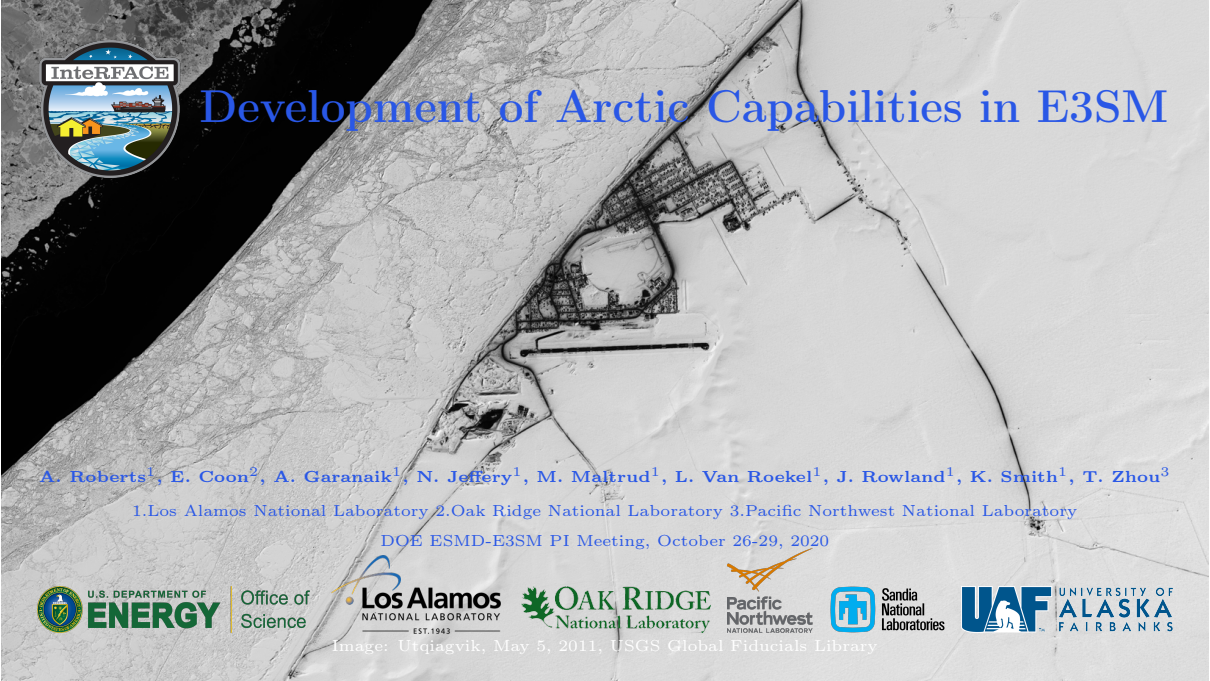


Development of Arctic Capabilities in E3SM

A. Roberts[1], E. Coon[2], A. Garanaik[1], N. Jeffery[1], M. Maltrud[1], L. Van Roekel[1], J. Rowland[1], K. Smith[1], T. Zhou[3]

1.Los Alamos National Laboratory 2.Oak Ridge National Laboratory 3.Pacific Northwest National Laboratory

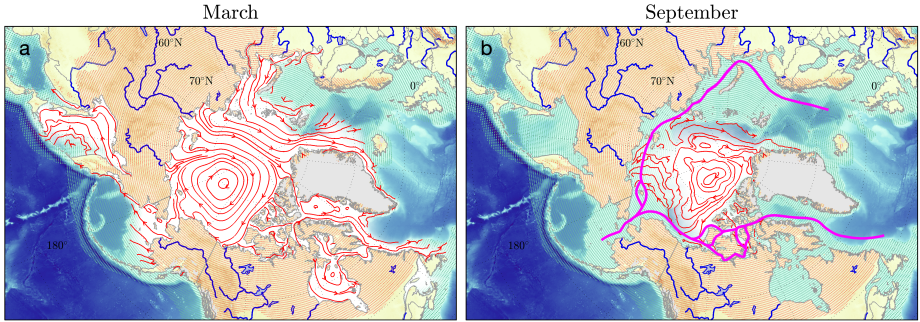
DOE ESMD-E3SM PI Meeting, October 26-29, 2020

