Coupled Ocean/Sea-Ice Modelling at the University of Alberta

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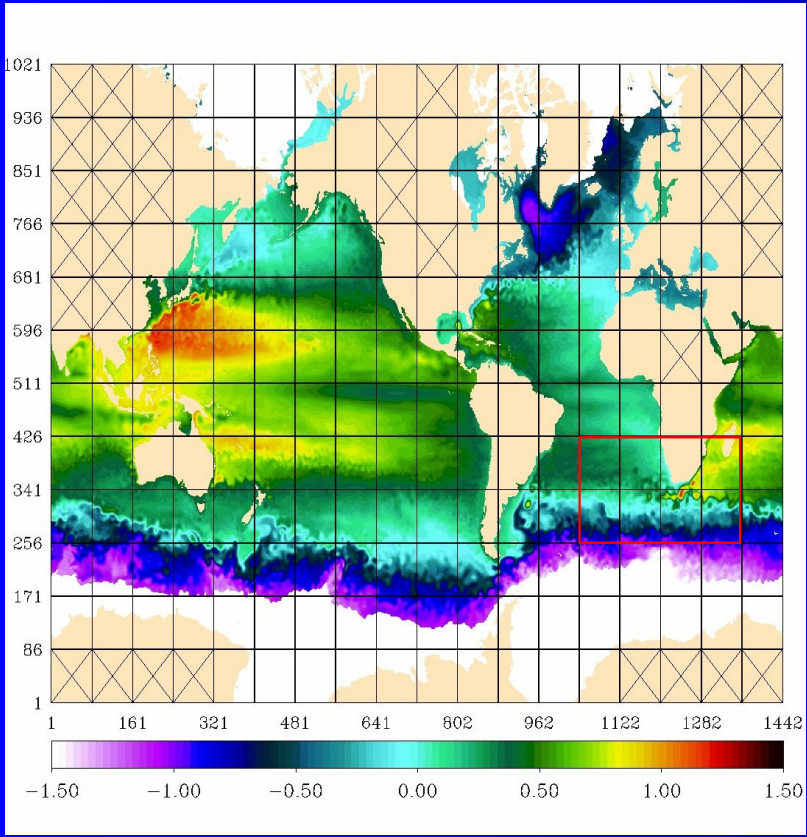
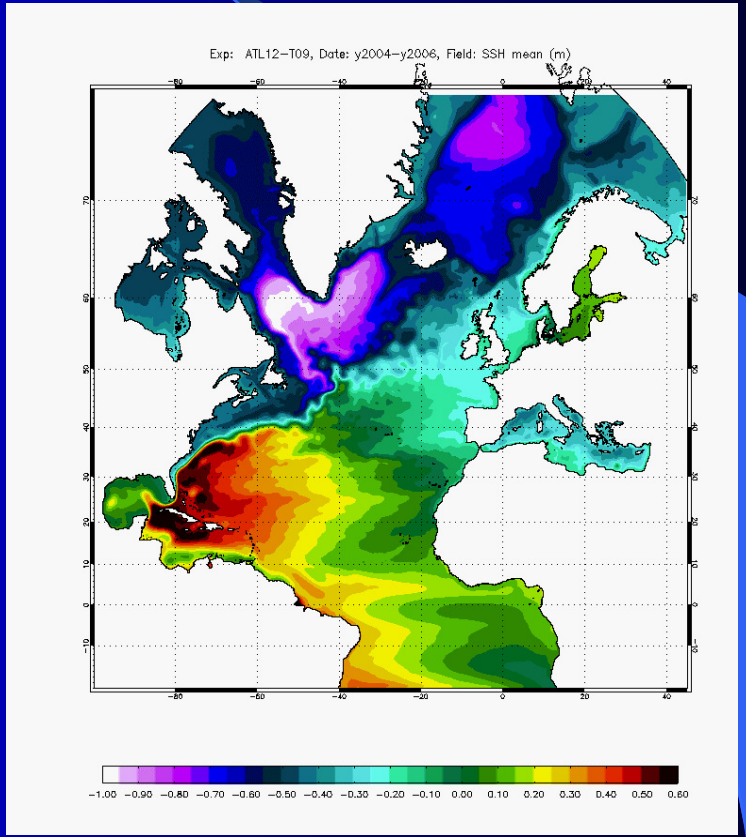
Outline

- I) Sub-Polar North Atlantic (NEMO)
  - Freshwater drift in coupled ocean/sea-ice models
  - Pathways for fresh/saline water in the sub-polar North Atlantic in coupled ocean/sea-ice models
  - Sea Ice Data Assimilation
- II) Arctic/Canadian Arctic Archipelago Modelling
  - Pan-Arctic Domain (NEMO)
  - CAA (NEMO)
- III) Unstructured Modelling using FESOM

