



マイクロ波による海水物理量計測に関する研究 -海水誘電率の計測-

A study on microwave measurement of sea ice physical parameters
-Measurement of sea ice dielectric constant-

若林 裕之, 中村 和樹 (日大)
長 康平(WNI)
J.T. Sri Sumantyo(千葉大)

CERES環境RSシンポジウム
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研究の目的

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- 海水モニタリングにおけるリモートセンシングデータの有効利用
 - 環境変動の把握
 - 氷海における航路の確保
- SARによる海水モニタリングの有効性評価
 - 周波数および偏波特性把握
 - 海水物理量(氷厚・表面ラフネス)抽出の可能性評価

今までの経緯

- 1993~2013までの海水観測実験(サロマ湖及び外洋)
- ERS-1/2, JERS-1, RADARSAT等の単偏波SARによる解析
 - 海水の成長に伴う後方散乱特性
 - 後方散乱の入射角特性を利用した海水物理量の抽出
- 多偏波SAR (Pi-SAR, PALSAR)データの解析
 - 海水物理量に感度の高いパラメータ検討
 - 薄氷域における海水検出精度向上

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SARによる海水物理量計測における問題点

地上観測データに起因する問題

- 海水の後方散乱特性:誘電率とラフネスに依存
 - 誘電率: 現地での直接測定が困難 > 氷の塩分濃度と表面温度からモデル推定
 - ラフネス: 広範囲の把握が困難 > 数少ない観測点のデータ使用
- 多様な氷厚に対するデータ取得の問題
 - テストサイト
 - サロマ湖: 氷厚範囲 20cm~40cm
 - 船舶による観測: 衛星同期観測やデータ解析における同定

問題点解決を目標にサロマ湖およびアラスカにおける観測実験を実施

- 海水表面誘電率の直接測定
- 薄氷域・厚氷域データの取得

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Test site 1 (Lake Saroma)



✓ Lake Saroma (150km²)

- Salt water lake connected to the Sea of Okhotsk with 2 channels
- Salinity of lake water is almost the same as that of sea water (> 30 ppt)
- Lake ice grows till 40 cm thick in winter time and is stable enough to get the ground truth data
- 44 sampling points with 1000 m interval set in 2012
- 117 sampling points in 2013
- Ship measurement conducted in the west part of the lake in 2012

✓ DC measurements

- 6 points (2012)
- 18 points (2013)

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Test site 2 (Barrow)



✓ Barrow landfast ice

- Stable growth thick First Year Ice (>1.4m)
- UAF mass balance station

✓ Barrow Mass Balance Site 2013

- N71.37086W156.52536
- Ice thickness: 134cm (Mar.17)
- Ice thickness: 159cm (June 09)

✓ DC measurements

- 7 points around mass balance site (March)
- 2 points around mass balance site (June)

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Satellite and Ground Observations(Saroma)

✓ Satellite observation

List of satellite data in 2012 observation period

Satellite/Sensor	Acquisition date	Acquisition mode	Incidence angle (deg.)
ENVISAT/ASAR	Feb. 14, Feb. 22	AP-mode HH+VV	32 (Feb.14) 23 (Feb.22)
RADARSAT-2	Feb. 18	Quad-pol	40

List of satellite data in 2013 observation period

Satellite/Sensor	Acquisition date	Acquisition mode	Incidence angle (deg.)
RADARSAT-2	Feb. 19	Quad-pol	40

✓ Ground truth experiment

- 2012/02/13-02/24
- 2013/02/14-02/22

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Satellite and Ground Observations(Barrow)

☑ Satellite observation

List of satellite data in 2013 observation period

Satellite/Sensor	Acquisition date	Acquisition mode	Incidence angle (deg.)
RADARSAT-2	Mar.17	Quad-pol.	46

☑ Ground truth experiment

- 2013/03/17-03/21
- 2013/06/12-06/15



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Summary of Saroma ground truth data (2012)

- ✓ East field: Sampling points were set with 1 km interval (44 points)
- ✓ West field: Ice thickness measurements by fishing boat(22 points)
- ✓ Measured data(mean value in East field)

- ice thickness(33.3cm)
- surface roughness(RMSHeight 3.3mm)
- surface salinity(12.4ppt)
- snow depth(9.6cm)
- dielectric constant(selected 6 points)



Location of sampling points in 2012 overlaid on RADARSAT-2 HH image

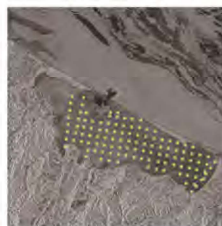
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Summary of Saroma ground truth data (2013)

- ✓ Sampling points were set covering whole lake (117 points)

✓ Measured data(mean)

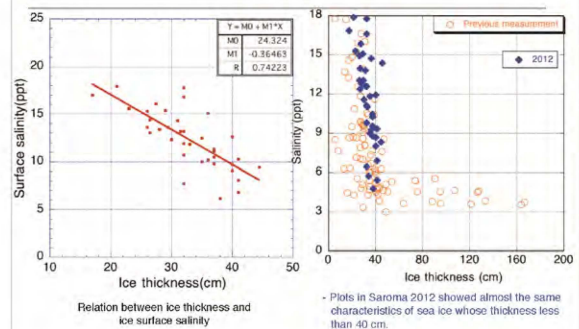
- ice thickness(32.7cm)
- surface roughness
- surface salinity(12.4ppt)
- snow depth(10.0cm)
- dielectric constant(selected 17 points)



Location of sampling points in 2013 overlaid on RADARSAT-2 HH image

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Relation between ice thickness and ice surface salinity (2012)



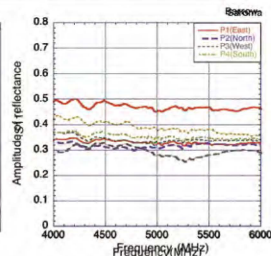
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Ice dielectric constant measurement (Free space method)



Measuring system for ice surface dielectric constants.