Image: Utqiagvik, May 5, 2011, USGS Global Fiducials Library

Interdisciplinary Research for Arctic Coastal Environments

1. The purpose of model development in InteRFACE
2. The E3SM Configuration in InteRFACE: Shipping and Oceanography
3. Improvements to Oceanic Mixing and Stratification
4. Benthic Biogeochemistry
5. Permafrost Hydrology and Runoff
6. Collaboration with Waves NGD, CICE Consortium and ICoM
7. Project Integration and Timeline

The purpose of model development in InteRFACE



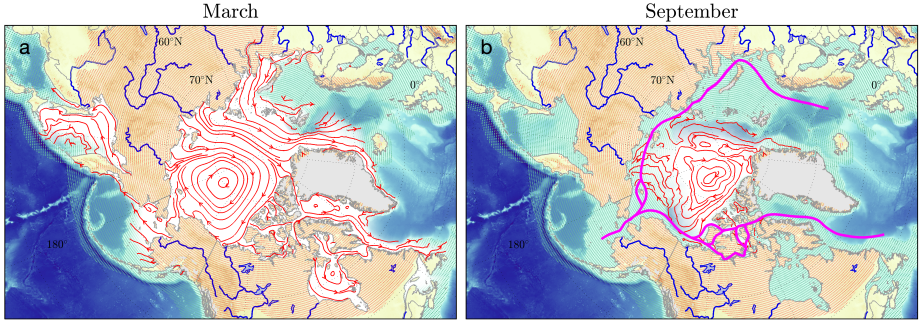
Above: Sea ice drift from 30-years of E3SM-HR (Caldwell et al. 2019), permafrost extent (orange), marine BGC (green mesh), major rivers (blue) and coastal shipping channels (magenta).

1: How realistic are fully-coupled E3SM ensemble projections of land hydrology and the Arctic Ocean, including sea ice and biogeochemistry, over the observational period from 1979 to the present?

2: What impact does global internal variability have on the timing of seasonal sea ice breakup along Alaskan coasts and transport routes in E3SM, and on autumnal freeze-up in the 21st century?

3: Work closely with RGMA and MSD programs on integrated question related to (1) and (2) above.

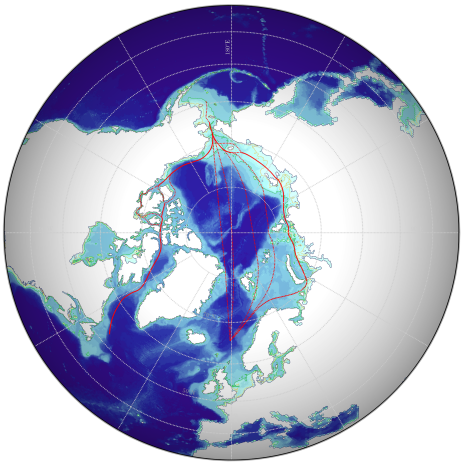
Arctic coastal interactions are heavily dependent on sea ice

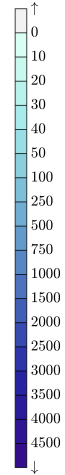


Above: Sea ice drift from 30-years of E3SM-HR (Caldwell et al. 2019), permafrost extent (orange), marine BGC (green mesh), major rivers (blue) and coastal shipping channels (magenta).

These questions are being addressed by implementing important missing elements in a high state of readiness for coupled polar applications: 1 - Improvements in mixing and stratification; 2 - Implementation of Benthic Biogeochemistry; 3 - Advances in modeling permafrost hydrology; 4 - Improvements in coastal sea ice representation

