Coseismic Slip Model of the 2008 Wenchuan Earthquake Derived From Joint Inversion of InSAR, GPS and Field Data

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Outline

- Background
- ALOS PALSAR data
  - Ascending normal mode interferograms.
  - New descending ScanSAR interferograms.
- Modeling
  - Comparison with scarp height
  - Determine fault dip
  - Joint inversion with InSAR, GPS, and scarp height.
- Results and Conclusions
  - InSAR constrain shallow slip.
  - GPS constrain deep slip.
  - Shallow slip is dominant.

Background

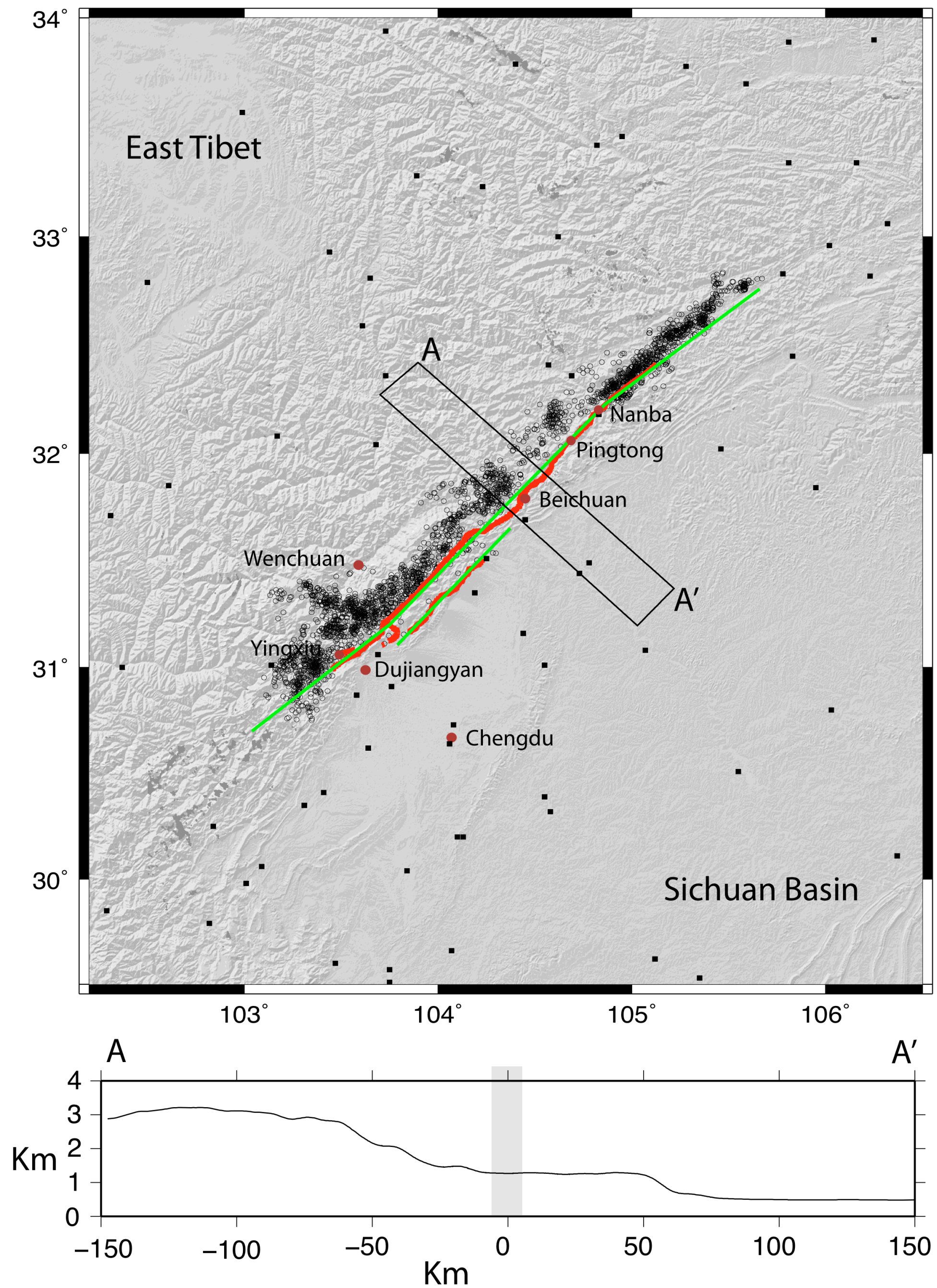
- Geodetic and Geologic measurement indicate long (> 2000 year) recurrence interval on these faults [Burchfiel et al., 2008].

- Magnitude 7.9 earthquake (May 12th, 2008) occurred along Longmen Shan thrust fault zone.

- Vector GPS data at 109 sites [WGCMONC, 2009].

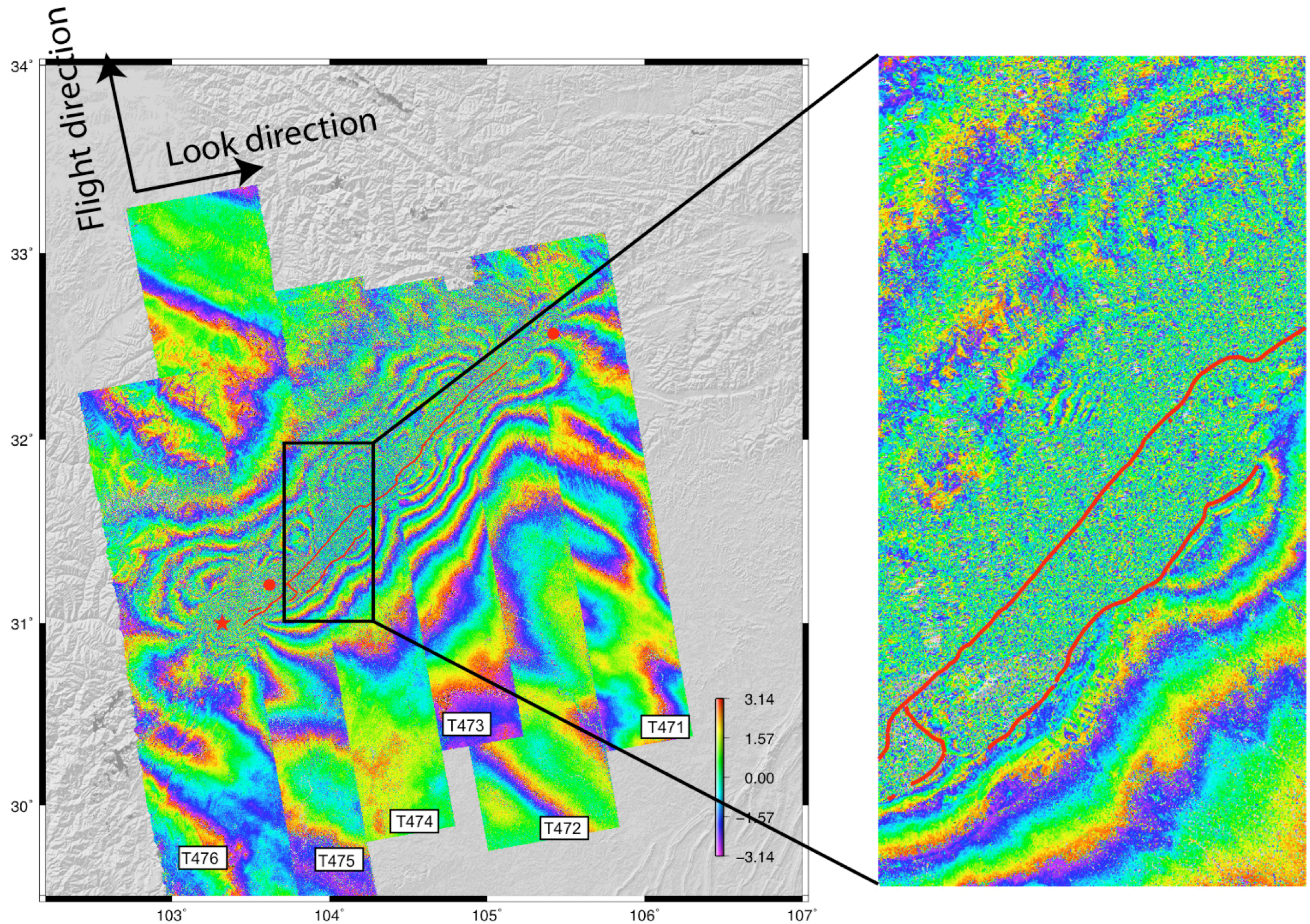
- A 290 km long coseismic surface rupture is well mapped [Liu et al., 2009]

