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



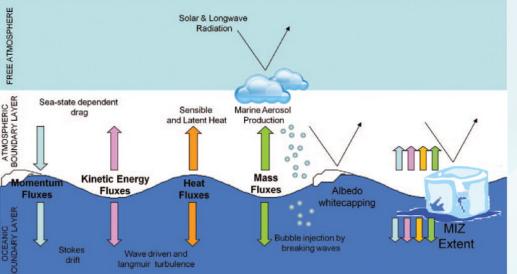


A new E3SM NGD project

- 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?



PYCNOCLINE

Wind-wave dependent processes in the coupled climate system Towards coupled wind-wave-AOGCM models

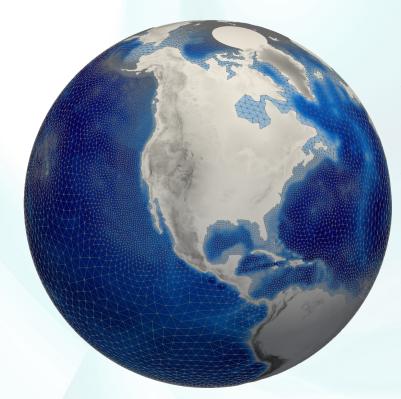
Cavaleri et al. (2012)

 Wind-generated waves are an important interfacial process in the climate system

Some cross-component interactions include:

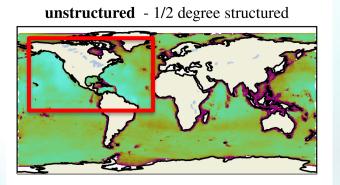
- Ocean vertical mixing
- Sea-state dependent drag
- White-capping albedo
- Sea-ice floe size

WAVEWATCHIII Progress

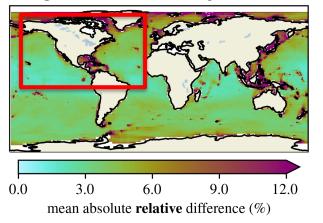


- WW3 implemented into E3SM as a separate component
- New unstructured capability successfully validated
 - 2 degree resolution globally
 - ½ degree resolution for depths < 4km in U.S. coastal regions
 - Unstructured mesh is compared to 2 degree and ½ resolution structured meshes

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



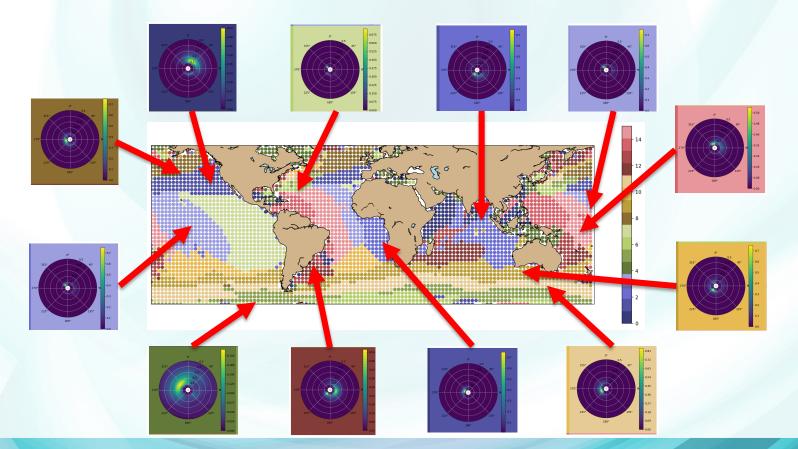
2 degree structured - 1/2 degree structured





- 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

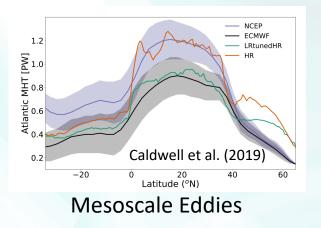


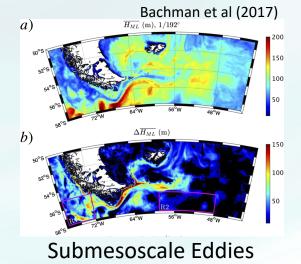
Where we are going

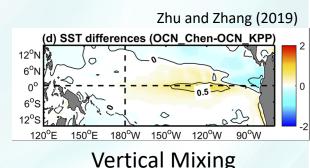
Improving ocean model fidelity

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)