NEMO Modelling Configurations: Atlantic/Global



Global ¼ ORCA025 domain

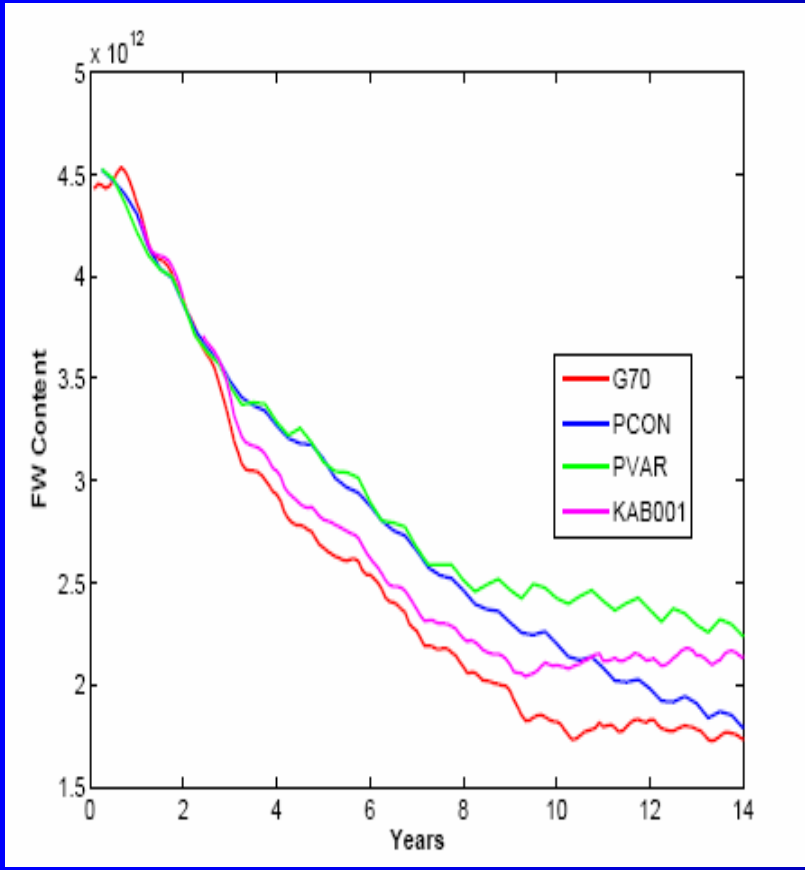


¼ degree Atlantic domain

Configuration Details

	G70	KAB001	KAB002	PVar	PCon
Domain	Global	Global	Global	N.Atl	N.Atl
Integration Period	1958-2004	1958-2004	1985-2004	14 perpetual years	14 perpetual years
Radiation Fluxes	CORE	CORE	CORE	CORE	CORE
Turbulent Fluxes	ERA40	CORE	CORE	CORE	CORE
Precipitation	Mod-CORE	CORE	CORE	CORE	CORE
3-D Restoring in Polar Regions	None	180 days	None	N/A	N/A
SSS Restoring	60 days	300 days	60 days	60 days	60 days
SSS Restoring Under Ice	15 days	180 days	60 days	15 days	15 days
GM Parameterization	No	No	No	Spatially Varying	Constant

Drift in NEMO Configurations



- Still significant drift in ice-ocean models
- Regional/global configurations – same behavior
- Perpetual Year/Inter-annual forcing – same behavior
- 2 Stages
  - I) First 2-3 years – same in all experiments – probably related to inconsistencies with initial conditions
  - II) 3-15 years – significant differences between runs

