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

Topic C: River and Urban Flash Flood Forecasting and Mitigation

(C-2) Rainfall Radar System and Its Utilization for Flood Warning

Nov. 5, 2015

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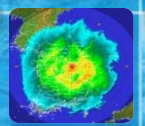


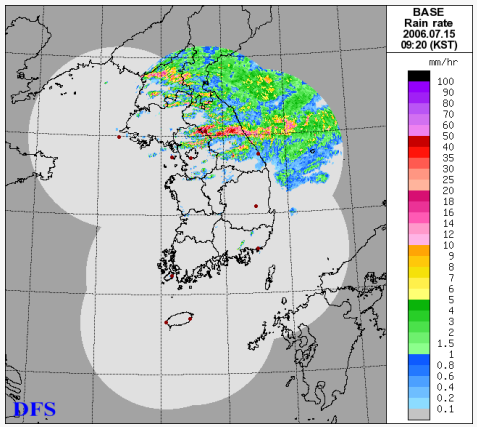

Contents

1. New Vision of Flood Forecast
2. Rainfall Radar (RR) System and Operation
3. RR's Utilization for Flood Warning

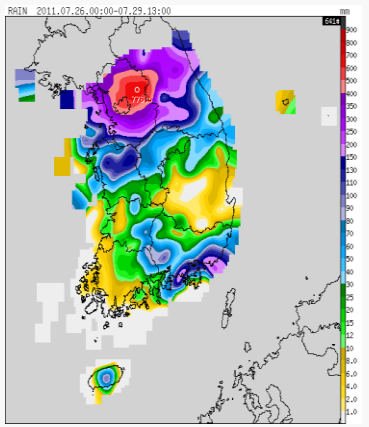
1. New Vision of Flood Forecast

Rainfall Characteristics are Changing

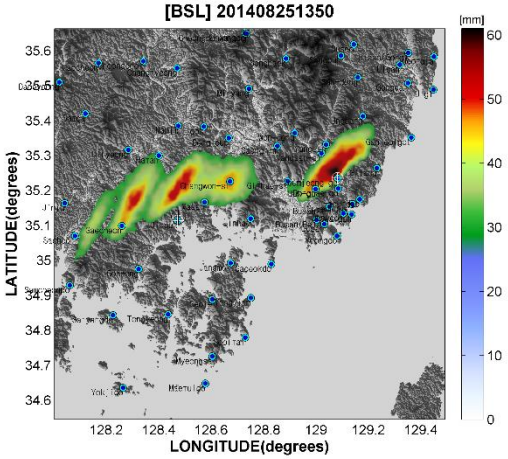
More Locally Concentrated Heavy Rainfall



Rainfall in Jul. 2005



Rainfall in Jul. 2011



Rainfall in Aug. 2014

Stronger Rainfall Intensity

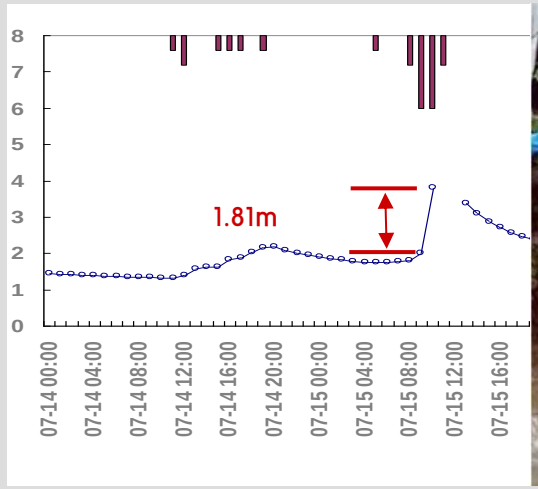
Rapid Water Level Rise due to Localized Torrential Rainfall
Bringing Secondary Damage due to Landslide

Flood Characteristics are Changing

Typical Flash Flood

Rapid rise of Water Level in a short time (Urban and Mountainous Area)

Difficulties in Evacuating due to Rapid River Flow



Increase of Frequency Exceeding Design Flood

2002 : Typhoon RUSA, Gangnung, 870mm/day(PMP)

2006 : Upstream of Han River, Exceeding Design Flood(80yr)

2011 : Levee Overtopping in Tributary Rivers

Damage Types are Changing(1/3)

Vehicles Submerged and Casualties in the river

- Increasing Use of Waterfront Facilities
- Railways and Roads around the River
- Parking Area in flood plane
- Camping and Performing Area in the Waterfront

Flooded Roads(2011)

Parking Area(Tancheon, 2013)

Damage Types are Changing(2/3)

Submerged Roads and Residential Area

Drainage System with Low Design Rainfall Frequency (5~10yr)
Flood Pumping Station with Low Design Frequency (less than 10yr)
Flood Damage from the Lack of Urban Drainage Ability

Gangnam(2011)

Suwon(2012)

Gonjiam(2013)

ChunCheon(2013)

Busan(2014)

Damage Types are Changing(3/3)

Landslide in the Urban Area

Increasing Damage Scale caused by Localized Torrential Rainfall
(ex. 2002: Ty. RUSA, 2003: Ty. MAEMI, 2011: Umyun Mt., 2012: Gunsan)

Umyun Mt.(2011)

Gunsan(2012)

Providing for Flood Forecast & Information

Flood Forecast

One of the Non-Structural Countermeasure
Forecasting River Flow
Informing Possibility of the Floods in advance

Minimize flood damage

Forecast Size and Generation Time of the Flood → **Pre-Information Notice**

세계기상기구(World Meteorological Organization, WMO)

Definition of Flood Forecast

Predict Water Level, Stream flow, Occurrence Time, Duration of Floods caused by Rainfall or Snowmelt

Predict River Flow prior to the Floods

Providing for Flood Forecast & Information

Enforcement Rules Article No.23 of River Law in Korea

Flood Forecast is issued If Water Level is Expected to Reach or Exceed at Watch or Warning Level

- **50, 70% of Design Flood, 60, 80% of Design Flood Water Level**
- **The Current flood Forecast is being Conducted in the Event that the River Overflows its Levee**

Enforcement Rules Article No.24 of River Law in Korea

Director General of River Flood Control Office should Announce to Media Agencies, Governmental Agencies and Other Organizations

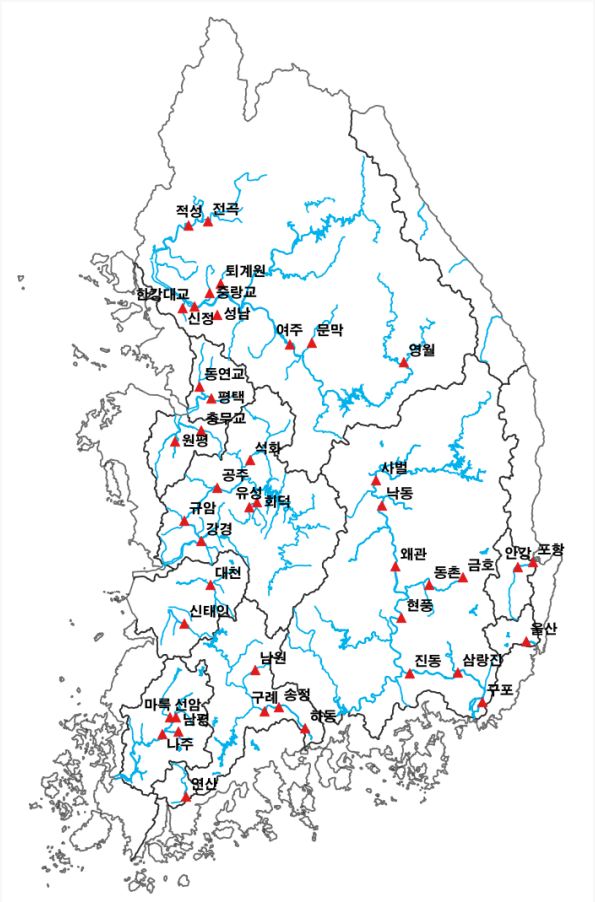
Issuing Flood Forecast to the Related Organizations

- Sanding FAX, TEXT
- Uploading Website
- Using Phone

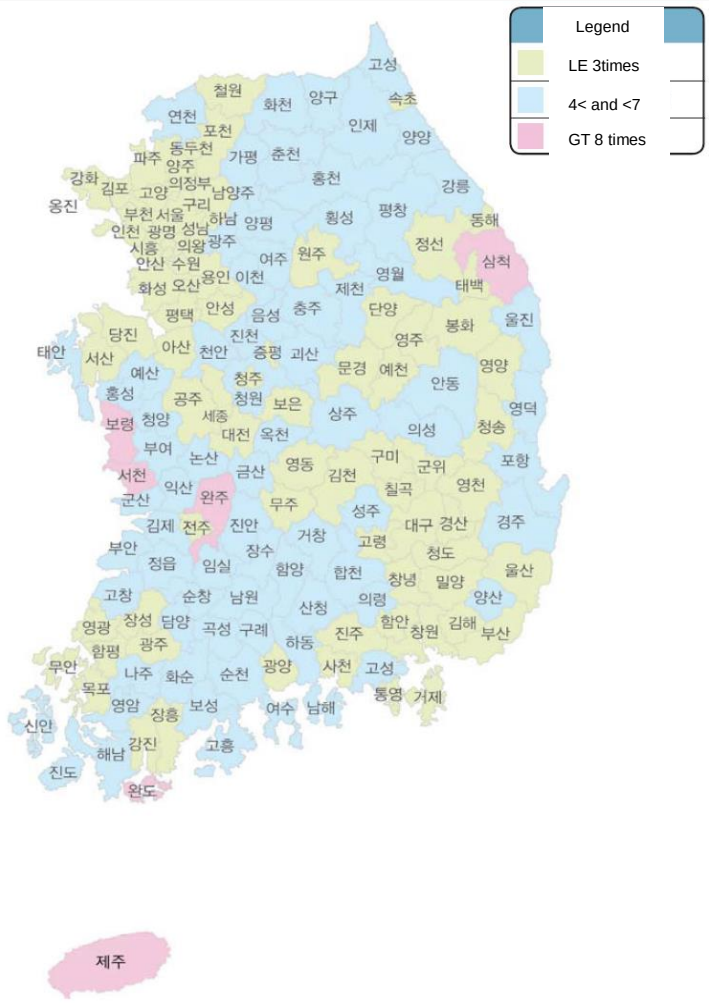
Director General

Providing for Flood Forecast & Information

Current 43 Flood Waring Stations



Severe Flood Damage Areas During Last 10 years



Providing for Flood Forecast & Information

To Improve Structural Countermeasures, First Thing is to build or Maintain Levees, But…

Informing Possibility of Damage due to Overflow of a levee through flood Forecasting. The Criteria of Watch or Warning Level is too High,

Waterfront, Camping, Performing Areas are already Submerged in Lower Water Level than Watch or Warning Level

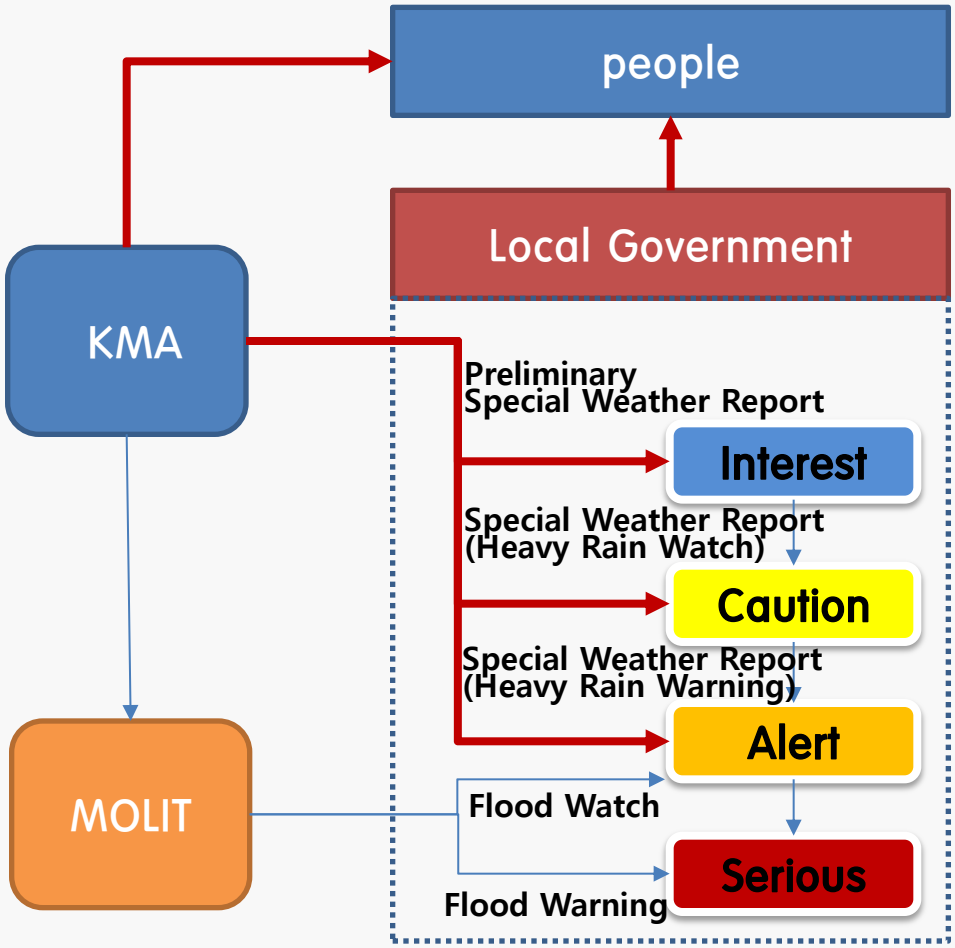
Difficulties in Reduction of Flood damage

Need to Provide Flood Risk Information Widely…

Providing Real-Time Water Level, Flow Rate, Release of Dam and Reservoir, Flood Forecast Issues, Inundation and Information to

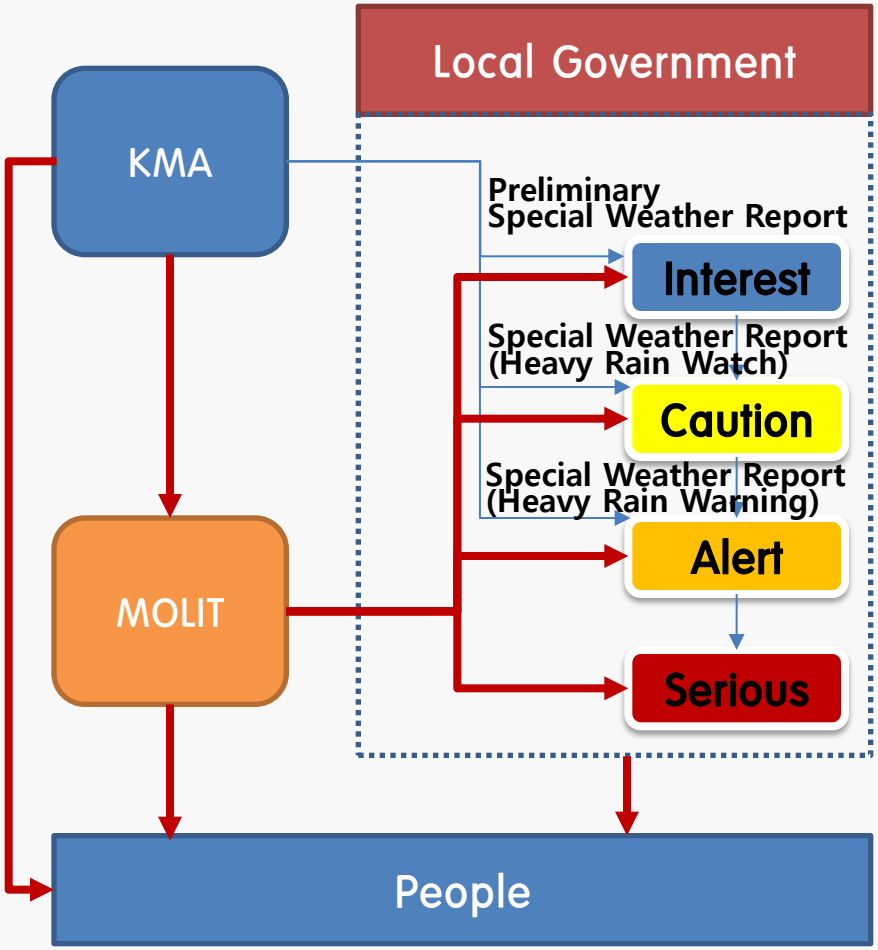
- **Main Road and Railway Control around Rivers**
- **Management of the Vulnerable Sections**
- **Waterfront Park, Bicycle Road in the flood Plane**
- **Pumping Station, Site under Construction, etc**

Status of Flood Emergency Response



- Flood Response Activities Start with Preliminary Special Weather Report (Korea Meteorological Administration)
- Flood Forecast Based on a levee is used to Evacuate Residents from the Expected flooded District
- Flood Watch and Warning is used only as Reference Data for Alert Working
- Lack of Prior Preparation about no Damage District
- Various Information, Lack of Conditions Predicted

Improvement of flood forecast



- Providing Flood Risk Information phase with 4 Levels of Flood Emergency Response
- Changing Forecasting Target from Warning station to Spatial Areas - Basin, Administrative District and Vulnerable Areas to the Floods
- Providing Various Guidelines
- Improving Organizational system

Flood Forecast Paradigm is Changing

Changing Focused on People's Life !

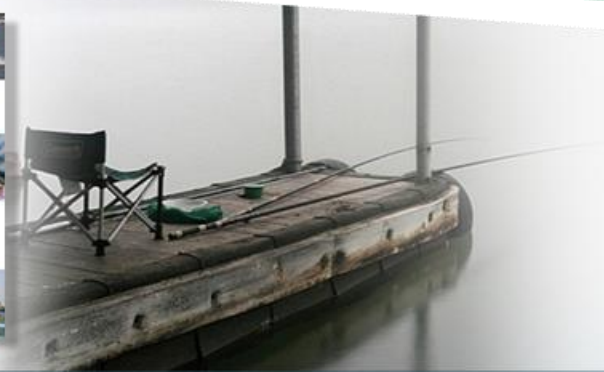
Expanding from River to Basin

Expanding Flood Forecast Area to the Administrative District

- Changing from Point(Line) to Space

Forecasting Inundation of the Infrastructure around River

- Main Road, Railway, Bikeway



Expanding Flood Forecast Area to Waterfront Park

- Parking lot, Camping, performing area

Securing Lead Time for Flood Response

Focusing on People's Life

Improving Information Providing System for Easy Delivery

- Pass Directly to the People with Smart Phone and Internet

Providing Flood Information Customized People's Life

- Leisure, Waterfront Activities, Cultural Performing

Strengthening Cooperation with Related Organizations

- Joint Training and Workshops about Hydrological, Weather, Disaster Reduction with Related Organizations

2. Rain Radar System and Operation

Contents

Flood Forecast needs Radar

- Configuration of Flood Forecast
- High Resolution Rainfall from Radar

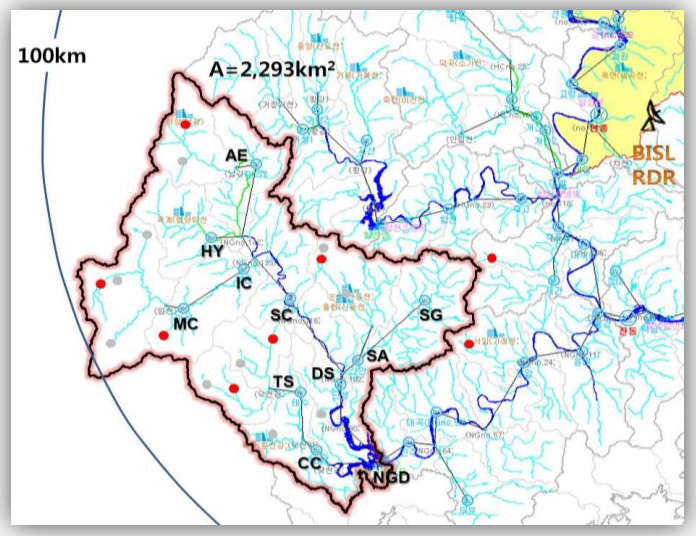
Repeating & Increasing Flood Disasters !

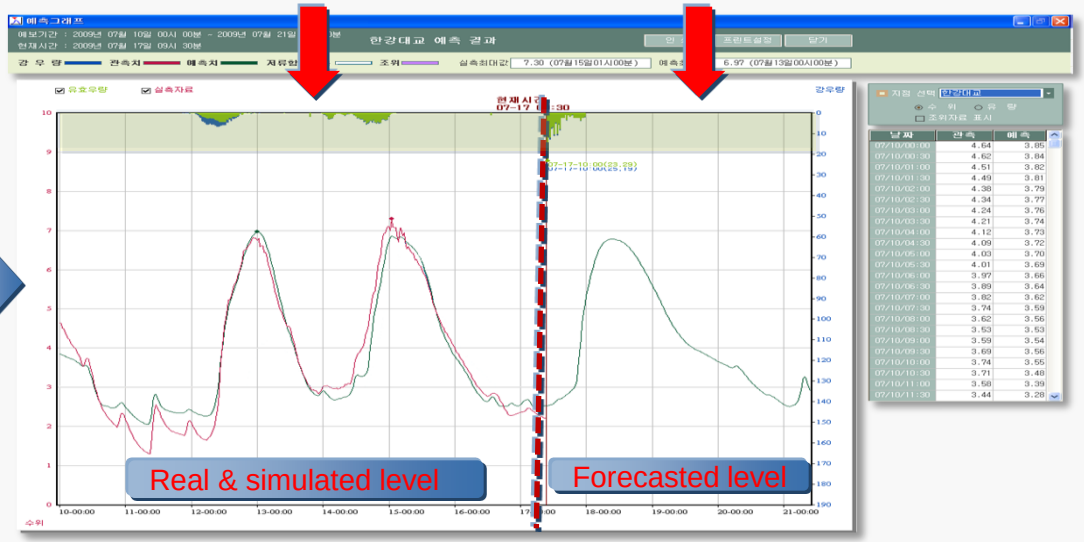
Configuration of Flood Forecast

Rainfall

measured

Forecasted





Target Area

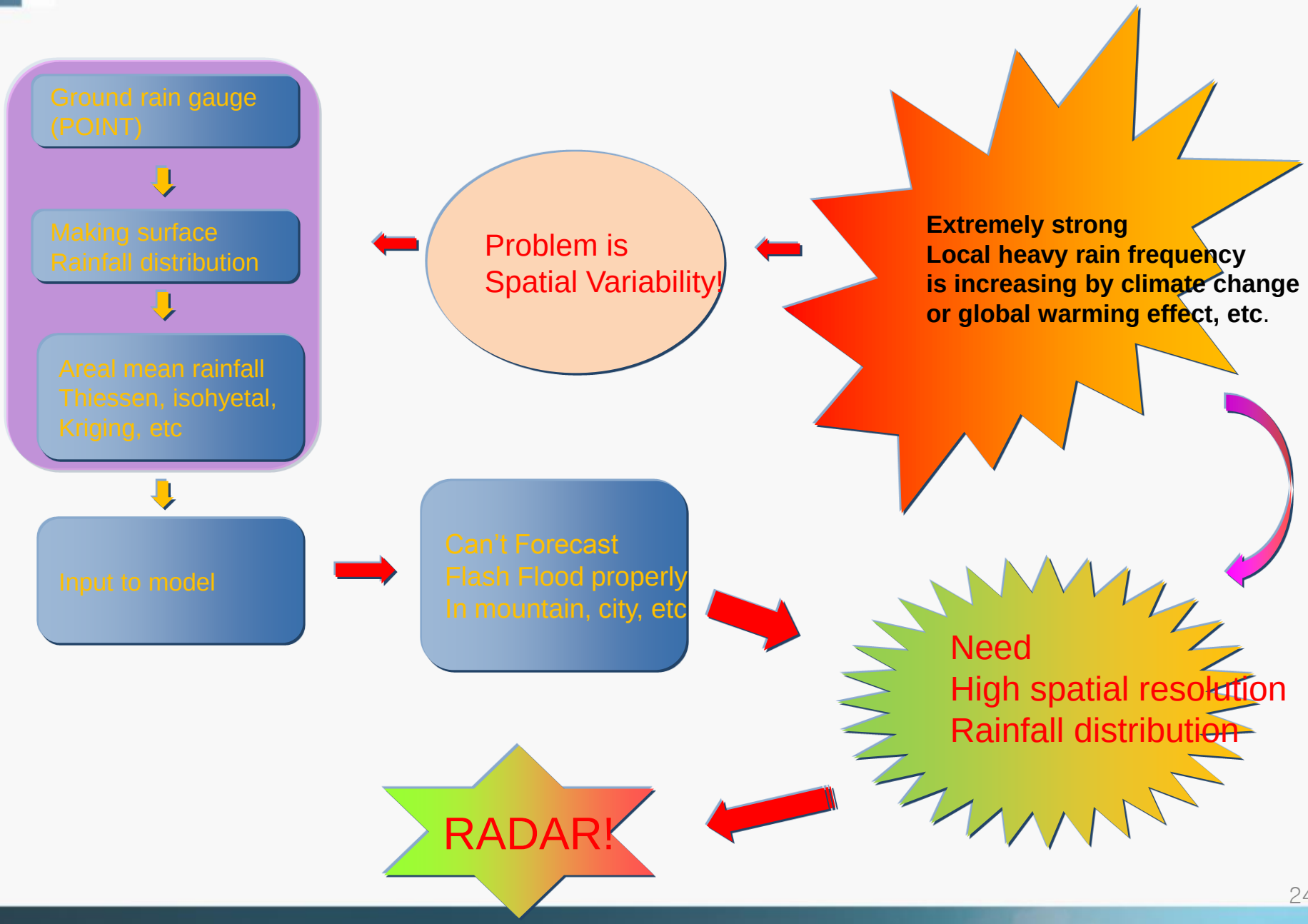
River Basin, Mountain Valley, Urban area, etc

* Rain gauge , water level, and discharge station, etc

Flood(Run-off) Model

Lumped, Distributed, Storage, etc (Hydrometeorology, GIS, Basin Characteristics)

Rainfall Data from Ground Gauges



History of FFS(Flood Forecasting System) in Korea

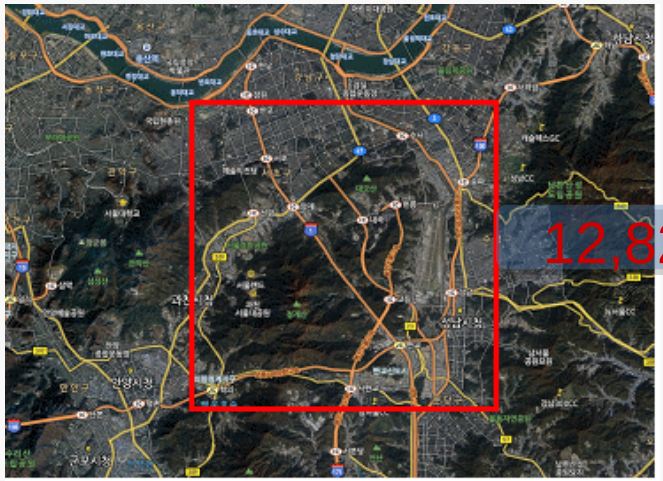
1993~ 1997	• Development of FFS for Seven Major Medium Rivers
2000	• Installation of the first Rainfall Radar at Imjin River
2002~ 2004	• Setting up Rainfall Radar Master Plan for Flood Forecasting • Development of Tributary FFS in Urban Area
2005	• Formation of River Information Center in Han River
2009~ 2016	• Installation of Six S-band Dual-Pol Rainfall Radars • Development of Flash Flood Forecasting System

Radar Gives High Resolution Rainfall Distribution

- Recently frequent local heavy rains triggered by climate change causes severe damages.
  → Traditional point rain gauge based flood forecast has shown the limits in space and time resolution

- Using rain radar which can observe areal rainfall and rain system evolution, local flash flood forecasting is possible!

