[Appendix]

Information about Sea Ice Research and the International Symposiums in Mombetsu

1) Sea ice researches in Mombetsu

Mombetsu is located in the center of the shore of the Sea of Okhotsk of Hokkaido and is good for sea ice observations (Fig.1, 2). The Sea Ice Research Laboratory Hokkaido University was established here in 1965 and the International Symposium was held in 1986 and continued until now (Table 1).

Fig. 1 Sea ice at Mombetsu (2003, Feb. 25). Recently, it is rare to see such beautiful sea ice in Mombetsu.

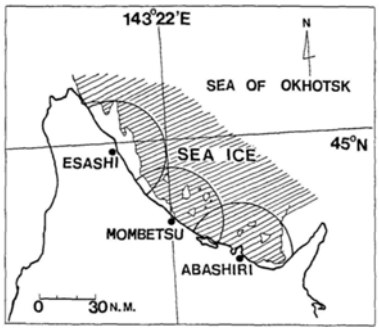

Fig. 2 Location of Sea-ice radars and its observation range (Aota *et al*, 1988).

Table 1 Events and facilities associated with sea ice in Mombetsu

Year	Events and facilities
1965-2004	Sea Ice Research Laboratory of Hokkaido University was established
1969-2004	Drift-Ice-Radar Network (at 3 sites along the coast)
1986-	1st International Symposium on Okhotsk Sea and Sea Ice
1986-2004	Air-Sea-Ice Observation Tower was built off the shore of Mombetsu
1987-1996	1st sightseeing ice breaker "Garinko I" (39 ton) was launched
1991-	Okhotsk Sea Ice Museum of Hokkaido was established
1996-	"Okhotsk Tower" for sightseeing and marine observations was constructed
1997-	"Garinko II" (150 ton)
2020	35th International Symposium on Okhotsk Sea and Polar Oceans
2021-	"Garinko III" (366 ton)

2) International Symposiums in Mombetsu

The subjects of the symposium were mainly on sea ice physics, and engineering for oil development in the icy sea, and biology and fishery in the early period. Recently the subjects changed to the environment subjects covering marine environments, global warming, and the Arctic Sea Routes (Northern Passage in the Arctic Ocean) (Fig. 3, 4).

Fig. 3 Variation of symposium subjects in the past 35 years.

Fig. 4 International Symposium.

Fig. 5 Air-Sea-Ice Observation Tower (Left) changed to Okhotsk Tower (Right).

Fig. 6 Archimedes' screw vehicle was developed to Sightseeing Icebreaker Garinko.

3) Contribution to local society

"Air-Sea-Ice Observation Tower" to measure the sea-ice pressure to the pillar of an oil field platform has been reborn as the Okhotsk Tower for tourism and ocean observation purposes (Fig. 5). The experimental vehicle with two Archimedes' screws for transportation in the icy sea was changed to sightseeing icebreaker ships, which became a symbol of Mombetsu (Fig. 6). The scientific knowledge of biology and fishery contributed the systematic scallop fishery, by which the scallop production increased dramatically from 1980 to 1990 (Fig. 7).

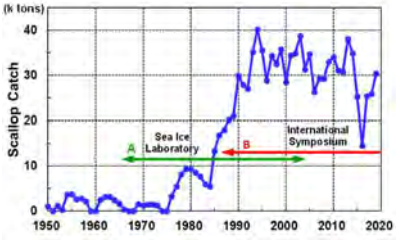

Fig. 7 Scallop catch in Mombetsu.

4) Global warming and sea ice decrease

The sea ice duration in a winter continues to decrease and the temperature increases especially in the past 30 years. If this trend continues, we would see sea ice once every two years in winter by 2050, and it will be once every six years by 2100 (Fig. 8). The sea ice in Mombetsu is becoming "**Endangered Species**".

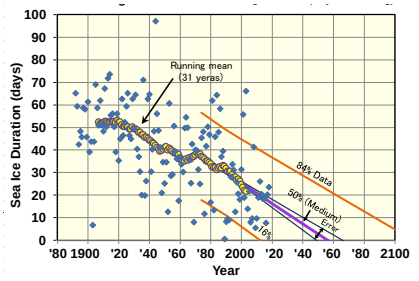

Fig. 8 Changes of sea ice duration at Abashiri. Circles is the 31-years running mean, a blue thick line is a regression line, and orange thick curves shows deviation rage.

References

Takahashi, S. (2021) Contribution of scientific results to society: Case studies of UArctic activity in Greenland and symposium in Mombetsu in Japan. Polar Science, 29 (100687), 1-9.

Takahashi, S., T. Kuwahara, H. Ishihara (2020) Recent change of sea ice along the Okhotsk coast of Hokkaido. Proceedings of the 35th International Symposium on Okhotsk Sea and Sea Ice, Mombetsu, Japan, 35, 215-217.

