Geomorphic and seismological comparison of large strike-slip earthquakes in the Pamirs reveals structural control on rupture extent

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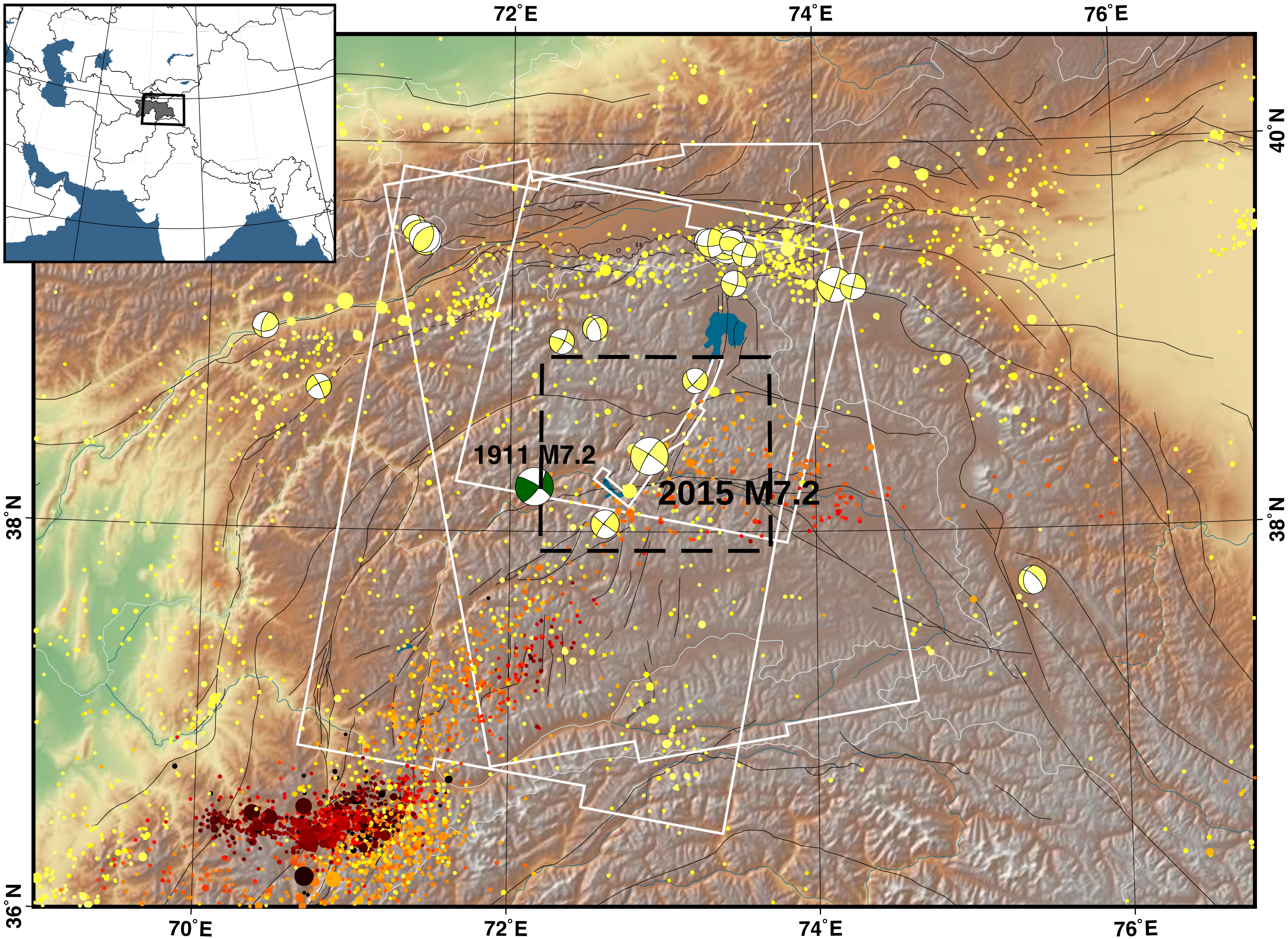
COMET

