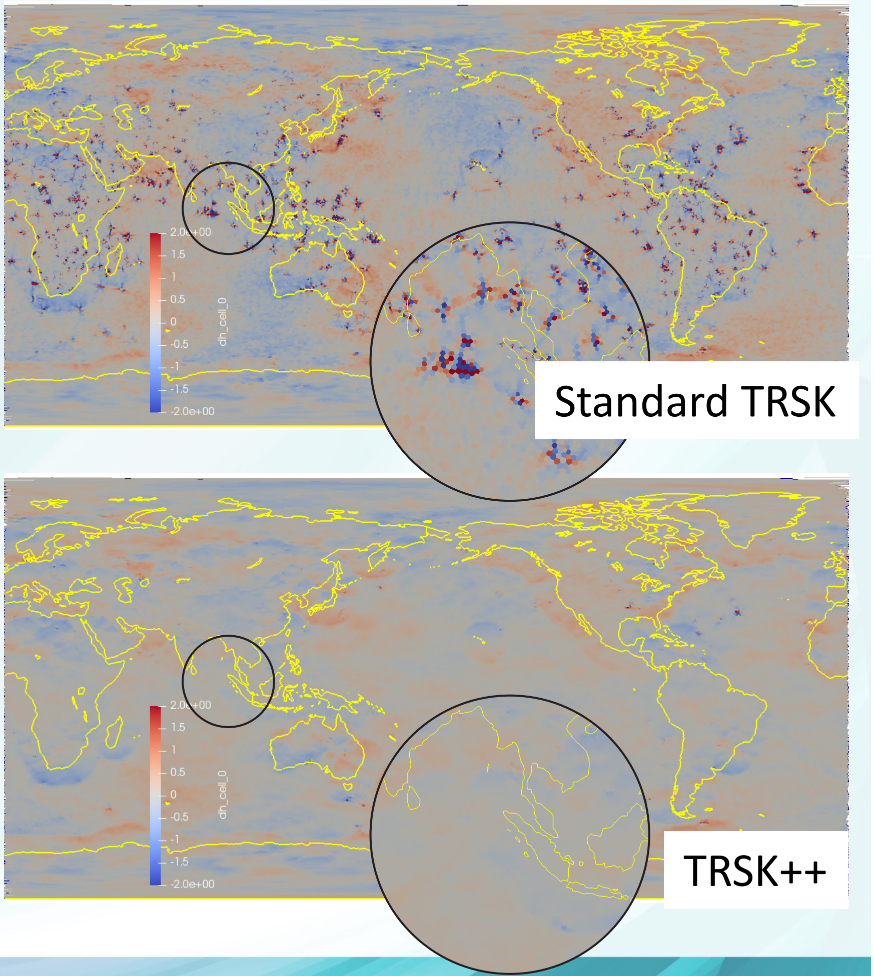
- Complete rewrite as python pkg.
  - Improved flexibility and code reuse
  - Easier use on E3SM machines
  - More standard development approach
- Extensive documentation
- Porting or development of 92 test cases (19 land-ice, 73 ocean)