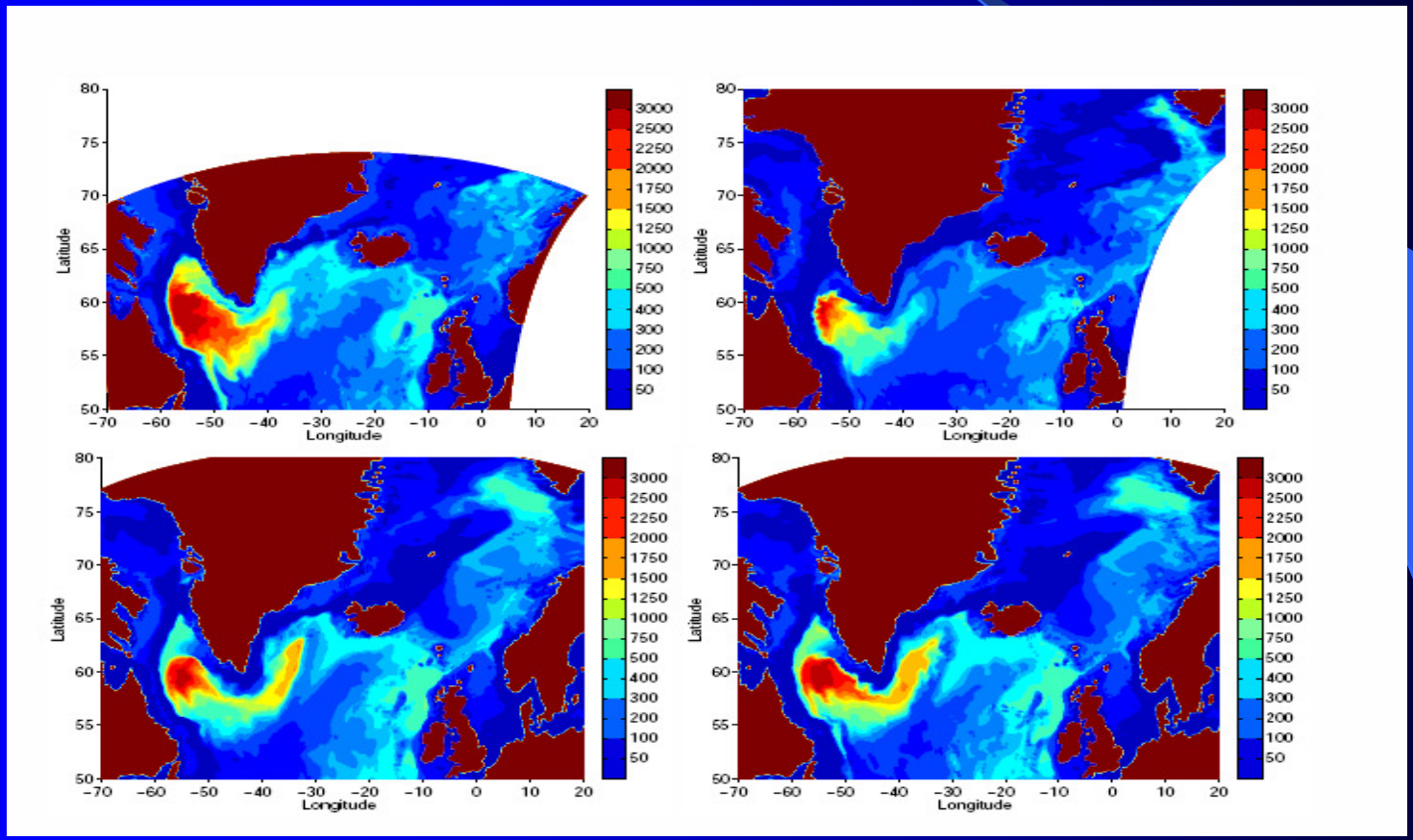
Winter Mixed Layer Depths

G70

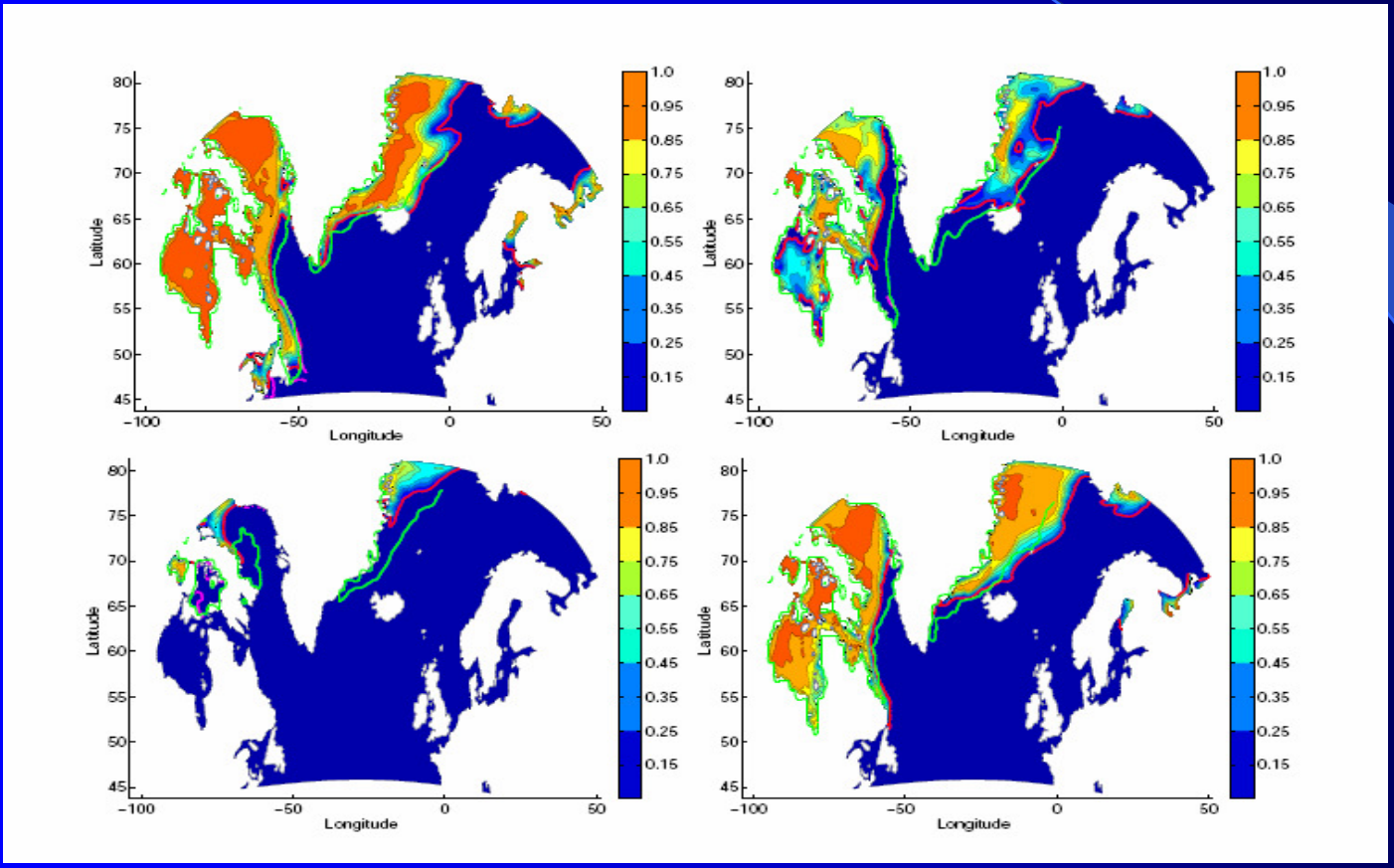
KAB 001

PVar

PCon



Sea Ice in PVar



Little ice in Labrador Sea – equivalent to 1.6 mSv of precipitation upon melting

