高精密GPS 與現地監測系統應用於順向坡深層滑動之案例研究(2)

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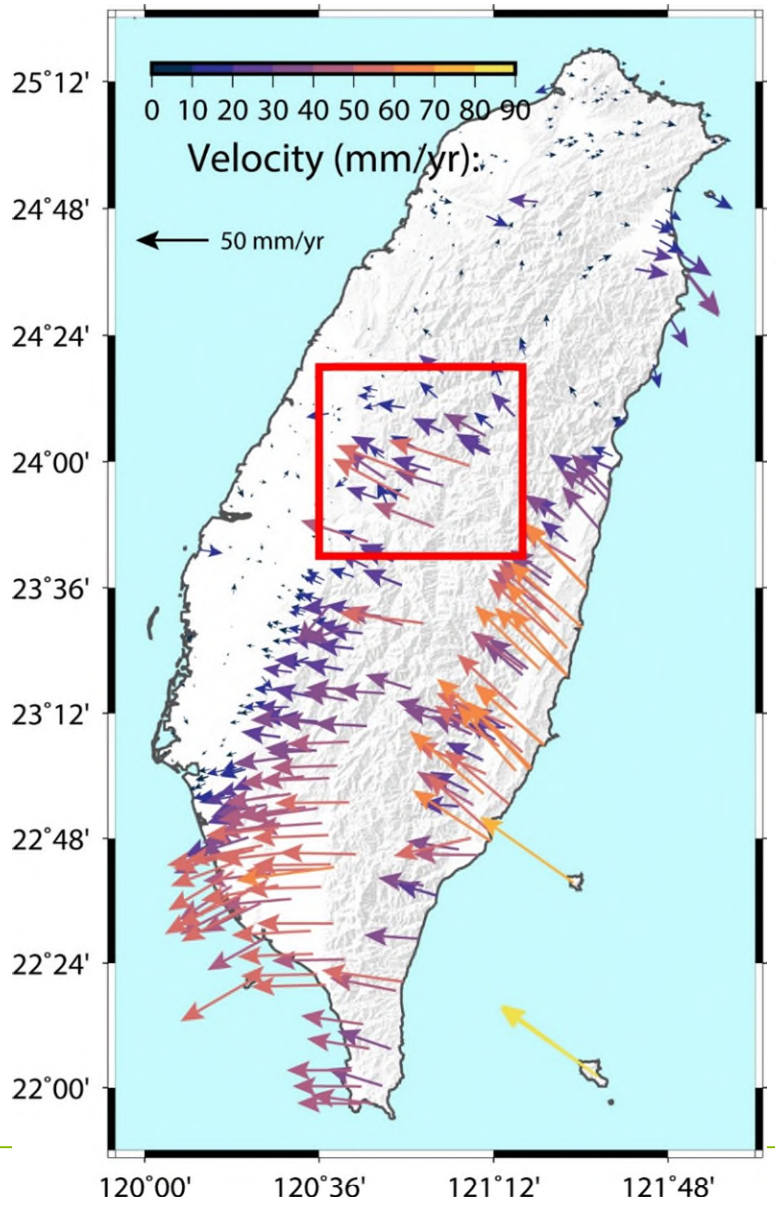
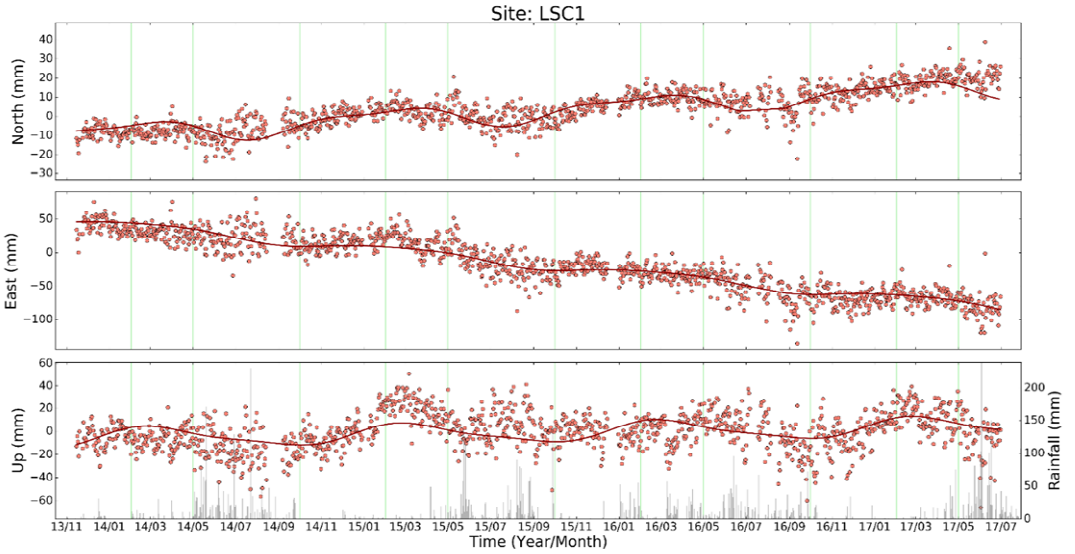
Content

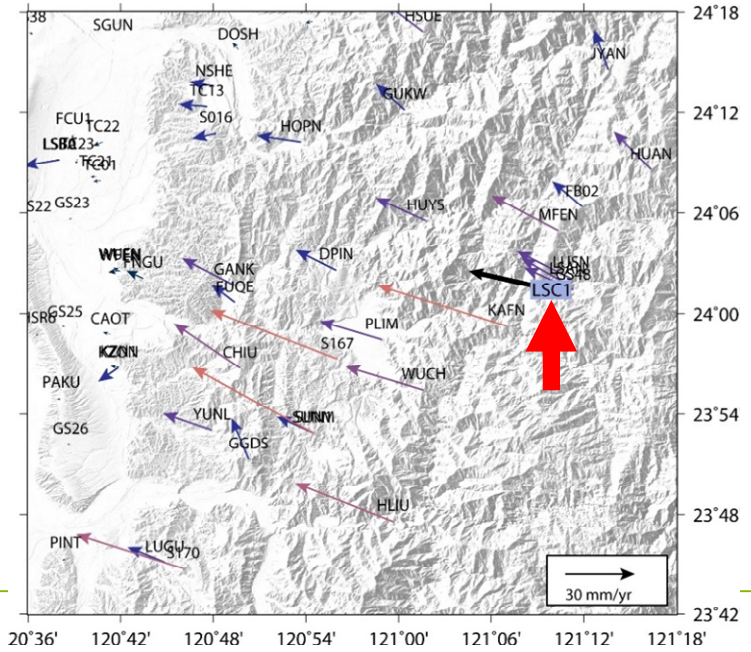
- Common applications of GPS
- GPS applied in sedimentary and metamorphic rocks
- Summary

