Dragon-4 ID: 32431 Seismic detection with InSAR data

Chinese partners :

Institute of Geology, China Earthquake Administration

Jianbao Sun

Xu Xiwei

Zheng-Kang Shen : also at PKU & UCLA

Han Yue (PKU)

and students (Mingjia Li, and others)

European partners:

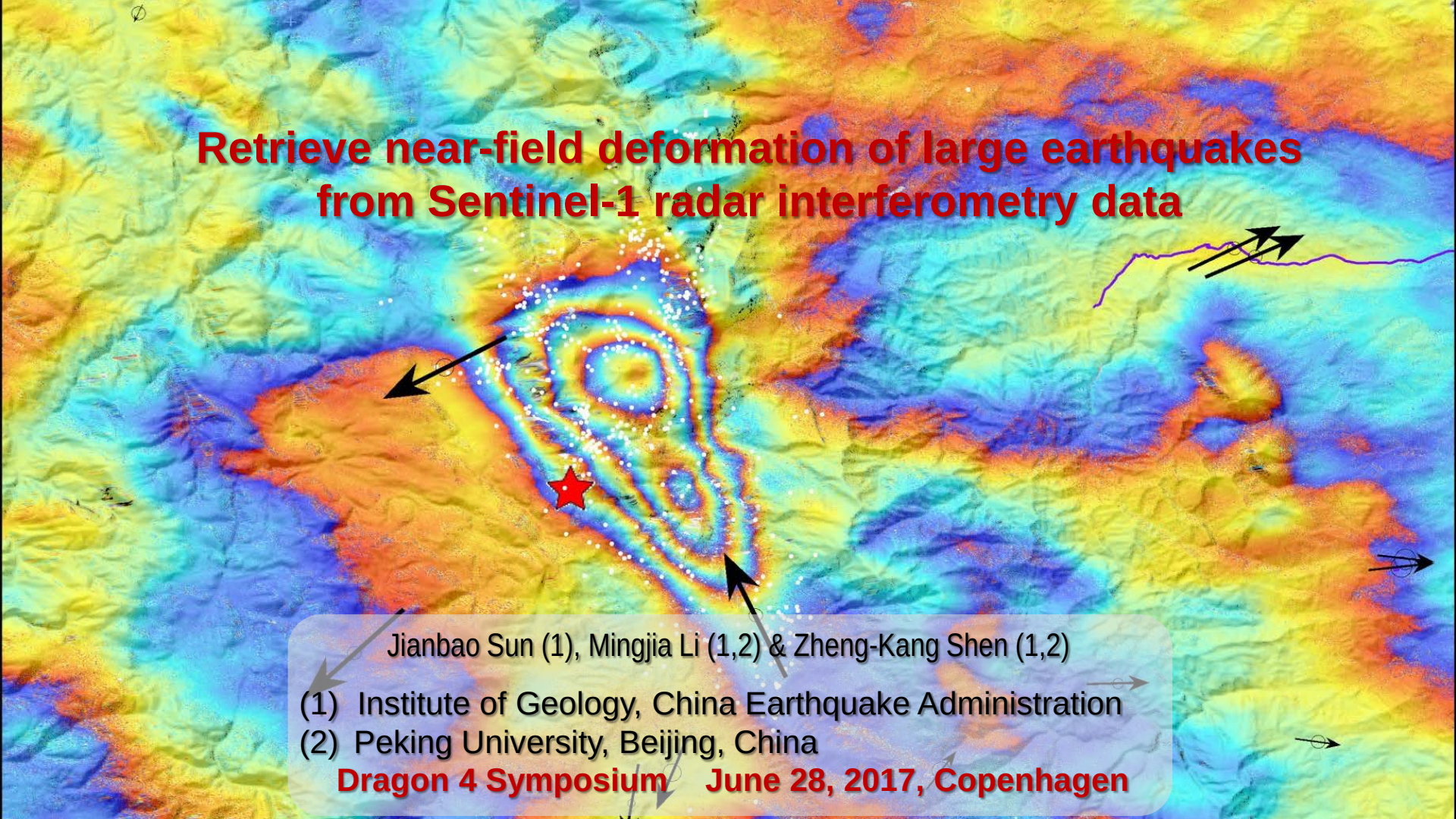
University of Grenoble, France

Cecile Lasserre

Marie-Pierre Doin

and students (Simon Daout, Laetitia Lemrabet)

Retrieve near-field deformation of large earthquakes from Sentinel-1 radar interferometry data



Jianbao Sun (1), Mingjia Li (1,2) & Zheng-Kang Shen (1,2)

(1) Institute of Geology, China Earthquake Administration
(2) Peking University, Beijing, China

Dragon 4 Symposium June 28, 2017, Copenhagen

Outline

→ Motivation

→ Methodology

→ Applications

- 2015 Chile Illapel Mw 8.3 Earthquake (subduction zone)
- 2016 Italy Earthquake Sequence (no significant surface ruptures)
- Dec. 07, 2015, Mw 7.2 Tajikestan Earthquake (surface ruptured event)
- Nov. 25, 2016, Aketao, Xinjiang Mw 6.6 Earthquake (mountains+basin)
- Jul. 3, 2015 Mw 6.4 Pishan Earthquake case (postseismic time series)

→ Conclusions

Motivation

→Phase model of InSAR data.

$$\phi_{insar} = \phi_{def} + \phi_{topo} + \phi_{atm} + \phi_{orbit} + \phi_{noise}$$

→Phase unwrapping is necessary for obtaining surface deformation.

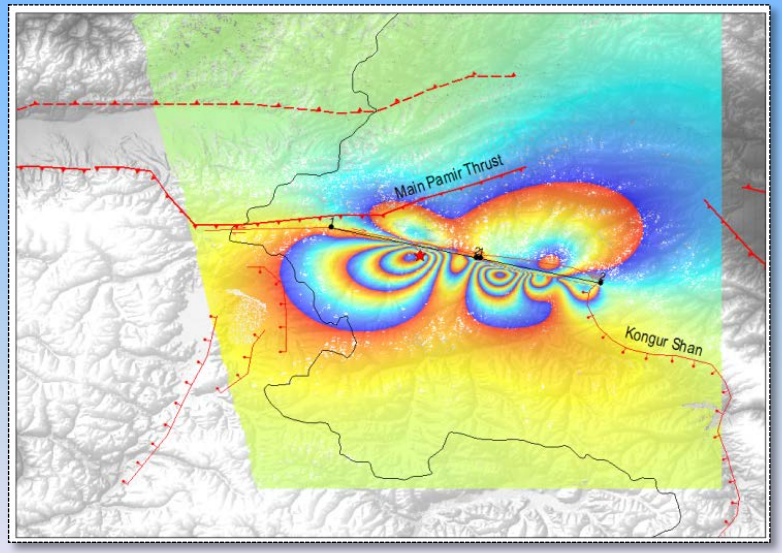
ϕdef: earthquake, volcano, subsidence, landslides, glacier motion etc. Correlated locally-spatially, smooth surface changes, except across surface ruptured faults (elastic or viscoelastic deformation assumed in lithosphere).

ϕtopo: correlated with spatial baseline, and depending on accuracy of DEM.

ϕatm: correlated locally-spatially, and uncorrelated in time.. DEM-related atmosphere (Jolivit, 2011; Bekaert, 2015 etc.).

ϕorbit: correlated globally-spatially.

ϕnoise: random in space and time. a proxy for PS identification with low ϕnoise (Hooper, 2004).



Surface deformation prediction of the Nov. 25, 2016 China Earthquake

Motivation

→The factors preventing successful InSAR phase unwrapping.

ϕdef: strong ground shaking and damages made by earthquakes, small-scale changes relative to earthquake deformation, such as building collapse, landslide, liquefaction etc.

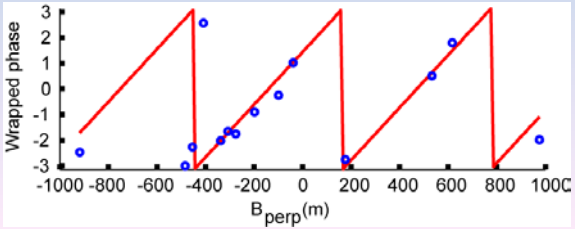
ϕtopo: random DEM errors, which is difficult to be estimated with bad baseline distribution, or no very accurate co-registeration available for time series stacks (SBAS) due to Doppler centriod frequency changes, filtering, geocoding etc.

ϕatm: DEM-related atmospheric delays, normally small compared with earthquake deformation. No abrupt changes expected, thus limited effects for unwrapping.

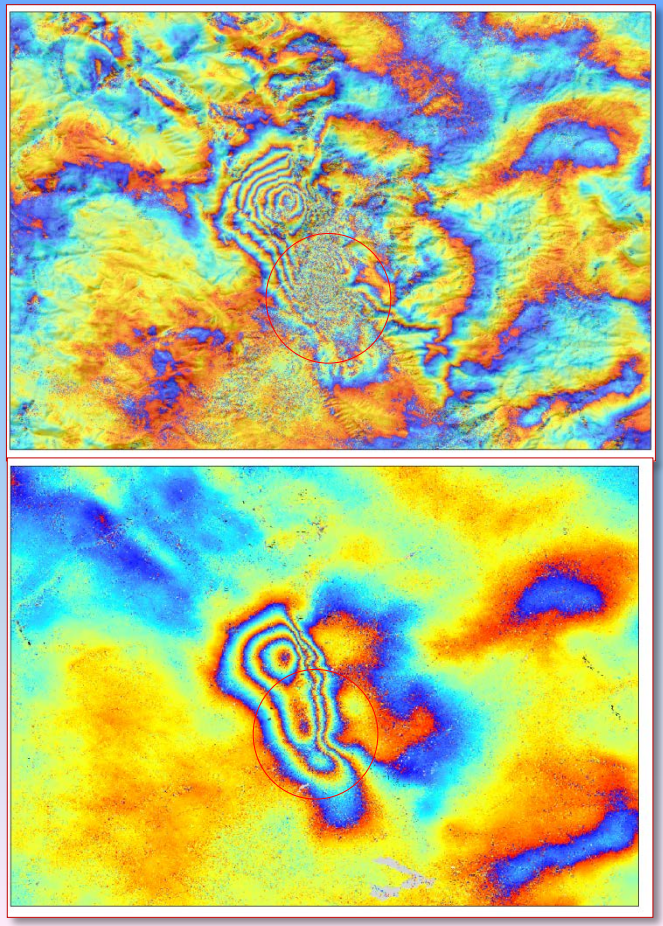
ϕorbit: Basically little influence on phase unwrapping.

ϕnoise: Ignorable on phase unwrapping after power spectral filtering.

Others: Layover and shadow in radar imagery



(Hooper, 2006).



Motivation

→Coherence model of InSAR, following Zebker and Villasenor, 1992, Hanssen,1999:

$$\gamma_{tot} = \gamma_{geom} \times \gamma_{DC} \times \gamma_{vol} \times \gamma_{thermal} \times \gamma_{temporal} \times \gamma_{processing}$$

- It is vital to measure the near-field information as it reflects the fault rupture mechanics in shallow or middle crust, closely related to seismic hazards or earthquake physics. Geodetic data has better resolving power of earthquake models at shallow depth as well.

