Debris Flow Pre-warning Threshold and its Comparison with Monitoring Data

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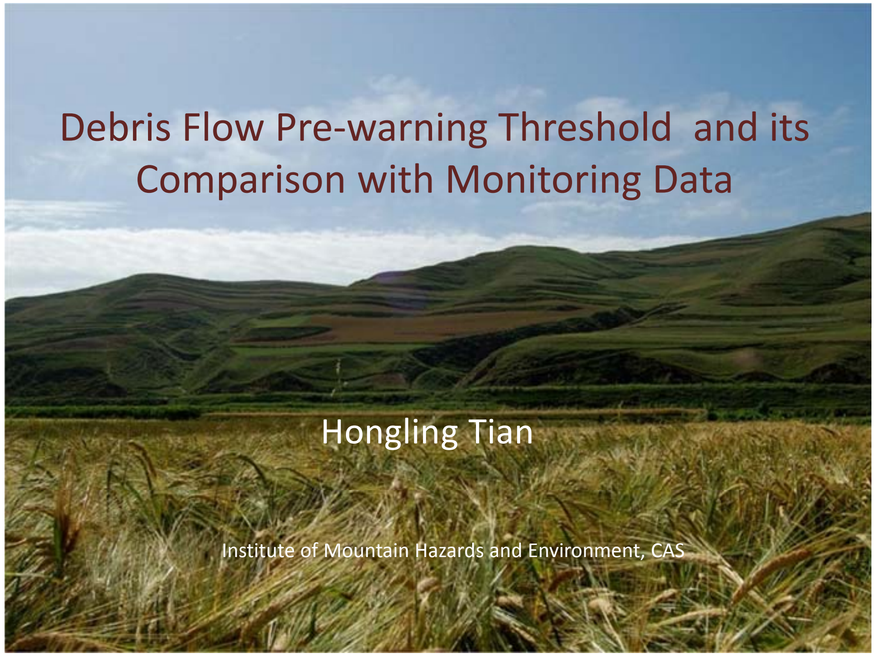
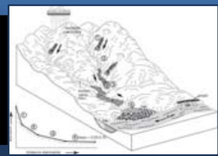
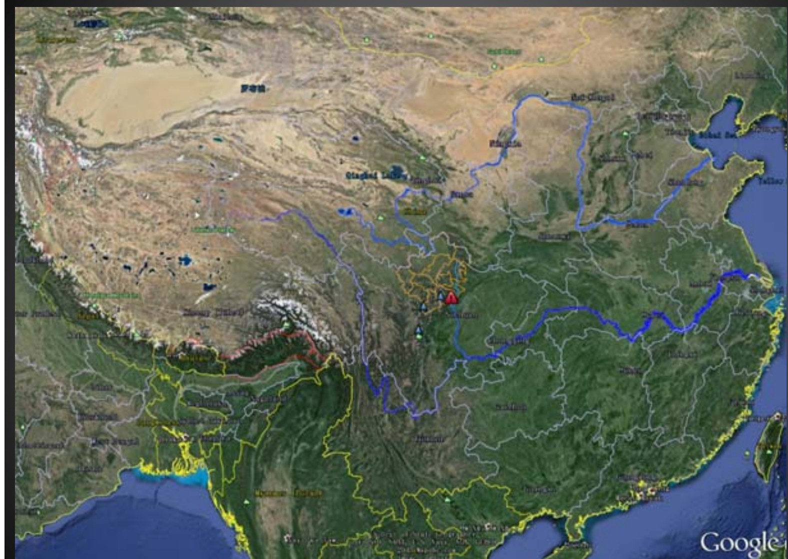


After-quake Debris Flow in Sichuan

Methodology for debris flow threshold



Camparison between the thresholds and monitoring data



Debris Flow Disasters in Sichuan, China

Aug.8 2010

Zhouqu

Aug.13 2010

Qingping

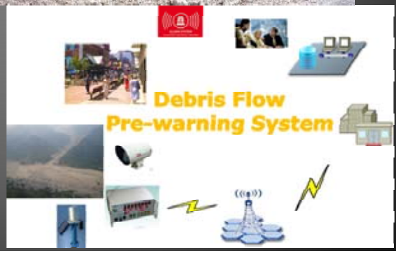
Location	Rain(mm)	Deposits($10^4 m^3$)	Dead
Zhouqu	96.3	144	1744
Qingping	227	310	12

(Provided by Zhang Jinshan)

Mitigations for Debris Flow

- Engineering works

- Pre-warning and alarm



When should the alarm be released?

Parameters
Rainfall Intense/Duration
Water Contents
Pore pressure
Water/Mud level
Soil pressure
Slope deformation
Ground Sound

Threshold for debris flow pre-warning

Methodology

- Statistics
- Geotechnical analyze
- Experiment

Background

Characteristics of after-quake debris flow

Chi-chi Earthquake, Taiwan

- Most deposits will turned into debris flow (Chen, et al. 2009a; Liu, et al. 2008)
- The hourly rain intensity and cumulative rainfall to induce debris flow is only 1/3 compare to those of before earthquake (Lin 2003).
- Debris flow occurred in much smaller catchment than before-earthquake

The rainfall threshold to triggering debris flow is obviously lower than it before earthquake until now (Chen 2008; Shieh, et al. 2009).