Many coseismic slip models for this earthquake: [e.g., Ji & Hayes, 2008; Kobayashi et al., 2009; Hao et al., 2009; Shen et al., 2009; Tong et al., 2009]



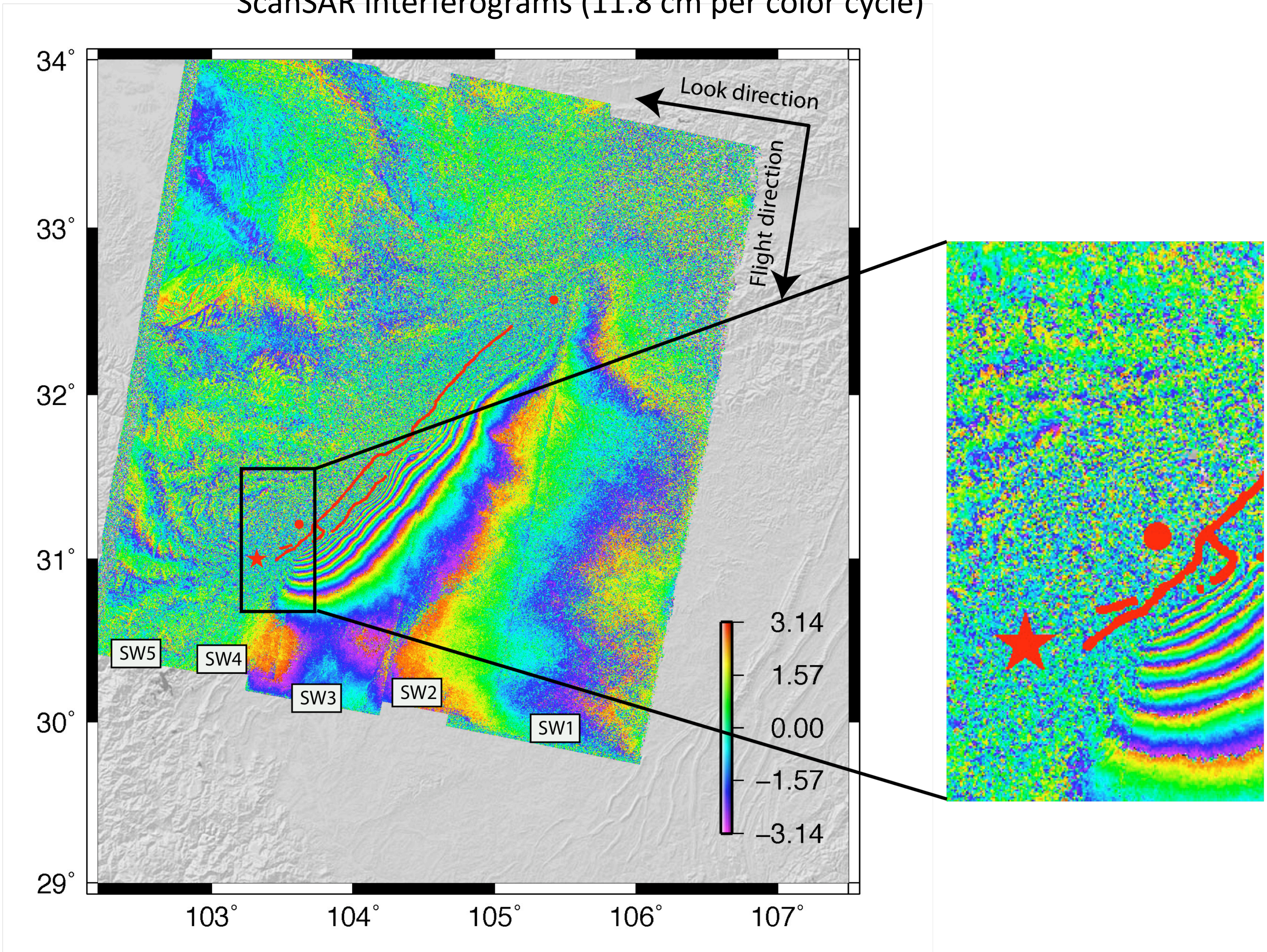
Ascending ALOS PALSAR

Swath mode interferograms (11.8 cm per color cycle)



Descending ALOS PALSAR

ScanSAR interferograms (11.8 cm per color cycle)



Elasic modeling and inversion scheme

Finite fault dislocation model in elastic half space. [Okada, 1985; Fialko, 2004]

$$\begin{bmatrix} G_{los} \\ G_{GPS} \\ \lambda S \end{bmatrix} \begin{bmatrix} m_{strike} \\ m_{dip} \end{bmatrix} = \begin{bmatrix} d_{los} \\ d_{GPS} \\ 0 \end{bmatrix}$$

$$A \cdot m = d$$

$\min \|Am - d\|$

s.t. $\quad m_{dip} > 0$

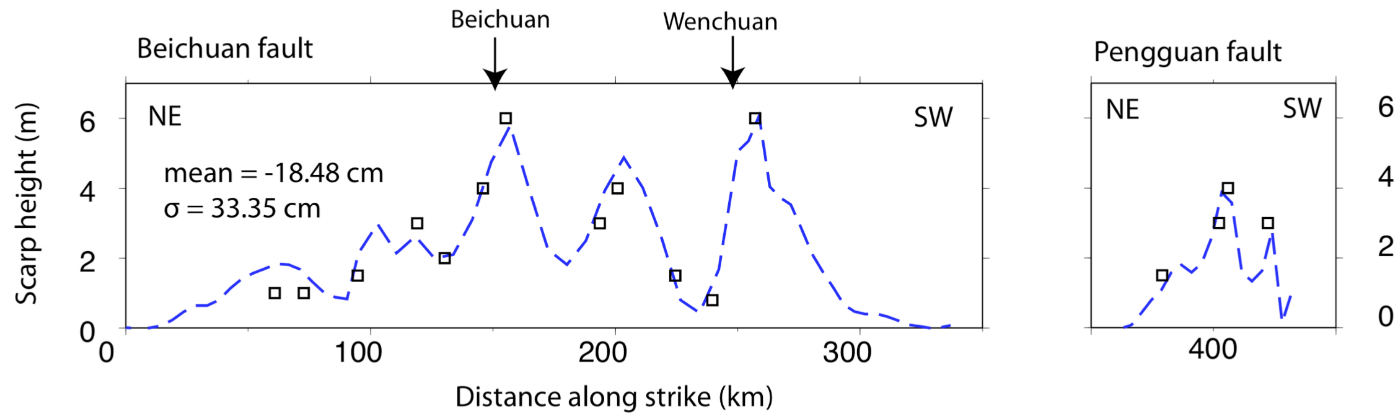
$\quad m_{strike} < 0$

$\quad D \cdot m > s$

where $D = G_{hanging} - G_{foot}$

s is scarp height measurements.

Constraints from scarp height measurement



- Scarp height measurements constrain the near field (shallow) deformation where interferograms are decorrelated.

- Vertical offset from model correlates well with the scarp height data.

