



云南东川泥石流国家野外科学观测研究站

State Field Observation and Research Station of Debris Flow in Dongchuan, Yunnan

中国科学院东川泥石流观测研究站

Dongchuan Debris Flow Observation and Research Station, Chinese Academy of Sciences

Long-term monitoring on debris-flow field at Jiangjia Ravine, China and digital data management

Dongri SONG

Dongchuan Debris Flow Observation and Research Station (DDFORS),
Chinese Academy of Sciences

May 30th, 2024

Content

- 1 Dongchuan Debris Flow Observation and Research Station (DDFORS)**
- 2 Debris-flow observation at DDFORS**
- 3 Key findings based on the observational data**
- 4 Digital data management**



Landslide and debris-flow hazards in China

More than $6.4 \times 10^6 \text{ km}^2$ of the territory consists of complex, tectonically-active terrain with a monsoon climate.

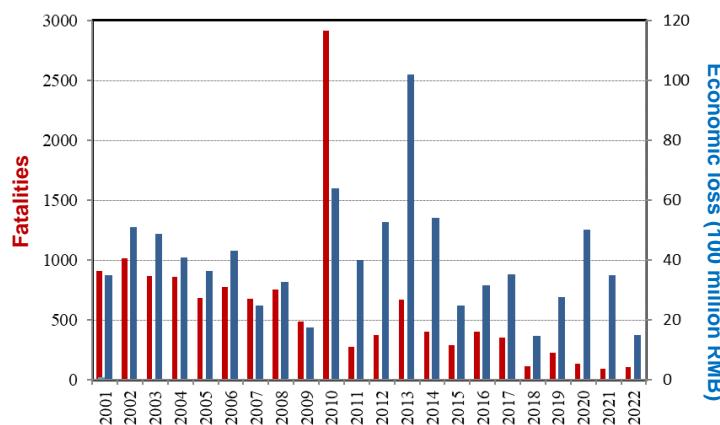
Mountain hazards are widely distributed and threaten the towns, roads, and hydropower engineering.

Exposure

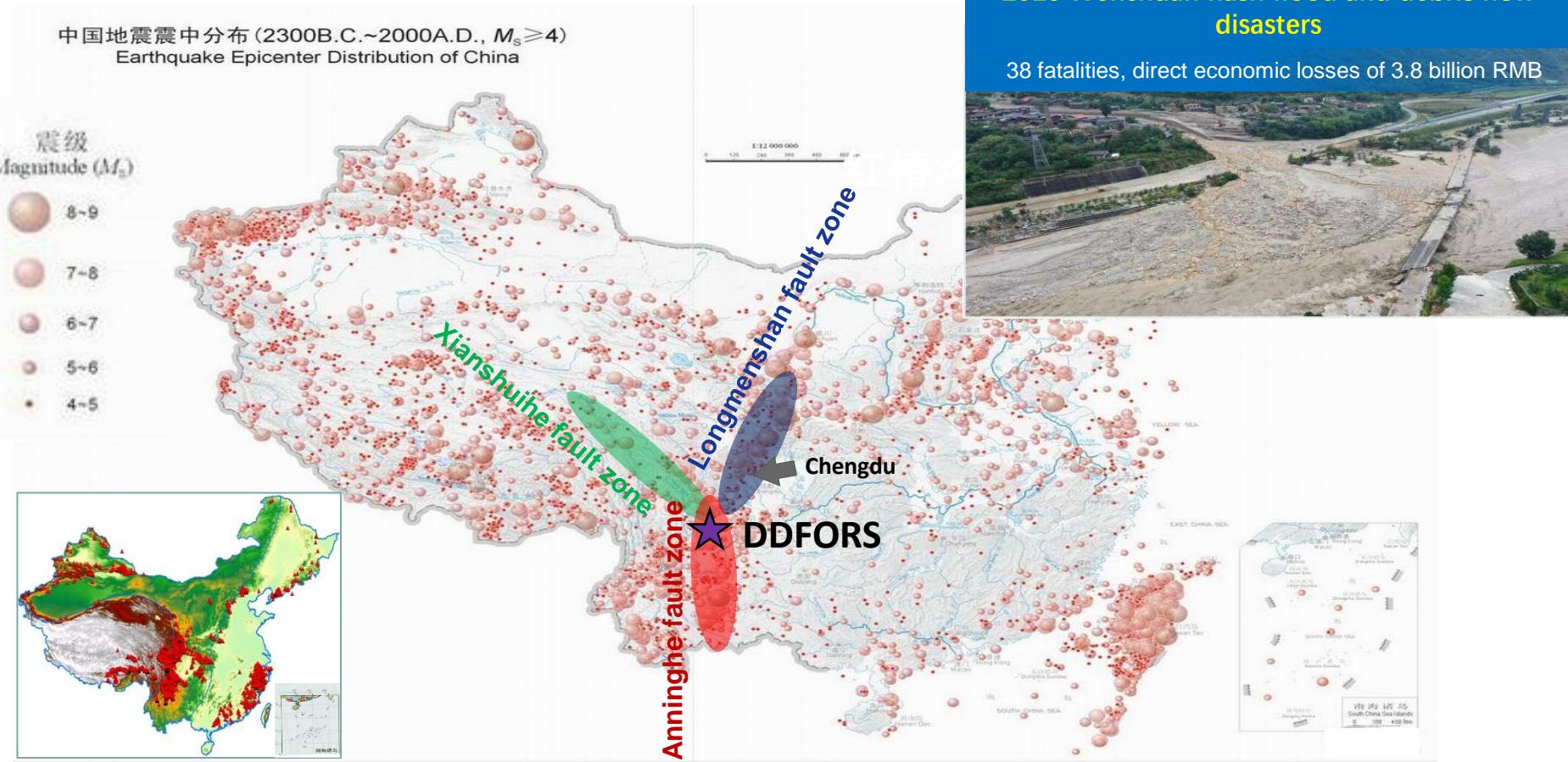
- **90% of hydropower plants**
- **50% of major roads and railways**
- **70% of towns**

