Measurement of sub-pixel displacement with optical imagery

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Measuring displacement

- Interferometric SAR
  - Active signal
  - Measurements in cm-scale
  - Displacements in line of view
  - Limited data
- Optical imagery
  - Passive signal
  - Measurements in m-scale
  - Horizontal displacements
  - Widely available data

Optical displacement measurement

- Detection of sub-pixel displacements
  - by sub-pixel image correlation
- Needs precise correction
  - ortho-rectified and co-registered images
- Difficult due to sensitivity to uncertainties in image systems and platform movements

COSI-CORR software (1)

- **C**o-registration of **O**ptically **S**ensed **I**mages and **C**orrelation
- Developed by CalTech Tectonics Observatory*
- Freely available for non-commercial research
- IDL/ENVI plugin

*http://www.tectonics.caltech.edu/slip_history/spot_coseis/

COSI-CORR software (2)

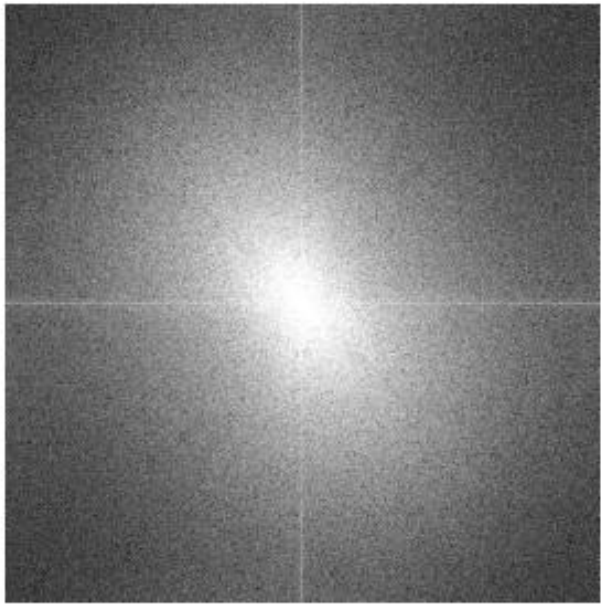
- COSI-CORR is solely based on topography and ancillary data provided with the observing platform
  - positions, velocities, attitudes variations, pointing directions for spacecrafts, and calibration reports
- Can be used for (aerial) photos and Quickbird, SPOT and ASTER imagery
- Topography can also be generated from this imagery using other software

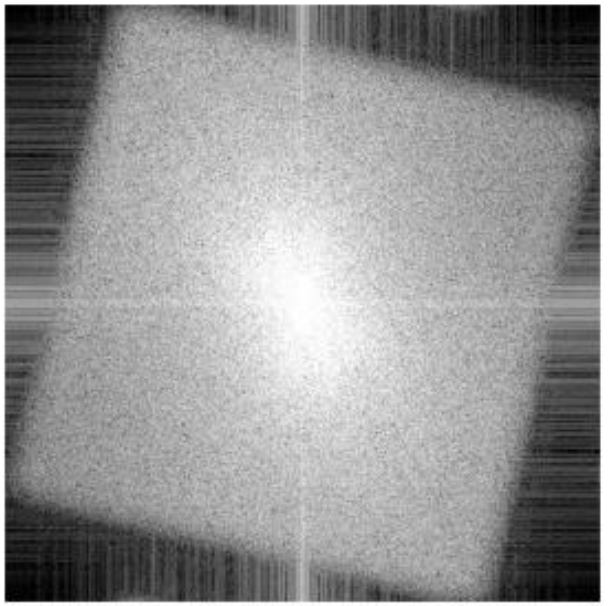
Ortho-rectification

- Correction of image pixel locations to a common projection
- Software requires a master image (ortho-rectified image of the original situation) and a slave image (uncorrected image of the new situation) to calculate spatial correlation in a kernel
- Ortho-rectification relies on automatic generation of ground control points (GCP) to warp the slave image to a master image

