Research Institute
for Natural Hazards
& Disaster Recovery

Cutting-edge landslide monitoring and early warning system

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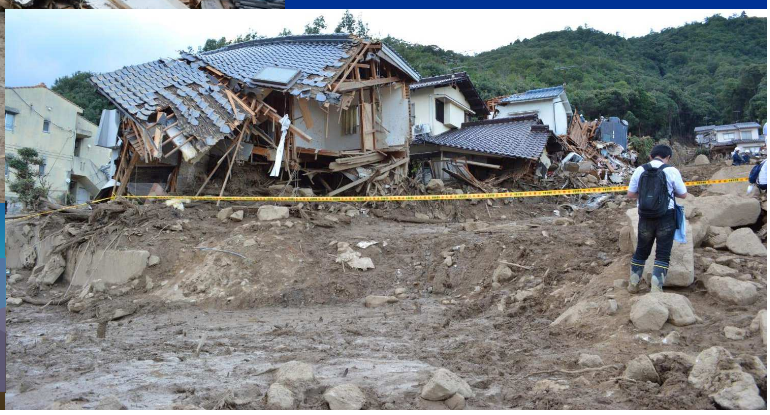
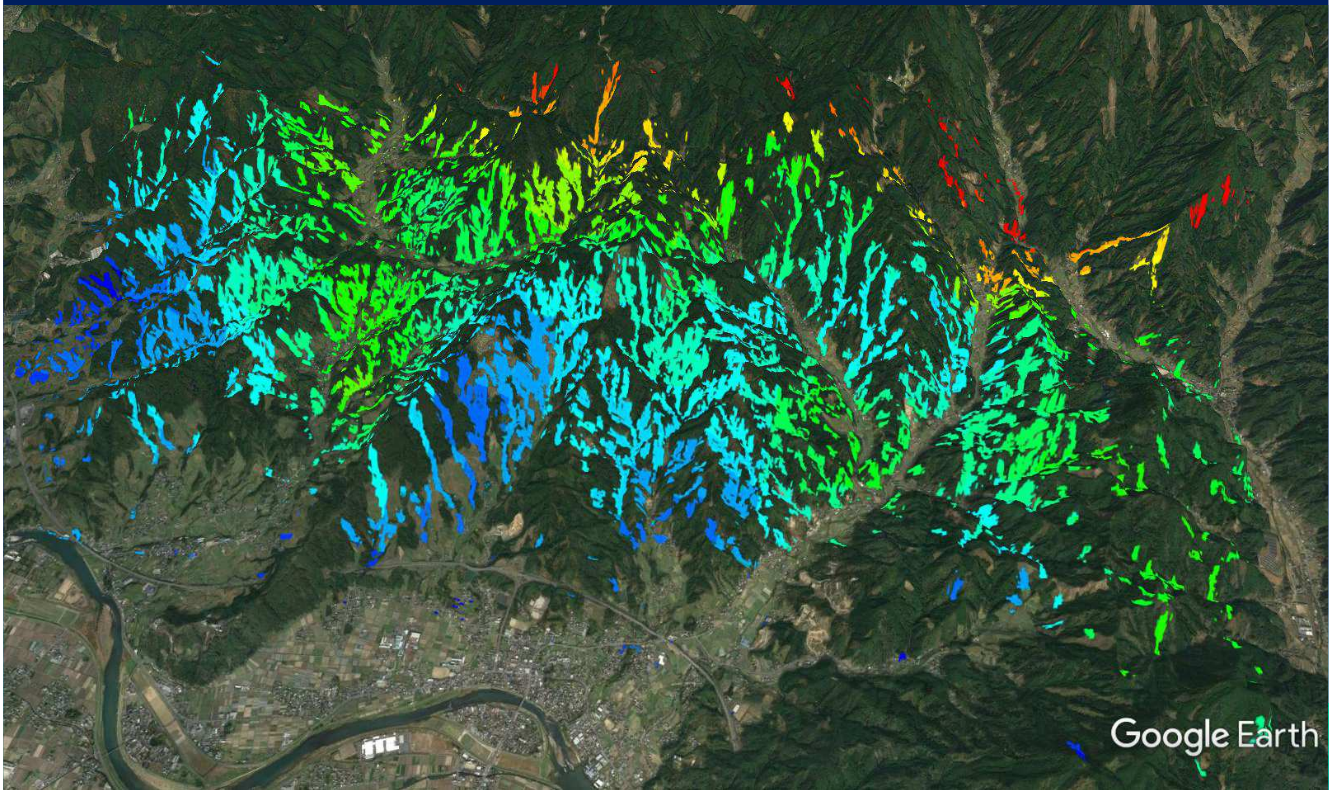
Recent serious landslide disasters in Japan

landslide and flood disaster in July 2017 in Fukuoka and Oita prefecture, claiming 37 lives



Landslide disaster in August 2014 in Hiroshima city, western Japan, claiming 75 lives

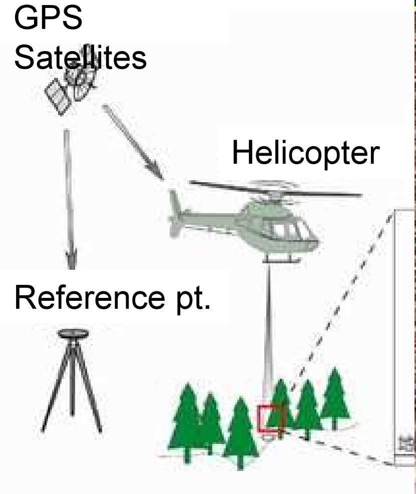
Swarm landslides induced by the July 2017 Northern Kyushu extreme rainfall

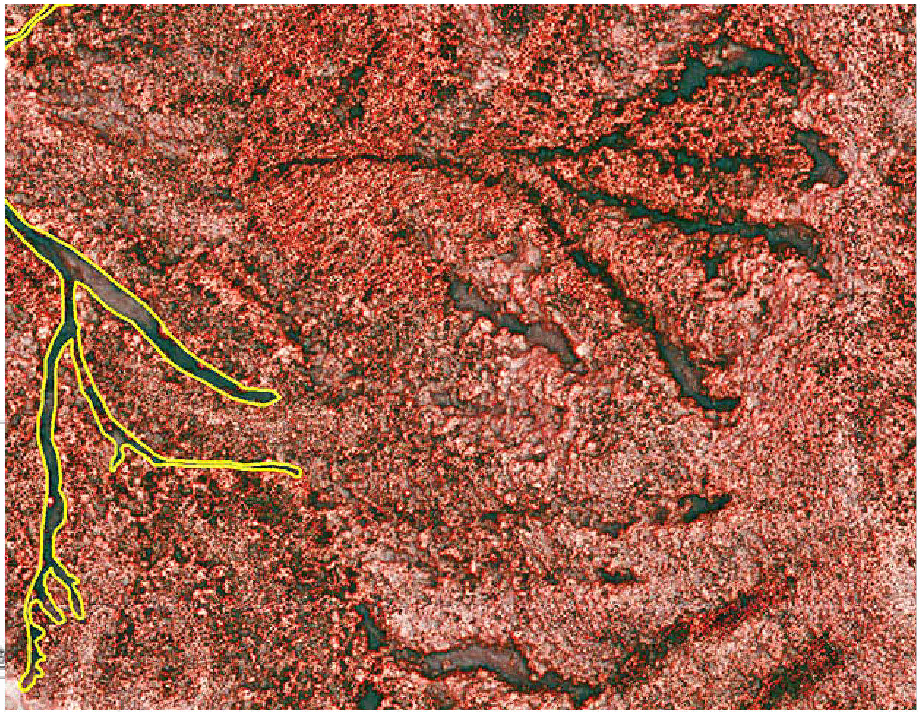


ADVACNED LANDSLIDE MONITORING TECHNIQUES

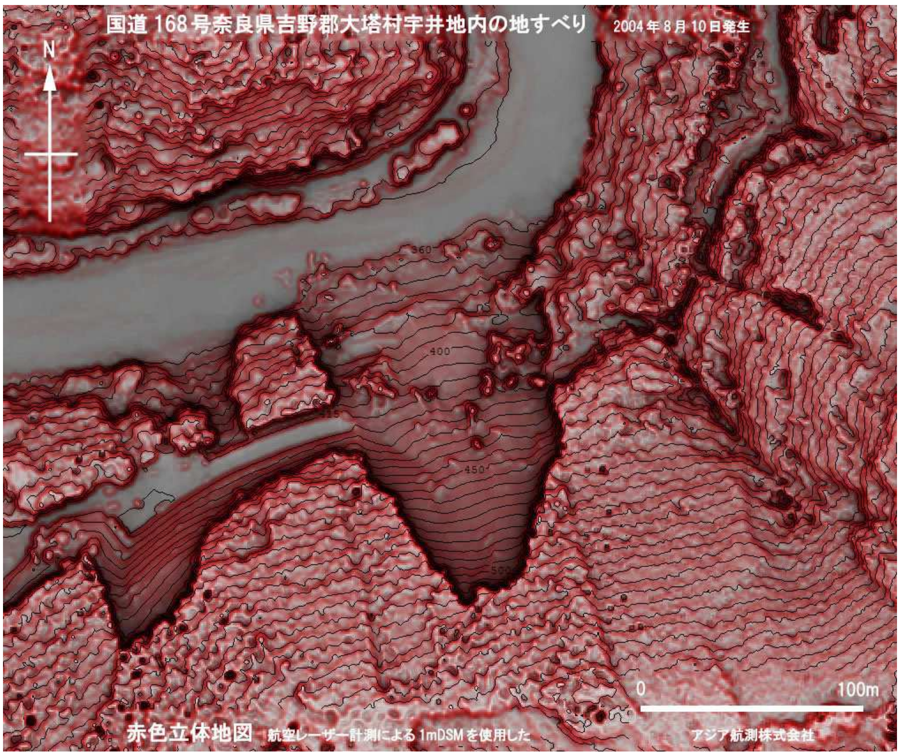
Airborne laser scanner penetrating forests to extract old landslide scars hidden under the forests

Example : July 2009
Hofu city debris flow
disaster area, western

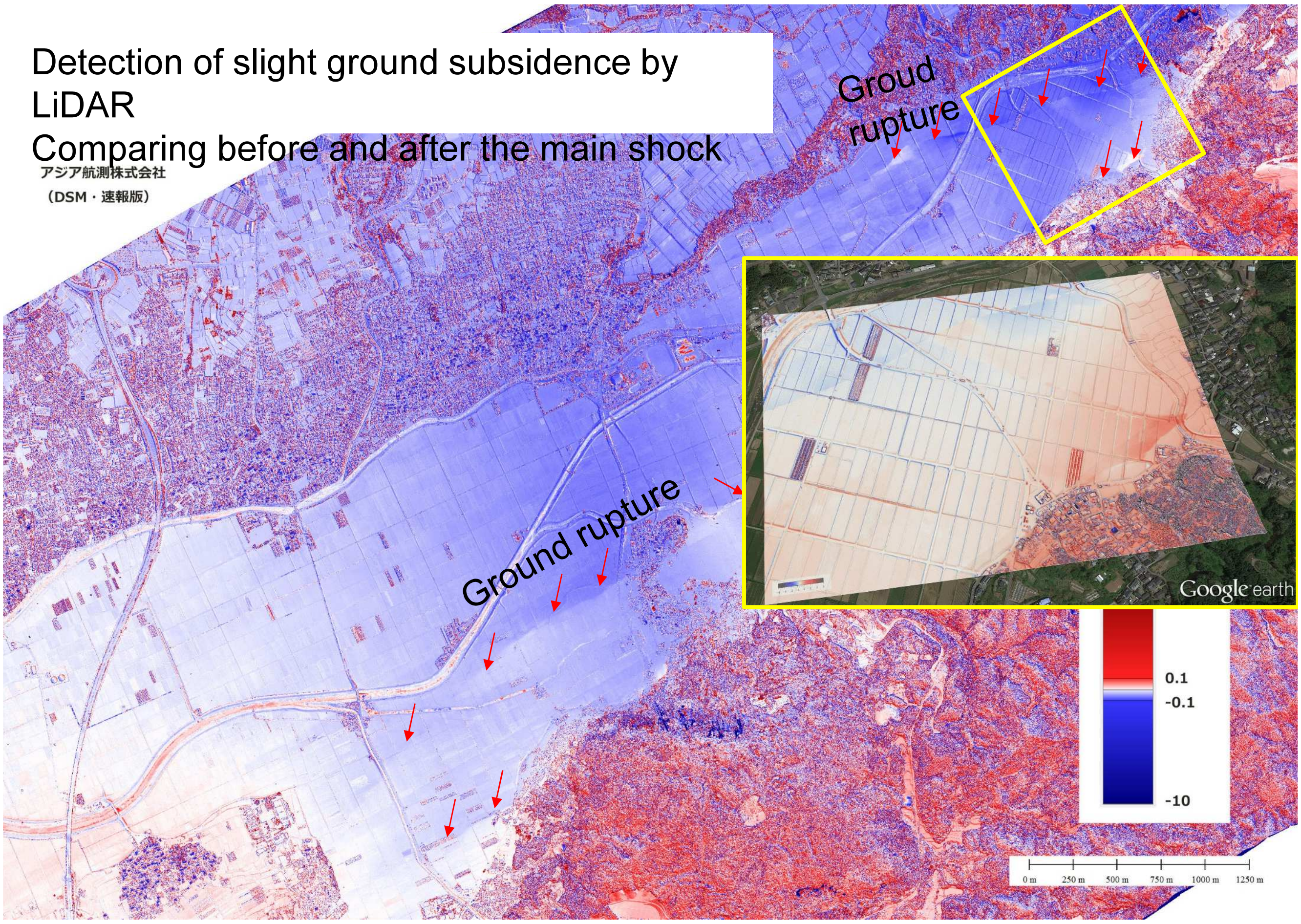




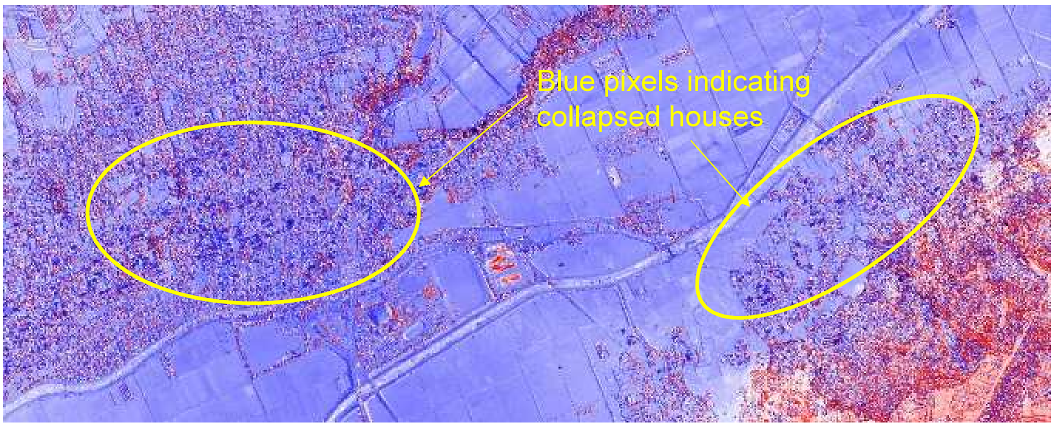
“Red relief map,” developed by Asia Air Survey, which is a filter to emphasize landslide head scarp and source areas

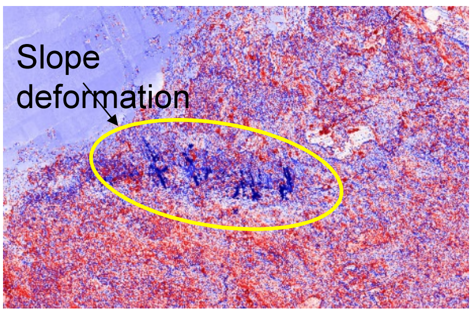


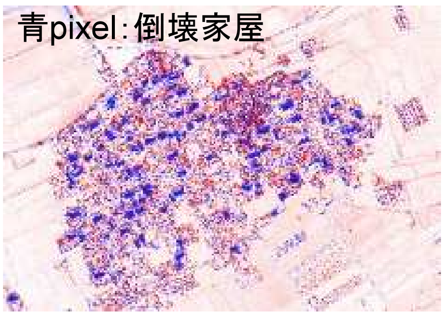
Detection of slight ground subsidence by LiDAR
Comparing before and after the main shock

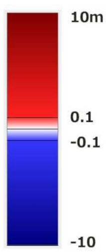


Another application of LiDAR to disaster reconnaissance immediately after the quake





