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Tsinghua University

ESCAPE/WMO Typhoon Committee Roving Seminar, Vientiane, LAO PDR, Nov 4-6, 2015

Topic B: Part 1
Modeling and prediction of flash flood
altered by sediment transport in mountain streams

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Nov 4, 2015

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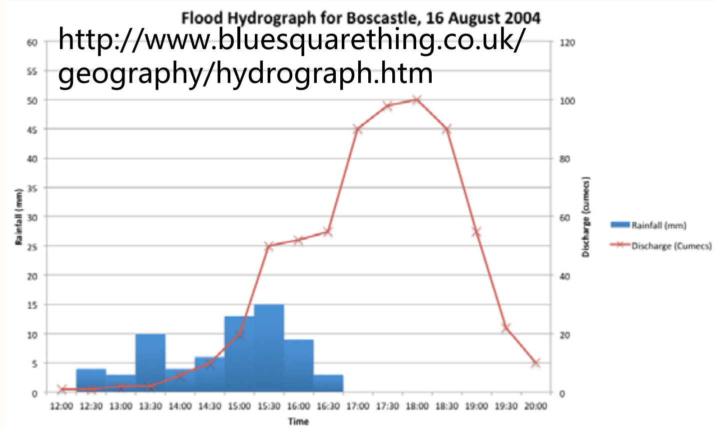
Outline

1. Overview of flash flood hazards
2. Modeling of flash flood
3. Exaggerated flood hazard
4. Toward future: ongoing efforts
5. Summary

What is flash flood?

Flash flood:

- Short duration & high magnitude
- Sudden & destructive
- Common in mountain streams
- **Rainstorm, landslide dam failure, glacial lake outburst**, etc.



Several hours; > bankfull discharge

Flash flood hazard?

Flash flood disasters:

People & animals are hurt/killed, and assets/infrastructure are damaged/destroyed through **(1) flushing away** and/or **(2) inundation**.

Serious all over the world!

June 10, 2005: a primary school, Shalan Town, Heilongjiang Province. 105 students were killed.

Flash flood hazard?

Flash flood disasters:

People & animals are hurt/killed, and assets/infrastructure are damaged/destroyed through **(1) flushing away** and/or **(2) inundation**.

Pattern 1: Extreme rainstorm → extreme flash flood

e.g. Increasing extreme weather events due to climate change

Flash flood hazard?

Flash flood disasters:

People & animals are hurt/killed, and assets/infrastructure are damaged/destroyed through **(1) flushing away** and/or **(2) inundation**.

Pattern 2: Regular rainstorm → extreme flash flood

e.g. exaggerated flooding impacts

1) Impounded water releases suddenly

Barrier lakes or glacier lakes outburst.

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Flash flood hazard?

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2) Flood flow is choked, resulting in water level rising

Boulders,
drifting wood,
bridge, house…

Flash flood hazard?

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3) Sediment transport and river aggradation

Deposited sediment

Flash flood hazard?

Flash flood disasters:

People & animals are hurt/killed, and assets/infrastructure are damaged/destroyed through **(1) flushing away** and/or **(2) inundation**.

Pattern 3: Regular rainstorm → regular flash flood

e.g. lack of effective warning, preparedness, or awareness

Impacting factors?

Flash flood disasters:

People & animals are hurt/killed, and assets/infrastructure are damaged/destroyed through **(1) flushing away** and/or **(2) inundation**.

Weather: Typhoon, Monsoon, Cyclone, Rainstorm…

Underlying surface: Topography, geology, vegetation…

Human activities: Urbanization, deforestation …

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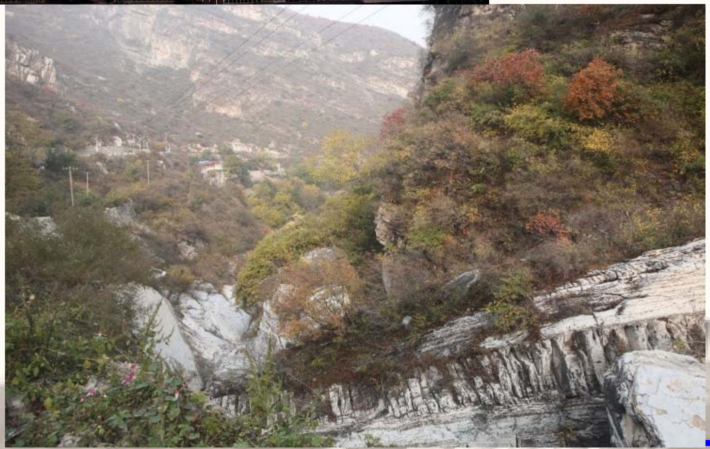

☆ Natural factors

- ✓ **Heavy rain**
- ✓ **Steep terrain**
- ✓ Sufficient loose material
- ✓ Drift wood, boulders, and other floats

☆ Human factors

- ✓ Road/buildings occupying flood plain or passage
- ✓ Limited-size bridge or culvert
- ✓ Building in streams
- ✓ Destroyed bed structures
- ✓ Man-made slagheap/sandpile…

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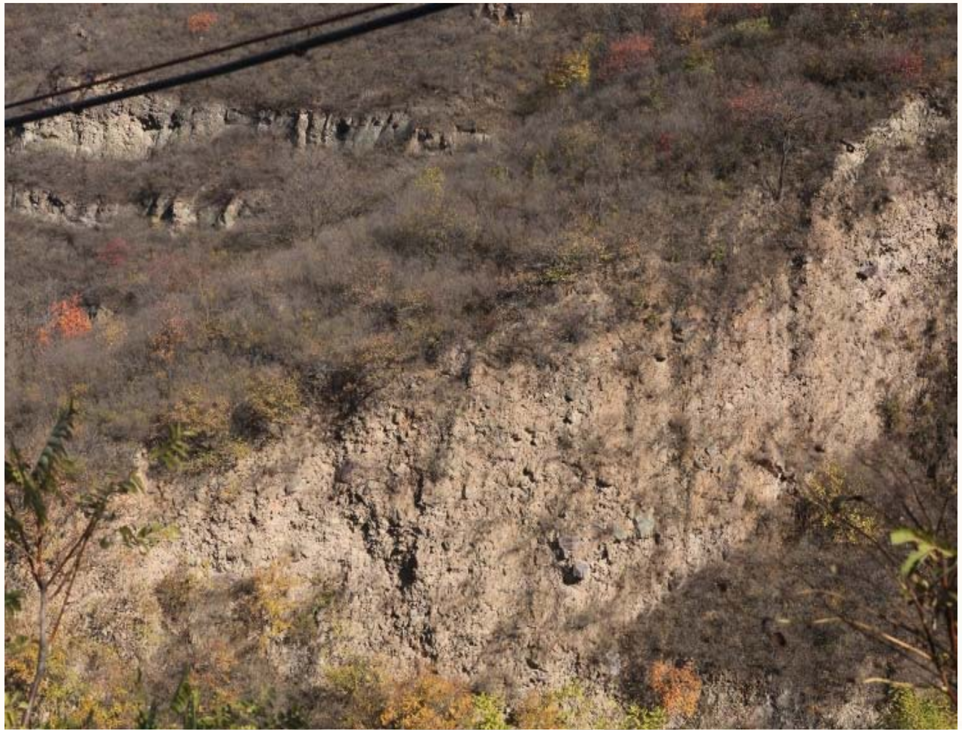
Weathered rock-soil, landslides, debris flows



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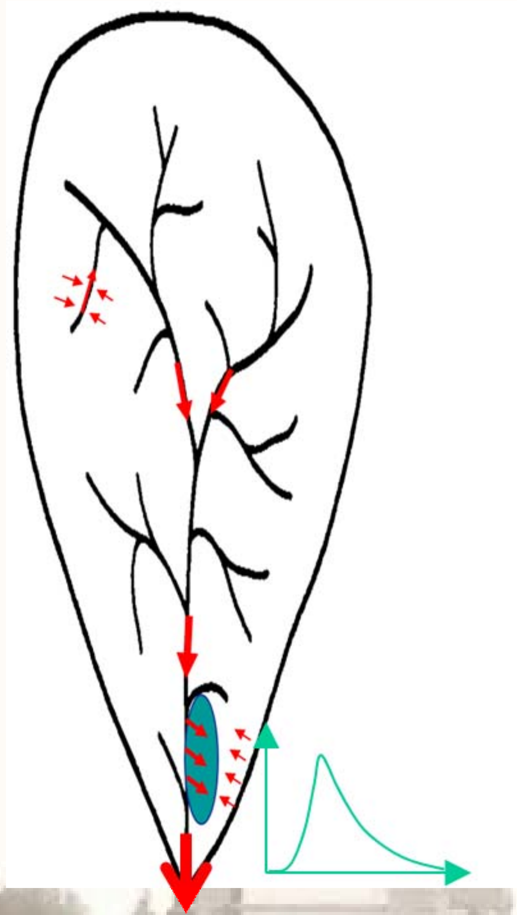
How to model?

Flash flood: Forms from hillslope to stream within a watershed



Hydrological process: rain-runoff modeling

Hydrodynamic process: flood routing

Sediment transport process: aggradation/degradation

Wood dynamics: congestion effects

Debris flow dynamics: …

Accurate models: reasonably take into account various processes and mechanisms

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How to model?

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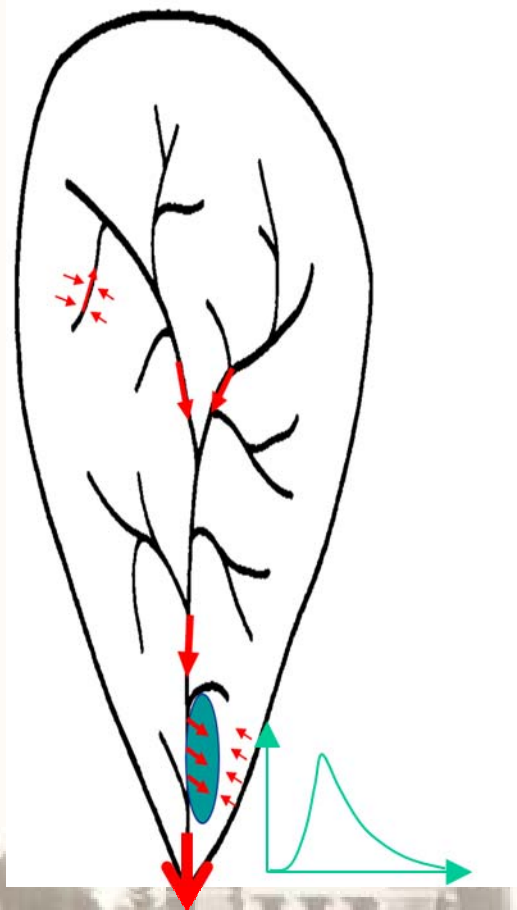


Hydrological simulation:

fast calculation

fast data access and save

Flood routing:

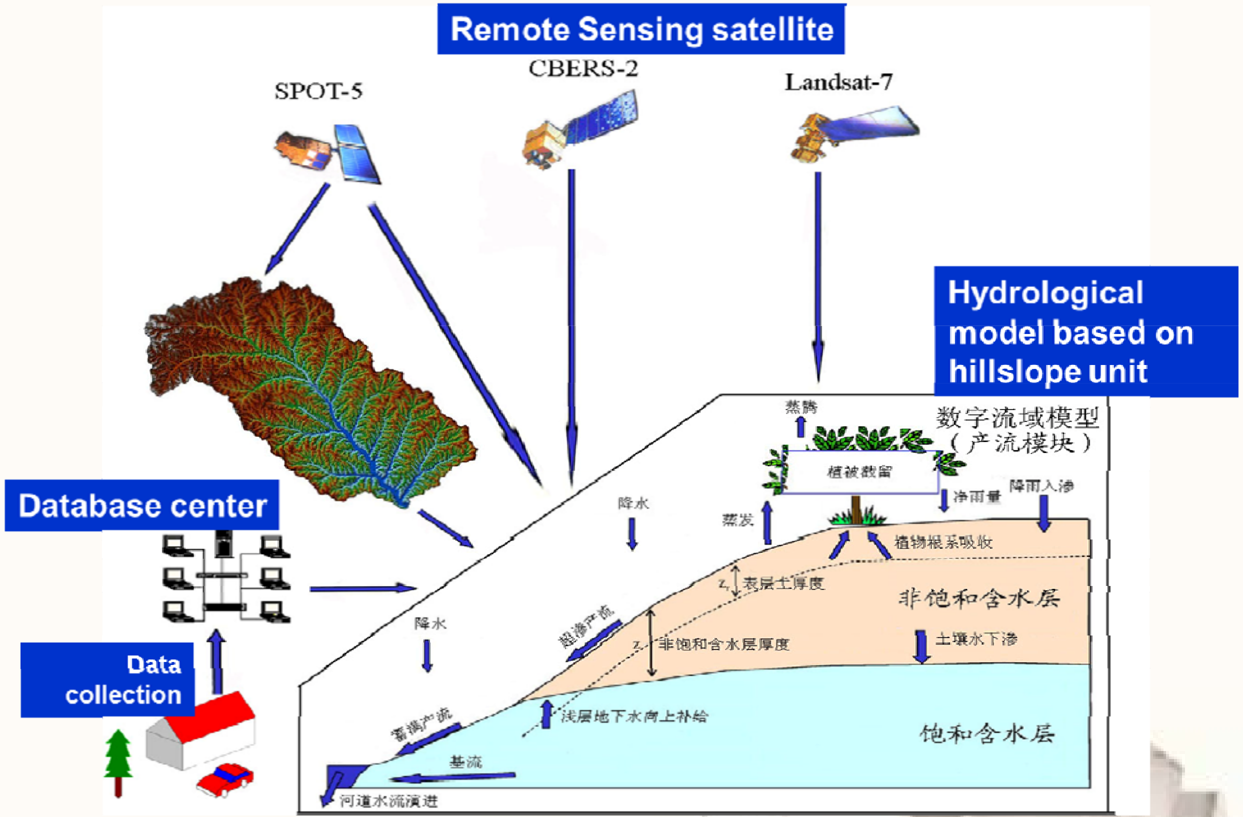
robust numerical algorithm

Efficient models: fast, robust simulation with acceptable accuracy

Digital Watershed Model

A GIS-supported, physically-based, distributed modeling system

Developed by Tsinghua University for coupled hydrological-hydraulic simulation in large-scale river basins.

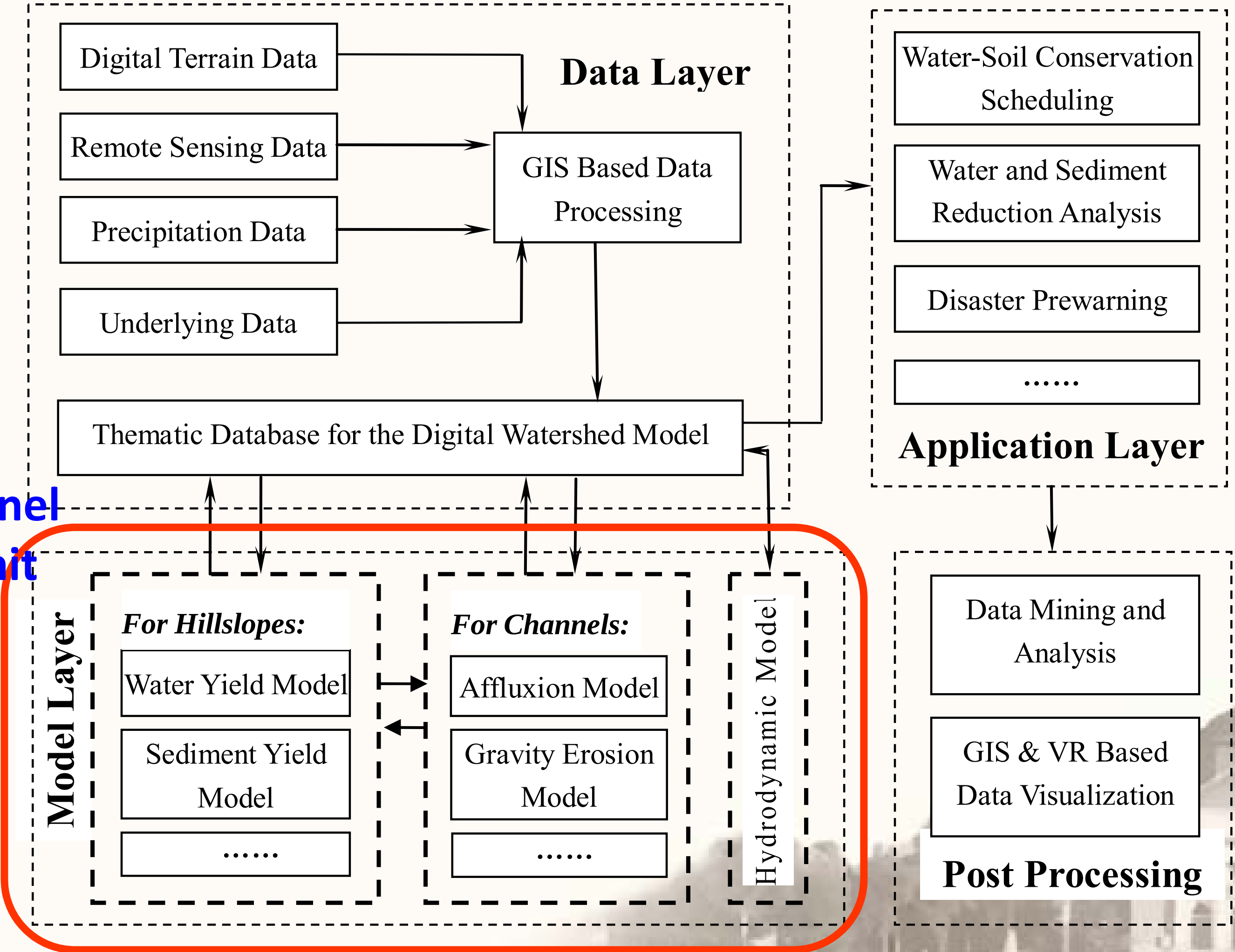


References:
Wang GQ, Fu XD, Shi HY, Li TJ, 2015. Watershed Sediment Dynamics and Modeling: A Watershed Modeling System for Yellow River. Advances in Water Resources Engineering. Springer International Publishing 1-40.

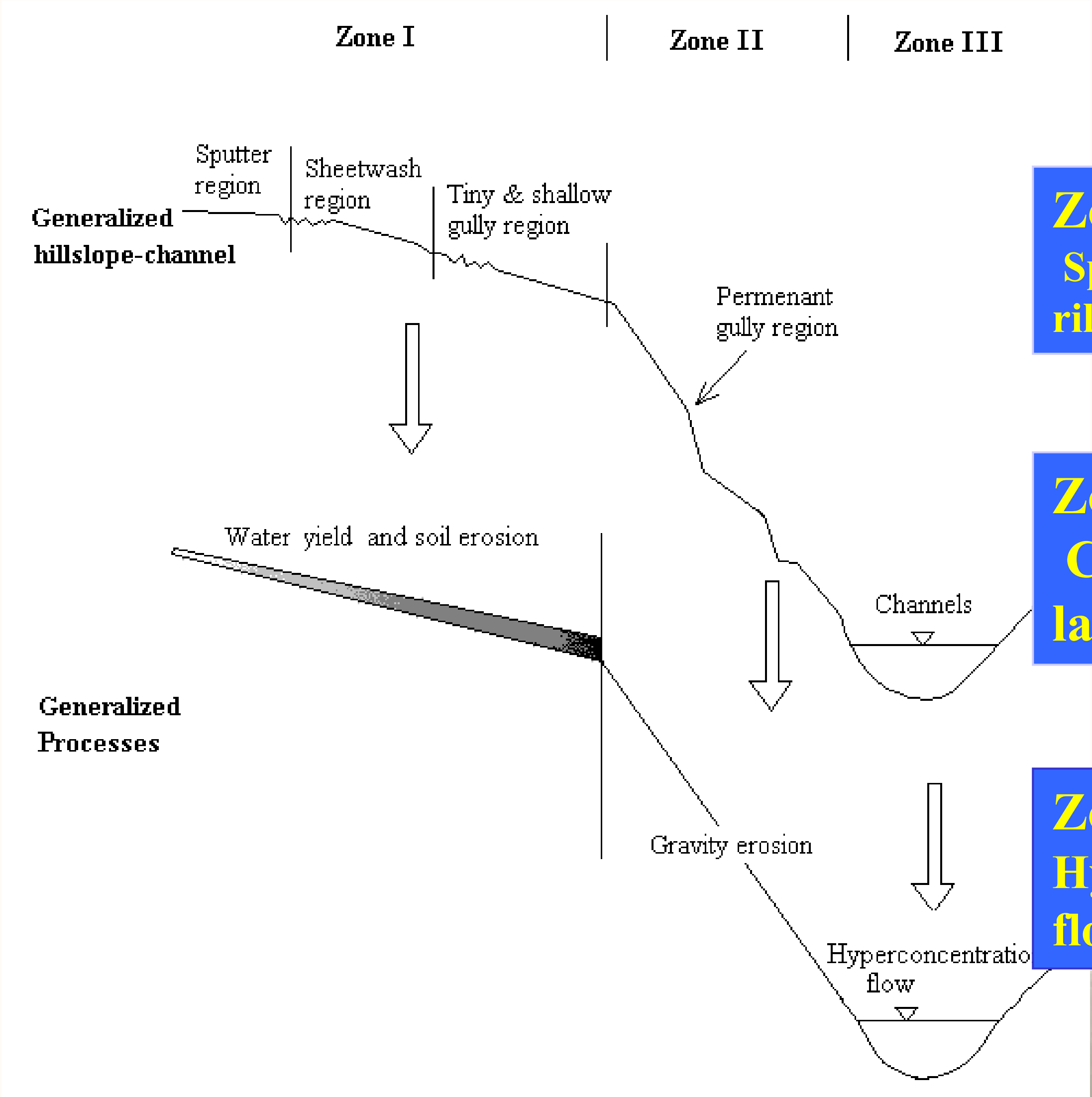
Digital Watershed Model

A GIS-supported, physically-based, distributed modeling system

Hillslope-channel as the basic unit



Hillslope-channel as the basic unit

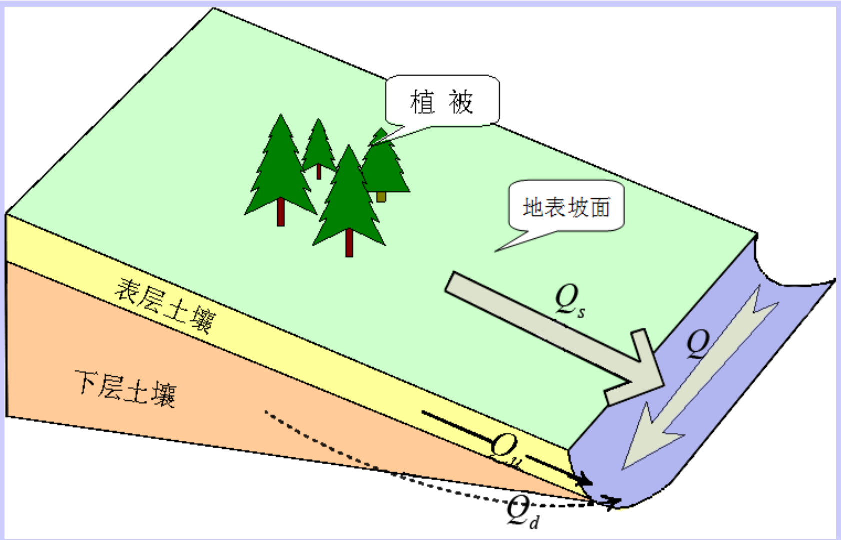


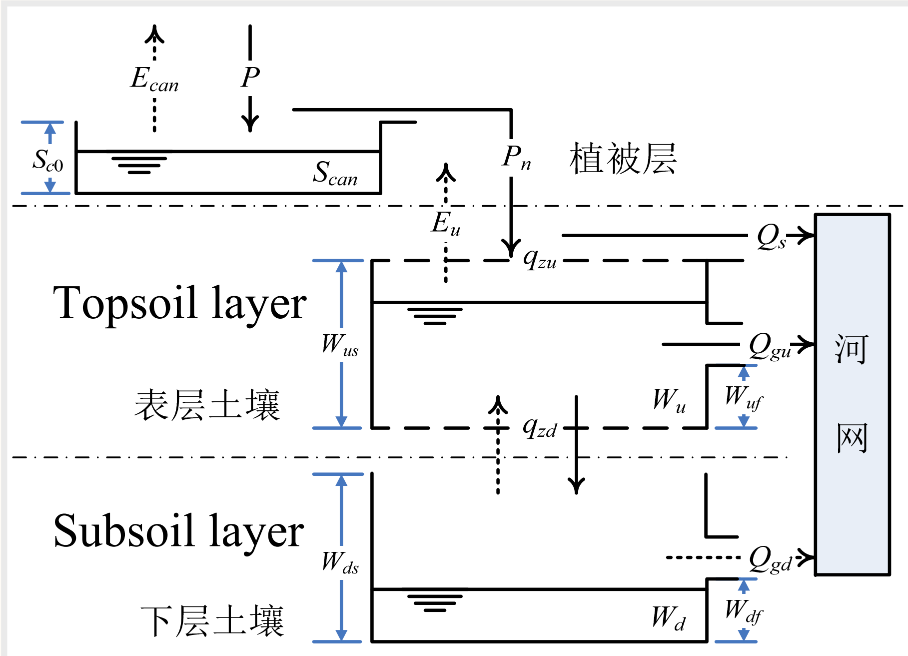
Zone : phenomena	Simulation model
Zone I: Sputter, sheet and rill erosion	Hillslope sediment yield
Zone II: Collapse and landslides	Gravitational erosion
Zone III: Hyperconcentrated flow	Non-equilibrium flow routing

Hillslope-channel as the basic unit

Hydrological processes

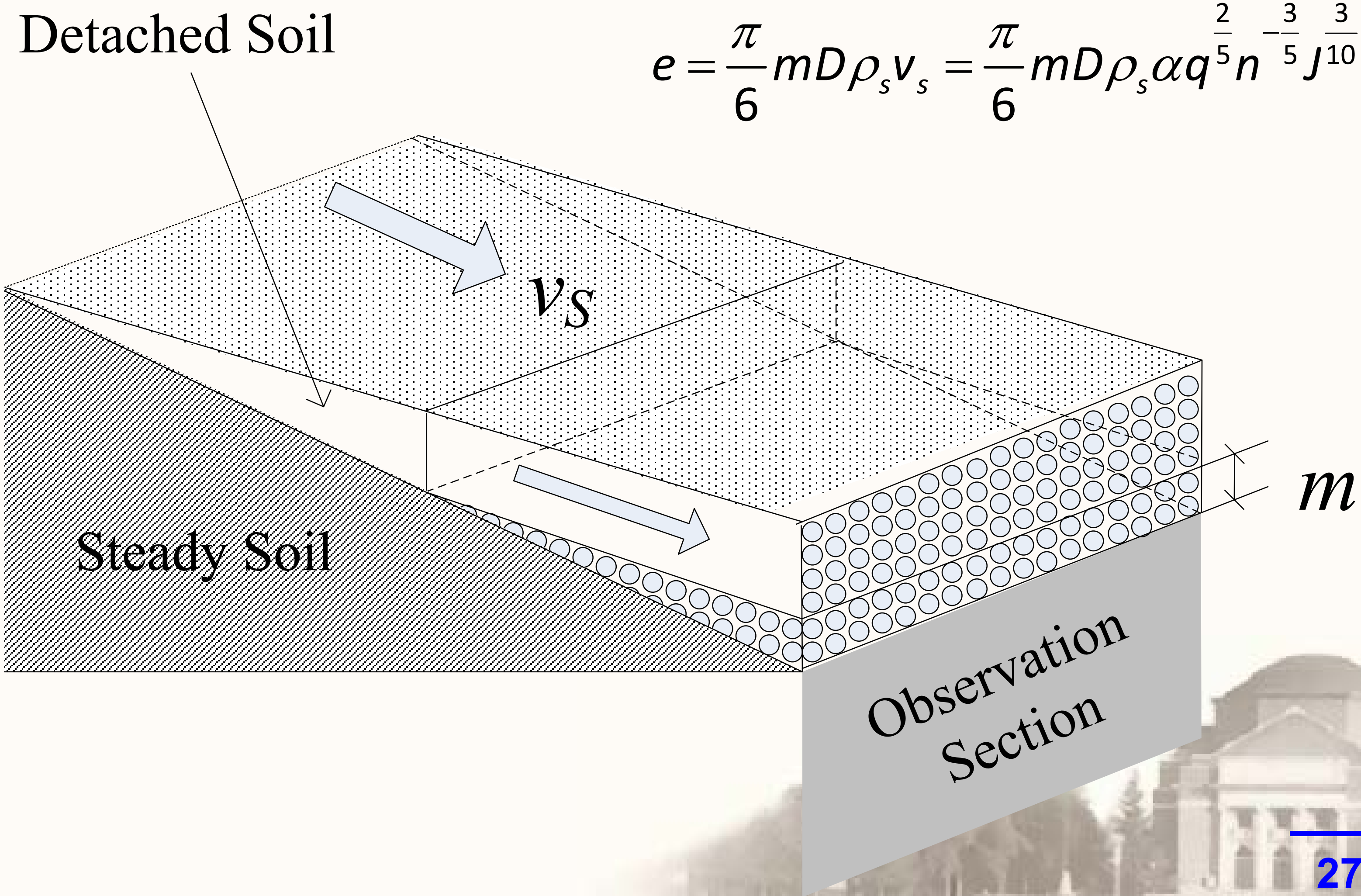
- Vegetation interception: S_{can}
- Evapotranspiration: E_{can} , E_u
- Surface infiltration: q_{zu}
- Soil water redistribution: q_{zd}
- Water discharge: Q_{gu} , Q_{gd}