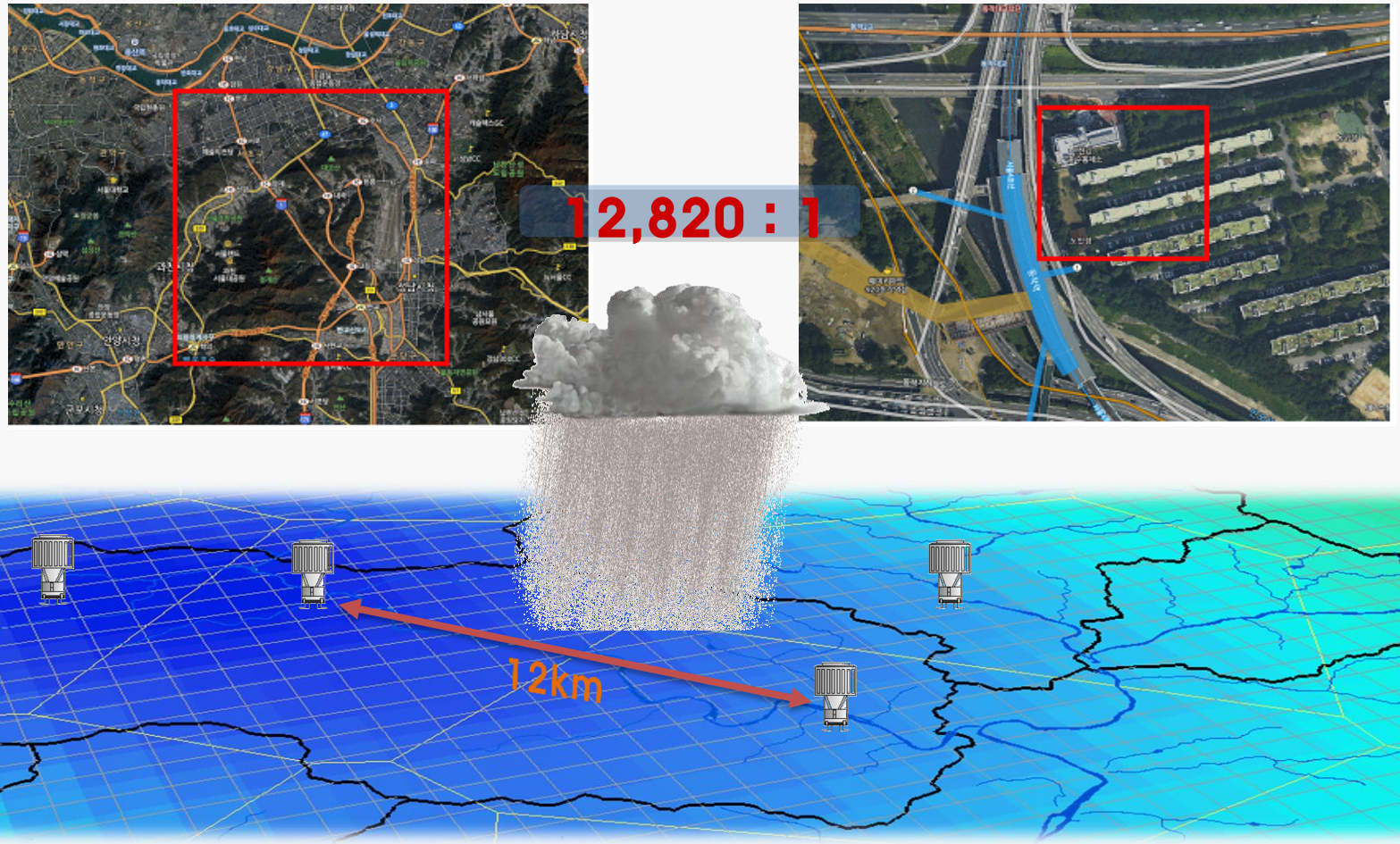
Ground rain gauge :
one per 200㎢(14km×14km), 10 min interval



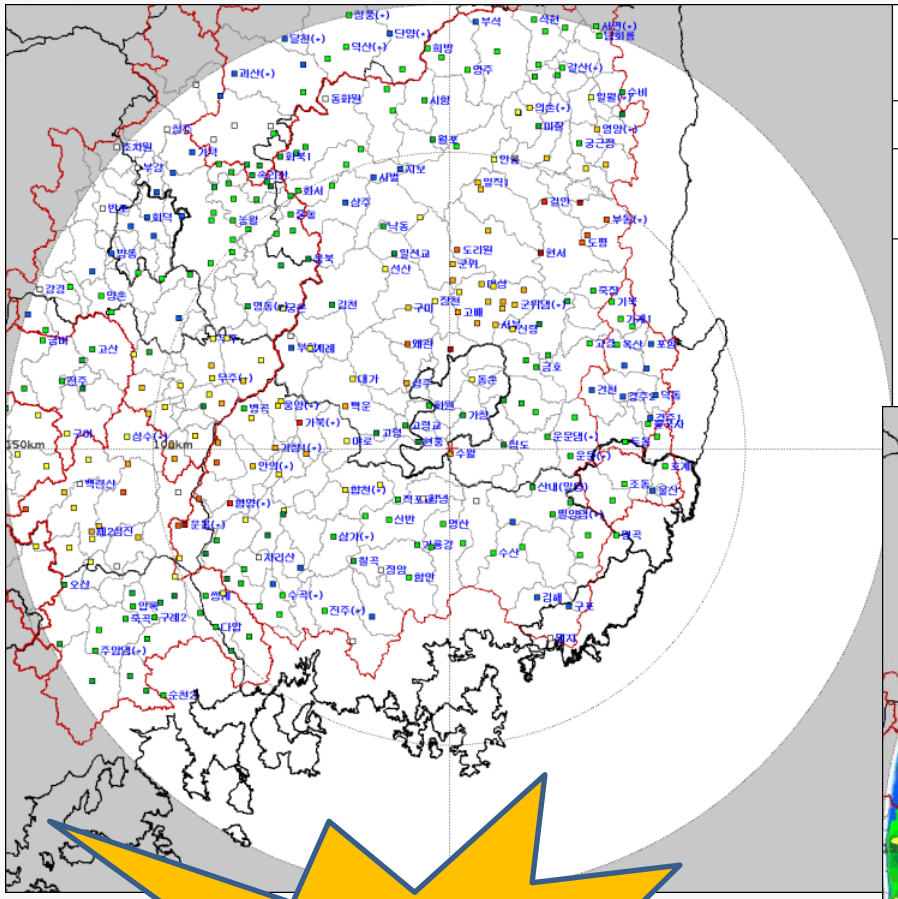
12,820 : 1

Rain radar :
~ 0.1563㎢(125m×125m), 2.5 min interval

Radar Gives High Resolution Rainfall Distribution

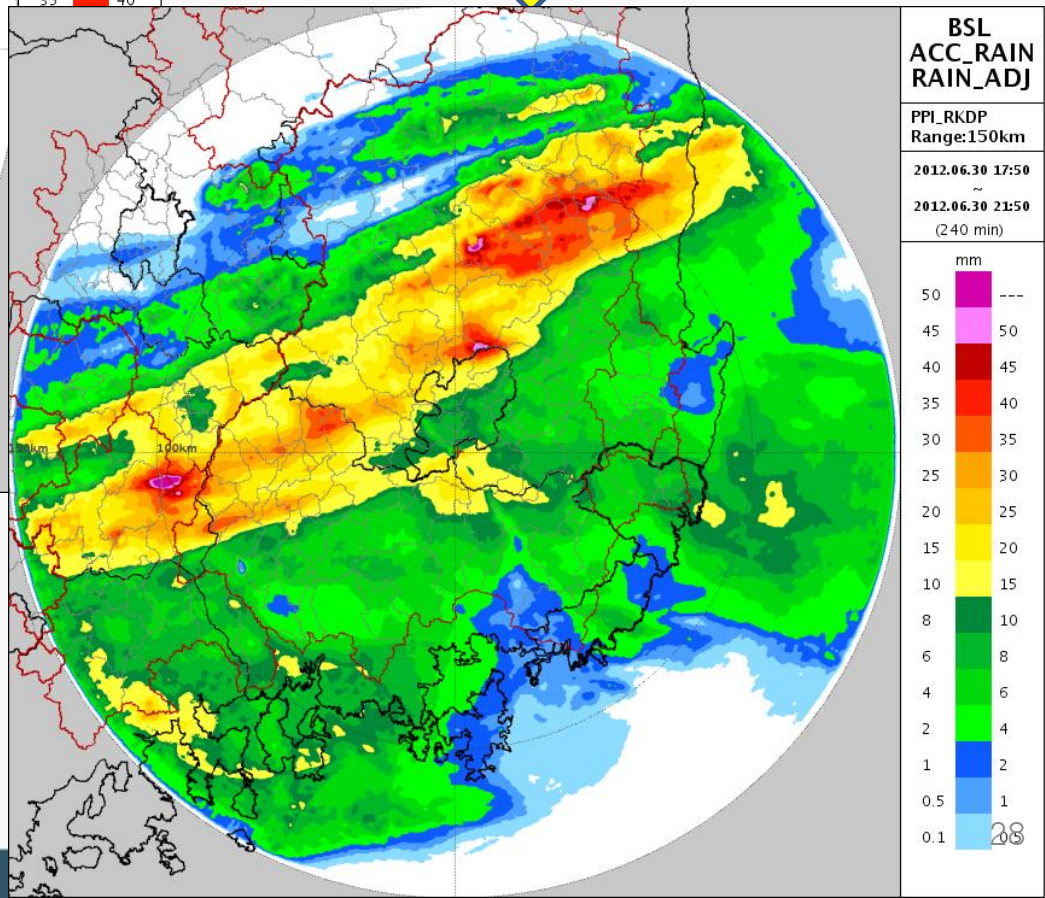


Comparison between Gauge and Radar Image

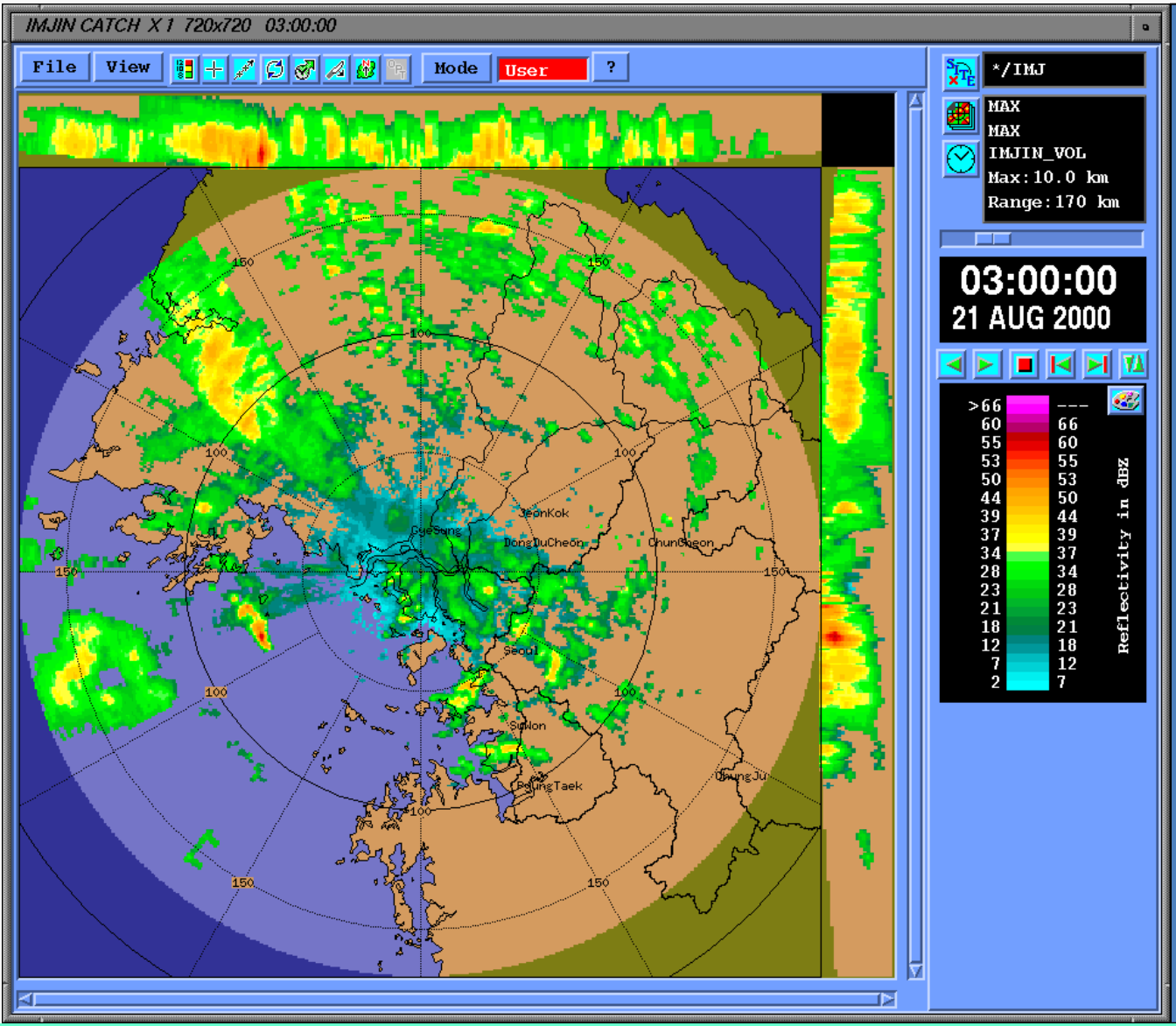


Cannot understand spatial distribution

Spatial distribution of rainfall is clear by the radar image!



General Characteristics of Radar Image



Radar Rainfall Distribution is High Resolution in Space & Time

Able to acquire the rainfall distribution, intensity, movement, development, etc. in real time base

II Radar - Generals

- What is radar?
- Historical evolution of Radar

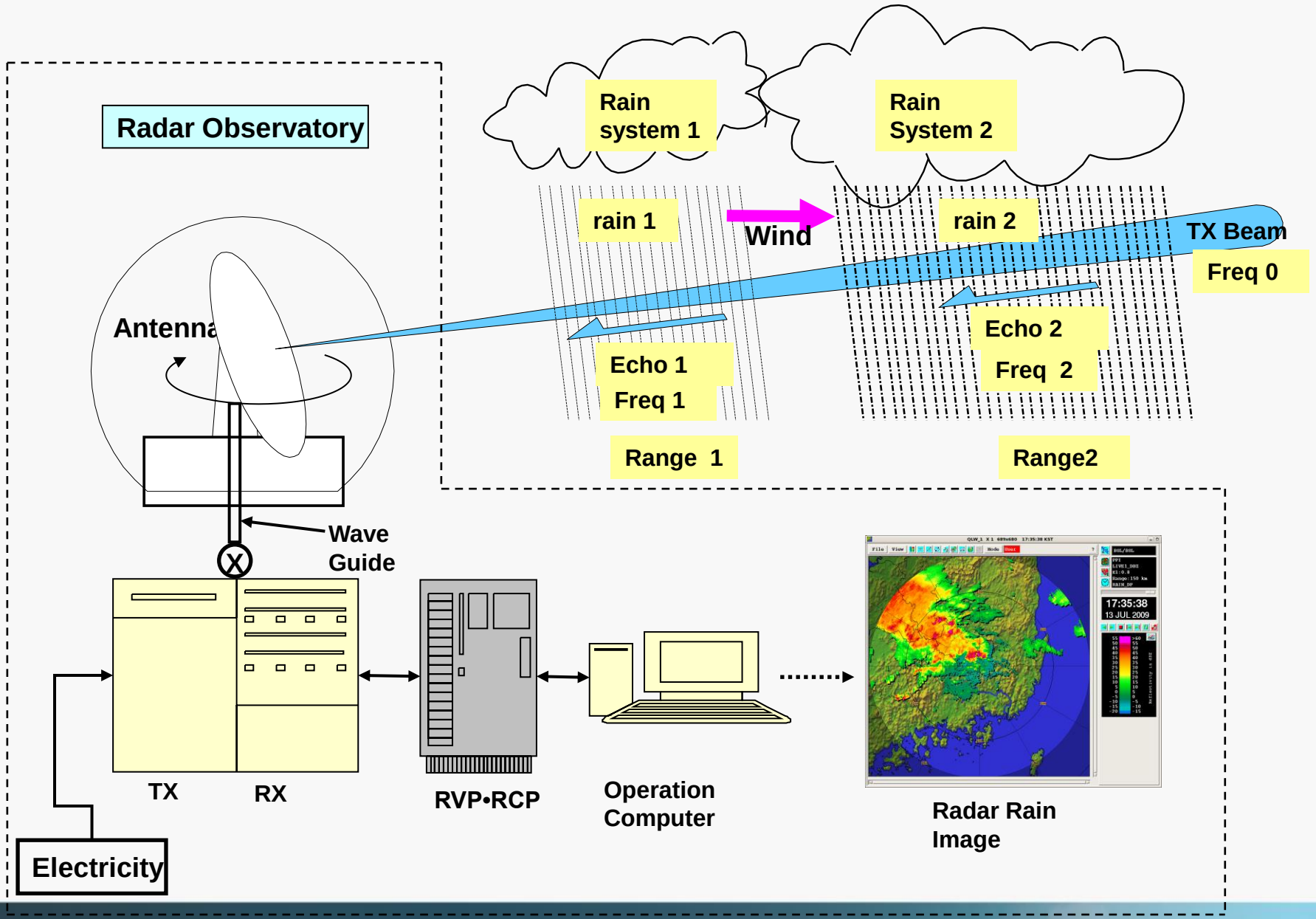
What is the Radar?

Detection Systems of Targets in the Atmosphere by Radio

Radio	EM (Electromagnetic Wave): Micro Wave
Detection	Existence(Intensity), Location(XYZ), Movement(Radial)
Targets	Precipitations, Aircrafts, insects, Chaffs, AP, etc
System	Weather(Precipitation) Radar, Air Surveillance Radar, Marine Radar, Wind Profiler, SAR, etc

Radar is an active remote sensing instrument used for detection and locating targets in the atmosphere and over seas, being utilized in various fields.

Configuration of Radar Rain Observation



What is the Radio ?

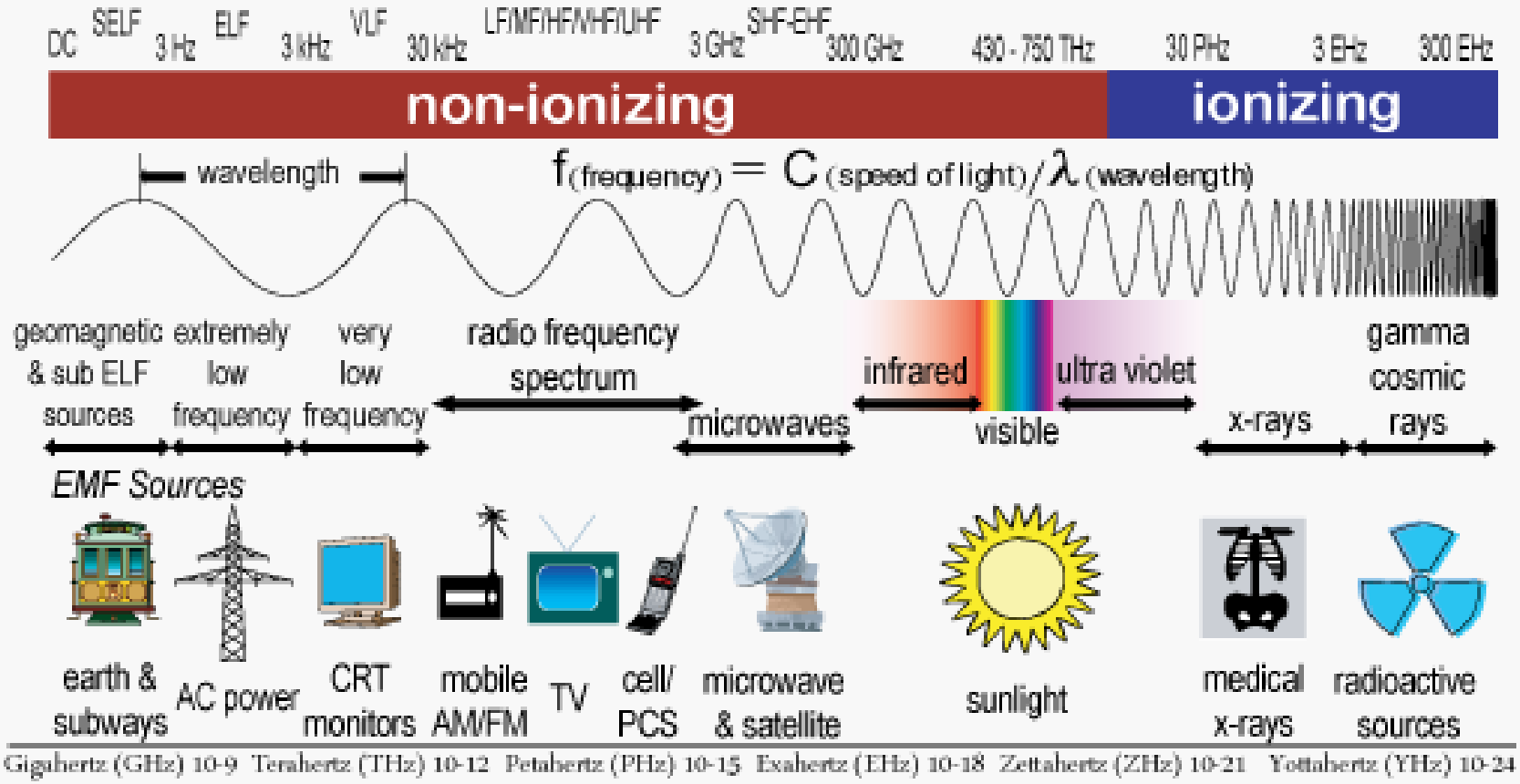
Electromagnetic wave : Transverse Wave that is fully explained by Maxwell's four equations

$$E^{(i)} = \frac{A(\theta,\varphi)}{R} \exp[j2\pi f(t - \frac{R}{c}) + j\psi]$$

A-amplitude, R – range, f – frequency, c – speed of light, ψ – unknown constant phase

Amplitude	Power of the Radio (TX / RX) → Intensity, Sensitivity
Frequency	Interaction with targets depending on dielectric characteristics and dimension(size) : L,S,C,X,K,W bands
Phase	Movement of the target(Doppler effect), Radio's speed decreasing in dielectric medium → phase delay
Polarization	Plane of the EM wave oscillation : horizontal, vertical, circular

THE ELECTROMAGNETIC SPECTRUM



Gigahertz (GHz) 10-9 Terahertz (THz) 10-12 Petahertz (PHz) 10-15 Exahertz (EHz) 10-18 Zettahertz (ZHz) 10-21 Yottahertz (YHz) 10-24

Radar Radio Frequency Band

Rain radar use M/W(Micro-Wave) :

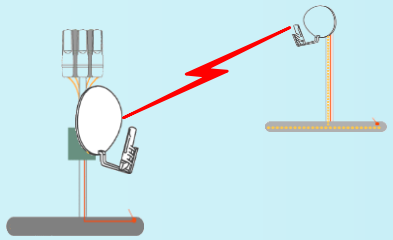
SHF(Super High Frequency) region of Frequency ranging 3 ~ 30GHz

Characteristics

- good directionality➔ duplicative usage of a frequency
- large volume data transmission

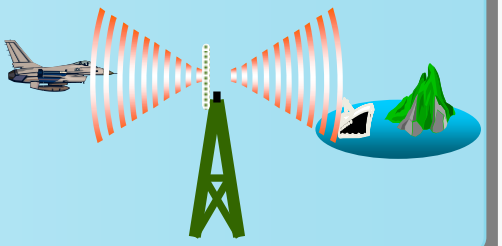
Usages

M/W Repeater



Sat. Comm. BroadCasting

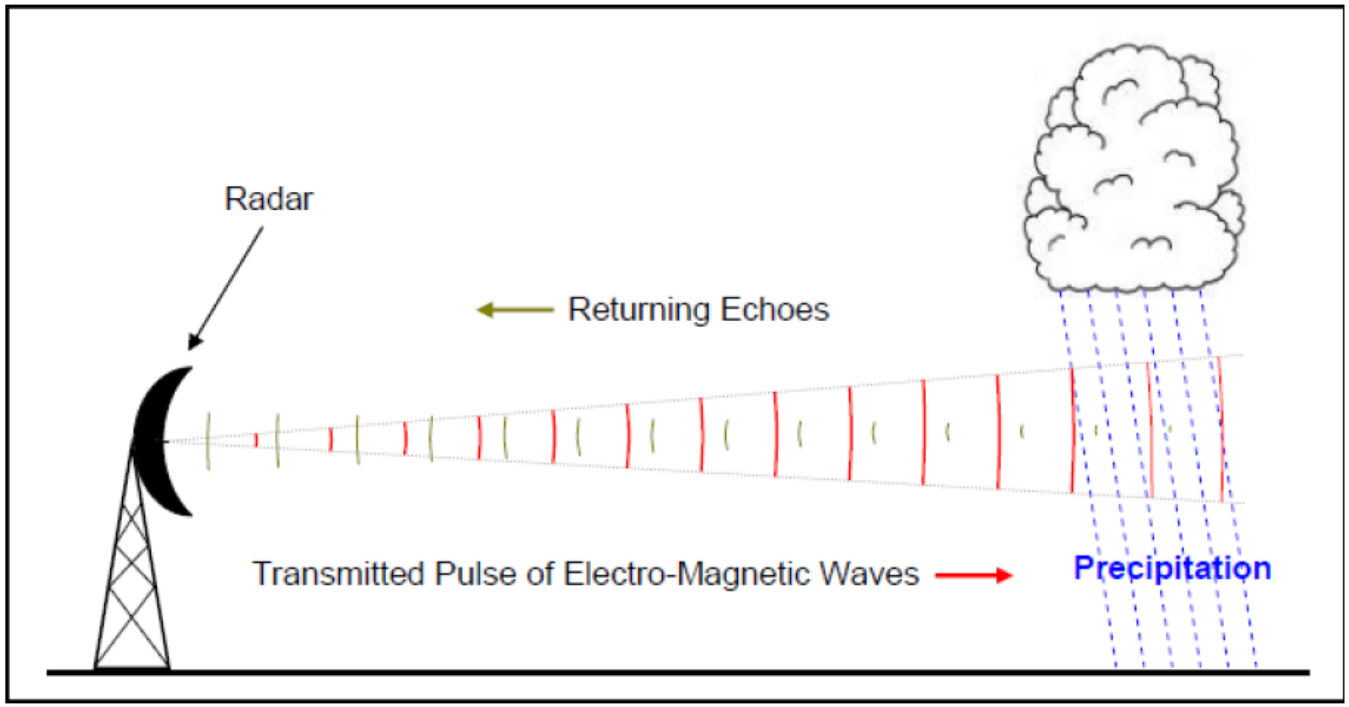
Radar



Radar Frequency Band

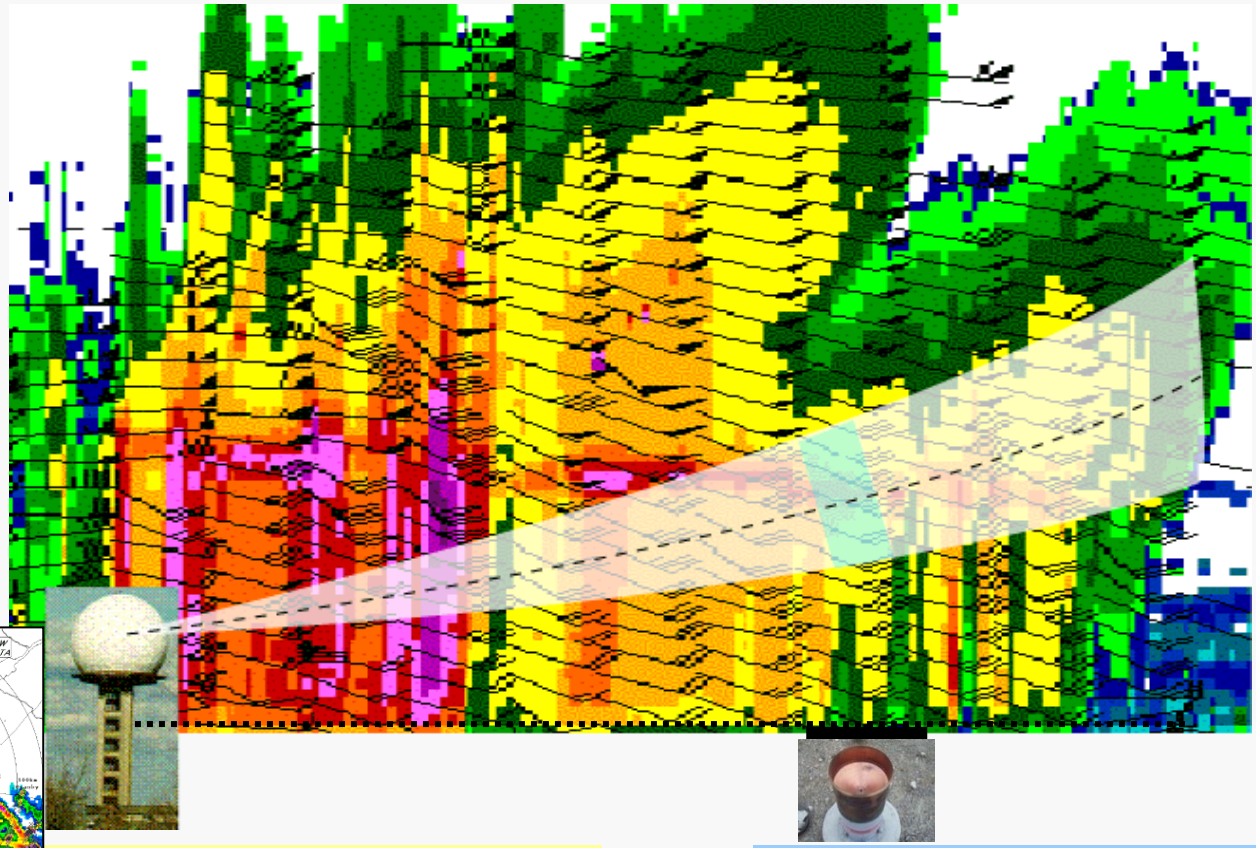
Band Designation	Frequency	Wave Length	
VHF	30 – 300 MHz	10 – 1 m	Wind Profilers (6m, 75cm, 22cm)
UHF	300 – 1000 MHz	1 – 0.3 m	
L	1 – 2 GHz	30 – 15 cm	
S	2 – 4 GHz	15 – 8 cm	Radars for Precipitation (10,5,3 cm)
C	4 – 8 GHz	8 – 4 cm	
X	8 – 12GHz	4 – 2.5 cm	
K_u	12 – 18GHz	2.5 – 1.7cm	Radars for Cloud or Fog (9mm, 3mm)
K	18 – 27GHz	1.7 – 1.2cm	
K_a	27 – 40GHz	1.2 – 0.75cm	

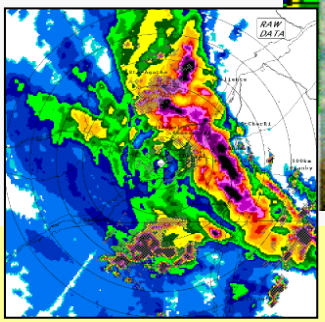
How does radar work ?



