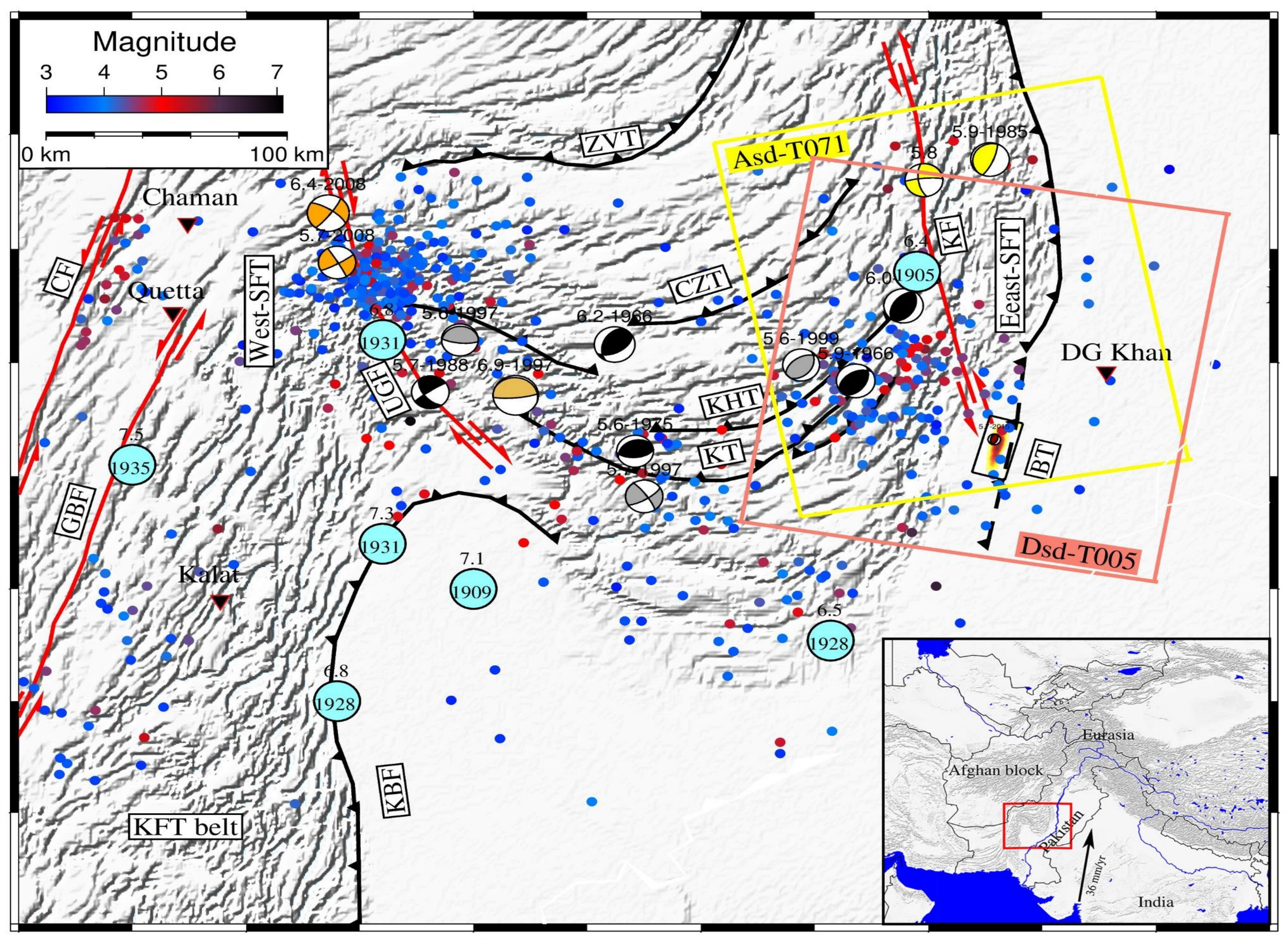
Coseismic fault-propagation folding during the 2015 Mw 5.7 Dajal earthquake on the Sulaiman Fold and Thrust belt from Sentinel-1A