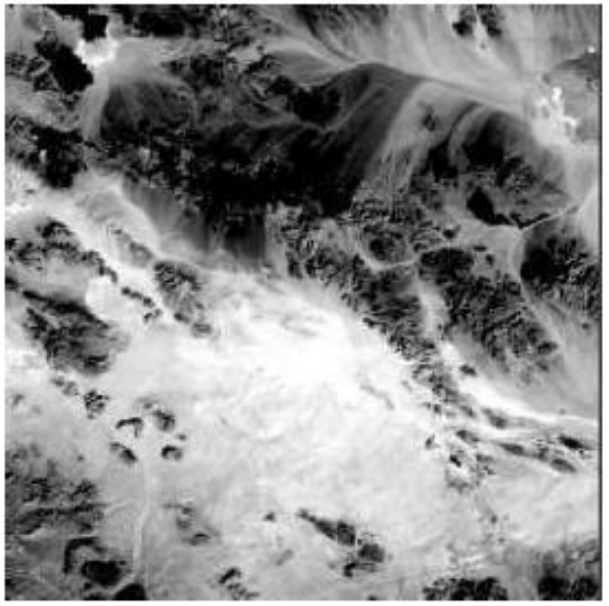
Ortho-rectification (2)

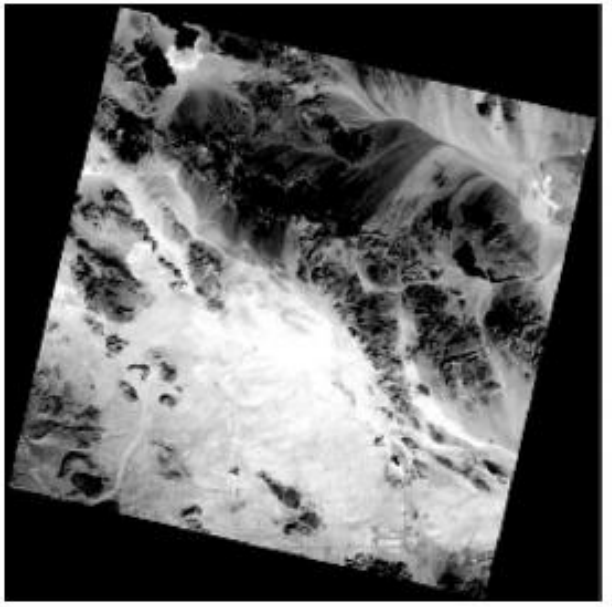
- Image spectrum in fourier domain





- Ortho-rectification result





Displacement calculation

- Horizontal ground displacements are retrieved from the sub-pixel correlation of the pre- and post-earthquake ortho-rectified images
- Image correlation is achieved with a processor that estimates the phase plane in the Fourier domain
- Two correlation images with East-West and North-South components of the horizontal ground displacement

