Los Alamos NATIONAL LABORATORY

CLIMATE, OCEAN AND SEA ICE MODELING PROGRAM

The Los Alamos Sea Ice Model
A CICE 5.0 Update

U.S. DEPARTMENT OF ENERGY | Office of Science

Outline

1. **For Release in 2013**
   - Infrastructure & efficiency improvements
   - 2 multiphase physics approaches
   - 2 new melt pond schemes
   - Biogeochemistry
   - Anisotropic rheology “EAP"
2. **Continuing Development**
   - Anisotropic rheology “EDC"
   - JFNK viscous-plastic rheology
   - Topography/mechanical redistribution
   - Icebergs
   - Ice-ocean coupling
   - MPAS
   - Snow physics

Infrastructure & efficiency improvements

- Tracer handling
- CPP options for categories, layers, tracers
- Read/write extended grid (with ghost cells)

from CESM:

- Tony Craig's grid decompositions, ice halos
- OpenMP threads
- Parallel I/O (PIO/pnetcdf)
- miscellaneous parameters, etc.

from HadGEM:

- Gregorian calendar with leap years

Multiphase Physics — 2 Approaches

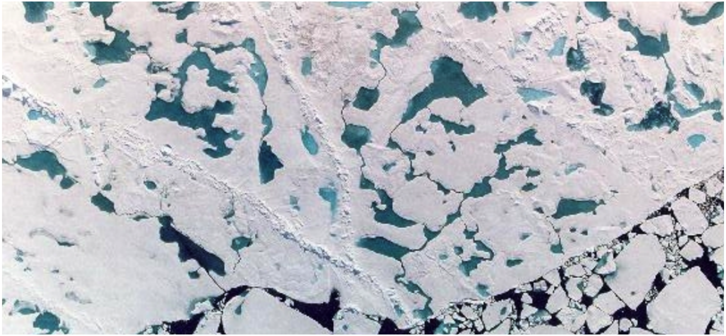
Equations	Variables
Conservation of energy	Enthalpy
Conservation of salt	Bulk salinity
Ice–brine liquidus relation	Liquid fraction ϕ
Darcy flow through a porous medium	Vertical velocity

$$X_{bulk} = \phi X_{brine} + (1 - \phi) X_{ice}$$

1. Mushy Layer thermodynamics from the ground up
   Adrian Turner
2. Bitz & Lipscomb 1999 thermodynamics
   + coupled vertical salinity transport model
   Nicole Jeffery

Melt Ponds in CICE

1. implicit: old shortwave parameterization reduces albedo
2. crude description for testing delta-Eddington radiation
3. explicit, empirical: CCSM4/CESM1 pond scheme "cesm"



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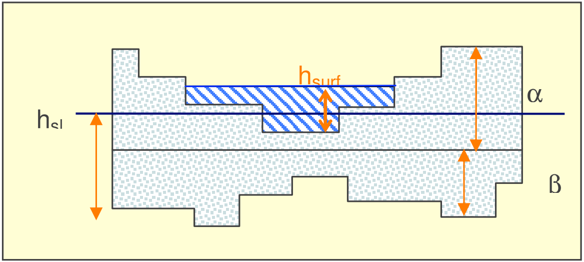

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5. fusion of 3 and 4 "lvl"

   from 3: pond shape

   from 4: physics-based pond volume reductions

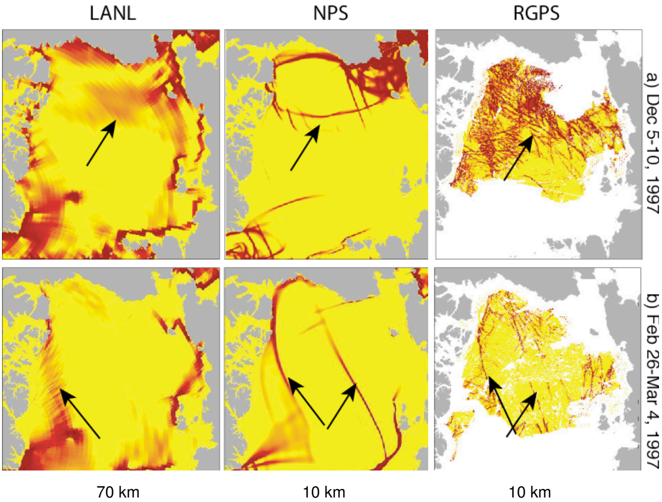
   NEW carry pond area, volume as tracers on level ice

Biogeochemistry

This session:

Scott Elliott	“Biogeochemistry in the upcoming CICE release"
Clara Deal	CCWG DMS recap
Nicole Jeffrey	“Modeling biogeochemistry in the ice interior: The CICE release and beyond"

Constitutive Modeling Shear Deformation



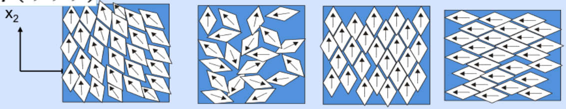
Kwok et al., "Variability of sea ice simulations assessed with RGPS kinematics." J. Geophys. Res., 2008.

