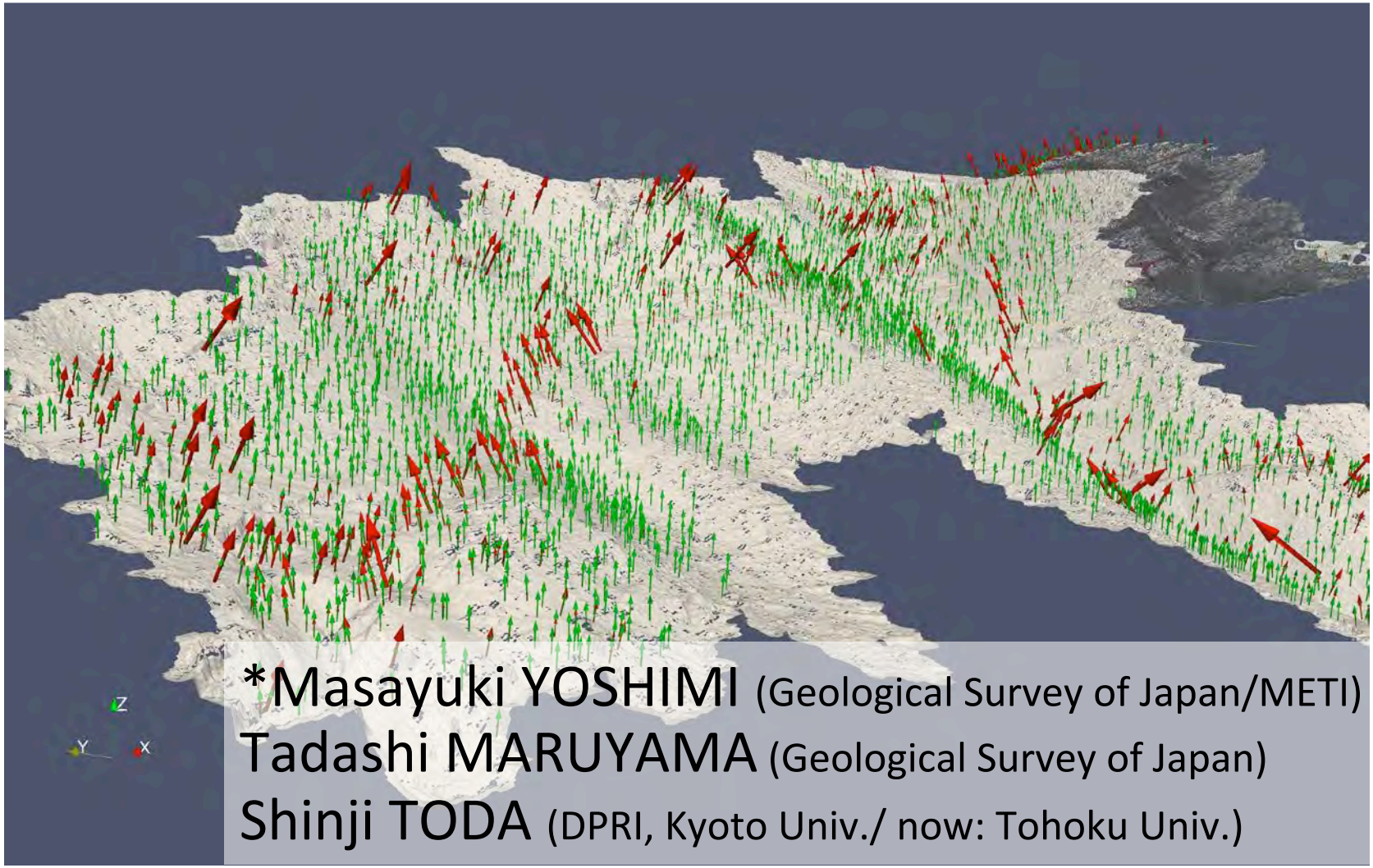
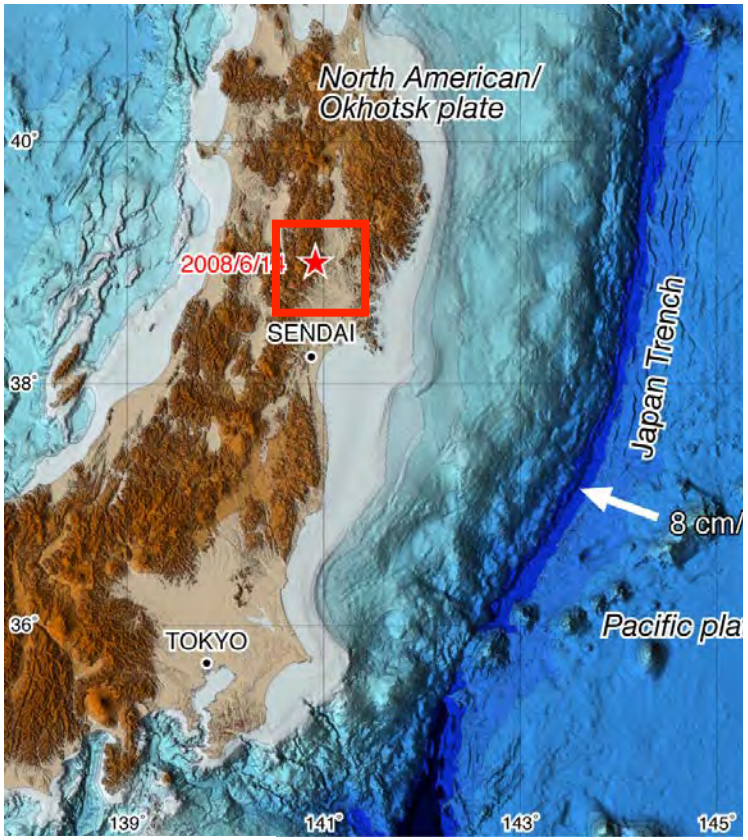
Superfine mapping of the earthquake surface ruptures in the forests with terrestrial LiDAR

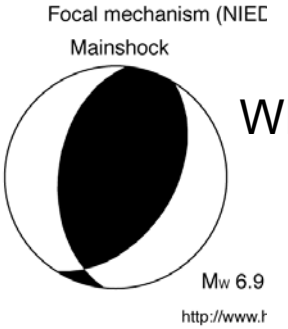
18 Sep. 2013 VISES workshop@ERI



*Masayuki YOSHIMI (Geological Survey of Japan/METI)
Tadashi MARUYAMA (Geological Survey of Japan)
Shinji TODA (DPRI, Kyoto Univ./ now: Tohoku Univ.)

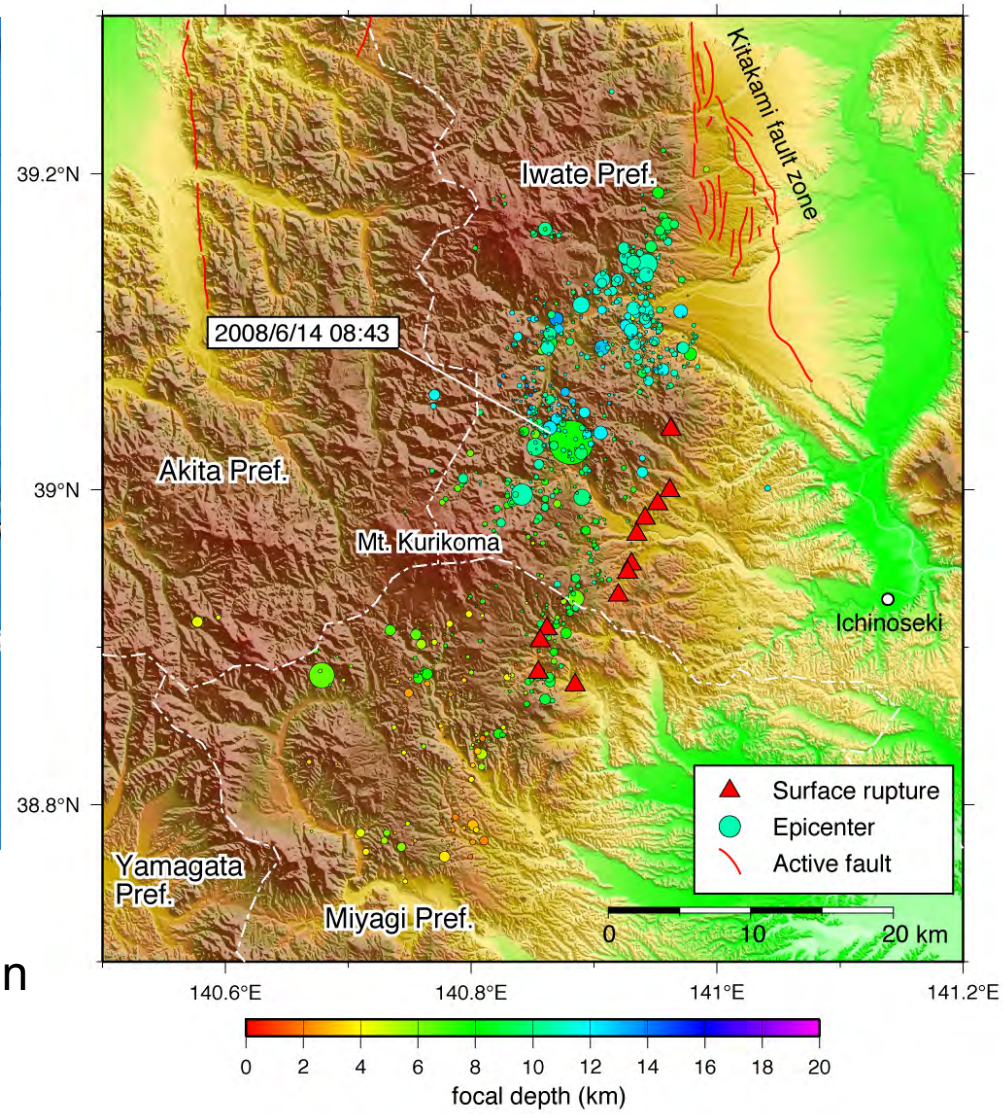
2008 Iwate-Miyagi Inland earthquake (M6.9)