Loss

- **Average fatalities: 608**
- **Percentage of flood deaths: 60%**
- **Annual economic loss: 4 billion RMB**



Frequent earthquakes aggravate mountain hazards



Distribution of debris flow-prone watersheds

Location of DDFORS: N26°14', E103°08'

Debris flow on Aug 2nd, 2023



Debris flow on July 23rd, 2019



Gentle slope but high velocity: 3-4°, ~10 m/s
High discharge: 500 m³/s
Residual layer: >1 m

Debris flow blocking the river channel (around 2000)



Dongchuan Debris Flow Observation and Research Station (DDFORS)

Long-term debris-flow observation since 1961



Founded in 1961

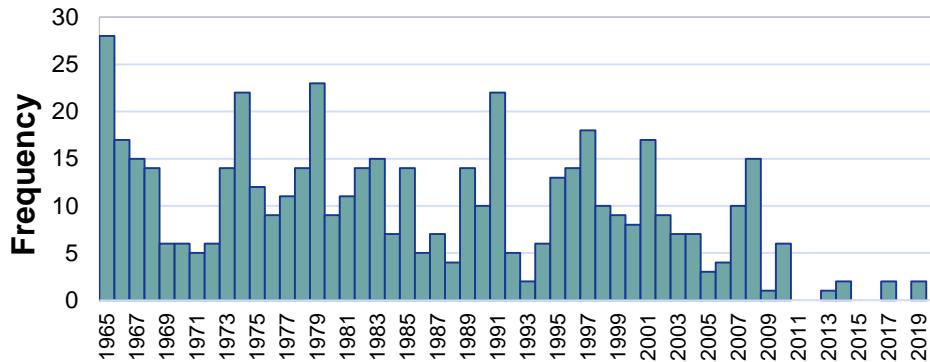


Became one of the five open field observation stations of CAS in 1988



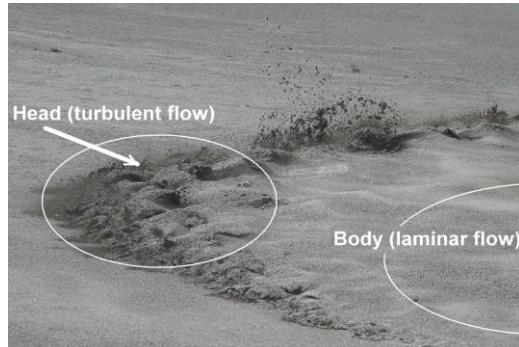
Upgraded to State Key Field Observation Station in 2000

Frequent debris-flow events



- ◆ Jiangjia Ravine – debris flow triggered by rainstorm
- ◆ Mount St. Helens, Mount Yakedake -volcanic debris flows
- ◆ Alps (Illgraben) - debris flow triggered by snow melting

“Debris-flow museum” in China and supplies advantageous research conditions



- Diverse debris-flow regimes and kinematic processes

Academic contributions to international debris-flow research



- ◆ Validation of debris-flow dynamics models (Iverson 1997, 2003, 2013; Takahashi, 2007)
- ◆ Prototype and validation of the roll-wave theory (Zanuttigh and Lamberti 2007; Arai et al. 2013)
- ◆ Prototype and validation of the debris-flow particle segregation theory (Major 1997)
- ◆ Important supplementary data for international sediment research



Ideal research site for debris-flow observation and prototype validation



February 22, 2011
Zhao-Yin Wang, Ph.D., M.ASCE
Professor of Geotechnical Engineering
Tsinghua University
Beijing 100084
China

Dear Dr. Wang:

We are pleased to inform you that you have been selected by the Environmental & Water Resources Institute to receive the 2011 Diane Abbott Lecture Award. The award citation will read: "For his unique contributions to understanding debris flows and their impact on infrastructure, and for his leadership in developing integrated management approaches for debris flows." His research interests include debris flow dynamics, stream evolution and restoration, and integrated river basin management. "In currently being used to address complex environmental erosion and sedimentation problems in China and abroad."

We hope that you can personally accept the award, which consists of a plaque and a cash prize in the amount of \$1,000. During the World Environmental and Water Resources Congress, May 22–26, 2011, in San Antonio, Texas, you will receive the award from the ASCE President. If you are unable to attend the Congress, please let us know so we can make other arrangements. We will be happy to mail the plaque to you. Please contact Mr. Michael J. Rosati, ASCE Awards Manager, Ms. Rosati can receive your registration form by fax (703/295-6271) or by email (mrosati@asce.org).

