Contributions of ALOPS / PALSAR data for
Cryospheric Science and
Expectations to the next generation
L-band SAR Satellites

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Contributions of ALOS / PALSAR for Cryospheric Science

I. Sea Ice monitoring on Okhotsk Sea
   • Operational use by JCG, Combined use of optical satellite

II. Understanding the formation mechanism of Polynya
   • At Cape Darnley, Antarctica. Formation of AABW.

III. Mapping of ice sheet flow velocity
   • DInSAR, use of GDEM
   • Offset tracking

IV. Extraction of grounding line
   • Challenging, long revisit cycle

V. Applications to mountain glacier
   • Mapping, monitoring of surging glacier

Remaining Issues for SAR data utilization

Expectation to the next generation SAR

Summary
I. Sea Ice monitoring in Okhotsk Sea

- ALOS / PALSAR data is operationally used by JCG (Japan Coast Guard)
- In blue circles, features of sea ice can be clearly identified, while it seems to be difficult to interpret the sea ice in area by red circles. (Cho, 2009, PI215-1-6)
I. Sea Ice monitoring on Okhotsk Sea

Sea Ice Concentration

PALSAR ScanSAR Intensity Image

20, February, 2011 ALOS/PALSAR ScanSAR
II. Understanding the formation mechanism of Polynya

- Unknown new AABW formation area was found
- PALSAR data is used for validation of microwave radiometer-derived ice thickness

(Ohshima, 2009, PI322-1-8)
Formation mechanism of Cape Darnley polynya

Grounded iceberg tongue

Coastal current

Wind

Supernal image

Westward coastal current

Offshoreward wind

100km

100km

Streaks of new ice

Iceberg tongue

Iceberg tongue (fast ice)

Accumulated first-year ice

Anchor iceberg

Cross section

Filtering effect of Iceberg tongue
III. Mapping of ice sheet flow velocity
- DInSAR, use of GDEM

Comparison of flow velocity with that measured by GPS

<table>
<thead>
<tr>
<th></th>
<th>Period</th>
<th>Flow rate (cm/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PALSAR</td>
<td>2010/6/9 - 2010/7/25</td>
<td>3.0 (LOS)</td>
</tr>
<tr>
<td>GPS</td>
<td>2012/5/2 - 2012/5/11</td>
<td>14.9</td>
</tr>
</tbody>
</table>

Location of GPS site is (-69.008N, 40.139E), which is indicated by an asterisk in the figure.

2010/06/09-2010/07/25
Red: approaching to the satellite
Blue: getting away from the satellite
IV. Mapping of ice sheet flow velocity

- Offset tracking

December 2007 – February 2008

June 2008 – August 2008

© METI / JAXA. Analyzed by AIST
V. Extraction of grounding line

- Challenging, long revisit cycle

Grounding line and ice sheet flow velocity analysis result using ALOS / PALSAR data on Lazarevisen, Dronning Moud Land. Left view (a) shows the grounding line extracted by differencing of two interferogram and right image (b) shows the flow velocity field estimated by offset tracking analysis using two images. Position of fast flow area coincide with decorrelated area on interferogram.
VI. Applications to mountain glacier

Mountain glaciers in West Kunlun
(Yasuda & Furuya, 2013 Remote Sens. Environ.,)
Intensity image (path516, Feb. 2007 – Feb. 2011, 13 scene)

Remaining Issues for SAR data utilization

Application side:
- Use of Coherence
  - snowfall mapping
  - monitoring of permafrost melting
- DEM generation
  - For higher latitude area than SRTM coverage.
  - ASTER GDEM is available, but not perfect
  - Problem of penetration depth of microwave to ice sheet

Hardware / operation system:
- Revisit cycle
  - Improvement of interferometric coherence
- Wide area observation
  - For monitoring of sea ice condition
  - With polarimetric observation, if possible
- Use of polarimetry
  - Present polarimetry observation is still experimental mode
  - Expectation of operational data availability
### Expectations to the Next Generation SAR (NG-SAR)

NG-SAR: Employ Digital Beam Foaming system and twin satellites
- High observation frequency (twin satellites)
- Wide swath Stripmap observation
- Improve the chance to observe full polarimetry