LiCS
LOOKING INSIDE THE CONTINENTS FROM SPACE

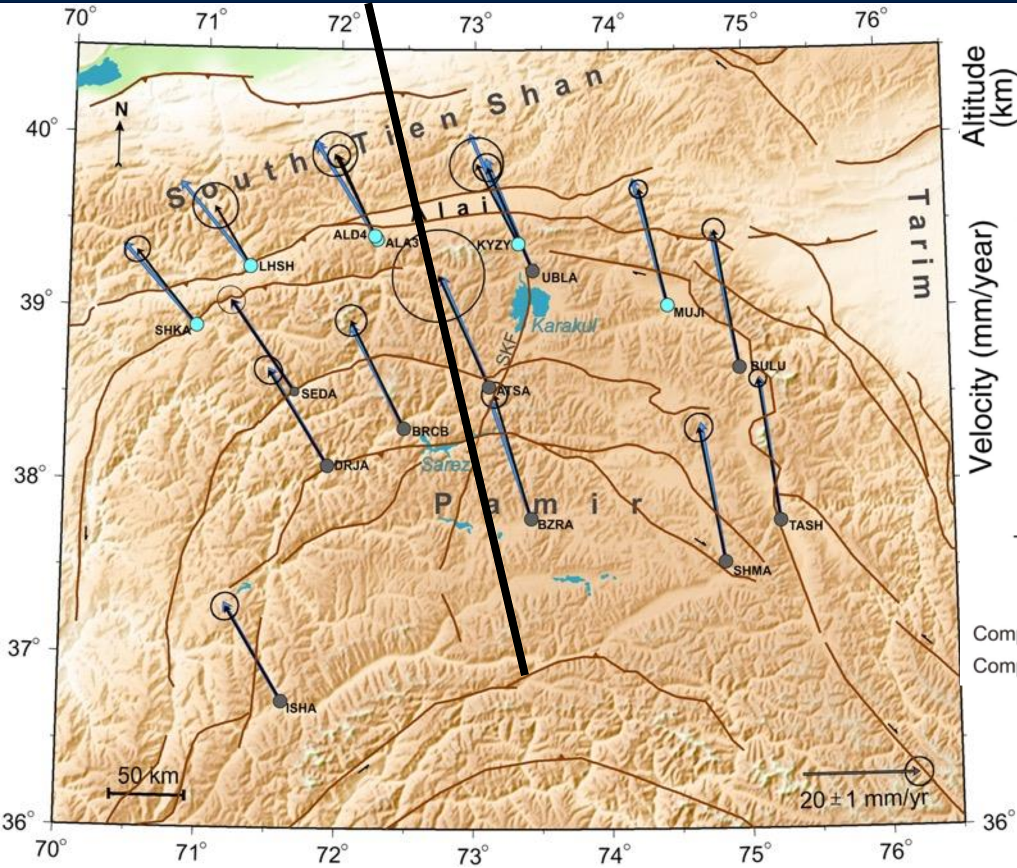
NERC
SCIENCE OF THE ENVIRONMENT

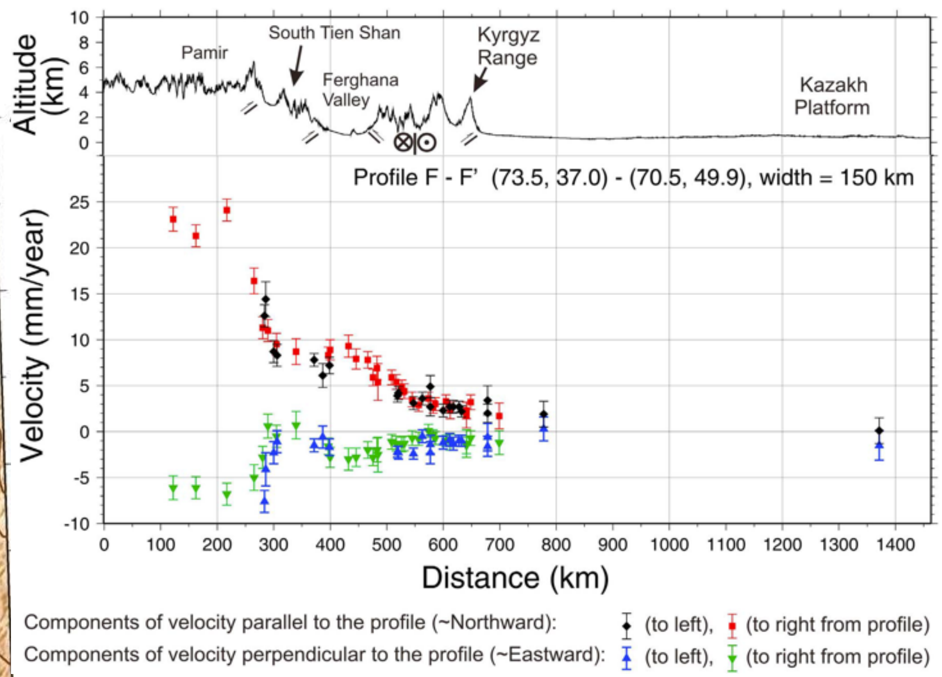
Event Details & Satellite Imaging

7 Dec 2015 07:50 UTC (12:50 local) **38.211°N 72.780°E** ± 5.5 km d=2**2.0**±1.7 km



Deformation of the Pamirs





Zubovich et al., 2010

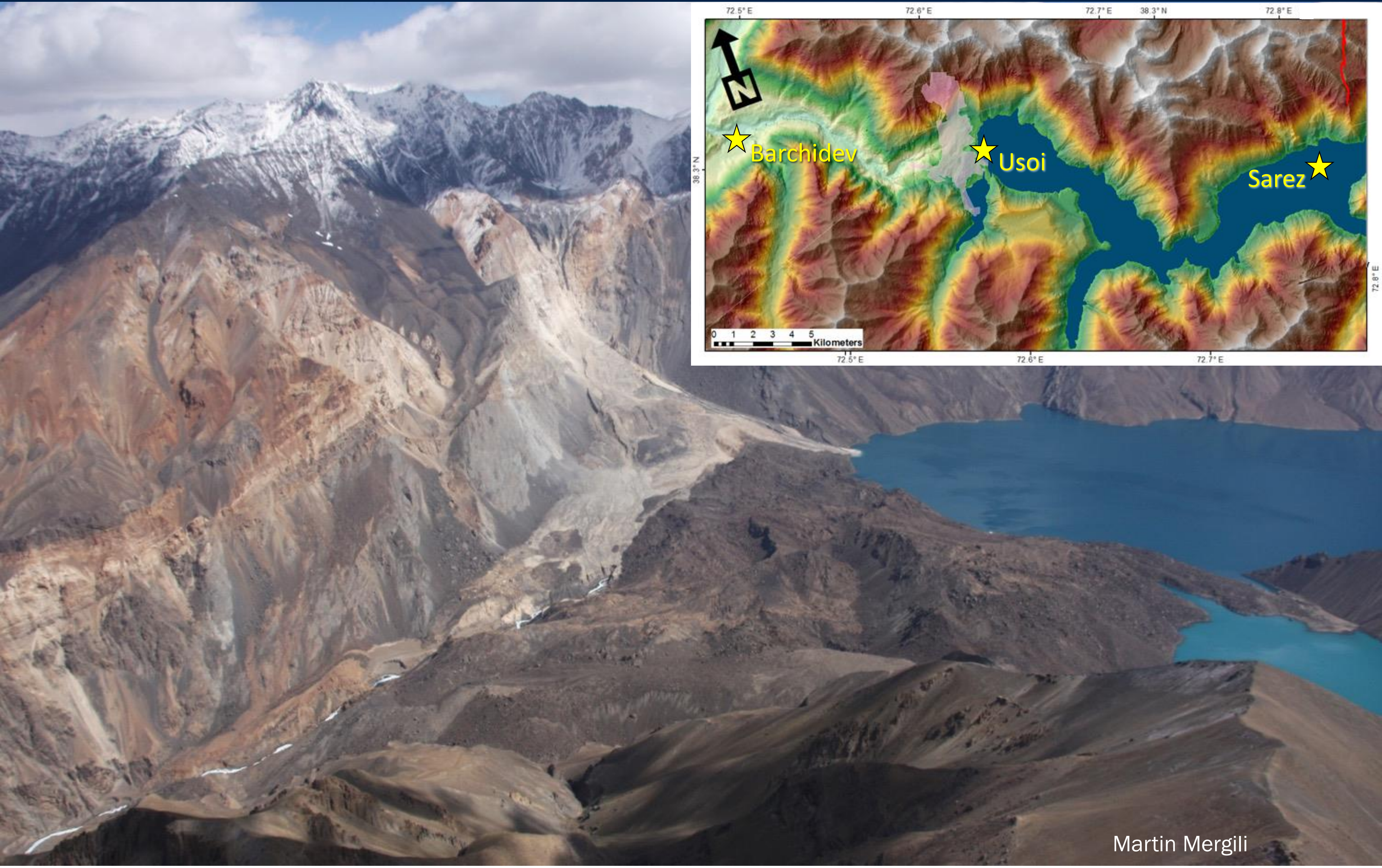
15 mm/yr convergence
most at Alai Valley

8 mm/yr westward
motion of Pamir

Recent analysis concludes that any sinistral slip on existing structure (Karakul-Sarez oblique-normal fault) is **not discernable** within GPS uncertainties;

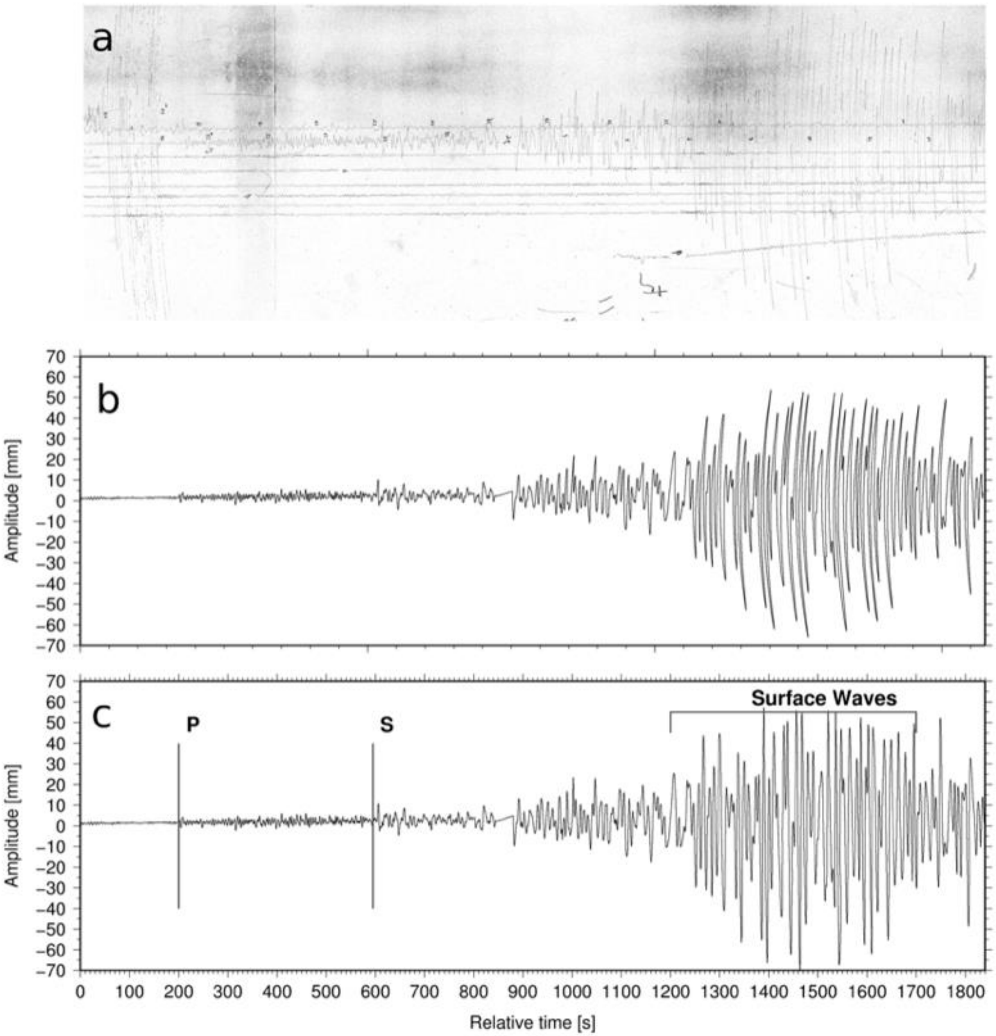
However, clockwise rotation of GPS vectors indicate westward component of crustal extension to west of KSF; not to east

1911 Usoi Landslide & Sarez Lake



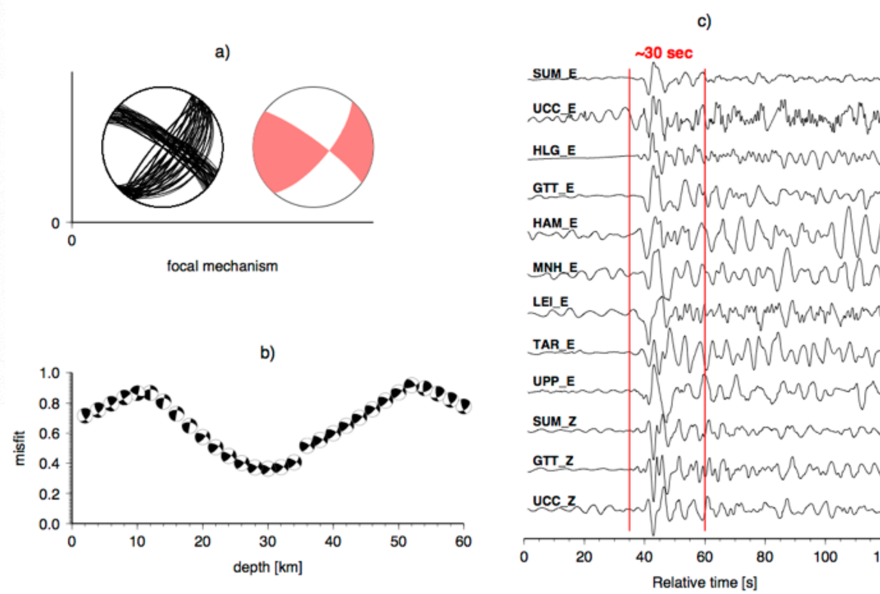
Margottoni et al., 2013, Landslide Inventory and Susceptibility and Hazard Zoning (Vol 1), in *Landslide Science and Practice*, Springer Berlin Heidelberg, doi:10.1007/978-3-642-31325-7

