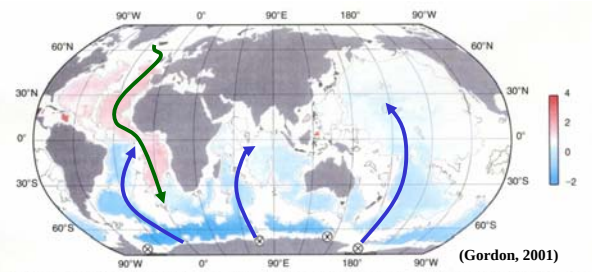
Potential Temperature of Bottom Water

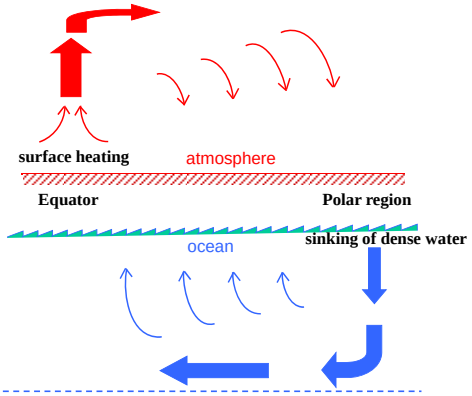


(Gordon, 2001)

Figure 2 Bottom potential temperature along the seafloor, for oceanic areas deeper than 4000 m. The four symbols along the coast of Antarctica mark the places where Antarctic Bottom water forms.

Formation of cold, AABW and saline, NADW actively drives meridional ocean circulation in the world oceans.

Global Circulation in Atmosphere and Ocean



Global Ocean Circulation

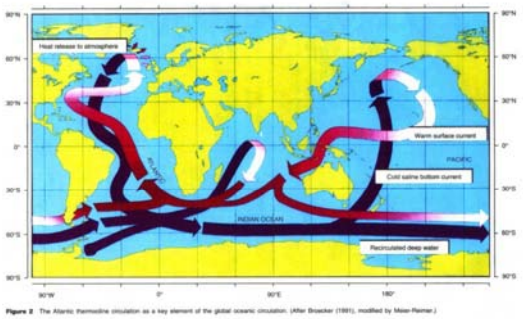


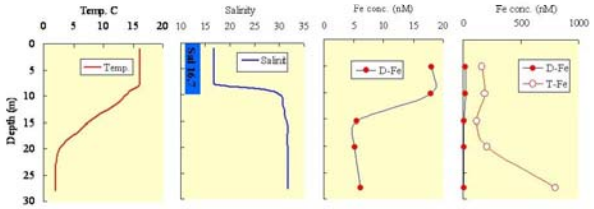
Figure 2 The Atlantic thermoline circulation as a key element of the global oceanic circulation. (After Broecker (1991), modified by Meier-Reimer.)

NADW and AABW are produced in "polar oceans", through the atmospheric cooling and sea ice formation

アムール川河口の鉄の観測結果

- 低塩分の表層水で高溶存鉄濃度 >15 n
- 底層で高粒子態鉄濃度 > 500 nM

データ(2006年8月)は、西岡氏(北大低温研)より提供



What are the important roles of ocean for us?

(1) The ocean greatly contributes to the maintenance of "A Calm Earth Environment".

(2) The ocean has inexhaustible " Resources", for examples, water, fishery, mineral and microbial resources.

……..???

This nice system is composed of the following processes

(1) Severe meteorological condition (cold, strong wind)

(2) Sea ice formation (Ice factory)

- **cold, oxygen-rich Dense Shelf Water (DSW) formation**
- **Absorption of CO2, O2 from the atmosphere**

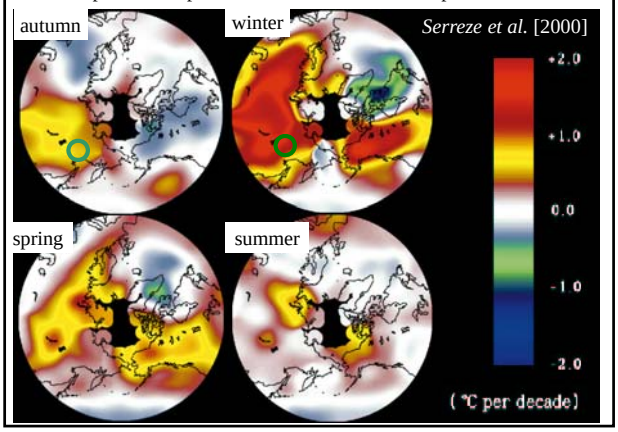
(3) Run-off of iron, nutrients through Amur River