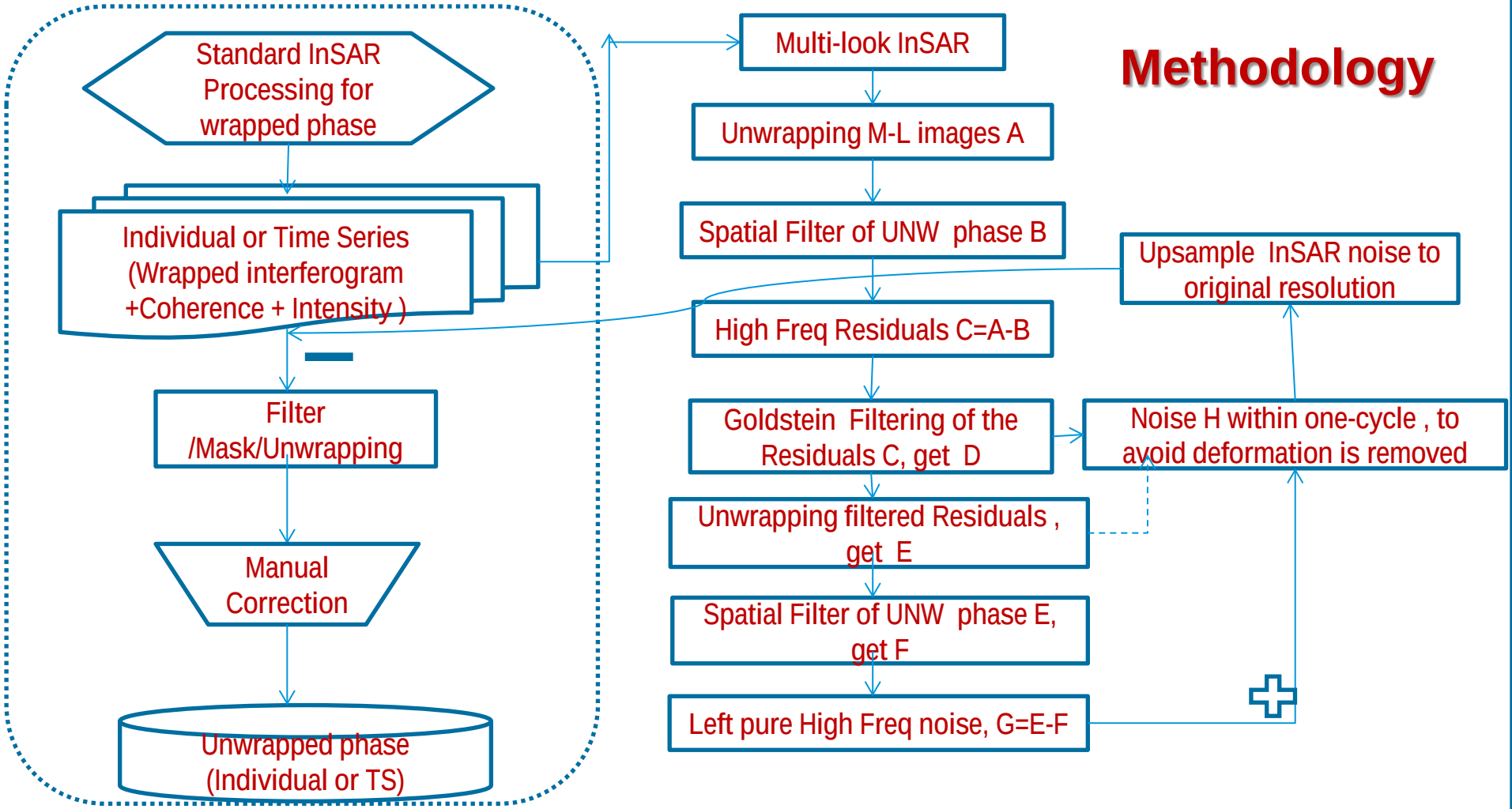
- Feasibility of extracting the near-field deformation signals of large earthquakes.

The 6-day revisiting cycle of the Sentienl-1A/1B with optimized spatial baseline will greatly reduce the temporal/spatial decorrelation effects.

(Definition of the near-field). All areas surrounding seismic fault, except those with physical signal loss due to strong ground motion or shaking, e.g., neighbour pixel differential phase exceeding 3.14 radians.

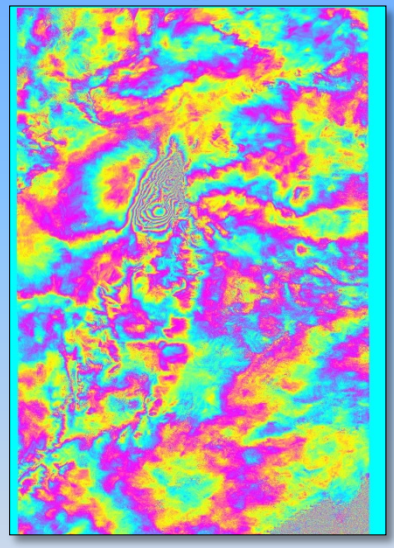
- For earthquake studies, it would be good to avoid manually corrections on phase unwrapping given bulk of data available for time series analysis.

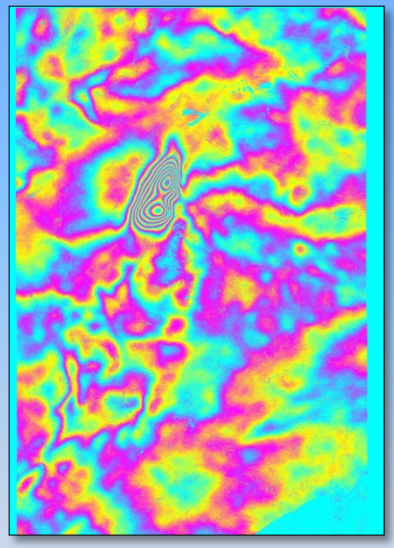
Methodology

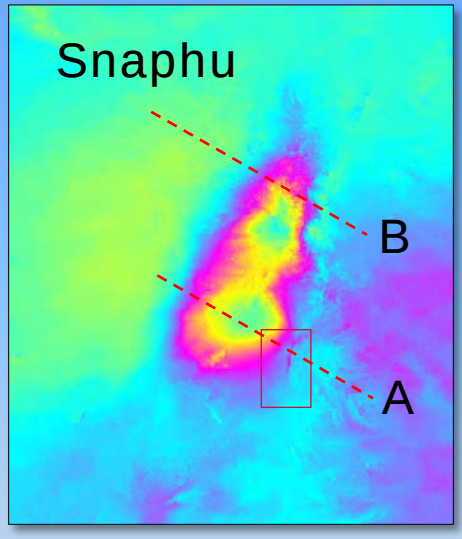


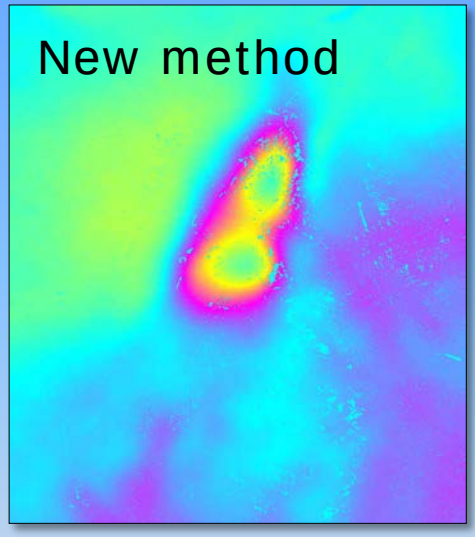
Applications

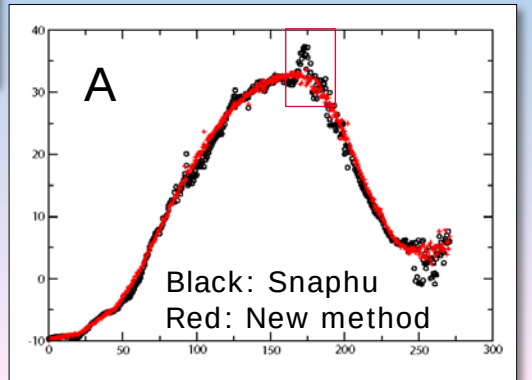
- 2016 Italy Earthquake Sequence

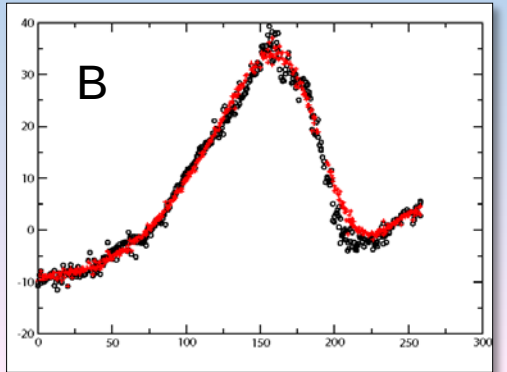












Comparison between two unwrapping results, radar coordinators

160815S1A_160827S1A_T117_iw3

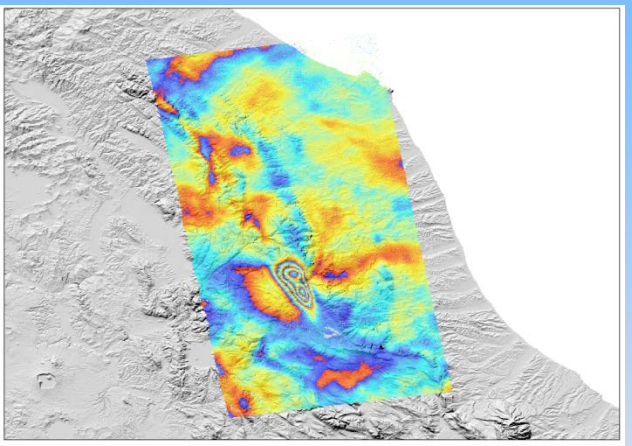
Snaphu unwrapping after filtering(L)

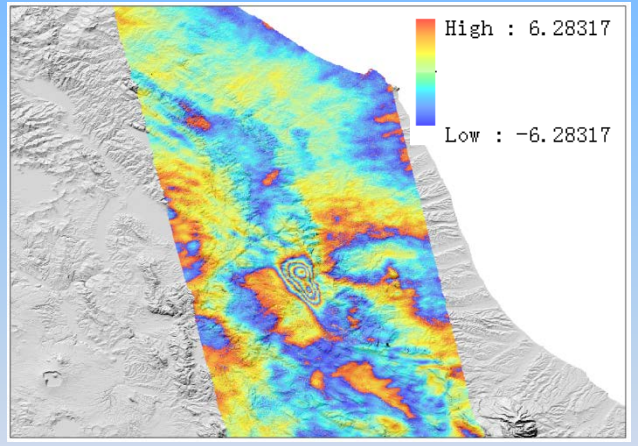
New strategy for unwrapping(R)

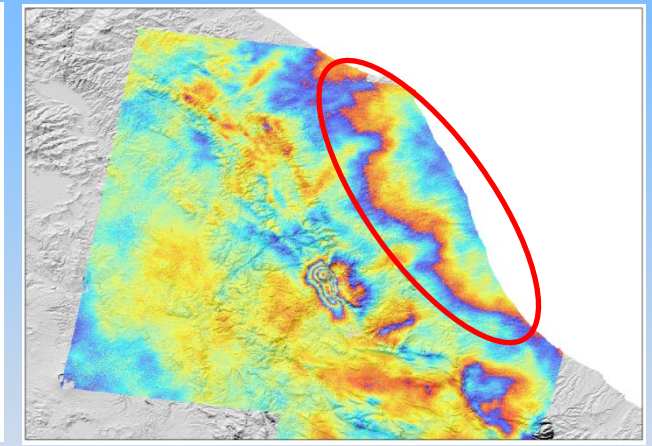
Same filter strength applied!