Anisotropic Rheology

EAP

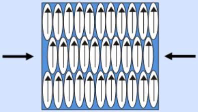
The degree of local anisotropy is estimated by the structure tensor **A**

$\psi(h, \boldsymbol{\tau}; \mathbf{x}, t)$



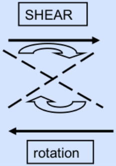
$$\mathbf{A} = \frac{1}{2}\begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix} \quad \mathbf{A} = \begin{pmatrix} 0 & 0 \\ 0 & 1 \end{pmatrix} \quad \mathbf{A} = \begin{pmatrix} 1 & 0 \\ 0 & 0 \end{pmatrix}$$

$$\mathbf{A} \equiv \langle \boldsymbol{\tau} \otimes \boldsymbol{\tau} \rangle = \int \psi \tau_i \tau_j \, dh d\tau$$



Stress depends on lead orientation, **A**

$$\sigma = \sigma(h, \dot{\varepsilon}, A)$$



Lead orientation, **A,** evolves

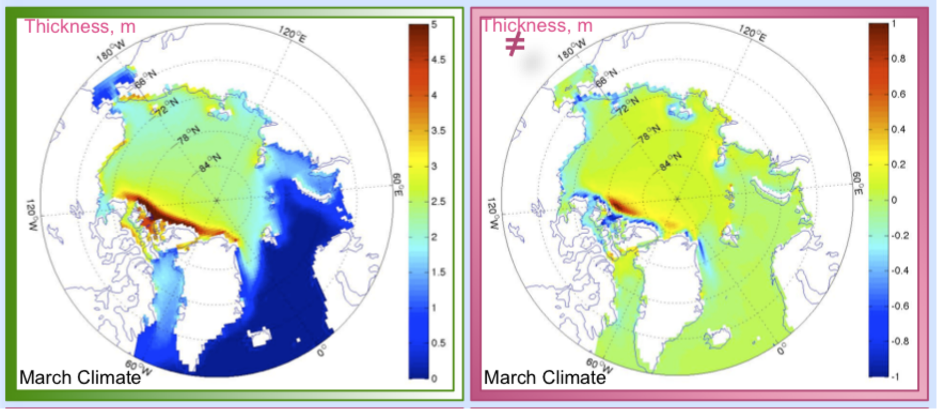
$$\frac{DA}{Dt} = F_{therm}(A) + F_{frac}(A, \sigma)$$

elastic
anisotropic
plastic

M. Tsamados et al.
CPOM
U. Reading, UK

Anisotropic Rheology EAP

EVP Thickness EAP



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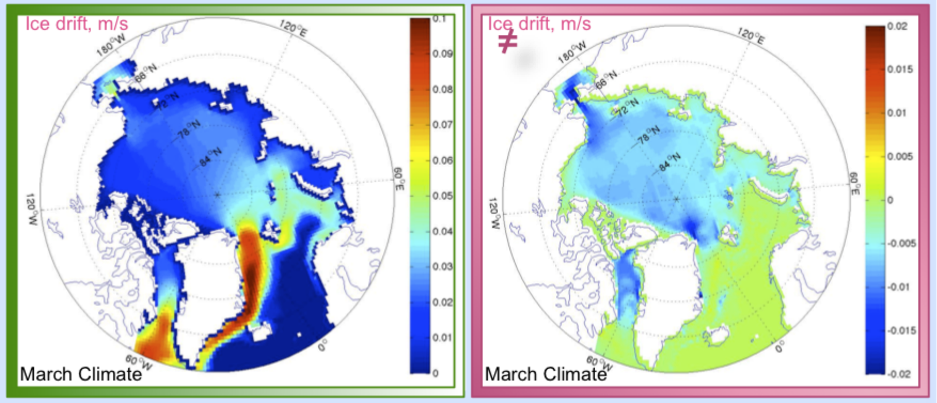

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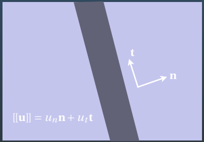
Continuing...

