Los Alamos NATIONAL LABORATORY

CLIMATE, OCEAN AND SEA ICE MODELING PROGRAM

The Los Alamos Sea Ice Model *CICE* Progress and Plans

February 16, 2012

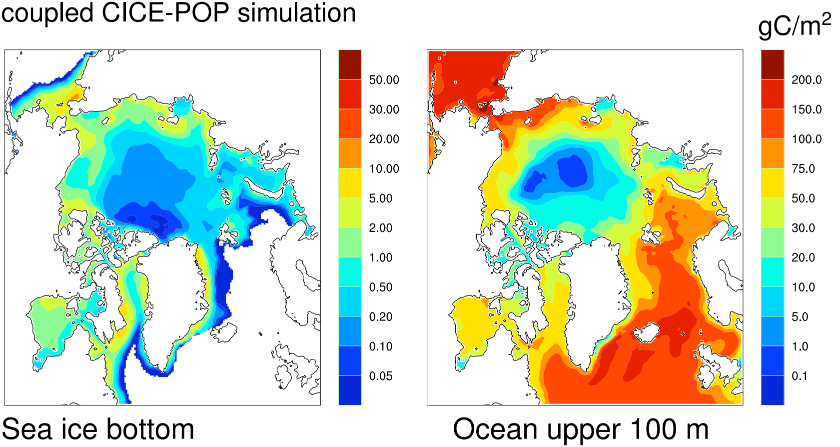
U.S. DEPARTMENT OF ENERGY | Office of Science

Outline

Annual Carbon Production, 1998–2007

IARC/UAF

coupled CICE-POP simulation



Jin et al., “Modeling study of the Arctic sea ice and ocean primary production and model validation in the Western Arctic,” Deep-Sea Res., submitted 2010.

Popova et al., “What controls primary production in the Arctic Ocean? Results from an ecosystem model intercomparison,” J. Geophys. Res., submitted 2010. **AOMIP**

Deal et al., “Large-scale modeling of primary production and ice algal biomass within arctic sea ice in 1992,” J. Geophys. Res. 116, 2011. (stand-alone CICE)

Ice Algal Biogeochemistry for Full Arctic, with DMS Release

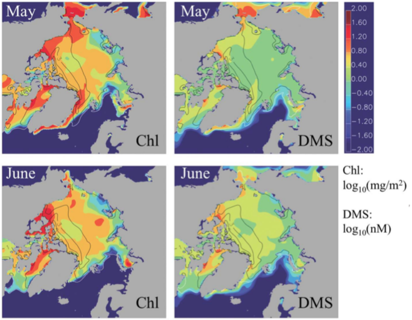
Objective

Marine ecodynamics influence high latitude climate via greenhouse gases and aerosol precursors, emitted from both ocean and ice. We present the first regional scale model of sea ice sources for dimethyl sulfide (DMS), primary natural carrier of sulfur to the atmosphere.

Approach

- Driven by ice algae & nutrients in CICE
- N, Si, C, pigments alongside S cycle
- Large DMS fluxes from ice into margins, leads and peripheral seas
- But data for comparison very sparse
- Renewed measurement activity recommended for all Arctic waters

Chlorophyll & DMS produced by CICE algae: Pigments in ice, trace gas below and in margins



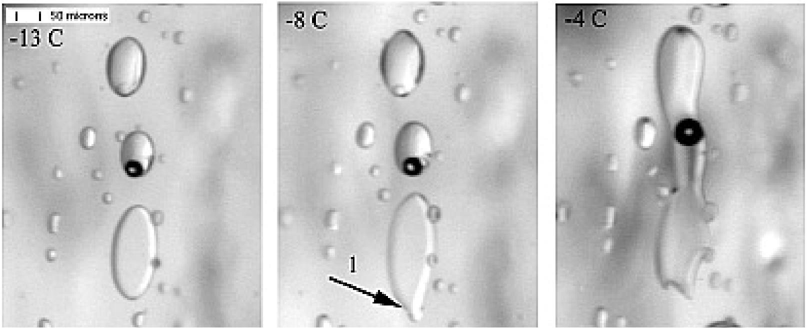
Impact

Simulations of marine aerosol precursors will enable uncertainty quantification for cloud optical effects across Arctic system

Elliott, S., Deal, C., Humphries, G., Hunke, E., Jeffery, N., Jin, M., Levasseur, M. and Stefels, J. 2012. Pan-Arctic simulation of coupled nutrient-sulfur cycling due to sea ice biology. Journal of Geophysical Research, doi:10.1029/2011JG001649.