Applications

- 2016 Italy Earthquake Sequence (no significant surface ruptures)

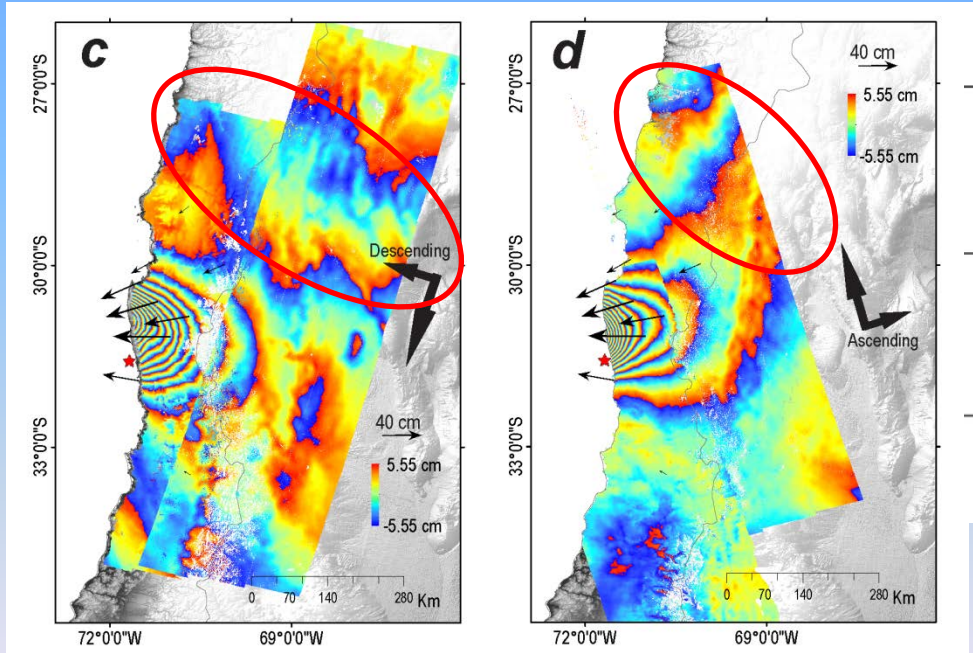


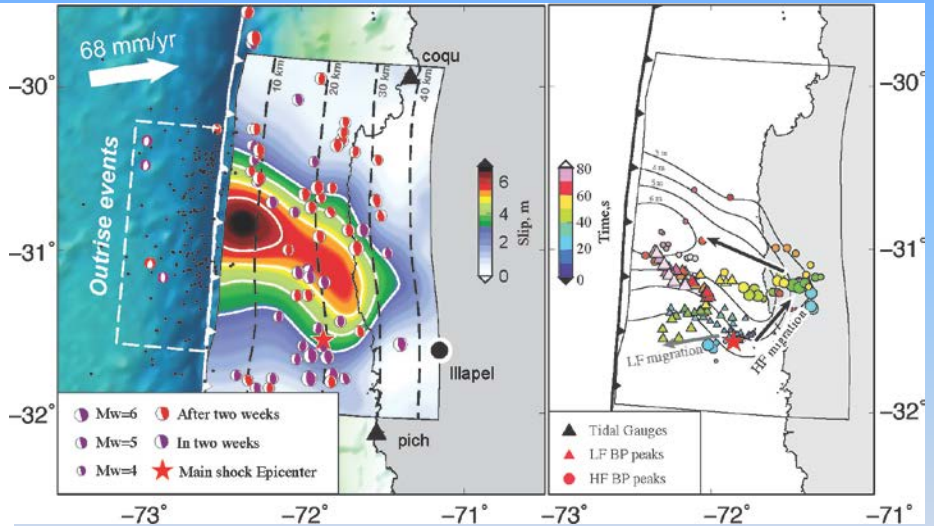




Sentiel-1A/1B data processed with both SNAP and ISCE software
Linear orbital ramps removed
ECMWF correction tested with TRAIN (by David Bekaert, JPL)

- 2015 Chile Illapel Mw 8.3 Earthquake (subduction zone)

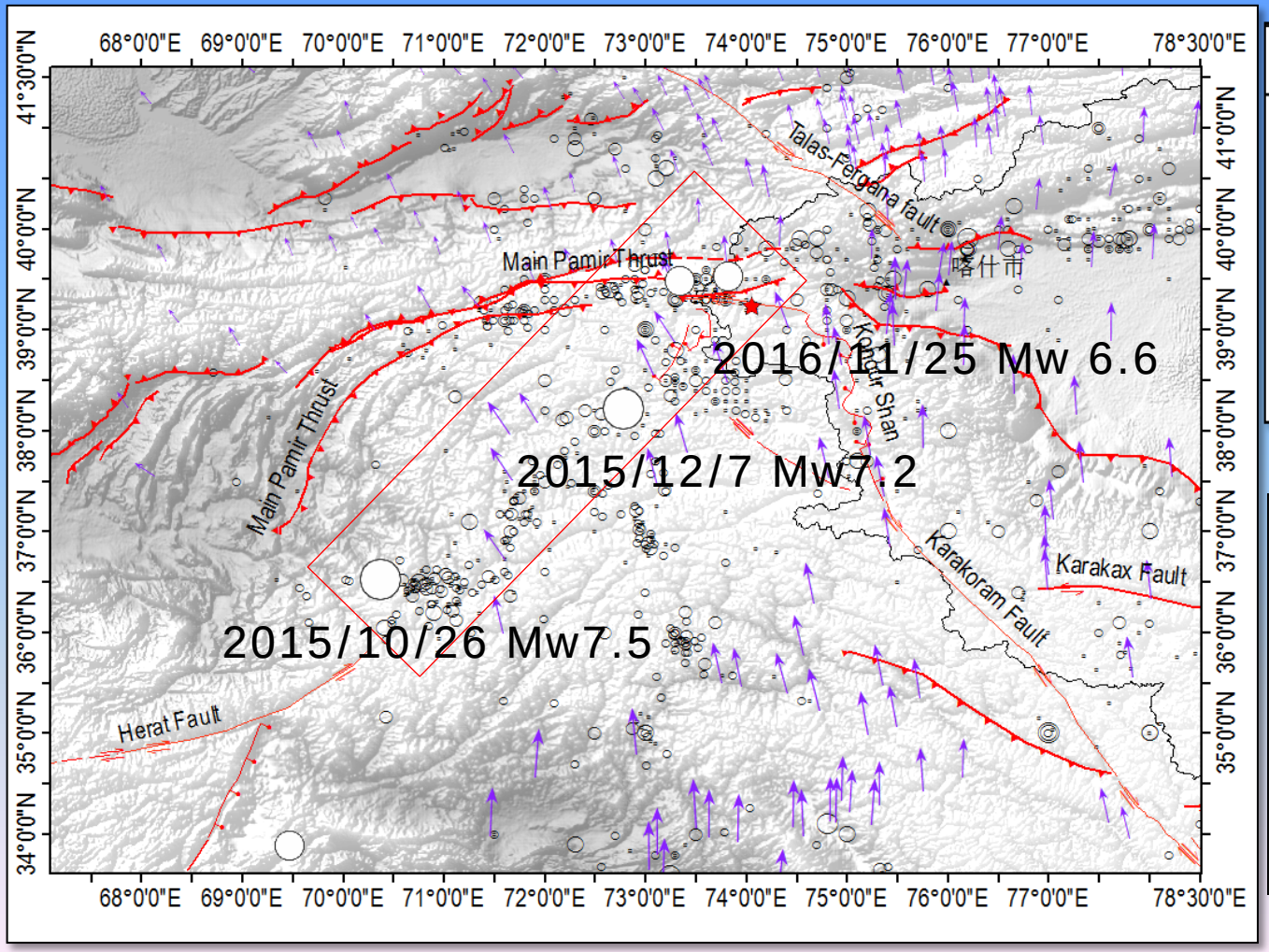


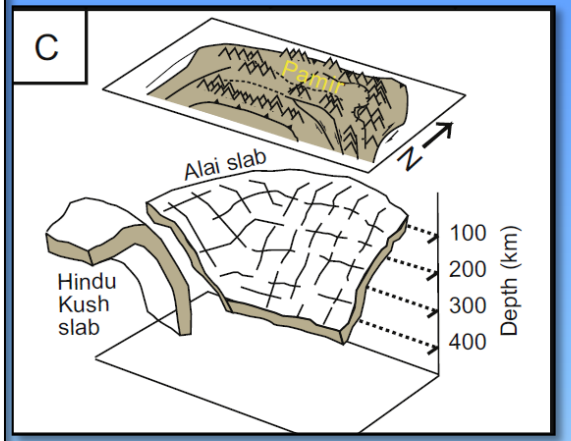


4 track S1A data as long as > 500 km
Calibrated with near-field GPS data

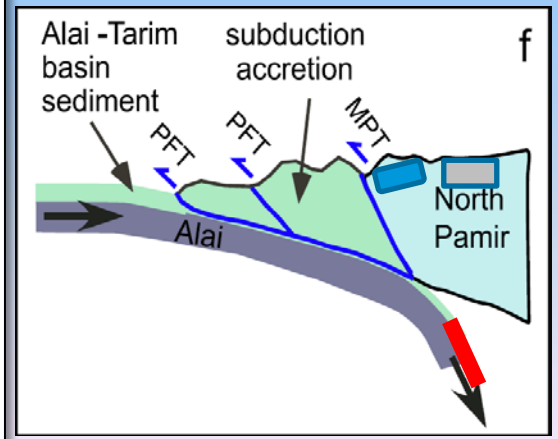
Joint inverison with InSAR+GPS+ Teleseimc+Tunami data
Back-Projection imaging