(4) East Sakhalin Current (wind-driven western boundary current)

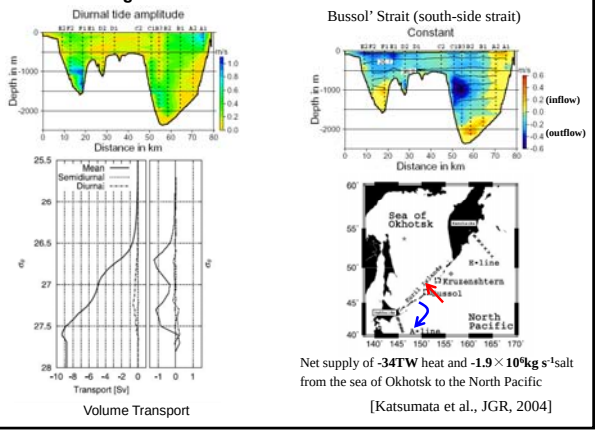
(5) Outflow of cold, oxygen-rich DSW with iron and nutrients to the North Pacific

(6) Upward transport of iron and nutrients by vertical mixing in Oyashio region in winter

Trend map of air temperature in the Northern Hemisphere in 1966–1995



Water Exchange between the Sea of Okhotsk and the North Pacific

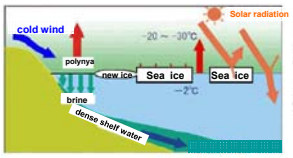


Volume Transport

Net supply of **-34TW** heat and **-1.9×10⁵kg s⁻¹**salt from the sea of Okhotsk to the North Pacific

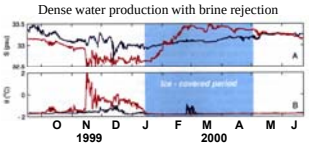
[Katsumata et al., JGR, 2004]

Evidence of Dense-Shelf Water Production and its Transportation



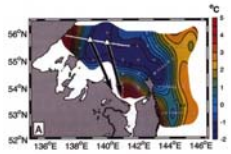
Coastal Polynya Processes

Dense water production with brine rejection



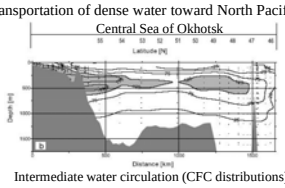
〔**Shcherbina et al., 2004**〕

Transportation of dense water toward North Pacific



Locations of moorings on the continental shelf

Central Sea of Okhotsk



Intermediate water circulation (CFC distributions)

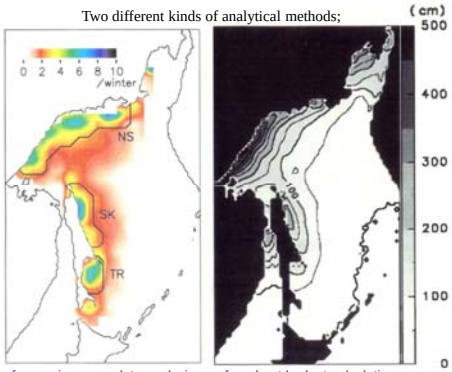
〔**Yamamoto et al., 2004**〕

Locations of Sea-Ice Formation in the Sea of Okhotsk

Two different kinds of analytical methods;

Almost all the sea ice entirely covering with the Sea of Okhotsk forms in the northwestern coastal polynya.

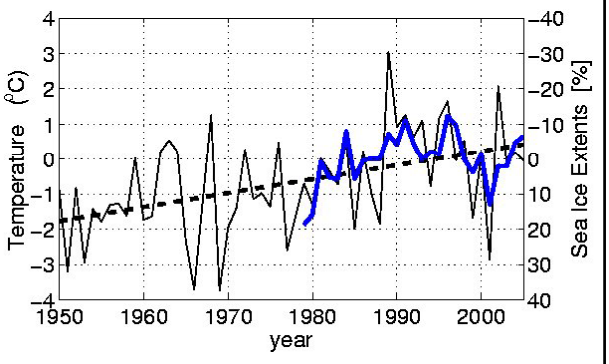
From the structural analyses, the thick ice is composed of several ice plates with different ice growth history, and it does not form in the coastal polynya directly, but dynamically grows through the rafting processes during the southward drifting.



