Current Activities for Flood Forecasting Enhancement in Korea

2007. 12. 4

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Current Flood Damage and Their Causes

Abnormal Weather & Climate Change Impacts

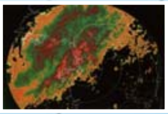
Flood vulnerability analysis, structural and nonstructural adaptation measures

Short Forecast Lead Time

Use of numerical weather forecast information for real-time short-term flood forecast

Urban Flood Damage Reduction

Development of the coupled radar rainfall and urban flooding modeling system



Improvement of the Existing Forecasting Models

Develop a state space form of stochastic dynamic Kalman filtering model for real-time prediction and updating system

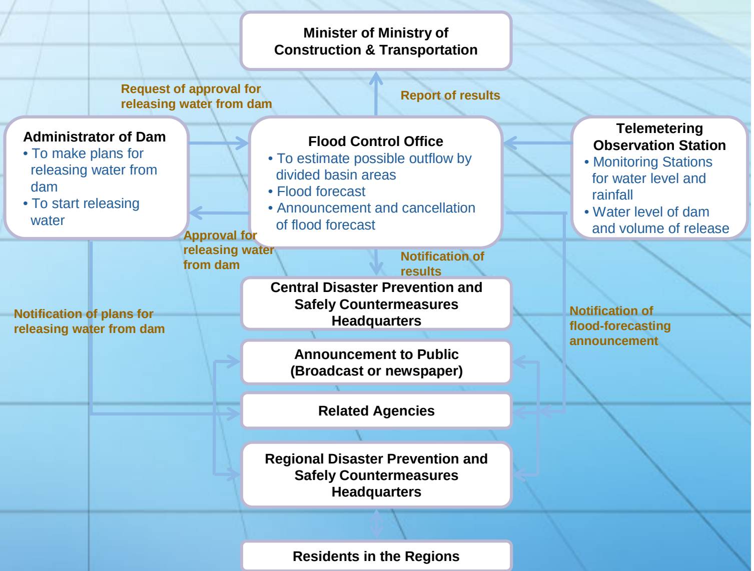
Flash Flood Damage Reduction

In addition to classical forecasting system, develop a new flood forecasting model system

Current Flood Forecasting System (FFS)

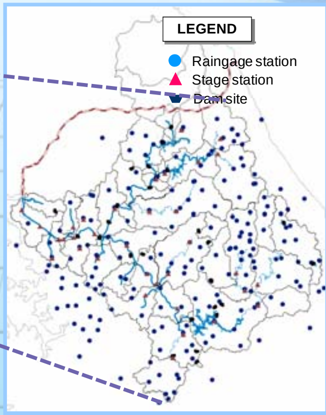
- **FFS**
  - **Hydrologic and Meteorologic Observation System**
  - **Watershed and River Modeling System**

FFC Organization



Flood Forecasting and Warning Process

▪ FFS Observation Networks

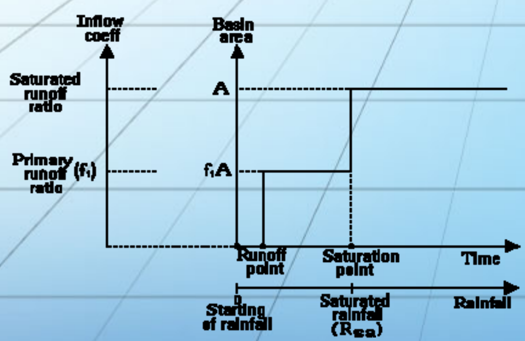


Basin	Area (km^2)	%	Raingage No.	Stage No.
Han R.	26,018	26.1	153	96
Nakdong R.	23,817	23.9	165	140
Geum R	9,810	9.9	99	100
Young. & Seom.R	3,371	4.9	81	92
Total	63,016	68,2	498	302

※ Up to 2006

▪ Watersheds and River Routing Models

- Watershed Routing
  - Storage function method
- River Routing
  - Storage function method
  - Kinematic Wave method
  - Muskingum method
  - DWOPER



$$\frac{ds(t+T_i)}{dt} = r_{ave}(t) - q(t+T_i)$$

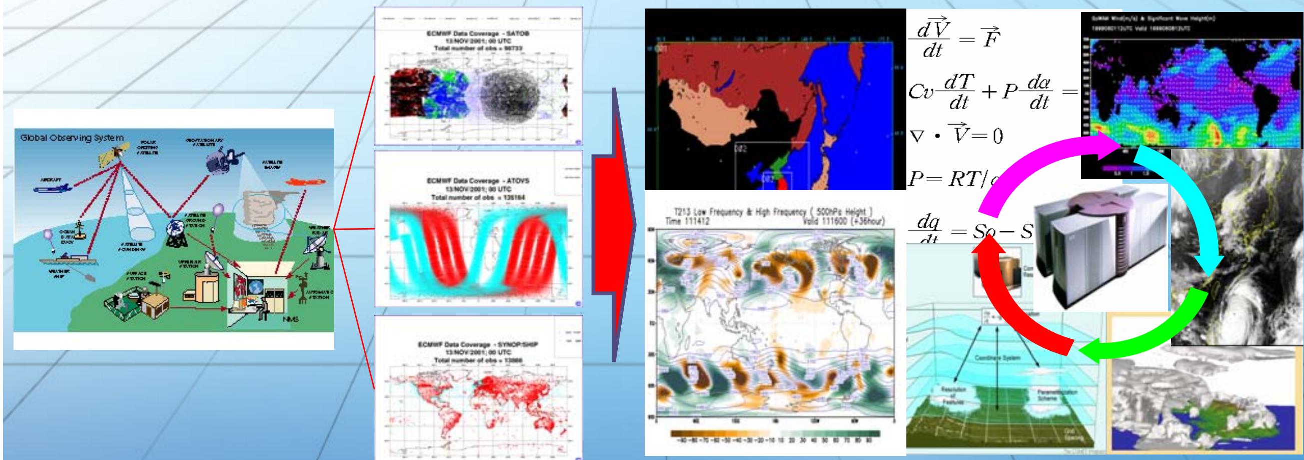
$$s(t) = k \cdot q(t)^p$$

$$r_{ave}(t) = \begin{cases} f_1 r_{ave}(t) & \sum r_{ave} < R_{sa} \\ r_{ave}(t) & \sum r_{ave} \geq R_{sa} \end{cases}$$