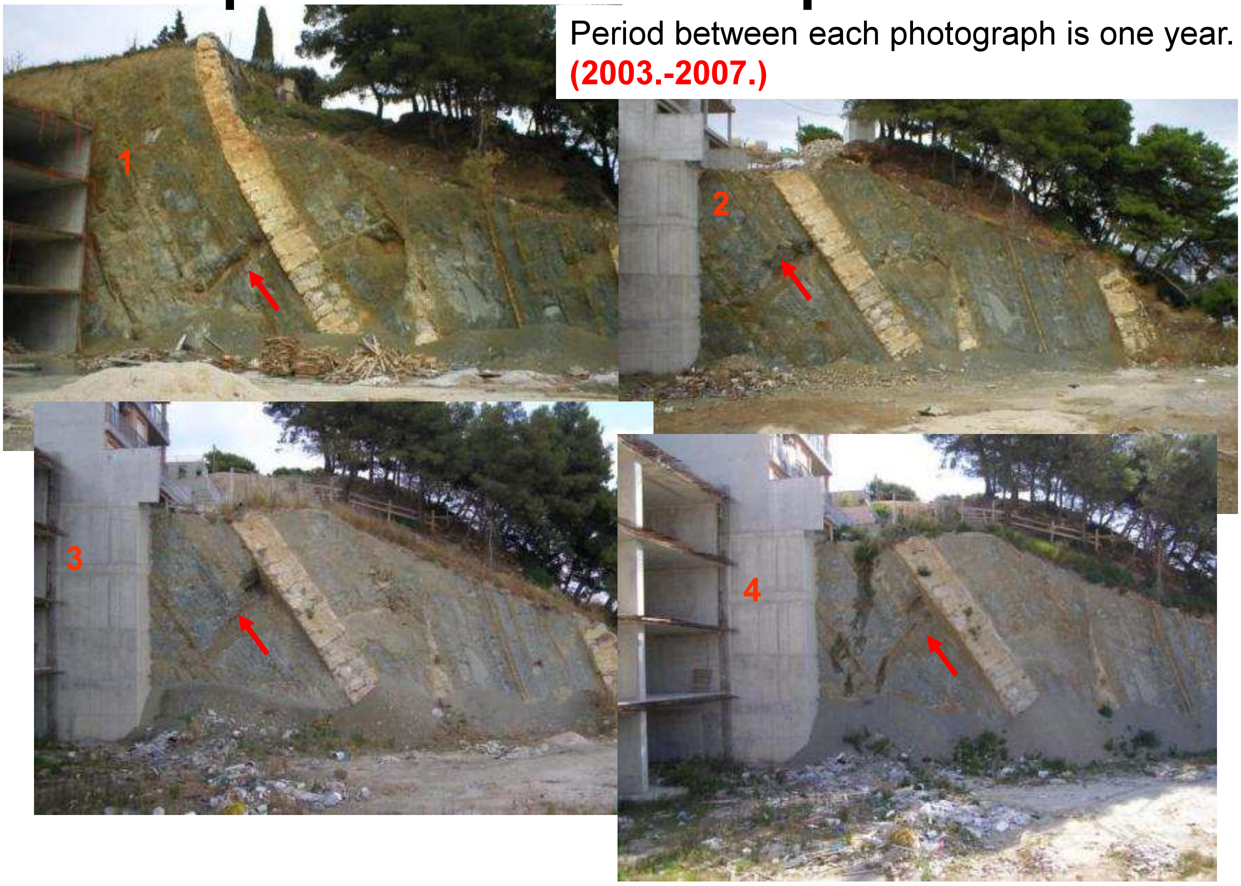




Laser-scanner on drones

Development of an erosion process

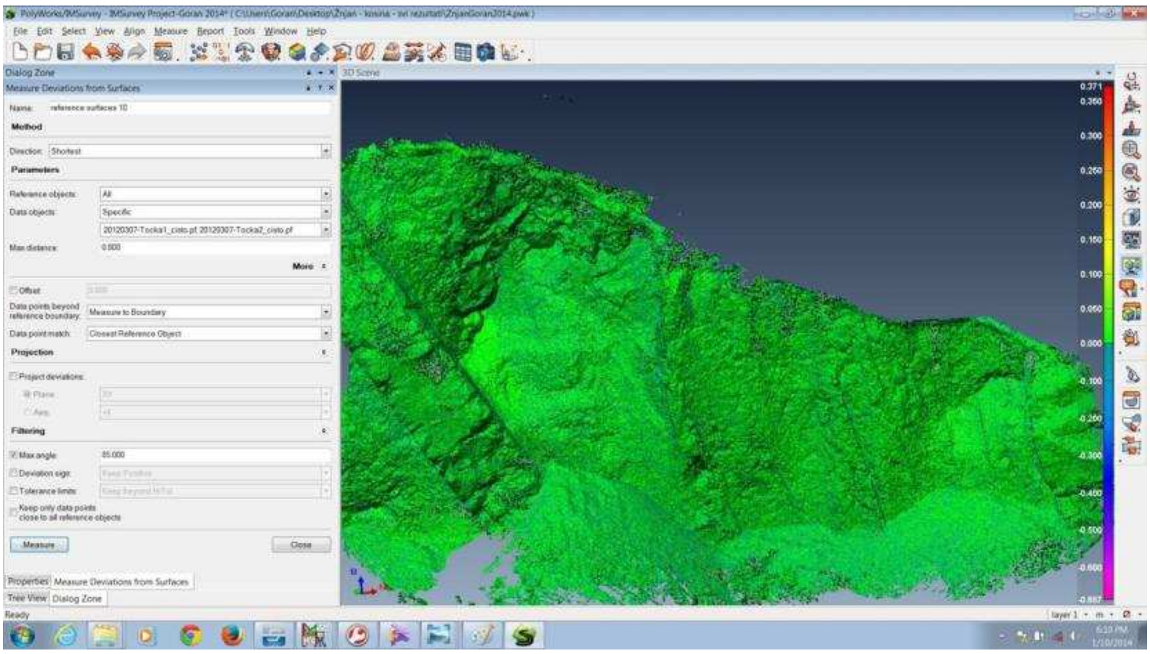
Period between each photograph is one year.
(2003.-2007.)



Results

ZONE 1 – comparisson of TLS scans

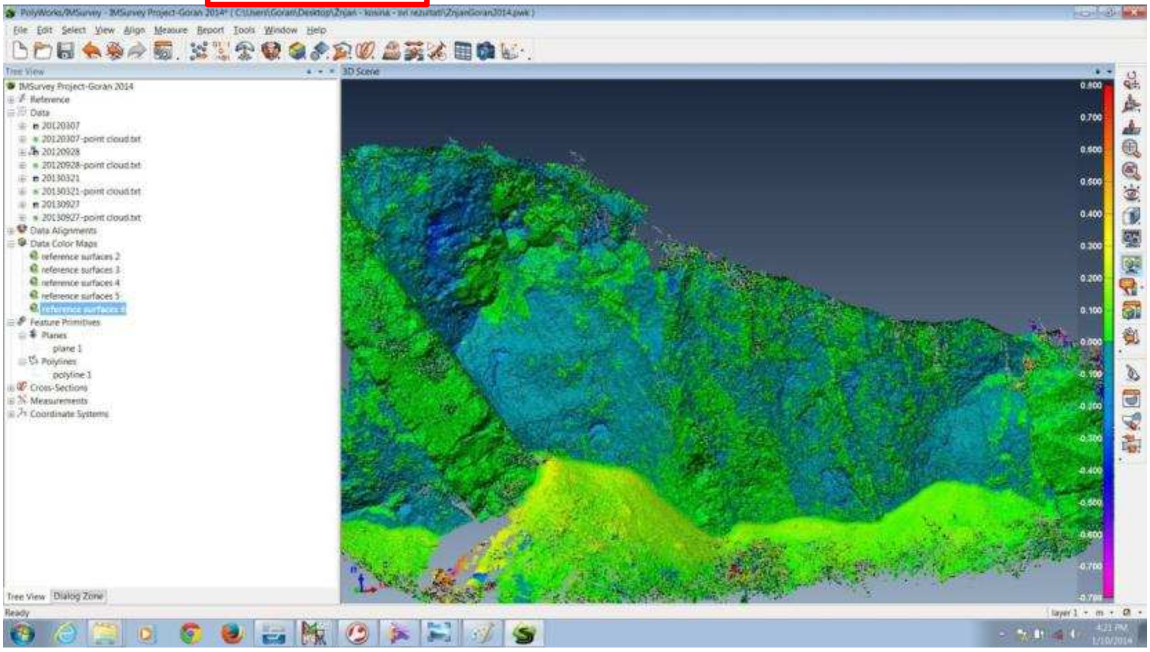
2012/03/07



Results

ZONE 1 – comparisson of TLS scans

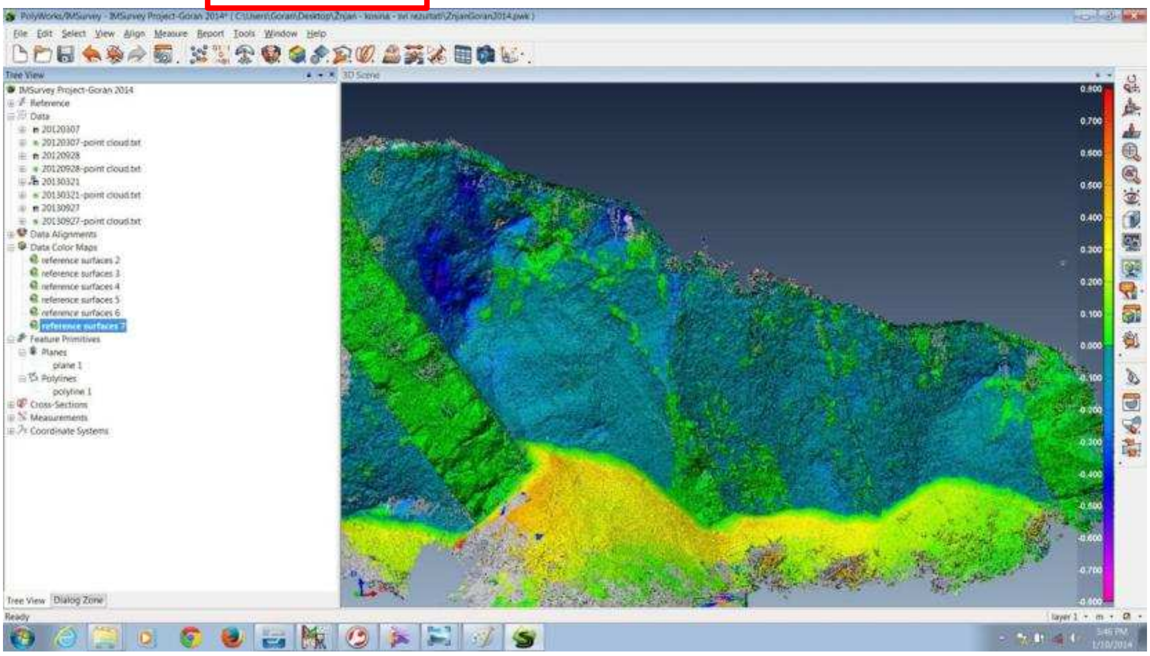
2012/03/07 - 2012/09/28



Results

ZONE 1 – comparisson of TLS scans

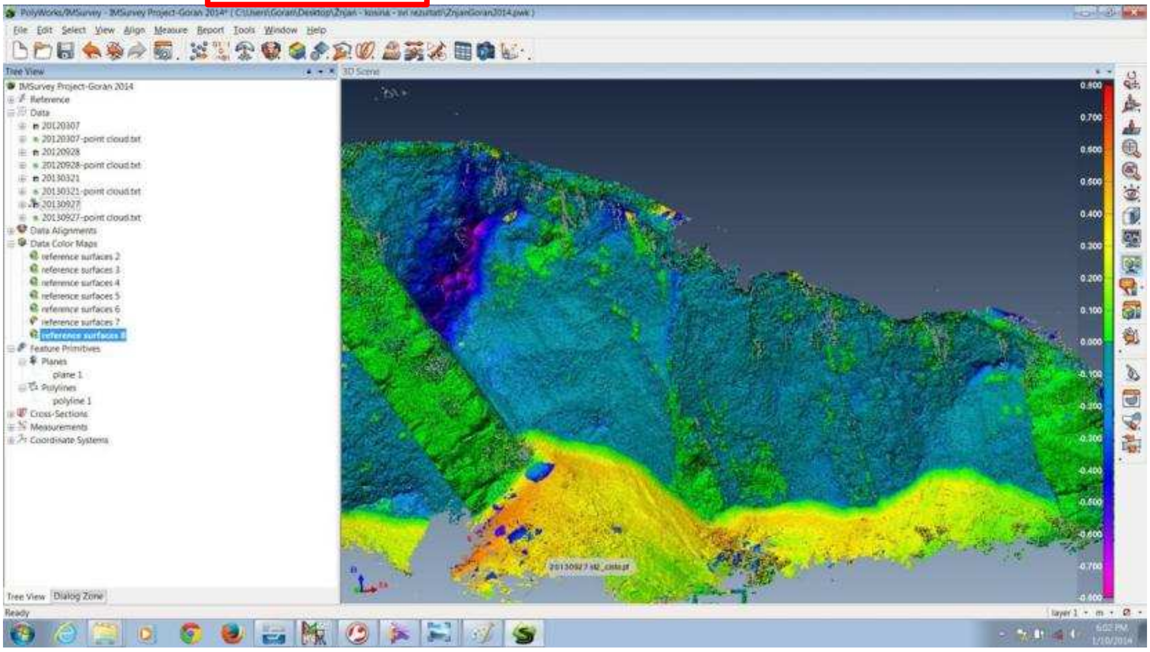
2012/03/07 - 2013/03/21



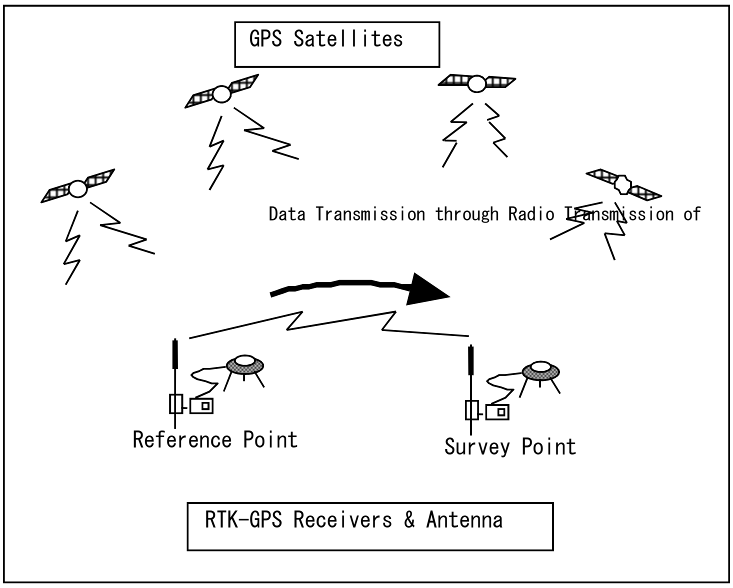
Results

ZONE 1 – comparisson of TLS scans

2012/03/07 - 2013/09/27

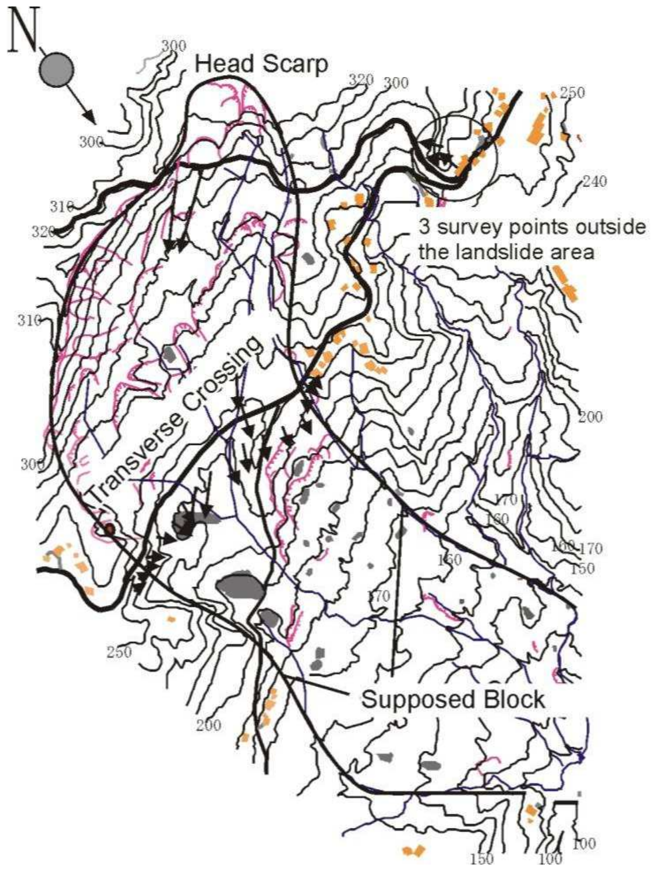


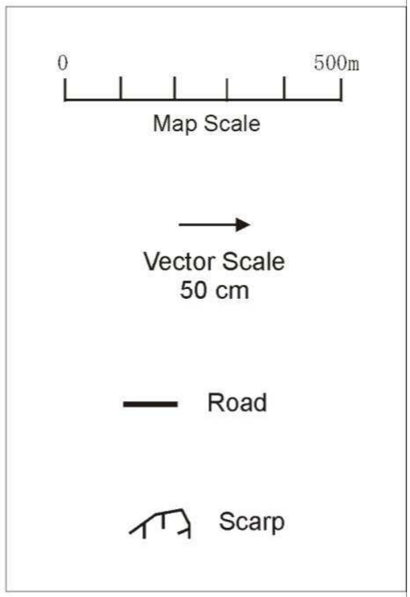
Application of short-time RTK-GPS (GNSS) to landslide monitoring



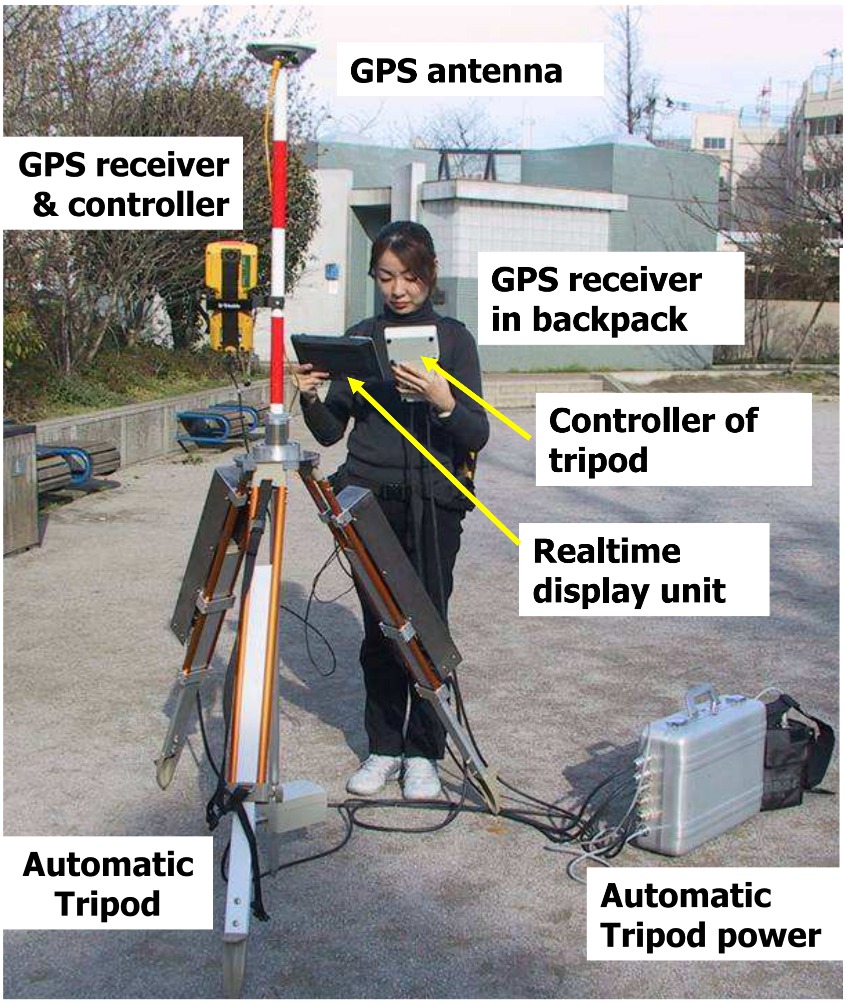
Schematic illustration of data transmission in Real Time Kinematic GPS

Movement monitoring at Okimi Landslide





Distribution of survey points in Okimi landslide site and displacement vectors detected by RTK-GPS in November 2000 - June 2001.