An et al., 2017, BSSA

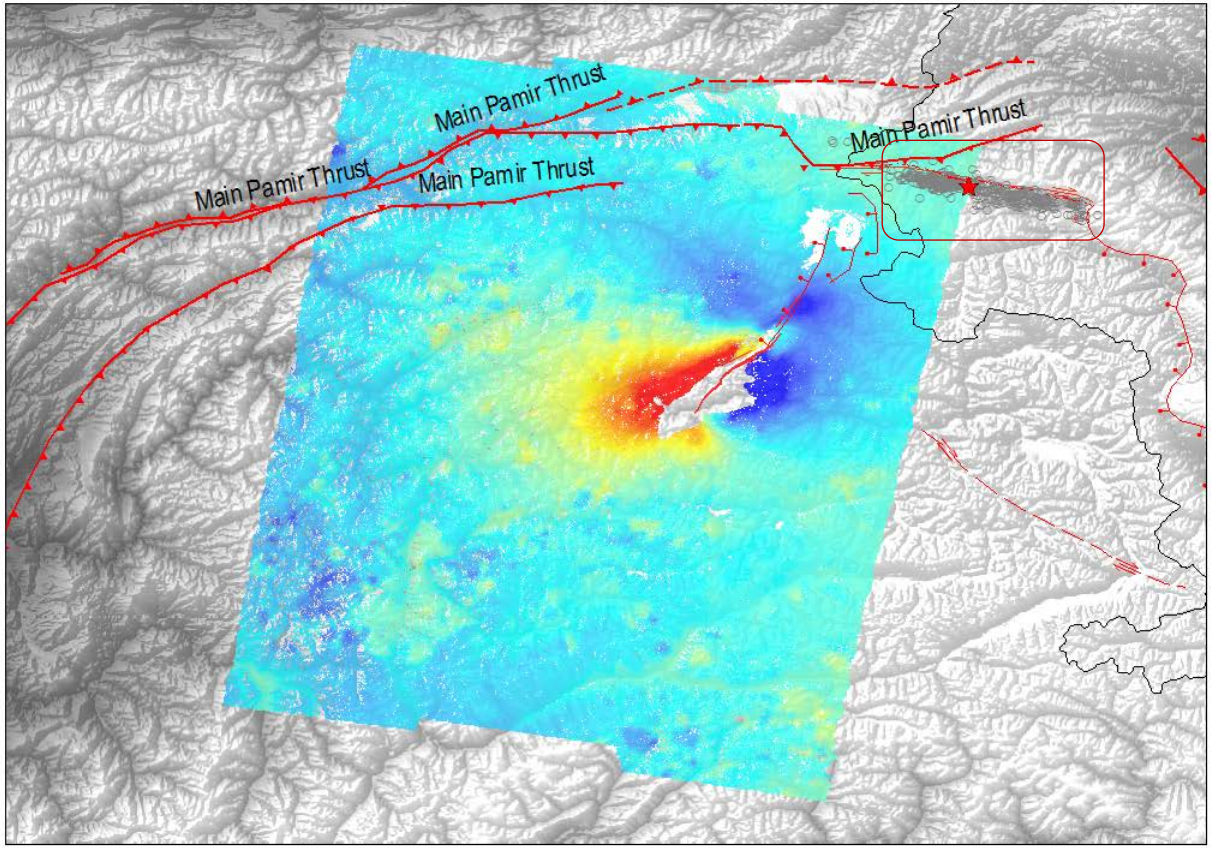




Sobel et al, 2013



- Dec. 07, 2015, Mw 7.2 Tajikestan Earthquake (surface ruptured event)



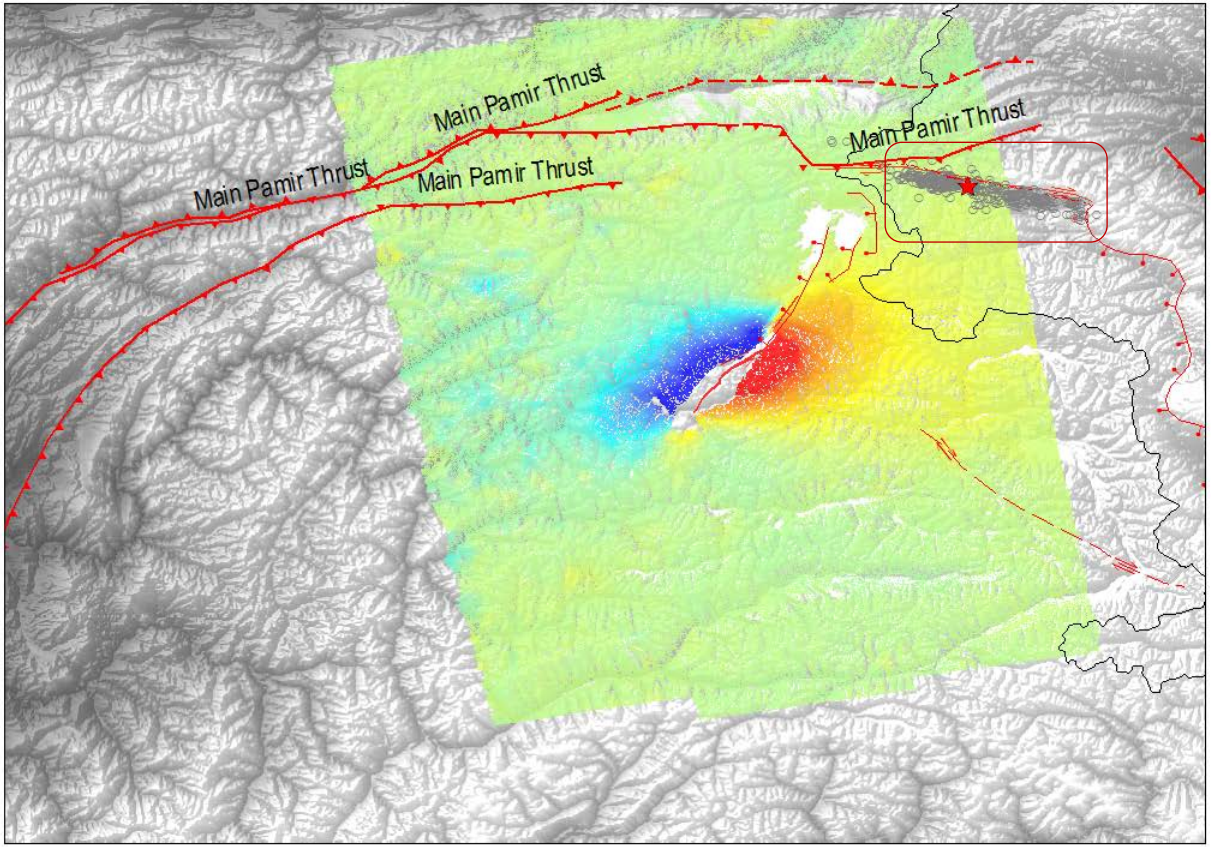
High : 3.14159

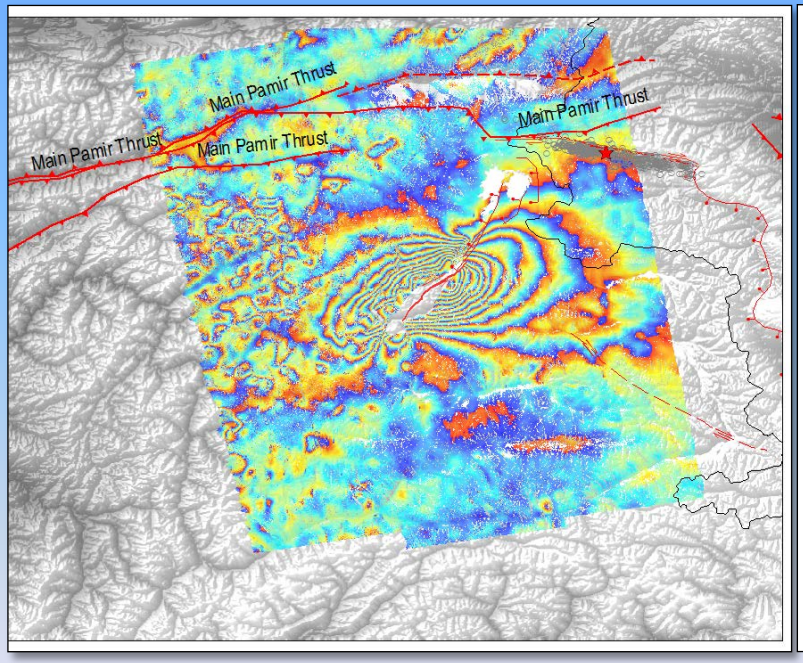
Low : -3.14159

High : 67.3429

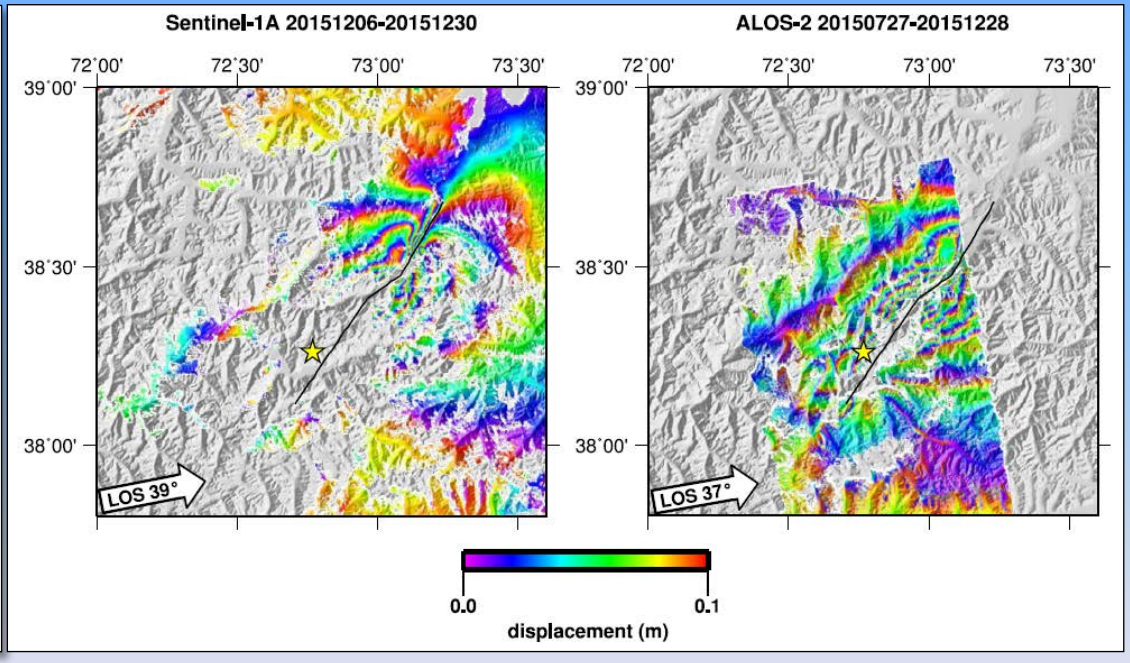
Low : -38.531

- Dec. 07, 2015, Mw 7.2 Tajikestan Earthquake (surface ruptured event)