M. Tahir Javed [1], Farhan Javed [3], Sylvain Barbot [2], Carla Braitenberg [1], Aamir Ali [4]

[1] Department of Mathematics and Geosciences, University of Trieste, Italy, [2] Department of Earth Sciences, University of Southern California, USA
[3]Centre for Earthquake Studies, National Centre for Physics,, Pakistan,,[4] Department of Earth Sciences, Quaid-i-Azam University, Islamabad, Pakistan

Introduction

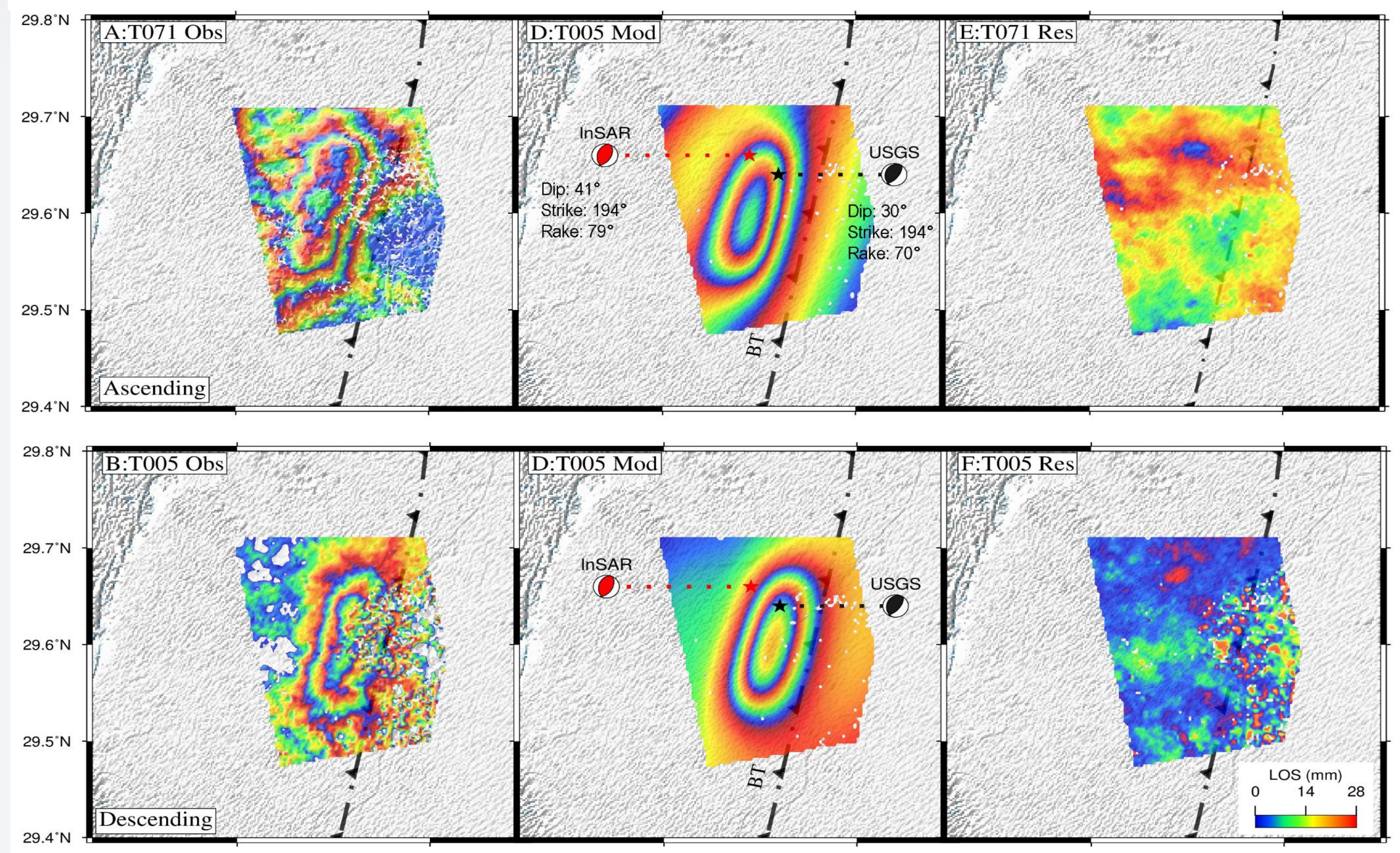
The continental collision at the western boundary of the Indian continent formed the tectonically complex transpressional zones of the Sulaiman Fold Thrust (SFT) and Kirthar Fold Thrust (KFT) belts. Seismic hazard around the SFT is considered elevated, but shortening across its eastern boundary is poorly understood because of the scarcity of moderate-sized earthquakes in the last decades. Here, we use Sentinel-1A interferometry to analyze the coseismic crustal deformation and source fault geometry associated with the 2015 moment magnitude 5.7 Dajal earthquake that occurred on the boundary thrust in the SFT belt. The line-of-sight displacements amount to ~45 and ~50 mm for the ascending and descending interferograms, respectively, due to thrust-dominated slip over a blind fault. Finite fault modeling indicates the presence of a shallow décollement branching into a shallow ramp at approximately 7 km depth. The Dajal earthquake seems to have propagated along the base of the ramp, presumably representing coseismic fault-propagation folding. A few aftershocks occurred in the surrounding anticline. We suggest that folding of the shallow sediments by flexural slip at the eastern boundary of the SFT belt may have restricted the rupture propagation.



