CICE in ROMS

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Wise Words from Hernan

- All sea ice models are the same (in-breeding)
- All sea ice models are terrible
- Satellites measure ice concentration (more or less)
- We need to assimilate ice volume

Outline

- **CICE pronunciation**
- **CICE components**
  - Dynamics
  - Thermodynamics
- **CICE user controls**
  - Build script
  - ice_in
- **Examples**
- **Future directions**

Pronunciation

"We pronounce the model name as "sea ice", but there has been a small grass-roots movement underway to alter the model name's pronunciation..."

- English "sice"
- French "cease"
- Japanese "shii-aisu"
- Italian "chee-chay"

- **Don't call it "sis"**

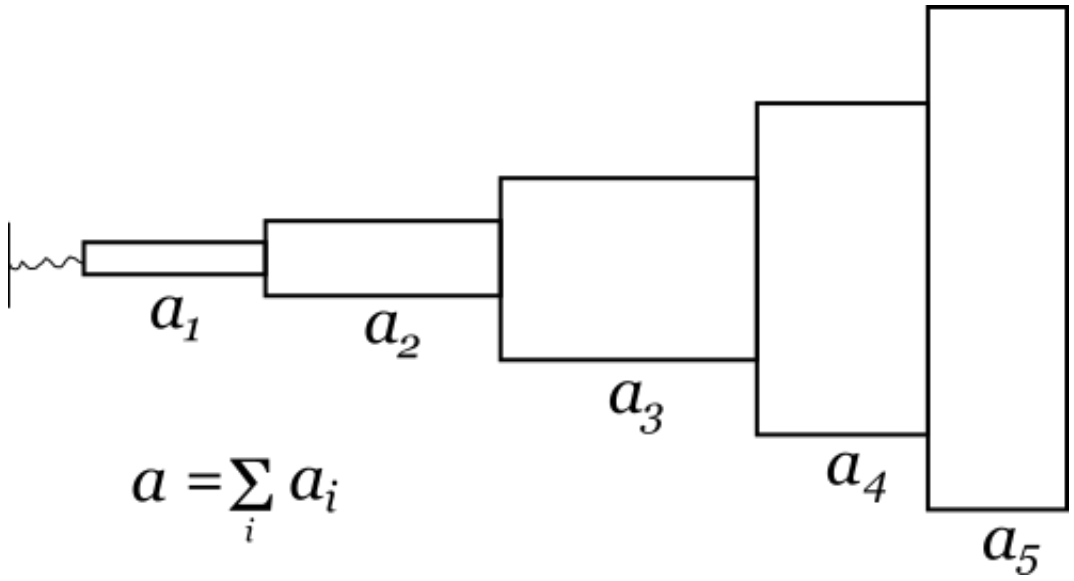
Fundamental CICE Equation

$$\frac{\partial g}{\partial t} = -\nabla \cdot (g\mathbf{u}) - \frac{\partial}{\partial h}(fg) + \psi$$

- $g(\mathbf{x}, h, t)\, dh$ **is the ice thickness distribution function**
- **u is velocity vector**
- f **is the rate of thermodynamic ice growth**
- ψ **is the ridging redistribution function**

Ice Thickness Distribution

- **Each cell has a number of different ice thicknesses (compile-time option) and open water**



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Advection of Tracers

- **Each tracer is advected using one of these equations:**

$$\frac{\partial \left(a_{in} T_n\right)}{\partial t} + \nabla \cdot \left(a_{in} T_n \mathbf{u}\right) = 0$$

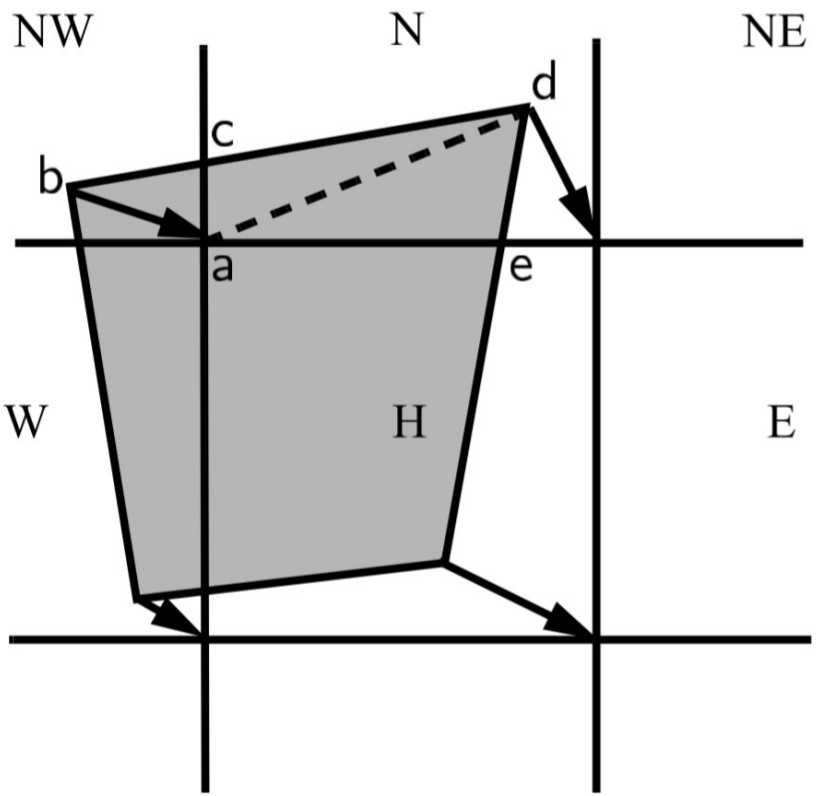
$$\frac{\partial \left(v_{in} T_n\right)}{\partial t} + \nabla \cdot \left(v_{in} T_n \mathbf{u}\right) = 0$$

$$\frac{\partial \left(v_{sn} T_n\right)}{\partial t} + \nabla \cdot \left(v_{sn} T_n \mathbf{u}\right) = 0$$

Horizontal Transport

- **Upwind or incremental remapping, latter better for:**
  - Conservation
  - Non-oscillatory
  - Monotonic
  - Second-order accurate
  - Efficient for many tracers

Incremental Remapping



- Compute weights once per timestep
- Use on all tracers
- Some tracers numbered NICELYR* NICECAT

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Changes in Thickness Space

- Like 2-D remapping, but in 1-D thickness space
- Compute thickness changes due to thermodynamics
- Remap the ice thickness categories
- Can't move more than one category per time-step

Mechanical Redistribution

- Under convergence, convert thin ice to thick ice.
- Several choices to make, based on values of krdg_partic, krdg_redist and kstrength
- I have long been unhappy with kstrength=0 (Hibler, 1979)

Dynamics

$$m\frac{\partial \mathbf{u}}{\partial t} = \nabla \cdot \sigma + \vec{\tau}_a + \vec{\tau}_w - \hat{k} \times mf\mathbf{u} - mg\nabla H_\circ$$

- **Momentum equation:**
  - Internal ice forces
  - Atmospheric stress
  - Ocean stress
  - Coriolis
  - Sea-surface tilt

Rheology

- **EVP – elastic-viscous-plastic**
  - Emulates viscous-plastic rheology
- **EAP – elastic-anisotropic-plastic**
  - New variable is local structure tensor
  - Rhombus-shaped floes
- **Both use elastic waves for computational efficiency**
- **Ice strength, yield curve both part of rheology**

Landfast Ice

- **Lemieux parameterization via bottom stress**
  - Deepest ice keels drag on the bottom and slow the pack ice
  - Parameterized ice thickness distribution – can be used with one ice class
  - Requires bathymetry
  - New to CICE

Thermodynamics

- **Three options**
  - Zero-layer of Semtner
  - Bitz and Lipscomb with fixed salinity profile
  - “Mushy” with evolution of salinity profile
- **Heat fluxes and temperature profiles are computed through the ice and snow**
- **Temperature-dependent specific heat for brine pockets (options #2 and #3)**