Characteristics of after-quake debris flow

Wenchuan earthquake (Cui, et al 2010)

- Many debris flow occurred in the gullies that were not debris flow gullies before earthquake;
- The critical rainfall decreased significantly;
- Debris flow occurred with high frequency and in group;
- The density increased about 10%-30%, the transitional or viscous flows occurred in many gullies of turbulent flows.
- The discharge increased by about 50% ~100%,

Methodology for Rainfall triggering landslides threshold

1) rainfall duration-intensity threshold methods,
2) Cumulative and Antecedent Rainfall methods (CR and AR),
3) Long cumulative rainfall methods,
4) Actual rainfall methods
5) Simplified hydrogeological or soil water balance methods
6) Rainfall-stability analysis coupled methods
7) Complete slope methods.

Polemio M. 2000

Empirical relationship between rainfall intensity, rainfall duration

Rainfall thresholds for the initiation of landslides

Critical precipitation threshold:

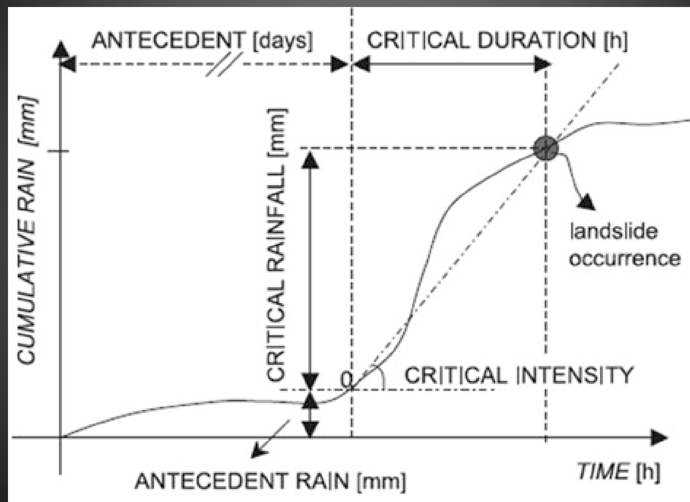
- Daily
- Hourly
- 10minutes

Intense / Duration Model

Equation	Researcher	Year	location
$I=14.82D^{-0.39}$	Nel Caine	1980	
$I=4.93D^{-0.50}$	Innes	1983	
$I=0.74D^{-0.56}$	Bacchini	2003	Dolomites, northeast Italy
$I=2.2D^{-0.44}$	Crostata	2008	
$I=6.61D^{-0.77}$	Coe	2008	

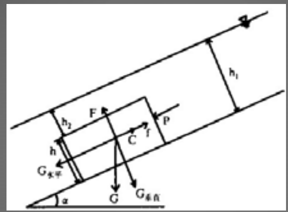
D: Rainfall Duration (h)
I: Rainfall Intense (mm/h)

Definition of rainfall parameters



(Francesco Castelli, 2013)

Initiation condition



Bai 2006

Takahashi 1991 $$\tan\theta \geq \frac{c(\sigma-\rho)}{c(\sigma-\rho)+\rho\left(1+\frac{1+h_0}{d}\right)} \times \tan\varphi$$

Iverson 1997 $$\tau = (\sigma-\rho)\tan\varphi + c$$

Possible factors influencing debris flow initiation

- Topography, Angle>15° (Takahashi, 1991)
- Material parameters
- State of stress
- Water