The earthquake with Mw 5.6 that was occurred on 23 October, 2015 at 00:27:39 (Coordinated Universal Time, UTC) 10 km of NNW of Dajal and 55 km of SSW of Dera Ghazi Khan. InSAR enables us to investigate sources of crustal deformation accurately in the complicated regions of the SFT belts caused by northward movement of Indian with Eurasian plate. Southward movement is accommodated with the right-lateral Urghargai fault and left-lateral Kingri fault in the western and eastern zone of the SFT belt, respectively

Results and Discussion

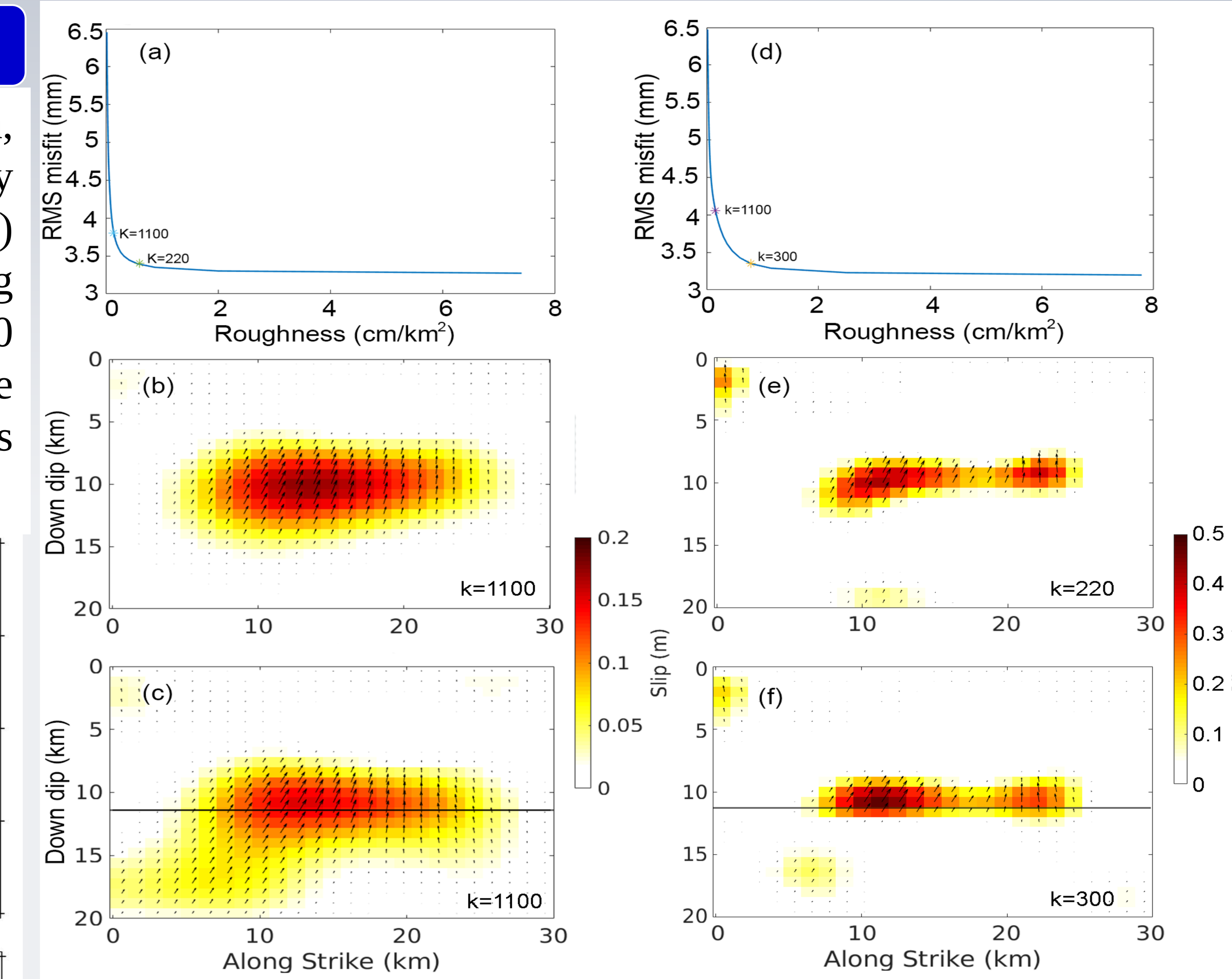
We estimate the ruptured fault geometry such as fault dip, strike, length, width, rake, slip, epicentre and depth of 2015 Dajal earthquake by inverting the LOS displacement through the Bayesian inversion (GBIS) approach (Bagnardi & Hooper, 2018). The ascending and descending interferograms show the surface deformation of approximately 45 and 50 mm along their respective LOS direction. Synthetic models with a single fault patch agree well with InSAR observed data, with average residuals of the order of 2.0 mm for both interferograms.