Anisotropic Rheology
EDC

elastic-decohesive fracture model

in collaboration with Kara Peterson, Sandia National Laboratories

- Intact ice modeled as elastic
- Leads modeled as discontinuities
- Model predicts initiation of a lead and its orientation
- Traction is reduced with lead opening until a complete fracture forms

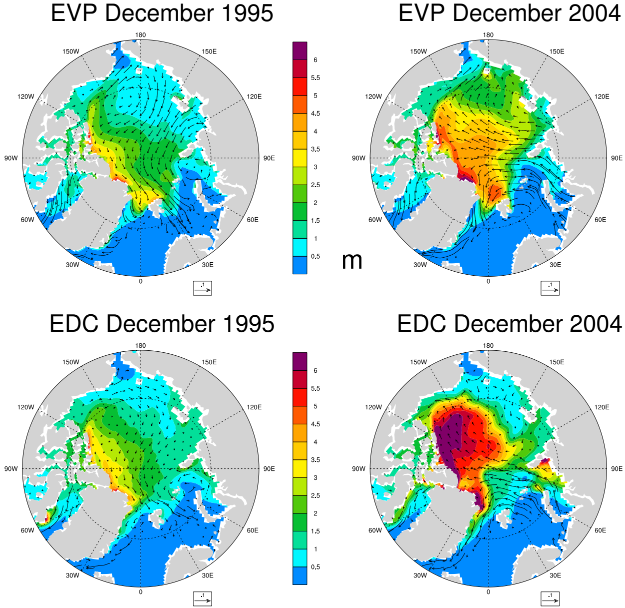


The University of New Mexico

Schreyer, H., L. Monday, D. Sulsky, M. Coon, R. Kwok (2006), Elastic-decohesive Constitutive Model for Sea Ice, J. of Geophys. Res., 111, C11S26, doi:10.1029/2005JC003334.

Deborah Sulsky GFDL Ocean Climate Model Development Meeting, Oct. 28-30, 2009

CICE tests Jan 1995 - Dec 2004



thickness and velocity

modified CORE atmo forcing

1° grid

initially thin ice

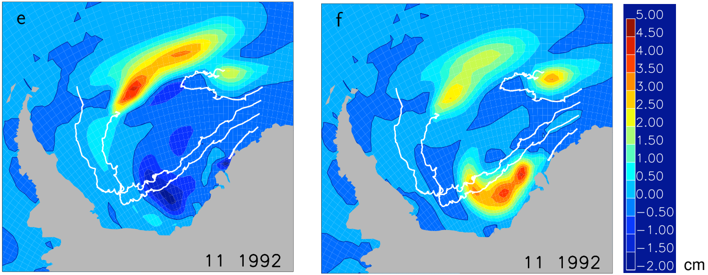
JFNK viscous-plastic rheology

Jean-Francois Lemieux, Bruno Tremblay, et al.
are adding JFNK VP option to CICE

Topography/mechanical redistribution

Ute Herzfeld and Brian McDonald
“Ice deformation in Fram Strait—Comparison of CICE simulations with analysis and classification of airborne remote-sensing data"

Icebergs in CICE



Δ deformed ice *h* Δ level ice *h*

$\Delta =$ with bergs - without bergs

Evaluating: Thermodynamics
Size distribution
CESM coupling

Future: Berg mass flux from CISM

E. Hunke and D. Comeau, Sea ice and iceberg dynamic interaction. *J. Geophys. Res.* **116**, 2011.

Sea ice-ocean coupling

High-Res session (yesterday):

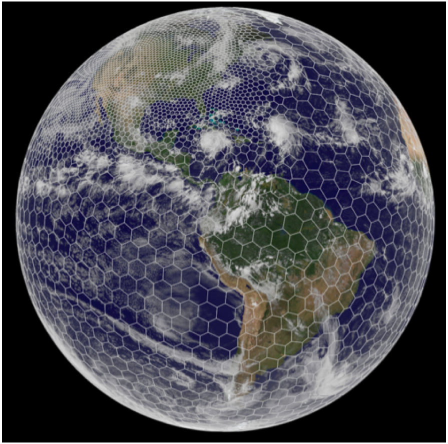
Dave Bailey, Julie McClean, Andrew Roberts

Coupled ice-ocean stability analysis:

Beth Wingate, Jared Whitehead, Terry Haut

MPAS Model Prediction Across Scales

An unstructured-grid framework for climate modeling



Incorporating CICE Physics

Step 1: column processes
- thermodynamics
- ice thickness distribution

Step 2: 2D processes
- momentum
- constitutive equation
- transport

Snow physics

New snow parameterizations:

- Spatial distribution
  Snow depth over level and deformed ice
- Depth hoar
  Grain size as a function of temperature gradient
- Wind packing
  Snow density as a function of wind speed

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