行政法人 國家災害防救科技中心
National Science and Technology Center for Disaster Reduction

The Application of Transdisciplinary Techniques on Slope Disaster Monitoring in Taiwan

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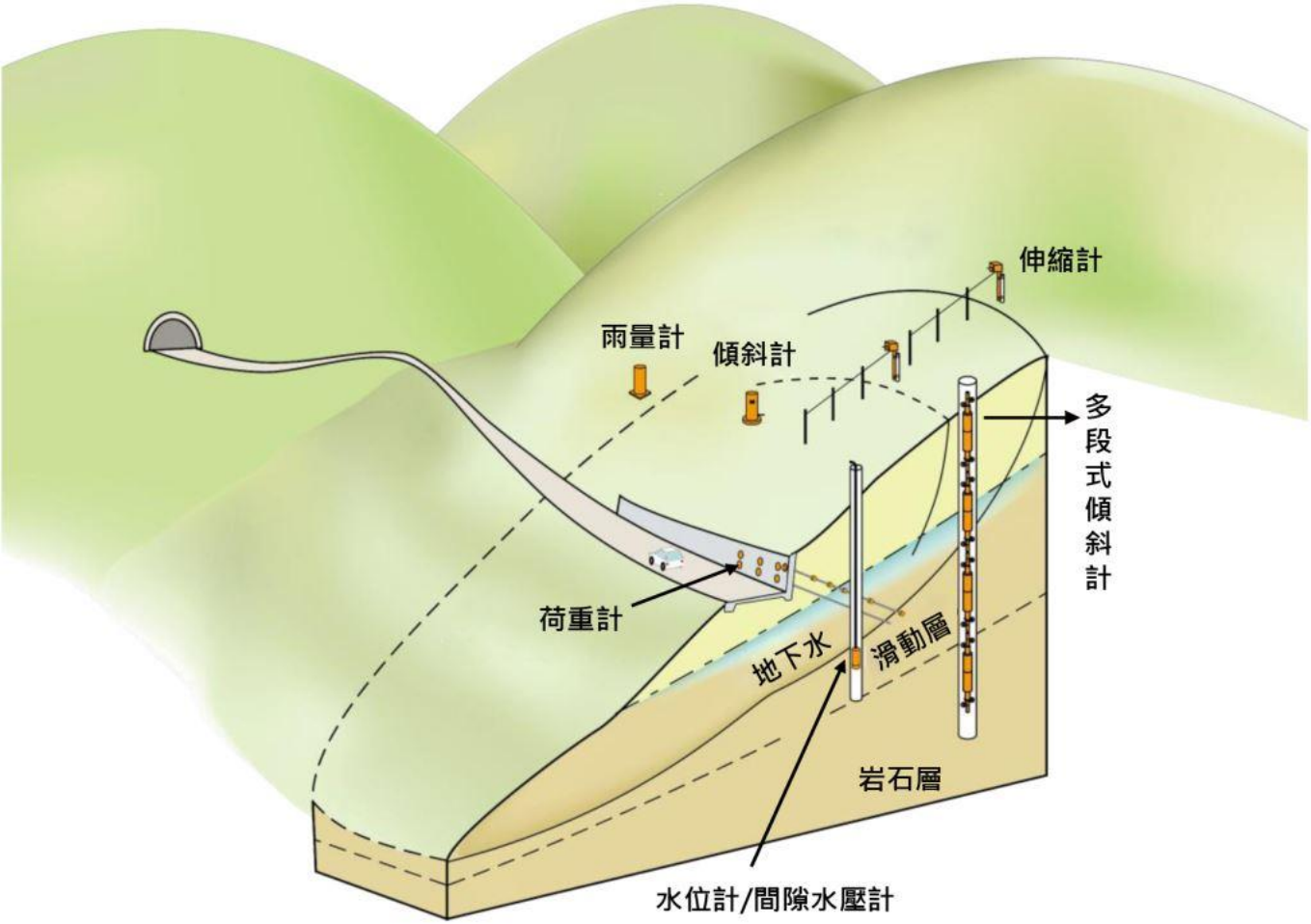
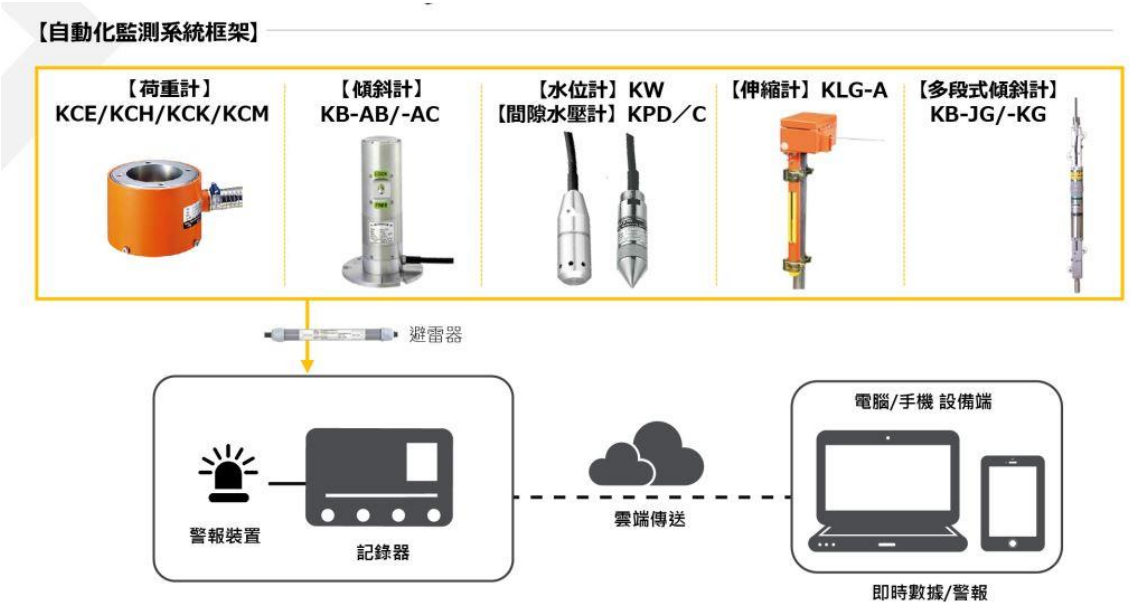
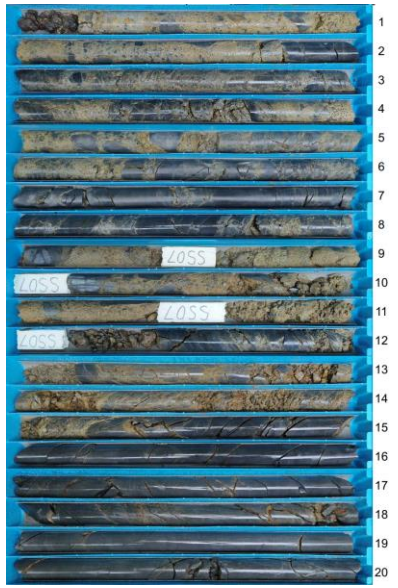
National Science and Technology Center for Disaster Reduction

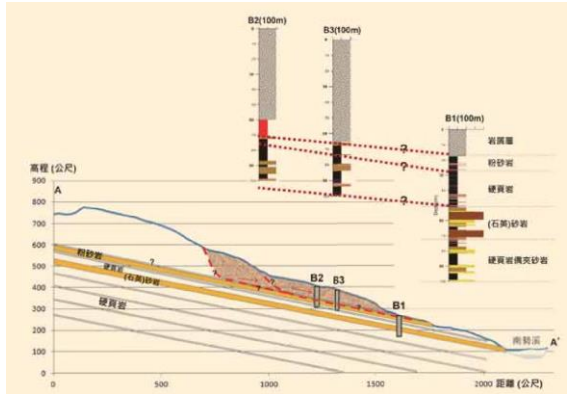
Field investigation and monitoring

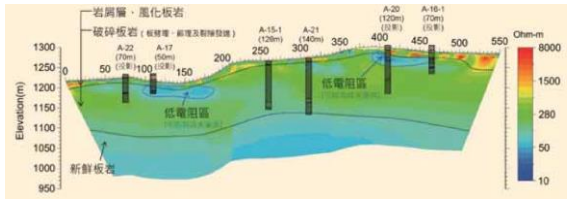
- Very important work for awareness
- Deeply and truly understand the environmental condition and creeping behavior, BEFORE sliding.
- How many sites we need to concern?







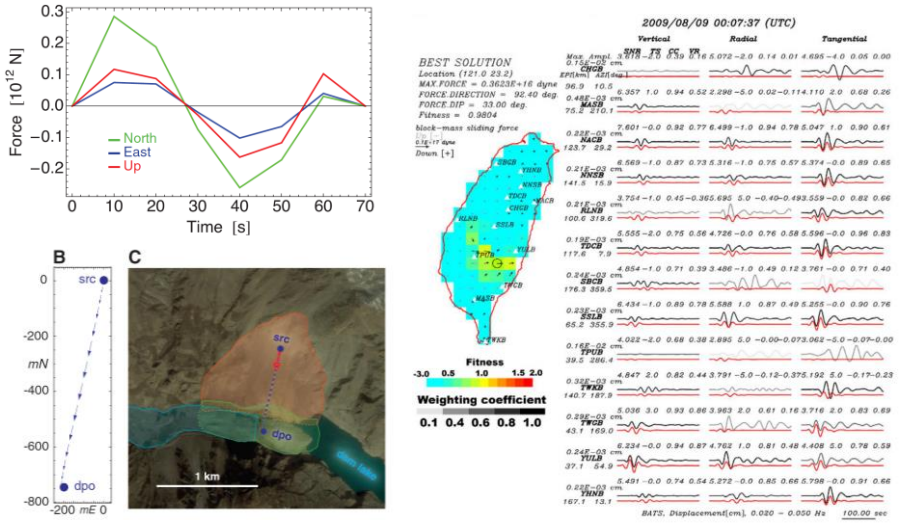




Seismology can help

- Seismology becomes a promising way to monitor slope disasters remotely and continuously.
  - Far field: monitor deep-seated landslide by national seismic network (A>0.2 km^2 or V>10^6 m^3)
  - Near field: monitor shallow landslide, rockslide, debris flow by local network (more necessary)
- Challenge: the auto-processing technique is needed and should be trustworthy and efficient.
- Challenge: small scale movement generates seismic wave with higher frequency.
- Challenge: local network deployed near village or road where lots of random noise exists.
- The technical gap is how to deal with Noise.

