Typhoon Committee Roving Seminar
Lao DPR, 4-6 Nov., 2015

Topic C: River and Urban Flood Forecasting and Mitigation

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

2015. 11. 6.

Director, Dong-ryul Lee

HRDRC **Hydrological Radar Disaster Research & Data Center**

Korea Institute of Civil Engineering and Building Technology

KICT KOREA INSTITUTE of CIVIL ENGINEERING and BUILDING TECHNOLOGY

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

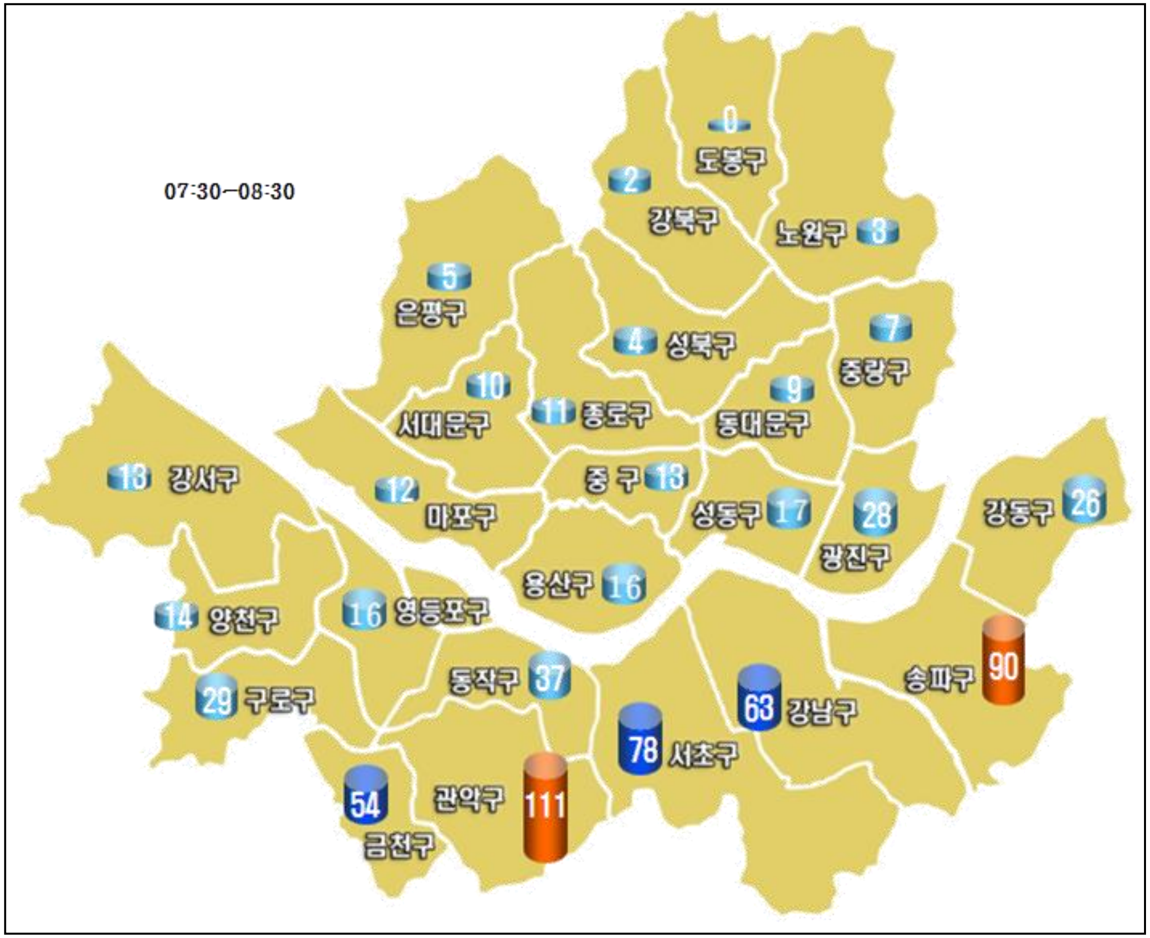
  - **Typically associated with small fast responding basins**
  - **Can occur in normally dry areas with no visible stream channel, including urban areas**

- **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

Flood damages at downtown Seoul in 2012 (12mm/15min)



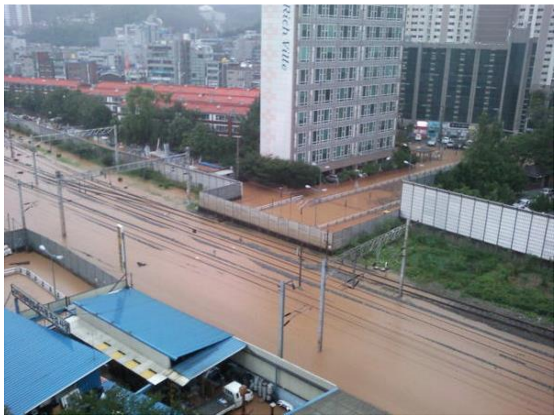
Hourly rainfall rate (mm/hr) on 27/JUL/2011 (07:30-08:30)

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)

Cheonggye stream
(Seoul, 2012)

- Typical damages by inundation: depths of 0.1–0.5 m, durations of 2–3 hours

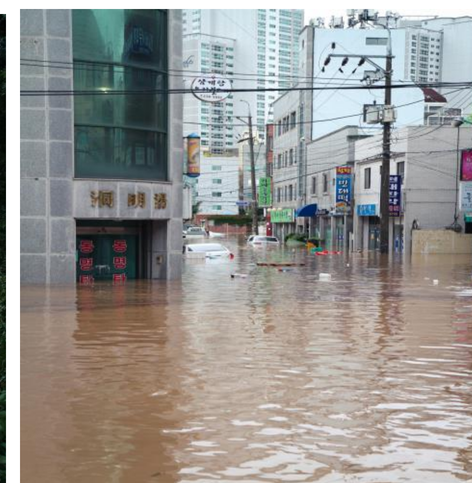
Inundation at downtown
Seoul, 2010

Residential area
Seoul, 2011

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

Characteristics of flash flood

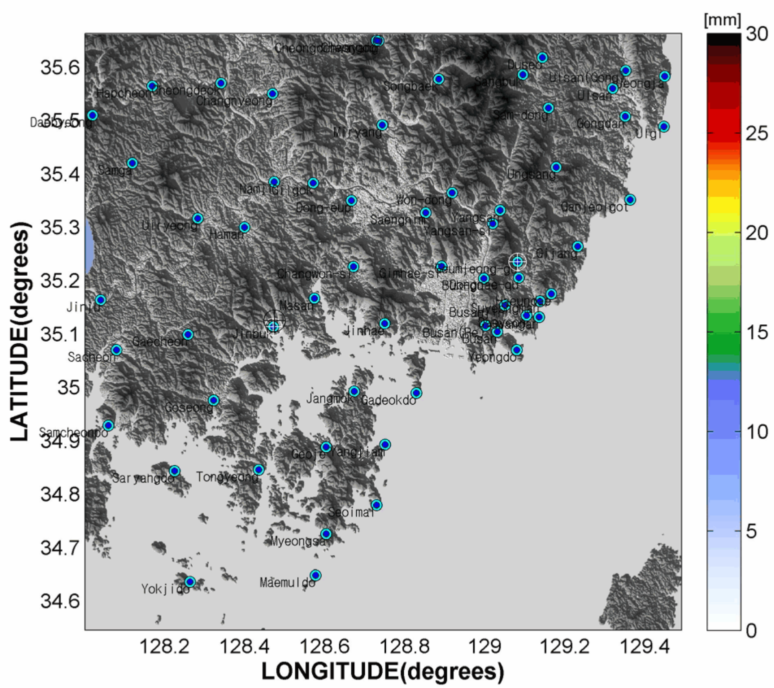
◆ Urban areas (2014, Busan)



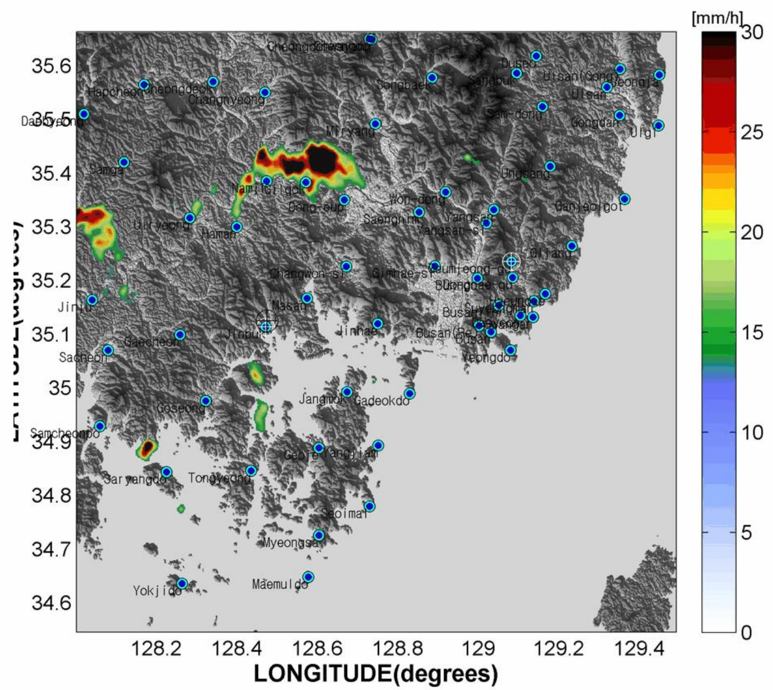
Characteristics of flash flood

◆ Heavy Rainfall Evolution during 2014 FF in Busan

Ground Gauge Rainfall (10min)



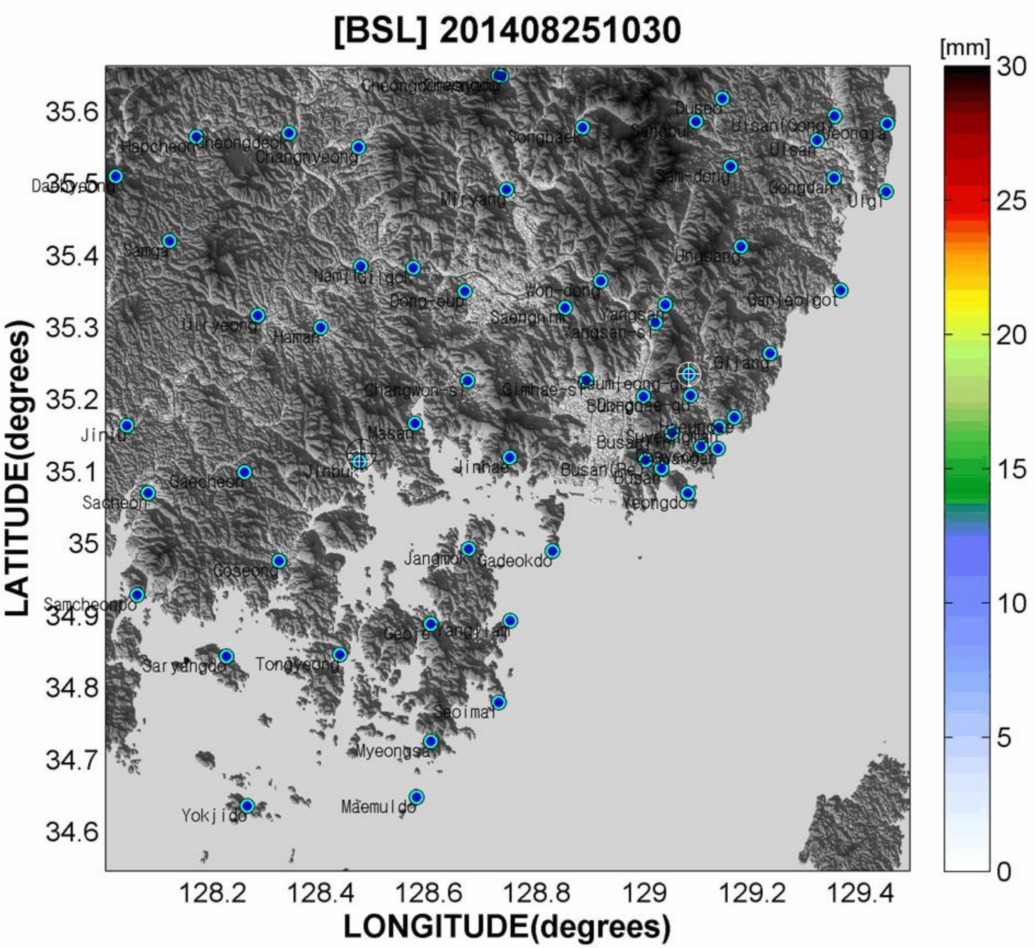
Bisuel Radar rainfall (2.5min)



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>

<landslides in mountainous areas>

Severe snowstorms in Winter

[Massive traffic accident, Seoul]

[Greenhouse collapse]

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

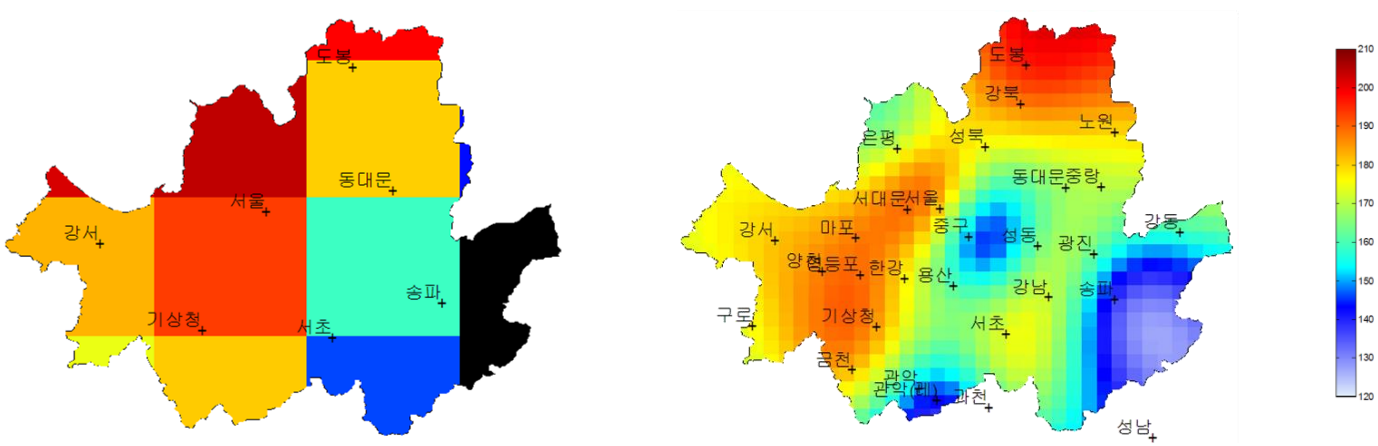
폭설 대비 소금·염화칼슘 5만t 확보

(서울=연합뉴스) 이 율 기자 = 서울시가 서울에 내리는 폭설을 예측할 수 있는 폐쇄회로(CC)TV를 기존 5곳에서 8곳으로 확대했다. 시는 또 이번 겨울 폭설에 대비해 소금과 염화칼슘 5만t을 확보했다.