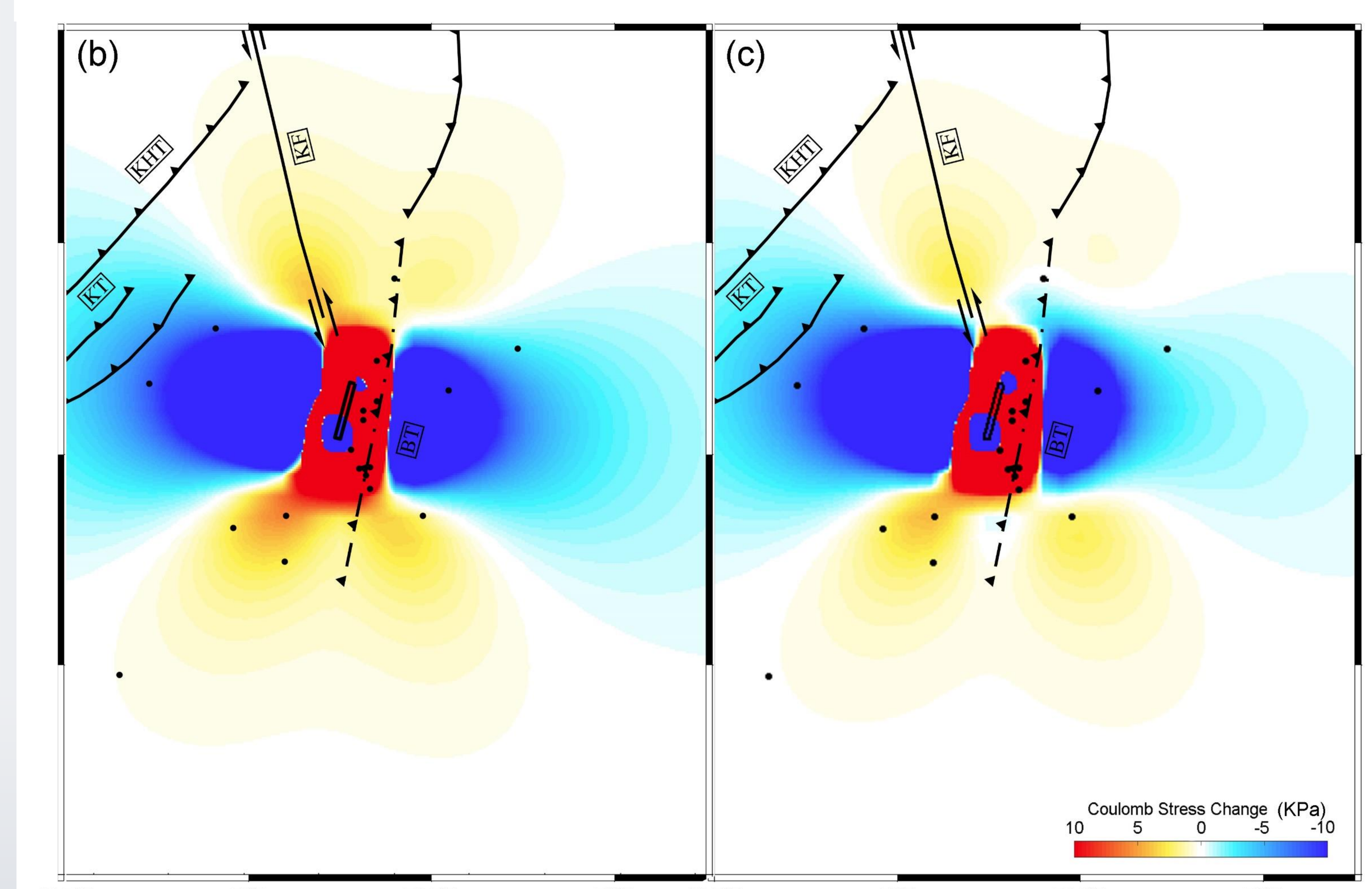


Model	Latitude (°)	Longitude (°)	Dip (°)	Strike (°)	Rake (°)	Depth (km)	Length (km)	Width (km)	Slip (m)	M_0 10^{17}Nm	Mw
USGS GCMT	29.638	70.326	30	194	70	15.5	-	-	-	3.096	5.59
			47	182	68	11.0	-	-	-	1.792	5.44
			41	186	56	12.0	-	-	-	3.471	5.63
ISC	29.618	70.353	46	192	45	19.8	-	-	-	-	5.5
InSAR	29.662 ±0.004	70.289 ±0.003	41 ±3	194 ±2	79 ±8	6.9 ±0.3	15.7 ±0.6	2.8 ±0.3	0.28 ±0.04	3.94 ±1.0	5.66 ±0.08

We also investigate the slip distribution on the extended fault plane considering a single fault and a ramp-décollement fault system of fault propagation fold structures. We perform a finite fault inversion through the least squares method (Jónsson et al. 2002) and it indicates the maximum slip is concentrated around the hypocenter of the earthquake, with around 90% of slip occurred within an area of about 16 × 4.0 km² from base to top of ramp of fault propagation fold.

In addition, We calculate the Coulomb failure stress changes (ΔCFS) for 2015 Mw 5.7 Dajal earthquake on optimally inverted fault geometry to investigate the stress changes and correlation with spatial distribution of aftershocks.





Conclusions

- InSAR analysis and modelling reveals thrust dominated (85%) slip in up dip direction with a small strike-slip component (15%) that is in good agreement with the tectonic context of the transpressional zone of the SFT belt.
- Source fault geometry along with the corresponding uncertainties of the 2015 M 5.7 Dajal earthquake shows the existence of a ramp-décollement fault system along the boundary thrust (BT) that helps to understand the crustal deformation mechanism at the eastern part of the SFT belt. The ΔCFS is found consistent and fitted well with the distribution of aftershocks

References

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- Jonsson, P., & Eklundh, L. (2002). Seasonality extraction by function fitting to time-series of satellite sensor data. *IEEE Transactions on Geoscience and Remote Sensing*, *40*(8), 1824–1832. https://doi.org/10.1109/TGRS.2002.802519