Impact of Topography on Circulation and Water Mass Transformation in 0.72° HYCOM-CICE Arctic Ocean

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Contribution from Alexandra Bozec (COAPS FSU)

Schamtic representation of high-density shelf plume sinking down the continental slope

Cyclonic Ci

c Water

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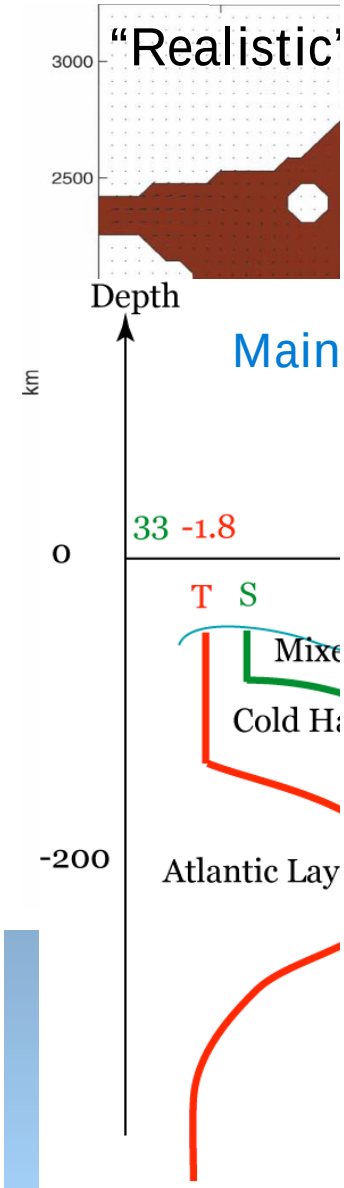
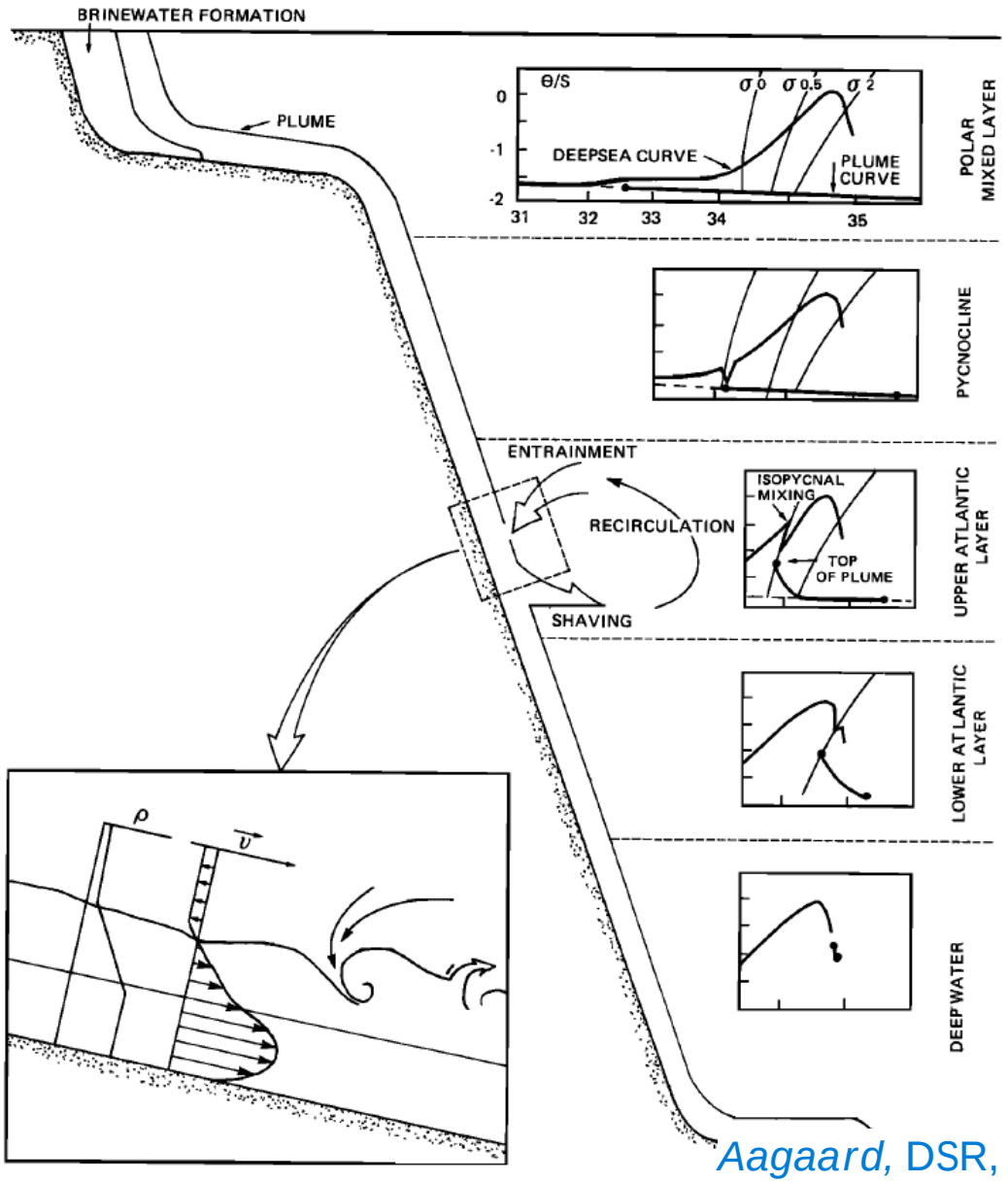
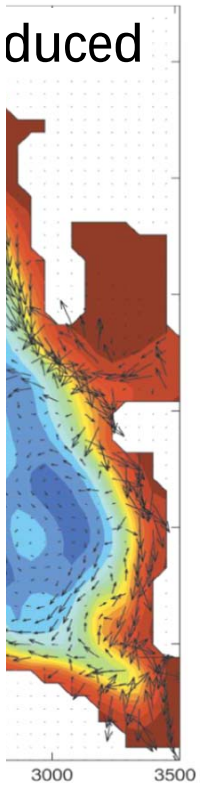