Thermodynamics

- **Solve for each ice thickness category:**
  - Surface temperature from surface heat fluxes: latent, sensible, longwave, shortwave
  - Heat flux through ice
  - Shortwave light penetration
    - Delta-Eddington
    - CCSM3 (implicit ponds)

Melt Ponds

- **Three different schemes, all need delta-Eddington radiation**
  - CCSM
  - Topographic
  - Level ice

$$\frac{\partial}{\partial t}(a_{pnd}a_i) + \nabla \cdot (a_{pnd}a_i\mathbf{u}) = 0$$

$$\frac{\partial}{\partial t}(h_{pnd}a_{pnd}a_i) + \nabla \cdot (h_{pnd}a_{pnd}a_i\mathbf{u}) = 0$$

Growth and Melt

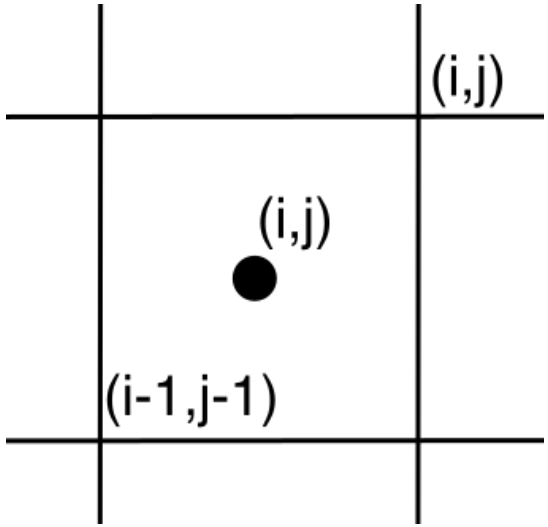
- **Surface temperature must be freezing or colder**
  - Extra enthalpy goes to melting
- **Bottom temperature at freezing**
  - Freeze or melt depending on balance of heat fluxes
- **Frazil ice added to thinnest category or to whole cell**
- **Sublimate or deposit at surface**
- **Rebalance thicknesses after above**

More Thermo

- **Lateral melt**
  - Adjust ice energy and fluxes
  - Assume floe diameter of 300 m
- **Snow ice formation**
  - When snow weighs down ice to submerge ice surface
  - Convert snow into ice

Horizontal Grid

- **Arakawa B-grid**
- **Can create NetCDF grid file from ROMS grid with Python script**
  - Uses the same grid
  - There's CICE code to read it...
  - NE convention (ROMS is SW)
- **No nesting**



Boundary Conditions

- **Place away from ice edge**
- **Can specify boundary values with "restore_ice" option**
  - Persistent initial conditions by default
  - Requires "restart_ext" option
- **Unreleased branch BC code?**

Domain Decomposition

- Set size of tiles at compile time
- All tiles numbered 1 to nx_block, 1 to ny_block (halo of 1)
- On each tile, each step, build list of cells with ice to compute over
- Load-balance by having similar amounts of ice on all tiles
- Tiles on global grids like slices of an orange (or tripole equivalent)

Exchange of Information

- **ROMS to CICE**
  - Atmospheric forcing fields
  - Frazil ice formed/available heat
  - Surface ocean properties
- **CICE to ROMS**
  - Ice concentration
  - Heat, salt and momentum fluxes
- **ROMS must compute bulk fluxes over water and merge with fluxes from CICE**

Albedo

- **ROMS default has shortwave radiation being net into the water**
  - Preprocess shortwave to account for albedo
- **Ice/snow/melt ponds affect albedo, so incoming shortwave must be before albedo corrections**
  - Don't preprocess shortwave
- **Various options exist…**

ROMS Albedo Options

- **ALBEDO_CLOUD – needs clouds**
  - Water only
- **ALBEDO_CURVE – function of latitude**
  - Water only
- **ALBEDO_FILE**
  - Ice and water
- **Careful what you pass to CICE**
  - And don't lie to it about dates because it only computes albedo when the sun shines

CICE Compile-time Options

- SITE – points to config in CICE's bld directory
- SYSTEM_USERDIR – where to put object files
- SRCDIR – location of CICE code
- RES – name of domain
- GRID – dimensions of horizontal grid
- NTASK – number of MPI processes

Continued…

- **BLCKX – size of tiles in i-direction**
- **BLCKY – size of tiles in j-direction**
- **NICELYR – number of vertical ice layers**
- **NSNWLYR – number of vertical snow layers**
- **NICECAT – number of ice thickness categories**

Continued…

- Tracer options
- BGC options
- IO_TYPE – none, pio or netcdf
- THRD – for OpenMP

ice_in

- **Run-time switches for many things (namelists)**
  - Time variables
  - Grid setup
  - Restart
  - Dynamical choices (EVP vs EAP, etc)
  - Output control
- **NPROCS must match compiled-in value!**

Sea Ice Options for ROMS

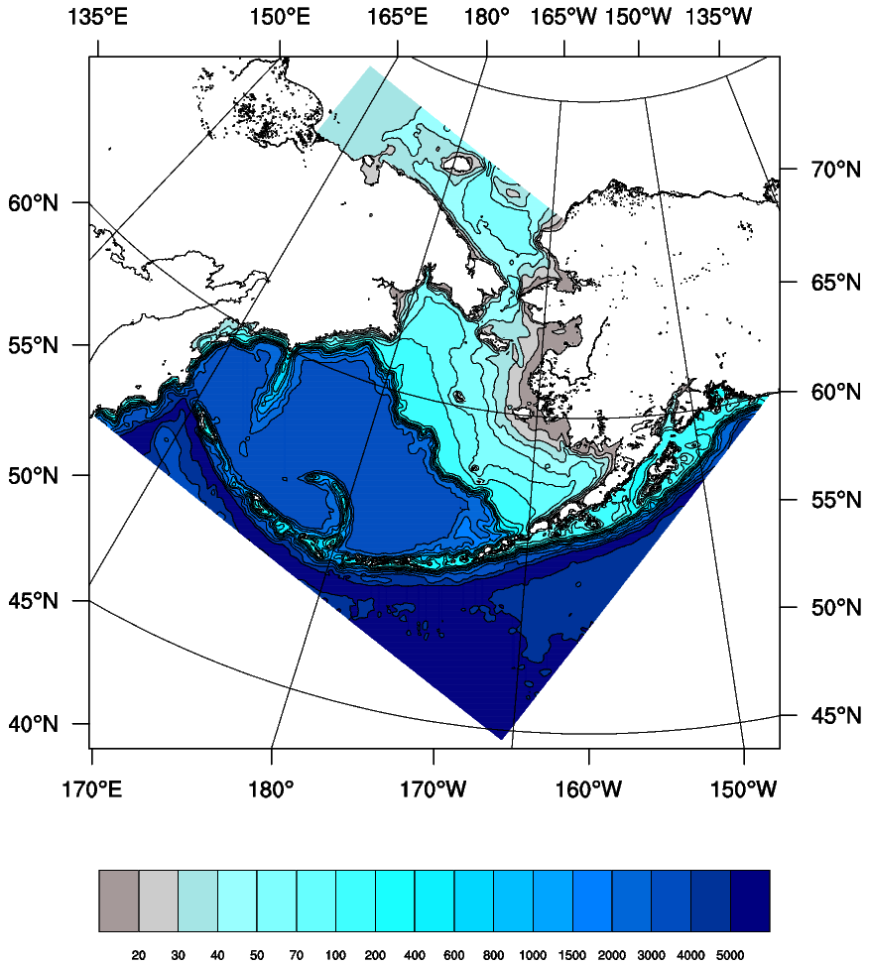
- **Budgell ice – presentation from two years ago**
  - Be sure to get updates from fall 2015!
- **CICE with fake coupler**
  - Very slow
- **Norwegian CICE-ROMS:**
  - https://github.com/metno/metroms
- **PolarCOAWST**
- **Hernan's? Sasha's?**

Examples

- **Bering Sea**
  - 10 km WRF grid
- **Arctic2**
  - Also known as PAROMS
- **Both are ice-ocean only, using the fake coupler (so far)**