COMMON APPLICATIONS OF GPS

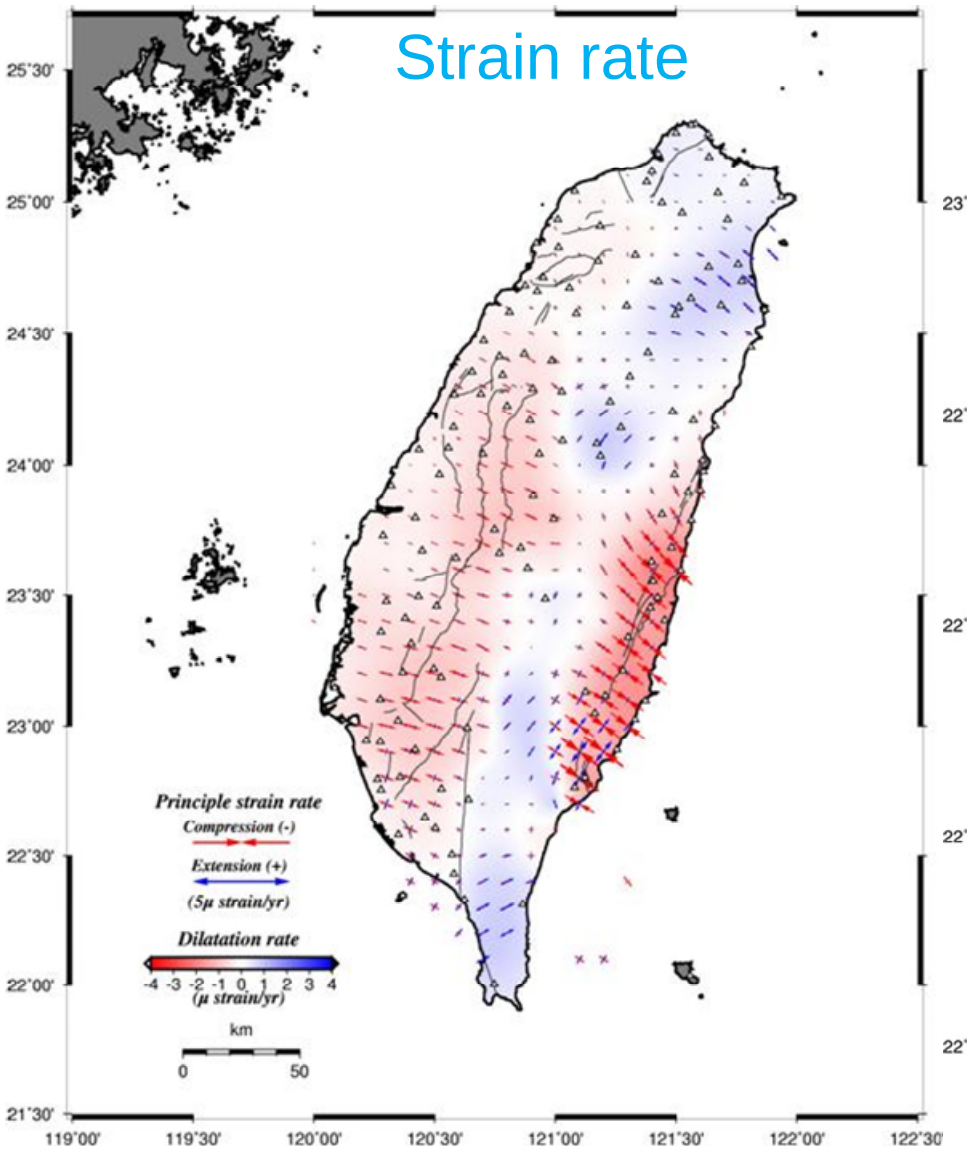
GPS velocity field of Taiwan

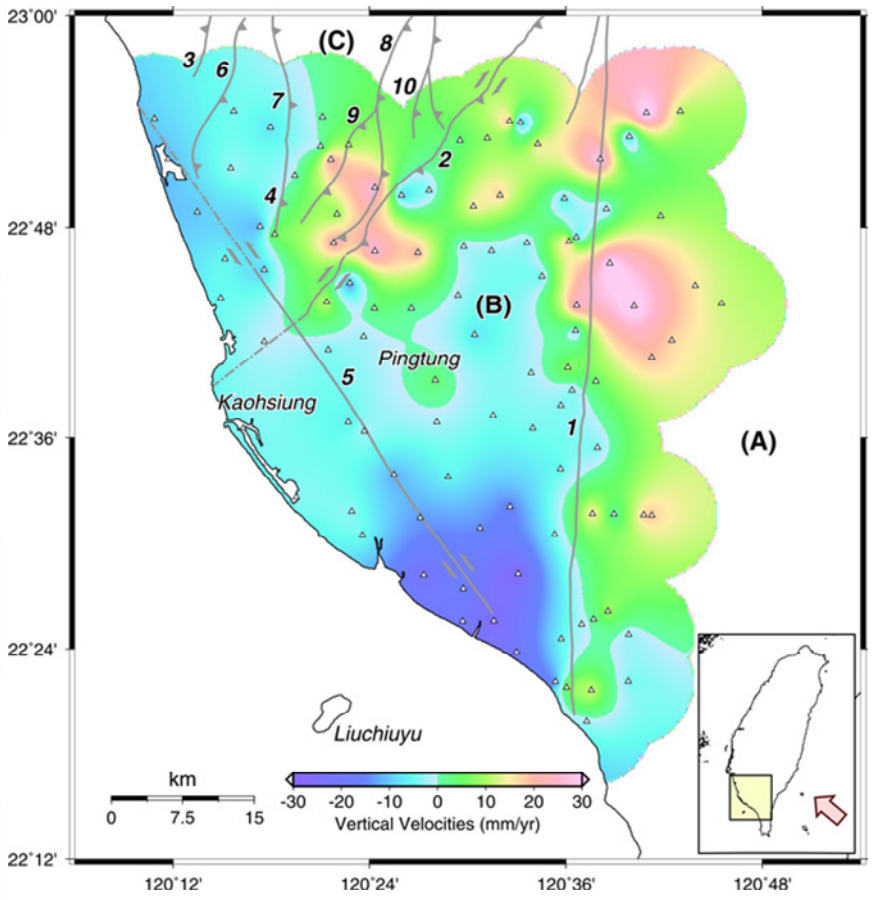






Vertical velocity and strain rate derived from GPS





(Ching et al., 2007)

GPS application to landslide

- Areas of extension and compression
- Movement boundary: fault, slip/sliding limit
- Areas of uplift and subsidence

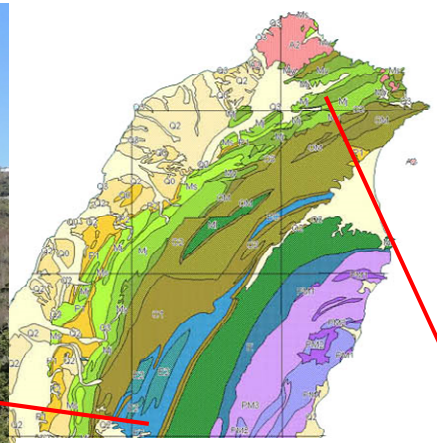
→ For slope movement study:
Landslide area, failure mechanisms, movement trend.

GPS APPLIED IN SEDIMENTARY AND METAMORPHIC ROCKS

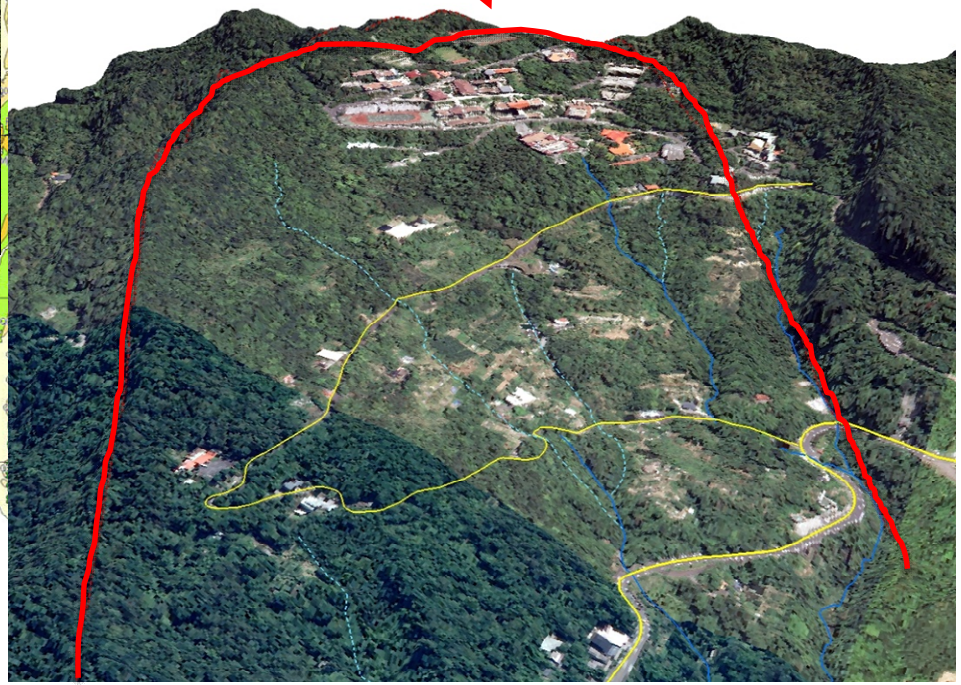
Study sites



Lushan (slate)



Dalunshan
(sand and shale)