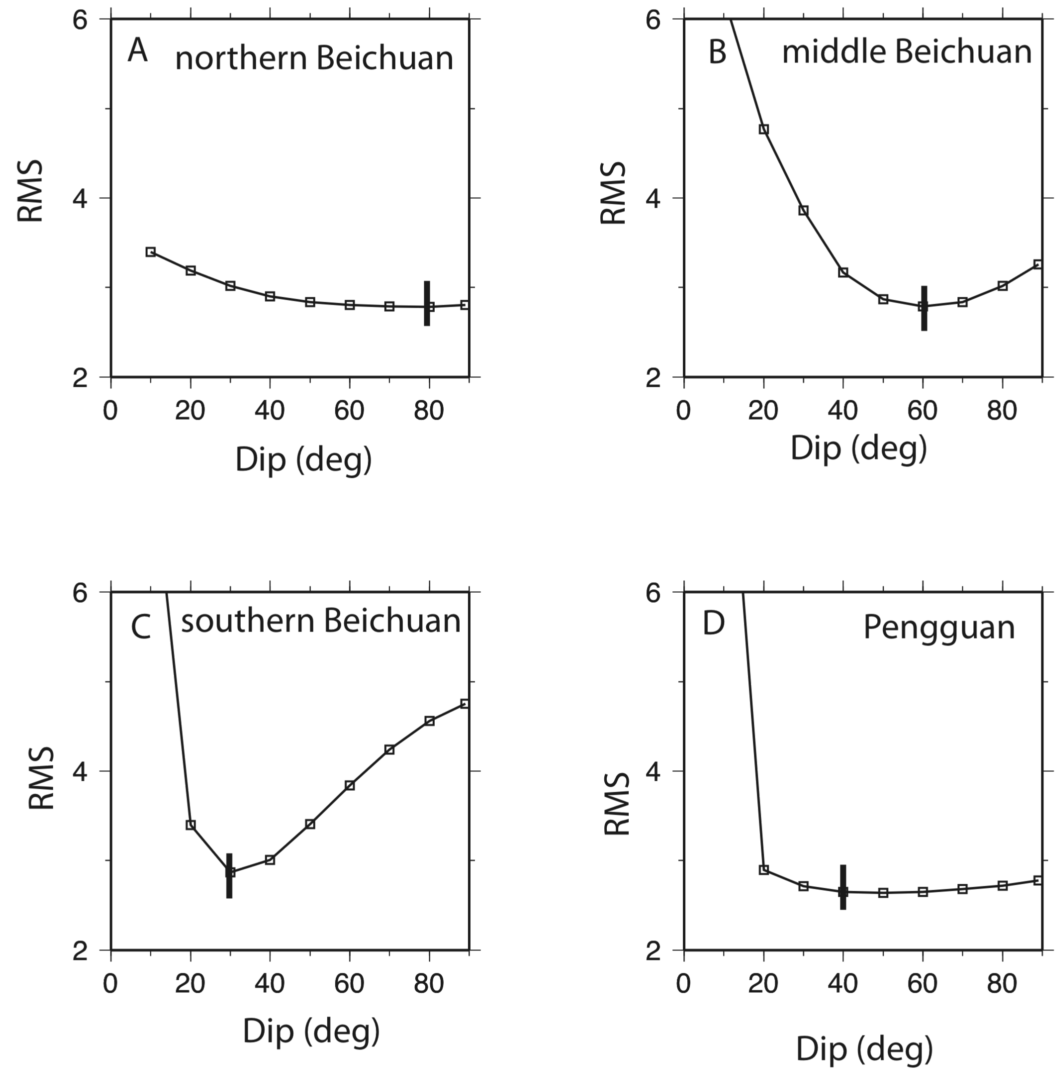
[Data from Liu et al., 2009]

Parameter Search to Determine the Fault dip

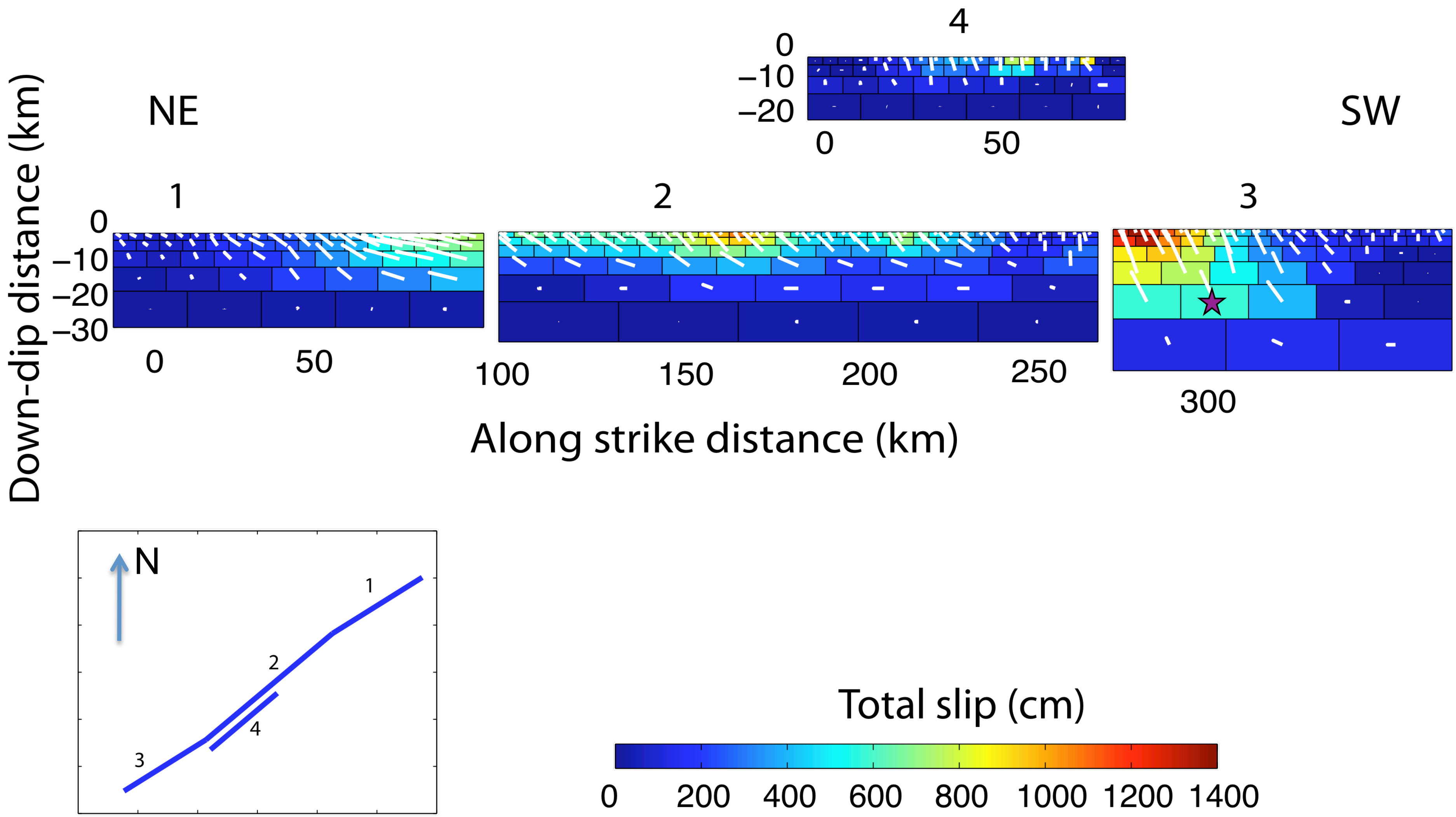
- Seismicity relocation is not confined within a plane.

- Series of inversions:
  -> Variation of fault dip angle along the strike.

- The fault motion is changing from ~30 deg thrust in the south to ~80 deg strike slip in the north.

