The maintenance of layered structure in the Arctic Ocean by the Atlantic water inflow

GRENE-Arctic

T. Kawasaki [*,+] and H. Hasumi[*]

[*]Atmosphere and Ocean Research Institute, University of Tokyo, Kashiwa, Chiba, Japan

[+]Arctic Environment Research Center, National Institute of Polar Research, Tachikawa, Tokyo, Japan

1. Introduction

Building a numerical model that can reproduce mechanism responsible for the formation of and changes to the structure of the Arctic Ocean
→ Gaining an understanding of the role of the sea ice-ocean system in the Arctic Ocean amid global climate change

Ice edge in Atlantic is at higher latitude than that in Pacific
→ The effect of inflow of Atlantic water on the sea ice in the Arctic Ocean is significant.

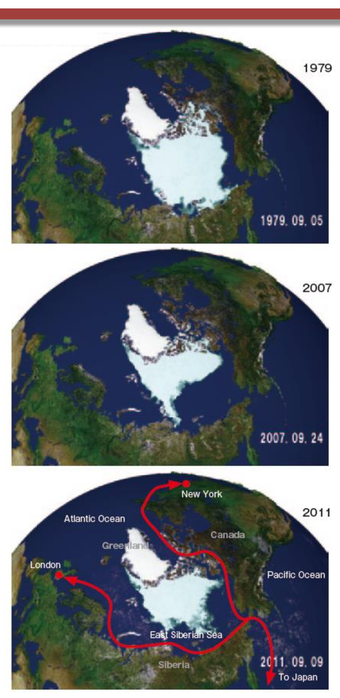


Fig. 1: Distribution of sea ice on the day when its total area of coverage is at a minimum and Arctic sea routes (AMSR-E data, Source: JAXA)

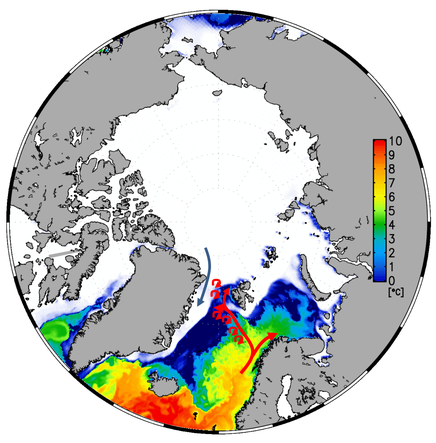


Fig. 2: SST in winter (color) and sea ice concentration (white) in our model

Fram Strait
- West Spitz Bergen Current (Northward; its width ～10-20km)
- eddies (< 20km)

→ Fine structure influences the heat and freshwater exchange

We focus on
- The effect of heat of the Atlantic water on the Arctic sea ice
- The modification of water mass in Barents Sea and Arctic Ocean

2. Model description

- COCO 4.5 (OGCM with sea ice)
- Sea Ice: Multi-category + EVP rheology (Hunke & Dukowicz, 1997)
- Grids: 1280 x 768 (hor.) x 45 (vert.)
- Surface Boundary Condition: CORE daily
- Surface Mixed layer scheme: GLS mixed layer scheme(Umlauf & Burchard, 2003)
- Vertical Diffusivity: 0.01 x 10^{-4} m^2/s (Rainville & Winsor, 2008)

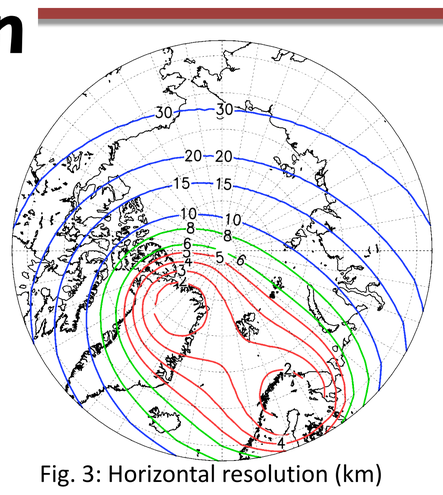


Fig. 3: Horizontal resolution (km)