- Slope gradient
- Water regime
- Particle size distribution

Cui, 1993

Soil penetrability play an important role in debris flow initiation

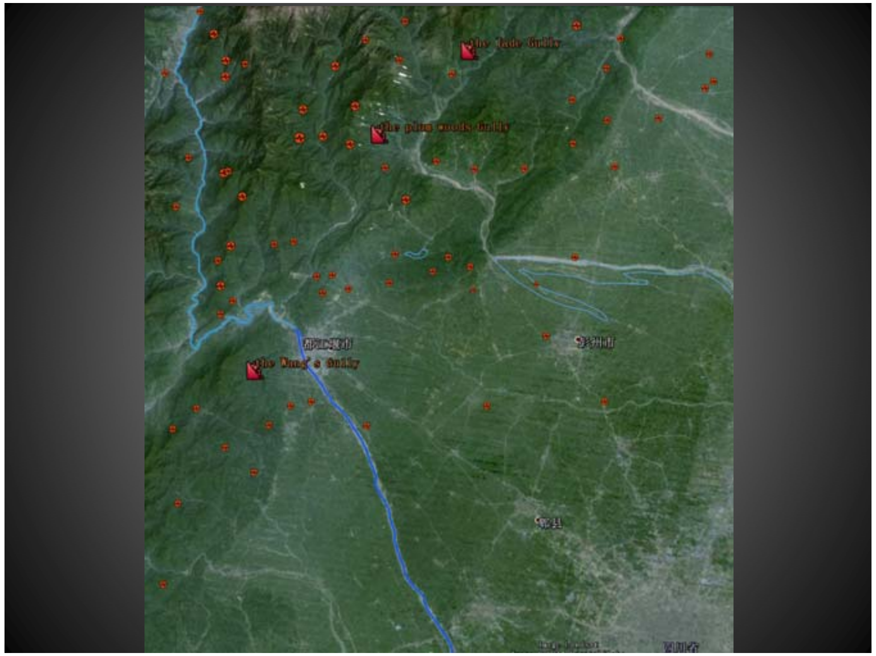
G Klubertanz, 2009

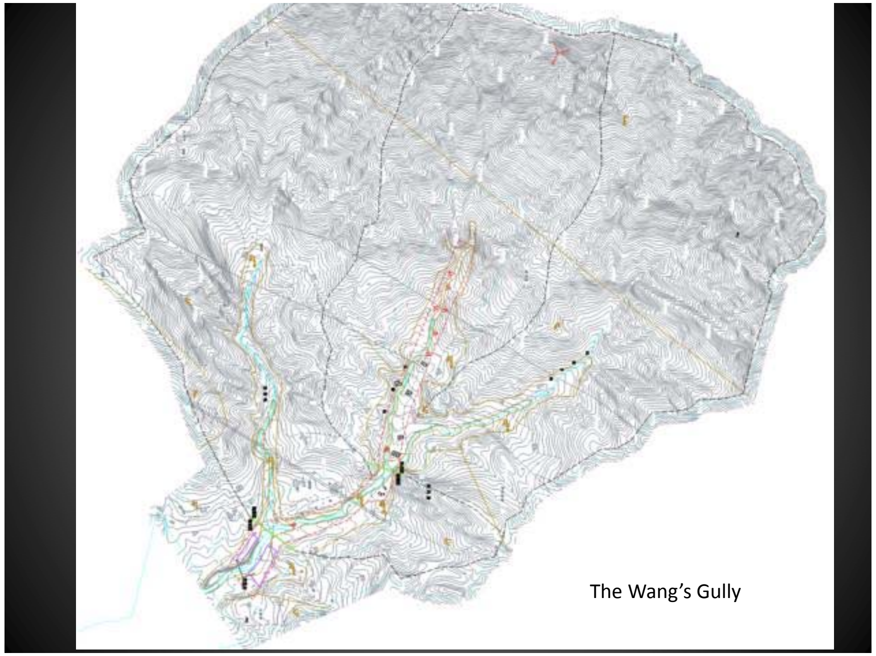
Mechanical model

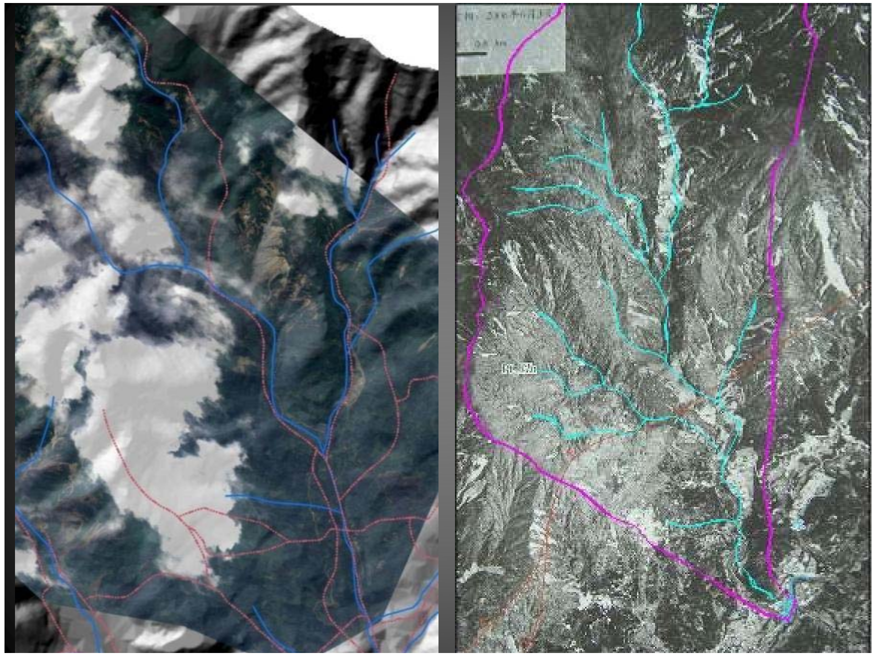
- Unsaturated soil mechanic model
- Hydrologic and hydro-dynamic model
- Distributed model

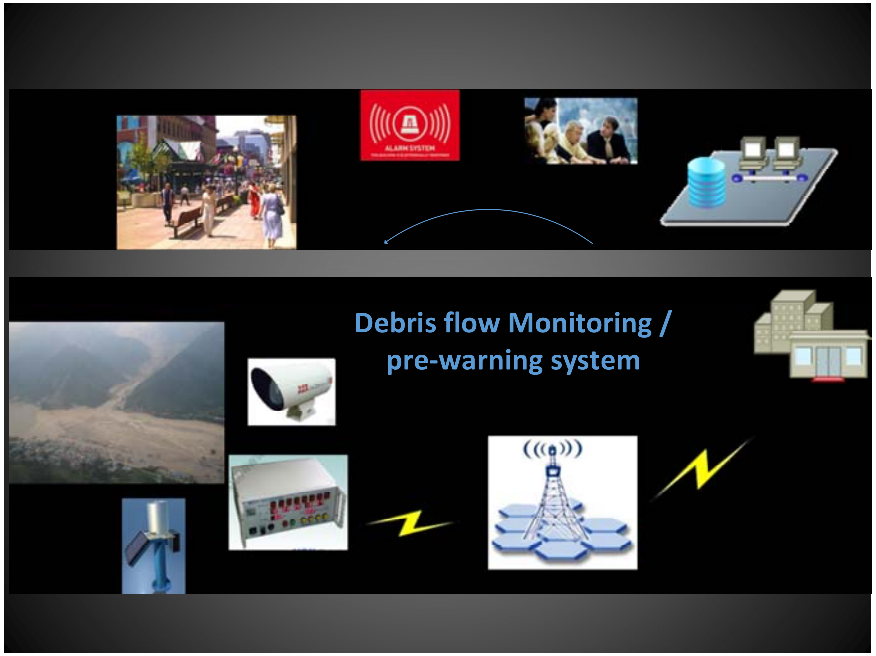
Threshold for debris flow pre-warning in Wenchuan earthquake struck area