Discretization progress

Std TRSK diverges in Linf norm



Variable Resolution Mesh

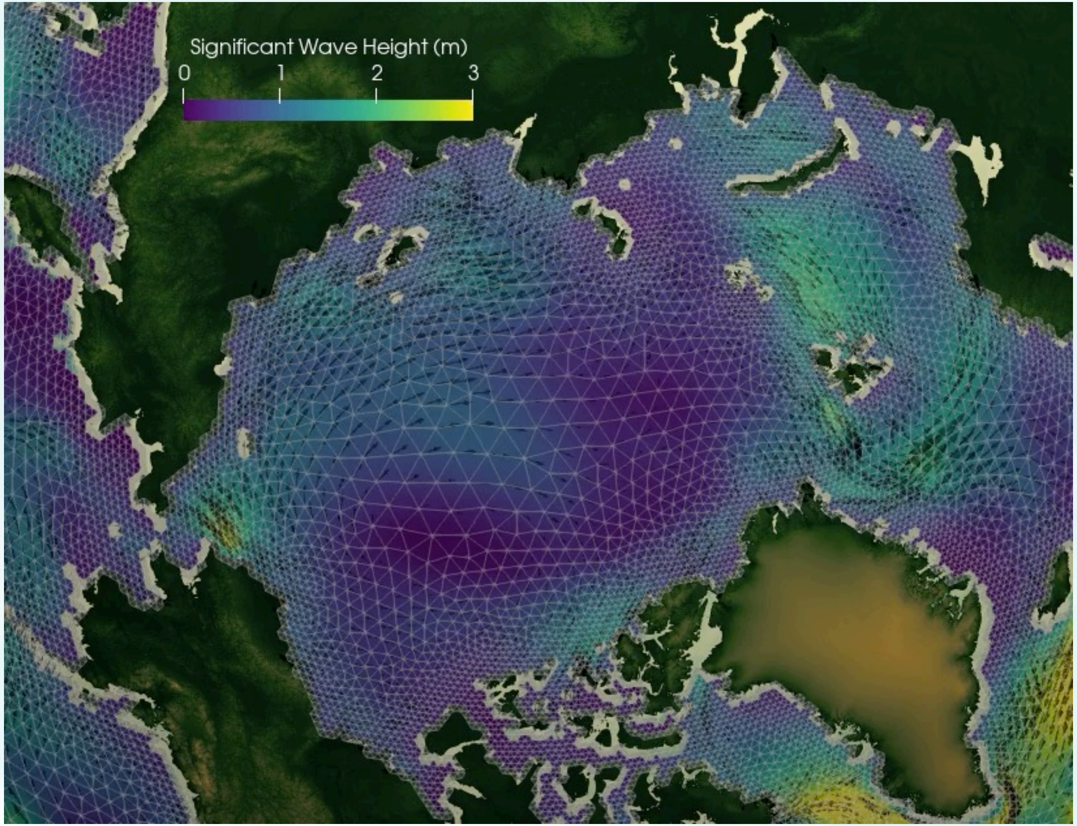


Williamson TC2 test case

Next Steps

Wave Modeling

- Moving toward applications
  - Stokes Drift and Langmuir Turbulence
  - CO_2 flux changes through Arctic
- Still working on implementation
  - Currently porting wave source terms to GPU



Callies - 2020

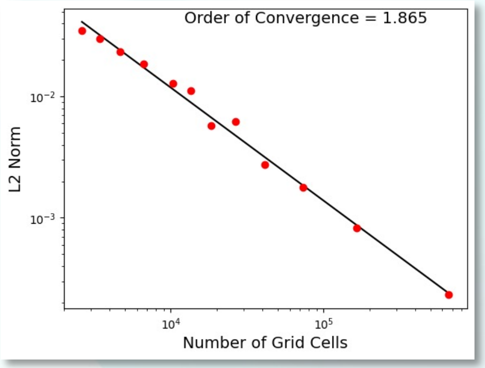
Physics

- Vertical Mixing
  - Run new closure in global configuration
  - Add entrainment equation –Arctic Halocline
- Mesoscale Eddies
  - Implement EKE based scheme
  - Understand where resolution is necessary for AMOC
- Submesoscale Eddies
  - Conduct parameter sweeps to improve current submesoscale closures
  - Coupled ocean/atmosphere LES

Framework and Testing

- Rebuild the framework to emphasize performance over flexibility
  - Port framework to C/C++, API still TBD
- Emphasize tight coupling between domain and computational scientists
  - Coding standards
  - Testing
  - Quicker on ramp to GPU
- Increased testing: Operator convergence, unit testing, validation
- Build the new dynamical core upon the semi implicit solver and explore new timestepping methods for the baroclinic mode
- Continue to explore TRSK++ ideas
  - Some TRSK cases appear unstable.

compass - Configuration Of MPAS Setups

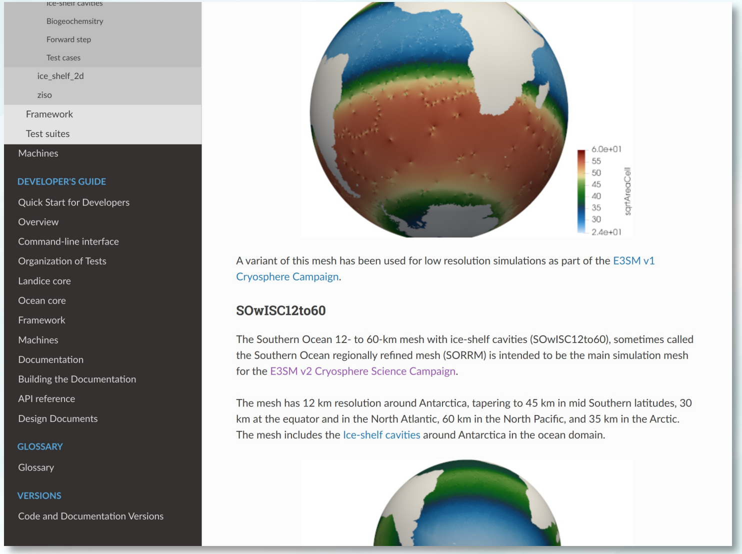


Find out more

- Development: https://github.com/MPAS-Dev/compass/tree/master
- Documentation: https://mpas-dev.github.io/compass/latest/