- Difficult to find unique parameter set
- Require experts for operational use

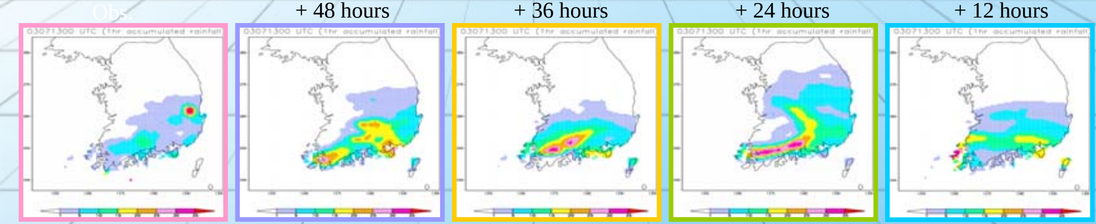
Activity I — Use of Numerical Weather Forecast for Real-Time Flood Forecasting

- **Numerical weather prediction at KMA/MOST**
  - GDAPS for 110×110 and 220×220km
  - RDAPS for 30×30km (5-km res. Test)
  - GTS network for global observations of on-site and RS data
  - Short-term(48 hrs), weekly(48hr-7days), long-term (monthly, seasonal, bi-annual) weather forecast information are provided

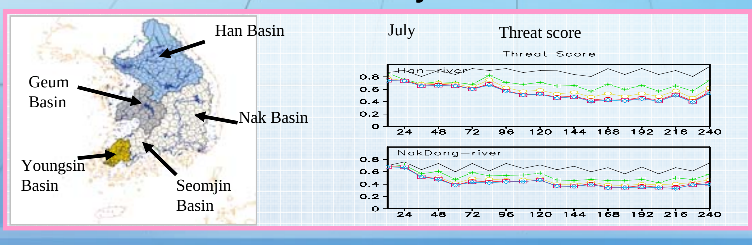


Evaluation of Weather Forecast Accuracy

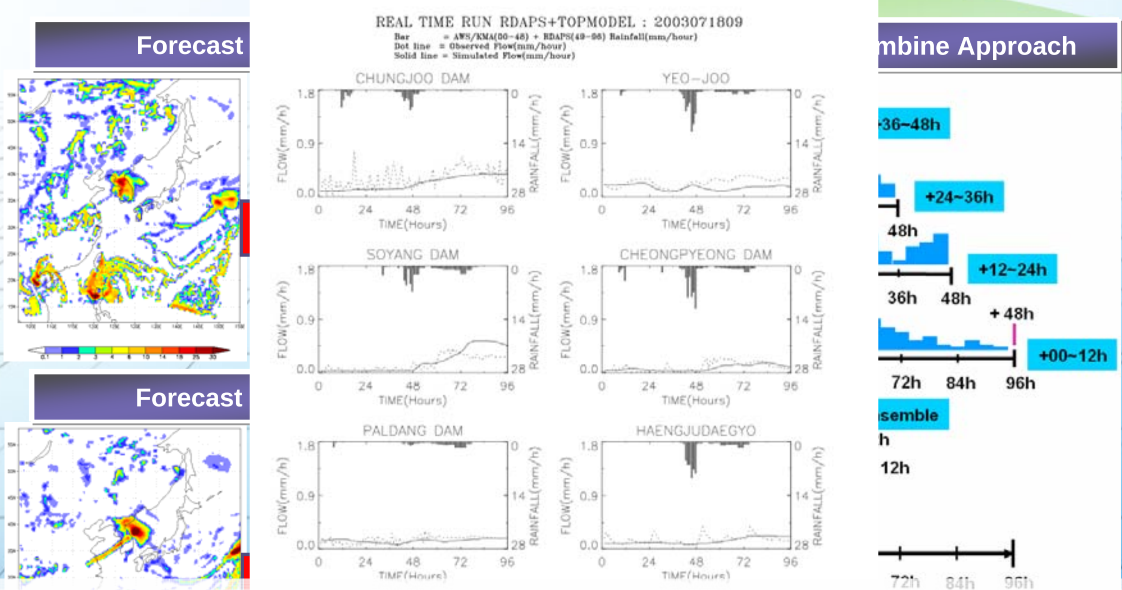
- **RDAPS 48 hours forecast**
  - Until 12 hours: underestimate due to spinup time
  - 24~48 hours: overestimate
  - 12~24 hours: most accurate
    bias score: 0.8~0.9 threat score: 0.4
    accuracy: 0.8 rmse: 2 mm/12hr



- **GDAPS 10 days forecast**
  - Threat score: 0.7 until 3 days



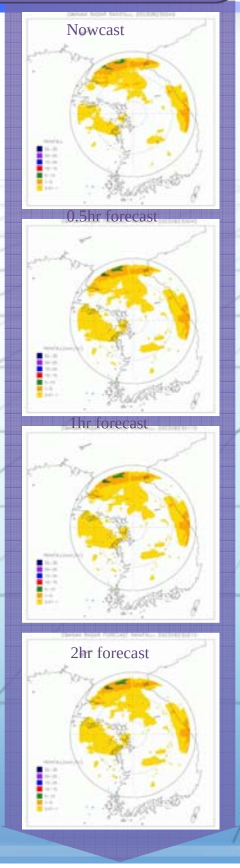
RDAPS numerical weather forecast (data : 2003.7.18.00-07.24.12)



- Need to increase the spatial resolution from 30 km to 5km
- Increase the numerical weather forecasting accuracy and develop some adjustment techniques
- Use of weather radar and satellite data for flood management