1911 Event Source Debate



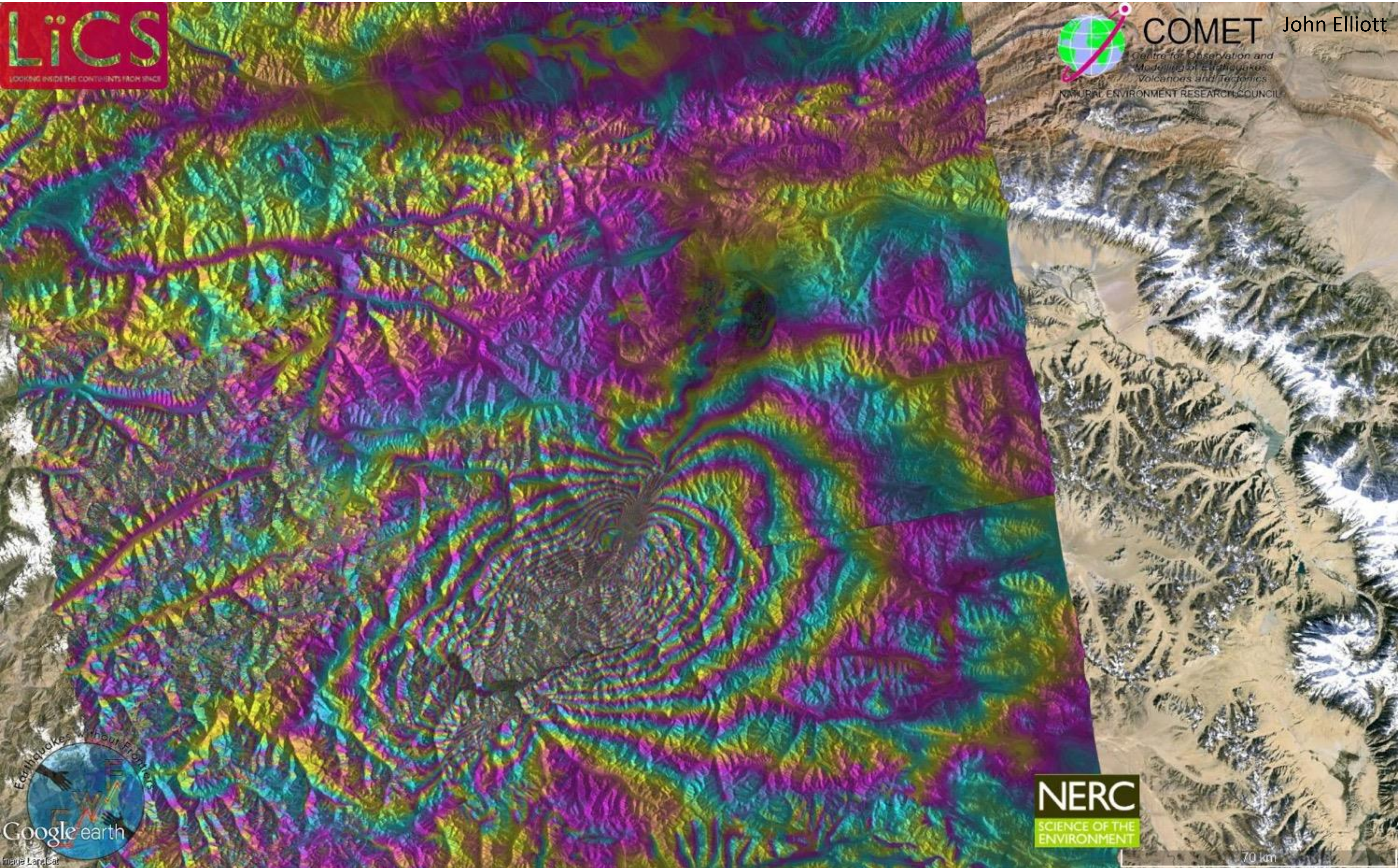
Kulikova et al., 2015

- Seismogram ambiguity:
  - Landslide vs. earthquake
- Galitzin ‘15 & Oldham ’23 debate energy budget vs. frequency content
- Modern reanalysis **confirms double-couple source**



2015 Event imaging: Sentinel-1 InSAR

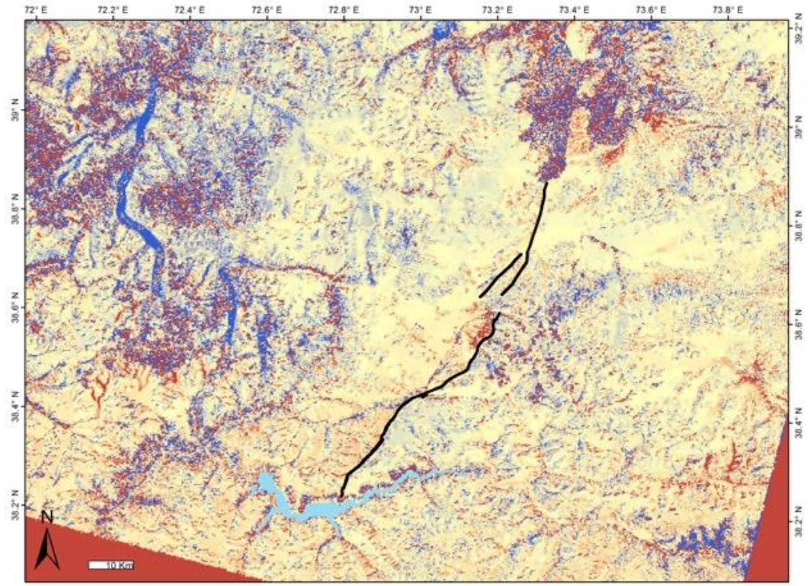
Descending: Dec 6 – Dec 12 Ascending: Dec 6 – Dec 30



2015 Event imaging: Sentinel-1 InSAR

Fault trace from InSAR

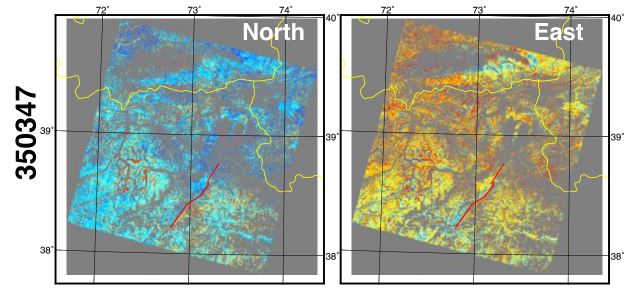
Landsat-8 (15-m) pixel-tracking

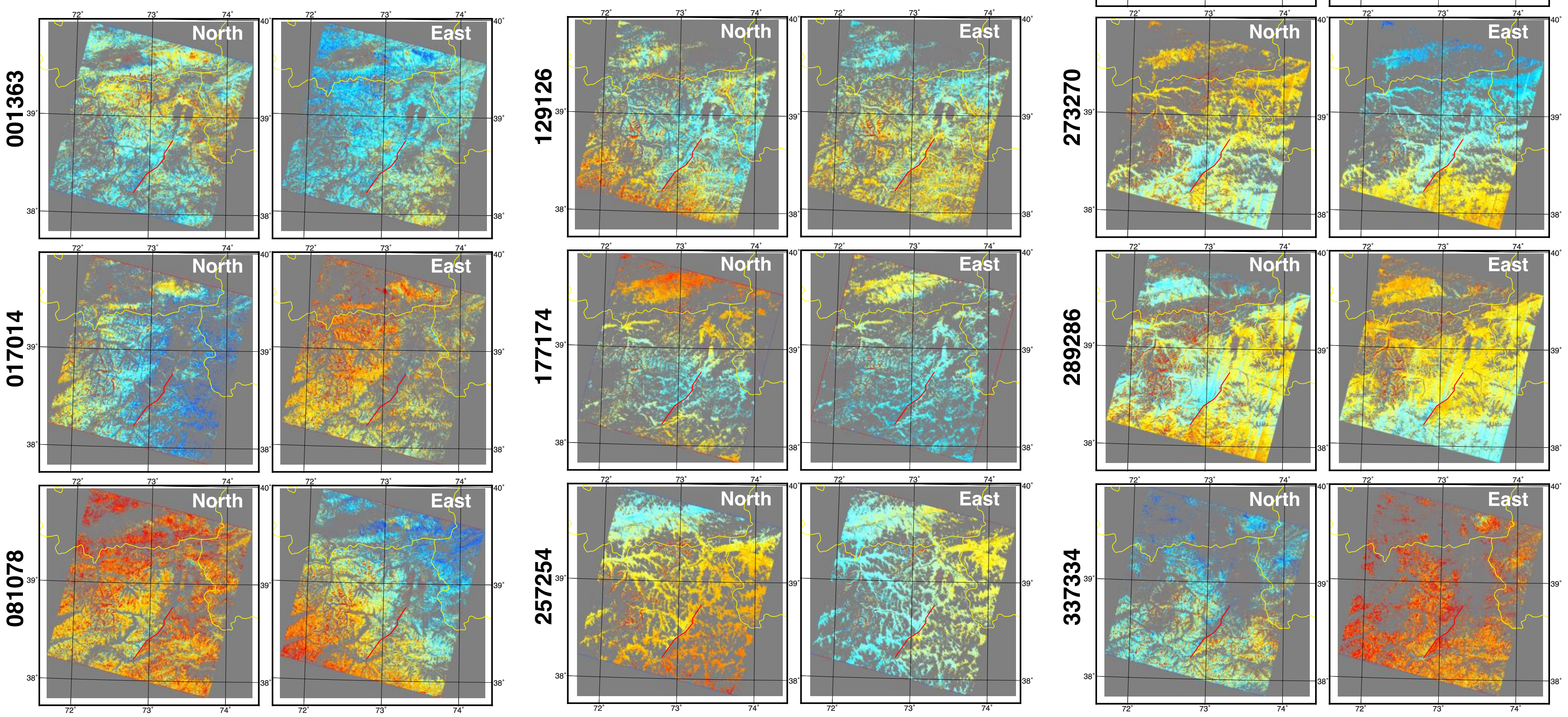


- Cosi-corr for N & E comps. of displacement btwn images
- Landsat-8 benefits:
  - stable orbit,
  - wide footprint,
  - frequent (16-day) revisit of exact scene
- Challenges to detecting tectonic displacement:
  - Decorrelation (changes in reflectance by snow & moisture)
  - Apparent distortion from shadows (sun incidence angle)
- Solution: year-spanning image pairs minimize seasonal artifacts
  - **10 cloud-free pairs of 22 available for 2015-2016**