- Brief introduction to monitoring system
- Thresholds for debris flow pre-warning
- Compare with Monitoring data

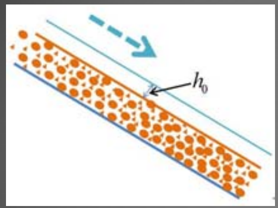


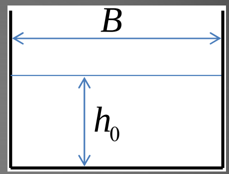

The Wang's Gully




ALARM SYSTEM
Debris flow Monitoring /
pre-warning system

Dr. Jiang's calculation





critical rainfall threshold $P_{ac} = P_b + P_c$

P_b: antecedent water contents
P_c: 1 hour cumulative rainfall

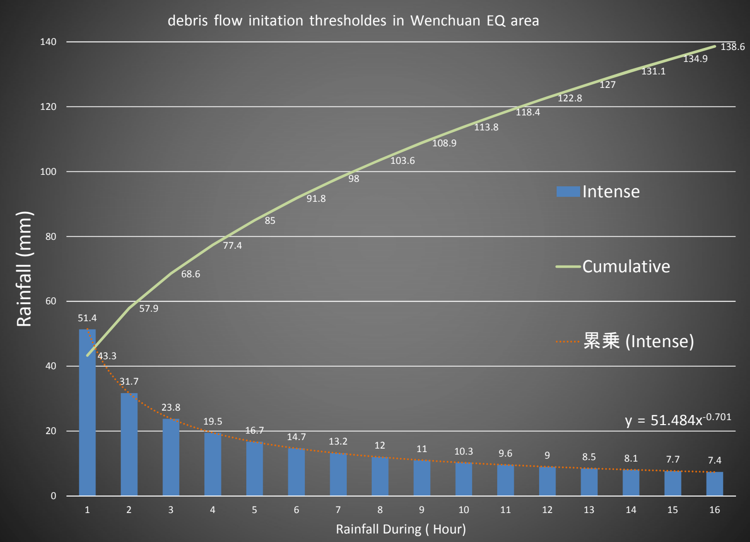
STORED-FULL RUNOFF $H = P_c - (I_m - P_b)$

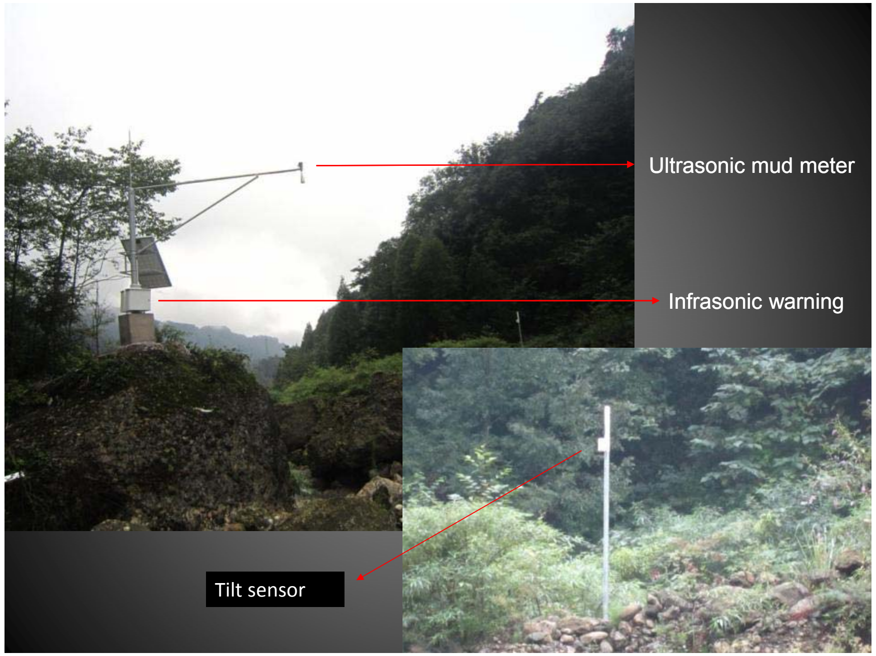
critical water depth $h_0 = \left[\frac{C_*(\rho_s - \rho_w)\tan\varphi}{\rho_w \tan\theta} - \frac{C_*(\rho_s - \rho_w)}{\rho_w} - 1 \right] d_m$

Experiment (Jiang & Meng)

Thresholds (mm)

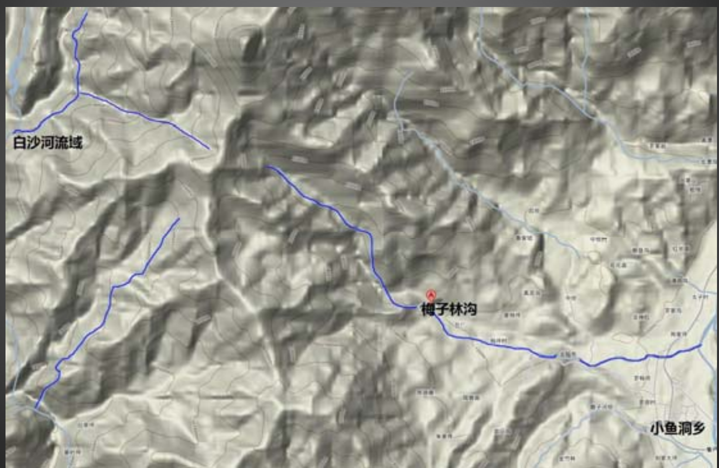
Name in Kanji	Gully name		Calculation	Experiment	Statistical	threshold
王家沟	Wang's		90	143	110	90
梅子林沟	Plum woods		96	94	87	87
玉石沟	Jade	main	82	89		82
		branch	80	221.5		80