Summary of Bering Sea

- Start in September with no ice
- Watch ice grow and retreat with seasons
- WRF-ROMS for Nov 2011 storm (future plan)



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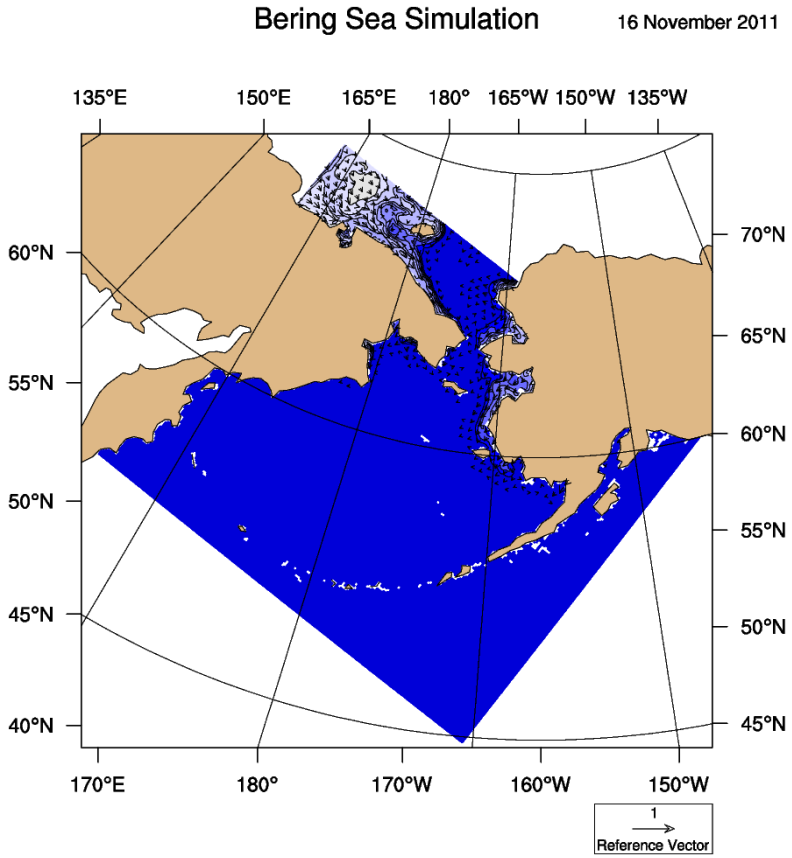
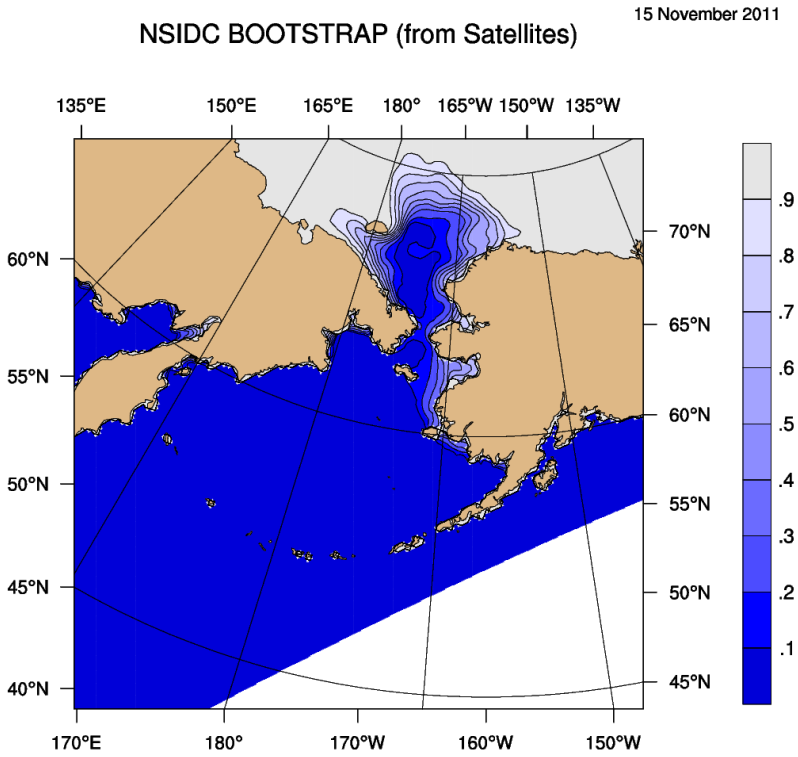
November 2011





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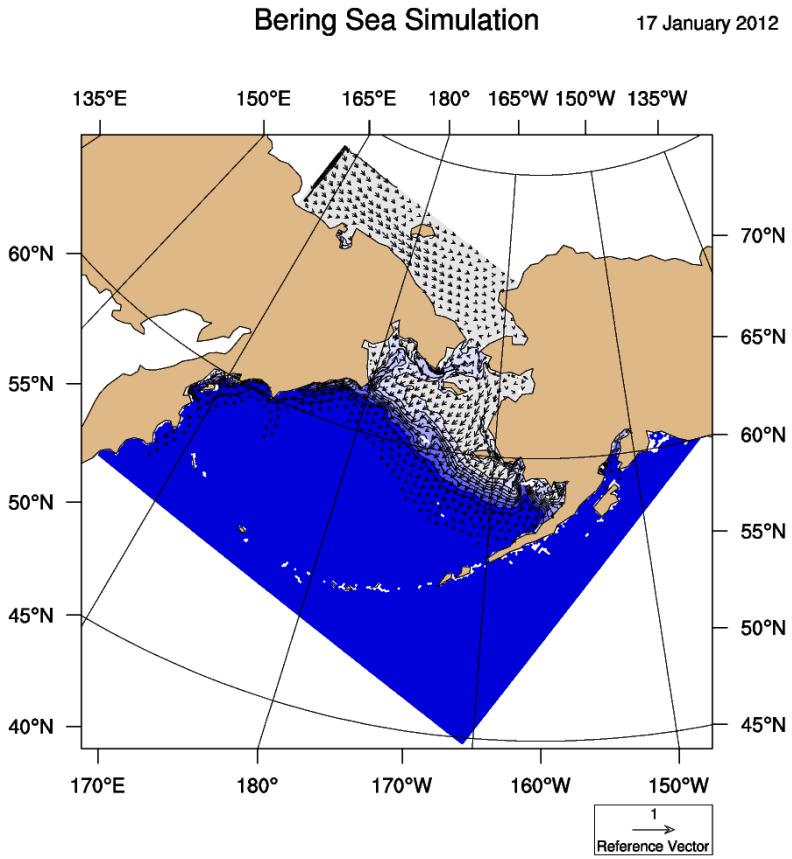
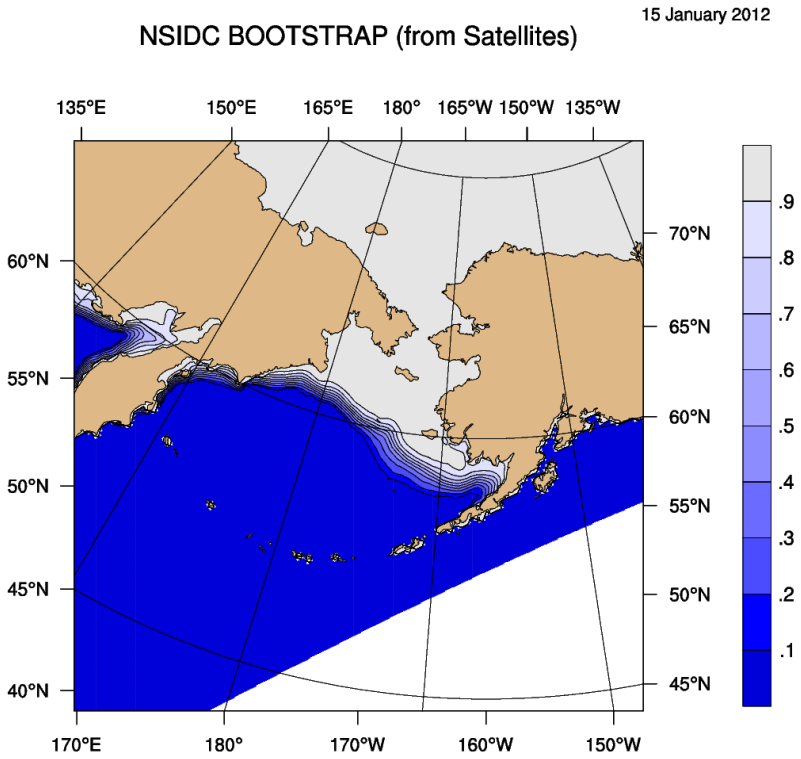
January 2012