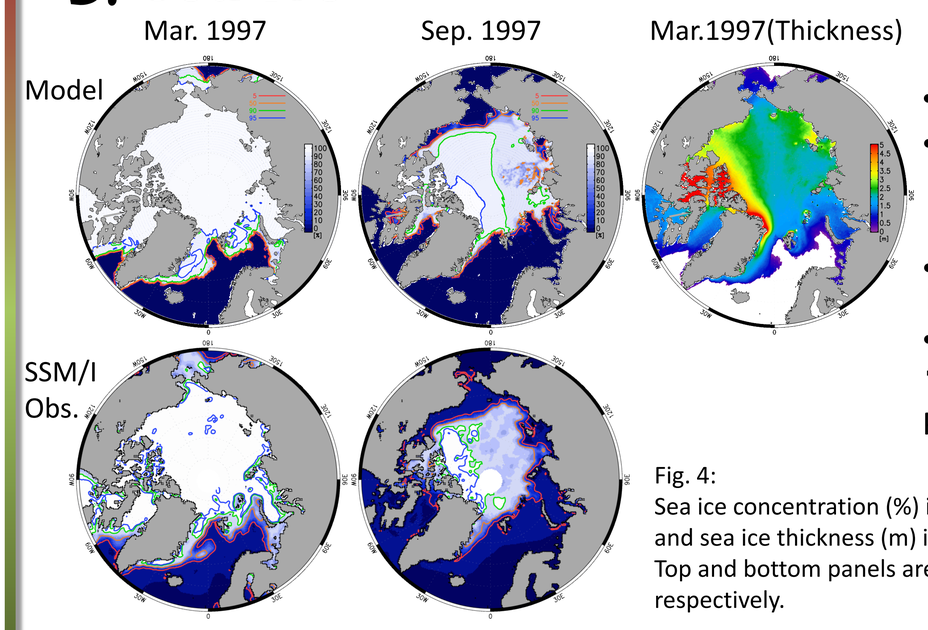
- Albedo: 0.7 on sea ice & 0.9(-5℃)-0.75(0℃) on snow
- Initial Condition: no sea ice and flows, PHC data-set (temperature, salinity)

Schedule

Nudging to PHC of Salinity in all and Temperature below 50m depth	CORE daily forcing Without nudging

Jan 1st, 1980 — Spin-up of sea ice and mean current — Jan 1st, 1990 — Main analytical period — Jan 1st, 2008

3. Sea ice



Consistency with obs.
- Sea ice concentration
- Thick around CAA and Northern coast of Greenland
- Thin around Eurasian Basin

Inconsistency with obs.
- Too thick off Alaska

∵ inflow and transport of Pacific water are few

Fig. 4:
Sea ice concentration (%) in winter (left) and summer (center) and sea ice thickness (m) in winter (right).
Top and bottom panels are model and satellite obs. (SSM/I), respectively.

4. Inflow of Atlantic water

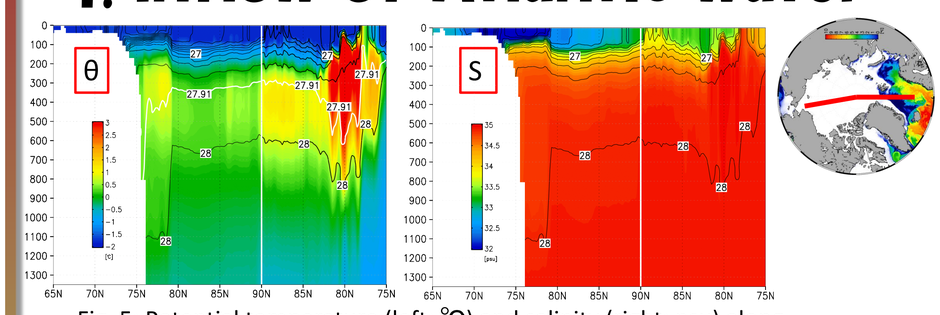


Fig. 5: Potential temperature (left; ℃) and salinity (right; psu) along red line in sub map on Mar. 1997. Contour: potential density (kg/m^3).

- Low salinity water lies near sea surface
- Mixed layer is developed in winter
- Warm Atlantic water ventilates along pycnocline(27.91 kg/m^3)

- Warm/salty Atlantic water inflows through Fram Strait
- Cold/fresh water inflow through St. Anna Tough from Barents Sea
- Cyclonic current is consistent with the previous studies (e.g., Aagaard , 1989; Karcher et al., 2003)

$$\mathrm{HT} = \int_V [\theta - \theta_{\mathrm{ref}}]\, dV$$

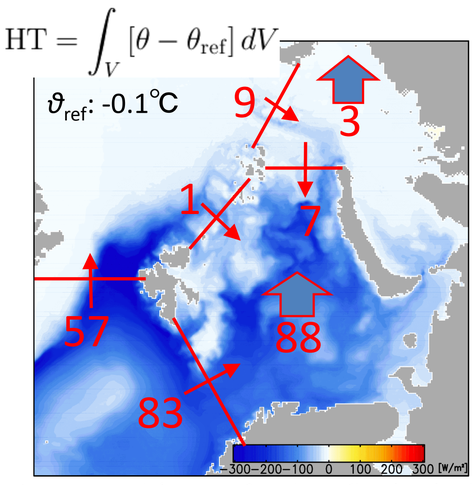


Fig. 7: Lateral / sea surface heat flux (TW). Blue shade indicates sea surface cooling by atmosphere.