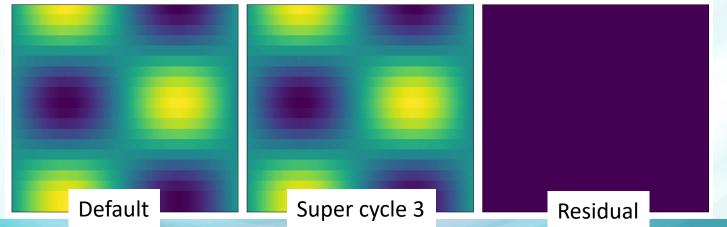




Improving ocean model performance

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

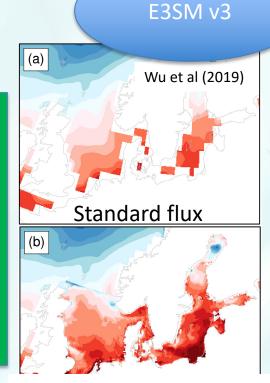


Advancing Coastal Ocean Modeling

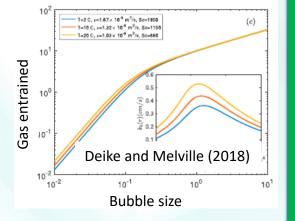
Influence of Waves on the Ocean

•

•



Sea state dependent flux



Air-sea gas exchange

NGD Targets

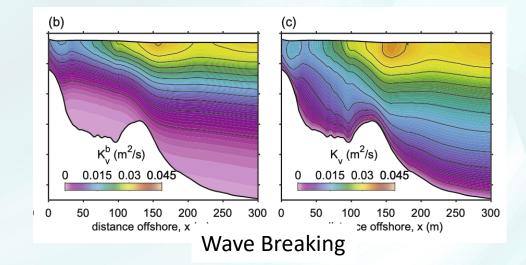
- Link sea state from WAVEWATCHIII to the coupler
- Implement sea spray and bubble parameterization

Temperature and momentum fluxes

Influence of Waves on Coastal BGC

E3SM v3

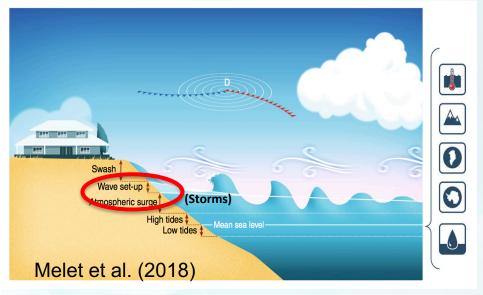




NGD Targets

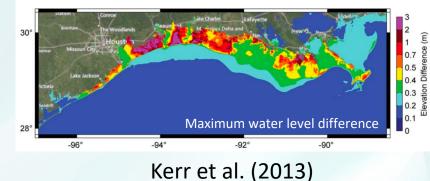
- Couple Stokes drift to the ocean
- Add wave driven mixing to vertical mixing closure

Coastal Inundation



E3SM v4

Wave contribution to water levels during Hurricane Ike



NGD Targets

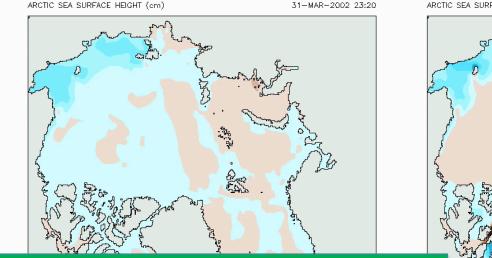
• Coupling of radiation stress to ocean model and tides