from microwave data analysis
Kimura and Wakatsuchi (JGR, 2003)

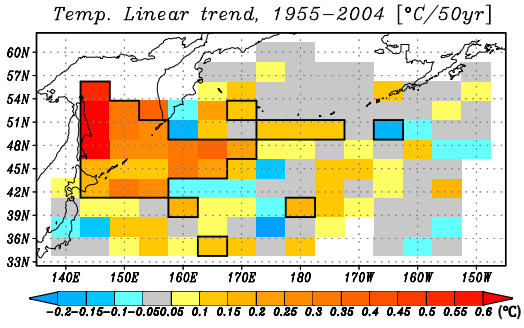
from heat budget calculation
Ohshima et al. (JMST, 2003)

気温（黒色）と海氷面積（青色）の年々変動



Warming of intermediate-waters (about 200-1000 m layer) in the North Pacific during the past 50 years

Temp. Linear trend, 1955–2004 [℃/50yr]



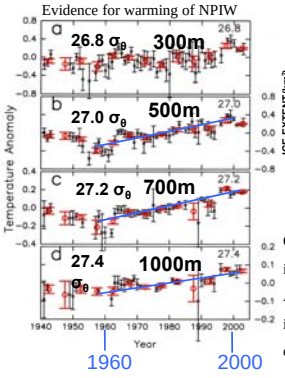
(Nakanowatari et al., GRL, 2007)

Far Eastern Eurasian region just north of the Sea of Okhotsk is coldest in the Northern Hemisphere, while is mostly sensitive for the global warming.

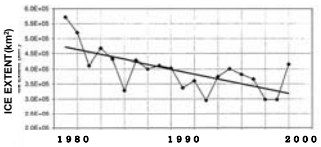
Because this region is located near cold, Arctic region with the positive feedback effect, from the presence of sea ice cover, snow cover and permafrost etc., the effect of global warming there is accelerated.

Effect of global warming on the North Pacific Intermediate Water

Evidence for warming of NPIW



Decreasing trend of Okhotsk sea ice extent

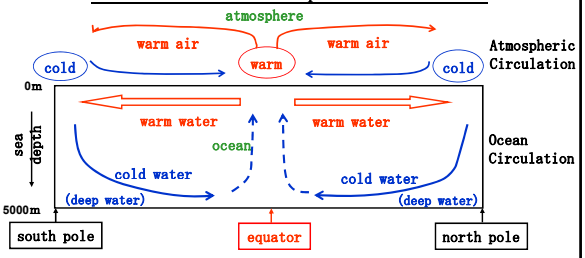


(Itoh, 2005)

Our hypothesis

Global warming causes the decreases of both sea ice formation and dense-shelf water production. As this result, the intermediate-water circulation in this region will be weakened, and the go-down of biological productivity will occur probably.

Heat Flow in Atmosphere and Ocean



Engine which drives global ocean circulation is ;

surface water sinking in "polar oceans" through the atmospheric cooling and sea ice formation

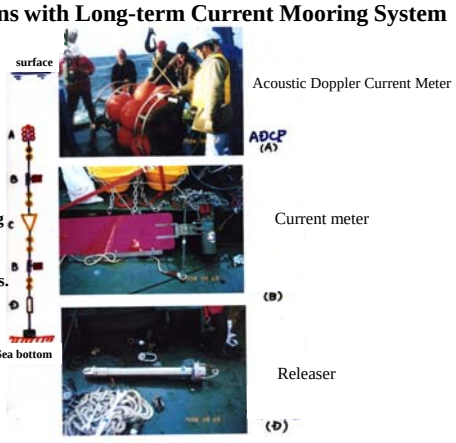
The Ocean

Of the earth surface, about 70% area is the ocean ▪ and about 85% area of it is deeper than 3000m; hence, the ocean has a great amount of heat content.

▪The transportations of heat and materials to the entire world ocean occur through the global ocean circulation.