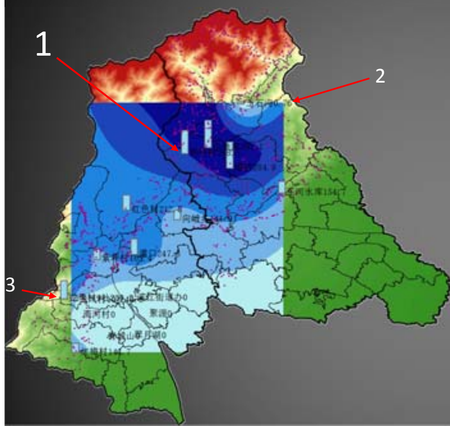




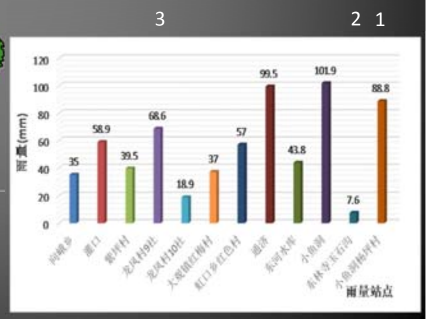
Comparison to Monitoring data

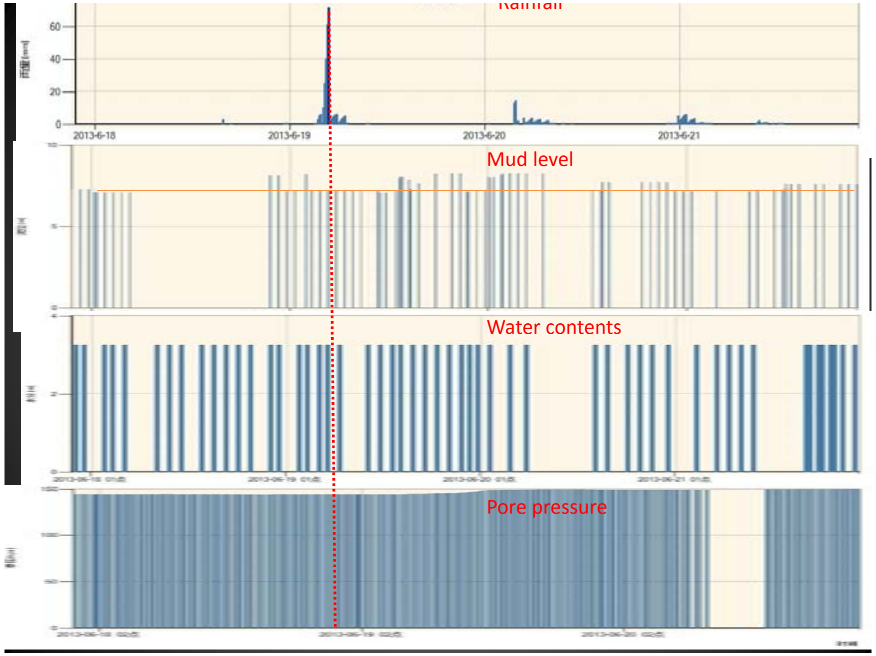
1. June 19, 2013, the Plum woods Gully



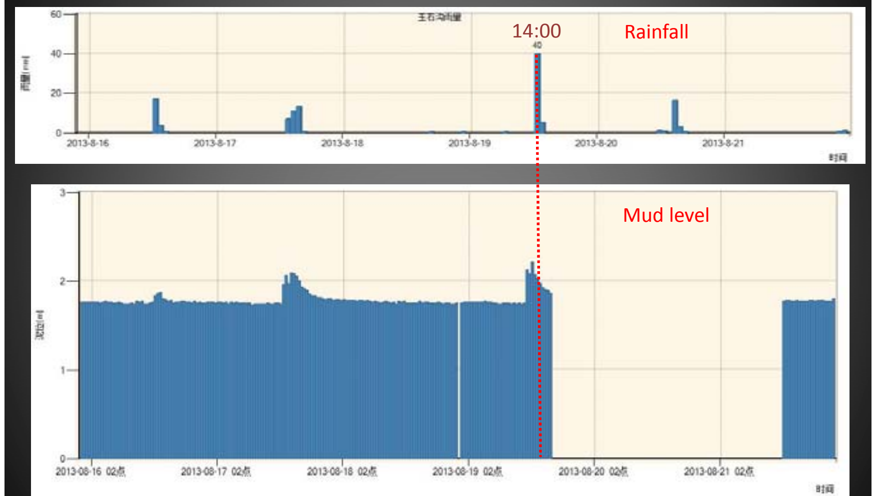


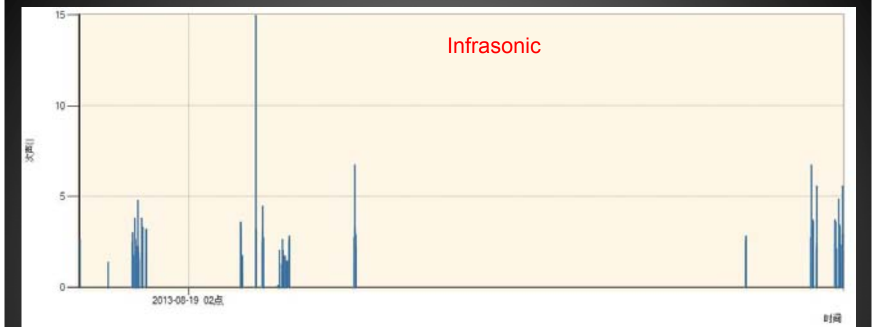
June 19, 2013

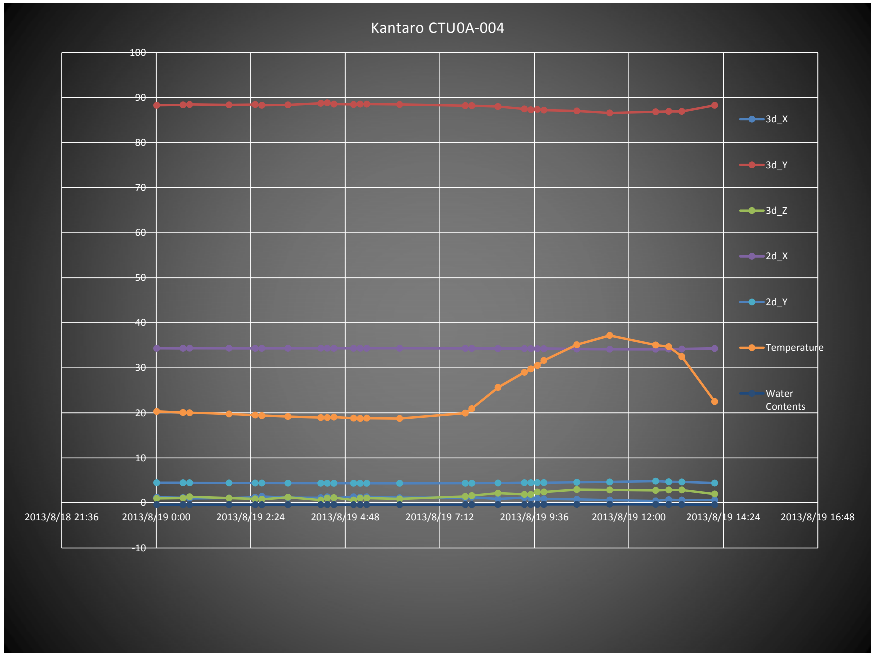




2. Aug 19, The Jade gully