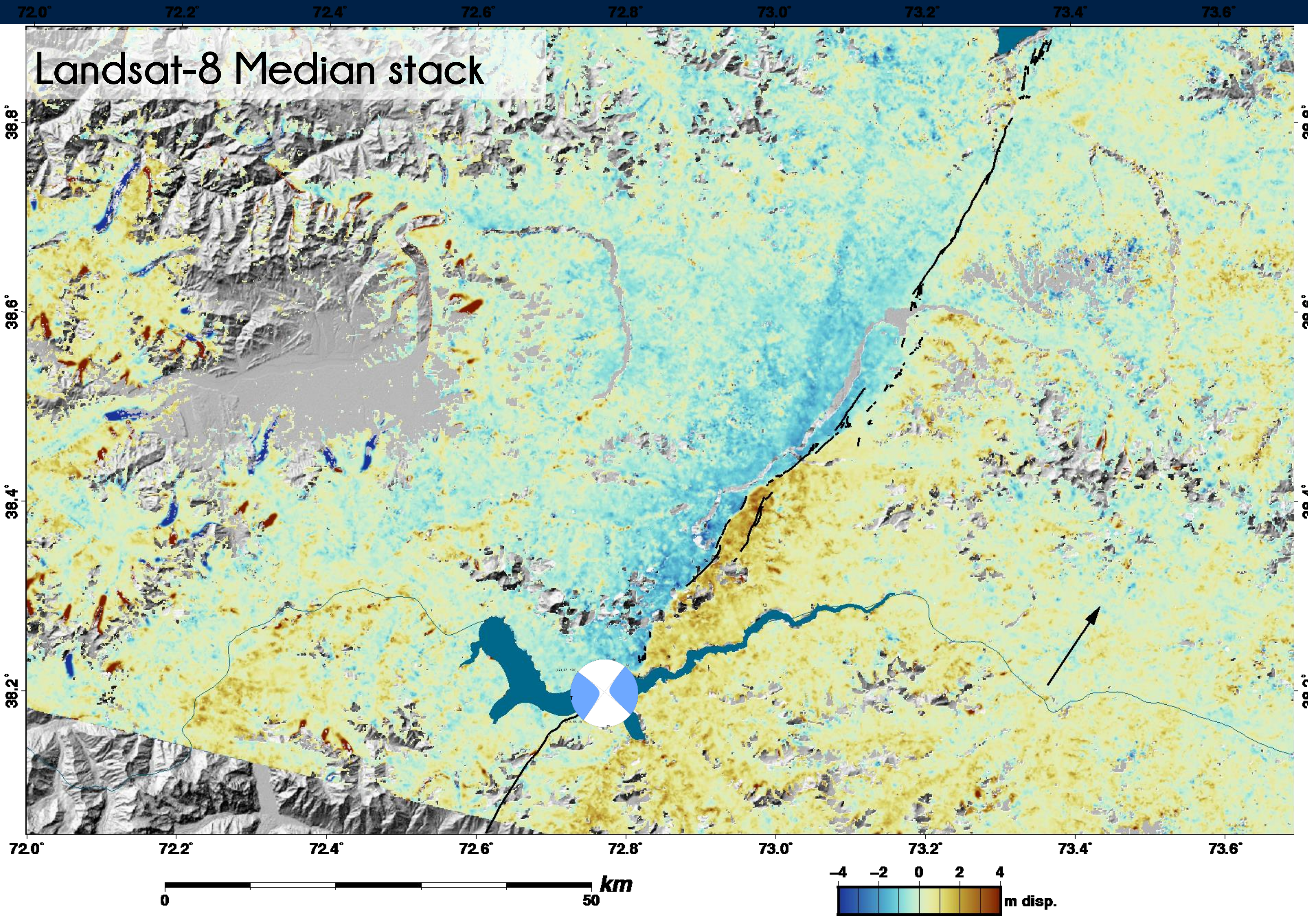
Landsat-8 year-long displacement fields

- All scene pairs show strong discontinuity along KSF.
- Vast differences in coverage
- Strongly varying long-wavelength signal
  - uncorrected orbital & line-of-sight errors

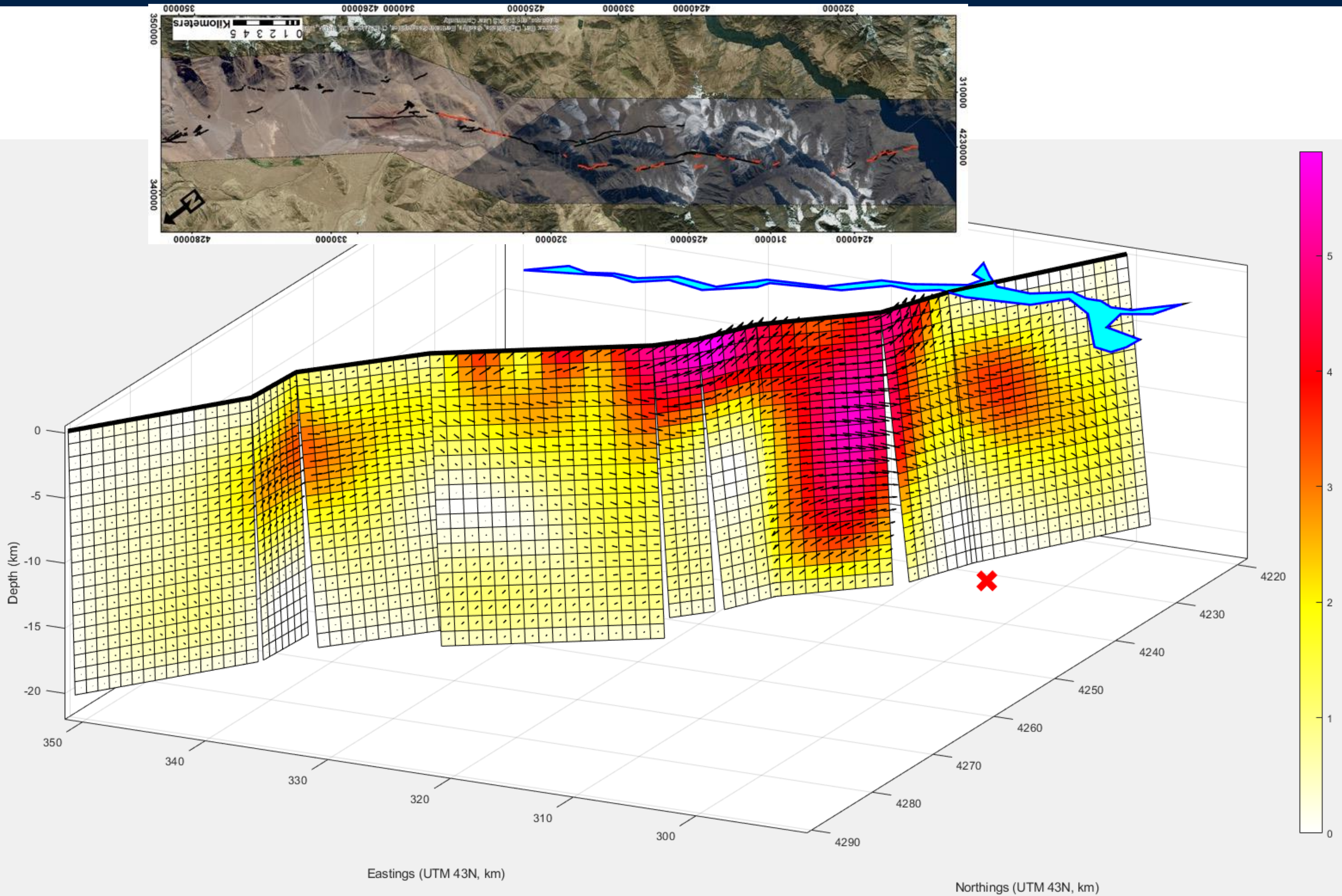




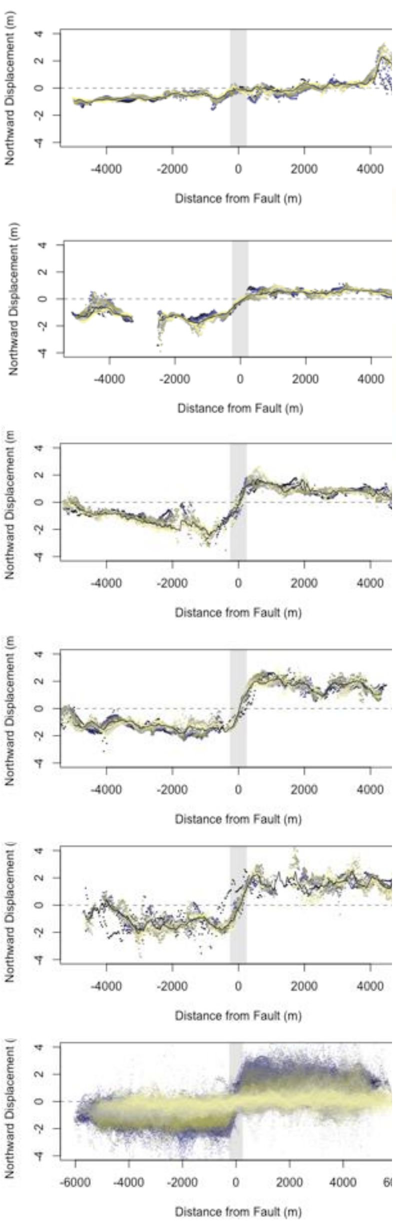
Improved imaging of near-field deformation