Sends out pulses of electromagnetic radiation in a narrow beam
Radiation scatters off targets, some returns to the radar
Radar listens for the return pulse
Targets can be weather or any physical object

Measuring Difference between Gauge and Radar





Instantaneous spatial distributions of the precipitation observing with some time interval

Ground Rain Gauge

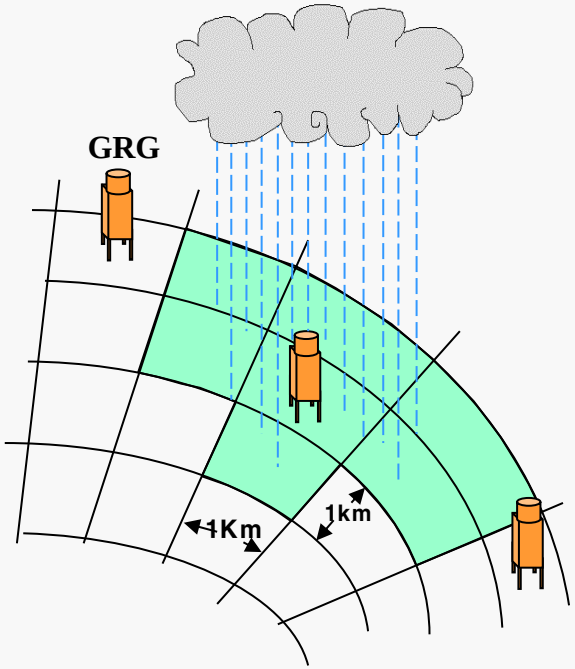
Continuous (temporal) measurement at a point (spatial)

Ground Rainfall Gauges (GRG) & Rainfall Radar (RR)

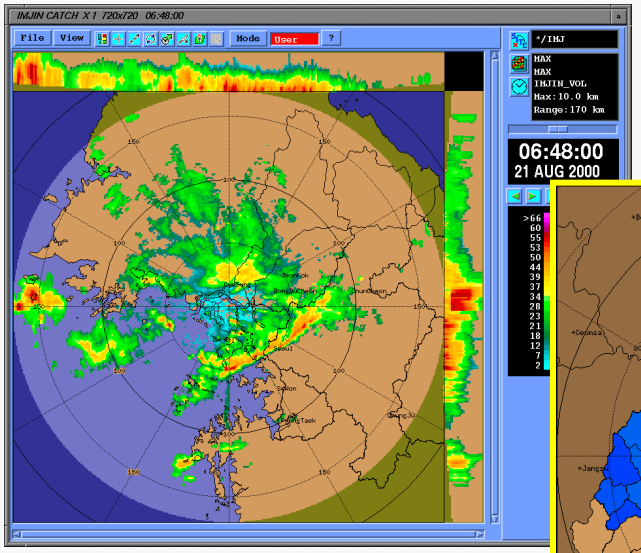
GRG(Diamenter: 20 cm)

Covering Area in Korea

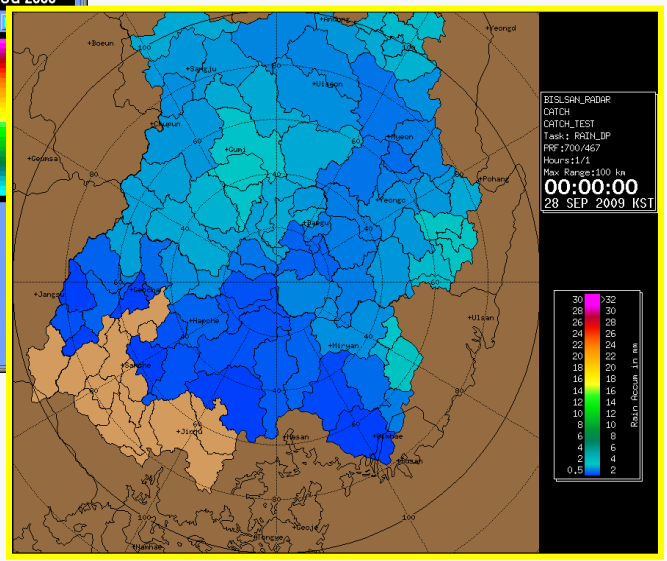
≒ 166 ㎢/ 1 station



RR Coverage = 1㎢/ 1Grid



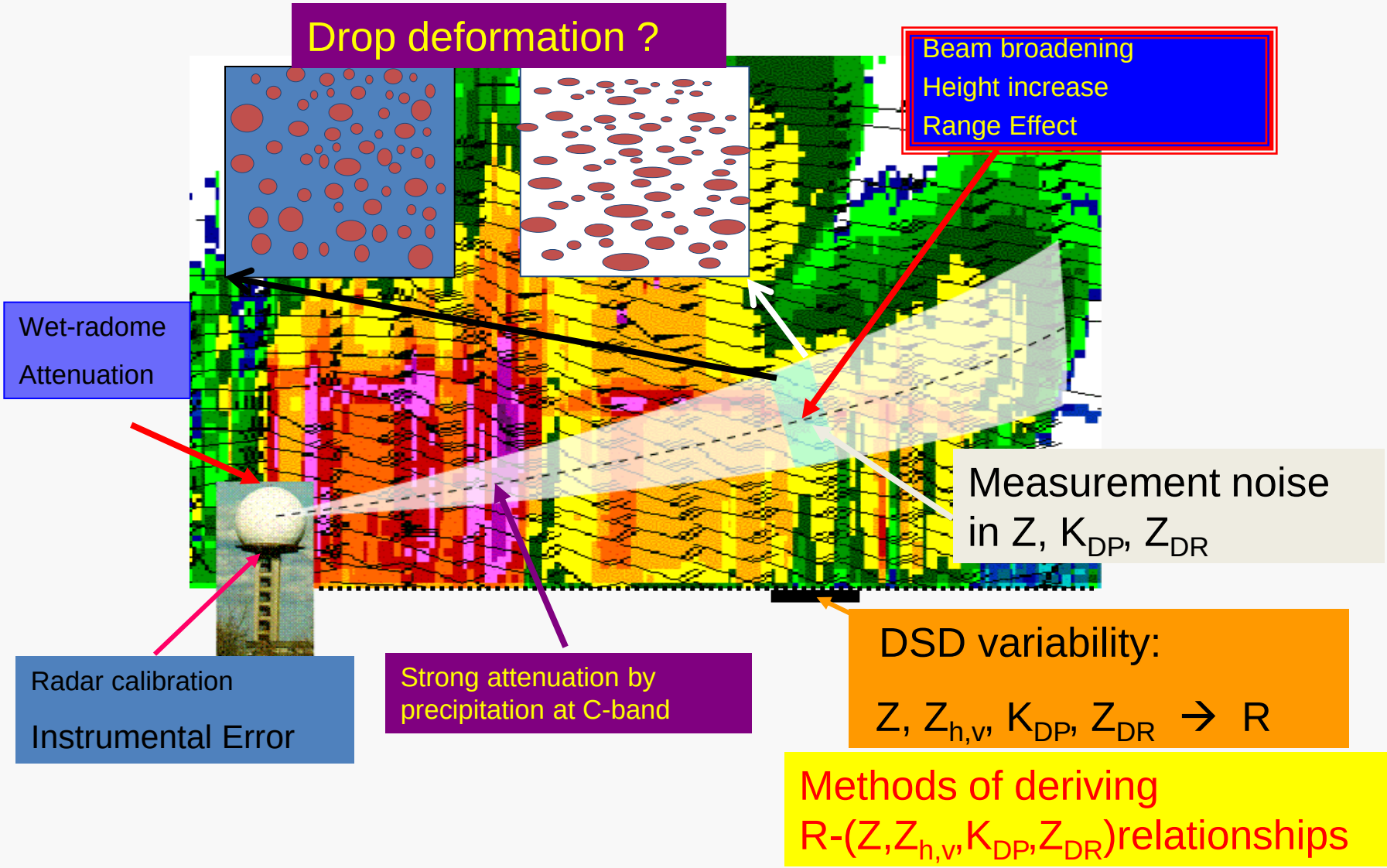
Reflectivity of Imjin RR



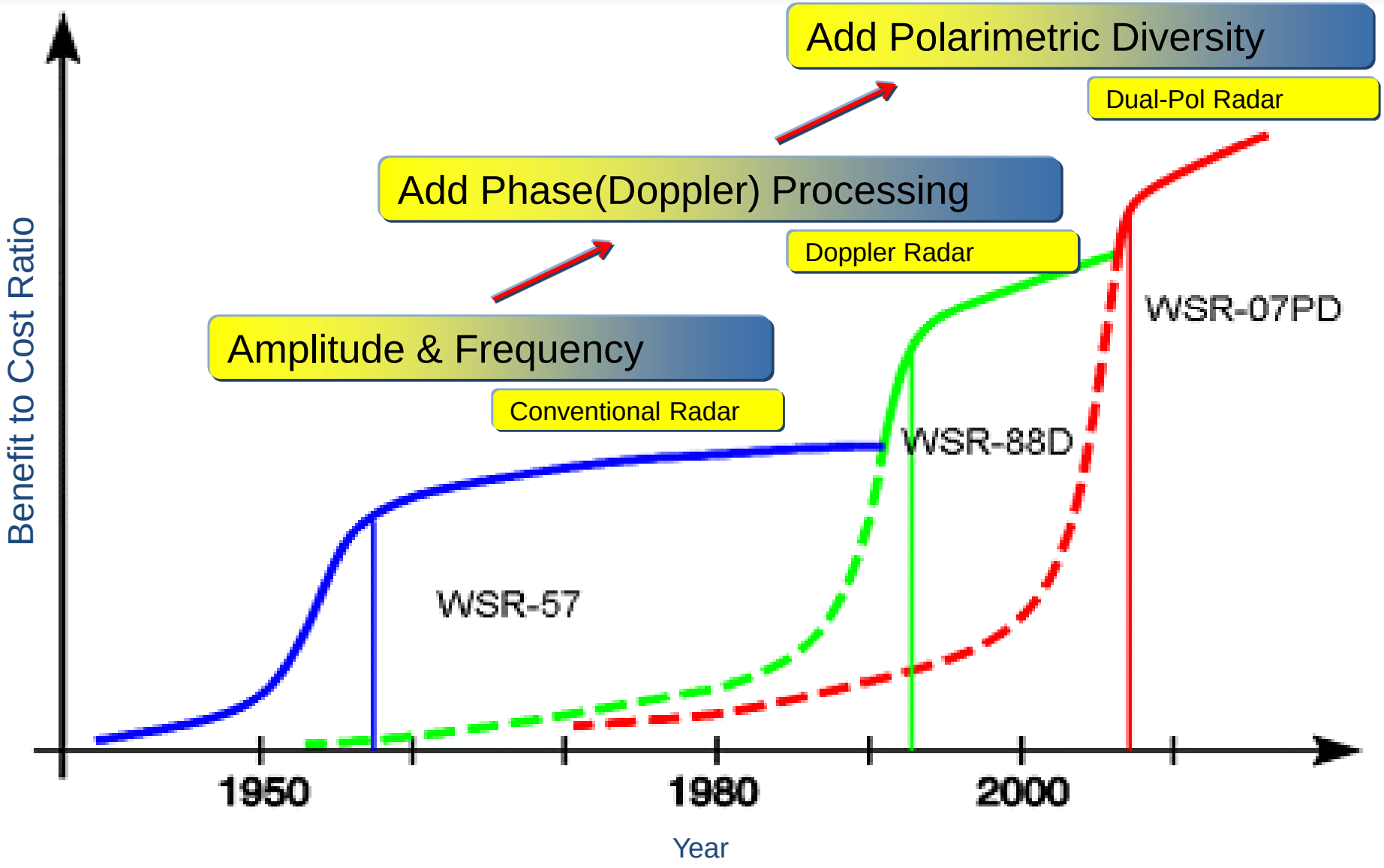
Mean Area Rainfall
using Radar Rainfall

- Rainfall Estimation in Ungauged Area
- Flash Flood
- Localized Heavy Rainfall
- QPF

Radar Data Quality Problems



Historical Evolution of the Radar

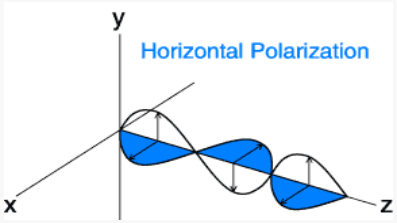


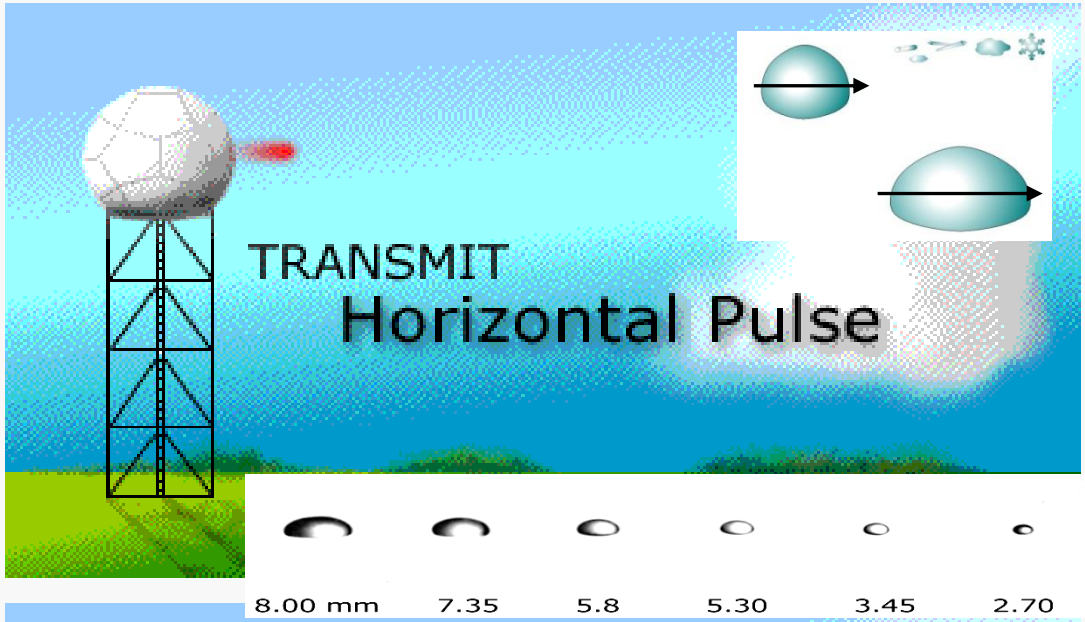
III Dual Polarization radar

- Basic Concepts and observables
- Major characteristics of the applications
- Dual-Pol Data Characteristics

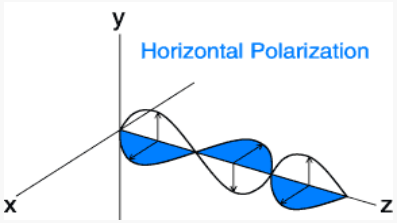
Comparison : Single vs Dual Polarization

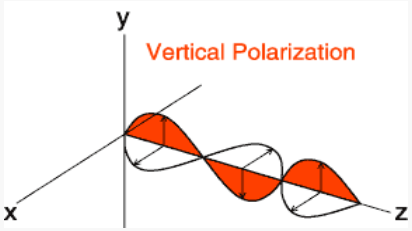
Conventional (Single Pol)

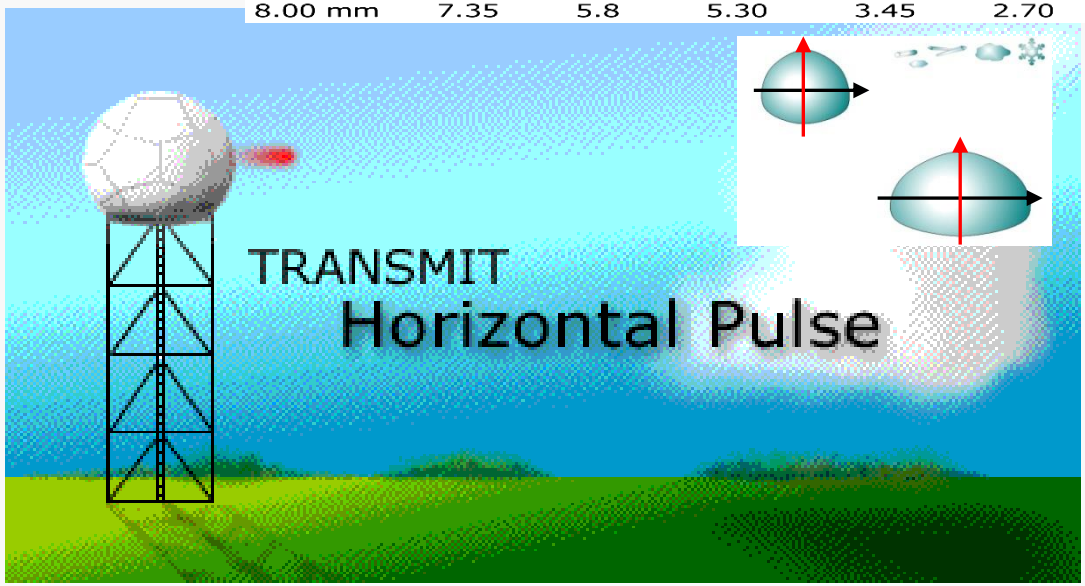




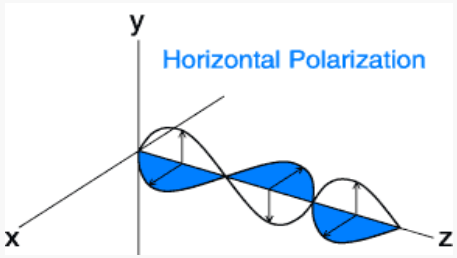
Polarimetric Radar

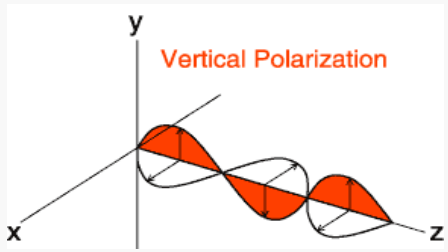


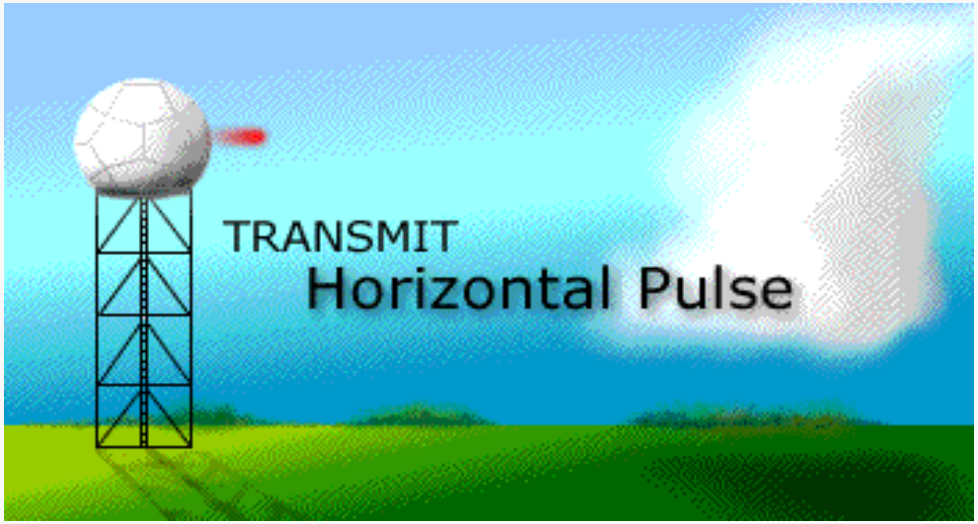


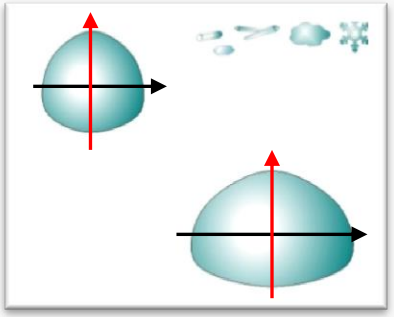


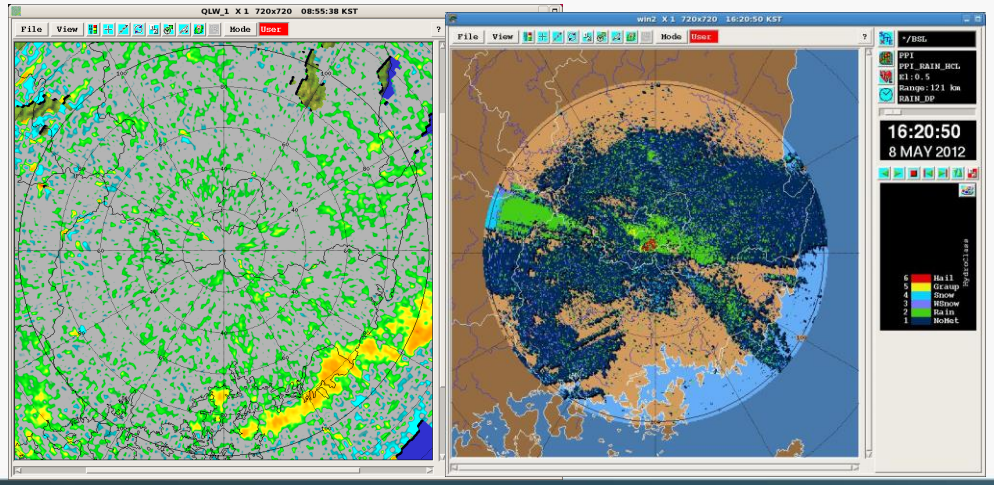
Hydrometeor Classification











Radar Observables(Moments, Parameters)

Conventional Radar

Z(Reflectivity factor) only
→ Location and Intensity

Doppler Radar

Conventional + Doppler processing data
Z, Vr(Doppler Velocity), SW(Spectrum width)
→ Location, intensity and movement

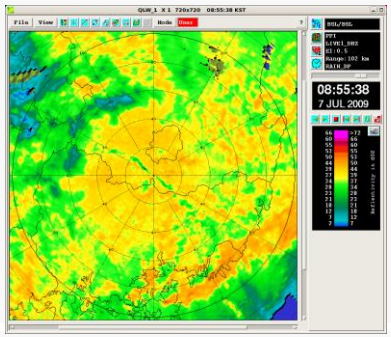
Polarization Radar

Conventional + Doppler + Polarization Processing data

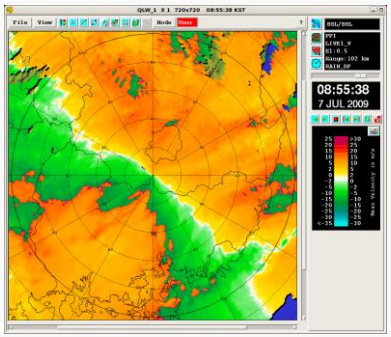
$$Z_{DR},\ LDR,\ \Phi_{DP},\ K_{DP},\ \rho_{HV}$$

→Location, intensity, movement and
target physical characteristics(types, attenuation, etc)

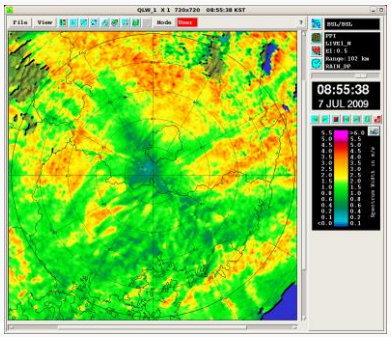
Images of Radar Observables



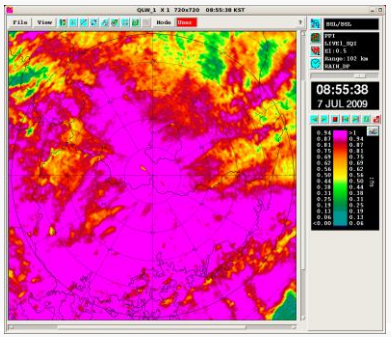
Reflectivity(Z)



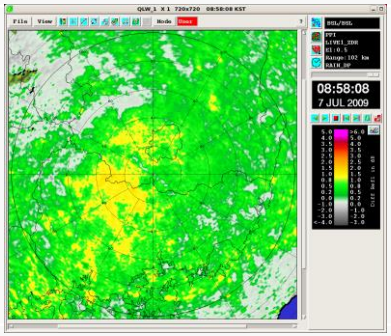
Doppler Velocity



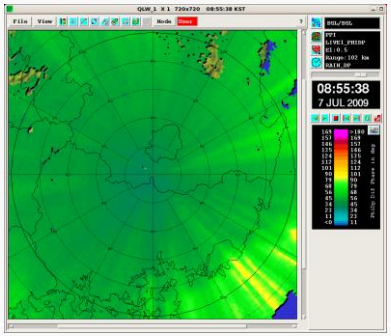
Spectrum Width



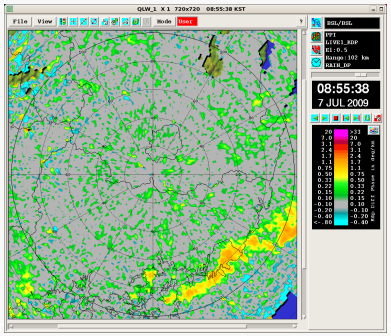
SQI



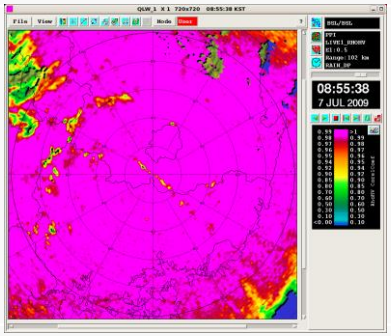
Z_{DR}



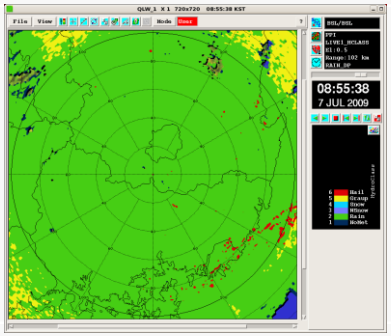
Φ_{DP}



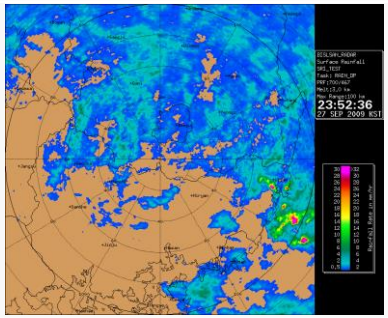
K_{DP}



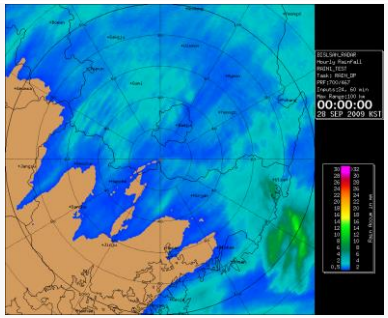
ρ_{HV}



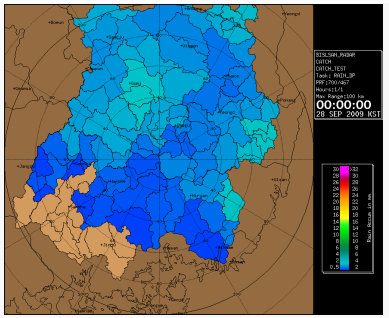
HydroClass



Rain Intensity(2.5)

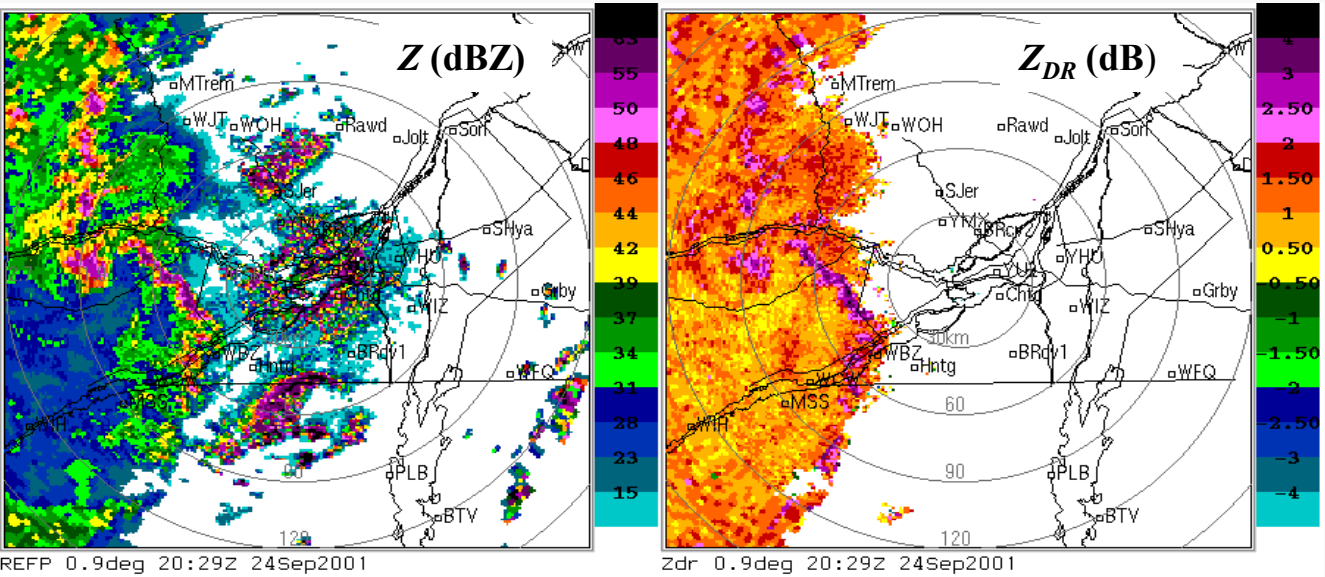


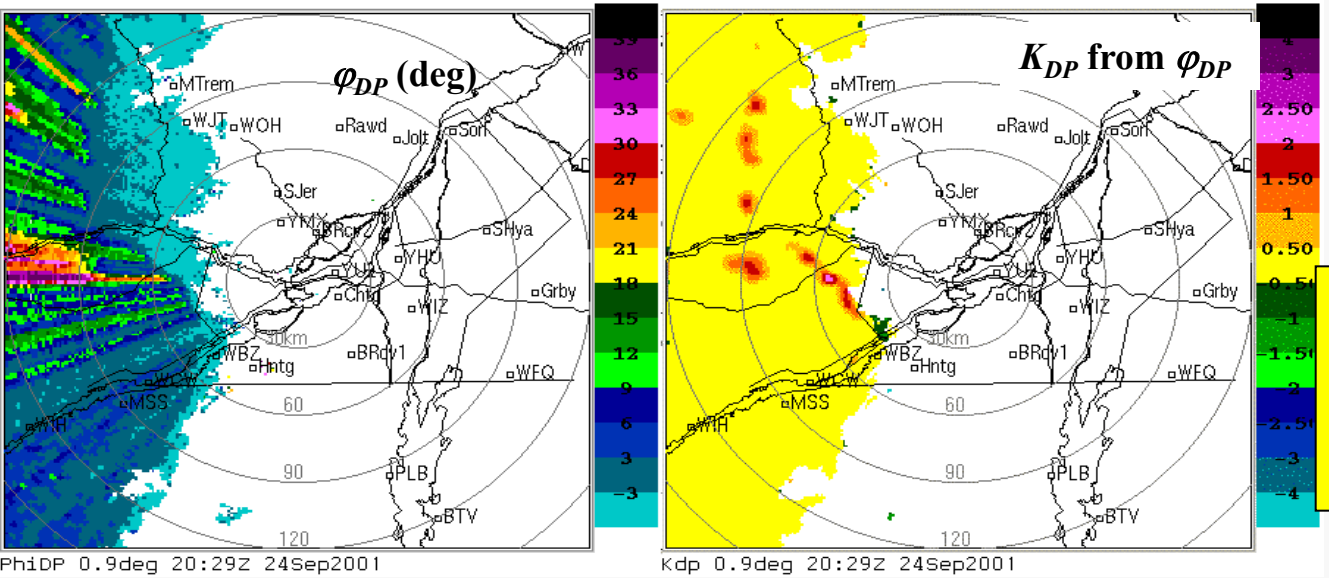
Rainfall(1H)