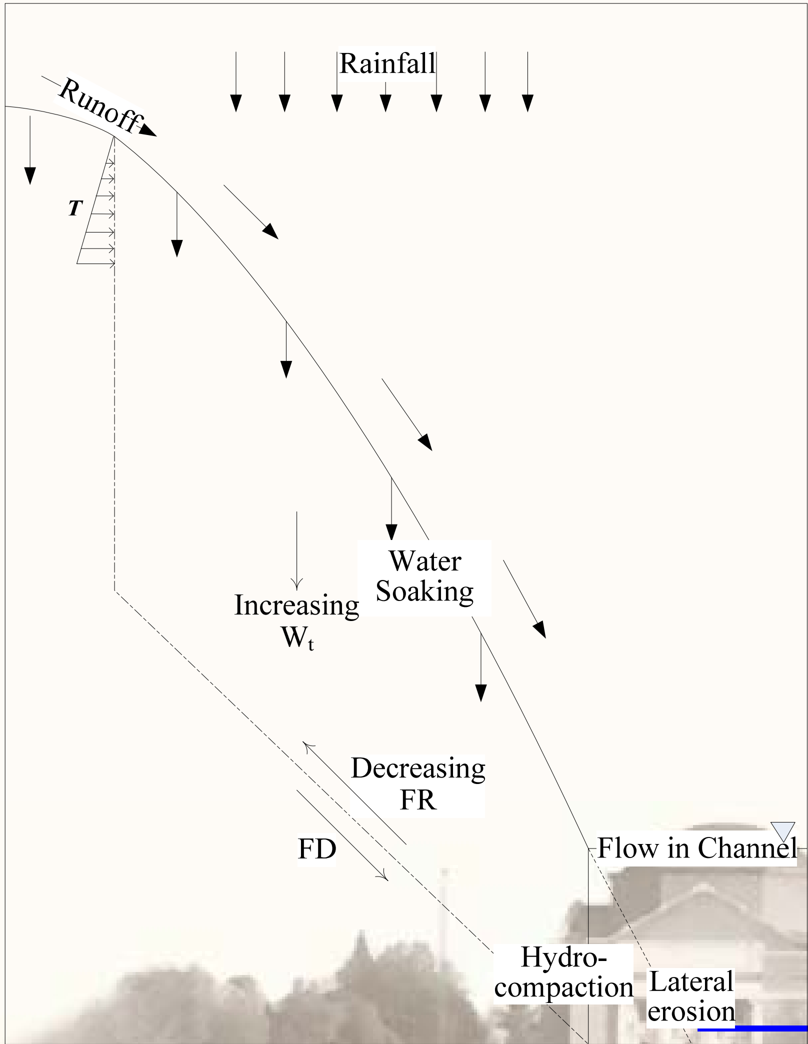
Hillslope-channel as the basic unit

$$e = \frac{\pi}{6} m D \rho_s v_s = \frac{\pi}{6} m D \rho_s \alpha q^{\frac{2}{5}} n^{-\frac{3}{5}} J^{\frac{3}{10}}$$



Hillslope-channel as the basic unit

- Gravitational erosion is formulated as stochastic soil body destabilization
- The confluence of rainfall and runoff is considered



Hillslope-channel as the basic unit

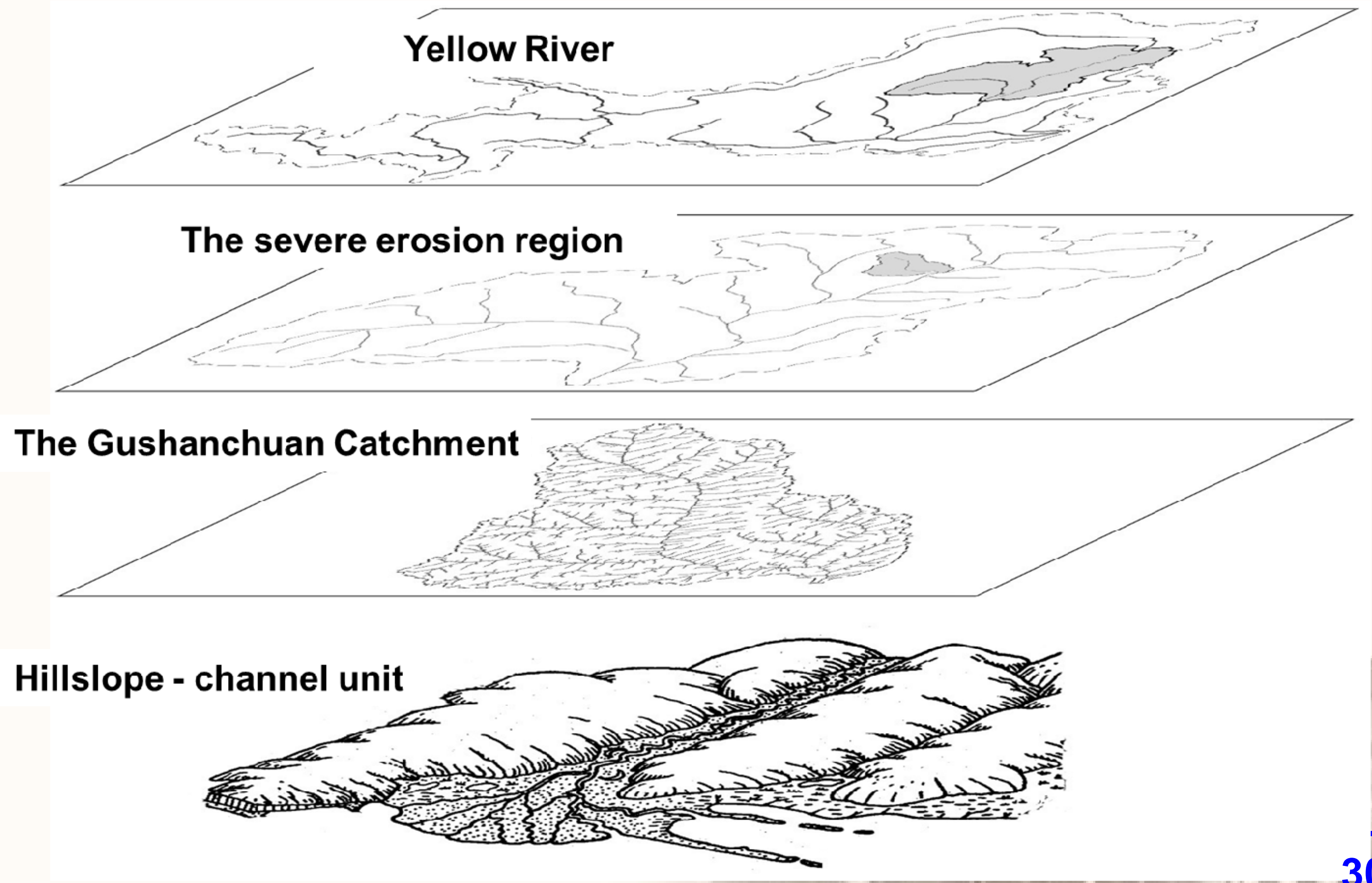
- Diffusive wave equation is used
- Cross-section of channel is assumed to be V-shape
- The integrated format of non-equilibrium suspended sediment transport equation is used:

$$S = S_* + \left(S_0 - S_{0*}\right) e^{\frac{-\alpha q L}{\omega_s}} + \left(S_{0*} - S_*\right) \frac{q}{\alpha \omega_s L} \left(1 - e^{\frac{-\alpha q L}{\omega_s}}\right)$$

- Sediment transport capacity
  - ☆ Zhang proposed formula (Ni J. R. et al., 2004), or
  - ☆ Fei (2004) derived formula especially for channels

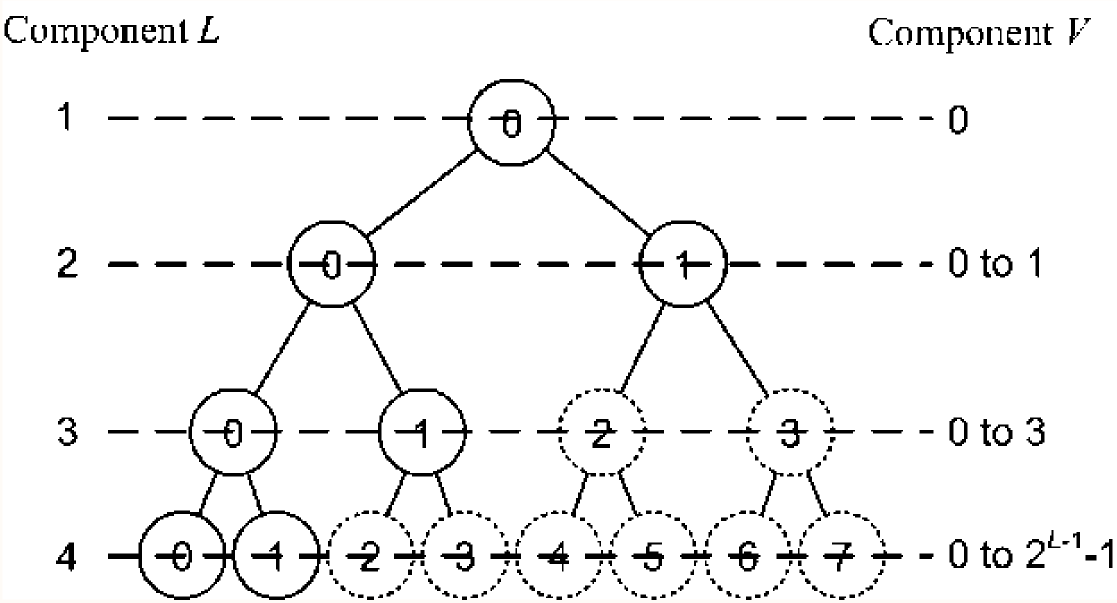
Digital Watershed Model

From basic unit to the whole basin: a hierarchy of river segments (structured river network)



Digital Watershed Model

A hierarchy of river segments: Drainage network coding method based on binary tree theory.



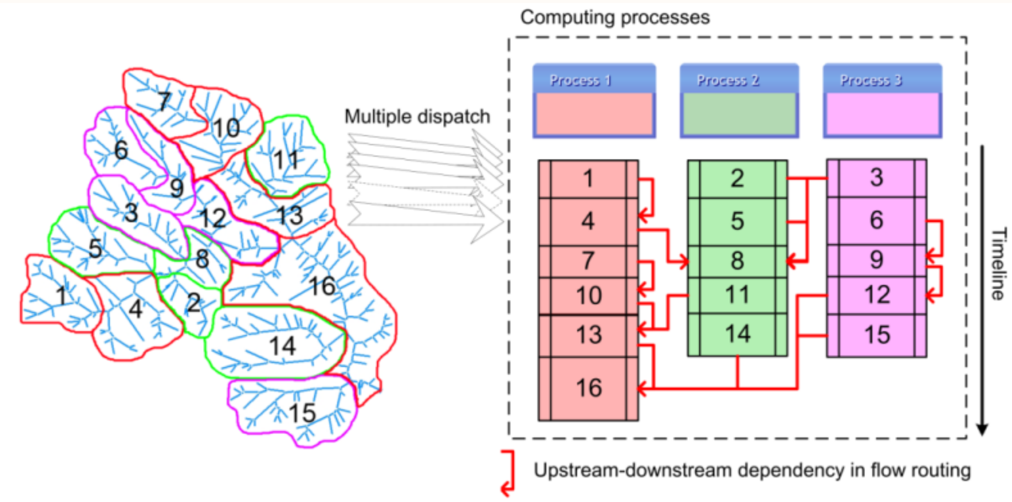
- The topological relationship could be expressed by river codes
- River segments could be retrieved effectively

Assuming the dentritic drainage network as a binary tree:
The first number (*Length*) represents the logical distance to the outlet
The second number (*Value*) represents the logical distance to the main stream

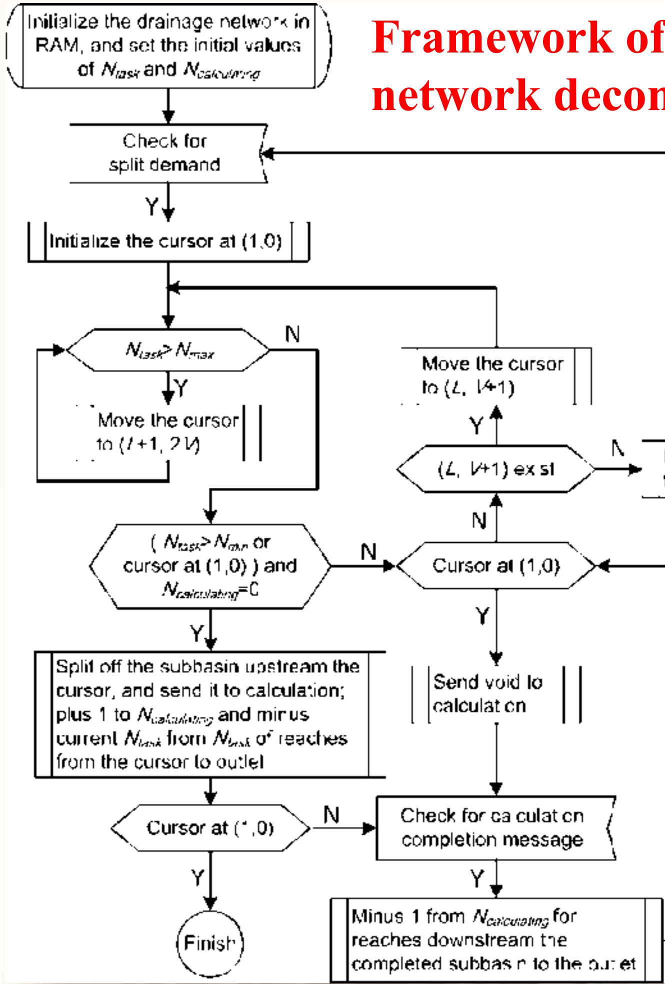
Digital Watershed Model

Parallel computing based on the river code

- ☆ Dynamic parallel computing technology
- ☆ Parallel computing based on decomposition for different subbasins at a same time
- ☆ Improving the simulation efficiency



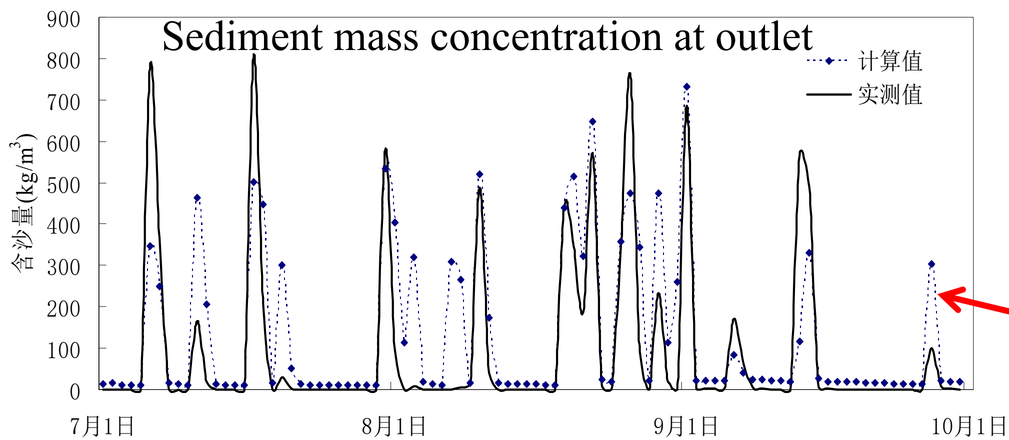
Framework of drainage network decomposition

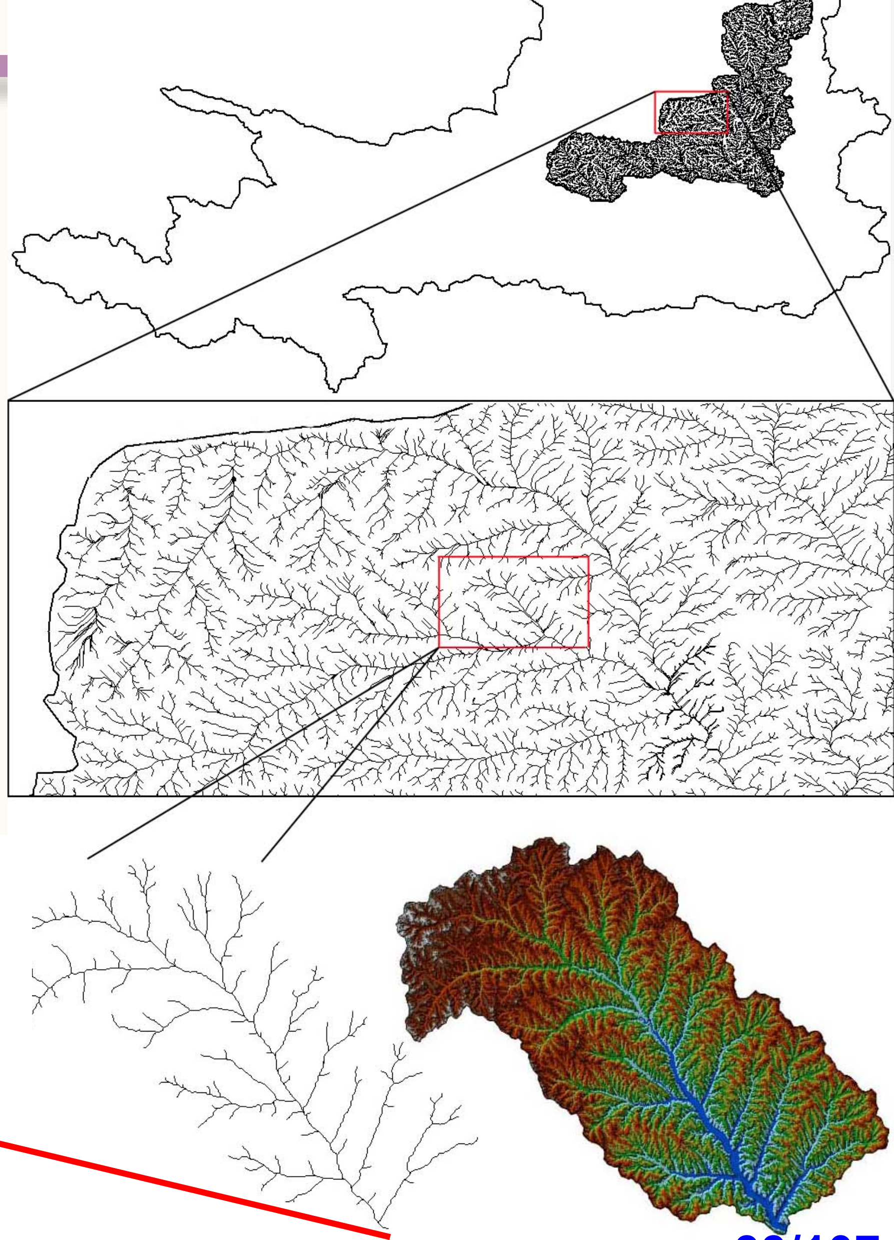


Digital Watershed Model

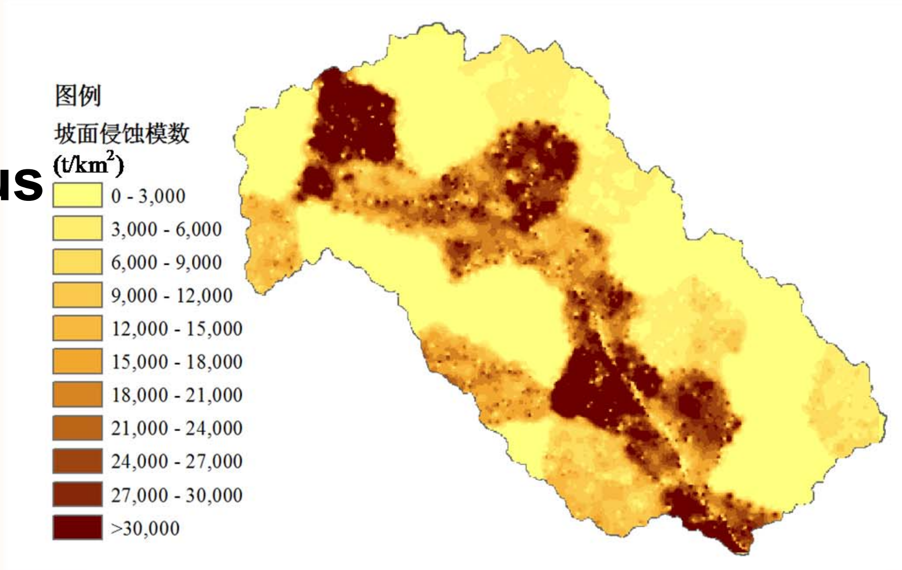
Chabagou basin

- ❖ It lies in Zizhou County, Shaanxi Province.
- ❖ The total area is 205 km^2.
- ❖ A lot of observation stations have been setup since 1959, which makes the observation data accessible.



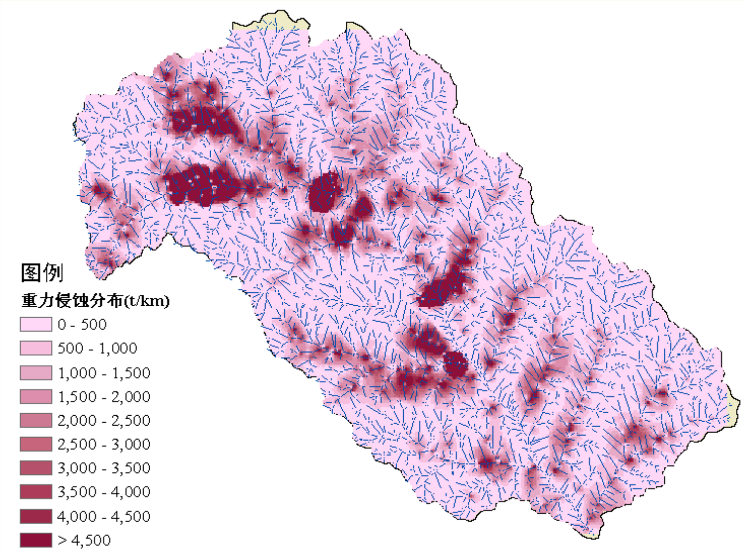


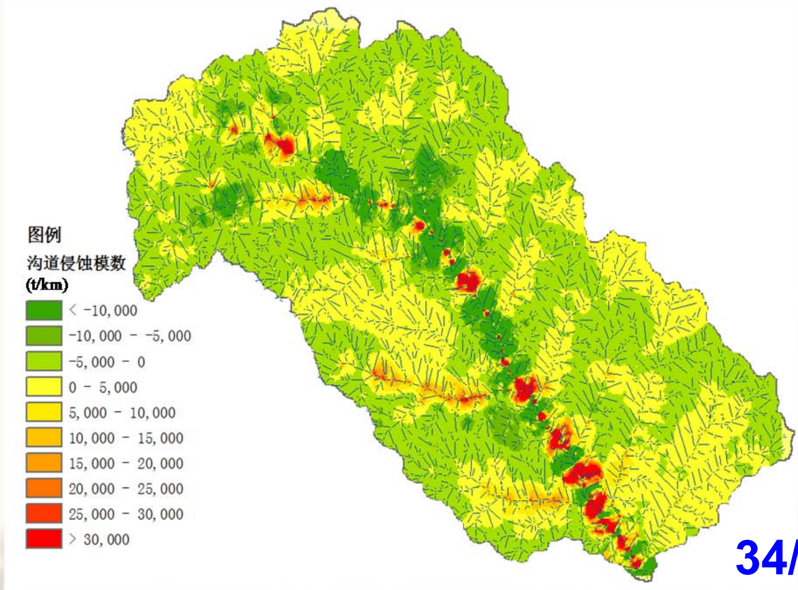
Chabagou basin



Components of erosion modulus

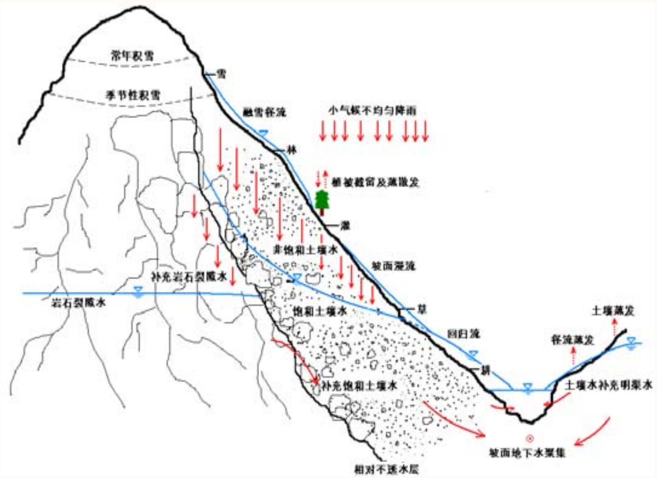
- Slope erosion
- Gravitational erosion
- Stream erosion/sedimentation