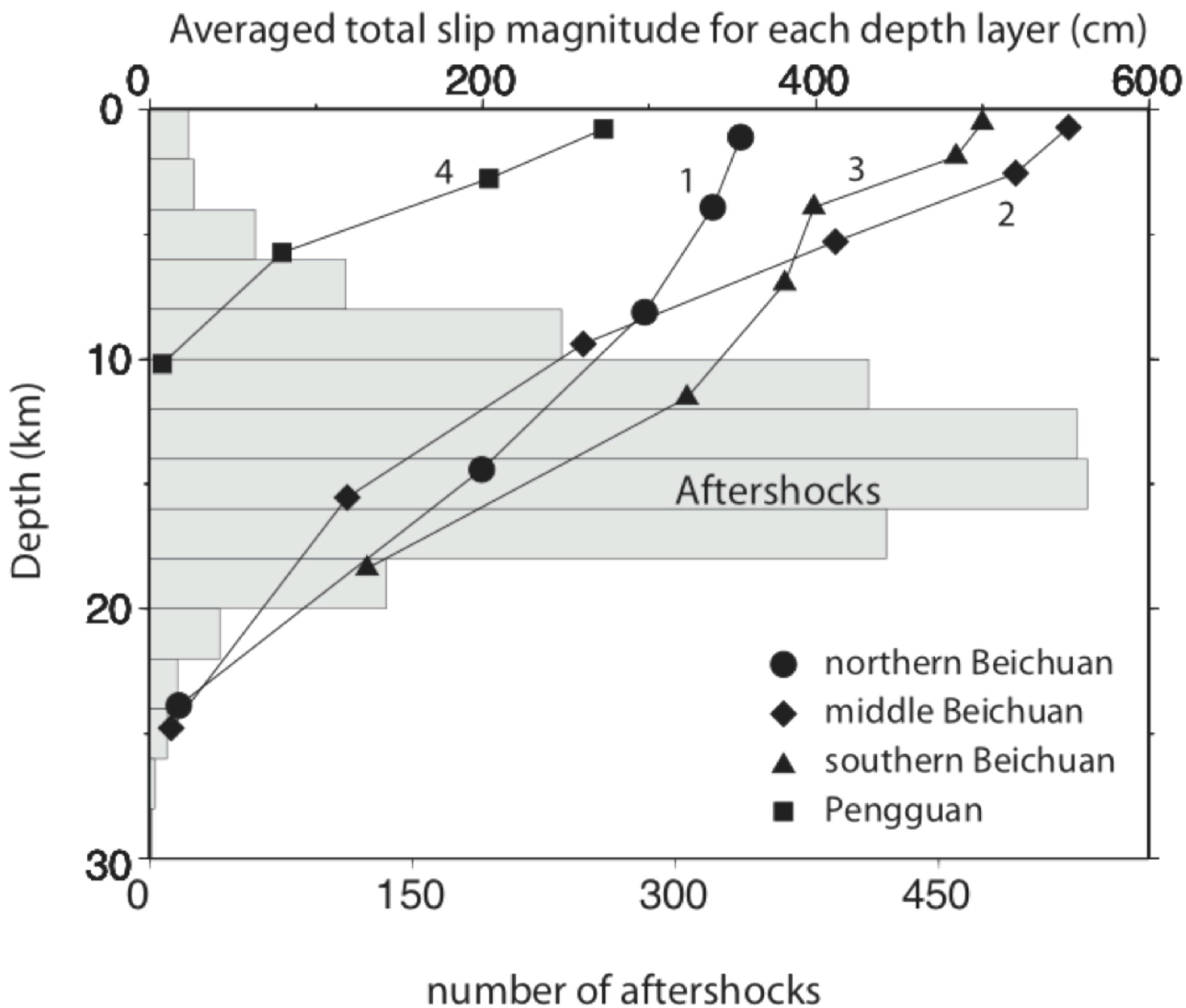


Coseismic slip model from joint inversion



Coseismic slip changing with depth

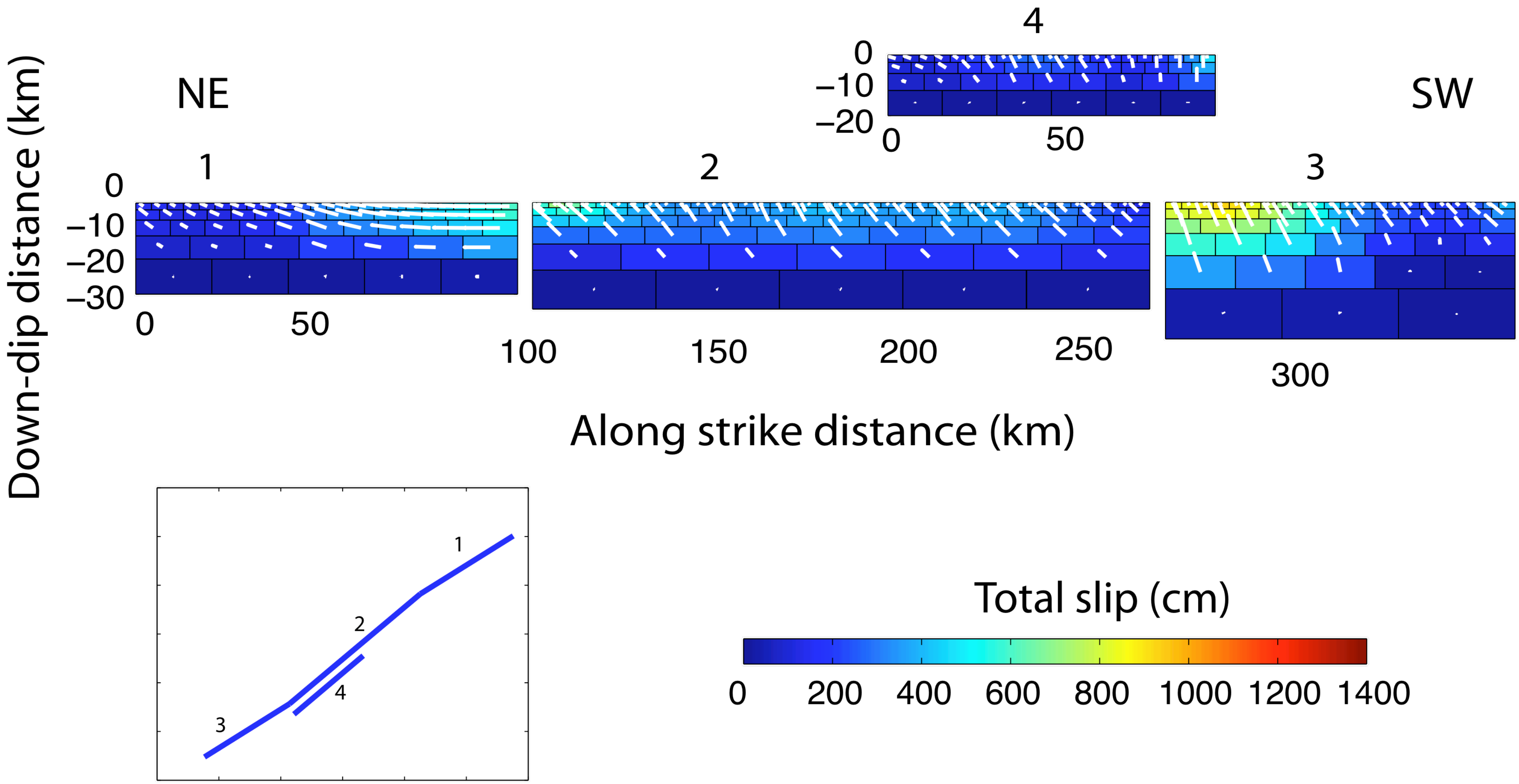
- Slip magnitude decreases with depth.
- Slip is shallower in the middle segment (8 km), but deeper in the north and south segment (12km).
- Aftershocks [Huang et al., 2008] are below the maximum slip area.