Water Circulation in the Sea of Okhotsk, revealed by this project

Observations with Long-term Current Mooring System



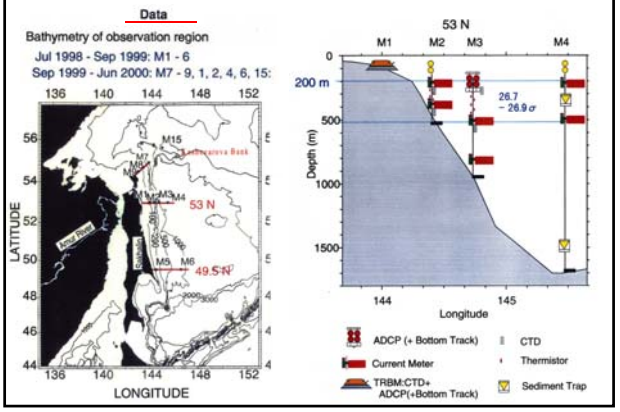
Acoustic Doppler Current Meter

Current Mooring System; is composed of these instruments.

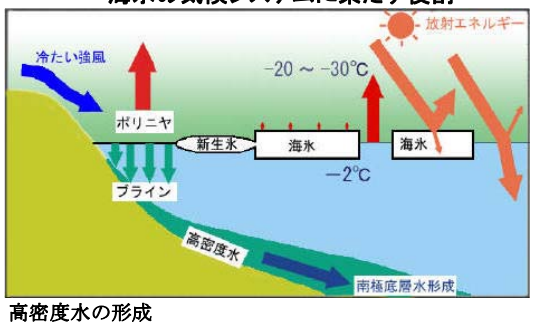
Current meter

Releaser

CURRENT MOORING OBSERVATIONS



海氷の気候システムに果たす役割



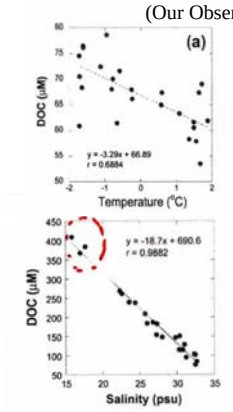
高密度水の形成

海氷生成の際に高塩分（従って高密度）の水（ブライン）が排出され重い水ができるため、それが海洋の底層や中深層に潜り込む。

南極沿岸ポリニヤ→南極底層水（世界で一番重い海水）

Evidence of possible nutrient supply from the Amur River

(Our Observational Results)



Colder, fresher water (originated from the Amur River) has more nutrients.

Water nearest the mouth of the Amur River has more nutrients

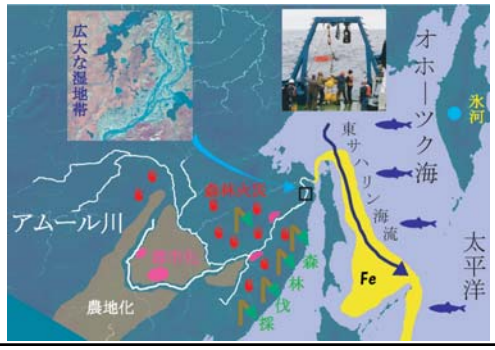
DOC; dissolved organic carbon

POC; particulate organic carbon

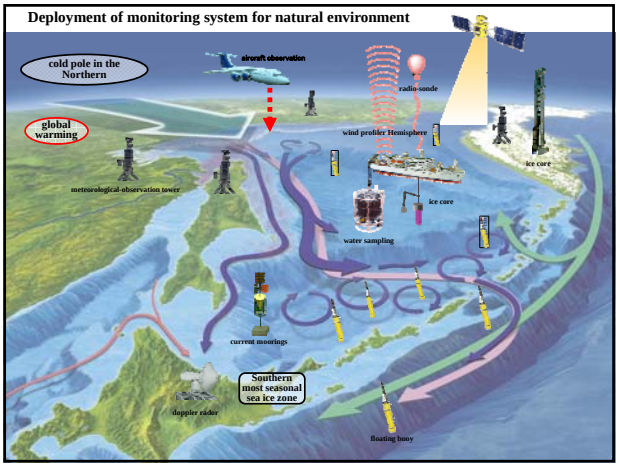
(Nakatsuka et al. 2004)

Amur-Okhotsk Project（２００５～２００９）

(Investigation for the understanding of iron-cycle system)