Activity II

Development of Radar Rainfall & Flood Forecasting System for Urban Watersheds

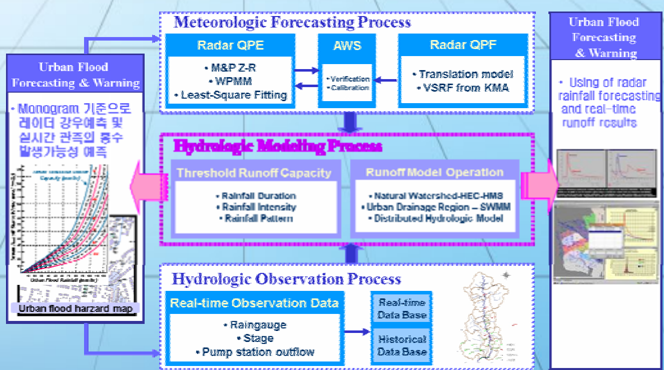


Objectives

– To develop radar rainfall and forecasting system for Jung-rang urban watershed

Method

– Consists of four processes: Meteorological Forecasting Process, Hydrologic Observation Process, Hydrologic Modeling Process, and Urban Flood forecasting & Waning Process

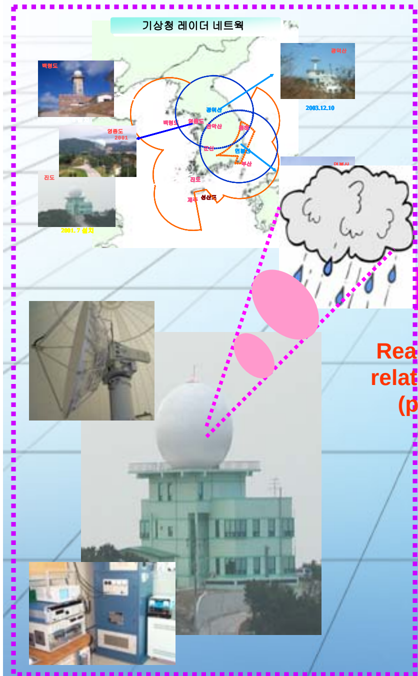


Major outcomes

– To estimate and forecast real-time radar-driven rainfalls
– To provide algorithms for real-time flood forecast

Nowcast and short-term forecast with radar data

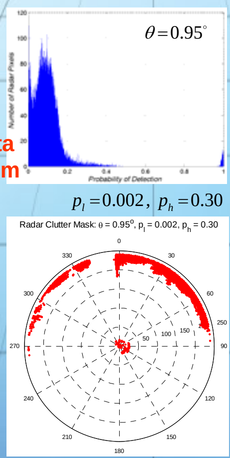
Radar operation and signal data process (KMA)



Real-time data relation system (planning)

Incorrect radar data treatment

- ✓ POD frequency analysis
- ✓ Beam blockage remove
- ✓ Ground Clutter remove



Quantitative Precipitation Estimation(QPE)

- ✓ Marshall-Palmer Z-R Eq.
- ✓ Window Probability Matching Method
- ✓ Least-Square Fitting Method

Real-time radar rainfall bias adjustment

- ✓ Bias adjustment method application
- ✓ Real-time stochastic bias adjustment method application

Quantitative Precipitation Forecast (QPF)

- ✓ Translation Model ✓ VSRF from KMA

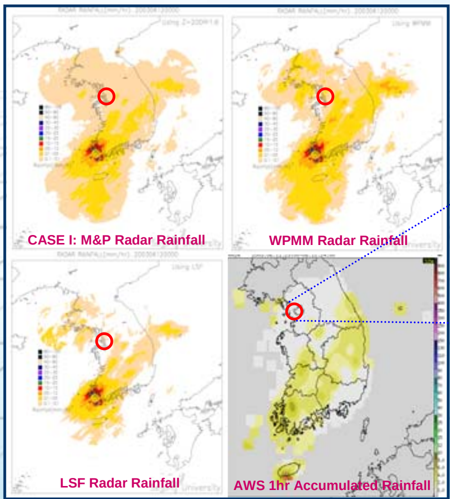
FP

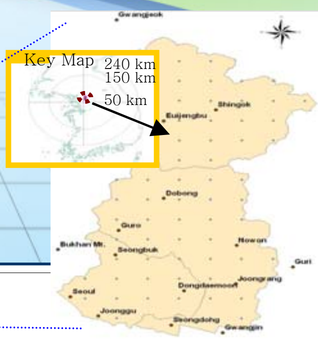
FFG

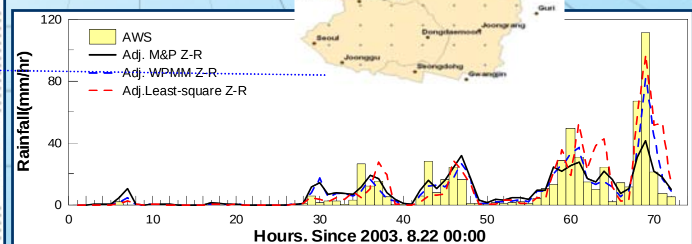
Hydrologic Modeling Process

- ✓ SWMM model
- ✓ HEC-HMS
- ✓ Distributed hydrological Model

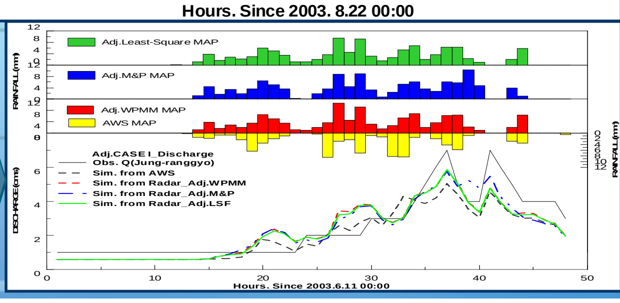
Rainfall & discharge estimates







Hydrologic application of radar-driven rainfalls for flow simulation



- Real-time stochastic bias adjustment and forecasting algorithm

WSR-88D Precipitation Adjustment Algorithm

- Process model of the mean-field bias

$$A_{t+1} = A_t + w_{t+1}$$

- Observation equation

$$\overline{G}_{t+1} = \overline{R}_{t+1} A_{t+1} + \overline{e}_{t+1}$$

- Bias

$$A_t = \frac{\sum_{j=1}^{N_g} R_r(t,j) R_g(t,j)}{\sum_{j=1}^{N_g} R_r^2(t,j)}$$

Adaptive Error Parameter Algorithm

- Stochastic logarithmic bias model

$$\beta_{t+1} = \beta_t + w_{t+1}$$

$$z_{t+1} = \beta_{t+1} + v_{t+1}$$

$$\beta_t = \ln \left[\frac{\sum_{j=1}^{N_g} R_g(t,j)}{\sum_{j=1}^{N_g} R_r(t,j)} \right]$$