Please direct your attention to other important information. As you will see, we ask your assistance as we prepare publicity about your award. Except for the Congress registration fees, there is no cost to you for attending the Congress. We will provide you with a travel guide through the process of obtaining discounted documents and making your travel plans.

Please accept my personal congratulations on this important milestone in your career.

Sincerely,

Patrick J. Vittor
Patrick J. Vittor, P.E., M.ASCE
Environmental & Water Resources Institute
Executive Director

cc: Wayne C. Huber, P.E., M.ASCE, Chair, EWRI Awards Committee
Michael J. Rosati, ASCE, Chair, Student Award Committee
Ann Rutherford, Past chair

ASCE - AMERICAN SOCIETY OF CIVIL ENGINEERS

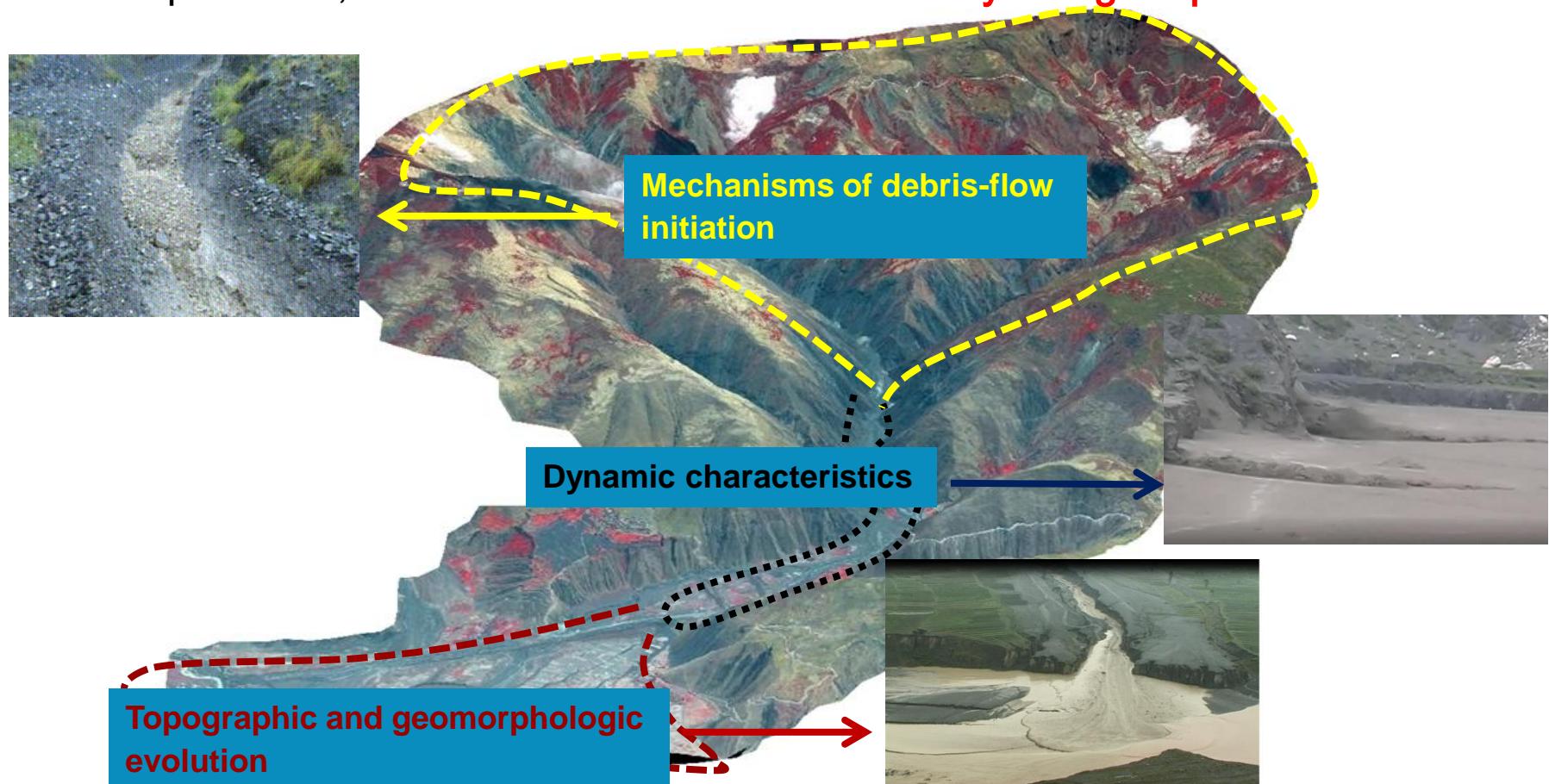
Content

- 1 Dongchuan Debris Flow Observation and Research Station (DDFORS)**
- 2 Debris-flow observation at DDFORS**
- 3 Key findings based on the observational data**
- 4 Digital data management**