Deployment of monitoring system for natural environment



Summary

(1) Characteristic Features of the Pan-Okhotsk

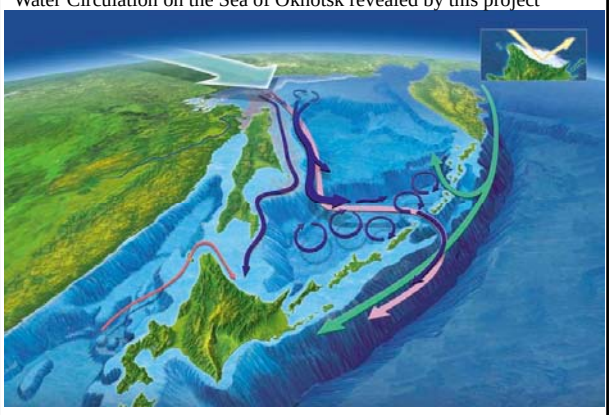
- Coldest Zone and Southernmost Seasonal Sea Ice Zone
- Very Sensitive for Global Warming
- High Biological Productivity (rich Sea)
- Location for Ventilation of the NPIW

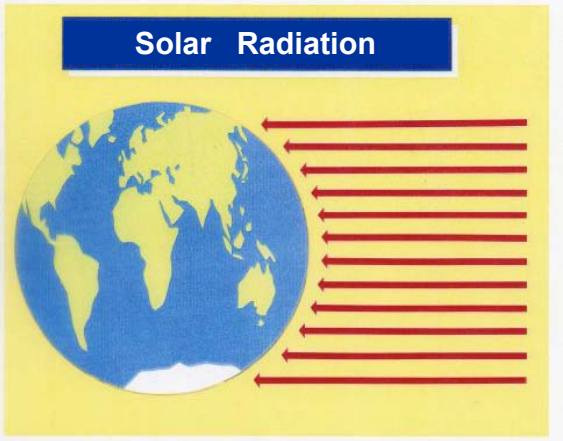
(2) New Findings Revealed by Our Project

- Locations of Sea Ice Formation
- Structure and Seasonal Variation in the ESC
- System of Material Cycle, Keeping Rich Sea
- Effect of Global Warming on Biological Productivity

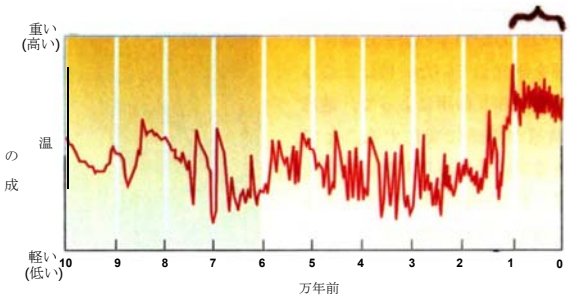
(3) Importance of Cold Ocean in Environment

Water Circulation on the Sea of Okhotsk revealed by this project

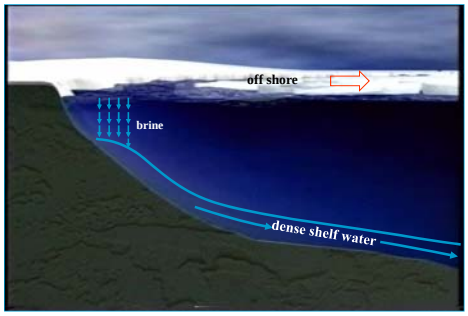




過去10万年間の地上気温変動

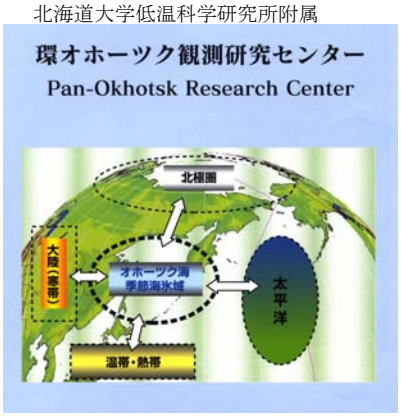


Sea Ice Formation and Dense Shelf Water Production off Siberia Coast



JST

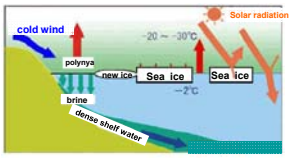
北海道大学低温科学研究所附属



Why is the ocean important for us?

- A simple answer is because the ocean has great resources of water, fisheries, minerals and most minute lives (microorganisms) like bacterias etc, and produces a calm earth environment.
- Therefore, we should learn the system of earth environment which produces and maintains the above important resources.

Evidence of Dense-Shelf Water Production and its Transportation



Polar oceans play an important role as the engines of the global ocean circulation, producing two deep water,

(1) North Atlantic Deep Water (NADW),

(2) Antarctic Bottom Water (AABW).

These two heavy, deep waters are produced by (1) atmospheric cooling of warm, saline water and (2) brine rejection with sea-ice formation.