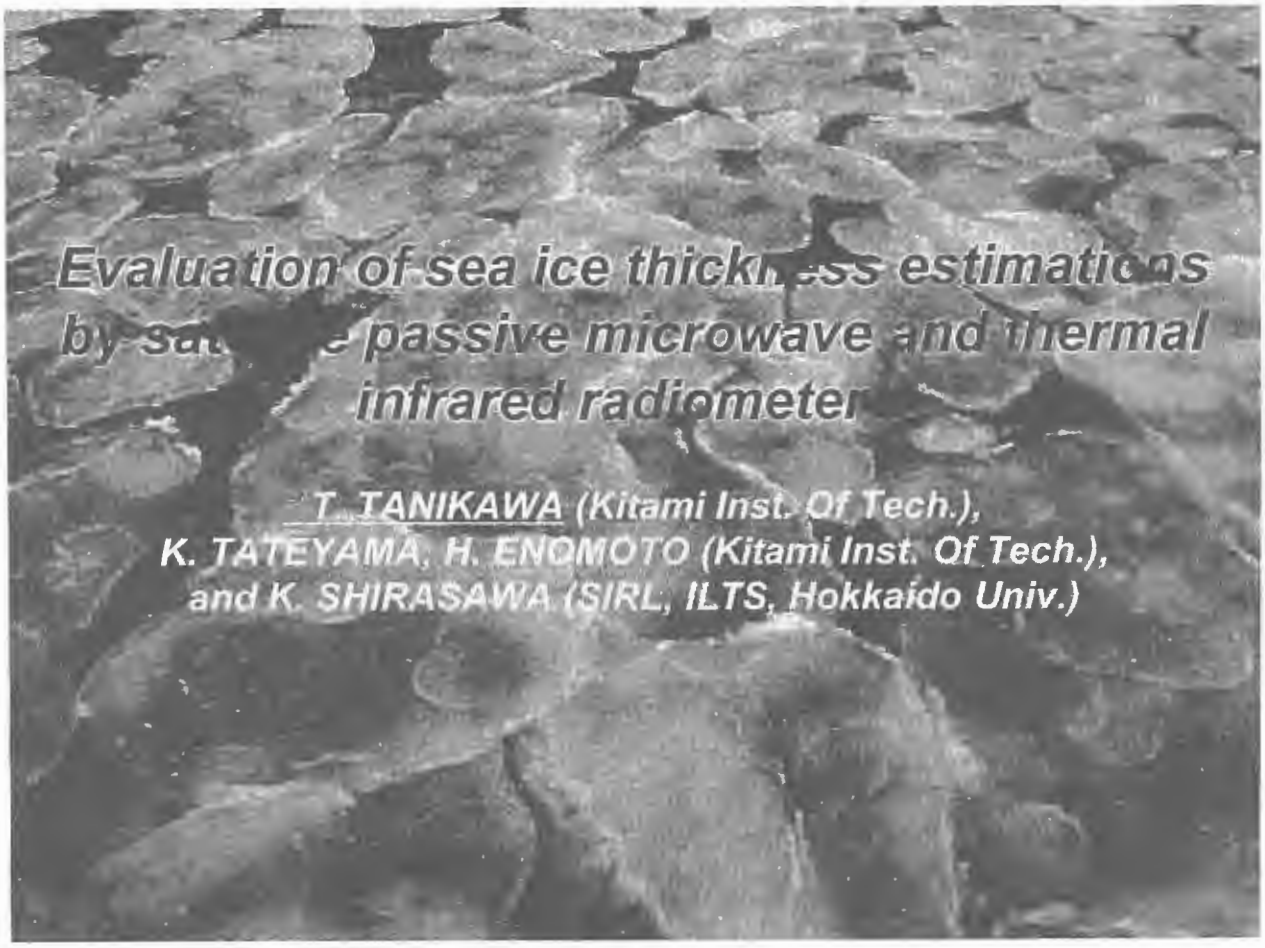


Background

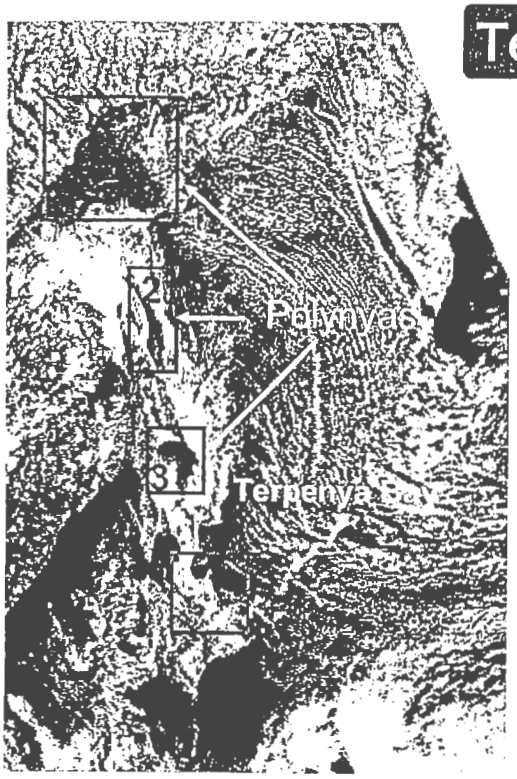
Sea ice thickness estimation by the satellite remote sensing

Qualitatively → Quantitatively

□**AVHRR ice thickness**: AVHRR + Heat flux
- -Groves and Stringer [1991]: AVHRR + Kuhn's model
- -Drucker et al. [2003]: AVHRR + Yu and Rothrock [1996]

□**Active microwave ice thickness**: ERS, RADARSAT
- - Kwok and Cunningham [2002] : RGPS
- - Peacock and Laxon [2004] : altimeter

□**Passive microwave ice thickness**: SSM/I
- - Tateyama et al., [2002]: $R_{37V/85V}$, $R_{19H/85V}$, PR_{19}
- - Martin et al., [2004]: R_{37}



Test site

Terpenya Polynya

'Terpenya Bay' polynya in 1997 winter.

- no ice movement
- no snow cover

Thick ice

Data and Spatial Resolution

□DMSP SSM/I

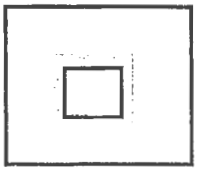
✓Tateyama algorithm [2002]
✓Martin algorithm [2004]
- Daily brightness temperature (BT) from DMSP SSM/I

For validation

□NORR AVHRR

✓**Yu and Rothrock algorithm [1996]**
- Daily surface temp. data from NOAA AVHRR
- Daily meteorological data from NCEP/NCAR reanalysis

□Ship-borne video data (for thick ice)



NCEP/NCAR: 2.5° mesh → 280km×280km
AVHRR: 1.1km × 80pixel → 88km×88km
SSM/I: 12.5km × 6pixel → 75km×75km

Method 1 Tateyama algorithm (2002)