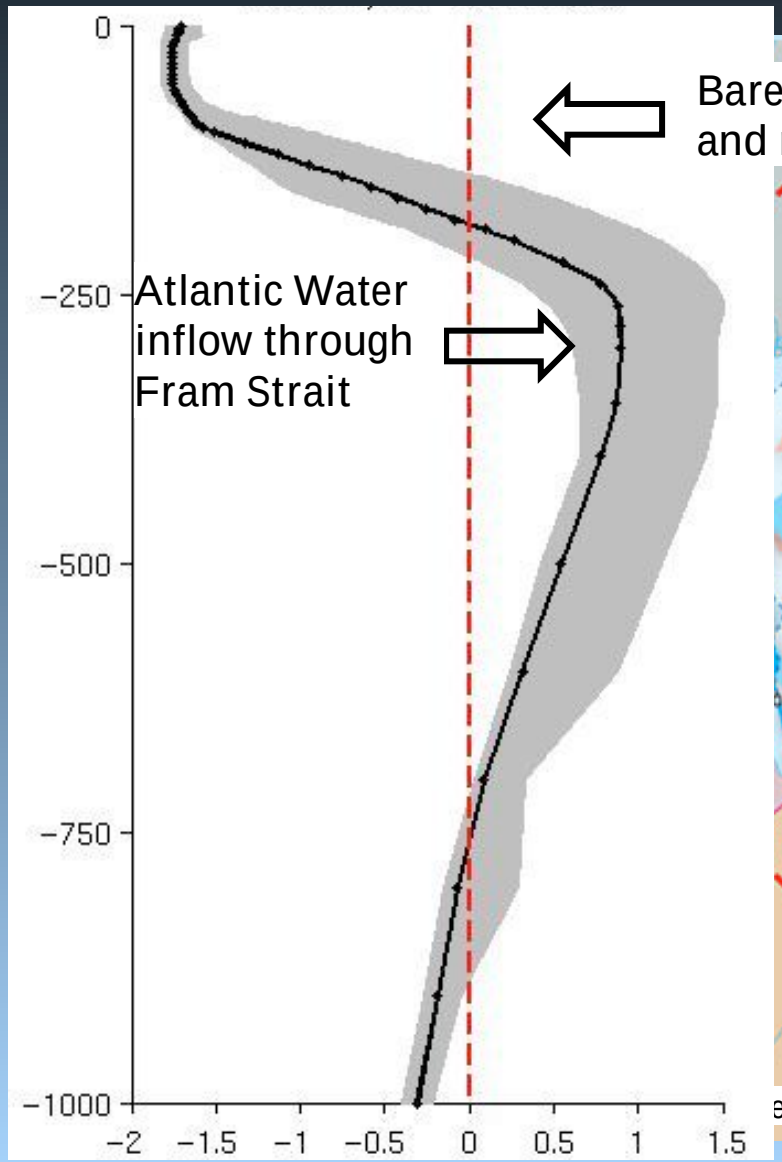




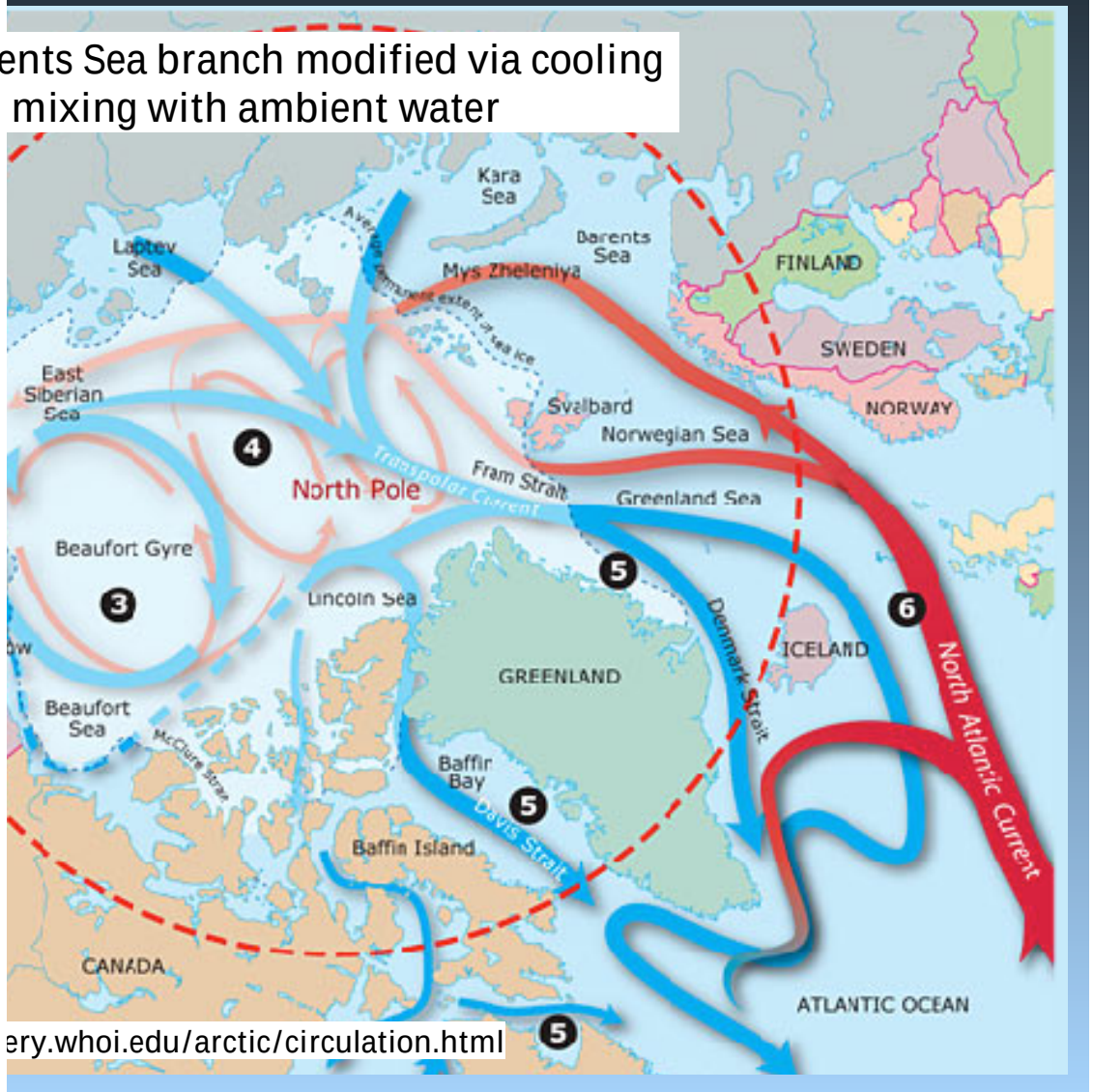
PV
, 2005

Aagaard, DSR, 1981

Maintenance of the Thermohaline Structure in the Arctic Ocean



Barents Sea branch modified via cooling and mixing with ambient water



ery.whoi.edu/arctic/circulation.html

0.72° HYCOM/CICE (ARCc0.72)

HYbrid Coordinate Ocean Model (HYCOM)

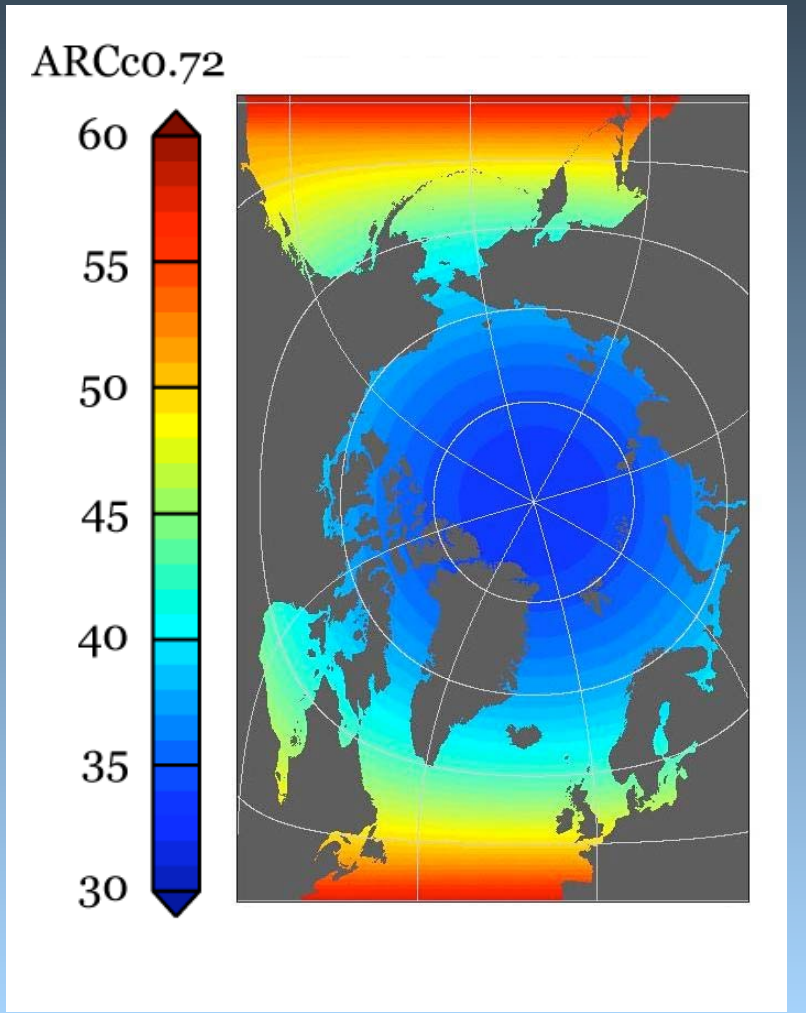
Los Alamos Sea Ice Model (CICE 4.0)

- Multi-category ice thickness
- Energy conserving thermodynamics
- Energy-based ridging scheme
- Elastic-viscous-plastic (EVP) ice dynamics

0.72° ARCc

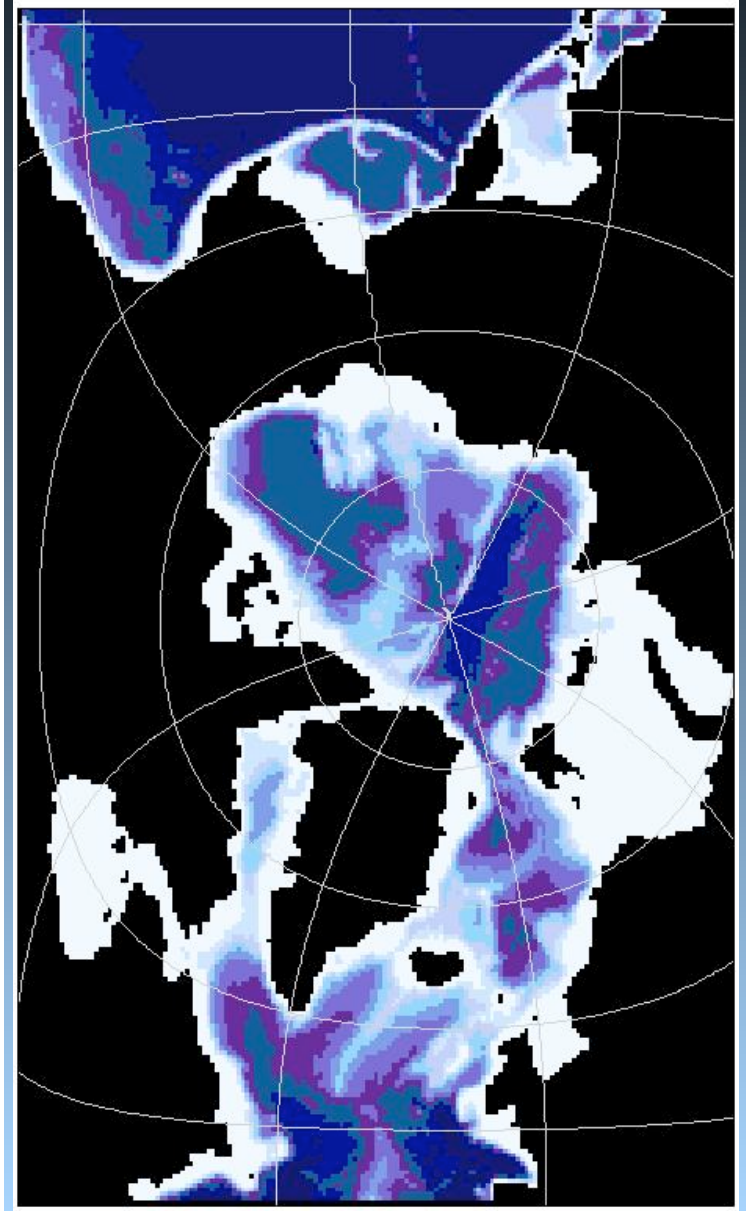
- Arctic-only grid is a sub-region of the tripole grid
- 32 vertical ocean levels
- Atlantic and Pacific boundaries
  - Closed (no-ice) in CICE
  - Closed but with relaxation to climatology in HYCOM