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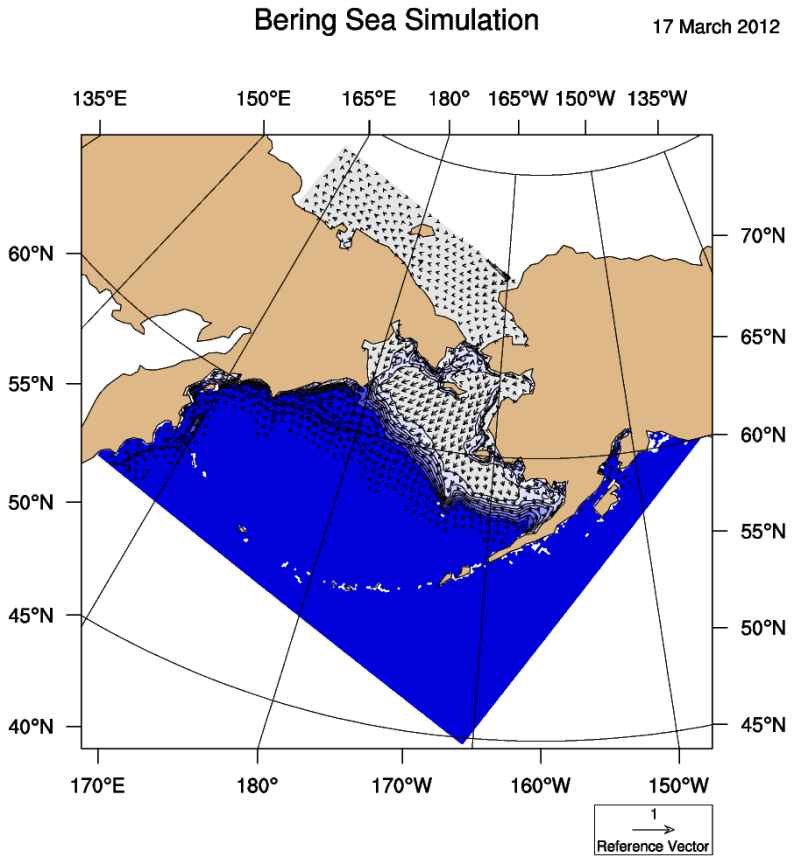

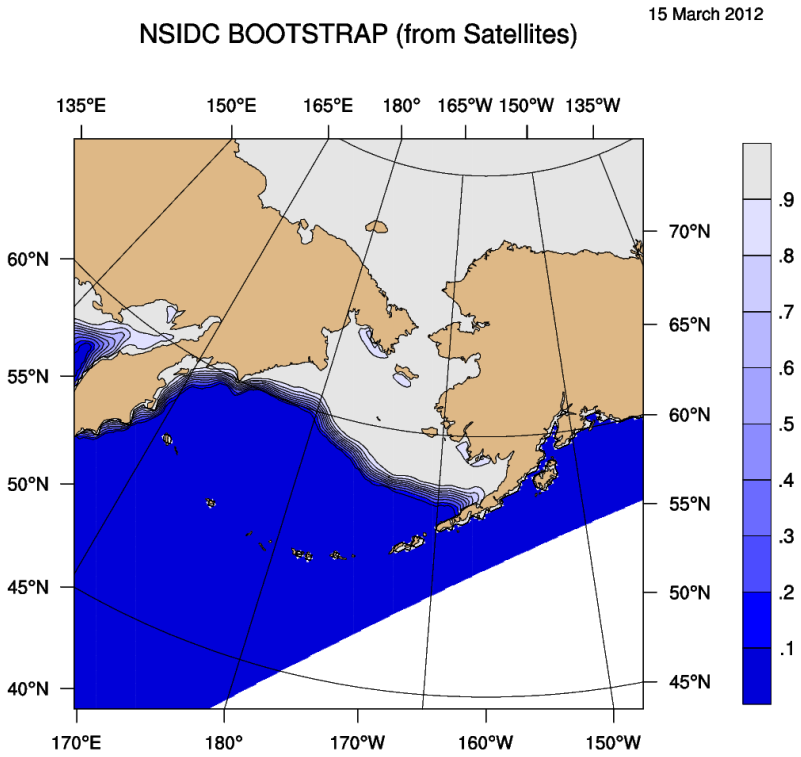

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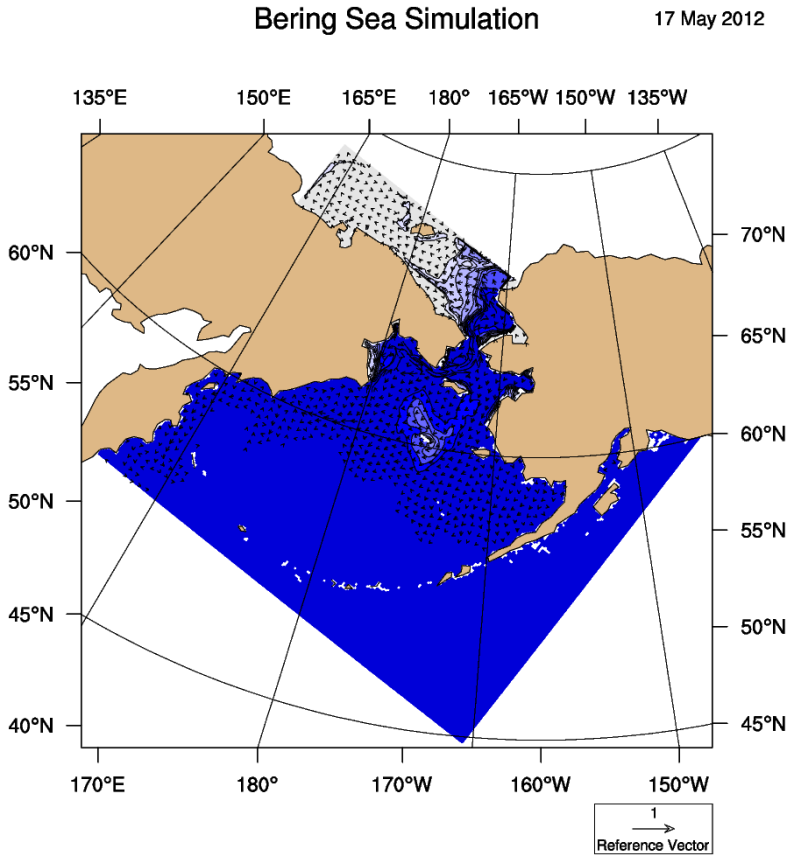