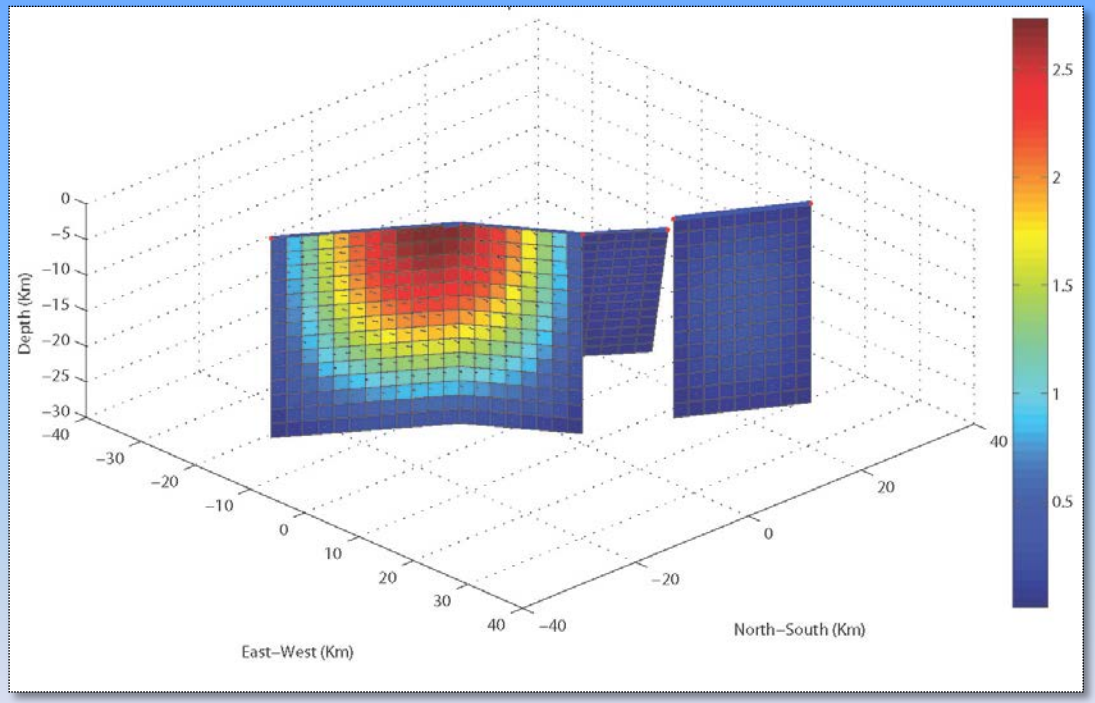


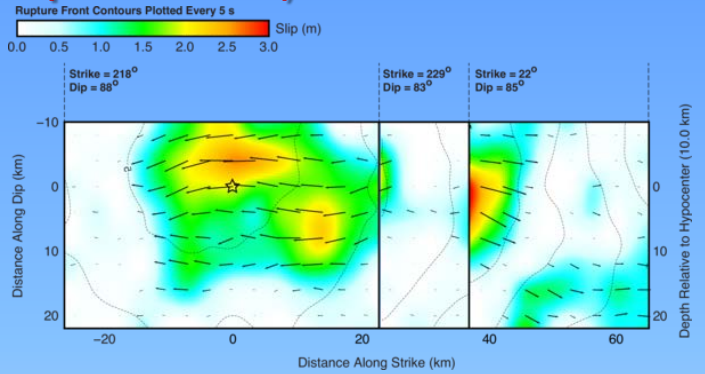
This study



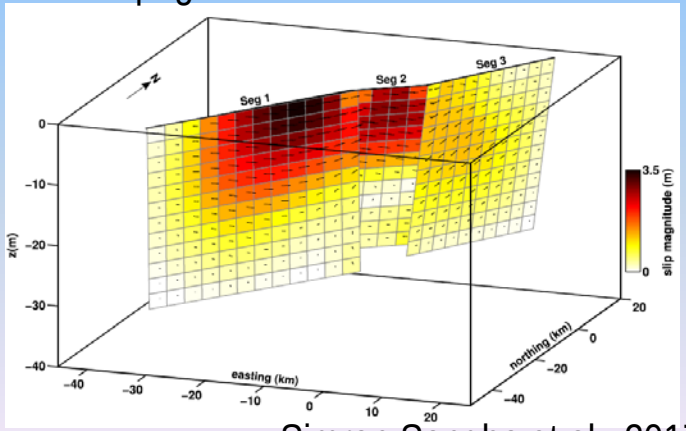
Simran Sangha et al., 2017

- Dec. 07, 2015, Mw 7.2 Tajikestan Earthquake (surface ruptured event)





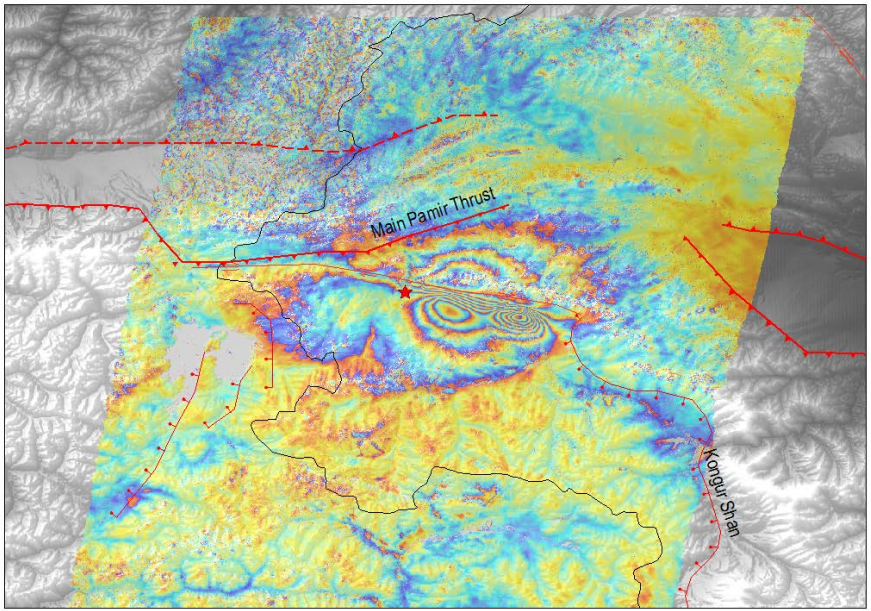
https://earthquake.usgs.gov/earthquakes/eventpage/us100044k6#finite-fault

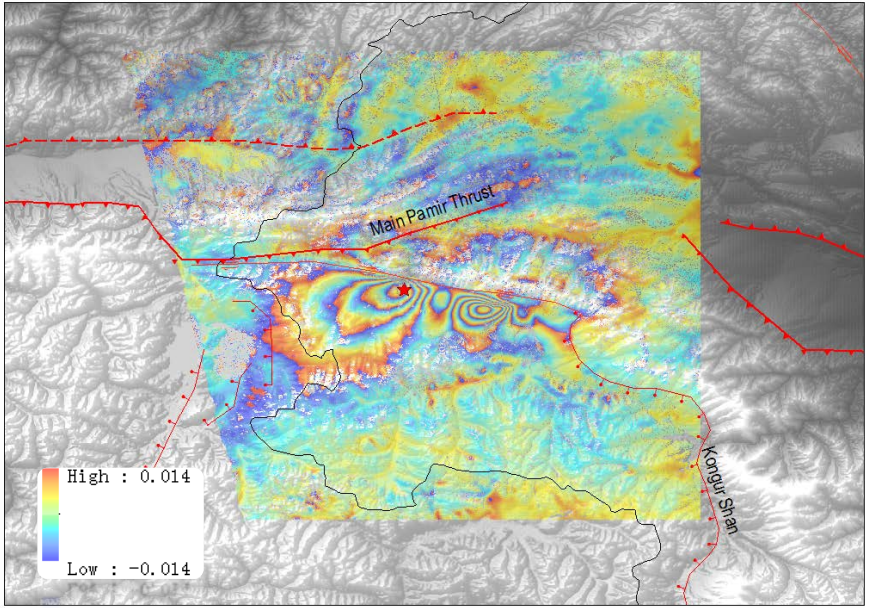


This study: slip solution from InSAR+Landsat 8 data, 4.5E+19 Nm
Mostly vertical fault, dipping segment has no significant slip!

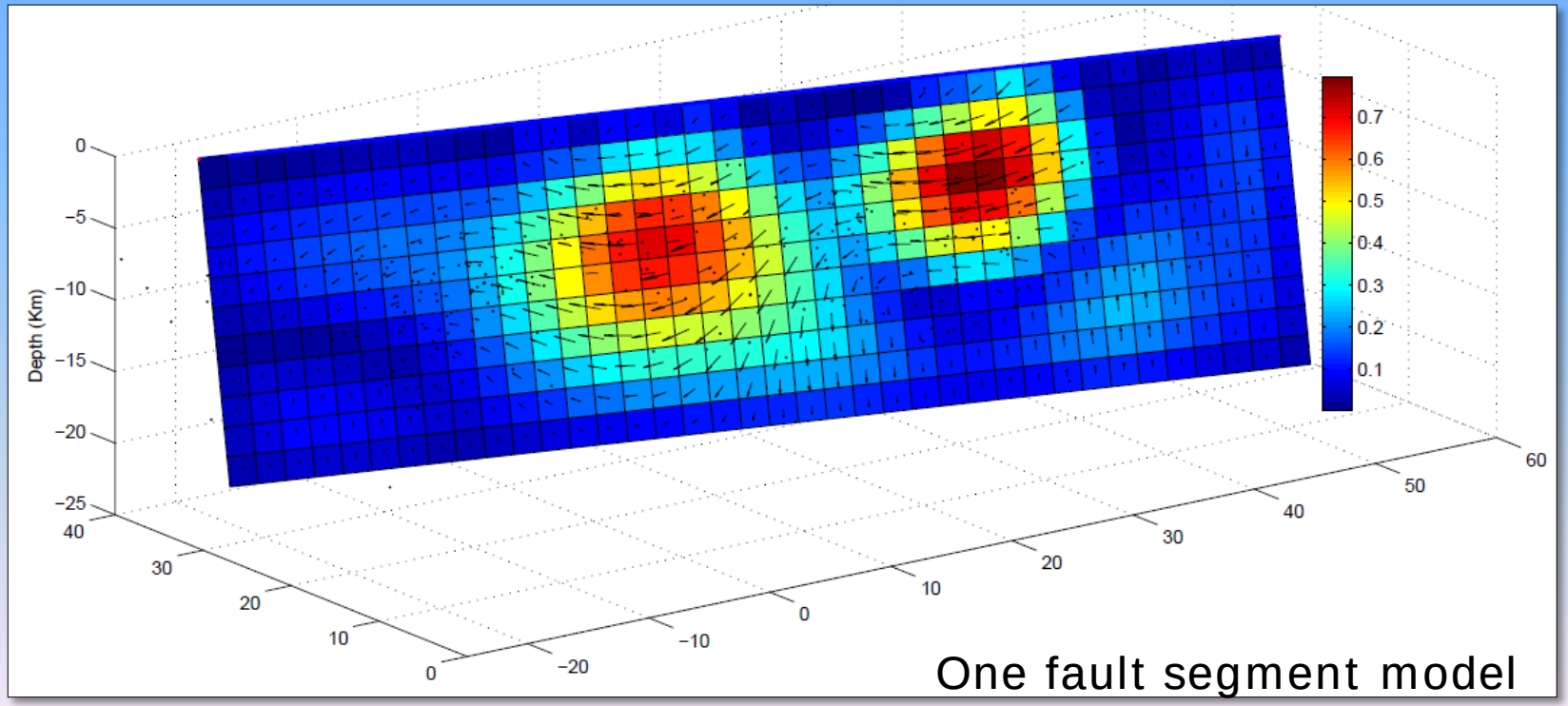
Simran Sangha et al., 2017

- Nov. 25, 2016, Aketao, Xinjiang Mw 6.6 Earthquake





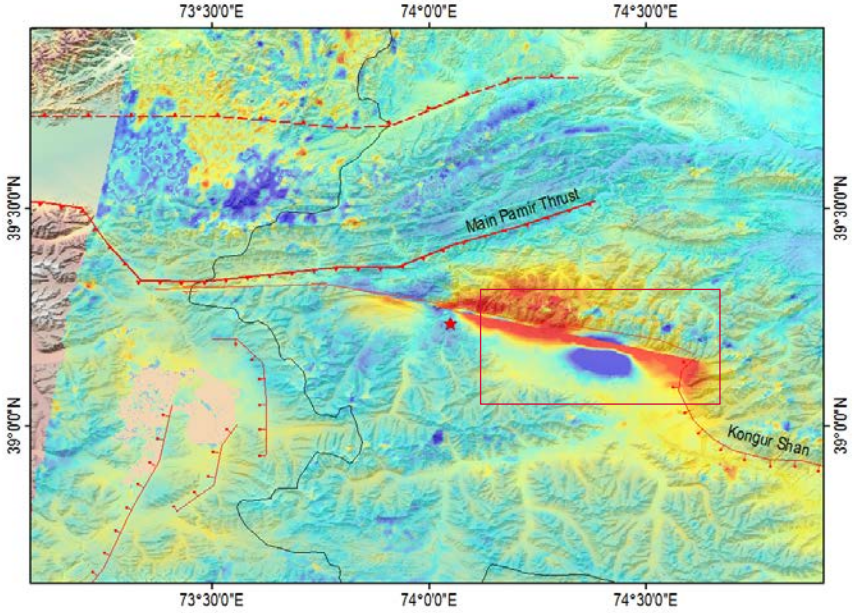
- Nov. 25, 2016, Aketao, Xinjiang Mw 6.6 Earthquake