Horizontal Resolution (km)



Topography in 0.72° ARCc

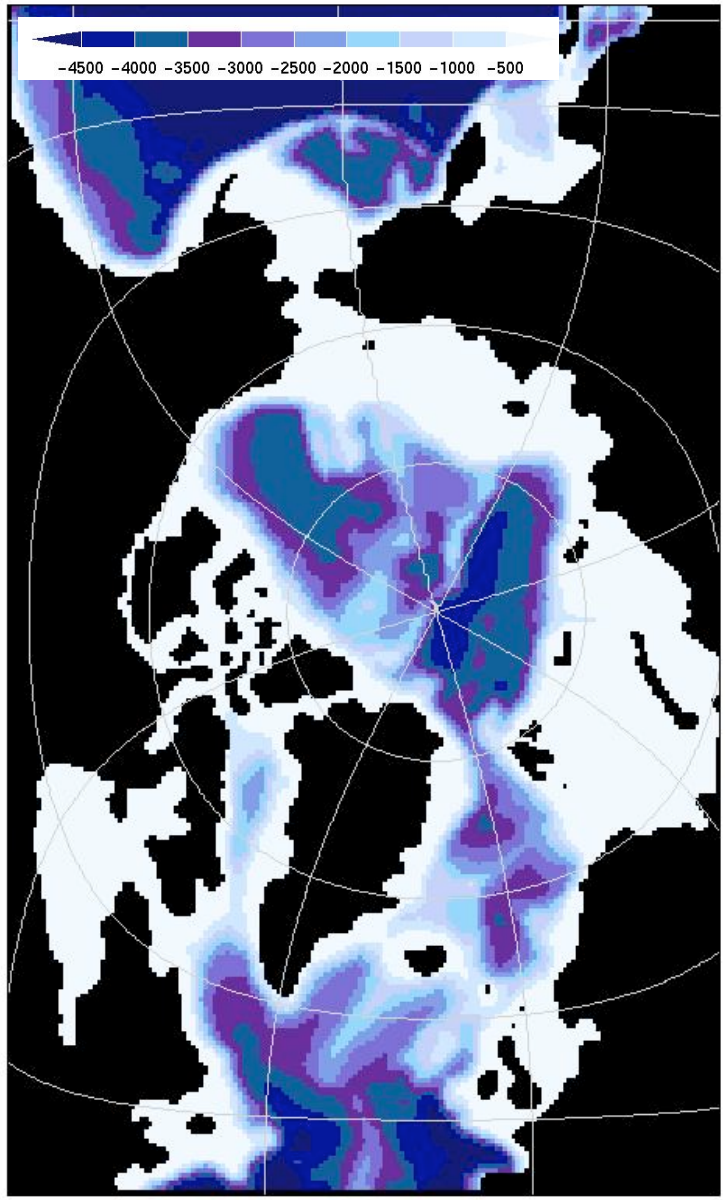
Simplified Topography ("ST")



Major improvements:

- Open Bering Strait
- Open shelves
- Improved representation of CAA
- Better interaction between Barents & Kara Seas

Realistic Topography ("RT")



Test Run with Simplified Topography (ARCc0.72 – 060)

HYCOM Initialization:

- From ocean only run (with energy loan ice model, 39 yrs of model integration performed at the Naval Post-Graduate School)

CICE initialization:

- From ice-only run 1999-2003

HYCOM Spin-up:

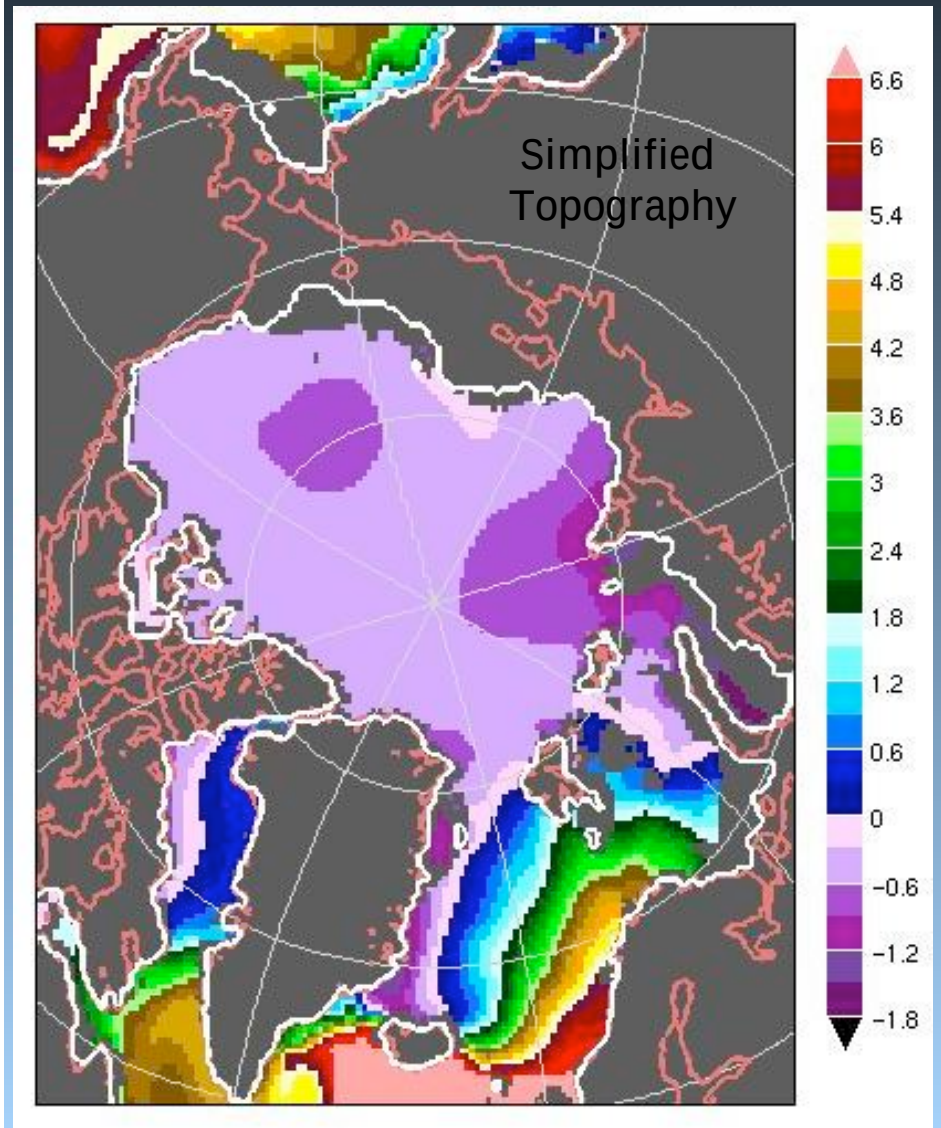
- 5-year run with climatology (ERA40)
- 3-year run with 2000-2002 forcing