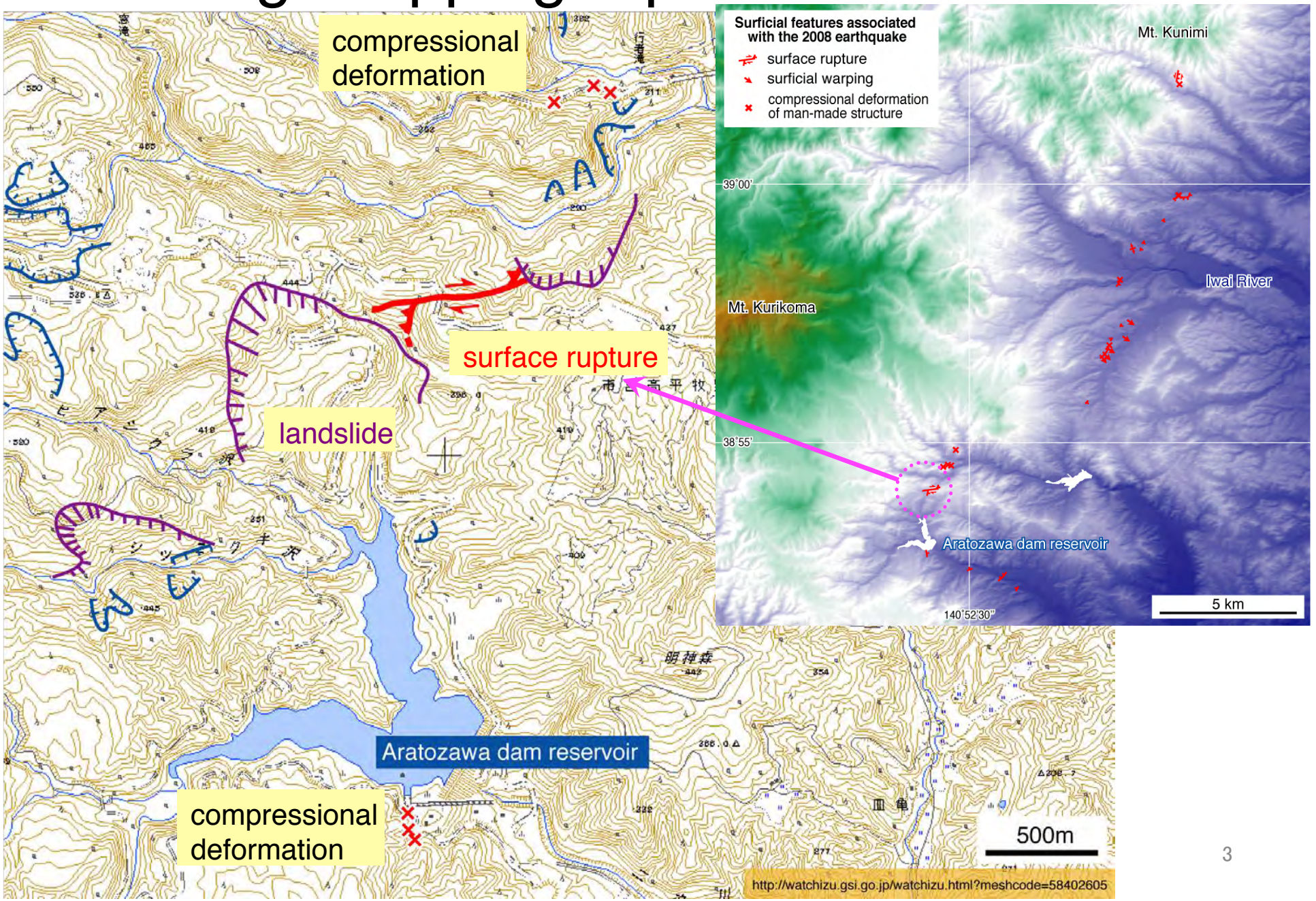
WNW-ESE compression

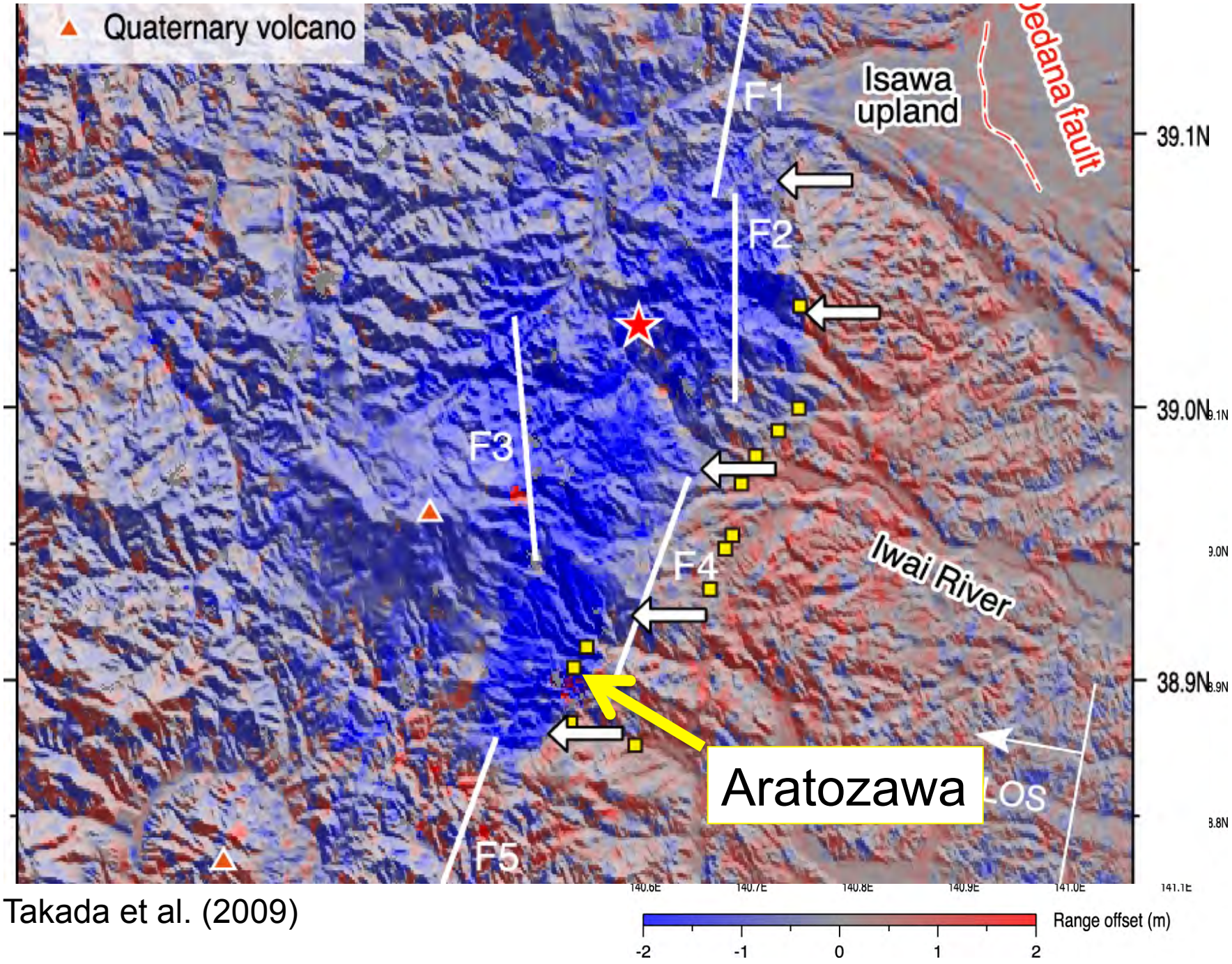
Toda et al. (2010)



We found spotty surface ruptures along east margin of the source area

Large slipping rupture at the south

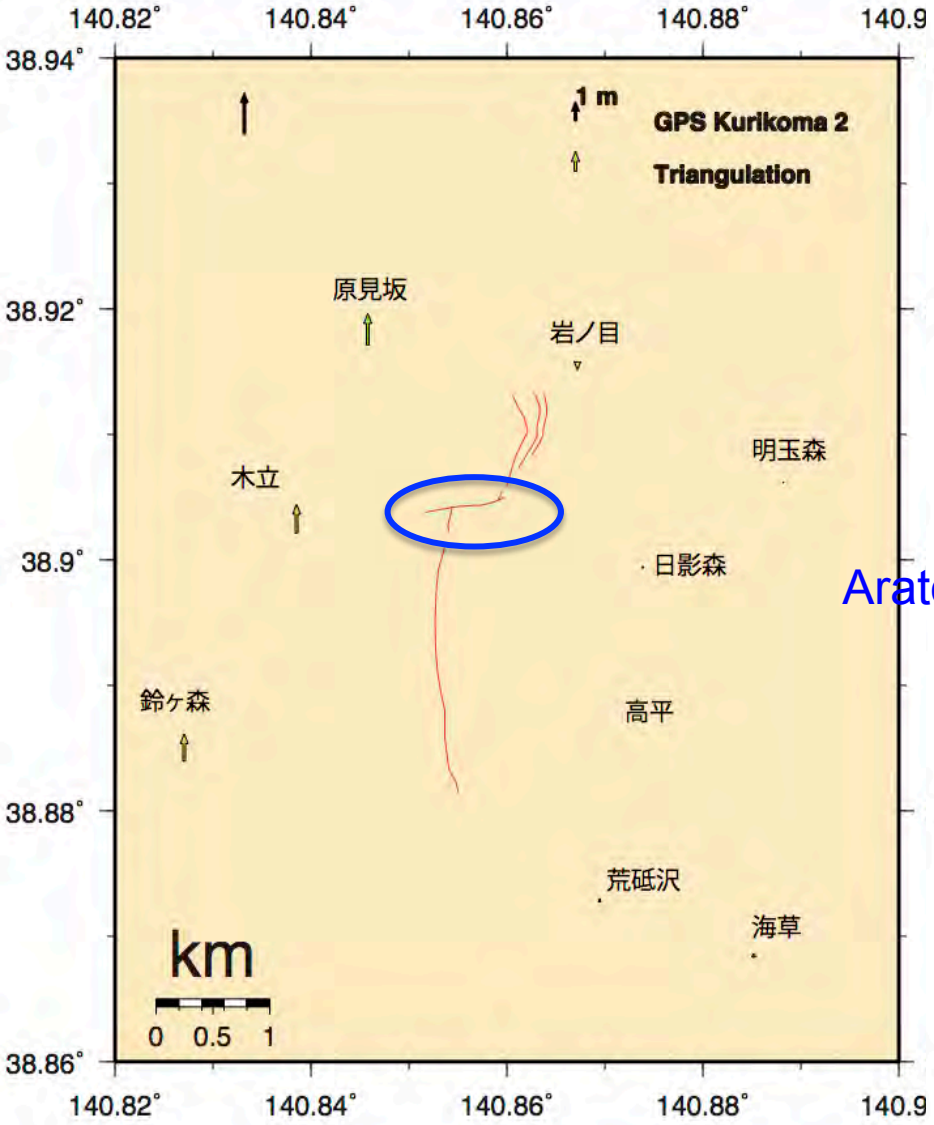




Takada et al. (2009)

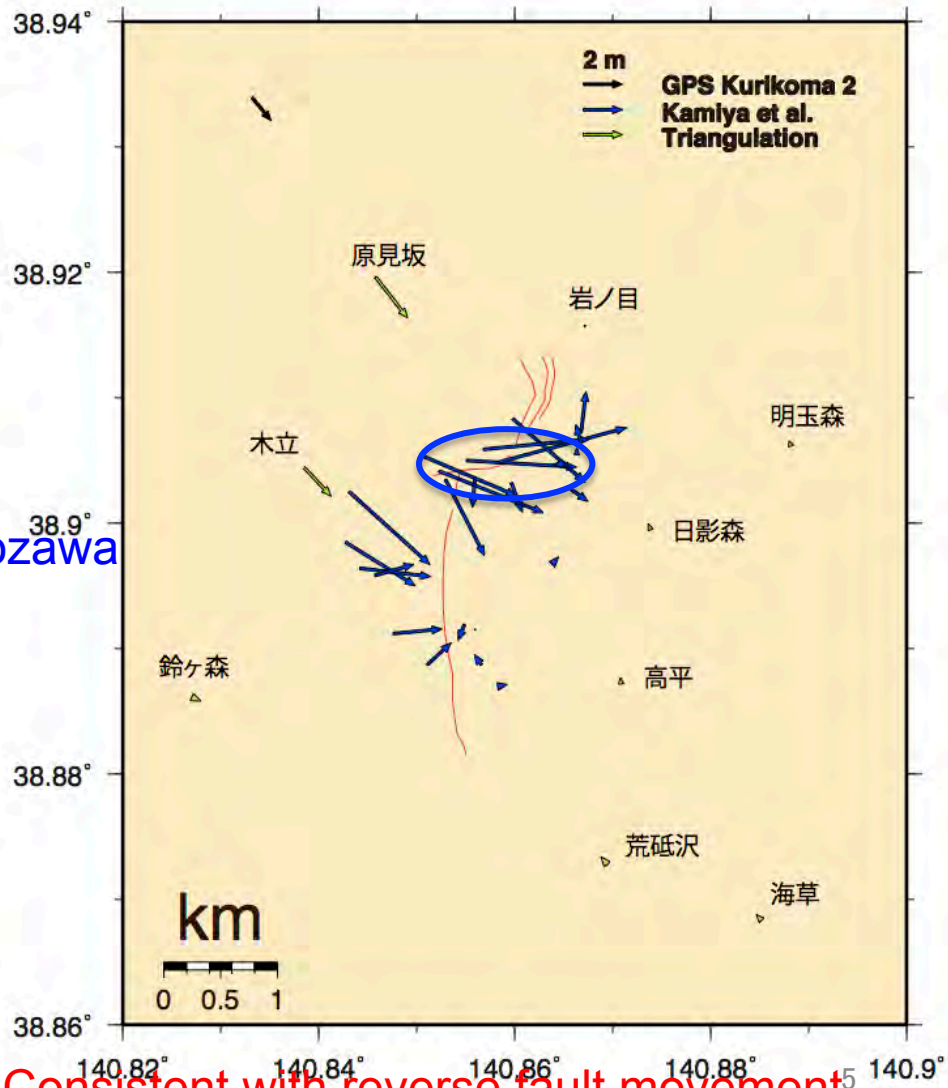
Triangulation result around the site

Vertical (Post – Pre Eq.)



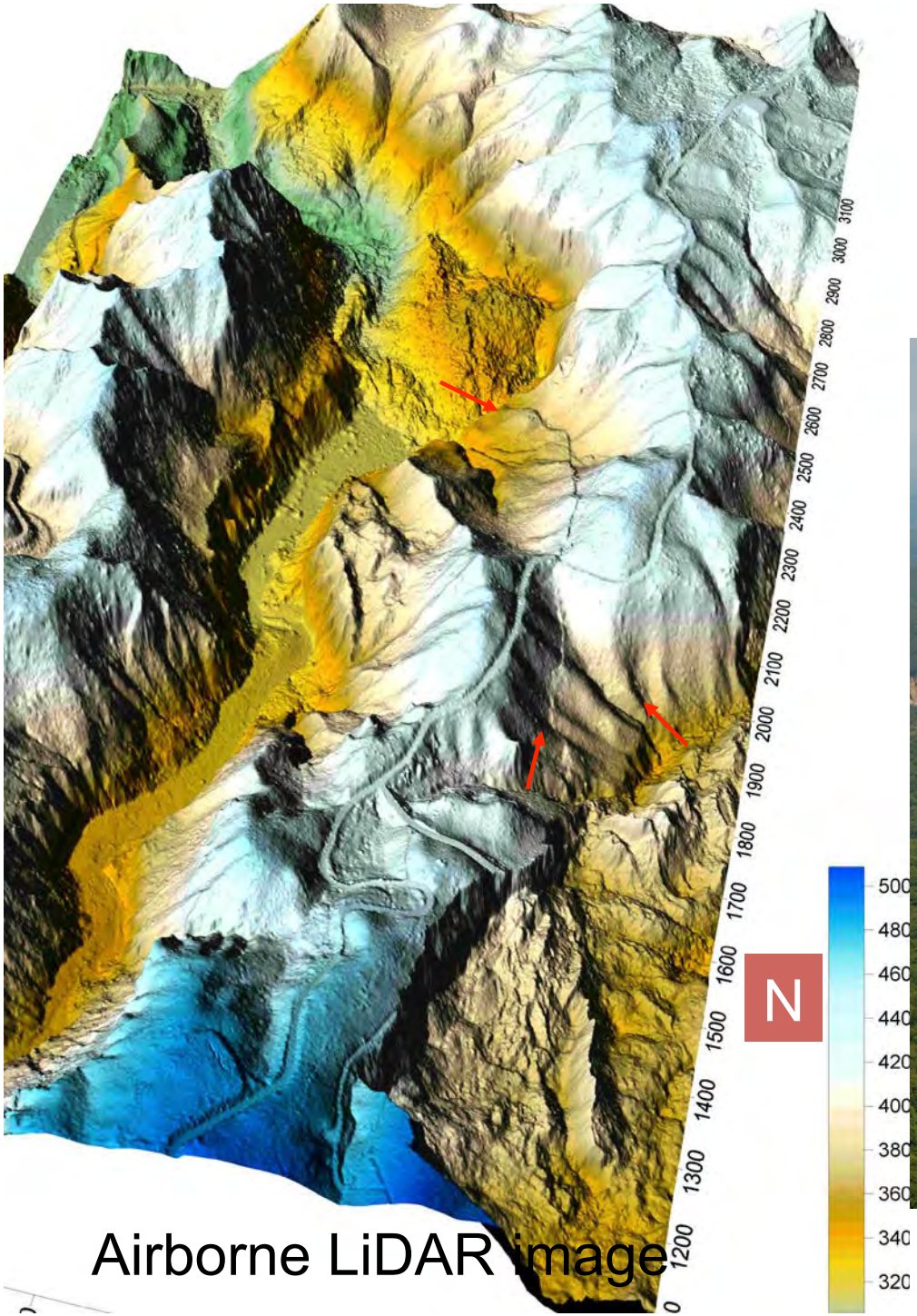
Awata (2009) Personal comm.

Horizontal (Post – Pre Eq.)