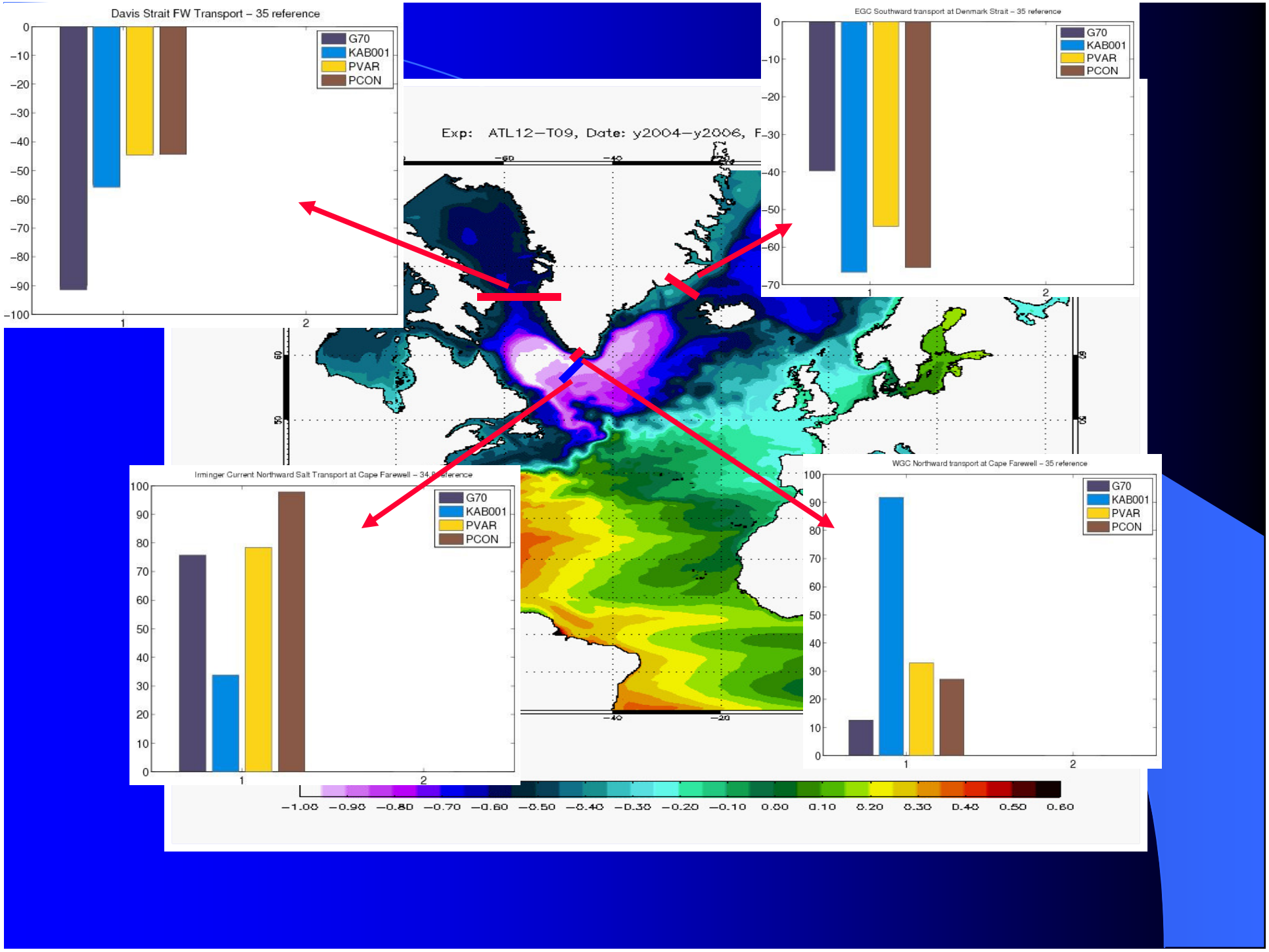
Net Precipitation:

PVar: 39 mSv

PCon: 44 mSv

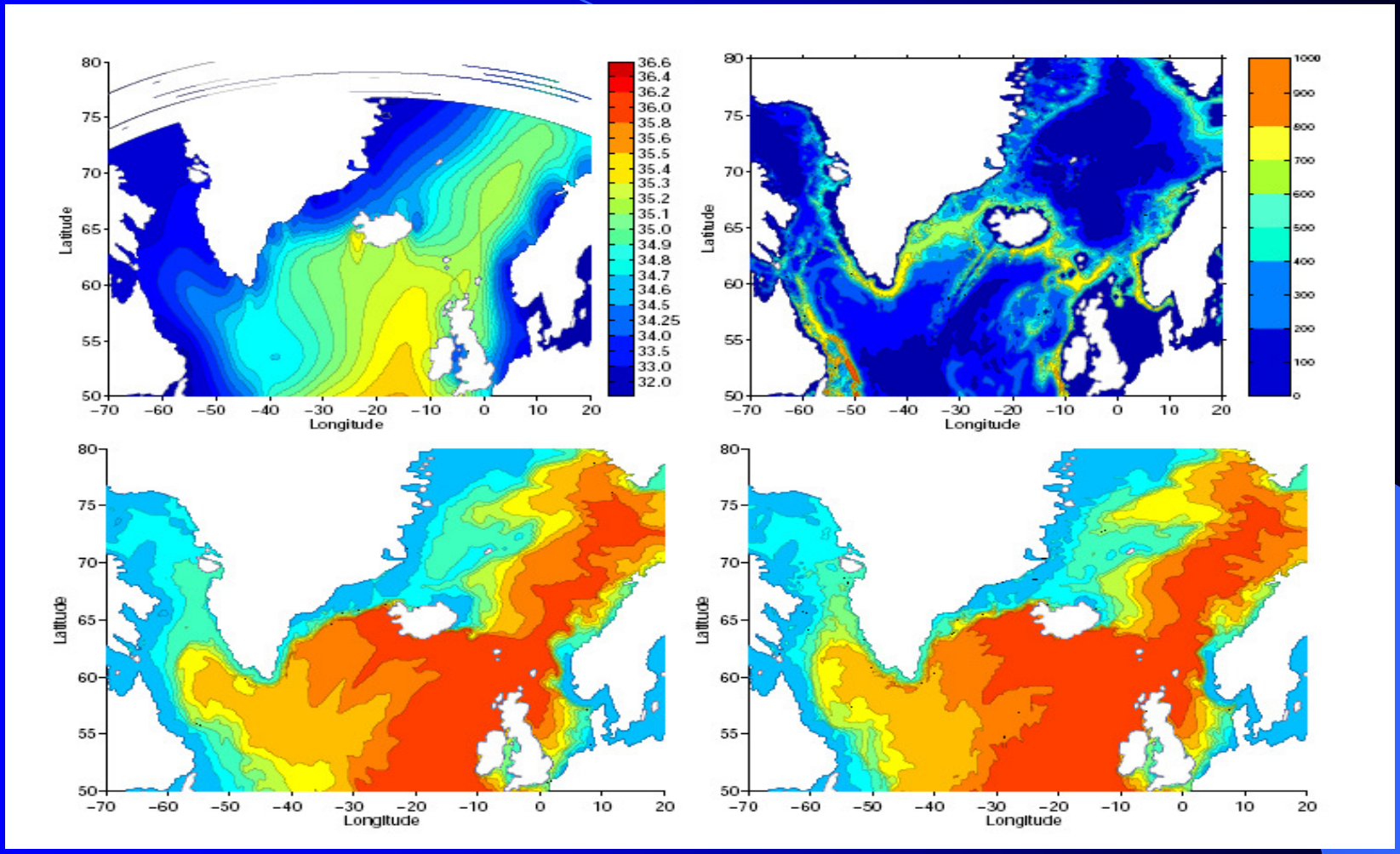
Red Line – ice edge from Walsh 1 degree climatology