Model Run: 2003-2006

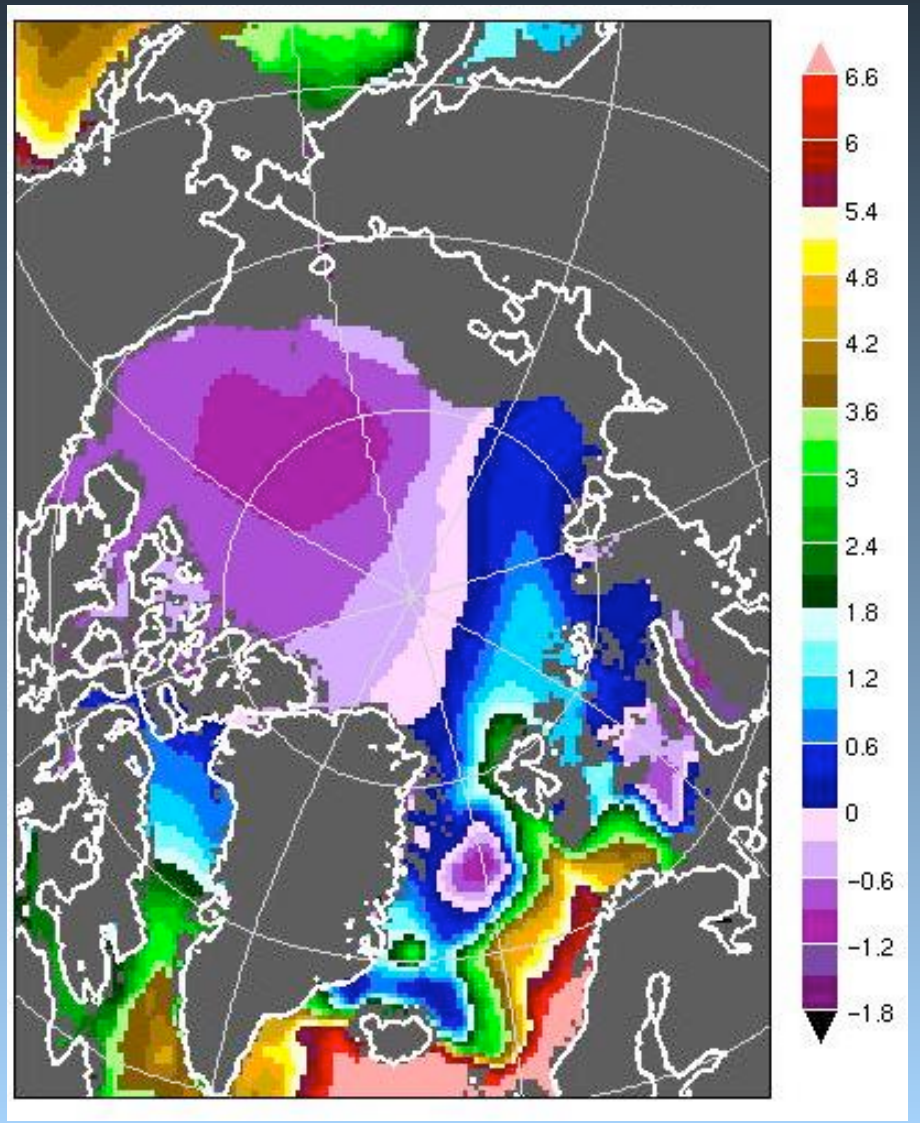
Atmospheric forcing:	3 hourly NOGAPS 0.5˚ fields
Lateral OBs:	relaxation to T/S climatology
Rivers:	climatology
Barotropic/barocl Δt:	20 s/360 s
CICE Δt:	3600 s

Temperature Field at 200 m

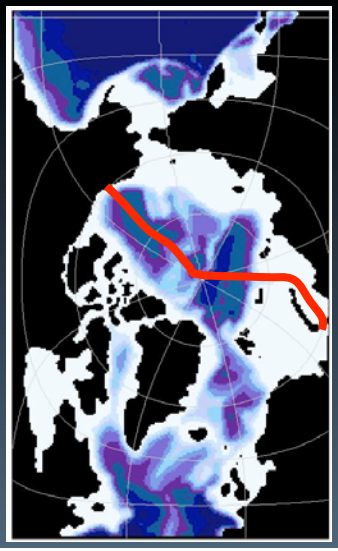
ARCc0.72 – 060 (ST NRL)

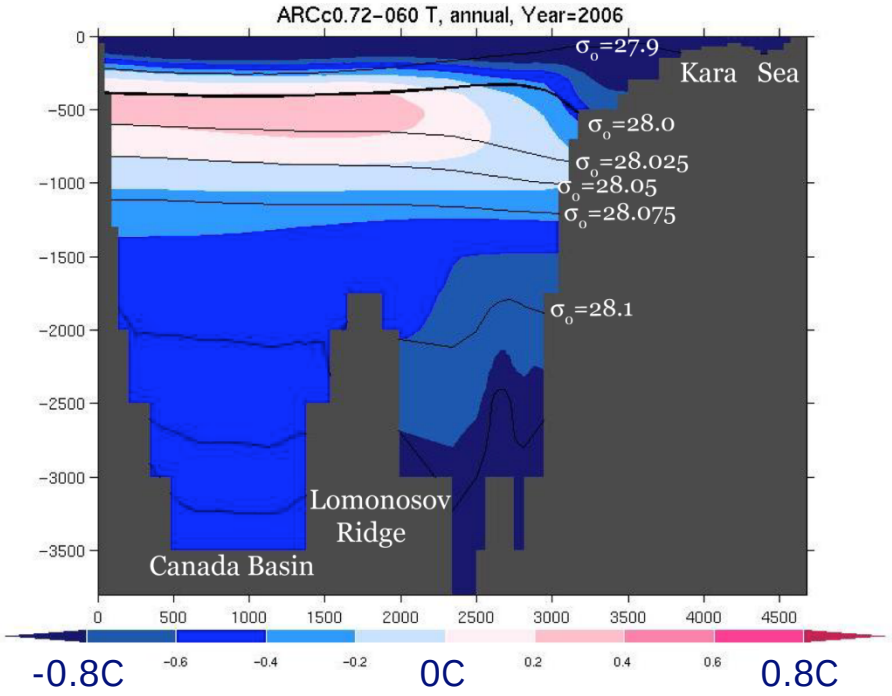


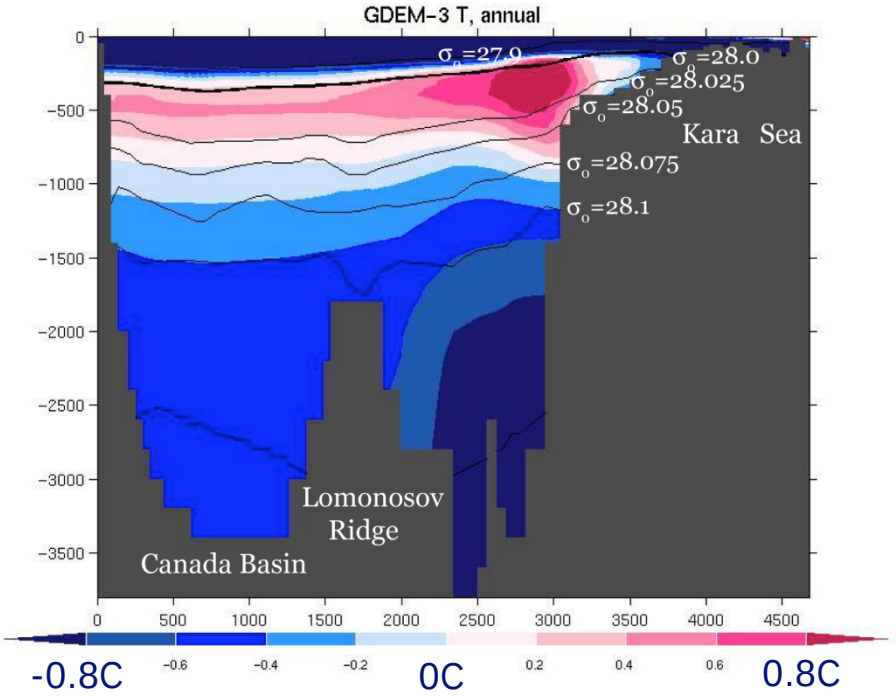
GDEM-3



Vertical Cross-Section of the T Field







Model Experiments

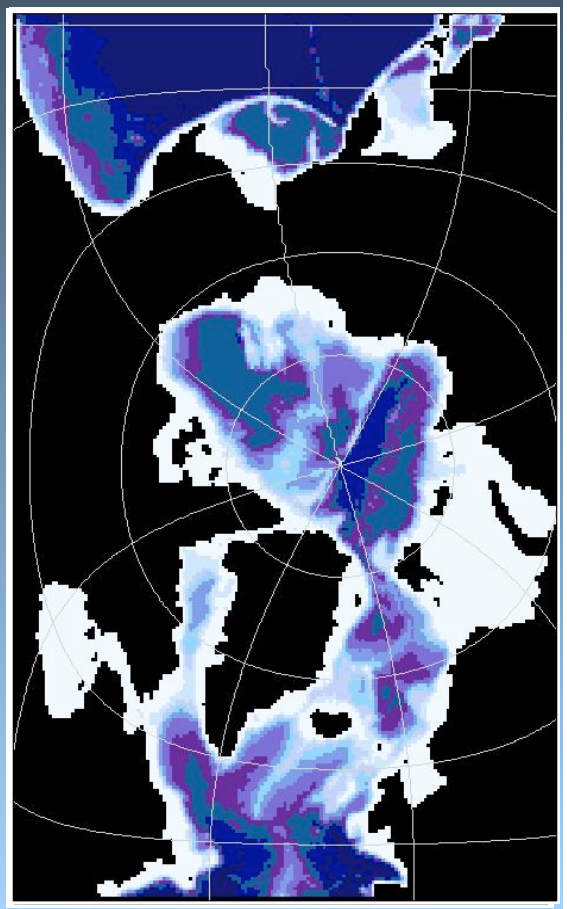
ARCc0.72, 2003-2009, (COAPS):