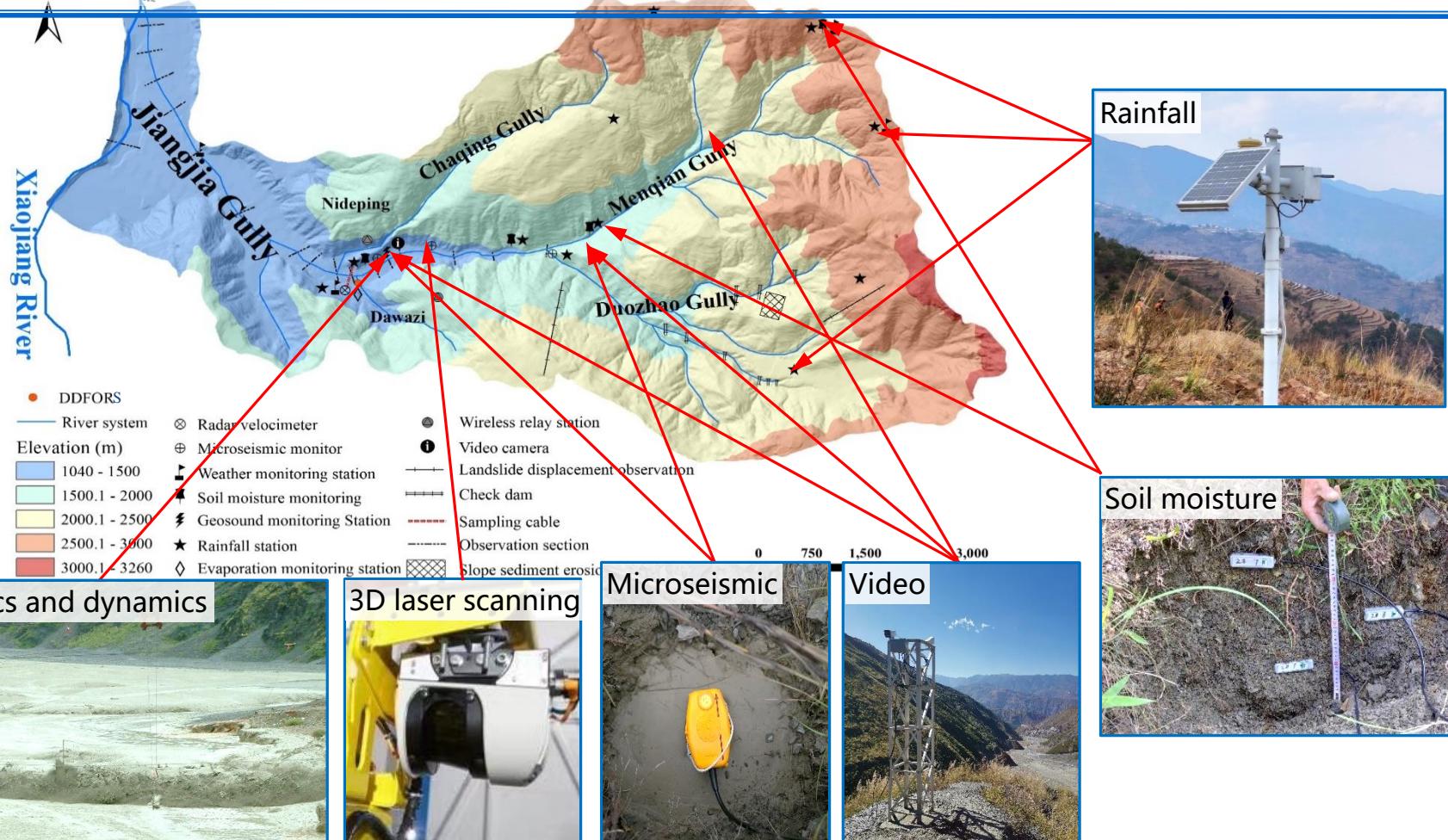


Observation of the whole debris-flow process

Unlike slope failure, debris flow is a **catchment-scale hydrological process**



Observation facility in Jiangjia Ravine (Upgrade in progress)



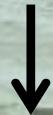
Ultrasonic mud-level sensor

Observation of
debris-flow
dynamic
process

2nd Debris flow surge



Steel Pile with Load cells



1st Debris flow surge



Debris flow
sampling



- Kinematics: velocity, flow width, and flow depth
- Rheological properties, particle size distribution, and bulk density
- Impact load are measured in some of the debris-flows events

Long-term evolution of the debris-flow channel



Soil erosion and hydrographic monitoring



Erosion and deposition monitoring in the channel



Landform changes and river evolution

Content

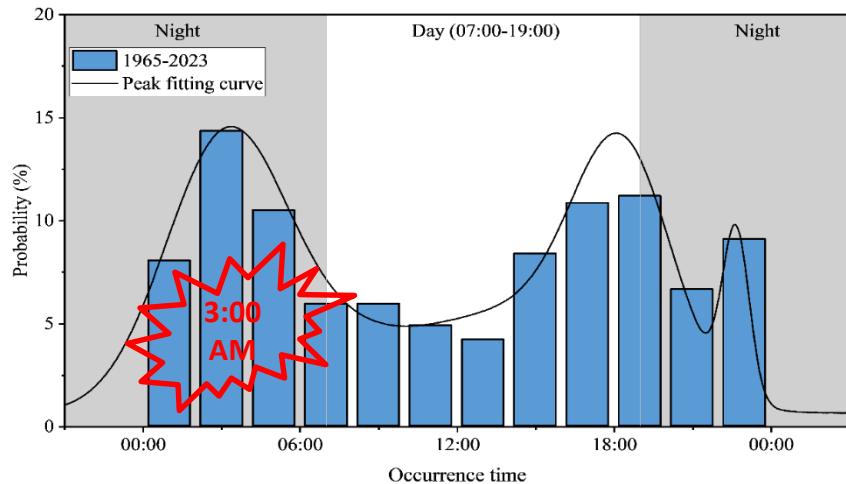
- 1 Dongchuan Debris Flow Observation and Research Station (DDFORS)**
- 2 Debris-flow observation at DDFORS**
- 3 Key findings based on the observational data**
- 4 Digital data management**