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 Minstry of Land, Infrastructure, and Transportaion
- Supporting actual work-site operations of flash flood & snow management in local governments around KICT
- Strenthening international radar R&D networks

<Urban Area Flooding>

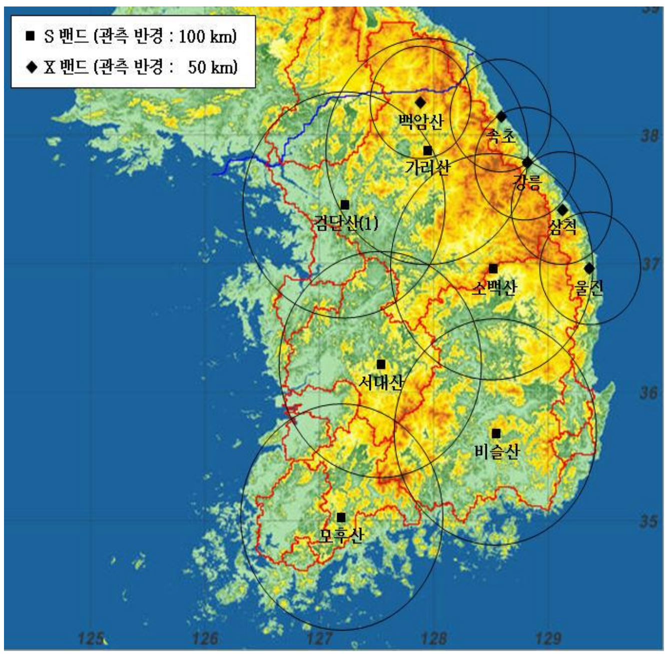
<GyungBu Highway Snowstorm>

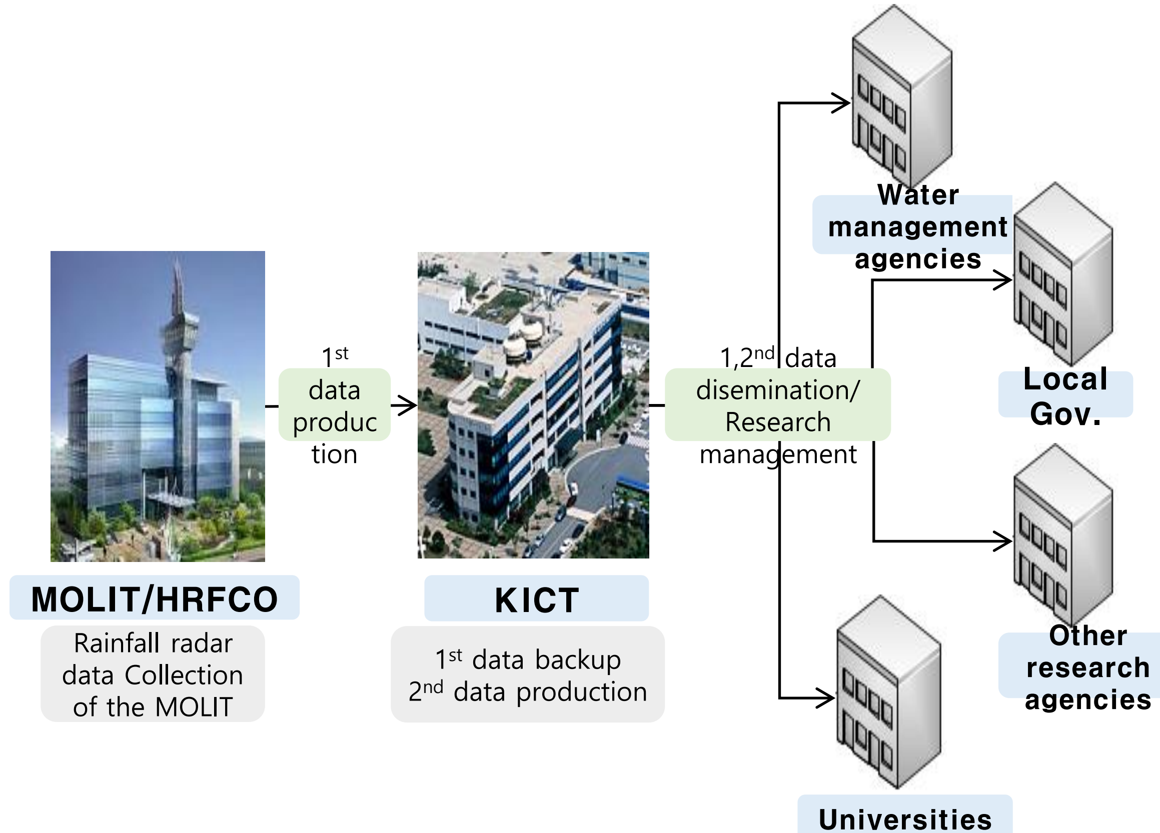
HRDRC Activities

- 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

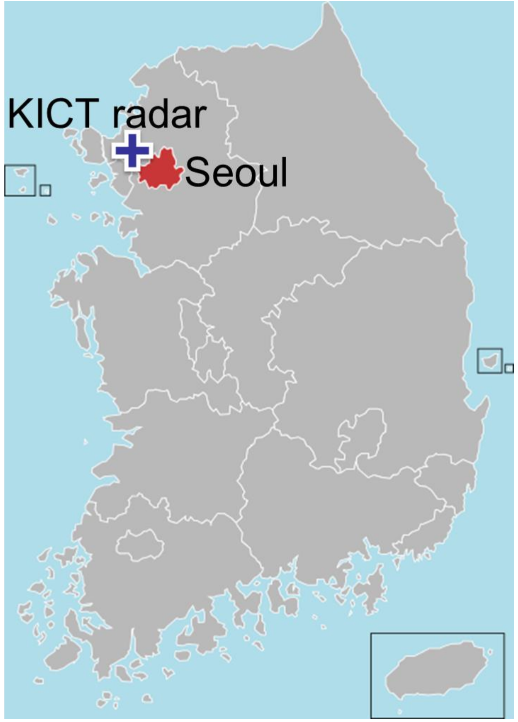
- Radar : Rainfall radar of the MOLIT(Imjin, Bisl, Sobaek radar)
- Data : Observation radar data(before/after QC), Estimated rainfall Int.





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

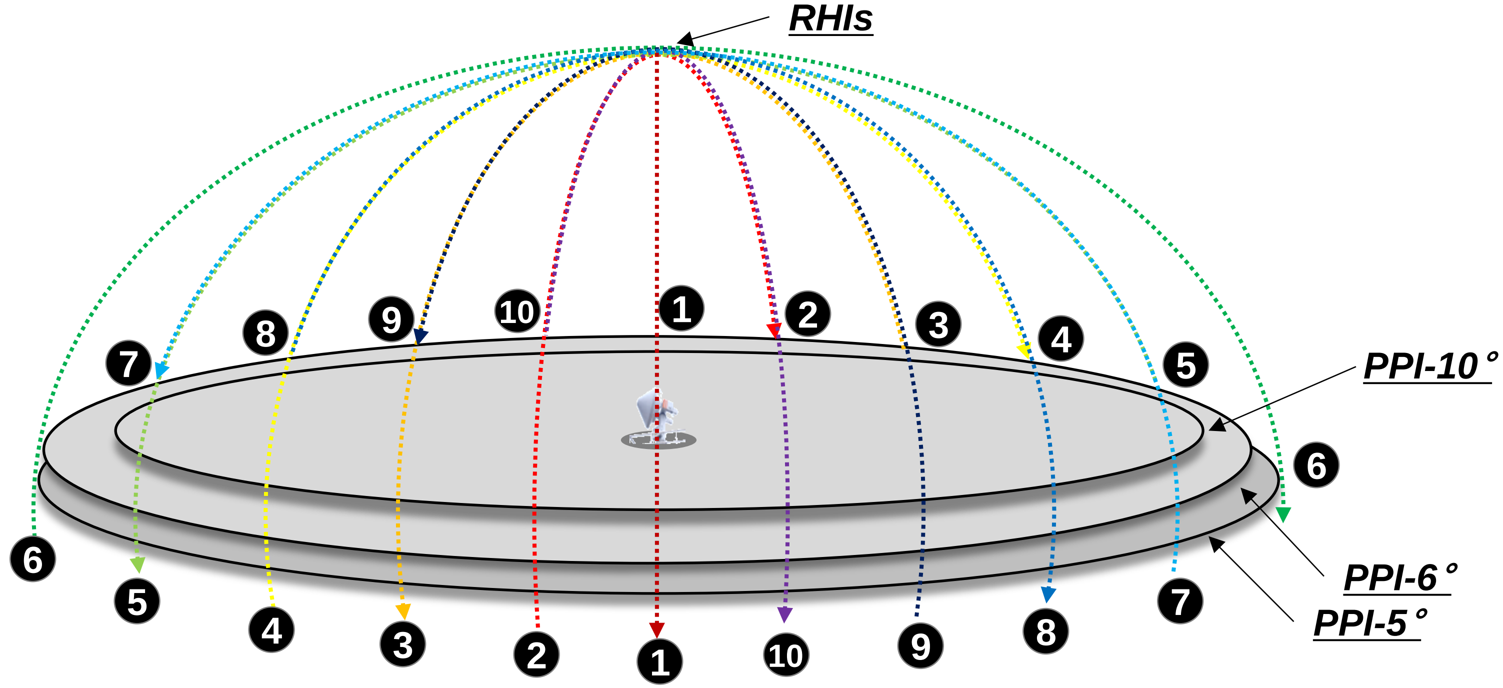
Introduction Video of HRDRC

HRDRC Website

- Website : http://hrdrc.kict.re.kr

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

5 minutes

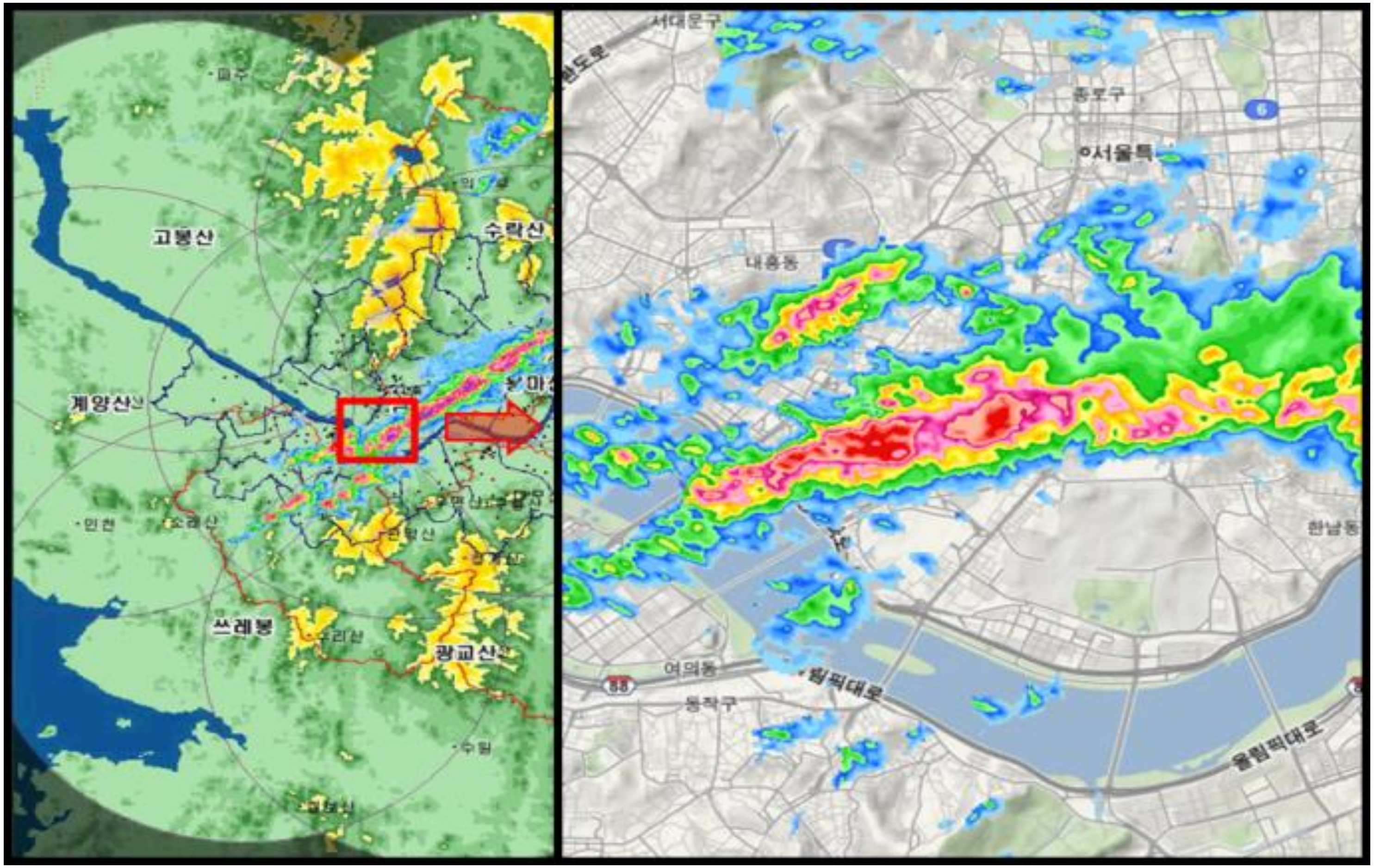
	Scan Type	Azimuth	Elevation	Deg. / Sec.
In 1 minute	PPI	0.0 to 359.9 deg.	5.0 deg.	15.0
	RHI	0.0 deg.	0 to 180.0 deg.	19.0
	RHI	18.0 deg.	180 to 0.0 deg.	19.0
In 1 minute	PPI	36.0 to 35.9 deg.	6.0 deg.	15.0
	RHI	36.0 deg.	0 to 180.0 deg.	19.0
	RHI	54.0 deg.	180 to 0.0 deg.	19.0
In 1 minute	PPI	72.0 to 71.9 deg.	5.0 deg.	15.0
	RHI	72.0 deg.	0 to 180.0 deg.	19.0
	RHI	90.0 deg.	180 to 0.0 deg.	19.0
In 1 minute	PPI	108.0 to 107.9 deg.	6.0 deg.	15.0
	RHI	108.0 deg.	0 to 180.0 deg.	19.0
	RHI	126.0 deg.	180 to 0.0 deg.	19.0
In 1 minute	PPI	144.0 to 143.9 deg.	5.0 deg.	15.0
	RHI	144.0 deg.	0 to 180.0 deg.	19.0
	RHI	162.0 deg.	180 to 0.0 deg.	19.0
	PPI	180.0 to 179.9 deg.	10.0 deg.	15.0