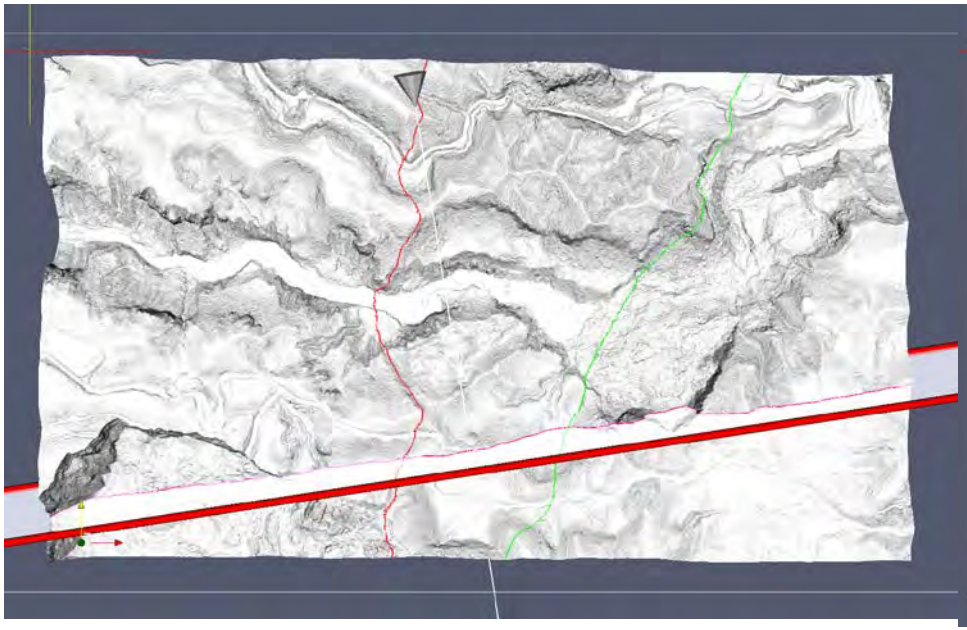


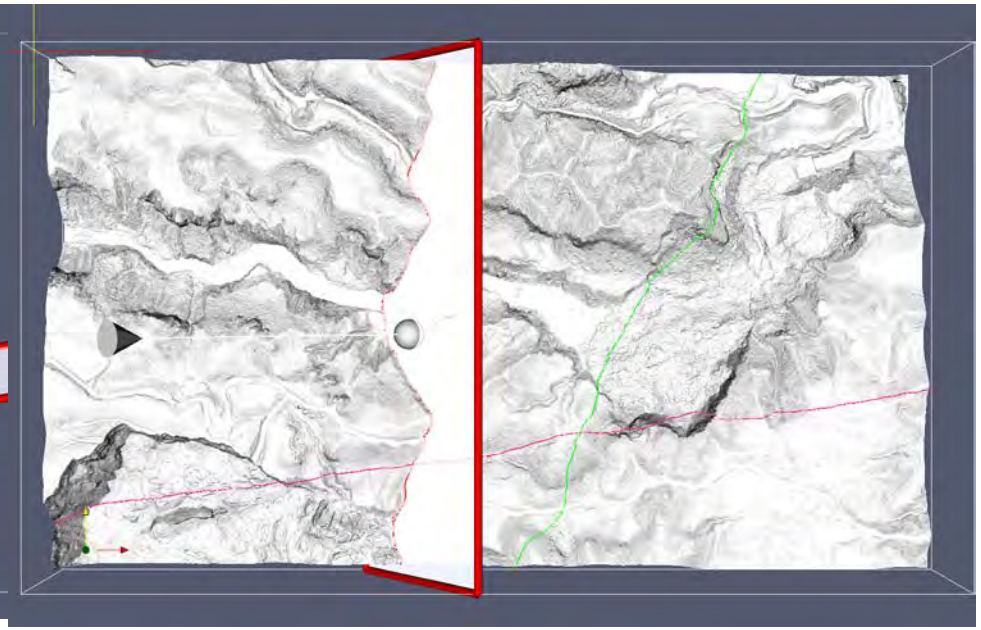
Aratozawa

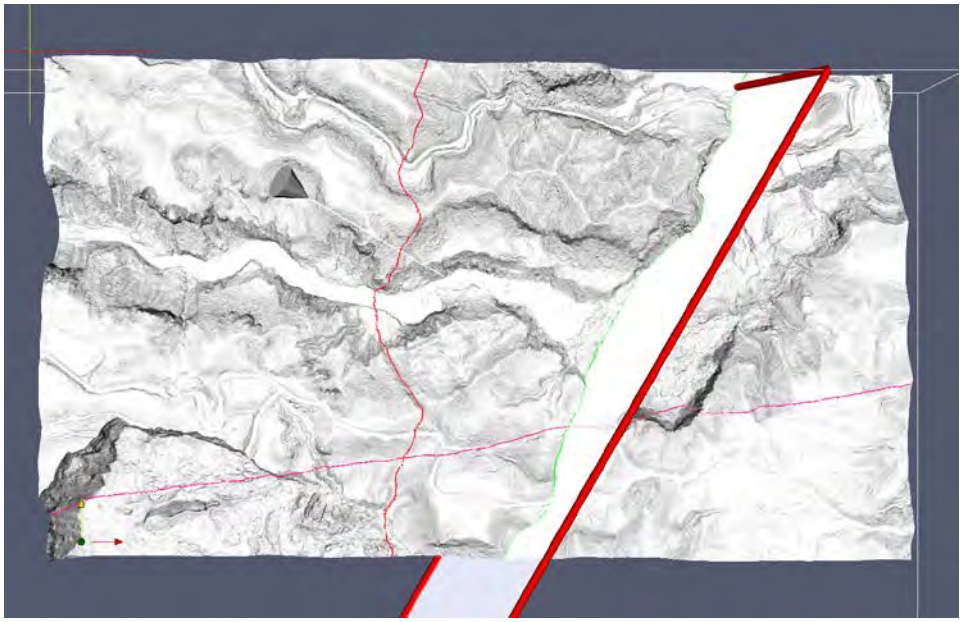
Consistent with reverse fault movement



Airborne LiDAR image



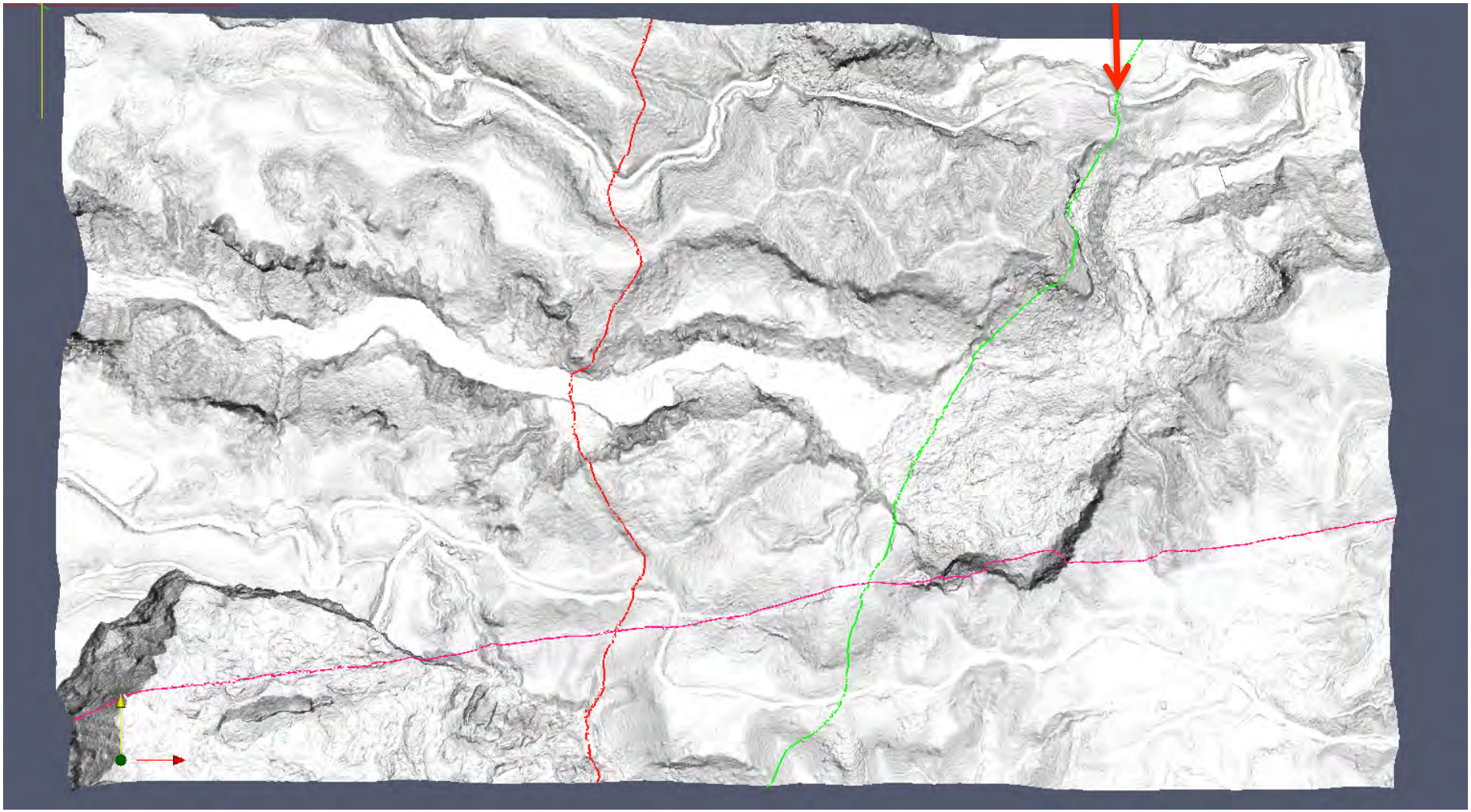




Combination of
2 thrust & 1 strike slip faults
explains surface trace

Yoshimi et al. (2008) @ AGU

1 m shortening



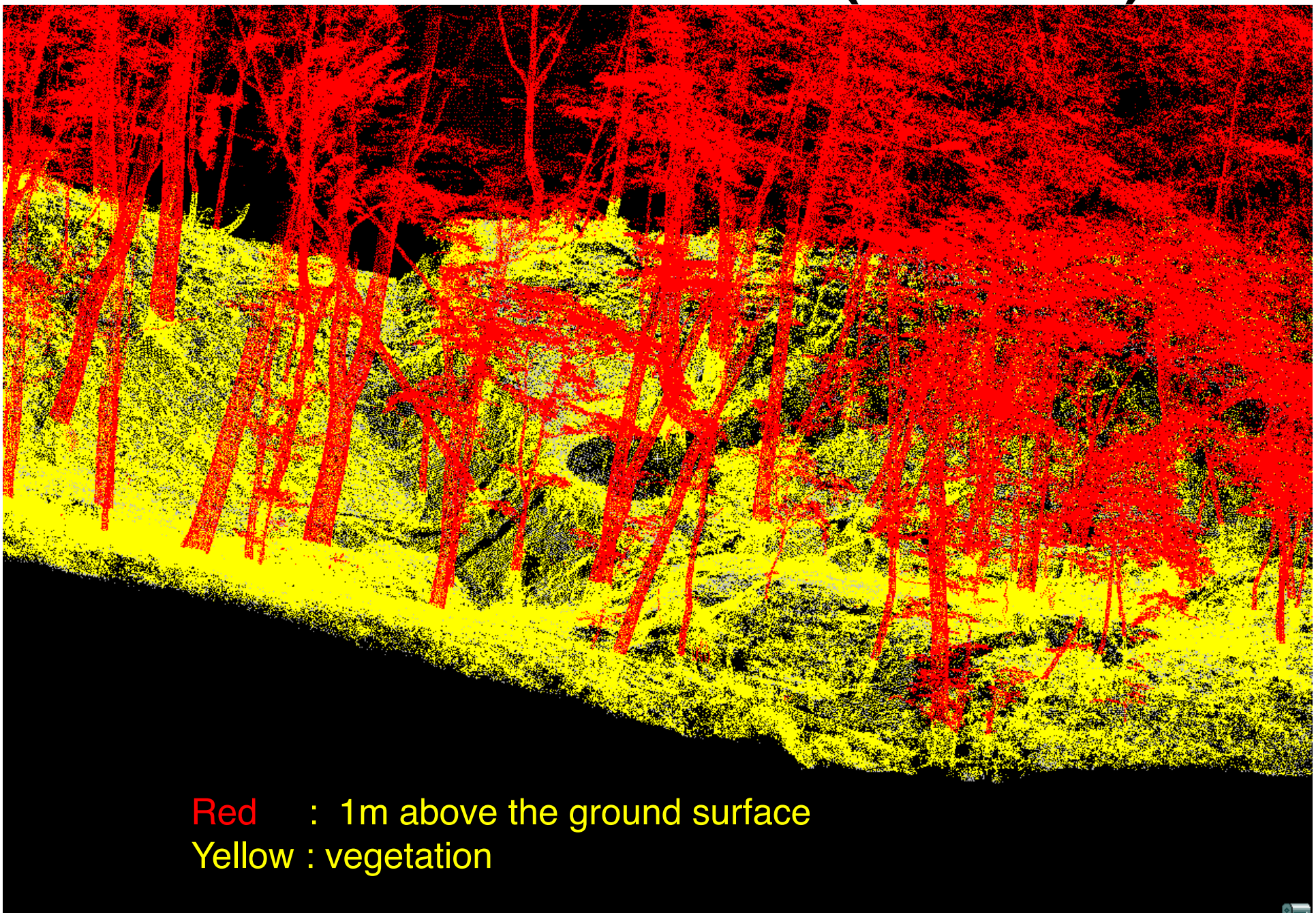
Yoshimi et al. (2008) @ AGU

Large slip rupture

Large slip thrusting

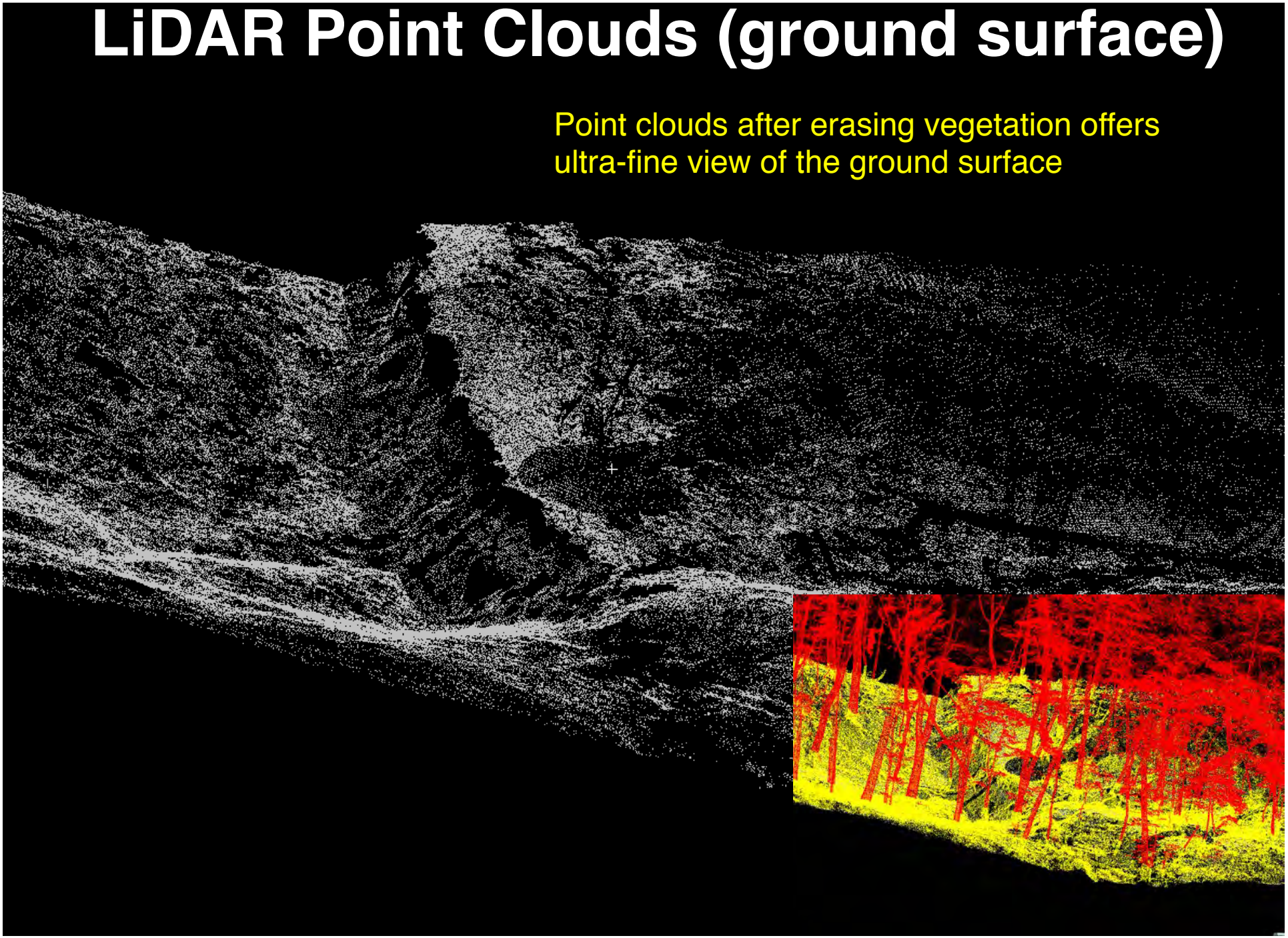
LiDAR mapping in the forest

LiDAR Point Clouds (raw data)