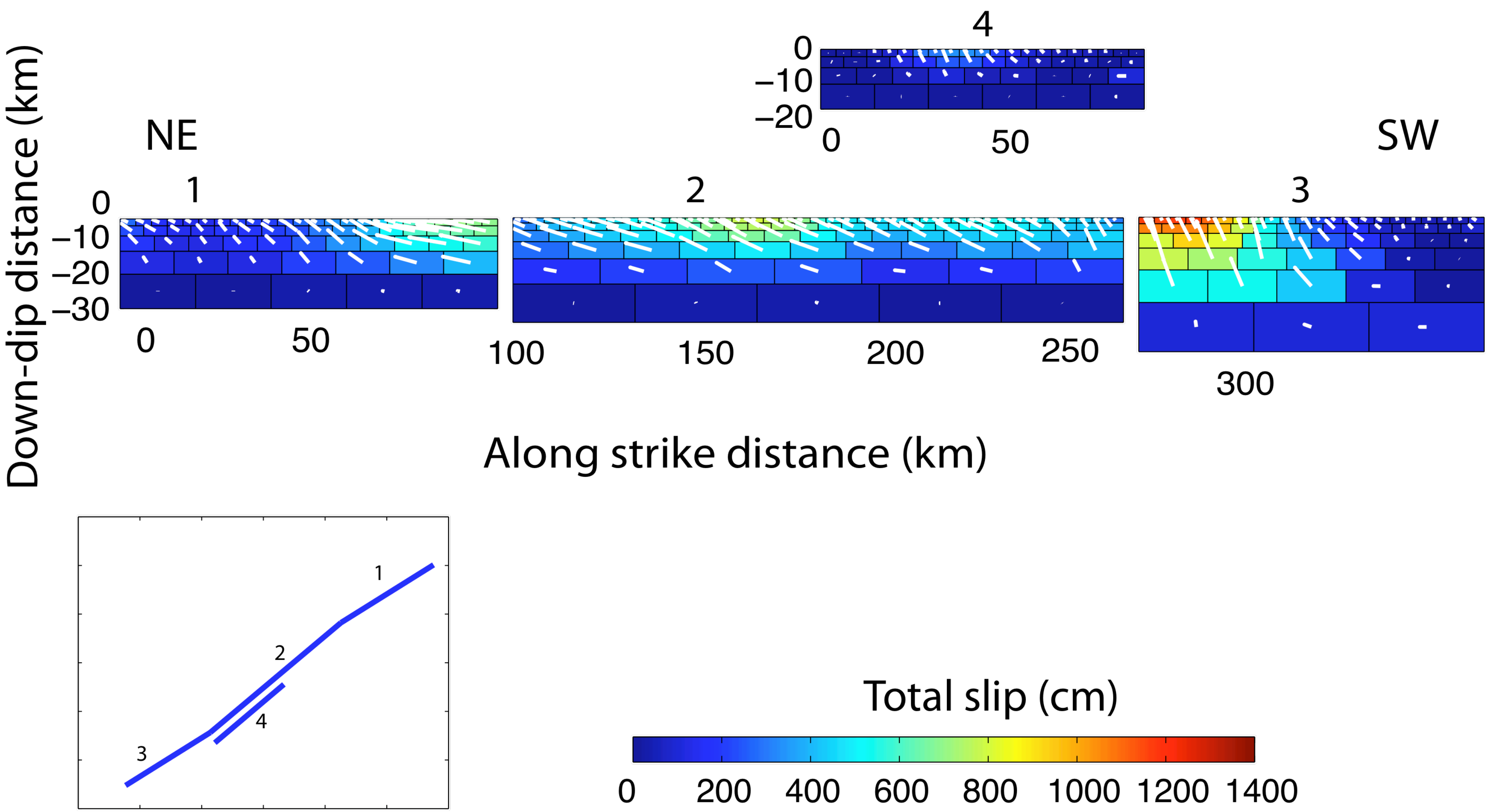
Results and Conclusions

- ALOS PALSAR interferograms provided nearly complete coverage from two look directions.
- Finite fault modeling in elastic half space:
  - InSAR -> spatial coverage and spatial resolution.
  - GPS -> absolute level of displacement.
  - scarp height -> offset on the fault.
- Geodetic moment is nearly equally partitioned into thrust (6.47x10^20 Nm) and strike-slip (5.42x10^20 Nm) and overall moment (9.25x10^20 Nm) agree with the teleseismic estimate.
- The modeling infers that shallow slip is dominant in this oblique thrust event.
- Aftershocks are mainly below the depth of major slip.
- Coseismic model will provide starting model for postseismic modeling.