1) Realistic Topography ("RT")
2) RT, closed Bering Strait
3) RT, closed CAA
4) RT, isolated Kara Sea
5) ST (replicated NRL test run)

HYCOM Initialization:
- Climatology

CICE initialization:
- 3m ice where $t < t_{freezing}$

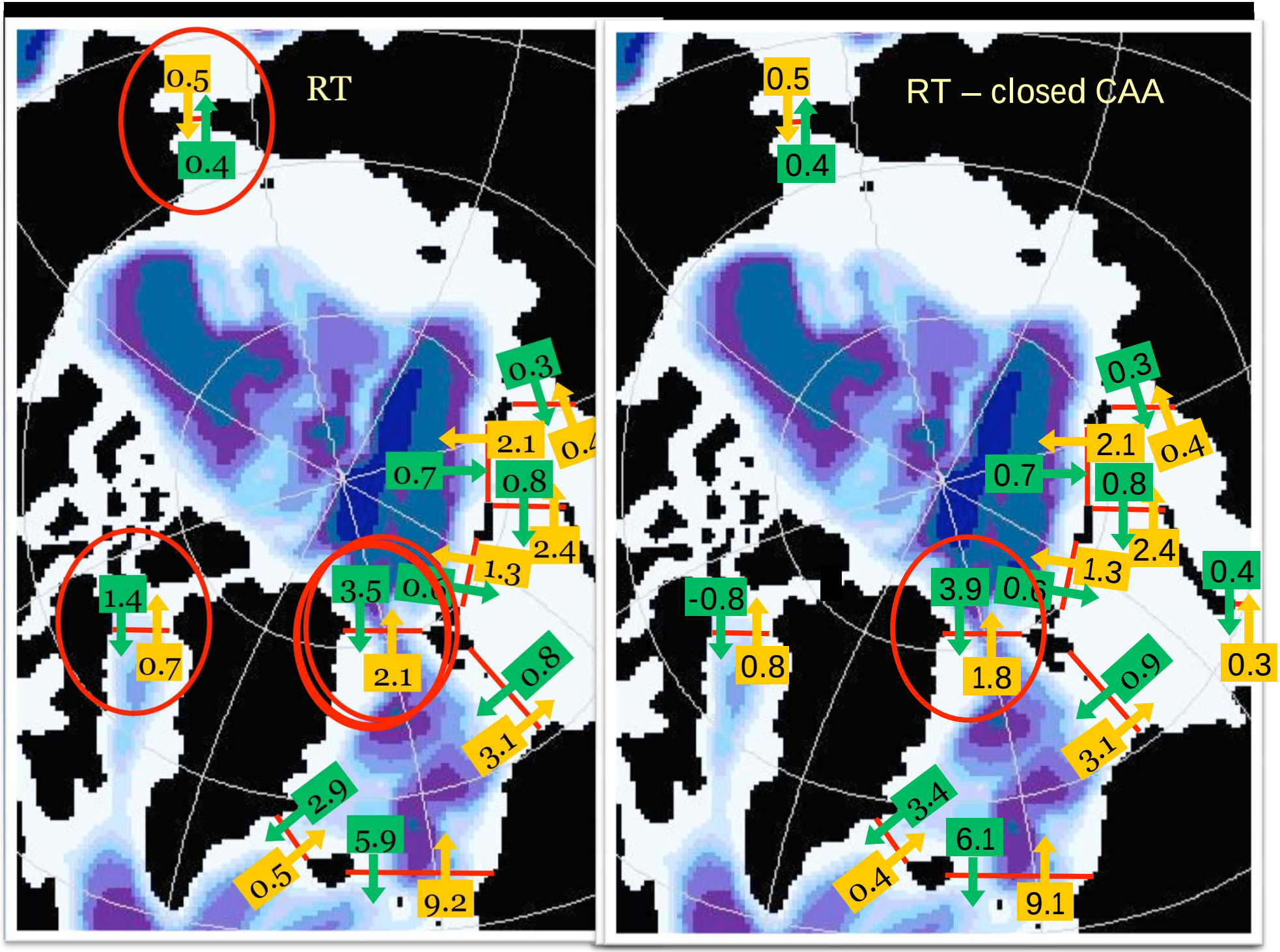
HYCOM/CICE Spin-up:
- 1-year run with climatology
- 5-year run with 2003 forcing