Green Line – ice edge for Canadian Ice Service charts (mean average)


Davis Strait FW Transport – 35 reference
G70
KAB001
PVAR
PCON
EGC Southward transport at Denmark Strait – 35 reference
G70
KAB001
PVAR
PCON
Exp: ATL12–T09, Date: y2004–y2006, F
Irminger Current Northward Salt Transport at Cape Farewell – 34
G70
KAB001
PVAR
PCON
WGC Northward transport at Cape Farewell – 35 reference
G70
KAB001
PVAR
PCON
−1.00 −0.90 −0.80 −0.70 −0.60 −0.50 −0.40 −0.30 −0.20 −0.10 0.00 0.10 0.20 0.30 0.40 0.50 0.60

Top left: Levitus SSS field – EGC rep that is restored to not good

Var GM Kappa coefficient



Bottom left (Pvar), bottom right (Pcon): high kappa in Pvar releases EPE and thus prevents significant salt exchange by resolved eddies across boundary of EGC

WGC At Cape Farewell

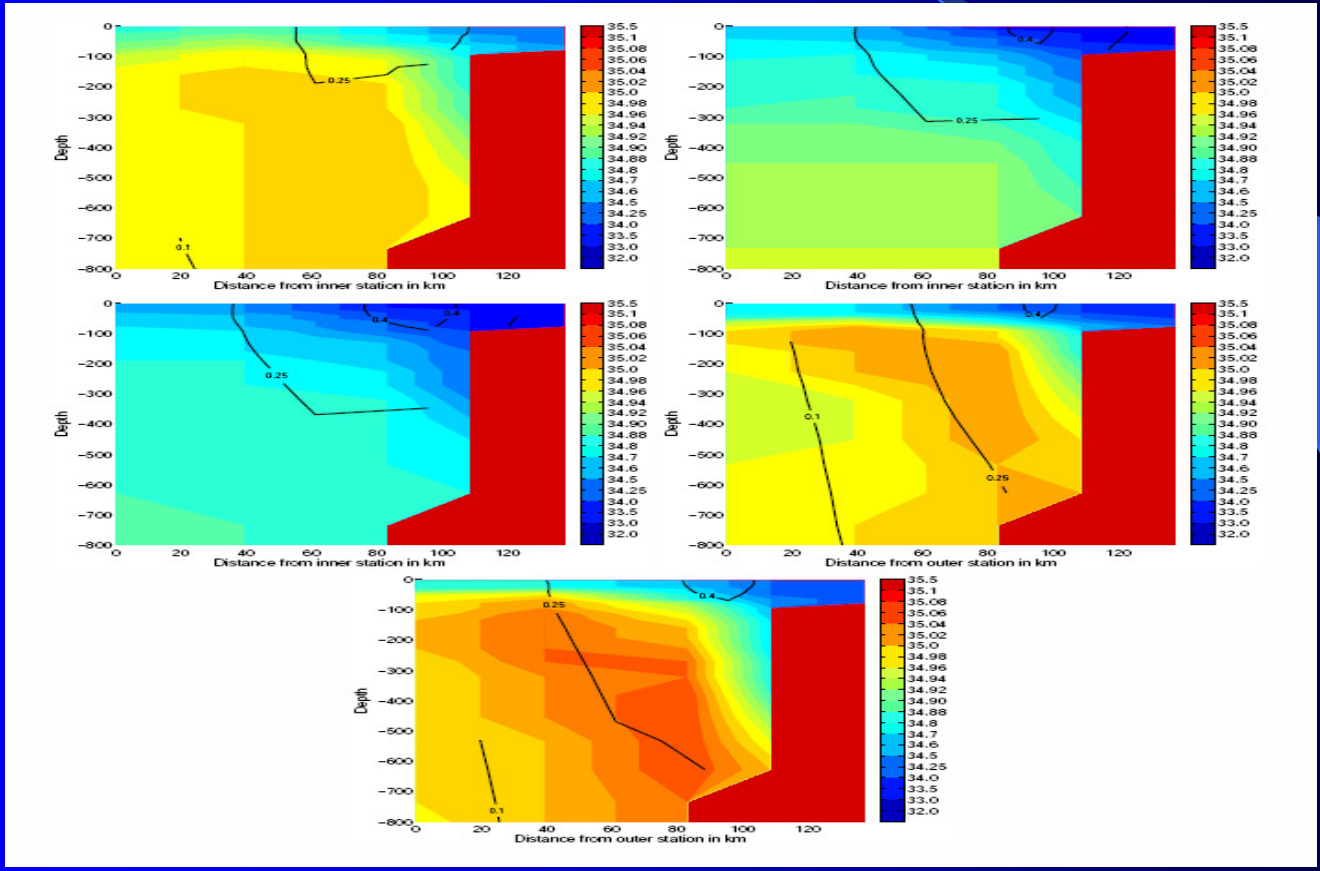
G70

KAB001

KAB002

PVar

PCon



Summary

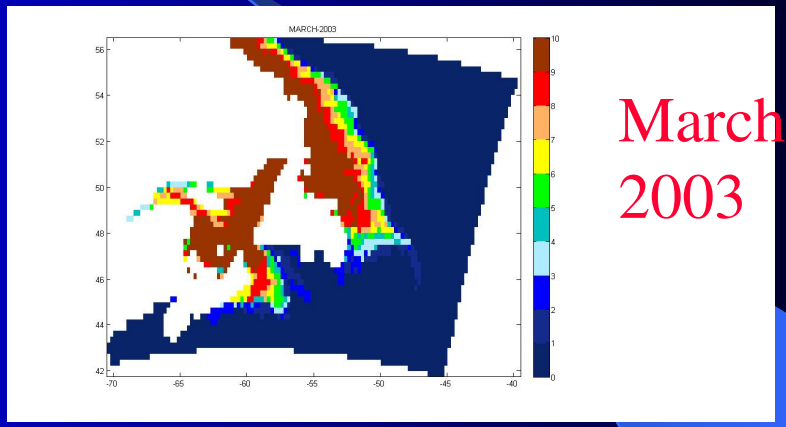
- Still significant drift in ice-ocean models
- Regional/global configurations – same behavior
- Perpetual Year/Inter-annual forcing – same behavior
- 2 Stages
  - I) First 2-3 years – same in all experiments – probably related to inconsistencies with initial conditions
  - II) 3-15 years – significant differences between runs
- Has big impact on mixed layer depths and density of Labrador Sea Water
- Related to:
  - Long Term: Freshwater Provision by East/West Greenland Currents
  - Initial (Possibly): Salty Water Provision by Irminger Current