LiDAR Point Clouds (ground surface)

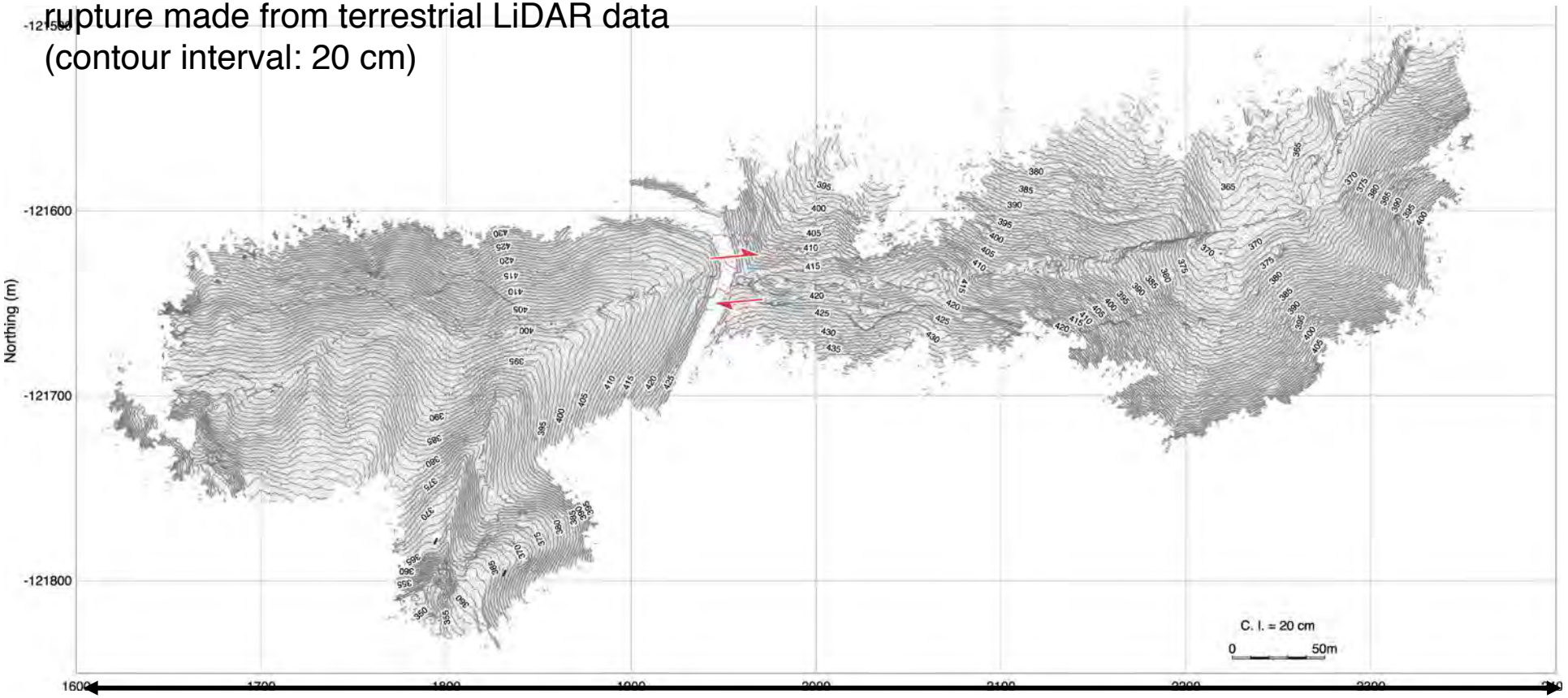
Point clouds after erasing vegetation offers ultra-fine view of the ground surface



Terrestrial LiDAR mapping

The LiDAR-derived ultra-high accuracy digital elevation models rendered overall topographic features associated with the ruptures

Topographic contour map along the surface rupture made from terrestrial LiDAR data (contour interval: 20 cm)

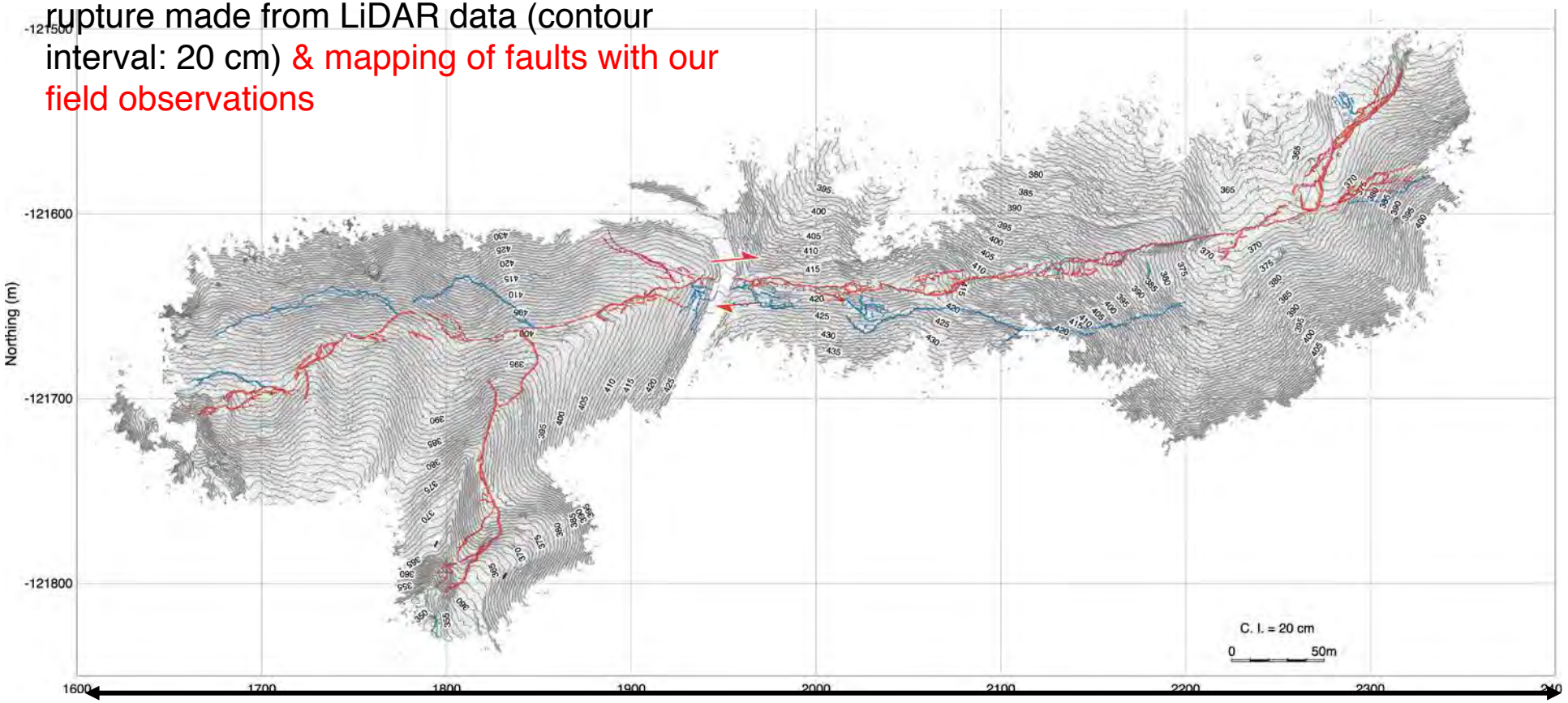


Maruyama, Toda, Yoshimi et al. (2009)

Terrestrial LiDAR mapping

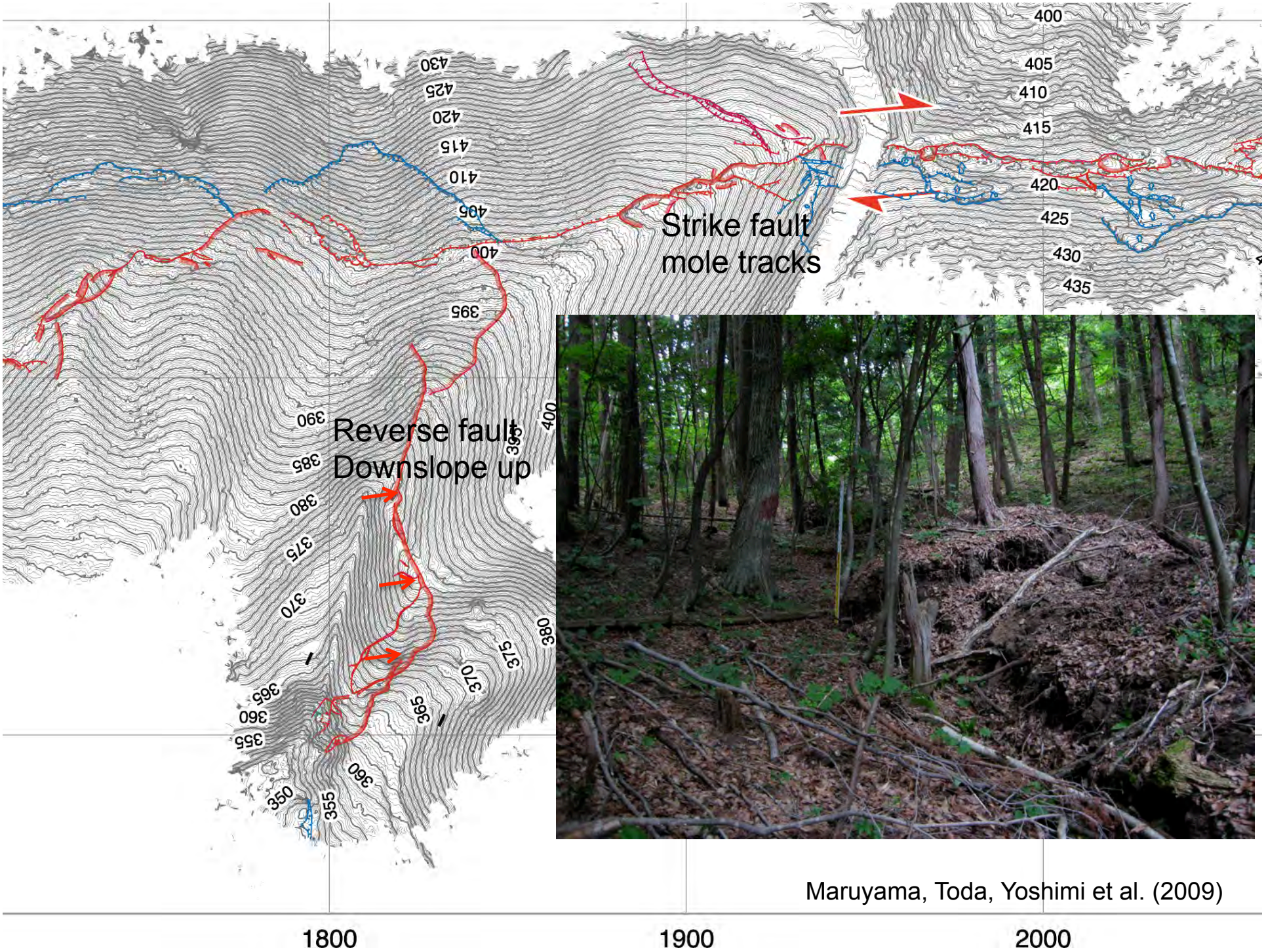
The LiDAR-derived ultra-high accuracy digital elevation models rendered overall topographic features associated with the ruptures

Topographic contour map along the surface rupture made from LiDAR data (contour interval: 20 cm) & mapping of faults with our field observations

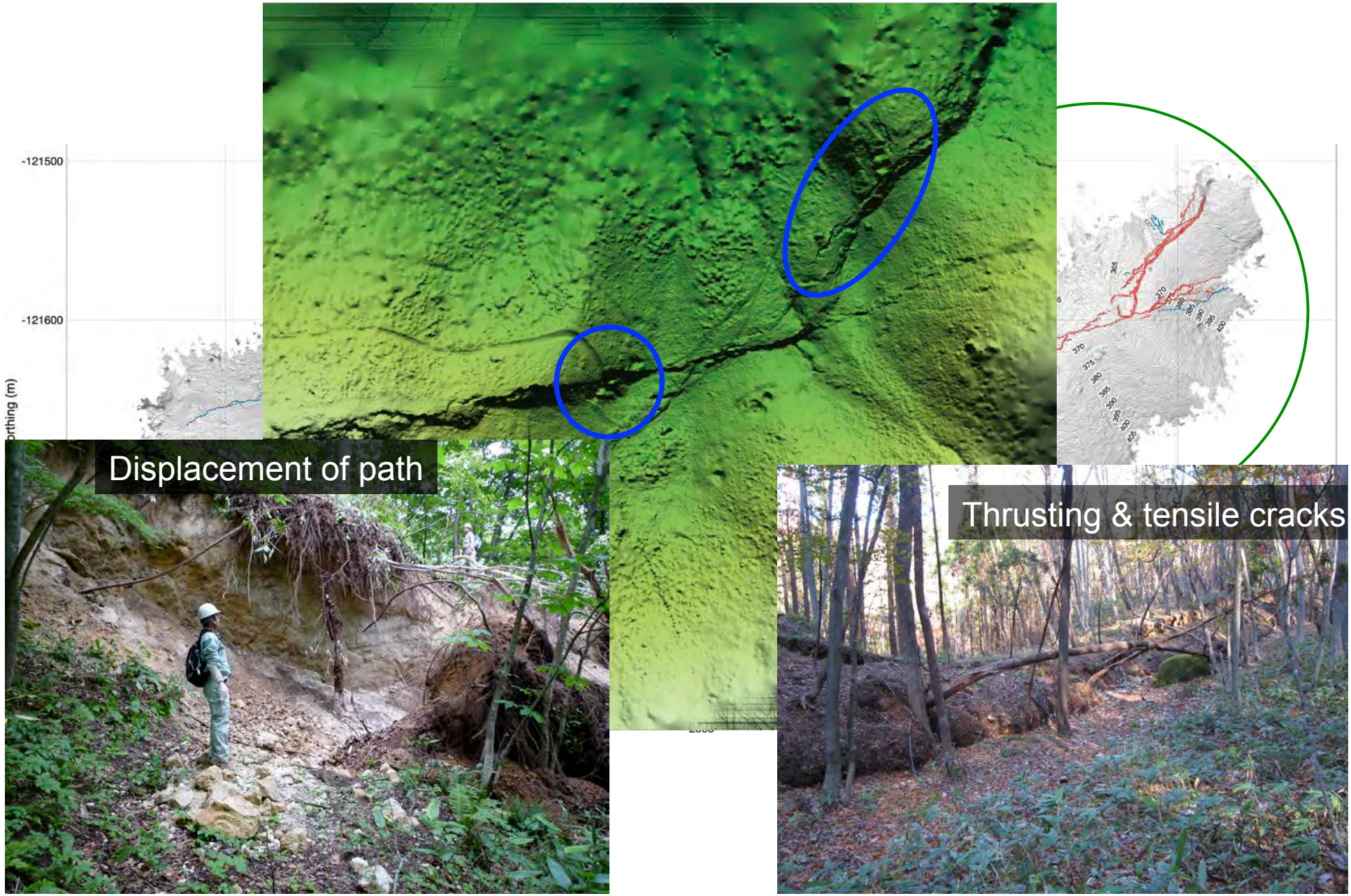


800 m

Maruyama, Toda, Yoshimi et al. (2009)