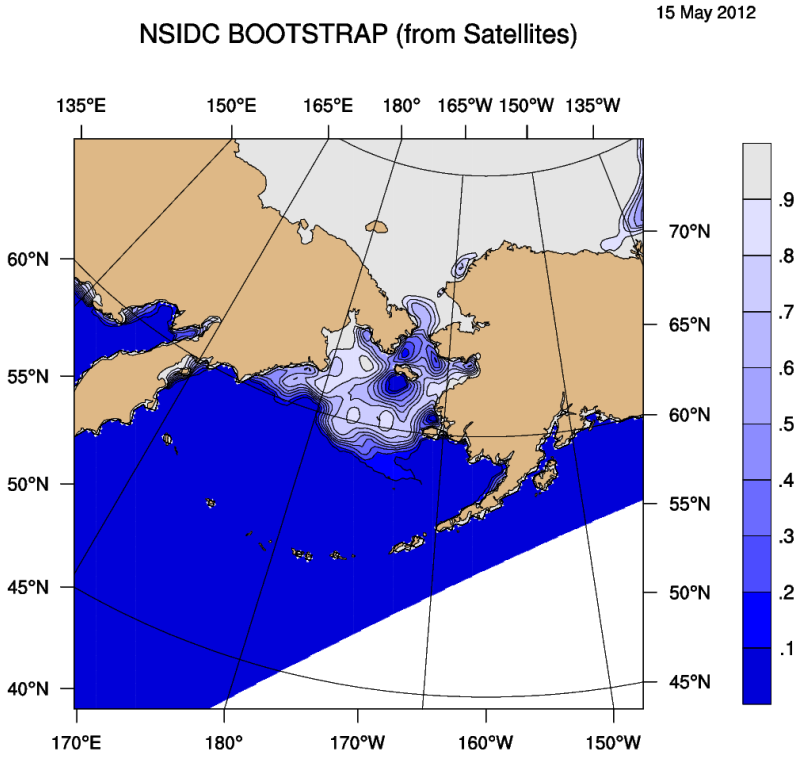

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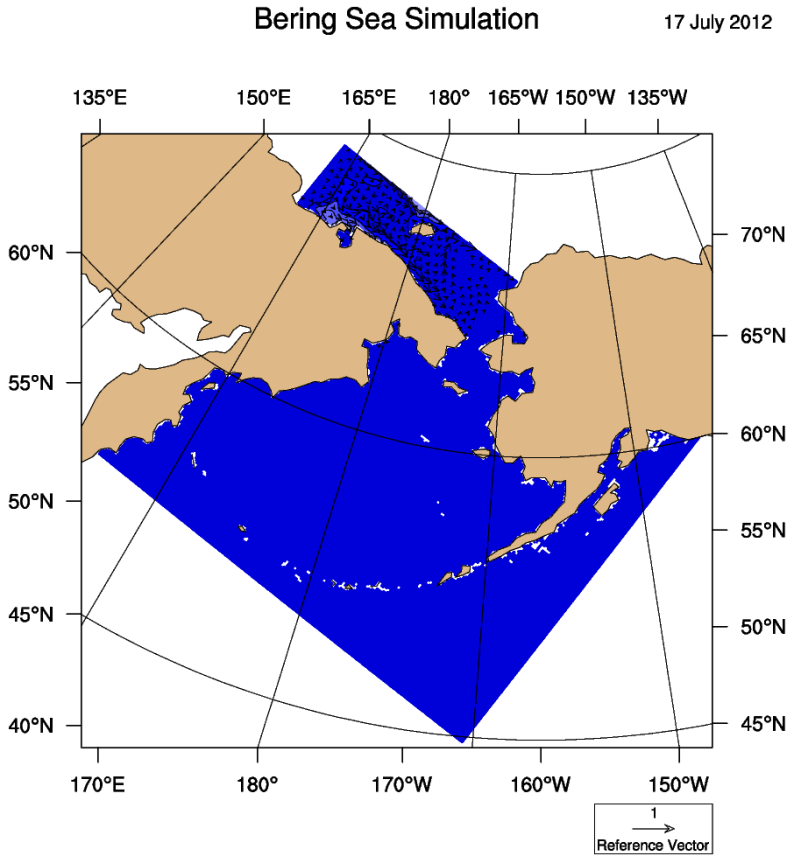