- Kalman Filter for log-bias

$$\hat{B}_{t+1}^{-} = \exp\left\{ \hat{\beta}_{t+1}^{-} + 0.5 P_{t+1}^{-} \right\}$$

$$\sum_{t+1}^{-} = \left(\hat{B}_{t+1}^{-} \right)^2 \left(\exp\left\{ P_{t+1}^{-} \right\} - 1 \right)$$

Maximum Likelihood Autoregressive Algorithm

- First-order autoregressive process

$$\beta_t = \ln \left[\frac{\sum_{j=1}^{N_g} R_g(t,j)}{\sum_{j=1}^{N_g} R_r(t,j)} \right]$$

- Bias prediction equation

$$\beta_{t+1} = a_1 \beta_t + w_{t+1}$$

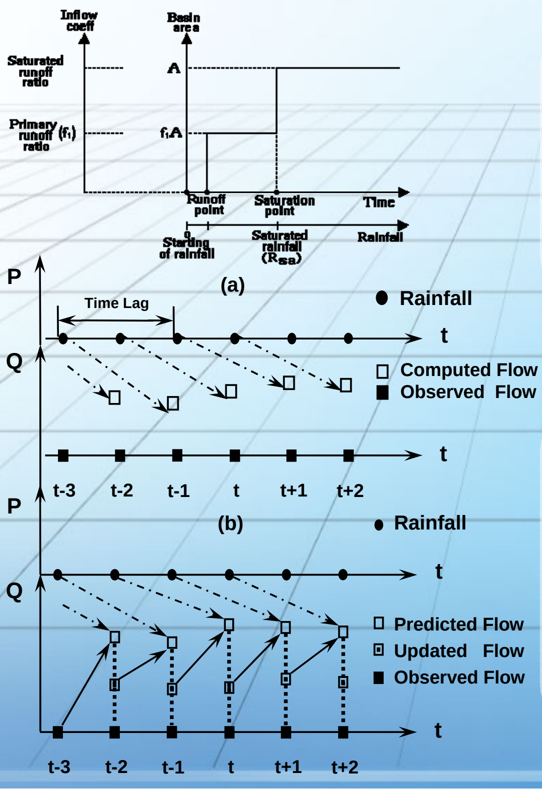
- Error variances

$$Q = a_2 (1 - a_1^2)$$

$$R(\eta) = a_3 \eta^{a_4}$$

Activity III Development of State Space Form of Stochastic Dynamic Flood Forecasting Model

- Stochastic dynamic flood forecasting model



$$\frac{ds(t+T_i)}{dt} = r_{ave}(t) - q(t+T_i)$$

$$s(t) = k \cdot q(t)^p$$

$$r_{ave}(t) = \begin{cases} f_1 r_{ave}(t) & \sum r_{ave} < R_{sa} \\ r_{ave}(t) & \sum r_{ave} \geq R_{sa} \end{cases}$$

$$\frac{dq(t)}{dt} = \frac{1}{kpq(t)^{p-1}} (r_{ave}(t - T_i) - q(t))$$

$$\frac{dq(t+T_i)}{dt} = \frac{1}{kpq(t+T_i)^{p-1}} (r_{ave}(t) - q(t+T_i) - w(t+T_i))$$

$$Z_k = h_k(q_k) + V_k$$

Prediction and updating processes

– **Prediction step**

$$\frac{dq(t+1)}{dt} = \frac{1}{kp\tilde{q}(t+1)^{p-1}}\left(r_{ave}(t+1-T_l) - \tilde{q}(t+1)\right)$$

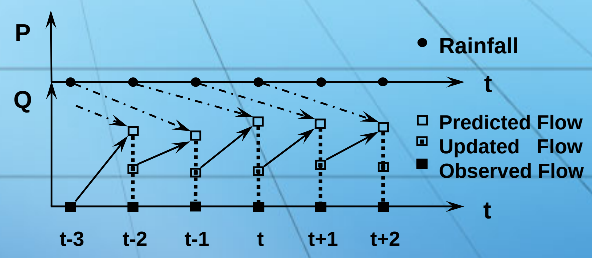
$$\frac{dP(t+1)}{dt} = \frac{2}{kp}\{(1-p)r_{ave}(t+1-T_l)q^{-p} - (2-p)q^{1-p}\}P(t+1) + Q(t+1)$$

– **Updating step**

$$\hat{q}_k(+) = \hat{q}_k(-) + K_k[z_k - h_k(\hat{q}_k(-))]$$

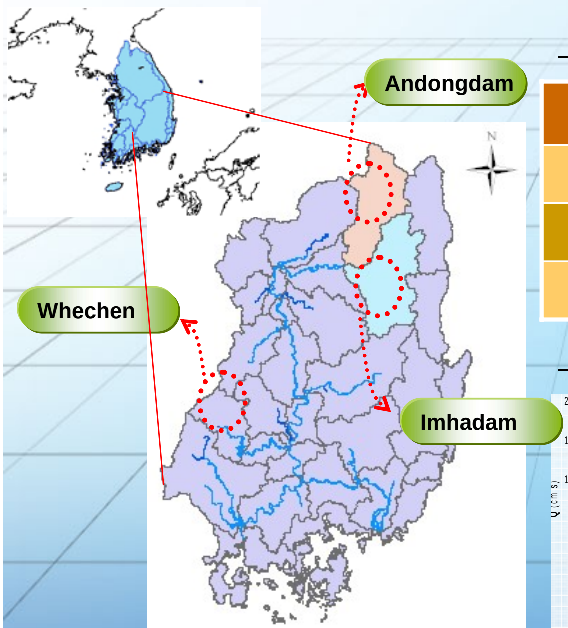
$$P_k(+) = [I - K_k H_k(\hat{q}_k(-))]P_k(-)$$

