Field experiments for the DPR algorithm development

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The Japan PMM PI meeting, TKP Takehashi Conference Center, Tokyo,
Target

Contribute to the scattering table at Ka-band radiowaves, particularly for solid precipitation

This fiscal year (JFY2013)

Continue rain observation at Sapporo

Observation: done. Data analysis: yet

Continue data analysis for Okinawa, Mt. Fuji, Nagaoka experiments

Nearly done. Need more careful analyses

Conduct melting layer observation at Zao

On going
Actually JAXA direct experiment

Ka-radar collaboration

EORC/JAXA: Y. Kaneko, K. Komachi, K. Yamamoto, R. Oki
  Management, logistics, observation

NICT: K. Nakagawa, H. Hanado
  Observation, Ka-radar maintenance

NIED: K. Iwanami, S. Nakai
  Collaboration for snow observation (Tsukuba, Nagaoka)

Hokkaido Univ.: Y. Fujiyoshi, M. Nishikawa
  Collaboration for snow observation, data analysis

Nagoya Univ.: H. Minda
  NU instrument maintenance

Yamaguchi Univ.: K. Suzuki
  Video sonde operation including tethered balloon

Dokkyo Univ.: K. Nakamura: PI
Scattering Table
With BB, 0<D0<2 mm
Dual Ka radar experiment in Nagaoka

- Mobile precipitation observation system (MOS)
  - parsivel
  - Humidity and Temperature Probe (HMP155)
  - 2DVD
- melted fraction meter

Elevation +1.4°
Time-range section of $Z_m$ - snow events -

- 2012/02/03
  2:00 ~ 3:00

- 2012/01/13
  8:30 ~ 9:30

range resolution: 12.5 m
temporal resolution: 10 s
Japan’s ground validation plans

- **Zao** (melting layer, snow)
  - Fall 2013 –

- **Nagaoka** (wet snow)

- **Mt. Fuji** (melting layer)

- **Sapporo** (dry snow)
  - Apr. 2012 – Fall 2013

- **Tsukuba** (rainfall/melting layer)

- **Okinawa** (rainfall/melting layer)
  - Jul. 2011

- **Zao** (melting layer, snow)
  - Fall 2013 –
We are here.

November 14, 2014
International conferences

Nakagawa et al., Kaneko et al., EGU 2013
Nishikawa et al., Nakagawa et al., IGARSS 2013
Nishikawa et al., Nakagawa et al., 36th Radar Conference
Nakagawa et al., AOGS
Nishikawa et al., Nakagawa et al., 29th ISTS
Results of field experiments for the DPR algorithm development

Masanori NISHIKAWA

Institute of Low Temperature Science,
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and Ka-radar collaboration
Topics and Objective

Results of measurements of snow and melting layer using the dual Ka-band radar system are reported.

1) Field Experiment 1 (Sapporo/Nagaoka):

To understand behavior of $k$-$Z_e$ of snow, measured $k$-$Z_e$ plots are classified by temperature.

$k$-$Z_e$ relations of snow are summarized for the algorithm.

2) Field Experiment 2 (Mt. Zao):

First results of $k$-$Z_e$ relations of melting layer at Mt. Zao are presented.
Results 1:
k-$Z_e$ relations of snow
Dual Ka radar experiment in Sapporo

Mobile precipitation observation system (MOS)
$k$-Ze plots by every 1 °C for all snow events in Sapporo