Strike fault
mole tracks
Reverse fault
Downslope up
Maruyama, Toda, Yoshimi et al. (2009)
1800
1900
2000

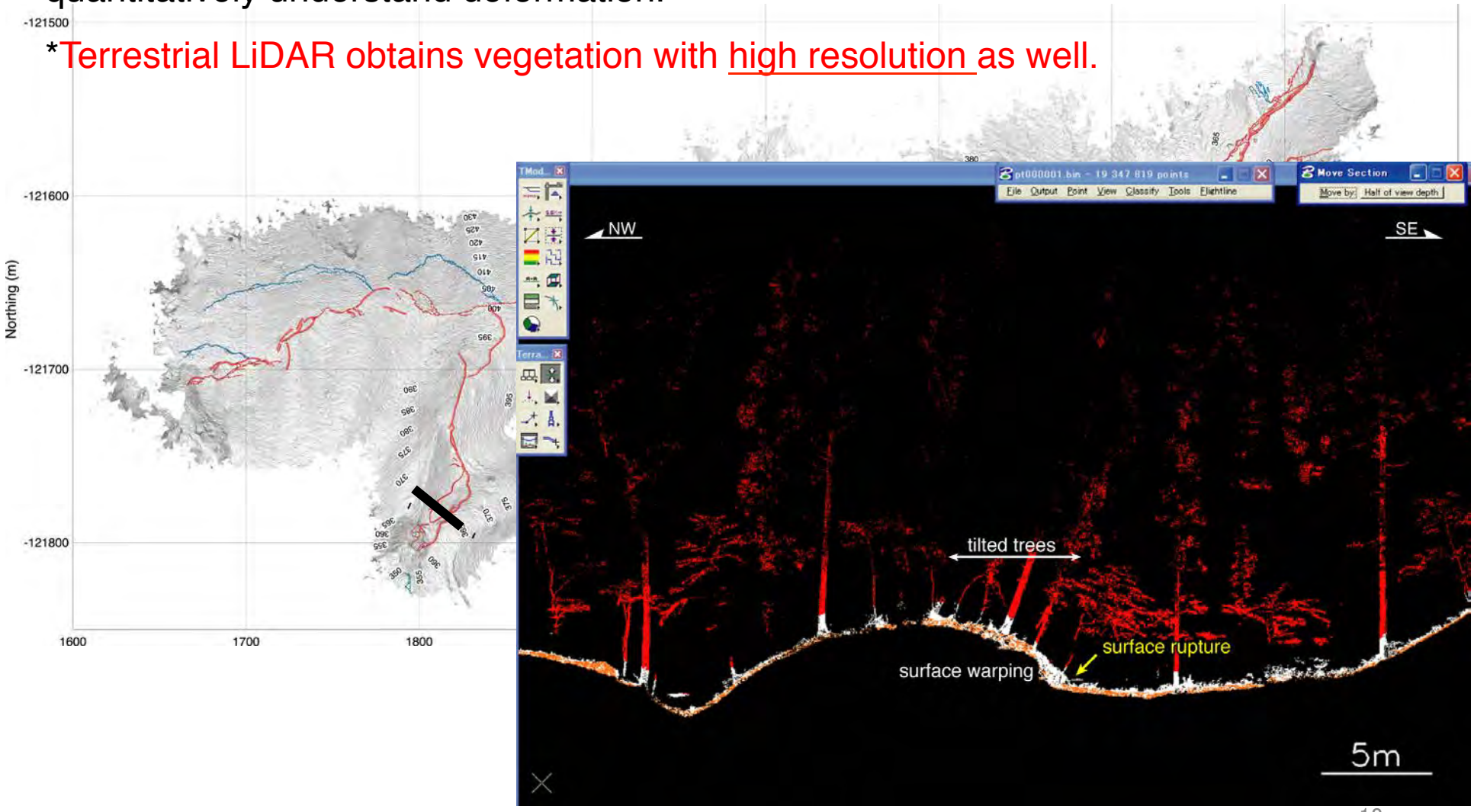
Terrestrial LiDAR mapping



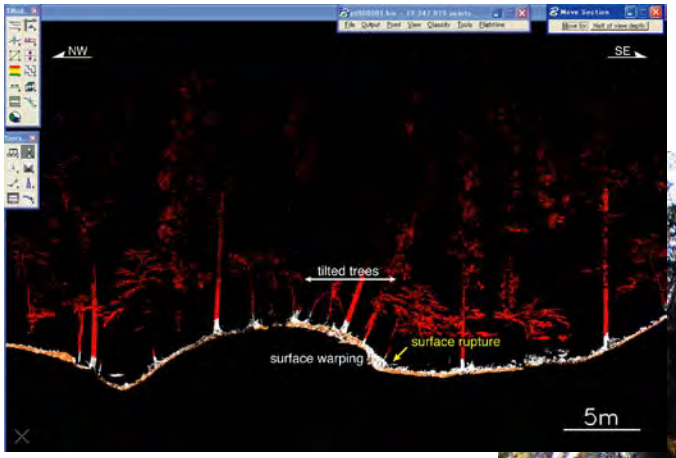
Vivid imaging helped by trees and grass

We get ultra-fine topography data, but, need more information to quantitatively understand deformation.

*Terrestrial LiDAR obtains vegetation with high resolution as well.



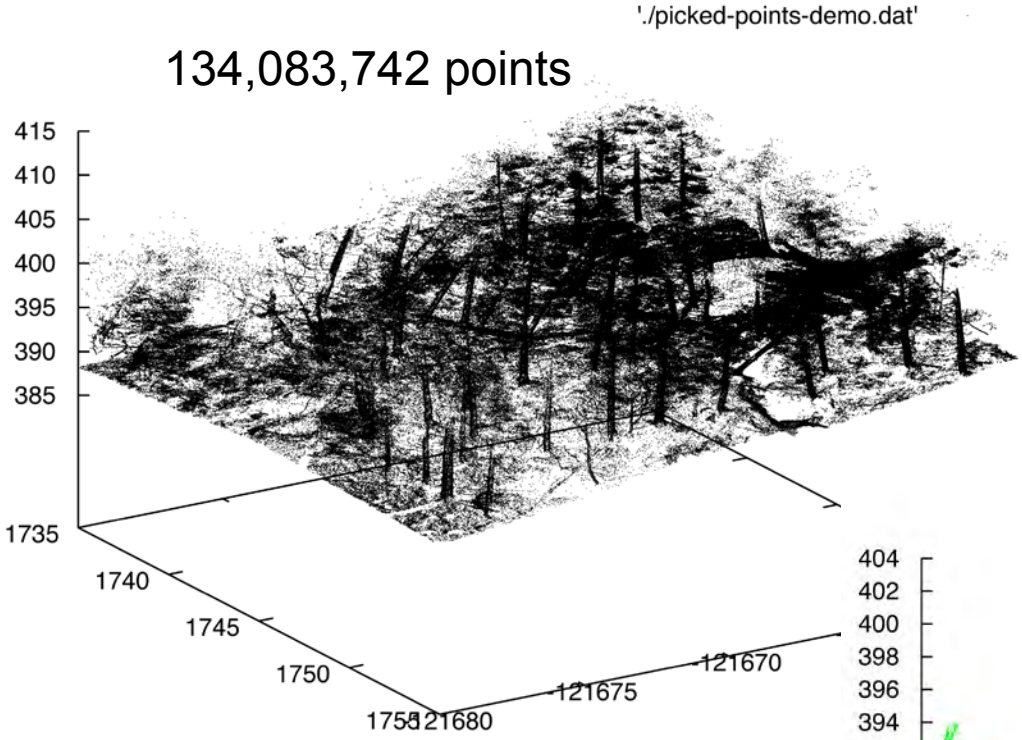
Cypress tree tilting along the rupture



Tree tilting helps ground deformation recognition.

Photo by M.Yoshimi

Extraction of trees from point clouds



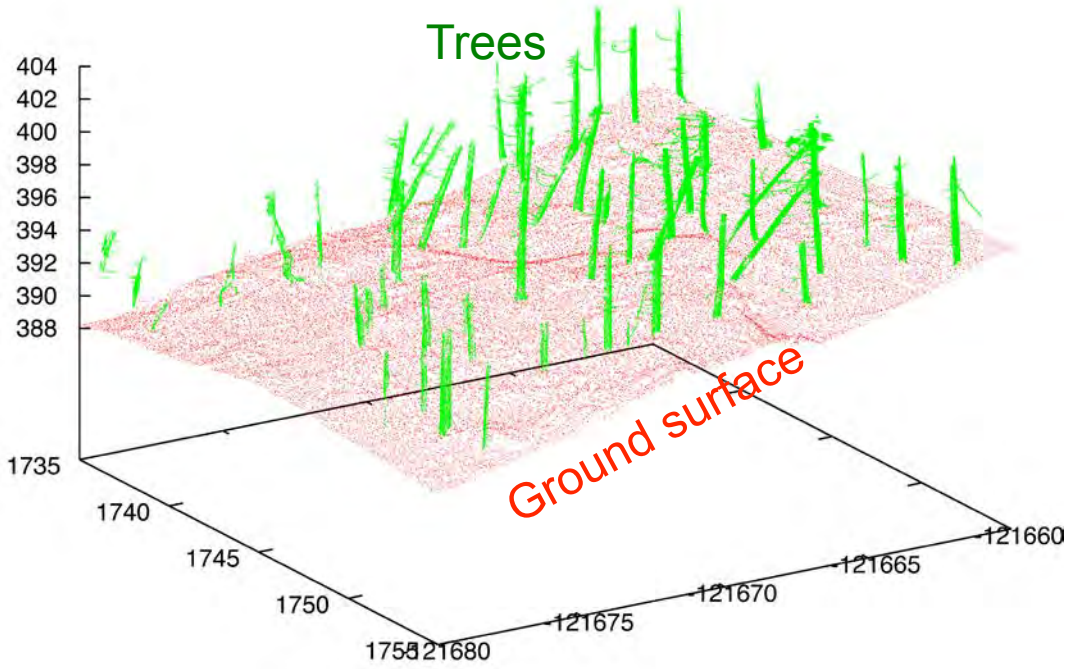
134,083,742 points

Raw point clouds
(figure: only small part)

Point classification

1st STEP Ground identification:
lowest and widest surface

2nd STEP: Tree grouping
group dense points with threshold
d<2.5cm, h>2m, etc..

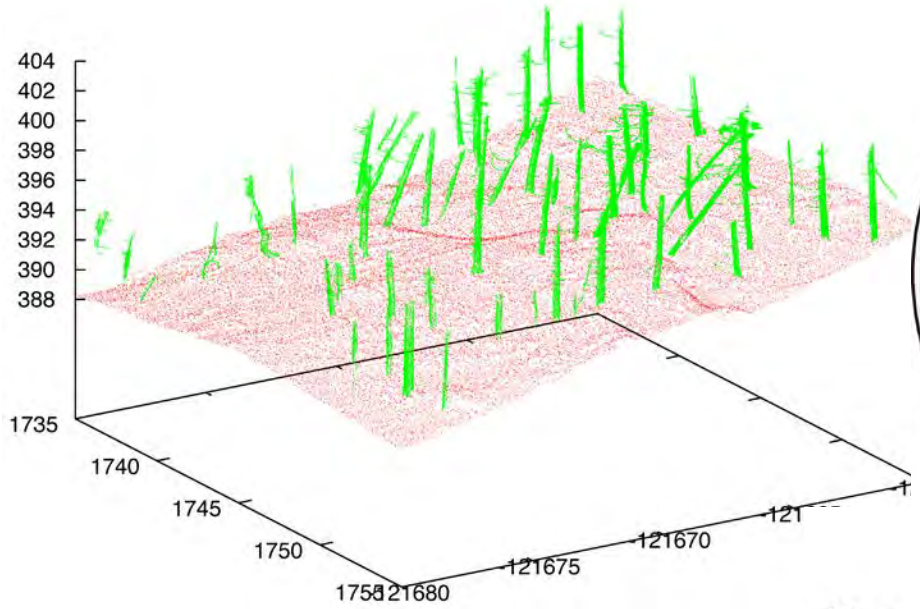


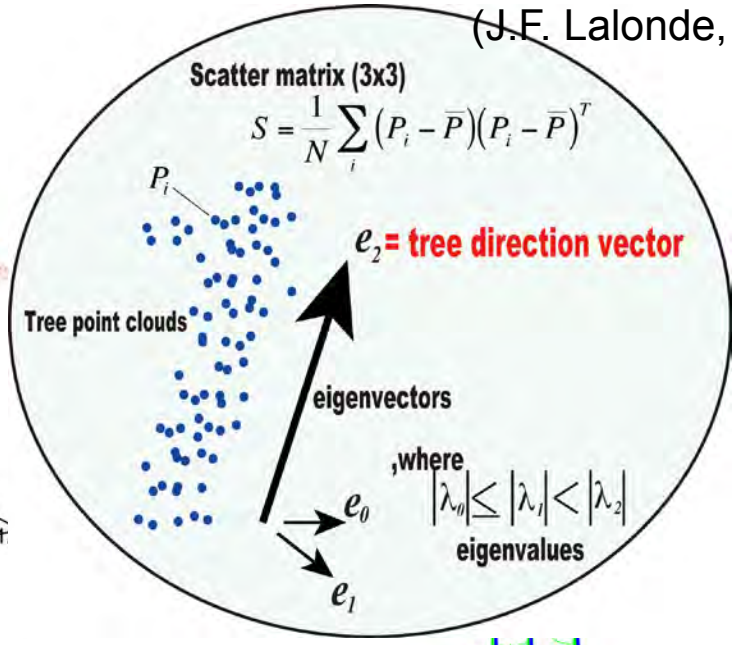
17,194,745 points for >4000 trees

Yoshimi et al. (2009) ESC

Tree direction vector from point clouds

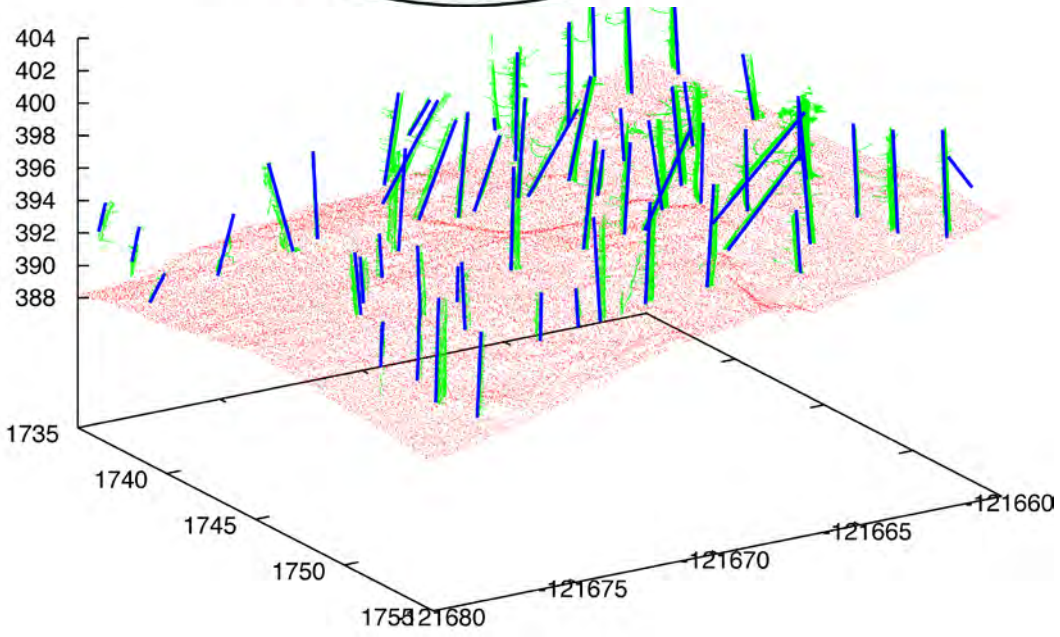
(J.F. Lalonde, et al (2006))