Area Rainfall

Improvement of QC and rainfall Estimation





Z, V, W

+

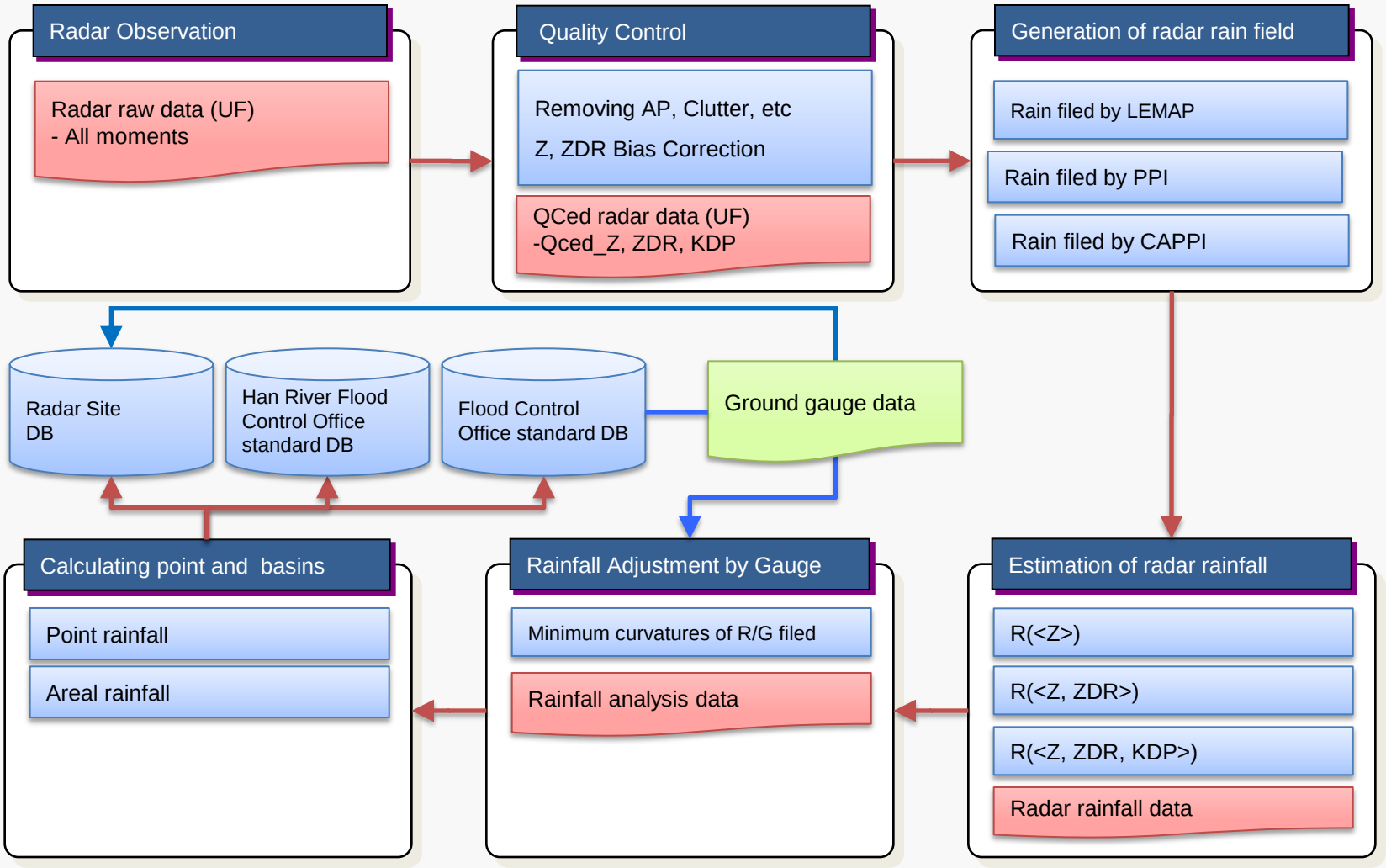
Polarimetric Variables

Z_{dr}, Φ_{DP},

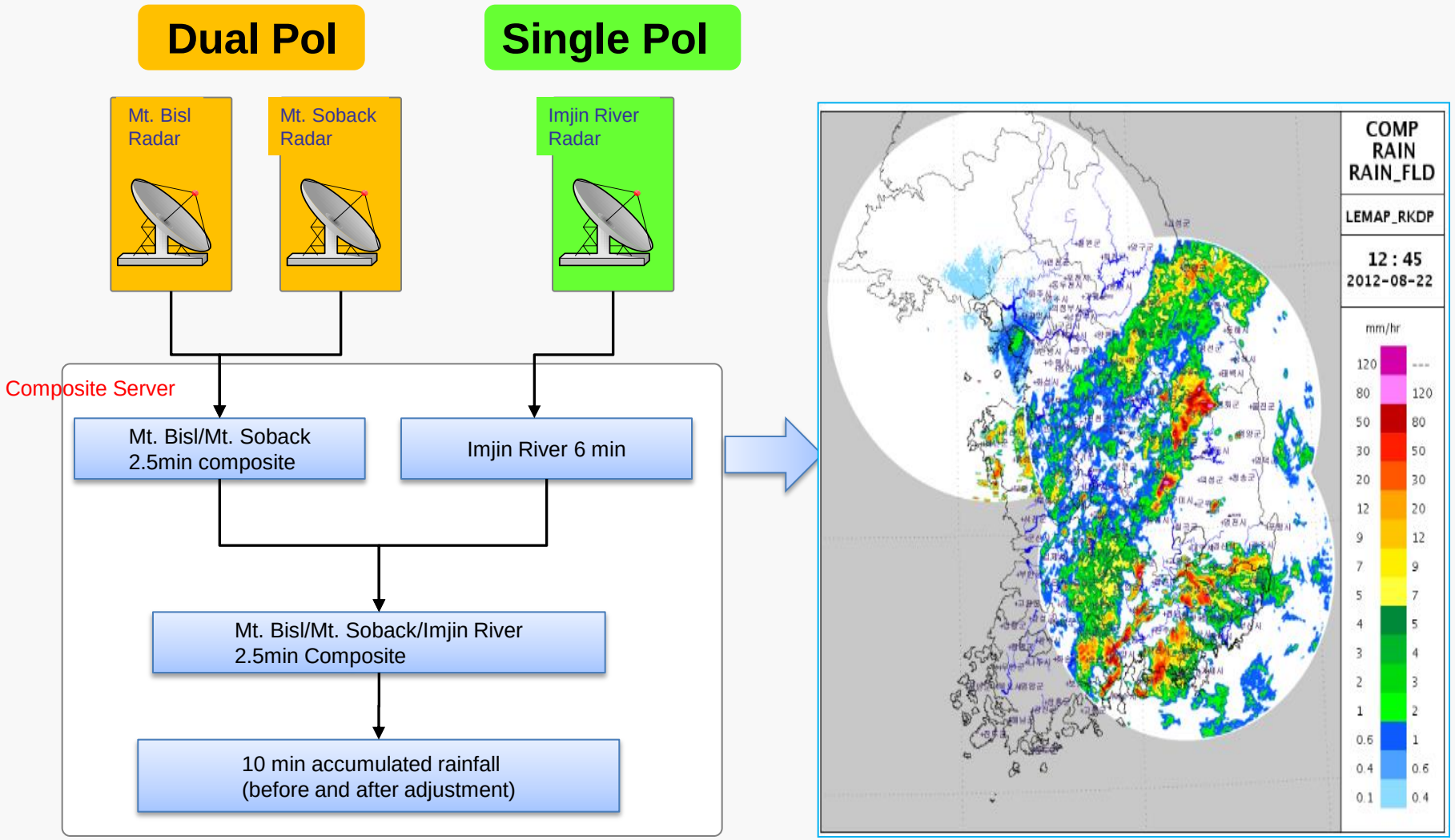
K_{DP}, ρ_{DP}

Improvement of Quality Control Rainfall Estimation

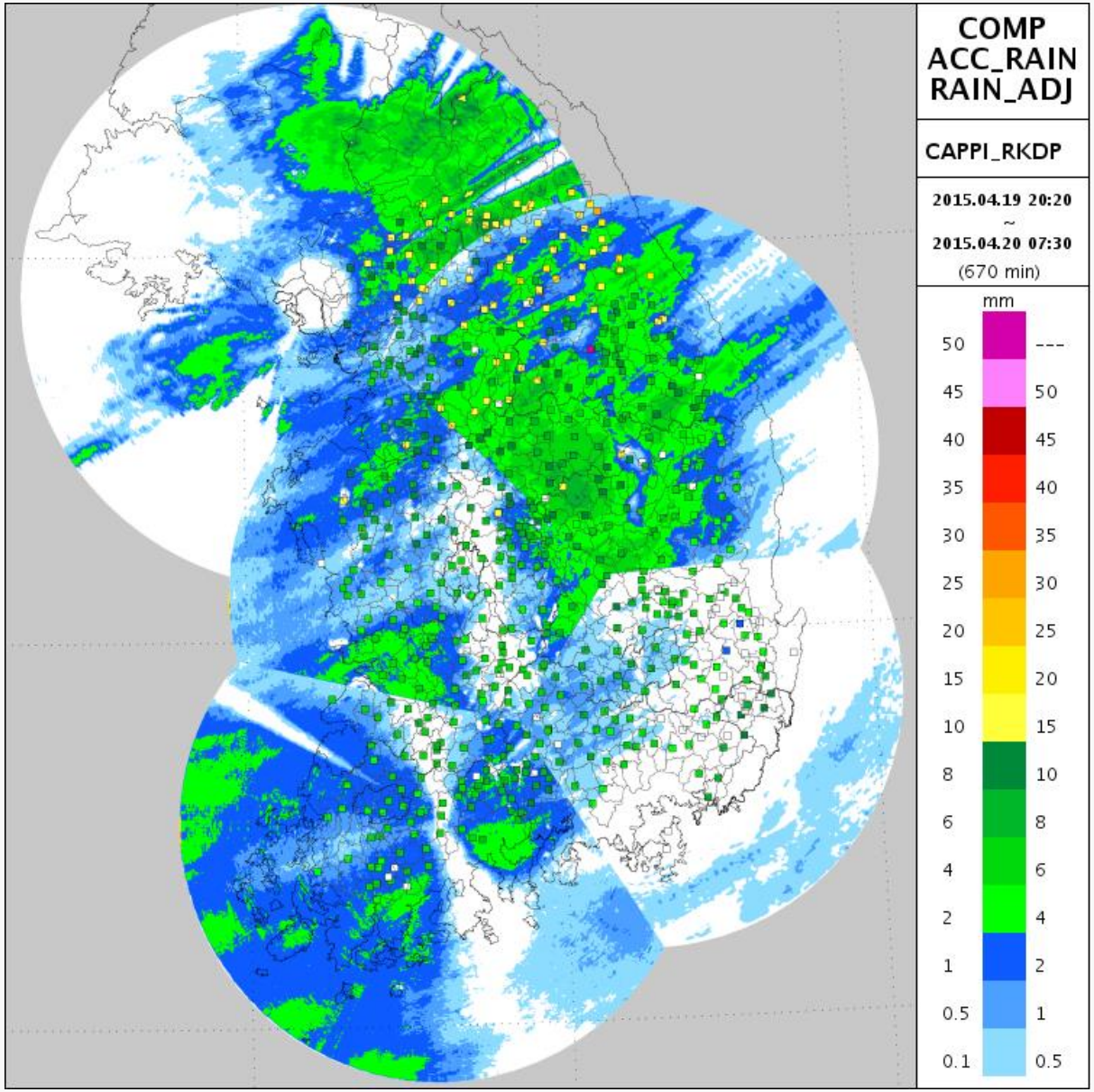
Block diagram of QC Procedures



Rain Radar Network Image Mosaic



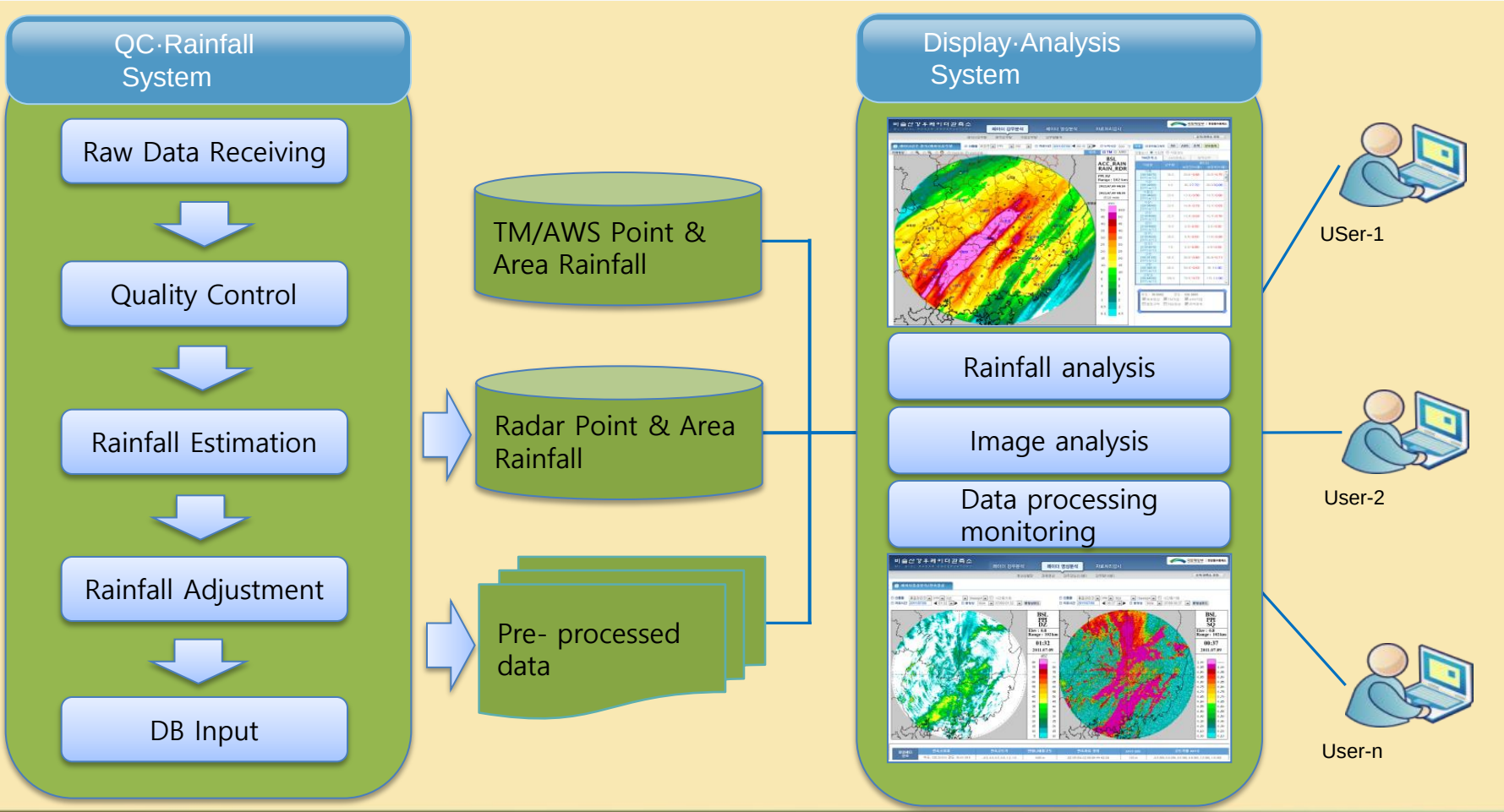
Radar Data Composite



Data Analysis and Application System

System configuration and data flow

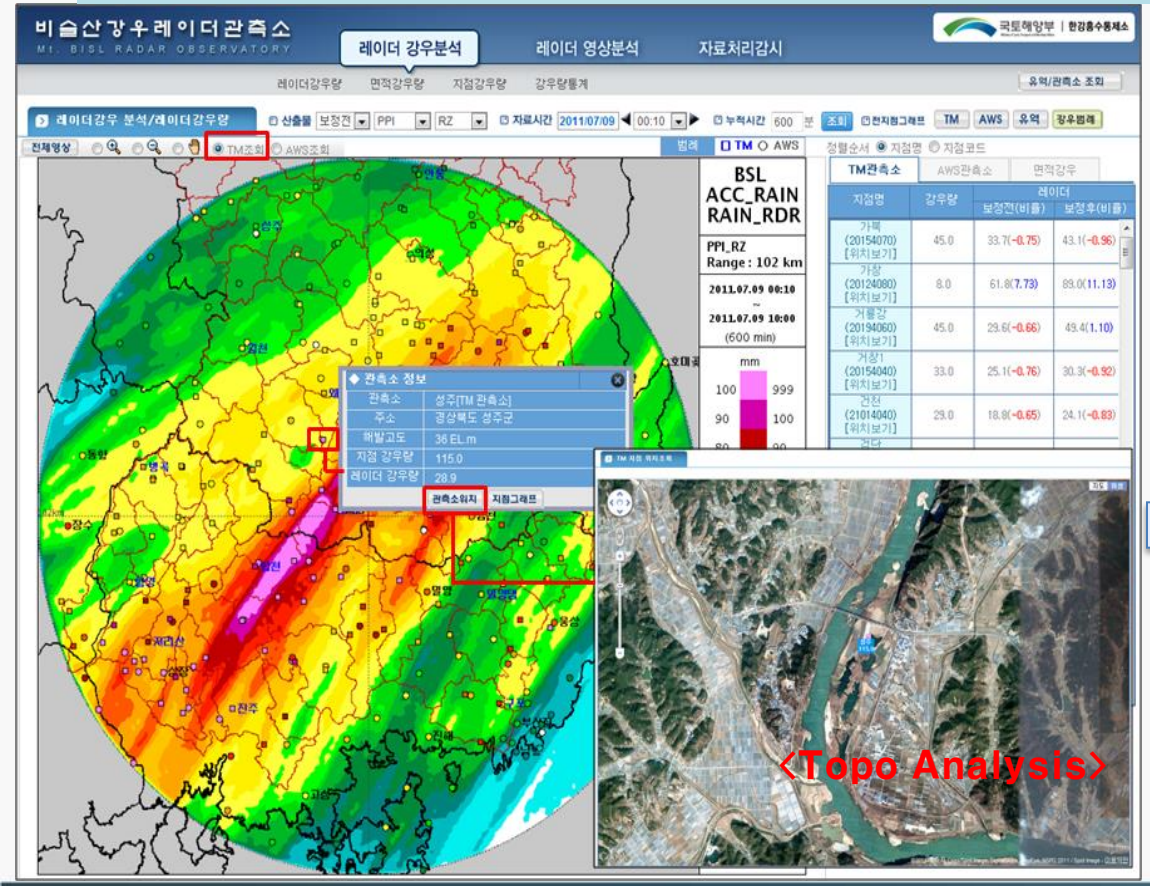
- **QC · Rainfall System** : preprocessing such as raw data receiving, rainfall, DB input
- **Display · Analysis System** : Radar and Rainfall Image, data processing monitoring

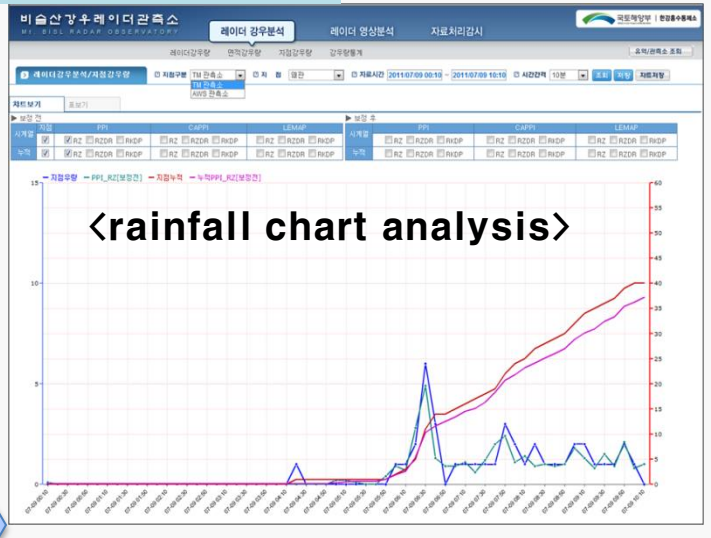


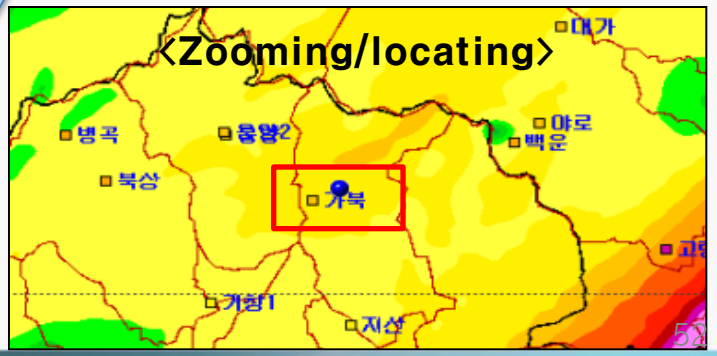
Display and Analysis System

Radar Data and Rainfall Analysis

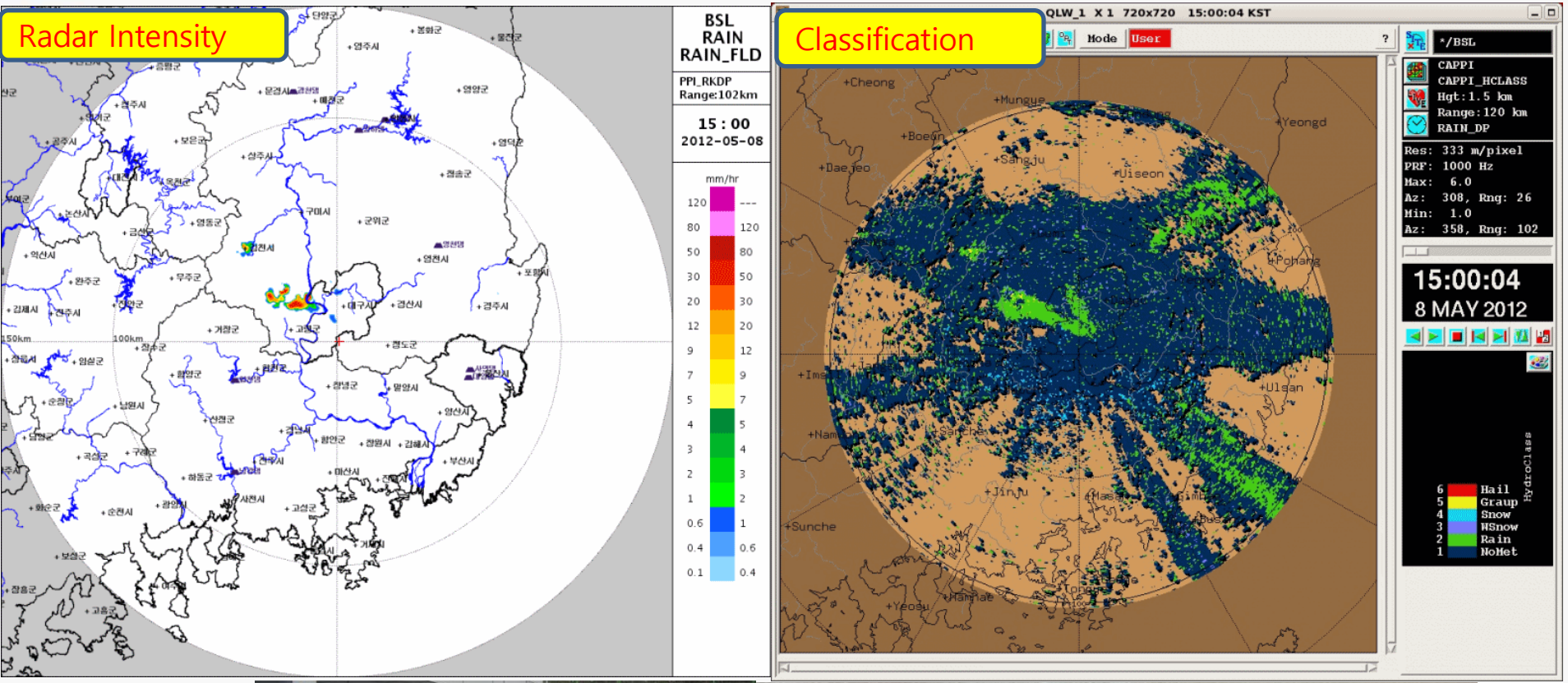
- Overlapping gauge data and geological information on radar image
- Table and Chart display of rainfall information
- Zooming and topographical display for local analysis

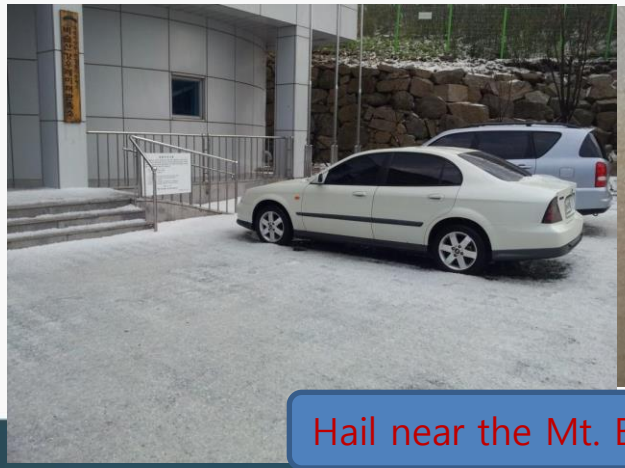






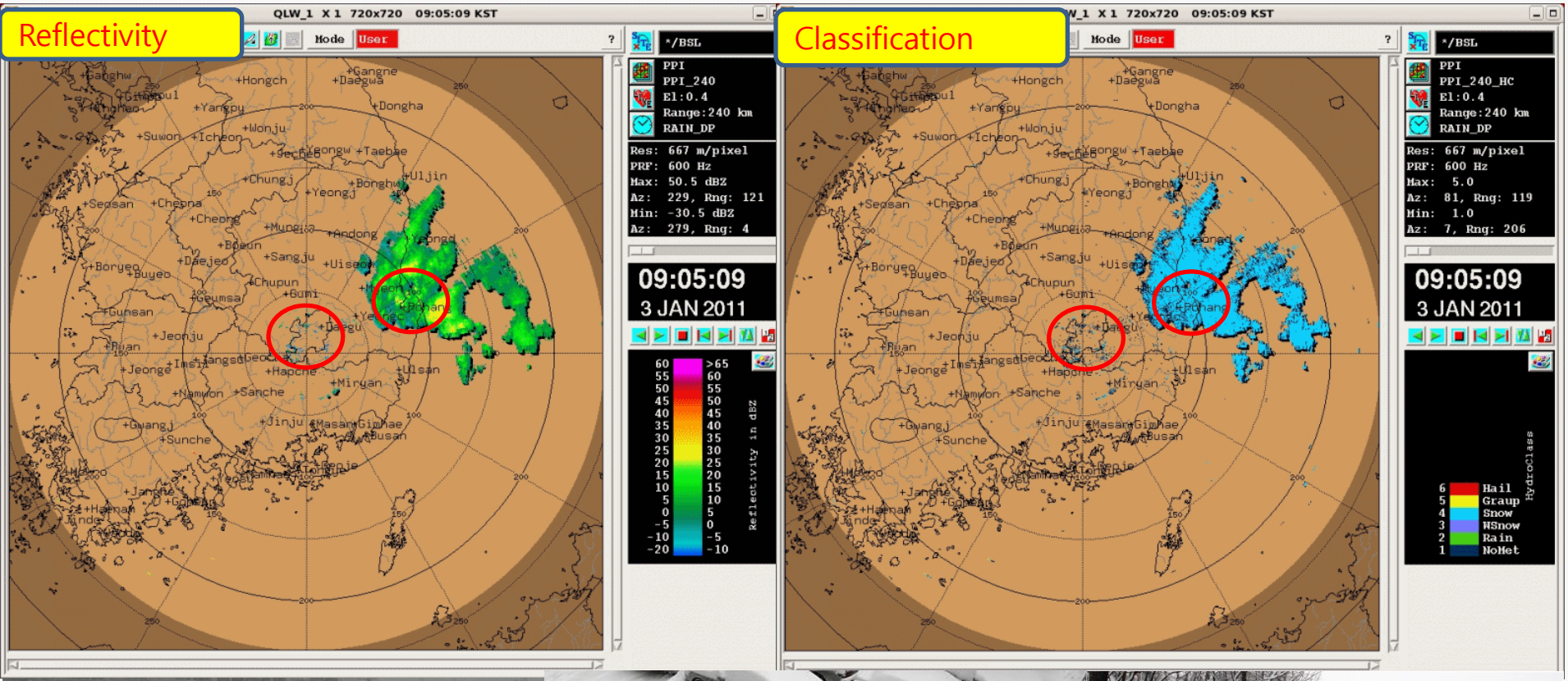
Hail Detection by Hydrometeor Classification





Hail near the Mt. Bisl Radar site

Heavy Snowfall Detection



News for local heavy snow

Benefits from Dual Polarization

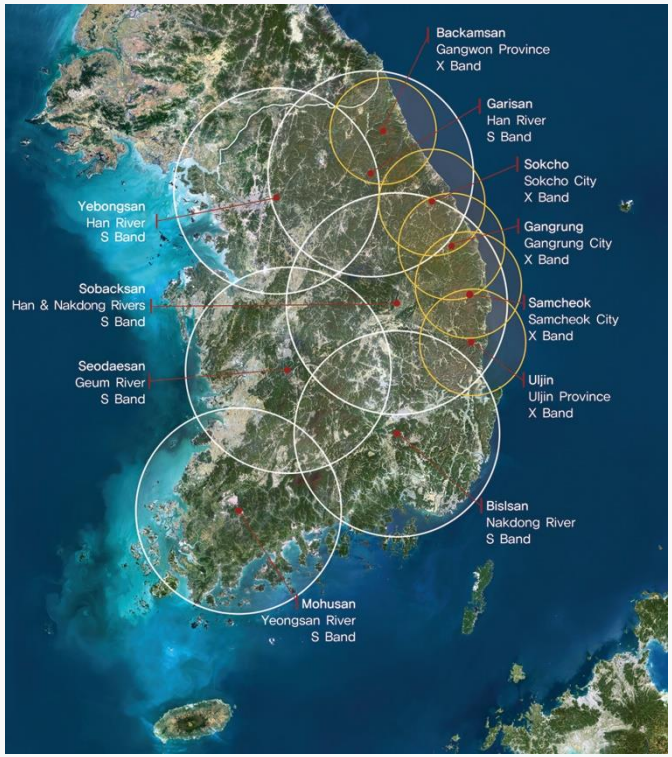
- Flash Flood Warnings
  - Precipitation estimation accuracy improves from ±35% to ±20%
- Tornado & Severe Thunderstorm Warnings
  - Tornado debris cloud detection improves warning lead time
  - Probability of hail detection improves from 88% to 94%
  - Probability of hail false alarm improves from 39% to 8%
- Winter weather products
  - Snowfall estimation improves
  - Detect of rain-snow line more accurately
- Data quality for storm-scale numerical model forecasting
  - Detect 99% of non-meteorological scatterers (such as birds, insects, etc.)
- Estimated $690 million annual benefit from water management and flash flood forecasts*

*Benefit analysis based on (1) *NEXRAD Technical Requirements for Precipitation Estimation and Accompanying Economic Benefits,* Hudlow, et. al., 1985; and (2) *Dual Polarization Cost Benefit Analysis*, Zrnic, 2003

IV Polarization Radar Operation for Flood Forecasting in KOREA

- Radar Networking
- Rainfall Estimation and Error
- Applying to Flood forecasting

Polarimetric Radar Networking Milestone of MOLIT



Location	'05	'06	'07	'08	'09	'10	'11	'12	'13	'14	'15 ~ '16
Bisuel											
Mohu											
Soback											
Seodae											
Gari											
Yebong											
Mini(5)											
Installed radars	-	-	-	-	1(1)	-	1(2)	-	-	2(4)	7(11)

- (Phase 1) 6 S-Band Completion until 2015 in major rivers

  * Han River(Gari, Yebong), Gum River(Seodae), YoungSan River(Mohu), Nakdong(Bisuel, Soback)

- (Phase 2) 5 X-Band Completion until 2017 for blind areas``

  * based on the operational experience of S-Band, the locations of X-Band will be adjusted.