Surface deformation

Lushan





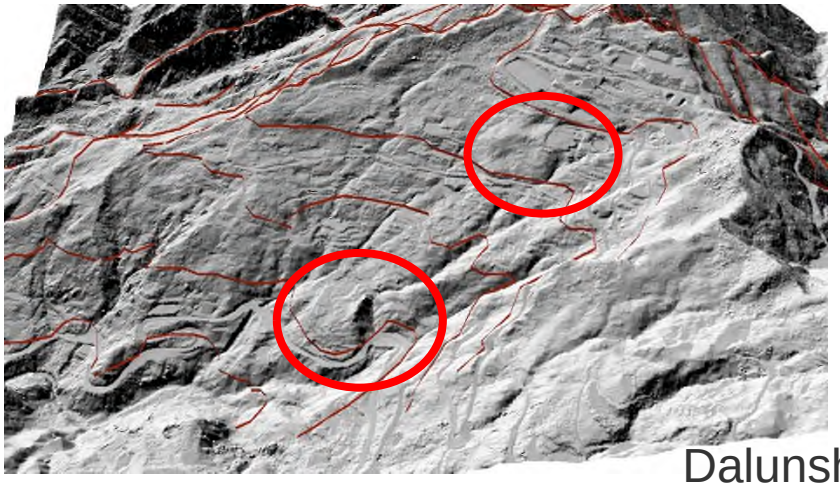
Dalunshan

Splitting of the retaining walls



Lushan

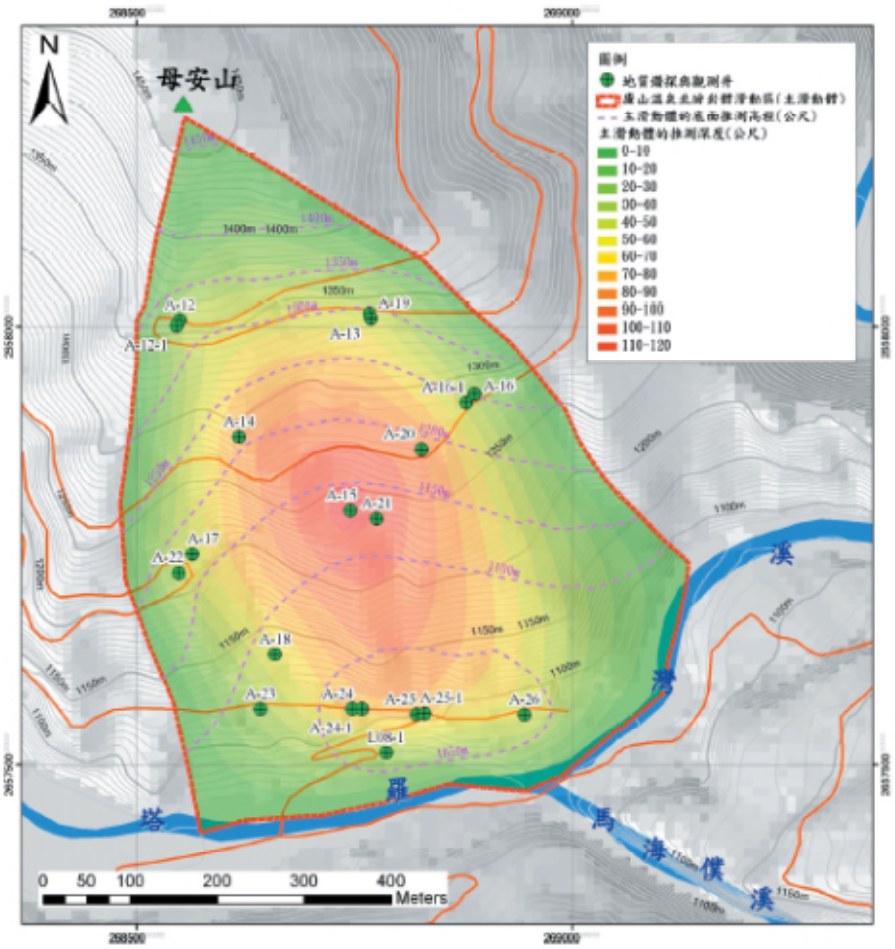
Kink structure and buckling fold



Dalunshan

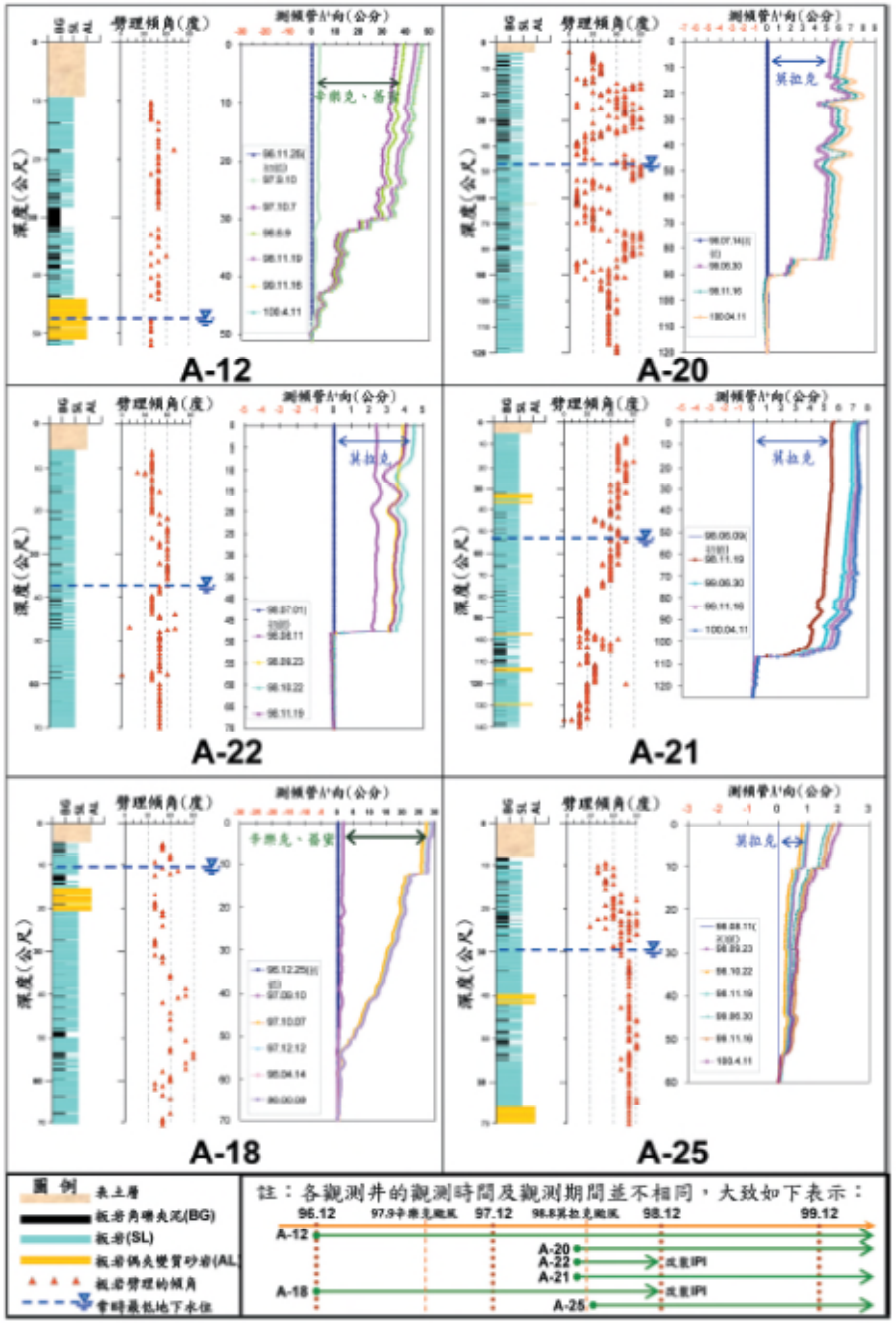
Accumulation and bulge at toe

Depth of the sliding surface of Lushan north slope



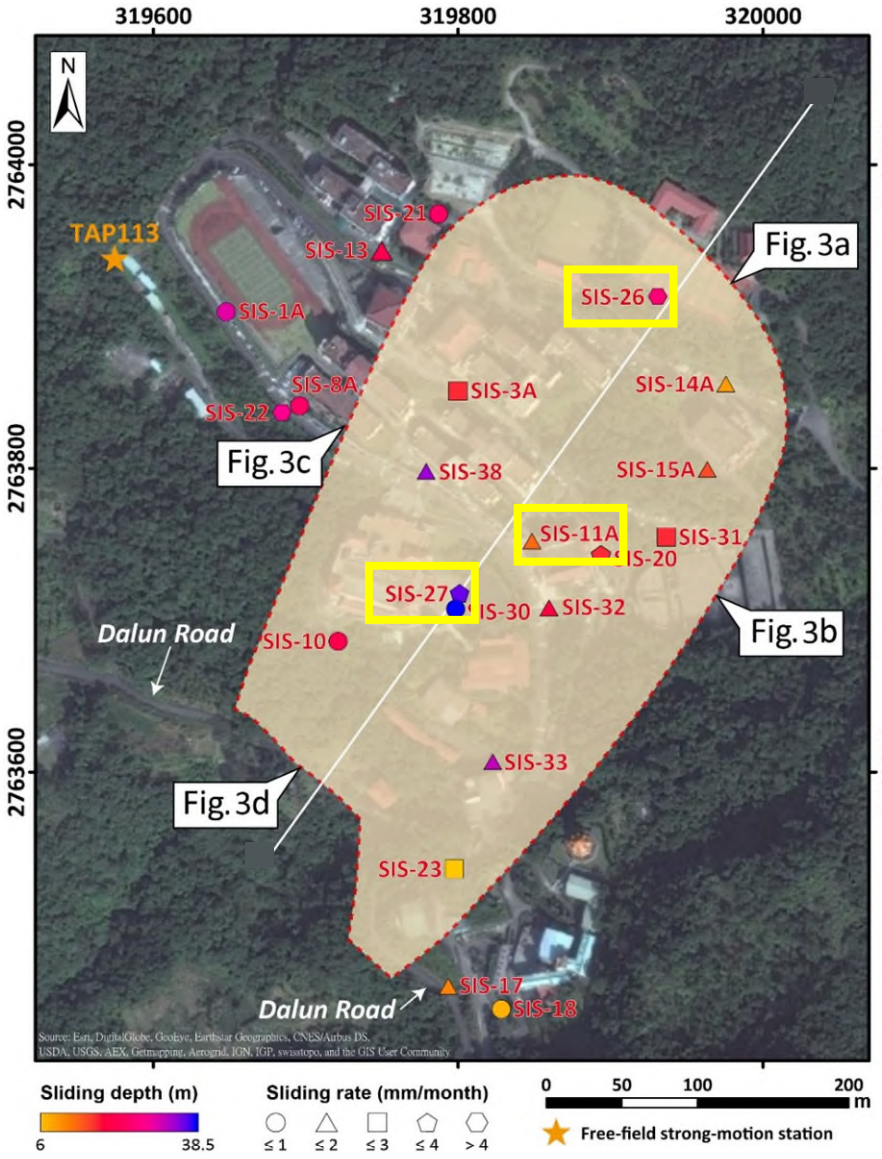
林錫宏、紀宗吉, 2012

Heavy rainfall events accompanied by large slip at 30–100 m deep sliding surface, while moderate slip occurred inter-annually above 20-30 m deep.

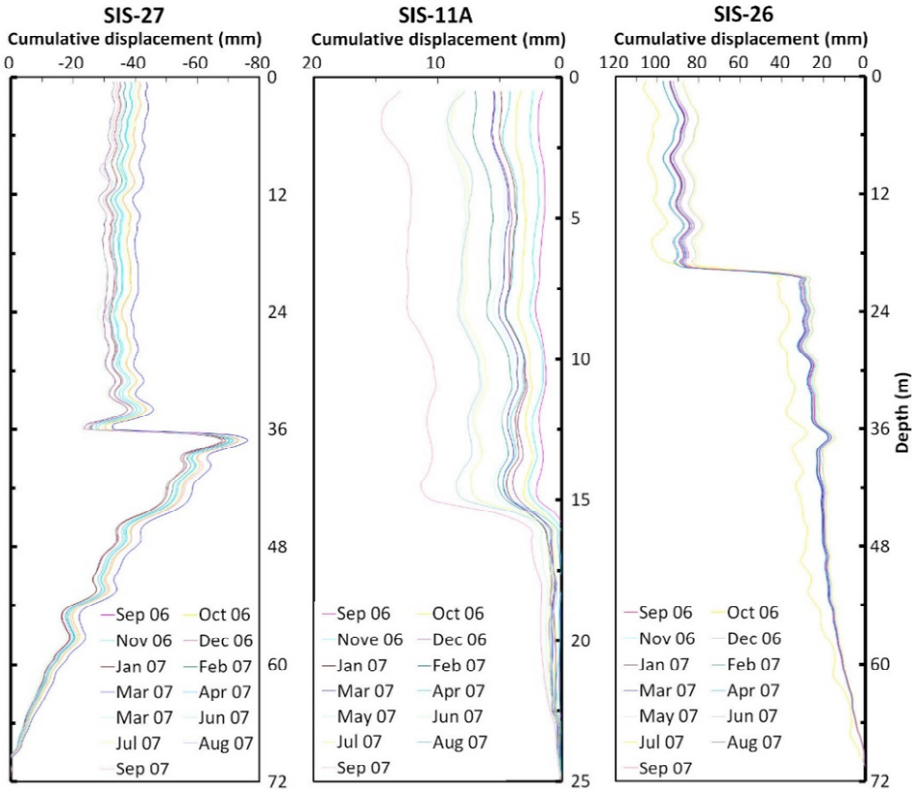


Data derived from inclinometers

Depth of the sliding surface of Dalunshan



Data derived from inclinometers



(Tseng et al., 2017)

GPS observations

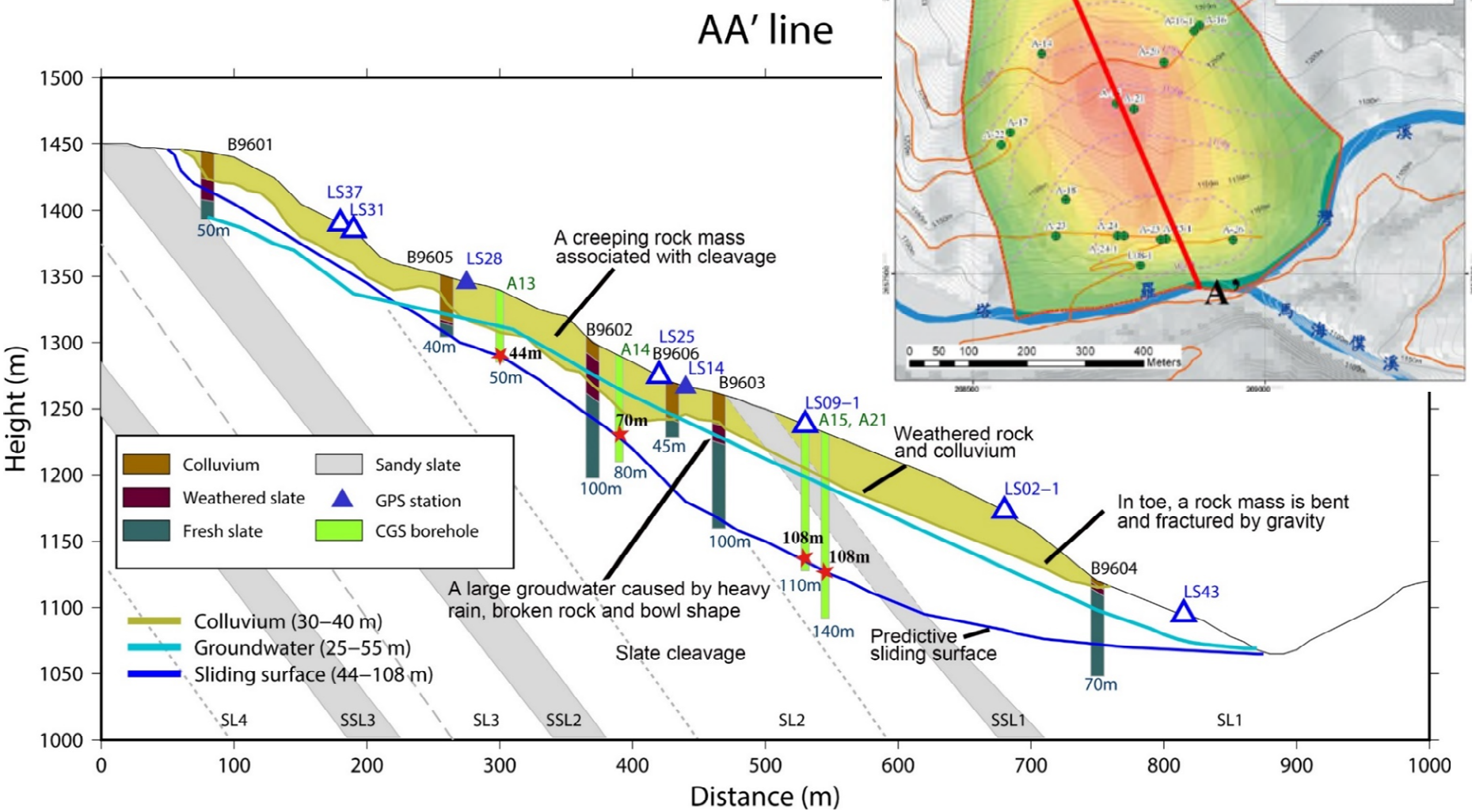
Single-frequency	
Receiver type	TU840 L1 GPS Allis communications co., ltd.
Antenna type	GLONASS OUTDOOR ANTENNA Allis communications co., ltd.
Processing software	RTKLIB