Multiphase Physics
Vertical Tracer Transport

Adrian Turner
Nicole Jeffery



courtesy B. Light, JGR 2003

Multiphase Physics
Vertical Tracer Transport

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H. Eicken

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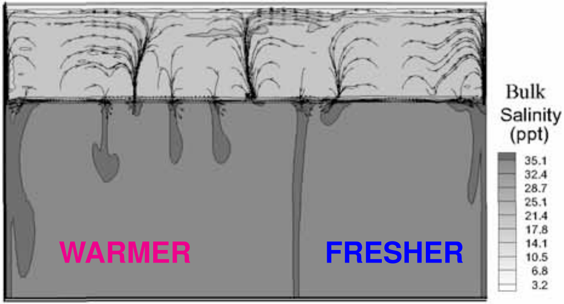
FREEZING: Gravity Drainage



Oertling and Watts, JGR 2004

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 (A. Turner)
2. Bitz & Lipscomb 1999 thermodynamics + coupled vertical salinity transport model (N. Jeffery)

Multiphase Physics — Turner's Approach

Exact Newton solver for current vertical thermodynamics

- 30% faster than original tridiagonal solver

JFNK solver for current vertical thermodynamics

- improved speed by using full Jacobian as preconditioner
- 20% slower than original tridiagonal solver

JFNK solver with fully prognostic salinity

- can handle full non-linear coupled problem
- Mushy layer physics formulation with gravity drainage, flushing
- Status: testing 1D (tank and field experiments) and 3D global simulations

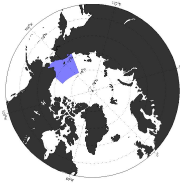
Multiphase Physics — Jeffery's Approach

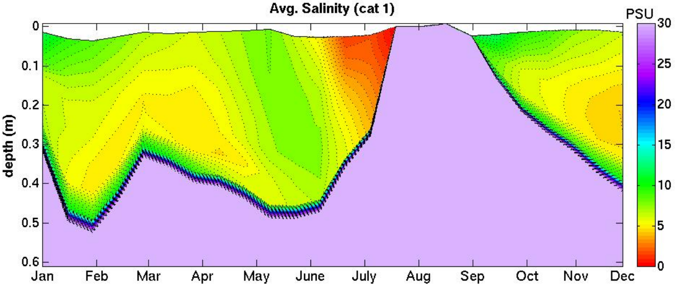
Current thermodynamics (BL99)

+ new vertical transport model

Tracers:

- brine height
- salt
- biogeochemical constituents (algae, nutrients, etc.)





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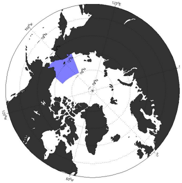
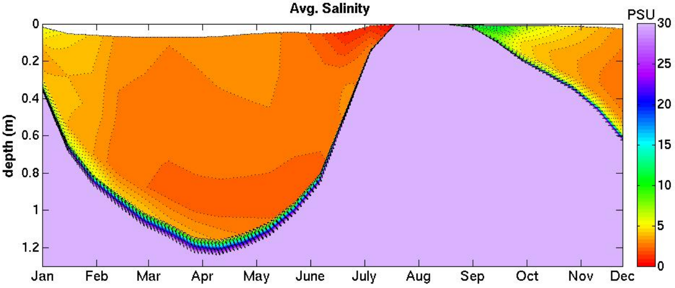
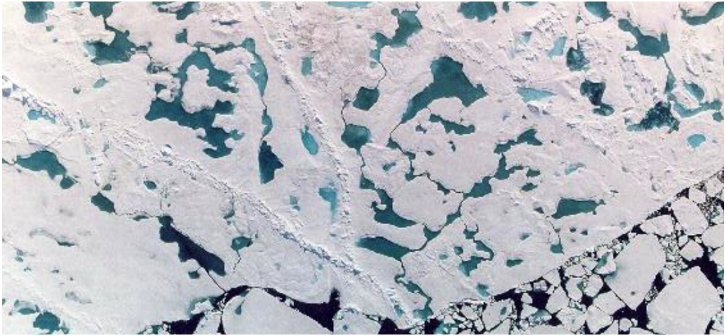




