Quality control of weather radar data by using dual-polarization

7 February 2018
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Principle of dual-polarization weather radar

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Basic scheme of dual-pol radar

Merits:
• Quality control
• Rain rate estimation,
• Hydrometeor classification

Transmitting and receiving both horizontally (H) and vertically (V) polarized wave

Ice crystal / Snow
Graupel
Hail
Heavy Rain
Large rain drop
Rain drop

Merits:
• Quality control
• Rain rate estimation,
• Hydrometeor classification

Transmitting and receiving both horizontally (H) and vertically (V) polarized wave
Basic scheme of dual-pol radar

- Two receivers for H & V
- Two transmitters or single transmitter which output wave is divided to H & V
- Isolation between H & V is crucially important
Two observation mode

Simultaneous Transmitting and Receiving mode (STAR or Hybrid mode)

Alternate H/V mode (ALT mode)
## Dual-pol data

### Conventional Doppler weather radar

<table>
<thead>
<tr>
<th>Observed parameter</th>
<th>Derived texture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reflectivity $Z$</td>
<td>$S(Z)$</td>
</tr>
<tr>
<td>Doppler velocity $V$</td>
<td>$S(V)$</td>
</tr>
<tr>
<td>Velocity width $W$</td>
<td>$S(W)$</td>
</tr>
</tbody>
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### Dual-polarization weather radar

<table>
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<tr>
<th>Observed parameter</th>
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<tr>
<td>Differential reflectivity $Z_{dr}$</td>
<td>$S(Z_{dr})$</td>
</tr>
<tr>
<td>Correlation coefficient $\rho_{hv}$</td>
<td>$S(\rho_{hv})$</td>
</tr>
<tr>
<td>Differential phase $\Phi_{dp}$</td>
<td>$S(\Phi_{dp})$</td>
</tr>
</tbody>
</table>

**Spatial derivative**

Specific differential phase $K_{dp}$
Dual-pol data

- Transmit
- Vertical wave
- Horizontal wave

- Receive

Precipitation particle (scattering target)

Amplitude ratio $\rightarrow$ Zdr
Phase difference $\rightarrow$ $\Phi_{dp}$, $K_{dp}$

Fluctuation in phase and amplitude $\rightarrow$ $\rho_{hv}$
**Zdr: Differential reflectivity**

- **$Z_{DR}$**: Shape of particle
  - Ratio between horizontal and vertical reflectivity factor.
  - Reflects aspect ratio of scattering targets.
  - Possible range of values: generally -4 to 10 (dB)
  - Useful for Rain rate estimation and hydrometeor classification

$$Z_{dr} = 10 \log_{10} \left( \frac{Z_{hh}}{Z_{vv}} \right)$$

- **Negative** ($Z_{hh} < Z_{vv}$)
- **Close to zero** ($Z_{hh} = Z_{vv}$)
- **Positive** ($Z_{hh} > Z_{vv}$)

- **Large Hail**
- **Light rain**
- **Drizzle**
- **Graupel**
- **Hail**
- **Rain drop**
- **Biological target**

Courtesy of Mr. Umehara
Zdr: Differential reflectivity

MRI-C 2014 06/24 14:37:18JST RHI AZ=229.6 deg
Reflectivity (dBZ)

MRI-C 2014 06/24 14:37:18JST RHI AZ=229.6 deg
Differential Reflectivity (dB)

Distribution of Hydrometeors

Graupel
Big rain drops
Hail

Rain
\( \rho_{hv} \): Correlation coefficient

- \( \rho_{hv} \): Diversity in shape
  - Correlation coefficient between horizontal and vertical signal.
  - Reflects diversity of scattering targets within a bin.
  - Possible range of values: 0 to 1 (none units)
  - Useful for hydrometeor classification and QC
\( \rho_{hv} \): Correlation coefficient

Reflectivity \( Z \) (dBZ)

Correlation coefficient \( \rho_{hv} \)

Distance from radar (km)

Height (km)
**Φ**<sub>dp</sub>: Differential phase

- **Φ<sub>DP</sub>**: Rain rate / Water content
  - Phase difference between horizontal and vertical signals.
  - Reflects aspect ratios of precipitation particles on the beam path.
  - Possible range of values: folded in -180 to 180 deg (0 – 360 deg)
  - In weather echo, monotonically increasing with range (continuous)
  - Not affected by rain attenuation

![Diagram illustrating the concept of Φ<sub>dp</sub>](image_url)

Path accumulated value

**Φ<sub>dp</sub>** (deg)

- moderate
- light
- heavy

Courtesy of Mr. Umehara
Φdp: Differential phase

Z (dBZ)  Φdp (deg)
Kdp: Specific differential phase

- **K_{DP}:** Rain rate / Water content
  - Change of $\Phi_{DP}$ in a unit distance
  - Reflects aspect ratios of precipitation particles on the beam path.
  - Possible range of values: generally -2 to 10 (deg/km)
  - Not affected by rain attenuation
  - Useful for rainfall rate estimation (especially for heavy rain)
  - Noisy against light rain
  - Not sensitive to ice particles

Kdp (deg/km) vs. $\Phi_{DP}$ (deg/km)

Range:
- **Moderate**
- **Light**
- **Heavy**

Courtesy of Mr. Umehara
Kdp: Specific differential phase
Textures of dual-pol data

Texture: Spatial Fluctuation

- Generally defined as standard deviation parameters
- Reflects the roughness of the value distribution
- Reflects the characteristics of targets (depends on parameter)
- Useful for QC and hydrometeor classification

\[
Texture(X_{a,b}) = \sqrt{\frac{\sum_{i=-(m-1)/2}^{(m-1)/2} \sum_{j=-(n-1)/2}^{(n-1)/2} (X_{a,b}-X_{a+i,b+j})^2}{mn}}
\]
$S(\Phi_{DP}) :$ textures of $\Phi_{DP}$

- $S(\Phi_{DP}) :$ Standard deviation of $\Phi_{DP}$
  - Reflects sparseness or non-uniformity of scattering targets within sampling volume
  - Possible range of values : larger than 0
  - Can clearly indicates precipitation echo
  - Useful for hydrometeor classification and QC

Probability density distribution of $S(\Phi_{DP})$

Sugier and Tabary (2006)
Merits of using dual-pol data

- Quality control
- Rain rate estimation
- Hydrometer classification
Dual-pol data

Conventional Doppler weather radar

**Observed parameter**
- Reflectivity $Z$
- Doppler velocity $V$
- Velocity width $W$

Derived texture
- $S(Z)$
- $S(V)$
- $S(W)$

Dual-polarization weather radar

**Observed parameter**
- Differential reflectivity $Z_{dr}$
- Correlation coefficient $\rho_{hv}$
- Differential phase $\Phi_{dp}$

Derived texture
- $S(Z_{dr})$
- $S(\rho_{hv})$
- $S(\Phi_{dp})$

Spatial derivative
Specific differential phase $K_{dp}$