Status of Radar Installation of MOLIT

Bisuel RR('09.06, Metstar)

Soback RR('11.11, Metstar)

Mohu RR('14.08, SELEX)

Sedae RR('14.09, SELEX)

Radar System Specifications of MOLIT

Sub-System	Components	Specification	Note
Transmitter	Frequency	2850 ~ 2900 MHz	S Band
	Polarization	H+V, H	Dual Polarization
	Tube	Klystron	
	Peak Power	750KW	
Antenna	Dish Size	8.5m	Gain 45dB
	Beam width	0.95°	
	Scan Speed	1 ~ 36°/sec	Max 6rpm
	Scan Range	AZ 0~360°, EL -2°~92°	
Receiver & RVP	Receiver Type	Heterodyne, Digital	Dual Channels(H and V)
	MDS	-114dBm	
	Dynamic range	100dB	
	Signal Processor	Digital I/Q	Clutter Suppression
Data	Moments	Z, V, W, SQI, ZDR, PhiDP, KDP, RhoHV, Hclass	Dual_Pol parameters
	Time series	Raw I/Q data	

Scan Strategy

Clear Mode (VCP_C)

range	PW	Tilts	Resolution	Scanning time	Polarization	moments
200Km	2μs	~4 ELs	1° * 250m	150sec	H+V	Dual_Pol parameters

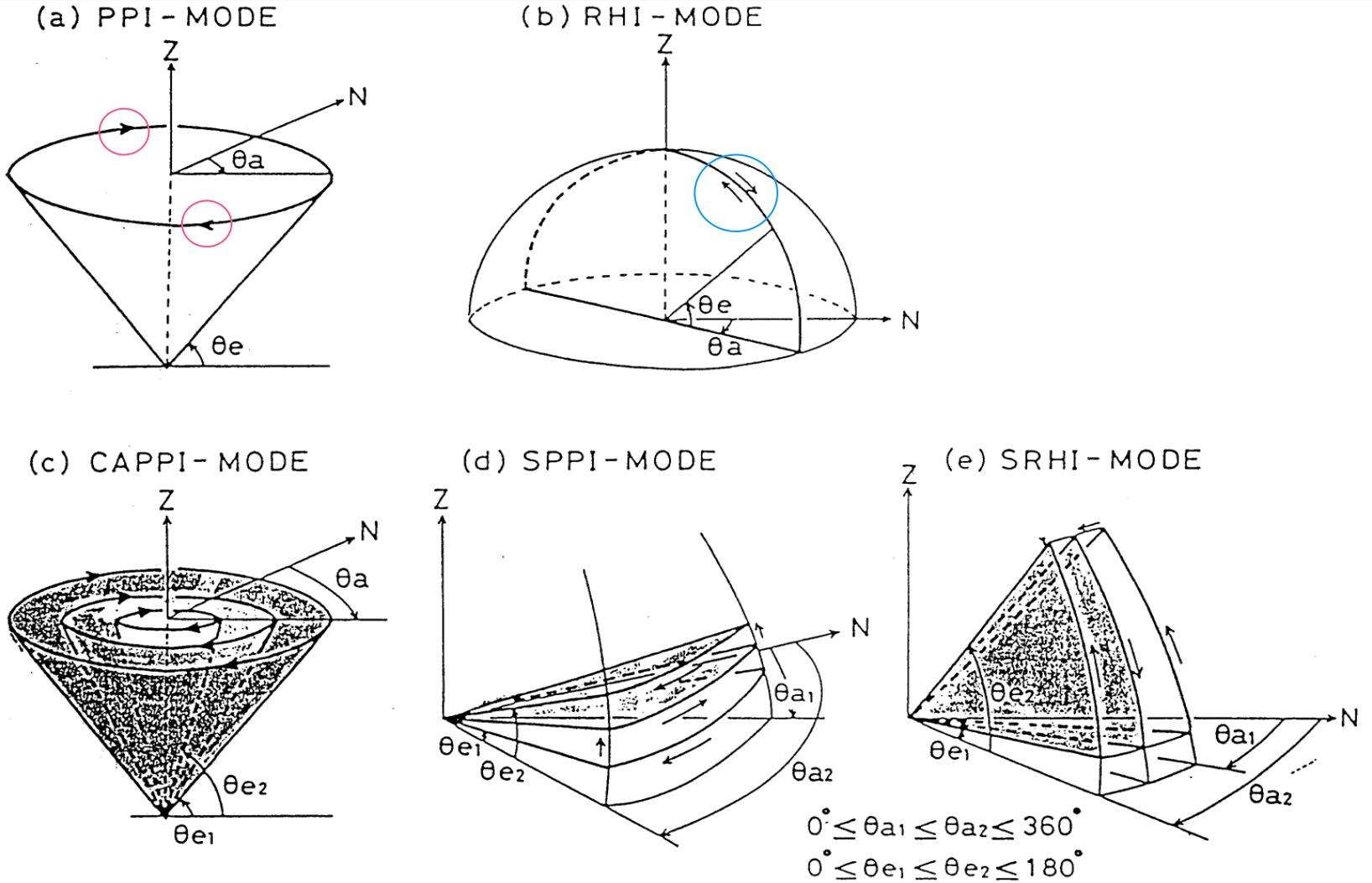
Rain Mode(VCP_R)

range	PW	Tilts	Resolution	Scanning time	Polarization	moments
100Km	1μs	~6 ELs	1° * 125m	150sec	H+V	Dual_Pol parameters

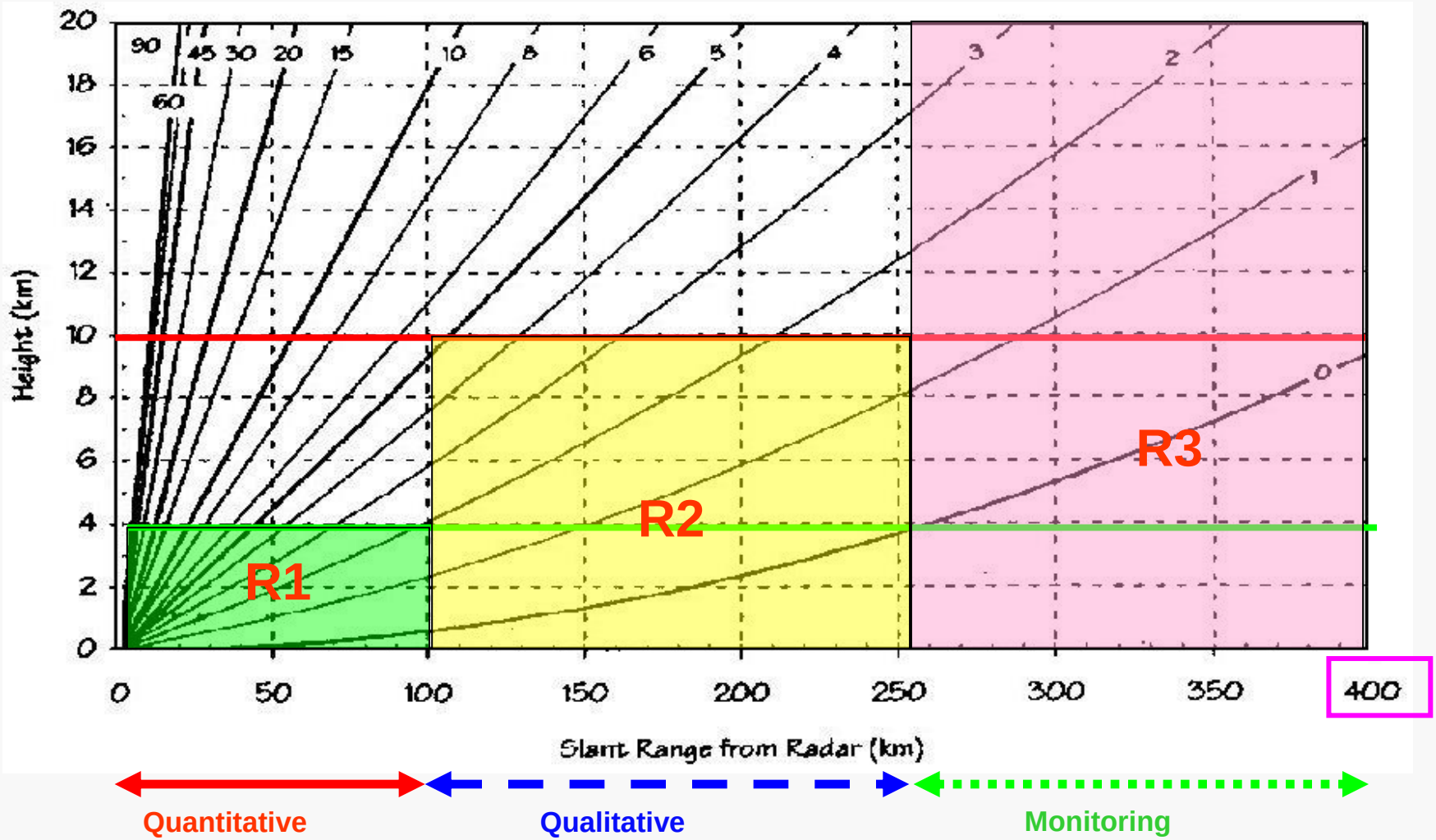
ZDR_CAL Mode(Vertical)

range	PW	Tilts	Resolution	Scanning time	Polarization	moments
20Km	1μs	EL 90°	125m	120sec	H+V	Dual_Pol parameters

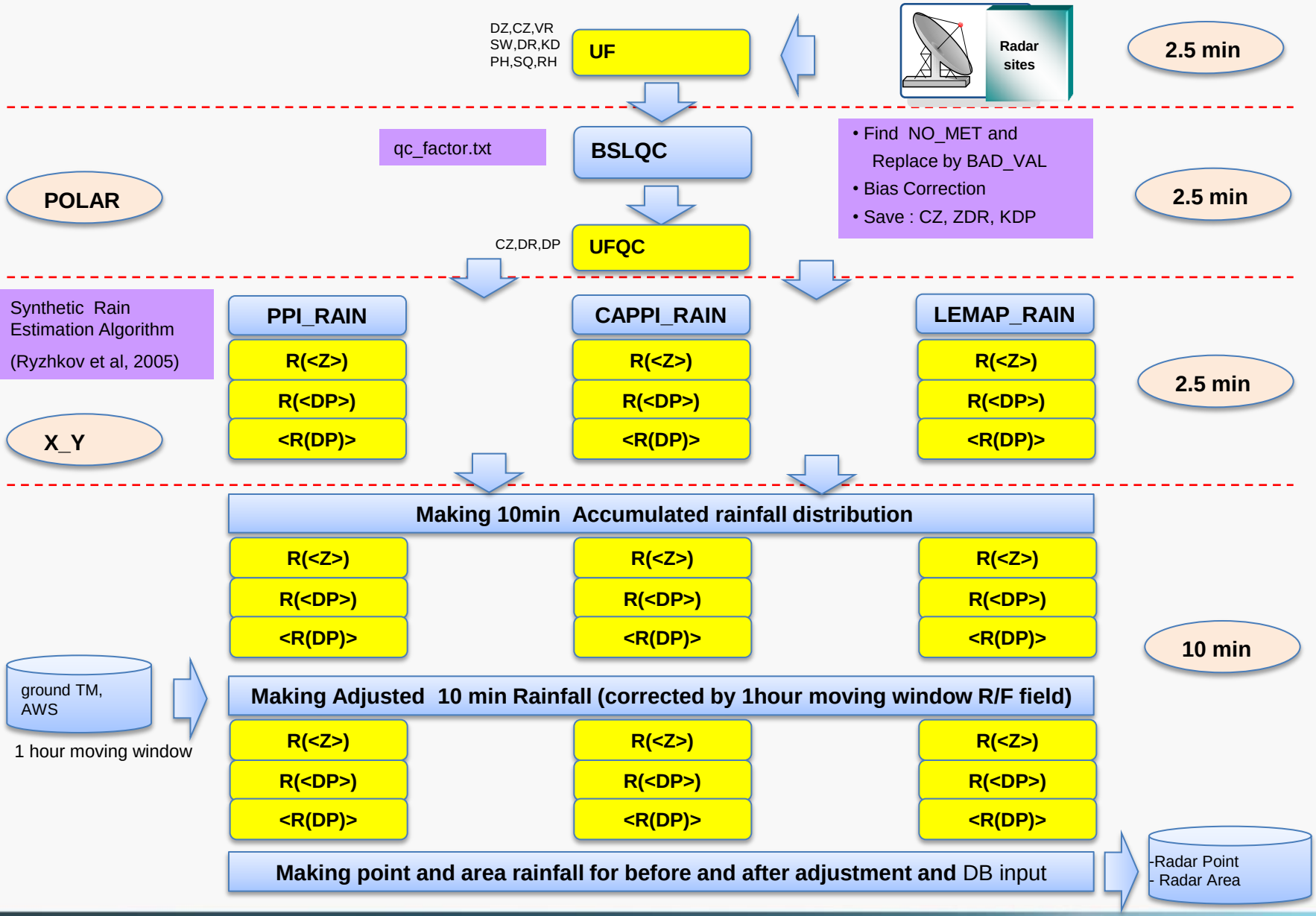
Radar Scan Mode



Radar Beam heights by Elevation and Range



Data Processing Procedures



Radar Rainfall Conversion Algorithm

1. R(Z) : Z-R relationship(traditional method)

$$R(Z) = 1.70*10^{-2} * Z^{0.714} \longrightarrow Z = 300R^{1.4}$$

2. R(ZDR) : Bringi and Chandrasekar(2001)

$$R(Z, Z_{DR}) = 6.70*10^{-3} * Z^{0.714} Z_{DR}^{-3.43}$$

3. R(KDP) : Rhyzhkov(2005) (NEXRAD prototype) → Being used in MLTM

$$R(Z) = 1.70*10^{-2} * Z^{0.714}$$

$$R(K_{DP}) = 44.0 | K_{DP} |^{0.822} sign(K_{DP})$$

$$R = \overline{R(Z)} / f_1(\overline{Z_{DR}}) \quad if \ \overline{R(Z)} < 6\,mm/h$$

$$R = \overline{R(K_{DP})} / f_2(\overline{Z_{DR}}) \quad if \ 6 < \overline{R(Z)} < 50\,mm/h$$

$$R = \overline{R(K_{DP})} \quad if \ \overline{R(Z)} > 50\,mm/h$$

where,

$$f_1(\overline{Z_{DR}}) = 0.4 + 5.0 | \overline{Z_{dr}} - 1|^{1.3}$$

$$f_2(\overline{Z_{DR}}) = 0.4 + 3.5 | \overline{Z_{dr}} - 1|^{1.7}$$

$$\overline{Z_{dr}} = 10^{0.1\overline{Z_{DR}(dB)}}$$

$$R(K_{DP}) = \alpha K_{DP}^{\beta}$$

$$R(Z_H, Z_{DR}) = \alpha Z_H^{\beta} 10^{0.1\gamma Z_{DR}}$$

$$R(K_{DP}, Z_{DR}) = \alpha K_{DP}^{\beta} 10^{0.1\gamma Z_{DR}}$$

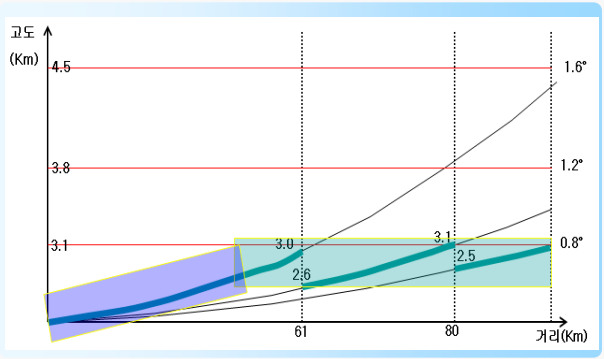
$$R(Z_H, K_{DP}) = \alpha Z_H^{\beta} K_{DP}^{\gamma}$$

Spatial Sampling from VCP data

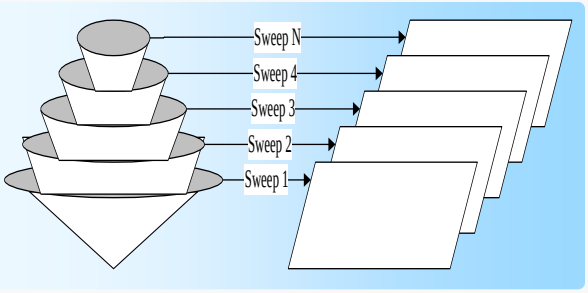
Spatial radar data to be converted into rainfall

QC RADAR DATA

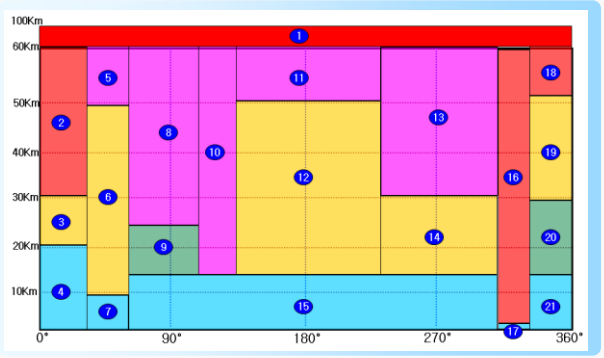
CAPPI

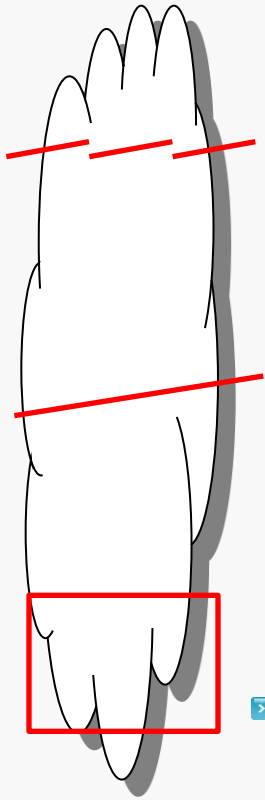


PPI



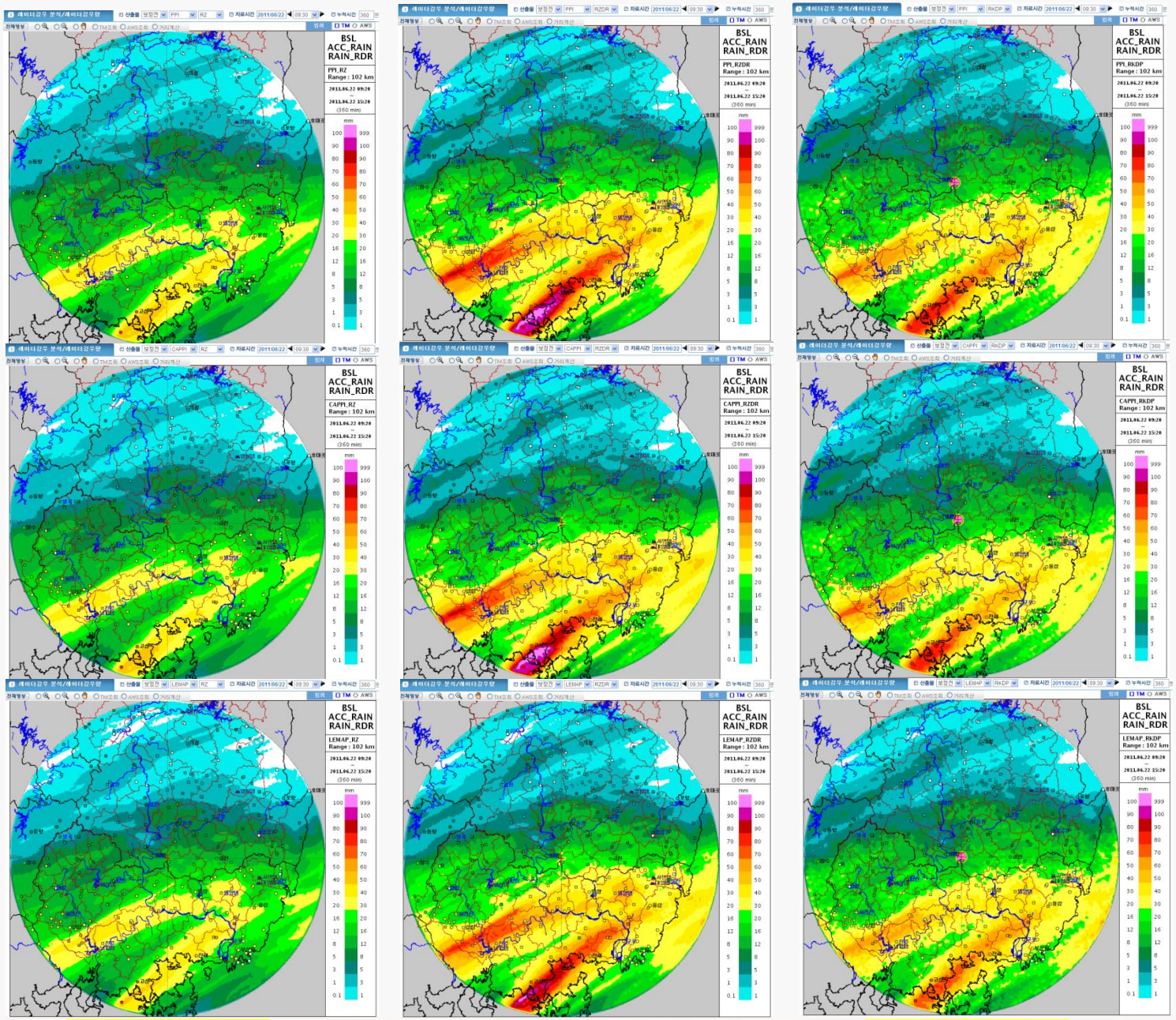
LEMAP



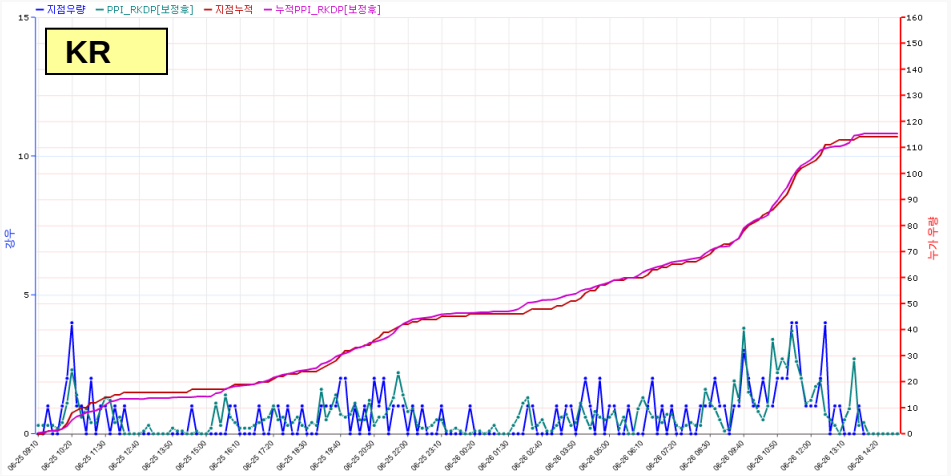


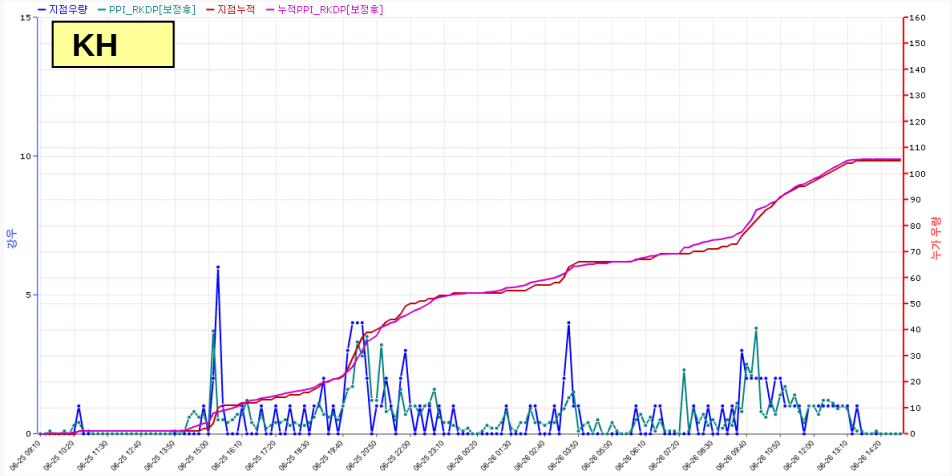
- Extract 2.0 Km CAPPI
- around 0.8 degree PPI
- Lowest Elevation Map considering topological condition around radar sites without clutter contamination

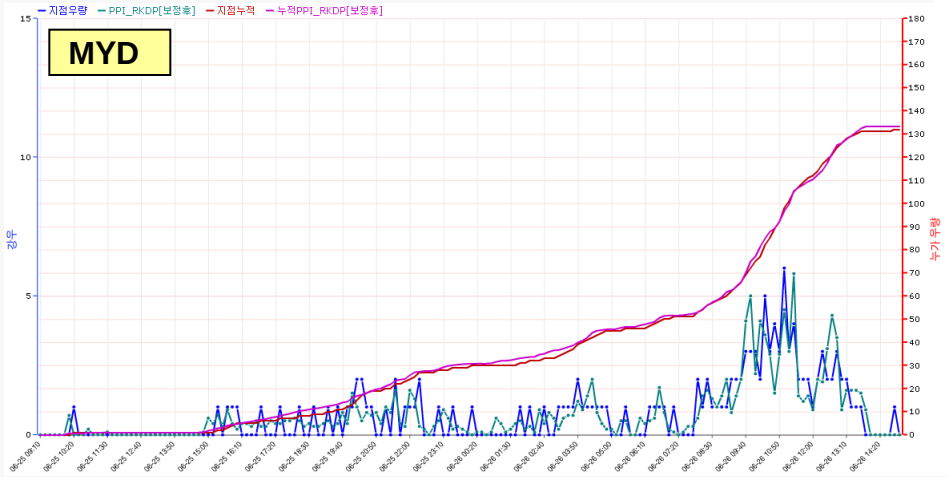
Comparison of all rainfall products from the system