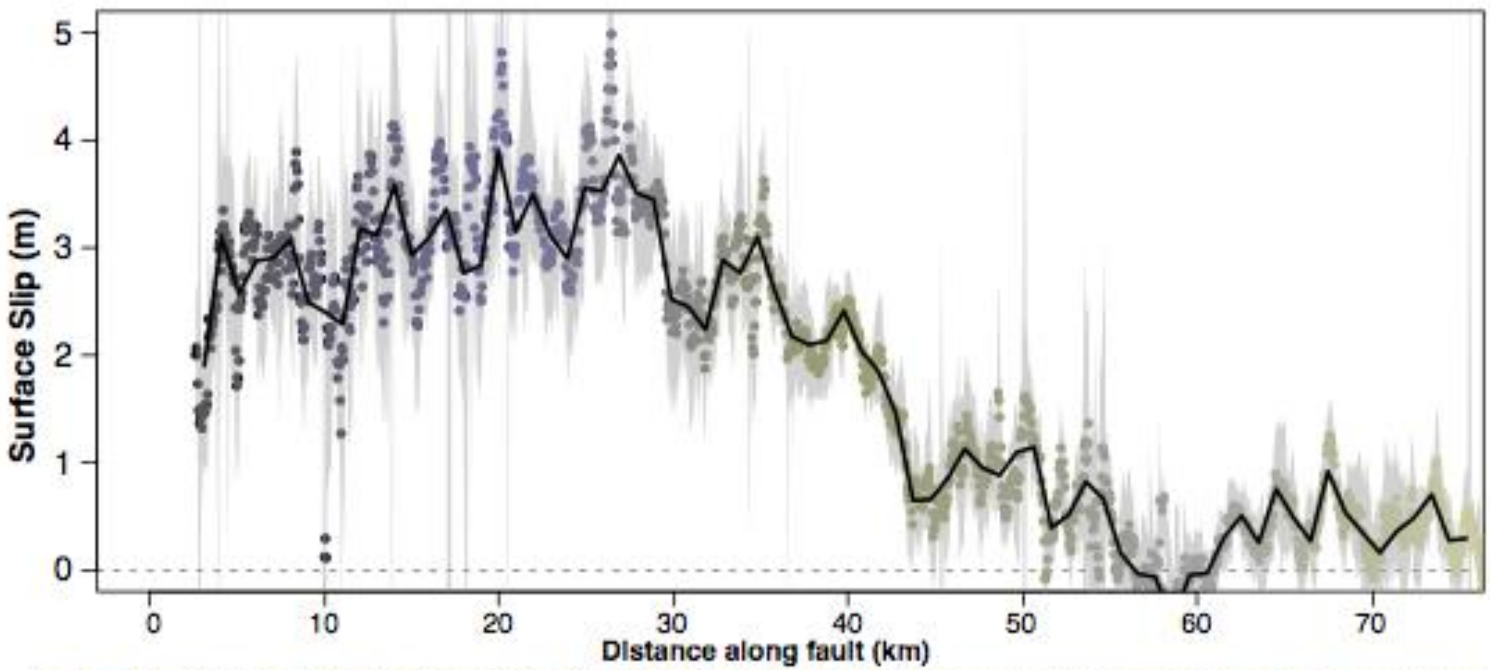


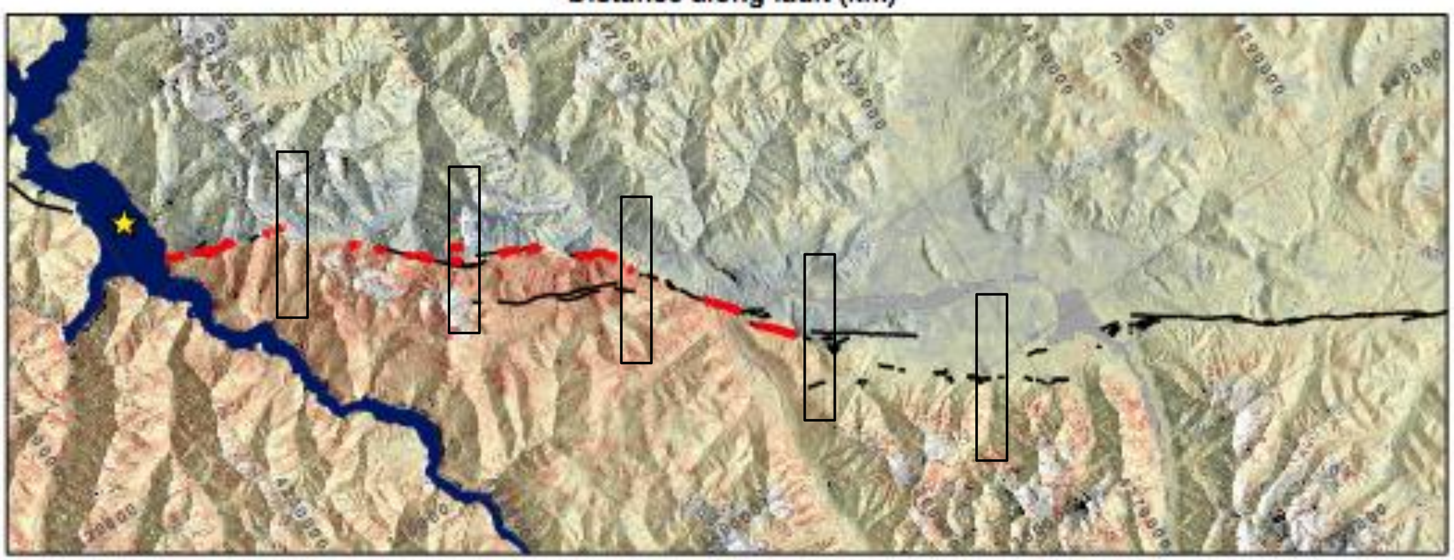
Joint slip inversion on detailed fault



Surface Slip Distribution

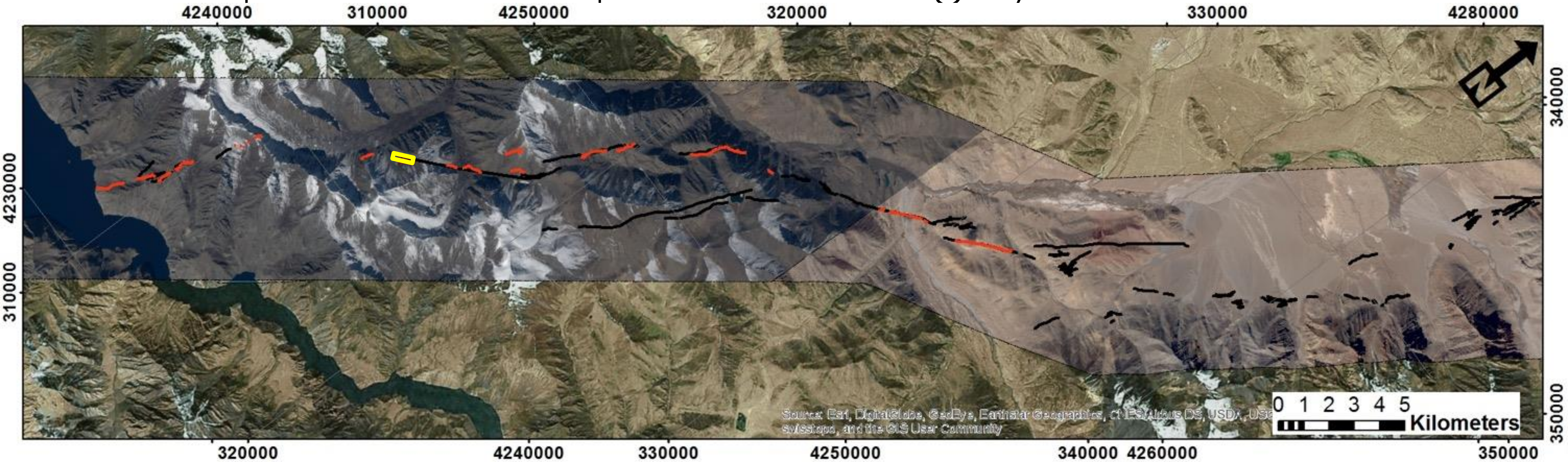






Near-field coseismic offsets

Surface ruptures visible in post-event imagery



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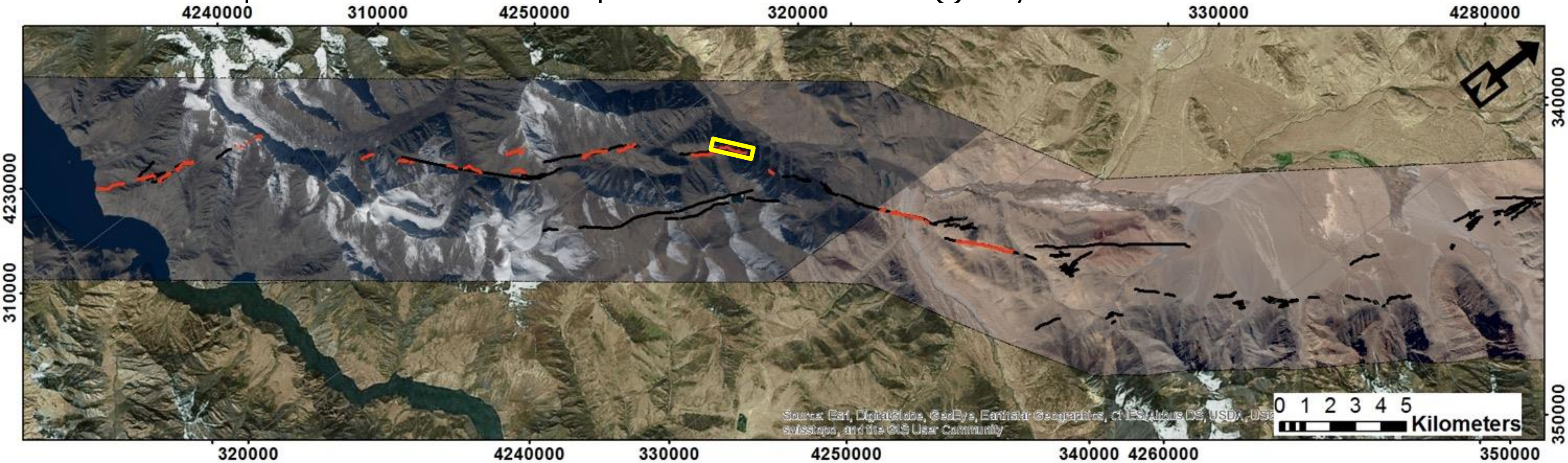