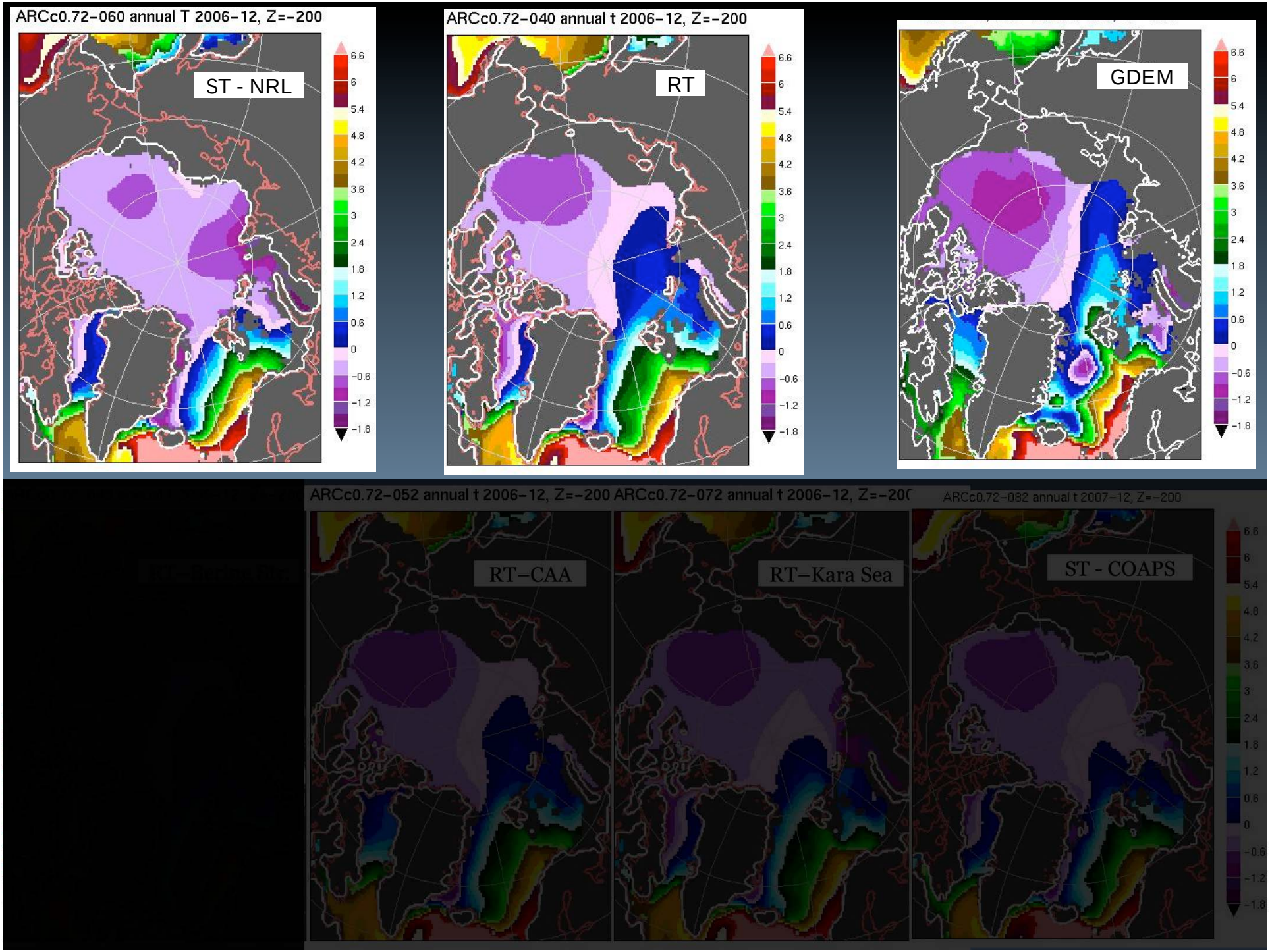


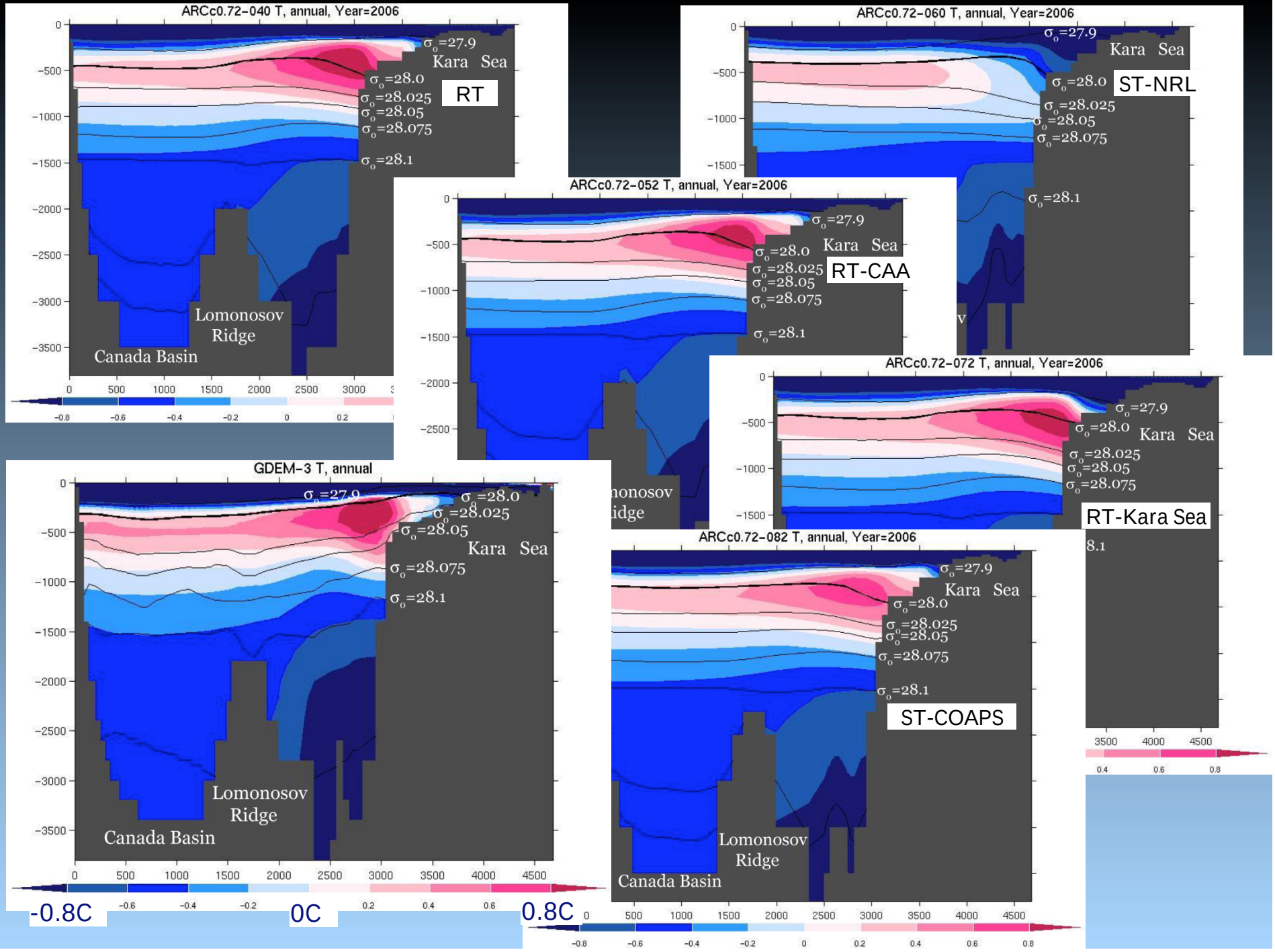
Model Runs:

Atmospheric forcing:	3 hourly NOGAPS 0.5˚ fields
Lateral OBs:	relaxation to T/S climatology
Rivers:	climatology
Barotropic/barocl Δt:	20 s/360 s
CICE Δt:	1800 s

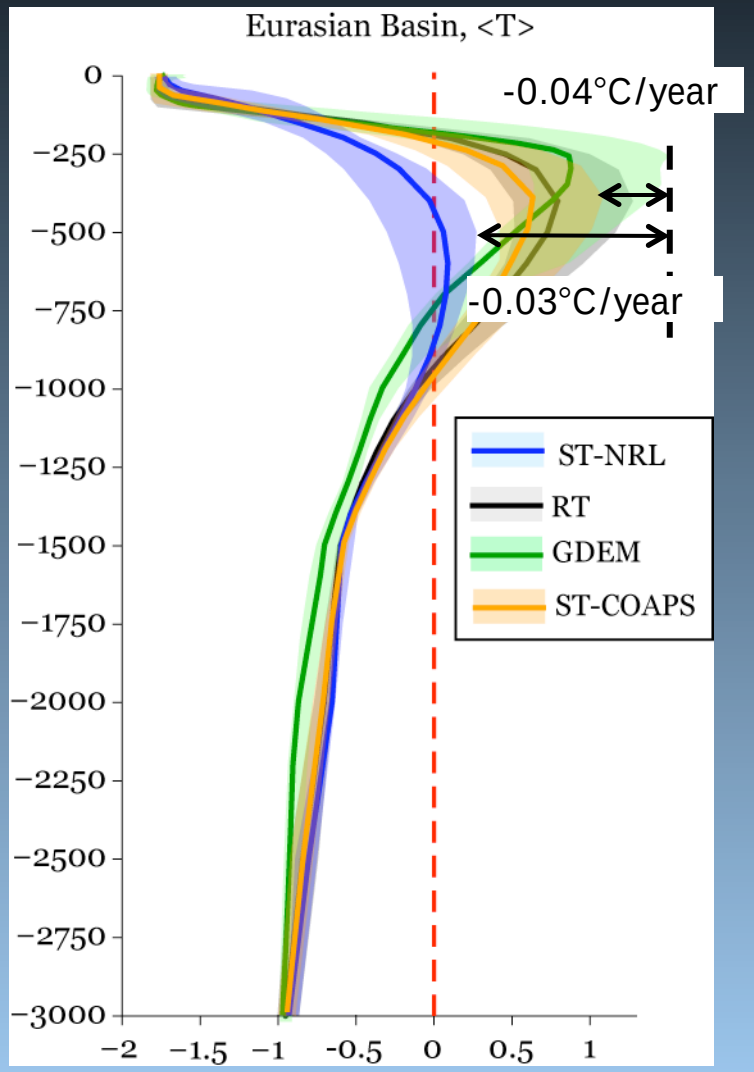
Model Results

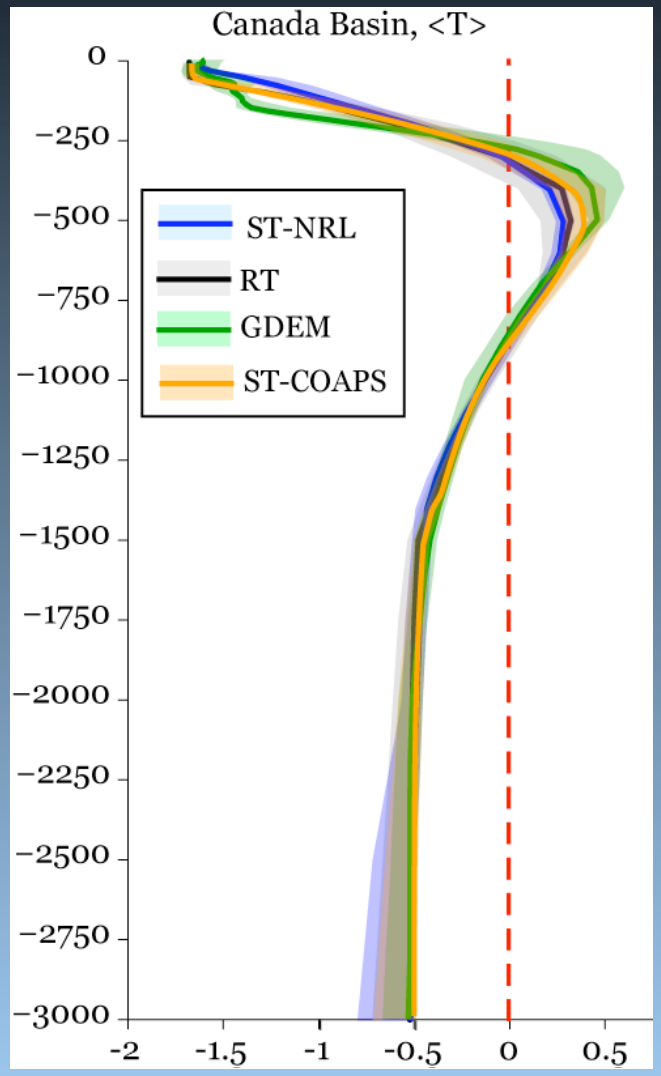

RT
0.5
0.4
0.3
2.1
0.4
0.7
0.8
2.4
1.3
1.4
0.7
3.5
2.1
0.8
3.1
2.9
0.5
5.9
9.2
RT – closed CAA
0.5
0.4
0.3
2.1
0.4
0.7
0.8
2.4
1.3
0.4
-0.8
0.8
3.9
0.6
1.8
0.9
0.3
3.1
3.4
0.4
6.1
9.1


