プロジェクト－２

XおよびLバンドSARを使用したオホーツク海南部の海氷散乱特性
(SARデータを用いた海氷物理量推定の高精度化に関する研究)

SEA ICE CHARACTERISTICS IN THE SOUTHERN REGION OF OKHOTSK SEA OBSERVED BY X- AND L- BAND SAR

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Outline

- Study background and research objectives
- Test site and SAR data
- Ground truth experiment
- Data analysis
- Summary and future work

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Study background

Role of sea ice monitoring

- Sea ice extent and volume are related to local as well as global climate change
- Sea ice acts as an insulator between air and water
- Sign of decreasing sea ice extent in the Arctic Ocean

Importance of SAR data

- Microwave remote sensing plays an important role in monitoring sea ice in cryosphere due to its all weather capabilities
- SAR data from TerraSAR-X and ALOS were available during wintering period in 2010

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Research objectives

Objectives

- Possible use of SAR data to monitor sea ice in the southern region of Okhotsk Sea
  - Backscattering characteristics(Frequency, Polarization)
  - Develop a method to extract sea ice physical parameters

Our past experience

- Field experiments from 1992 to 2012(Lake Saroma)
- Single-pol SAR analysis (ERS-1/2,JERS-1,RADARSAT)
- Polarimetric SAR analysis (Pi-SAR, PALSAR)

Dual-pol. TerraSAR-X data

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Test sites

hotsk
tertime
ss than 1 m
n Japan)
tsk with 2 channels
at of sea water
and is stable enough

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Satellite and Ground Observations

Satellite observation

List of satellite data used in this analysis

satellite sensor	observation date	observation time (UT)	polarization	incidence angle (scene center)
TerraSAR-X	2010/02/18	08:12	HH+VV	36.8°
ALOS PALSAR	2010/02/20	12:37	HH+VV+ HV+VH	24.0°
TerraSAR-X	2010/02/24	08:04	HH+VV	20.8°

Ground truth experiment :2010/02/16-02/26

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Satellite images (HH-pol)

TerraSAR-X(2010.02.18) High incidence angle | TerraSAR-X(2010.02.24) Low incidence angle | ALOS/PALSAR (2010.02.20)

-Slant range complex data provided by Pasco and JAXA were used in this research

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Ground truth sampling points

TerraSAR-X(2010.02.18) High incidence angle (62 points) | TerraSAR-X(2010.02.24) Low incidence angle (62 points) | ALOS/PALSAR (2010.02.20) (36 points)

-Sampling points were approximately set 500 m interval on the east part of Lake Saroma

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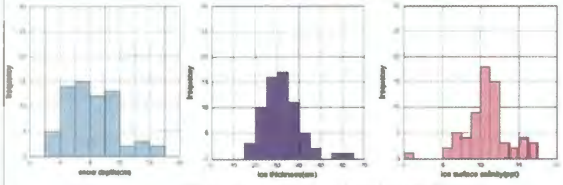
Summary of ground truth data 1

- Mean of measured data
  - snow depth : 8.0 cm
  - ice thickness : 31.5 cm
  - ice surface salinity : 10.8 ppt



-Typical ice on the lake found in mid February

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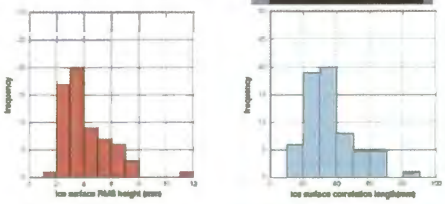
Summary of ground truth data 2

- Mean of measured surface roughness (Roughness comb measurements)
  - RMS height: 4.2mm
  - Correlation length: 35.8mm