Development of periodical slope health check system (2001～2002)

(1) Developmet of automatic tripod system

・to control to hold GPS antenna within 1mm of precision

・high speed to set antenna above target mark

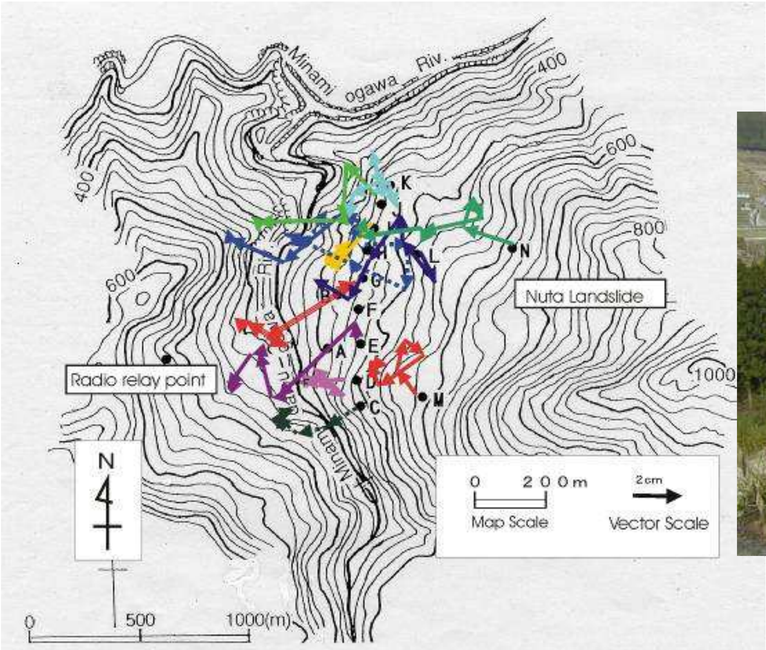
・realize survey on very soft ground

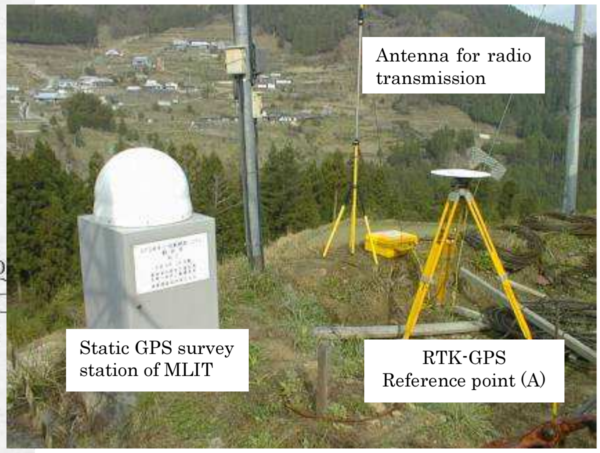
(2) Realtime display & analyze system for RTK-GPS

・display every 1 sec surveyed point on handy-PC display

・display also previous surveyed points to compare

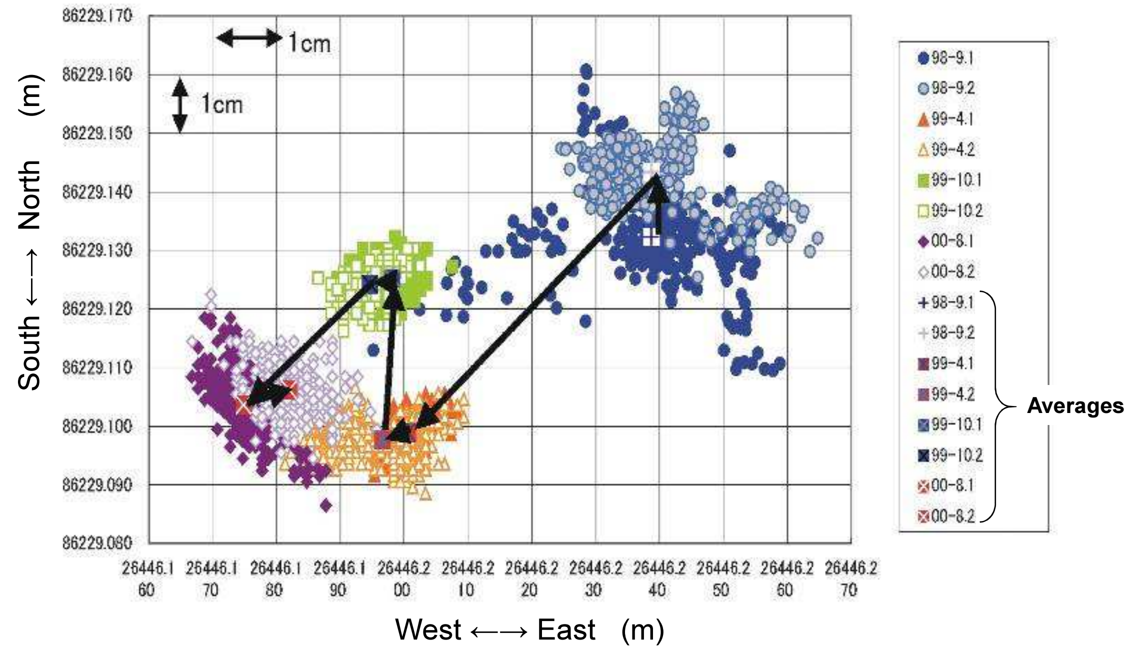
Movement monitoring at Nuta Landslide





Distribution of survey points in Nuta landslide site and displacement vectors detected by RTK-GPS in September 1999 - August 2000.

Example of obtained movement vector



Movement of point E in Fig. 6 in September 1999 - August 2000. Filled circles show the positions obtained by RTK-GPS 5-minutes observation under 1-second sampling condition.

Proposed ‘periodical check system of slope stability’

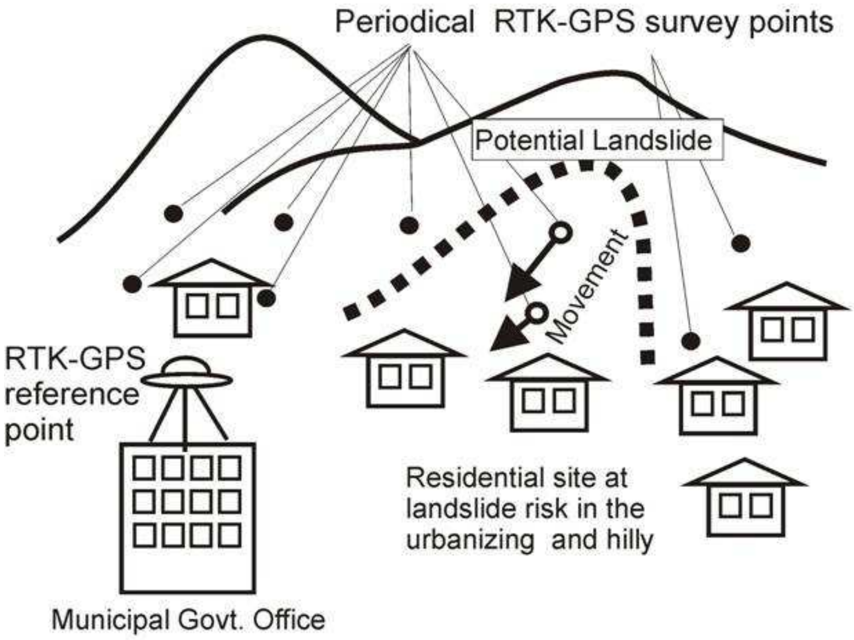
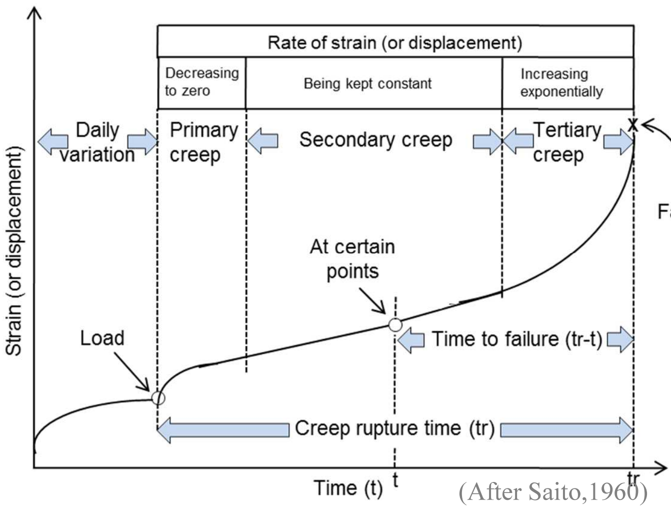


Fig. 9 Schematic illustration of the Periodical Health Check System of Slope Stability.

Large-scale flume test for landslide studies, using large-scale artificial rainfall simulator at the National Institute for Earth Science and Disaster Prevention, Tsukuba, Japan

Fukuzono method to predict landslide occurrence time

- 1960 – Saito (on Secondary and Tertiary creep) : on graphical analysis of extensometer monitoring data.
- 1985 – Fukuzono (on Tertiary creep): in large scale flume tests: log of acceleration is proportional to log of velocity of surface displacement.



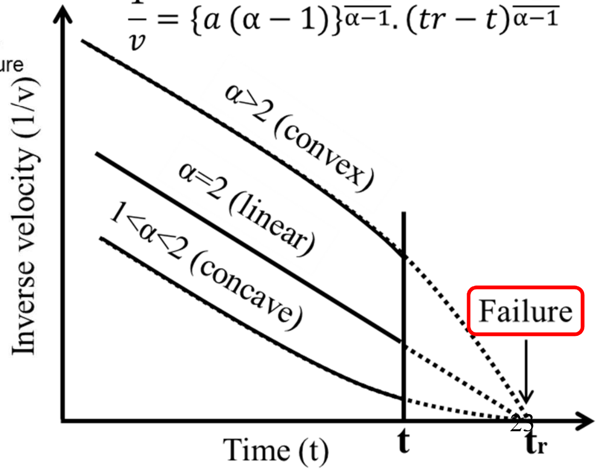
(After Saito,1960)

x: surface displacement, t: time,
A , α: constant

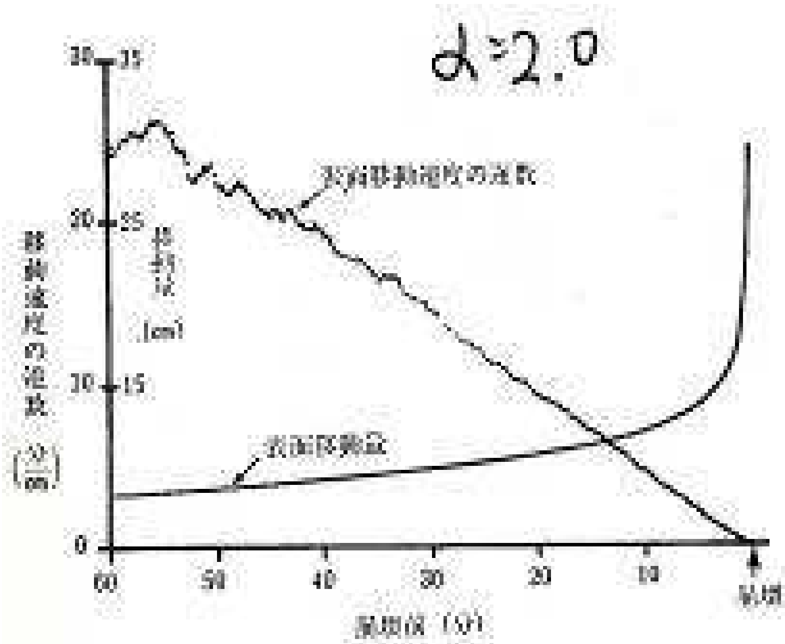
$d^2x/dt^2=A(dx/dt)^\alpha$

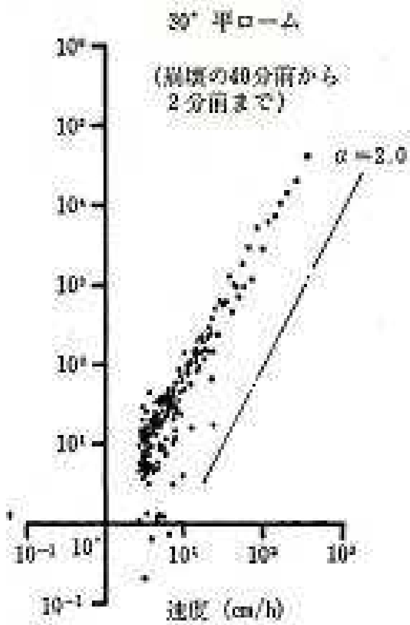
(by Fukuzono,1985)

$$\frac{1}{v} = \{a\,(\alpha-1)\}^{\frac{1}{\alpha-1}}.\,(tr-t)^{\frac{1}{\alpha-1}}$$



Fukuzono 1985





http://www.land-man.net/vajont/vajont.html

Vaiont dam landslide (1963), 250-M m^{3}, killed 2,000 residents


CORRIERE DELLA SERA

LE VITTIME SAREBBERO DUEMILADUECENTO

L'ONDA DELLA MORTE

www.thrillermagazine.it/rubriche/1698

www.alasinistra.it

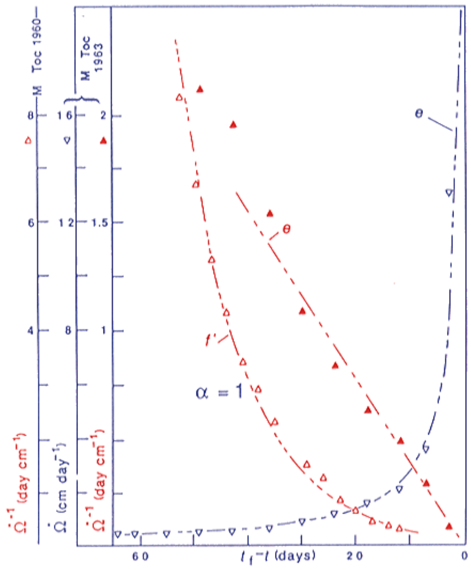


Fig. 3 *Mount Toc. Displacement rate $\dot{\Omega}$ (curve e) and inverse-rate $\dot{\Omega}^{-1}$ (curve e') against time before 9 October 1963 slope failure. Exponential inverse-rate against time (curve f') for fall 1960 movement.*

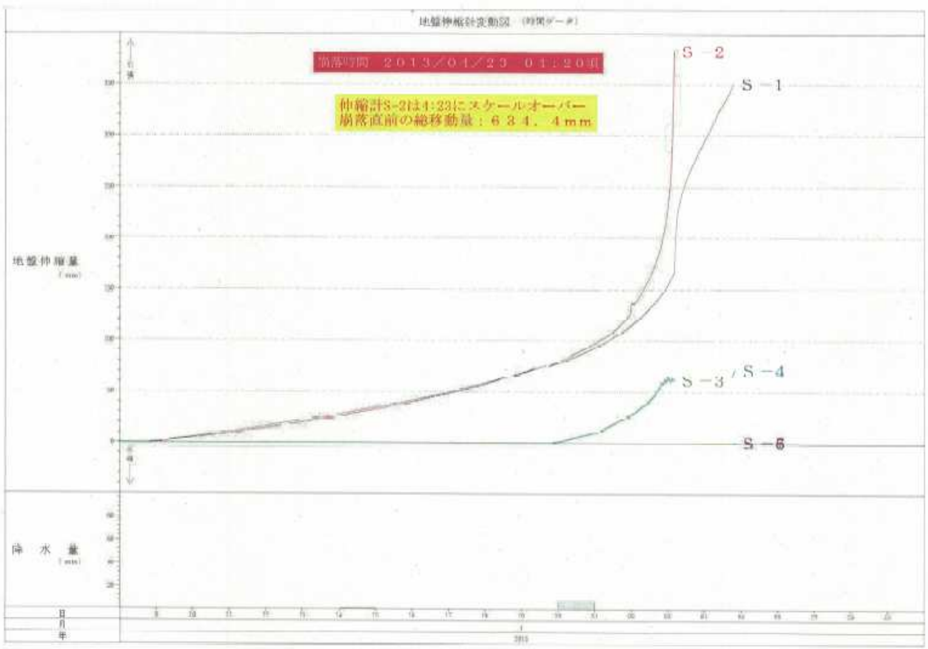
B. Voight 1989

Application of Tertiary Creep phenomenon to early warning and evacuation
Cracks which appeared on the ground marked by the white arrow (Shizuoka Newsaper web site)