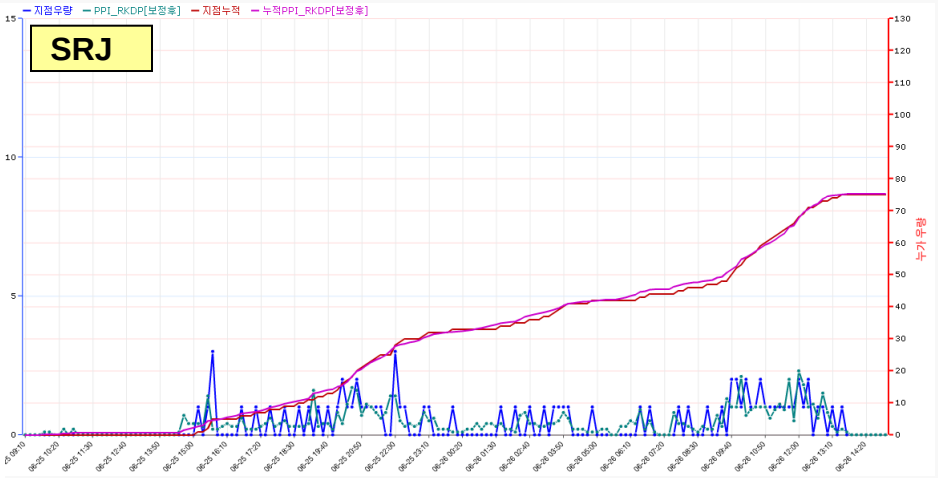


Time series and accumulation of gauge and radar









Radar Rainfall Difference from Gauge

(a) R(Z) : Single_Pol radar rainfall

Events(2011)	Average of fractional difference		Standard deviation of fractional difference	
	Relative(%)	Absolute(%)	Relative(%)	Absolute(%)
June 22	-16.5	18.3	16.1	18.3
June 25	3.8	51.4	72.7	51.3
July 9	-9.2	10.1	12.6	11.9
August 7	-5.5	13.0	16.4	11.4
Total Average	-6.9	23.2	29.5	23.2

(b) R(KDP) : Dual_Pol radar rainfall ▼

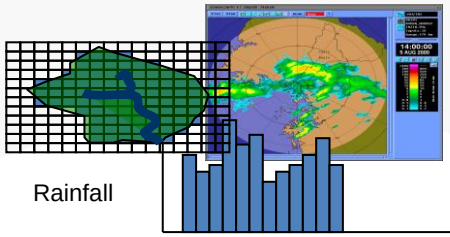
Events(2011)				
June 22	-5.0	12.6	15.8	10.7
June 25	2.4	8.4	16.2	14.0
July 9	-0.9	6.6	10.4	8.1
August 7	2.9	12.9	17.7	12.4
Total Average	-0.2	10.1	15.0	11.3

* **Averaged** for total rainfall of 140 TM points within Mt. Bisl Radar coverage(100km)

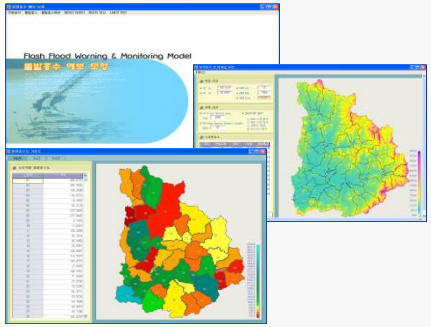
3. RR's Utilization for Flood Warning

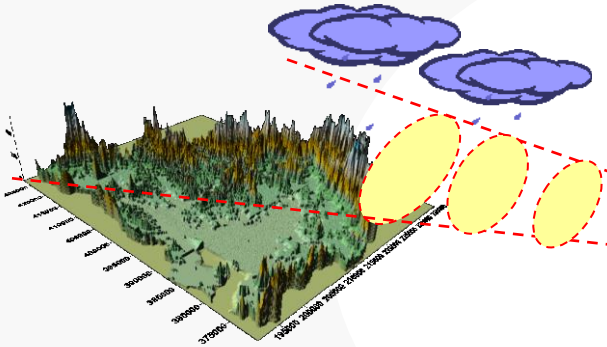
Applying to Operational Flood Forecasting System

Radar Data Processing System



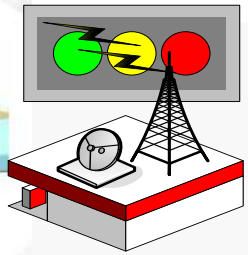
Flood Monitoring and forecast Model



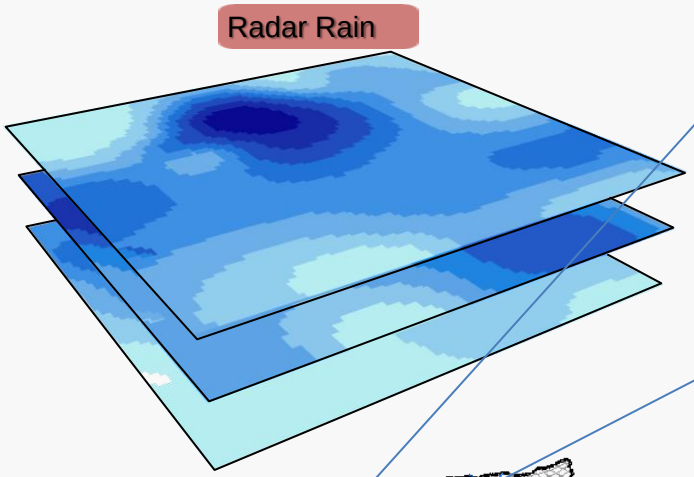


Rain Radar

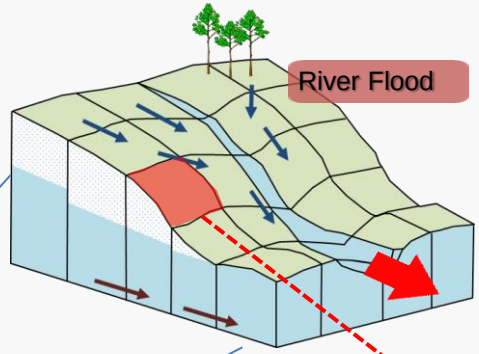
Issuing Flood warning



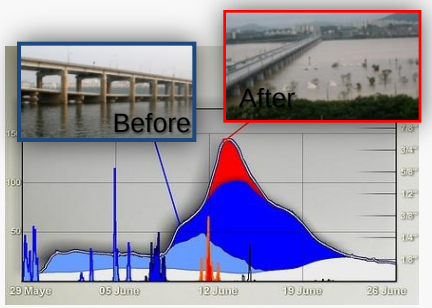
Applying fields of rain radar data

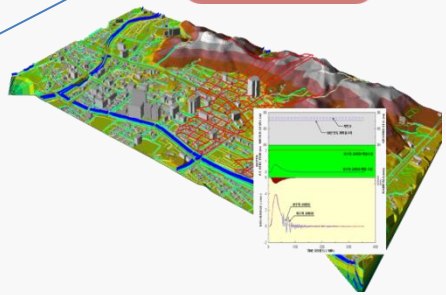


Radar Rain



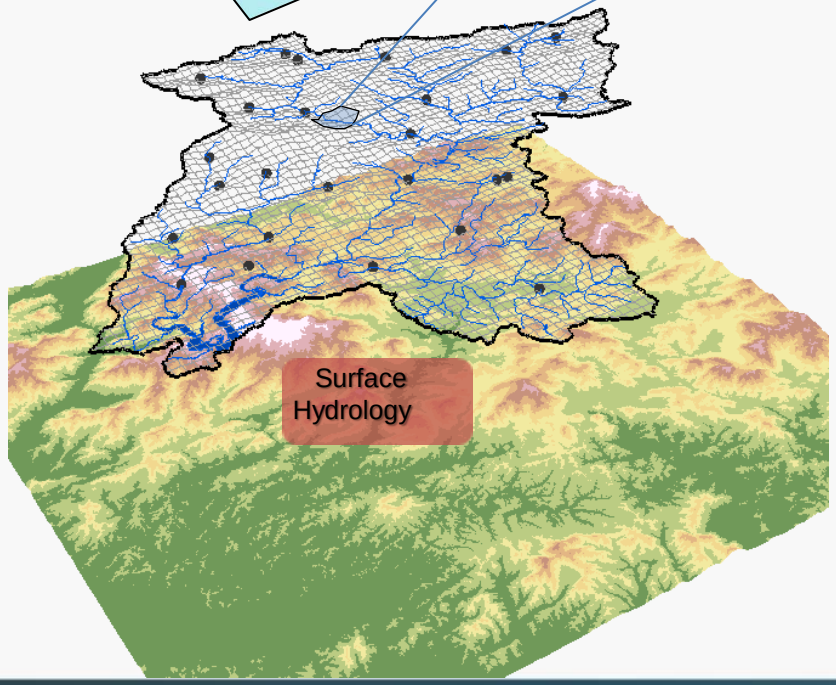
River Flood



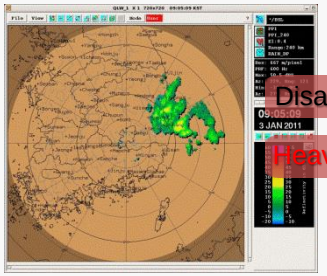


Urban Flood

Flash Flood

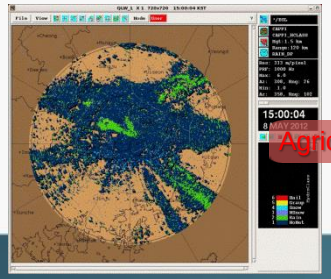


Surface Hydrology



Disasters

Heavy Snow

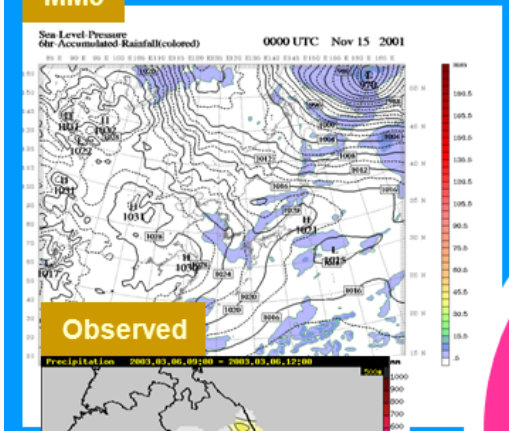


Agriculture

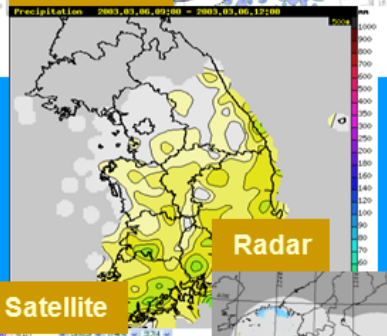
Flash Flood Prediction system

Meteorological Components

MM5

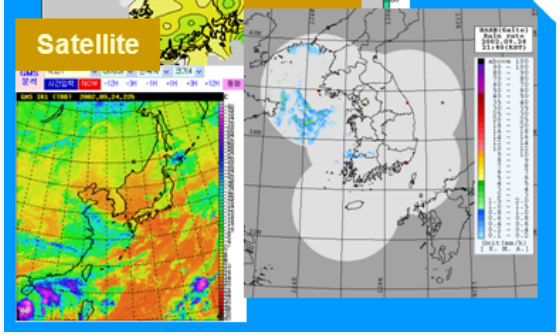


Observed



Radar

Satellite



Hydrologic Components

Threshold Runoff

- Manning's Bankfull Discharge
- Two Years Return Period Flow
- Snyder's Synthetic Unit Hydrograph
- GIUH

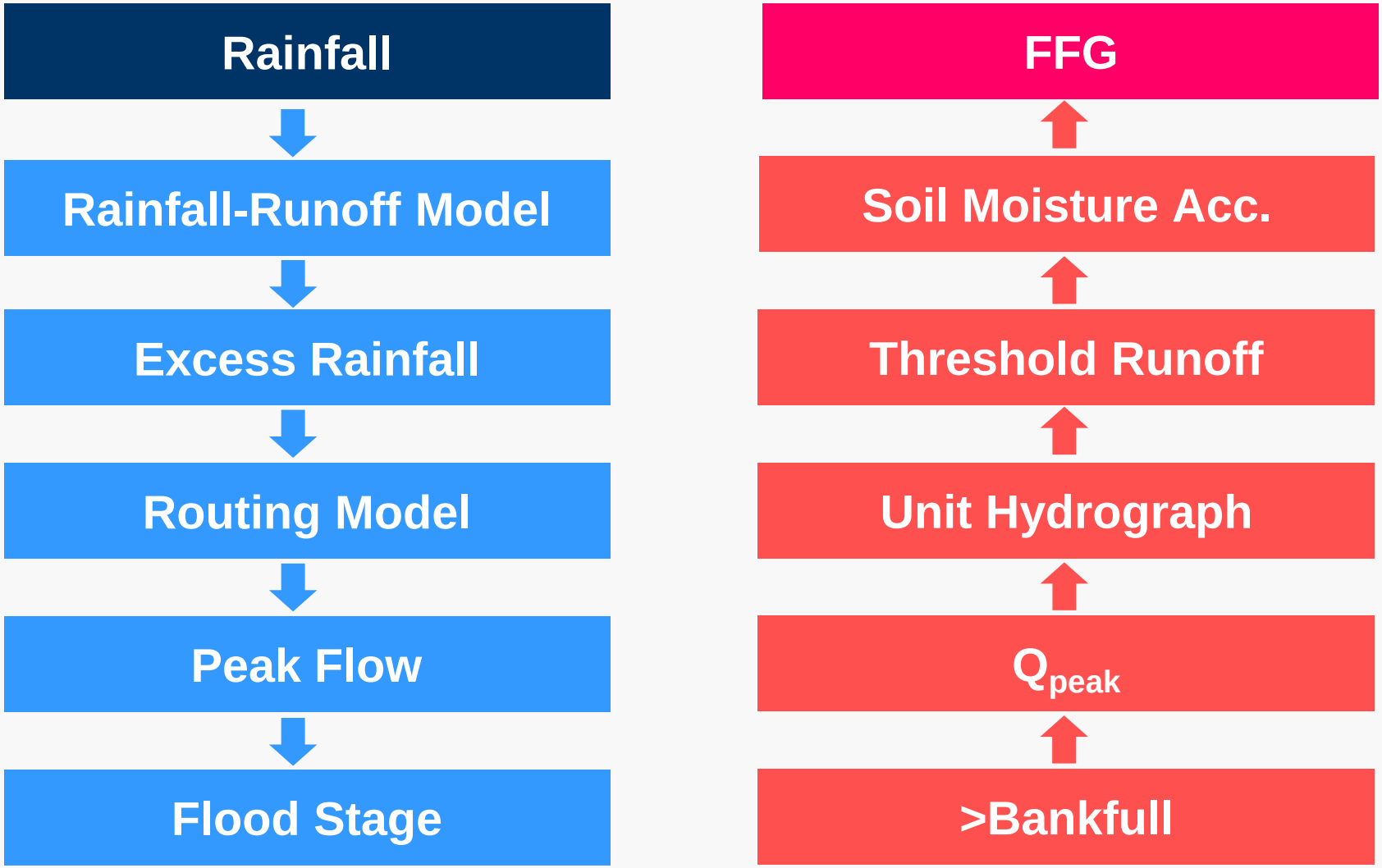
Estimation of Soil Moisture

- Sacramento SMA Model
- Mesoscale TOPMODEL
- VIC Model

Flash Flood Watching & Warning

FFG Computation

Process of Flash Flood Prediction system



Study Area

Namgang Dam Upstream Area

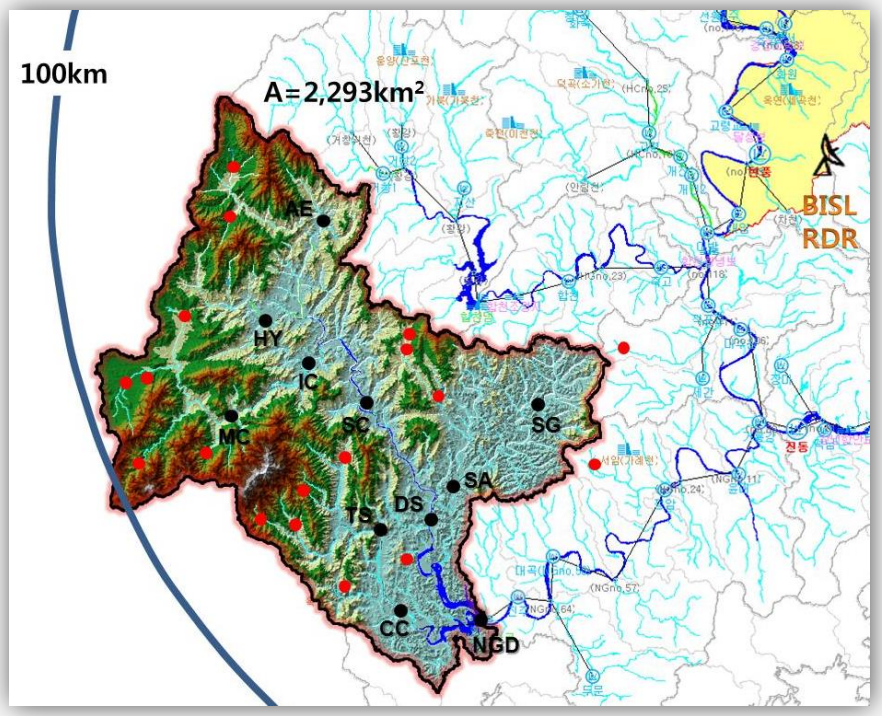
Characteristics of Namgang dam basin

Location	App. 128°E, 35°N
Basin Area	2,293 km^2
Basin Length	108 km
Elevation	45 ~ 1,915 EL.m
Land Use	Mountain
Annual MAP	1,514 mm

Available data

Raingauge St.	25
Stage St.	10
Dam	1
Sub-basins	14

Selected events : 16-20, Sep. in 2012

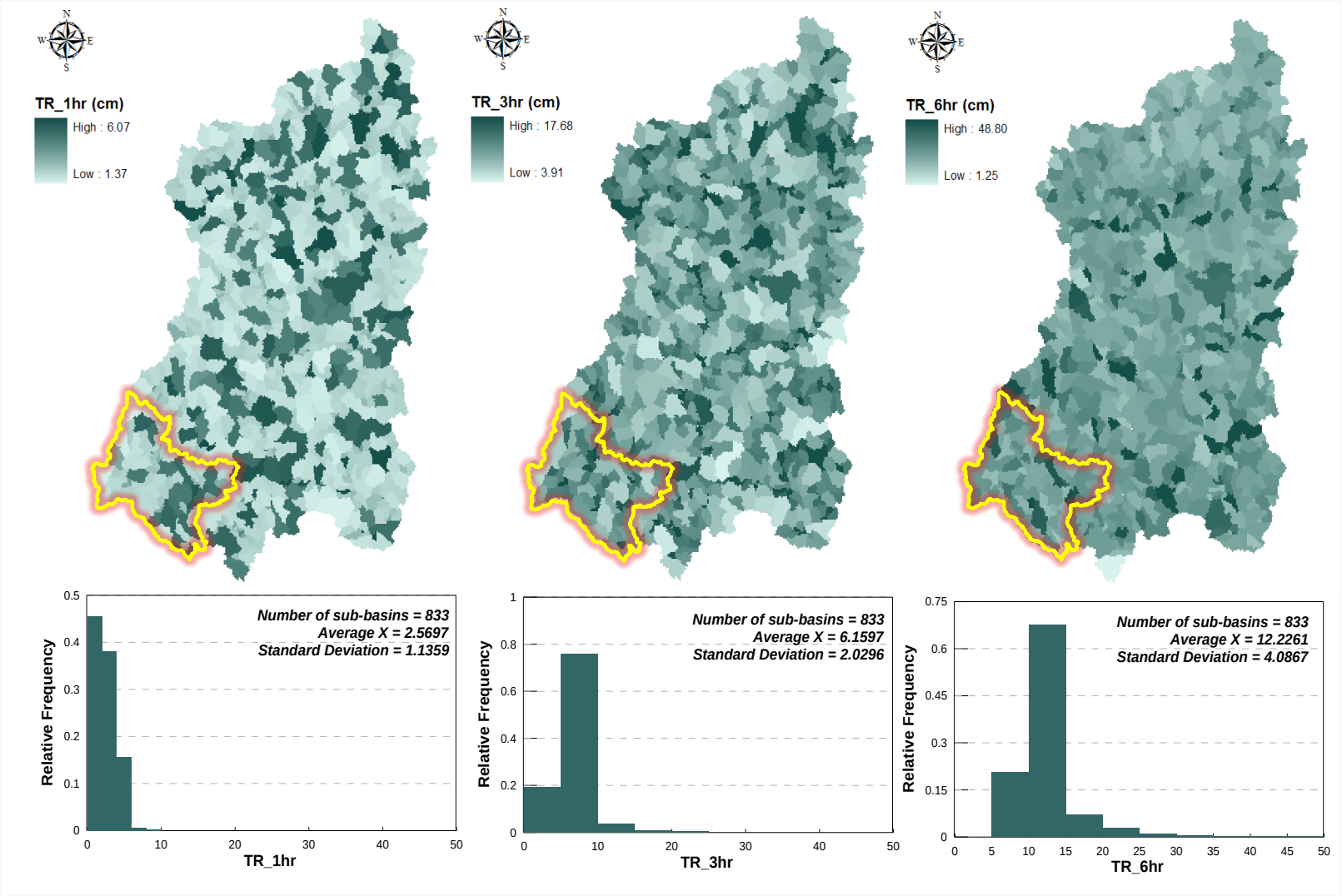


* AE = Aneui, HY = Hamyang, MC = Macheon, IC = Imcheon
SC = Sancheon, DS = Danseong, SG = Samga, SA = Shinan
TS = Taeseong, CC = Changchon, NGD = Namgang dam

< Study area of Namgang dam site >

Results of FF Prediction System

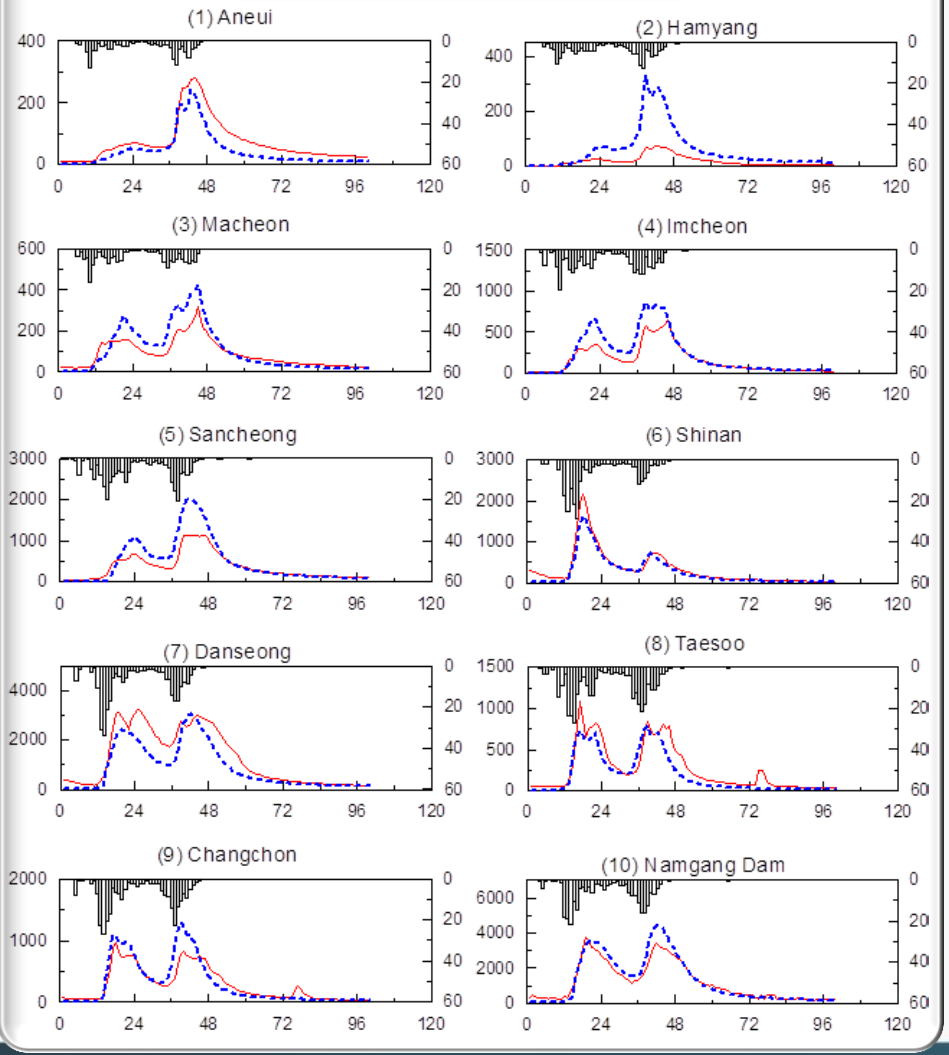
Threshold Runoff Results of Nakdong-River Basin



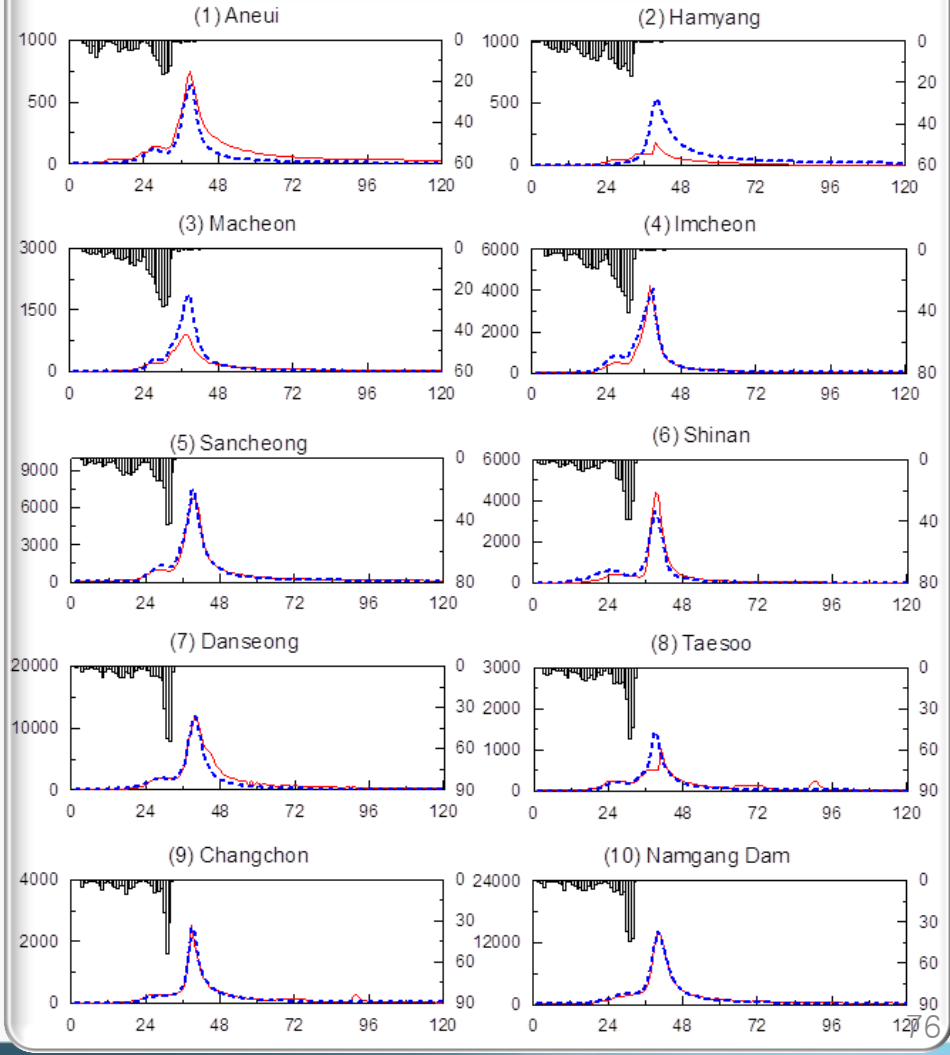
❖ Source : Results of IFLOOD project

Meso. TOPMODEL Results for Soil Moisture Accounting

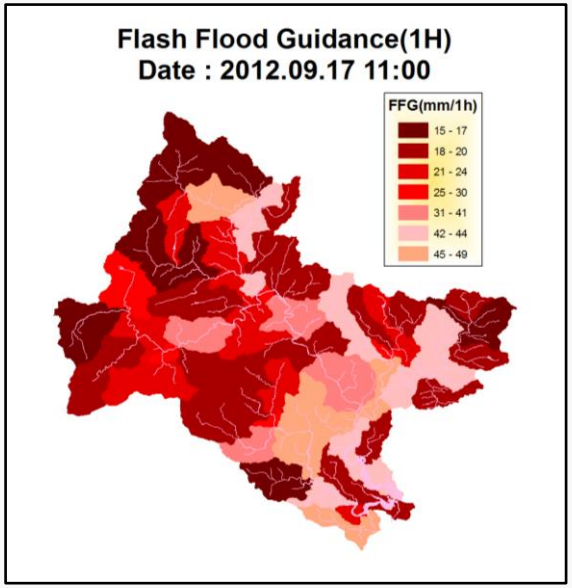
Event 2 : 22~26, Aug.

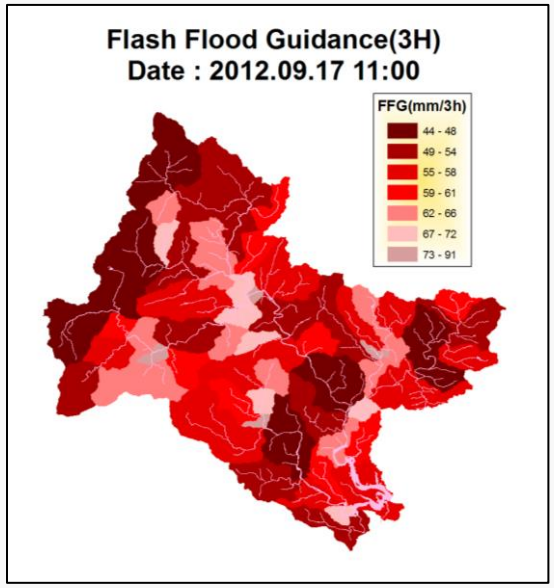


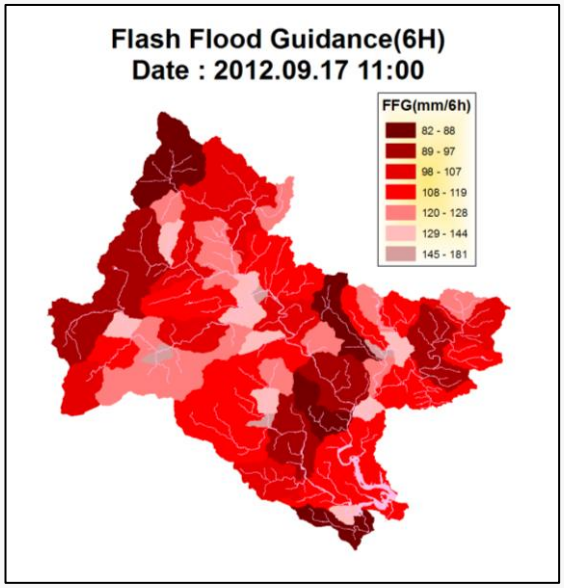
Event 4 : 16~18, Sep.