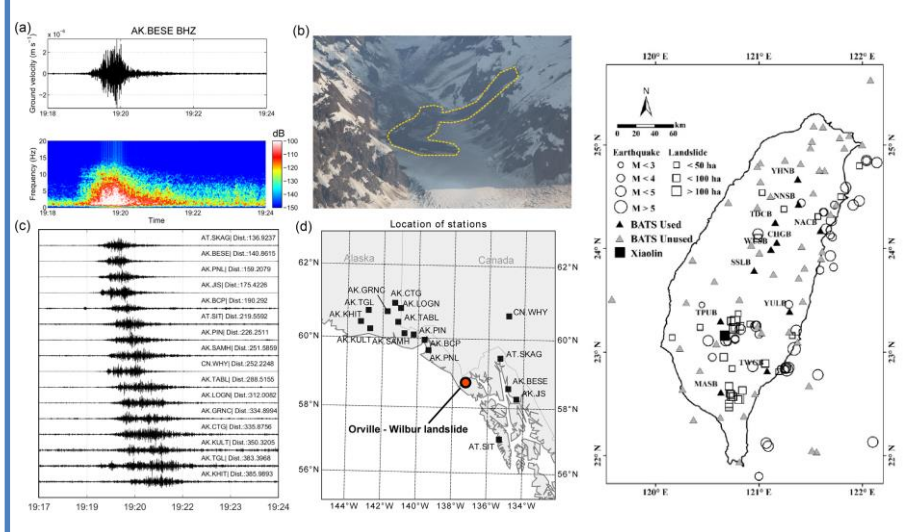
Far field monitoring by physical model



Ekström and Stark (2013)

W. Chao, *et al* (2017)

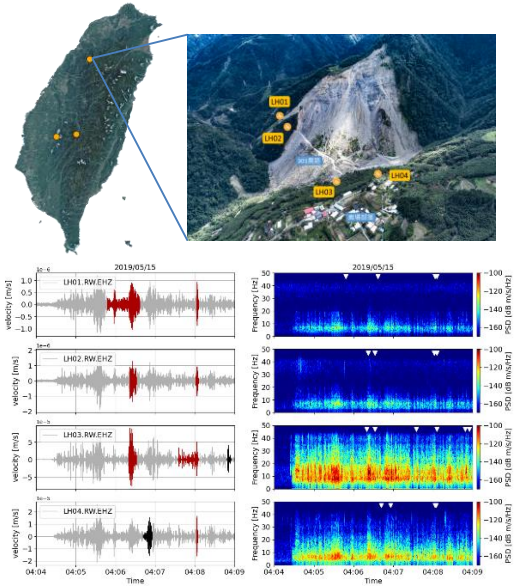
Far field monitoring by machine learning



C. Hibert, *et al* (2019)

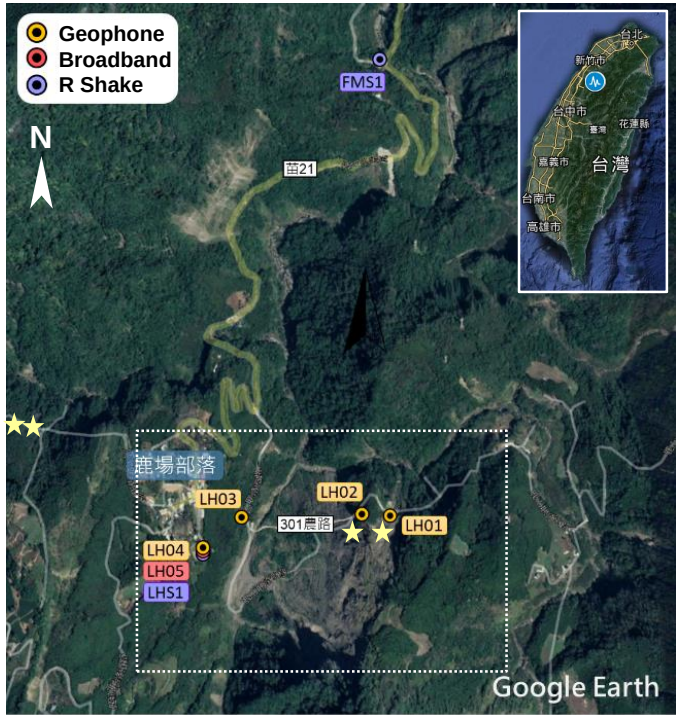
Lin, *et al* (2020)

Near field monitoring



Lu-Hu landslide, Miaoli, Taiwan

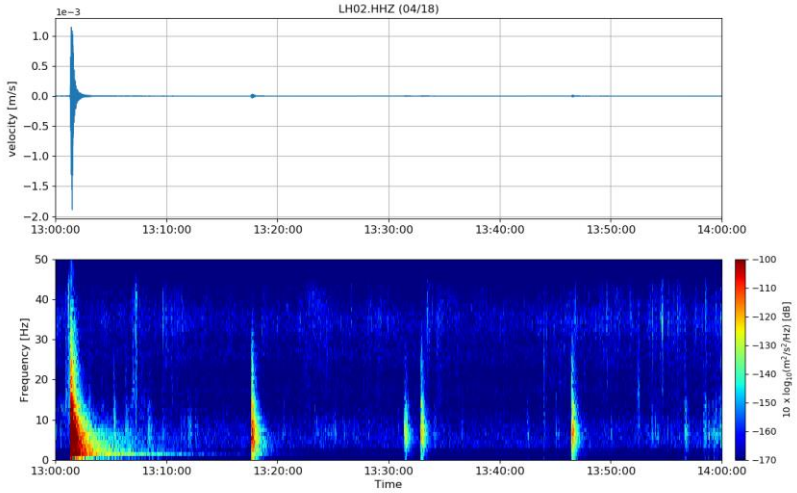
- Rockslide prone area since a significant landslide occurred in 2018
- Seismic network with 4 geophones have been deployed across the failure slope in 2019
- Seismic events of 4 witnessed rockslides have been recorded



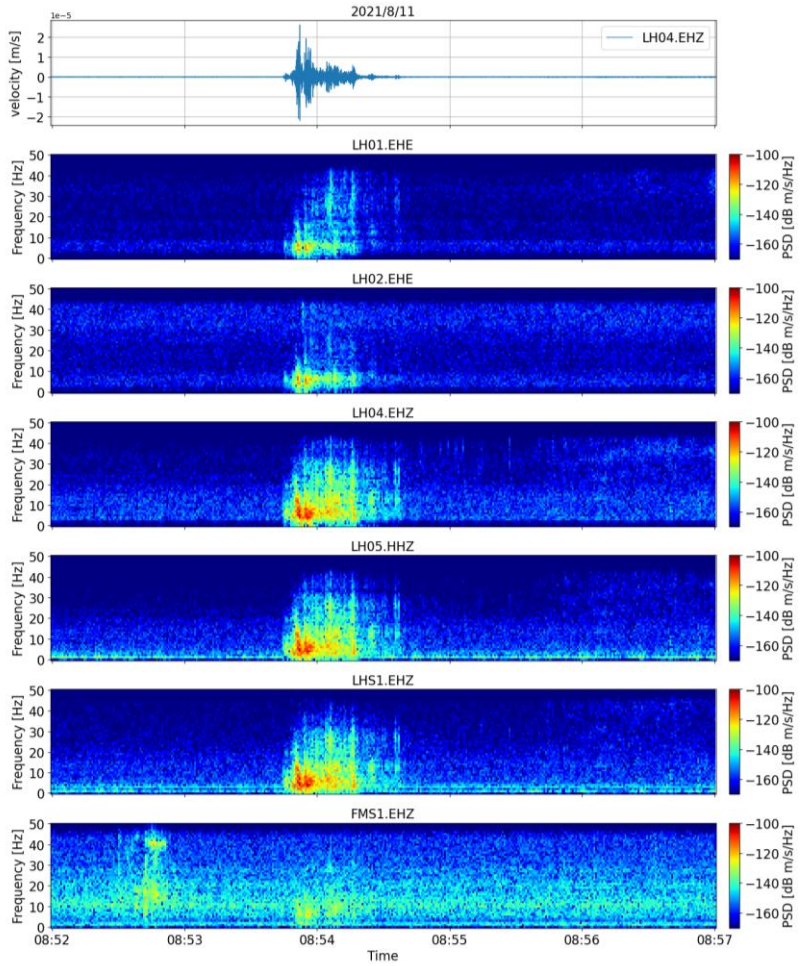
Different seismic events

- Unique patterns in time series and spectrogram reveal different sources
- Wave attenuation between sensors implies source location
- More types: farming, piping, villager activity, wind, rainfall, and thunder