Left: Before slide, Right: After the first slide

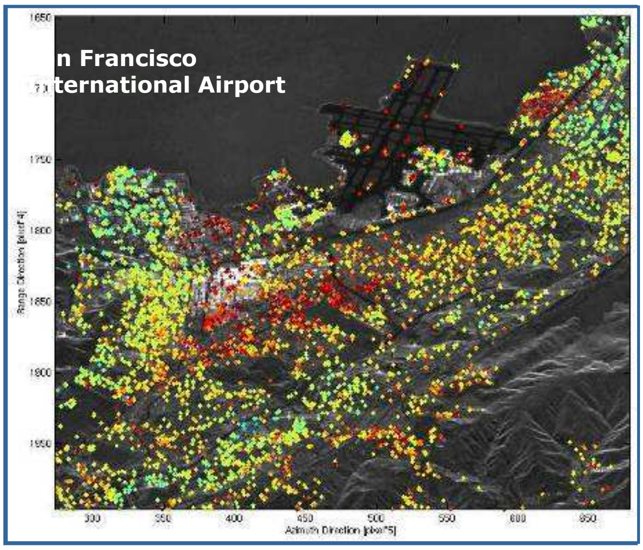
Extensometer record immediately before failure

(Succeeded to predict the time with precision of 40 minutes)

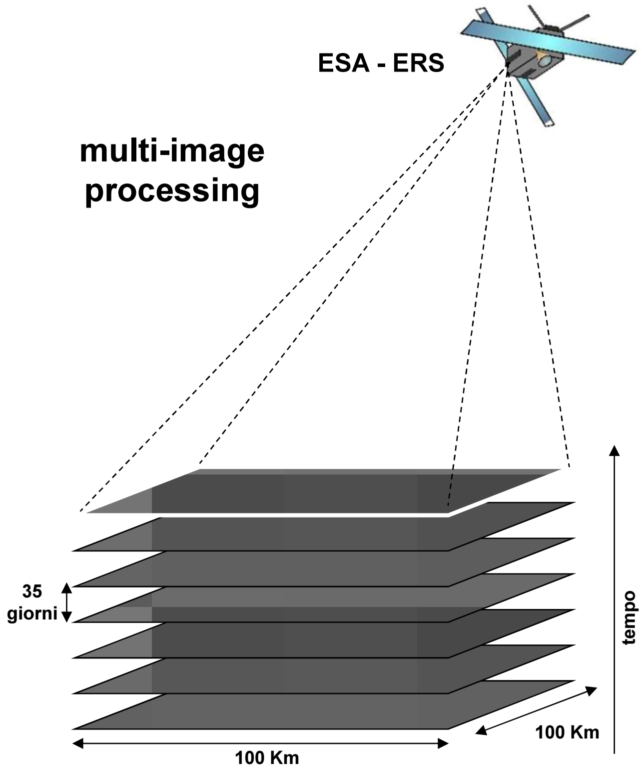


Persistent Scatterers Interferometry (PSI)

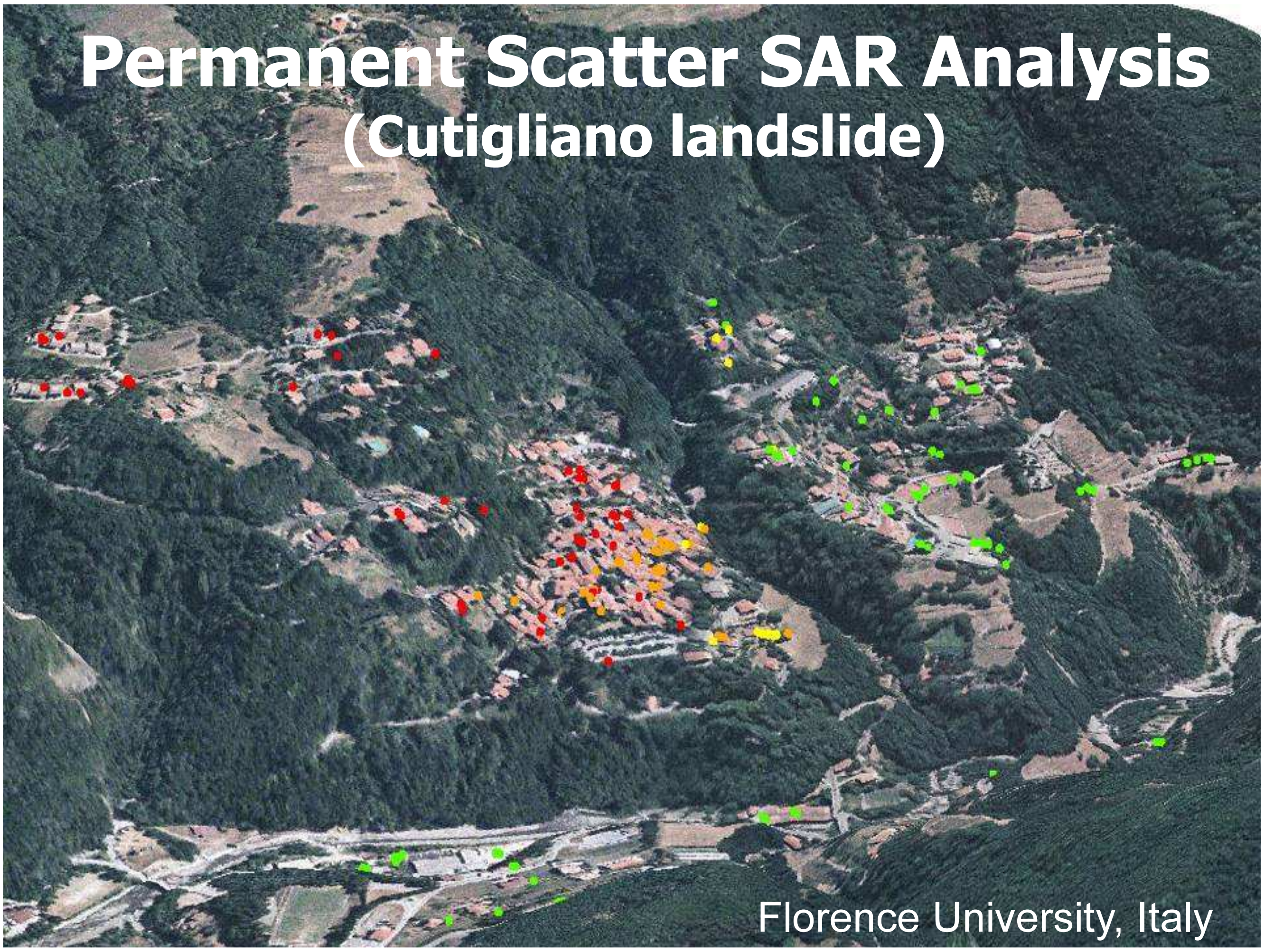
pixel by pixel analysis



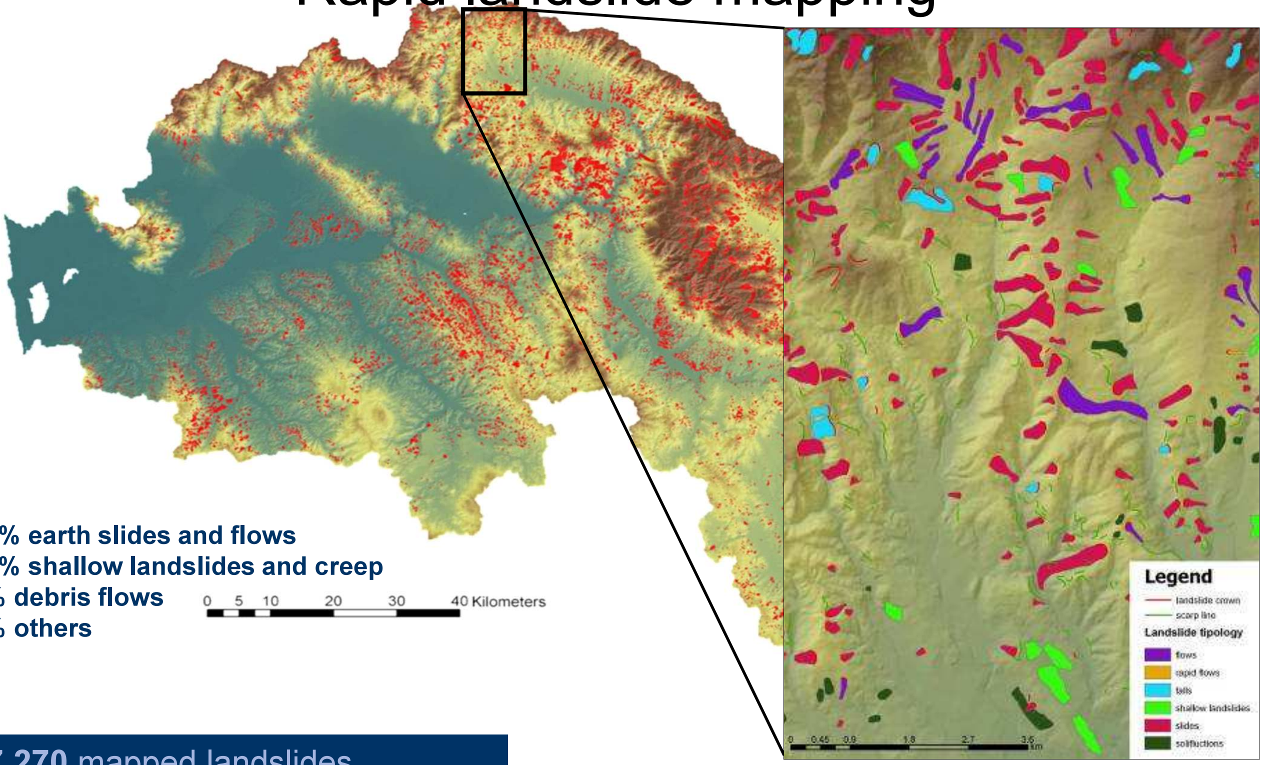
Processing technique of SAR images for measurement of ground deformations with millimetric accuracy



Dataset of SAR images



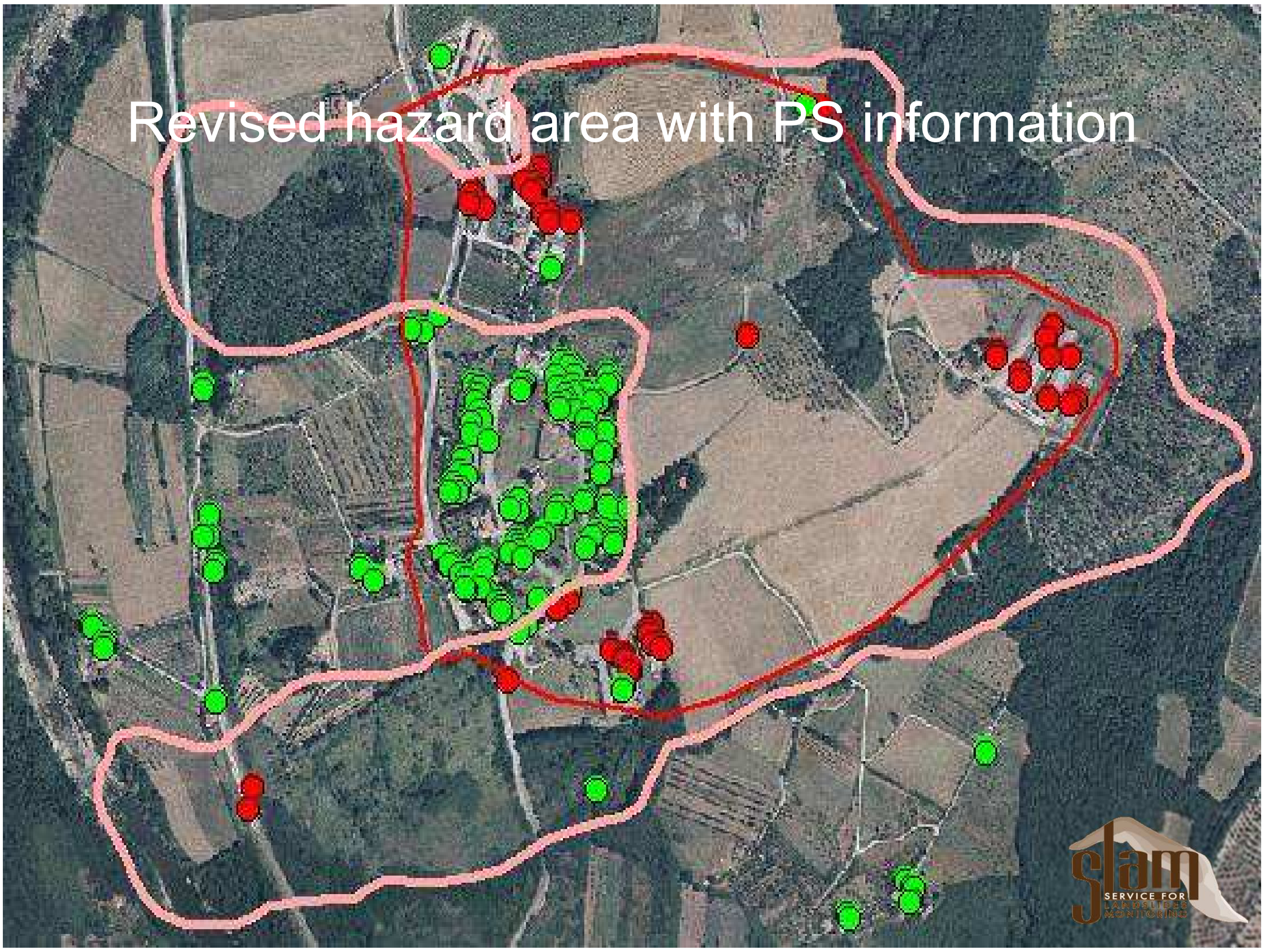
Rapid landslide mapping



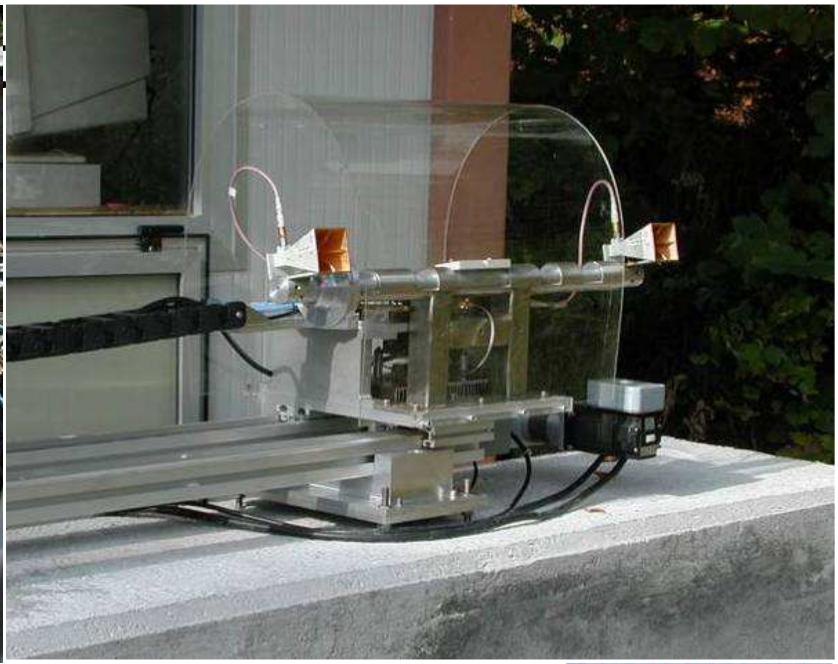
74% earth slides and flows
19% shallow landslides and creep
5% debris flows
2% others

27 270 mapped landslides
8.8 % landslide density

Revised hazard area with PS information

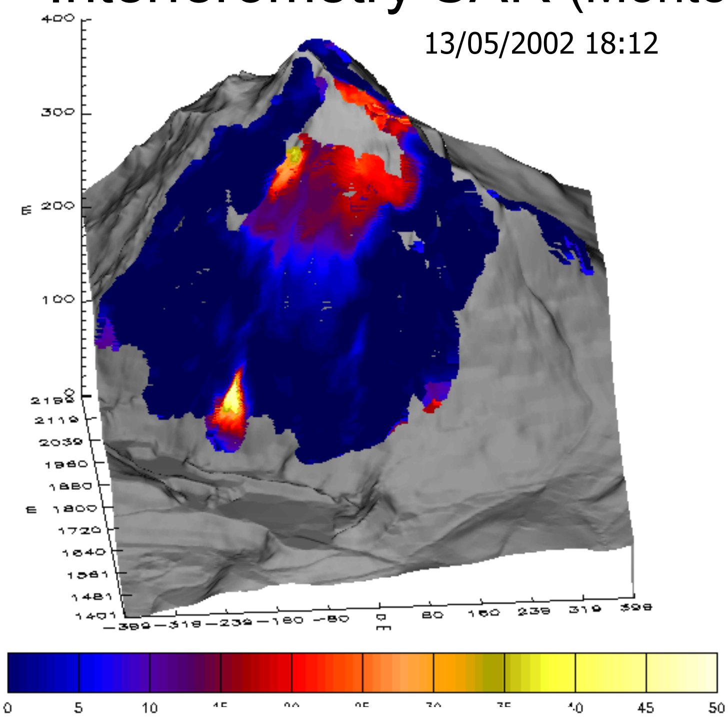


Ground based SAR



Portable SAR apparatus known as LISA (*Linear Synthetic Aperture Radar*), developed by the Joint Research Centre of the European Commission

