Topic C: River and Urban Flood Forecasting and Mitigation

(C-3) Strategies and Methods for Urban Flash Flood Forecasting and Warning

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Outline

1. Characteristics of Flash Flood
2. Strategies and Methods of FF Warning
3. KICT Hydrological RADAR
4. Its Applications for Urban FF
What is a Flash Flood?

- **Flash floods** are quick response flood events causing sudden flooding in small river basins. Flooding follows within **6 hours or less** after the heavy rain event.
  - Typically associated with small fast responding basins
  - Can occur in normally dry areas with no visible stream channel, including urban areas

- **River floods** are caused by heavy rain over long periods (days) in the upper catchment leading to rising water levels and flooding as the flood wave takes days to move down river.
Characteristics of flash flood

- Flash floods occurred by localized extreme rainfall with short duration of a few hours
- Difficulties of flash flood forecasting with high spatial-temporal resolution
- Floods in the ungauged areas

Hourly rainfall rate (mm/hr) on 27/JUL/2011 (07:30-08:30)
Characteristics of flash flood

- Urban areas (2010, 2011, Seoul)
Characteristics of flash flood

◆ Urban areas (2010, 2011, Seoul)
Characteristics of flash flood

Urban areas (Seoul)

- Rapidly rising stream water level (within an hour) due to heavy rainfall
  
  ![Hongje stream (Seoul, 2010)](image)
  ![Cheonggye stream (Seoul, 2012)](image)

- Typical damages by inundation: depths of 0.1–0.5 m, durations of 2–3 hours
  
  ![Inundation at downtown Seoul, 2010](image)
  ![Residential area Seoul, 2011](image)

- Optimal operation of drainage systems requires quick decision making processes (within 3 hours) with high spatiotemporal resolution.
Characteristics of flash flood

◆ Urban areas (2014, Busan)
Characteristics of flash flood

◆ Heavy Rainfall Evolution during 2014 FF in Busan

8/25/2014 07:30 ~ 15:30 (8hrs)
Characteristics of flash flood

◆ Heavy Rainfall Evolution during 2014 FF in Busan

8/25/2014 07:30 ~ 15:30 (hourly accumulated Rainfall during 8hrs)
Characteristics of flash flood

Mountainous areas

- Frequent and localized severe rainfall (880mm/24hr)
  - Orographic effects but coarse ground rainfall gages
  - Torrential flood runoff in the valley and steep streams

<torrential flood in steep stream>

<landsides in mountainous areas>
Severe snowstorms in Winter

CCTV Installation to monitor snowstorms in Seoul: 5 → 8 points

[Massive traffic accident, Seoul]

[Greenhouse collapse]
What is a practical flash flood warning system?

- Need to pinpoint where and when severe rainfall would occur in real time and advance.
  - both temporal and spatial high resolution rainfall measurements or estimates
  - rainfall estimates in the ungauged areas and flood warning
  - simulate fast runoff processes and related short response times

- X-band dual polarimetric radar is able to provide a useful platform for warn flash floods.
Establishment of HRDRC (Hydrological Radar Disaster Research & Data Center)

- Promoting R&D for disaster prevention of flash flood and snow using hydrological radar
- Building hub to disseminate rainfall radar data of Ministry of Land, Infrastructure, and Transportation
- Supporting actual work-site operations of flash flood & snow management in local governments around KICT
- Strengthening international radar R&D networks
HRDRC Activities

- Rainfall/Snow estimation and forecasting technology development
- Short-term flood forecasting technology to use hydrologic model of high accuracy
- Landslides, snow (transportaion, agriculture) and other natural disasters detection technology using hydrological data radar
- Disaster alarm technology development of rainfall radar network utilizing GIS mobile systems
- Data Dissemination of MOLIT rainfall radar
- International Hydro-Radar Workshop
Dissemination Hub of MOLIT Rainfall Radar Data

- Radar: Rainfall radar of the MOLIT (Imjin, Bisl, Sobaek radar)
- Data: Observation radar data (before/after QC), Estimated rainfall Int.
KICT Hydrological RADAR

- Operation of a X band dual-polarization radar for hydrological purposes
  - Manufacturer: Ridgeline Instruments (RLI)
  - Type: Magnetron with solid state modulator
  - Weight: 633 kg
  - Antenna: Parabola/1.8 m diameter
  - Peak power: 8 kW
  - Beam width: 1.4°
  - Max range: 50 km
  - Frequency: 9410±30 MHz
  - Scan speed: 10 rpm (max)

Coverage: 40 km radius
Current Research Work

- Development of Flood Warning and Snowfall Estimation Platform using Hydrological Radars (KICT)

1. Technology for Radar data storage and operation
   - X-band dual pol. KICT Radar operation

2. High Accuracy forecasting technology
   - Using hydrological radar, rainfall/snow estimation and forecasting system
   - High-resolution radar-based, real-time hydrological flood forecasting model

3. Technology of utilizing real-time radar data
   - Hydrological radar platform development, utilizing web and mobile alert
Introduction Video of HRDRC
HRDRC Website