5 minutes(RHI: AZ 9.0 deg. Shifted)

	Scan Type	Azimuth	Elevation	Deg. / Sec.
In 1 minute	PPI	189.0 to 188.9 deg.	6.0 deg.	15.0
	RHI	189.0 deg.	0 to 180.0 deg.	19.0
	RHI	207.0 deg.	180 to 0.0 deg.	19.0
In 1 minute	PPI	225.0 to 224.9 deg.	5.0 deg.	15.0
	RHI	225.0 deg.	0 to 180.0 deg.	19.0
	RHI	243.0 deg.	180 to 0.0 deg.	19.0
In 1 minute	PPI	261.0 to 260.9 deg.	6.0 deg.	15.0
	RHI	261.0 deg.	0 to 180.0 deg.	19.0
	RHI	279.0 deg.	180 to 0.0 deg.	19.0
In 1 minute	PPI	297.0 to 296.9 deg.	5.0 deg.	15.0
	RHI	297.0 deg.	0 to 180.0 deg.	19.0
	RHI	315.0 deg.	180 to 0.0 deg.	19.0
In 1 minute	PPI	333.0 to 332.9 deg.	6.0 deg.	15.0
	RHI	333.0 deg.	0 to 180.0 deg.	19.0
	RHI	351.0 deg.	180 to 0.0 deg.	19.0
	PPI	0.0 to 359.9 deg.	10.0 deg.	15.0

Target spatial and temporal resolutions

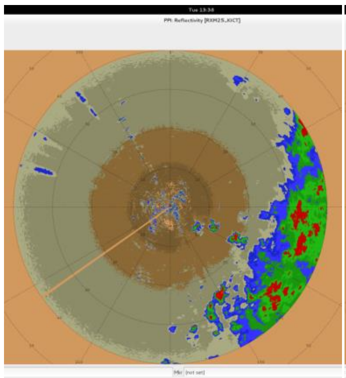
- [Spatial resolution] (As) 125~250 m → (To be) 60~100 m



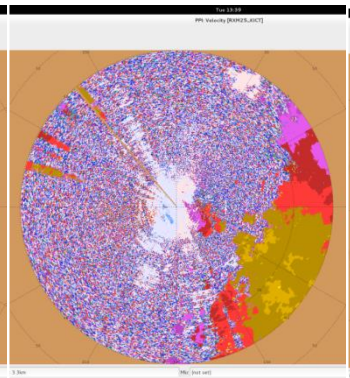
- [Temporal resolution] (As) 2.5~10min → (To be) 1 min