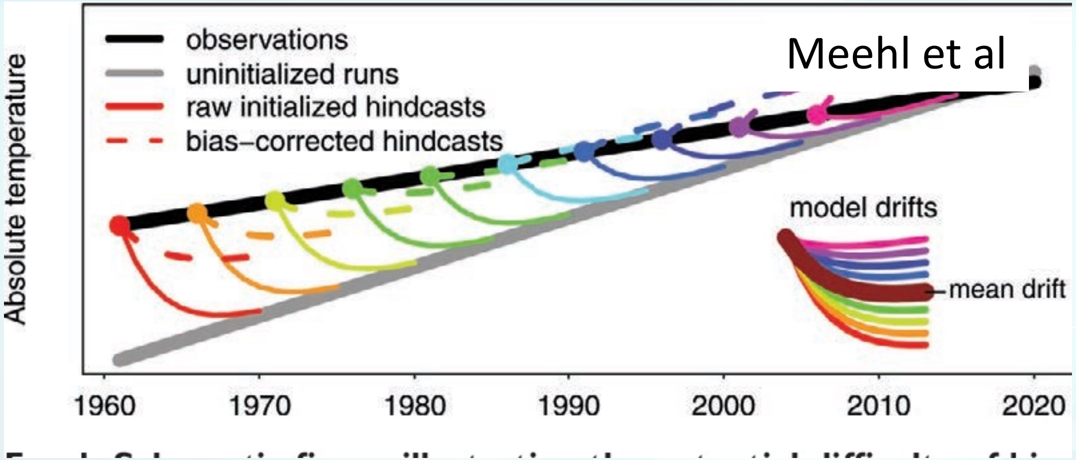
Short- and long-term plans

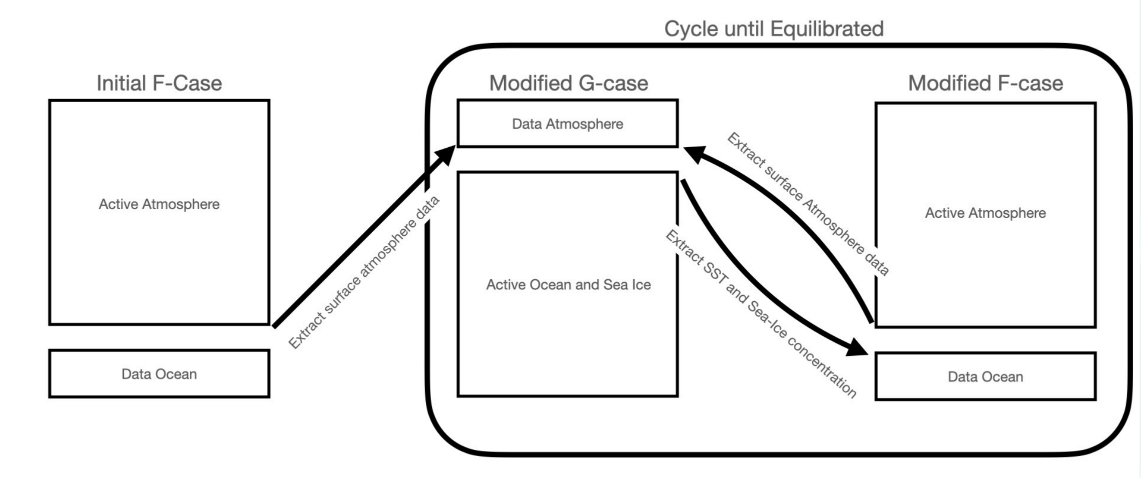
- Port ~70 additional test cases
- Develop new regression and convergence tests
- Build new E3SM meshes
- Run automated nightly testing
- Task parallelism with Parsl



Initialization

- Models spun up in a few ways
  - Atmosphere tuned in data ocean cases
  - Ocean spun up and tuned in data atmosphere/land cases
  - Data assimilation also used (esp. decadal prediction)
- Initial path forward
  - Implement method to do staged spin up of data ocean (F-case) and data atmosphere cases