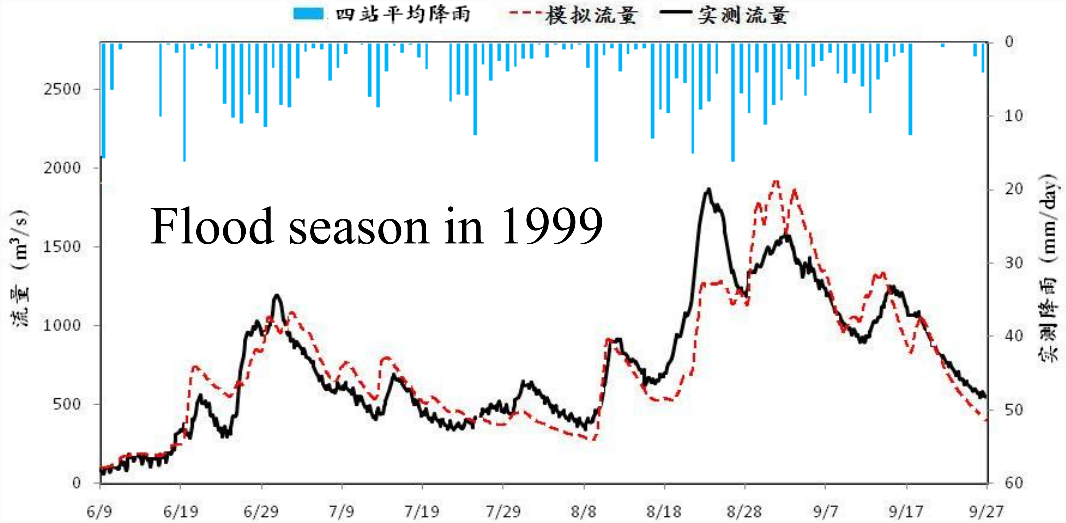


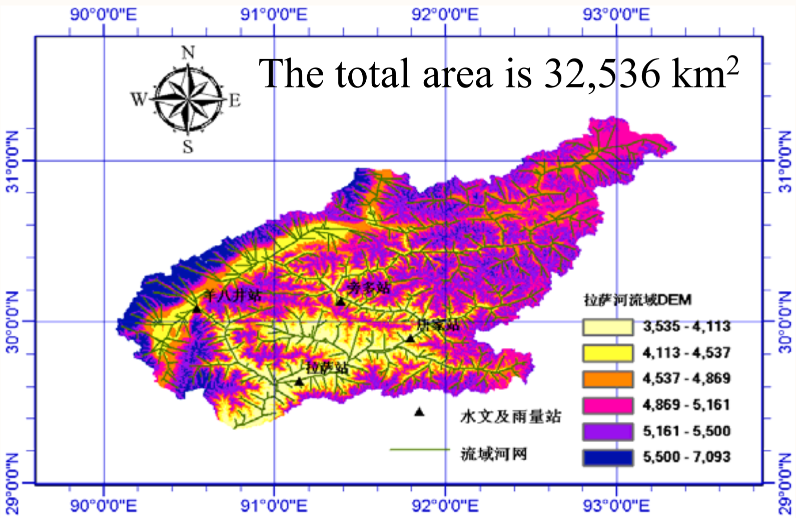


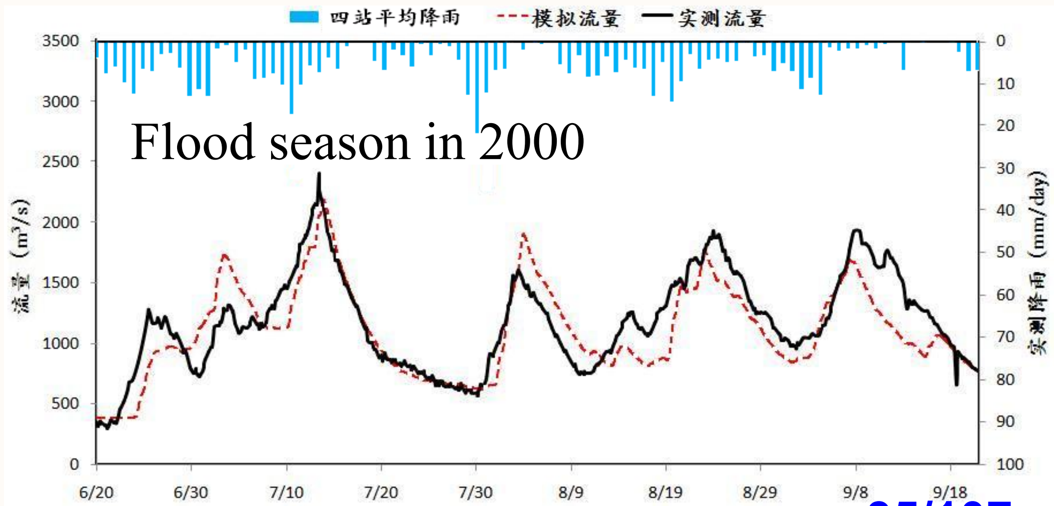
Digital Watershed Model

Lasha River basin









Recent Advances (RA)

RA1: Hydrological simulation:

- Rainfall data input: Spatial inhomogeneity
- Parameter calibration: sensitivity

RA2: Hydrodynamic simulation:

- Governing equations and numerical schemes
- Sediment transport and morphological models
- Flow resistance

RA3: Information techniques

- Parallel computing techniques

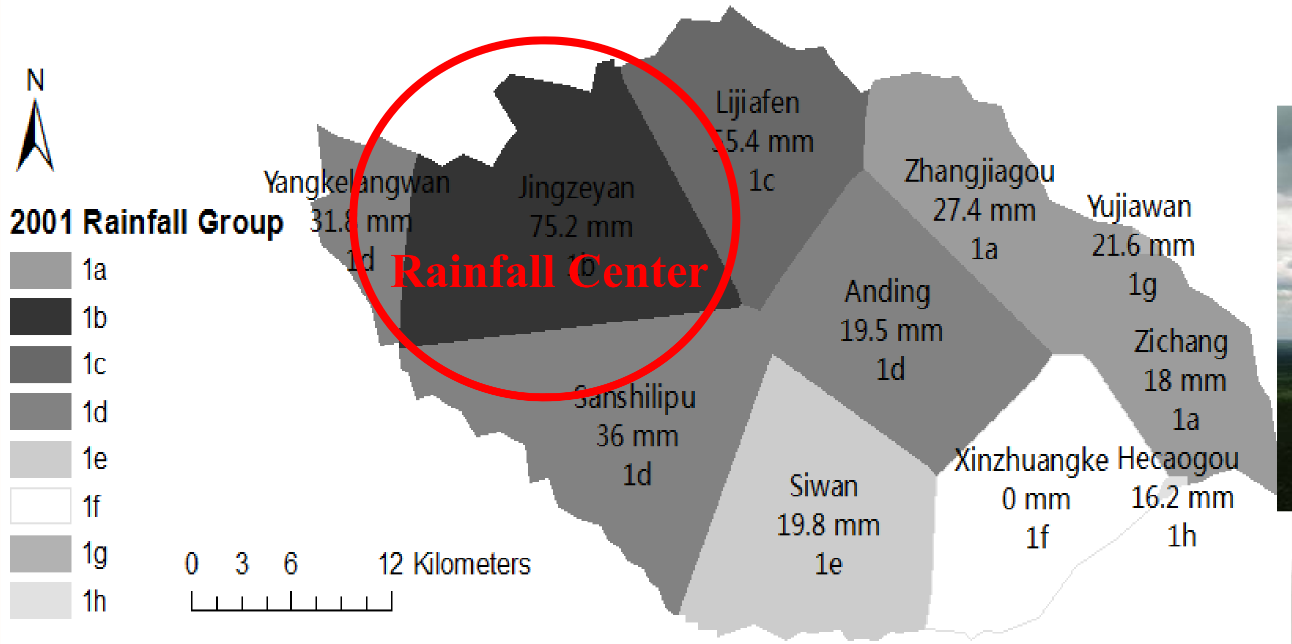
Recent Advances

Rainfall data Input: spatial inhomogeneity

☆ **Rainfall center:** Total rainfall depth is generally 2-5 times greater than those at the other stations.

☆ **Rainfall center:** typically involves only 1-2 stations (within 100 km^2) in the Loess Plateau

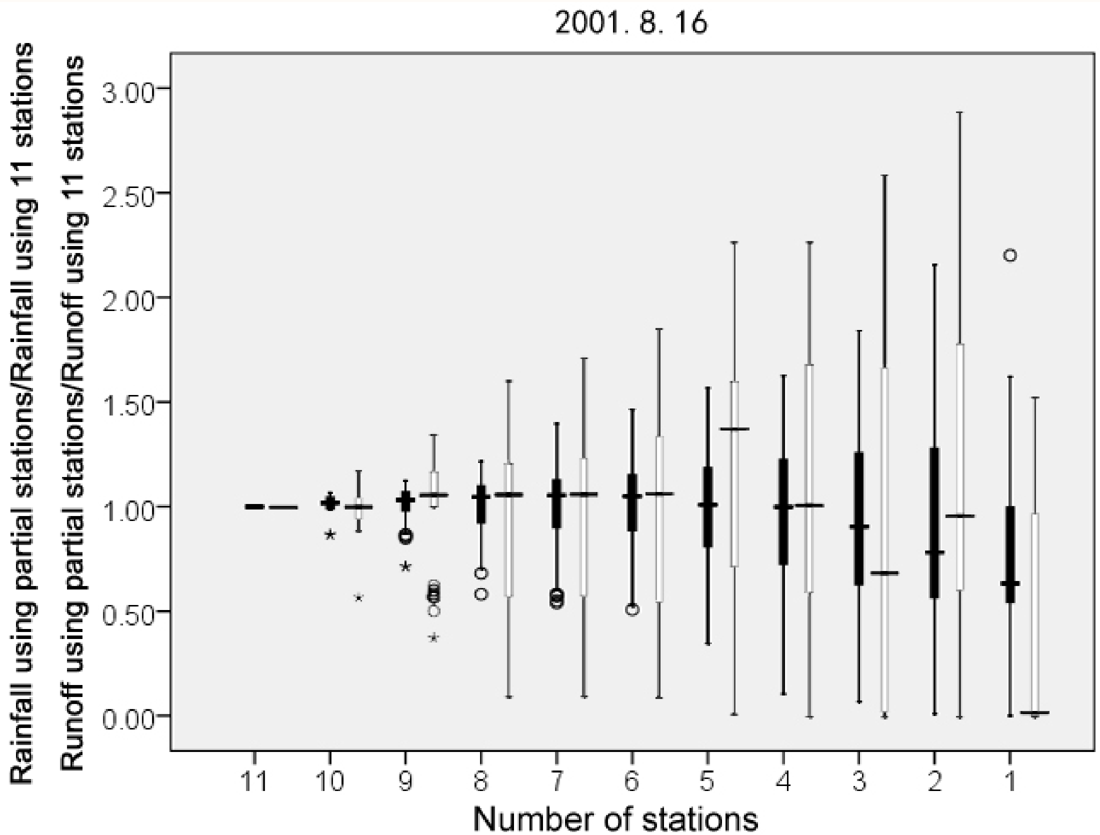
☆ **Problem: optimal density of rain gauges?**



Impacts of rain gauge density

☆ Box plots of average basin rainfall and simulated runoff with different combination of rainfall gauge stations.

☆ The NSE value presents worse results as the gauge number decreases



A box plot is a description of the data distribution, which denotes the 5 percentiles of the performance of quantitative variables, i.e., P2.5, P25, P50, P75, and P97.5.

The P25 – P75 range constitutes a box of the graphics, and the P2.5 – P25 and P75 – P97.5 ranges constitute the two whiskers.

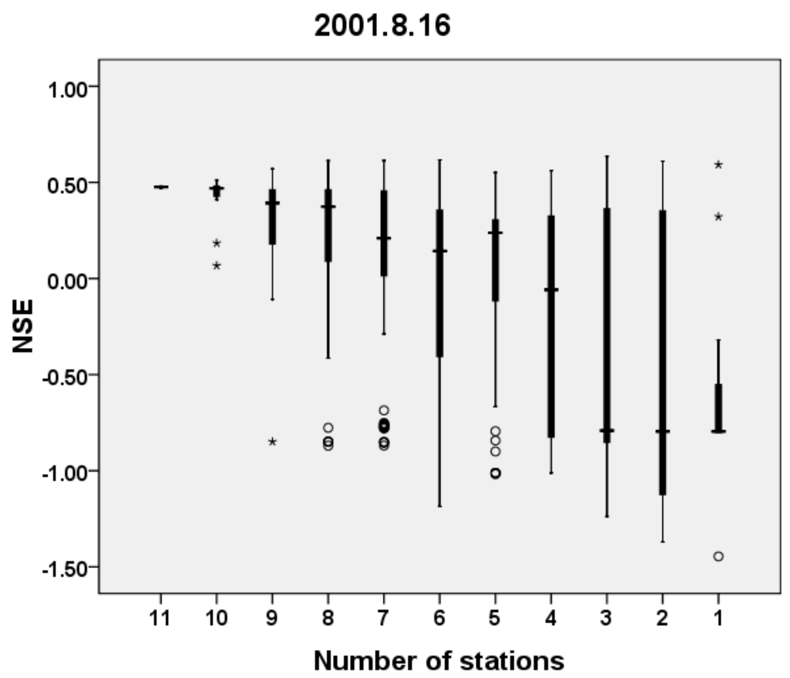
Using SPSS（Statistical Product and Service Solutions）

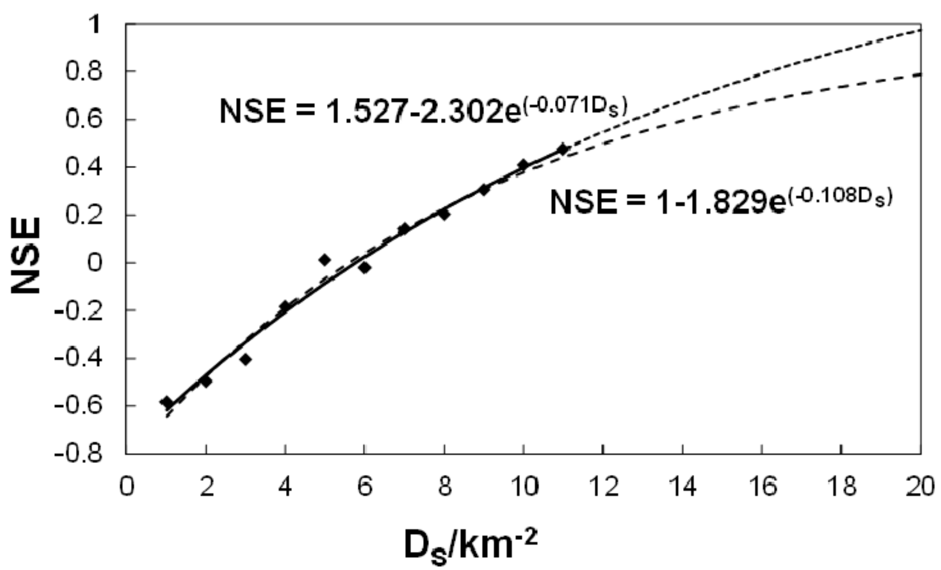
Impacts of rain gauge density

☆With the reduction of rainfall input, the NSE becomes worse.

☆The NSE value is satisfactory and could reach 0.8 if the D_S is more than 21 in this 930 km^2 area

➔ A rain gauge should cover no more than 45 km^2 in the loess plateau





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Model parameter calibration

☆Computing time remains an obstacle when a large-scale region model is calibrated using optimization techniques.

☆The major challenge is to break the limitation of the inevitable serial calculation along the main stem

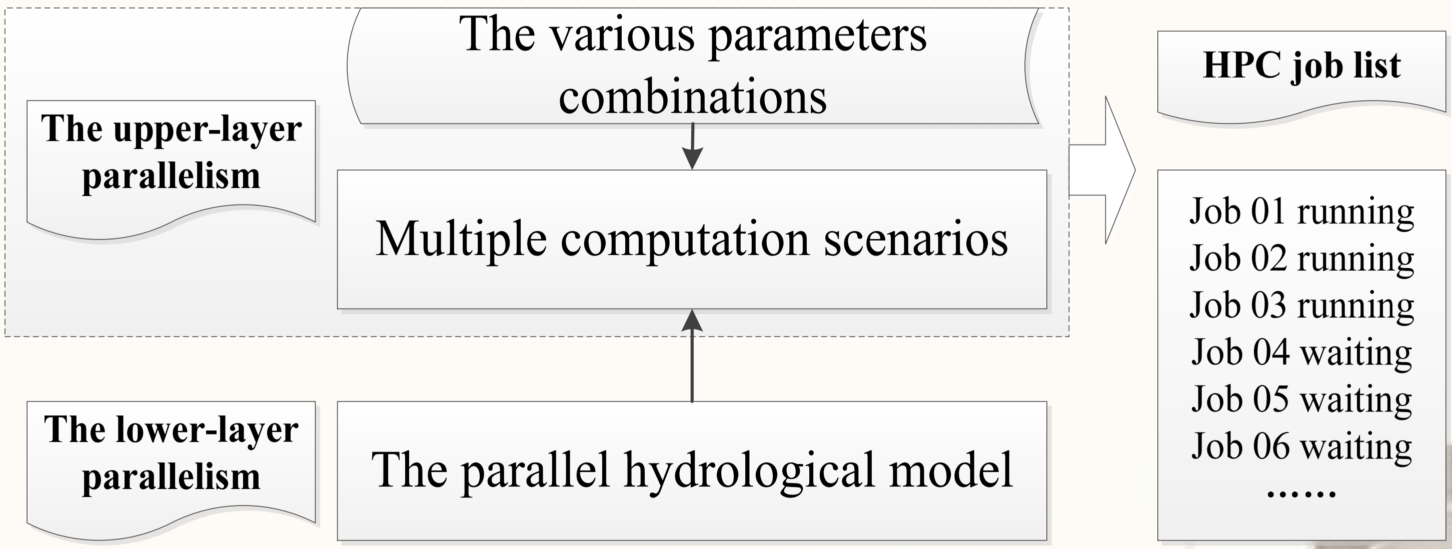
☆**Problem: How to save time?**

Double-layer parallelization technique for calibration

☆ **A parallelized model as the lower-layer is managed.**

☆ **Simulations with different parameters as the upper-layer run in parallel on an HPC.**

☆ Significantly improves the efficiency of model calibration.



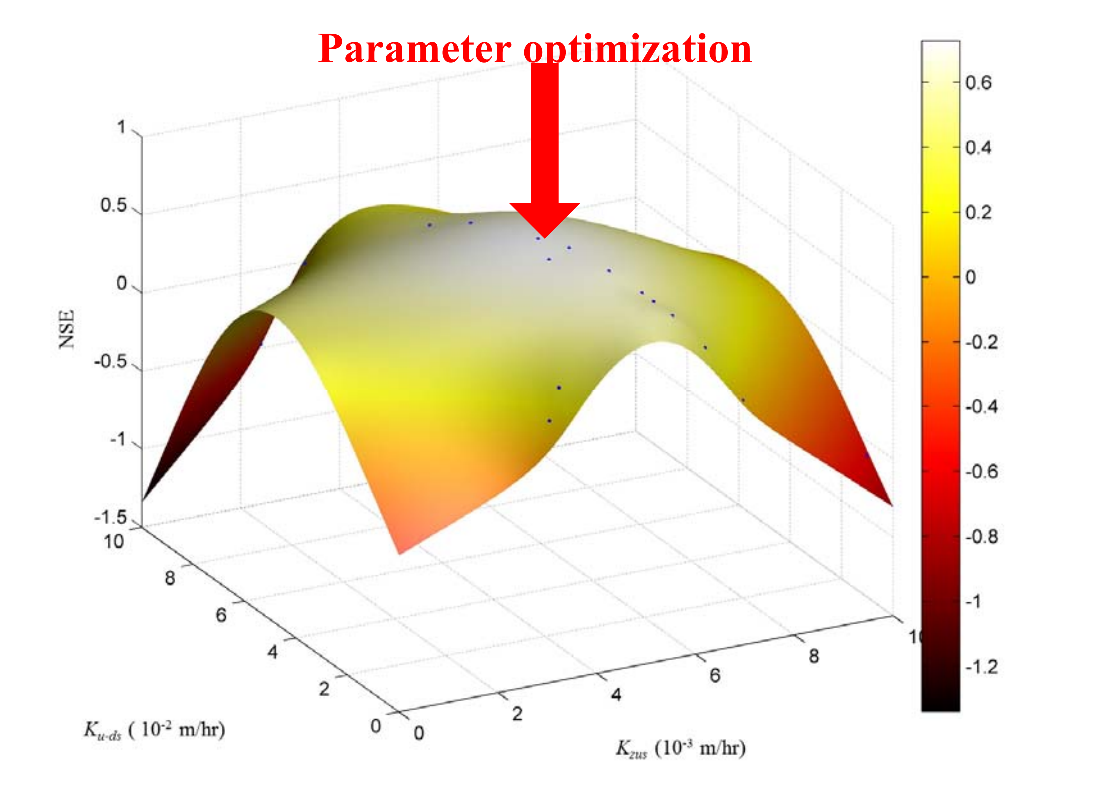
References:

Li et al., 2011. Dynamic parallelization of hydrological model simulations. Environmental Modelling & Software. 26, 1736-1746

Zhang, et al., 2015.Double-layer parallelization for hydrological model calibration on HPC systems. Journal of Hydrology. Under Review

Parameter sensitivity analysis

K_{zus}	**Vertical saturated conductivity of topsoil layer (m/hr)**
$K_{u\text{-}ds}$	Vertical saturated conductivity between topsoil and subsoil (m/hr)



Multidimensional parameter optimization

Parameter sensitivity analysis

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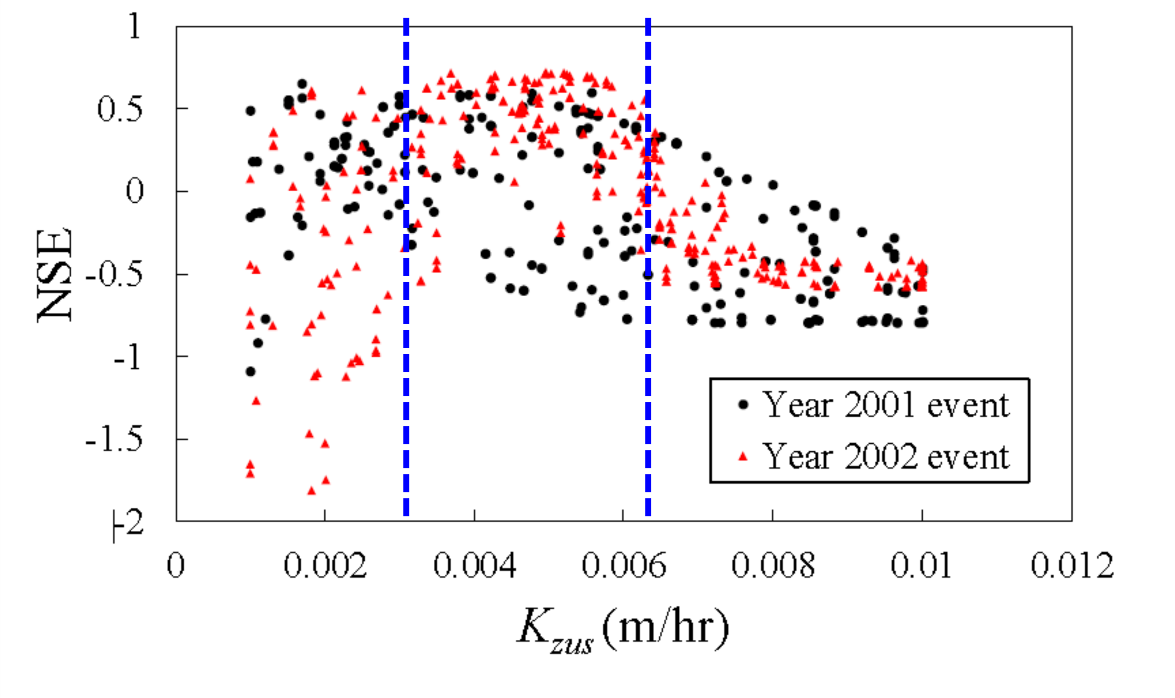
- GLUE（Generalized Likelihood Uncertainty Estimation）



Tolerance interval for K_{zus} is small, that means K_{zus} is sensitive.

Parameter sensitivity analysis

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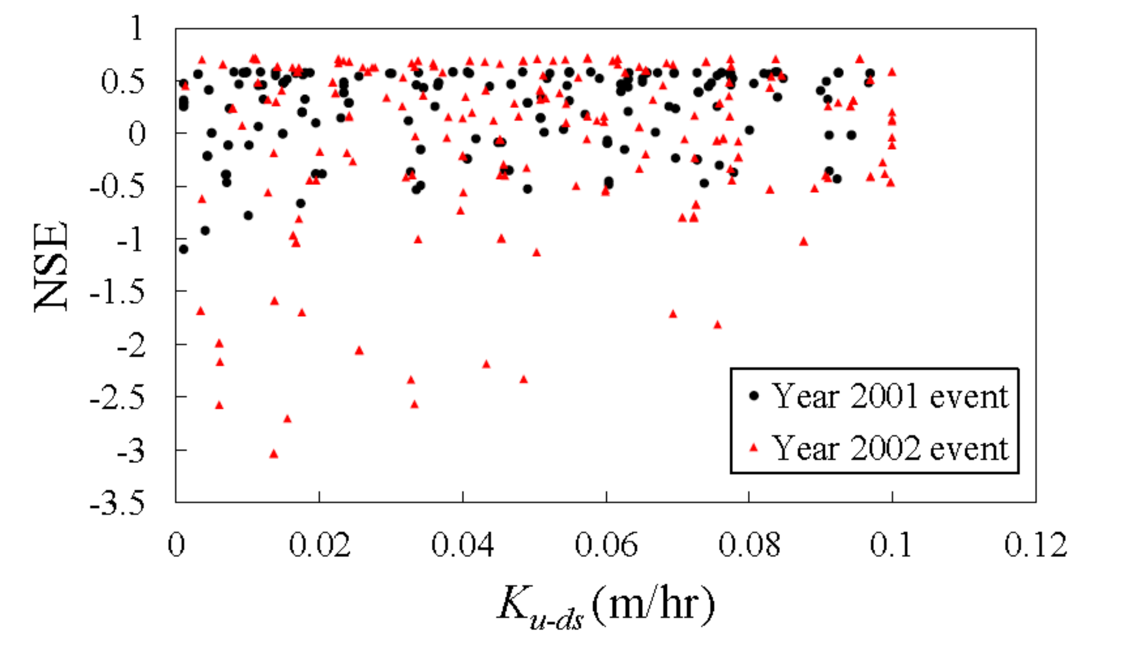

Tolerance interval for $K_{u\text{-}ds}$ is large, that means $K_{u\text{-}ds}$ is not sensitive.