The InteRFACE Model Configuration



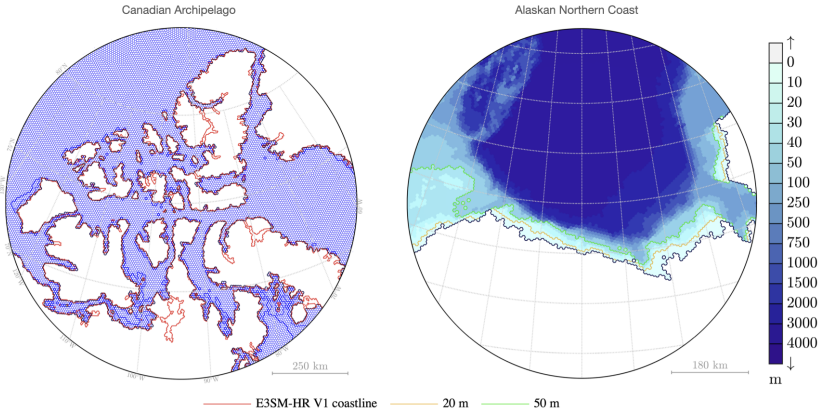


Landfast Ice Benthic Green Zone Shipping

We have worked with the E3SM Water Cycle group on the WC14 mesh, including features critical for modeling American Arctic coasts that help address energy-related questions. (circles locate maps in next slide)

The InteRFACE Model Configuration

Standard resolution atmosphere, tripole grid (1/8° runoff), and the WC14 ocean-ice mesh at 60 levels that refines shipping channels, benthic habitats, runoff and landfast ice.



Above: Expansion of circled areas in the previous slide to demonstrate local details

Coastal improvements in collaboration with X. Asay-Davis

A balance between resolution and ensemble generation

8km refinement

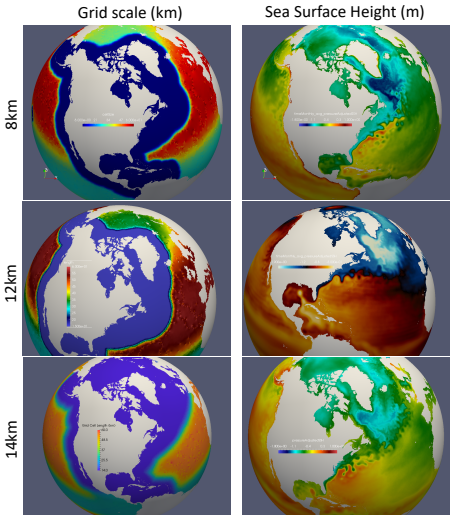
- Realistic Gulf Stream separation and Extension
- Strongly eddying in refined regions
- Refinement cuts through Subpolar & Beaufort gyre
- 850k core-hours/model-century

12km refinement

- Less realistic Gulf Stream separation and Extension
- Moderate eddying in refined regions
- Refinement cuts through Subpolar & Beaufort gyre
- 450k core-hours/model-century

14km refinement

- Less realistic Gulf Stream separation and Extension
- Moderate eddying in refined regions
- Grid refinement boundary is south of the Gulf Stream Extension, doesn't artificially modify gyres
- 330k core-hours/model-century

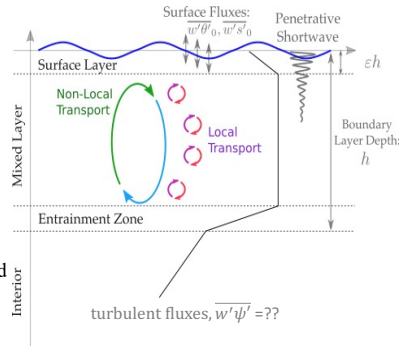


M. Maltrud Development of Regionally Refined Ocean/Sea Ice Meshes for E3SMv2 (see poster)

Oceanic Mixing and Stratification

GOAL: Better parameterization of Ocean surface boundary layer that:

- Physically based, energetics included
- Capture both local, non-local fluxes
- Computationally inexpensive with better accuracy
- Can easily integrate other physical phenomenon
- Can be implemented in large-scale ocean models