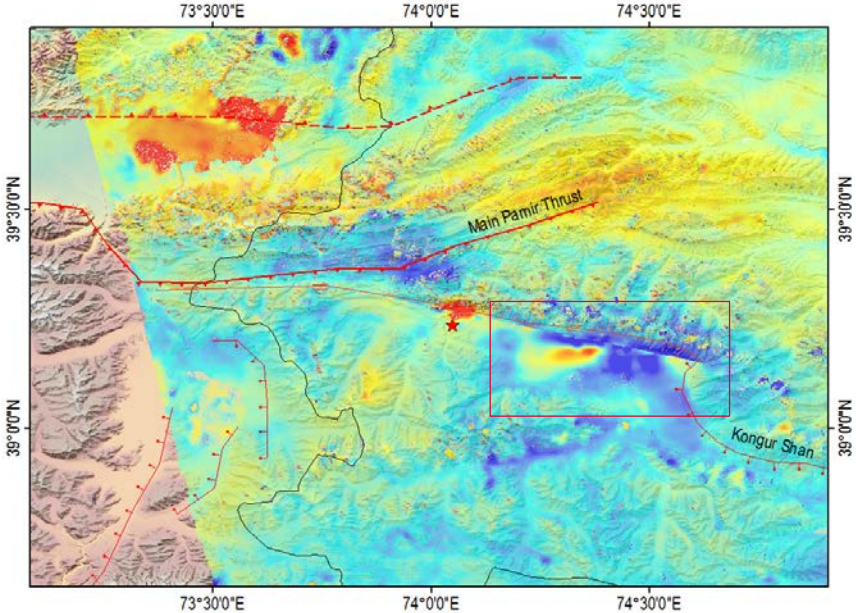


One fault segment model

Inversion method, Sun et al., 2013, JGR

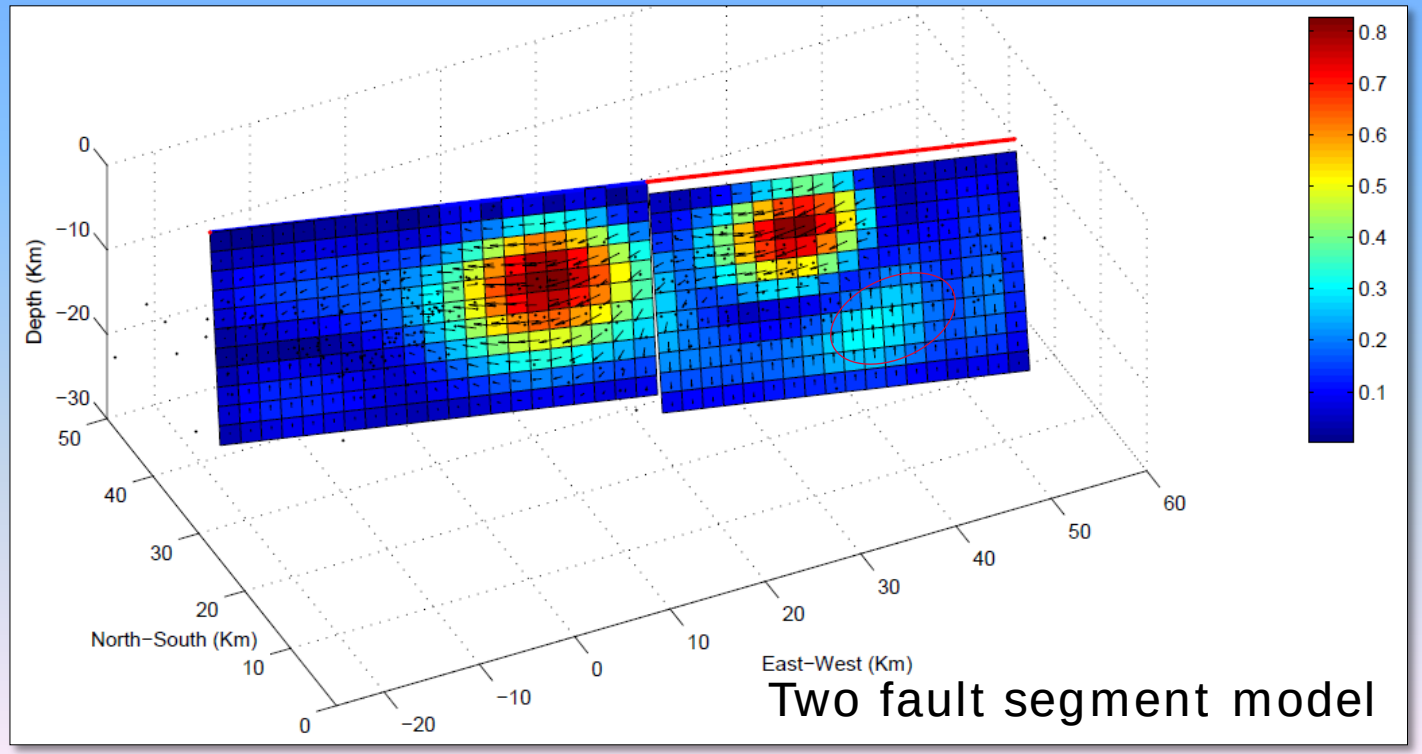
- Nov. 25, 2016, Aketao, Xinjiang Mw 6.6 Earthquake

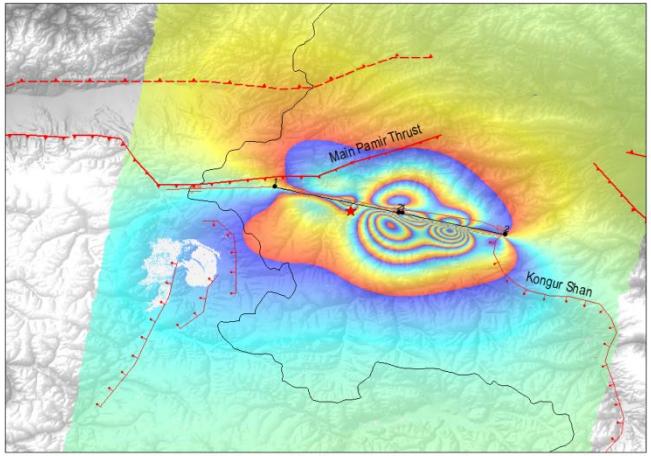


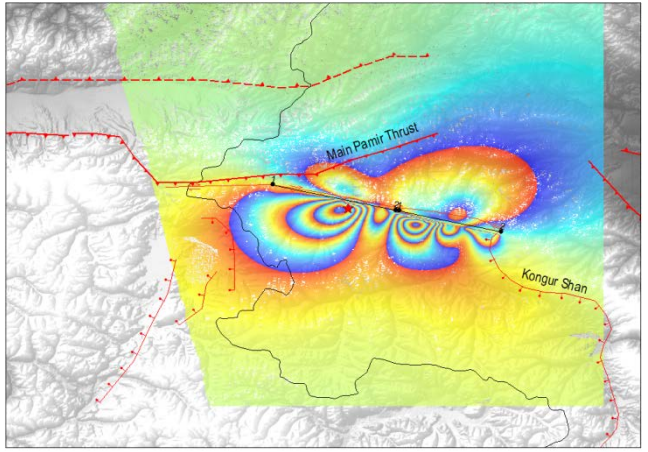


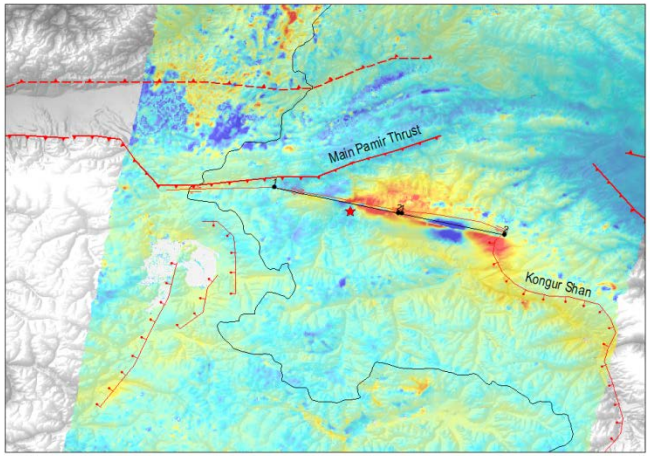
Residuals from one fault segment model

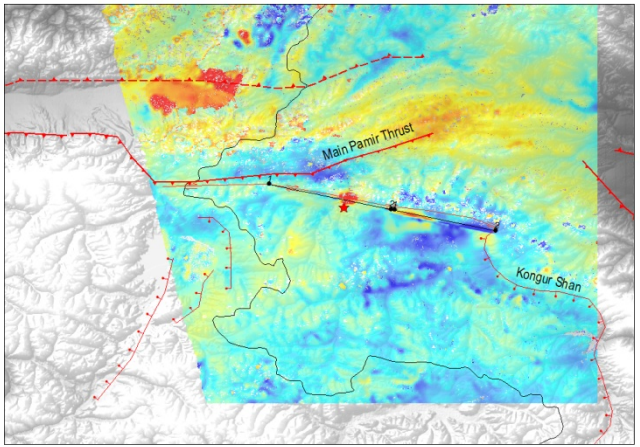
- Nov. 25, 2016, Aketao, Xinjiang Mw 6.6 Earthquake