Landslide Monitoring by Ground-based Interferometry SAR (Monte Beni landslide, Italy)



Start: 8/5/2002 13:59

End: 13/5/2002 18:12

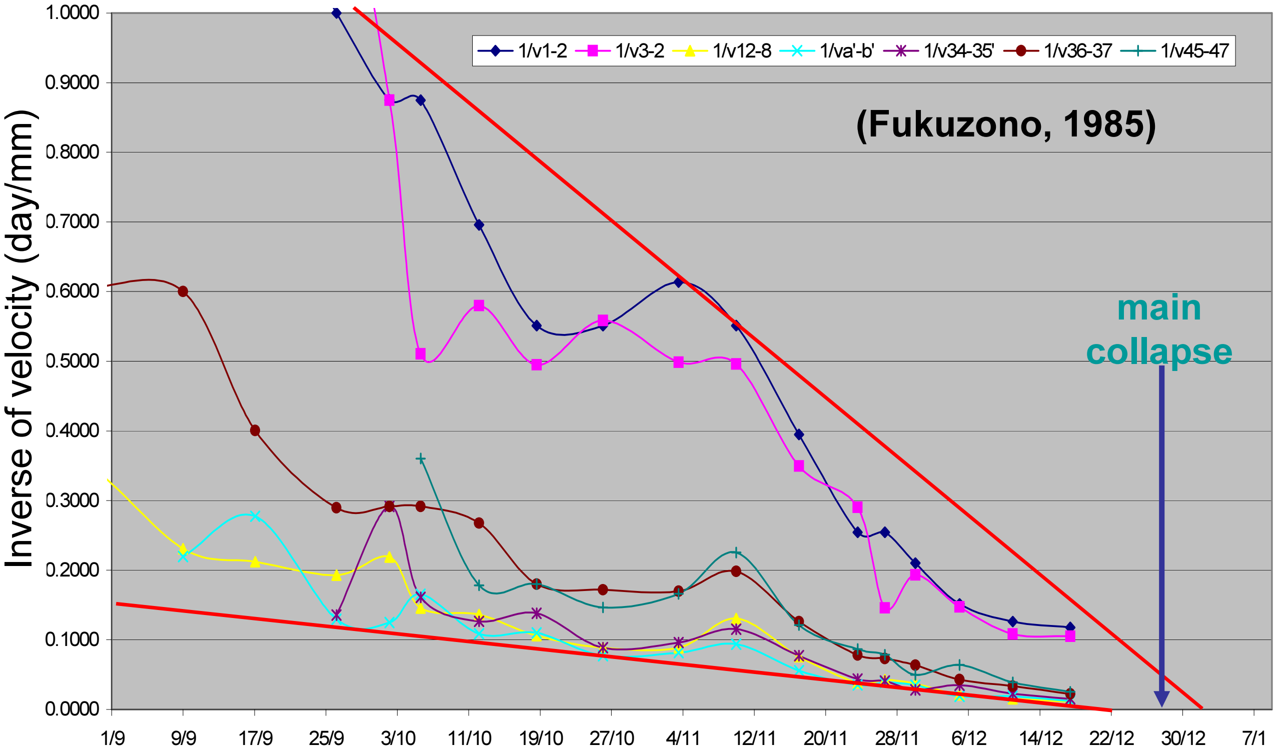
Interval: 124 h

Acquisition time: 40 min

Peak velocity: 0.48 mm/h

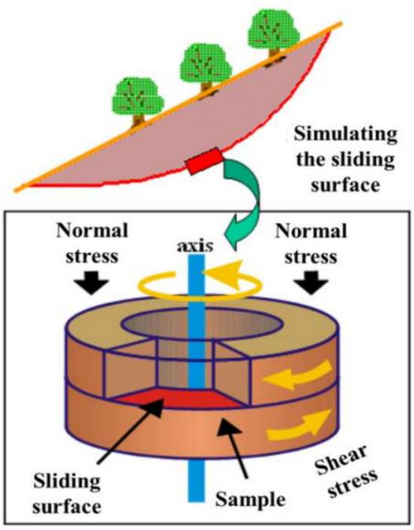
Mean Velocity: 0.16 mm/h

Prediction of the time of failure



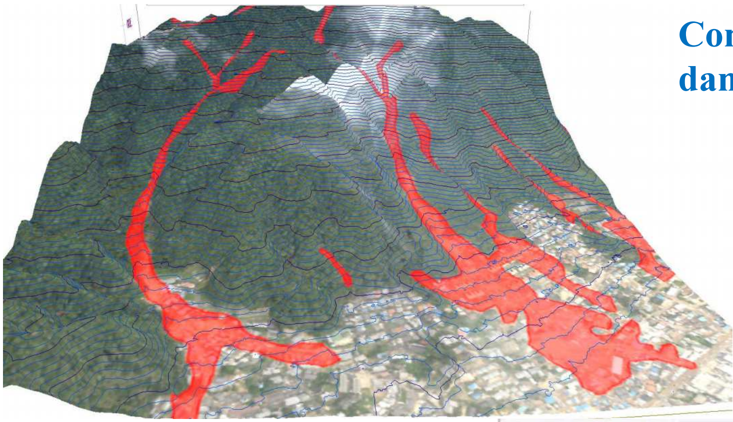
Ring shear apparatus (ICL-1, Sassa et al.)

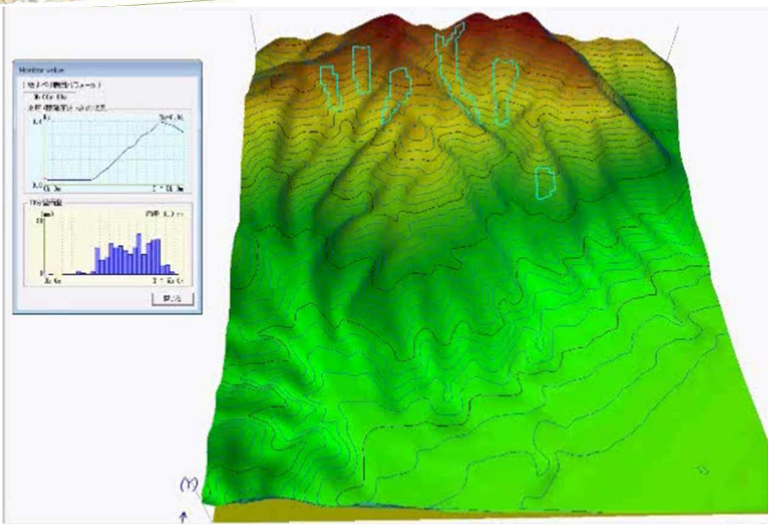
A transportable type which can load up to 1 Mpa.
Developed by JST-JICA SATREPS project



Concept of landslide geotechnical simulator.

Comparison of debris flow damaged area and simulation



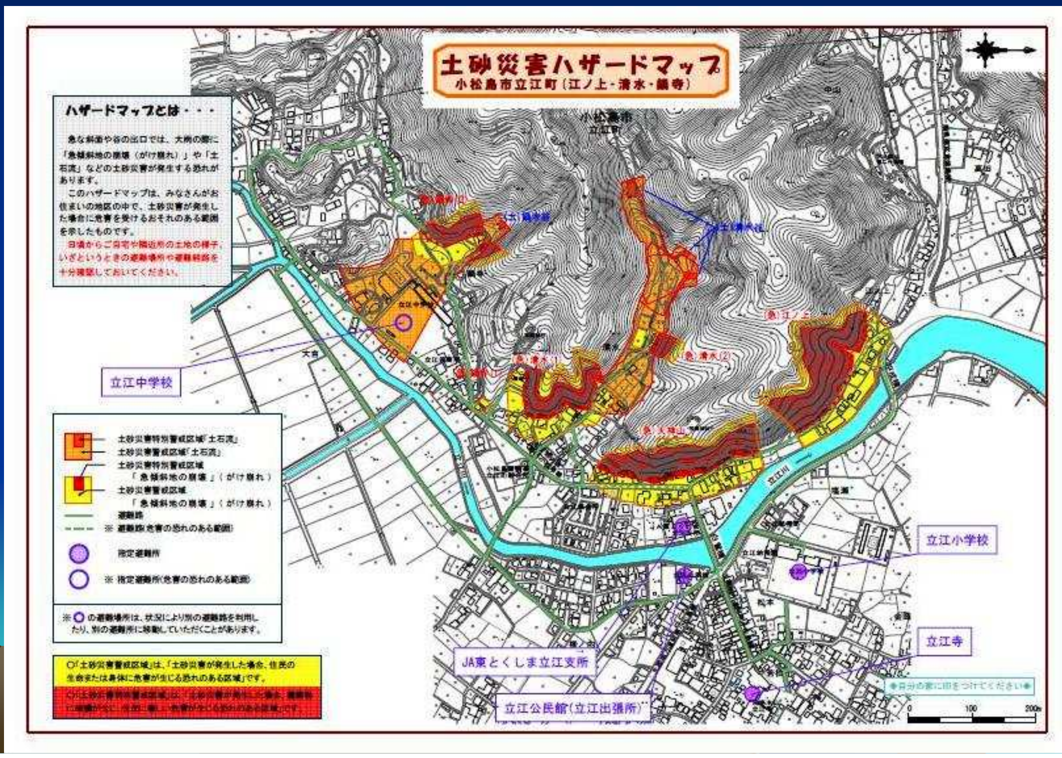


Above: Airphoto interpretation by the Geospatial Information Authority of GoJ

Right: simulation movie

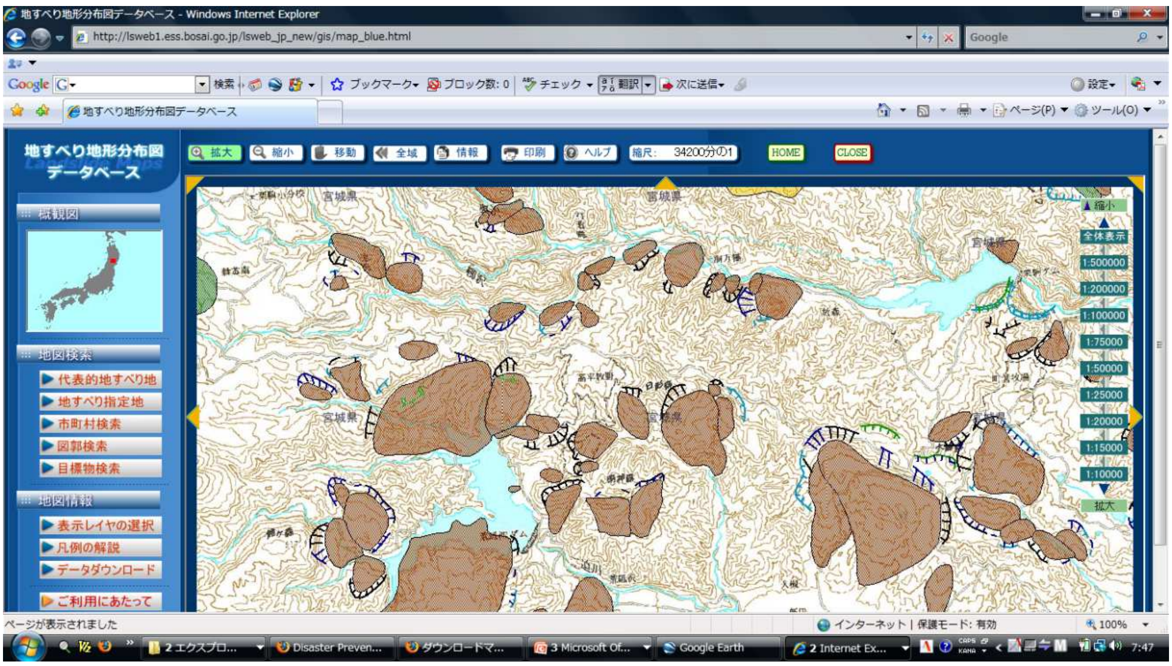
ADVANCED HAZARD MAPPING, EARLY WARNING, AND EVACUATION

Example of landslide hazard map prepared and distributed by Japanese municipal (prefectural) govt. Construction of new houses is prohibited in red zone.



Online landslide topography database (NIED, Japan)

More than 600,000 landslides topographies were extracted.



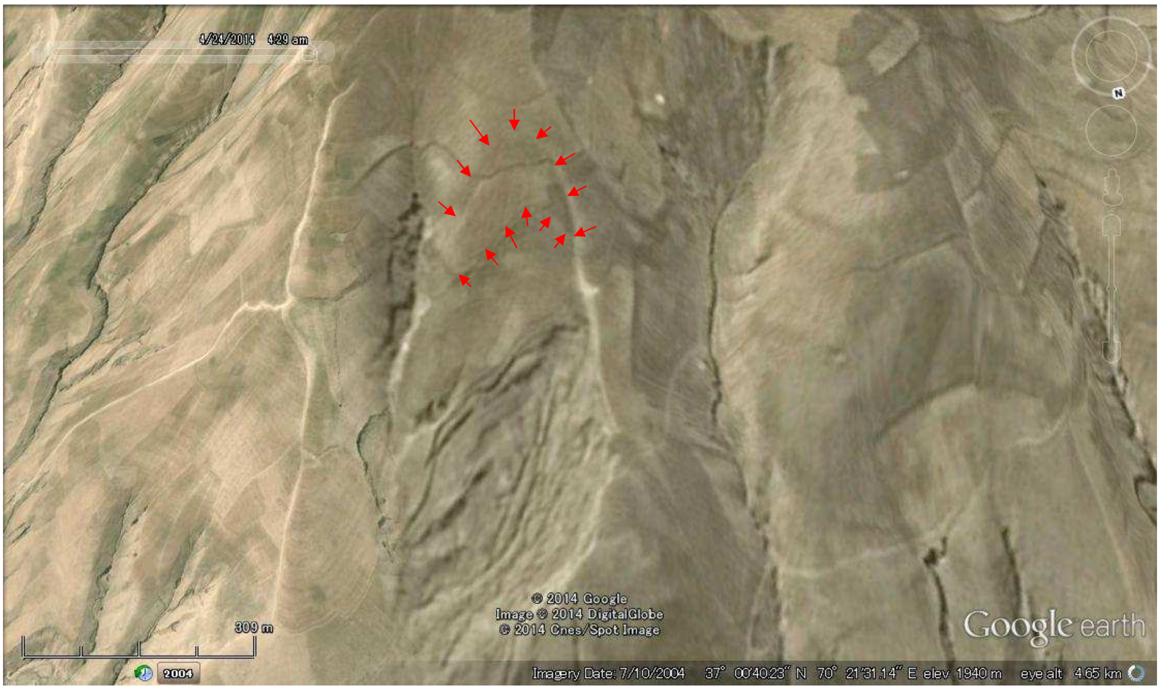
Google Earth Image Interpretation of landslide topography and its application for landslide susceptibility map

- Satellite / air photos and oblique image based on SRTM elevation data is embedded. Elevation can be exaggerated in the oblique image (x 0.5 to x 3)
- Large to small scale landslide scars and deposits can be extracted and marked online. Most of the new landslide take place inside past slide body or adjacent slope.
- Information can be shared online….discussion between experts in developed and developing countries is possible.

Source area frontal view

http://www.dailymail.co.uk/news/article-2620840/Aab-Barik-Image-shows-scale-devastation-wiped-Afghan-village-killing-2-700-leaving-thousands-homeless.html

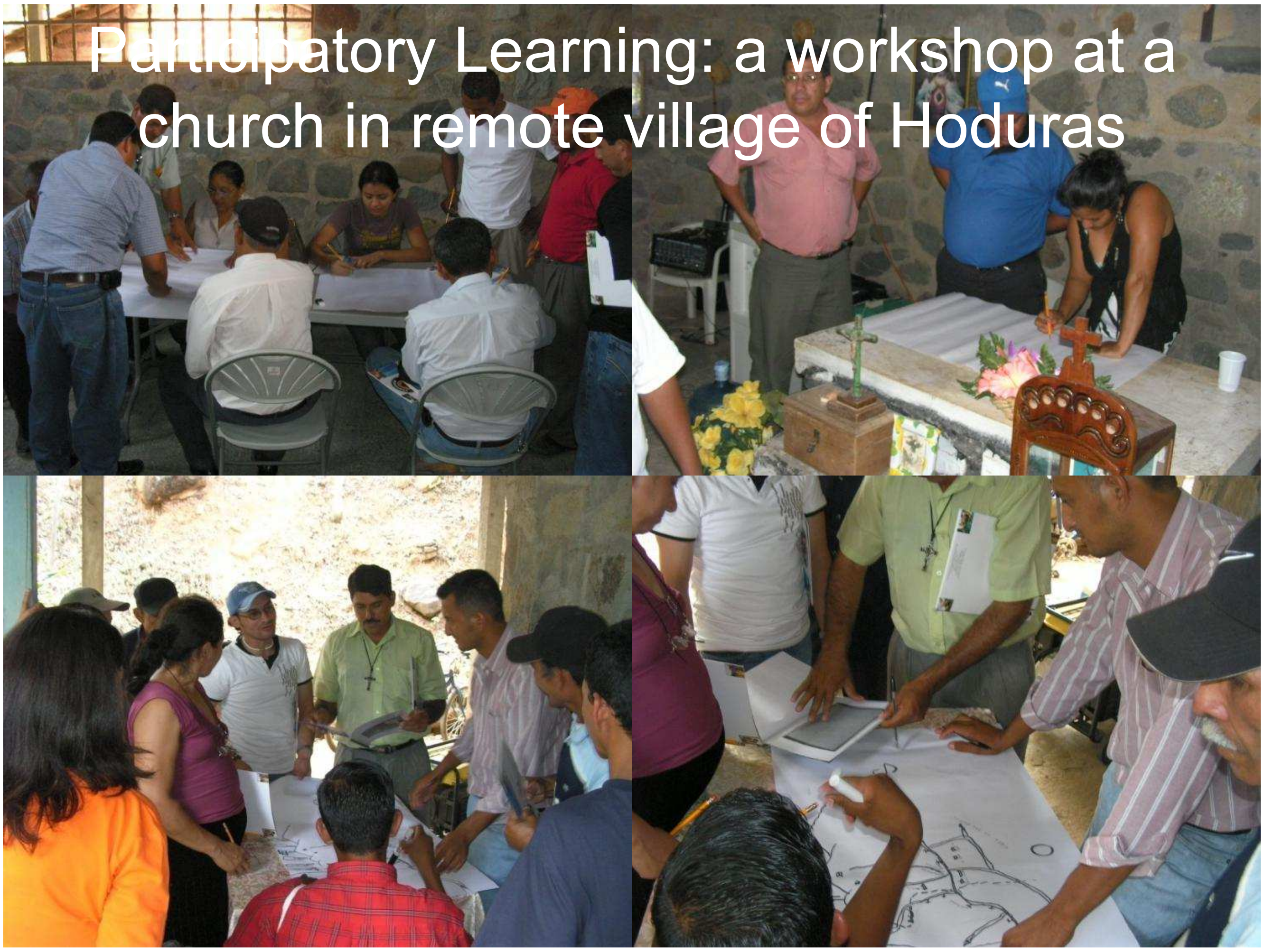
Source area before sliding (Google Earth) and depression lines which might grow into head scarps



Usoy landslide dam induced by 1911 eq.