#### Expected Sensor Mode of NG-SAR (at 30, April, 2013)

<table>
<thead>
<tr>
<th>Mode ID</th>
<th>Azimuth res.</th>
<th>Band width</th>
<th>Swath width (max)</th>
<th>Polarization</th>
<th>InSAR orbit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10 m</td>
<td>20 MHz + 5 MHz (ionospheric corr.)</td>
<td>350/175 km</td>
<td>Single/Dual/Full</td>
<td>Repeat/Single Strip map</td>
</tr>
<tr>
<td>3</td>
<td>10 m</td>
<td>80 MHz</td>
<td>175 km</td>
<td>Full</td>
<td>Single</td>
</tr>
<tr>
<td>4</td>
<td>10 m</td>
<td>80 MHz</td>
<td>175 km</td>
<td>Full</td>
<td>Repeat Stripmap</td>
</tr>
<tr>
<td>5</td>
<td>1 m</td>
<td>80 MHz</td>
<td>50 km</td>
<td>Single/Dual/Full</td>
<td>Repeat/Single</td>
</tr>
<tr>
<td>6</td>
<td>3 m</td>
<td>80 MHz</td>
<td>350 /175 km</td>
<td>Single/Dual/Full</td>
<td>Repeat/Single</td>
</tr>
<tr>
<td>7</td>
<td>50 m</td>
<td>20 MHz</td>
<td>350/175 km</td>
<td>Single/Dual/Full</td>
<td>Repeat/Single ScanSAR type</td>
</tr>
</tbody>
</table>
Mode 4 (10 m, 175km, Full Pol., Repeat pass) (able to alternate to mode 7)

<table>
<thead>
<tr>
<th>items</th>
<th>Target area</th>
<th>Observation frequency and season</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sea Ice detection</td>
<td>Okhotsk Sea</td>
<td>Dec. – Apr. Interval : 1-4day</td>
<td>Resolution :100m Swath :350km is preferable Full pol is preferable</td>
</tr>
<tr>
<td>Sea Ice detection</td>
<td>Arctic Sea Antarctic Sea</td>
<td>Monthly (Weekly is preferable)</td>
<td>ditto</td>
</tr>
</tbody>
</table>

**Expectations**
- Improvement in sea ice detection accuracy (with full polarimetry, for JCG)
- Detecting melt pond distribution
- Useful for study on ice edge
  - => Difficult to study with microwave radiometer data
### Mode 6 (3 x 3 m, 350 / 175 km, Single/Dual/Full pol., Repeat) 1/2

<table>
<thead>
<tr>
<th>items</th>
<th>Target area</th>
<th>Observation frequency and season</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glacier flow velocity estimation</td>
<td>Glacier, ice sheet</td>
<td>Monthly, Full Year</td>
<td>Offset tracking Inc. angle :40deg Need obs. Of Pole</td>
</tr>
<tr>
<td></td>
<td>Glacier, ice sheet</td>
<td>8 days interval, continuous obs.</td>
<td>3-pass InSAR</td>
</tr>
<tr>
<td>Grounding line extraction</td>
<td>Marginal zone of Antarctic coast line</td>
<td>8 days interval, continuous obs.</td>
<td>3-pass InSAR</td>
</tr>
</tbody>
</table>

### Expectations

- Make velocity map of entire Antarctic continent / Greenland (need observation of pole)
- Improvement in the InSAR coherency
- Update the position of grounding line mainly developed by ERS-1/2 InSAR (1995-96)
- Provide useful estimation for mass balance study on Antarctica / Greenland
## Mode 6 (3 x 3 m, 350 / 175km, Single/Dual/Full pol., Repeat) 2/2

<table>
<thead>
<tr>
<th>items</th>
<th>Target area</th>
<th>Observation frequency and season</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monitoring of Northern Sea route</td>
<td>Arctic sea</td>
<td>Every day Summer season</td>
<td>Full pol. or (HH+VV) High Inc. angle</td>
</tr>
<tr>
<td>Melting of permafrost on boreal forest</td>
<td>Siberia, Alaska</td>
<td>Every cycle May-October</td>
<td>Dual (HH+HV), Intensity image, InSAR</td>
</tr>
</tbody>
</table>

### Expectations

For Northern Sea route:
- Provide practical information about safe marine navigation with the aid of quick supply to customer

For permafrost monitoring:
- Provide information about greenhouse gas emission and land subsidence
Summary (1/2) From ALOS / PALSAR data,

Sea ice detection:
  Succeeded in operational use at Okhotsk sea by JCG.
  Deepen understanding the polynya and AABW formation at Cape Darnley, Antarctic sea

Ice sheet / glacier flow monitoring:
  Accurate and broad understanding of glacier flow velocity

Grounding line detection:
  Succeeded to extract grounding line by PALSAR data applying
  3pass InSAR
  Relationship between flow velocity and coherency
Summary (2/2) From Next Generation SAR data,

Sea ice detection:
- Improve the observation frequency (two satellites in 4 days interval)
- Full polarimetric observation (DBF technology) will improve the detection accuracy
- New scientific findings like distributions of melt pond, deep understanding of AABW source and so on.

Flow velocity monitoring:
- Improve the InSAR coherency bring in the clear interferogram
- Update the flow velocity map, find out the acceleration => useful for mass balance study

Grounding line detection:
- Improve the InSAR coherency bring in the clear interferogram
- Update the grounding line position => useful for mass balance study

Northern sea route:
- Frequent and wide observation enables the support of safe marine navigation

Monitoring of permafrost melting:
- Greenhouse gas (methane, co2) emission
- Land subsidence
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  K. Nakamura (Nihon Univ.)
  T. Yamanokuchi (RESTEC)
  K. Doi (NIPR)