Recent Advances

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RA2: Hydrodynamic simulation:

- Governing equations and its numerical schemes
- Sediment transport and morphological models
- Flow resistance

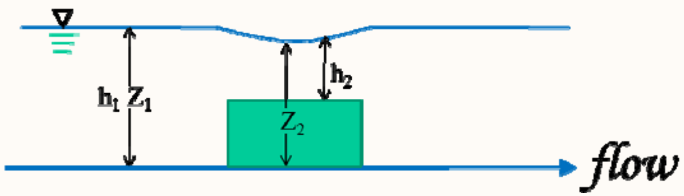
RA3: Information techniques

- Parallel computing techniques

Governing equation: 1D Saint Venant equations

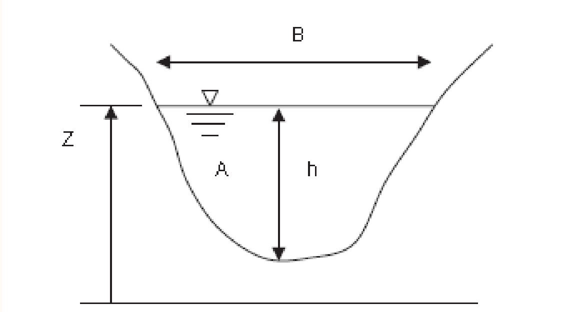
Mass: $$\frac{\partial A}{\partial t}+\frac{\partial Q}{\partial x}=0$$

Momentum: $$\frac{\partial Q}{\partial t}+\frac{\partial}{\partial x}\left(\frac{Q^2}{A}\right)=-gA\frac{\partial Z}{\partial x}-gS_f$$



- Suitable for arbitrary cross sections, but might lead to numerical instabilities when there is topography discontinuity

$$\frac{\partial Z}{\partial t}+\frac{\partial (Q/B)}{\partial x}=-Q/B^2\frac{\partial B}{\partial x}$$
$$\frac{\partial Q}{\partial t}+\frac{\partial}{\partial x}\left(\frac{Q^2}{A}\right)=-gA\frac{\partial Z}{\partial x}-gS_f$$

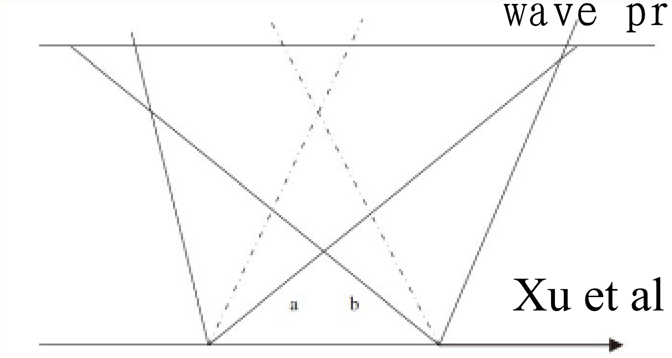


- The water surface is smooth even when there is topography discontinuity; the equation has the conservative form

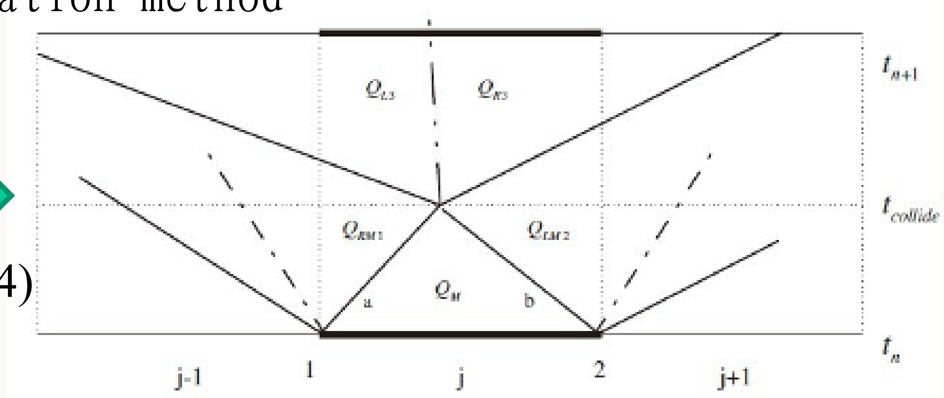
LTS (large time step) scheme for fast calculation

Flash flood calculation: instability; small value of CFL number

wave propagation method



Xu et al (2014)



Scheme	CFL Number	Physical Time（S）	CPU Time（S）	Efficiency (Roe=1)
Roe	0.8	200.8466	9.59827E-3	1
LTS	1.0	201.1399	7.29919E-3	1.32
LTS	2.0	201.1137	4.68578E-3	2.04
LTS	3.0	201.4131	3.60982E-3	2.63
LTS	4.0	204.9585	3.08502E-3	3.13
LTS	5.5	204.4628	2.61879E-3	3.70
LTS	15	213.9276	2.51696E-3	3.85

Recent Advances

RA1: Hydrological simulation:

- Rainfall data input: Spatial inhomogeneity
- Parameter calibration

RA2: Hydrodynamic simulation:

- Governing equations and numerical schemes
- Sediment transport and morphological models
- Flow resistance

RA3: Information techniques

- Parallel computing techniques

Recent Advances

Sediment transport and morphological models

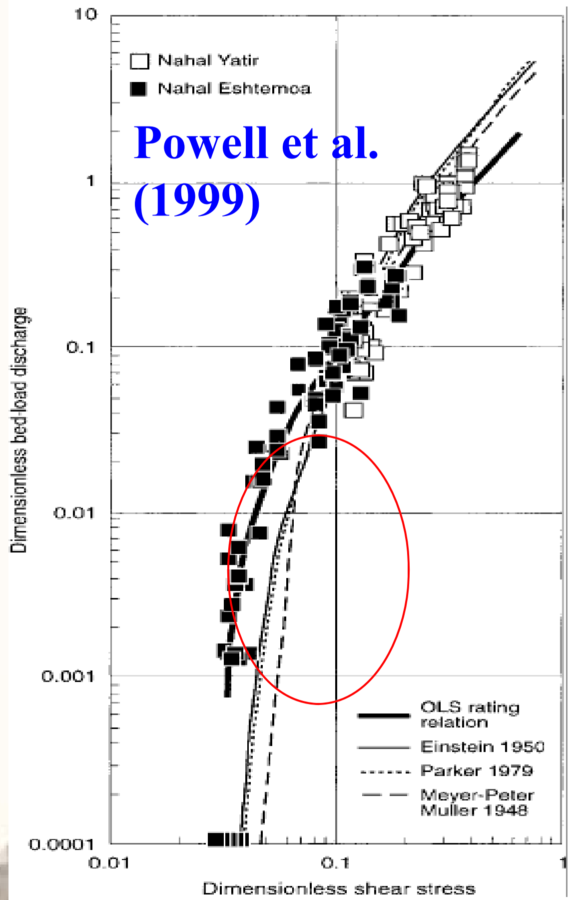
- Uniform sediments: Corrected Meyer-Peter and Muller equation (Wong and Parker 2005)

$$q^* = \begin{cases} \alpha_b\left(\tau^* - \tau_c^*\right)^{1.5} & \text{for } \tau^* > \tau_c^* \\ 0 & \text{for } \tau^* \le \tau_c^* \end{cases}$$

- Non-uniform sediments: Wilcock and Crowe equation (Wilcock and Crowe 2003)

$$W_i^* = \begin{cases} 0.002\phi^{7.5} & \text{for } \phi < 1.35 \\ 14\left(1 - \dfrac{0.894}{\phi^{0.5}}\right)^{4.5} & \text{for } \phi \ge 1.35 \end{cases}$$

$$\phi = \tau_b / \tau_{ri} \qquad W_i^* = \frac{Rgq_{bi}}{F_i u_*^3}$$



Sediment transport and morphological models

$$\frac{\partial z}{\partial t}+\frac{\partial (Q/b)}{\partial x}=-Q/b^2\frac{\partial b}{\partial x}$$

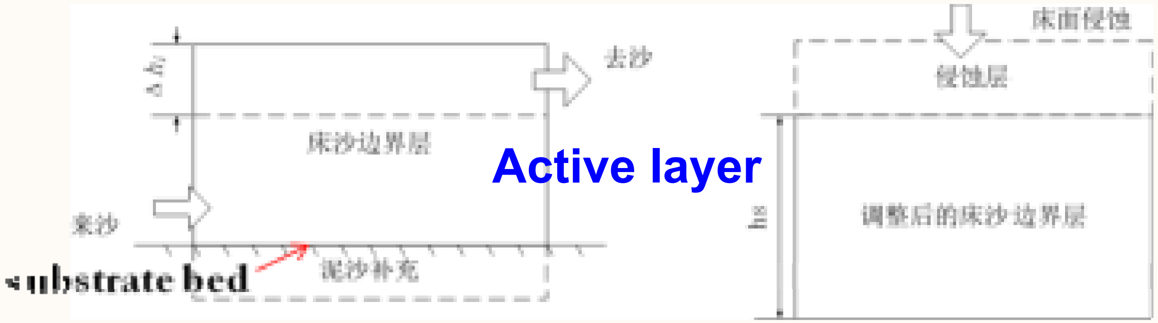
$$\frac{\partial Q}{\partial t}+\frac{\partial}{\partial x}\left(\frac{Q^2}{A}\right)=-gA\frac{\partial z}{\partial x}-gS_0$$

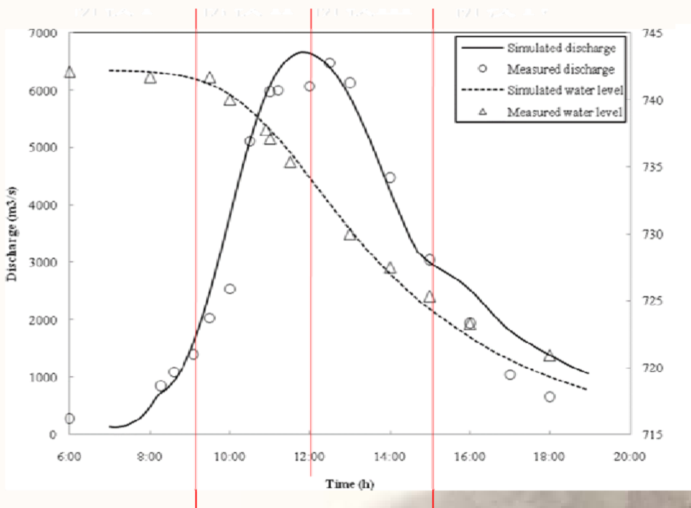
$$\frac{\partial \phi_d}{\partial t}+\frac{\partial (\phi_d P_d u_{sd})}{\partial x}=0$$

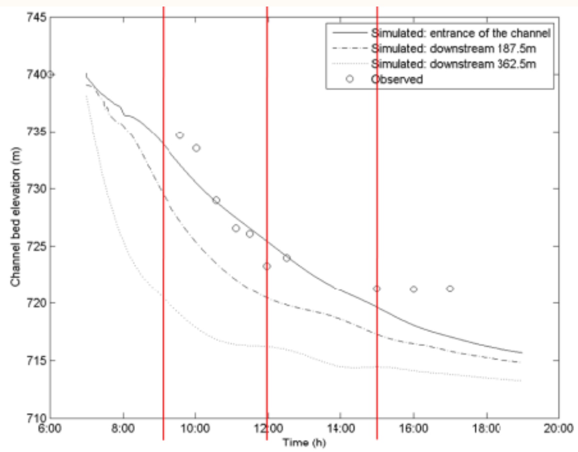
$$P_d=\begin{cases}1-\dfrac{u_{sd,c}}{u_f} & u_{sd,c}<u_f\\ 0 & else\end{cases}$$

$$u_{sd}=ku_f$$

Active layer model（Liu et al., 2012）

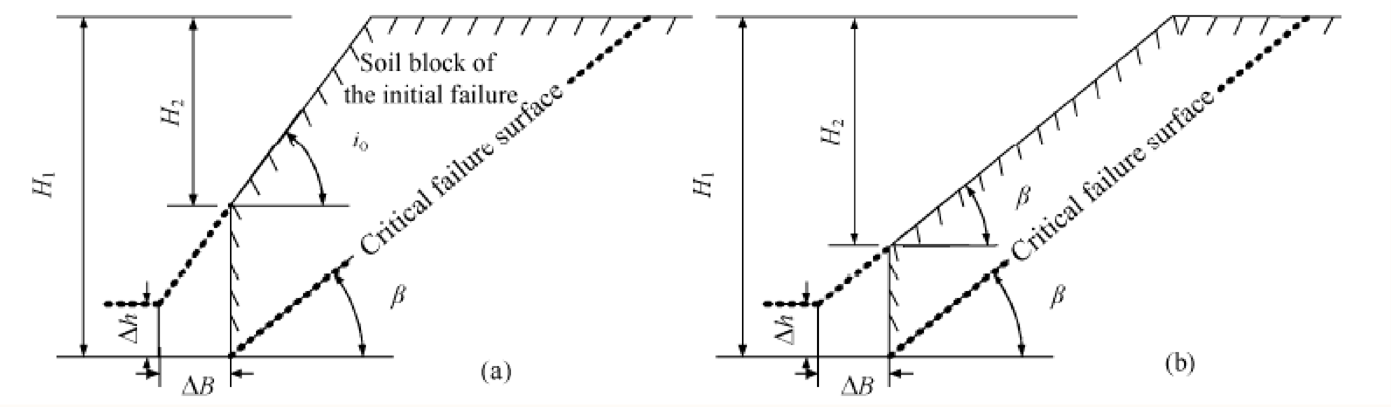






Bank erosion: Gravitational collapse model (Osman and Thorne, 1988)

Erosion under the coupled action of flow and gravity



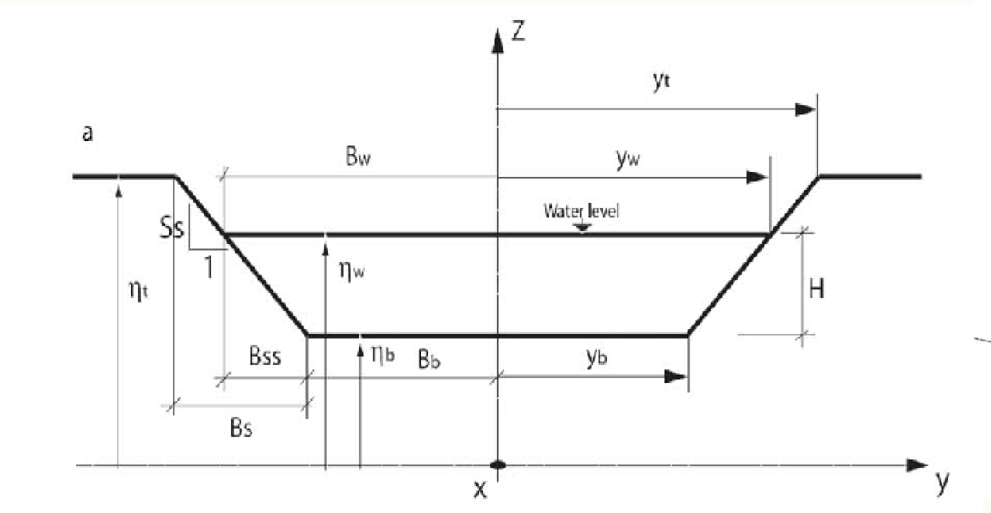
Flow shear stress: $\tau_f = \gamma_w n^2 u^2 h^{-1/3}$

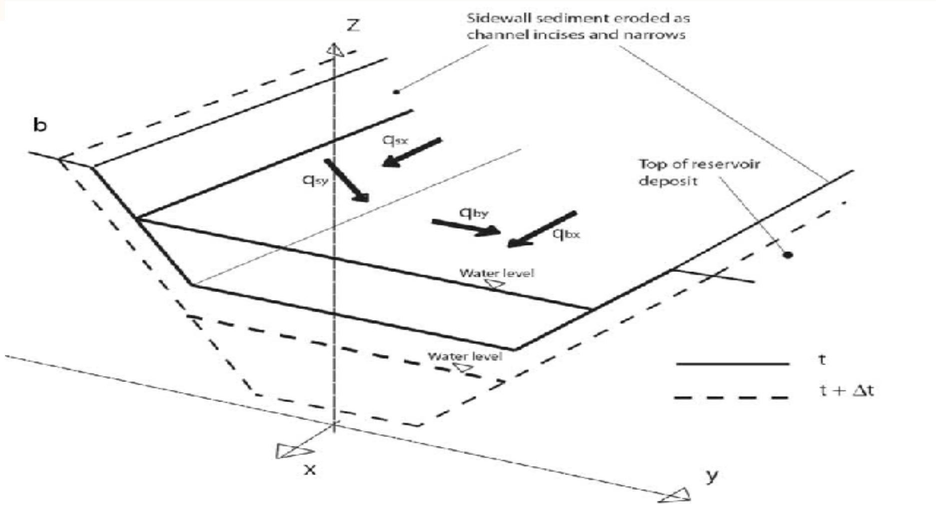
Critical shear stress: $\tau_c = 0.047(\gamma_{bk} - \gamma_w)d_{50}$

Bank retreat during Δt: $\Delta B = \dfrac{C_l(\tau_f - \tau_c)}{\gamma_{bk}} e^{(-1.3\tau_c)} \Delta t$

Bank erosion: Morphodynamic model (Cantelli et al., 2007)

Erosion caused by bedload transport at bed and banks





$$(1-\lambda_p)(\eta_t-\eta_b)\frac{\partial B_b}{\partial t}=(1-\lambda_p)\frac{\eta_t-\eta_b}{S}\frac{\partial \eta_b}{\partial t}+\frac{1}{S}\frac{\partial(q_{sx}H)}{\partial x}+\frac{\partial B_b}{\partial x}+q_{sy}$$

Recent Advances

RA1: Hydrological simulation:

- Rainfall data input: Spatial inhomogeneity
- Parameter calibration

RA2: Hydrodynamic simulation:

- Governing equations and numerical schemes
- Sediment transport and morphological models
- Flow resistance

RA3: Information techniques

- Parallel computing techniques:

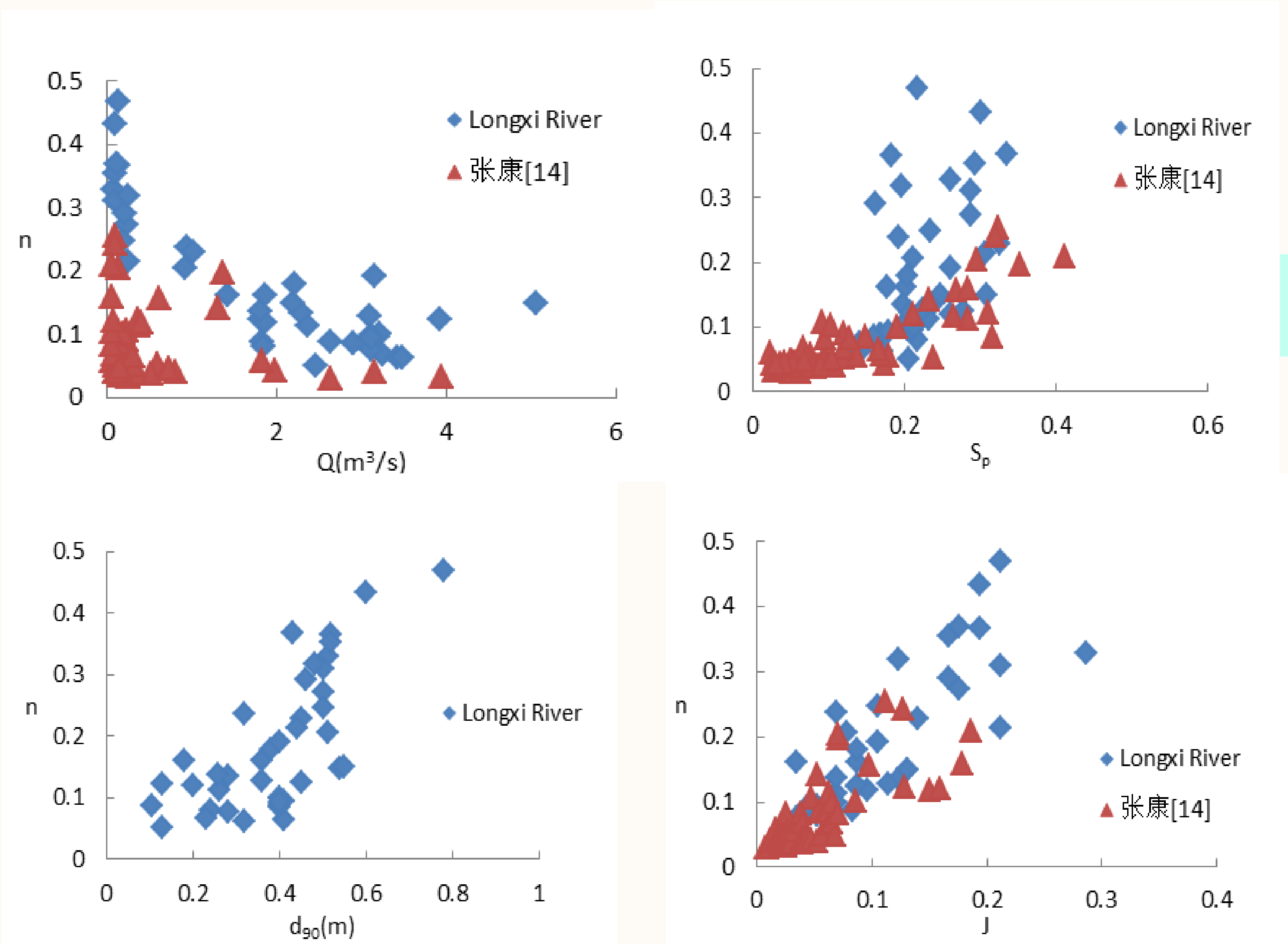
Recent Advances

Flow resistance: Manning coefficient *n*

$$U = \frac{1}{n} R^{2/3} S^{1/2}$$

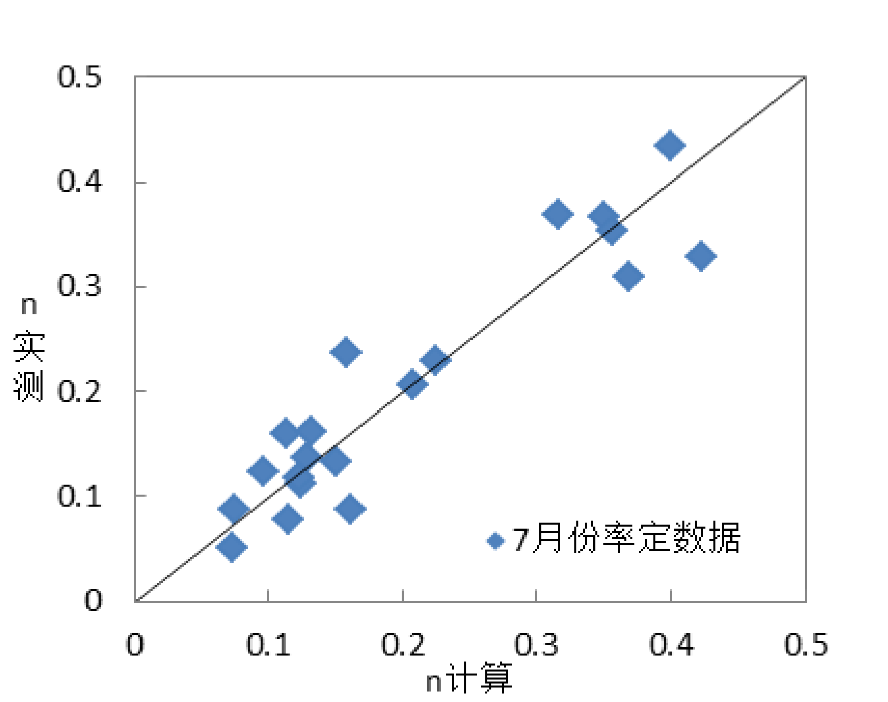
$$n = \frac{k_s^{1/6}}{A} ?$$

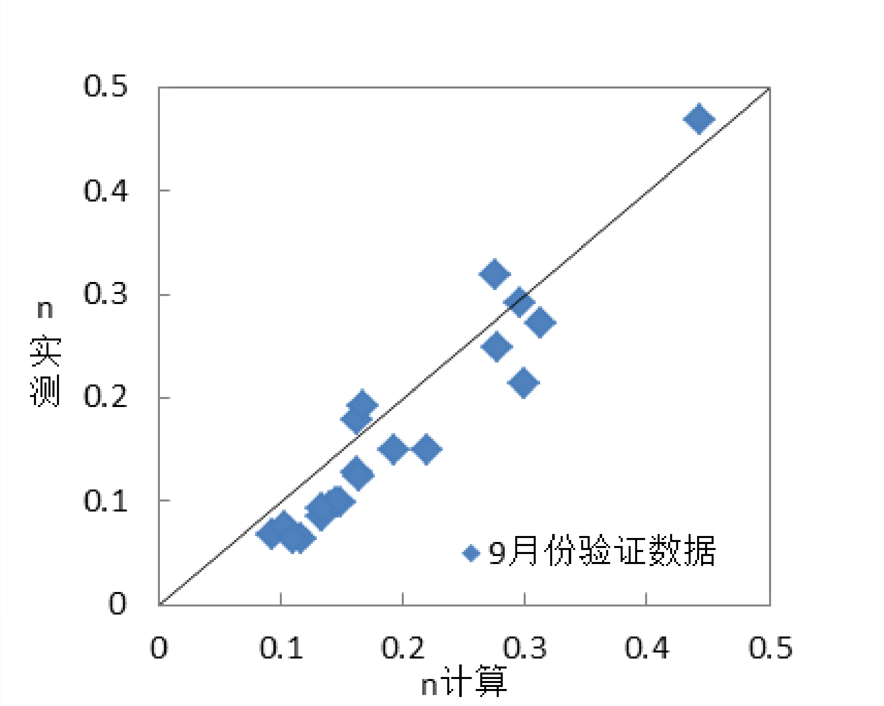
$$n = n\left(Q, d, J\right)$$



Proposed formula for mountain streams:

$$1/n = 0.66Q^{0.14}g^{0.43}/(d_{90}{}^{0.52}J^{0.26})$$





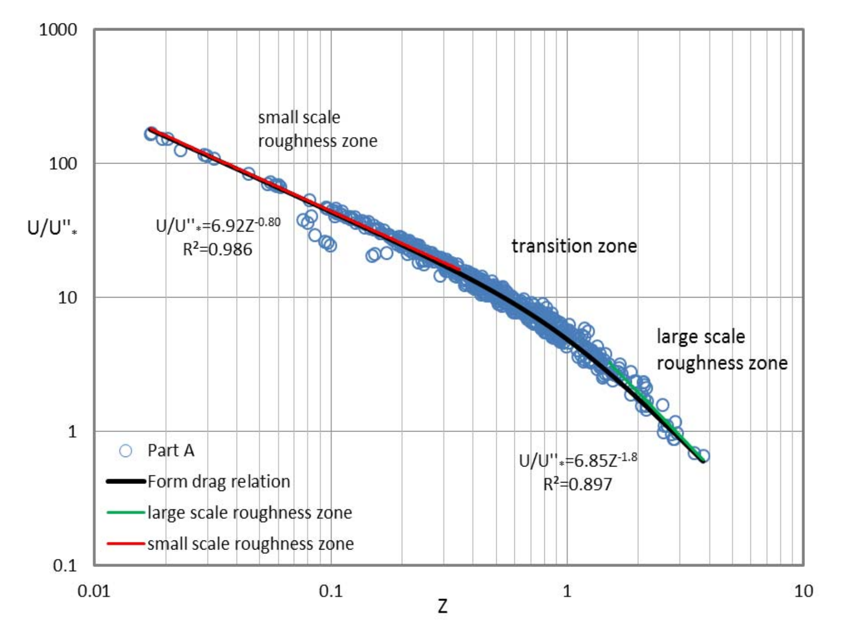
Applicable to mountain streams similar to the Longxi River

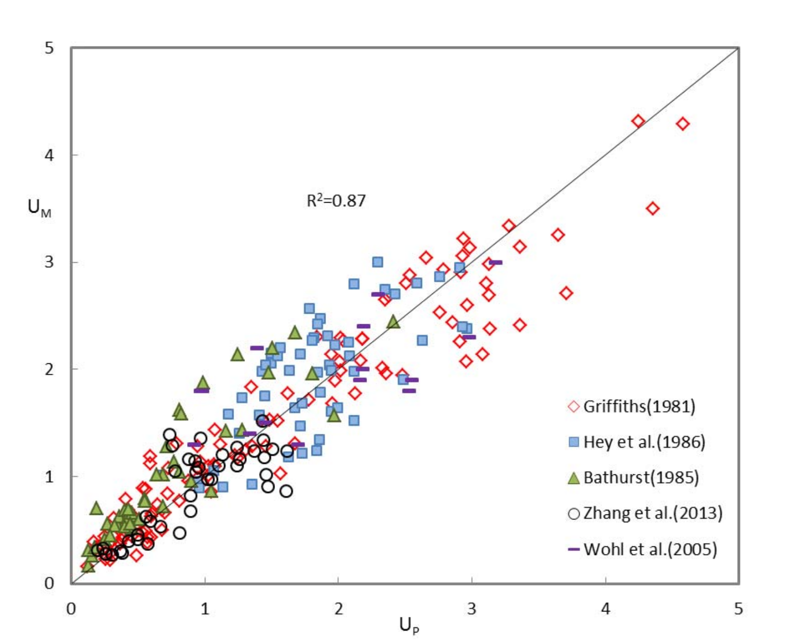
Recent Advances

A potentially unified formula of form resistance:

Validated against a large set of field data with slope ranging from 0.004% to 28.7% covering both alluvial and mountain rivers.

$$\frac{f''}{8} = \frac{Z^{1.6}}{6.92^2} + \frac{Z^{3.6}}{6.85^2}$$





Recent Advances

RA1: Hydrological simulation:

- Rainfall data input: Spatial inhomogeneity
- Parameter calibration

RA2: Hydrodynamic simulation:

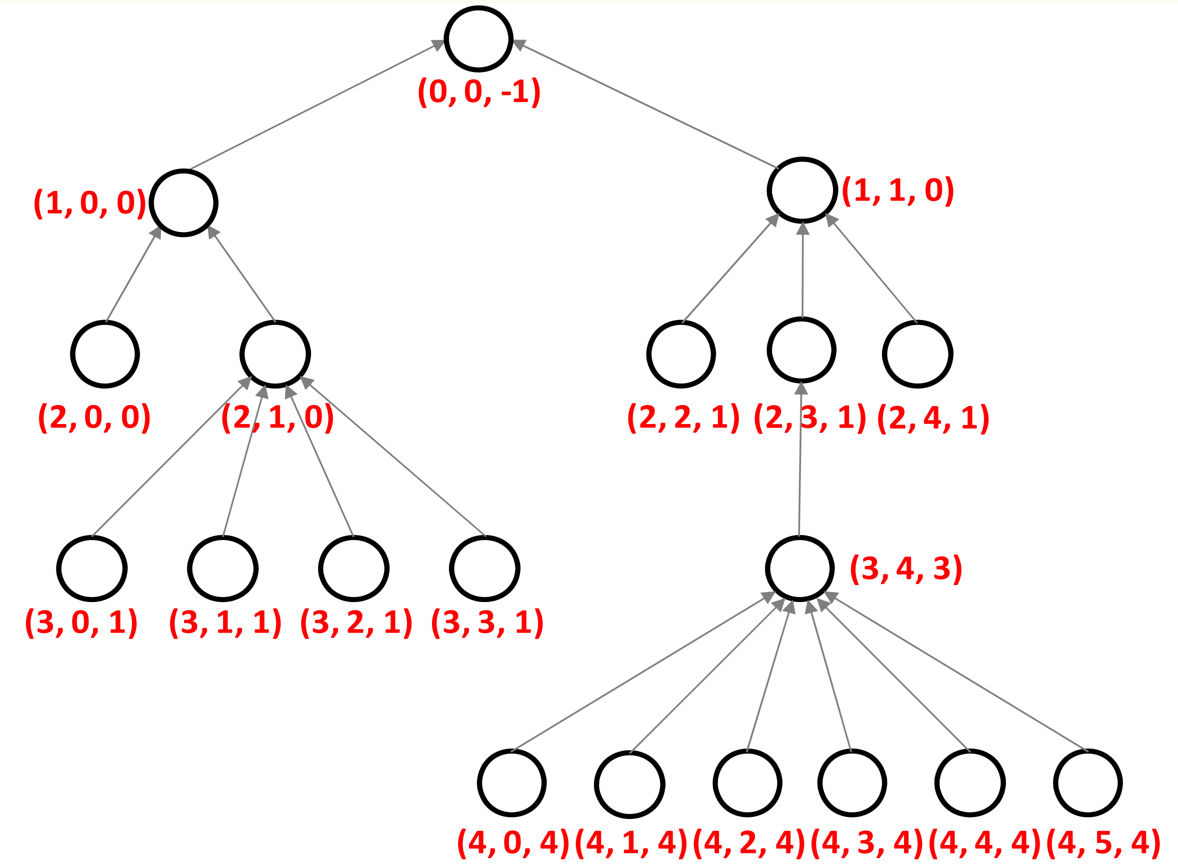
- Governing equations and numerical schemes
- Sediment transport and morphological models
- Flow resistance

RA3: Information techniques

- Parallel computing techniques

Universal drainage network coding method based on binary tree theory:
from (Layer Number, Node Number) to (Layer Number, Node Number, Pnode Number)

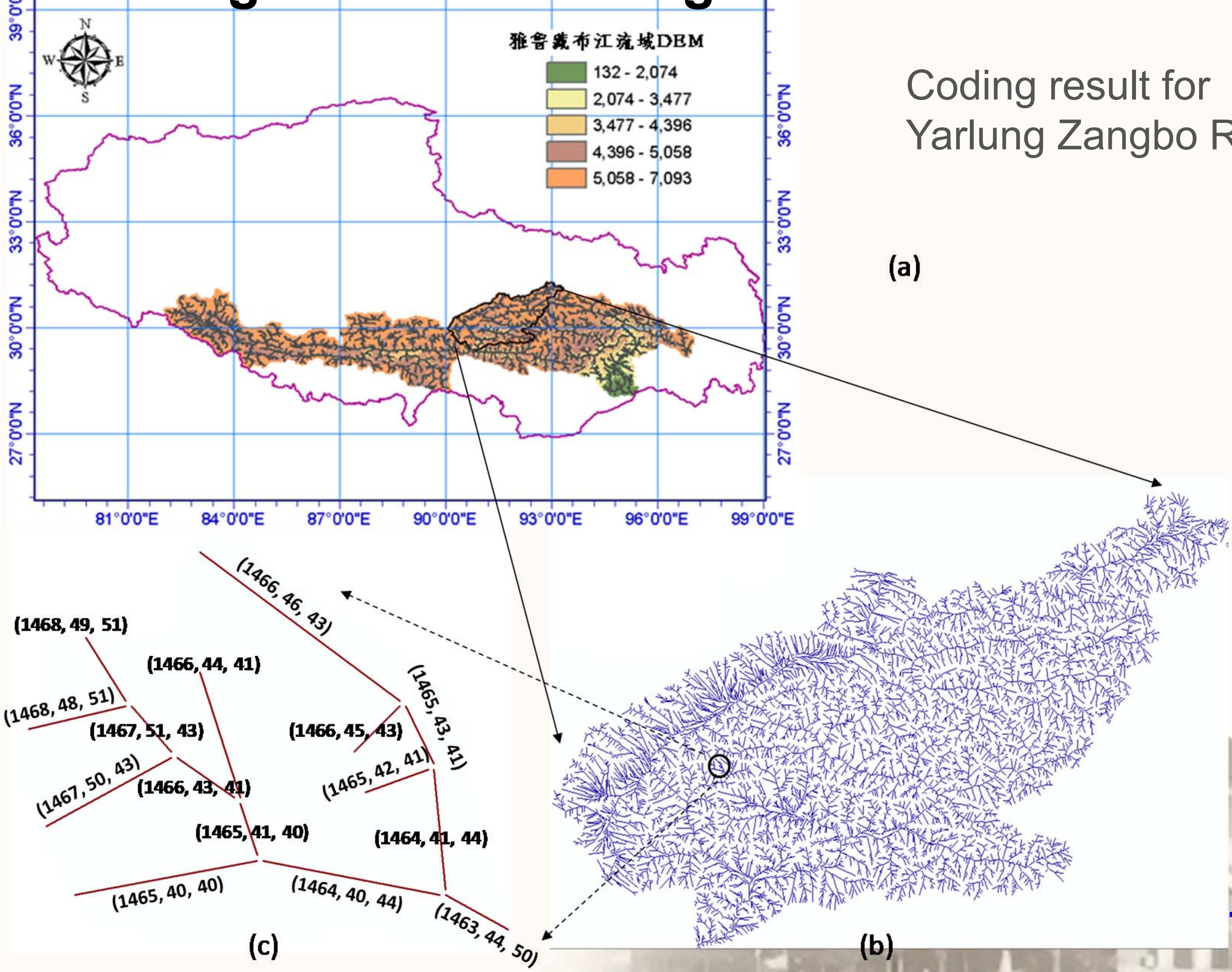
(Layer Number, Node Number, Pnode Number)



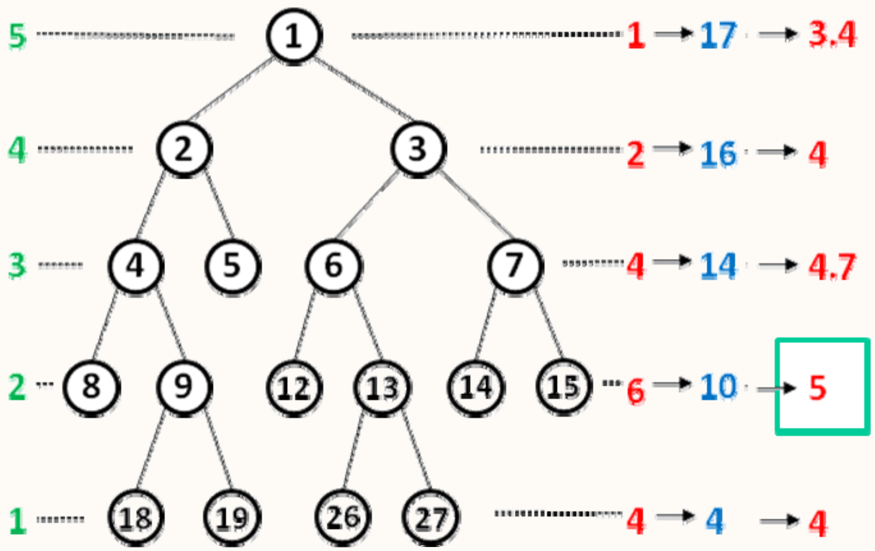
Recent Advances

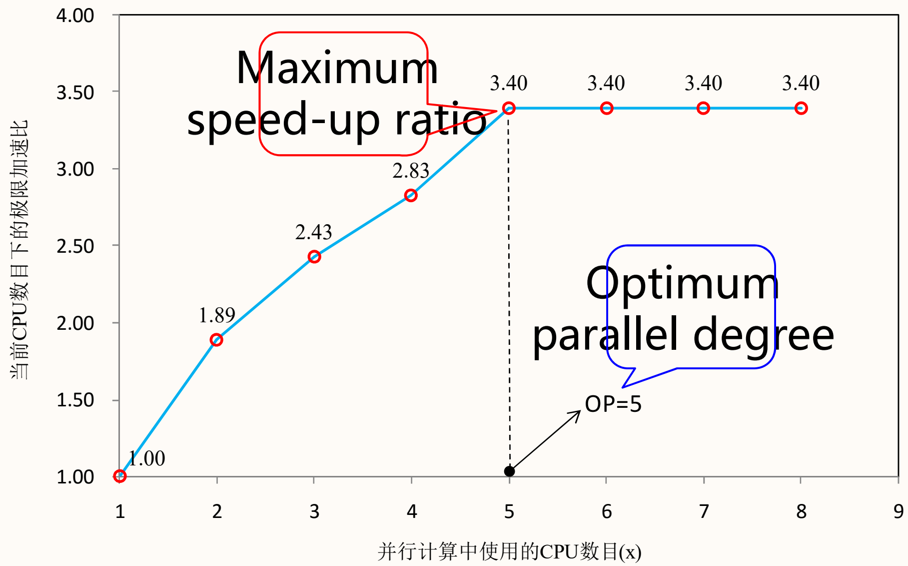
Universal drainage network coding method

Coding result for
Yarlung Zangbo River



Minimum CPU number for maximum speed-up ratio and its parallel computing algorithm





Speed-up ratio = time for serial calculation / time for parallel calculation

Optimum parallel degree

$$OP = \max\{n \in N \mid n = Ceil(\frac{CW(x)}{x})\ \ for\ all\ 1 \le x \le T\}$$

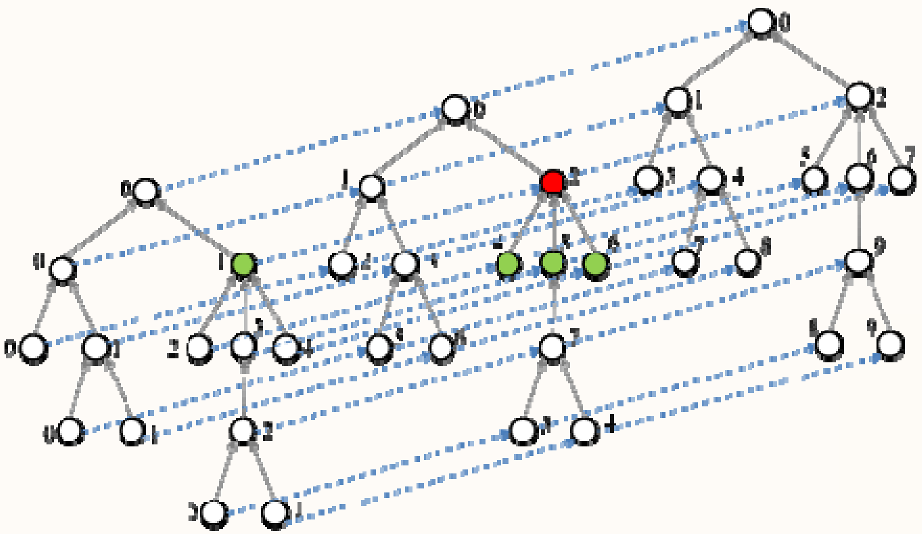
Wang et al. (2011, 2012, 2013)

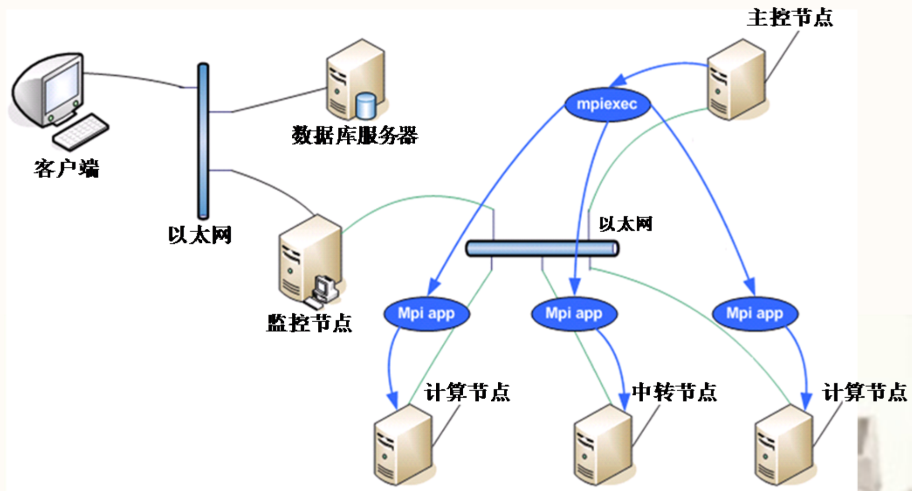
Parallel computing algorithm:

discretization in both space and time

$$R_{\max}(x)=\begin{cases}\min\{y=\dfrac{N}{\max\{L,Ceil(\dfrac{AWF(j)}{x}-j+L)\}},1\le j\le L\},1\le x<OP\\ \dfrac{N}{L},\ x\ge OP\end{cases}$$

$$OP=\max\{x=Ceil(\frac{AWF(j)}{j}),1\le j\le L\}\qquad R_{\max}(x)=\frac{T_s}{(T_p)_{\min}}\approx\frac{xN}{L-1+x}$$





Wang et al. (2011, 2012, 2013)

Tsinghua University

Outline

1. Overview of flash flood hazards
2. Modeling of flash flood
3. Exaggerated flood hazard
4. Toward future: ongoing efforts
5. Summary

Extreme hazard

Extreme flash flood disaster:

August 8, 2010: Zhouqu County in Gansu Province

3887 people were killed.

Cui et al (2010)

Extreme hazard

Extreme flash flood disaster:

August 13, 2010: Sichuan Province

- Wenchuan: 72 people killed or lost
- Qingping: 12 people killed or lost

Cui et al (2010)

清華大學 Tsinghua University

Extreme hazard

Caused by extreme flood or other reasons?

extreme flood?

other reasons?

Question 1: features of extreme flood?

Any differences from regular flash flood?

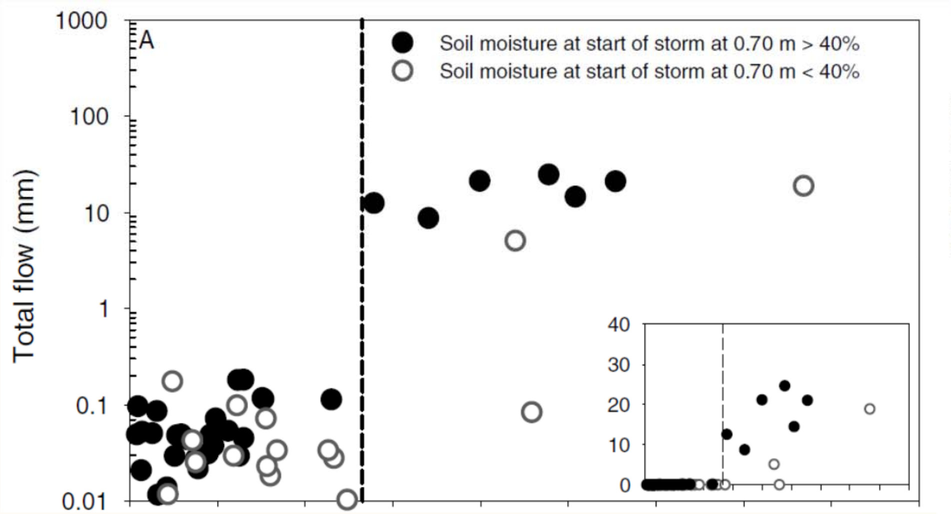
Defined as the flood with a 50-year water stage?

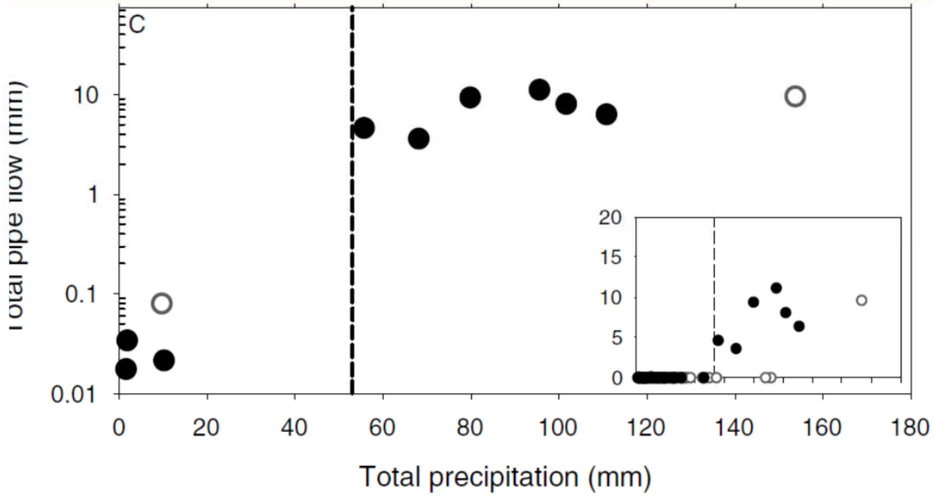
Question 2: formation mechanism?

Extreme hazard

Tromp-van Meerveld & McDonnell (2006, WRR, W02410):
Panola Mountain Research Watershed (Georgia, USA)
hillslope（50m long, 20m wide, 13°）

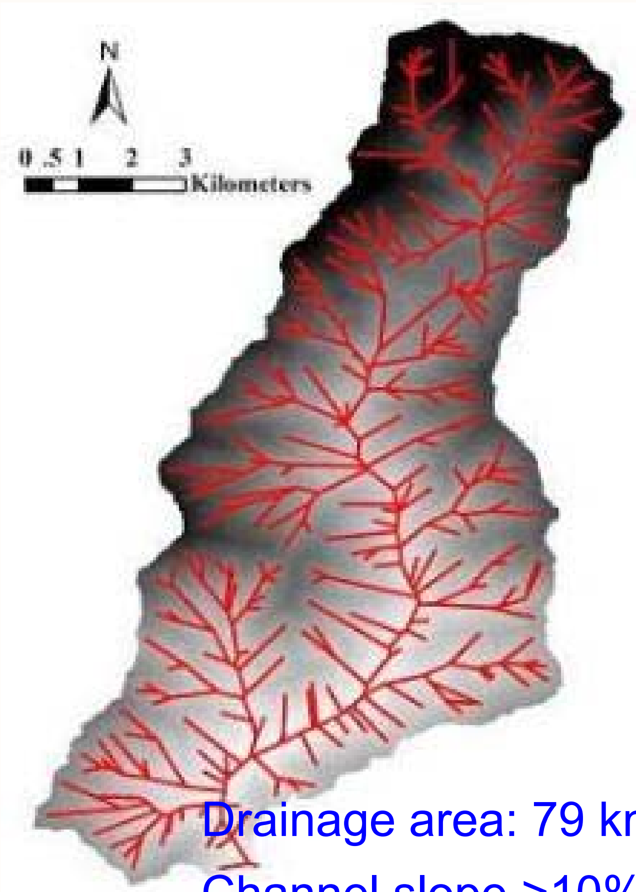
Observation: rainfall threshold and abrupt increase in runoff





Overview of Longxi River

- Close to the epicenter of the 2008 Wenchuan Earthquake
- Subsequent landslides and debris flows



Subsequent landslides and debris flows

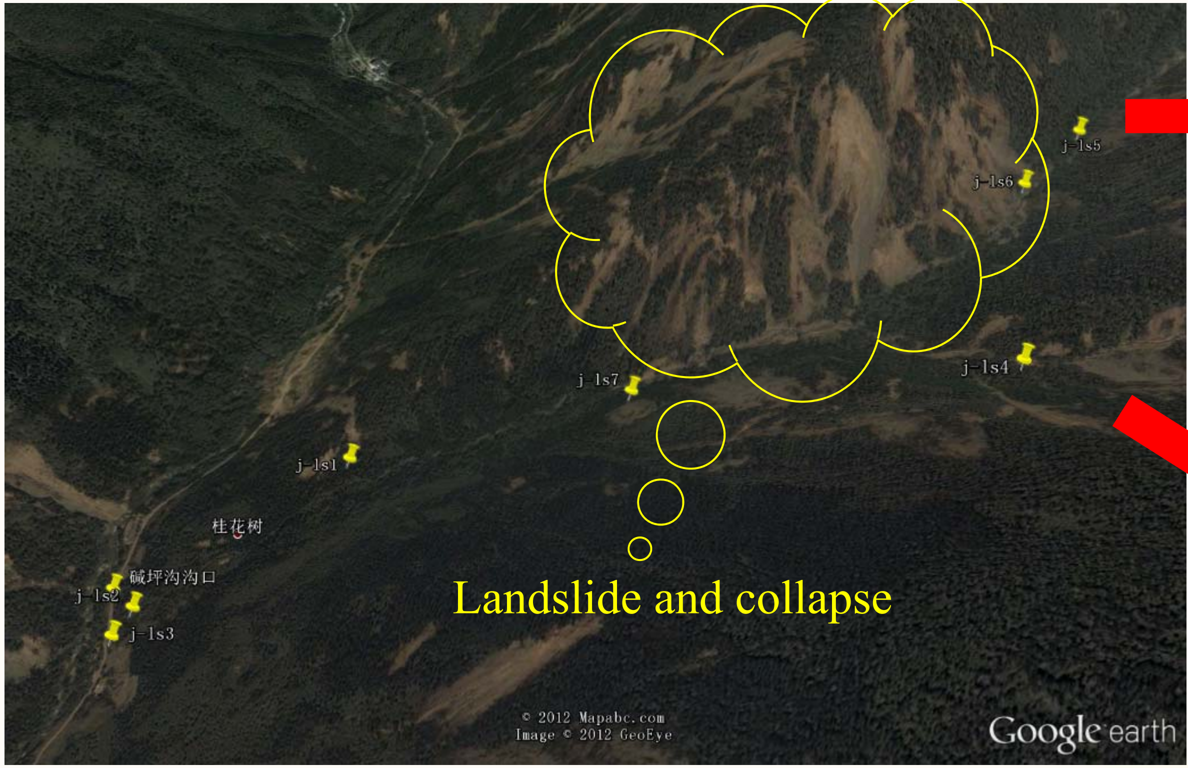
Drainage area: 79 km^2

Channel slope >10%

Overview of Longxi River

➢ **River deposition: average aggradation of 7~8 m**

Mass wasting following the 2008 Wenchuan earthquake



Overview of Longxi River

Heavy rainfall on Aug 13-14, 2010: Flooding

Yinxiu City (映秀):

- Epicenter of the 2008 Wenchuan earthquake
- Near to Dujiangyan 都江堰

Intense flood swallowed the buildings

Overview of Longxi River

Heavy rainfall on Aug 13-14, 2010: Flooding

Longxi River:

- Close to Yinxiu City
- Near to Dujiangyan 都江堰

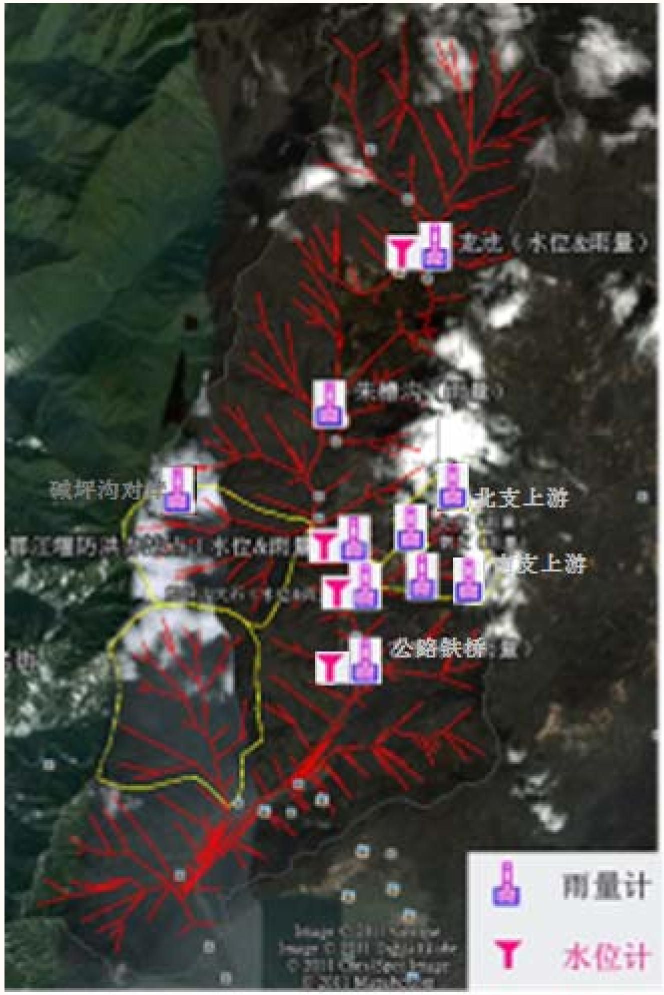
- Sediments filled the river
- The old channel disappeared