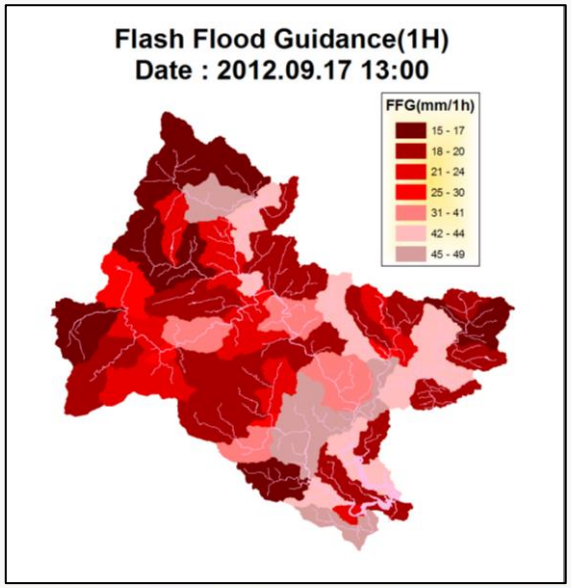


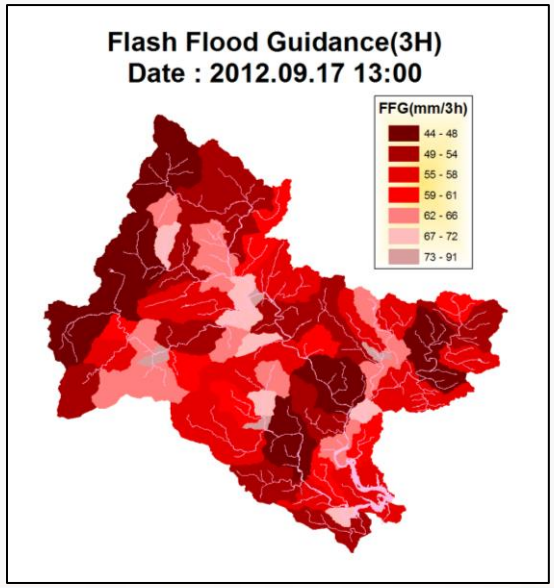
Flash Flood Guidance (FFG) during Typhoon “Sanba”

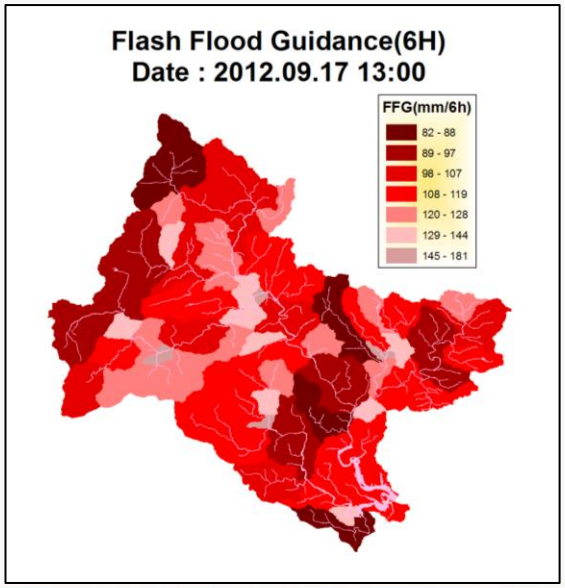




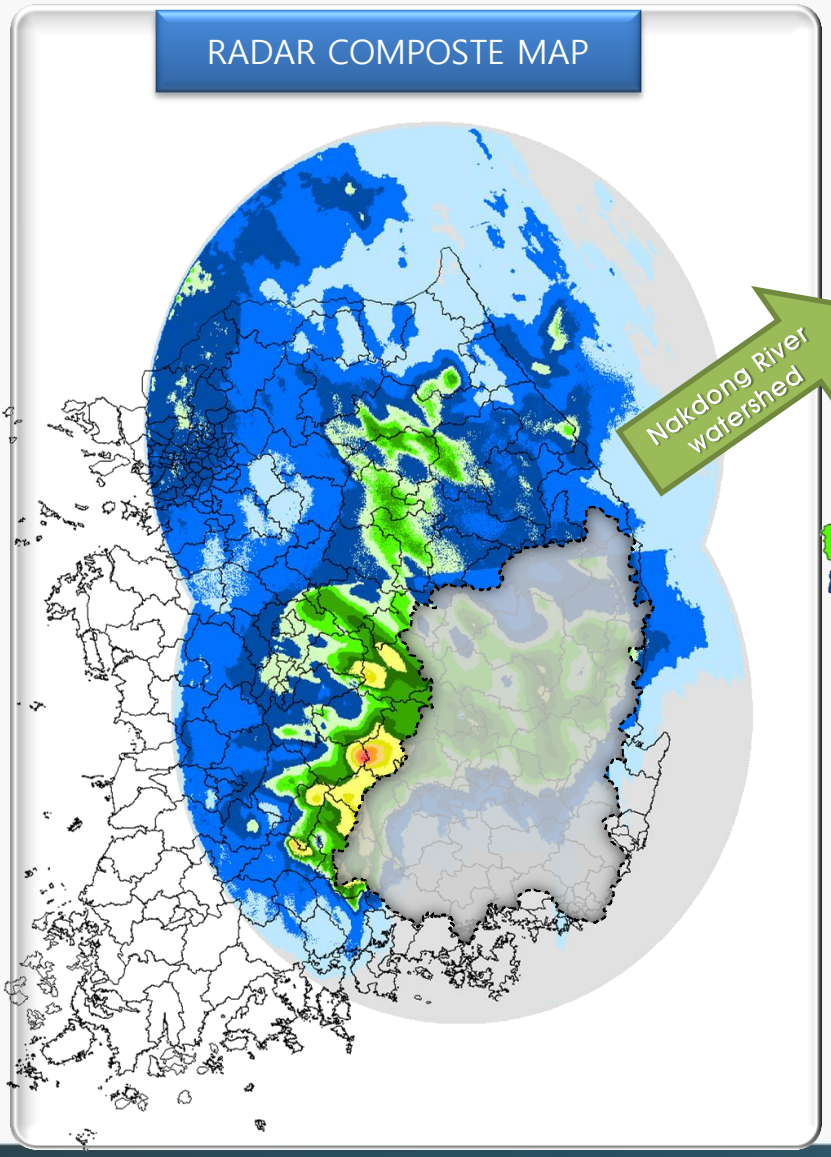






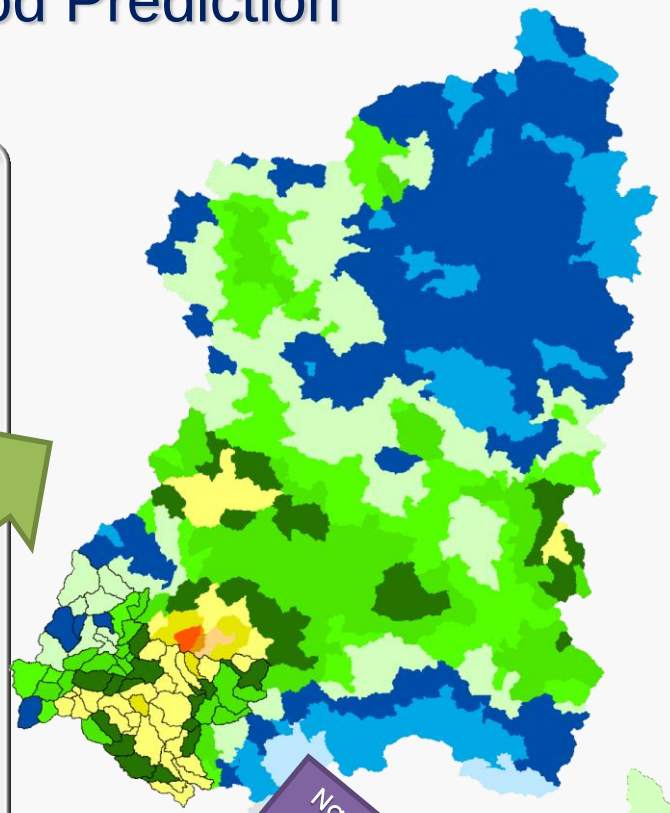


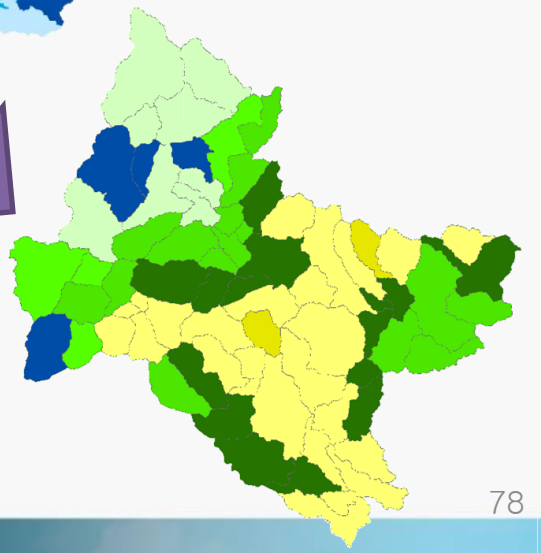
Radar QPE for Flash Flood Prediction



Nakdong River watershed

Namgang Dam Upstream Area

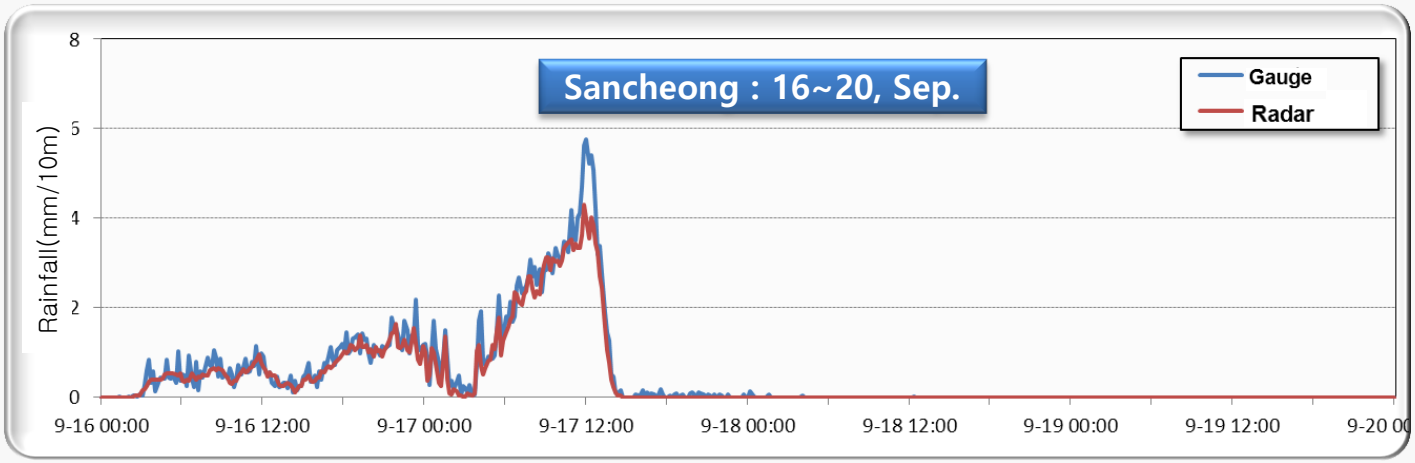


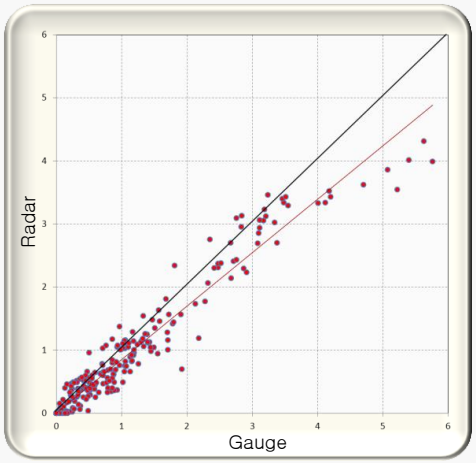


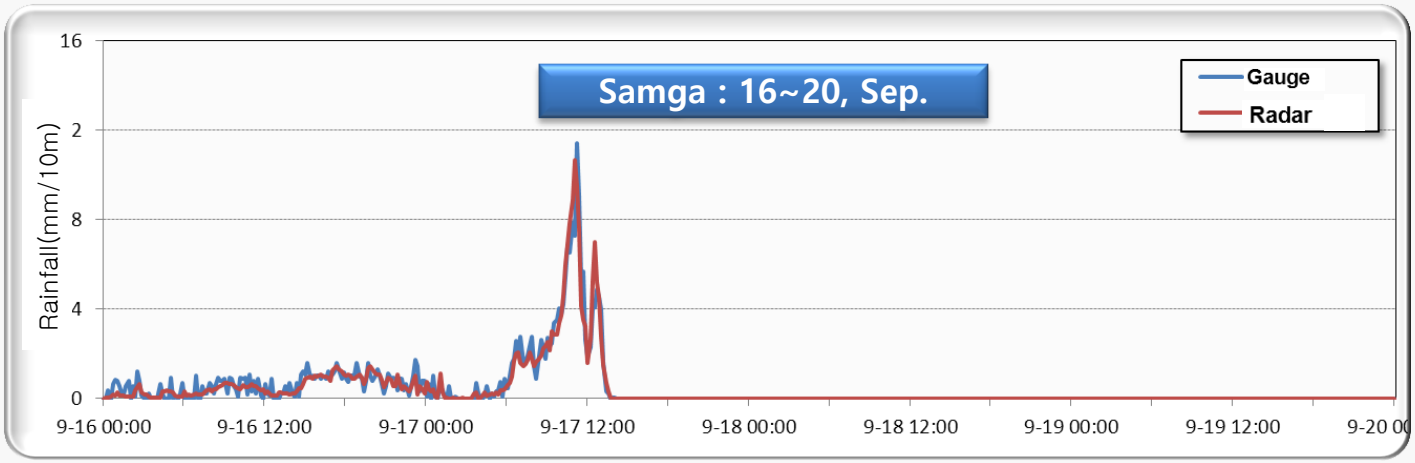
Radar Rainfall (mm/h)

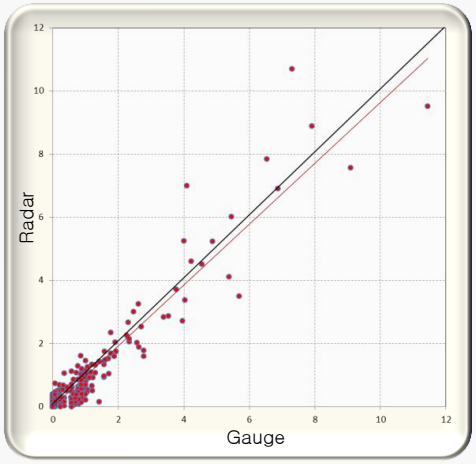
- 0
- 1 - 2
- 3 - 5
- 6 - 10
- 11 - 15
- 16 - 20
- 21 - 30
- 31 - 40
- 41 - 60
- 61 - 80
- 81 - 100
- 101 - 120
- 121 - 140
- 141 - 160
- 161 - 180
- 181 - 200

Temporal Variation of Radar Rainfall



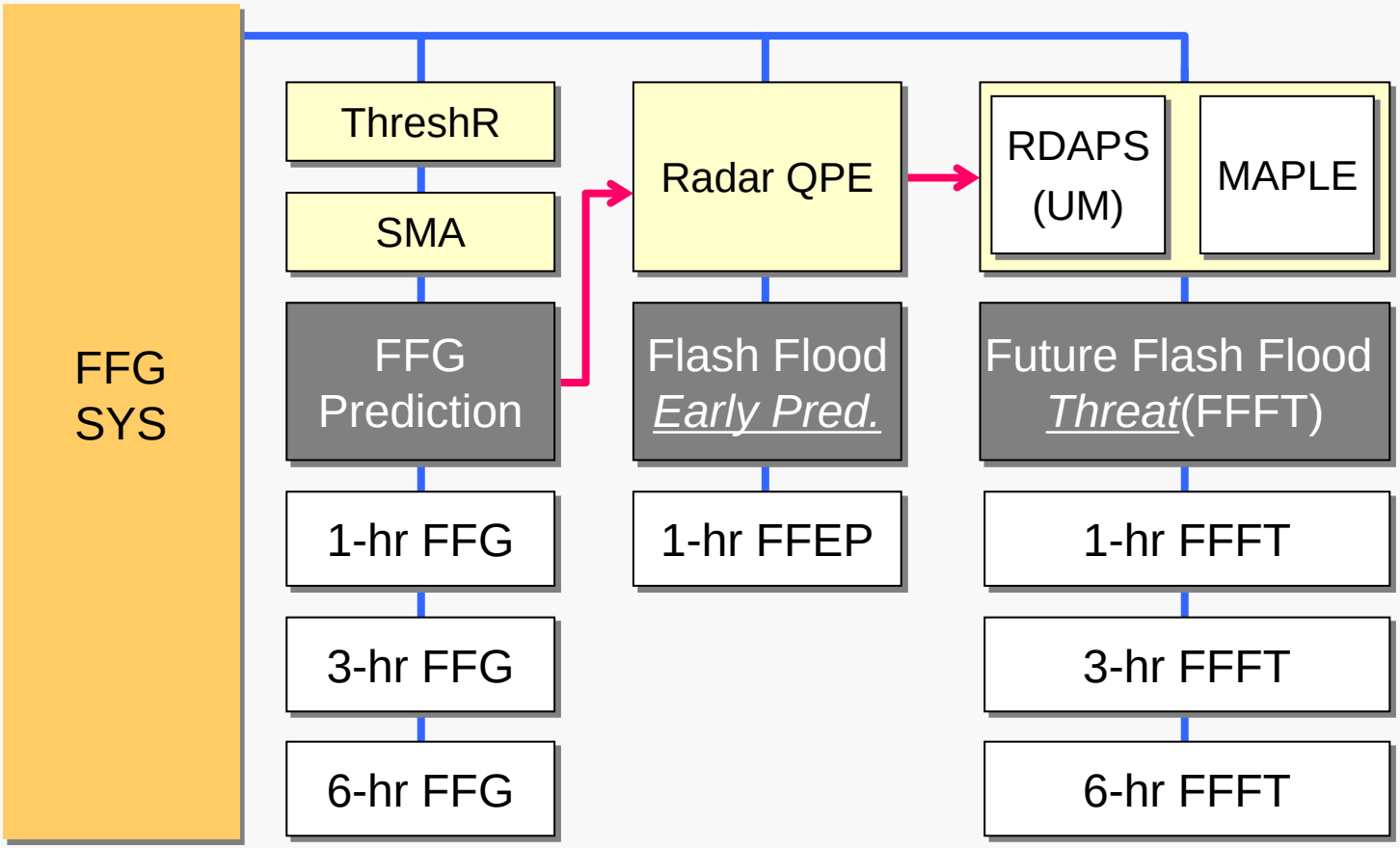




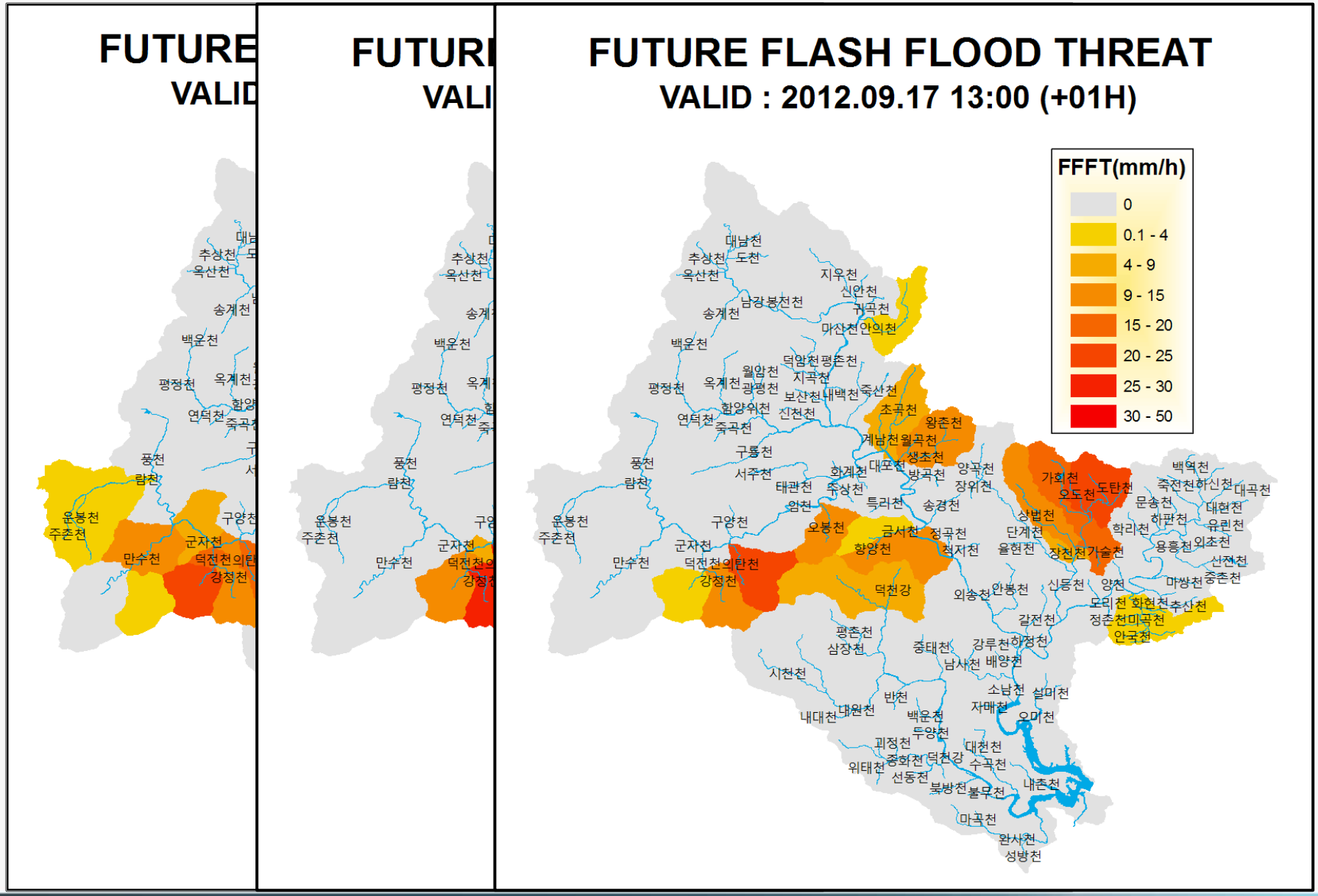


Integrated Operation for Flash Flood Prediction

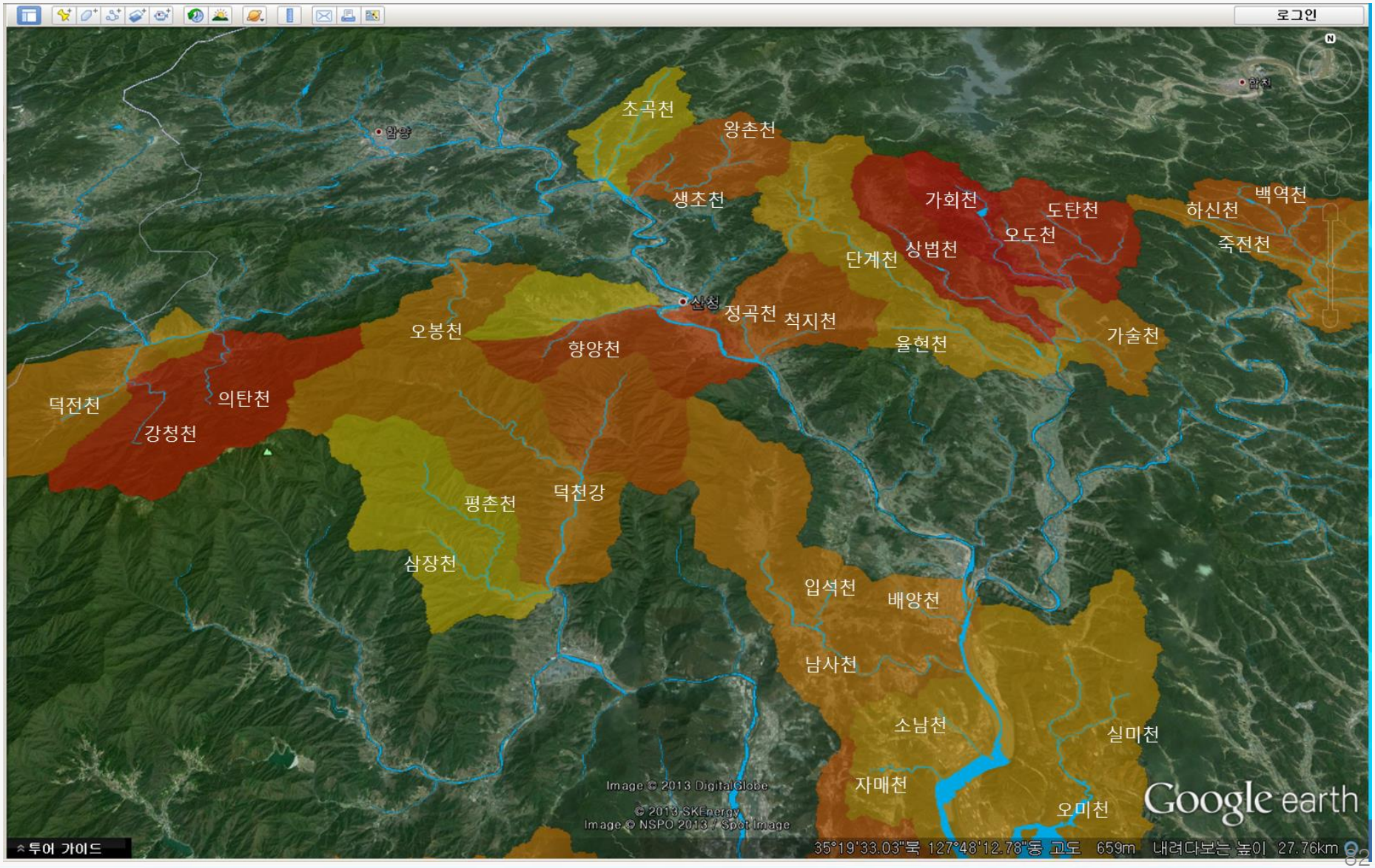
- Early flash flood prediction using radar QPE information
- Prediction of flash flood threat using QPF from UM and MAPLE



Flash Flood Threat during Typhoon “Sanba”

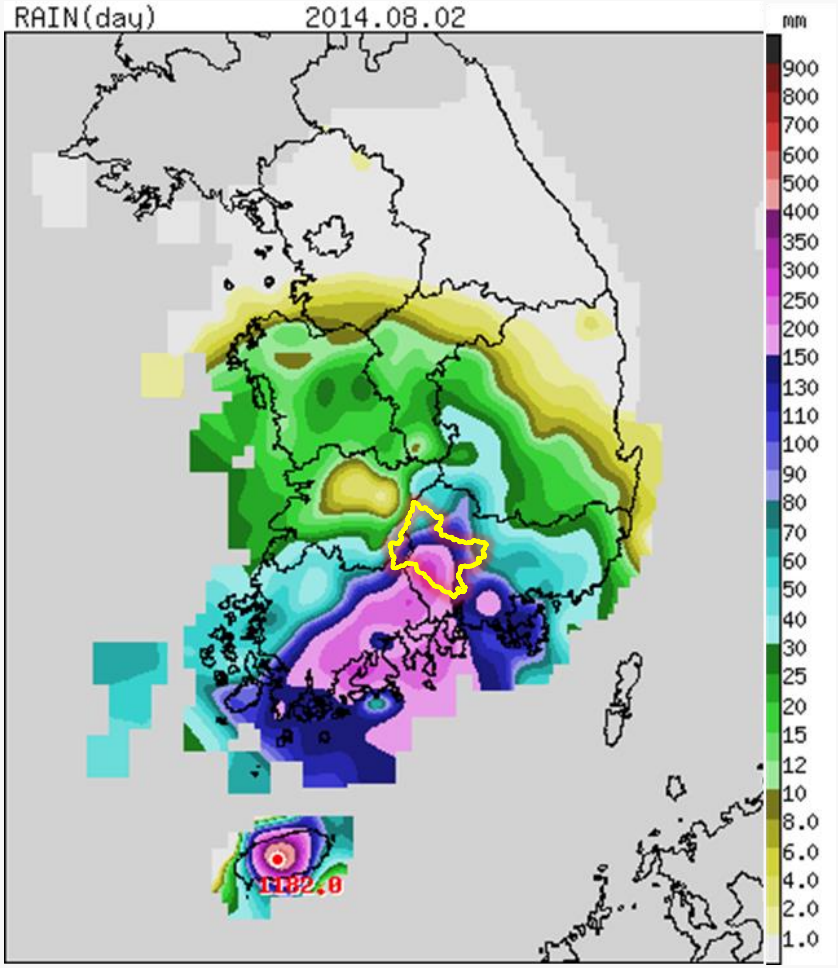


3D Spatial Display of Flash Flood Prediction Results



Real-Time Results of FFP System

Case of flash flood at some valleys of Mt. Ziri



YTN 뉴스 인쇄하기

인쇄하기 › 창닫기

지리산 계곡에 피서객 5명 고립...1시간만에 구조

2014-08-02 19:52

5 vacationer isolation at the Jiri valley

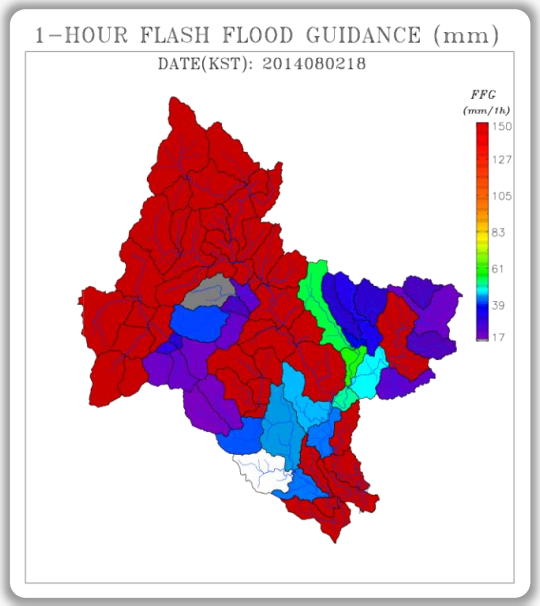
오늘 오후 3시 반쯤 경남 산청군 시천면 지리산 계곡에서 27살 조 모 씨 등 피서객 5명이 불어난 계곡물에 고립됐습니다.