- Website: [http://hrdrc.kict.re.kr](http://hrdrc.kict.re.kr)
KICT Radar Scan Strategy

- **5 Minutes Volume Scan**

  - 1 PPI + 2 RHIs in 1 minute
    - Observe vertical precipitation and volume scale hydrometeor
  - PPI is scanned 5° and 6° azimuth by turns.
    - can make one CAPPI (1.0km, 1.5km, 2km) per one turn (1 minute).
  - One 10° PPI is scanned for redundant time in 5 minutes scanning
    - for CAPPI interpolation in case of upper area than 6°.
  - For the second 5 minutes scanning, all RHIs’ azimuths are shifted +9°
    - to minimize the angles between adjacent RHIs for 10 minutes scanning (18° to 9°)
10-minutes Hybrid Scan Strategy

<table>
<thead>
<tr>
<th>Scan Type</th>
<th>Azimuth</th>
<th>Elevation</th>
<th>Deg. / Sec.</th>
</tr>
</thead>
<tbody>
<tr>
<td>PPI</td>
<td>0.0 to 359.9 deg.</td>
<td>5.0 deg.</td>
<td>15.0</td>
</tr>
<tr>
<td>RHI</td>
<td>0.0 deg.</td>
<td>0 to 180.0 deg.</td>
<td>19.0</td>
</tr>
<tr>
<td>RHI</td>
<td>18.0 deg.</td>
<td>180 to 0.0 deg.</td>
<td>19.0</td>
</tr>
<tr>
<td>PPI</td>
<td>36.0 to 35.9 deg.</td>
<td>6.0 deg.</td>
<td>15.0</td>
</tr>
<tr>
<td>RHI</td>
<td>36.0 deg.</td>
<td>0 to 180.0 deg.</td>
<td>19.0</td>
</tr>
<tr>
<td>RHI</td>
<td>54.0 deg.</td>
<td>180 to 0.0 deg.</td>
<td>19.0</td>
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<td>PPI</td>
<td>72.0 to 71.9 deg.</td>
<td>5.0 deg.</td>
<td>15.0</td>
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<tr>
<td>RHI</td>
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<td>0 to 180.0 deg.</td>
<td>19.0</td>
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<tr>
<td>RHI</td>
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<td>19.0</td>
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<td>PPI</td>
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<td>15.0</td>
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<tr>
<td>RHI</td>
<td>108.0 deg.</td>
<td>0 to 180.0 deg.</td>
<td>19.0</td>
</tr>
<tr>
<td>RHI</td>
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<td>180 to 0.0 deg.</td>
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<tr>
<td>PPI</td>
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<tr>
<td>RHI</td>
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<td>0 to 180.0 deg.</td>
<td>19.0</td>
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<tr>
<td>RHI</td>
<td>162.0 deg.</td>
<td>180 to 0.0 deg.</td>
<td>19.0</td>
</tr>
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<td>PPI</td>
<td>180.0 to 179.9 deg.</td>
<td>10.0 deg.</td>
<td>15.0</td>
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</tbody>
</table>

5 minutes

<table>
<thead>
<tr>
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<th>Deg. / Sec.</th>
</tr>
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<tbody>
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<td>PPI</td>
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<td>6.0 deg.</td>
<td>15.0</td>
</tr>
<tr>
<td>RHI</td>
<td>189.0 deg.</td>
<td>0 to 180.0 deg.</td>
<td>19.0</td>
</tr>
<tr>
<td>RHI</td>
<td>207.0 deg.</td>
<td>180 to 0.0 deg.</td>
<td>19.0</td>
</tr>
<tr>
<td>PPI</td>
<td>225.0 to 224.9 deg.</td>
<td>5.0 deg.</td>
<td>15.0</td>
</tr>
<tr>
<td>RHI</td>
<td>225.0 deg.</td>
<td>0 to 180.0 deg.</td>
<td>19.0</td>
</tr>
<tr>
<td>RHI</td>
<td>243.0 deg.</td>
<td>180 to 0.0 deg.</td>
<td>19.0</td>
</tr>
<tr>
<td>PPI</td>
<td>261.0 to 260.9 deg.</td>
<td>6.0 deg.</td>
<td>15.0</td>
</tr>
<tr>
<td>RHI</td>
<td>261.0 deg.</td>
<td>0 to 180.0 deg.</td>
<td>19.0</td>
</tr>
<tr>
<td>RHI</td>
<td>279.0 deg.</td>
<td>180 to 0.0 deg.</td>
<td>19.0</td>
</tr>
<tr>
<td>PPI</td>
<td>297.0 to 296.9 deg.</td>
<td>5.0 deg.</td>
<td>15.0</td>
</tr>
<tr>
<td>RHI</td>
<td>297.0 deg.</td>
<td>0 to 180.0 deg.</td>
<td>19.0</td>
</tr>
<tr>
<td>RHI</td>
<td>315.0 deg.</td>
<td>180 to 0.0 deg.</td>
<td>19.0</td>
</tr>
<tr>
<td>PPI</td>
<td>333.0 to 332.9 deg.</td>
<td>6.0 deg.</td>
<td>15.0</td>
</tr>
<tr>
<td>RHI</td>
<td>333.0 deg.</td>
<td>0 to 180.0 deg.</td>
<td>19.0</td>
</tr>
<tr>
<td>RHI</td>
<td>351.0 deg.</td>
<td>180 to 0.0 deg.</td>
<td>19.0</td>
</tr>
<tr>
<td>PPI</td>
<td>0.0 to 359.9 deg.</td>
<td>10.0 deg.</td>
<td>15.0</td>
</tr>
</tbody>
</table>