□ Tateyama algorithm is developed based on the SSM/I data and *in-situ* ice thickness data taken by ship-borne video camera.

The ice thickness H_T (m) is estimated using empirical equation;

$$H_T = -5.37 \cdot PR_{19} + 0.84 \cdot R_{37V/85V} - 0.07, \quad (1)$$

where

$$PR_{19} = \frac{TB_{19V} - TB_{19H}}{TB_{19V} + TB_{19H}}, \qquad R_{37V/85V} = \frac{TB_{37V}}{TB_{85V}}, \quad (2)$$

➢Sea-ice surface roughness ➢Temperature gradient

When a new ice signal is detected ($R_{37V/85V}$ <0.97), $^*R_{37V/85V}$ is converted to $R_{37V/85V}$ by following equation,

$$R_{37V/85V} = 0.3 \cdot \left({}^*R_{37V/85V} - R_{19H/85V}\right) + 0.6 \cdot R_{19H/85V} - 0.29 \quad (3)$$

Method 2 Martin algorithm (2004)

□ Martine algorithm is useful for ice production in polynyas.

➢This algorithm is developed based on the ratio of H- and V-polarized 37GHz channels.

The ice thickness H_M (m) is calculated using the following equation

$$H_M = \exp^{1/(\alpha R_{37} + \beta)} - \gamma, \quad (4)$$

where $\alpha = 230.47$, $\beta = -243.60$, $\gamma = 1.0080$, and,

$$R_{37} = \frac{TB_{37V}}{TB_{37H}}. \quad (5)$$

Method 3 Yu and Rothrock algorithm (1996)

□ Yu & Rothrock algorithm is based on surface-heat balance model using AVHRR thermal data.