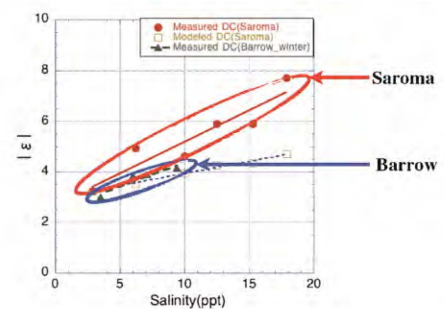
- Combination of a vector network analyzer, a horn antenna, and a dielectric lens.
- Free space method with rotating electric-field vector



Example of the measurement results for the reflected waves at the site with various ice surface salinities.

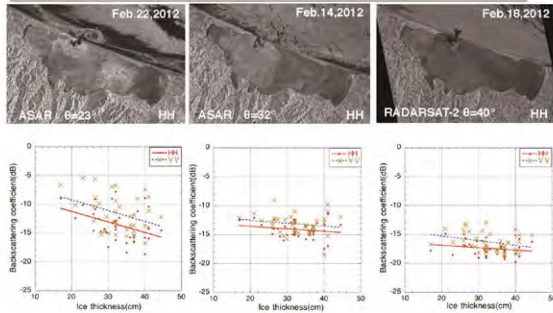
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Result of DC measurement -Saroma 2012 and Barrow 2013-



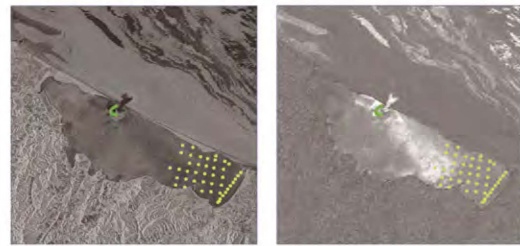
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Data analysis (Incidence angle characteristics)



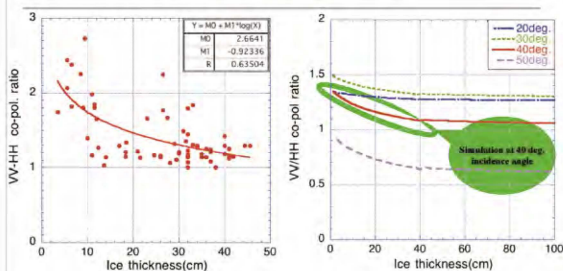
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RADARSAT-2 data analysis



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RADARSAT-2 data analysis 2



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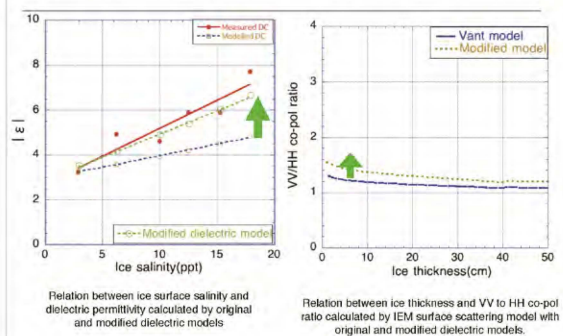
DC empirical model by Vant et al.(1978)

$$\begin{aligned}\epsilon'_i @ 5.4GHz &= (0.995 - 0.00154 * (5.4))\epsilon'_i \\ \epsilon''_i @ 5.4GHz &= (0.914 - 0.00546 * (5.4))\epsilon''_i \\ Re(\epsilon_i) &= \epsilon'_i = 3.05 + 7.20V_b \\ Im(\epsilon_i) &= \epsilon''_i = 0.024 + 3.29V_b \quad @ 4GHz\end{aligned}$$

V_b : Brine volume fraction
estimated from ice surface salinity
and temperature

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Adjustment of sea ice dielectric model



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Summary



- ✓ Ground truth observations were conducted at Lake Saroma and Barrow in 2012 and 2013.
 - ✓ Simultaneously with satellite observations
 - ✓ Measurements related to sea ice backscattering characteristics
- ✓ Dielectric constant measurements(Saroma)
 - ✓ Confirmed the relation between dielectric constant and ice surface salinity
 - ✓ Measured dielectric constants are larger than those from sea ice dielectric model >> needs DC model modification
- ✓ Data analysis of ENVISAT/ASAR and RADARSAT-2
 - ✓ ENVISAT: Lower incidence angle observation is better
 - ✓ RADARSAT-2: VV/HH co-pol. ratio is sensitive to ice thickness
- ✓ Dielectric constant measurements(Barrow)
 - ✓ 2 times measurements were conducted in March and June, 2013.
 - ✓ The measured data are under analysis

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今後の課題

- 誘電率計測の精度確認および精度向上
- 海水誘電率モデルの改良
- 継続したトゥルースデータ取得および衛星データ解析
→ サロマ湖、アラスカ・バロー定着氷

謝辞

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- Umiqのサポートを受けてバロー観測を実施。

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