5 minutes (RHI: AZ 9.0 deg. Shifted)

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<td>10.0 deg.</td>
<td>15.0</td>
</tr>
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</table>
Target spatial and temporal resolutions

- [Spatial resolution] (As) 125~250 m → (To be) 60~100 m

- [Temporal resolution] (As) 2.5~10min → (To be) 1 min
KICT X-band Radar Variables

**PPI Scan**
- Reflectivity
- Velocity
- Copolar Corelation
- Differential Phase
- Spectral Width

**RHI Scan**
- Reflectivity
- Velocity
- Differential Phase
High Resolution Radar Data Application

- Moment data based time-spanned radar observation
High Resolution Radar Data Application

• RHI Data
High Resolution Radar 3-D Display
Beam based 3D radar observation
Urban QPE Challenge

- High spatiotemporal observations are required in order to capture and monitor the highly localized, rapidly evolving rainfall events.

- Urbanization significantly magnifies the scale and impact of floods. Both the spatial resolution and temporal resolution are critically important in monitoring urban floods and flash floods.

- At urban area, ground clutters (buildings) and beam blockage are significant error sources of radar based QPE.
Why Classification and R-$K_{dp}$?

- Precipitation estimation using radar reflectivity can be overestimated by contamination of ground clutter, whereas partial beam blockage can cause underestimation.
- QC (non-meteorological target detection) is important
- $\phi_{dp}$ is not significantly impacted by partial beam blockage.
- $K_{dp}$ based rainfall conversion is attractive at X-band
  - Responds well to low rainfall rate
  - Avoids the uncertainty in attenuation correction
  - Immune to calibration factors
Slant Beam Radar Variables

(a) $Z_h$ (dBZ)

(b) $\phi_{dp}$ (deg)

Ground clutter

Distance along transect (km)

Elevation

2.0(deg)

2.4(deg)

3.4(deg)

3.4(deg)

4.3(deg)
Precipitation Classification and Quantification Using X-band Dual-Polarization Weather Radar (C & Q)

1. QC & Hydrometeor Classification
2. $K_{dp}$ Retrieval
3. Rainfall estimation
KICT RADAR OBSERVATIONS

07:33:59 UTC, Oct. 29, 2013
01:25:57 UTC, Sep. 13, 2013
Comparison of Radar and Ground Gauge Rainfall

Black: rain gauge
Red: $R(K_{dp}) = 23.7K_{dp}^{0.87}$ (New)
Blue: $R(K_{dp}) = 18.15K_{dp}^{0.791}$ (CSU)
Integrated use of both S-band and X-band radars

- S-band radar measures and predicts precipitation at national scales.
- Need to solve the disadvantages of short range and signal extinction in X-band radar through complementary use of C-band radar.
- Use X-band radar to fill gap of S-band radar

- Regions needed gap fill
  A: Mountainous areas
  B: Coastal areas
  C: Urban areas
Integrated use of both S-band and X-band radars

<KMA:S-band>  <KICT:X-band>  <Overlapped>
Urban Flash Flood Forecasting and Warning

- Pre-analysis of relationship between historic rainfalls and flash floods

<table>
<thead>
<tr>
<th>district</th>
<th>10min</th>
<th>30min</th>
<th>1hr</th>
<th>3hr</th>
<th>6hr</th>
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</thead>
<tbody>
<tr>
<td>Gangnam</td>
<td>20</td>
<td>30</td>
<td>47</td>
<td>73</td>
<td>108</td>
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<tr>
<td>Seocho</td>
<td>18</td>
<td>34</td>
<td>40</td>
<td>77</td>
<td>110</td>
</tr>
</tbody>
</table>

- Threshold rainfall (mm) triggering flash flood
Urban Flash Flood Forecasting and Warning
Location-based Mobile Service of Flash Flood Warning
Combination of Radar Information and Augmented Reality

Heavy Rainfall Case @ 11:00 - 17:00, Dec. 12, 2014
Combination of Radar Information and Augmented Reality
Combination of Radar Information and Augmented Reality

: Iphone, IPad
KICT radar observation: Tornado case (June 10, 2014 19:20-19:45 KST)
KICT radar observation:
Tornado case (June 10, 2014 19:20-19:45 KST)
KICT radar observation: Tornado case (June 10, 2014 19:20-19:45 KST)
KICT radar observation:
Tornado case (June 10, 2014 19:20-19:45 KST)
KICT radar observation
Snow storm (Dec. 12 2013 11:00-17:00 KST)
Thank you for your attention!