Climate drivers

- Ocean wetting and drying
- Improved vertical mixing

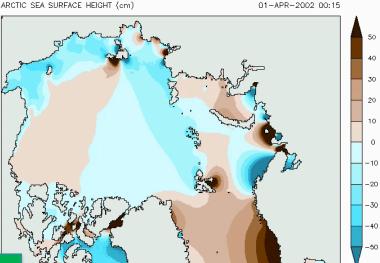
Influence of Sea-ice on Arctic Coast

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



NGD Targets

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



E3SM v4

FORCING: M2 TIDE & ERA-40 GEOSTROPHIC SURFACE WIND

Influence of ocean eddies on BGC

E3SM v4+

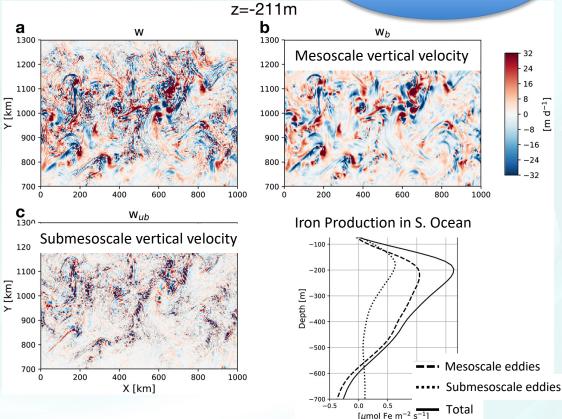
24 16

-16-24 d⁻¹]