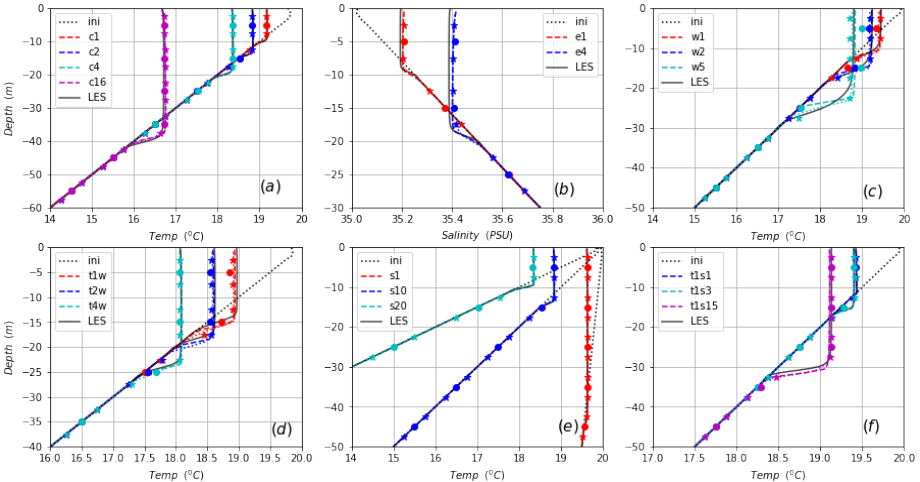


A new unified eddy diffusivity parameterization for OSBL
Assumed distribution high order closure (ADC)

- Cross fertilization of mass flux closure and higher order closure
- Fewer prognostic equation needed than a traditional high level closure and closure for higher order moments
- Inherent ability to represent non-local transport
- Lateral Entrainment and sub-plume scales are parameterized
- Higher moments are guaranteed realizable

New mixing implementation by A. Garanaik and L. Van Roekel (see poster in the Ocean-Coastal Session)

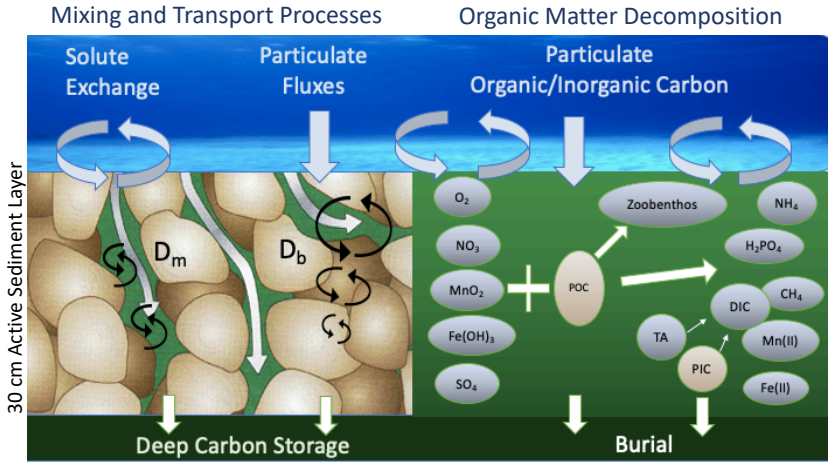
Mixing: Higher-Order Closure Results Compared to LES



Mean profile 1m: dashed line, 2m : dotted line, 5m: star, 10m: circle. Dotted black line: initial stratification, solid black: LES. Results are independent of vertical resolution.

Important result: Reduced dependence on vertical mesh configuration compared to KPP.

Ocean benthos biogeochemical module for MPAS-O in E3SM



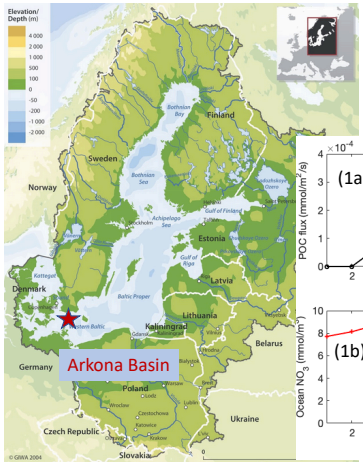
Current milestones

1) A 1D prototype model (Matlab) with 35 reactive tracers. Validating against observations in the Arkona Basin.