Melt Ponds in CICE

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



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JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 115, C08012, doi:10.1029/2009JC005568, 2010

Incorporation of a physically based melt pond scheme into the sea ice component of a climate model

Daniela Flocco,[1] Daniel L. Feltham,[1,2] and Adrian K. Turner[1]

Received 12 June 2009; revised 12 February 2010; accepted 13 April 2010; published 10 August 2010.

Melt Ponds in CICE

1. implicit: old shortwave parameterization reduces albedo
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4. University College London's approach
5. fusion of 3 and 4

   from 3: pond shape

   from 4: physics-based pond volume reductions

   NEW carry pond area, volume as tracers on level ice

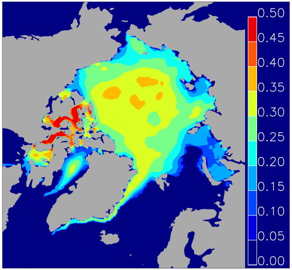
Level-Ice Melt Pond Physics

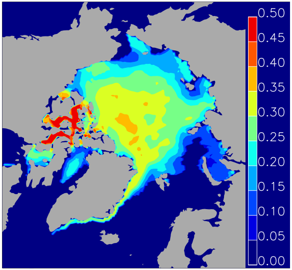
- Water input: rain, melting ice & snow
- Drainage: negative freeboard, permeability
- Snow infiltration by pond water
- Pond ice: clear, fresh
  - Stefan freezing
  - melting due to downward surface flux
  - snow accumulation blocks solar radiation below
- *Changes* in pond water volume: $\frac{\Delta h_p}{\Delta a_p} = 0.8$

Level-Ice Melt Ponds

pond area

(fraction of ice)