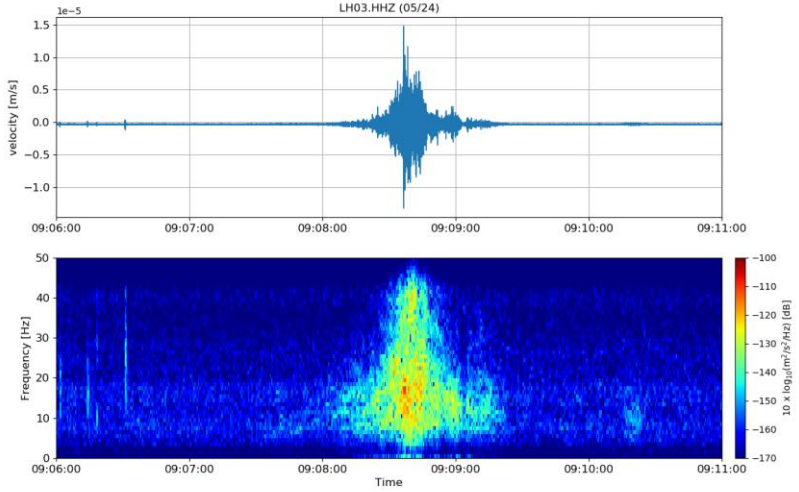
Earthquake and aftershocks



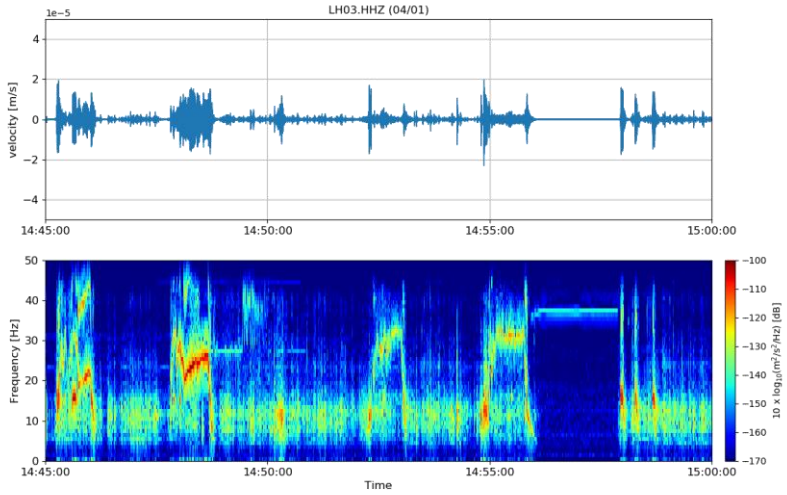
Rockslide



Car passing

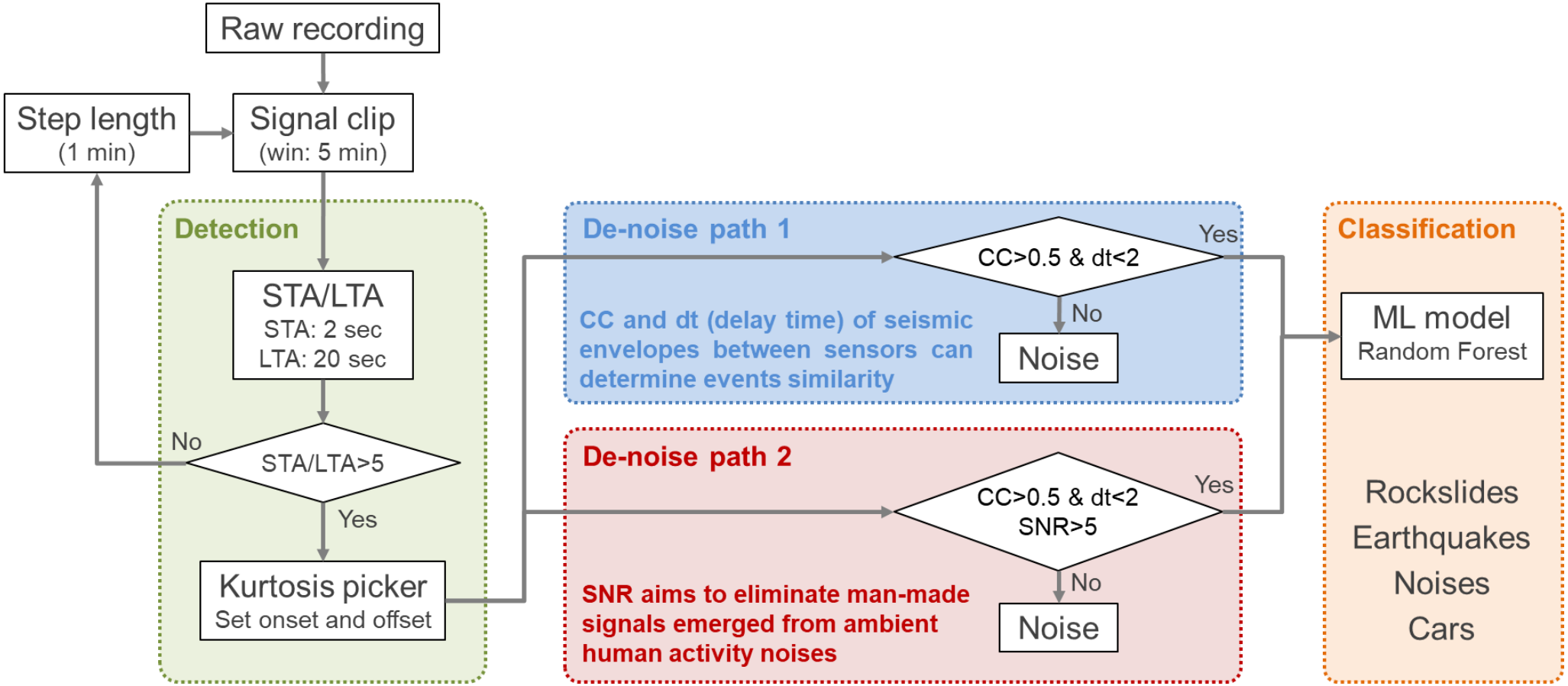


Machine operation and human activity



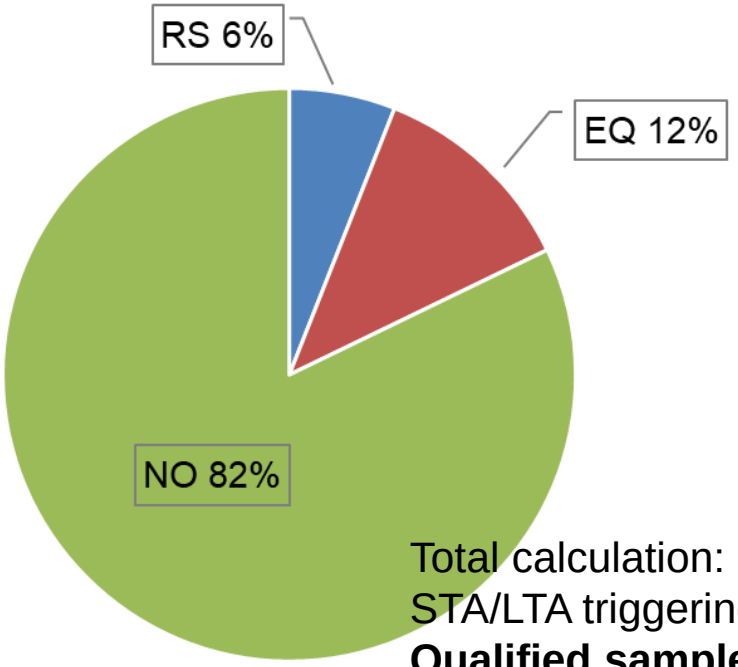
Automatic monitoring algorithm

- Detection: short term average/long term average (STA/LTA) and Kurtosis picker
- Noise elimination (de-Noise): signal-to-noise ratio (SNR) and cross-correlation (CC) analysis
- Classification: machine learning (ML) model



Noise-influenced database

- de-Noise: path 1
  - Test period: 2019/5/13-2019/5/21 (9 days)
  - Diverse noises dominate the sample pool so that machine learning model get lower sensitivity to RS and EQ



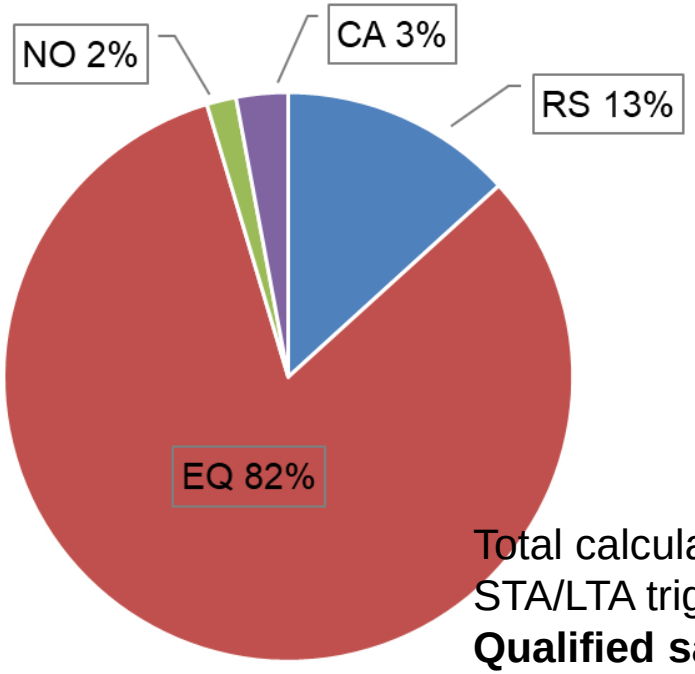
Total calculation: 51,840
STA/LTA triggering: 7,008 (13%)
Qualified sample: 1,952

Random Forest		Automatic			
		EQ	NO	RS	SEN
manual	EQ	138	93	0	59.7%
	NO	13	1584	7	98.8%
	RS	1	93	23	19.7%
	ACC	90.8%	89.5%	76.7%	89.4%

ACC: Accuracy; SEN: sensitivity

Noise-free database

- de-Noise: path 2
  - Test period: 2019/5/13-2020/6/13 (1+ years)
  - The performance of ML model is enhanced significantly because of decreased noises
  - AI-based seismic sensor is possible as next generation device



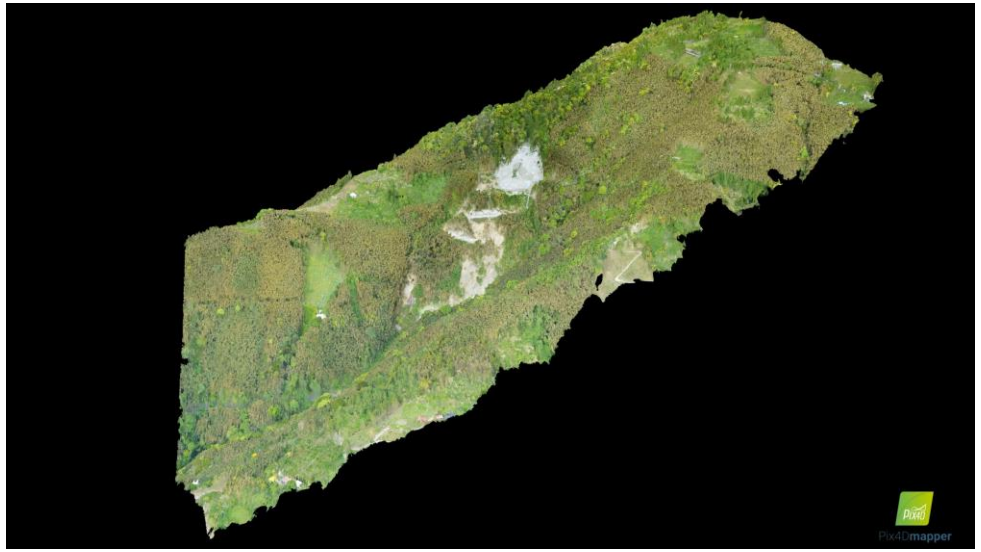
Total calculation: 588,960
STA/LTA triggering: 17,447 (3%)
Qualified sample: 5,022

The 2nd attributes		Automatic				
		CA	EQ	NO	RS	SEN
manual	CA	130	0	1	17	88%
	EQ	4	4082	6	32	99%
	NO	0	26	42	16	50%
	RS	5	135	7	519	78%
	ACC	93%	96%	76%	89%	95%