Coseismic slip model from GPS only

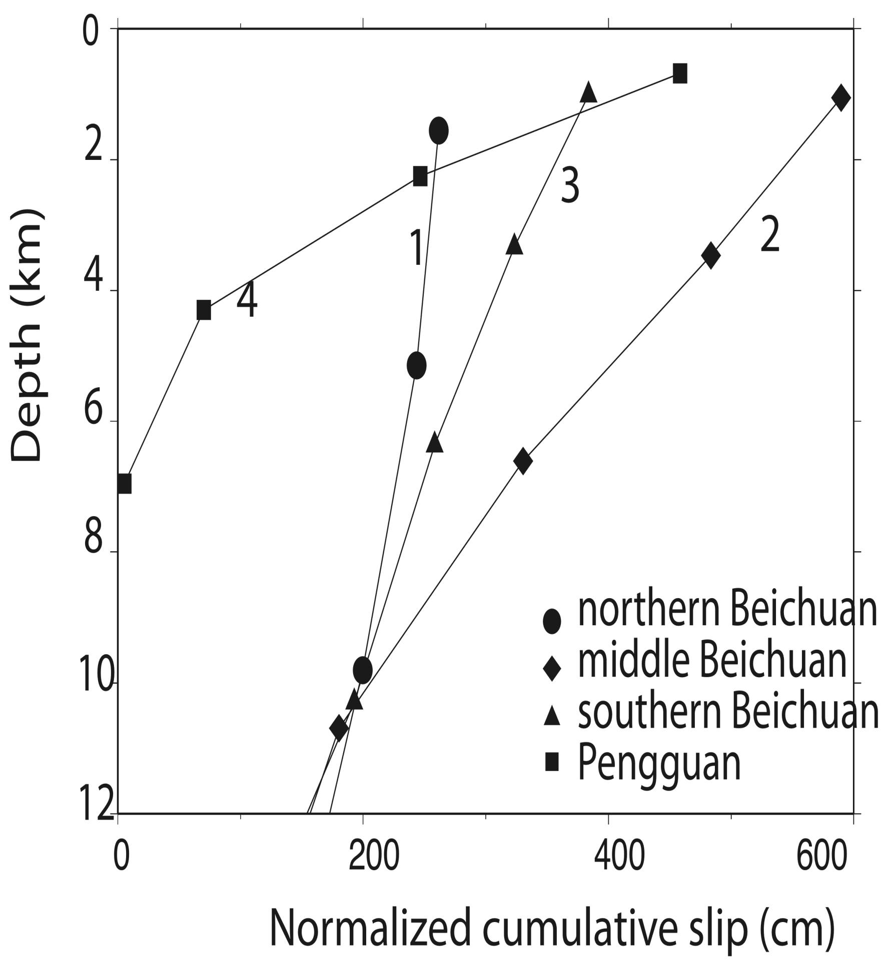


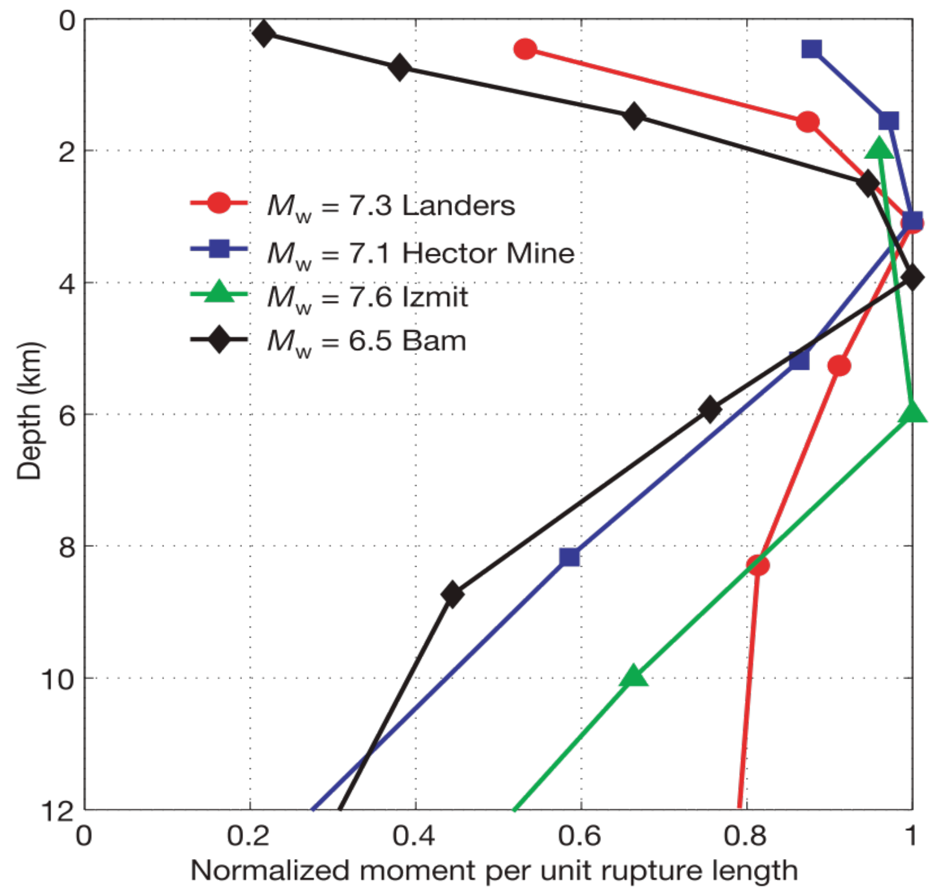
Coseismic slip model from InSAR only



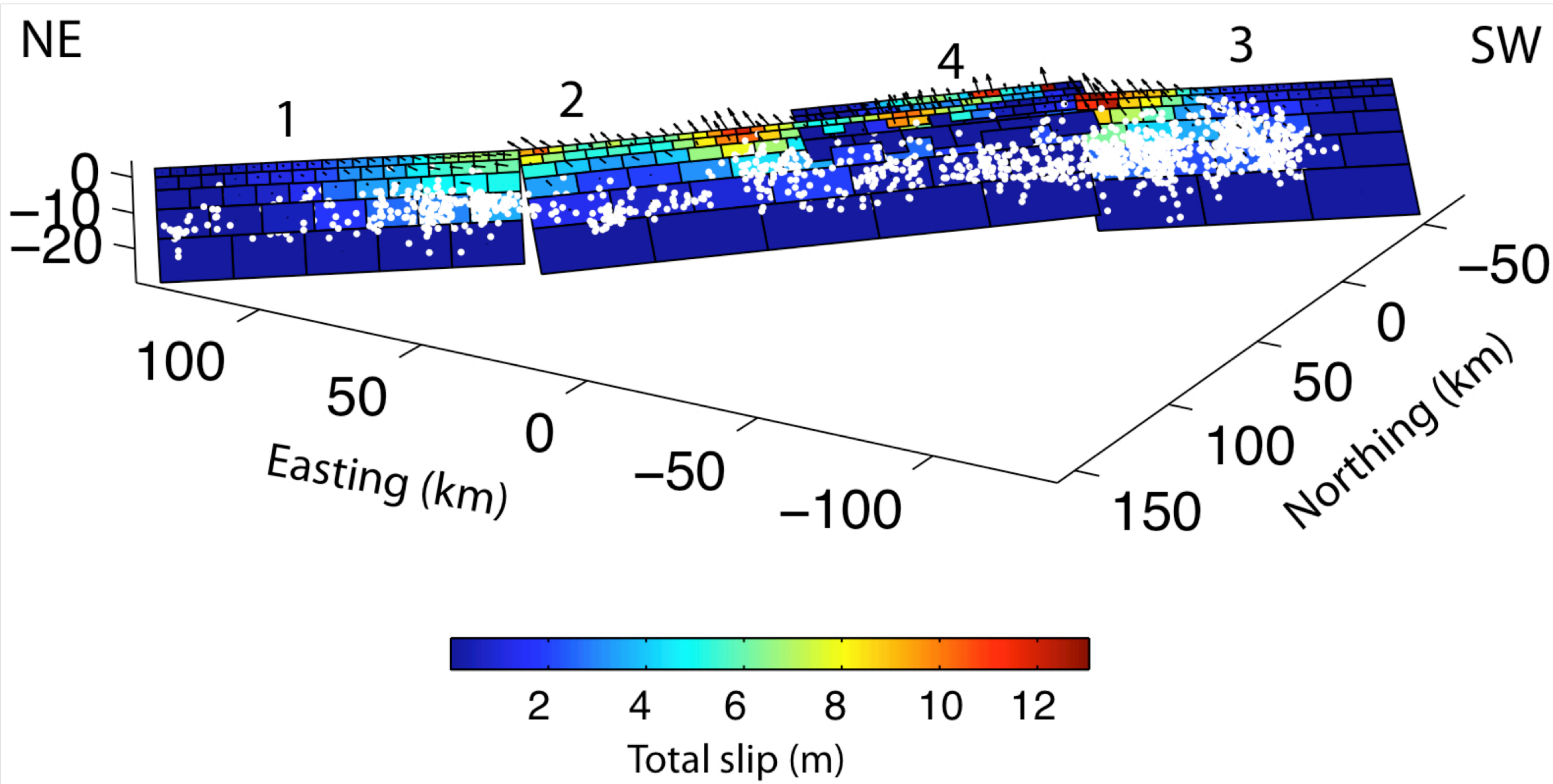
For Discussion

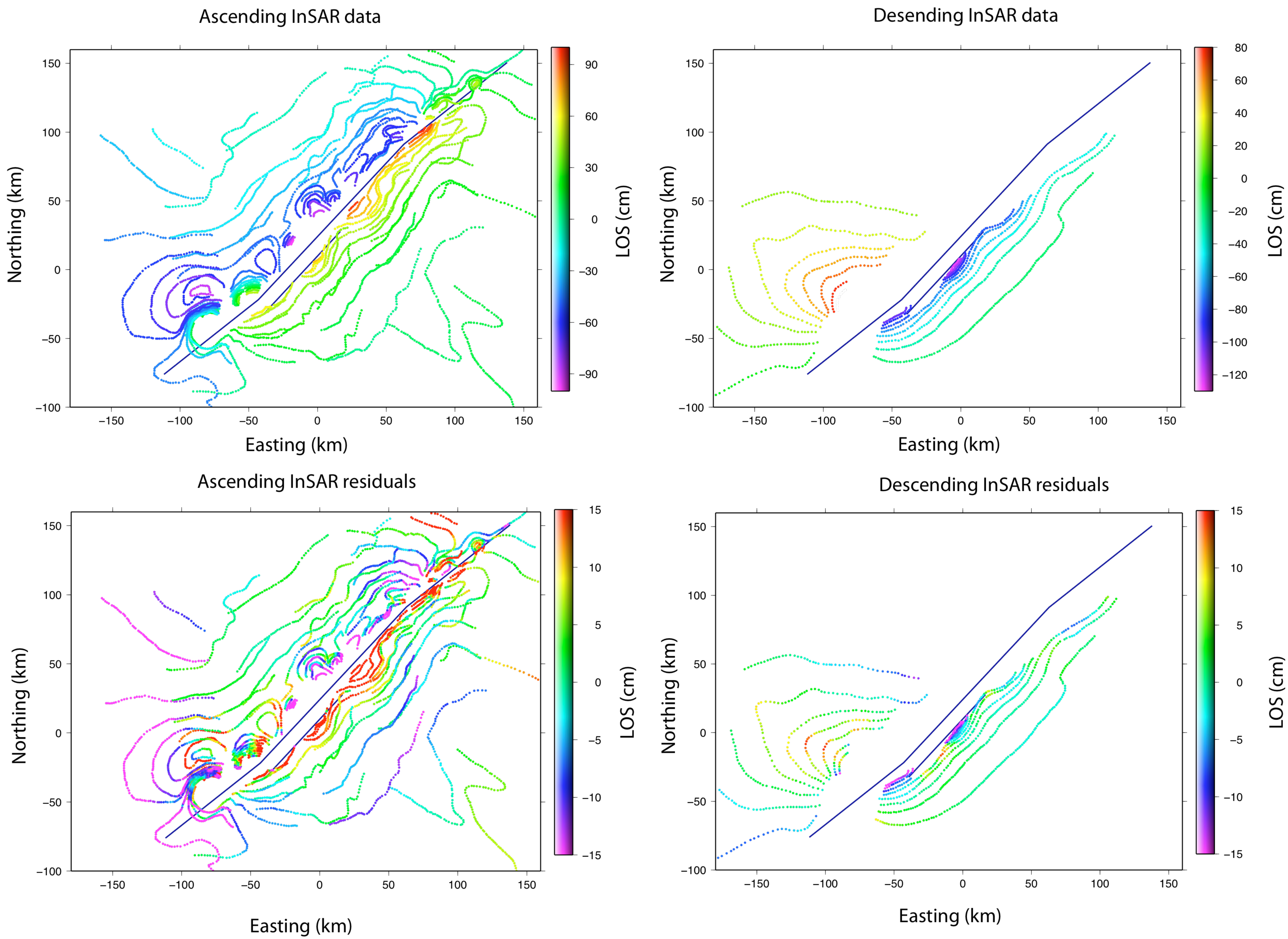
Why the coseismic slip has a deficit at shallow depth for the strike slip event, but not for thrust event ?



