Coastal wetland monitoring using multi-frequency polarimetric SAR

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Tidal wetlands (intertidal flats) → zones of interaction between marine and terrestrial environments → Highly productive fishery areas and have dynamic and diverse ecosystems.

Need environmental management → High development pressure (e.g. reclamation and marine pollution) → Highly vulnerable to climate changes.

Objective: Quantitative estimation of the surface geophysical parameters in tidal wetlands from polarimetric SAR data sets
Study Area – Suncheon Bay

Suncheon City

Goheung City
Study Area – Suncheon Bay
Geophysical Parameter Retrieval

- **Forward Scattering models**
  \[ F(\Theta) \rightarrow \Omega \]

\[ \Theta = \begin{cases} 
\text{Dielectric constant} \\
\text{Height distribution (s)} \\
\text{Autocorrelation (l)} 
\end{cases} \]

\[ \Omega = \{ \text{Independent combination of polarization measurements} \} \]

**Integral Equation Method** [Fung et al., 1992; Fung, 1994; Wu et al., 2001]

\[ \sigma_{pp}^0 = \frac{k^2}{2} \exp\left(-2k_s^2s^2\right) \sum_{j=1}^{\infty} \frac{\sigma_{pp}^j W^{(j)}(-2k_s,0)}{j!} \]

**Extended-Bragg Model** [Schuler et al., 2002; Hajnsek et al., 2003]

- **Coherency matrix** (Bragg scatter and the orientation of facets)

\[ \langle [T] \rangle = \frac{m_s}{2} \begin{bmatrix}
C_1 & C_2 \exp(-2\sigma^2) & 0 \\
C_2^* \exp(-2\sigma^2) & C_3[1 + \exp(-8\sigma^2)] & 0 \\
0 & 0 & C_3[1 - \exp(-8\sigma^2)]
\end{bmatrix} \]

\[ \sigma = \frac{\text{rms slope}}{\sin \theta} \]

\[ \rightarrow \text{Finding the set of unknown surface parameters from polarization measurement} \]

\[ \overline{\Theta} = F^{-1}(\Omega) \]
Surface sediments can be assumed to be fully saturated with water throughout intertidal mudflats.

The effect of the dielectric constant on backscatter signals can thus be neglected in the specific case of the intertidal mudflats.

The intertidal mudflat is an ideal study site for the reduction of surface variables.

Roughness parameters can be estimated from two independent polarization observations.

\[
\begin{bmatrix}
S \\
I
\end{bmatrix} = F^{-1} \begin{bmatrix}
\sigma^0_{HH} \\
\sigma^0_{VV}
\end{bmatrix}
\]

\[
\begin{bmatrix}
S \\
I
\end{bmatrix} = G^{-1} \left[ \left| S_{HH} + S_{VV} \right|^2 \right]
\]

Inversion from co-pol using IEM

Inversion using the extended-Bragg
### Experimental Results – AIRSAR

<table>
<thead>
<tr>
<th></th>
<th>RMS Height</th>
<th>Correlation Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>$s$ from $\sigma_{HH}^0, \sigma_{VV}^0$</td>
<td>$0.1$ cm</td>
<td>$6$ cm</td>
</tr>
<tr>
<td>$s$ from $\rho_{RLLL}</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$l$ from $\sigma_{HH}^0, \sigma_{VV}^0$</td>
<td>$0.1$</td>
<td>$3.8$</td>
</tr>
<tr>
<td>$l$ from $\rho_{RLLL}</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
RADARSAT-2

- 2008.12.14
- Fine Quad Pol (FQ6)
- Ascending
- Incidence angle: 24.5°~26.4°
Experimental Results – RADARSAT-2

rms height from AIRSAR

rms height from RADARSAT-2

0.3cm
Experimental Results – RADARSAT-2

<table>
<thead>
<tr>
<th>AIRSAR</th>
<th>RADARSAT-2</th>
</tr>
</thead>
</table>

[Images of RADARSAT-2 and AIRSAR data comparison]
Experimental Results – RADARSAT-2

**AIRSAR**
2000.09.30

**RADARSAT-2**
2008.12.14

**rms height**

0 0.7 cm
Study Area – Kyunggi Bay

- 2007.04.13
- Quad Pol Mode
- Ascending
- Incidence angle: 21.5°

- 2008.11.21
- Quad Pol (FQ16)
- Descending
- Incidence angle: 35.5°~37.0°
Natural intertidal mudflats

- Surface sediments are saturated with sea water

Reclaimed mudflats

- Surface water drained out
- Mud crack developed
Geophysical Parameter Inversion

- **Roughness Inversion for reclaimed mud flats**
  - Impossible to reduce the number of surface variables
  - Fully polarimetric inversion

\[
\begin{bmatrix}
m_v \\ s \\ l
\end{bmatrix} = F^{-1}
\begin{bmatrix}
|S_{HH} + S_{VV}|^2 \\ |\rho_{RRLL}| \\ \alpha_1
\end{bmatrix}
\]

- **Simulations**

<table>
<thead>
<tr>
<th>Soil parameters</th>
<th>Min.</th>
<th>Max.</th>
<th>Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>( m_v )</td>
<td>0.1</td>
<td>0.6</td>
<td>0.01</td>
</tr>
<tr>
<td>( s )</td>
<td>0.1 cm</td>
<td>1.5 cm</td>
<td>0.1 cm</td>
</tr>
<tr>
<td>( l )</td>
<td>1 cm</td>
<td>15 cm</td>
<td>0.1 cm</td>
</tr>
</tbody>
</table>
Experimental Results – PALSAR

<table>
<thead>
<tr>
<th>Moisture content</th>
<th>rms height</th>
<th>Correlation length</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reclaimed mudflat</td>
<td>Intertidal flats</td>
<td>Reclaimed mudflat</td>
</tr>
</tbody>
</table>

Moisture content range: 0 to 0.6
Rms height range: 0 to 0.4 cm
Correlation length range: 0 to 12 cm
rms heights

probably connected with the surface sediment texture of the intertidal flats

Surface roughness

Sand contents (%)

Distance from land (m)

Sand content

[Korea Ocean Research & Development Institute, 2004]
Experimental Results – RADARSAT-2

- Limitation of model
- Calibration
- Missing parameter
Future Study

ALOS PALSAR
RADARSAT-2
TerraSAR-X

SEOUL
Future Study

PALSAR 2007.04.13

RADARSAT-2 2008.11.21
Conclusions

- Application of polarimetric SAR data for intertidal flats was investigated with inversion of the roughness characteristics of surface sediments.
- First results of surface roughness parameters retrieval from L-band and C-band space-borne polarimetric SAR observations.
- Continuous monitoring using the multi-temporal, multi-frequency space-borne SAR data sets, such as ALOS PALSAR (L-band), RADARSAT-2 (C-band), and TerraSAR-X (X-band).