ARCc0.72-060 annual T 2006-12, Z=-200
ST - NRL
ARCc0.72-040 annual t 2006-12, Z=-200
RT
GDEM
ARCc0.72-052 annual t 2006-12, Z=-200 ARCc0.72-072 annual t 2006-12, Z=-200
ARCc0.72-082 annual t 2007-12, Z=-200
RT-CAA
RT-Kara Sea
ST - COAPS
6.6
6
5.4
4.8
4.2
3.6
3
2.4
1.8
1.2
0.6
0
-0.6
-1.2
-1.8


ARCc0.72-040 T, annual, Year=2006
RT
ARCc0.72-060 T, annual, Year=2006
ST-NRL
ARCc0.72-052 T, annual, Year=2006
RT-CAA
ARCc0.72-072 T, annual, Year=2006
RT-Kara Sea
GDEM-3 T, annual
ARCc0.72-082 T, annual, Year=2006
ST-COAPS
σ0=27.9
σ0=28.0
σ0=28.025
σ0=28.05
σ0=28.075
σ0=28.1
Kara Sea
Lomonosov Ridge
Canada Basin
-0.8C
0C
0.8C

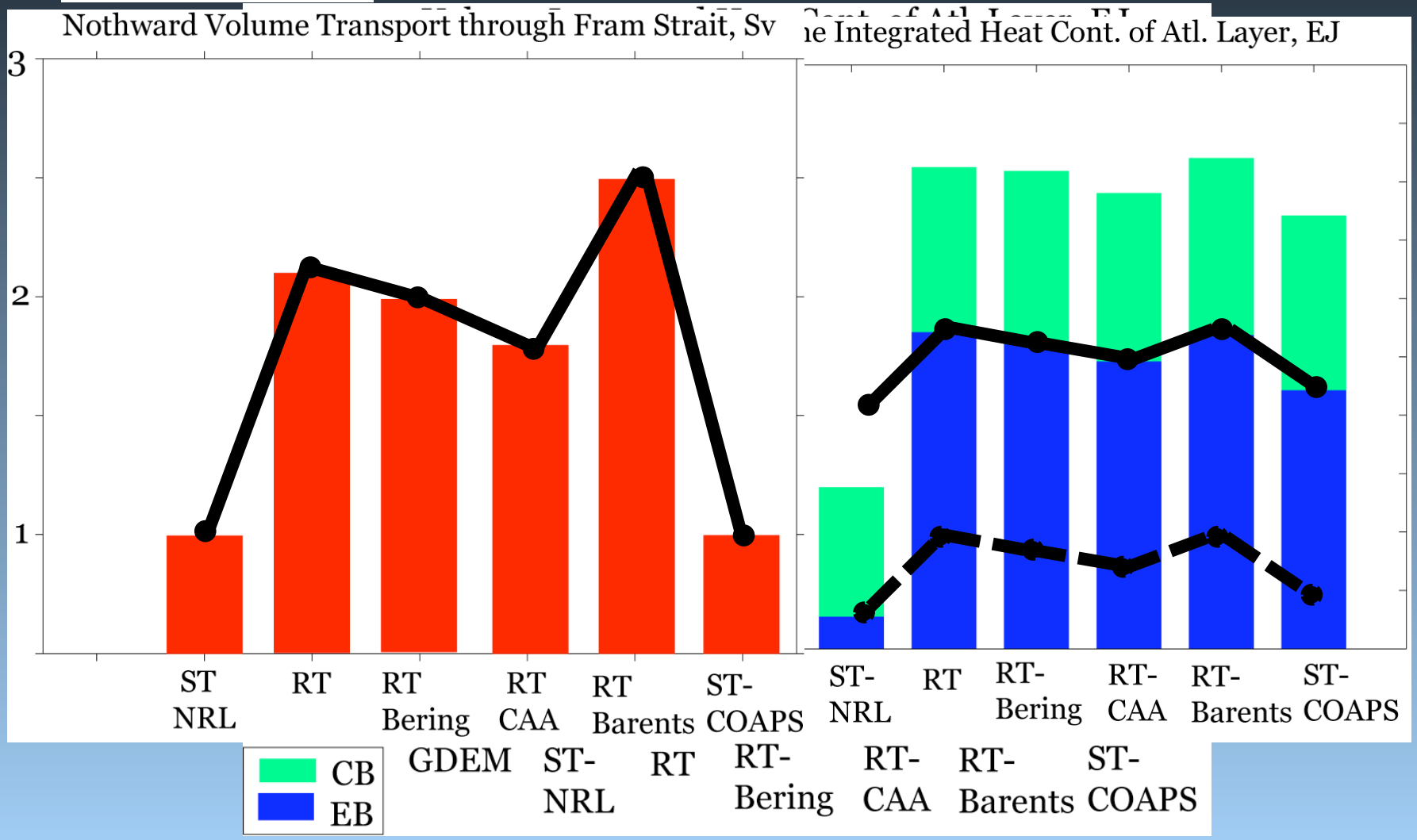
Temperature Profiles from ARCco.72 and GDEM





Volume Integrated Heat Content of Atlantic Layer

$$Q = \oint \int_{\theta>0} \rho C_p \theta \, dz \, d\Gamma$$



Depletion and Cooling of Atlantic Layer in ARCco.72

Atlantic water inflow is strongly underestimated in the model.
Observations suggest northward flow through Fram Strait ~12Sv
(*Schauer et al.*, in: "Arctic-Subarctic Ocean Fluxes", 2008).

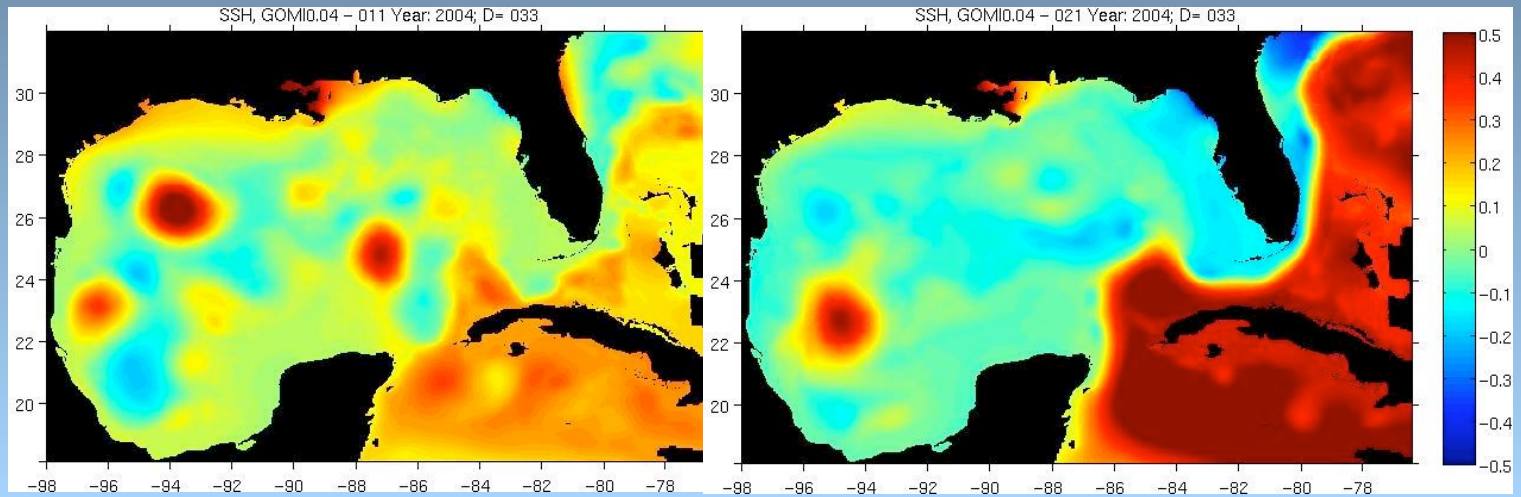
Possible reasons:

1) Unresolved flow structure in the Fram Strait
2) Relaxation vs nesting at the OBs