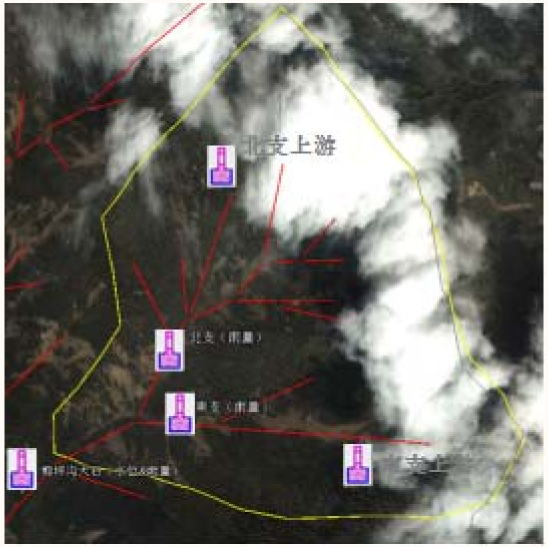
Case study of Longxi River

Field survey

Case of Longxi River

Monitoring system: rainfall, flow & soil moisture





1)Jiapinggou: rainfall, water stage, soil moisture profile

Area: 3 km^2

Channel slope: >20%

2)Longxi River: rainfall, water stage

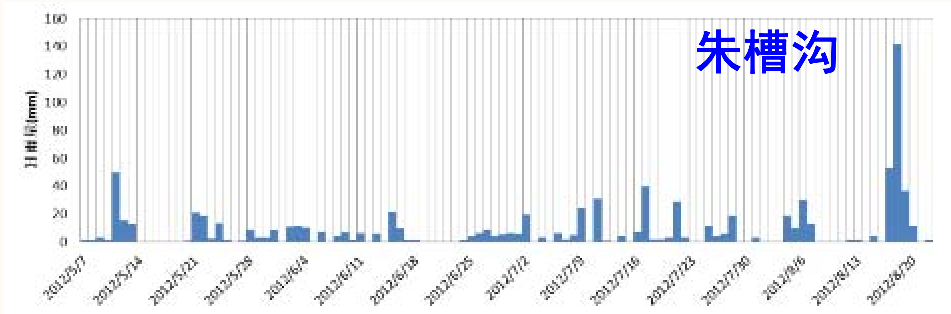
Drainage area: 79 km^2

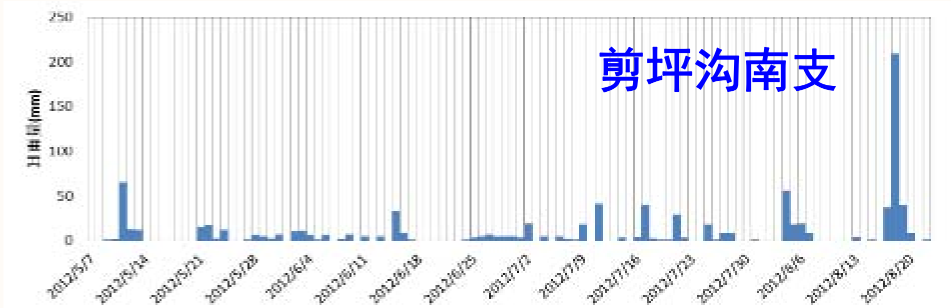
Channel slope >10%

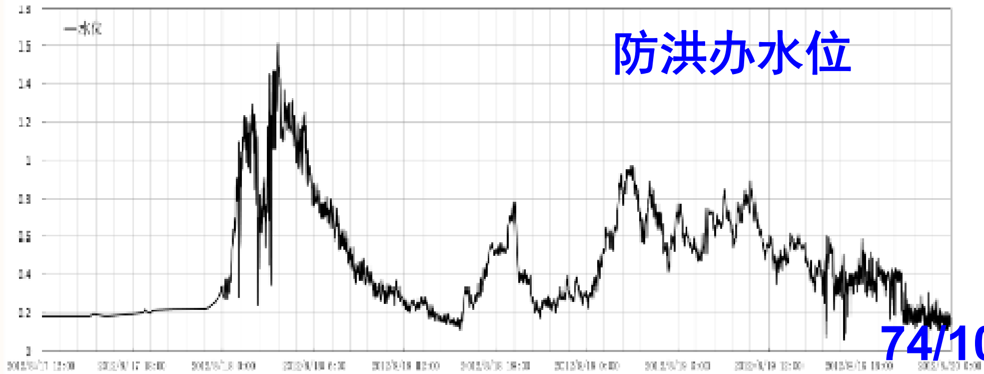
Case of Longxi River

Monitoring system: rainfall, flow, and soil moisture

水位计（上）与雨量计（下）

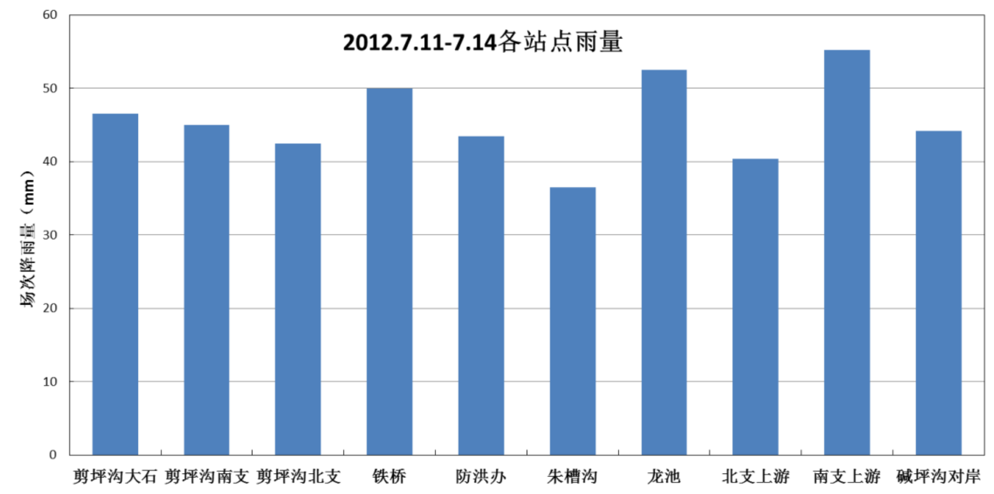


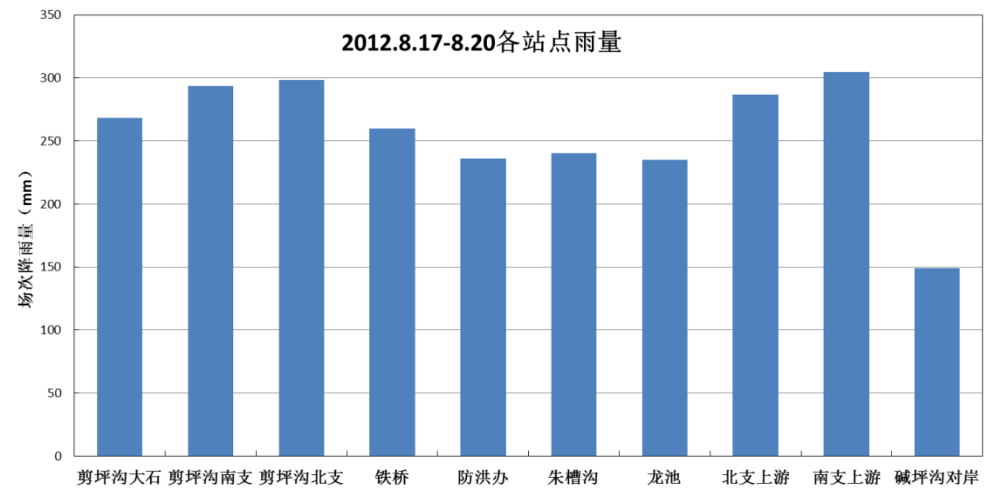


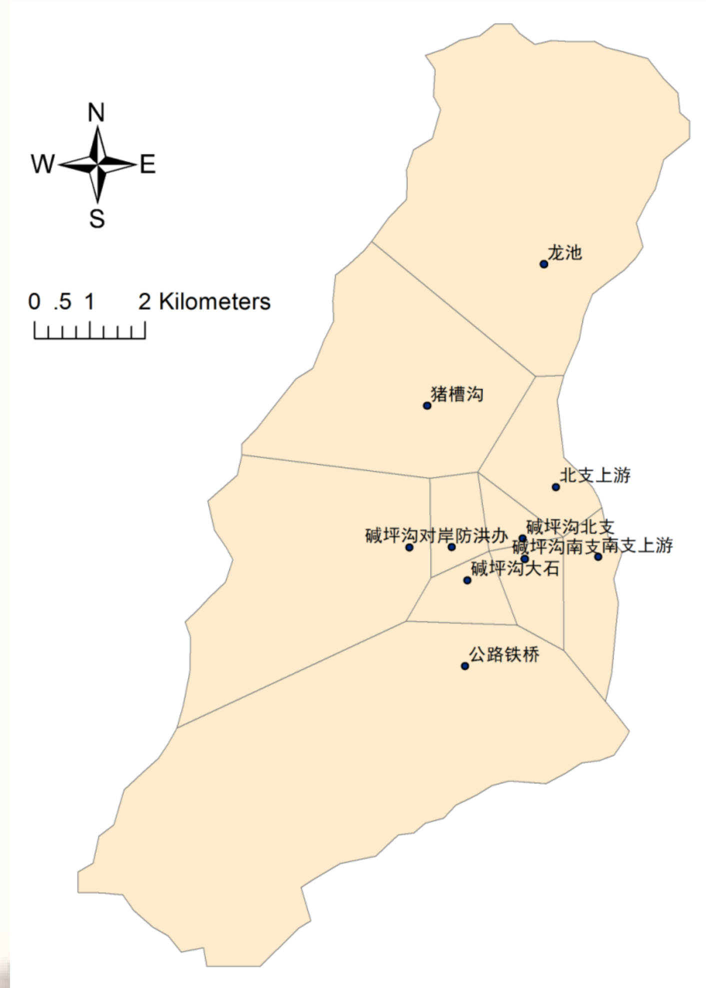


Case of Longxi River

Captured spatial inhomogeneity of rainfall







Case of Longxi River

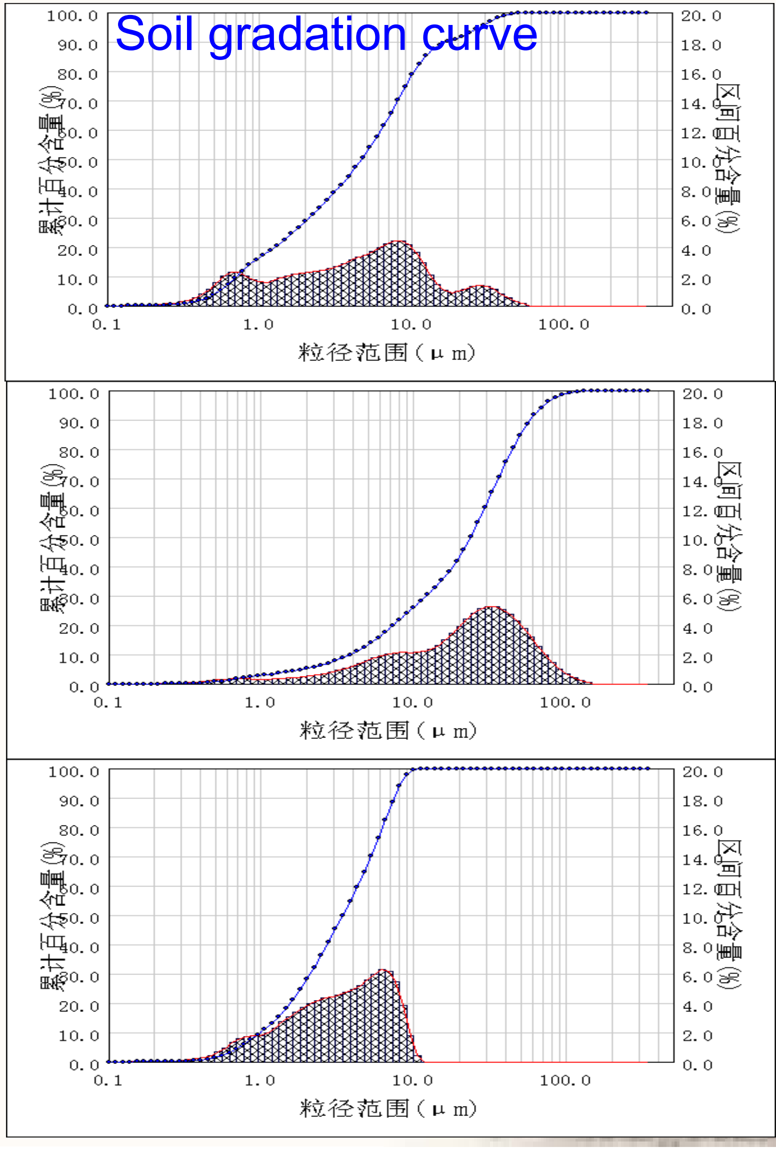
Installed soil moisture profiler

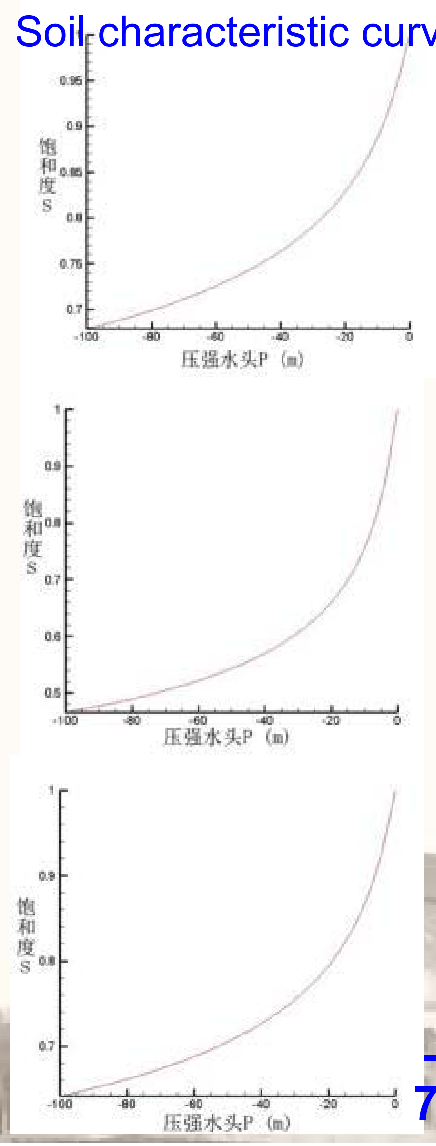
Case of Longxi River

Silty clay

Silt loam

clay





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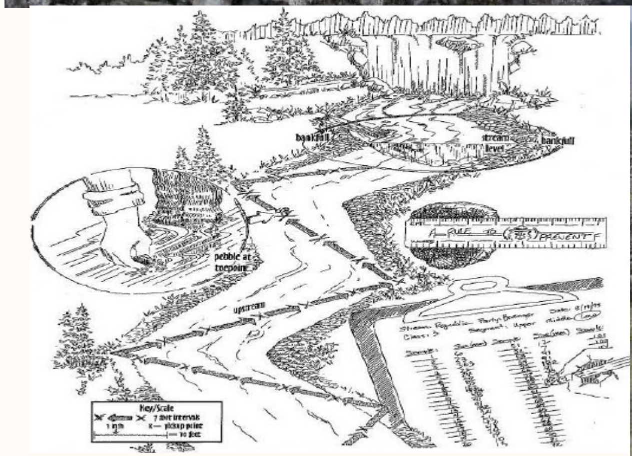
Case of Longxi River

Bed material gradation:

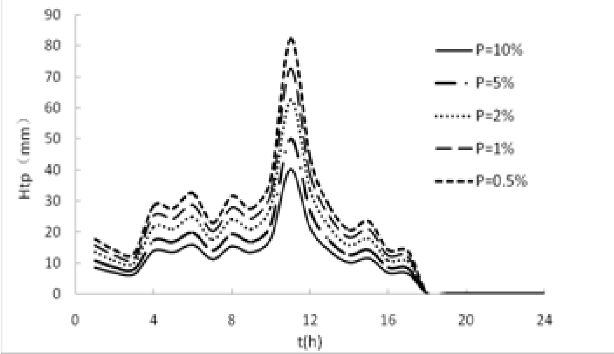


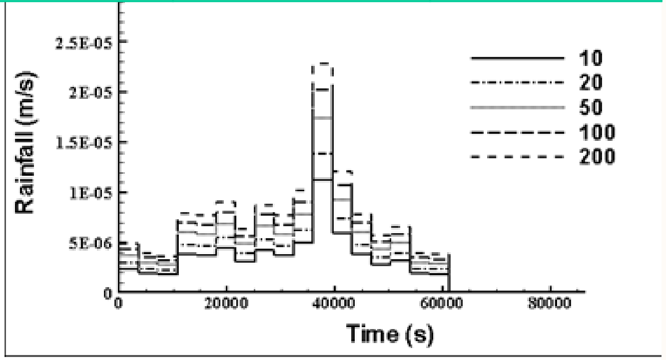
Design rainstorms

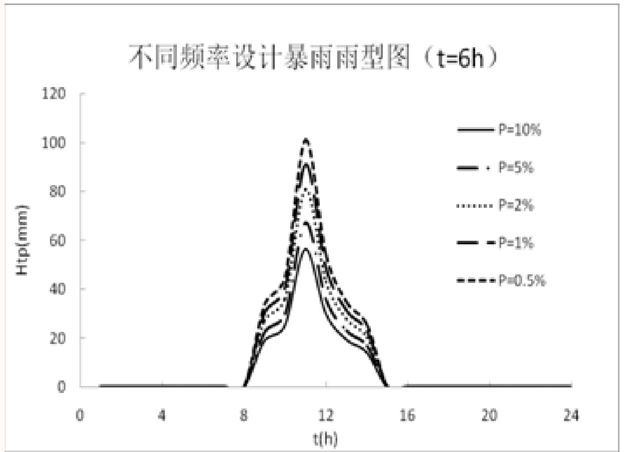
不同频率	最大降雨强度 (m/s)		总降雨量(mm)	
	历时6小时	历时24小时	历时6小时	历时24小时
十年一遇	1.57×10^{-5}	1.12×10^{-5}	164	233.64
二十年一遇	1.86×10^{-5}	1.39×10^{-5}	195	290.4
五十年一遇	2.25×10^{-5}	1.74×10^{-5}	235	364.32
一百年一遇	2.53×10^{-5}	2.02×10^{-5}	265	422.4
二百年一遇	2.81×10^{-5}	2.28×10^{-5}	294	477.84

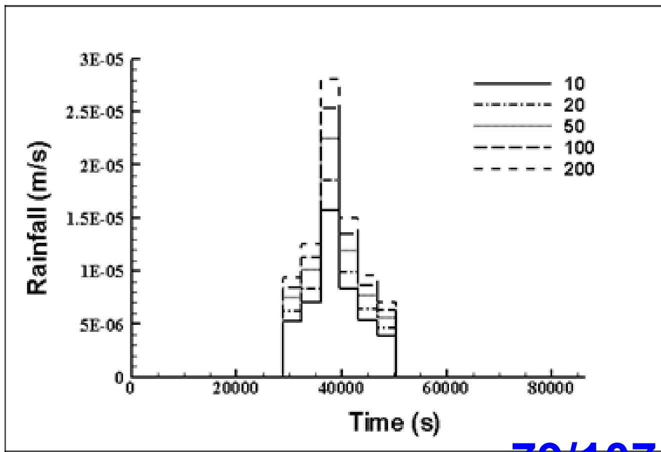
Recurrence interval:
10-, 20-, 50-, 100-, 200-year

Duration:
6 h, 24h





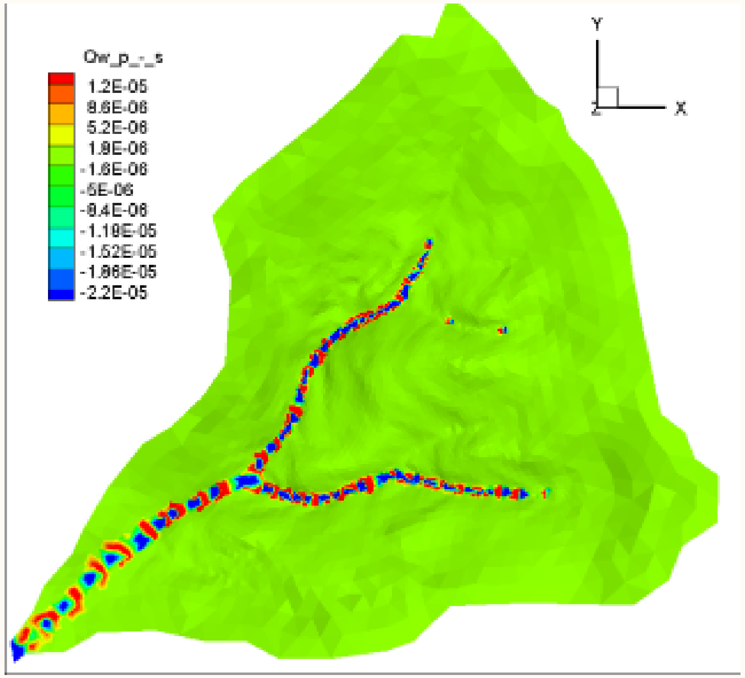


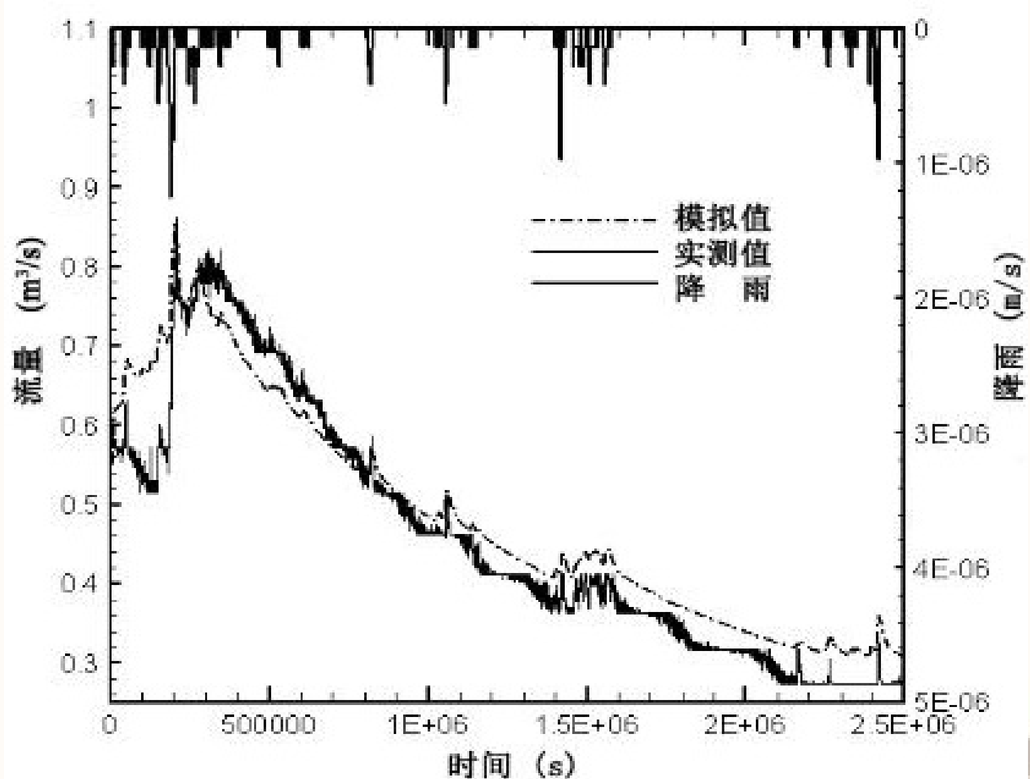


Case of Longxi River

Analysis of flood properties

InHM (Ran et al., 2013) provides hydrological boundaries under designed rainstorms



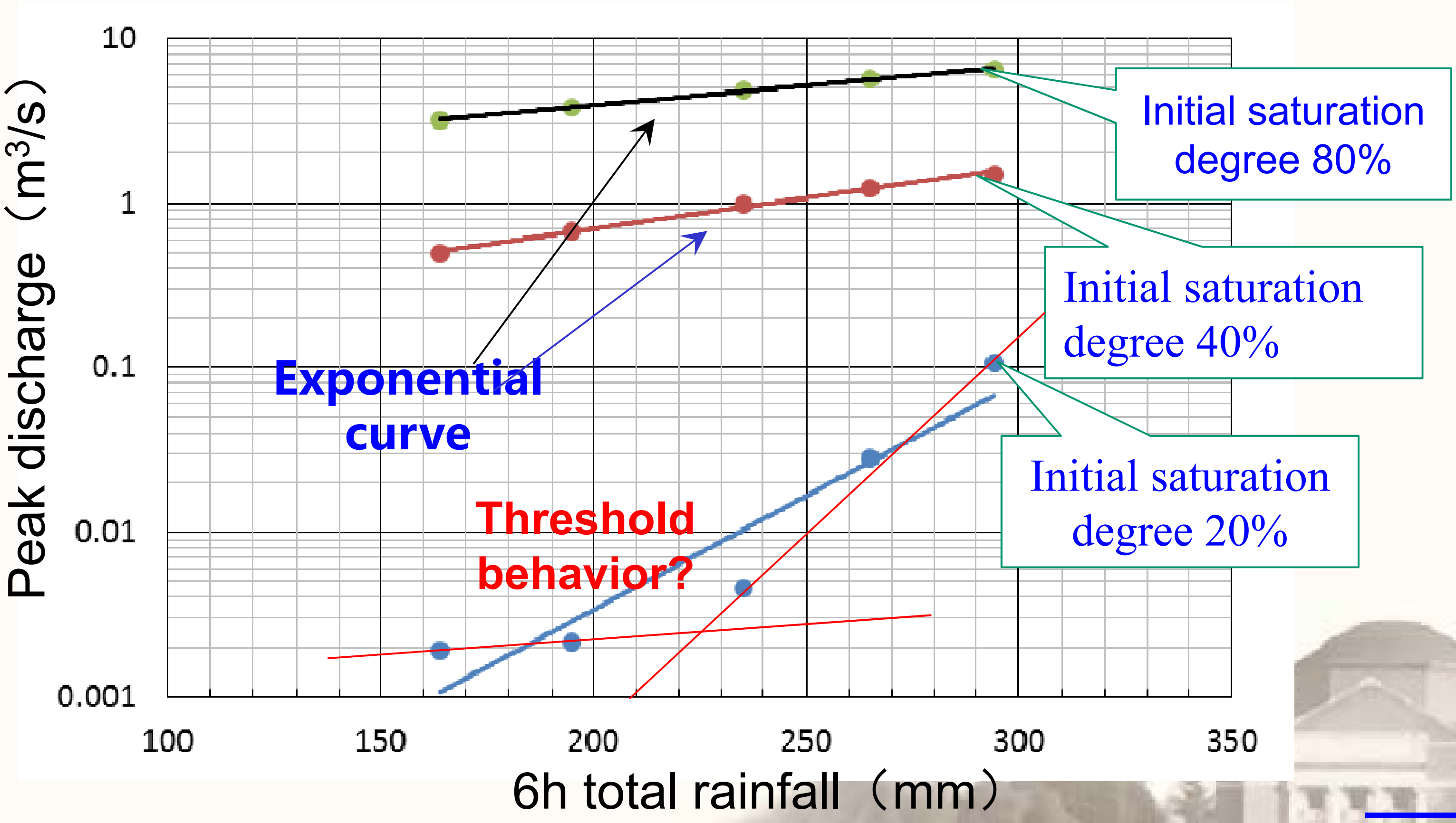


Case of Longxi River

Initial soil moisture significantly affects the peak discharge

(Jianpinggou, 6h rainstorm)

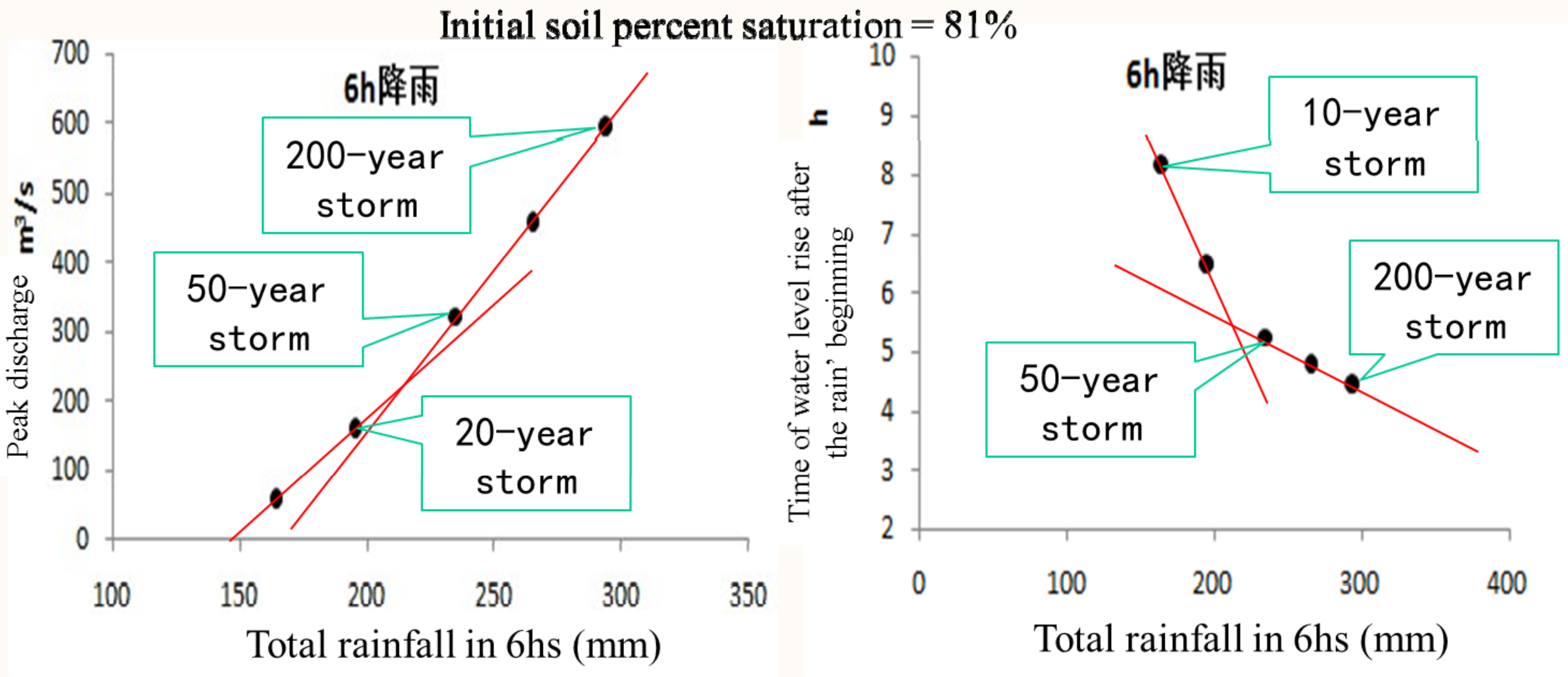
Soil percent saturation = 80% vs. percent saturation = 20%



Case of Longxi River

Peak discharge-total rainfall curve
Water level rising time-total rainfall curve

Threshold behavior at 50-year storm?