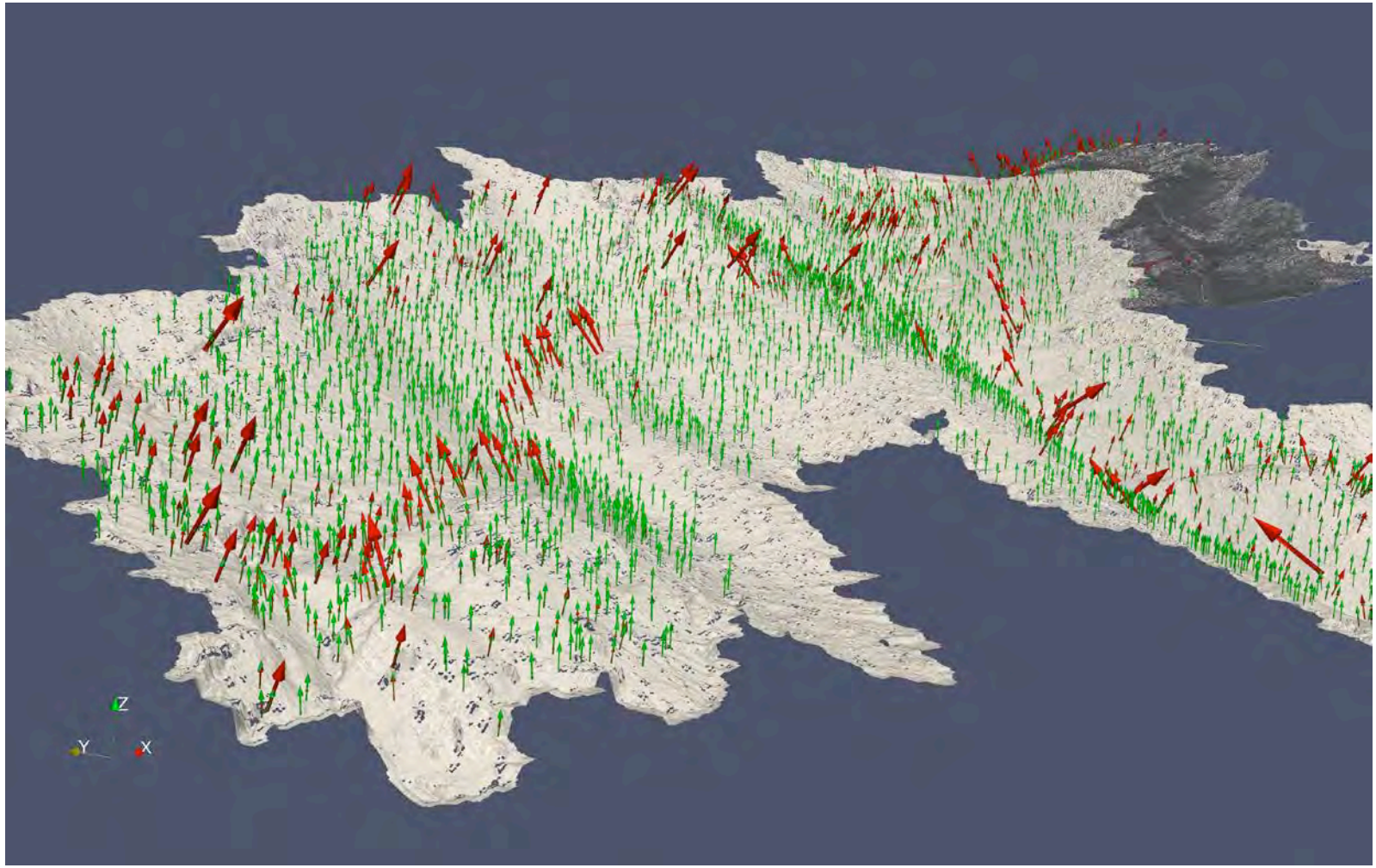
Principal component analysis of scatter matrix for each tree to obtain direction vector

Yoshimi et al. (2009) ESC



Tilted trees around surface rupture

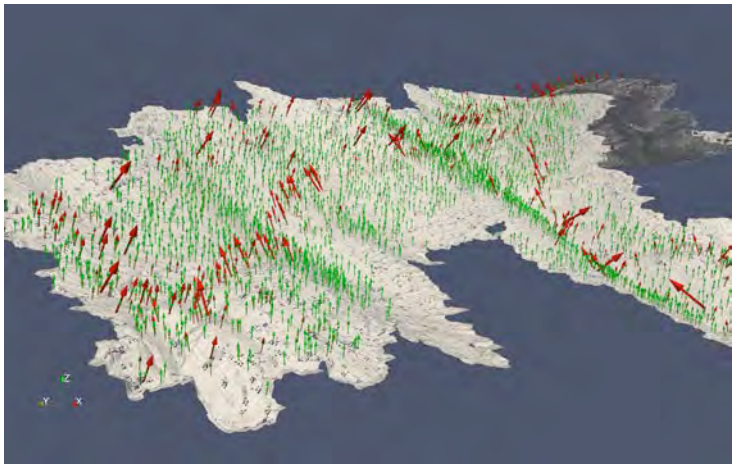
1. Tilted trees are concentrated around rupture.
2. Tilt directions show mechanical pattern associated with surface deformation.



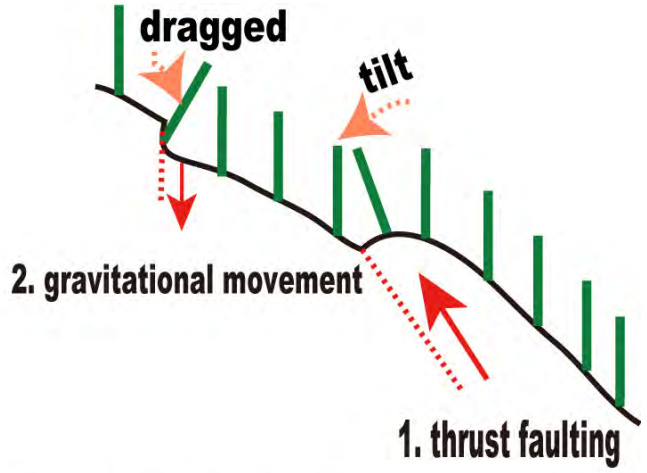
N=4768

Yoshimi et al. (2009) ESC

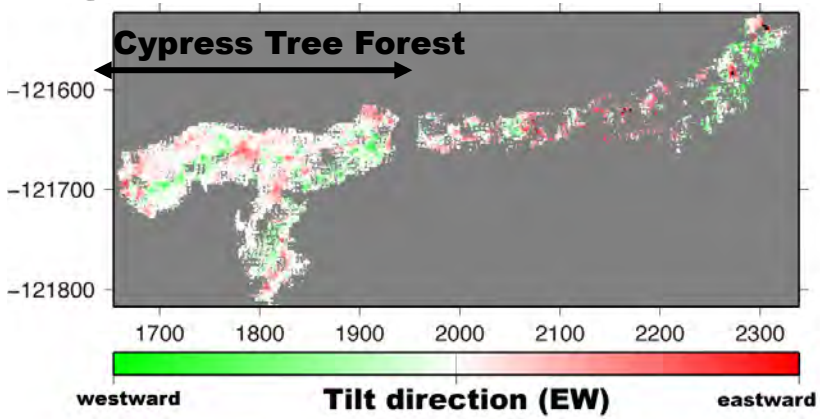
Tilt direction and angle distributions

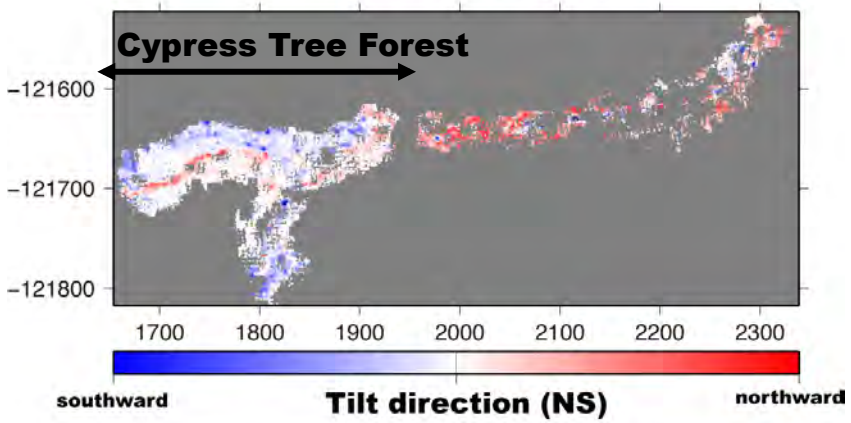


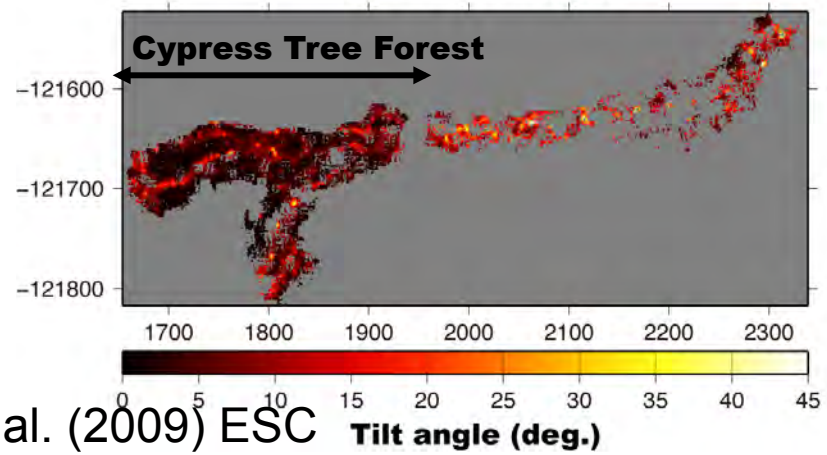
Deformation can be recognized from single image taken after rupturing if combined with tilting



Relation of ruptures and trees tilting (East part: cross section)