- 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! ۲



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

1				
ocean				landice
hurricane	global_ocean	baroclinic_channel	sub_ice_shelf_2D	Thwaites_varial dome
hurricane_wind_pressure USDEQU USDEQU	QU240 SO60to10wISC EC60to30wISC	10km 1km	5km	1km uniform_r 2000m var
tests utils winds build_me build_me	init se_par bgc_irk4_t init te init	rpe_test restart_ rpe_test t	restart_te Haney iterativ	sta resolutio decompositic ho_restart_tr restart_te: smokr or
windshust in ino huiloo buico	buili co co co .gi co ci ci ci ci build confi coi de buil con coi co	conficced a cea con cor ce ce	CC CC CO CC CO CC CO	ik cornanitortor corcor c corc alb
tett dis imp con cor	cont confi confi cont conti confi confi conti con con con con d	confi con cor	con o re co co co co	R na name ho decompc ho vs sia te cor cor
to utils hurr profi struc sandy synthetic	CON conti co	confi	con confir confir	c na name ne doctrine ne rocate halfar_ana dome che
ad_hoc _ h _ r _ g con o o cor c c	restart test	This is a second s	with frazil default .c	4km_ RI alt cc
m sir wi	ai col col con con con spin_up com con con temp	ipe_test t	coni con ci cor c c	star variable_resolution set
winds suna num pi	rk4_partition_t analysi: test ten EC60to30 QU240wISC ARM60to		coni con: cor	finalize slu thy decomposition_ ho_restart_test halfar_ar c
pa ve wi REAl main con cr cr cr	ni co co co co co init init init	threads_test co co cor con c p	Haney_num templat ten	setup_ ho decompositi restart test smoketes vis
USDEQU240at USDEQU1 USDEQU2 USDEQU6	WC14 buil cc cc co bi cc cc cc Ar At El	cc cc cc cc cc templa cor con	or or or or templat	slurm.e thwaite
build_i synthe builc sand builc sand builc sand		ziso tendency_verifica lock	_exchange Redi_verification	hydro-shmip MISMIP3D
bucc coco bc cc bc cc bc cc	buili con co co de lar co co co confii de confii co co buico co	20km 10km all 0.5	km SouthernOcea	standard_resolution co full_width minimal_widt
co cc co co	coa con land reciper cor co co spin up tel tel santi defer con o d	defau with_ defa Redi rpe	e_test all se_l	experiment A experim expe Stnd Stnd
sandy CCCVCCCVCCCV	con con regic cor		infococo: acoro:.jo	
USDEQU120at30cr USDEQU USDEQU scripts	con con regic reg reg confir and tempitempi con		nt nt cor c p cor cor c c	confi confi confi confi setul COLCOL CONFINENCI CONFINENCI CONFINENCI
	WC12 con con con		ini cor cor plo	overagiment P C S conf
build_mes sandy build_m∈ build_m∈ cor cre	init spin up HI120t012 tem ter	con con cc ple de	fault thread te ter	con con con s
USDEQU60at15cr5 buil c c buil c c inte spi	buik cont co co de lai cr cr cr cr config files	default ziso con con	Inread_le ler	con con con REA per per conf nam nam nam
build mes sandy sandy vec writ	coa: confi c	con con temp 16	config_fil tem	experiment_D peric st vis REAI albar mism plot_ se se
	coni coni landi rei rei cont ci ci confi confi confi	default de	fault	con con con s peric perio REAl cull_ plot_ plot_
USDEQU60at15cr5 config_files sandy synthe for	r cont cont region region tomplate f confi confi cor cop cull run tem ter	internal_waves overflow coa	stal isomip	
build_mes sandy con cont ct NOA SAN	drving slope	5km 1km Ma	ine USC 10km	hydro-radial initMIP-AIS circular-shelf
 con cont forwar init init 	analysis hybrid zstar variabl marsh flo	rpe_test defai rpe_test ini	t buil expt1 expt2	1000m RE pa plc bmb ctrl 1250m
USDEQU60at15cr5 config_files_ forwar	data cor 1km 250m 1km idealized	corocco o o cororoco bi	ματα έτε ατας ατας	decompos spinup. Test_er Test_er decompos ci
build_mes sandy conficconfic init_ max		cor conf pl o ci cor cor co plc or		oor oor
		COF conf 10km	and and and	restart_tes
soma	r0.0 r0.0 r0.0 r0		nfi scrip temp tem tem	oor oor o o o o o o o o o o o o o o o o
4km 32km 16km	10.0.00	surface waves Gaussian hi templa	atos	EISMINT2 confined-shelf EISMINT1
broken defau surfa defaul time_v 3layer	r0.0 r0.0 r0.0 r0.0 r0 qui coi coi c c coi coi c meshes forw for	A	sis members streams	25000m se 5000m alba 50000m che
32to4km cr cr cr cr cc cc cc cc cc co cc oor c c	zstar variableManningn zstar 1km 250i idea		de elia alo alo KPP lar mi	standard exc decom El decomposi co setu Mov El
cont cont CC CC CC CC default	11m 250m	thickness or	forci	Vis cocco
alime confi confi confi confi	IKm zstar_above_la init_ init_ init	1km analysis delaware high	mi oc ok se frazi shortu	color or or pe smoketest pe visu hydro-ramp
8km 3layer or	0000000000000 00 00 00 00 1km	lagra	validations	MISMIP+ greenland 20000m plo
broken defau surfa surface_	isomip_plus	20km sea_mount layer	sedir tim tim	atenderal rea DEA mir mir mir 200m
32tn8km cr cr c cr surface_resto cor c c 3layer	2km 5km viz seti seti se	6.7km meri	surfa water LIG fra: pro	standard_te alba decompositi smc , rai
cr cr cr comi com analy soma soma soma	Ocean0 Ocean Ocean0 Ocean1 _ ha	default . to mixe	test_zonal	REDEDET I mismit set restart test
	.git cor cor cor co	scripts		restart_test gree regression_s
dam_break	cor cor cor cor co		Tparticle: plo land ni rp it	test utility_scripts doc runtim READI genera list ma
default	unie_varying_out con c Con c Ocean2 te templi	USDEQU120a sc for planar	pl light	basic e che con mai RE/ RE RE moin READI genera
analysis 004m 012m	con cor con o p con con processir tomply under	t build_r harm sphere vertic	al_grid pl READ load c	960k con mak setu RE READ .gitignt clean_ genera setup_
	removeP temple upue	nm_te		READ .gitight clean_ genera setup_

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?