$$K_k = \frac{P_k(-)}{P_k(-) + R_k}$$



Developed model application

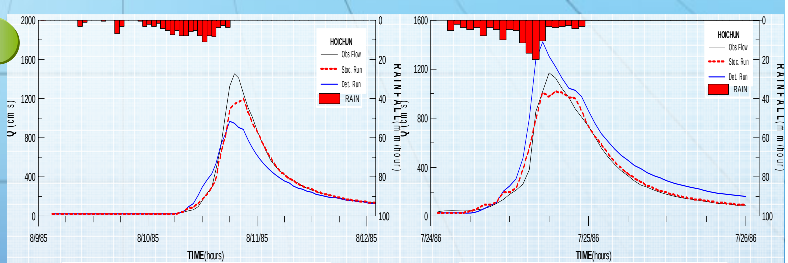
– Selected watershed: Nakdong river basins



– Estimated parameters

Basin	Flood event	Parameters				
		K	p	T_l	f_1	R_{sa}
Whechen	1983 ~ 1986	37.00	0.437	2.73	0.035	18.616
Andongdam	1998 ~ 2003	37.08	0.411	3.44	0.461	112.76
Imhadam	1998 ~ 2003	40.32	0.412	2.00	0.394	107.70

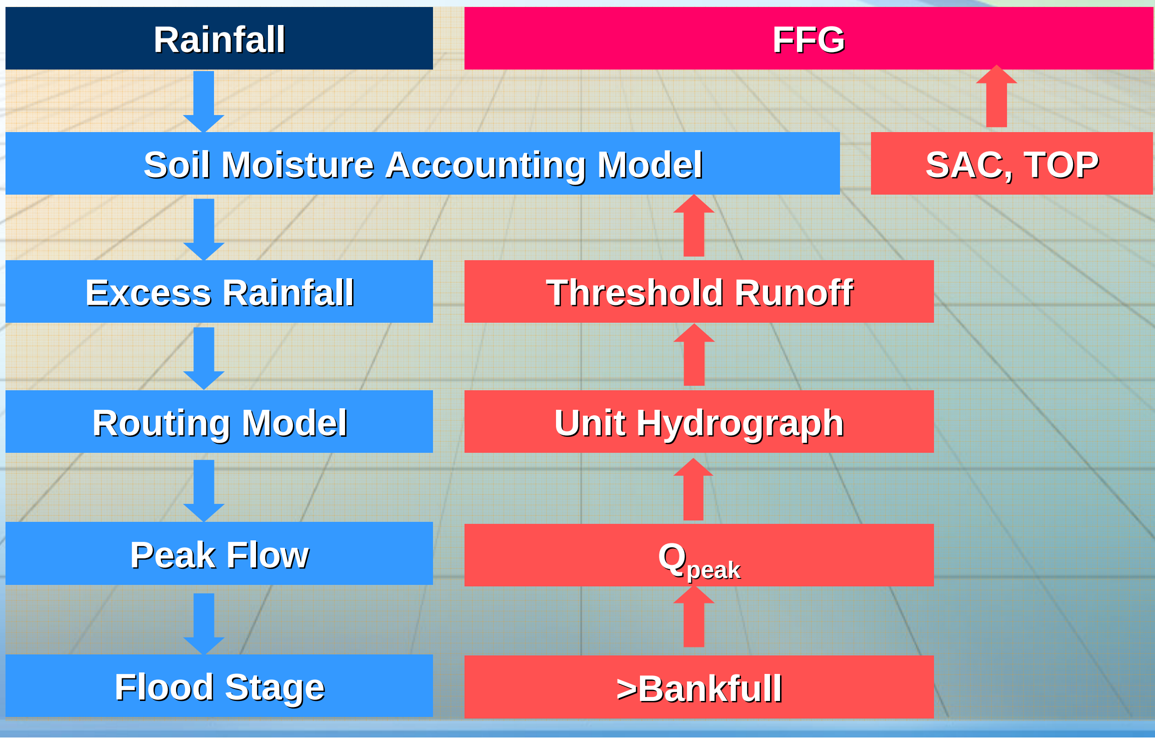
– Whechen



1985. 8. 9-12

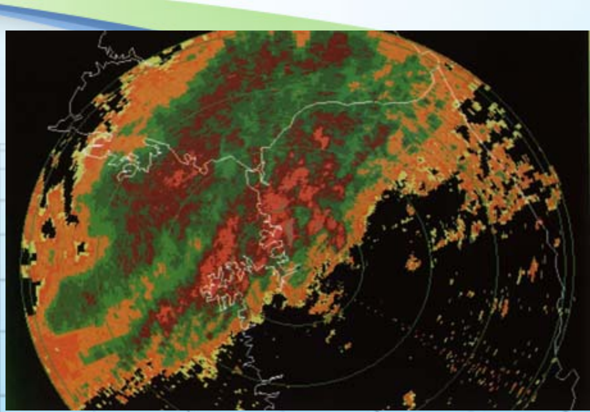
1986. 7.24-26

- **Flood Prediction (FP) and Flash Flood Guidance (FFG)**