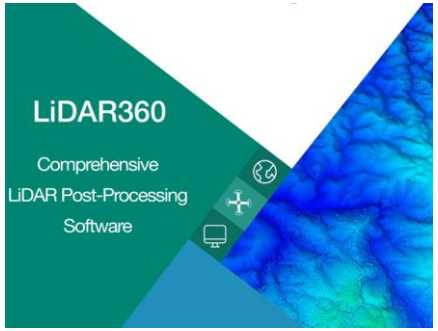
ACC: Accuracy; SEN: sensitivity

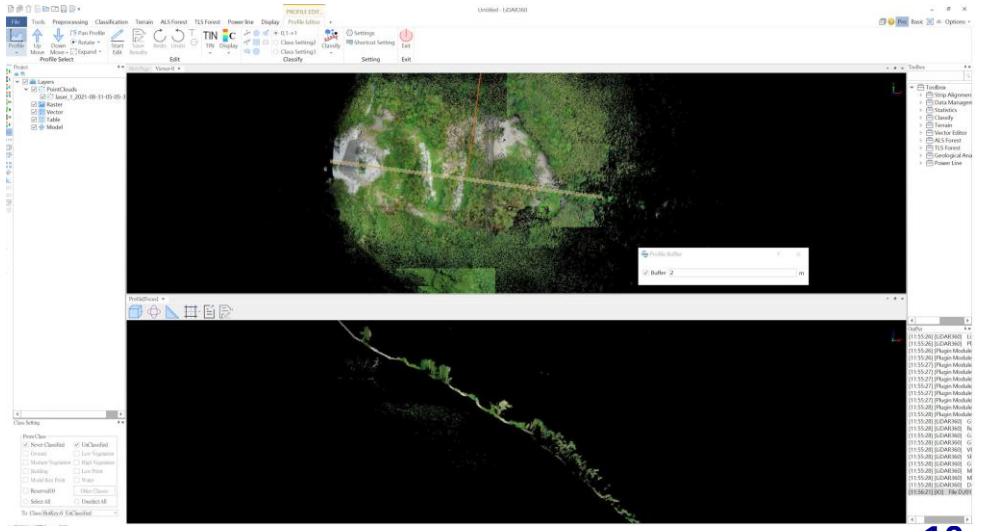
Aerophotography can help

- Drone is getting more popular in various application (filming, recreation, military usage)
- Provide broad viewpoint in geographic feature investigation
- Surveying with high resolution and efficient operation

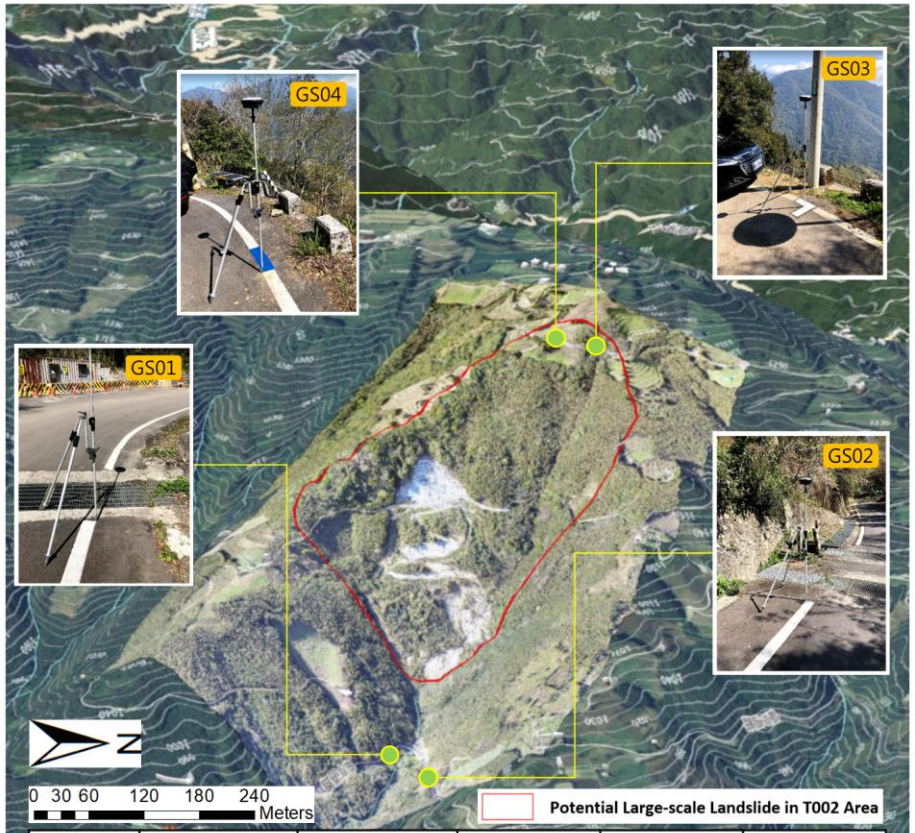


Featured with
- Optic Cam
- LiDAR
- Multispectral Cam



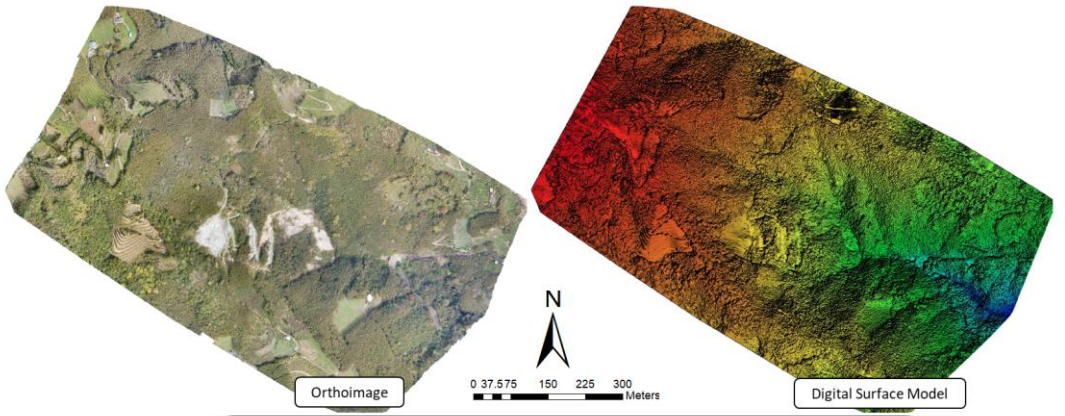


Particle image velocimetry (PIV)



location	N	E	H	2DCQ (m)	3DCQ (m)
GS01	2727934.495	290075.686	943.964	0.0066	0.0187
GS02	2727955.544	290223.663	953.164	0.0061	0.0186
GS03	2728250.002	289531.045	1320.367	0.0087	0.0232
GS04	2728198.694	289513.780	1332.095	0.0104	0.0308

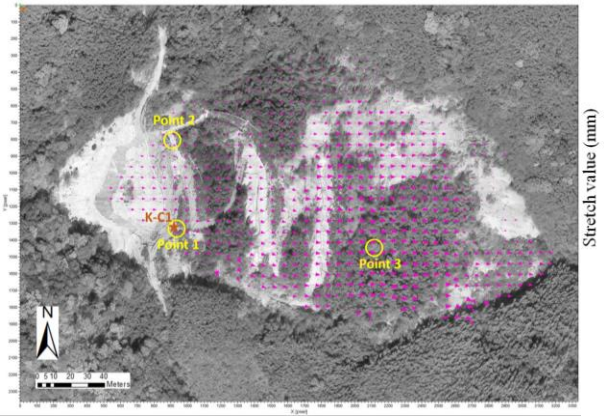
- Methodology
  - Capture orthophotos of the study site
  - Identify appropriate markers on the ground as reference points
  - Obtain the coordinates of the reference points by high-precision GNSS
  - Create the orthomosaic map and Digital Surface Model (DSM) with high resolution coordinate position

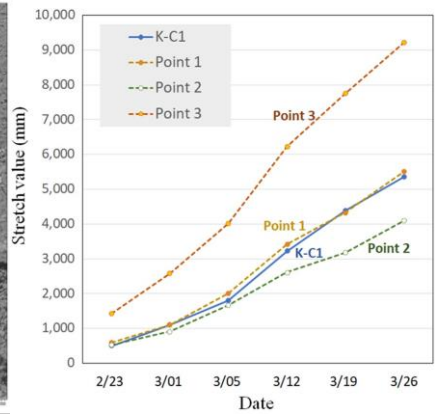


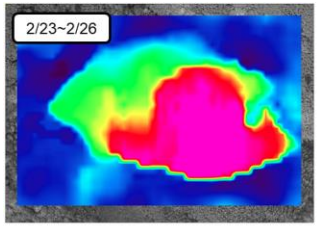
Project: 20210301
Average Ground Sampling Distance (GSD): 3.87 cm / 1.52 in
Area Covered: 0.519 km² / 51.9394 ha
Images: median of 78237 keypoints per image
Dataset: 475 out of 475 images calibrated (100%), all images enabled
Camera Optimization: 3.35% relative difference between initial and optimized internal camera parameters
Matching: median of 33275.9 matches per calibrated image
Georeferencing: yes, 4 GCPs (4 3D), mean RMS error = 0.031 m

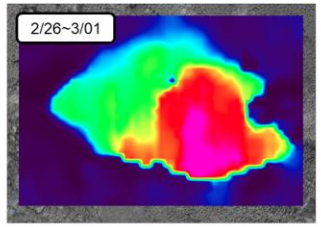
Particle image velocimetry (PIV)

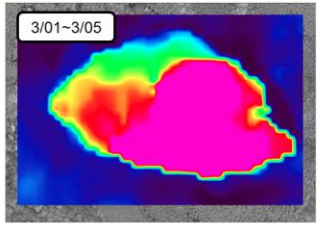
- PIV estimates pixel velocity by each orthomosaic pair.
- The stretch series corresponded with in-situ extensometer data.
- PIV provides spatial evolution of landslide.
- Time-lapse ortho-photography is more perceptible for observation.