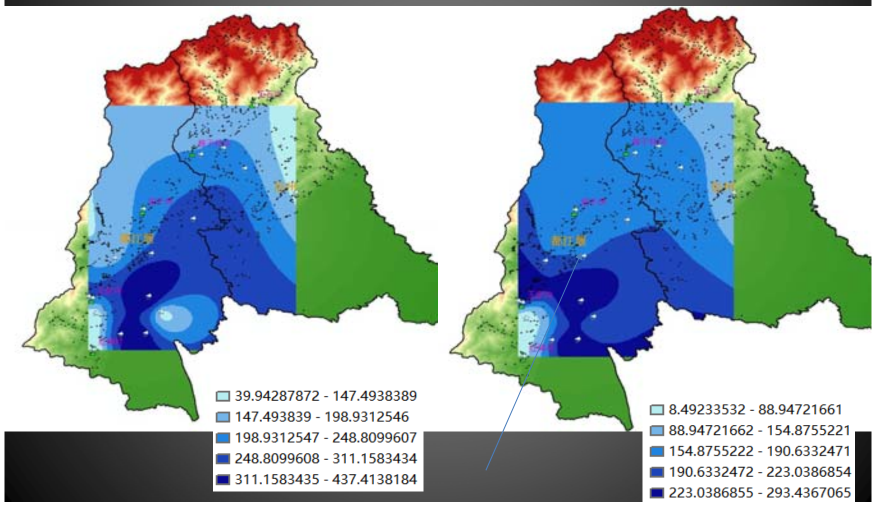




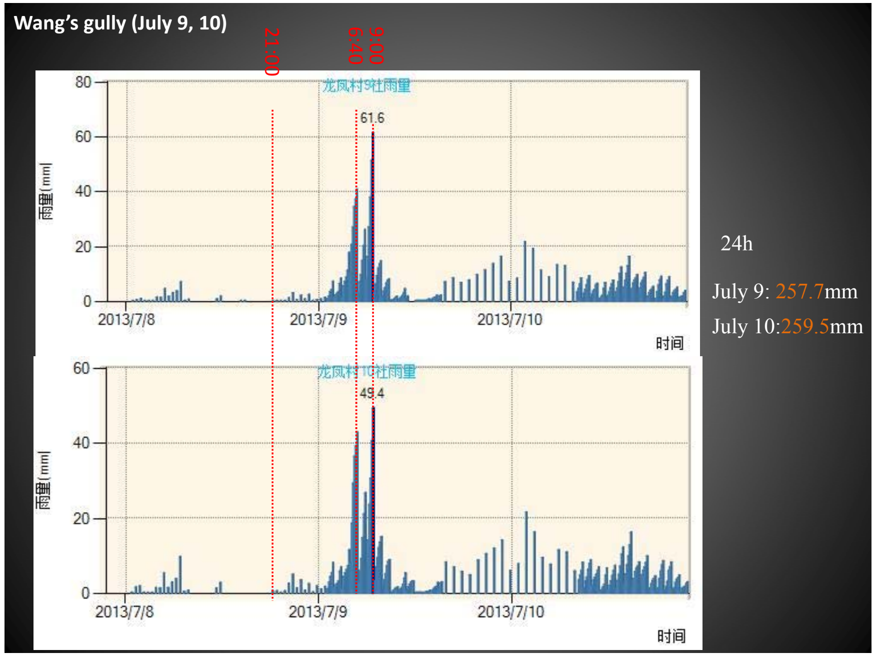
Factor	Time	Value	Variation	note
Rainfall	14:00	40mm	40mm	
Mud level（bridge）	13:03	-2.77m		normal
	14:33	-1.87m	0.9m	Max
	17:33	-2.62m	-0.75m	normal
Mud level（branch）	12:46	1.75m		normal
	14:16	2.21m	0.46m	max
	17:46	1.86m	-0.35m	normal
Infrasonic	16:31	6.74		Much noise
	16:38	5.57		