- **What is FFG ?**

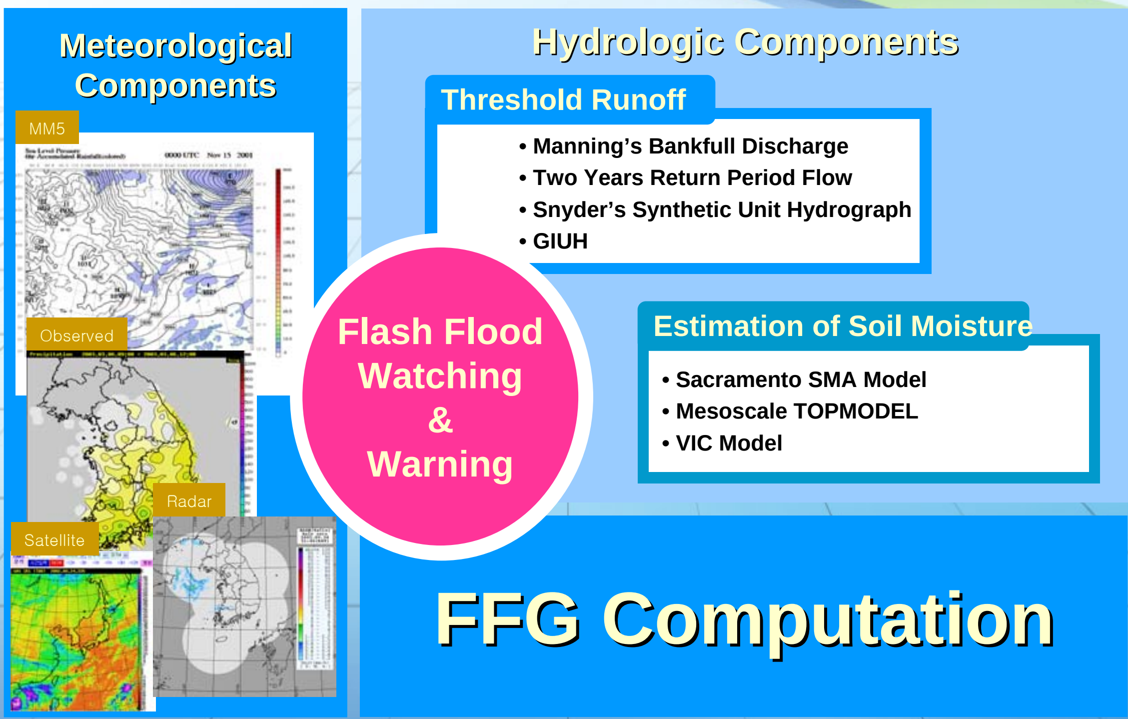
  FFG is the amount of rainfall needed in a specified period of time to initiate flooding on small streams



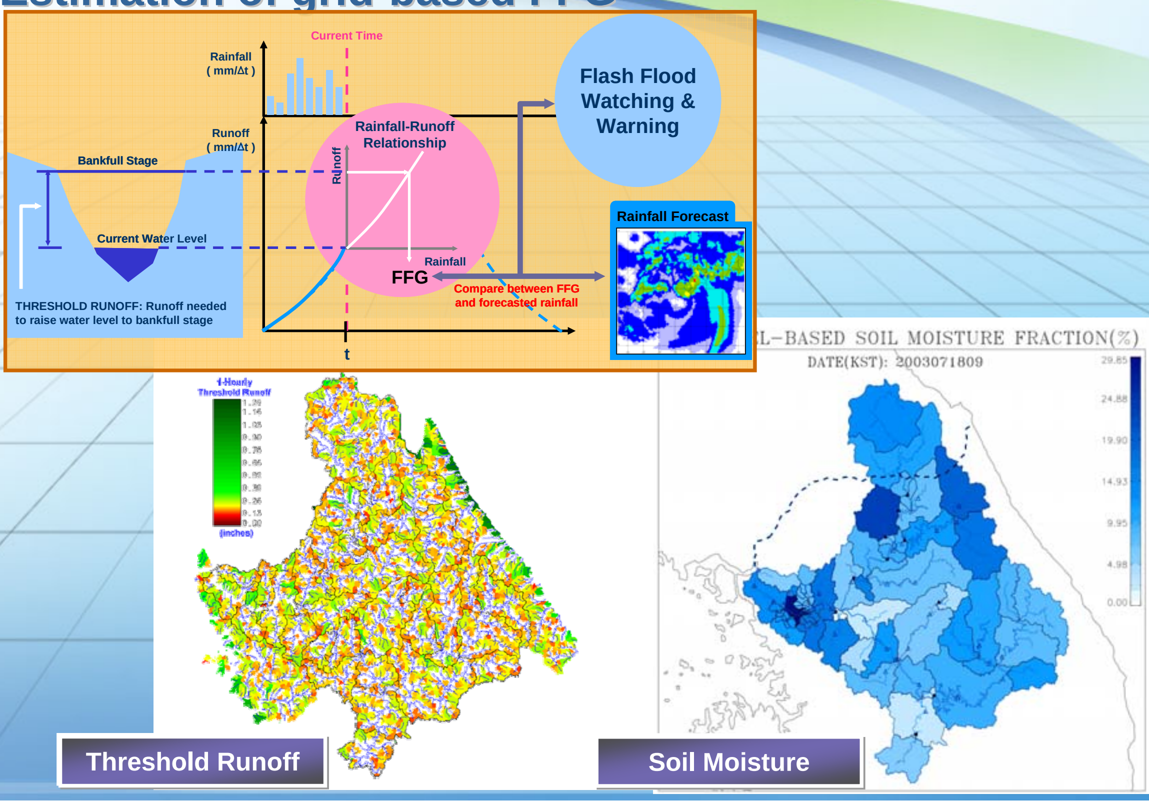
- **Forecast Lead Time ?**

  FFG is computed for 1-, 3-, and 6-hour durations optionally for 12-, 24-hour durations

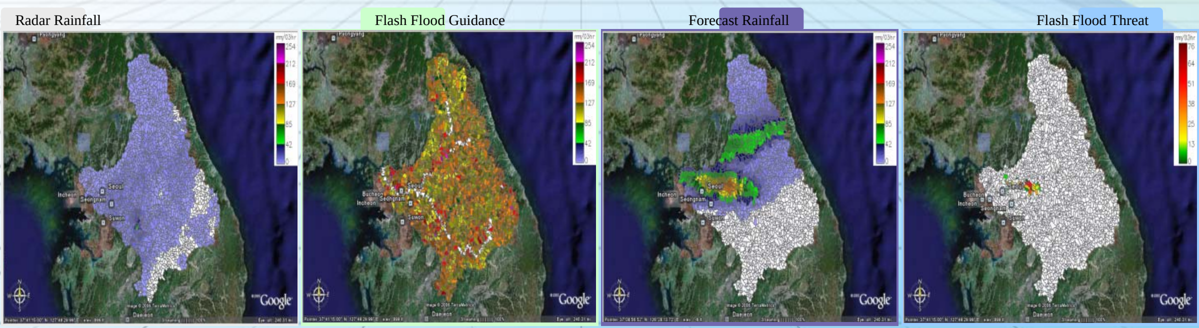
Component of FFG system



Estimation of grid-based FFG



- The development of a forecasting system such as Flash Flood Guidance (FFG) is essential for mitigation of flood disaster