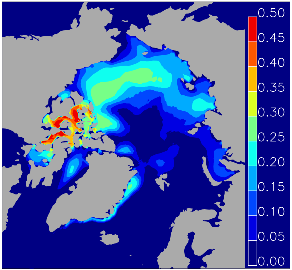


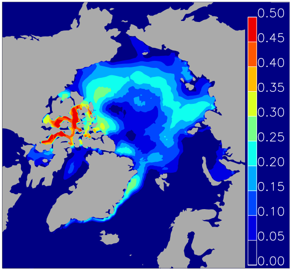


July 1980–2001

July 2000–2007

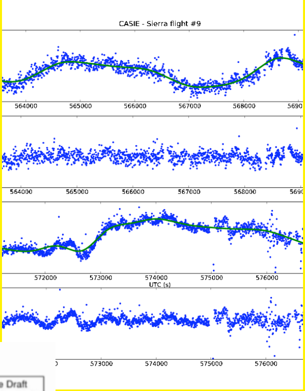
effective pond area



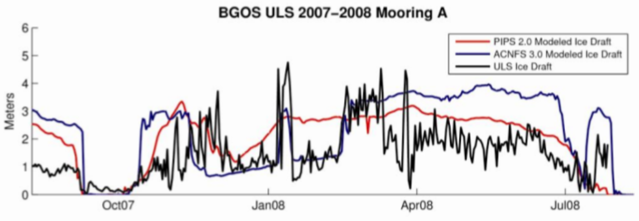


Topography

with Ute Herzfeld, UC Boulder

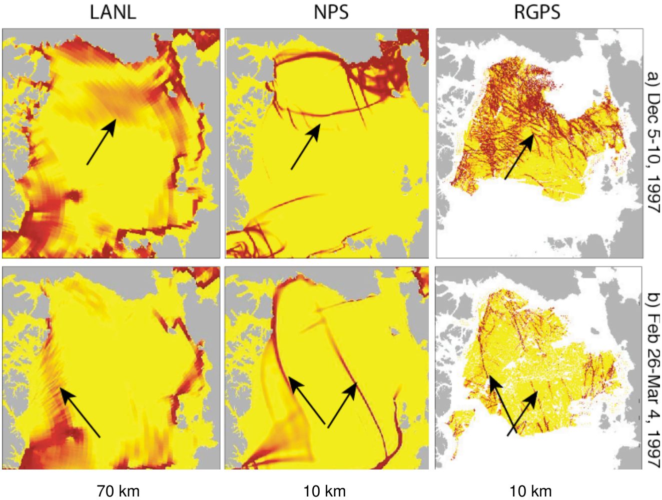


Parameterization of Ridges and Other Spatial Sea-Ice Properties From Geomathematical Analysis of Recent Observations



Naval Research Laboratory, Stennis Space Center

Constitutive Modeling Shear Deformation



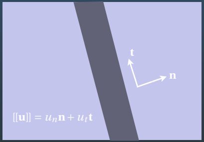
Kwok et al., “Variability of sea ice simulations assessed with RGPS kinematics.” J. Geophys. Res., 2008.

Elastic-Decohesive Rheology

anisotropic 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.

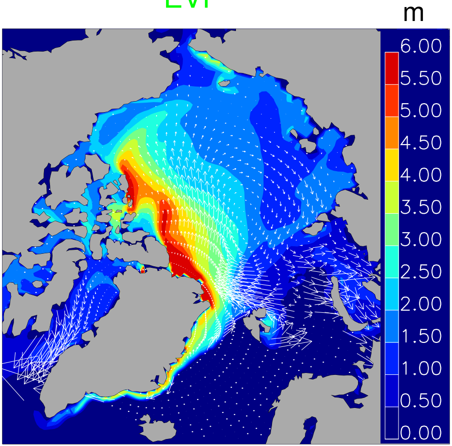
Deborah Sulsky GFDL Ocean Climate Model Development Meeting, Oct. 28-30, 2009

CICE tests 23 Feb - 11 Mar 2004

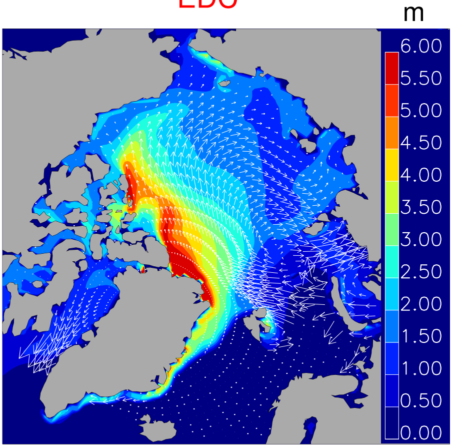
1° grid
modified CORE atmospheric forcing
initialized from CICE EVP 47-year run

thickness
and
velocity

EVP



EDC



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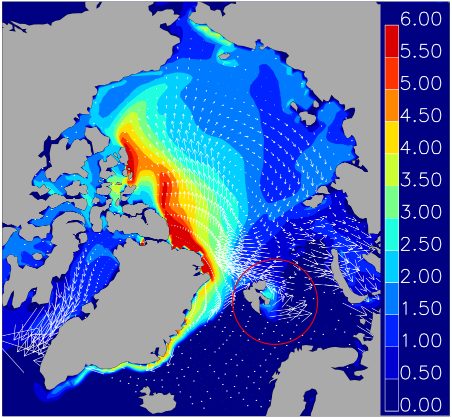