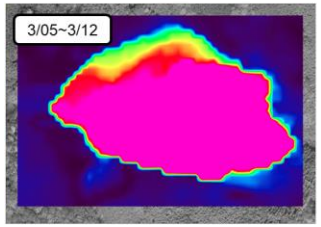


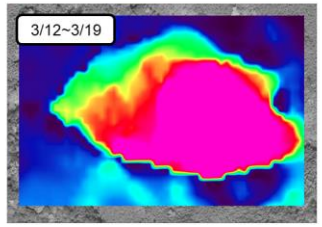


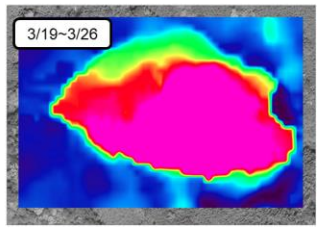


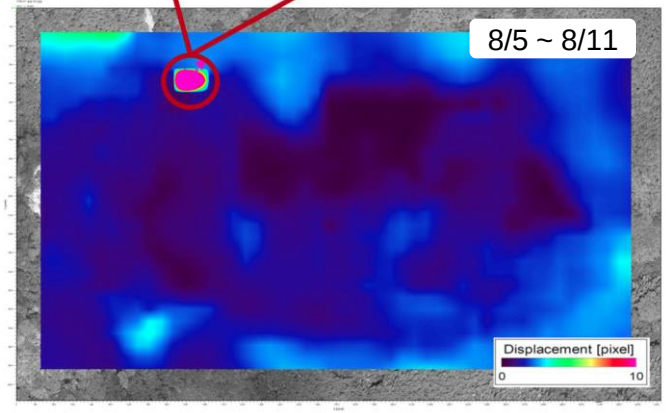


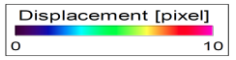


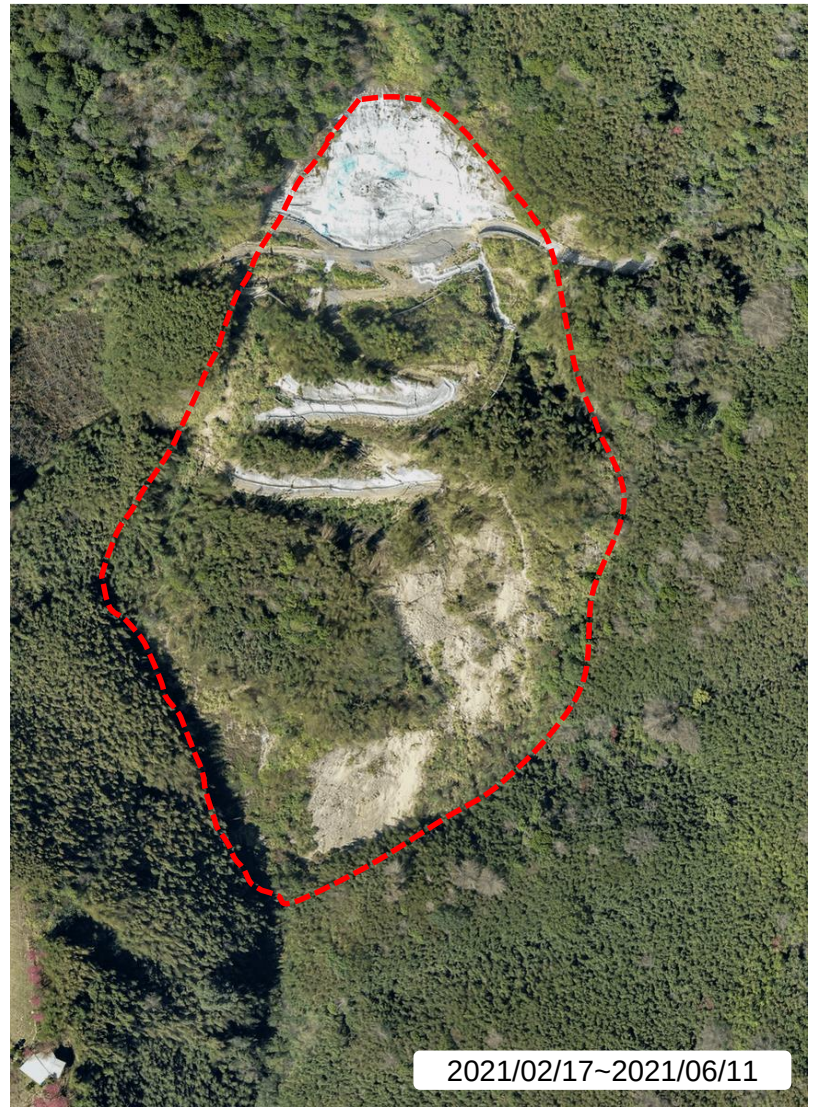






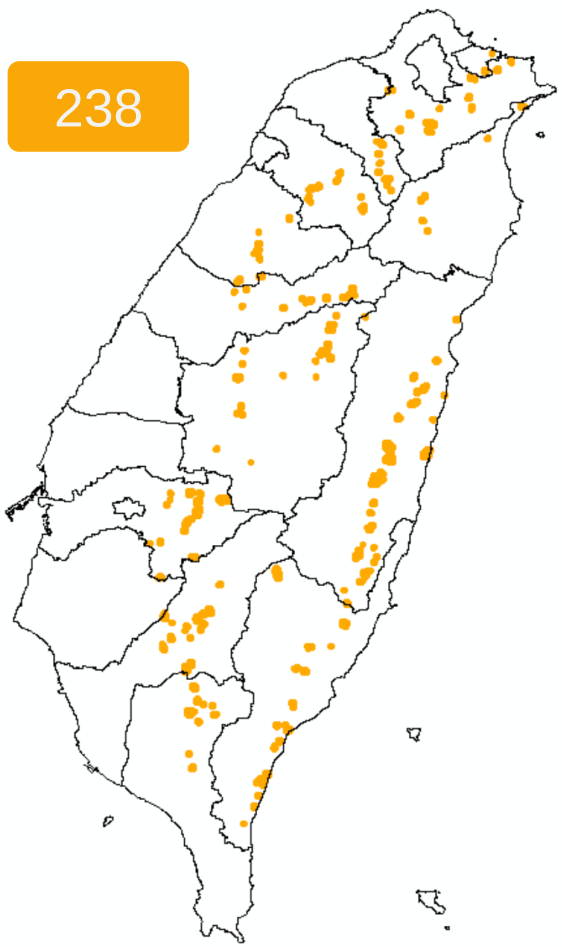


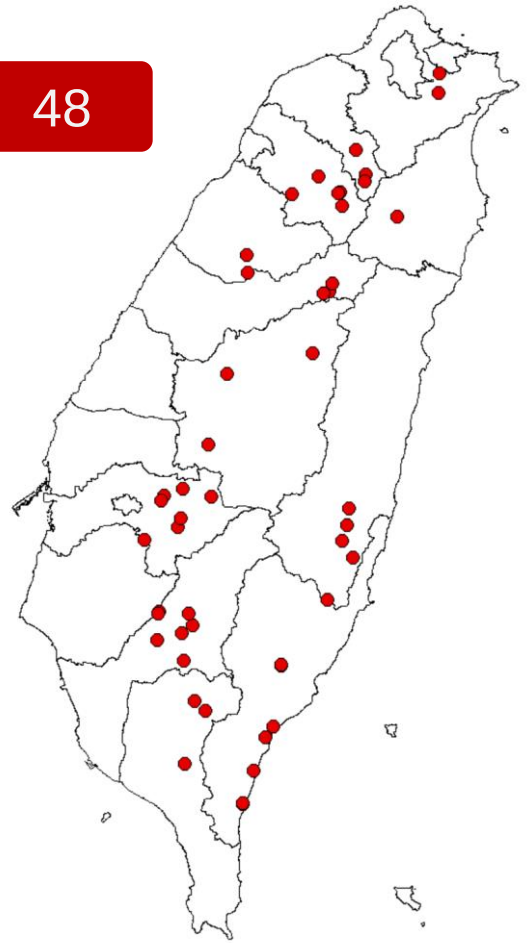




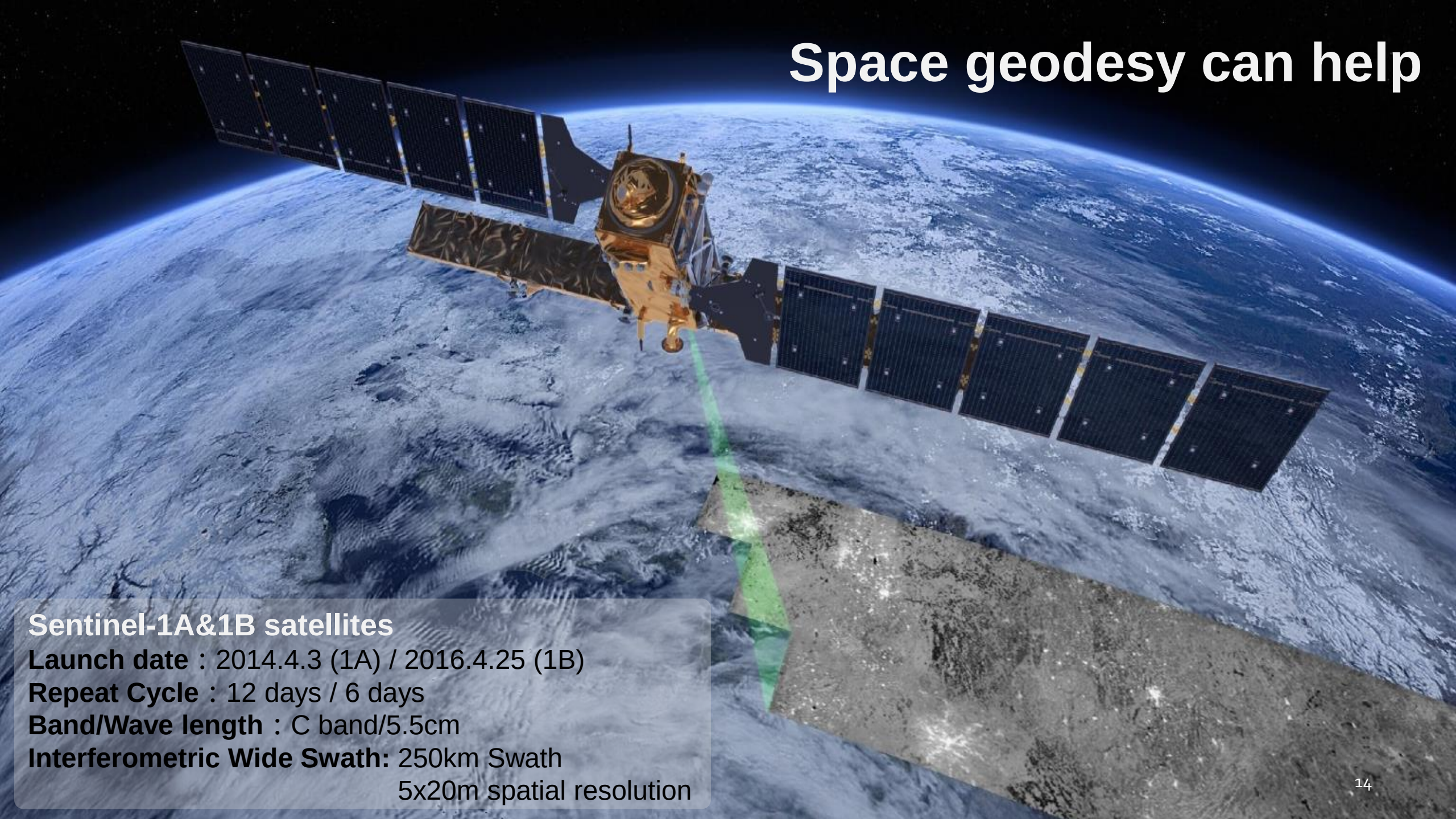
Survey History of Large-scale Landslide

- General survey by airborne LiDAR and recognize **9848** places of large-scale landslide potential areas since 2009.
- Identify **238** places containing protected targets with medium to high risk.
- Officially select **34** places with probable activity by InSAR, and increase to **48** places this year.