Dual-frequency	
Receiver type	Net R8 GNSS Trimble Navigation Limited.
Antenna type	Zephyr 2 Geodetic Trimble Navigation Limited.
Processing software	Bernese 5.0



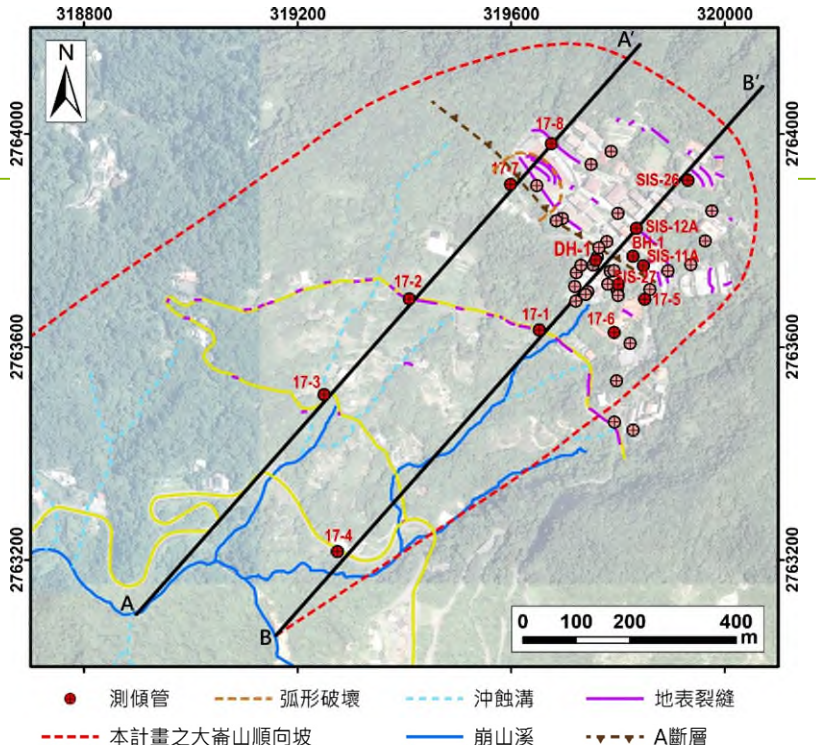


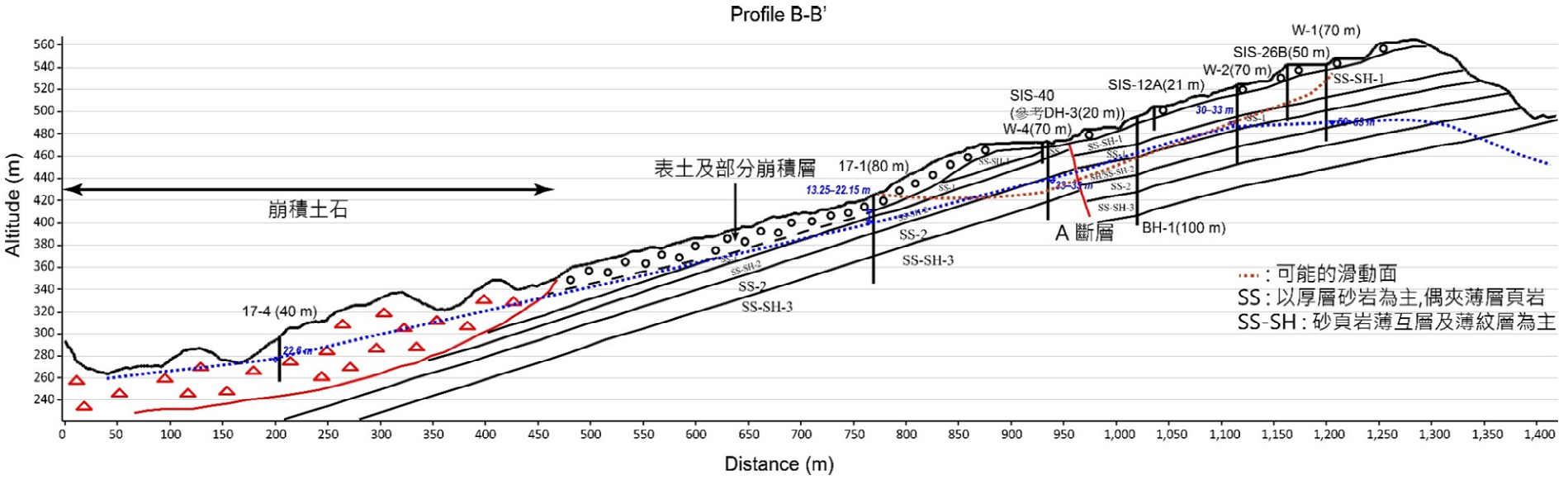
Along-dip landslide of Lushan north slope