    - Question: Cause of differences: NAC?, Med Water?, …? – investigation ongoing

Sea Ice Data Assimilation Plans

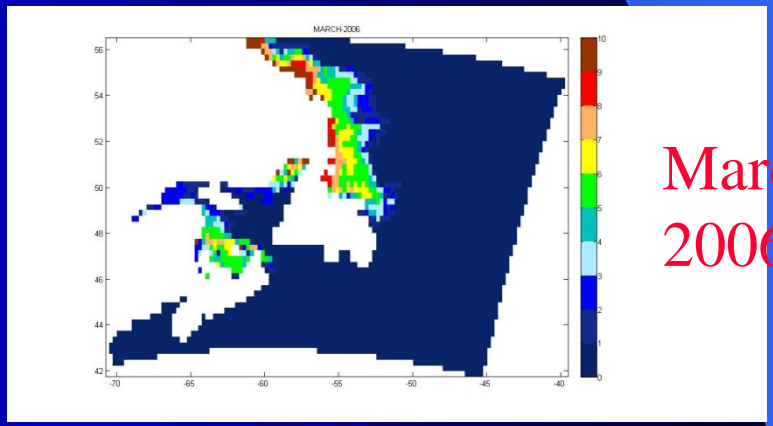
- Note: work being restarted because of personal issues (previous student leaving project)
  - Analysis now to be carried out by Anna Katavouta (M.Sc. Student)
- Use ¼ NATL4 NEMO configuration, with focus on Canadian east coast
- Plan to compare 4 approaches
  - Prognostic sea-ice
  - Simple sea-ice concentration nudging
  - 1-D, with correction of underlying T and S based upon correlations between sea-ice concentration and tracers
  - 3-D, with correction of T and S within a radius of influence based upon correlations between sea-ice concentration and tracers

Sea Ice Data Assimilation Plans

- Initially focus on 1 season – March
- Then repeat analysis for other seasons
- Use two years, 1 with high ice concentrations and 1 with low ice concentrations
- Sea ice concentration data will be taken from Canadian Ice Service charts



March, 2003

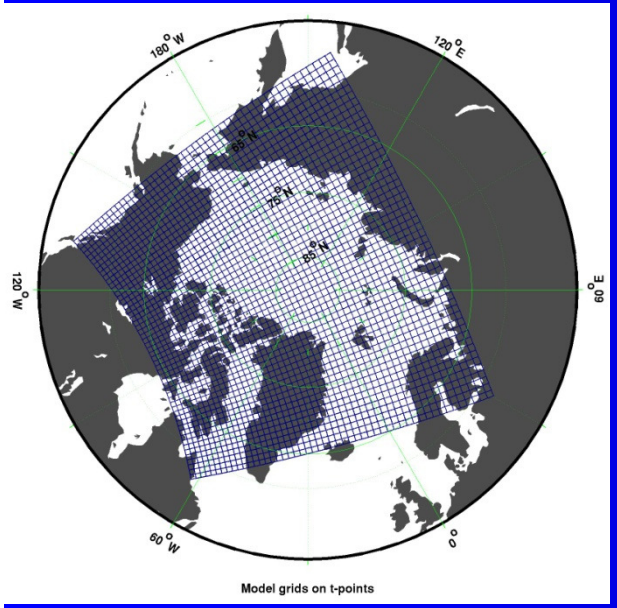


March, 2006

Arctic/CAA Modelling

- Goal is a high resolution ocean/sea-ice model of the CAA to look at climatic issues and variability
- However, to run such a limited domain model, we decided we needed a larger domain Pan-Arctic model to provide boundary data at the open boundaries of the CAA domain
- Pan-Arctic model is part of the Ph.D. of Xianmin Hu
- CAA model is part of the Ph.D. of John (Qiang) Wang