$k = 8.6 \times 10^{-2} Ze^{0.37}$ for $-4 \leq T < -3$

$k = 1.4 \times 10^{-1} Ze^{0.23}$ for $-3 \leq T < -2$

$k = 1.8 \times 10^{-1} Ze^{0.16}$ for $-2 \leq T < -1$

$k = 1.7 \times 10^{-1} Ze^{0.17}$ for $-1 \leq T < 0$

$k = 2.6 \times 10^{-1} Ze^{0.48}$ for $0 \leq T < 1$

$k = 8.4 \times 10^{-1} Ze^{0.22}$ for $1 \leq T < 2$

-4 ≤ T < -3

-3 ≤ T < -2

dry snow

-2 ≤ T < -1

-1 ≤ T < 0

0 ≤ T < 1

wet snow

1 ≤ T < 2
### Summary of $k$-$Z_e$ relations of Sapporo and Nagaoka experiments

<table>
<thead>
<tr>
<th>Temperature range</th>
<th>Sapporo</th>
<th>Nagaoka</th>
</tr>
</thead>
<tbody>
<tr>
<td>-12 ≤ T &lt; -11</td>
<td>$k=1.6\times10^{-1}Z_e^{0.44}$</td>
<td></td>
</tr>
<tr>
<td>-11 ≤ T &lt; -10</td>
<td>$k=1.3\times10^{-1}Z_e^{0.29}$</td>
<td></td>
</tr>
<tr>
<td>-10 ≤ T &lt; -9</td>
<td>$k=1.4\times10^{-1}Z_e^{0.24}$</td>
<td></td>
</tr>
<tr>
<td>-9 ≤ T &lt; -8</td>
<td>$k=1.9\times10^{-1}Z_e^{0.16}$</td>
<td></td>
</tr>
<tr>
<td>-8 ≤ T &lt; -7</td>
<td>$k=1.1\times10^{-1}Z_e^{0.33}$</td>
<td></td>
</tr>
<tr>
<td>-7 ≤ T &lt; -6</td>
<td>$k=1.0\times10^{-1}Z_e^{0.30}$</td>
<td></td>
</tr>
<tr>
<td>-6 ≤ T &lt; -5</td>
<td>$k=1.4\times10^{-1}Z_e^{0.22}$</td>
<td></td>
</tr>
<tr>
<td>-5 ≤ T &lt; -4</td>
<td>$k=1.4\times10^{-1}Z_e^{0.25}$</td>
<td>$k=6.4\times10^{-3}Z_e^{0.65}$</td>
</tr>
<tr>
<td>-4 ≤ T &lt; -3</td>
<td>$k=8.6\times10^{-2}Z_e^{0.37}$</td>
<td>$k=1.4\times10^{-2}Z_e^{0.45}$</td>
</tr>
<tr>
<td>-3 ≤ T &lt; -2</td>
<td>$k=1.4\times10^{-1}Z_e^{0.23}$</td>
<td>$k=1.0\times10^{-2}Z_e^{0.50}$</td>
</tr>
<tr>
<td>-2 ≤ T &lt; -1</td>
<td>$k=1.8\times10^{-1}Z_e^{0.16}$</td>
<td>$k=3.9\times10^{-2}Z_e^{0.24}$</td>
</tr>
<tr>
<td>-1 ≤ T &lt; 0</td>
<td>$k=1.7\times10^{-1}Z_e^{0.17}$</td>
<td>$k=4.6\times10^{-2}Z_e^{0.49}$</td>
</tr>
<tr>
<td>0 ≤ T &lt; 1</td>
<td>$k=2.6\times10^{-1}Z_e^{0.48}$</td>
<td>$k=3.3\times10^{-2}Z_e^{0.55}$</td>
</tr>
<tr>
<td>1 ≤ T &lt; 2</td>
<td>$k=8.4\times10^{-1}Z_e^{0.22}$</td>
<td>$k=3.8\times10^{-2}Z_e^{0.51}$</td>
</tr>
<tr>
<td>2 ≤ T &lt; 3</td>
<td>$k=3.7\times10^{-3}Z_e^{0.84}$</td>
<td></td>
</tr>
<tr>
<td>3 ≤ T &lt; 4</td>
<td>$k=9.1\times10^{-3}Z_e^{0.68}$</td>
<td></td>
</tr>
</tbody>
</table>
Results 2:
$k-Z_e$ relations of melting layer
Dual Ka radar experiment in Mt. Zao

Radar site1
SN001

Inter. site
MOS

Radar site2
SN002
X-band marine radar

elevation -4.1°
elevation +5.4°
Time-range section of $Z_m$ (2013/11/26 20-21)

SN001 EL $-4.1^\circ$ Altitude (m)

SN002 EL $5.7^\circ$ Altitude (m)

Hour (JST)

Range from Ka radar SN001 (km)

Range from Ka radar SN001 (km)

SN001

SN002
Estimation of $Z_e$ and attenuation at a melting layer
(2013/11/26 20:50)
Vertical profiles of $Z_e$, $dZ_e/dh$ and $k$
(2013/11/26 20:50)

Vertical profiles of $Z_e$, $dZ_e/dh$ and $k$ show the variation of reflectivity ($Z_e$),
vertical gradient of reflectivity ($dZ_e/dh$), and the index of refraction ($k$) with altitude.

- $Z_e$ peak
- $dZ_e/dh$ vs. Altitude (m)
- $k$ vs. Altitude (m)
- Melting layer (ML)
- Above the ML
- Above $Z_e$ peak
- Below $Z_e$ peak
$k-Z_e$ plots around the melting layer
(2013/11/26 20:50)

- Black circles: $k-Z_e$ above the ML
- Red circles: $k-Z_e$ above $Z_e$ peak within the ML
- Blue circles: $k-Z_e$ below $Z_e$ peak within the ML
Conclusion

1) $k-Z_e$ relations of snow

• Measured $k-Z_e$ plots were classified by temperature. Difference of $k-Z_e$ relations between wet and dry snow appeared.

• $k-Z_e$ relations obtained at two field experiments were summarized for the algorithm.

2) $k-Z_e$ relations of melting layer

• First results of $k-Z_e$ relations of melting layer were presented.

• Behavior of $k-Z_e$ at melting layer was illustrated and this results indicate measured $k-Z_e$ relations of snow obtained other field experiments were reasonable.
$k$-$Z_e$ plots by every 1 °C for all snow events in Nagaoka

\begin{align*}
  k &= 3.9 \times 10^{-2} \cdot Z_e^{-0.24} \\
  k &= 4.6 \times 10^{-2} \cdot Z_e^{0.49} \\
  k &= 3.3 \times 10^{-2} \cdot Z_e^{0.55} \\
  k &= 3.8 \times 10^{-2} \cdot Z_e^{0.51} \\
  k &= 3.7 \times 10^{-3} \cdot Z_e^{0.84} \\
  k &= 9.1 \times 10^{-3} \cdot Z_e^{0.68}
\end{align*}