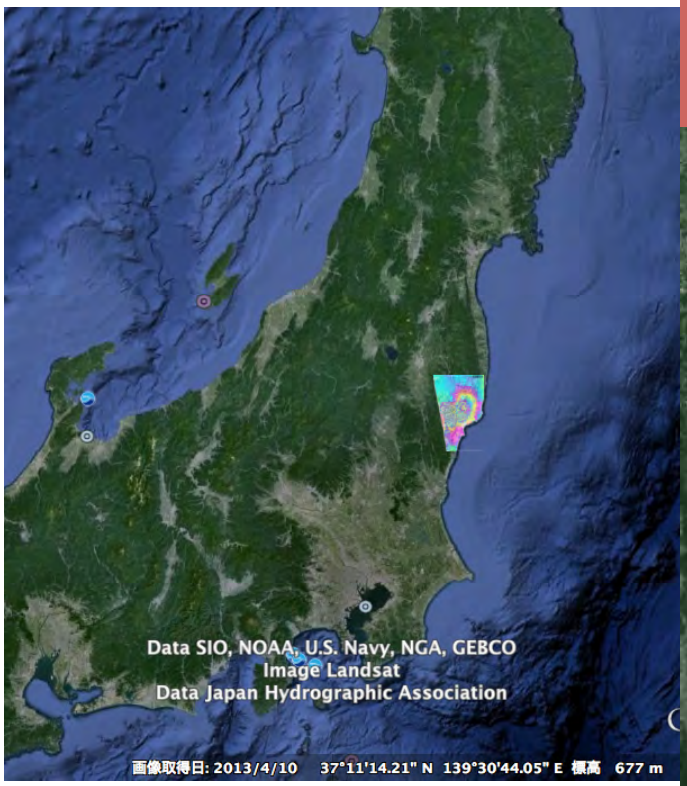


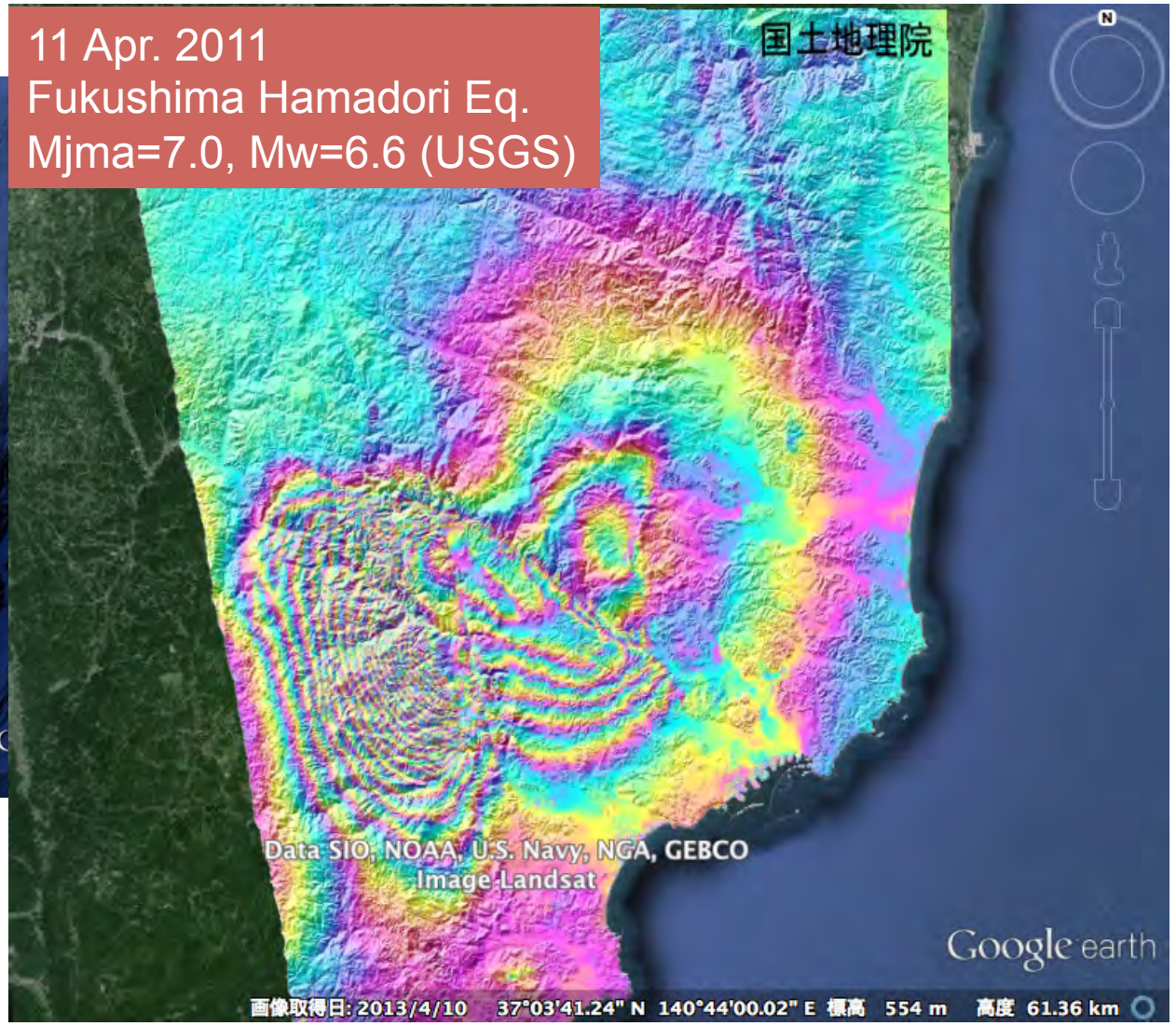




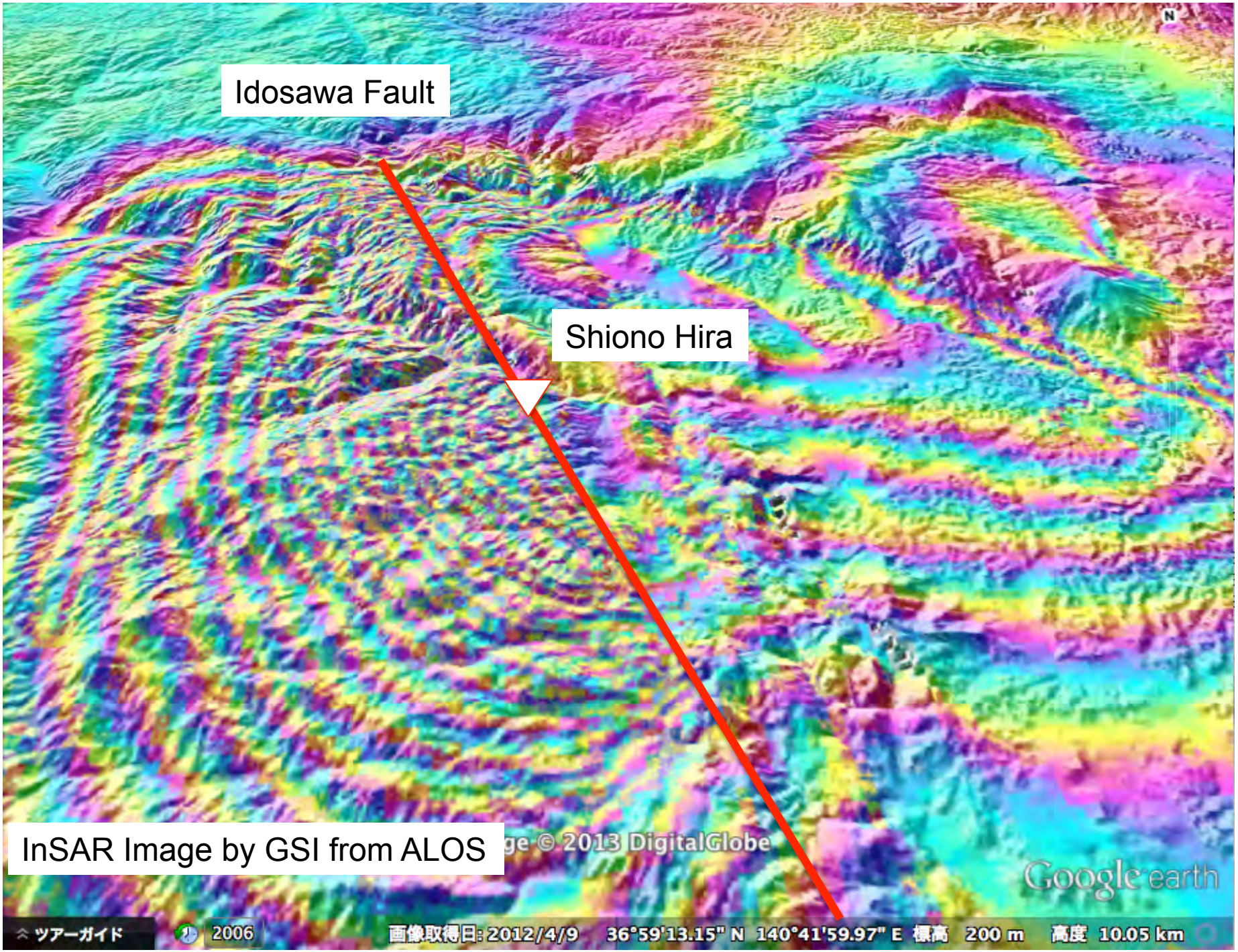
Yoshimi et al. (2009) ESC

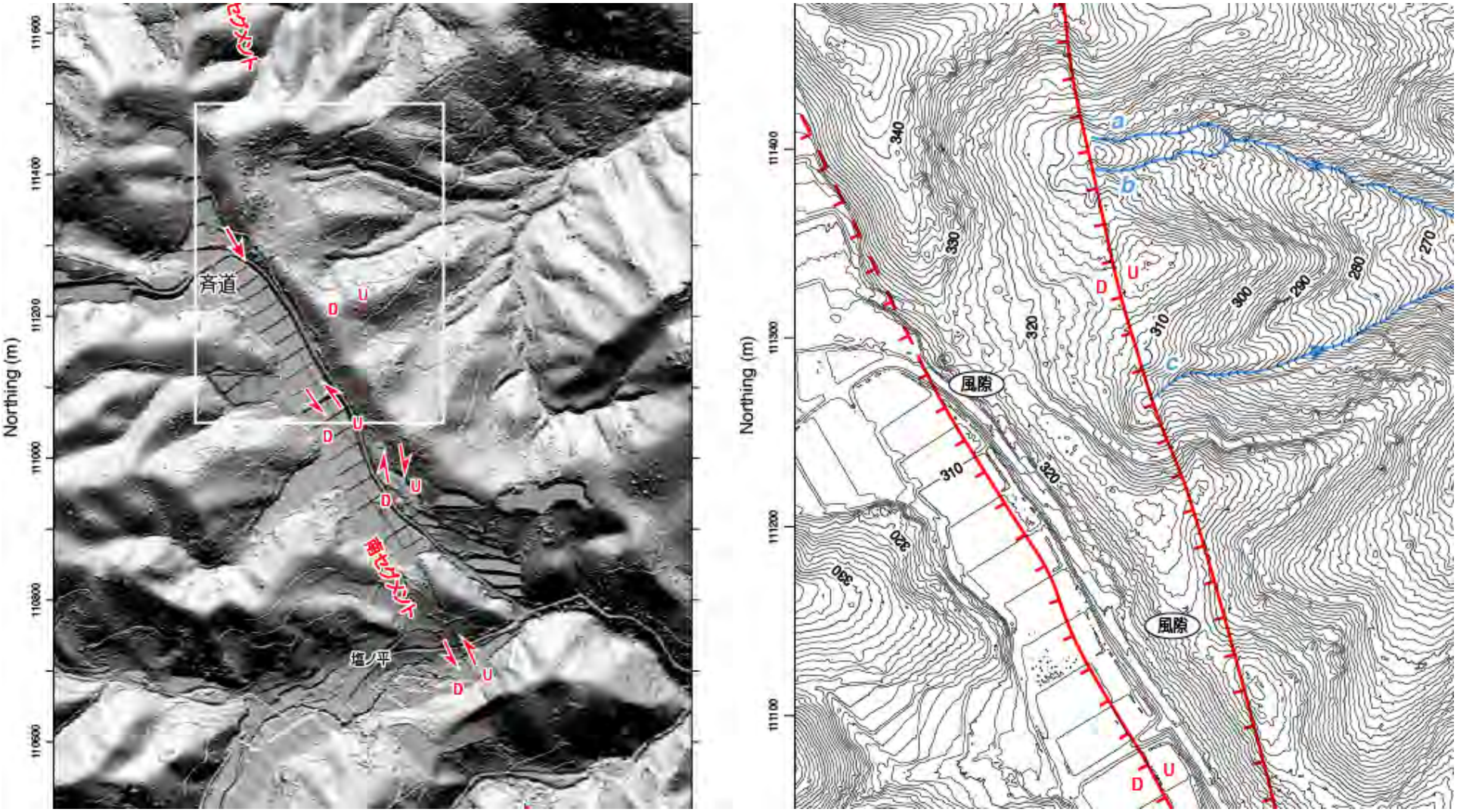
2011 Fukushima Hamadori Eq.





InSAR Image by GSI from ALOS


Idosawa Fault
Shiono Hira
InSAR Image by GSI from ALOS
ge © 2013 DigitalGlobe
Google earth
ツアーガイド
2006
画像取得日: 2012/4/9 36°59'13.15" N 140°41'59.97" E 標高 200 m 高度 10.05 km



Maruyama et al. (2012) AFERC/GSJ news

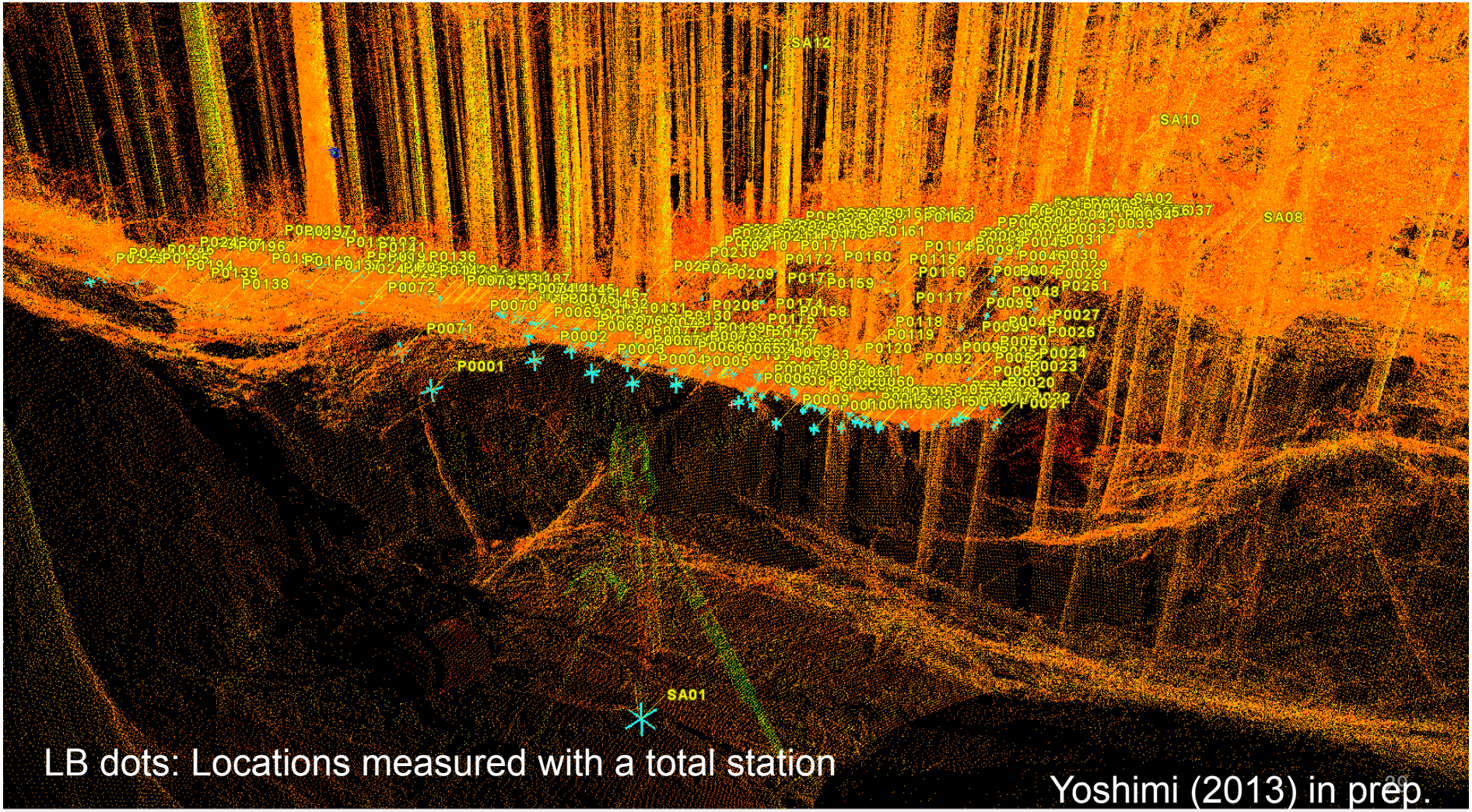
Surface rupture in the forest (Shionohira: Saido)

Yoshimi (2013) in prep.