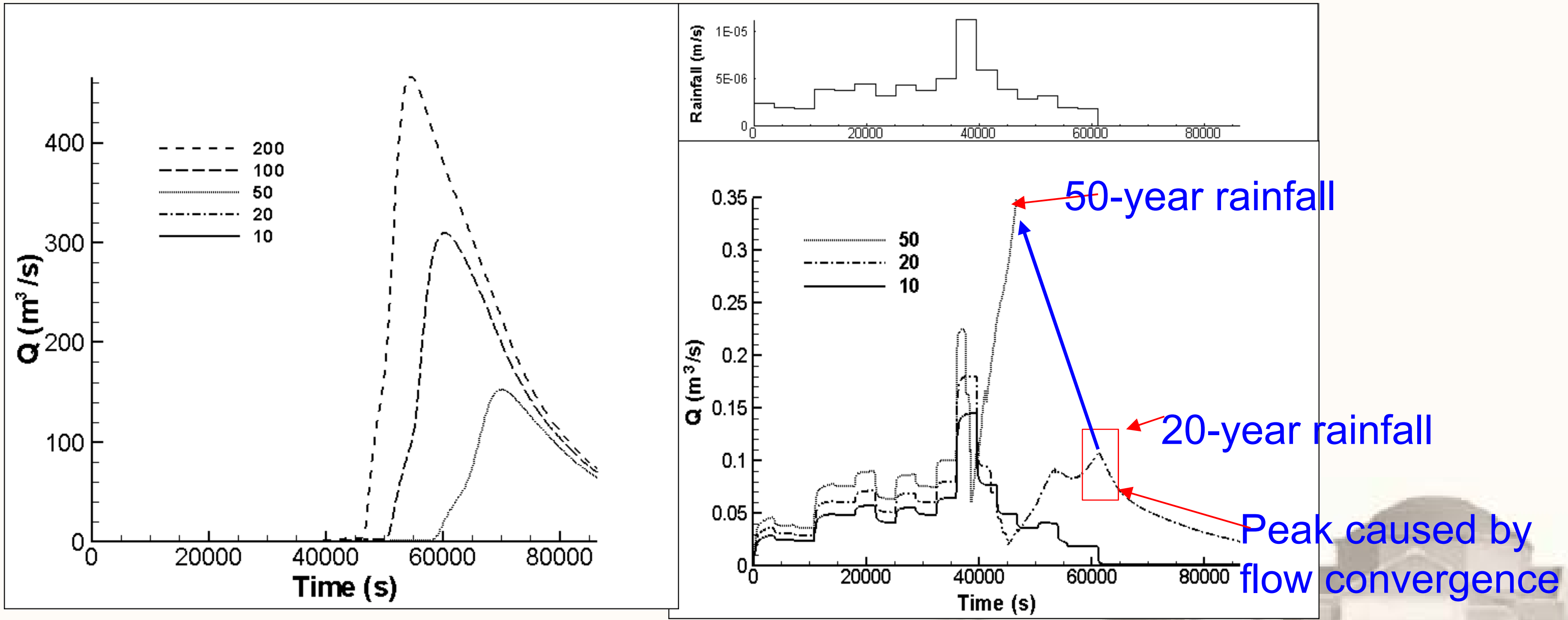
Case of Longxi River

Two peaks: hydrological response vs. flow convergence

Separate or merged peaks

Heavier rainfall → faster flow convergence → merged peaks

(around the 50-year rainfall) – explaining the threshold



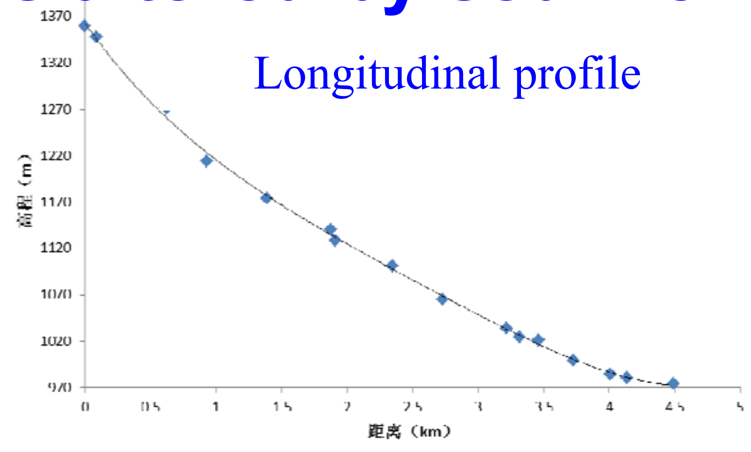
Nov 2011, Observed initial saturation degree 57%

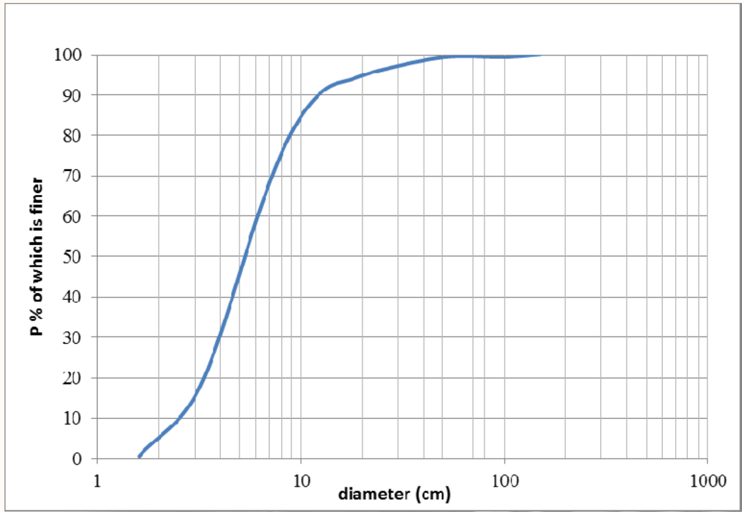
Case of Longxi River

Analysis of flood properties altered by sediment

- **Computational domain:**
  - ☆ Zhucao Valley to Nanyue Village, 4.4km
- **Cross section:**
  - ☆ Trapezoidal
  - ☆ Bed width: 12.0 m at inlet; 25.2 m at outlet.
- **Sediment size:** (pebble count method)

d_{90}: 0.1~0.5m; d_{50}: 0.05~0.2m





Analysis of flood properties altered by sediment

- **Proposed resistance formula (Zhang et al, 2012):**

$$1/n = 0.66Q^{0.14} g^{0.43} / (d_{90}{}^{0.52} J^{0.26})$$

- **Additional resistance from bedload transport** (Wang & Chien, 1985; Dietrich and Whiting, 1990; Matousek, 2013)

$$k_{sm} = 2.31\delta_b + k_s \qquad \delta_b = \frac{1.2 d_m (1-\cos\varphi)(\tau_b/\tau_c)}{1+0.2(\tau_b/\tau_c)}$$

Case of Longxi River

Analysis of flood properties altered by sediment

Scenarios of designed rainstorms:

Rainfall	Peak discharge
50-year	150 m^3/s
100-year	260 m^3/s
200-year	410 m^3/s

- ✓ **Before earthquake:** **fixed bed in computation**
- ✓ **After earthquake:** **movable bed covered with freely-erodible sediment**

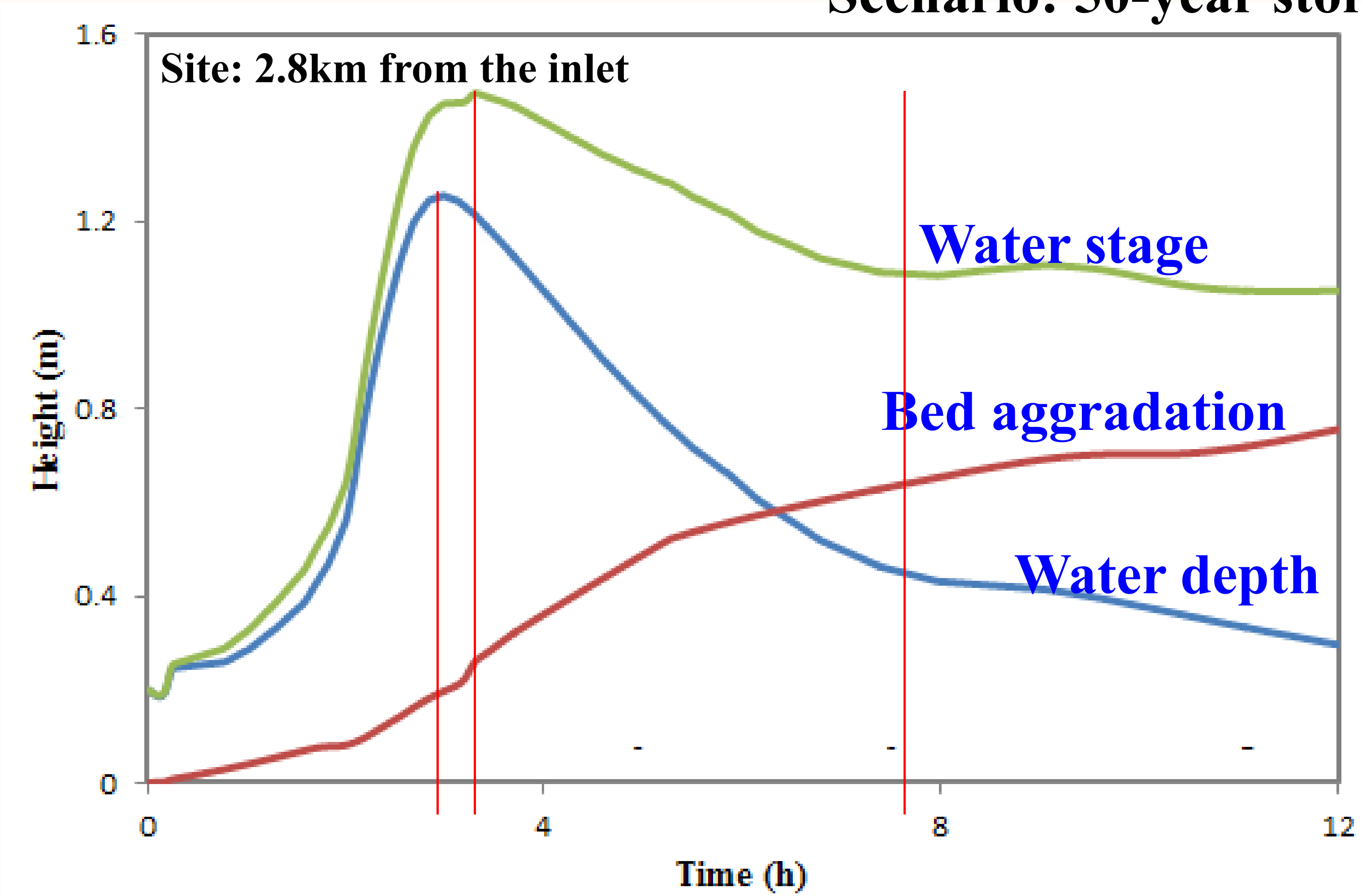
Analysis of flood properties altered by sediment

- Aug 18, 2012: a flood with peak discharge of 130 m^3/s at the inlet
- Field survey: flood stage at the steel bridge (3.8 km from the inlet) is 1.6 m.
- Simulation: flood stage at the same site is 1.80 m

Case of Longxi River

Analysis of flood properties altered by sediment

Scenario: 50-year storm

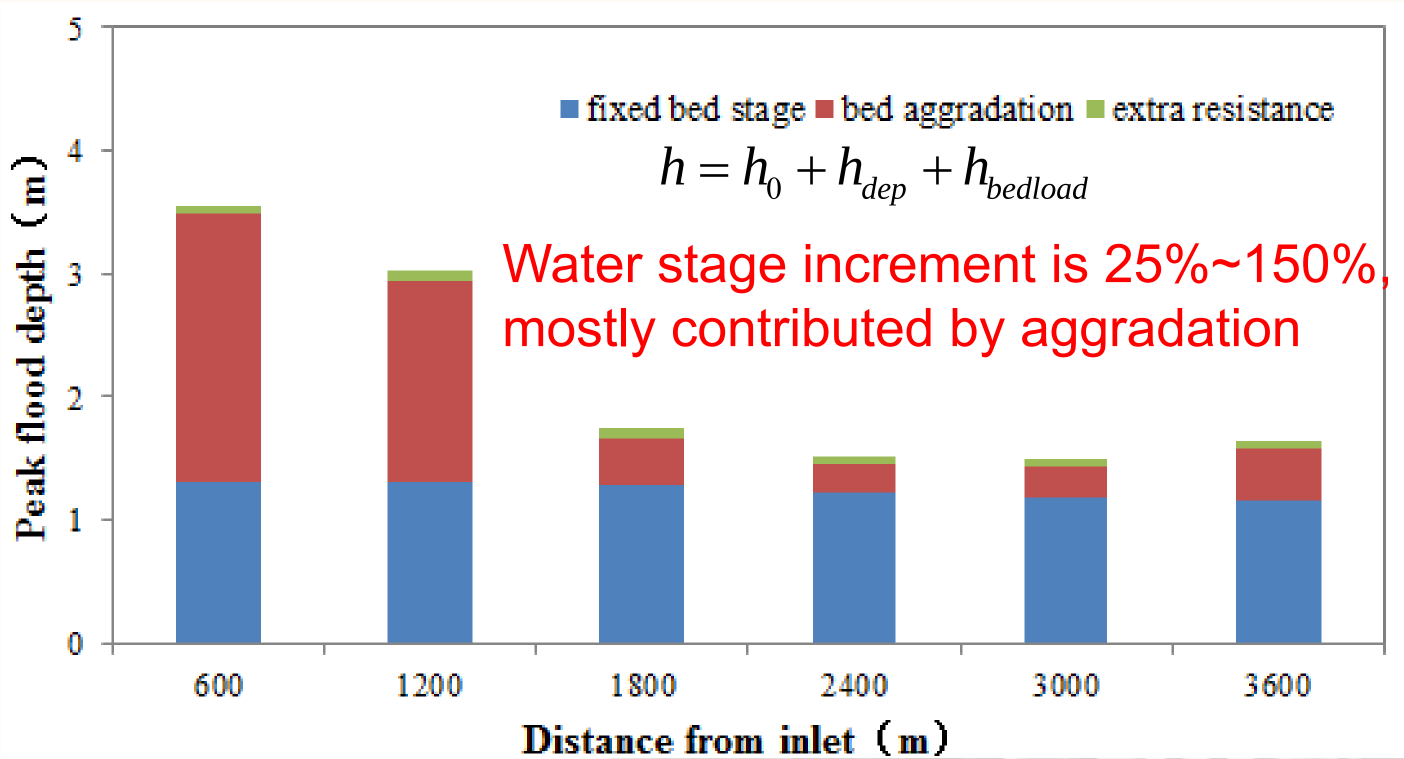


Case of Longxi River

Analysis of flood properties altered by sediment

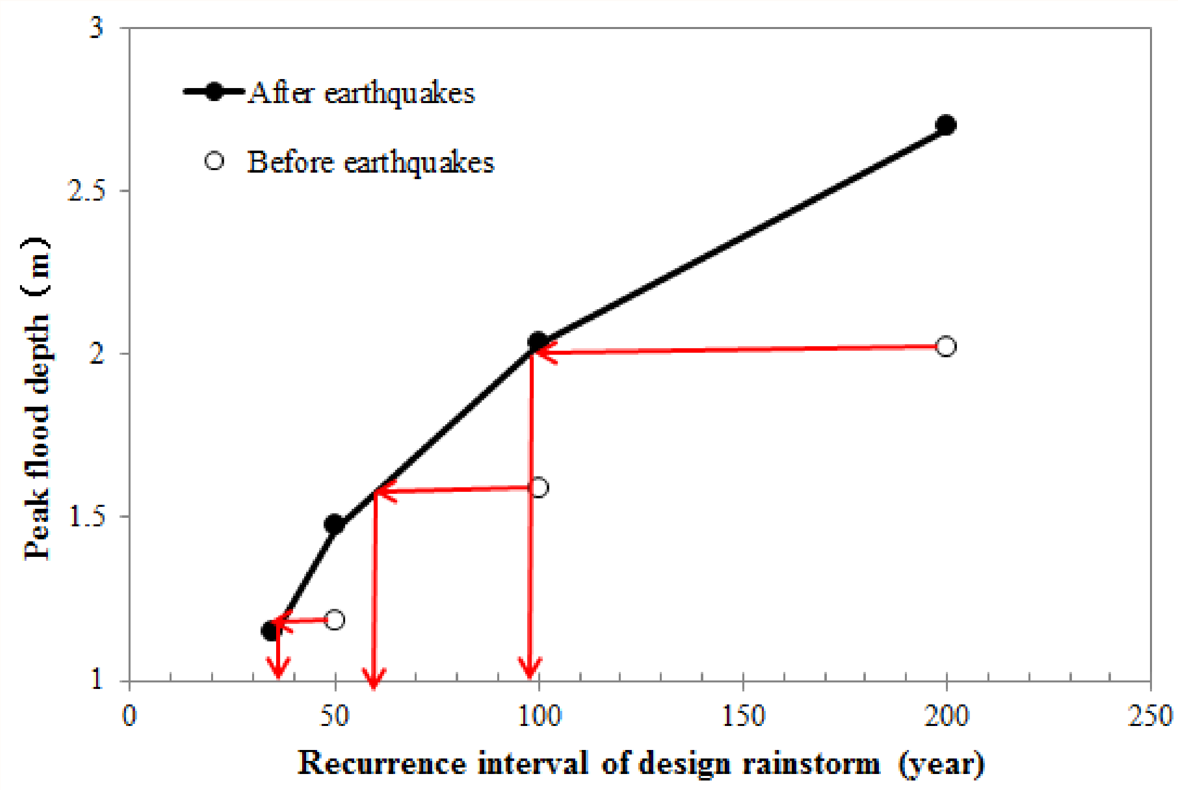
Before and after the earthquake (Scenario: 50-year rainfall)

- **Sediment deposit dominates**
- **Flood stage increment is larger in the upper reach**



Case of Longxi River

Analysis of flood properties altered by sediment



Landslide & debris flow

⬇

Loose solid material

⬇

Blocking of the channel

after	before
36 year	50 year
60 year	100 year
98 year	200 year

Flood stage increase due to deposit ➔

Decrease of flood disaster threshold

Outline

1. Overview of flash flood hazards
2. Modeling of flash flood
3. Exaggerated flood hazard
4. Toward future: ongoing efforts
5. Summary

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Ongoing efforts

Toward flood modeling and forecast in future

☆From small watershed to large river basins

☆From experts to common inhabitants

Facts:

Data for large-scale region

☆NWP data for forecast

☆Radar data for imminent forecast

☆Satellite data for history simulation

Model for large-scale region

☆ Distributed models

☆ HPC for hardware base

Use for community

☆ Web service for the public

Ongoing efforts

Data from numerical weather prediction (NWP)

The TIGGE data

- **THORPEX:**
  The Observing System Research and Predictability Experiment
- **TIGGE:**
  THORPEX Interactive Grand Global Ensemble

- **Participating agencies**
  e.g., CMA, CMC, CPTEC, ECMWF, NCEP, and UKMO

  The same temporal resolution (i.e., 6 hours)
  Different spatial resolutions (e.g., 9/16° for the CMA and 1° for the NCEP)

  The forecast lead time: 1-16 days

The GFS data……

Tsinghua University

Ongoing efforts

Satellite-derived rainfall datasets

The CMORPH

- **NOAA**
- **Morphing Technique**
- **Participating agencies**
  National Oceanic and Atmospheric Administration, Climate Prediction Center , e.g., SSM/I, AMSU-B, AMSR-E, TMI

Temporal resolution : 30 min
Spatial resolutions: 8 km
The downloadable time: about 4 hr after event
Satellite coverage：60 ° N ～ 60 ° S
Starting time：2003

The TRMM ……

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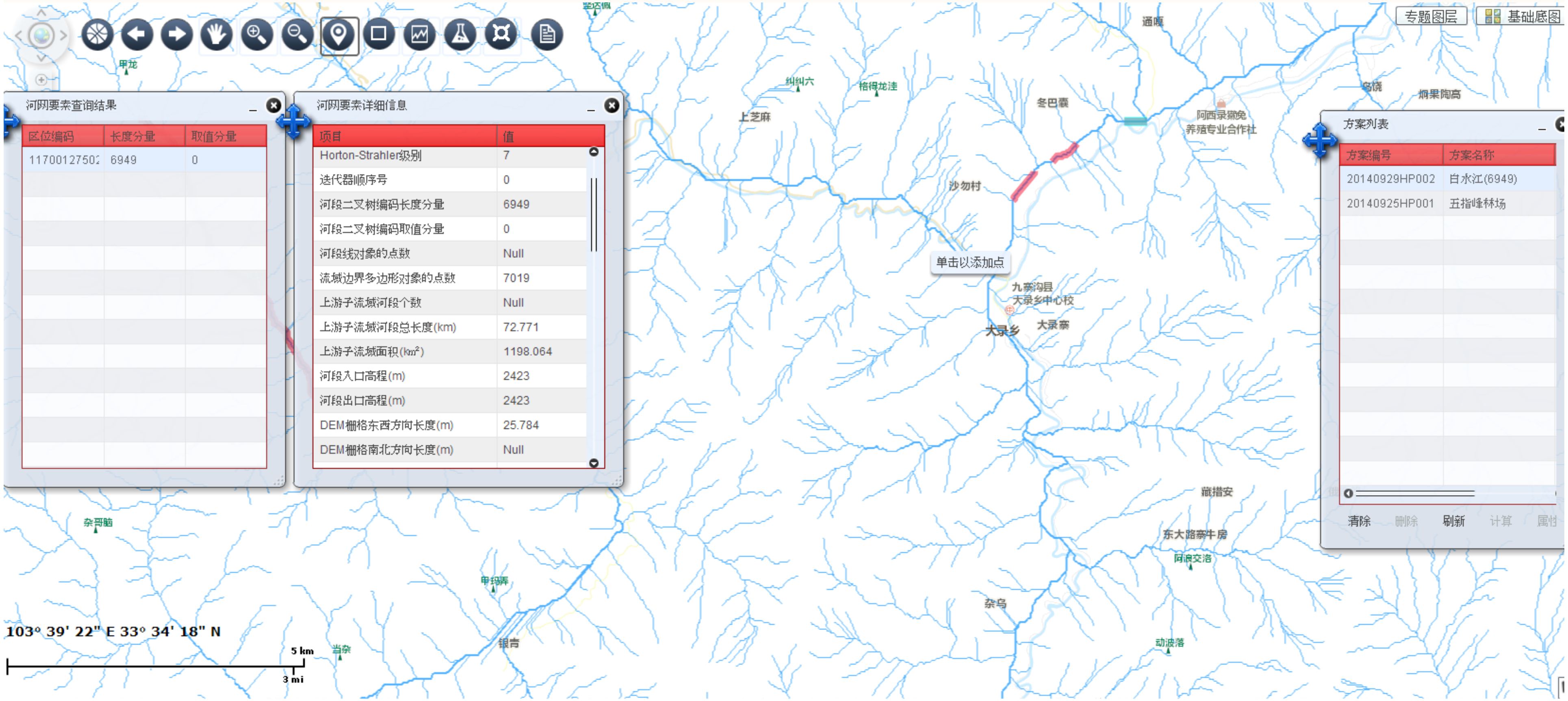
Ongoing efforts

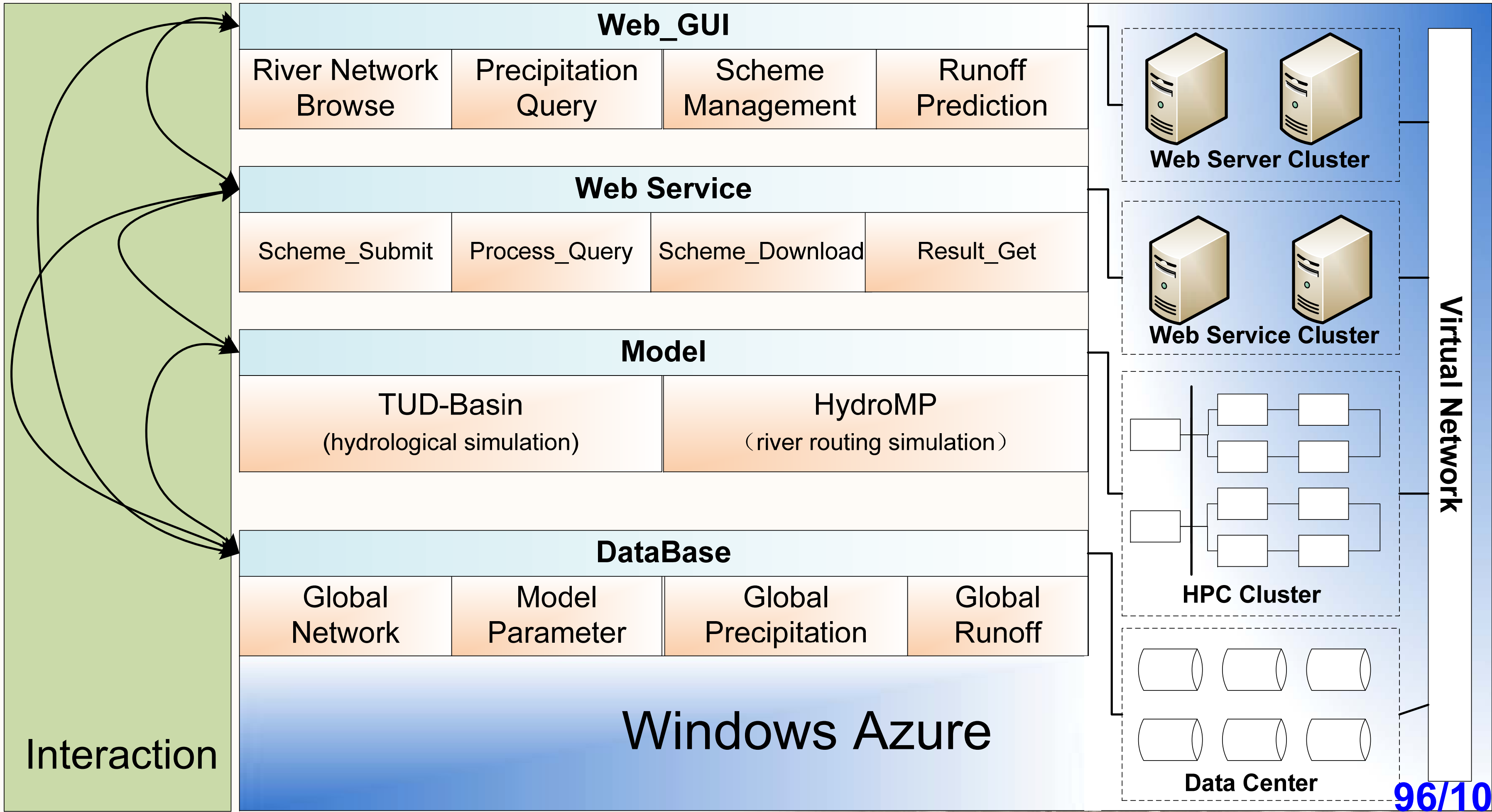
Global Drainage Network: Hydro30
High resolution river reaches with detailed information



Online: http://www.hydro30.org/

Ongoing efforts

Web service would be highly valuable for users to enhance the awareness of flood risk.



