Ch. 5: Applications in weather quantification and forecast (co-lectured with Dr. Ryzhkov)

- Fuzzy logic method for hydrometeor classification
- Quantitative precipitation estimation (QPE)
- DSD retrieval
- Attenuation correction
- Model parameterization and initialization

Calculations versus measurements

- A boundary can be drawn for calculated radar parameters
- Boundary becomes vague for real data
Earlier hail detection

- Aydin et al. (1986)

\[ H_{DR} = Z_H - F(Z_{DR}) \]

\[
F(Z_{DR}) = \begin{cases} 
60 & Z_{DR} > 1.74 \\
19Z_{DR} + 27 & 0 < Z_{DR} \leq 1.74 \\
27 & Z_{DR} \leq 0 
\end{cases}
\]

- \( Z_{DR} \) provides additional info
- Other PRD also useful

Important References on Fuzzy Logic Classification

Why classification

- Different relationships between microphysical parameters and polarimetric radar variables for different species of hydrometeors
- More accurate quantitative precipitation estimation
- Better understanding of cloud/precipitation microphysics
- Better data quality
- Optimally utilize PRD for model initialization/forecast

Why fuzzy logic

- PRD: a set of measurements ($Z, Z_{DR}, \rho_{hv}, K_{DP}$), how to combine them?
- Boundary vague, error
- Rigorous theory/result difficult to establish and not necessary for some applications
- Easy to understand
- Tolerant of inaccuracy
- Flexibility to use and build on
- NOT a cure-all: good for classification, not good for quantification
Fuzzy logic versus probability

- Many similarities in characterizing uncertain problem
- Main difference
  - Probability: nut set between a set and its complement: 50% rain, 50% hail
  - Fuzzy logic: not necessary nut set; e.g., melting hail

What is a fuzzy logic classifier

- A convenient way to map input to output
- Three steps
  - Fuzzification
  - Aggregation
  - Defuzzification
- Two components
  - Membership function
  - Weighting function
Partitions in the $Z_H$, $Z_{DR}$ Space

Examples of membership functions (from Ryzhkov)

$Z = 25$ dBZ, $Z_{DR} = 3.0$ dB, $\rho_{hv} = 0.55$, $SD(Z) = 5$ dB, $SD(\Phi_{DP}) = 35$ deg

<table>
<thead>
<tr>
<th>Class</th>
<th>$P(Z)$</th>
<th>$P(Z_{DR})$</th>
<th>$P(\rho_{hv})$</th>
<th>$P(\text{SD}(Z))$</th>
<th>$P(\text{SD}(\Phi_{DP}))$</th>
<th>A</th>
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</thead>
<tbody>
<tr>
<td>Rain</td>
<td>1.0</td>
<td>0.5</td>
<td>0.0</td>
<td>0.33</td>
<td>0.0</td>
<td>1.83</td>
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<tr>
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<td>0.0</td>
<td>0.5</td>
<td>1.0</td>
<td>0.5</td>
<td>3.00</td>
</tr>
<tr>
<td>Bio</td>
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<td>1.0</td>
<td>1.0</td>
<td>0.67</td>
<td>1.0</td>
<td>4.17</td>
</tr>
</tbody>
</table>
A Severe Thunderstorm (6/13/1997)

Vivek et al. 1999