KICT X-band Radar Variables

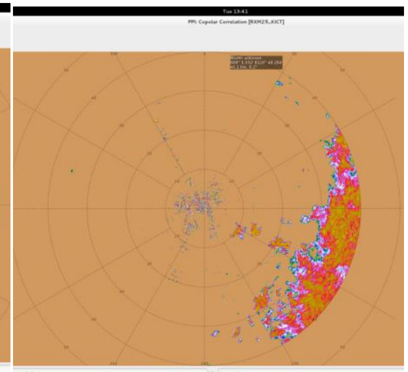
PPI Scan



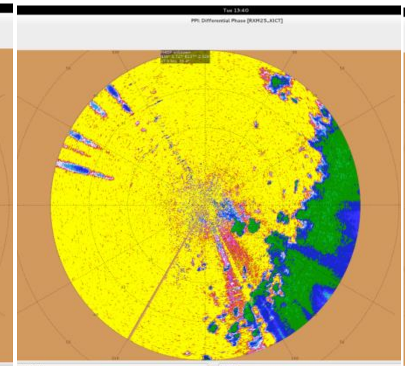
Reflectivity



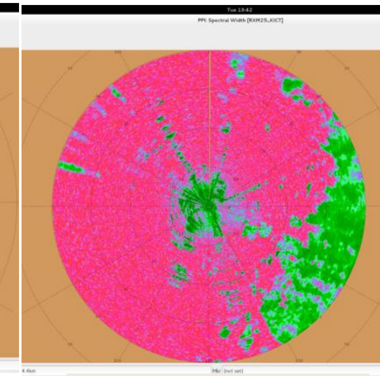
Velocity



Copolar Corelation

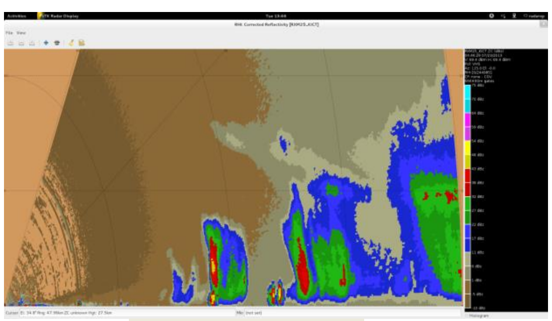


Differential Phase

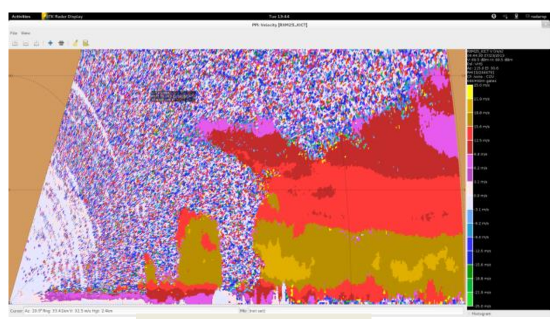


Spectral Width

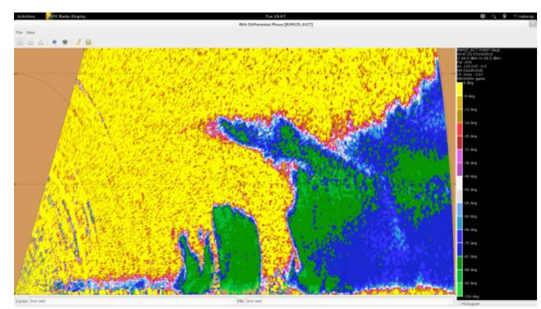
RHI Scan



Reflectivity



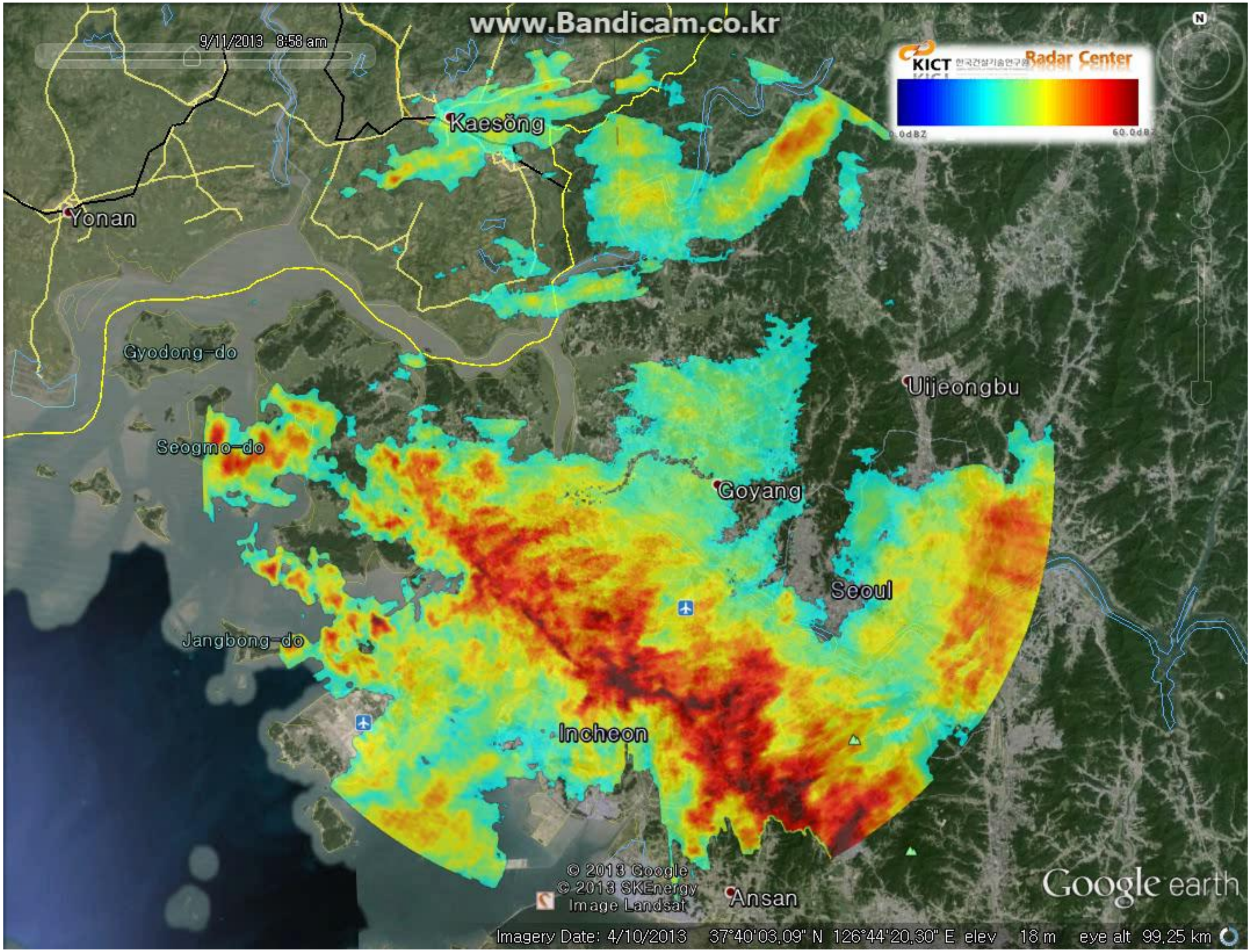
Velocity



Differential Phase

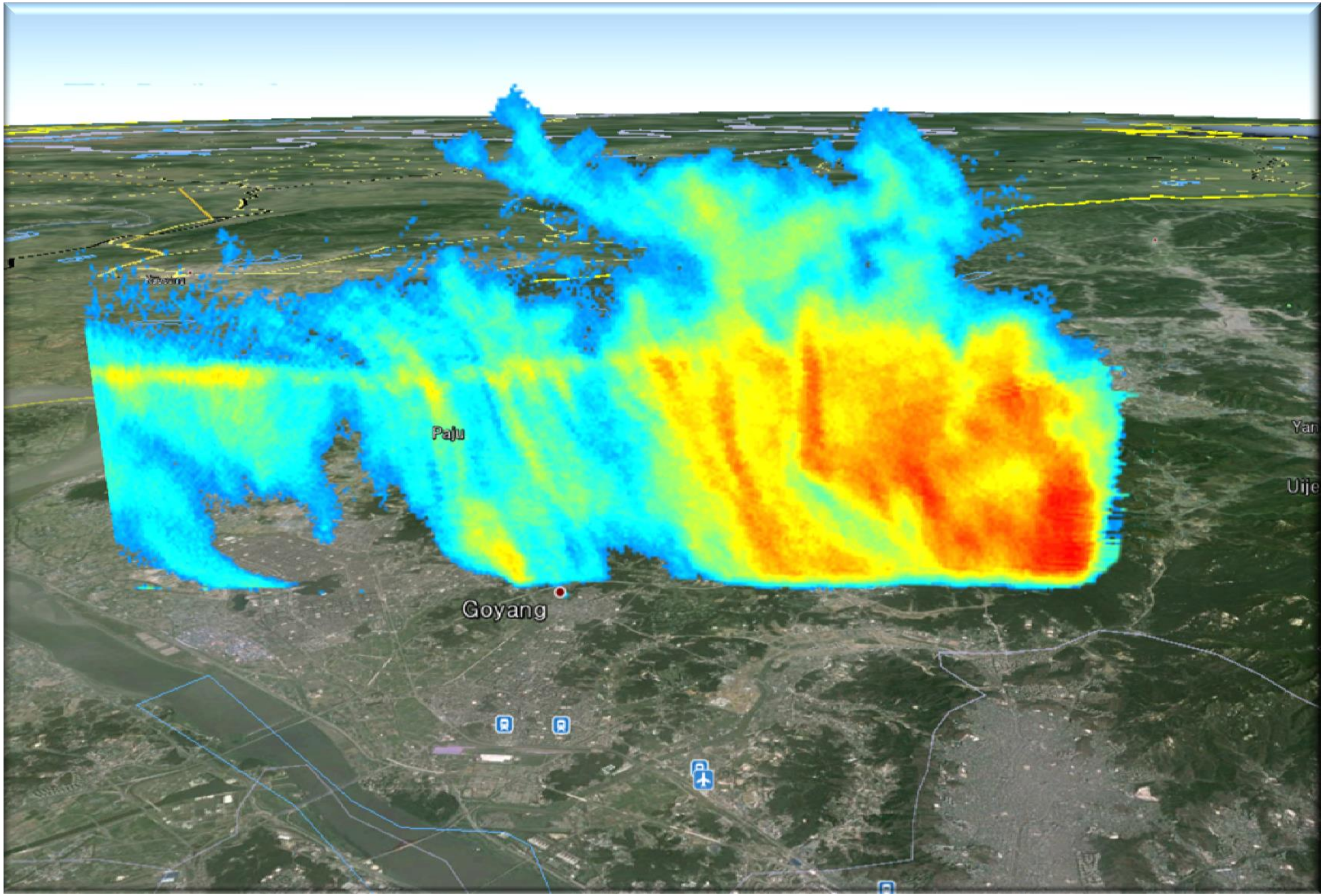
High Resolution Radar Data Application

- Moment data based time-spanned radar observation

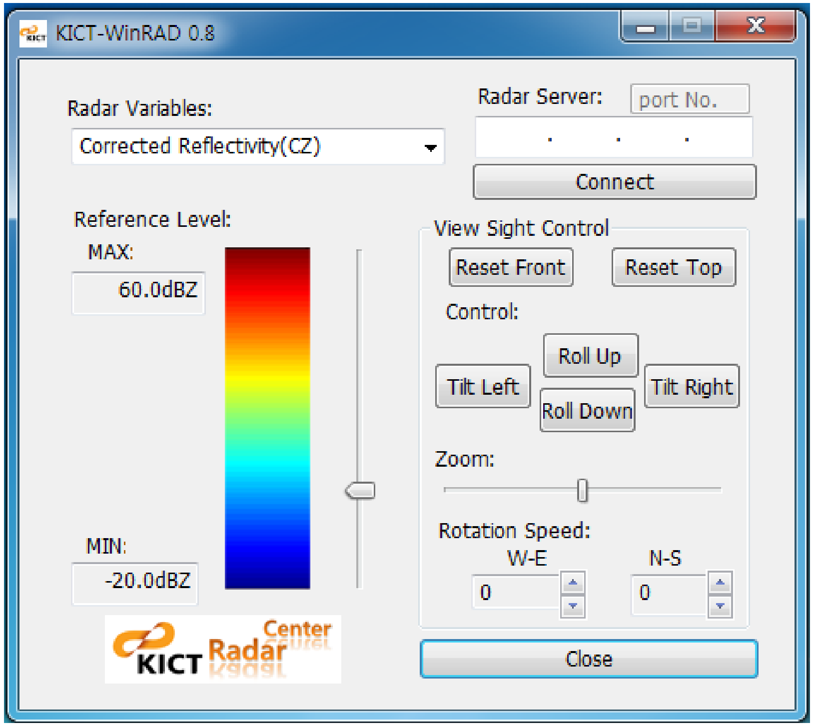


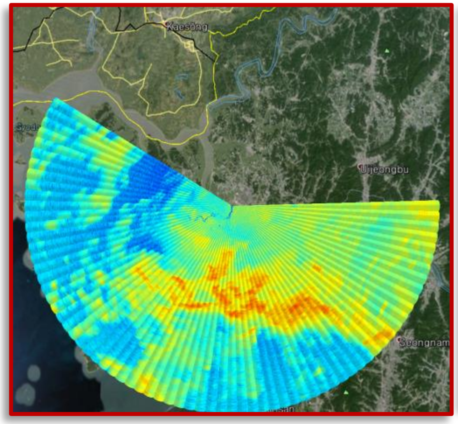
High Resolution Radar Data Application

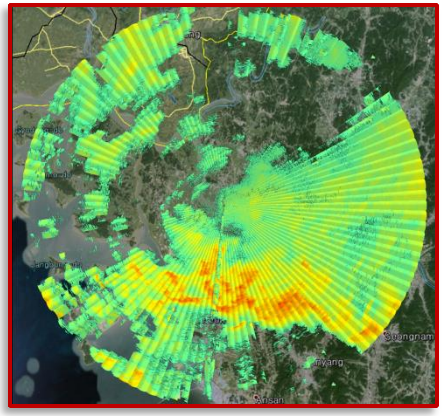
- RHI Data

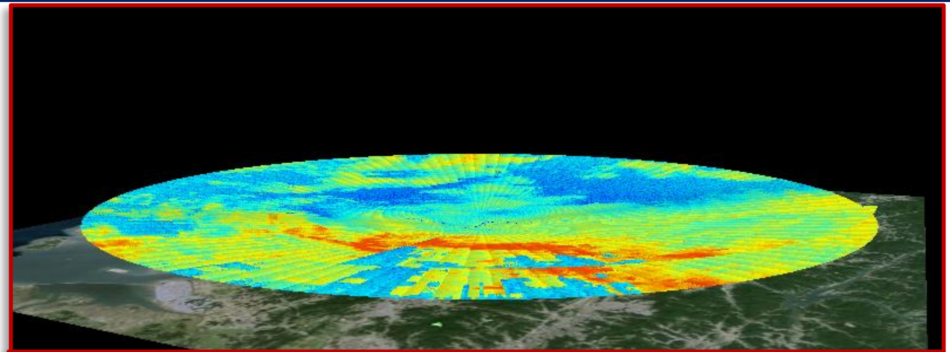


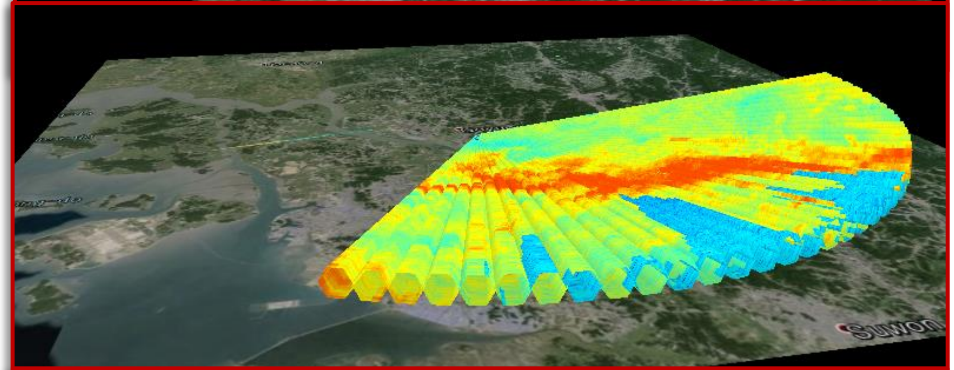
High Resolution Radar 3-D Display

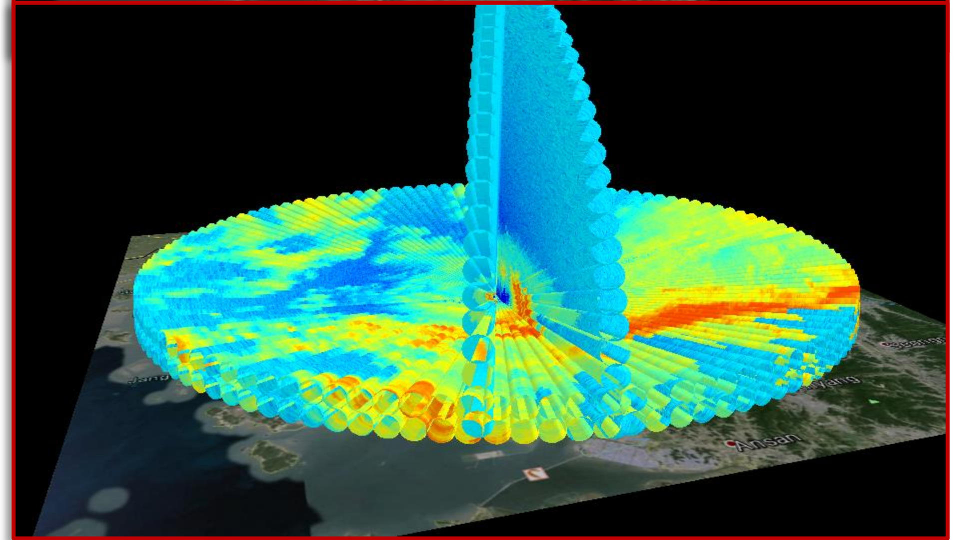




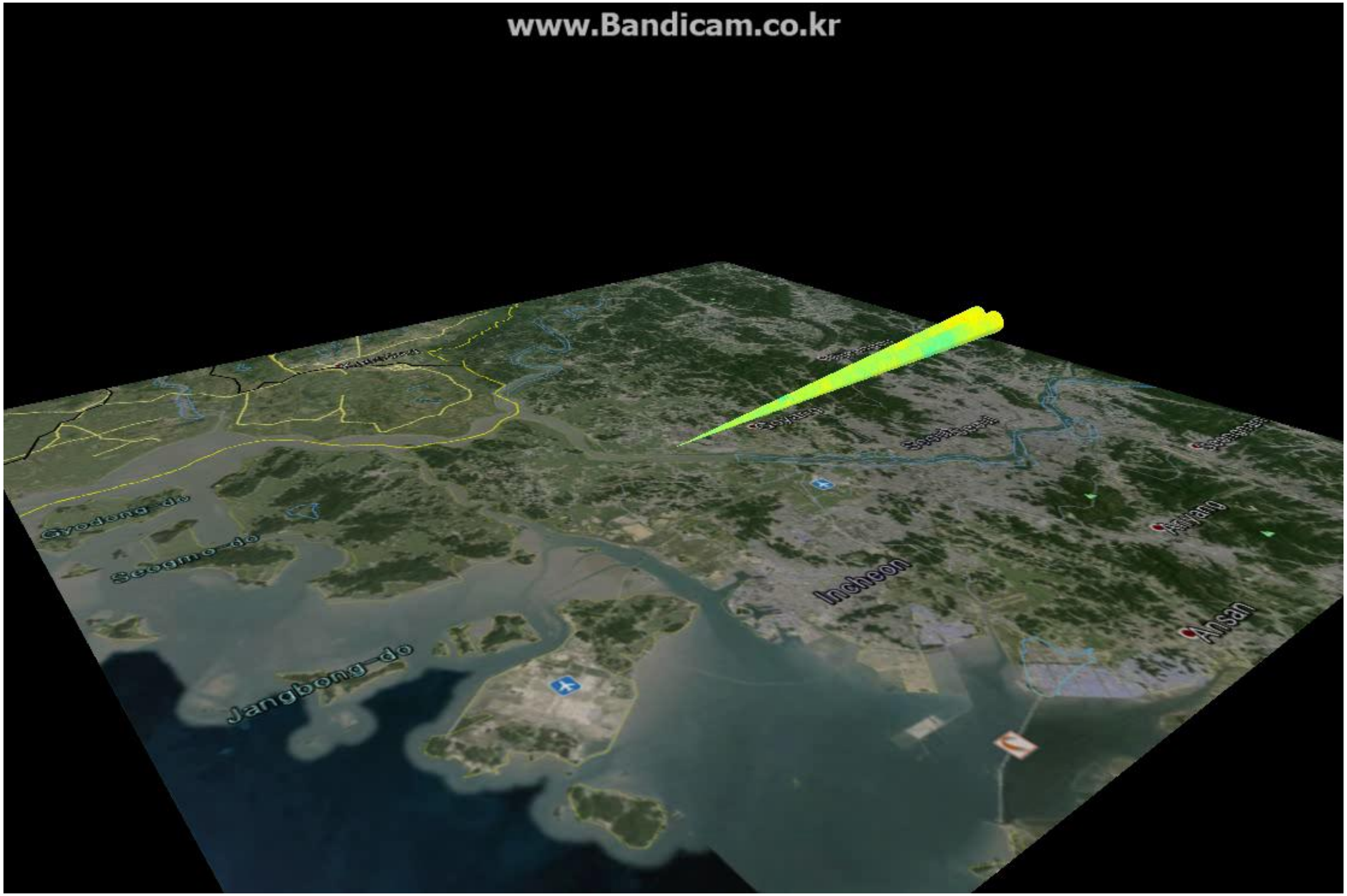








Beam based 3D radar observation



Urban QPE Challenge

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

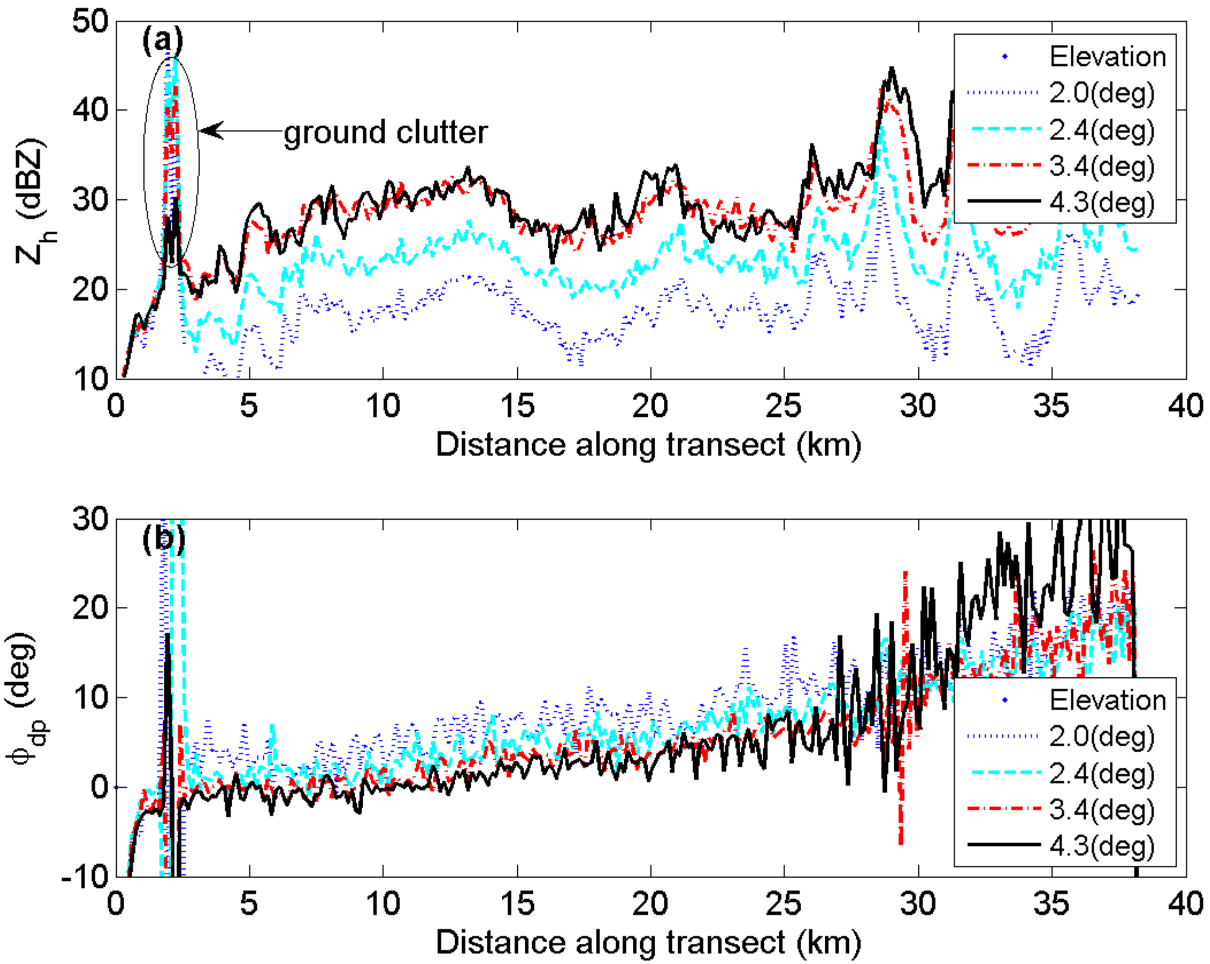
- Urbanization significantly magnifies the scale and impact of floods. Both the spatial resolution and temporal resolution are critically important in monitoring urban floods and flash floods.