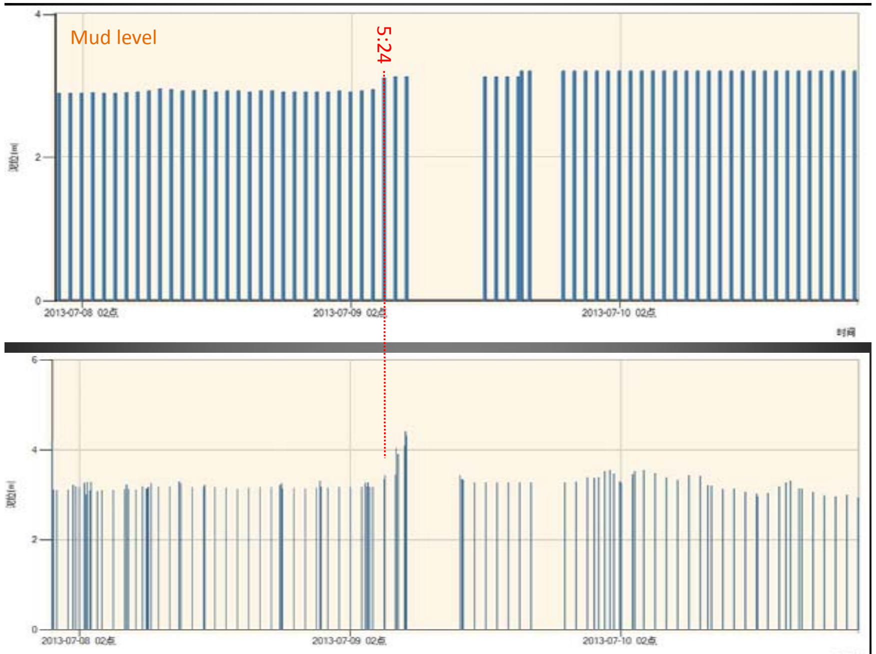
July 9

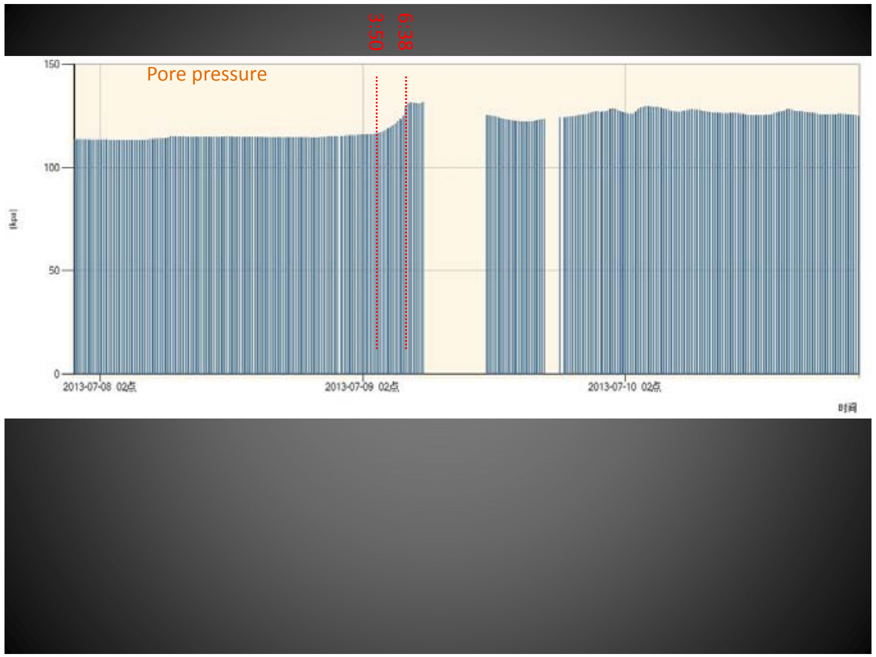
July 10

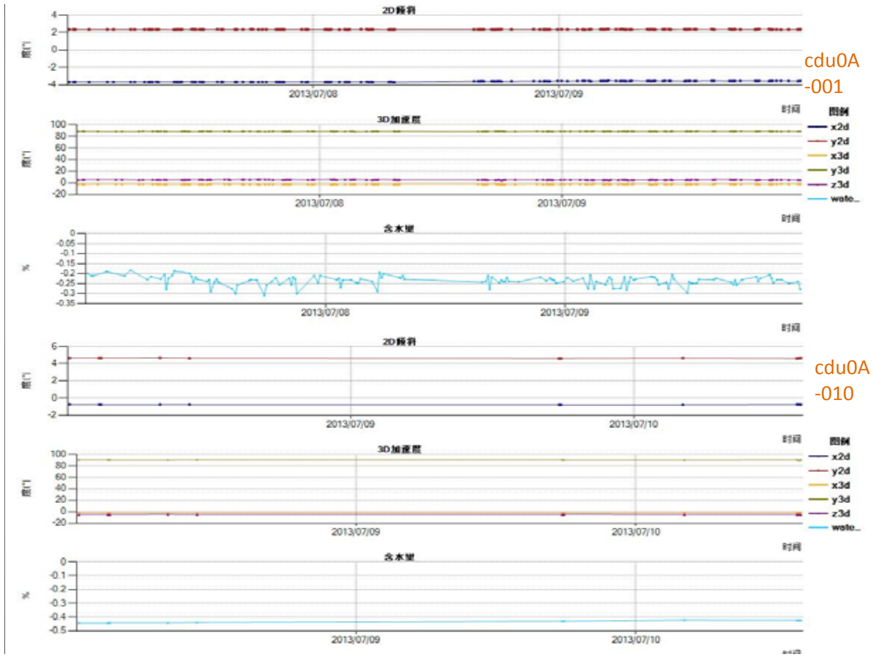


Landslide in Zhongxing

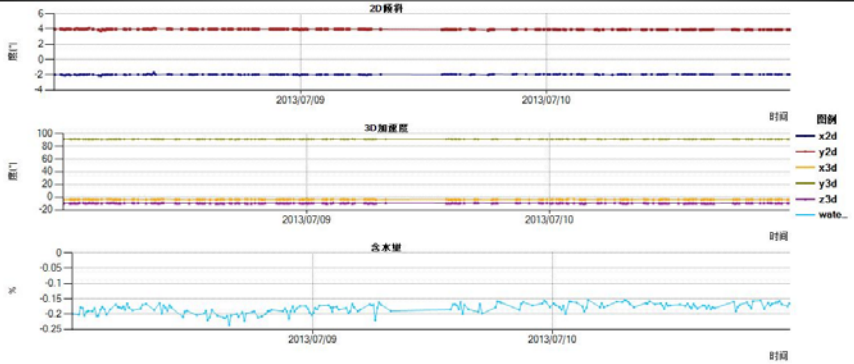

Wang's gully (July 9, 10)
21:00
6:40
9:00
龙凤村9社雨量
61.6
雨量(mm)
2013/7/8
2013/7/9
2013/7/10
时间
龙凤村10社雨量
49.4
雨量(mm)
2013/7/8
2013/7/9
2013/7/10
时间
24h
July 9: 257.7mm
July 10:259.5mm


Mud level
5:24
2013-07-08 02点
2013-07-09 02点
2013-07-10 02点
2013-07-08 02点
2013-07-09 02点
2013-07-10 02点


3:50
6:38
Pore pressure
2013-07-08 02点
2013-07-09 02点
2013-07-10 02点


cdu0A
-001
2013/07/08
2013/07/09