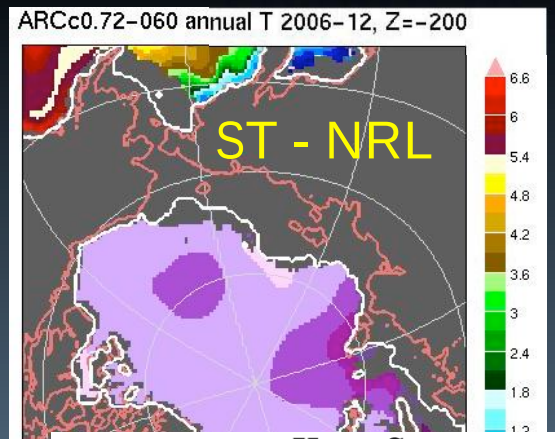
SSH from the 1/25° HYCOM of the Gulf Of Mexico (GOMlo.04)

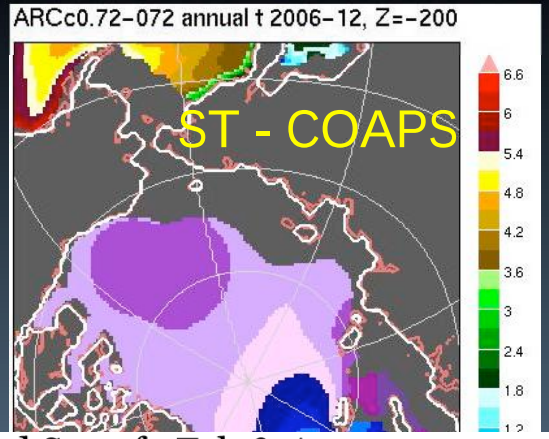
Relaxation to climatology of T, S, and layer thicknesses along the lateral OB

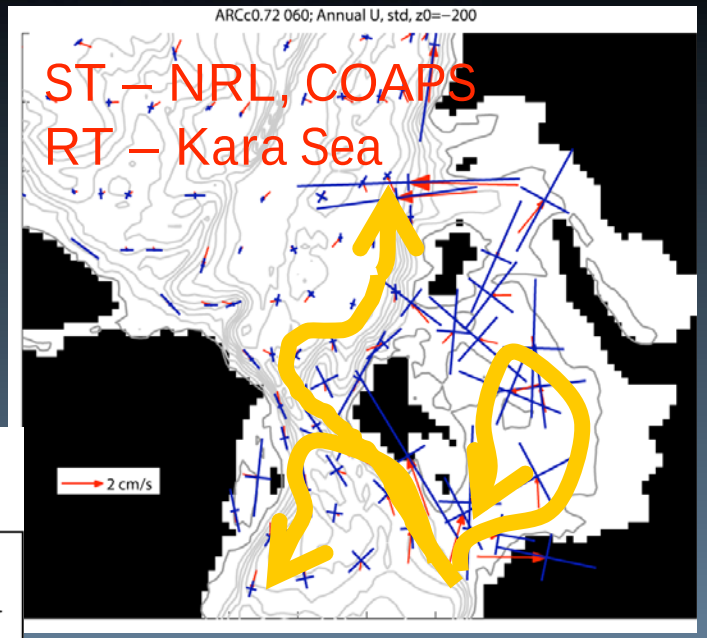
Nested into N. Atlantic 1/12° HYCOM

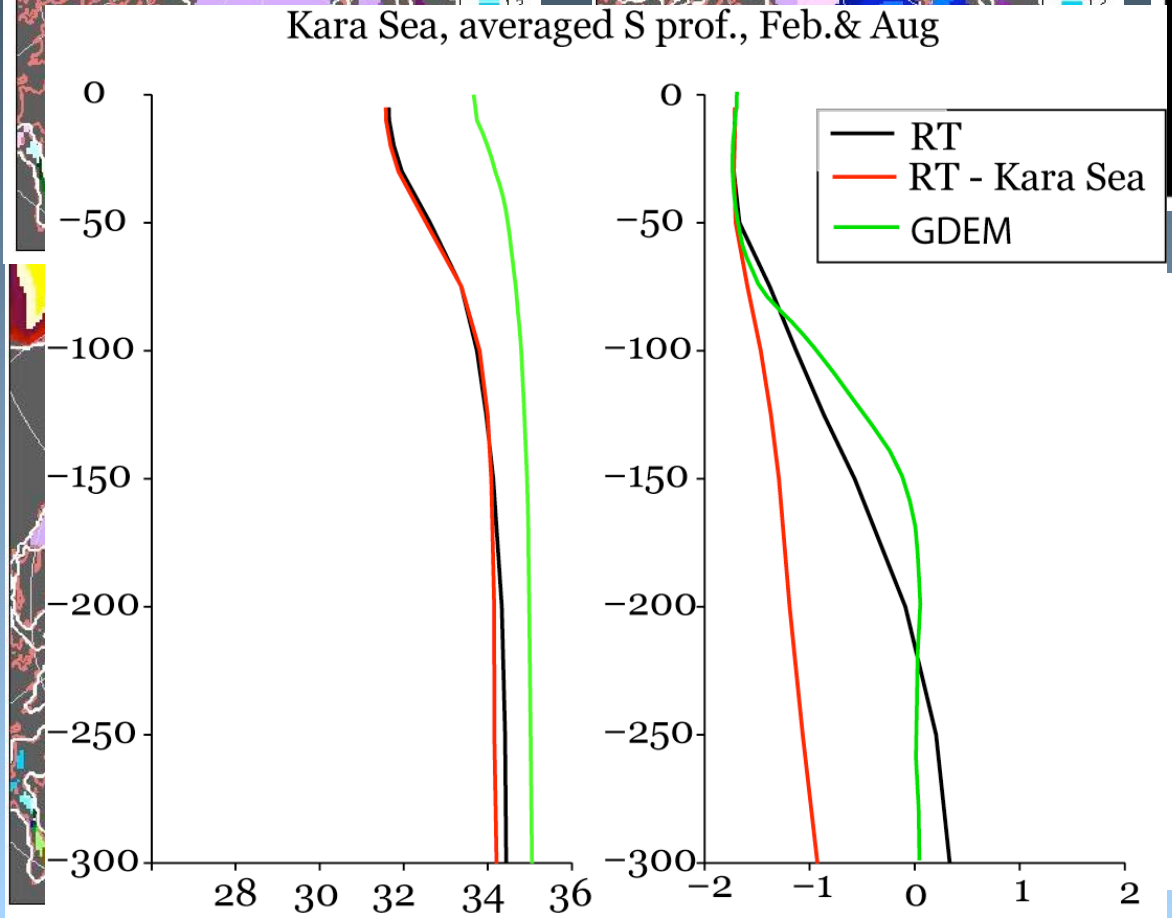


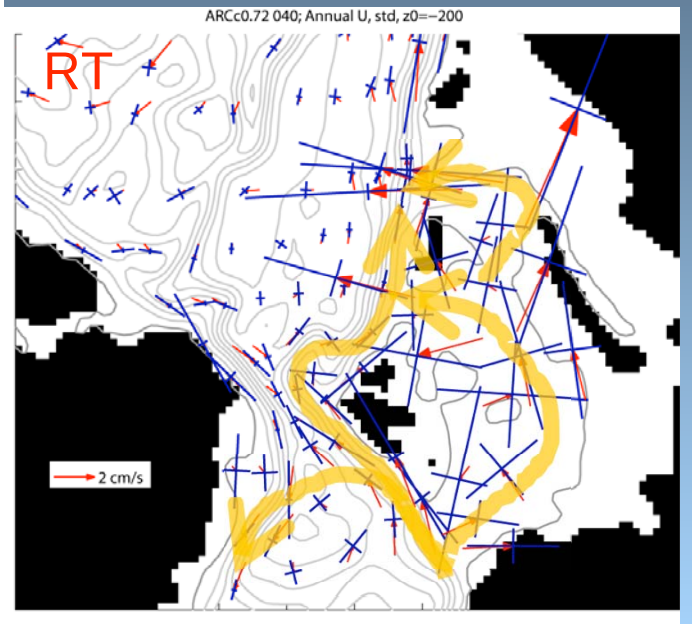
Origin of the Cold Anomaly in the T Field











Conclusions

- Biases in thermohaline structure of the Arctic Ocean in the test run of ARCc0.72 with simplified topography ("ST") are due to:
  - Underestimated inflow of Atlantic water through Fram Strait
  - Closed shelves
- Model simulations with realistic topography ("RT"):
  - Have better representation of the shelf circulation
  - Double the northward flow of Atlantic water through Fram Strait (still much lower than observed)
  - Slower depletion/cooling of the Arctic Ocean Atlantic Layer
- Model simulations with closed/open straits
  - Bering Strait inflow does not play a noticeable role in the thermohaline structure (for the coarse ARCc0.72 only!)
  - Open CAA increases Atlantic water inflow through Fram Strait