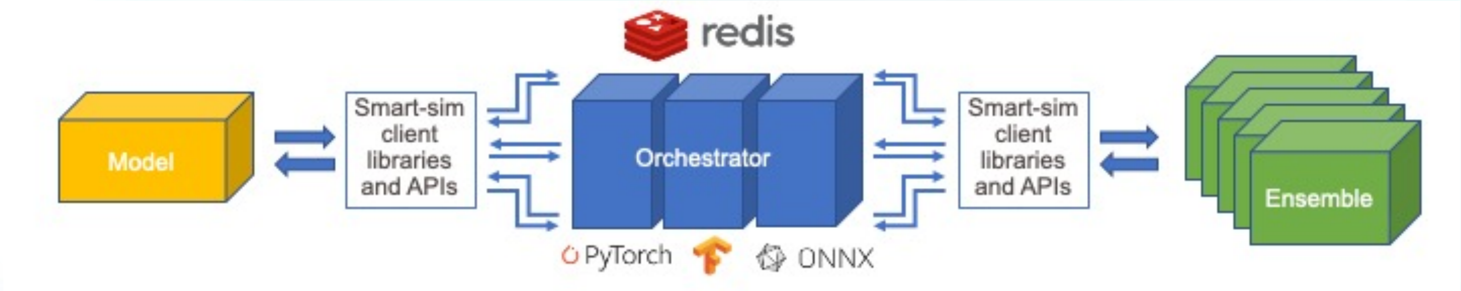




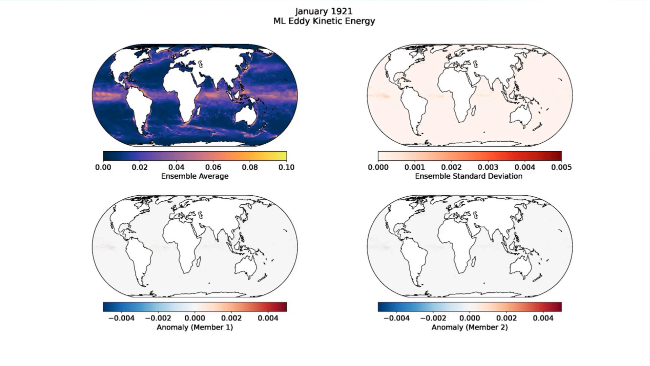
How to use ML/Ai?

ML/AI possibilities

- SmartSim: a scalable open source front end to ML/AI libraries

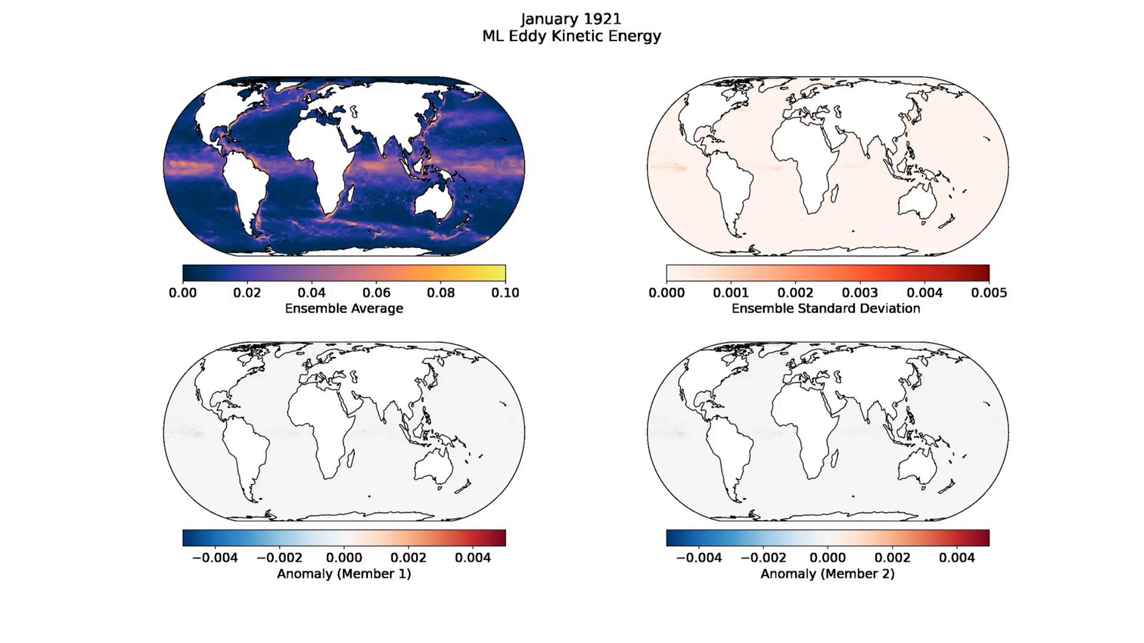


- Successfully applied to ocean GM parameterization
- First proof of concept is for submesoscale eddies
  - But many more possibilities exist.



Parameterization augmentation

- Submesoscales
  - Implement the standard Fox-Kemper (2008) parameterization
  - Explore use of AI to constrain the Kappa value in the scheme or the vertical structure function



ML/Ai: Smart Grid Design