- At urban area, ground clutters (buildings) and beam blockage are significant error sources of radar based QPE

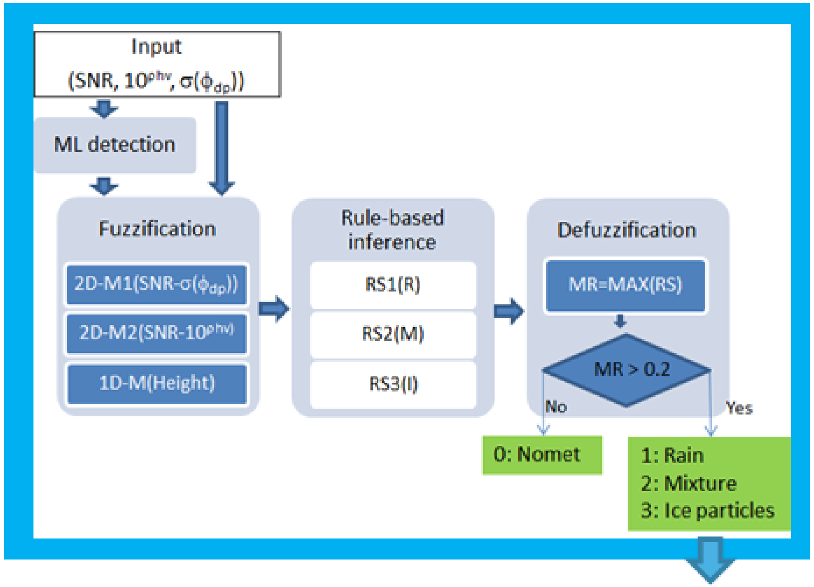
Why Classification and R-K_{dp}?

- 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
- ϕ_{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

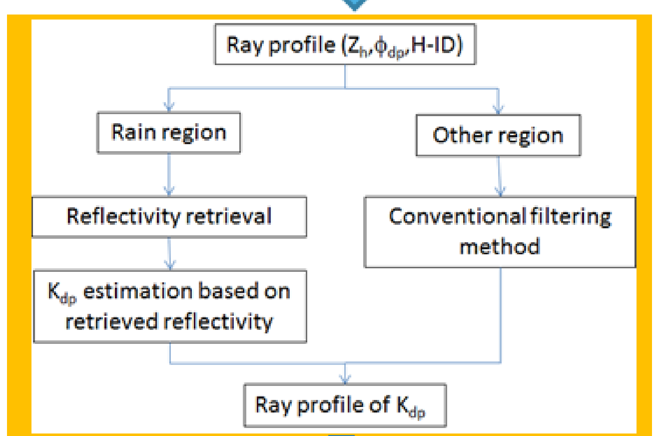
Slant Beam Radar Variables



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



1. QC & Hydrometeor Classification

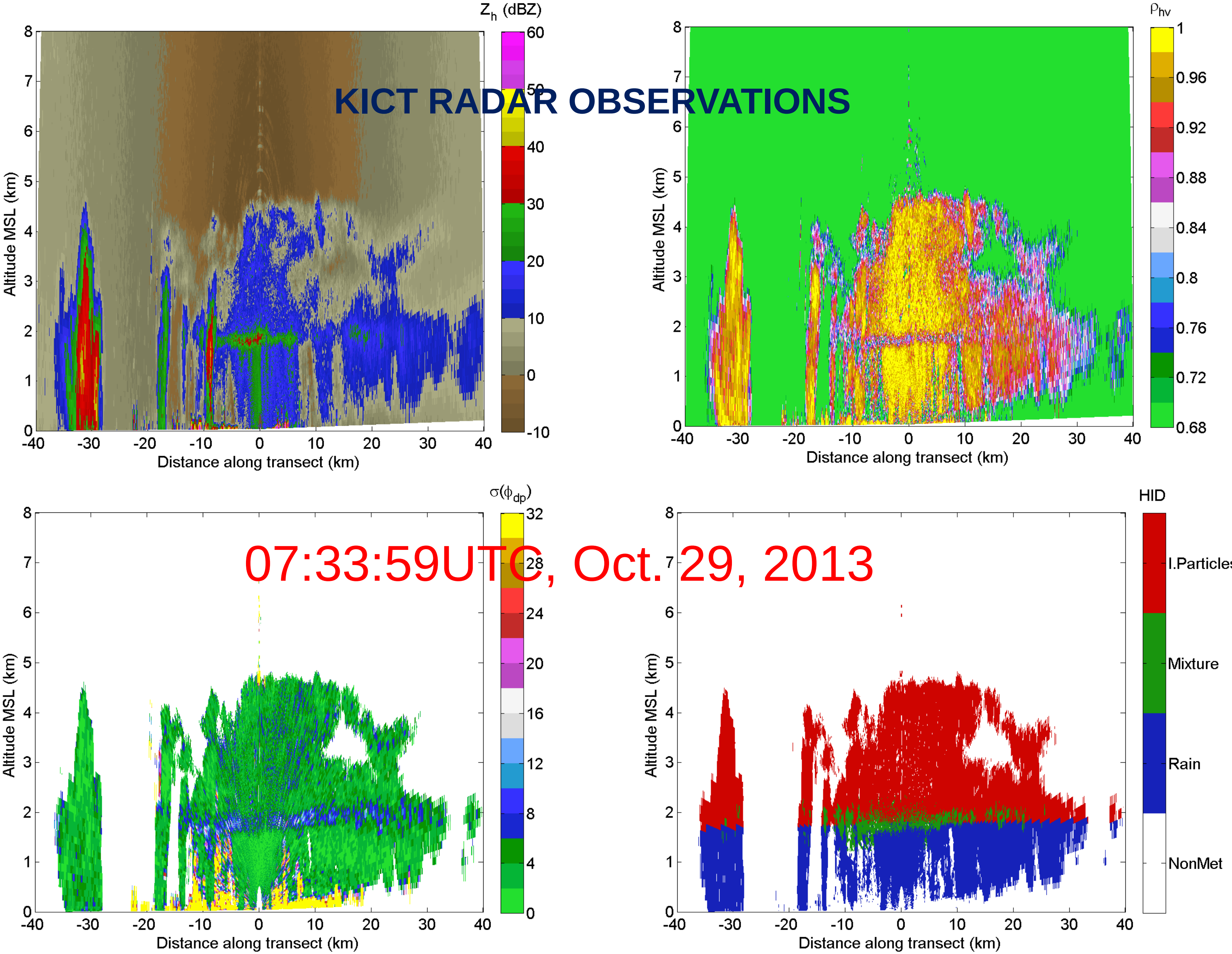


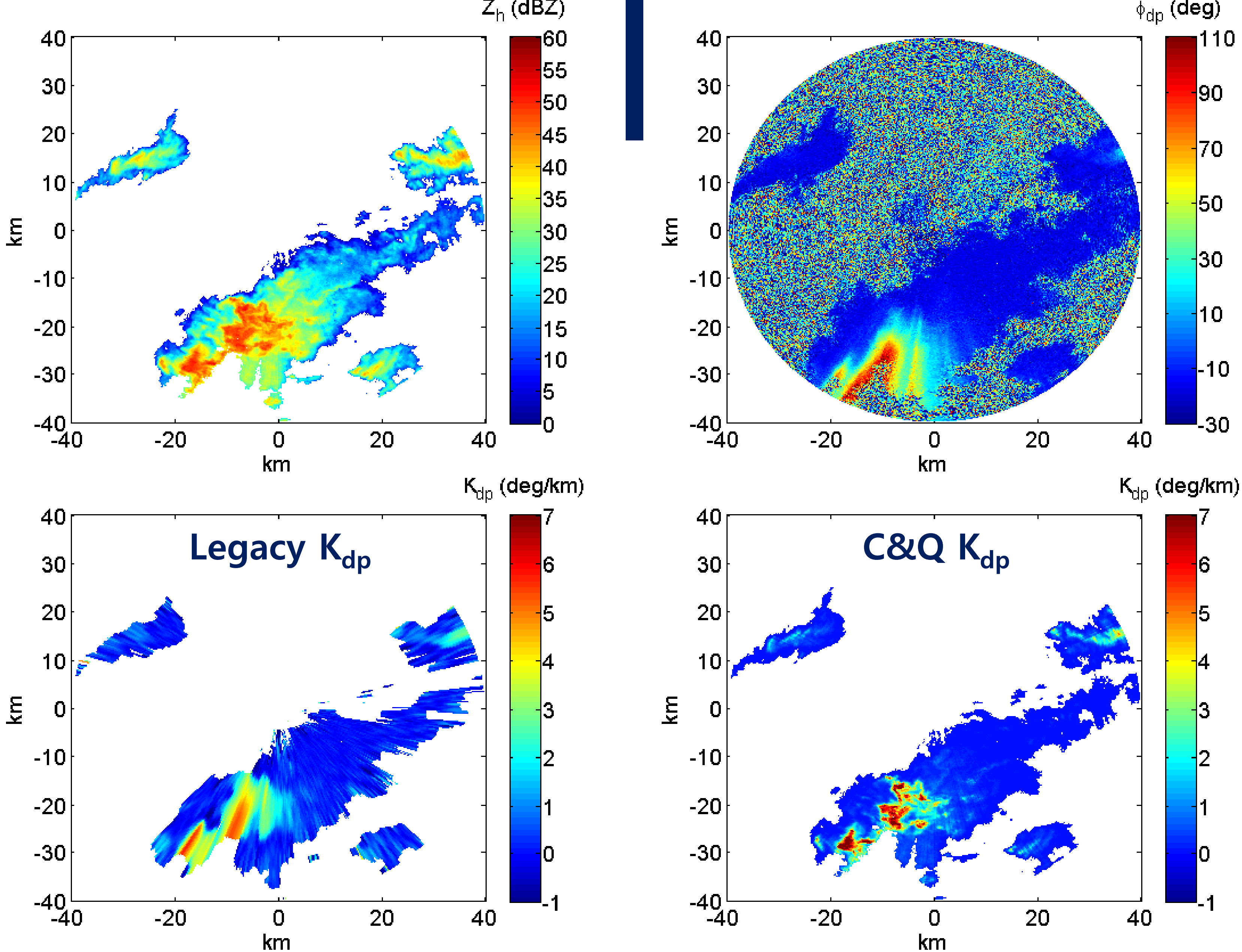
2. K_{dp} Retrieval

$$R = cK_{dp}^{d}$$

3. Rainfall estimation

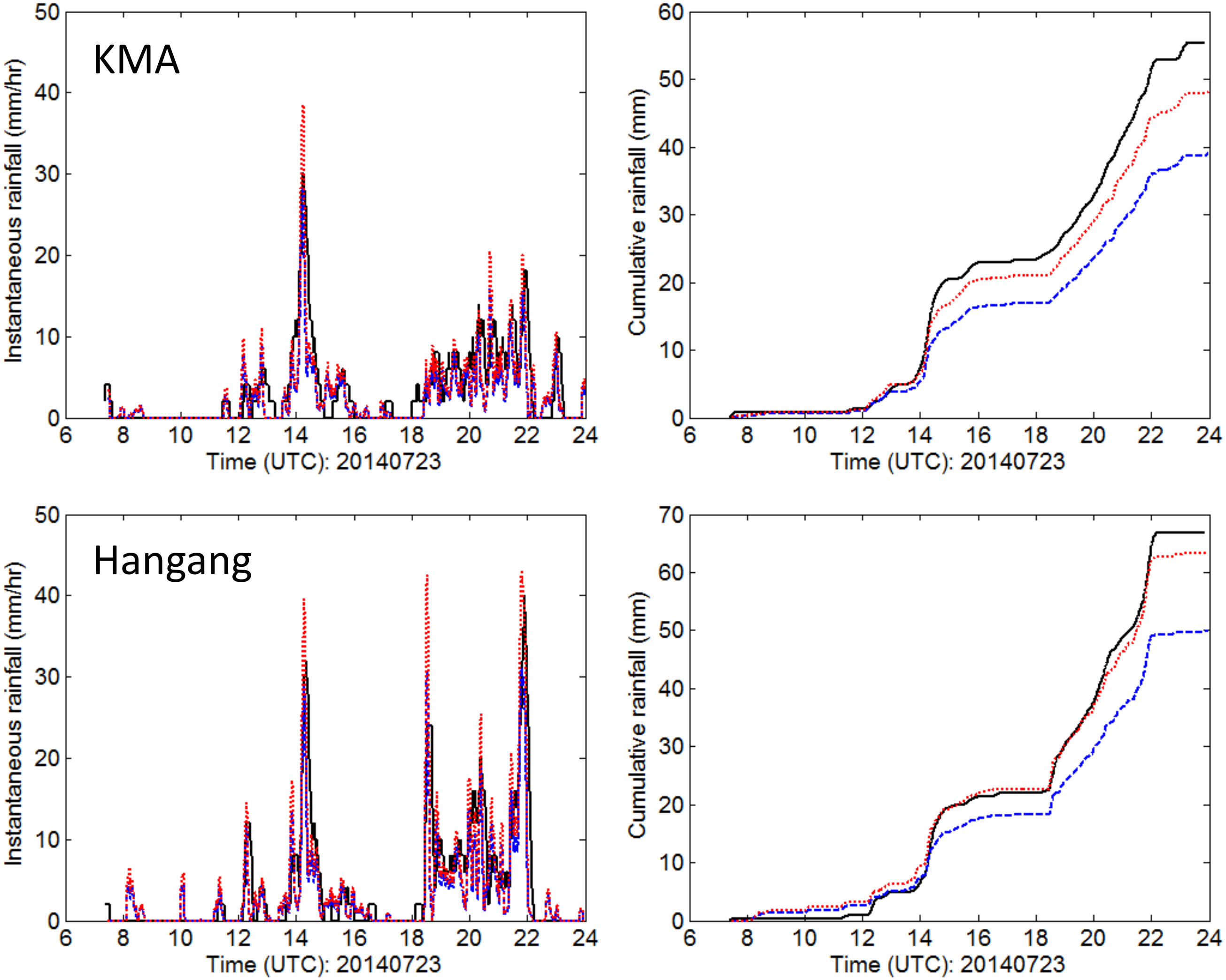
KICT RADAR OBSERVATIONS





01:25:57UTC, Sep. 13, 2013

Comparison of Radar and Ground Gauge Rainfall



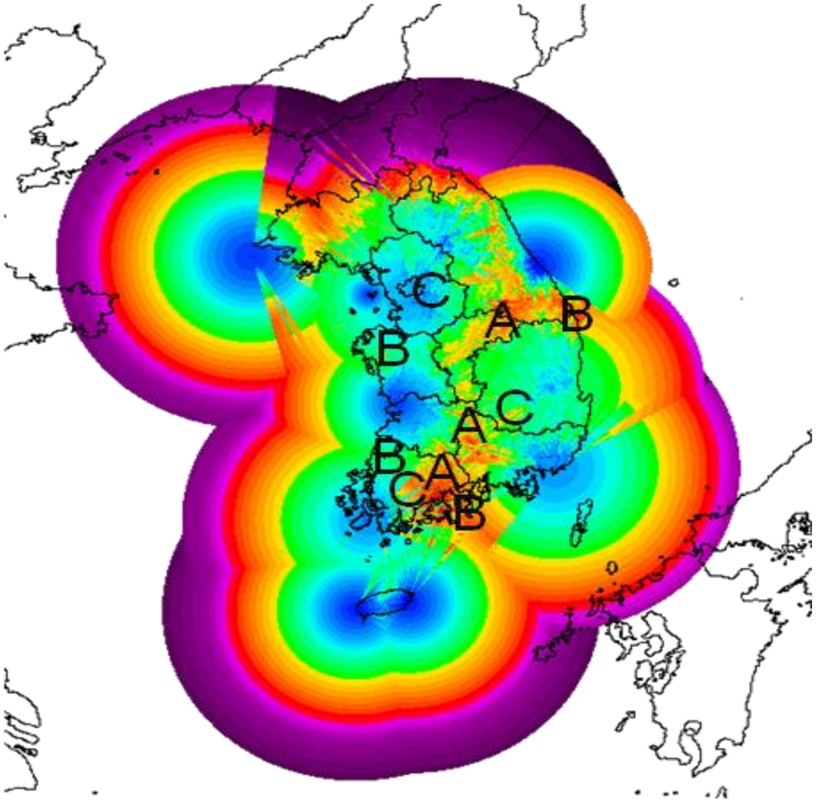
Black : rain gauge

Red : $\boldsymbol{R(K_{dp}) = 23.7K_{dp}^{0.87}}$ **(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