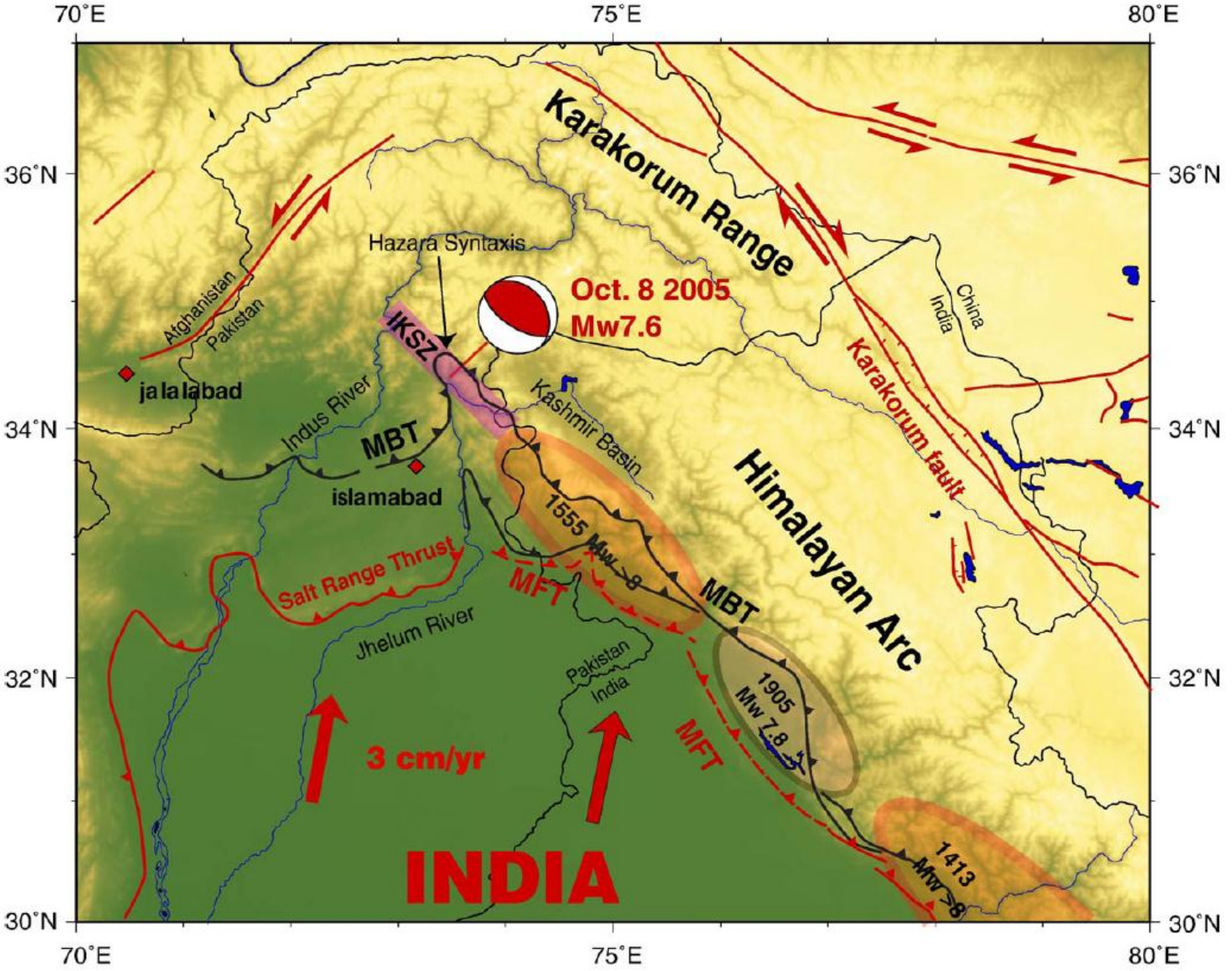
Accuracy

- Raw images are wrapped onto the topography within the DEM resolution, and pairwise co-registered with a 1/50 pixel accuracy.
- Measurement of horizontal fault offset with an accuracy on the order of 1/20 of the pixel size
- For ASTER, this gives a theoretical maximum accuracy of 1/20*15 = 0.75 m