Pan-Arctic Model



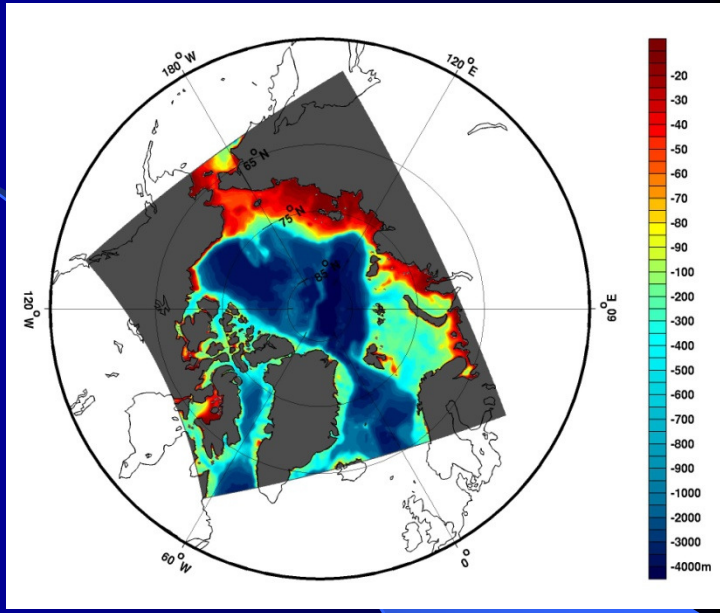
In Our Case:

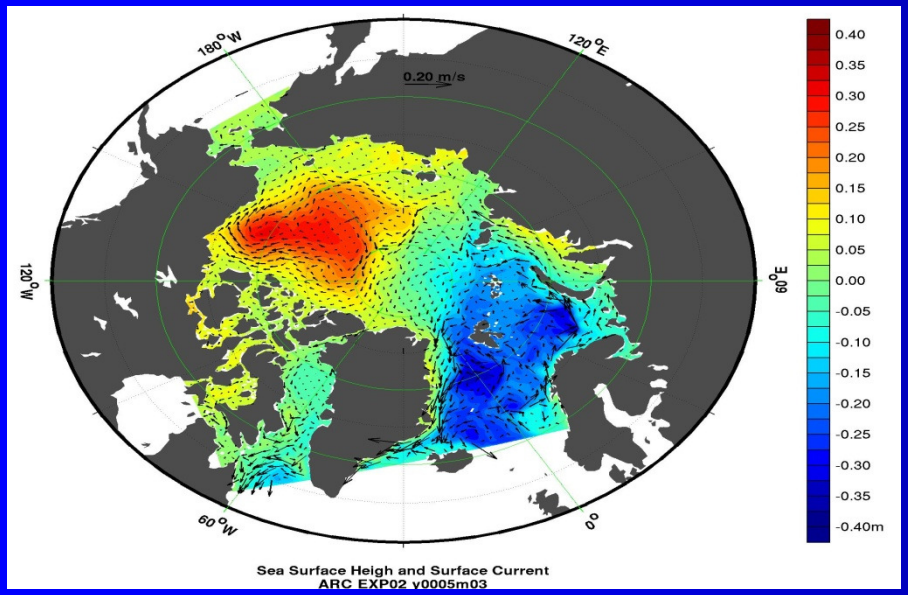
The two poles of the grid-sphere are projected (θ=+/-90) to (20N,95W) and (20S, 85W)

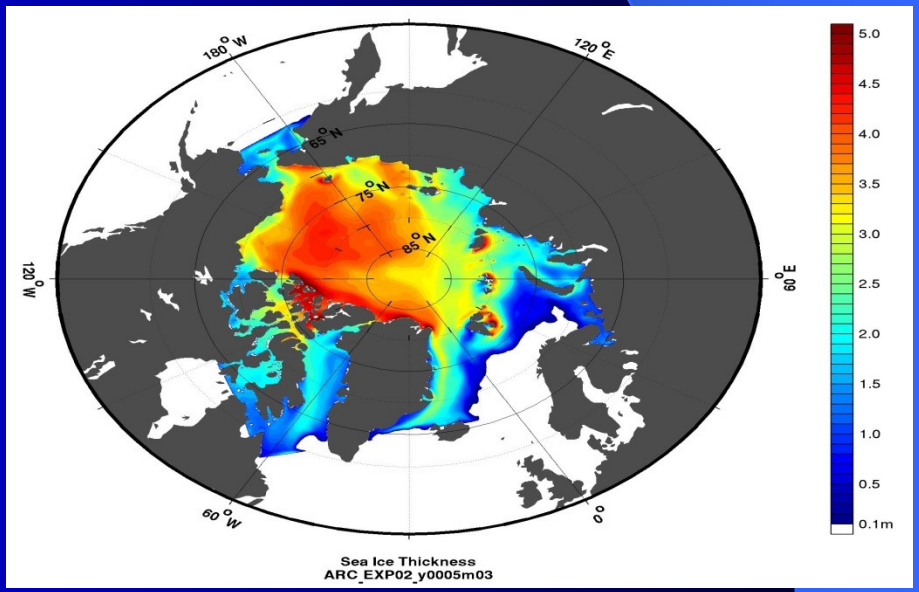
It is a special case of a tripolar grid.