Modified from 廬山地滑監測及後續治理規劃報告書，2007；林錫宏、紀宗吉, 2012

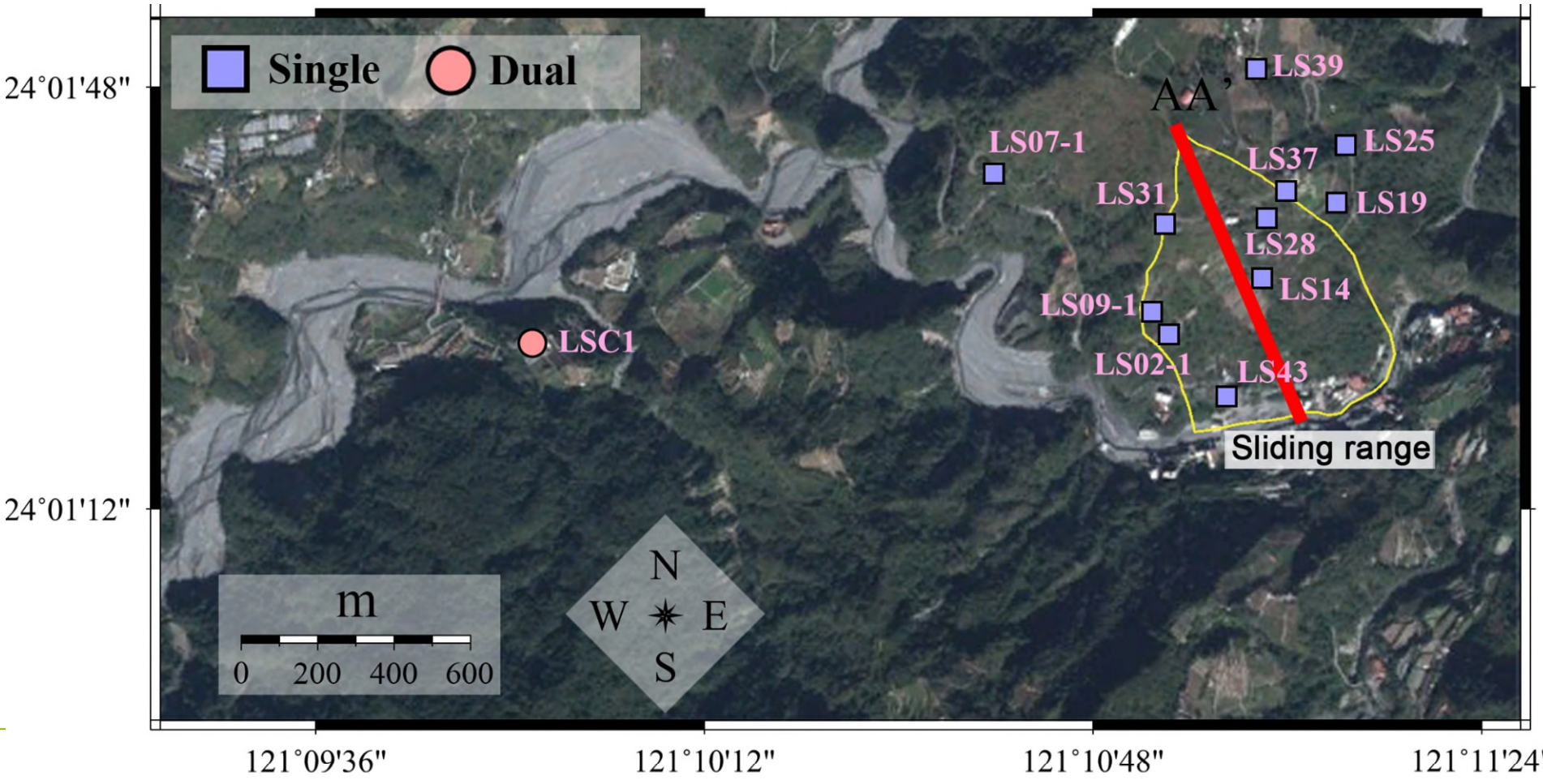
Dalunshan dip slope





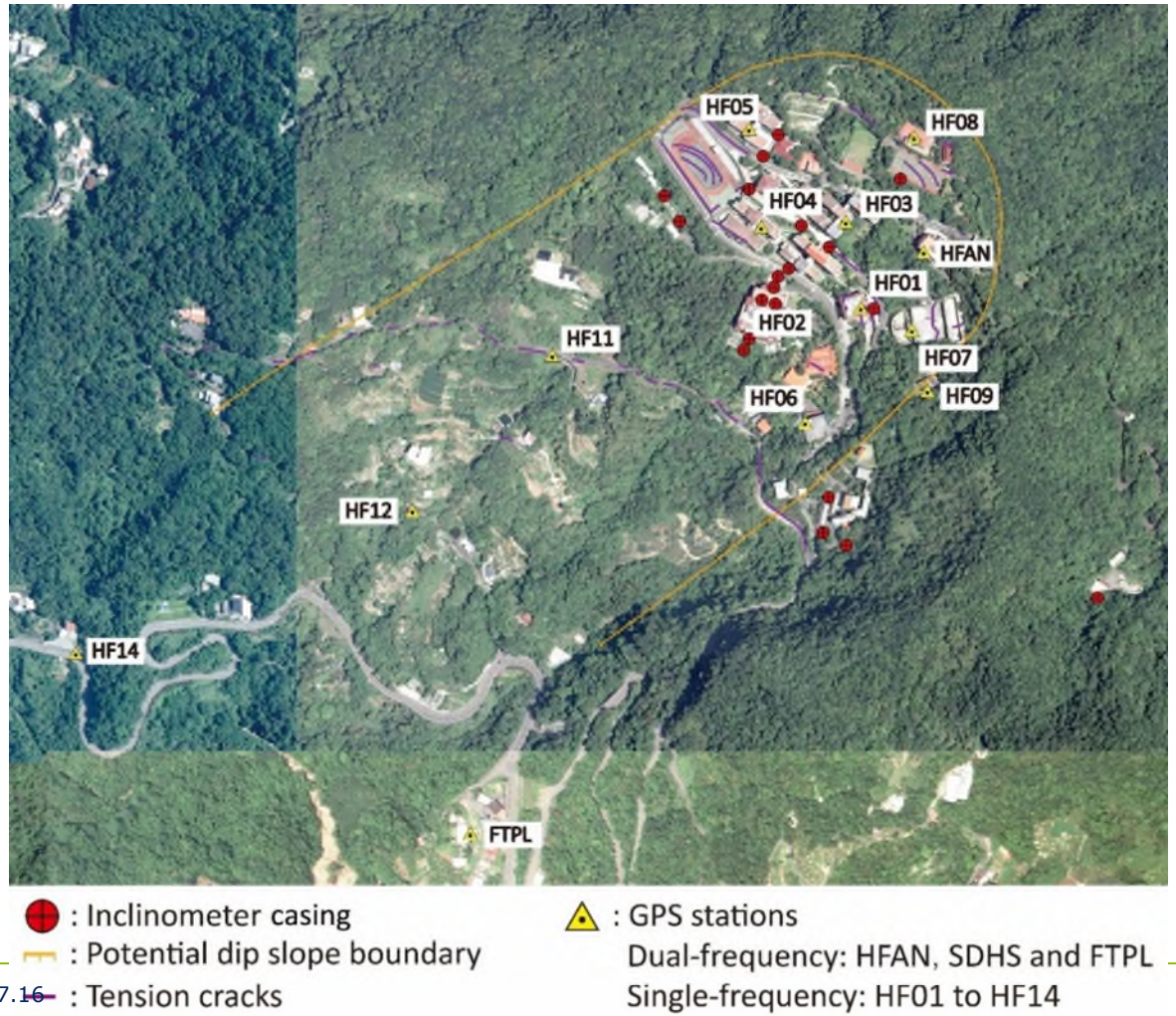
GPS network on Lushan north slope

- 1 Dual- and 11 Single-frequency GPS stations
- November 2013 ~ present



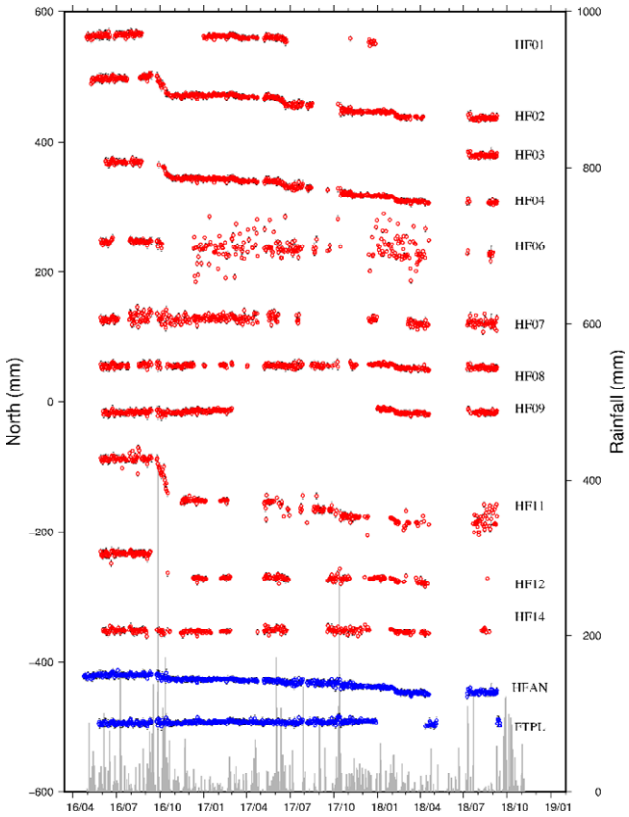
GPS network on Dalunshan dip slope

- 2 Dual- and 12 Single-frequency GPS stations
- May 2016 ~ present

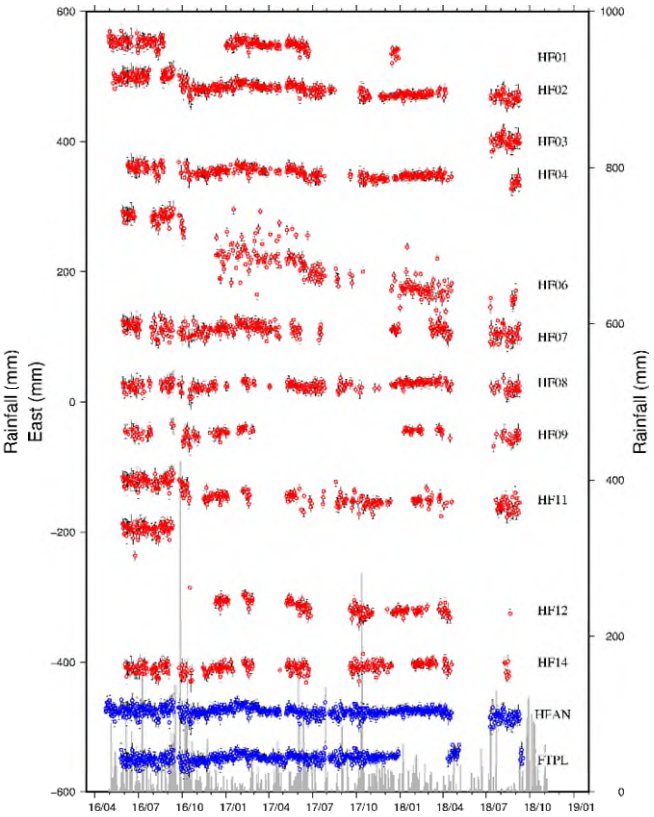


GPS time series of Dalunshan

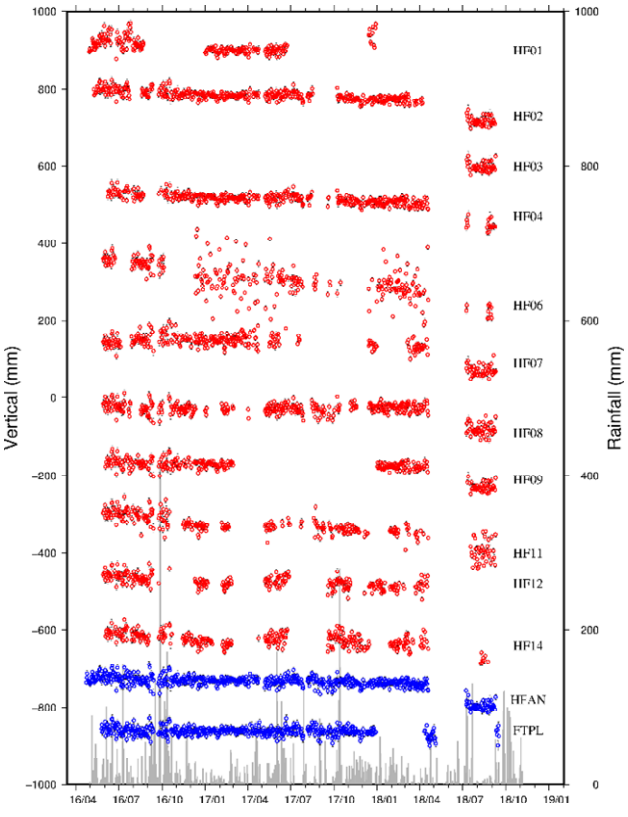
Daily solution during 2016.04–2018.10



N-S component



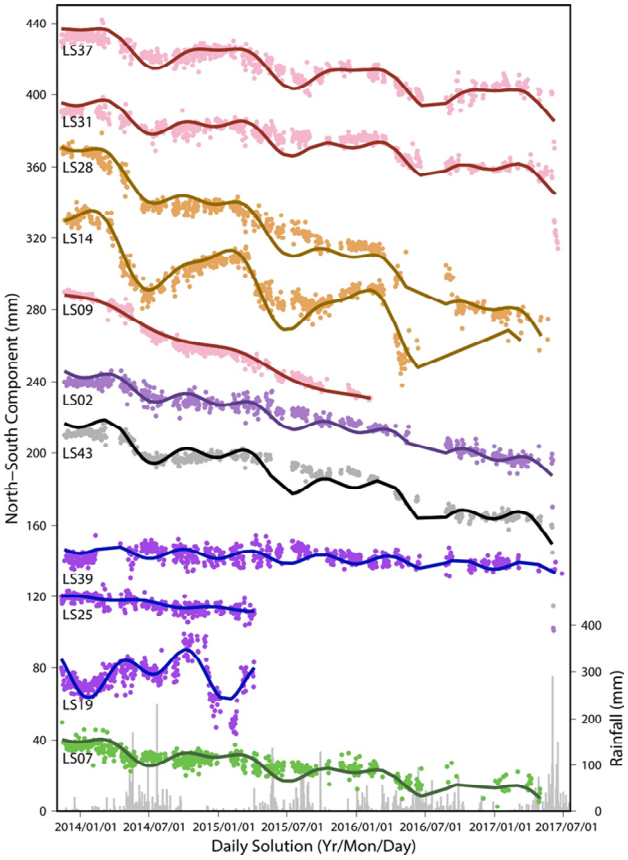
E-W component



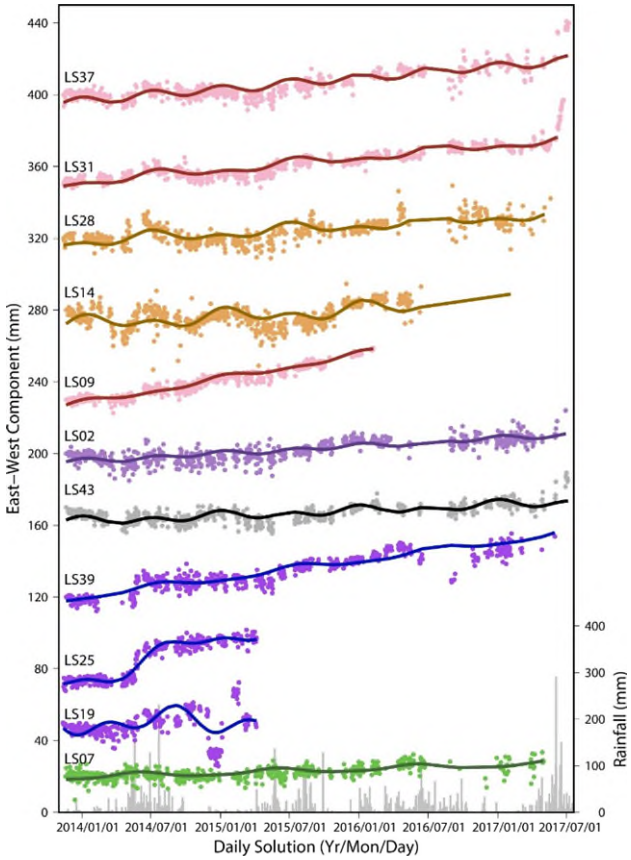
Vertical component

GPS time series of Lushan north slope

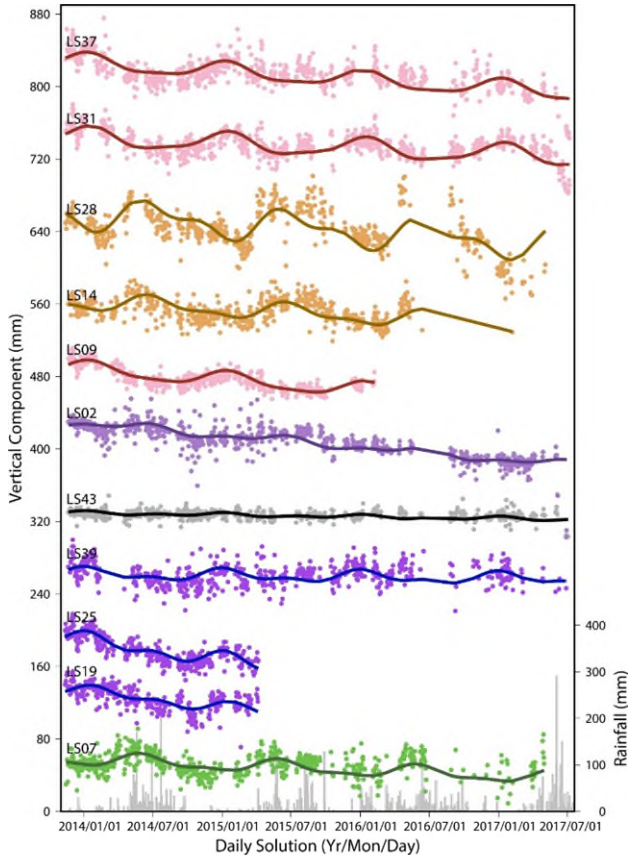
Daily solution during 201401.01–2017.07.01