2) A 3D (Fortran) implementation in MPAS_O, 1-way coupled with ocean BGC. Verifying against prototype model

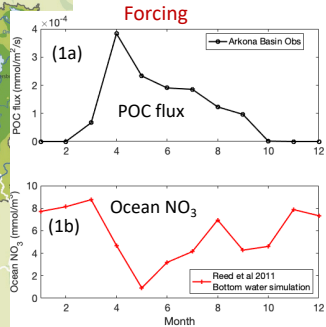
Benthic BGC implementation by N. Jeffery (Thursday talk in 3rd breakout D4S2)

Arkona Basin, Baltic Sea Benthic GBC Test Case Spin-up

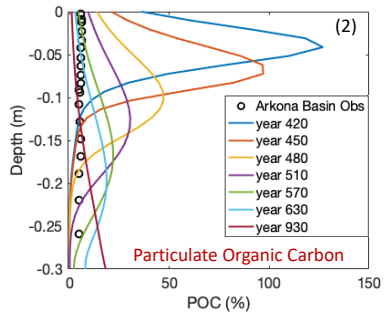


Validating the 1D Prototype Model

Seasonal climatology from (1a) observations and (1b) the Reed et al 2011 model of ocean bottom water



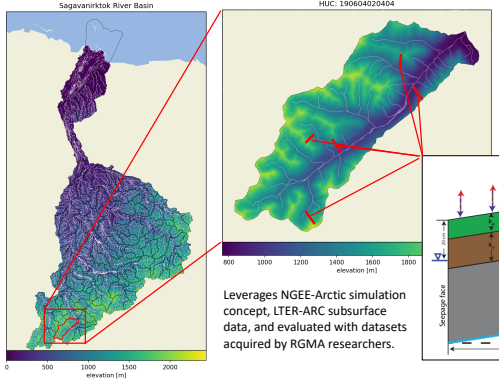
(2) Profiles of benthic POC from > 900 years of spin-up exhibit relaxation towards equilibrium



Benthic BGC implementation by N. Jeffery (Thursday talk in 3rd breakout D4S2)

Coupling the Advanced Terrestrial Simulator with MOSART

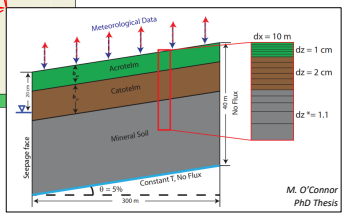
Saganavirktok River Basin (Prudhoe Bay, AK)



ATS-MOSART
Simulations on an ensemble of hillslopes, characterized by:

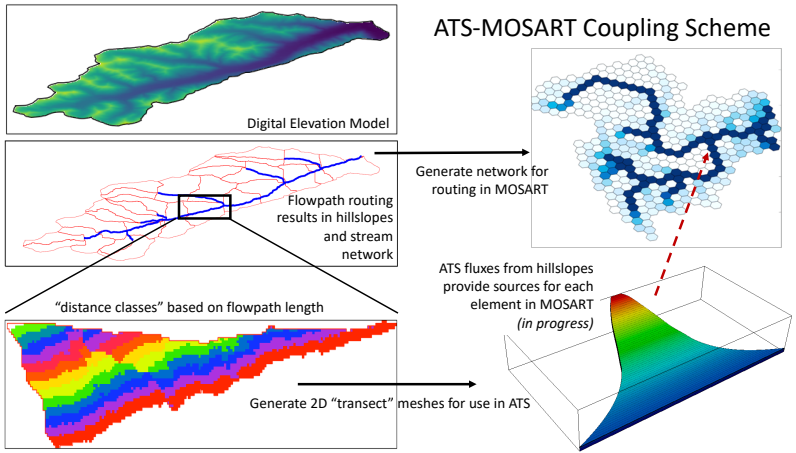
- slope, aspect,
- landscape/ vegetation type
- meteorological data
- soil structure

Leverages NGEE-Arctic simulation concept, LTER-ARC subsurface data, and evaluated with datasets acquired by RGMA researchers.