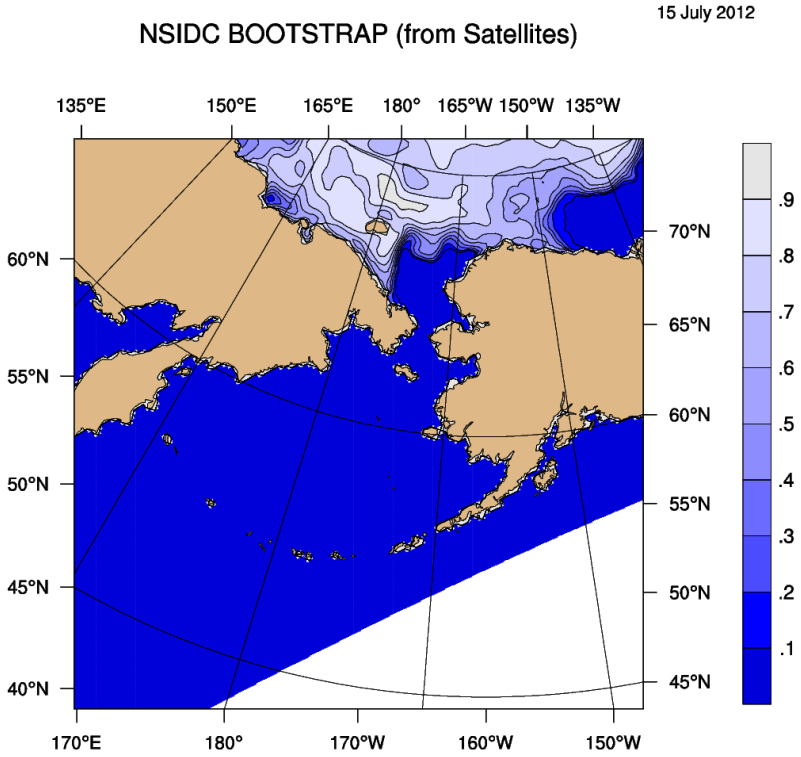

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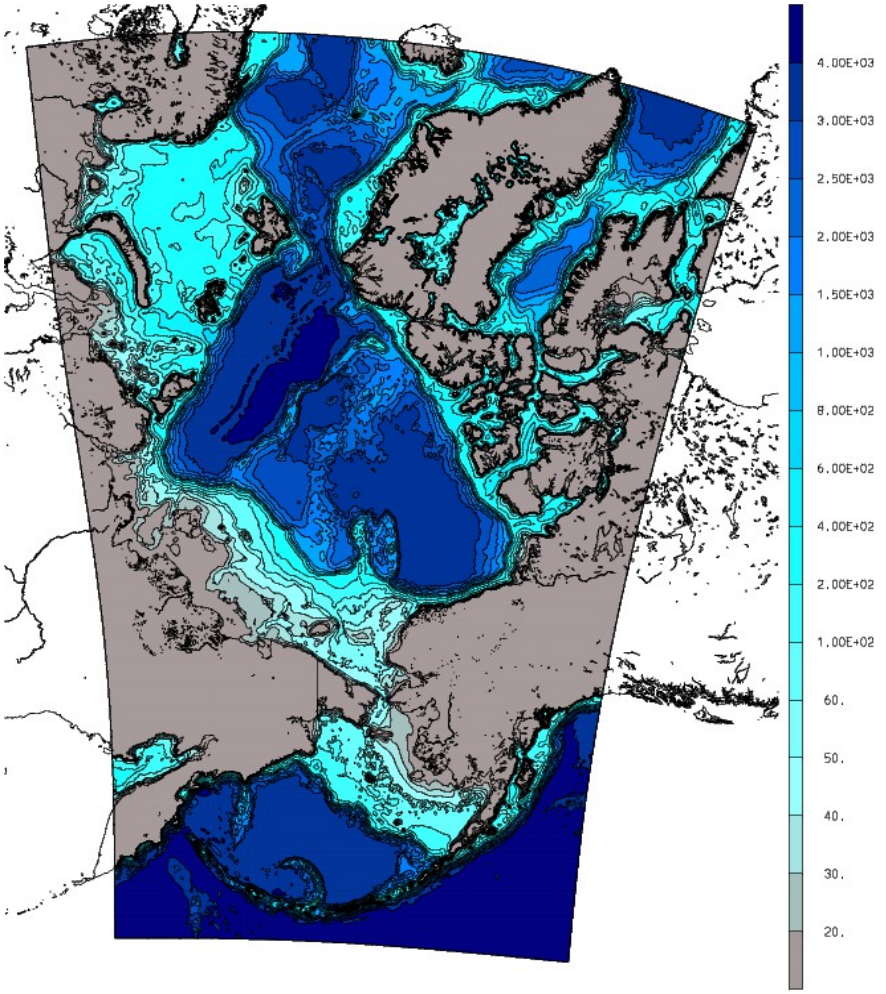
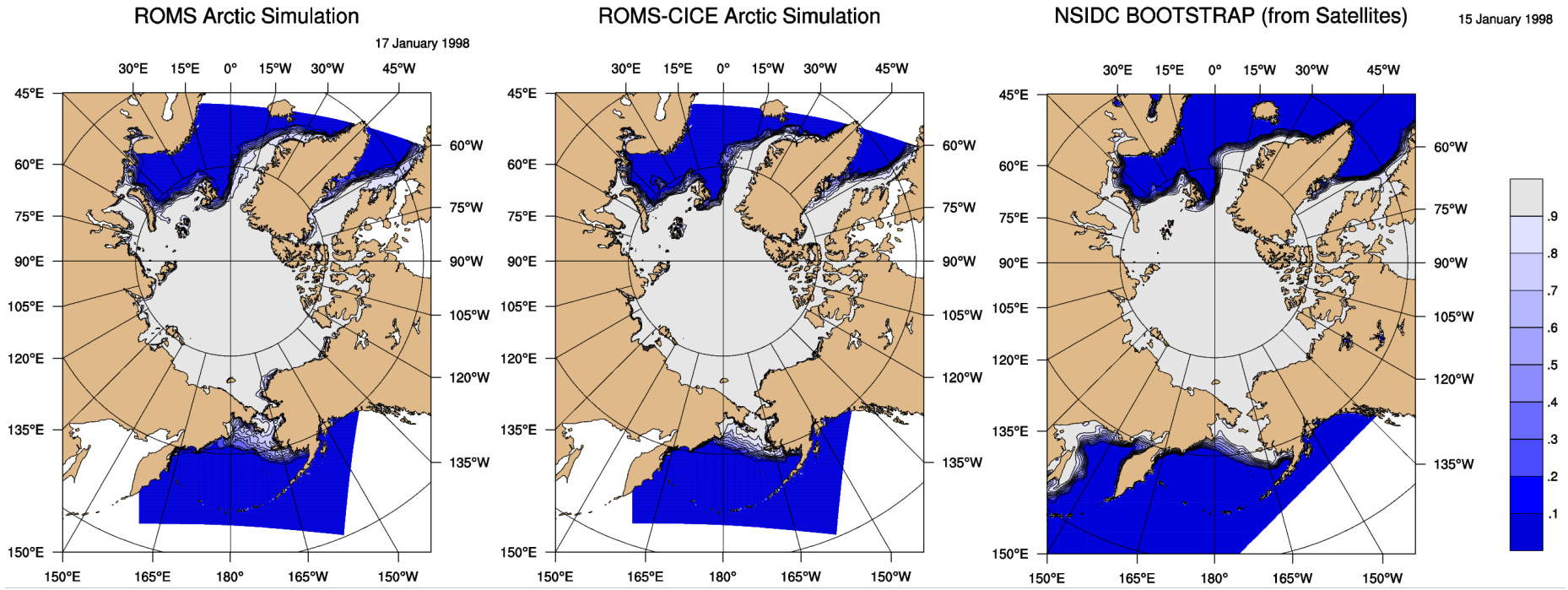
PAROMS

- **MERRA forcing**
- **Fresh water**
  - ARDAT in Arctic
  - Dai et al. elsewhere
- **GLORYS ice IC**
- **SODA/HYCOM IC/BCs**



January 1998



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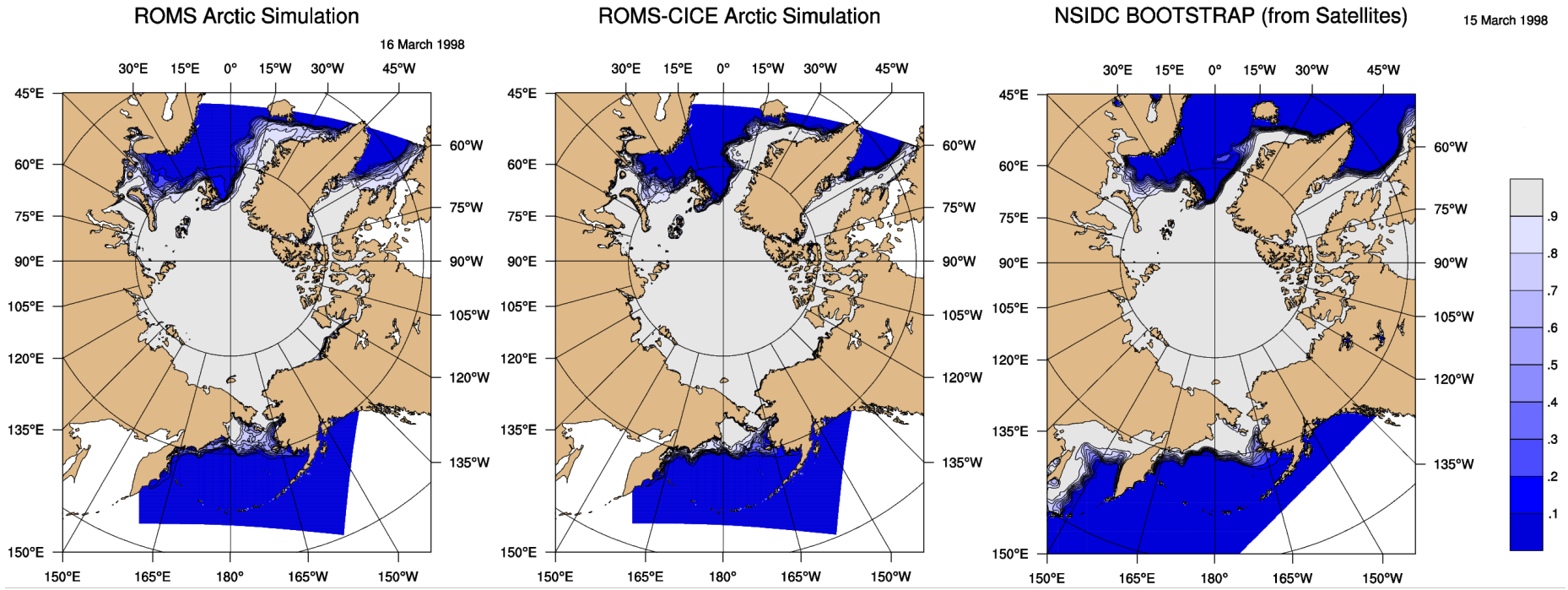