x2d
y2d
x3d
y3d
z3d
cdu0A
-010
2013/07/09
2013/07/10

cdu0A-012



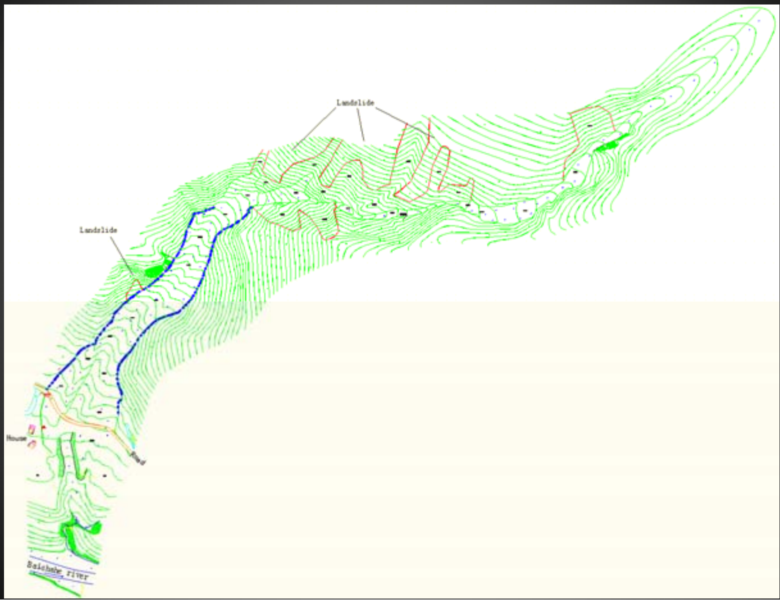
Discussion

1. (Earthquake) Debris flow thresholds exist? If exist, do they change with time ?
2. Rainfall is most important in debris flow, how to make a comprehensive thresholds.
3. How to predict a debris flow? Not observe it occurs

Future plan and Arrangement

- May, 2014 Monitoring system install in Yindongzi gully and Gangou gully
- Setup new monitoring systems in the near places
- Research in thresholds / method for debris flow pre-warning

Yindongzi gully, Hongkou



Gangou gully