Space geodesy can help

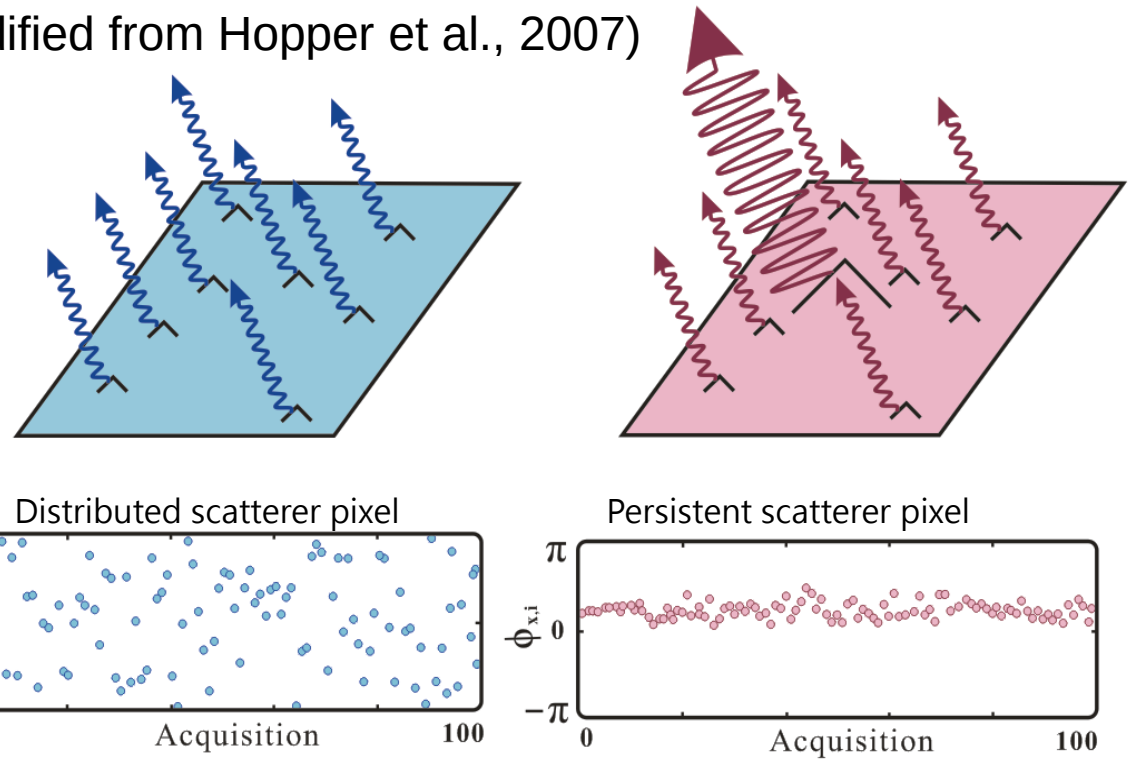


Sentinel-1A&1B satellites
Launch date：2014.4.3 (1A) / 2016.4.25 (1B)
Repeat Cycle：12 days / 6 days
Band/Wave length：C band/5.5cm
Interferometric Wide Swath: 250km Swath
5x20m spatial resolution

Persistent scatterers pixel, PS pixel

- Main idea: Find stable and strong reflective objects of a pixel
- From such strong scatterer, the surface information signal can be extracted from the background noise.

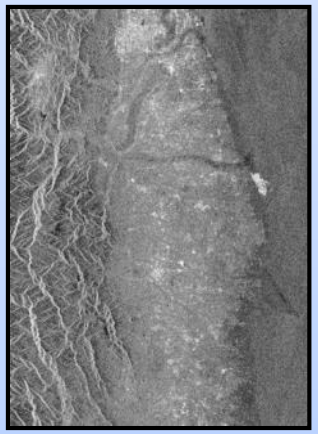
(Modified from Hopper et al., 2007)