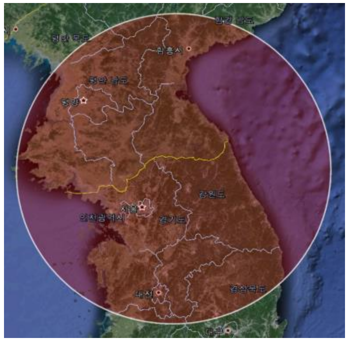
A: Mountainous areas

B: Coastal areas

C: Urban areas

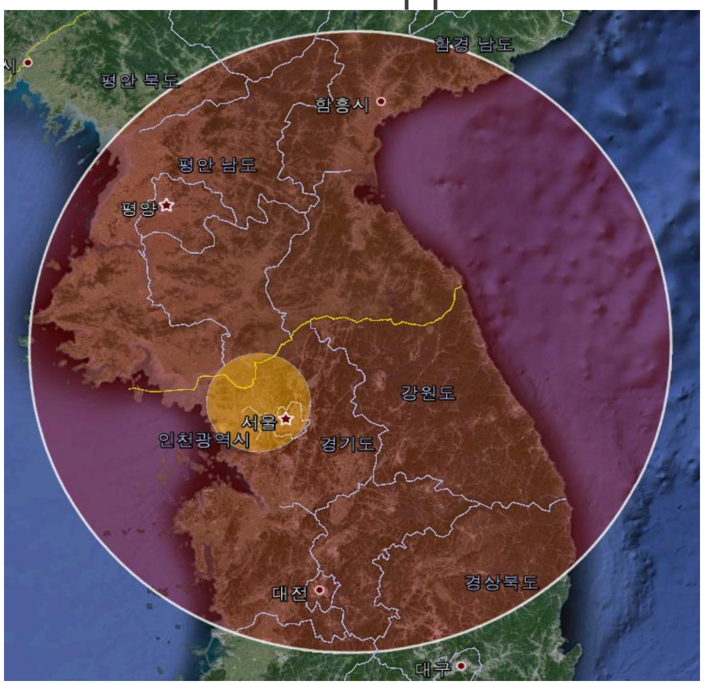
Integrated use of both S-band and X-band radars

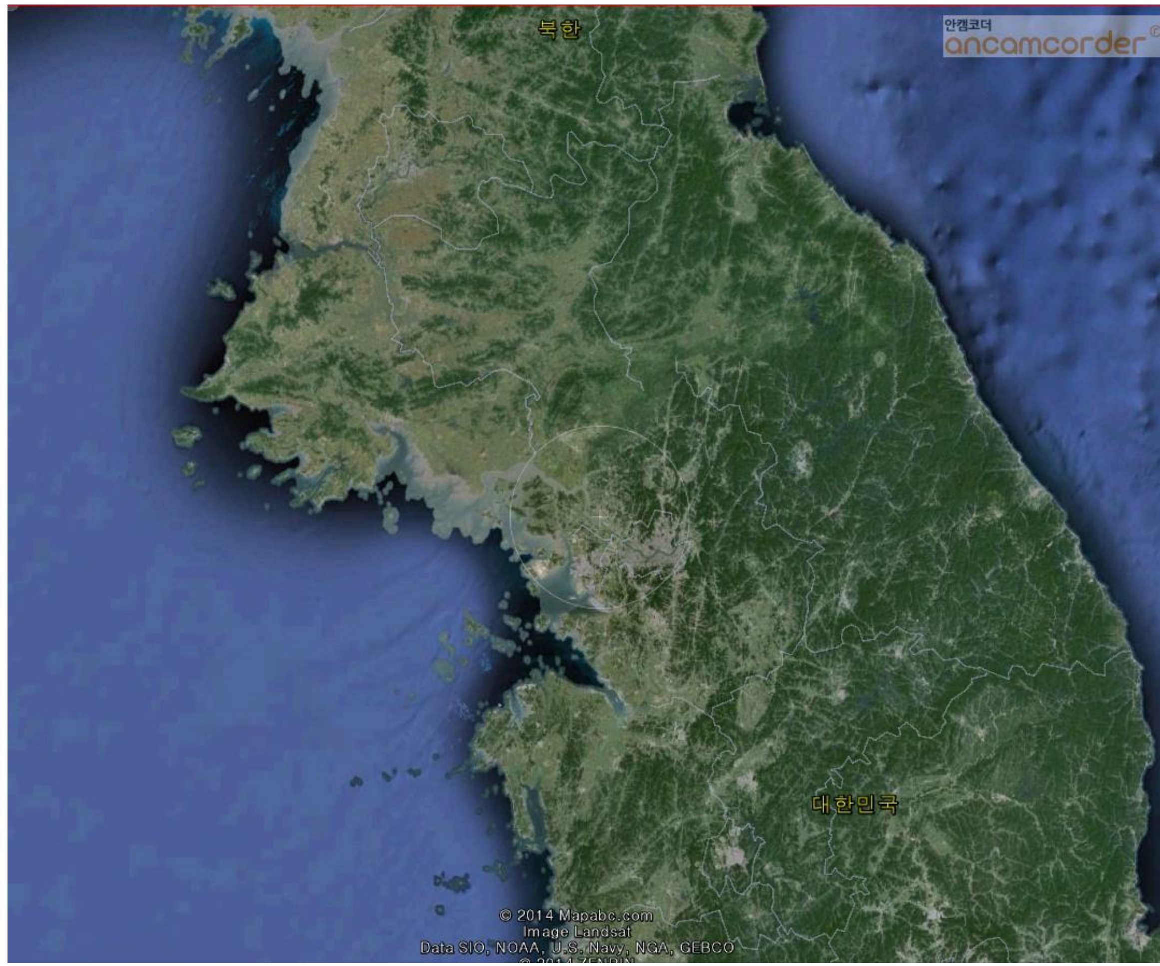
<KMA:S-band>



<KICT:X-band>

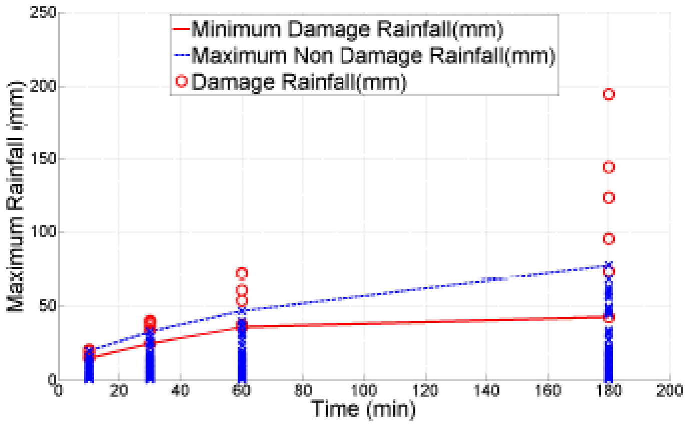
<Overlapped>





Urban Flash Flood Forecasting and Warning

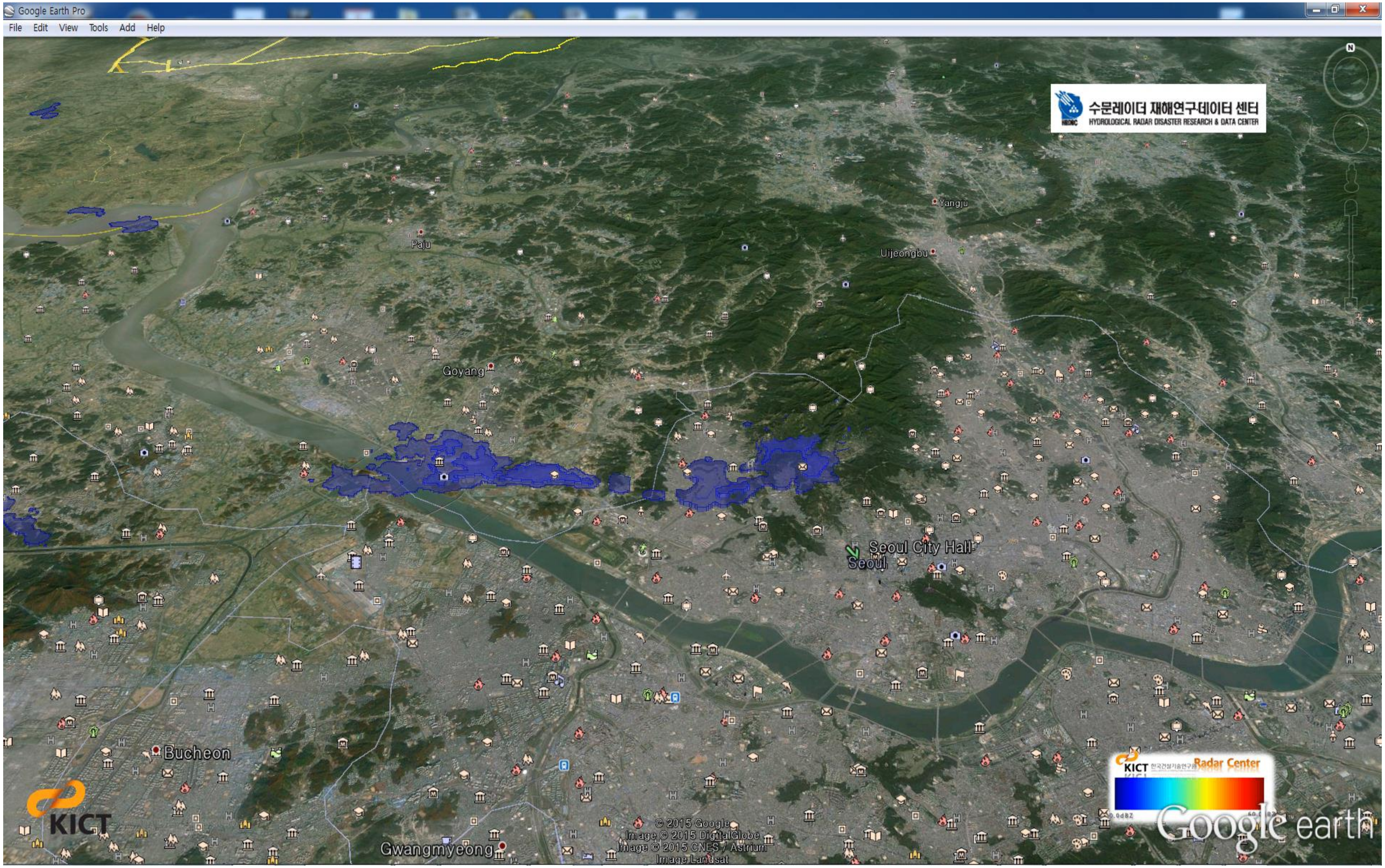
- Pre-analysis of relationship between historic rainfalls and flash floods



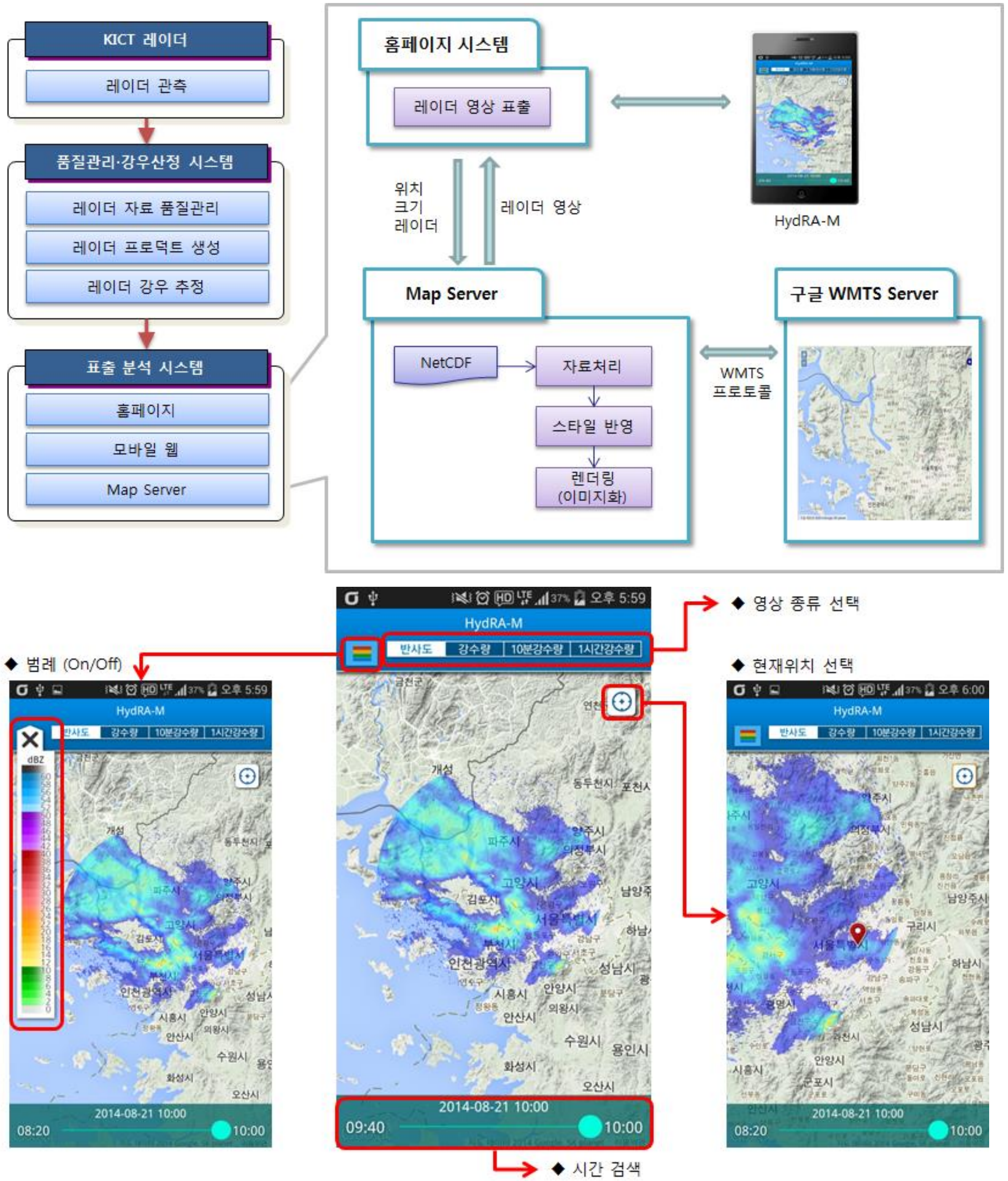
- Threshold rainfall(mm) triggering flash flood