- Need to develop FFG system considering man-made channel and urban drainage network
- Need to increase accuracy of flash flood forecast
- Need to combined technology among mesoscale forecast, radar and satellite information

Activity V Flood Vulnerability Analysis for Obtaining Reasonable Adaptation Measures

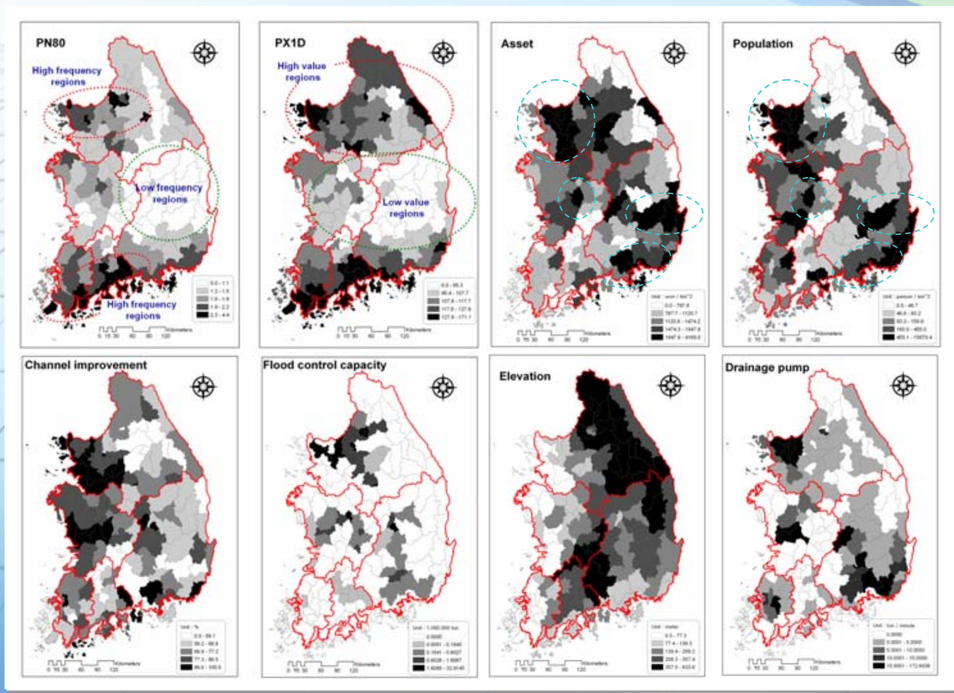
- Definition of flood vulnerability

$$Vulnerability = \frac{Exposure \times Sensitivity}{Adaptation}$$

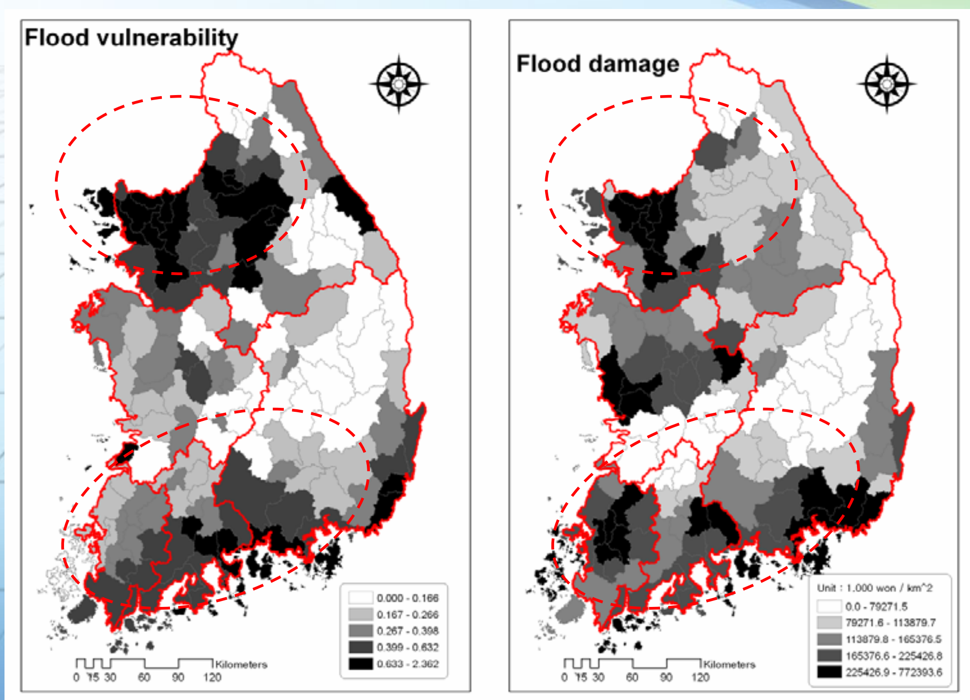
Flood vulnerability proxy variables

Index	Proxy variables	Description
Sensitivity	PN80	A number of days precipitation ≥ 80mm/day
	PX1D	Maximum precipitation of sum for 1-day interval each year
	MDF	Maximum daily discharge each year
	FN90	Frequency of discharge exceeding long-term 90th percentile
Exposure	ELEV	Mean basin elevation (m)
	POP	Bain population density (inhabitants/km^2)
	ASA	Density of assets (won/m^2)
Adaptation	CI	Channel improvement (%)
	PUMP	drainage pump capacity (ton/min.)
	DFC	Flood control capacity of dam (10^6 ton)