Appendix: Tables of Sea Ice Nomenclature

(Terminology of sea ice mainly revised from reference iii (WMO, 2014))

a) Classification by development process

Term (Feature)			Thickness (Color)
New ice (Recently formed ice)	**Frazil ice** (Fine ice crystals)		—
	Grease ice (Ice crystals forming a soupy layer)		—
Nilas (Thin elastic crust of ice)	**Dark nilas**		below 5 cm (Very dark)
	Light nilas		5-10 cm (Dark)
Pancake ice (Circular ice from 0.3 - 3 m in diameter with raised rims)			about 10 cm
Young ice (Transition stage from nilas to first-year ice)	**Medium first-year ice**		10-15 cm (Grey)
	Grey-white ice		15-30 cm (Grey-white)
First-year ice (Sea ice of not more than one winter's growth, developing from young ice)	**Thin first -year ice/ white ice**	**first stage**	30-50 cm (white)
		second stage	50-70 cm (white)
	Medium first-year ice		70-120 cm (white)
	Thick first-year ice		over 120 cm (white)
Old ice (Sea ice survived at least one summer's melt)	**Second-year ice**		up to 2.5 m (white)
	Multi-year ice		3 m or more (white)

b) Classification of floating ice by size

Term (Feature)		Size
Ice cake (Small floe)	**Small ice cake**	below 2m
	Ice cake	2-20m
Floe (Any contiguous piece of sea ice. Relatively flat.)	**Floe small**	20-100m
	Floe medium	100-500m
	Floe big	0.5-2 km
	Floe vast	2-10 km
	Floe giant	over 10 km

c) Classification of ice field* by size

(*One of drift ice arrangement. Others are "Belt", "Tongue", "Strip" and so on)

Term (Feature)		Size
Ice field (Area of floating ice consisting of any size of floes)	**Ice patch**	below 10 km
	Small ice field	10-15 km
	Medium ice field	15-20km
	Large ice field	over 20 km

d) Ice surface features (partial)

Term	Feature
Pancake ice	Circular pieces of ice, 0.3 - 3 m in diameter, about 10 cm in thickness, with raised rims
Rafted ice	Deformed ice formed by one piece of ice overriding another
Finger rafted ice	Rafted ice in which floes thrust 'fingers' alternately over and under the other
Ridge	A line or wall of broken ice forced up by pressure.
Hummock	A hillock of broken ice which has been forced upwards by pressure.

e) Opening in the sea ice

Term	Feature
Fracture	Any break or rupture through very close ice, compact ice, fast ice *etc*.
Fracture zone	An area which has a great number of fractures.
Lead	Any fracture or passage-way through sea ice where vessels can navigate.
Polynya	Any non-linear shaped opening enclosed in ice, including shore polyniya and recuring polynya.

f) Classification by concentration

Term	Concent-ration*
Compact ice	10
Consolidated ice	
Very close ice	9-10
Close ice	7-8
Open ice	4-6
Very open ice	1-3
Open water	below 1
Bergy water	
Ice-free	0

(*expressed in tenths)

Drift ice at Shiretoko Pen.

The ice is categorized into "Thin first-year ice/ first stage", "Ice cake", "Ice patch" and "Very close ice" by the classifications of a). b), c) and f), respectively.

g) Other terms relating to sea ice

Term	Definition
Fast ice	Sea ice which remains fast along the coast, attached to the shore or an ice front.
Drift ice / pack ice	Any area of sea ice other than fast ice. When concentrations are 7/10 or more, drift ice may be replaced by pack ice.
Ice cover	The ratio of an area of ice to the total area of sea surface within some large area; such as the Barents Sea.
Concentration	The ratio of the amount of the sea surface covered by ice as a fraction of the whole area, expressed in tenths.
First date of drift ice in sight	The first date when drift ice is in sight in winter season.
Last date of -	The last date when drift ice is out of sight.
Drift ice on shore	The state that drift ice arrives at seashore. It is categorized into completely touching type and partially touching type.
First date of shore lead appearance	The first date when the ice cover becomes 5/10 or lower and continues it until the last sate of drift ice in sight.
Brine	Highly concentrated salt water captured in ice when sea water is frozen. Brine get out gradually from the ice.
Ice algae	Phytoplankton algae living at the bottom of sea ice. It increases explosively during the spring when sea ice is melting.

Drift ice near Abashiri

Dark nilas is partially overlapped, forming "rafted ice". "Young ice" is seen beyond nilas

References

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iii) WMO (2014): Sea ice nomenclature, WMO No.259.

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from Mini Encyclopedia on Drift Ice