➢In absence of melting and a snow cover, heat energy balance at the ice surface can be assumed that conductive heat loss at ice-surface through the ice is equal to the total heat flux F_{TL}.

The ice thickness H_A (m) is calculated using the following equation,

$$H_A = \frac{K_i(T_F - T_i)}{F_{TL}}, \tag{6}$$

where K_i = 2.034 (W/m/K), T_F = –1.8 (°C). T_i can be calculated from the AVHRR data given by [Key and Haefliger, 1992],

$$T_i = a + b \cdot TB_{ch4} + c \cdot (TB_{ch4} - TB_{ch5}) + d \cdot (TB_{ch4} - TB_{ch5})(\sec\theta - 1), \tag{7}$$

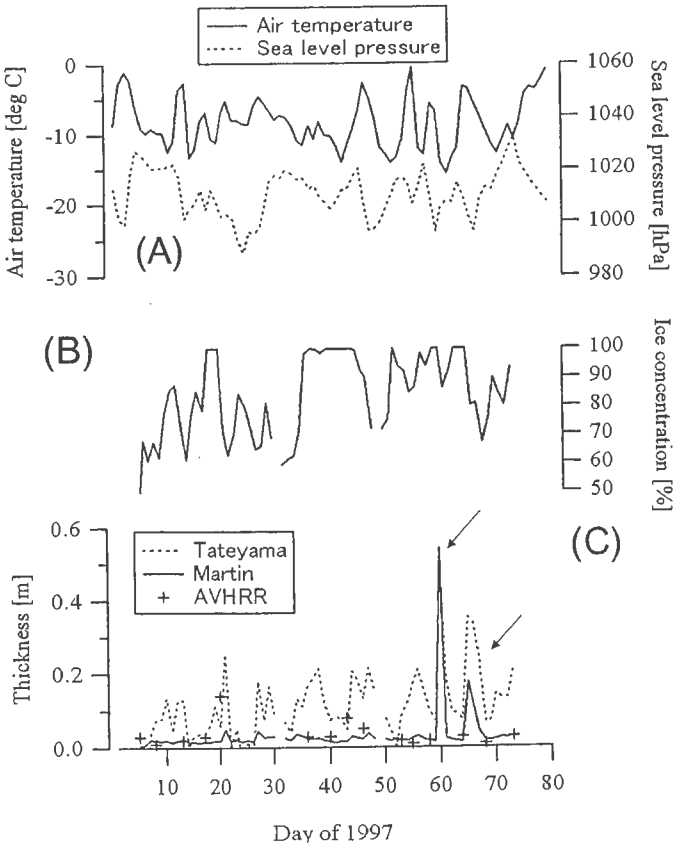
$$F_{TL} = F_{SH}(T_i) + F_{LH}(T_i) + F_{LW}(T_i) + F_{SW} + F_{DL}(T_a). \tag{8}$$

Results 1

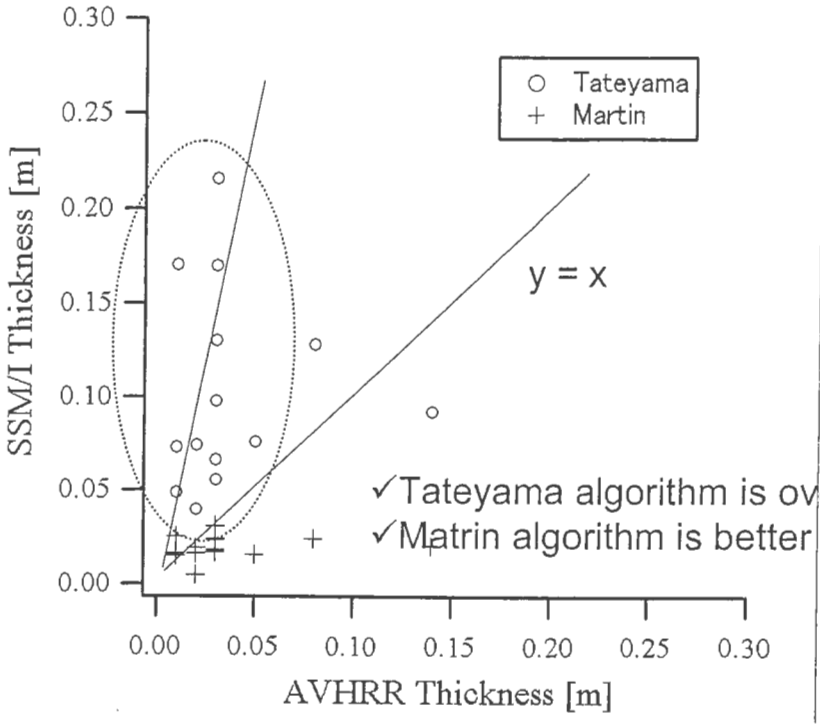
Meteorological data from NCEP/NCAR
- Air temp. at 1000 hPa
- Sea level pressure