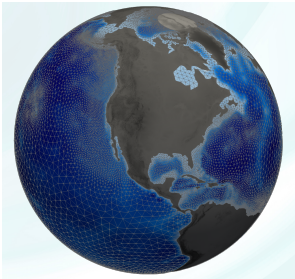
Proof of concept by E. Coon, J. Schwenk, and T. Zhou in collaboration with ICoM

Permafrost Hydrology: Coupling the ATS with MOSART

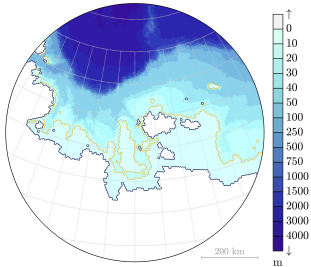


Proof of concept by E. Coon, J. Schwenk, and T. Zhou in collaboration with ICoM

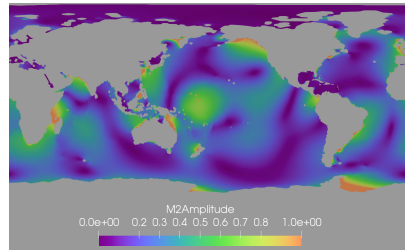
Sea Ice Model Development: Icepack in MPAS-SeaIce



NGD Collaboration: Wave-Ice Interaction
(Steve Brus)



CICE Consortium: Landfast and Wave-Ice
(Elizabeth Hunke)



ICoM: Ice-Tide Interaction
(Brian Arbic)

Icepack is being implemented and adapted in E3SM as part of InteRFACE and E3SM core developments, and in collaboration with a number of ESMD entities.

Project Integration using E3SM V2 and Future Timeline

Simulation Campaign				2020				2021				2022		
Task	Code Base	Configuration	Quarter:	1	2	3	4	1	2	3	4	1	2	3
2.1	E3SMV2	G	InteRFACE configuration baseline											
		BP	InteRFACE 1950 atmospheric constituents 200-year baseline											
		BH	InteRFACE 1950-2015 10-member historic ensemble baseline											
2.2	V2+I+64L	MPAS	Landfast ice development											
		G	Landfast ice experimentation											
		BP	Landfast ice coupled 1950 atmospheric constituents 200-year											
		BH	Landfast ice coupled 1950-2015 10-member historic ensemble											
2.3	V2+64L	LES	Mixed layer LES experiments											
		MPAS	Mixed layer development											
		G	Mixed layer experimentation											
		BP	Mixed layer coupled 1950 atmospheric constituents 200-year											
		BH	Mixed layer 1950-2015 coupled 10-member historic ensemble											
2.4	V2+I+64L+W	MPAS	Wave code development											
		G	Wave experimentation											
		BP	Wave coupled 1950 atmospheric constituents 200-year											
		BH	Wave ice coupled 1950-2015 10-member historic ensemble											
2.5	V2+64L+M	ATS	Hydrology development with ATS											
		BP	Hydrology coupled 1950 atmospheric constituents 200-year											
		BH	Hydrology coupled 1950-2015 10-member historic ensemble											
2.6	V2+I+64L+B	MPAS	BGC development											
		G	BGC experimentation											
		BP	BGC coupled 1950 atmospheric constituents 200-year											
		BH	BGC coupled 1950-2015 10-member historic ensemble											
2.7	V2+I+64L	BF	Projection 2015-2050 SSP5 from O1-BH 10-member ensemble											
		BF	Projection 2015-2050 SSP5 from O3-BH 10-member ensemble											
	V2+I+64L+M+B	BF	Projection 2015-2050 SSP5 from O6-BH 10-member ensemble											

InteRFACE model configurations: MPAS: Model for Prediction Across Scales; LES: Large Eddy Simulations; ATS: Advanced Terrestrial Simulator; G: E3SM ice-ocean forced with JRA-55; BP: Fully coupled (B-case) 100 year simulation with perpetual 1950 HighResMIP atmospheric constituents; BH: B-case with transient atmospheric constituents from 1950 to 2015 with 10 ensemble members; BF: forward projections to 2015-2050. Code base notation follows the ESMD Tasks.