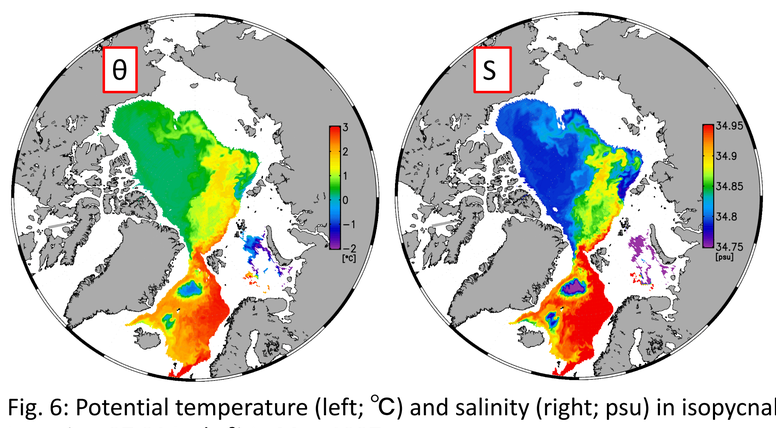


Fig. 6: Potential temperature (left; ℃) and salinity (right; psu) in isopycnal layer (σ_θ=27.91 kg/m^3) in Mar. 1997

Fram Strait
- Mooring obs. (Schauer et al., 2008): 30TW
- Inverse estimation(Tsubouchi et al., 2012): 43TW

Barents Sea Opening
- Mooring obs. (Smedsrud et al., 2010): 73TW
- Inverse estimation (Tsubouchi et al., 2012): 103TW

Heat flux at Fram Strait and Barents Sea Opening is quantitatively well reproduced

5. Fine scale phenomena

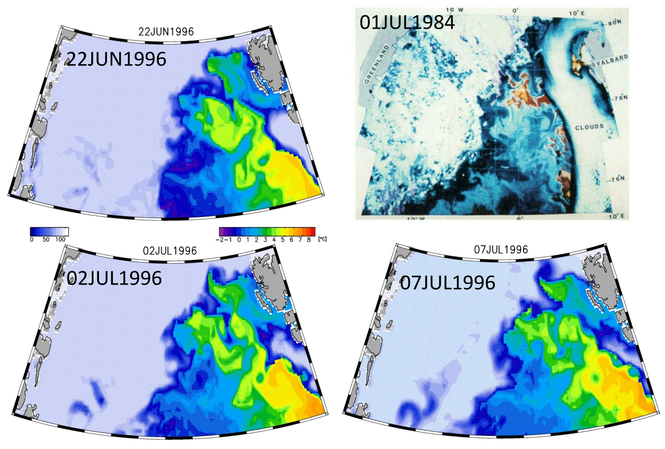


Fig. 8: Sea surface temperature and sea ice concentration around the Fram Strait. Upper right panel is satellite obs. (Johannessen et al., 1987)

Eddy activities around the Fram Strait
- Mesoscale eddies transport warm Atlantic water westward
- Margin of sea ice is meandered

Sea ice formation in the Barents Sea
- The sea ice is formed at the coastal polynya along the Novaya Zemlya
- Qualitative/quantitative consistency with obs.

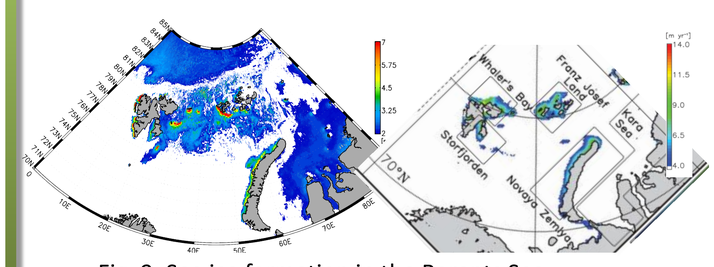


Fig. 9: Sea ice formation in the Barents Sea. Right figure indicates is an estimation by satellite obs. (Tamura & Ohshima 2011)

Table 1: Sea ice formation (km³/year)

	Obs.	Model
Novaya Zemlya	298±44	364
Franz Josef Land	331±73	203
Storfjorden	137±35	101
Kara Sea	342±71	526

6. Conclusion

- Our model reproduced:
  - Distribution of the sea ice (concentration & thickness) **[Fig. 4]**
  - Inflow of warm/salty water through the Fram Strait **[Figs. 5, 6]**
  - Inflow of cold water through the Barents Sea and St. Anna Trough **[Figs. 5, 6]**
  - Cyclonic current along the continental slope at the Atlantic water layer **[Fig. 6]**
  - Heat flux at the Fram Strait and Barents Sea Opening **[Fig. 7]**
  - Sea ice formation (polynya / brine rejection) in the Barents Sea **[Fig. 9, Tab. 1]**
- Warm/salty water is transported westward by mesoscale eddies around the Fram Strait **[Fig. 8]** → The eddy activity influences heat flux at the Fram Strait

Problems of our model & Future work

- The Atlantic Water inflows through the Barents Sea is too fresh **[Fig. 6]**
  → River runoff or sea ice melting in the Barents Sea is overestimated ?
- Detailed Analyses of ...
  - Freshwater flux
  - Change of water properties in the Barents Sea
  - Relationship between heat flux and eddy activities at the Fram Strait

E-mail: kawasaki@aori.u-tokyo.ac.jp