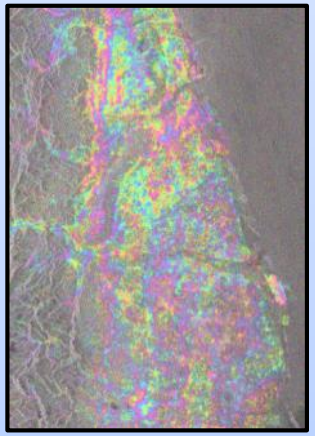
Multitemporal InSAR, MTInSAR

DInSAR

SAR images



Interferograms

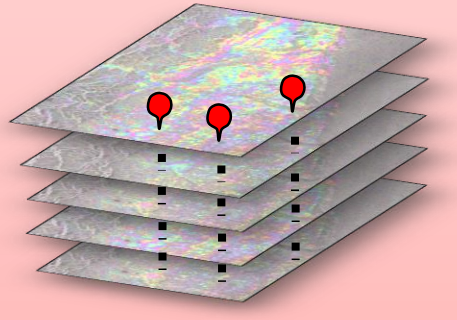


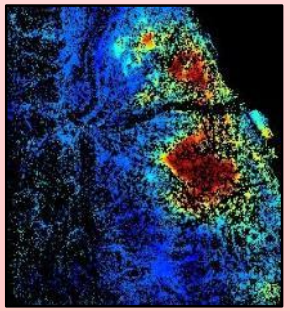
Sentinel Application Platform, SNAP

snap2stamps

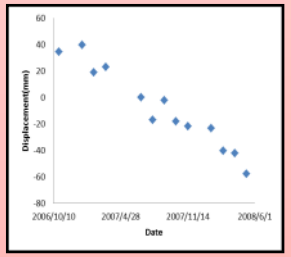
MTInSAR

Phase stability estimation and PS selection





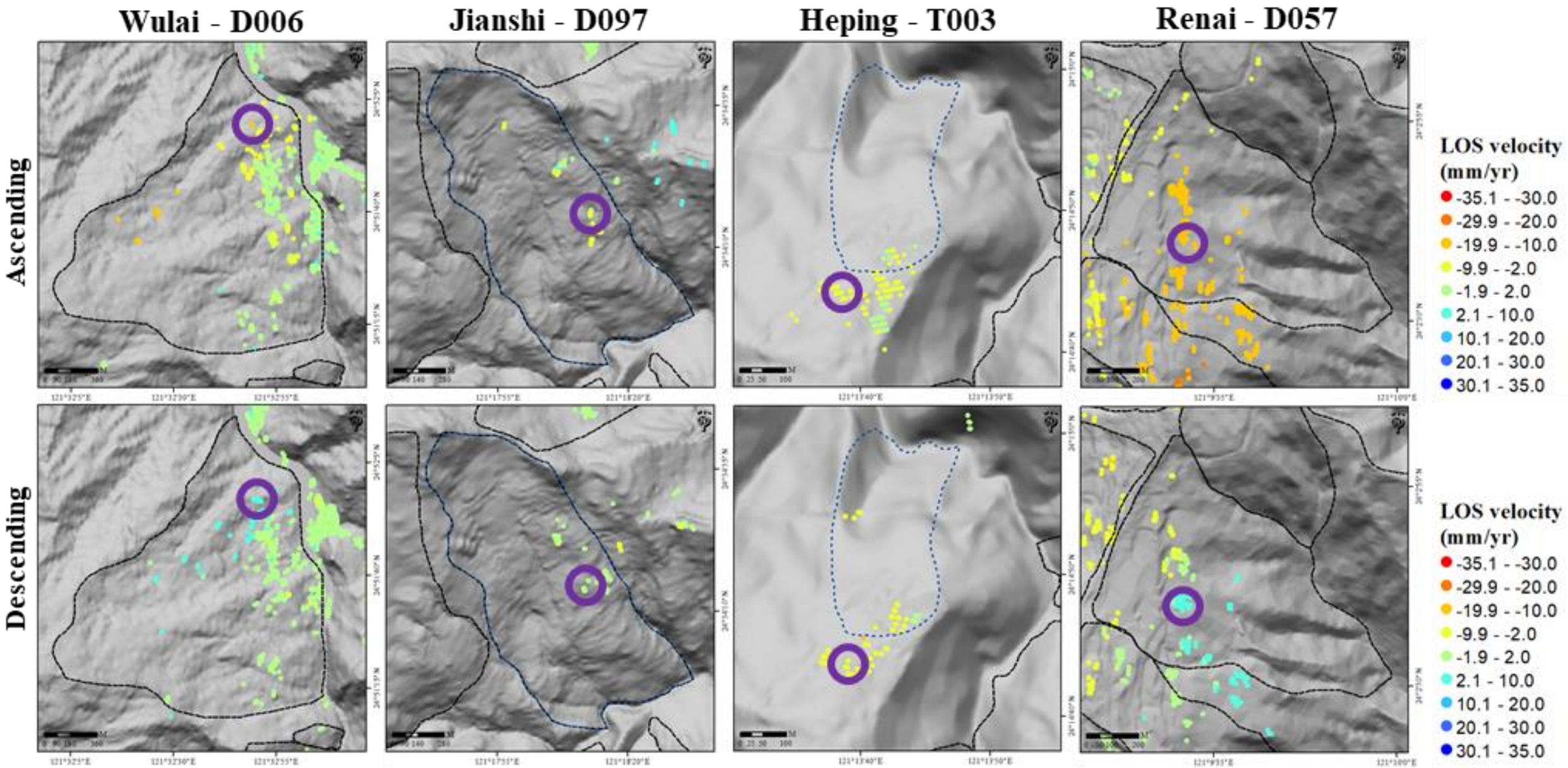
Velocity field map



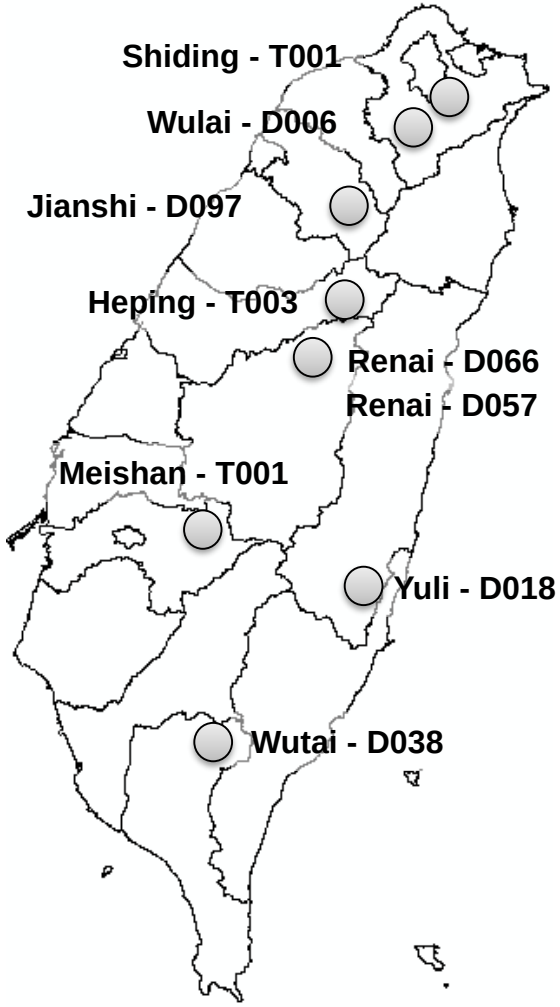
Displace-ment time series

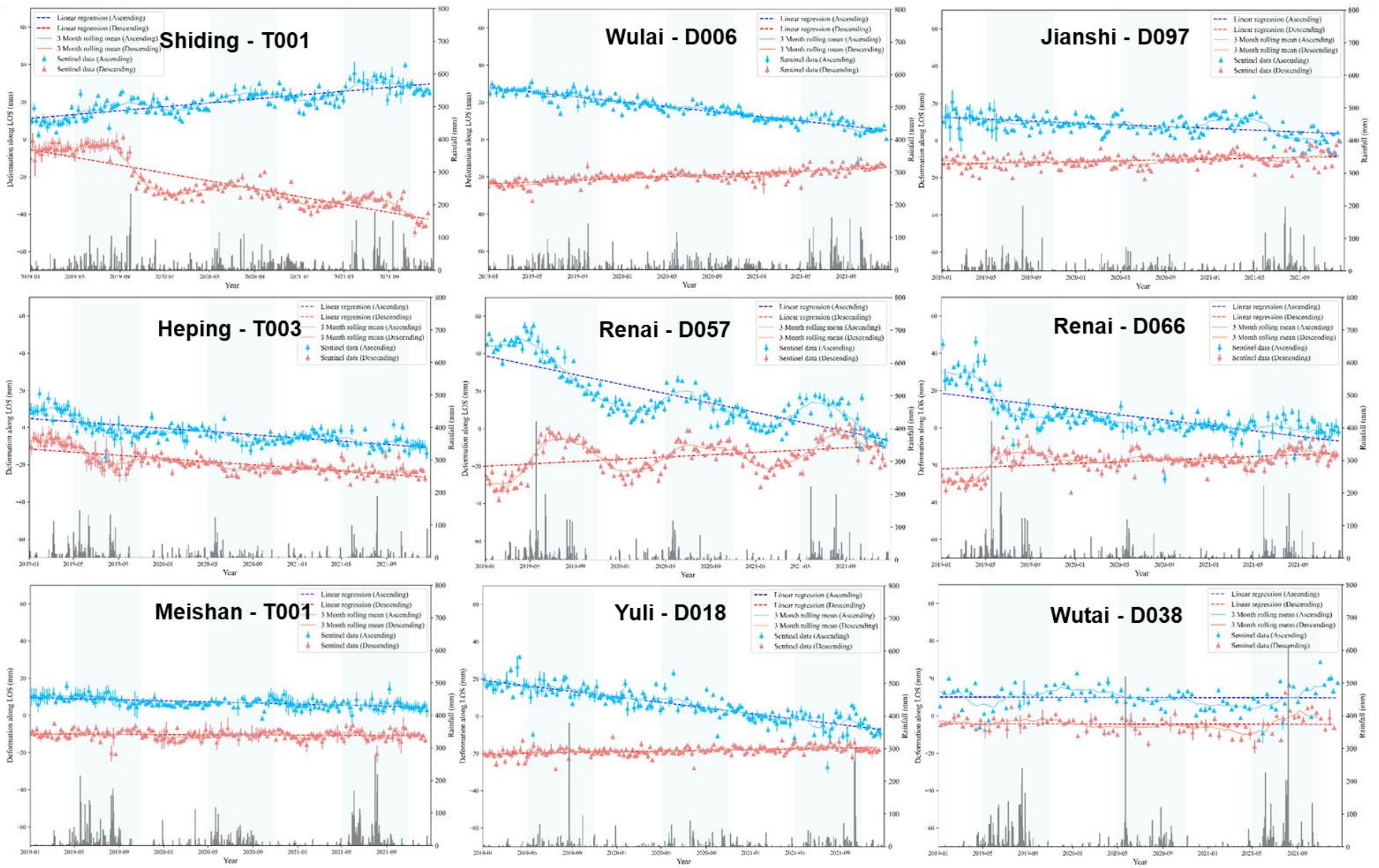
Stanford Method for Persistent Scatterers, StaMPS

The activity of large-scale landslides



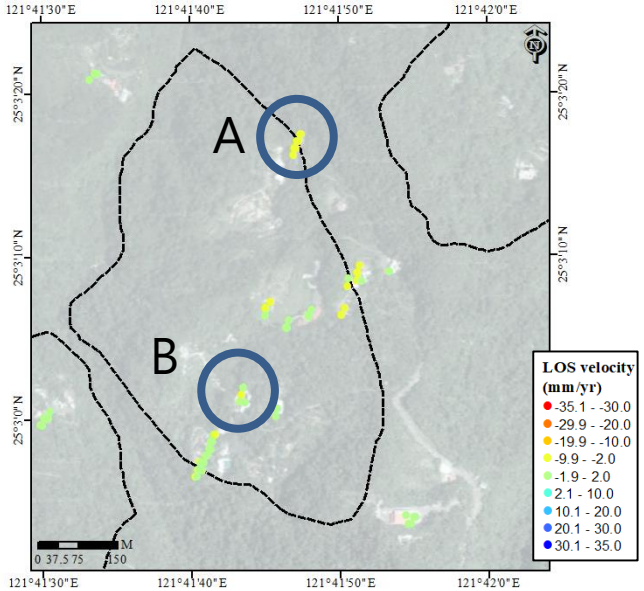
Time series interpretation

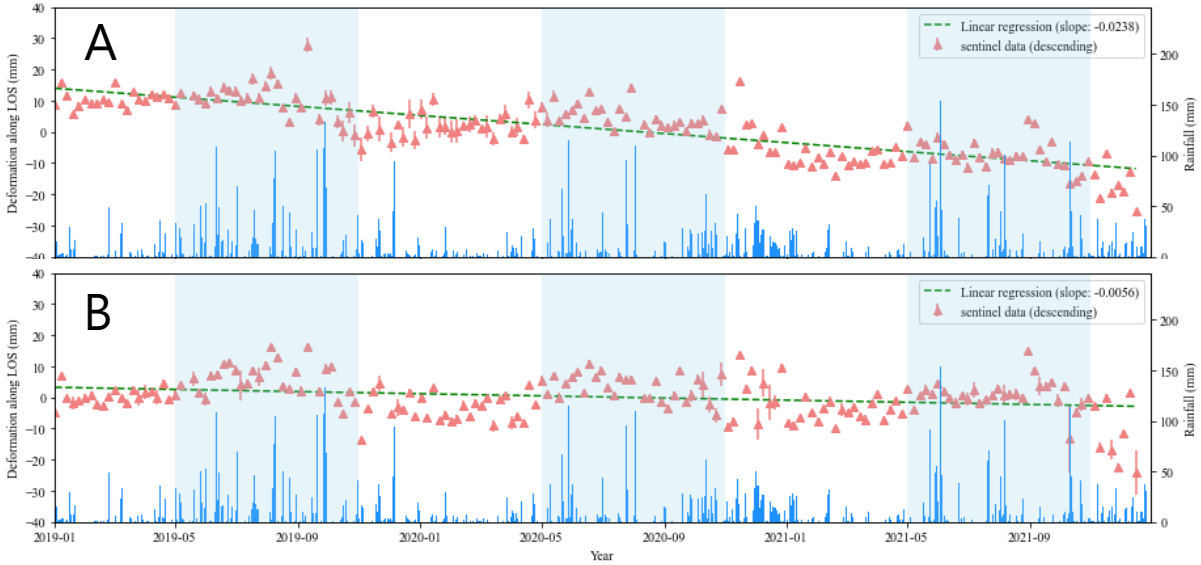




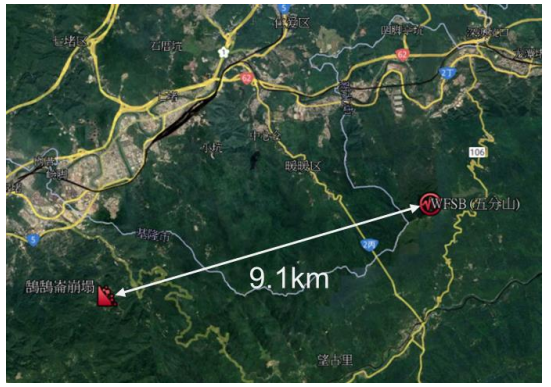
Landslide in Huhulun, 2022

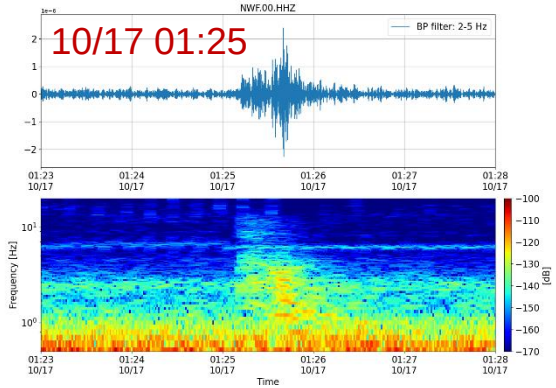
- 2019-2021 PSInSAR result (descending)

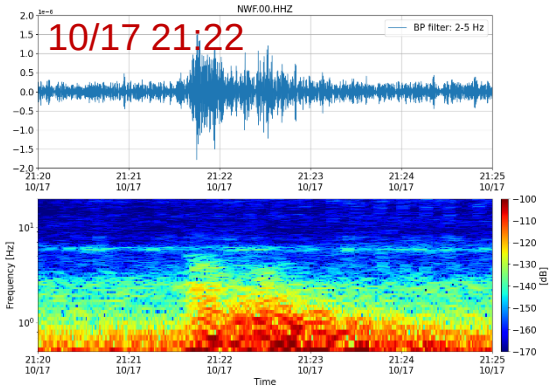


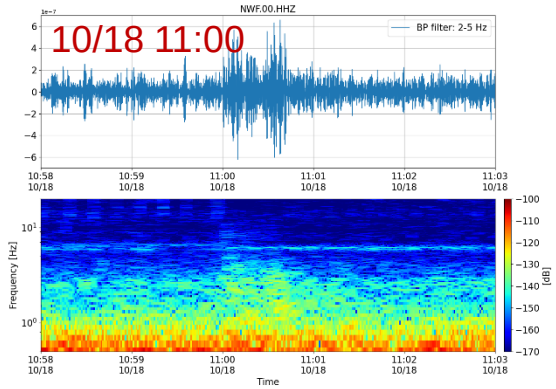


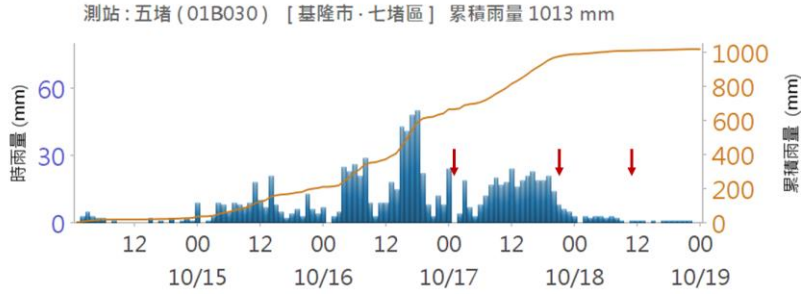
- Seismic wave recorded by WFSB Broadband Station