- At least four measurements were averaged at each sampling point

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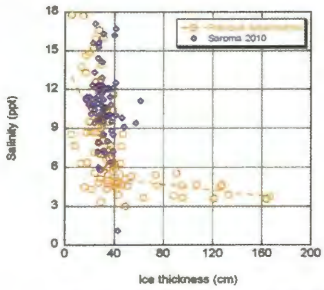
Relation between ice thickness and ice surface salinity comparison of 2010 and previous experiments



- Plots in Saroma 2010 showed almost the same characteristics for sea ice of the thickness less than 40 cm

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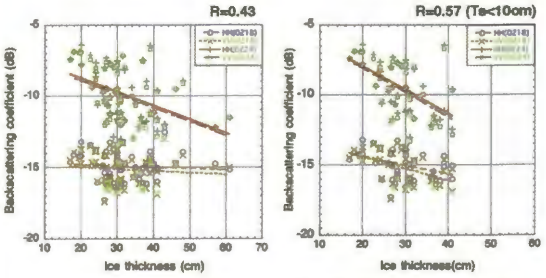
Ice thickness vs backscattering coefficient(TerraSAR-X)



- Backscattering coefficient at lower incidence angle is correlated with ice thickness, especially at small snow depth area

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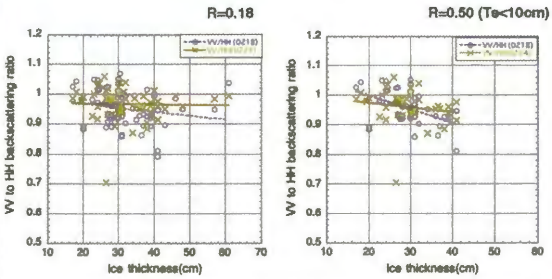
Ice thickness vs co-pol ratio (TerraSAR-X)



- Co-pol ratio in higher incidence angle at small snow depth has some relation with ice thickness (no strong correlation)

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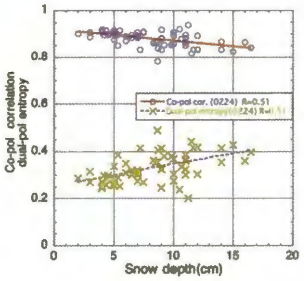
Snow layer related parameters (TerraSAR-X)



- Co-pol correlation and dual-pol entropy in lower incidence angle have weak relations with snow depth

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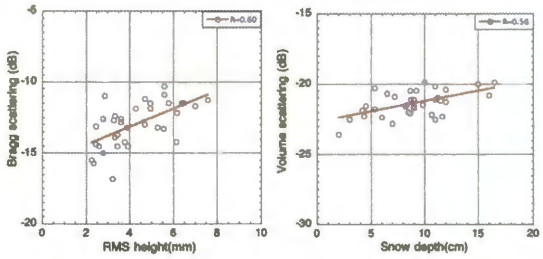
FD decomposition vs. truth data (PALSAR)



- Freeman and Durden three component decomposition gives reasonable relation to RMS height and snow depth

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Summary of regression analysis at Lake Saroma

☑ **Relation between TerraSAR-X and ground truth data**

- Ice thickness : relatively higher correlation found in lower incidence angle at small snow depth area
- Ice surface roughness : no significant relation was found
- Lower incidence angle observation is better
- Contribution of snow layer to backscattering coefficient cannot be ignored

☑ **Relation between PALSAR and ground truth data**

- Ice thickness : *no significant relation was found*
- Snow depth and RMS height : 3 component decomposition result shows reasonable relations
- Scattering decomposition technique is useful to extract information of ice physical data

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Offshore area

TerraSAR-X and MODIS albedo 2010.02.18

- MODIS albedo used for sea ice detection is calculated as follows,

$$AI=0.3265*B1+0.4364*B3+0.2366*B4$$

where
AI: albedo
B1,B3 and B4: reflectances observed in Band 1,3,and 4

Classification rule based on MODIS albedo

- Open water (AI < 0.1)
- New ice (0.1 ≤ AI < 0.4)
- Young ice (0.4 ≤ AI < 0.6)
- First-year ice (0.6 ≤ AI)