3.1 Debris flows before dawn make nightmares in Southwest China

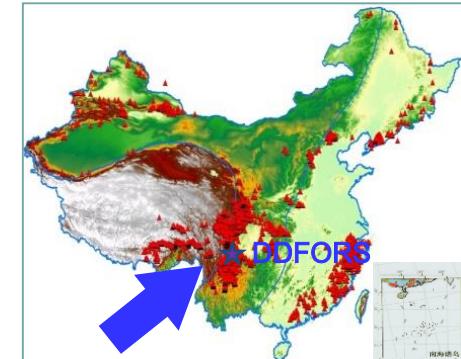


Embankment landslide (2:10 in 1st May 2024)
in Guangdong province (South China)



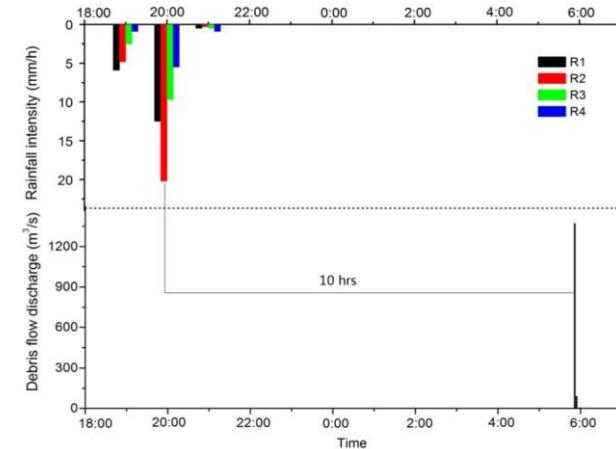
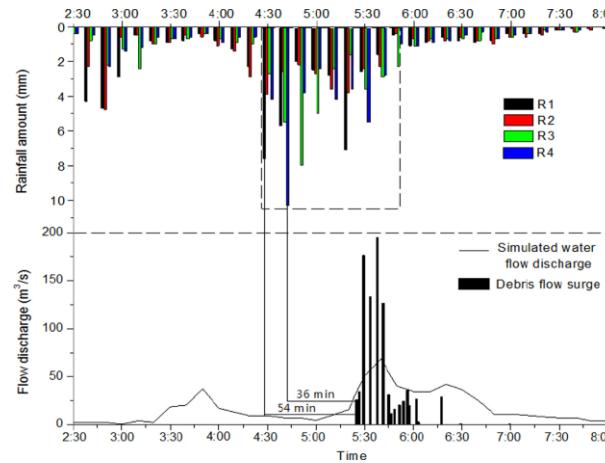
Timing of debris flows in Jiangjia Ravine

- Most deadly debris-flow events occurred **in the night**? Long-terms statistical data are needed.
- Occurrence of debris flow is related to heavy rainfall in the night.
- Rainfall-based early warning system would be effective!



3.2 Temporary damming-breaching of landslides dams magnifies the debris-flow discharge

A debris-flow event is a **catchment-scale hydrological process**



Landslide dams cause **temporary** blockage of the channel, and **magnifies** the discharge when breaching

2009.8.4 debris-flow event

τ : 36~54 min
 Q_d : $60.6 \text{ m}^3/\text{s}$
 Q_w : $64.3 \text{ m}^3/\text{s}$
 Q_d/Q_w : $1\sim 3$

Normal

2010.8.5 debris-flow event

τ : 10 h
 Q_d : $1370 \text{ m}^3/\text{s}$
 Q_w : $120 \text{ m}^3/\text{s}$
 Q_d/Q_w : 11.4