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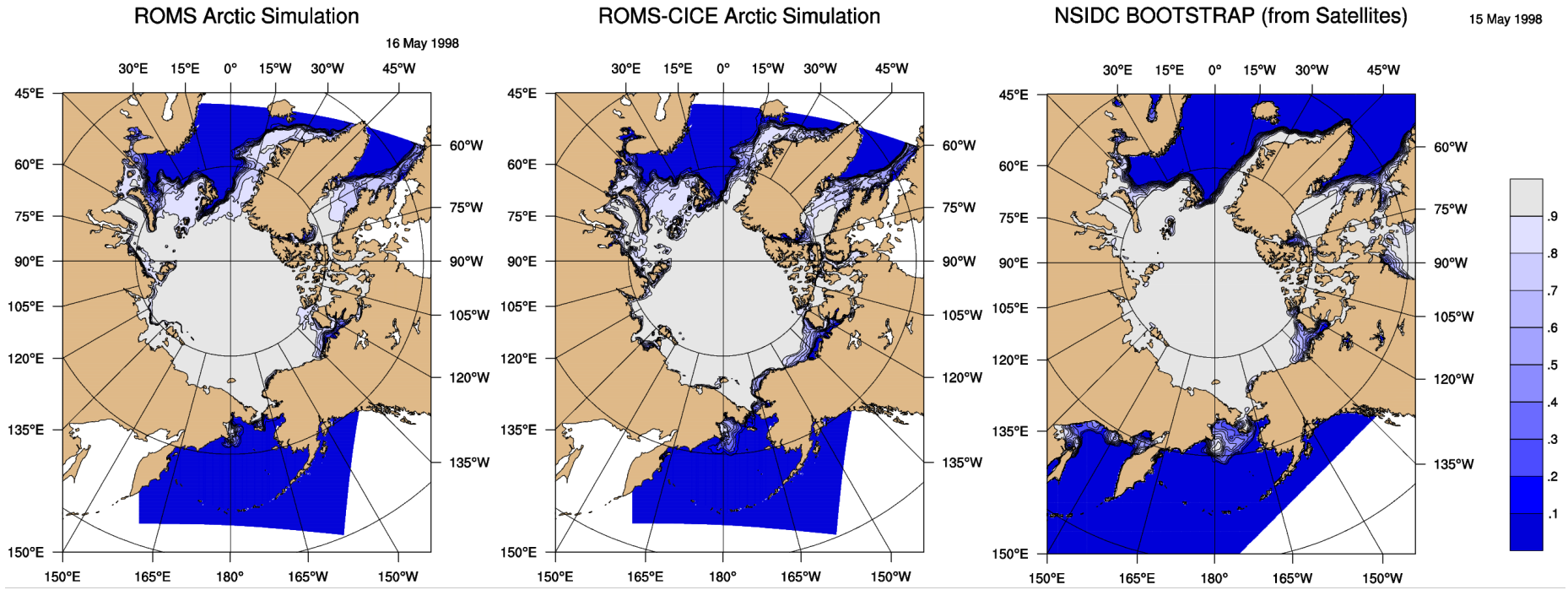

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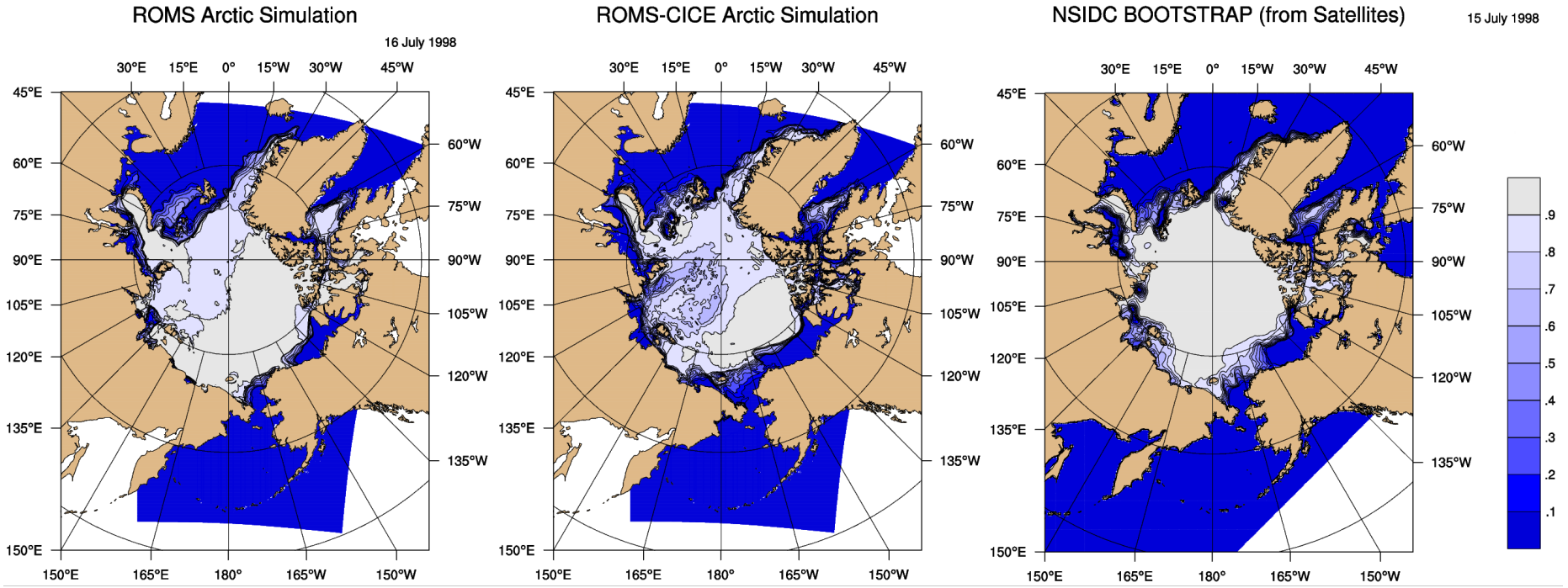

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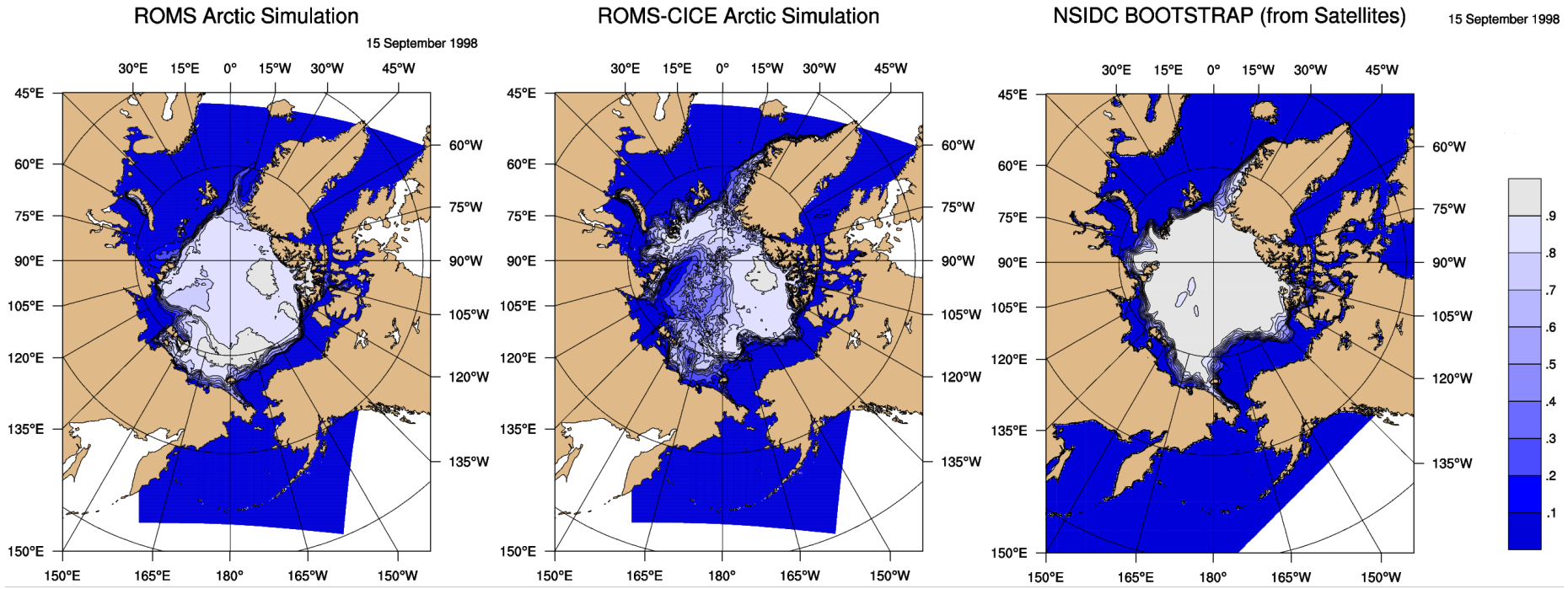