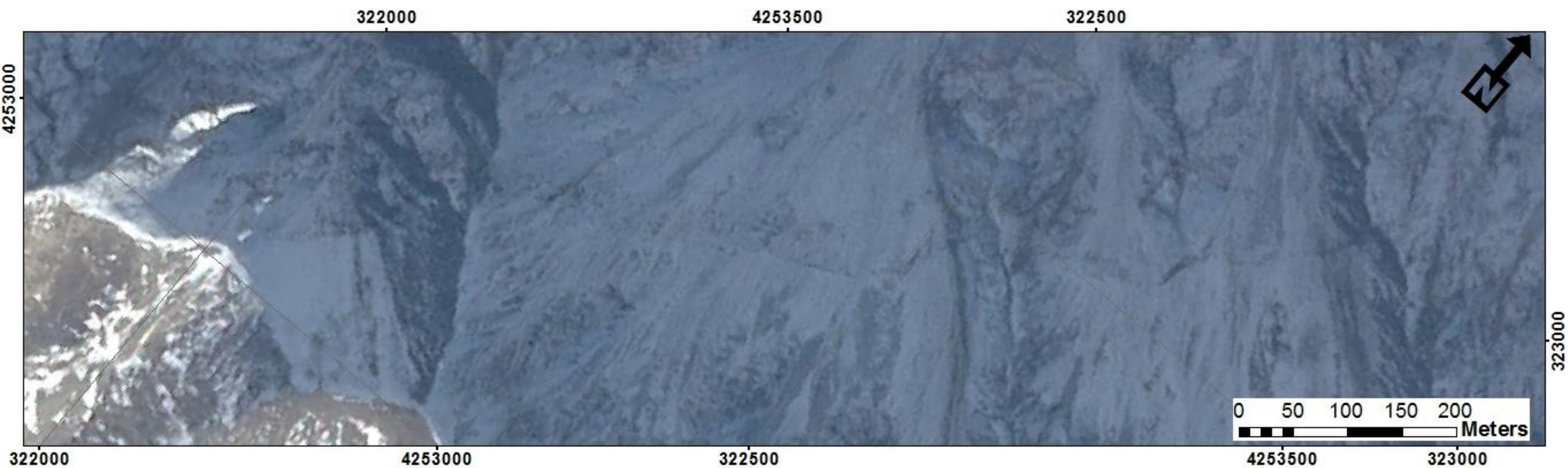

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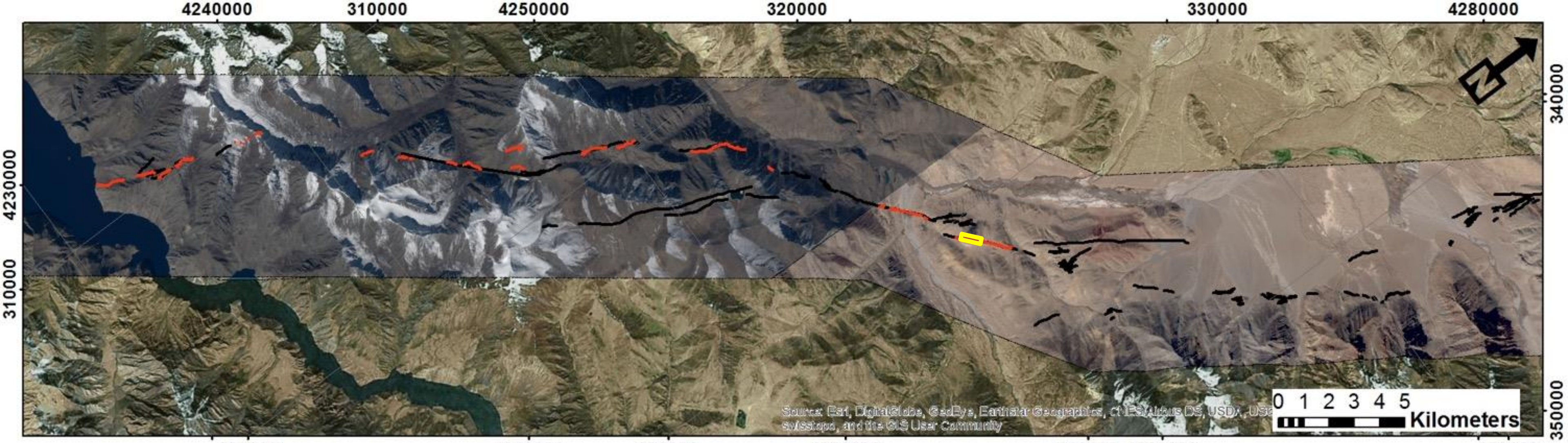

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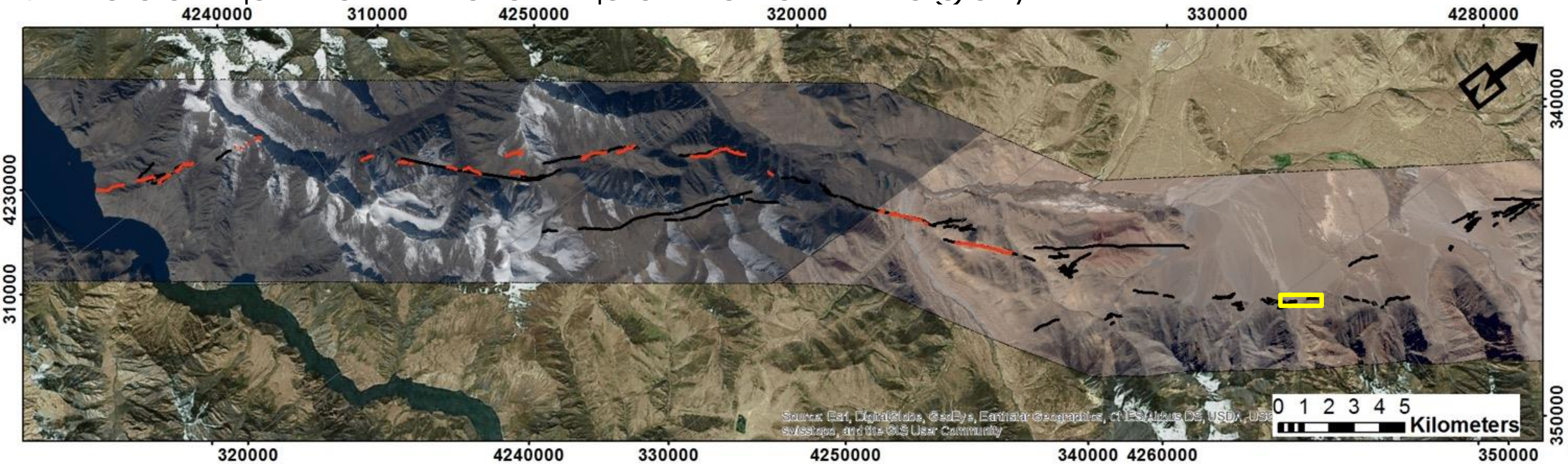
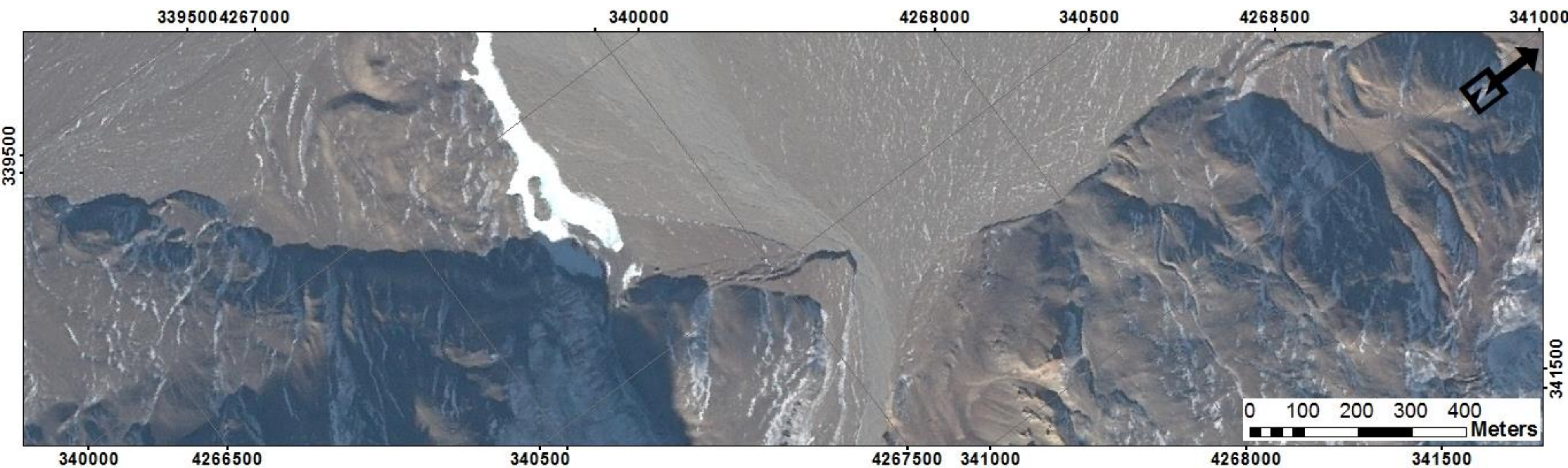