N-S component

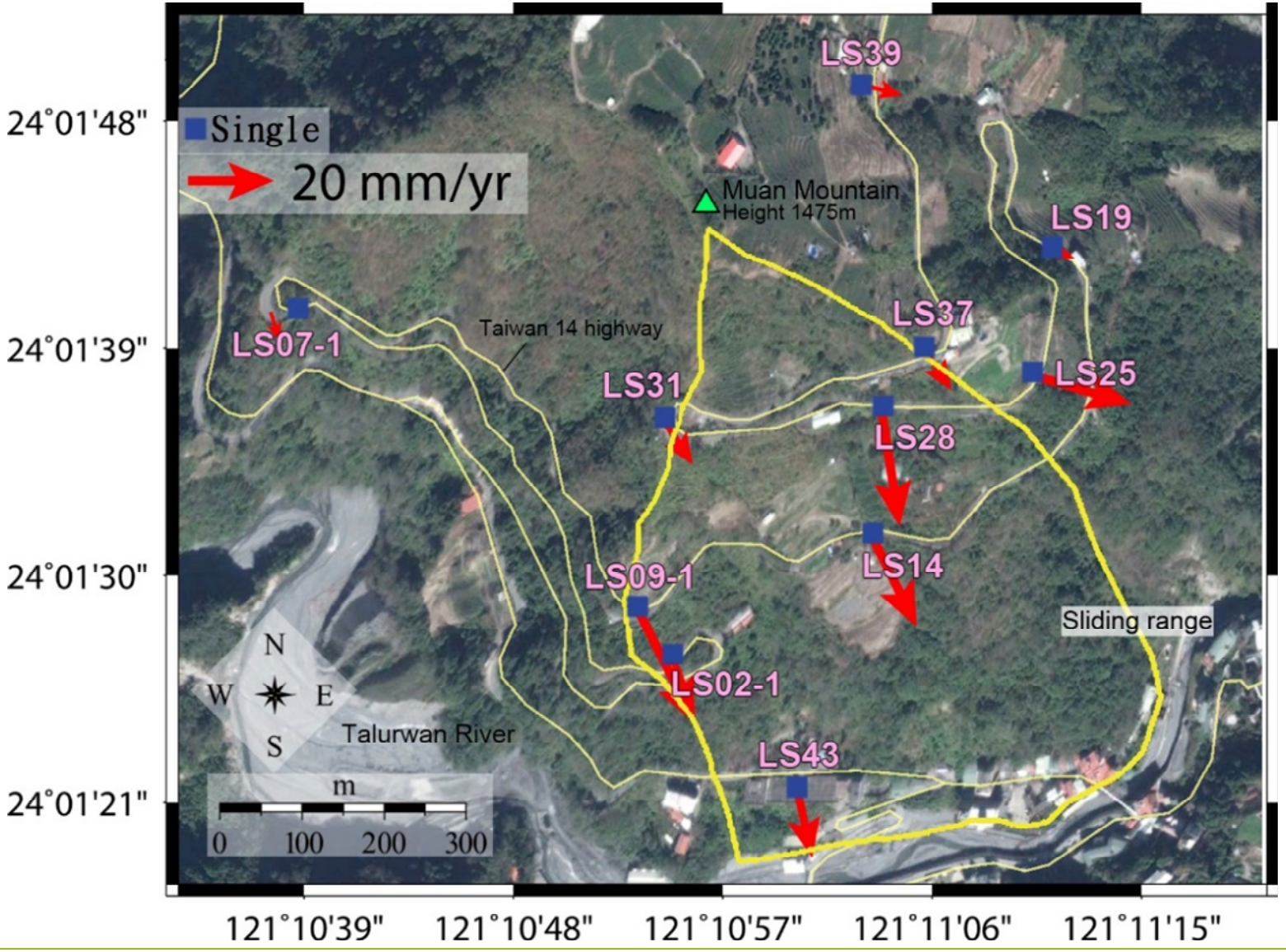


E-W component

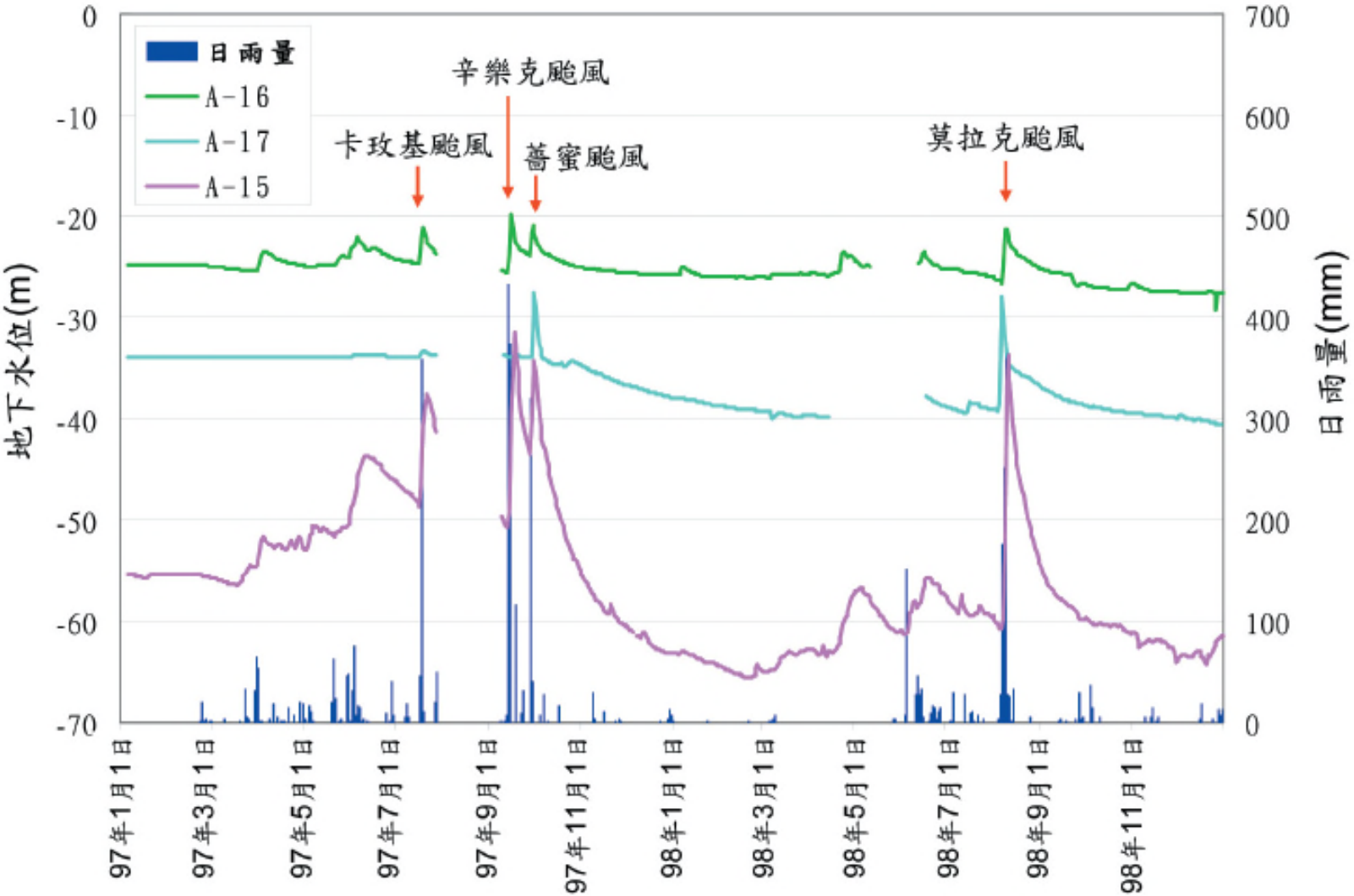


Vertical component

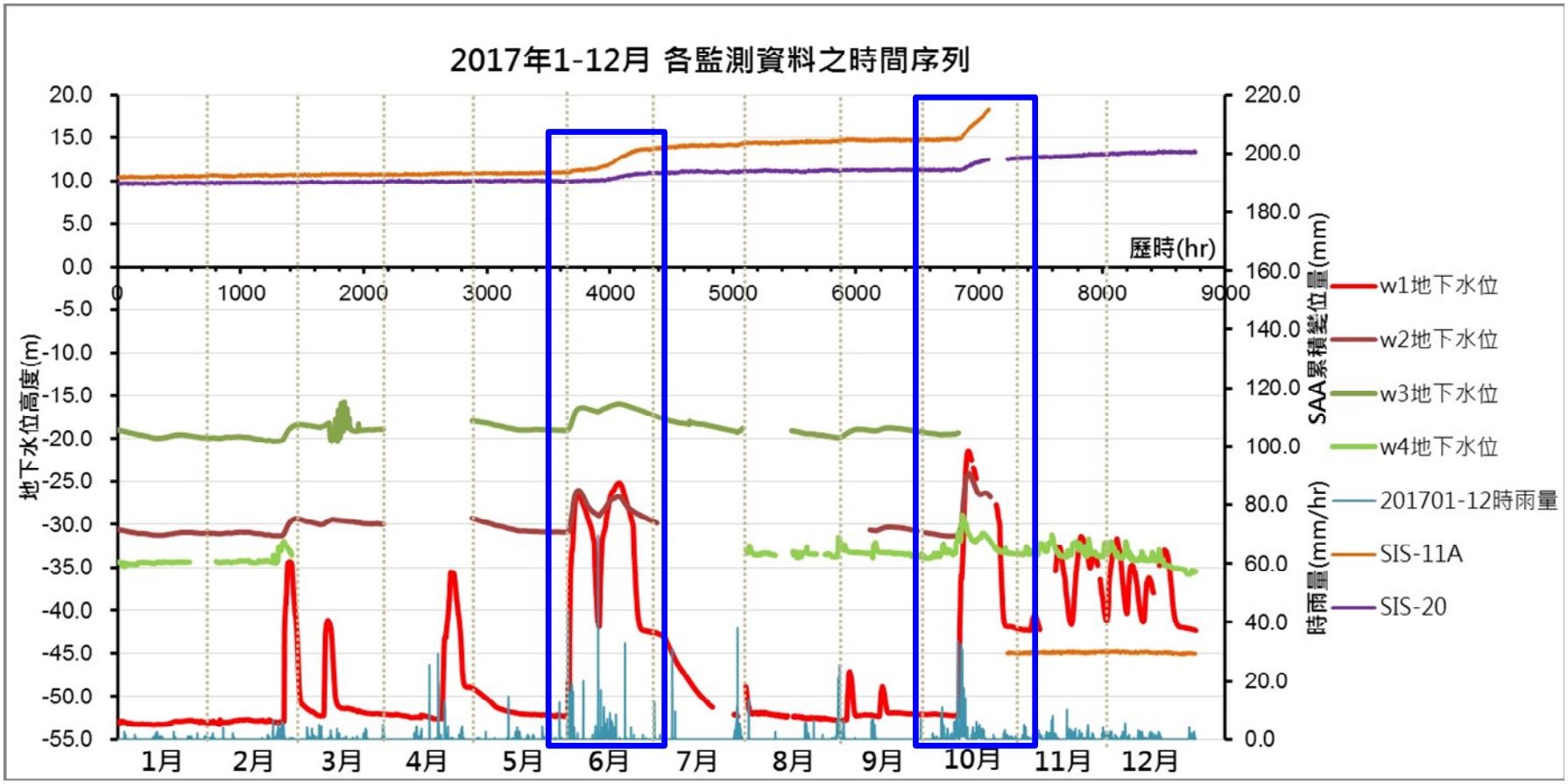
Horizontal velocity field of Lushan



Rainfall and groundwater are positively correlated on **Lushan north slope**