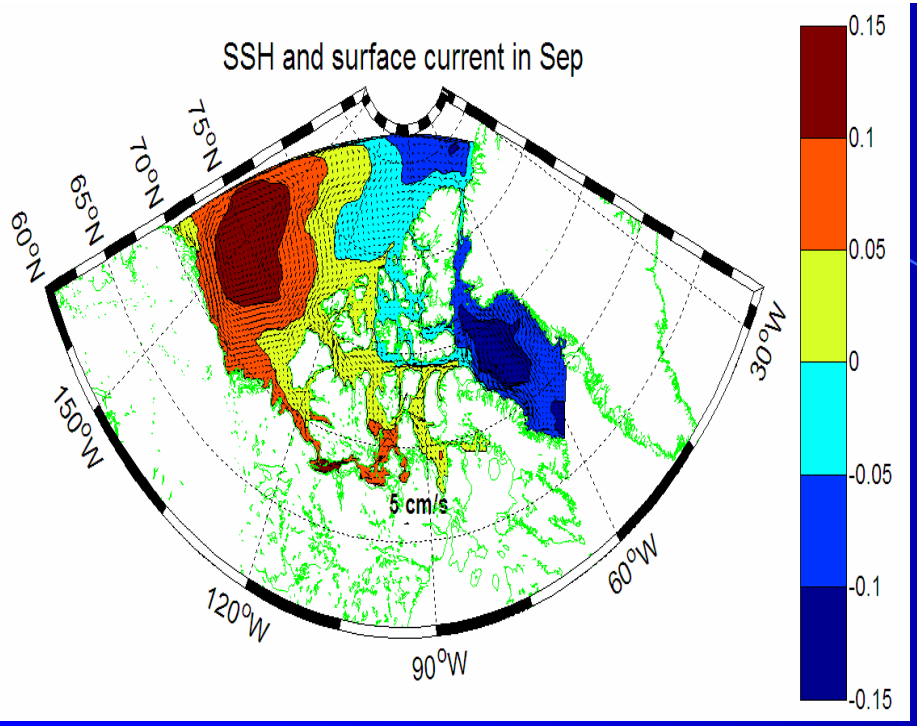
It is the same as a spherical coordinate transform

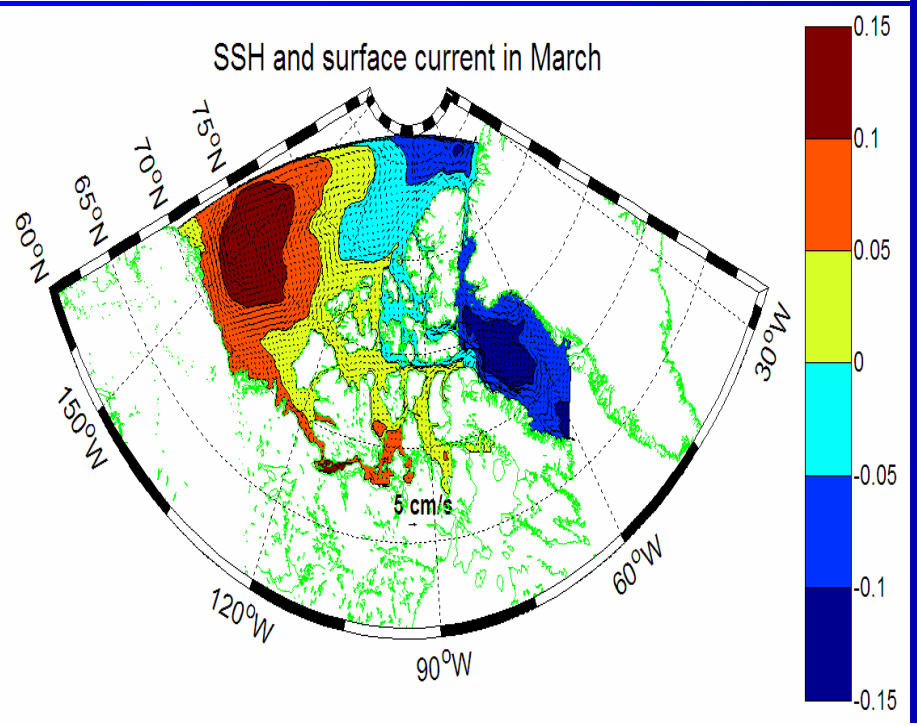
Model Grids: 432 x 400
Resolution: 11~16km











SSH and surface currents

- Tripolar grid, resolution 6.5-9.5 km, 7.5 km in Lancaster Sound, 268×446 grid points, 46 levels in vertical.
- NEMO (Nucleus for European Modelling of the Ocean) v3.1
- LIM2-EVP sea ice model,
- Results for initial 5 year simulation (plan is for 1998-2006 simulation)
- Limitation of preliminary simulation: Closed boundary condition (restoring buffers) until Pan-Arctic domain prepared and validated

Current State of Unstructured FESOM Model

- Coupled sea-ice ocean model:
  - Unstructured finite element
  - ocean: FEOM with tetrahedra (or prisms for the 3D meshing)
  - sea-ice: FEIM with either VP or EVP dynamics
- Data-assimilation scheme:
  - local particle filter
  - ensemble based
  - can be used for state and parameter estimation (both ice and/or ocean)

Data-assimilation

- Estimation of P* (Terwisscha van Scheltinga and van Leeuwen, 2009)
  - Method: local particle filter
  - Observations: sea-ice concentration
  - Results:
    - A seasonal cycle was found in the estimated density for P*
    - Maximum around 40000 N/m2
    - setup has some limitations - i.e. values for P* in [10000-40000], unrealistic ocean, concentration not a good proxi for ice strength, issues with NCEP forcing – results agree with measurements