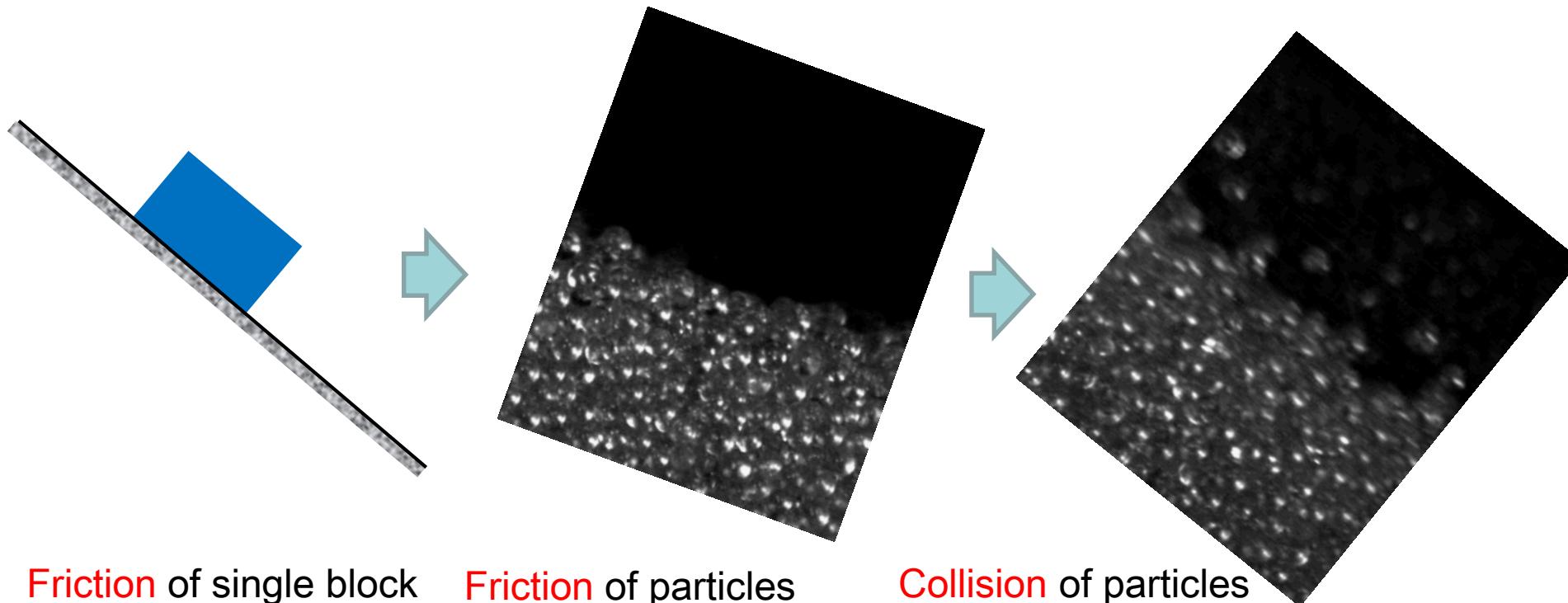
Abnormal

Classification of hydrological processes of surge debris flows:

the time lag τ , the ratio of debris-flow discharge to flood-flow discharge Q_d/Q_w

3.3 Flow resistance dominated by the coupled visco-collisional forces

Basic forces in dry granular flows: particle **friction**+particle **collision**



Friction of single block

Friction of particles

Collision of particles

3.3 Flow resistance dominated by the coupled visco-collisional forces

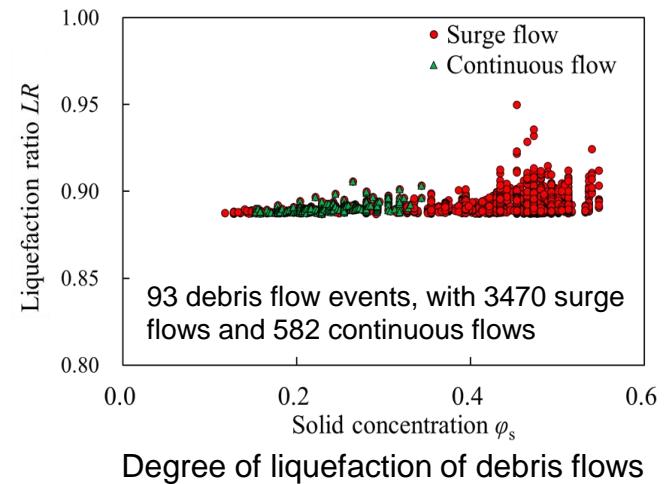
Intuitive flow resistance model considering particle friction and fluid viscous drag

$$\tau = \sigma_s \tan \phi + \dot{\gamma} \eta$$

Steady flow: $\tau = \rho g h \sin \theta$
 $\sigma = \rho g h \cos \theta$

Effective stress: $\sigma_s = \sigma - P$

$\rightarrow LR = \frac{P}{\sigma} = 1 + \frac{\dot{\gamma} \eta}{\sigma \tan \phi} - \frac{\tan \theta}{\tan \phi}$

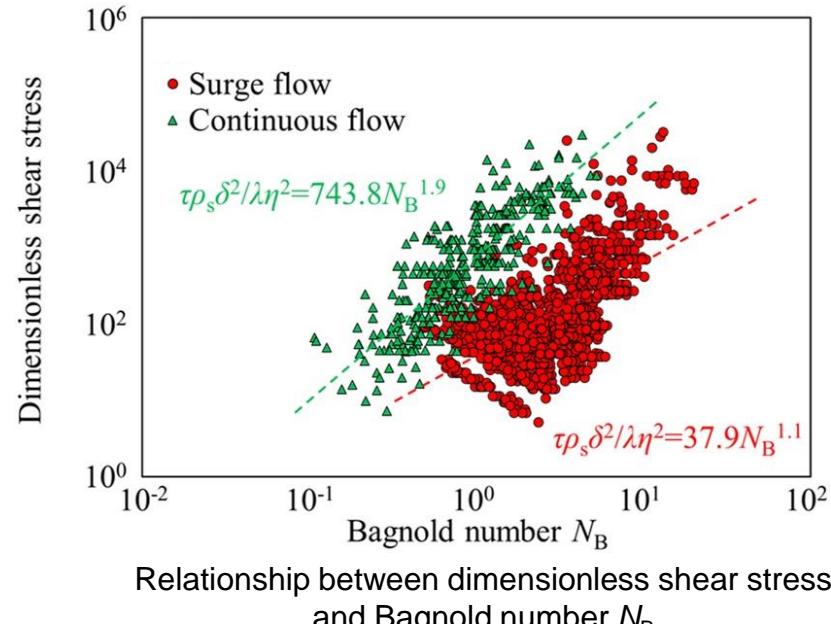


- Degree of liquefaction: 0.89~0.95, close to full liquefaction
- The particle friction provided by the effective stress is not the main source of flow resistance at DDFORS