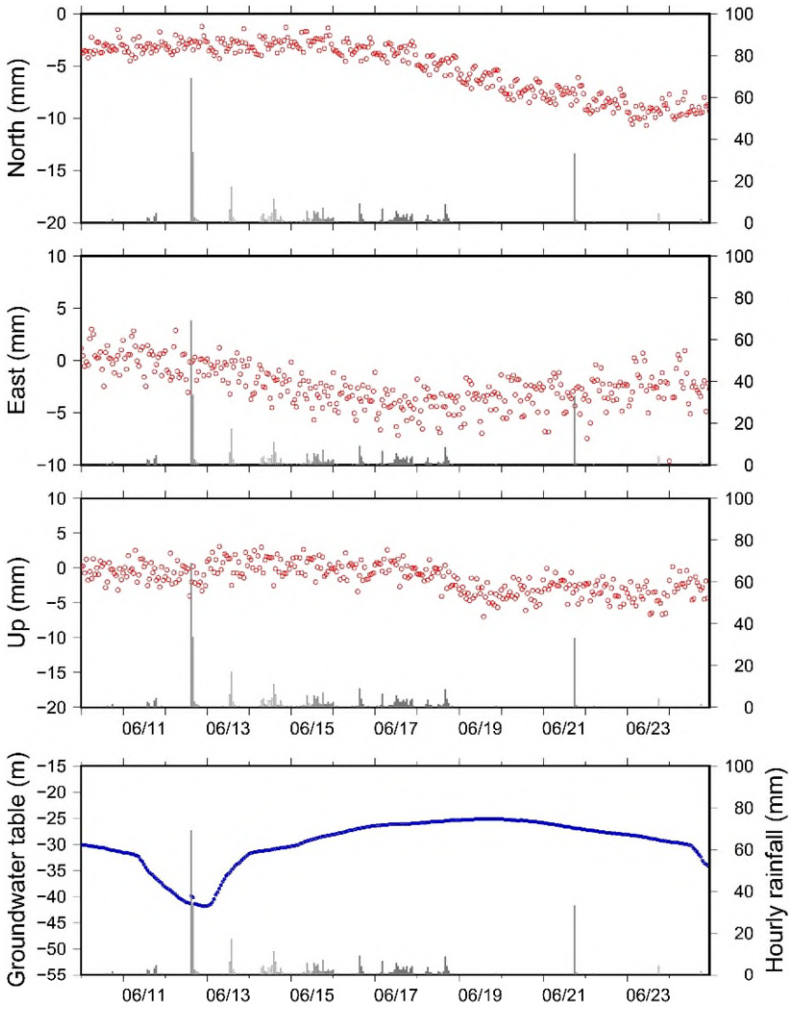


Rainfall and groundwater are positively correlated on Dalunshan dip slope

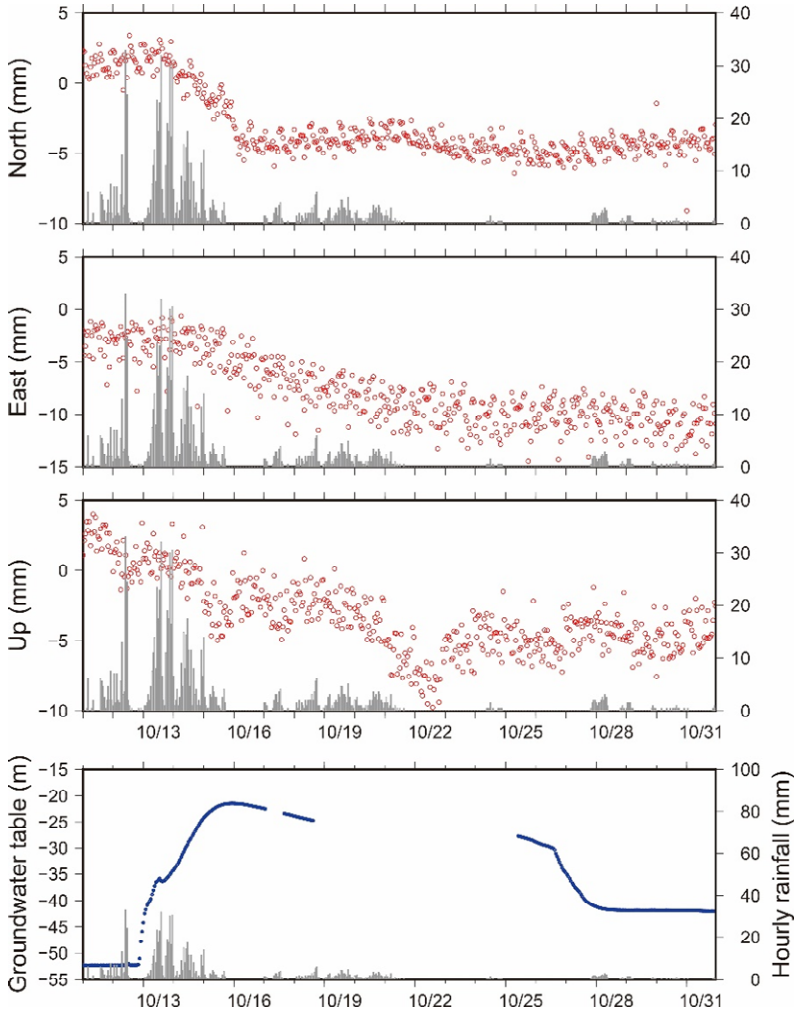


Surface displacement (hourly)

HF02 (2017.06.10-24)

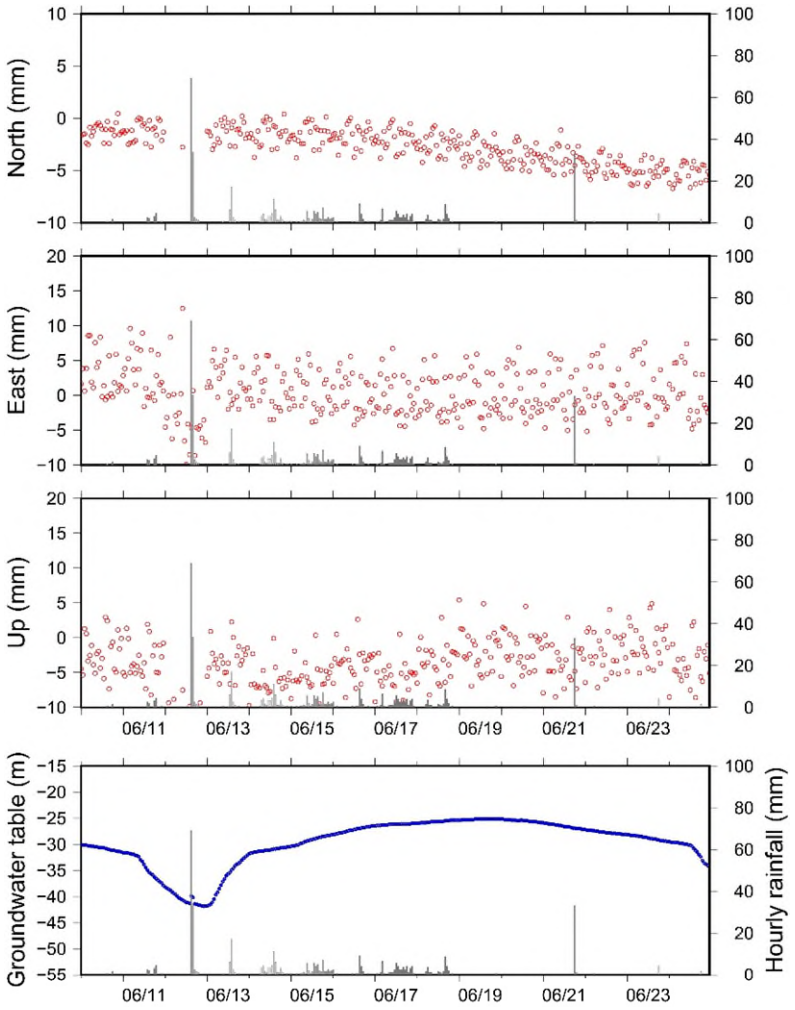


HF02 (2017.10.11-31)