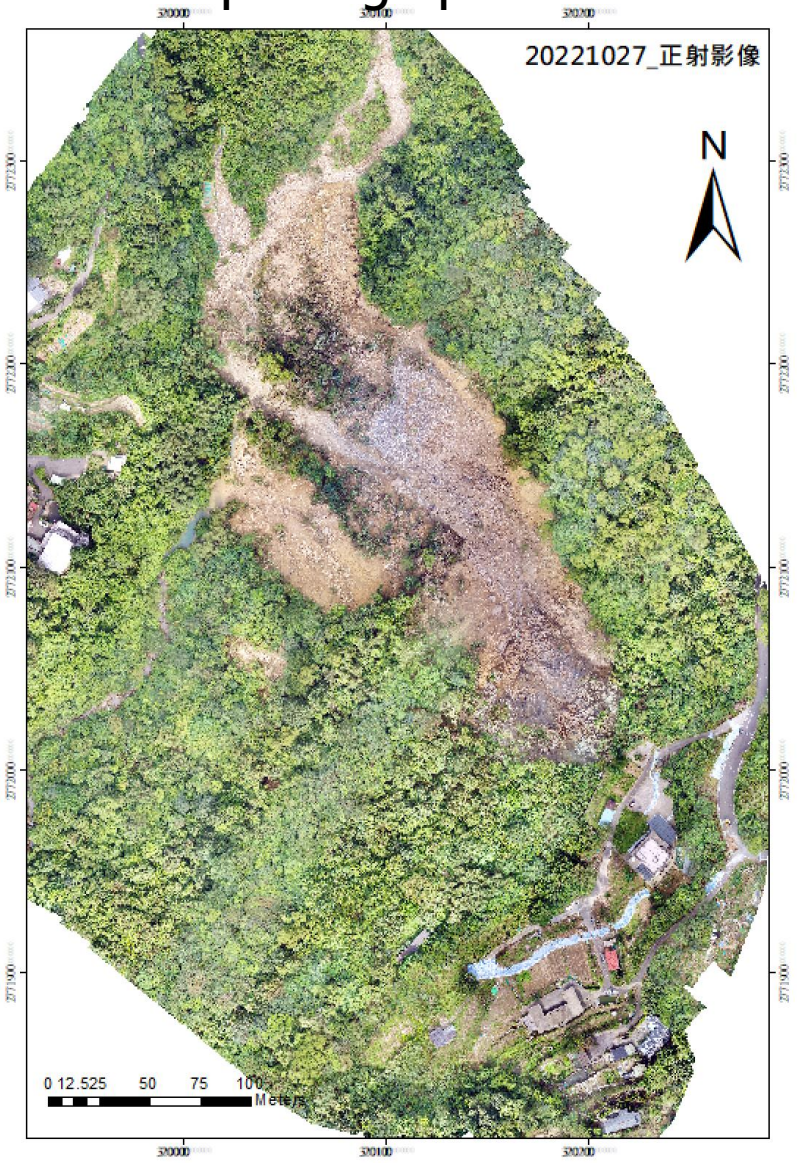


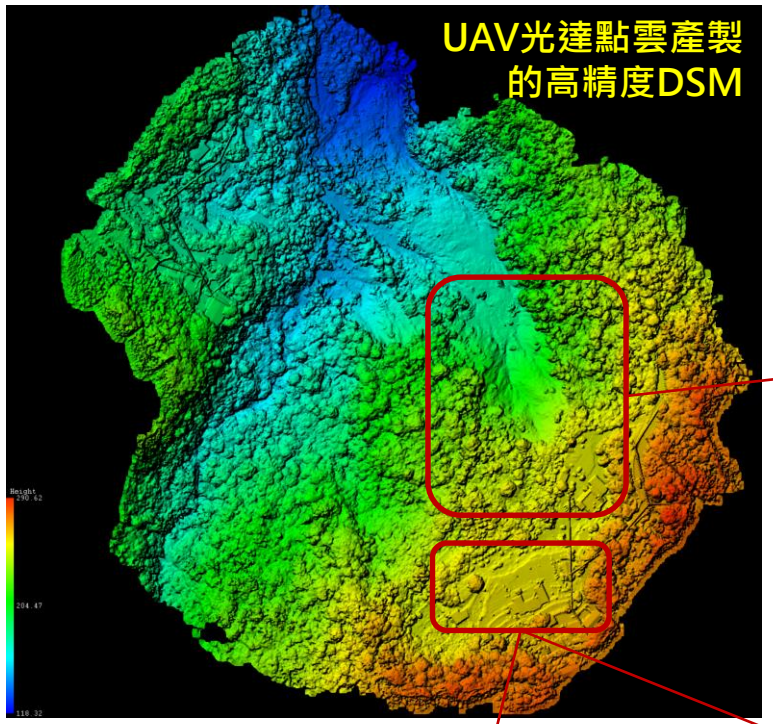




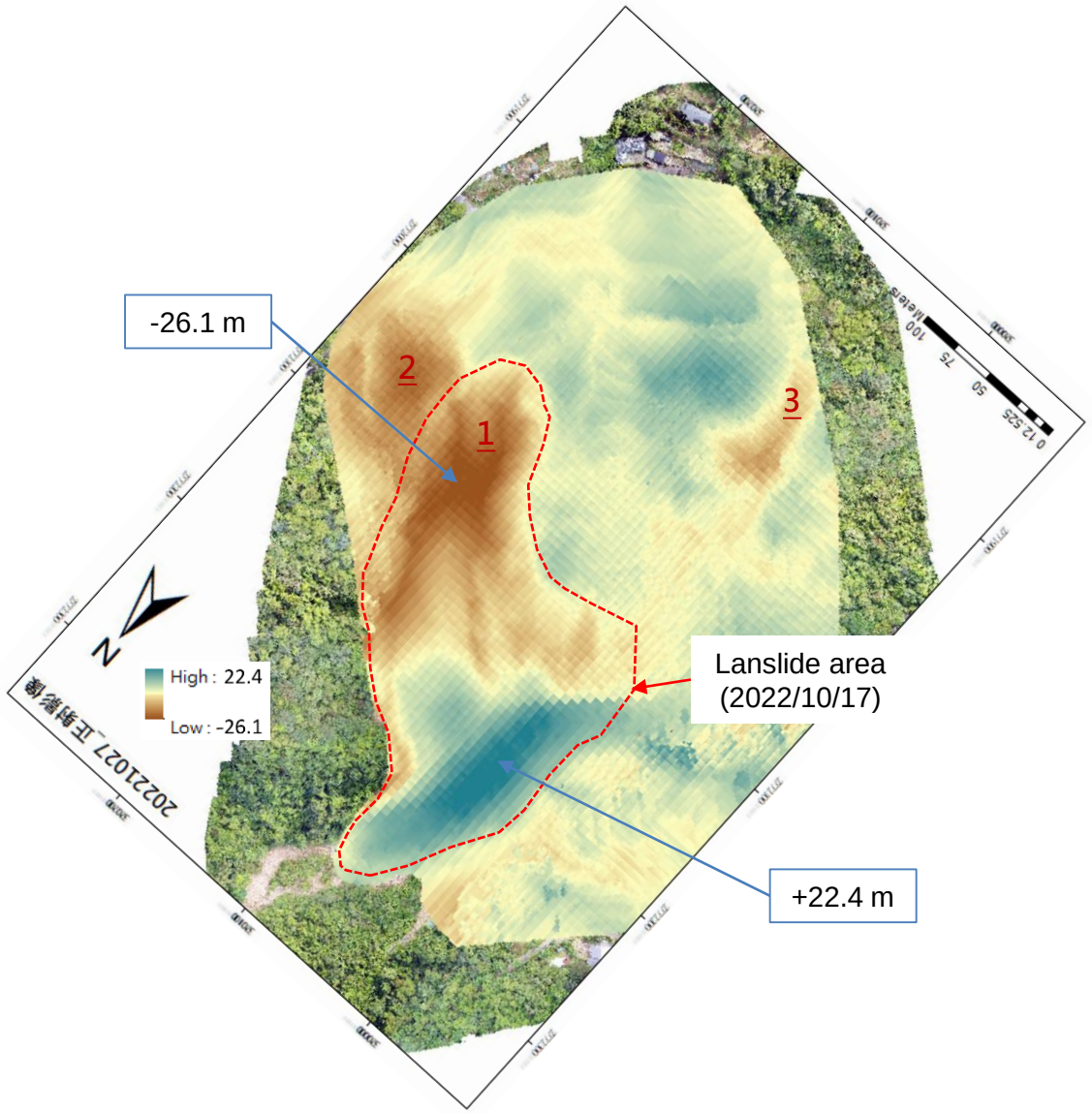
Landslide in Huhulun, 2022

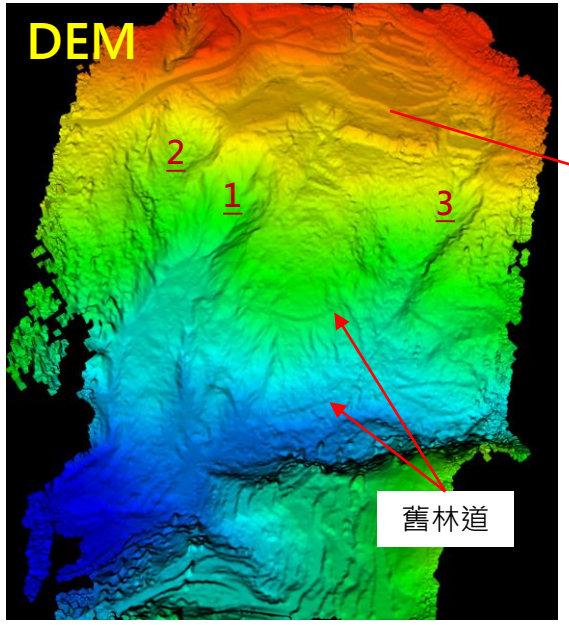
- Orthophotograph and LiDAR scaning in 10/21 and 10/27, 2022





Landslide in Huhulun, 2022





- The geographic features, such as landslide area, ancient scarp, and forest trail could be discovered on DEM (by LiDAR).
- The elevation changes of collapse and deposition areas can be estimated by comparison of dual DEM pairs.

Thank you for listening.