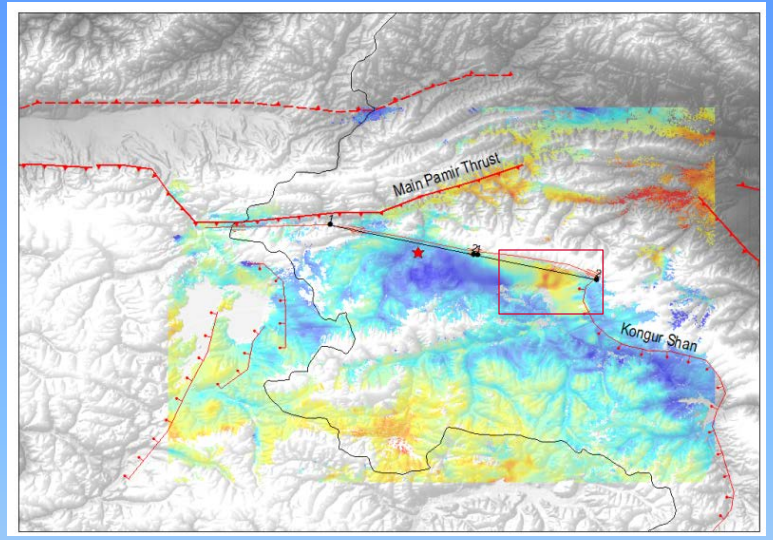


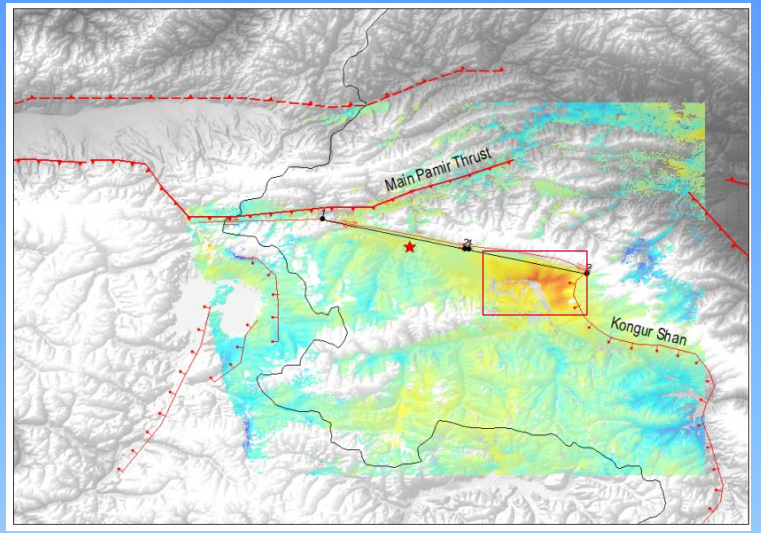


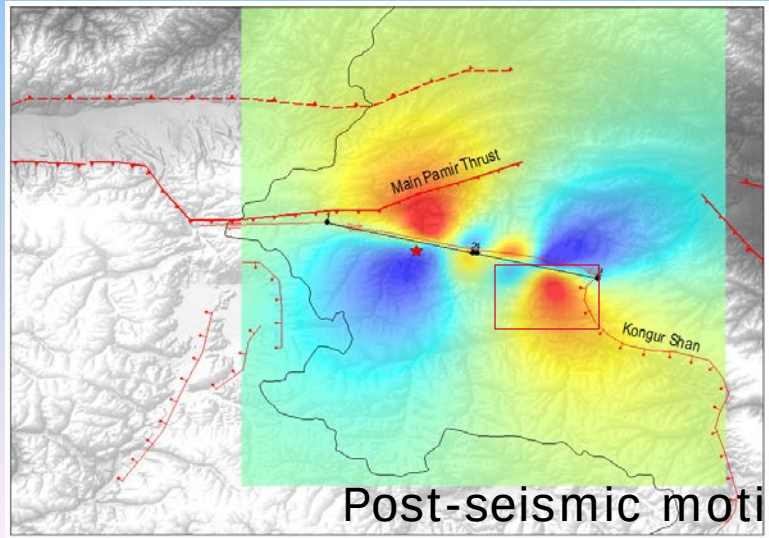


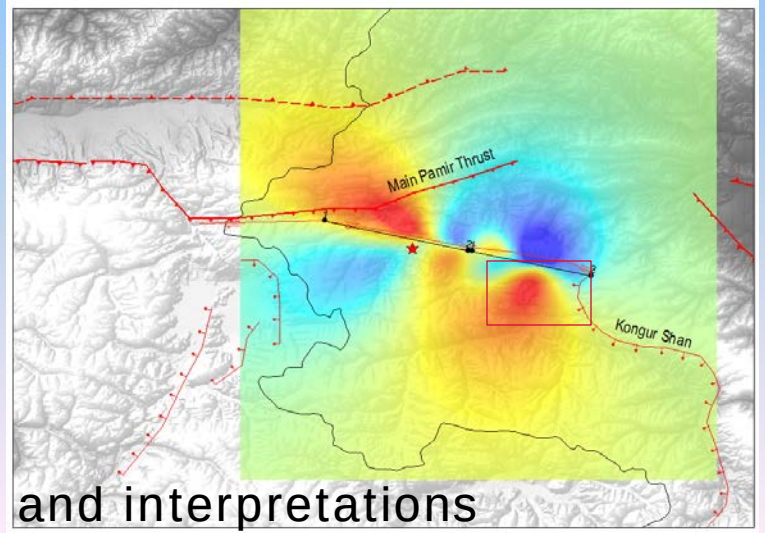


Model predictions and residuals



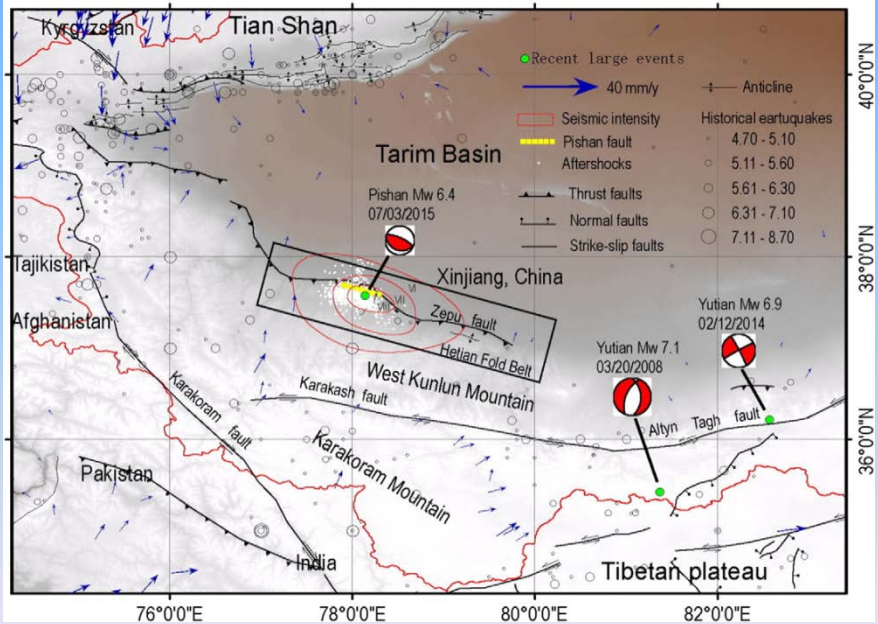


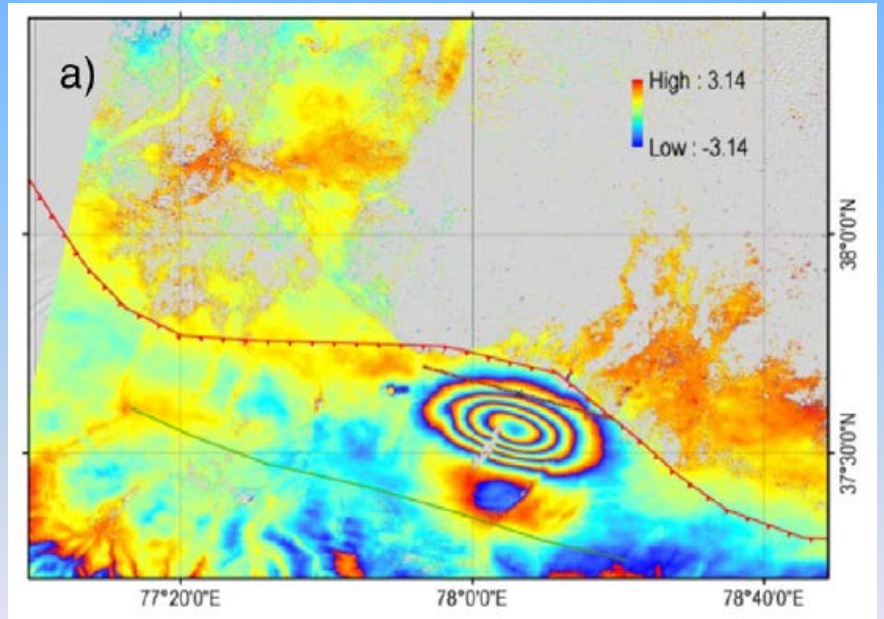




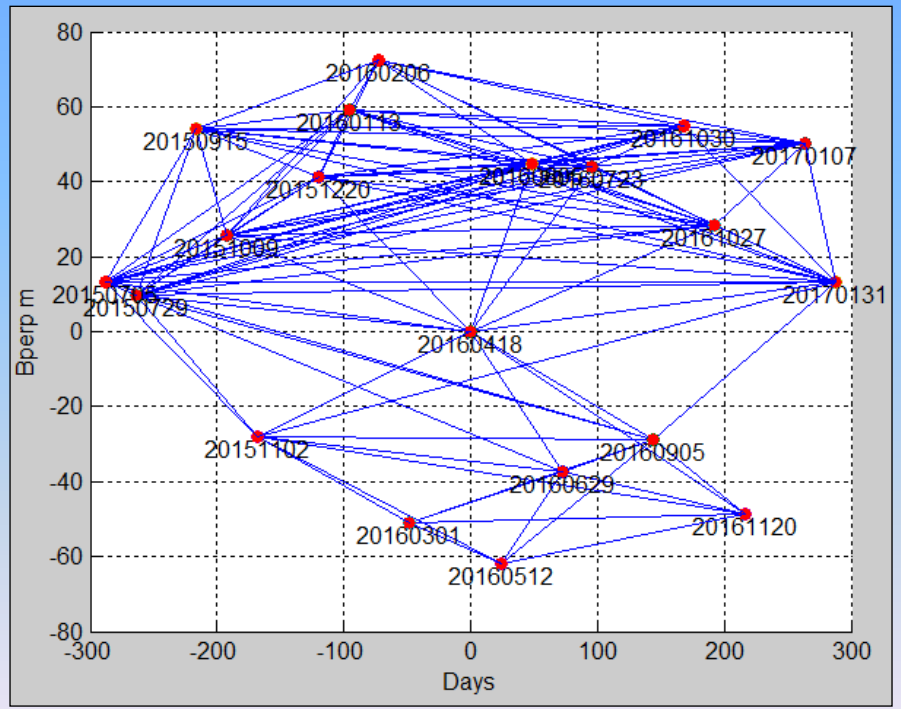
Post-seismic motion and interpretations

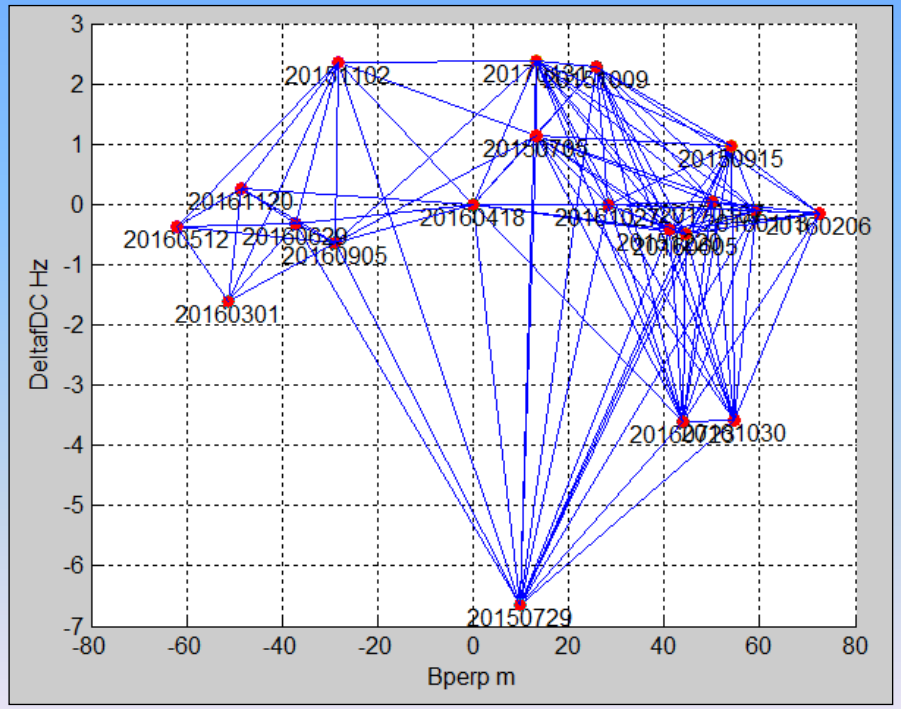
- Jul. 3, 2015 Mw 6.4 Pishan Earthquake postseismic time series