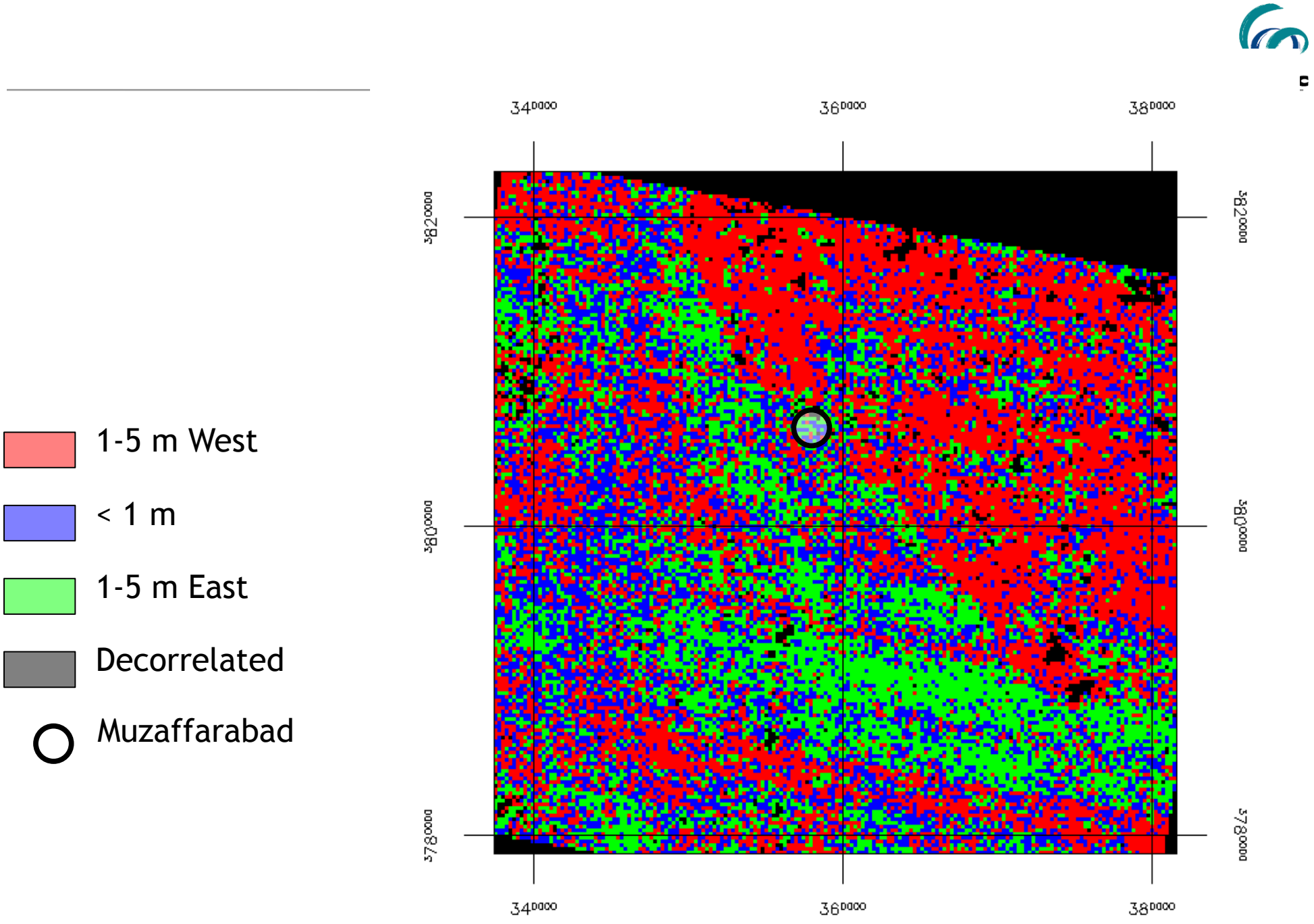
Application to Kashmir earthquake

- Applied to two ASTER scenes
  - November 14, 2000 and October 27, 2005
- DEM generated from ASTER stereo pair
- 32x32 pixels correlation window with 16 pixels step
- Ground resolution of 240 m. with (reported) accuracy of 2 m.