3.3 Flow resistance dominated by the coupled visco-collisional forces

The contribution of particle collision and fluid viscous drag can be unified by the **Bagnold number N_B**

$$\tau = a \left(\frac{\lambda \eta^2}{\rho_s \delta^2} \right) N_B^b \quad \longrightarrow \quad \tau = a \left(\frac{\lambda^{1+b} \eta^2}{\rho_s \delta^2} \right) \left(\frac{\rho_s \dot{\gamma} \delta^2}{\eta} \right)^b$$



The index b falls in the range of fluid viscous drag ($b=1$) and particle collision ($b=2$), indication **the joint contribution of both fluid viscous drag and particle collision**

- For surge flows, $b = 1.1$, $\tau = a \lambda^2 \dot{\gamma} \eta$, flow resistance is mainly contributed by the **fluid viscous drag**
- For continuous flows, $b = 1.9$, $\tau = a \lambda^3 \rho_s \dot{\gamma}^2 \delta^2$, flow resistance is mainly contributed by **particle collision stress**

- [INTRODUCTION OF JIANGJIA RAVINE] Cui, P., Chen, X., Wang, Y., Hu, K., & Li, Y. (2005). Jiangjia Ravine debris flows in south-western China. *Debris-flow hazards and related phenomena*, 565-594.
- Chen, Q., Song, D., Chen, X., & Zhong, W. (2023). Visco-Collisional Scaling Law of Flow Resistance and Its Application in Debris-Flow Mobility. *Journal of Geophysical Research: Earth Surface*, 128(2), e2022JF006712
- Du, J., Zhou, G. G. D., Tang, H., Turowski, J. M., & Cui, K. F. E. (2023). Classification of stream,hyperconcentrated, and debris flow using dimensional analysis and machine learning. *Water Resources Research*, 59, e2022WR033242.
- Jiang, Y., Hu, X., Liang, H., Ning, P., & Fan, X. (2023). A physically based model for the sequential evolution analysis of rainfall-induced shallow landslides in a catchment. *Water Resources Research*, 59, e2022WR032716.
- Yan, Y., Tang, H., Hu, K., Turowski, J. M., & Wei, F. (2023). Deriving debris-flow dynamics from real-time impact-force measurements. *Journal of Geophysical Research: Earth Surface*, e2022JF006715.
- Yang, H. J., Zhang, S. J., Hu, K. H., Wei, F. Q., Wang, K., & Liu, S. (2022). Field observation of debris-flow activities in the initiation area of the Jiangjia Gully, Yunnan Province, China. *Journal of Mountain Science*, 19(6), 1602-1617.
- Guo, X., Li, Y., Cui, P., Yan., H., & Zhuang., J. (2020). Intermittent viscous debris flow formation in Jiangjia Gully from the perspectives of hydrological processes and material supply. *Journal of Hydrology*, 589, 125184.