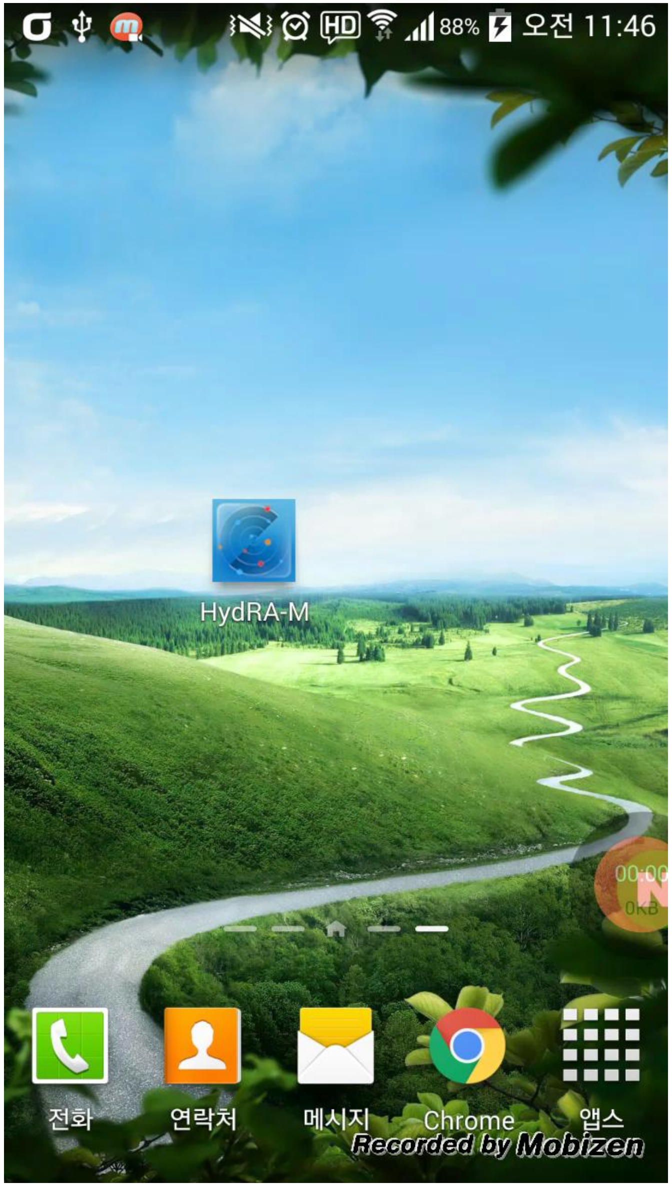
district	10min	30min	1hr	3hr	6hr
Gangnam	20	30	47	73	108
Seocho	18	34	40	77	110

Urban Flash Flood Forecasting and Warning



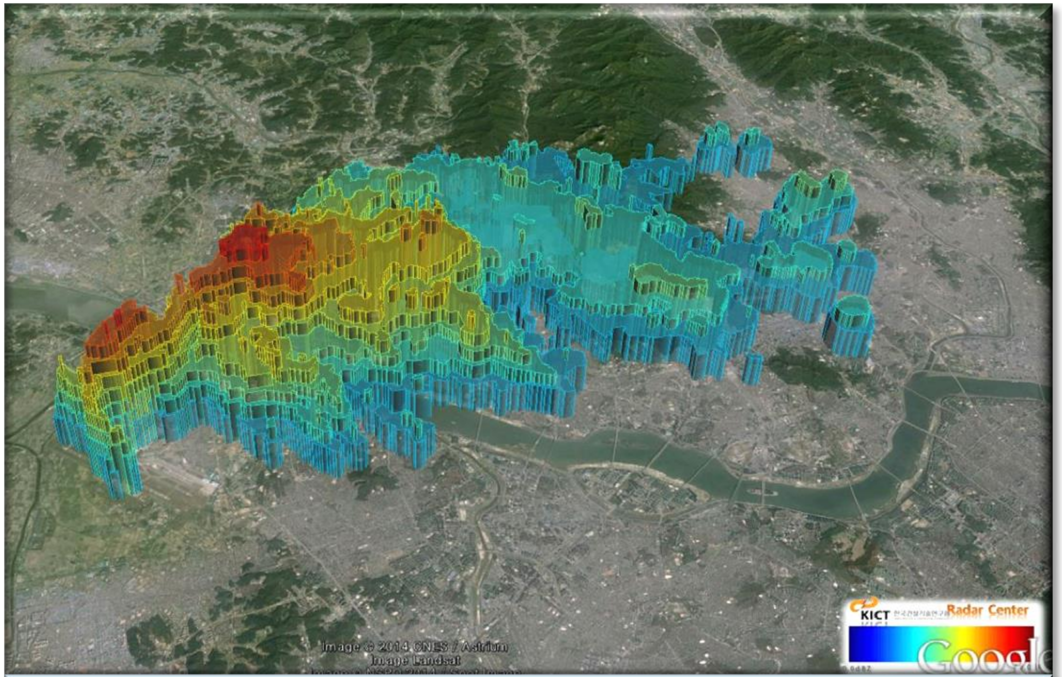
Location-based Mobile Service of Flash Flood Warning

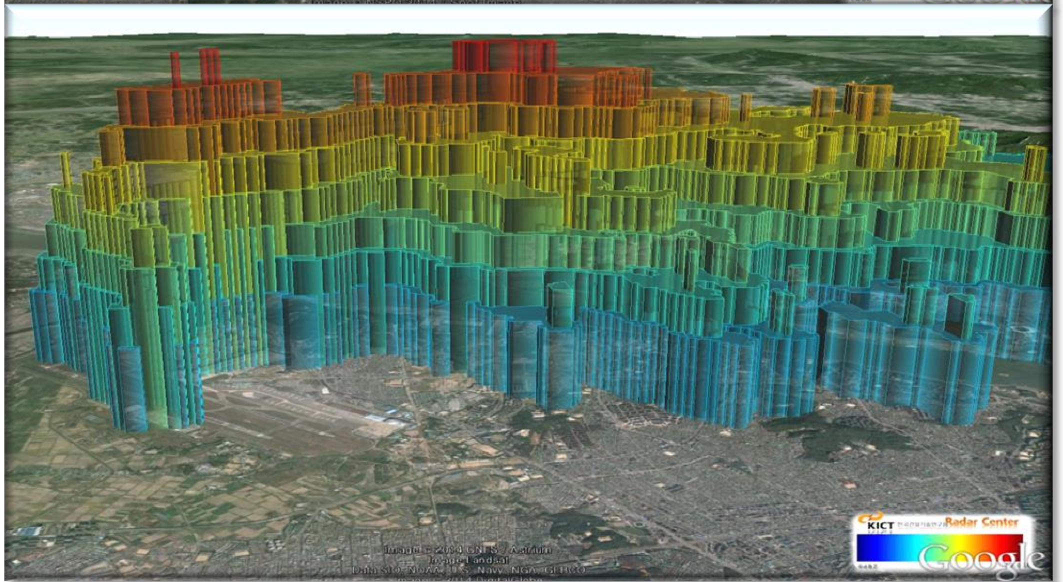


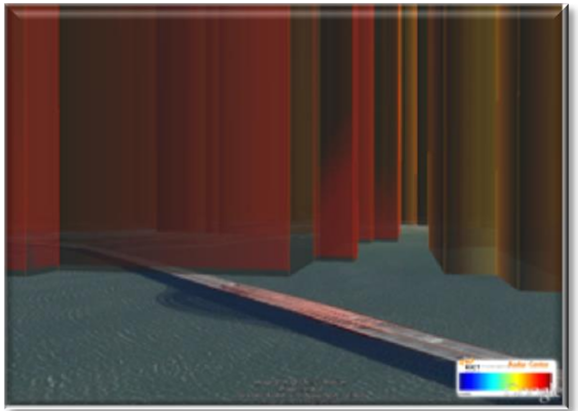


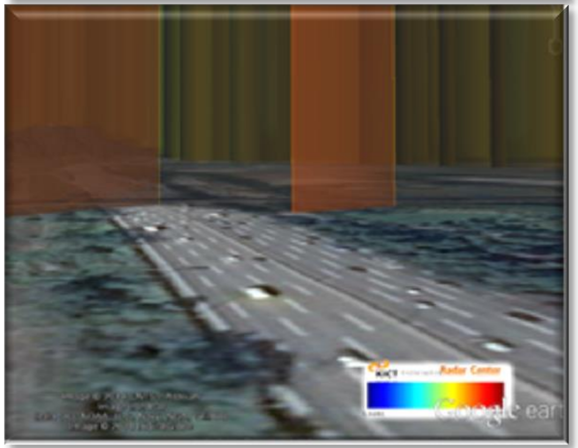
Combination of Radar Information and Augmented Reality

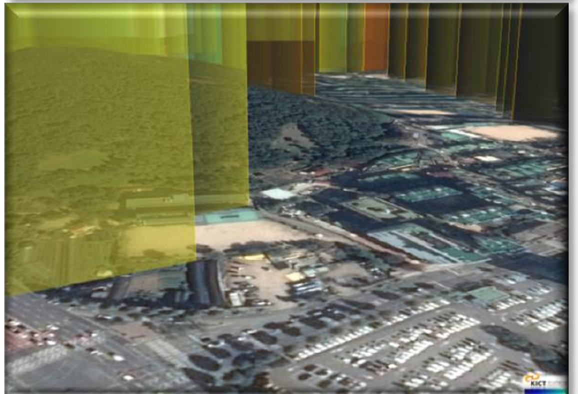
Combination of Radar Information and Augmented Reality







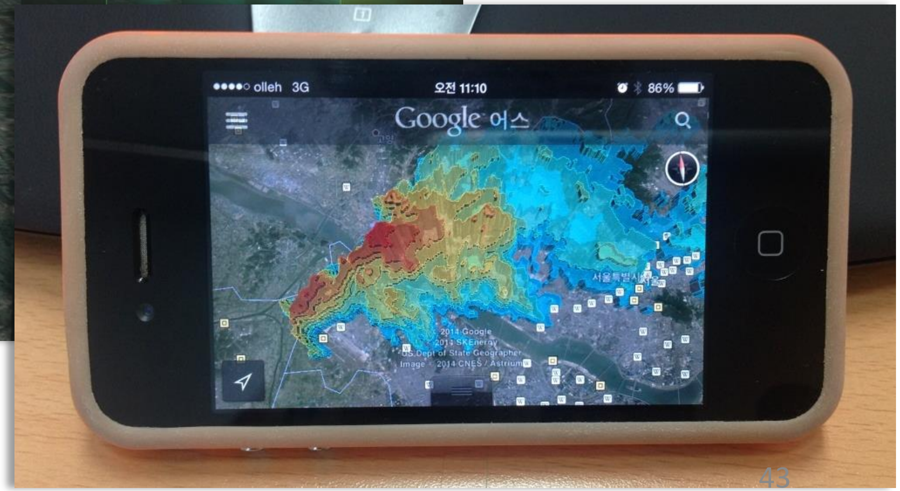




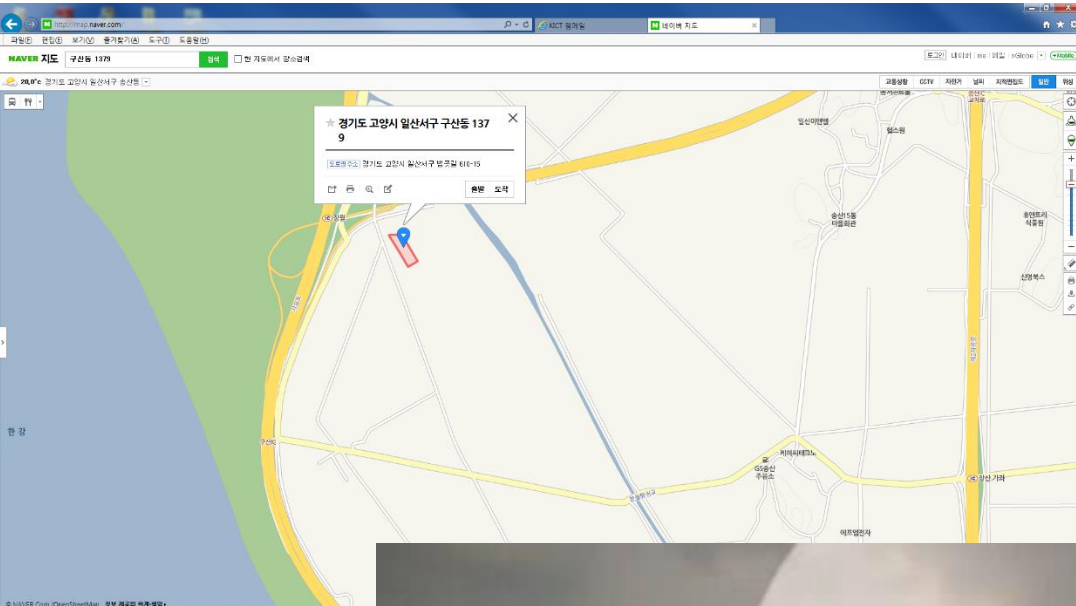
Combination of Radar Information and Augmented Reality

Mobile 3D precipitation information system

: Iphone, IPad



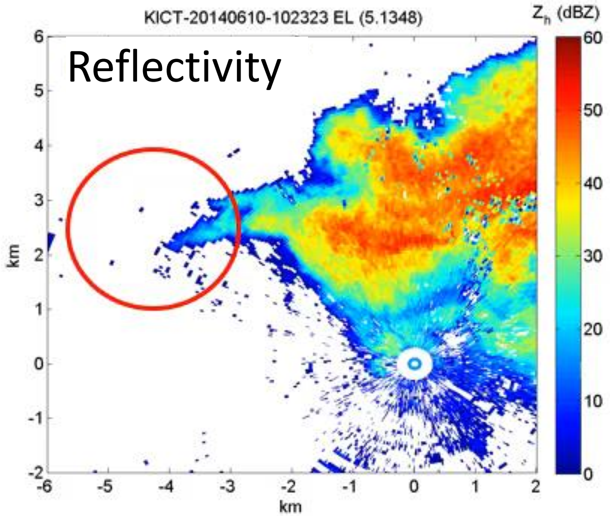
KICT radar observation:
Tornado case (June 10, 2014 19:20-19:45 KST)