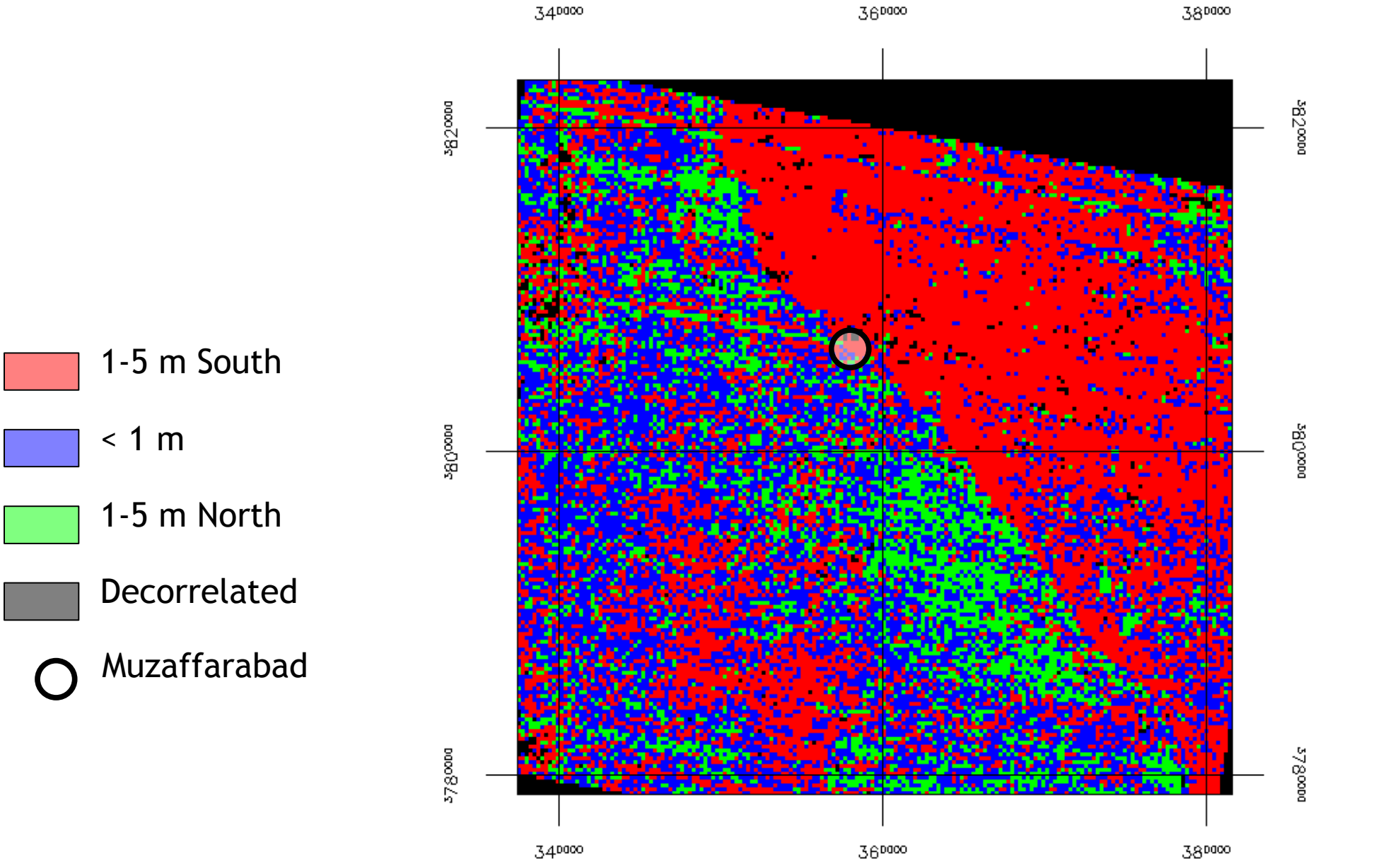
Tectonic setting of Kashmir



East-West displacement