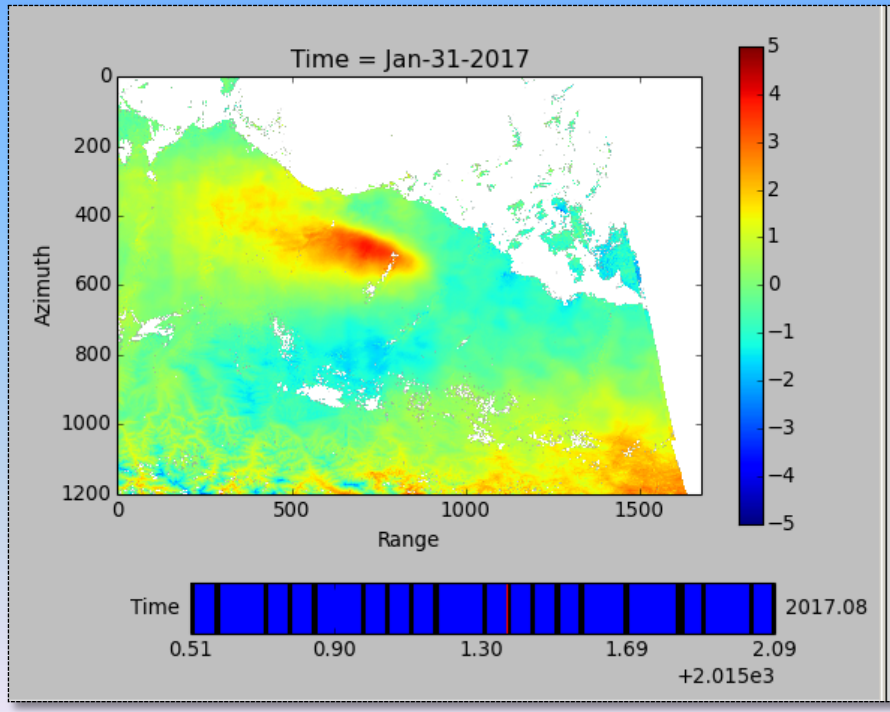
- Jul. 3, 2015 Mw 6.4 Pishan Earthquake postseismic time series

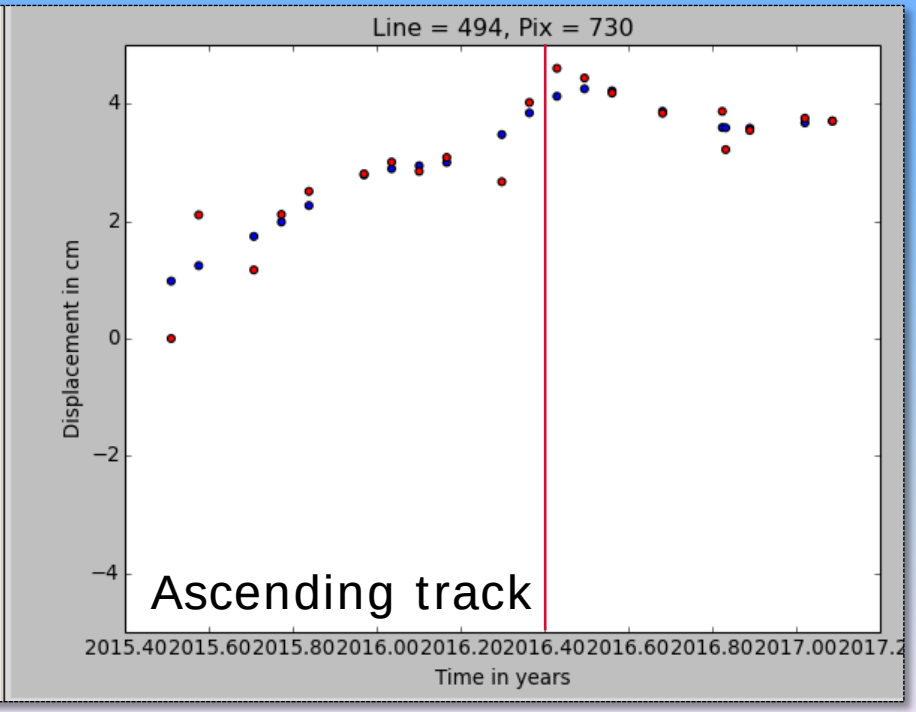




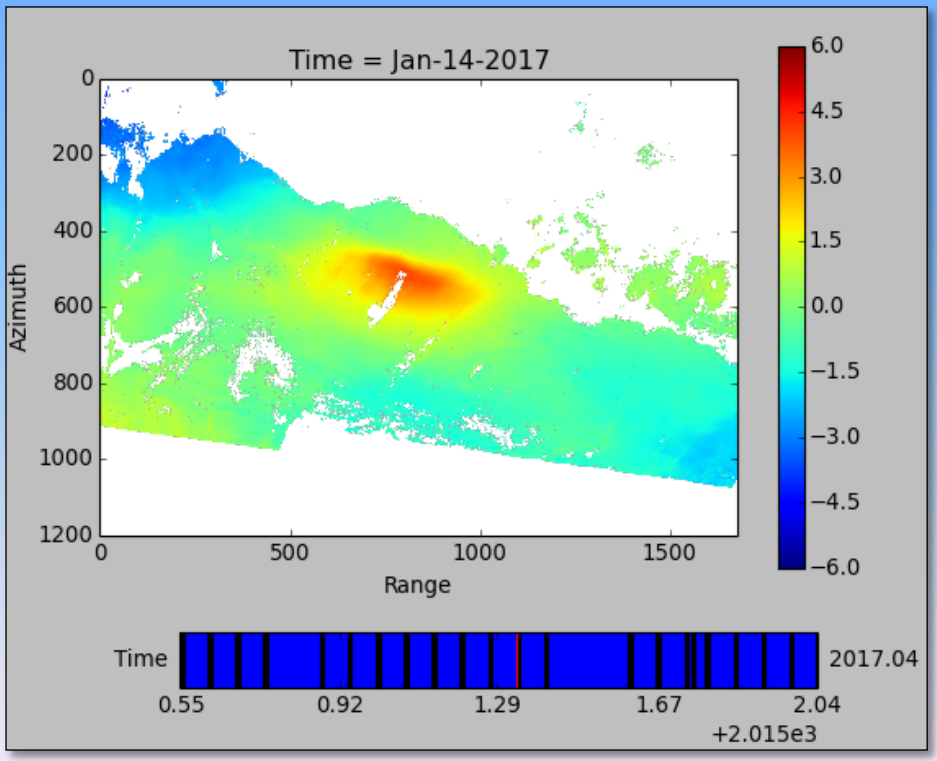
Applications

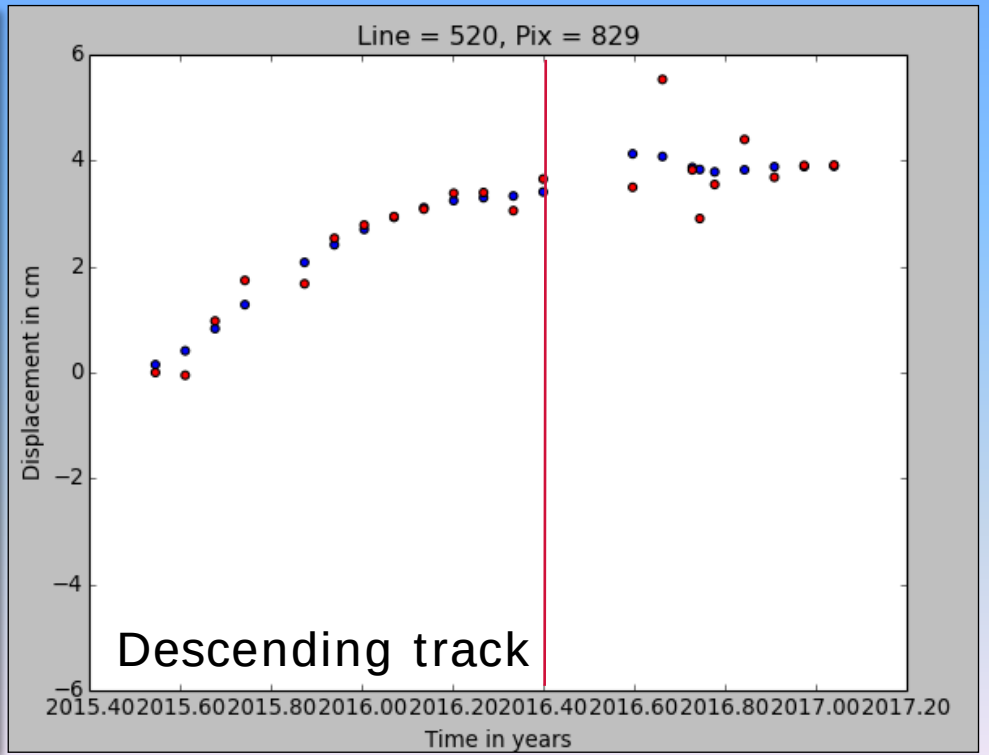
- Jul. 3, 2015 Mw 6.4 Pishan Earthquake postseismic time series





- Jul. 3, 2015 Mw 6.4 Pishan Earthquake postseismic time series





Conclusions

1. We use a simple strategy to separate high- and low-frequency component of the wrapped phase, and remove the high-frequency noise from the wrapped phase, then we do conventional phase unwrapping of large earthquakes. This is possible for retrieval of some near-field information, which is important to earthquake physics and seismic hazard evaluations.

2. In contrast to direct phase unwrapping with the localized optimization or global optimization algorithms, this method may be applicable to Sentinel-1A/1B missions, which is designed with optimal temporal/spatial baselines for InSAR community. But it is not limited to Sentinels, as it is not sensor specific workflow.

3. With fast increasing SAR catalogue, it would be possible to automatic generate wrapped interferograms, but basically not possible for unwrapped interferograms, as the latter is a nonlinear operation for InSAR processing. With this new method, we expect it would be possible for automatic earthquake cycle deformation extraction.

Thanks for your attention!