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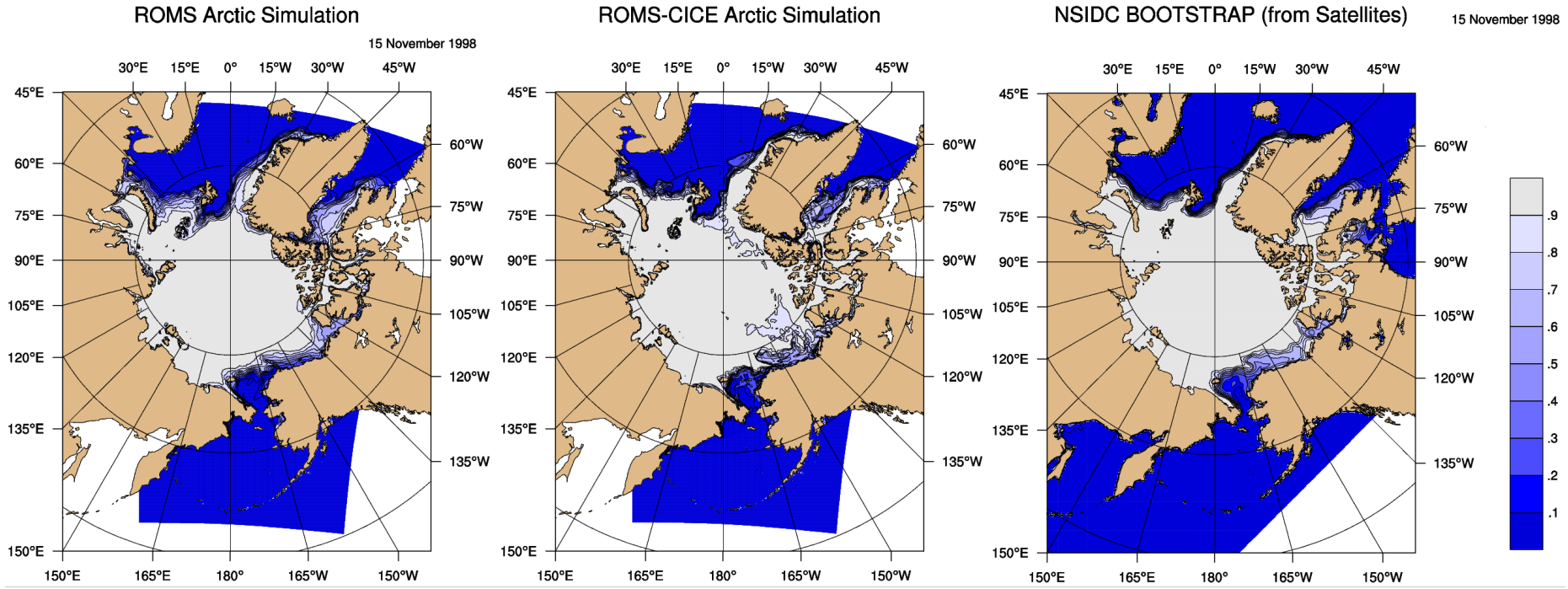

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Learn More

- **CICE comes with very complete manual in doc directory**
- **Many relevant papers in doc/PDF directory**

Random Tips

- **Circumpolar considerations**
  - GLOBAL_PERIODIC
  - grid_coords.F (floats, stations)
- **Tell CICE the truth about the date**
  - Albedo
  - Output filenames

Future Plans

- **PolarCOAWST group activities**
  - With WRF
  - With ice shelves
- **CICE Consortium**
  - Continue improvements to CICE

Biogeochemistry

- Ice algae on the bottom, near oceanic source of nutrients
- A number of options described in the manual and other papers
- Not yet attached to an ocean BGC model – need to exchange flux_bio array

Aerosols

- **Particles landing on ice surface**
- **Two tracers per aerosol**
  - Surface scattering layer (for radiation computation)
  - Snow or ice interior
- **Rates of gain/loss: faero_atm and faero_ocn**

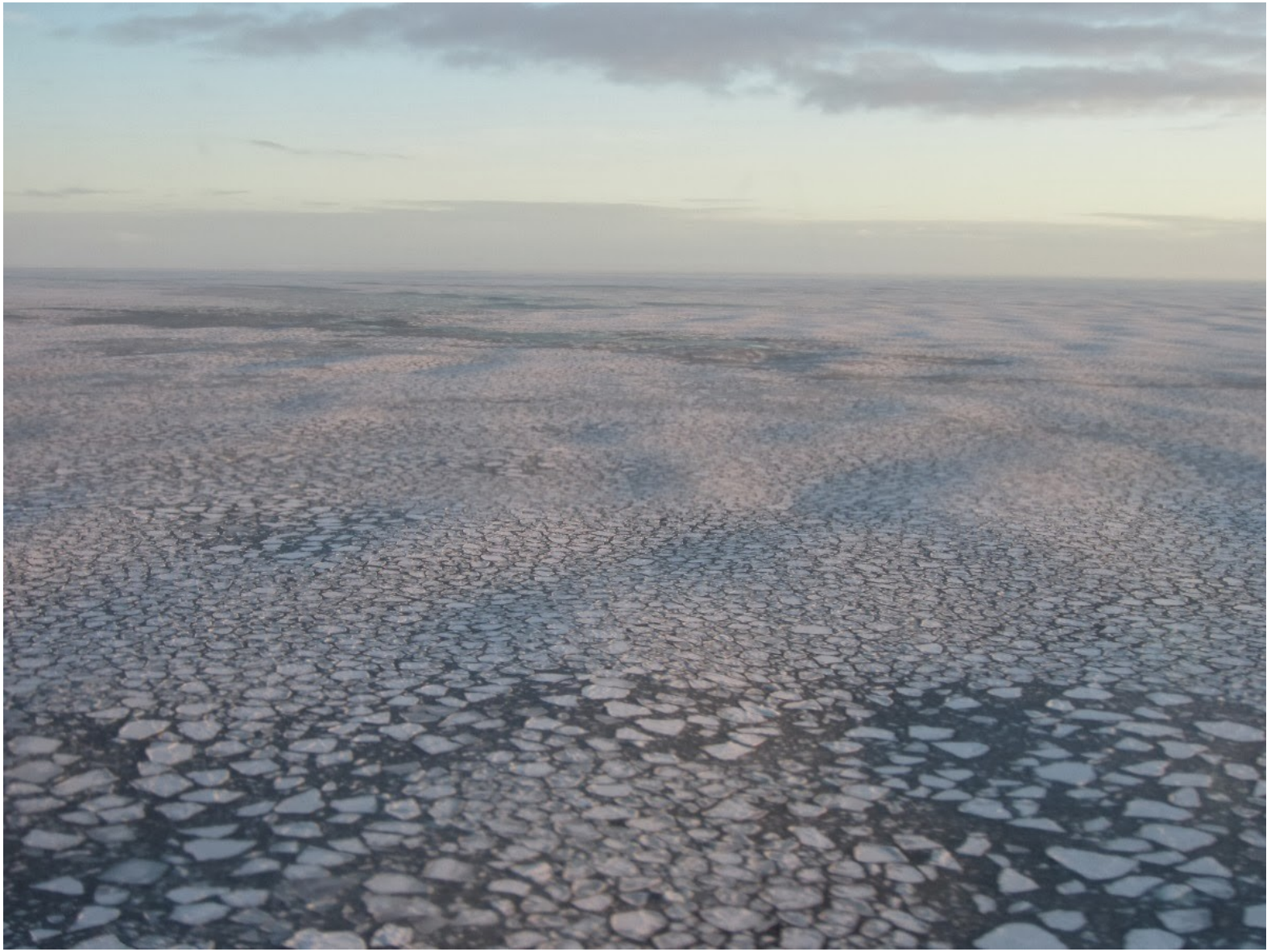
A few words about pyroms

Pyroms → PyCNAL

Python2 → Python3

Scrip → ESMF (coming…)

- **Future improvements will be going into PyCNAL**
- **Both on github (ask me about git)**



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