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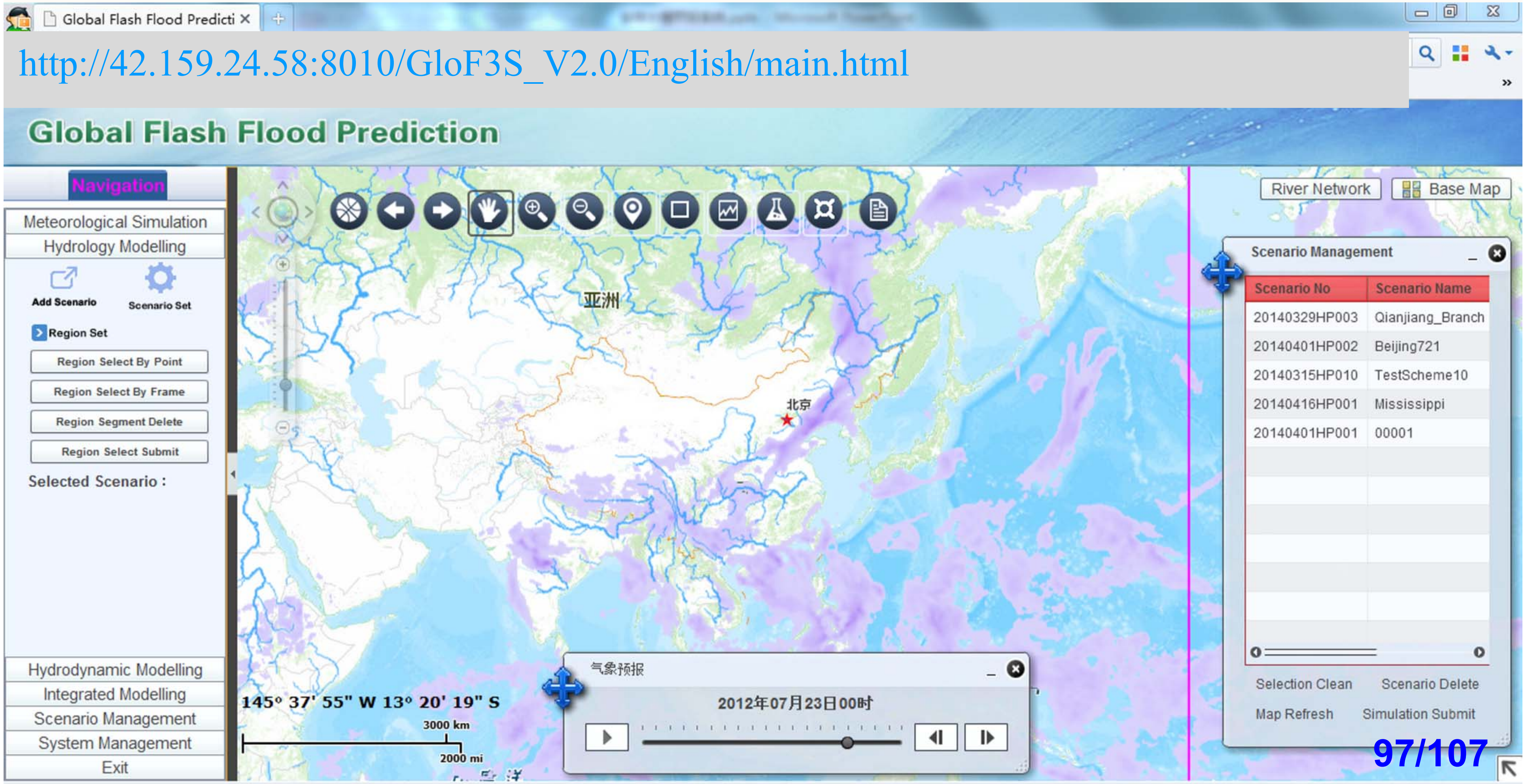
Ongoing efforts

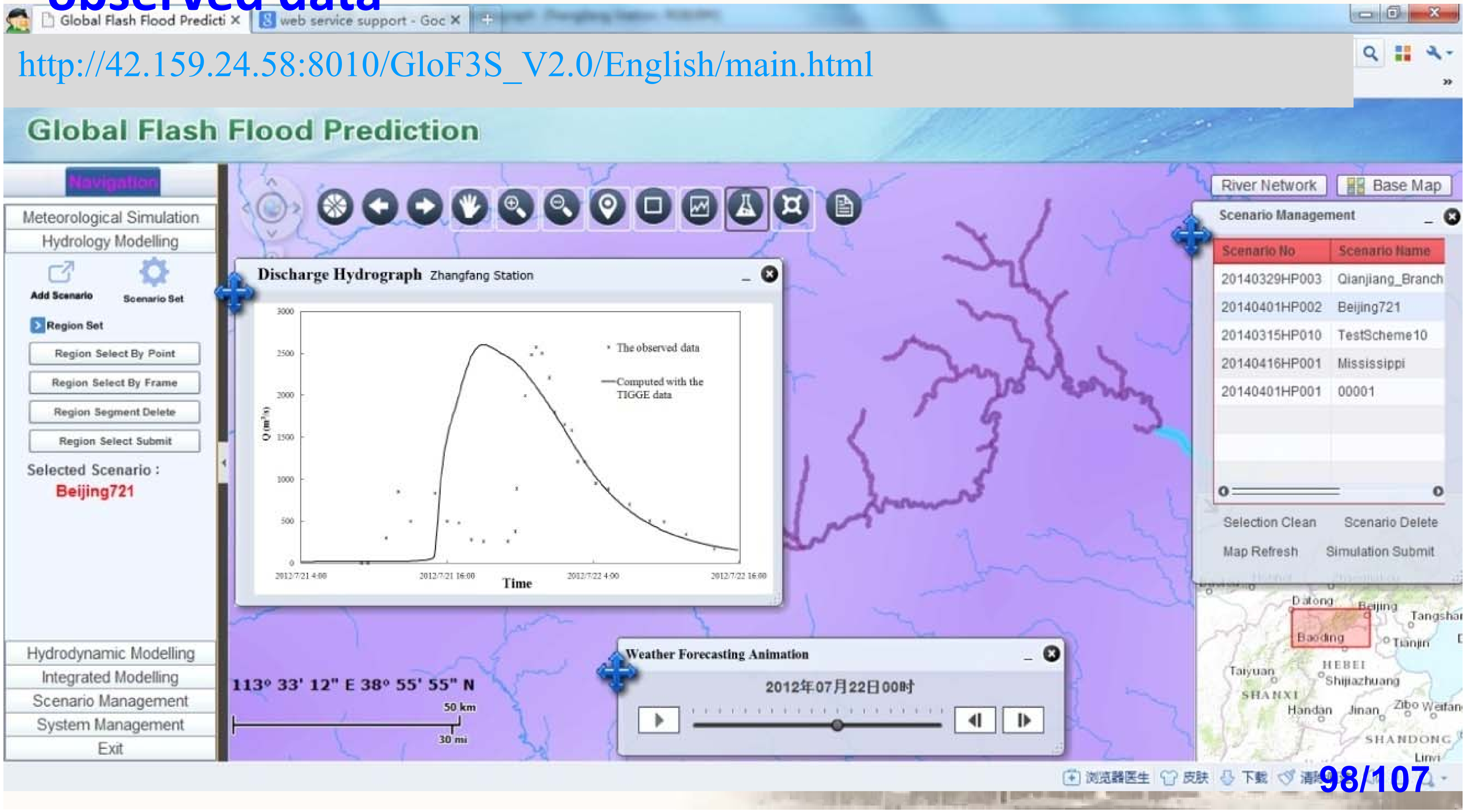
Submit the simulation case online
Case simulation based on the NWP data



Ongoing efforts

Based on the HPC system: Simulation results with observed data

http://42.159.24.58:8010/GloF3S_V2.0/English/main.html



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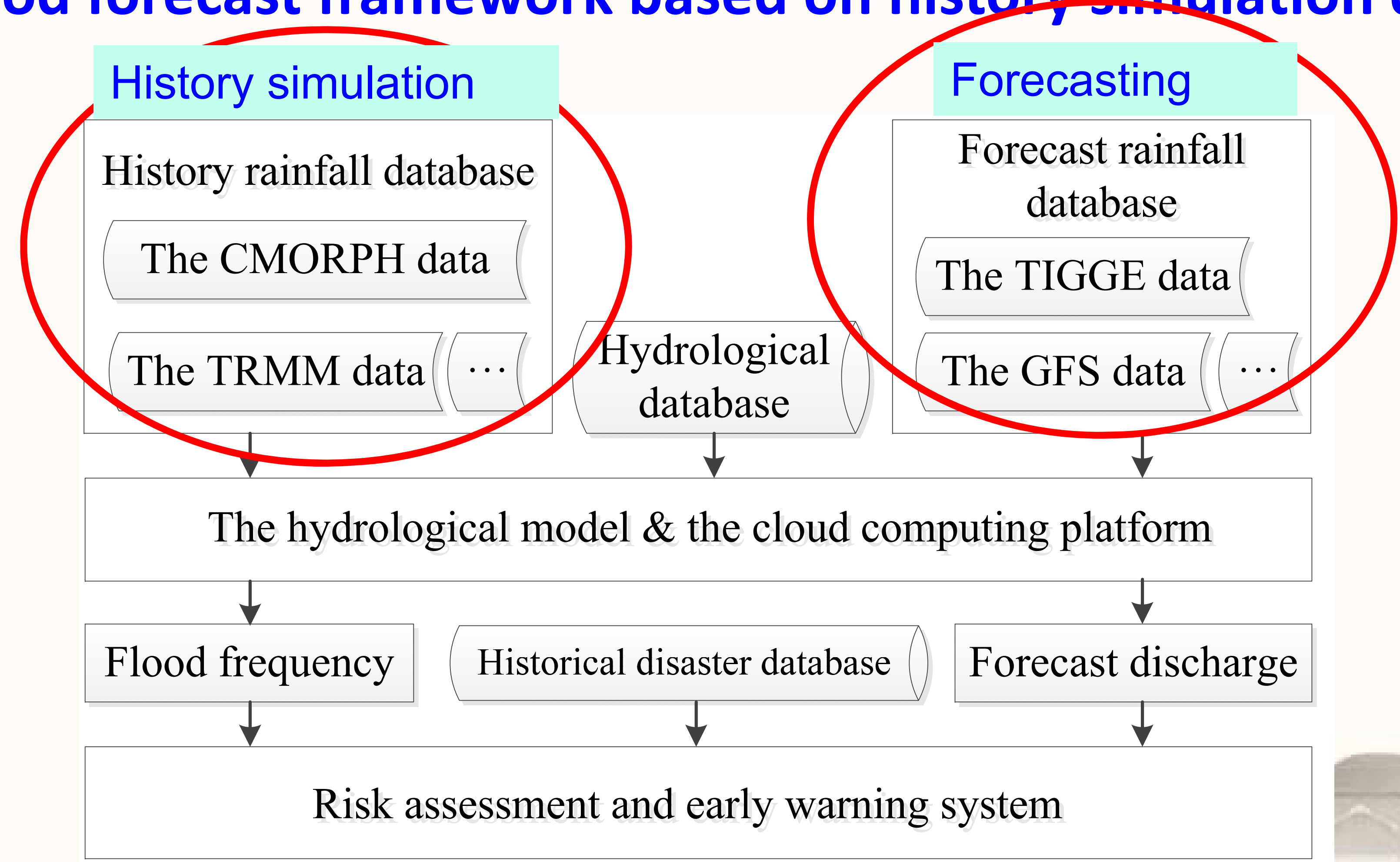
Ongoing efforts

Flood forecast framework based on history simulation data



References:
Shi HY, Li TJ, Liu RH, Chen J, Li JY, Zhang A, Wang GQ. 2015a. A service-oriented architecture for ensemble flood forecast from numerical weather prediction. Journal of Hydrology 527: 933-942.

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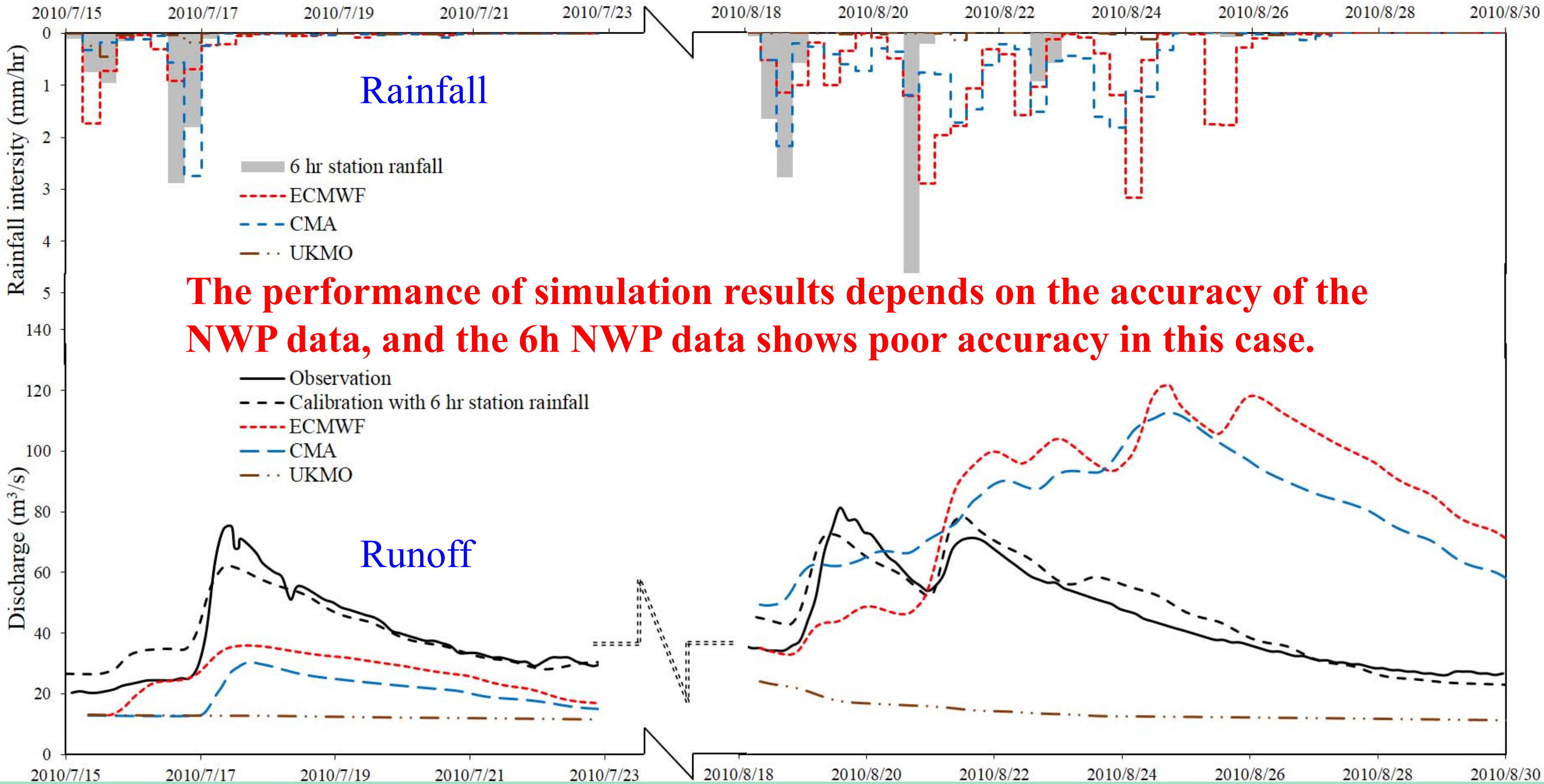
Ongoing efforts

Requirement of data resolution: Case in Southern China



The performance of simulation results depends on the accuracy of the NWP data, and the 6h NWP data shows poor accuracy in this case.

Basin： Baishuijiang river in Sichuan Province

Area： 1198 km^2 Period： 2010.7-8 NSE of calibration： 0.83

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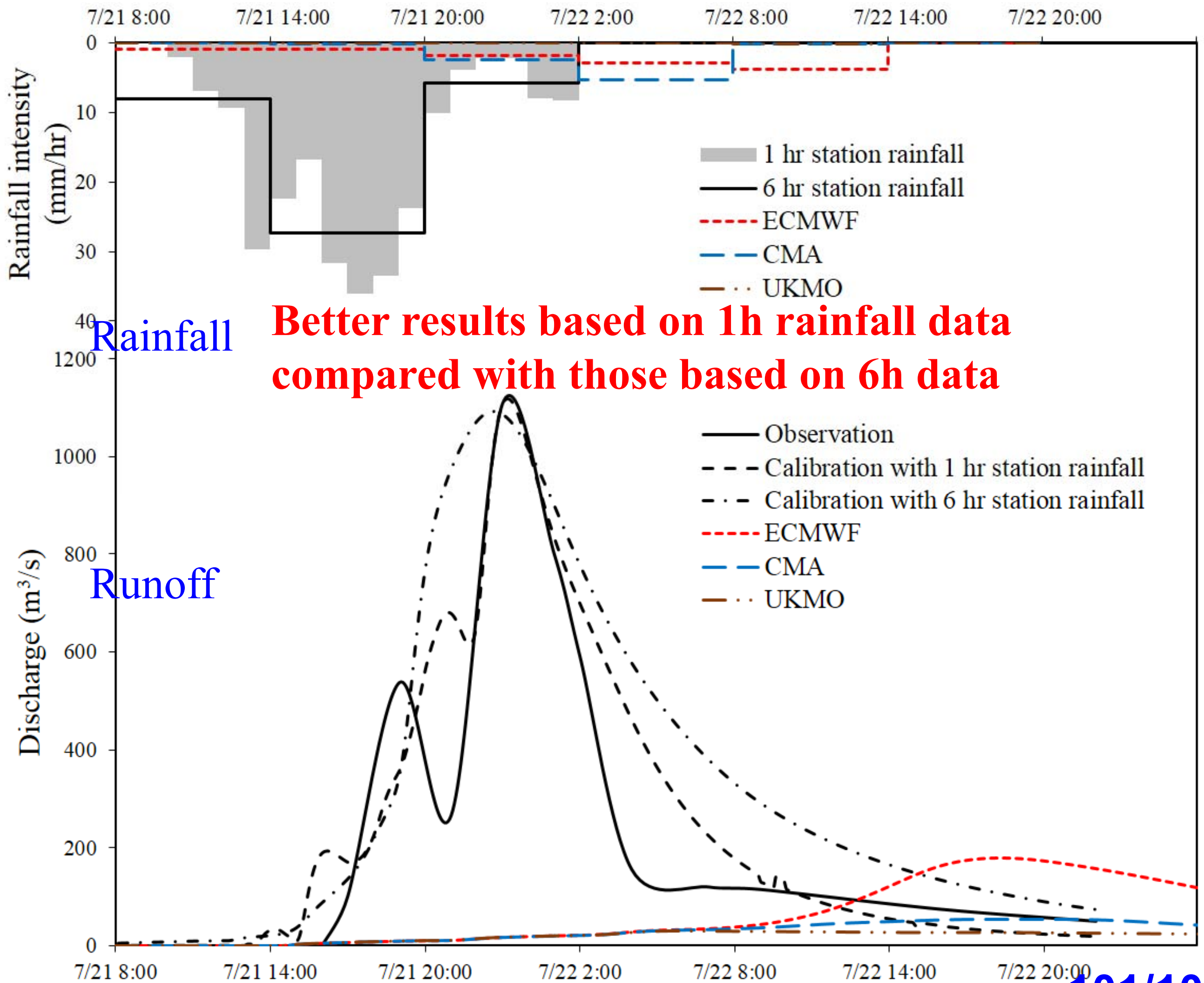
Ongoing efforts

Requirement of data resolution: Case in Northern China

Basin: Dashihe river (Tributary of Jumahe River) in Beijing
Area： 513 km^2
Period： 2012.7.21-22
NSE of calibration : 0.75



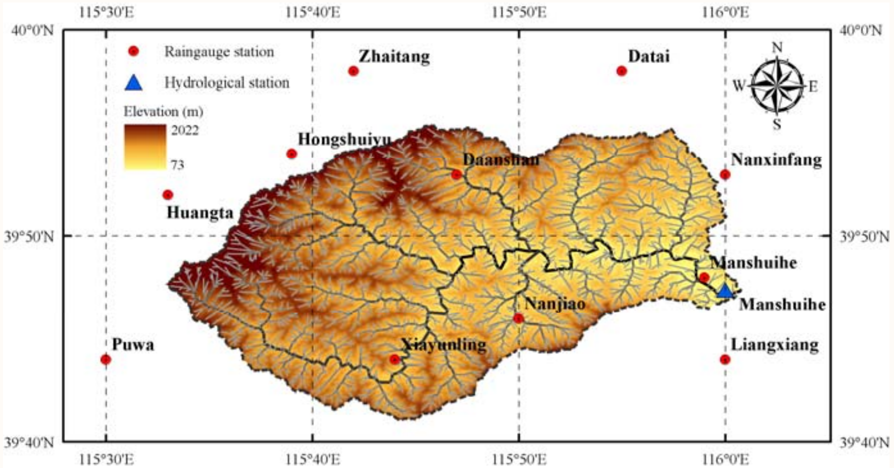
Ongoing efforts

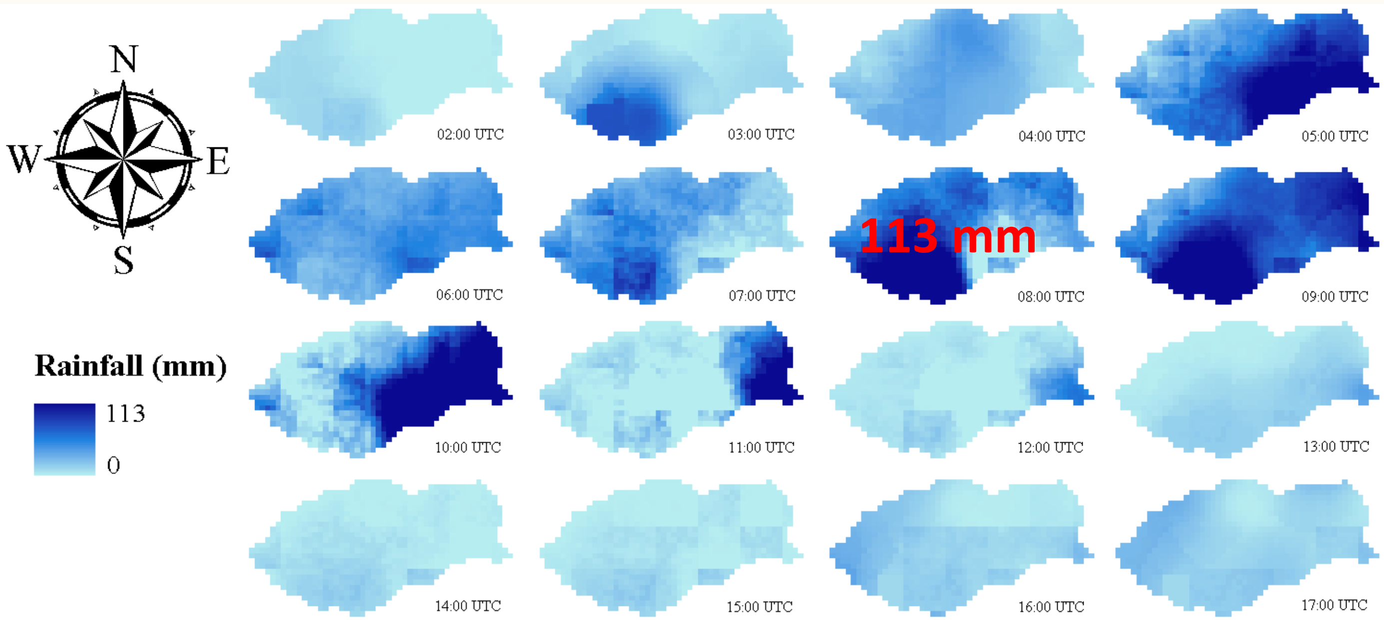
Merged data from rainfall gauges and satellite (CMORPH)

Study area and area

Dashihe River

- **11 rainfall stations**
- **1 hydrological station**
- **1 hour resolution merging process**

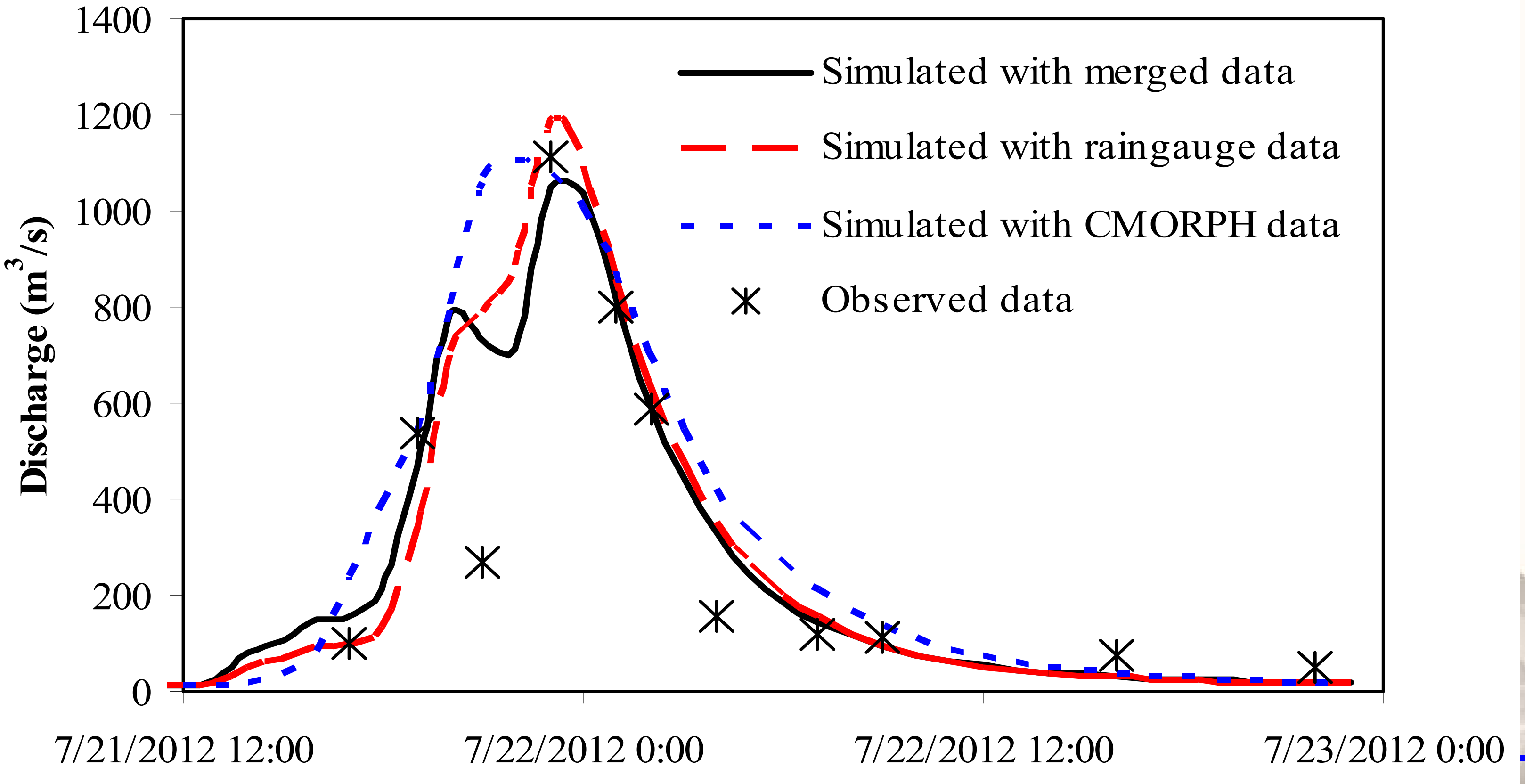




Ongoing efforts

Merged data from rainfall gauges and satellite (CMORPH)

The simulation results based on the merged data show the best performance: with two runoff peaks found in the observation



Summary

1. Overview of flash flood hazards
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Summary

- Flash flood hazard is affected by both the weather and underlying surface conditions. Its formation and developing into a disaster is very complicated.
- The Digital Watershed Model is a couple hydrological-hydraulic modeling system that can simulate the runoff and soil erosion for large drainage basins. It is featured through its physically-based processes and information techniques.
- Extreme flash flood differ from a regular flash flood through its peak discharge (the stage rising time) – total rainfall relationship. Both hydrological response and flow convergence contribute to its formation.

Summary

- Sediment transport and aggradation may significantly change the properties of flash flood. It can result in extreme flash flood hazard, in particular, in earthquake hit regions.
- Toward flash flood modeling and forecast in future, the extension from small watershed to large river basins and from experts to common inhabitants is emerging.

Thank you!

Questions and Discussions?