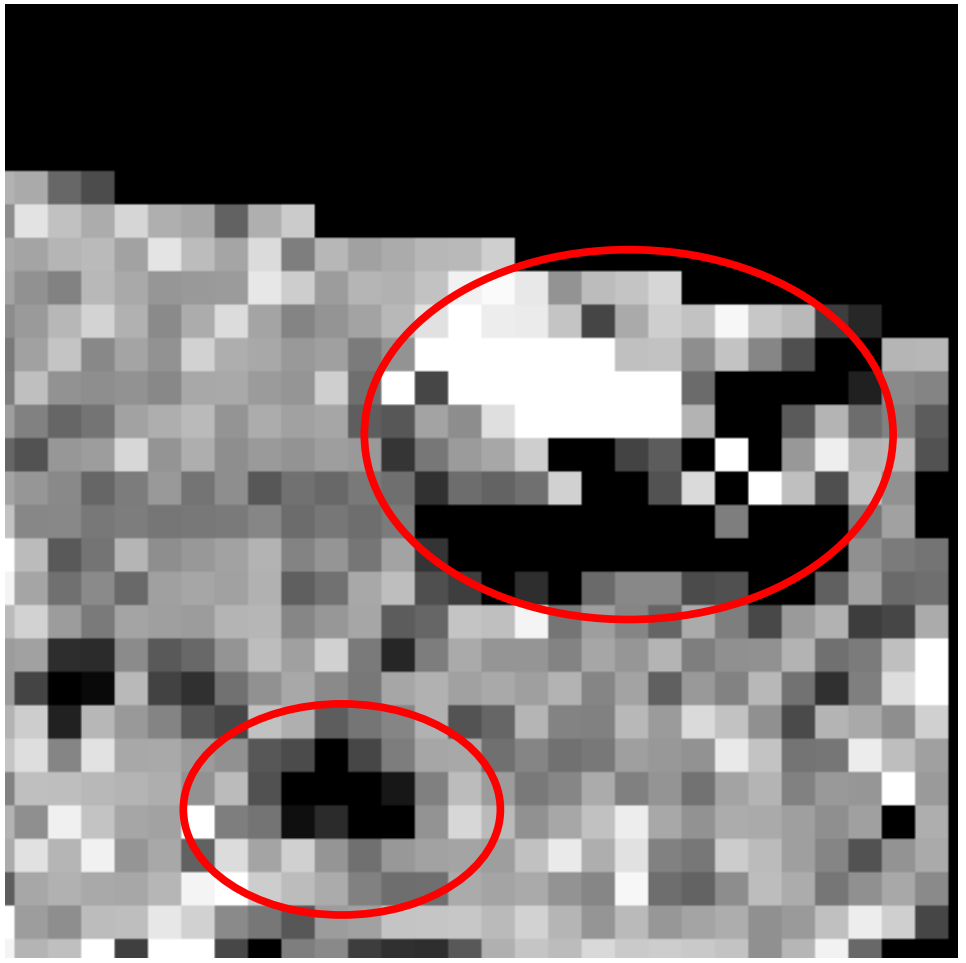


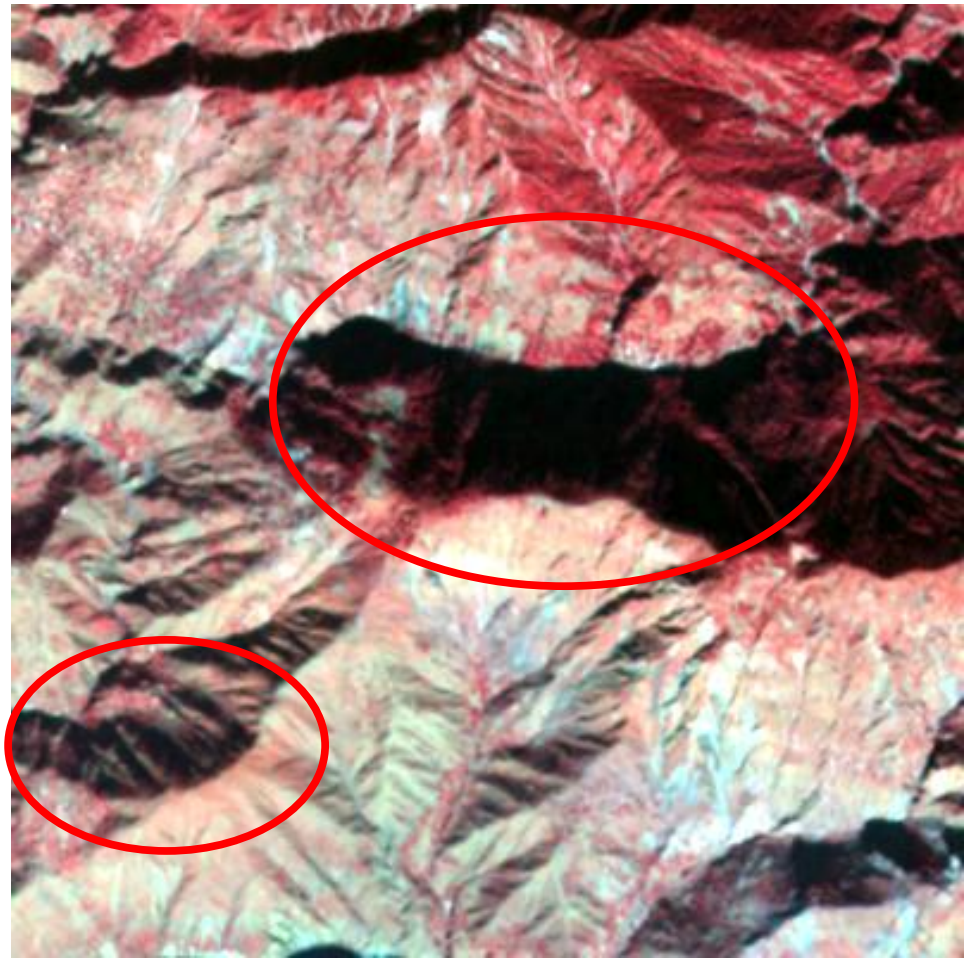
North-South displacement