Ice concentration from the SSM/I

Estimated ice thickness from SSM/I and AVHRR data



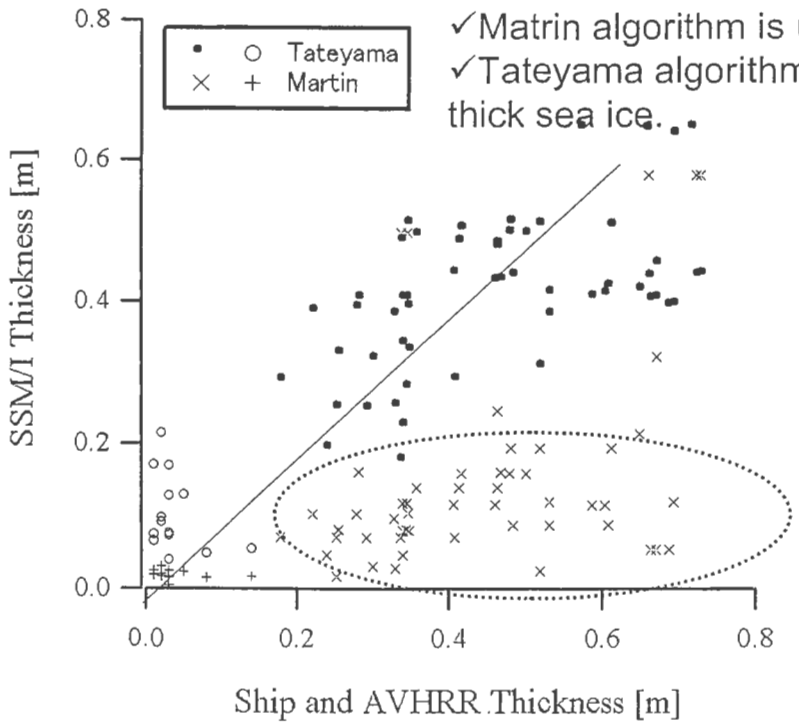
Comparison 1 — *Thin* Sea Ice



✓Tateyama algorithm is overestimated.
✓Matrin algorithm is better for thin sea ice.

Comparison 2 — *Thick* Sea Ice

✓Matrin algorithm is underestimated.
✓Tateyama algorithm is better for thick sea ice.



Discussion

□Uncertainties in the ice-thickness from AVHRR data.

✓ Ice thickness derived from AVHRR agrees with that from upward looking sonar within 10%.
✓A coarse spatial resolution of AVHRR (1.1 km).
✓The largest uncertainty is in NCEP data.
- a course spatial resolutions of (2.5°x 2.5° ; 280 km x 280km)
- covers the bay and surrounding land.

✓High thin cold clouds and low warm fogs over polynya.

Summary

Ice thickness estimation algorithms for thin sea ice in the Terpeniya Bay and for thick ice in Sea of Okhotsk were validated.

□Tateyama algorithm:

✓A very poor relationship with AVHRR of RMSE 0.17 m for < 0.2 m thick ice.
✓A high correlation with the thick ice of RSME 0.14m.

□Martin algorithm:

✓Efficient result for thin ice with RMSE 0.04 m.
✓A coarse accuracy for thick ice with RMSE 0.47 m.

✓Tateyama algorithm and Martin algorithm are suitable for thick ice and thin ice estimation, respectively.