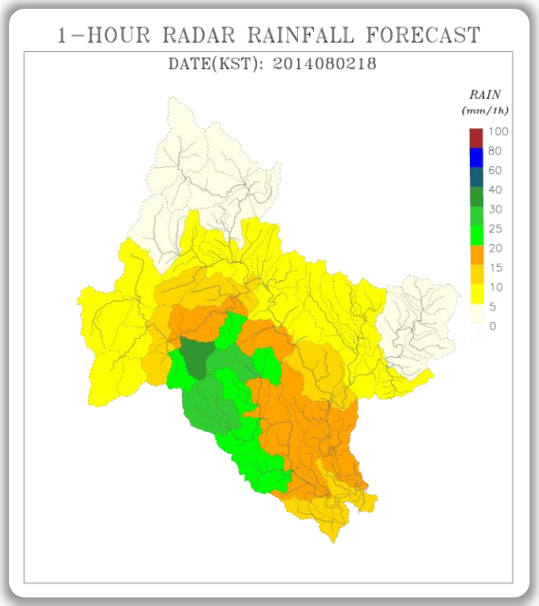
조 씨 등은 출동한 산악구조대에 의해 1시간여 만에 구조됐습니다.

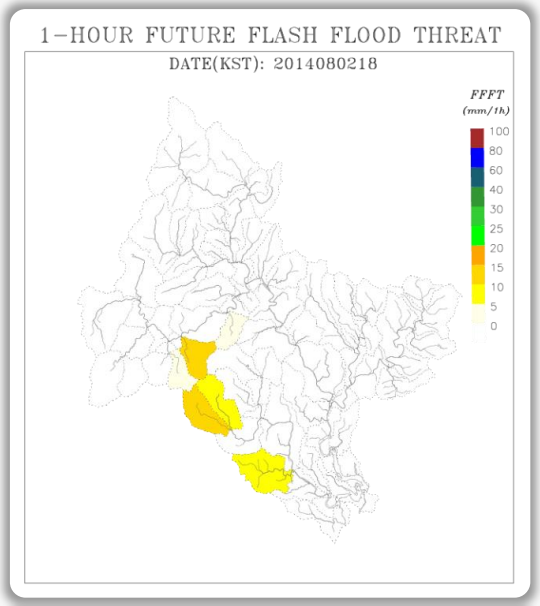
산청군 지리산 일대에는 태풍 나크리의 영향으로 오늘 낮 호우주의보에 이어, 저녁 7시를 기해 호우경보가 내려진 상태입니다.

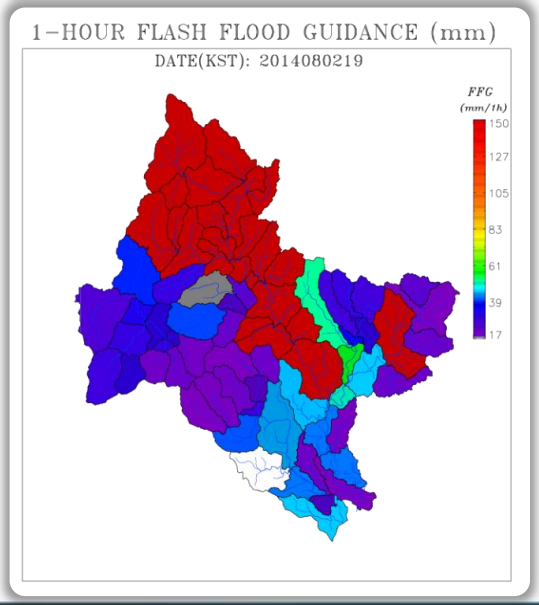
이종원 [jongwon@ytn.co.kr]

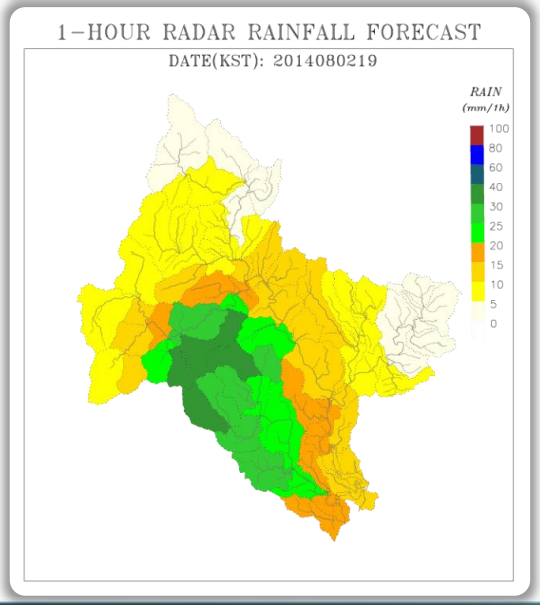
Real-Time Results of Flash Flood Prediction System

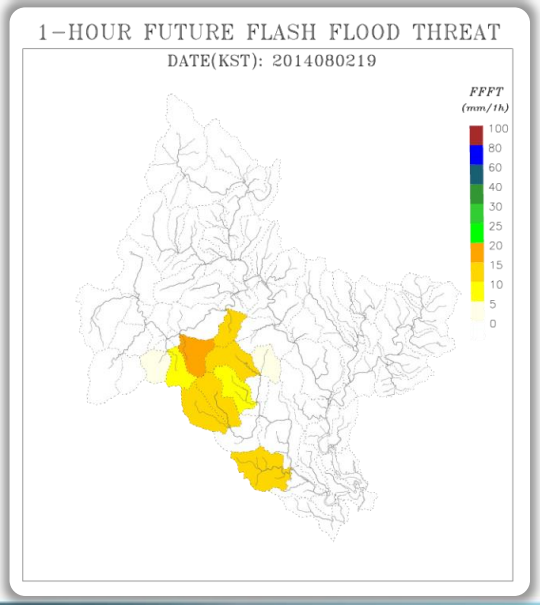


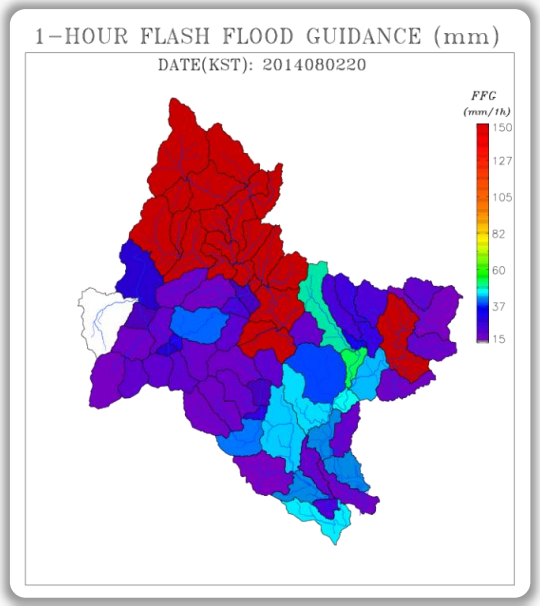


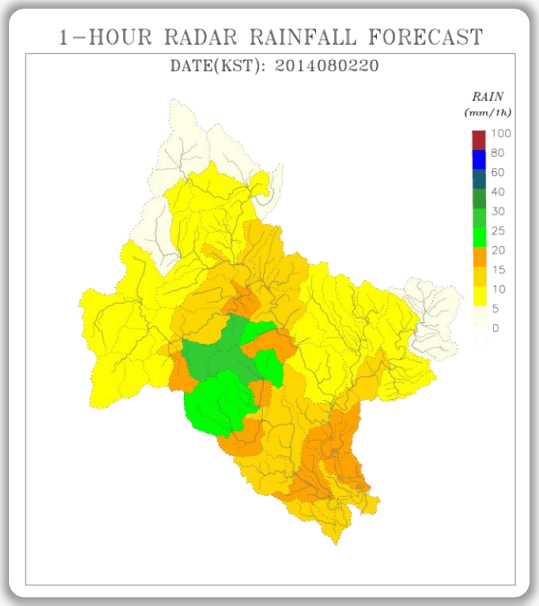


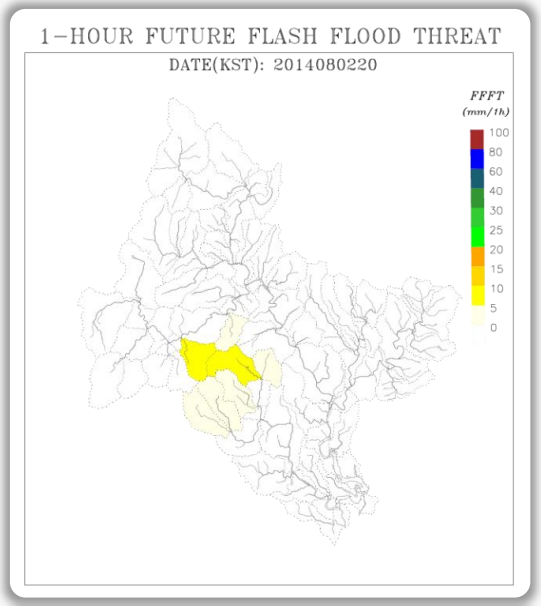


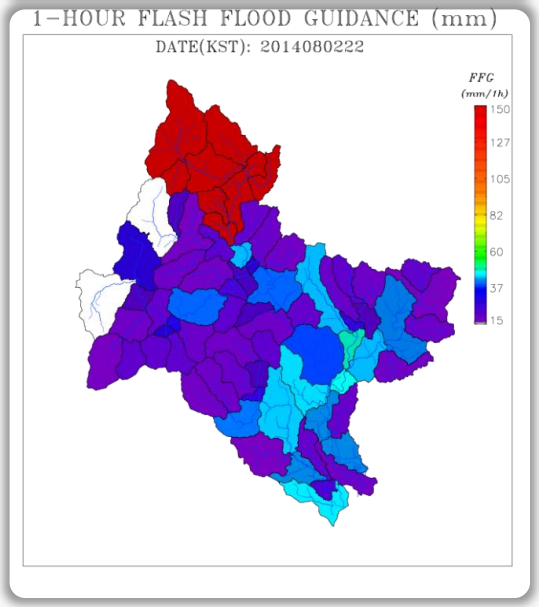





1-HOUR FLASH FLOOD GUIDANCE (mm)
DATE(KST): 2014080220
FFG
(mm/1h)
150
127
105
82
60
37
15


1-HOUR RADAR RAINFALL FORECAST
DATE(KST): 2014080220
RAIN
(mm/1h)
100
80
60
40
30
25
20
15
10
5
0


1-HOUR FUTURE FLASH FLOOD THREAT
DATE(KST): 2014080220
FFFT
(mm/1h)
100
80
60
40
30
25
20
15
10
5
0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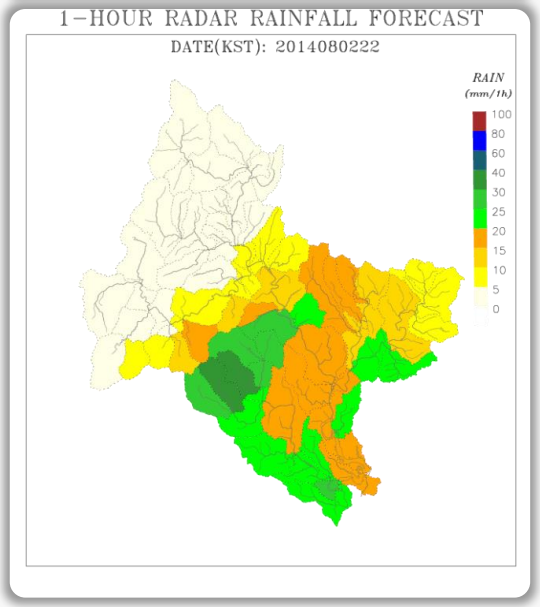
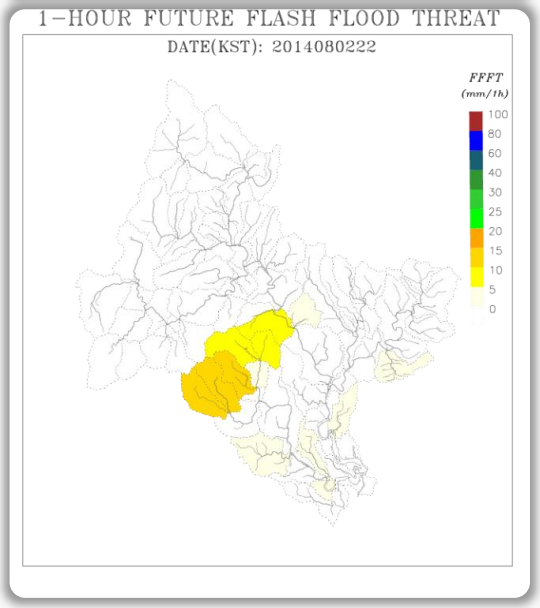
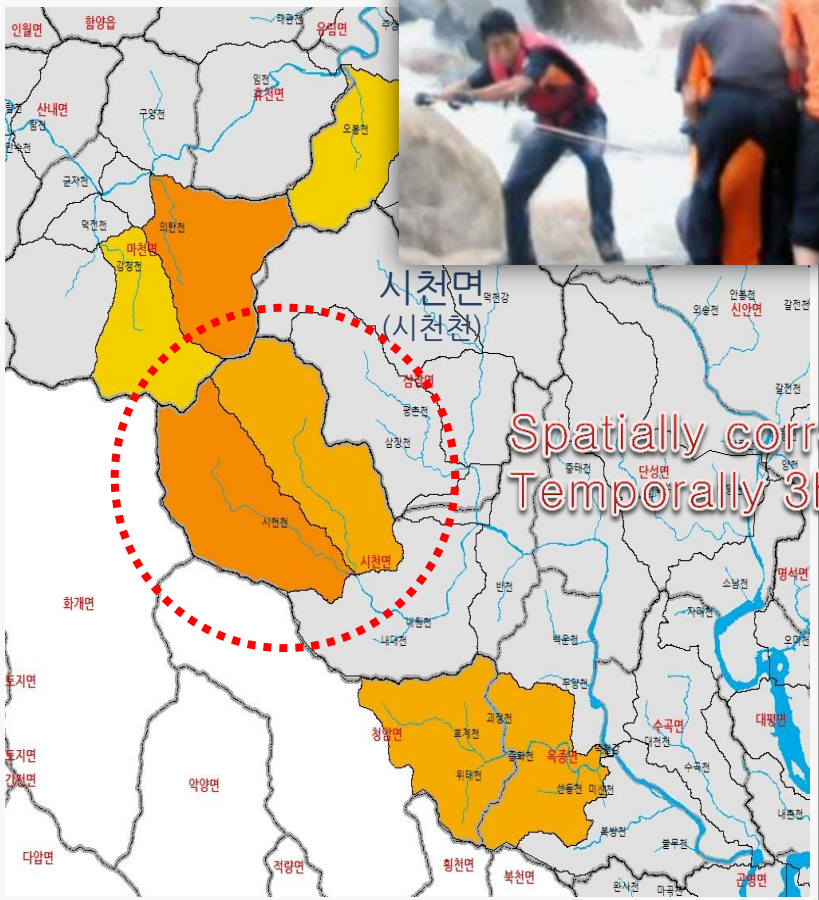
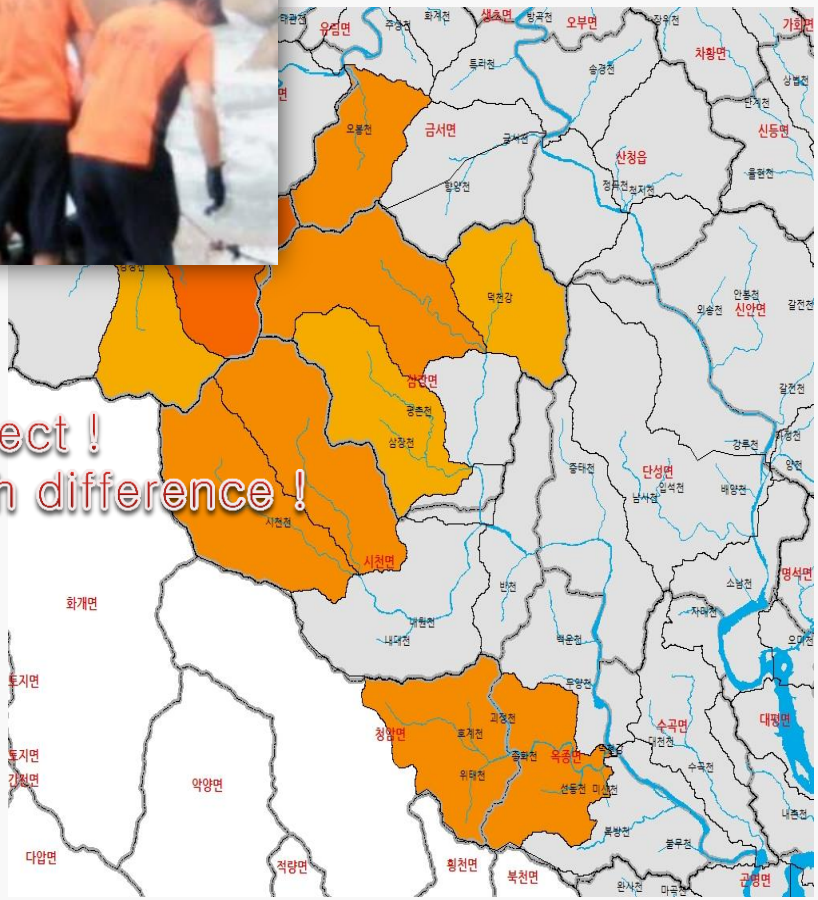
DATE(KST): 2014080222
FFG
(mm/1h)
150
127
105
82
60
37
15


1-HOUR RADAR RAINFALL FORECAST
DATE(KST): 2014080222
RAIN
(mm/1h)
100
80
60
40
30
25
20
15
10
5
0


1-HOUR FUTURE FLASH FLOOD THREAT
DATE(KST): 2014080222
FFFT
(mm/1h)
100
80
60
40
30
25
20
15
10
5
0

Analysis of Localized Flash Flood Prediction Results

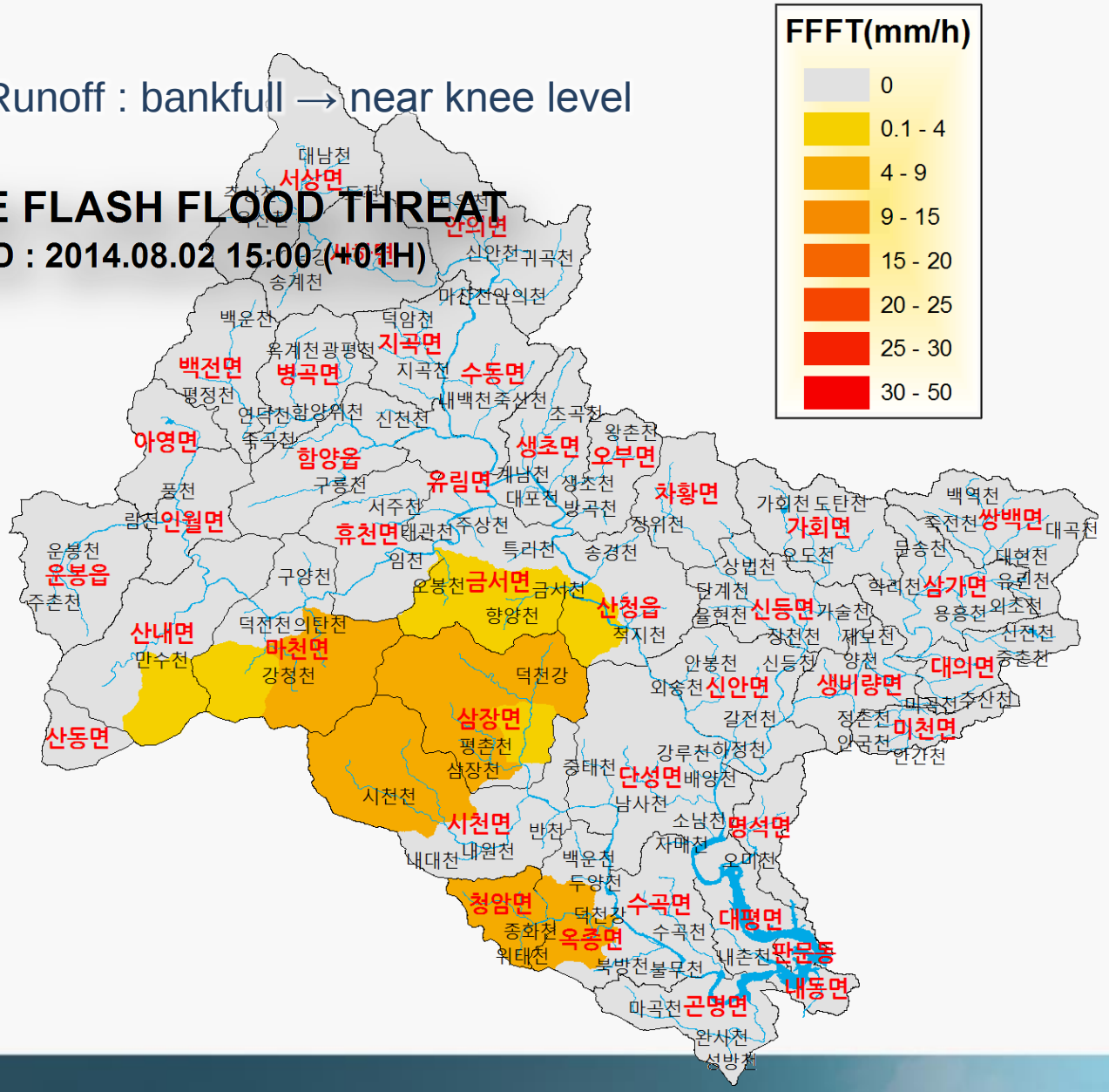
Time	6 p.m. 2, Au	n. 2, Aug.(+1H forecast)
Fore-casted results		

시천면
(시천천)

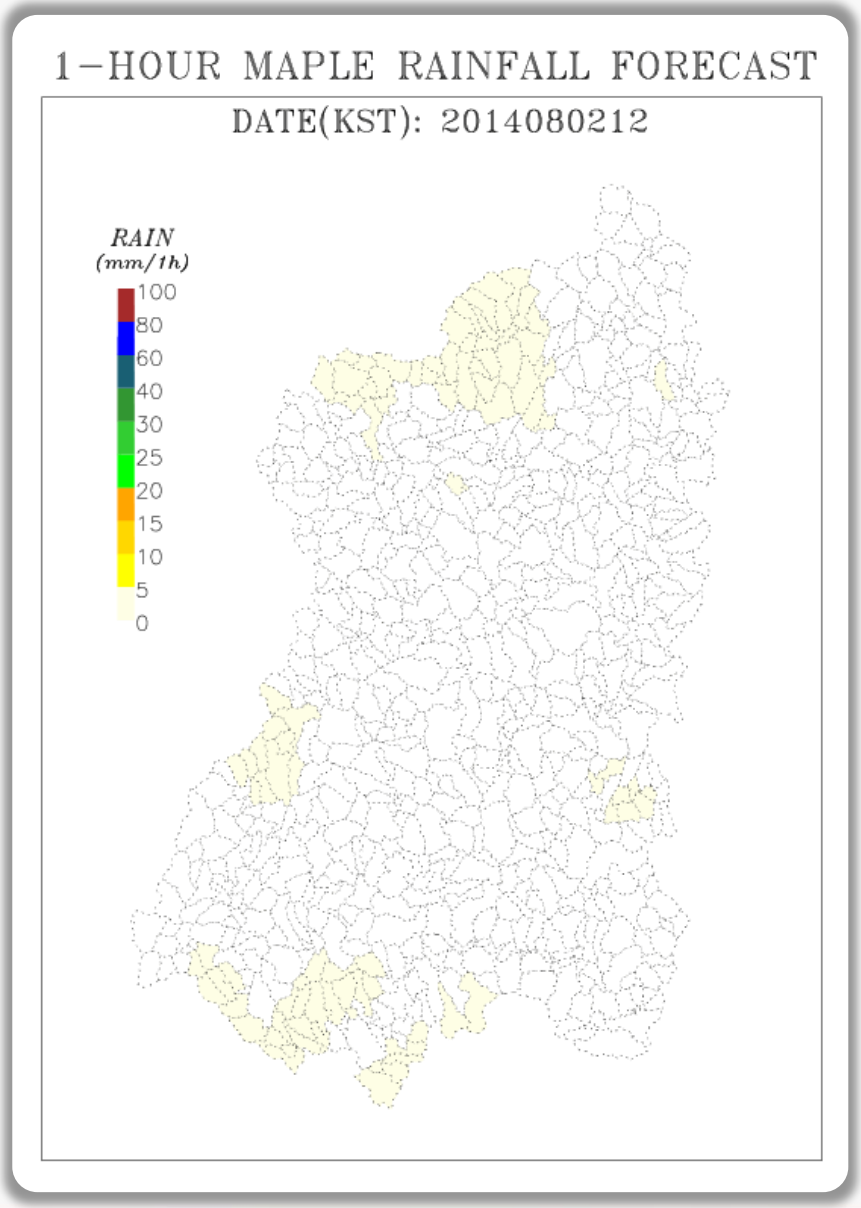
Spatially correct !
Temporally 3h difference !

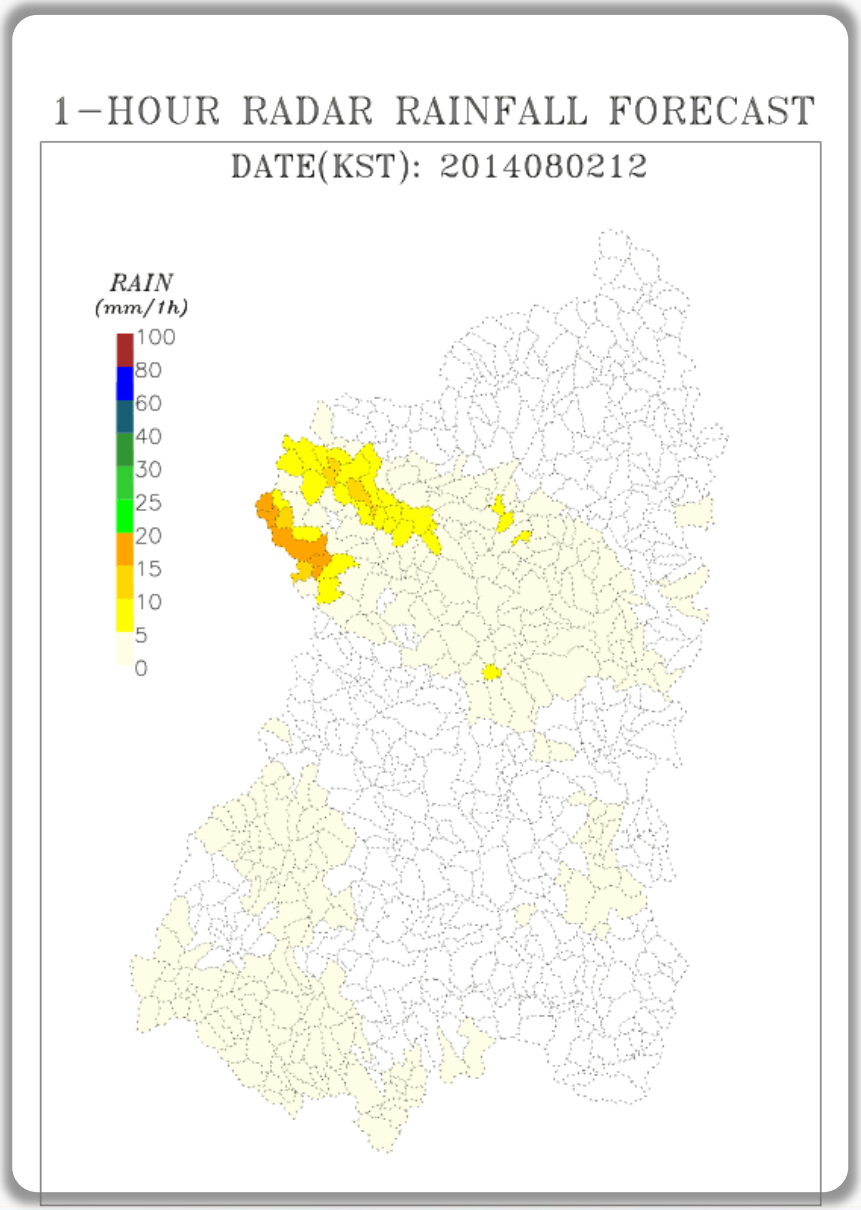
Adjustment Case of FFP Model for Vacationer Safety

- Threshold Runoff : bankfull → near knee level



Application Results of Radar QPF(MAPLE)






Thanks for your attention