Causes of de-correlation (1)

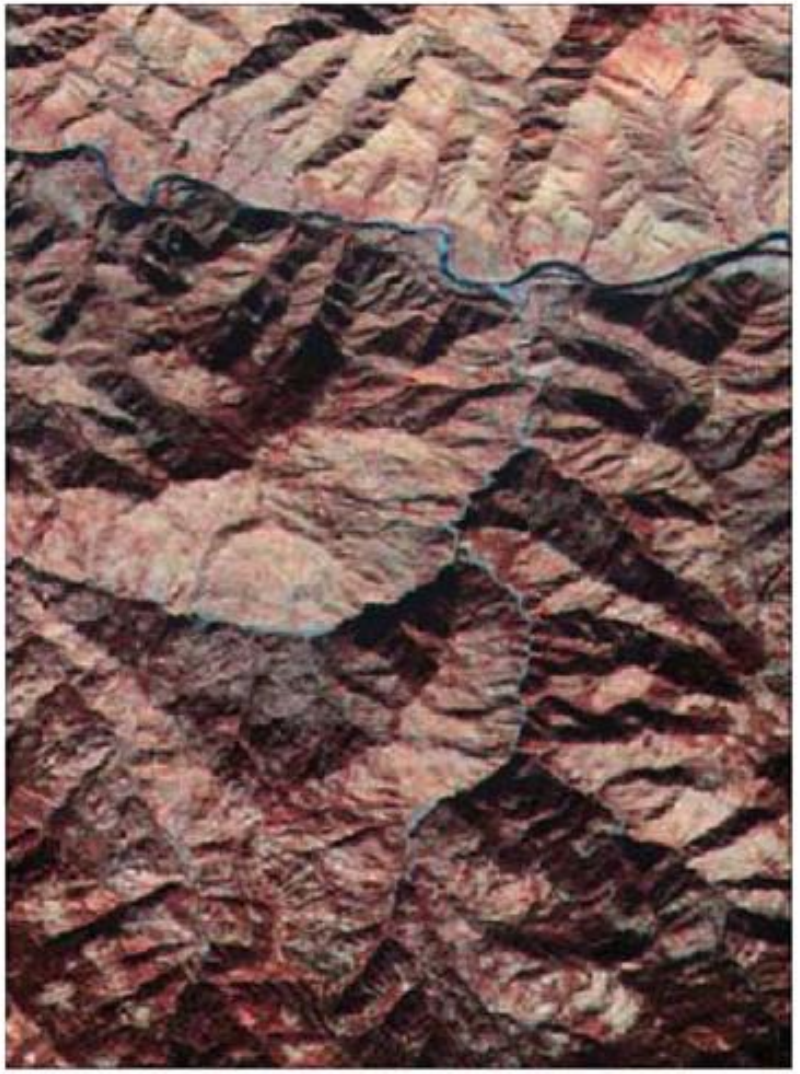
Topography leading to DEM & co-registration