Laser Scanning

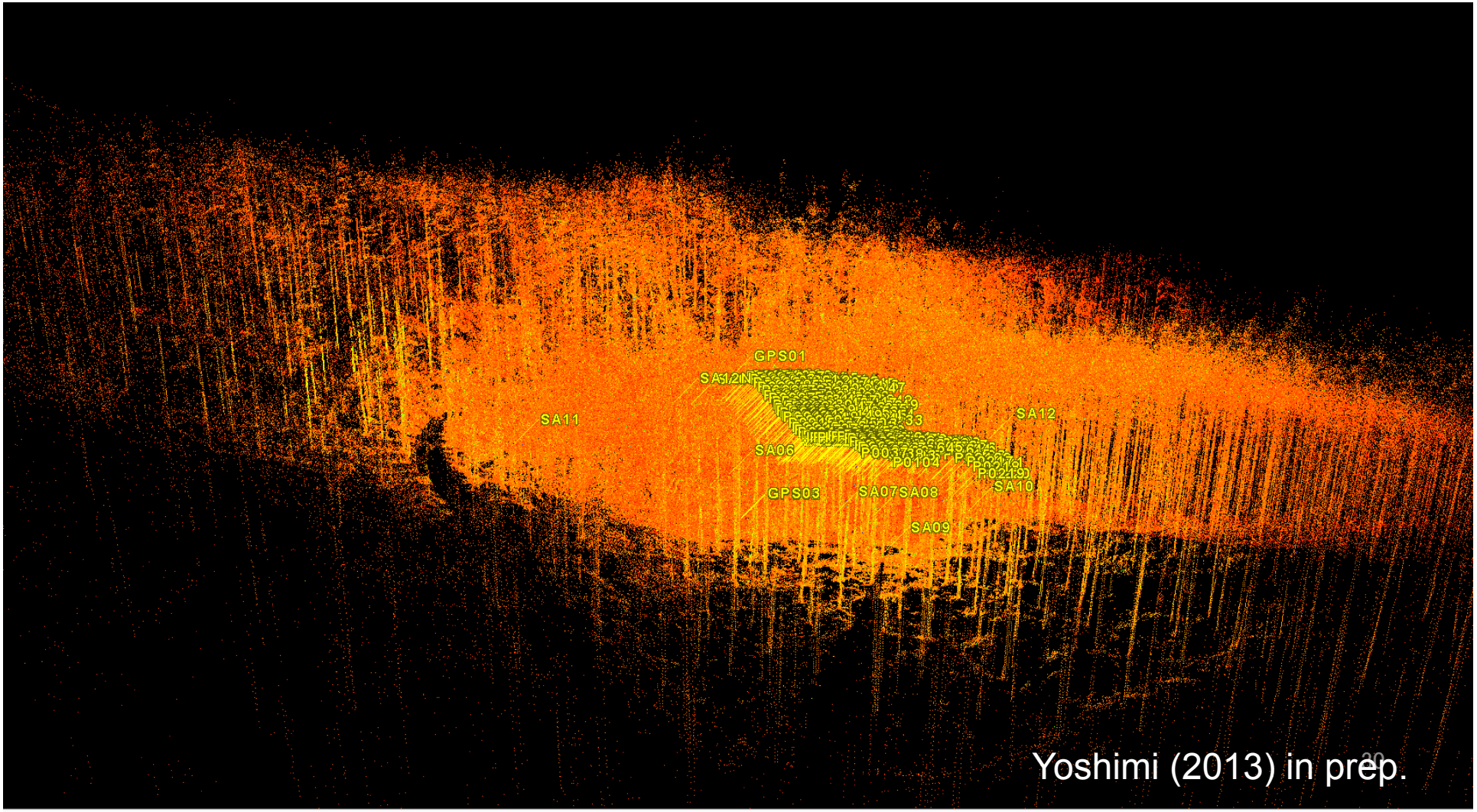
Yoshimi (2013) in prep.

Raw point clouds



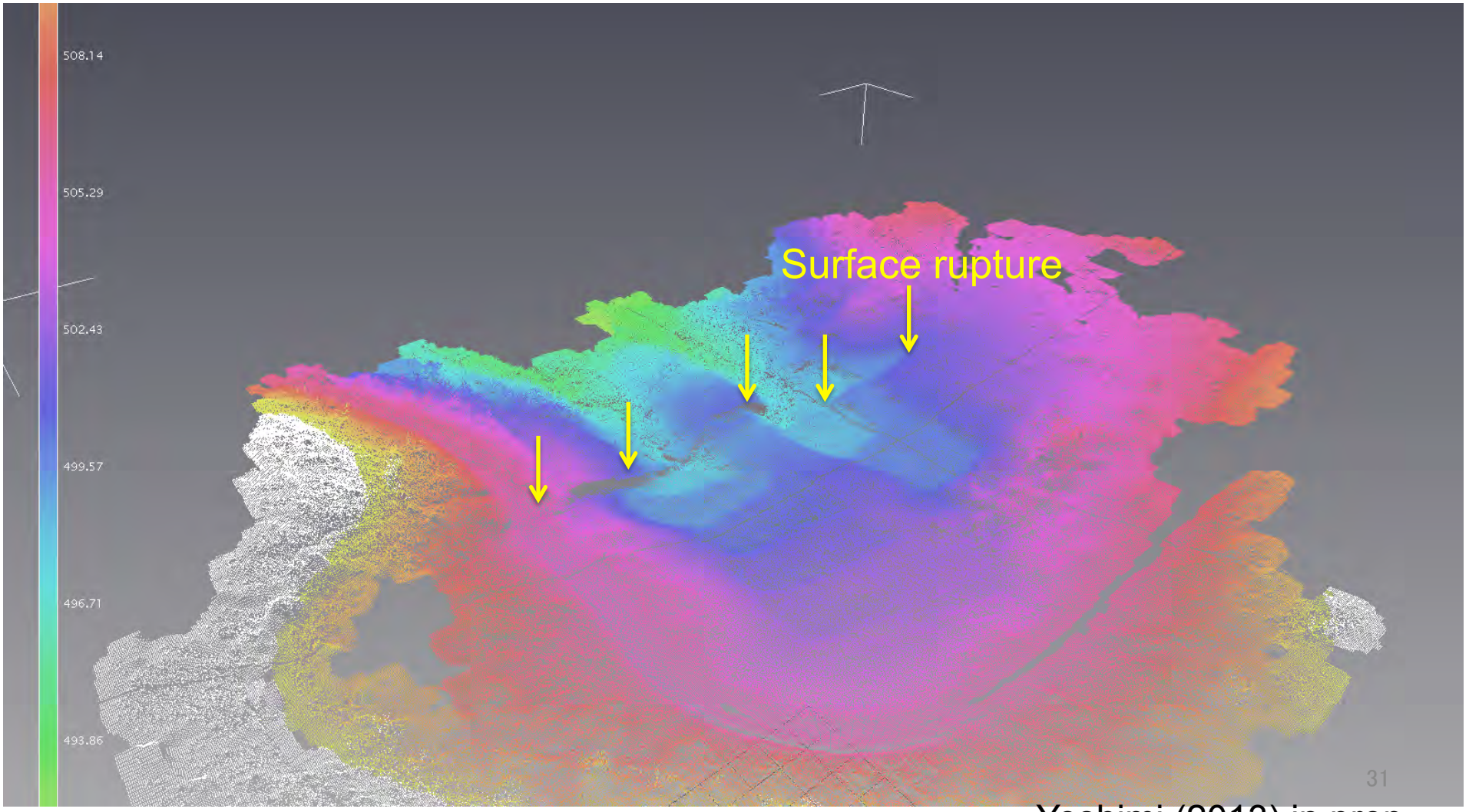
Point Clouds (30 million points)

Scan from 13 locations

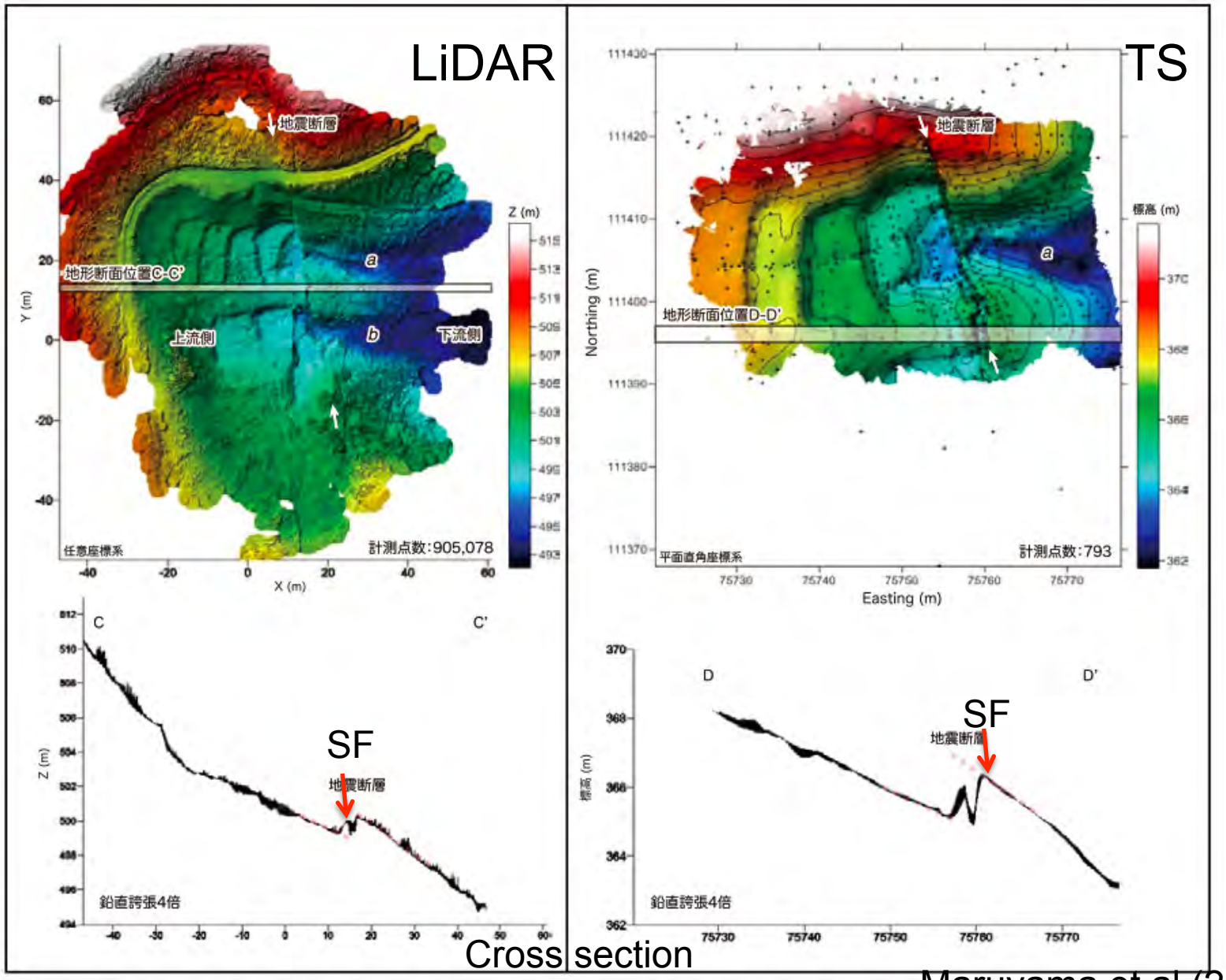


Yoshimi (2013) in prep.

Extracted ground surface

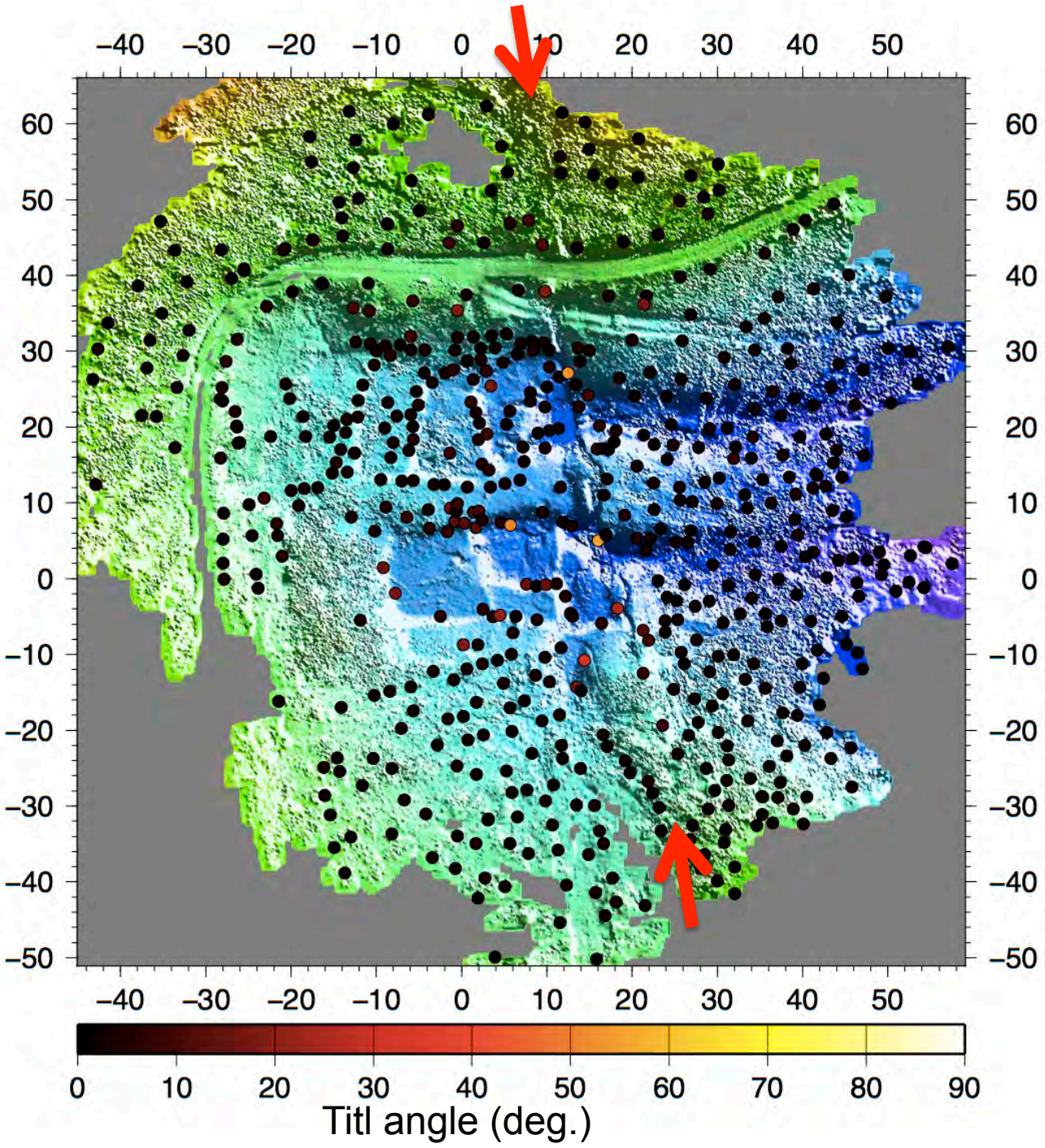


Yoshimi (2013) in prep.



Maruyama et al.(2012)

第６図　斉道地区周辺の詳細地形．左）地上型レーザスキャナーを用いた計測結果．右）トータルステーションを用いた計測結果．右図の計測範囲は左図の北半分に対応．断面位置は，第４図左の断面 A-A' にほぼ一致．図中の a, b は第４図右に示した小河川 a, b に対応．いずれも 2012 年 2 月 23，24 日に計測．



Tree tilt dist.

N=566

Tree tilting is not significant or concentrated around narrow area around the fault
- Normal fault

Yoshimi (2013) in prep.

Reverse fault

Normal fault

Conclusions

- Terrestrial LiDAR was deployed for surface rupture of the 2008 Iwate-Miyagi Inland earthquake & 2011 Fukushima Hamadori Eq. to obtain fine topography.
- Terrestrial LiDAR is powerful tool for restoring vivid image of surface faulting.
- Trees can be tiltmeters on the ground when combined with LiDAR, which provide important information for structure design against deformation.