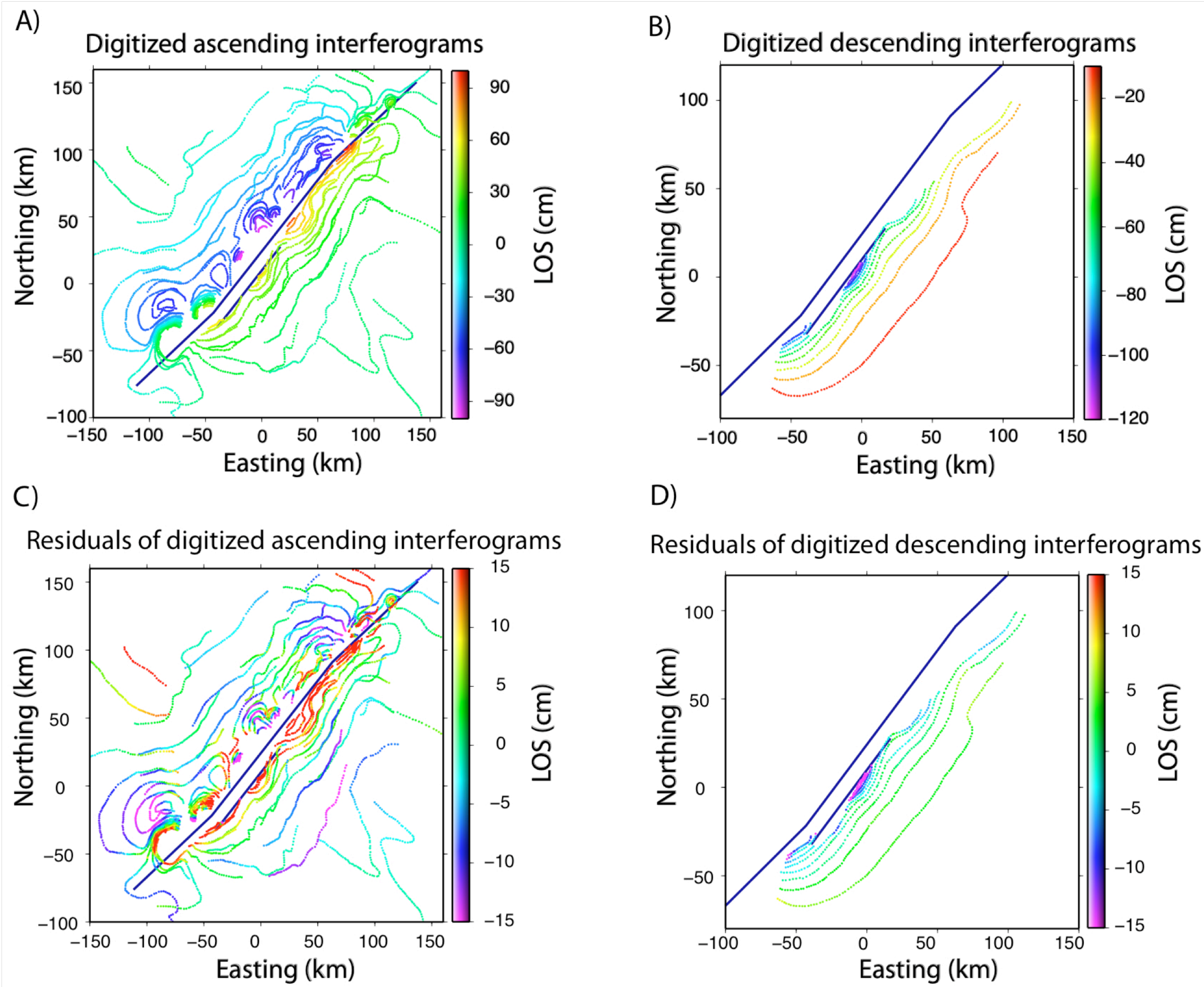


Coseismic slip model in 3D view

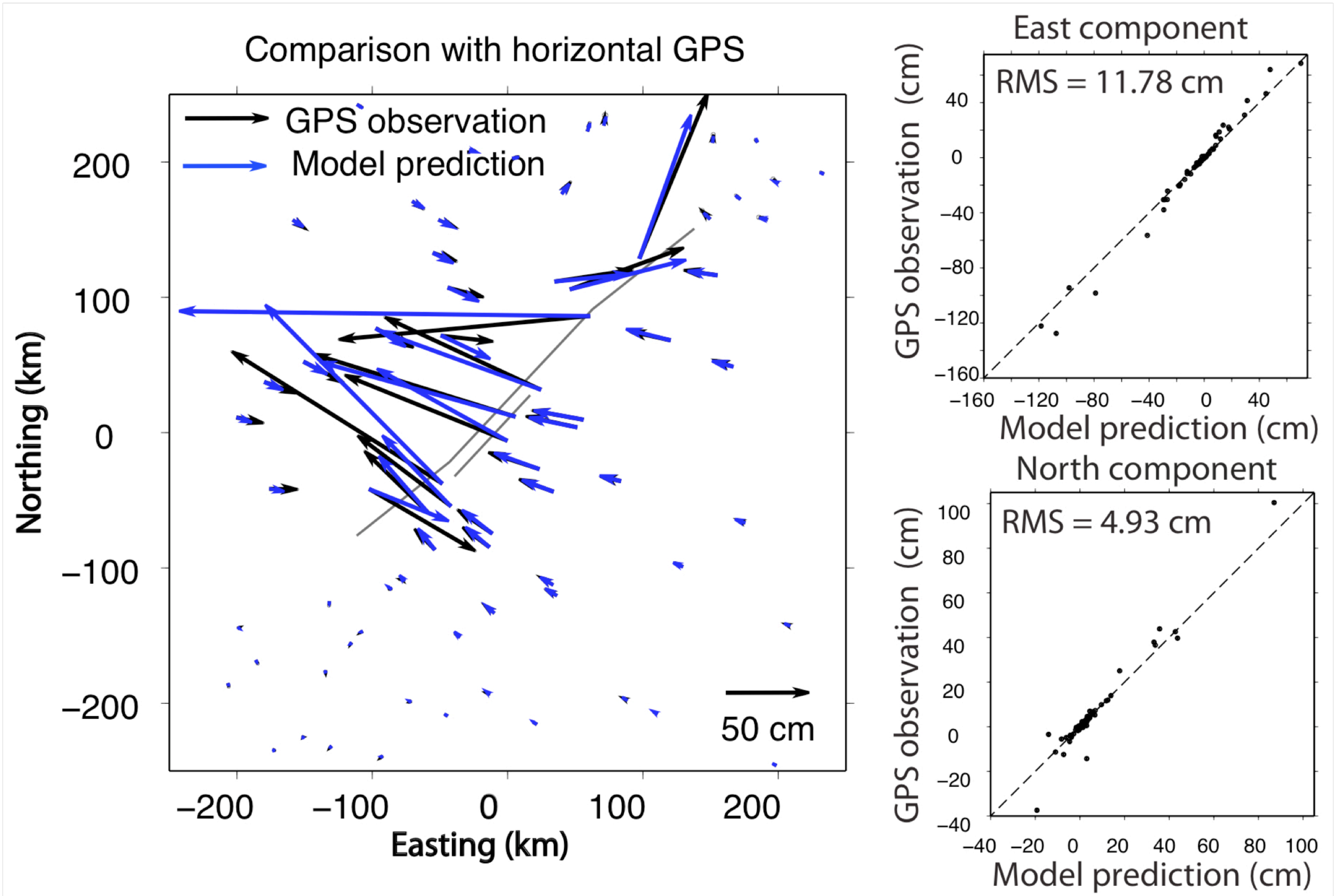




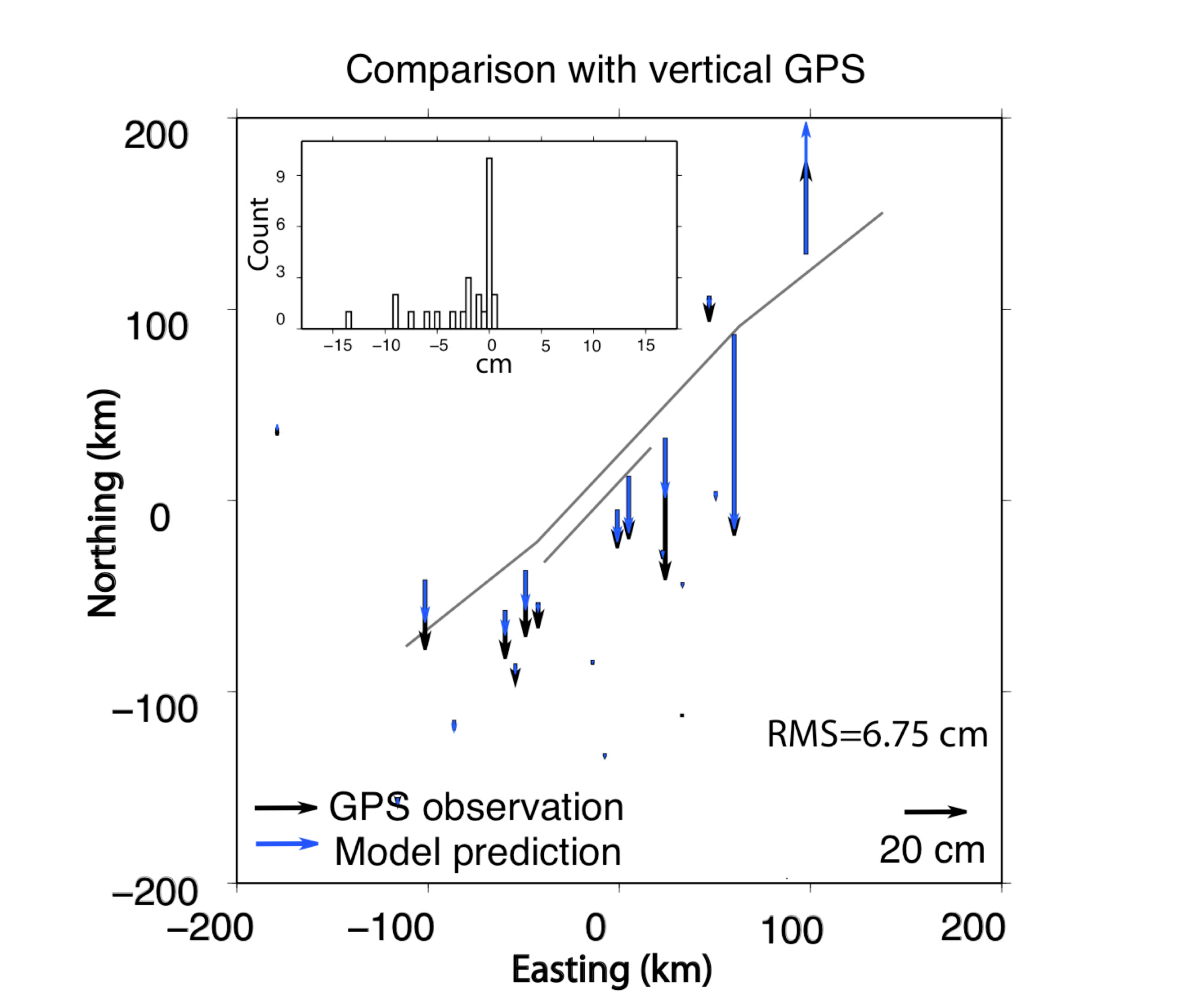
Ascending InSAR data
Desending InSAR data
Ascending InSAR residuals
Descending InSAR residuals
Northing (km)
Easting (km)
LOS (cm)
150
100
50
0
−50
−100
−150
90
60
30
−30
−60
−90
80
60
40
20
−20
−40
−60
−80
−100
−120
15
10