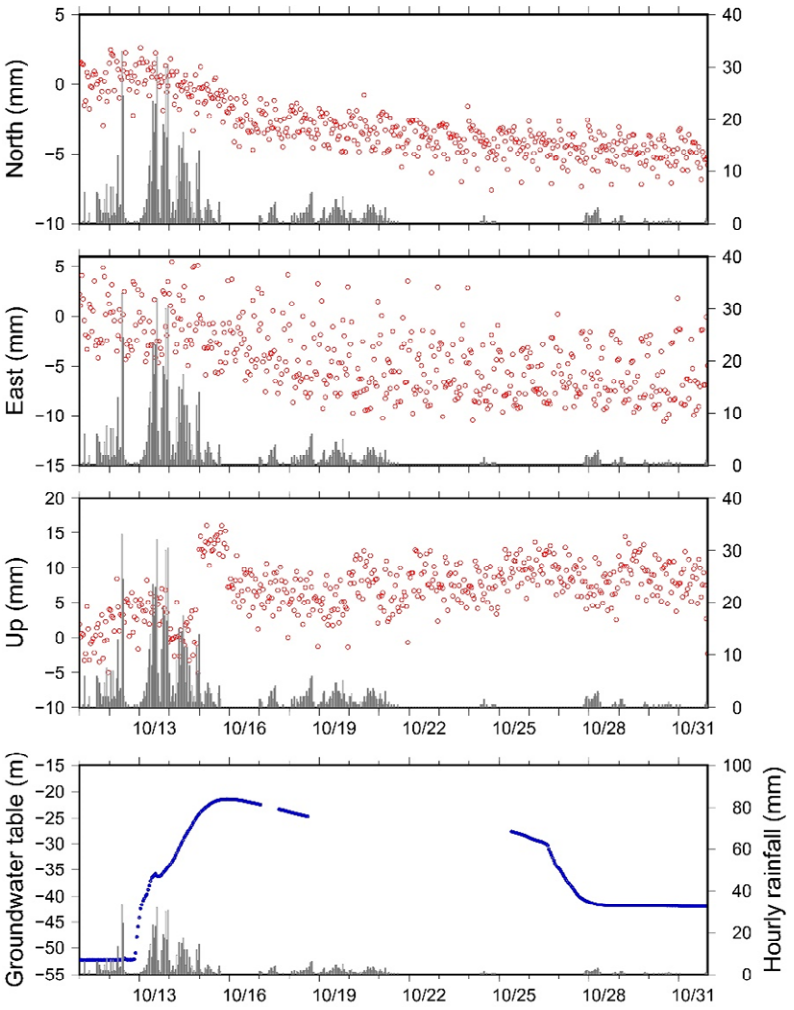


Surface displacement (hourly)

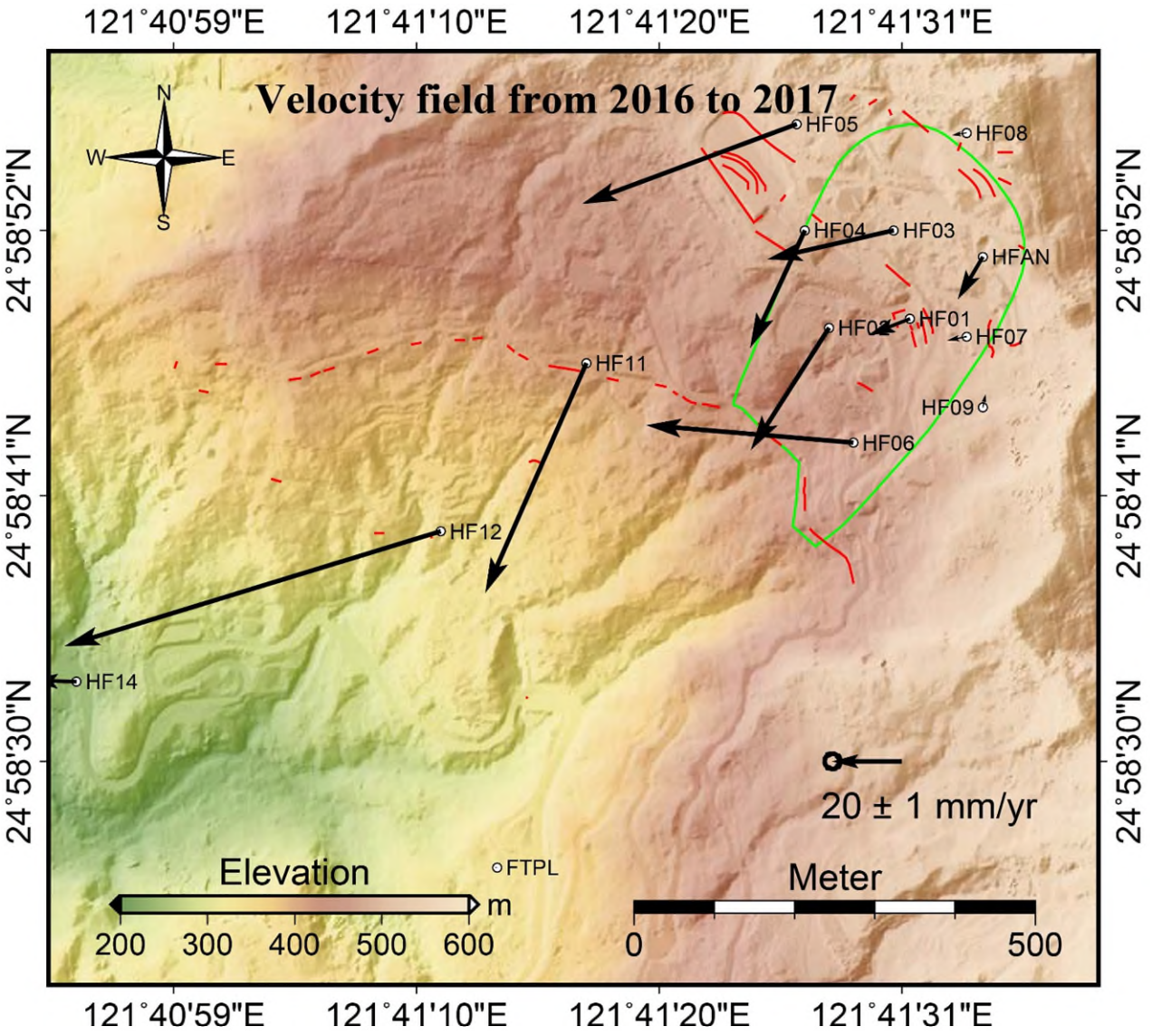
HF04 (2017.06.10-24)



HF04 (2017.10.11-31)



Horizontal velocity field of Dalunshan



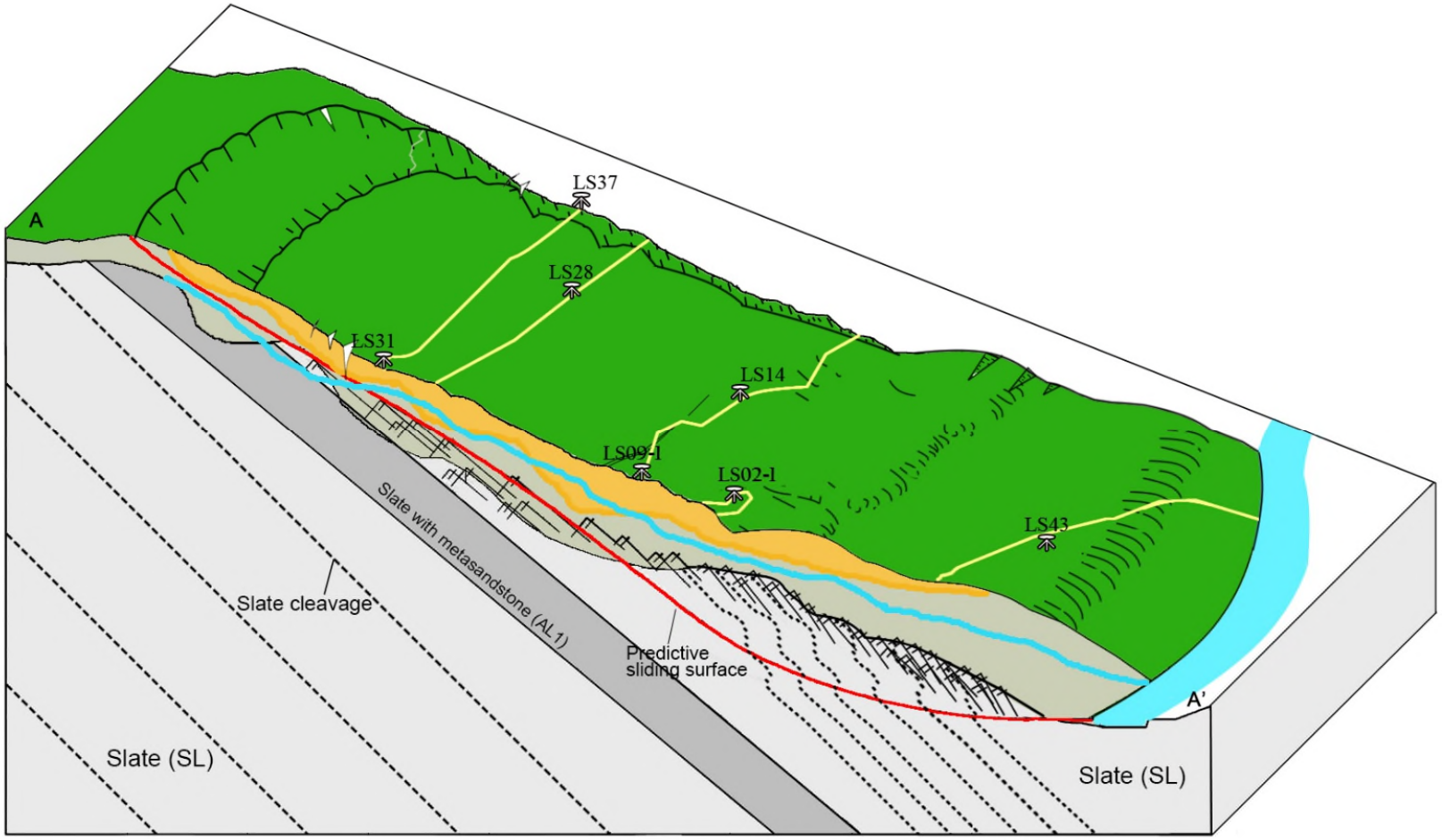
SUMMARY

Summary

- **Signs of slope movement** (in-situ survey)
  - splitting of artificial structures
  - surface cracks defining boundary; kink fold, buckling and bulge appearing at toe
- **Monitoring**
  - surface: GPS, leveling, surface point network
  - underground: inclinometer
  - rainfall gauge, groundwater gauge
- **Triggering by rainfall**
  - no rain: still or creeping
  - light rain: shallow, small-scale slip
  - heavy rain: deep, large-scale slip or faster creeping

→ sliding surface submerged by groundwater or not

- **Changes of creeping rate and the aquifer elasticity are critical to understanding of slope failure mechanisms.**


A
LS37
LS28
LS31
LS14
LS09-1
LS02-1
LS43
Slate with metasandstone (AL1)
Slate cleavage
Predictive
sliding surface
A'
Slate (SL)
Slate (SL)

THANK YOU