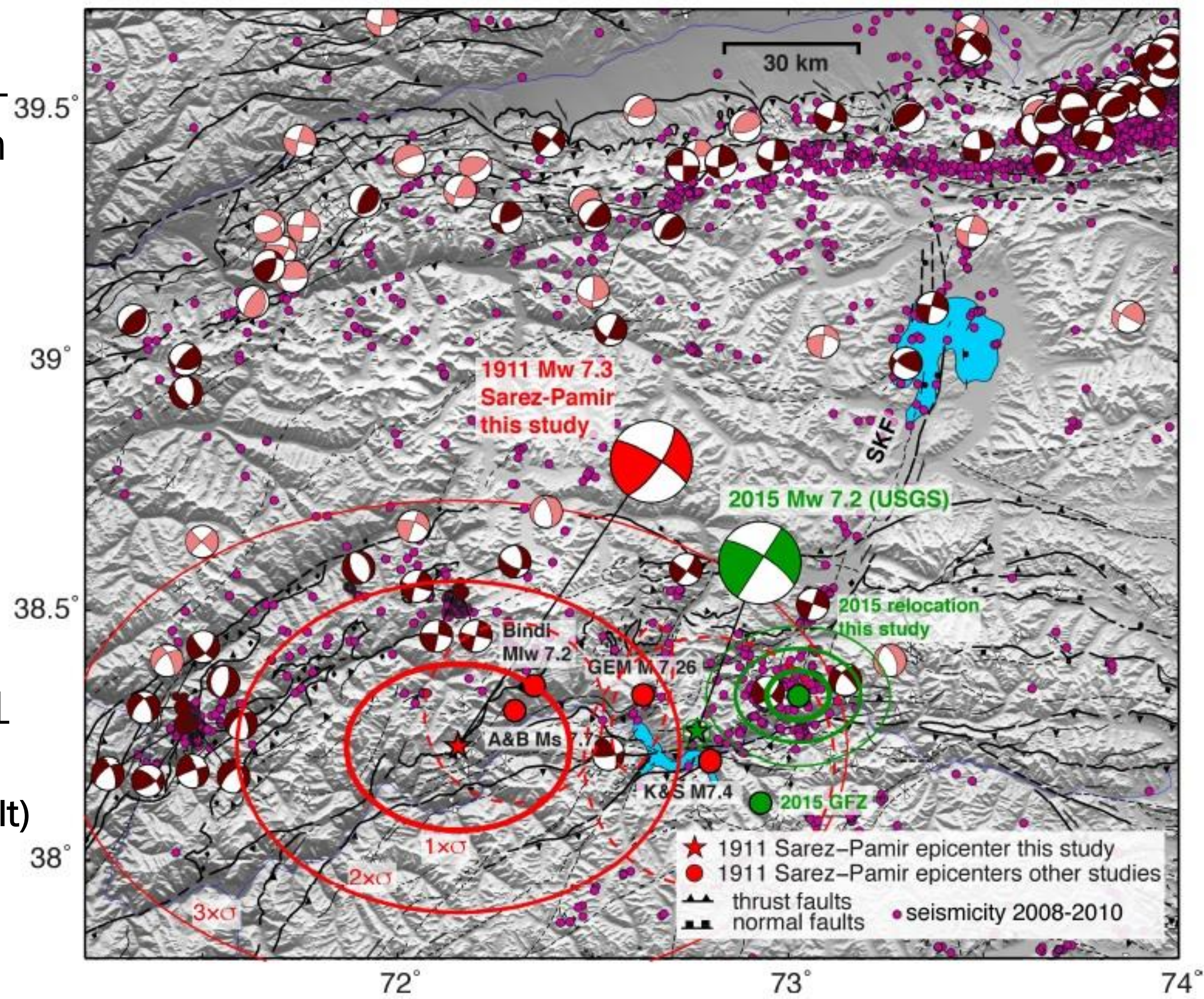
1911 vs. 2015 Sarez earthquake

Seismic re-evaluation of epicentres by Kulikova et al.

! S-P difference in 1911 was **6 seconds less** than S-P difference in 2015 at European stations

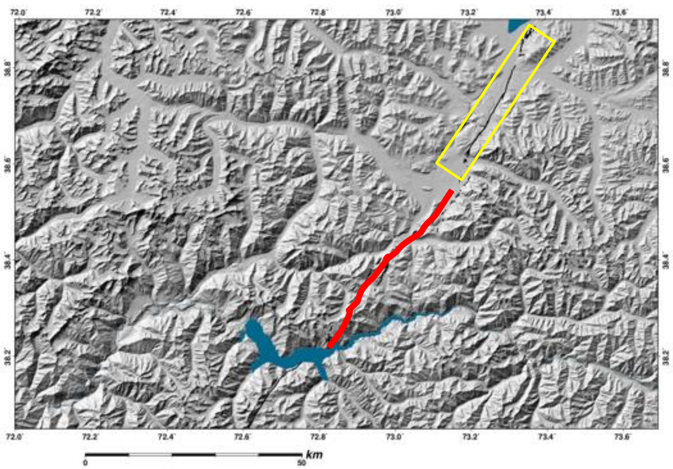
Depth difference only accounts for <2 sec diff

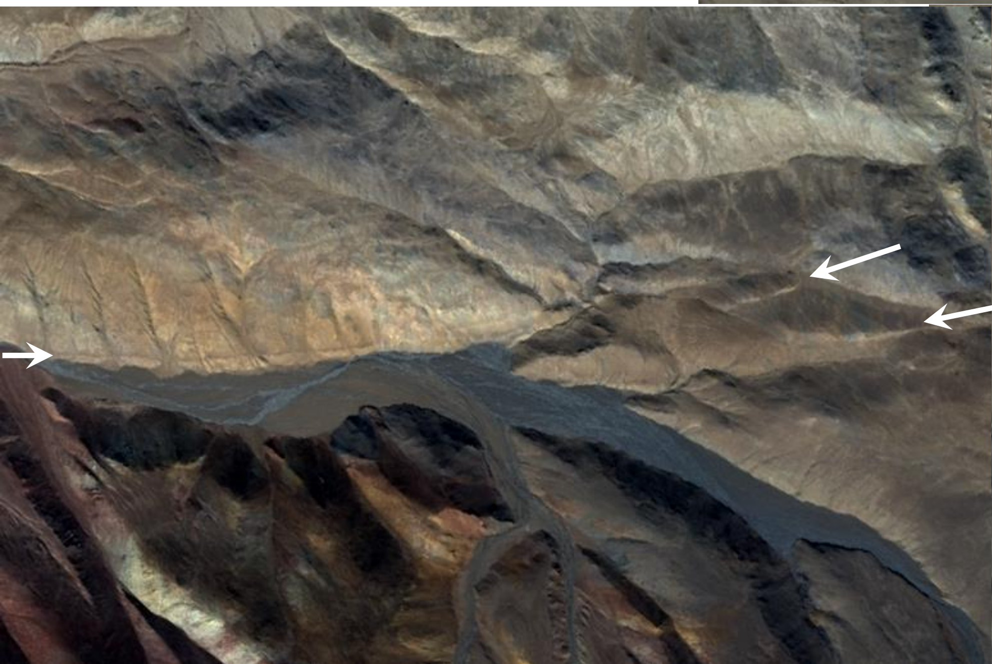
Remainder implies 1911 epicentre **70 km west**
(i.e., not on Karakul-Sarez Fault)