Reference
D.K.Hall, D.J.Cavalieri, T.Markus: Assessment of AMSR-E Antarctic Winter Sea-Ice Concentrations Using Aqua MODIS, IEEE Trans. on Geo-science and Remote Sensing, Vol.48, No.9, pp.3331-3339, 2010

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Offshore area

PALSAR backscattering and entropy 2010.02.20

Scattering entropy used for sea ice detection

$$H = \sum_{i=1}^{3} -P_i \log_3 P_i \qquad P_i = \frac{\lambda_i}{\sum_{j=1}^{3} \lambda_j}$$

$$T = \lambda_1 e_1 e_1^{*t} + \lambda_2 e_2 e_2^{*t} + \lambda_3 e_3 e_3^{*t}$$

Classification rule based on scattering entropy (H)

- Open water (H < 0.15)
- New ice (0.4 ≤ H)
- Young ice & First-year ice (0.15 ≤ H <0.4)

Reference
H. Wakabayashi, T. Matsuoka, K. Nakamura and F. Nishio Polarimetric characteristics of sea ice in the Sea of Okhotsk observed by airborne L-band SAR, IEEE Trans on Geo-science and Remote Sensing, Vol. 42, No 11, pp 2412-2425, 2004

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Backscattering characteristics of sea ice in the offshore area

	TerraSAR-X(2010/02/18)				PALSAR(2010/02/20)				
	HH(dB)	VV(dB)	VV-HH(deg.)	MODIS Albedo	HH(dB)	VV(dB)	HV(dB)	Scattering entropy	MODIS Albedo
New ice	-16.4	-15.0	6.5	0.15	-21.7	-21.0	-28.4	0.73	0.17
Young ice FY ice	-8.6	-9.4	8.0	0.25	-13.3	-12.5	-25.7	0.30	0.26
Open water	-19.3	-18.1	0.6	0.10	-9.8	-8.6	-26.1	0.13	0.095

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Summary of backscattering characteristics of sea ice in the off-shore region

- New ice area
  - PALSAR : -21 dB(VV) -21.7dB(HH)
  - TerraSAR-X : -15.0dB(VV) -16.4dB(HH)
    TerraSAR-X : 5 to 6 dB higher than PALSAR
- Young ice area
  - PALSAR : -12.5 dB(VV) -13.3dB(HH)
  - TerraSAR-X : -9.4dB(VV) -8.6dB(HH)
    TerraSAR-X : 3 to 5 dB higher than PALSAR
- Considering TerraSAR-X and PALSAR incidence angles, the difference of backscattering range would be much larger by using the same incidence angle
- TerraSAR-X is superior to PALSAR in detecting sea ice, especially detecting thin sea ice (e.g. New ice)

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Summary

- Ground truth experiment was conducted (Feb. 16 to 26, 2010)
  - In-Situ data at more than 60 sampling points were acquired
  - Backscattering calibration by reflectors was conducted
    - Absolute calibration coefficients were consisted with the provided cal coefficients.
    - Phase difference between HH and VV should be corrected at lower incidence angle.
- TerraSAR-X and PALSAR regression analysis on Lake Saroma
  - TerraSAR-X
    - Lower incidence angle observation is preferable for ice physical data extraction.
    - Contribution of snow layer to backscattering coefficient cannot be ignored.
  - PALSAR
    - Scattering decomposition is useful to extract information of ice physical data.
- Backscattering characteristics of sea ice in the offshore area
  - Backscattering coefficients for new ice and young ice were higher in X-band than that in L-band.

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Future work

- Develop a backscattering model of sea ice in X-band to include snow layer on the ice.
- Investigate an inversion technique to extract ice physical data, such as snow depth on ice, ice surface roughness and ice thickness.

Acknowledgement

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- TerraSAR-X data were distributed under the support of SAR technical application research committee organized by Pasco cooperation.

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