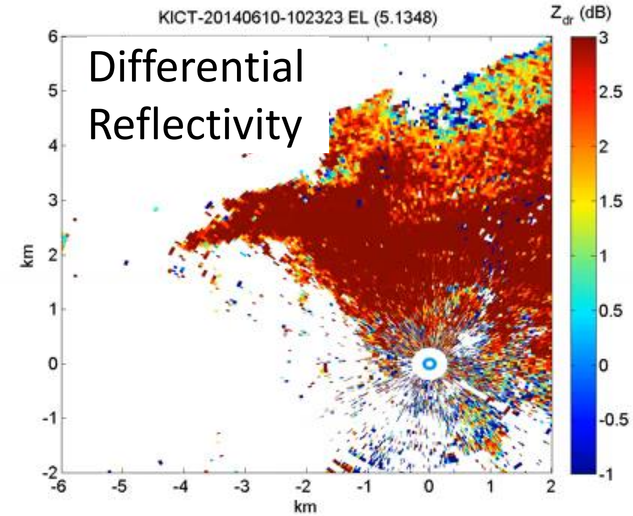


KICT radar observation:
Tornado case (June 10, 2014 19:20-19:45 KST)

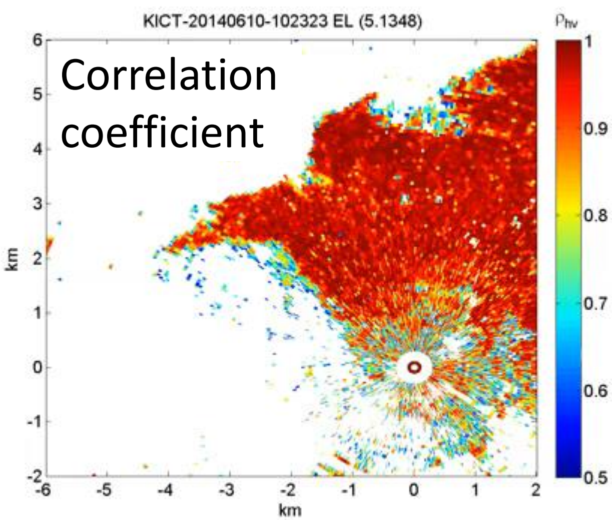
KICT radar observation:
Tornado case (June 10, 2014 19:20-19:45 KST)

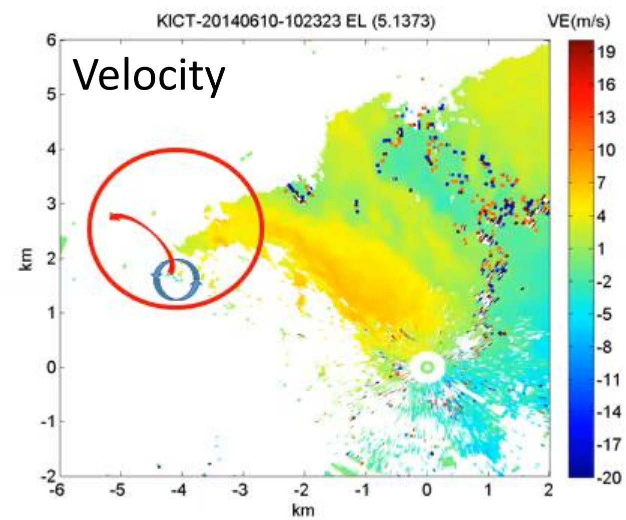
KICT radar observation:
Tornado case (June 10, 2014 19:20-19:45 KST)



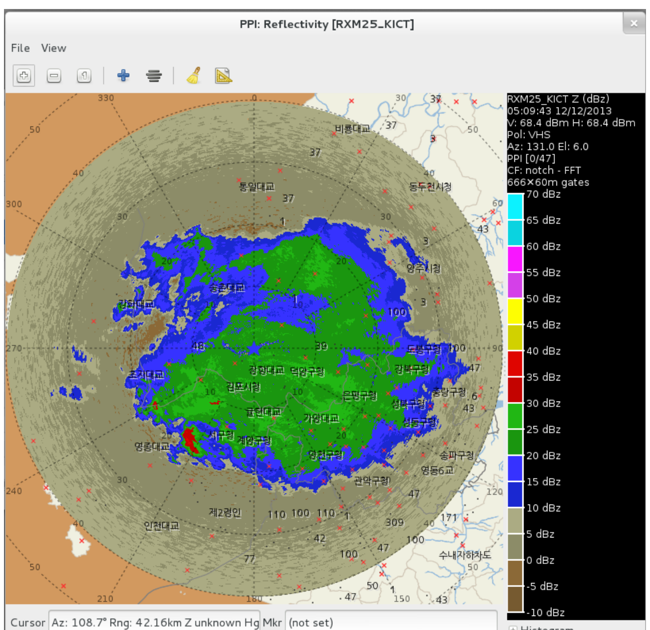


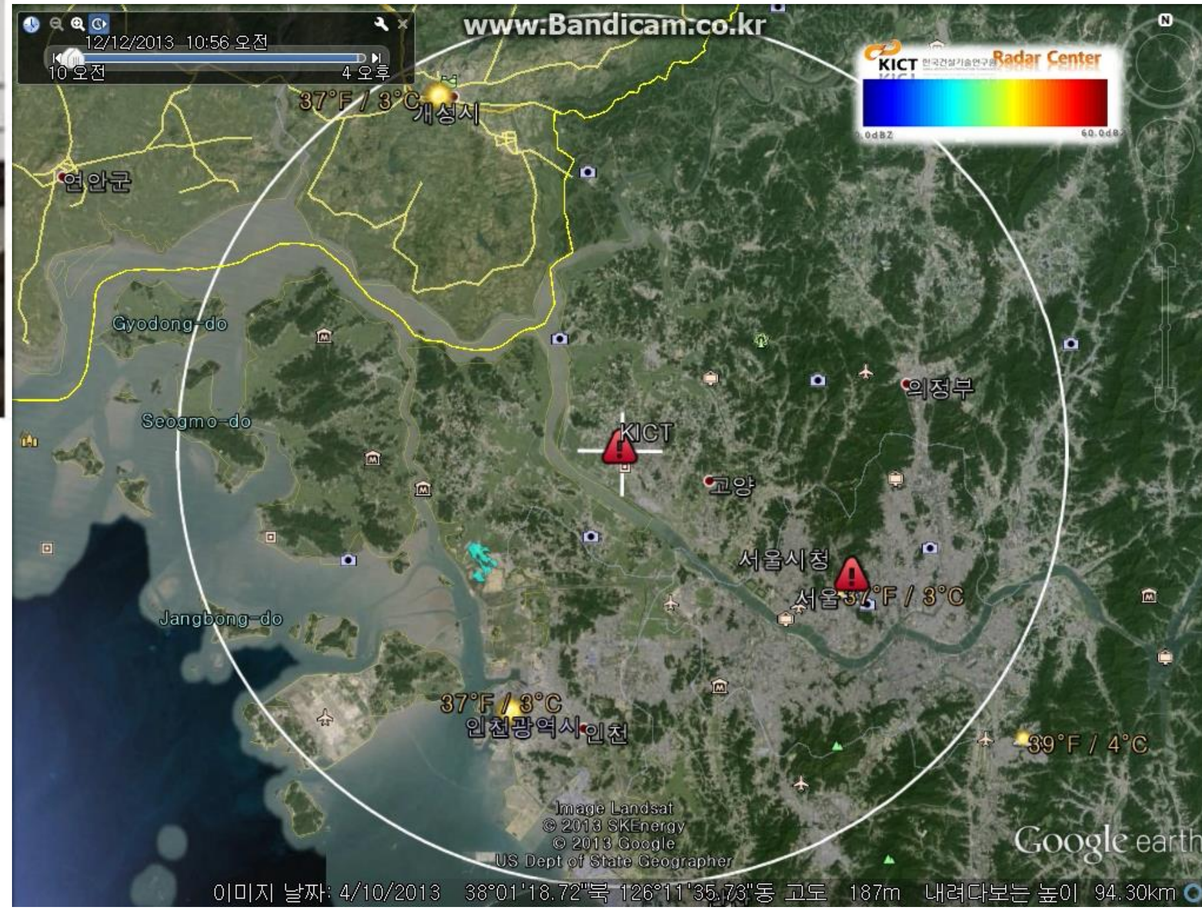
약한 징후

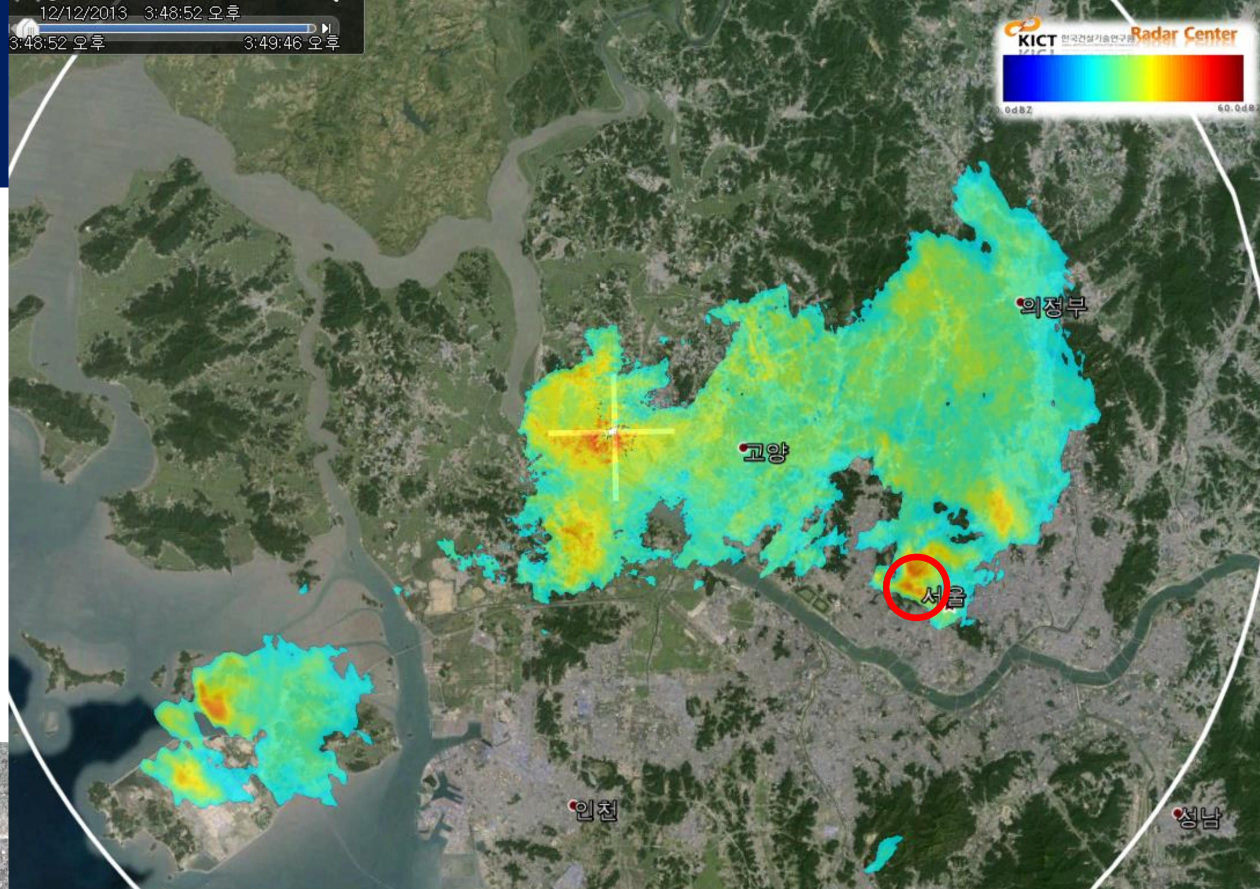


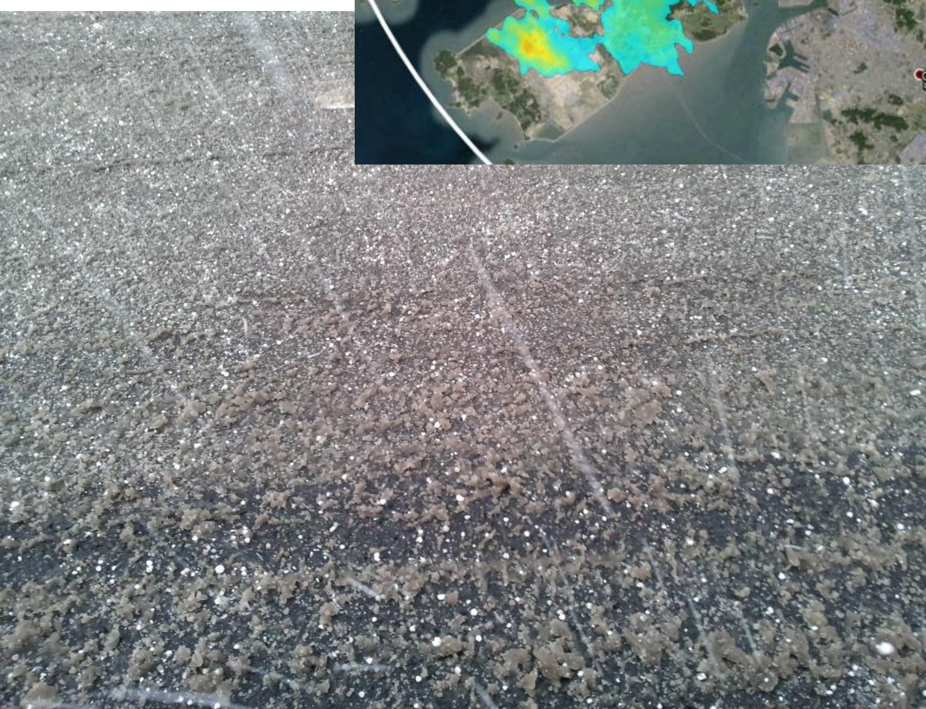


KICT radar observation
Snow storm (Dec. 12 2013 11:00-17:00 KST)






12/12/2013 3:48:52 오후
3:48:52 오후
3:49:46 오후
KICT
Radar Center
0dBZ
60.0dBZ
의정부
고양
서울
인천
성남



Thank you for your attention!

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