Evidence for other recent faulting

North of 2015 rupture





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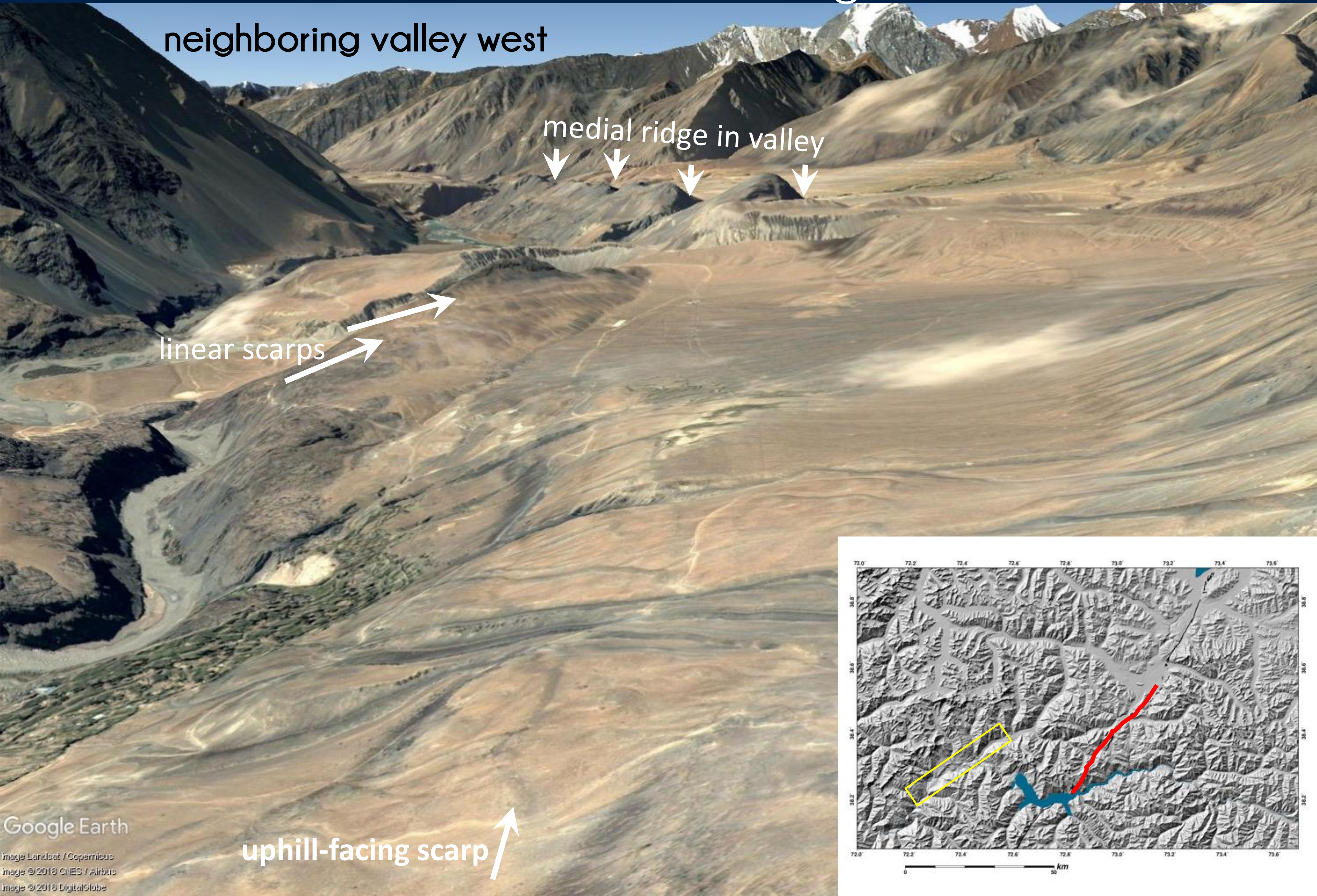
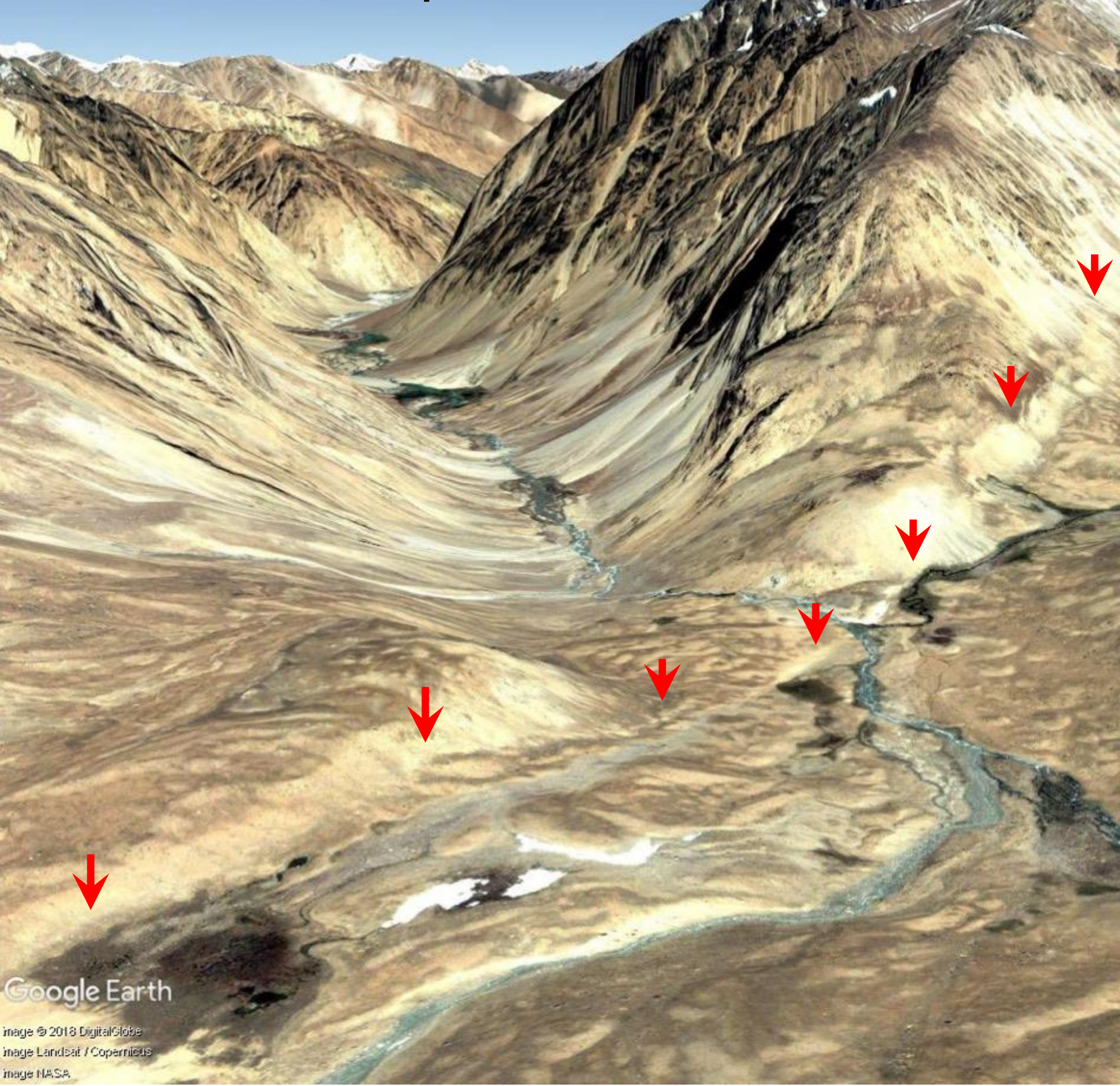
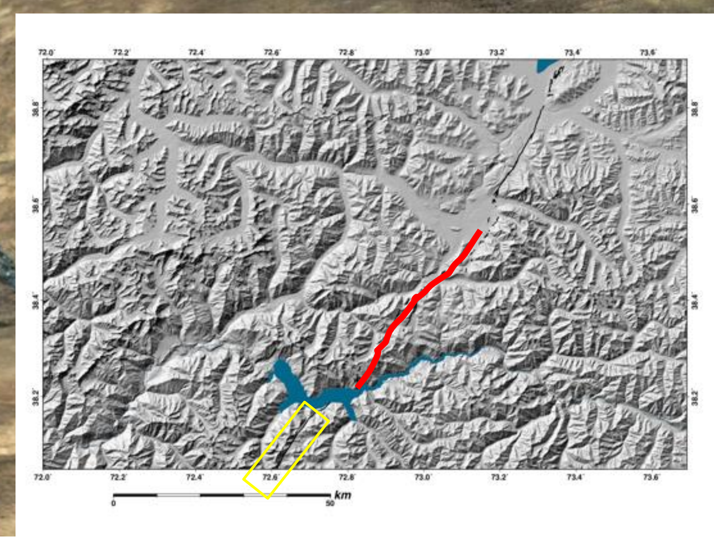


Evidence for other recent faulting

South of 2015 rupture





Seismological 1911 Source Test

Four candidate fault ruptures identified by geomorphology

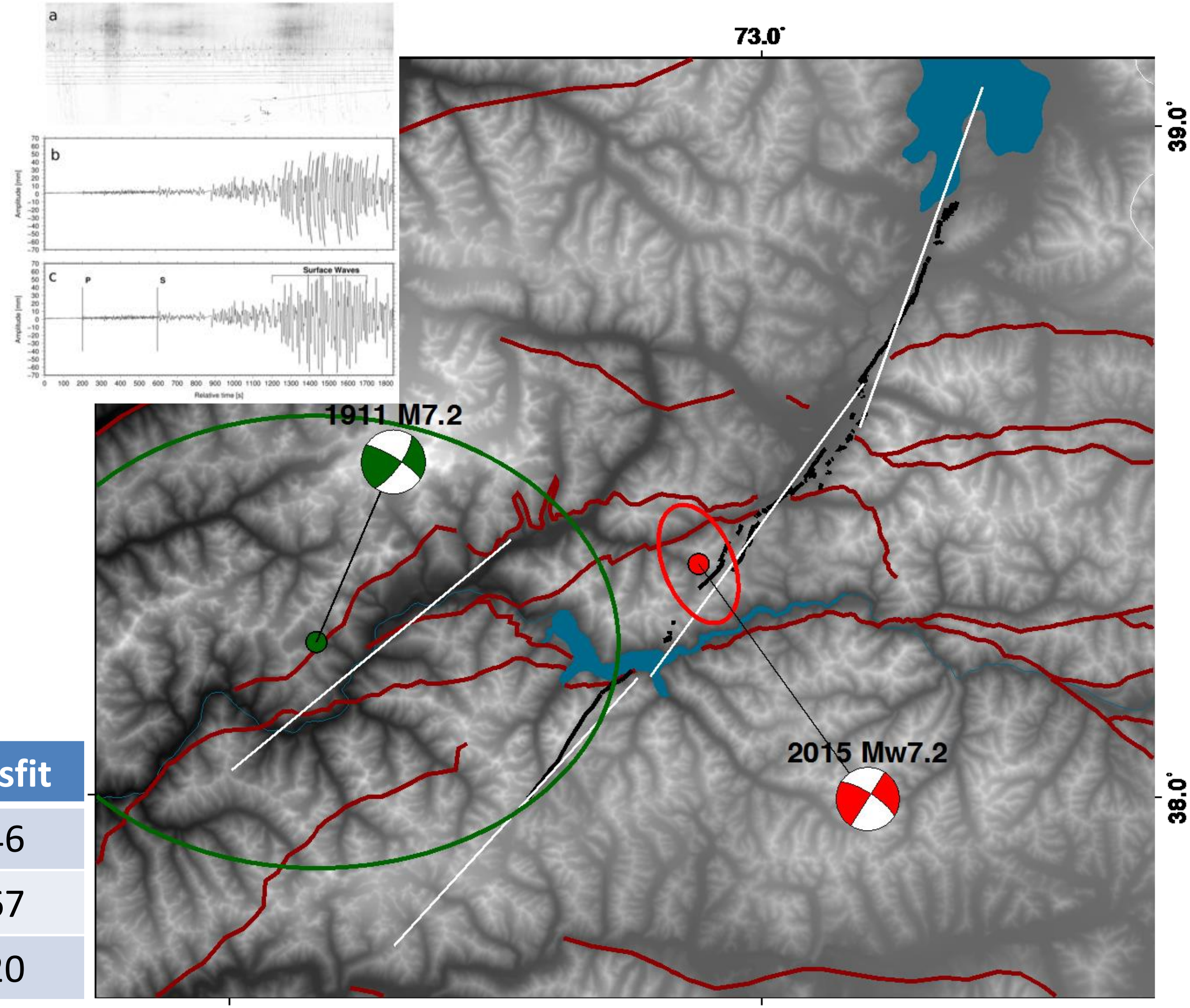
Generate synthetic seismograms for each at 12 stations w/1911 obs.

All sources given

dip = 73°W; rake = 12°

depth = 20km

misfit = inverse of correlation coefficient among all body wave phase arrivals



ID	Source	Strike	Misfit
1	west	050°	1.46
2	north	020°	1.67
3	south	042°	1.20

Conclusions

- Stacked year-spanning Landsat-8 correlations reveal comprehensive horizontal displacement field of major continental earthquake

- Total rupture ~80 km; surface rupture discontinuous, 40 – 60 km
- KSF to north shows more recent surface rupture
- 2015 ruptured *least* recently ruptured reach of Karakul-Sarez fault

- Extent of rupture (and previous KSF rupture?) controlled by intersection with thrusts/suture zones

- 1911 epicentre was not collocated with 2015

- Lowest seismological misfit 1911 source is SOUTH of 2015
- Three different large earthquakes on this fault zone, two instrumental