Seepages and associated small slides of the downstream side of the Usoy landslide dam

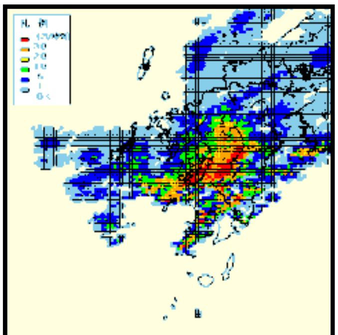
Participatory Learning: a workshop at a church in remote village of Hoduras



Participatory Learning: a workshop at a church in remote village of Hoduras

Soil Water Index (SWI)

*www.meteo.fr/cic/wsn05/DVD/presentations/THU-pm/**Sugiura**-7.28/THU-pm-**Sugiura**-7.28.ppt*



Radar AMeDas precipitation
&
VSRF precipitation
fo[illegible]s

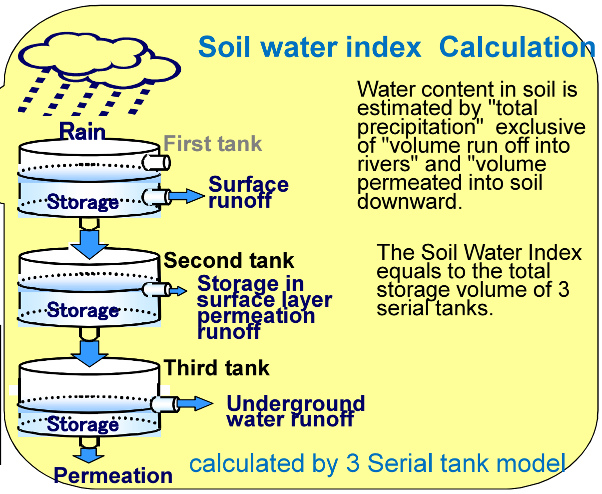
Soil water index
for every 5 by 5 km area
About 16,000meshes in Japan

Occurrence of landslides is closely related to soil water index.

SWI Archives for 5 by 5 km & <u>damage reports</u> for the last 10 years

Soil water index

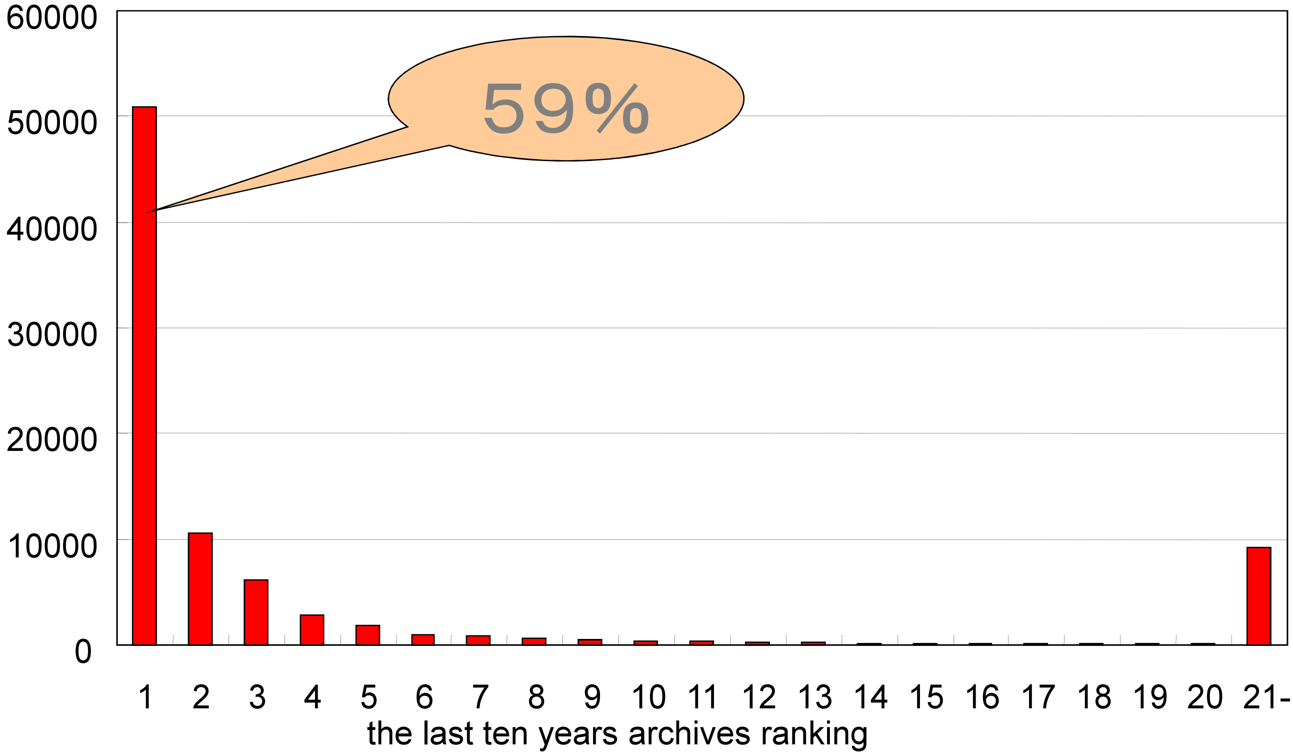
Comparison of current water content in soil with past records

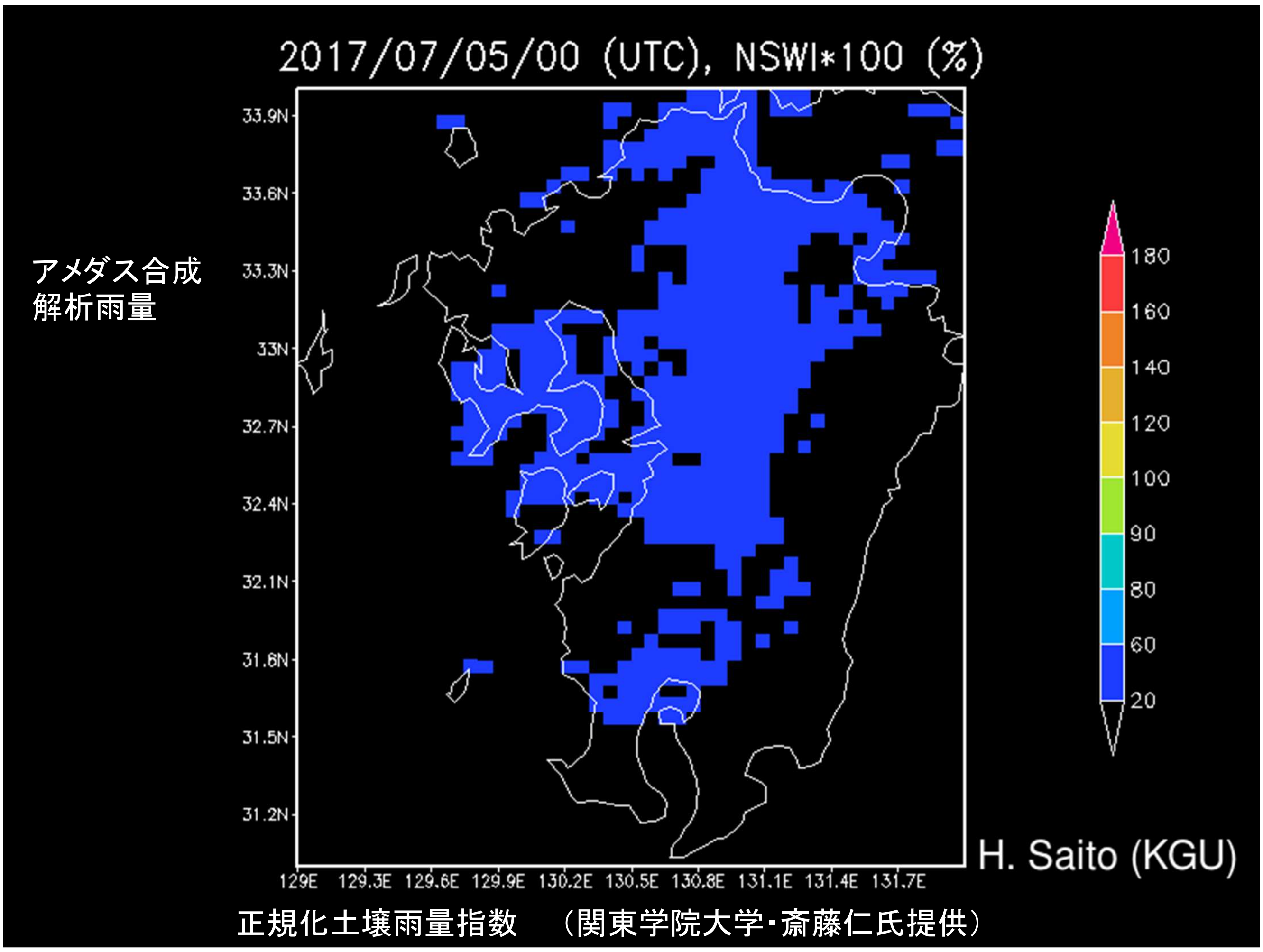


Advisories/warnings for heavy rain
How high the potential for landslides is for the last ten years

Soil Water Index (SWI)

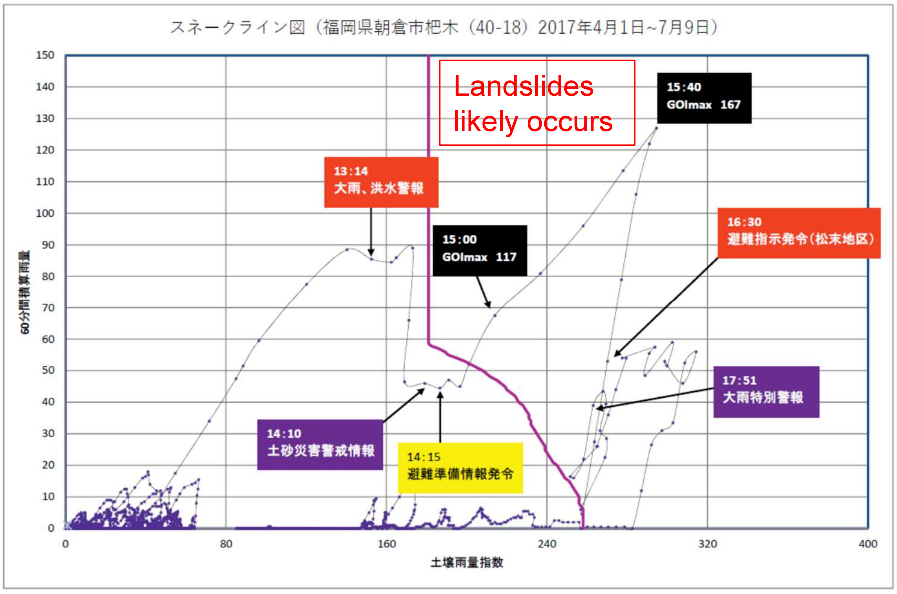
Relationship land-slide disasters and the ten years archives ranking in 1991-2000 per local governments





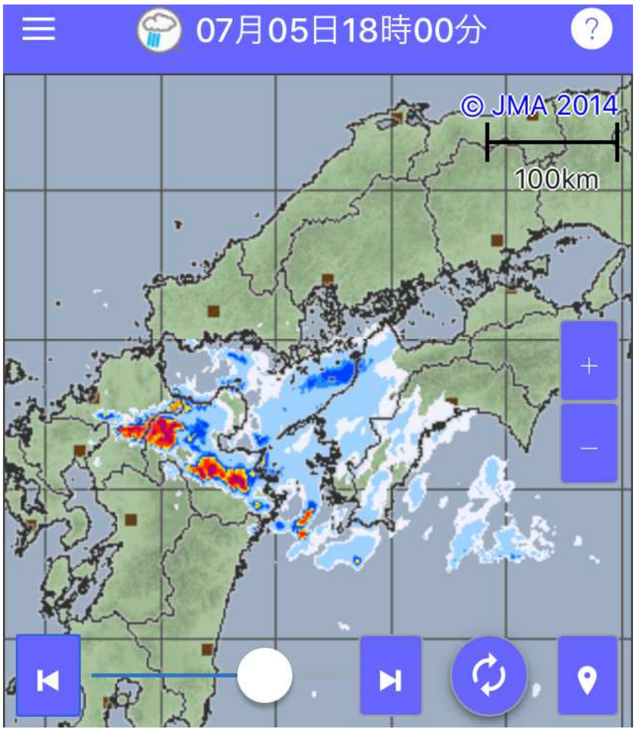
Snake-lines to issue landslide early warning by the JMA

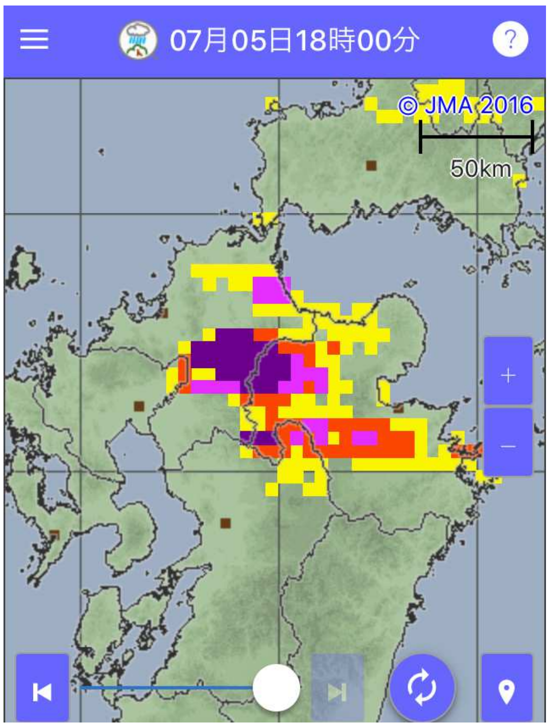
(Successfully issued warning before occurrence for about 70 % of actual landslide cases)



Plotting Soil-Water-Index value on x-axis and latest 60 minutes rainfall on y-axis. Violet lines is called as “critical line” (CL), an envelope of past 10 – 20 years snake-lines. JMA issues landslide warning to the communities 2-hours before snake line exceeds the CL. Data: Snake lines in Asakura city when the July 2017 Northern-Kyushu disaster took place.

Japan Meteorological Agency (JMA) provides real-time rainfall (left) and landslide risk (right) to the smart media

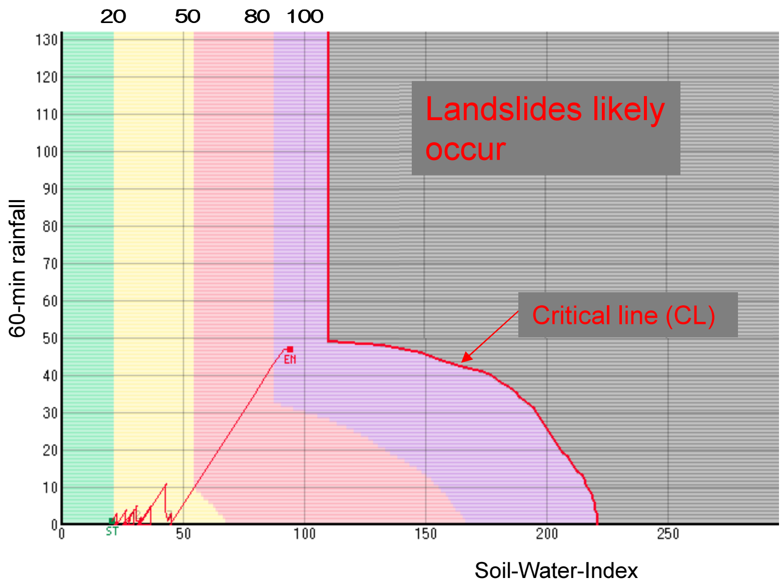




Screen capture at 18:00 JST when Northern-Kyushu extreme rainfall –induced landslide and flood disaster occurs.

Proposed “landslide risk index“ (GOI)

- A non-dimensional value which shows the current position of the snake line relative the critical line. Origin is zero, when it reaches the critical line, GOI=100.
- To enhance the capacity and reduce the pshychological pressure of residents for their decision of early evacuation.