For more information: <http://nsl.imde.ac.cn/en/>

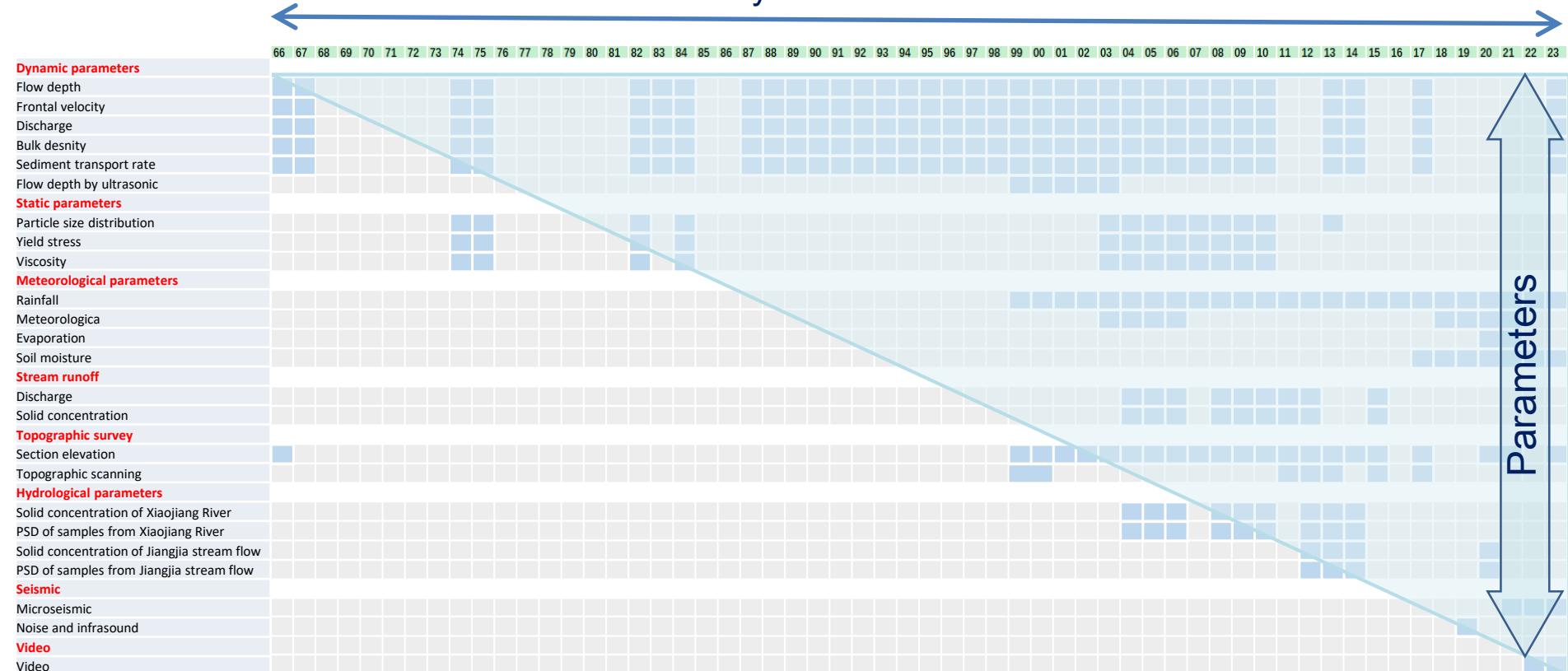
Content

- 1 Dongchuan Debris Flow Observation and Research Station (DDFORS)**
- 2 Debris-flow observation at DDFORS**
- 3 Key findings based on the observational data**
- 4 Digital data management**

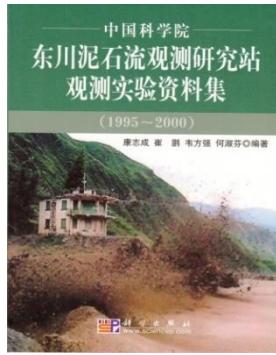
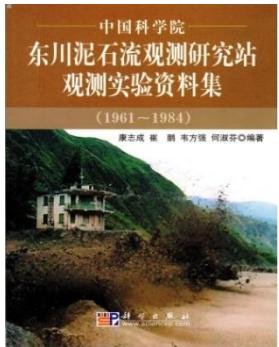


Overview of the observational data

~60 years' of observational data



Data availability



Datasets (before 2000) published in books
(we are now digitizing them)

国家科技资源共享服务平台 0951-4967592 Register Login 中文 EN

National Cryosphere Desert Data Center

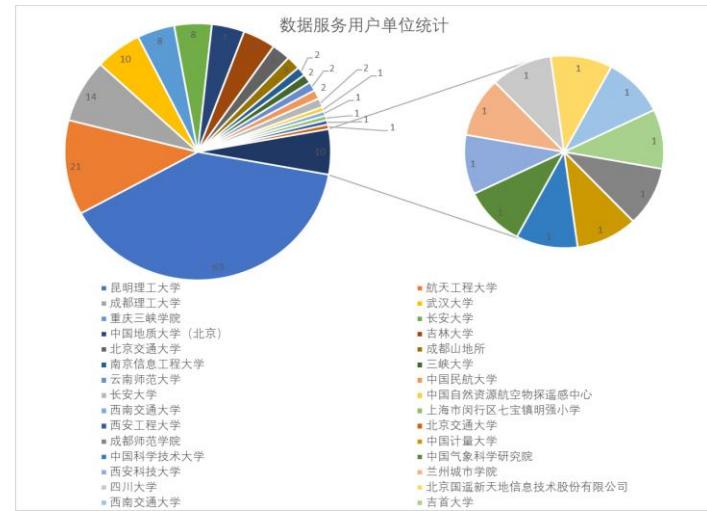
Home News Data resource Thematic data Models Natural Hazards Emergency response Science About

Observation data of debris flow in Dongchuan

Dongchuan Debris Flow Observation and research station of Chinese Academy of Sciences has semi-automatic debris flow field observation and research system and equipment, and multi-functional debris flow field experimental field, which is an important base for debris flow research and prevention.

Datasets (after 2000) available online:
<http://www.ncdc.ac.cn/portal/>

User statistics (2022)



- ◆ Observation data reaches 300 GB, used by more than 500 researchers in the past five years
- ◆ Supporting the construction of national major infrastructure and major scientific research projects

A brief summary

- 60 years' of debris-flow field observation has been carried out at DDFORS.
- Many interesting findings enhance our understanding to debris-flow hazard.
- A new campaign has just launched to further expand the time span and enhance the comprehensiveness of the data.
- The datasets are now available at National Cryosphere Desert Data Center (<http://www.ncdc.ac.cn/portal/>) and more data will be available within 2024.
- A description of the datasets will be published (target journal Earth System Science Data).



Thank you!

<http://nsl.imde.ac.cn/en/>

Dongri SONG
drsong@imde.ac.cn