Causes of de-correlation (2)

Major landslide leading to de-correlation



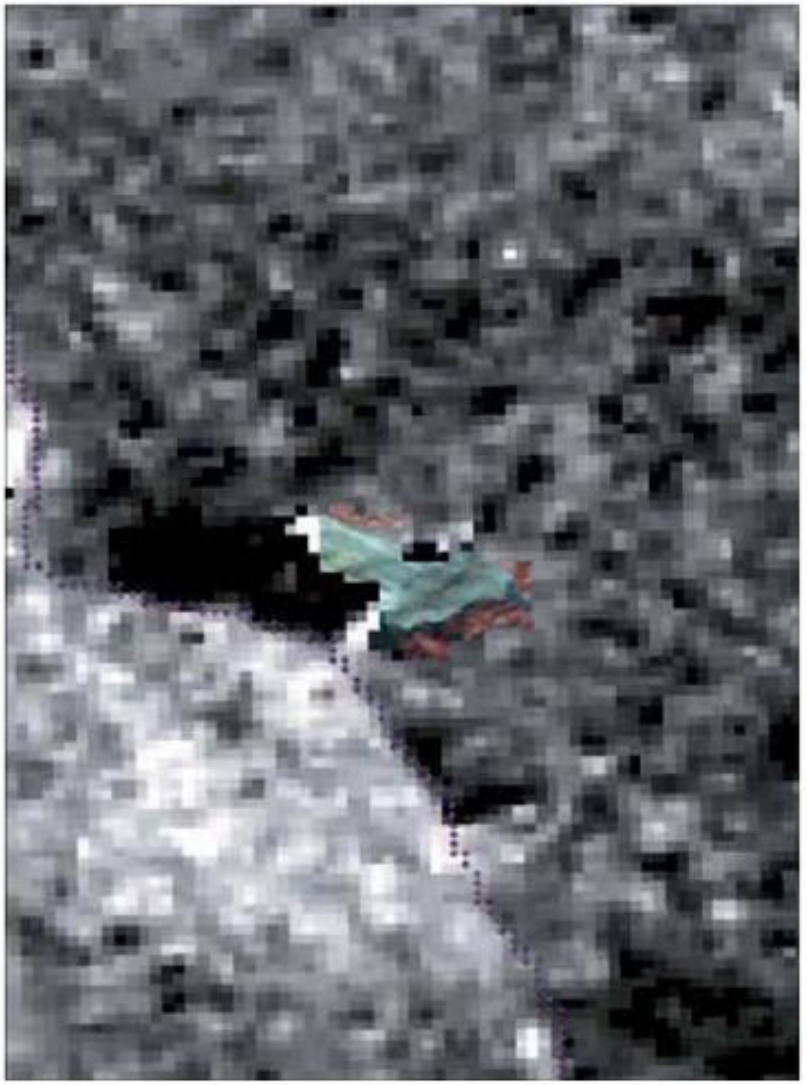


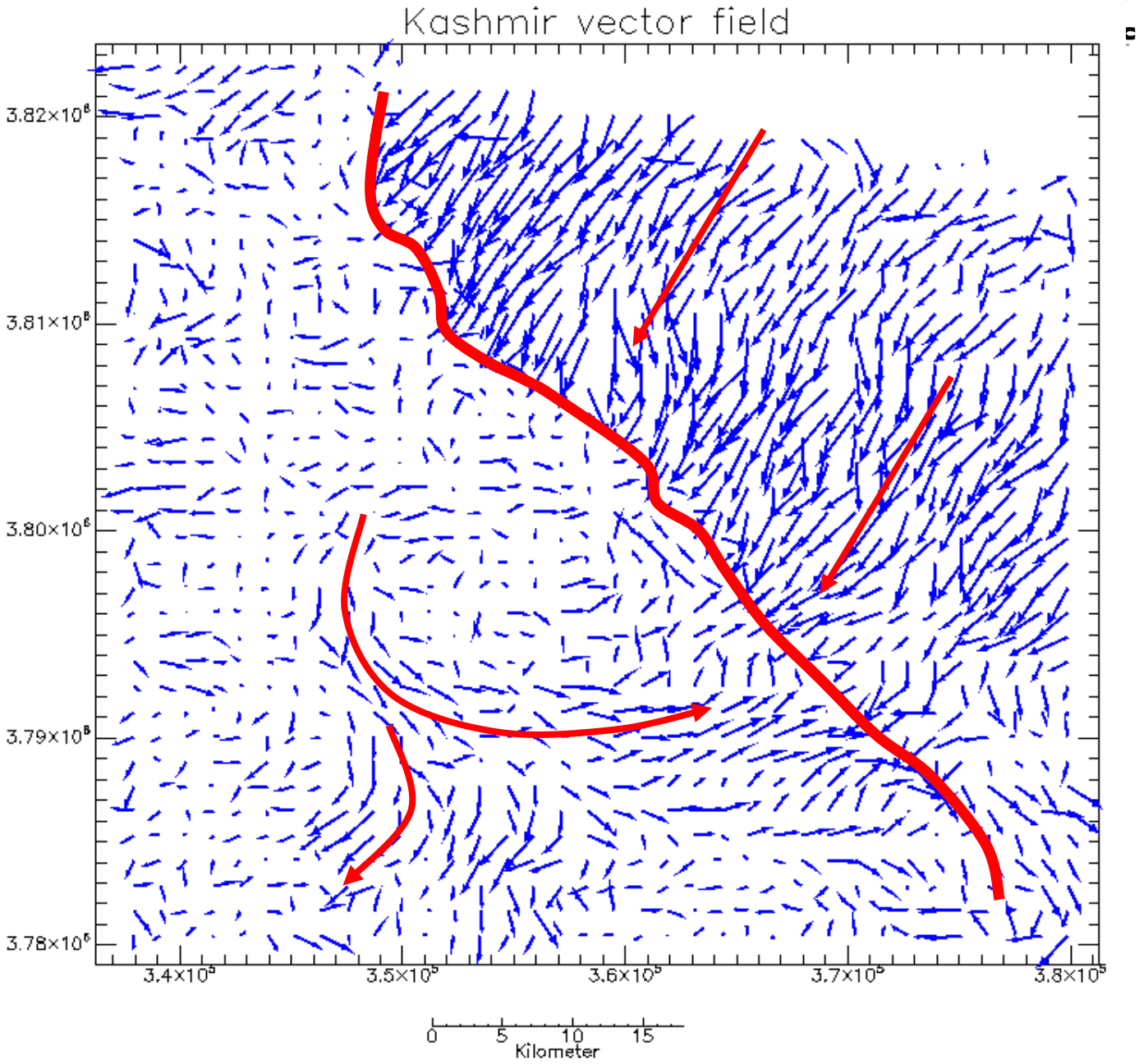
Figure by Avouac et al., 2006

Resulting vector field

Main fault

Movement

Vector field



References

J-P. Avouac, F. Ayoub, S. Leprince, O. Konca & D. Helmberger, 2006. *The 2005, Mw 7.6 Kashmir earthquake: Sub-pixel correlation of ASTER images and seismic waveforms analysis*. Earth and Planetary Science Letters 249 (2006) 514–528.

S. Leprince, S. Barbot, F. Ayoub & J. Avouac. *Automatic and Precise Orthorectification, Coregistration, and Subpixel Correlation of Satellite Images, Application to Ground Deformation Measurements*. IEEE Transactions on Geoscience and Remote Sensing, VOL. 45, NO. 6, June 2007