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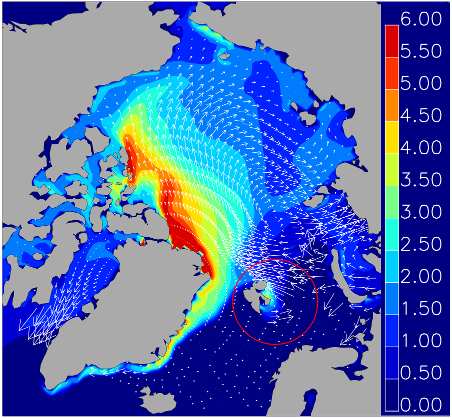

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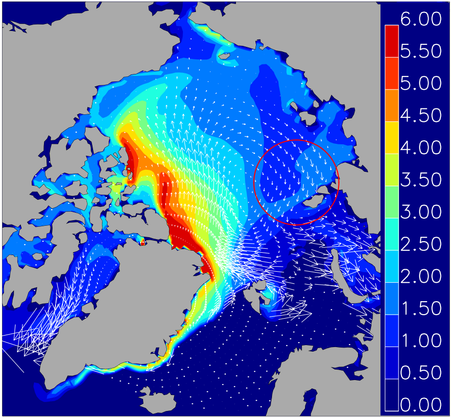
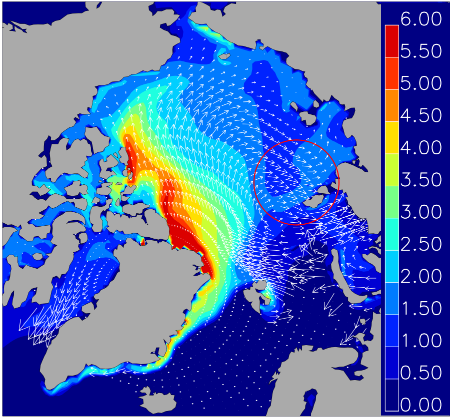
m



EDC

m



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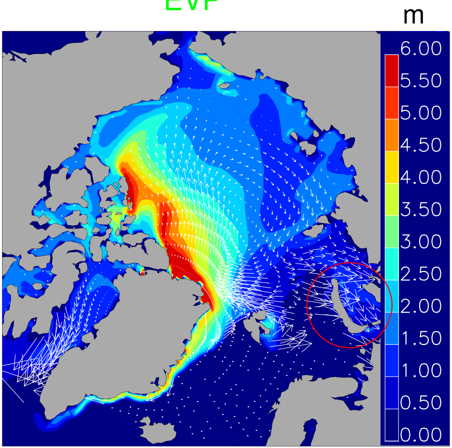
thickness and velocity

EVP



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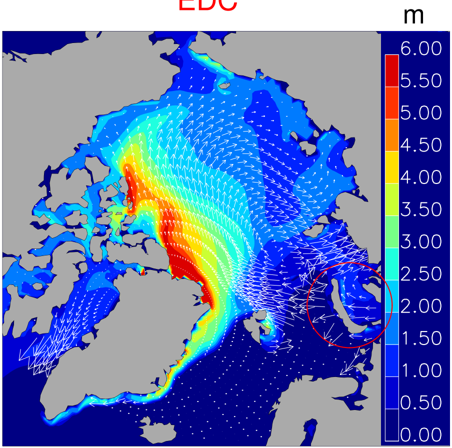

Ongoing work

http://oceans11.lanl.gov/trac/CICE/wiki/CiceDev

- CICE/CESM code infrastructure
- Other rheologies
  - Anisotropic “diamond” rheology (Wilchinsky/Feltham)
  - JFNK viscous-plastic rheology (Lemieux)
- MPAS
- Icebergs
- Ice-ocean coupling...

Workshop Announcement

Ice at the Interface:
Atmosphere-Ice-Ocean Boundary Layer Processes and Their Role in Polar Change

June 25-27, 2012
National Center for Atmospheric Research
Boulder, Colorado

with thanks to IASC, SCAR, CliC, NCAR