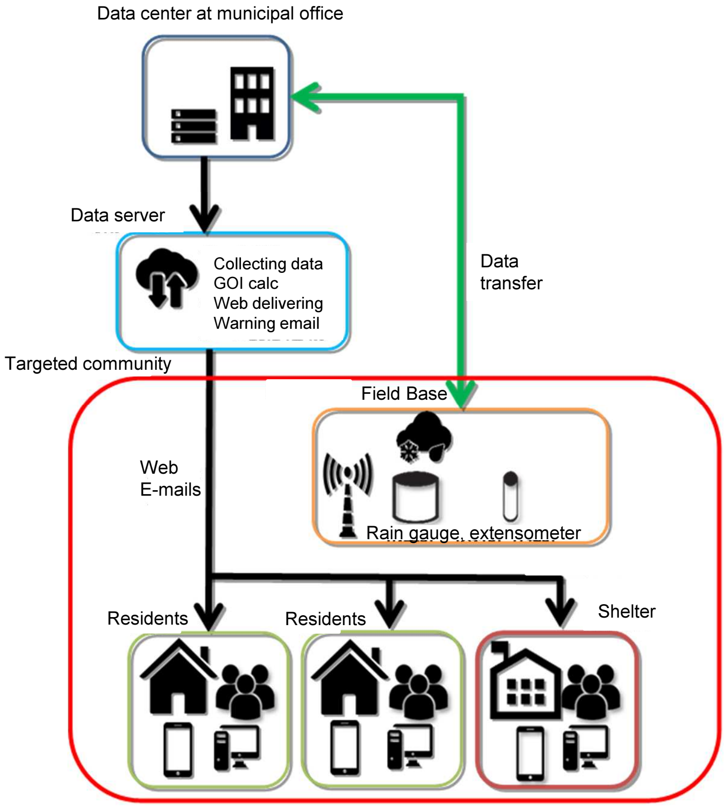
Social experiment and implementation at a landslide prone local community

- Localized extreme precipitation often occurs on slopes and cause serious landslides. They could not be detected by governmental rain gauge networks nor by rain-radars. Rain gauges should be installed on those landslide-prone slopes above communities.

- Social experiment of GOI is now undergoing at a small community of Niigata to validate the risk information system.

- Lecture for the residents on landslides and risk information literacy, as well as exercise of receiving and interpreting the information, are provided at their community house.

Landslide risk information (GOI) data delivery system



Data example delivered to smart media

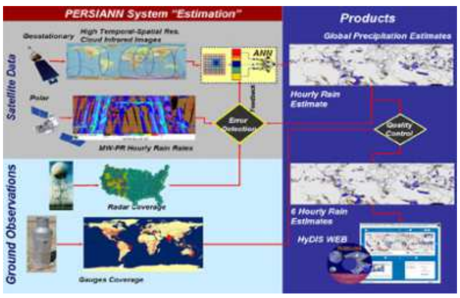
- Colors show the situation
- Landslide risk index (GOI) is indicated.
- History of past 60 minutes
- Link to JMA's rain radar site
- Link to landslide risk zone maps
- Present snake-line

Background of development of satellite-based global precipitation monitoring system

- Most of landslides are induced by torrential rain or earthquake (or both)
- Very limited number of rain gauges are available in vulnerable, developing countries.
- No implemented methodology for issuing warming of landslides in those countries
- TRMM (Tropical Rainfall Measurement Mission = US-Japan jointly launched satellite name) could be the solution for launching landslide quasi-realtime early warning system in developing countries.

TRMM-based Multi-satellite global precipitation monitoring system (TMPA)

- Most latest product: PERSIANN system … 0.25° (about 25 km space), 1-hour (time) resolution, covering 50°N - 50°S, since 2006.



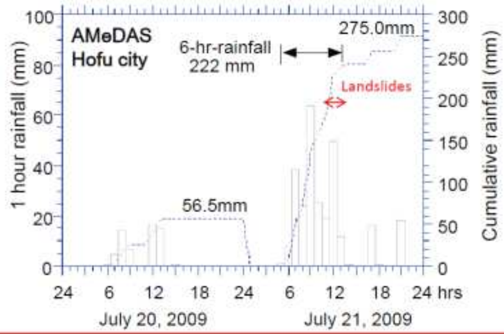
- Global monitoring supports providing precipitation data and constructing warning system in every developing country without ground-based rain gauge

Comparison of TRMM-based 3-hours precipitation and ground-based rain-gauge data

Ground rain gauge record

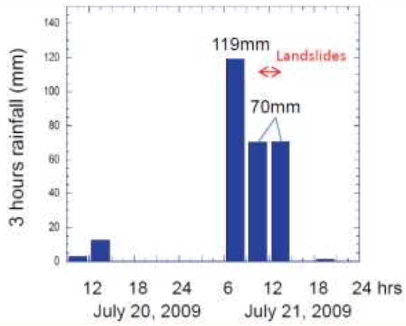
24-hr-rainfall : 265mm
9-hr-rainfall : 242 mm
6-hr-rainfall : 222 mm
1-hr-rainfall: 64 mm

15 killed by landslides



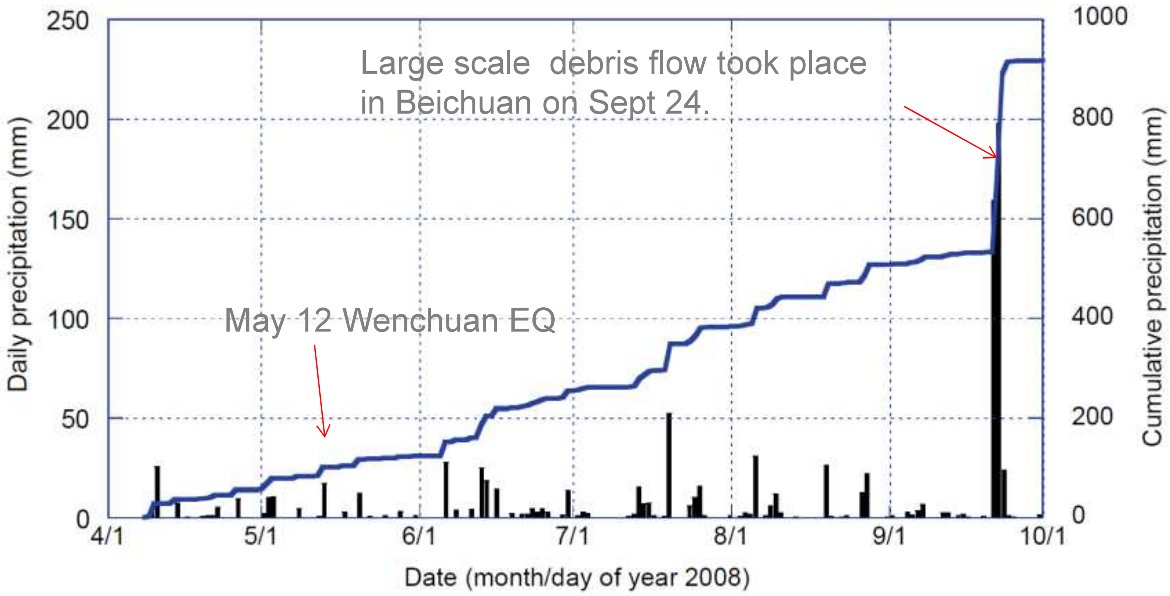
TRMM satellite rainfall monitoring

High correlation with rain gauge

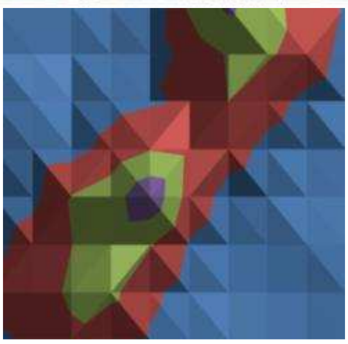


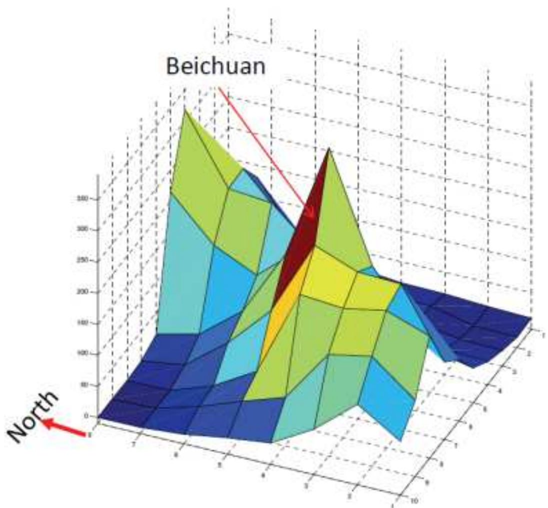
Sept 24 2008 debris flow disaster induced by torrential rainfall in the Wenchuan earthquake hit area, China

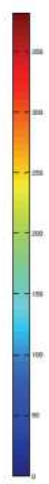
Daily and cumulative precipitation in the Beichuan monitored by TRMM



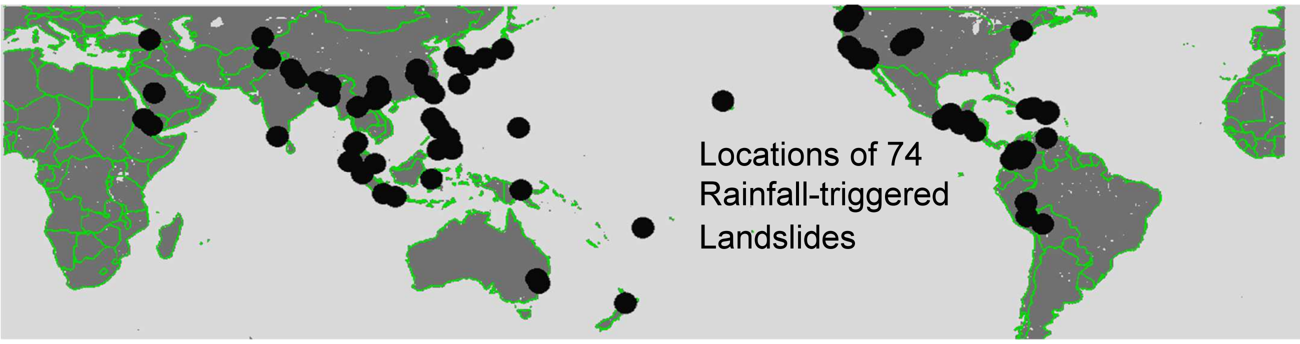
Torrential rainfall were observed along the epicenter area, which may have induced numerous debris flows

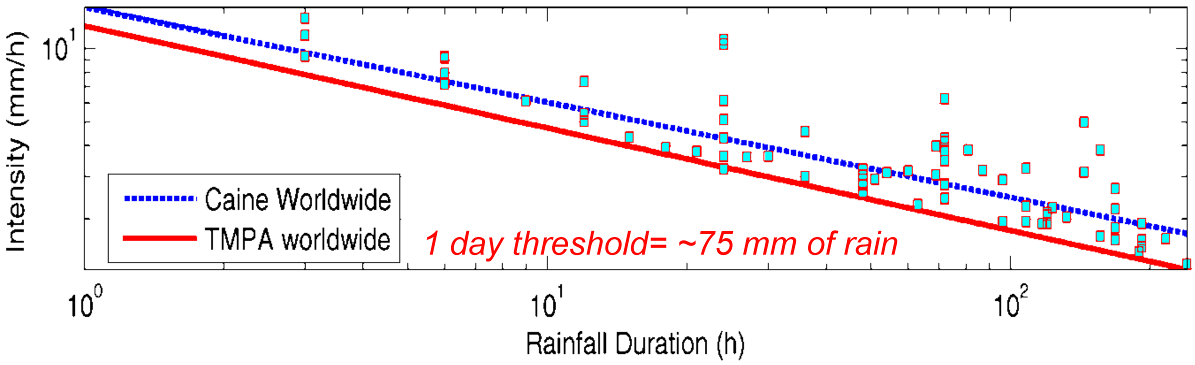






Relation of Rain Duration-Intensity Threshold and Landslide Occurrences



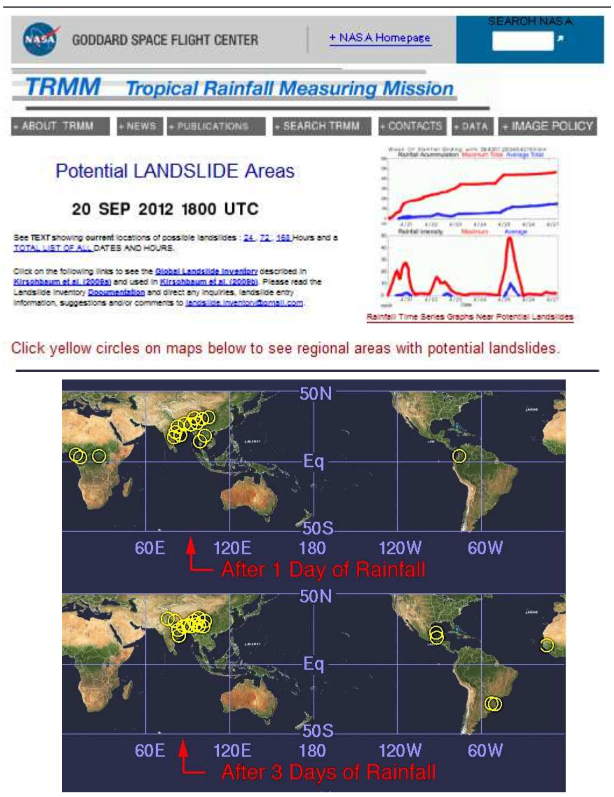


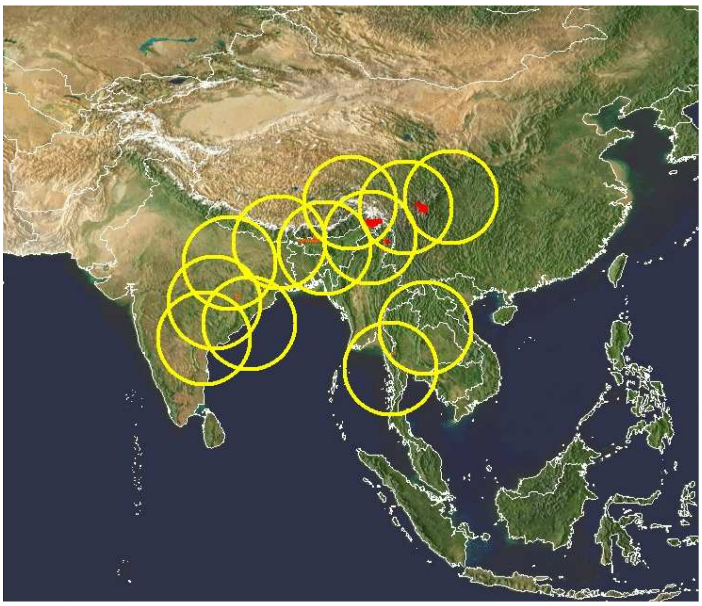
TMPA-based Threshold: I = 12.45 D -0.42

Caine's (1980) Threshold: I = 14.82 D-0.39

NASA's TRMM potential landslide warning web site

(experimental, Hydrology team of NASA Goddard Space Flight Center)

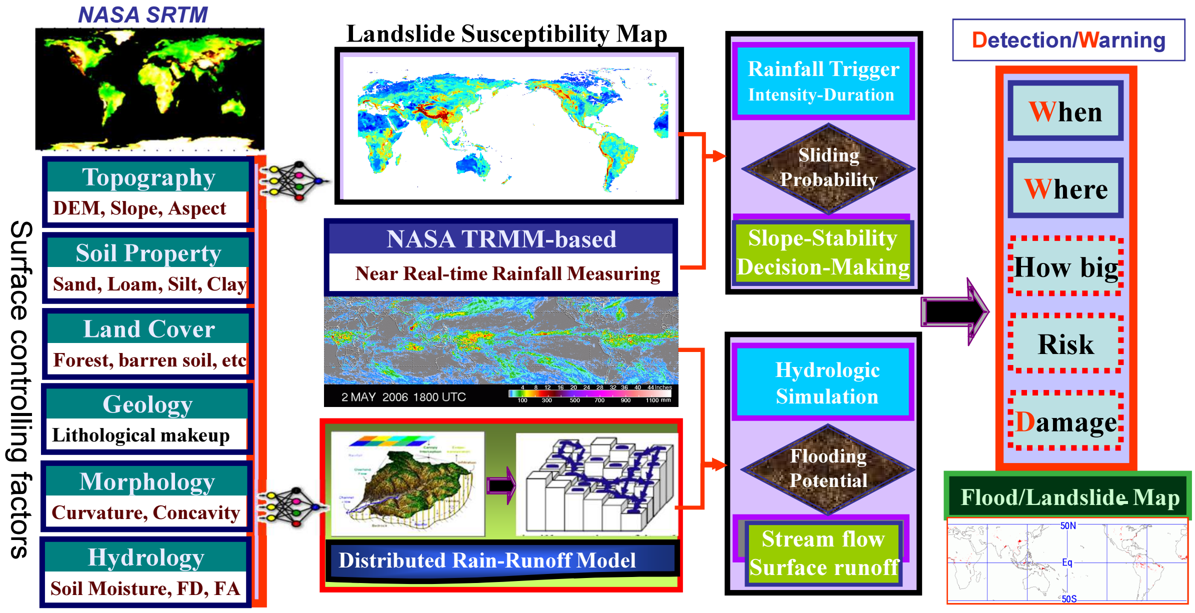




Landslide Potential

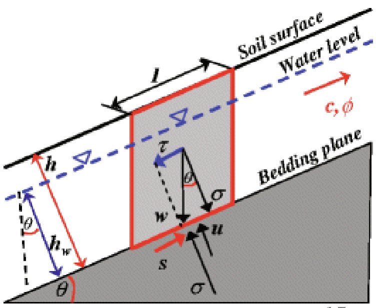
Likely	Very Likely

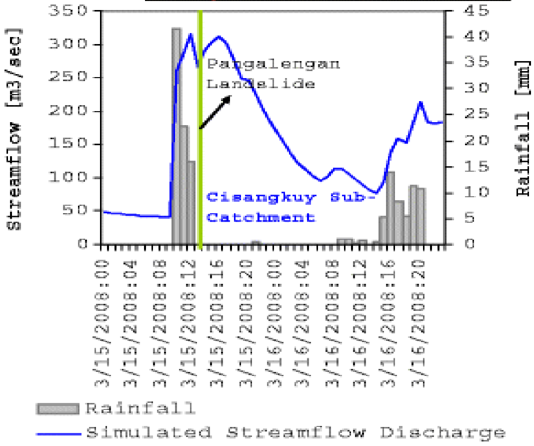
A Framework for Global Flood-Landslide Alert System