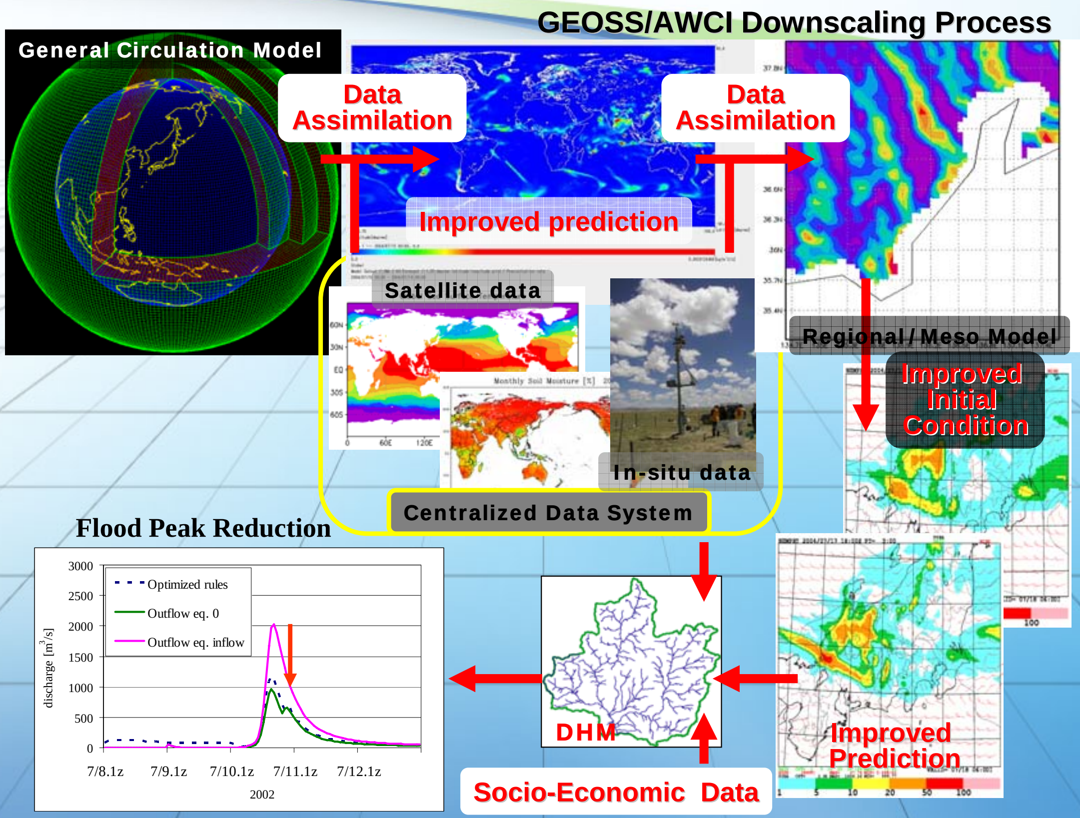
- **Sensitivity proxy variables on current climate condition**



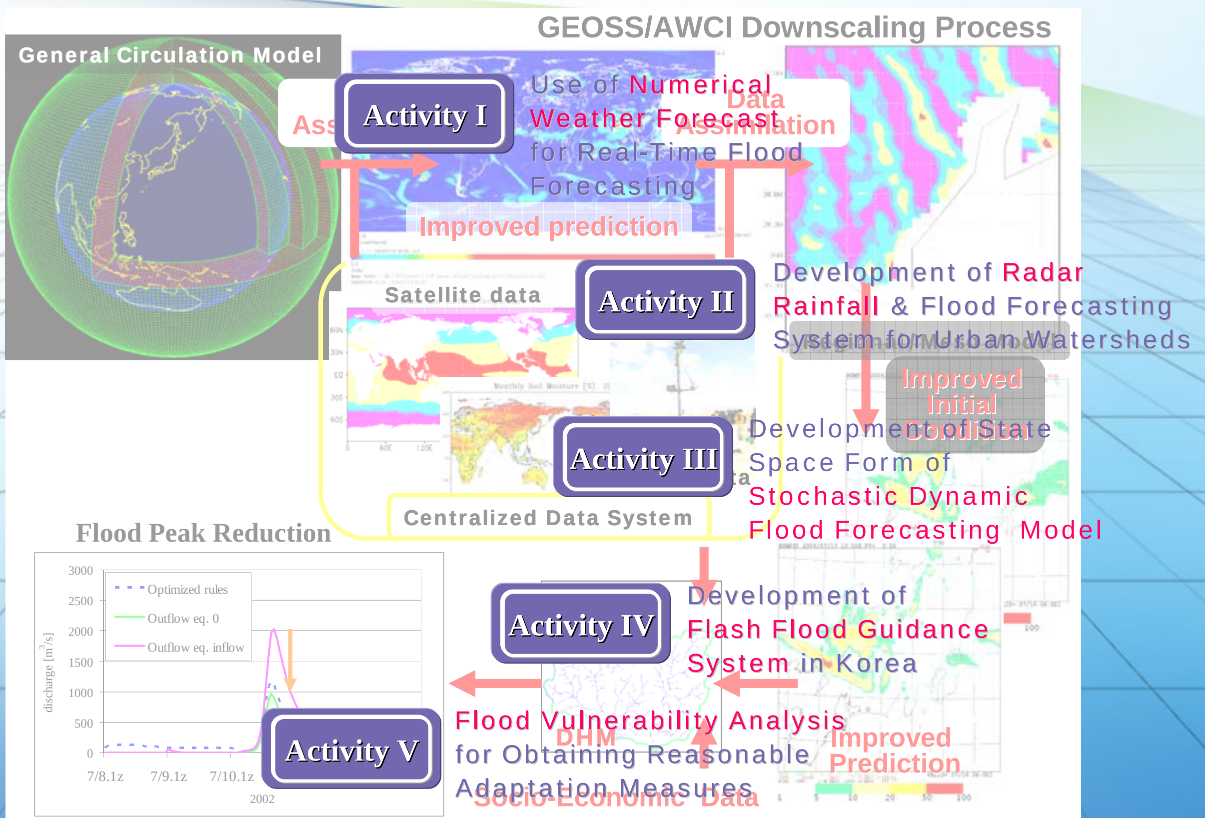
- **Flood Vulnerability vs. Flood Damage('71- '00)**



Summary and Future Directions



Summary and Future Directions



Thank you for your attention