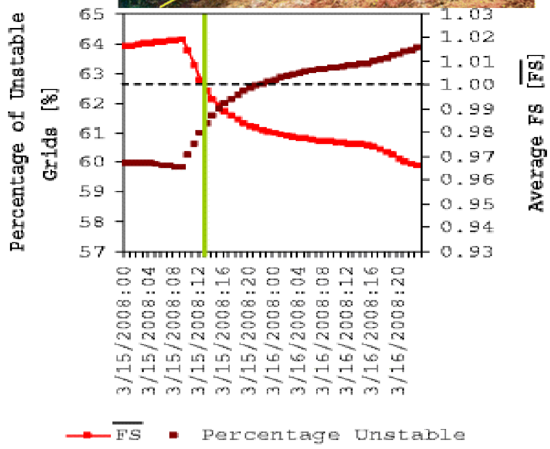


Hong et al., 2006, GRL; Hong et al. 2006, IEEE TGRS; Hong et al. 2006, Natural Hazards

Study on application of TRMM data to landslide early warning (Apip et al. 2010)



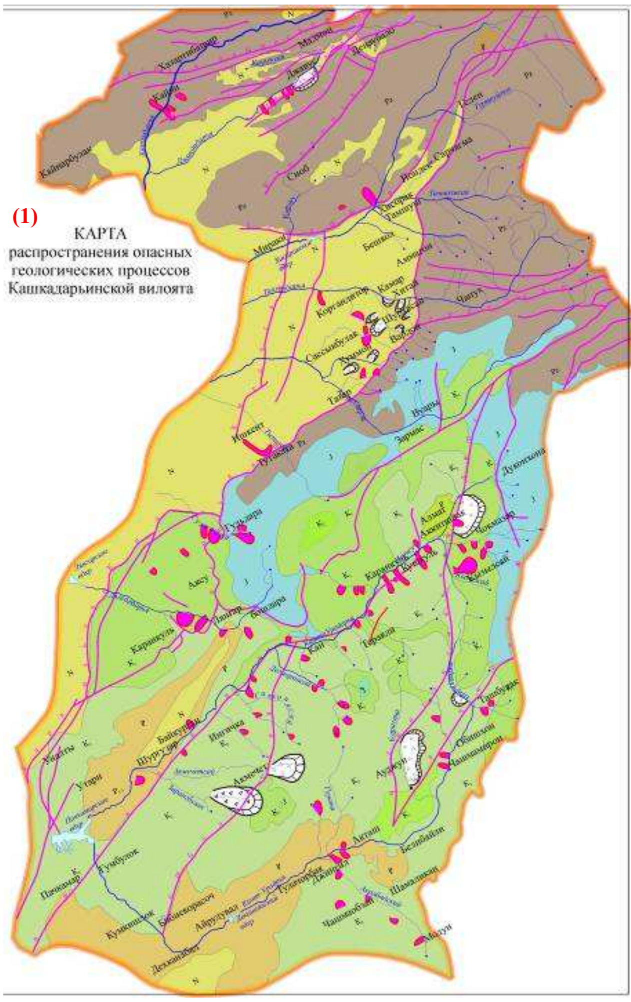


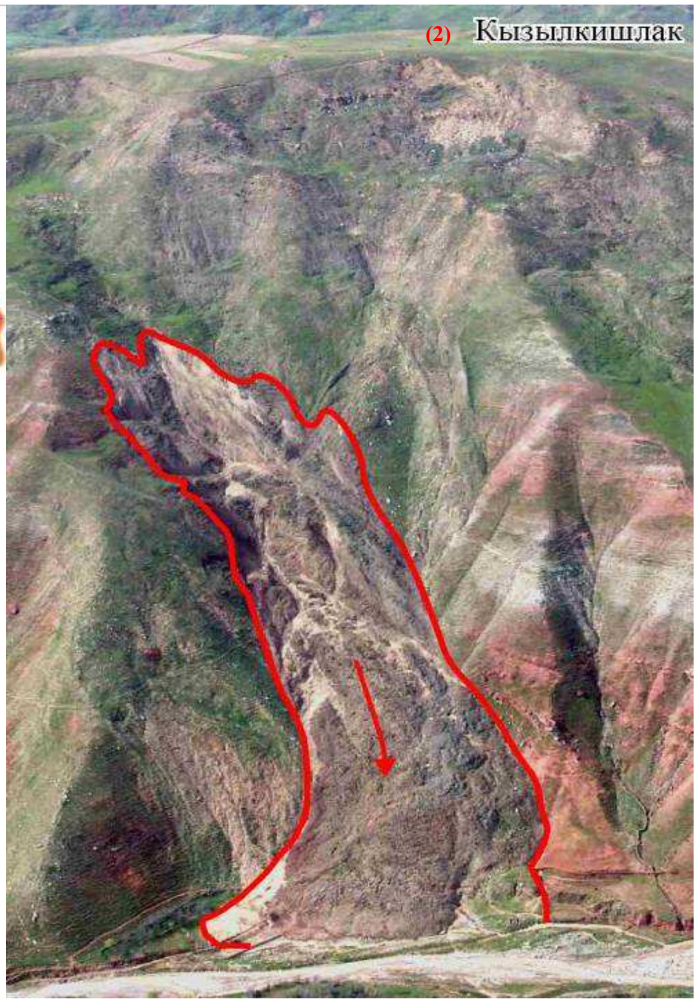


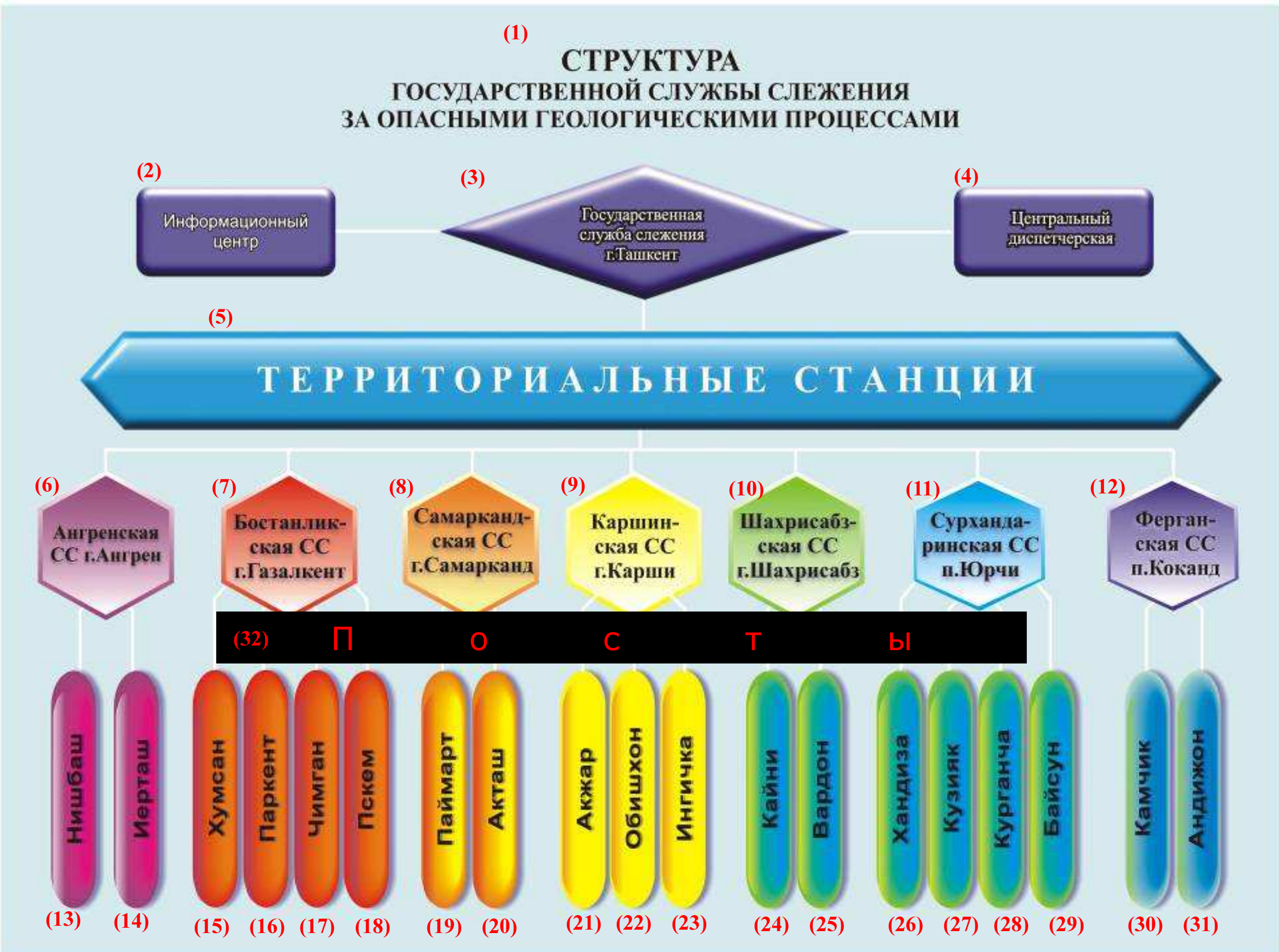
Landslide Disaster Mitigation System in Uzbekistan, Central Asia

- State Monitoring Service was set up in 1996 to collect nation-wide landslide precursor phenomena like cracks, from residents and shepherds.
- Emergency Management Committee examines and designate risk sites based on the info.
- Govt. can force the downslope residents to move to safer area temporary or permanently.
- Since 1996, no one was killed by landslides by the system.

(1) Р е с п у б л и к а У з б е к и с т а н


КАРТА
распространения опасных
геологических процессов
Кашкадарьинской вилоята


Кызылкишлак


СТРУКТУРА
ГОСУДАРСТВЕННОЙ СЛУЖБЫ СЛЕЖЕНИЯ
ЗА ОПАСНЫМИ ГЕОЛОГИЧЕСКИМИ ПРОЦЕССАМИ
Информационный центр
Государственная служба слежения г.Ташкент
Центральный диспетчерская
ТЕРРИТОРИАЛЬНЫЕ СТАНЦИИ
Ангренская СС г.Ангрен
Бостанлыкская СС г.Газалкент
Самаркандская СС г.Самарканд
Каршинская СС г.Карши
Шахрисабзская СС г.Шахрисабз
Сурхандаринская СС п.Юрчи
Ферганская СС п.Коканд
Посты
Нишбаш
Иерташ
Хумсан
Паркент
Чимган
Пскем
Паймарт
Акташ
Акжар
Обишхон
Ингичка
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Камчик
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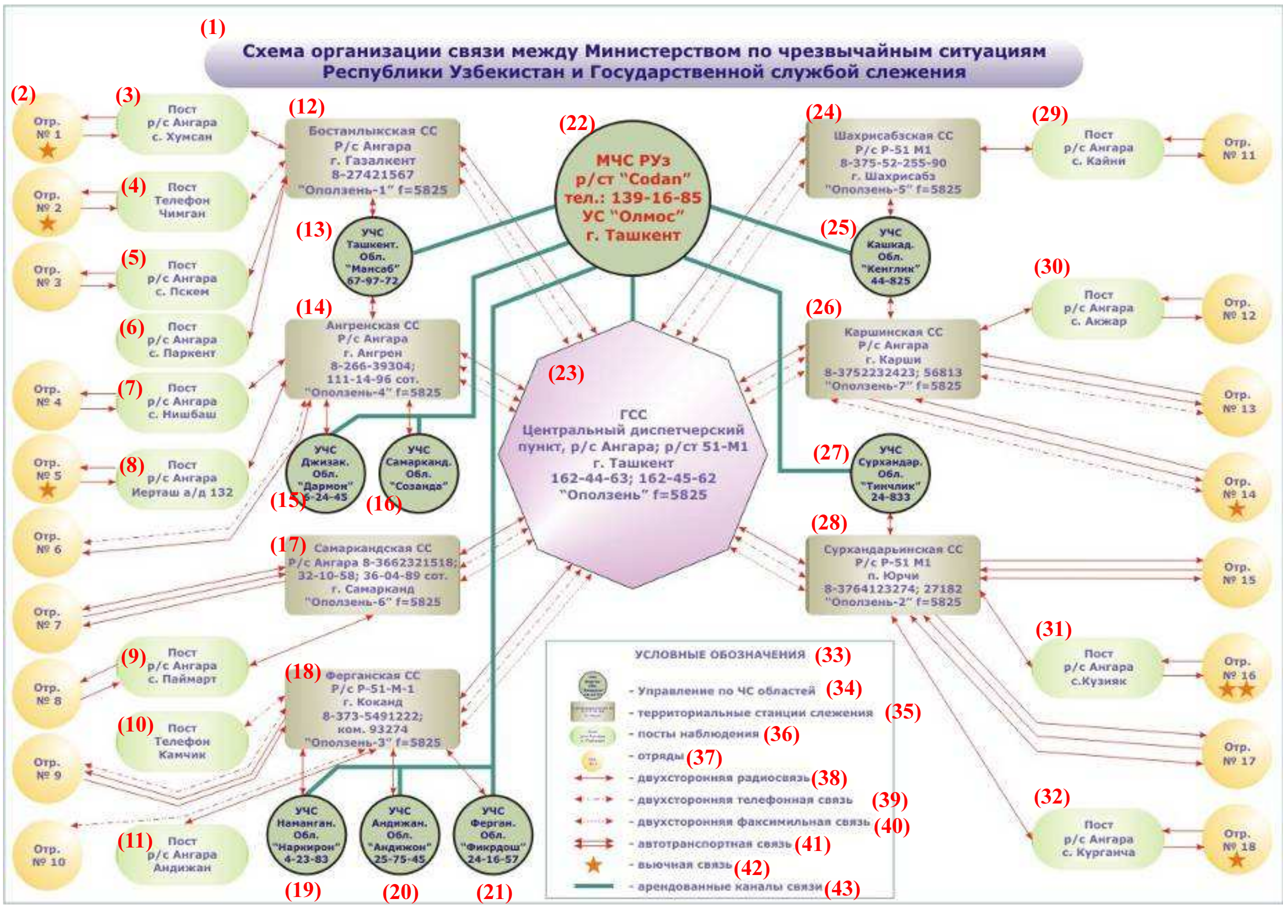


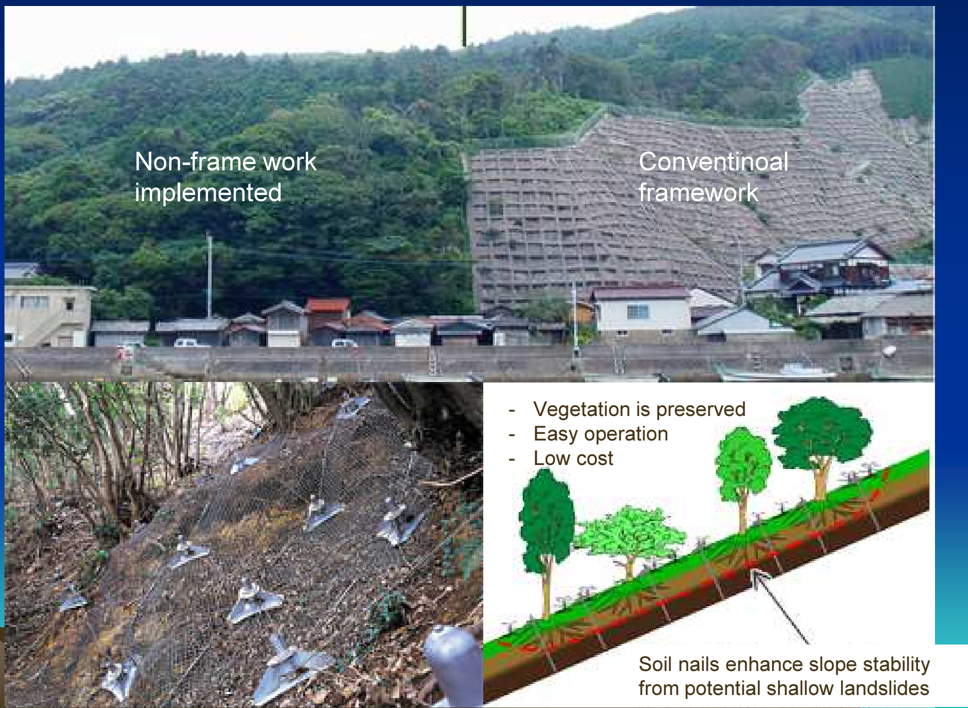
Conclusions

- Advanced technology based on LiDAR (GB/airbourne/drone), InSAR (PS, GB, etc.) will help to extract slope under landslide risk.
- New countermeasures techniques will help sustainable and ecological development of communities.
- Advanced early warning technology / indigenous engineering combined with community-based activities will enhance local resilience.

Thank you for your attention !!

NEW LANDSLIDE COUNTERMEASURE TECHNIQUES

Non-framework slope stabilization



Ring-net are used as countermeasure against rock falls and debris flows

Implemented in Hiroshima after Agusut 2004 debris flow disaster.