5
−5
−10
−15



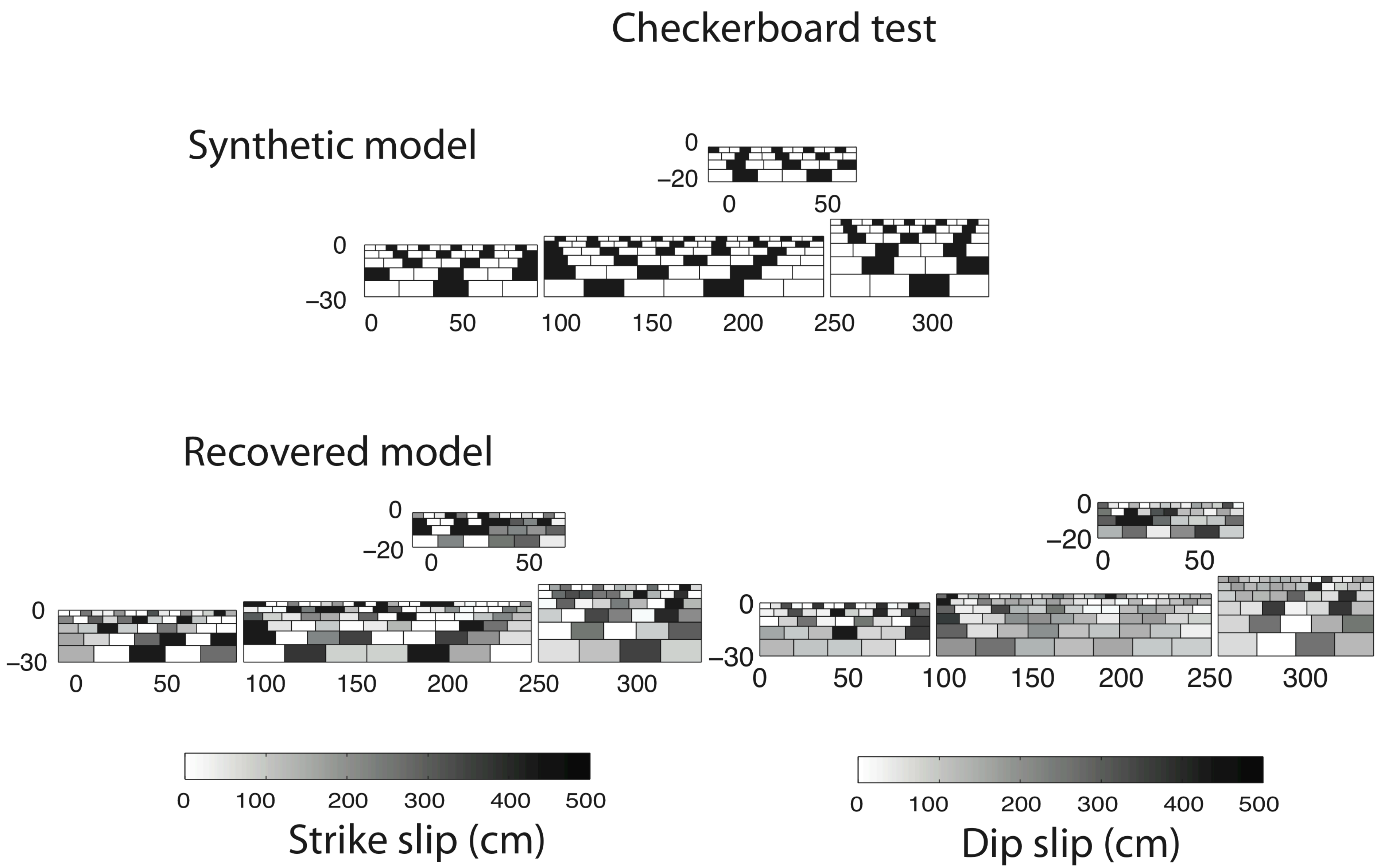
A)
Digitized ascending interferograms
Northing (km)
Easting (km)
LOS (cm)
B)
Digitized descending interferograms
Northing (km)
Easting (km)
LOS (cm)
C)
Residuals of digitized ascending interferograms
Northing (km)
Easting (km)
LOS (cm)
D)
Residuals of digitized descending interferograms
Northing (km)
Easting (km)
LOS (cm)



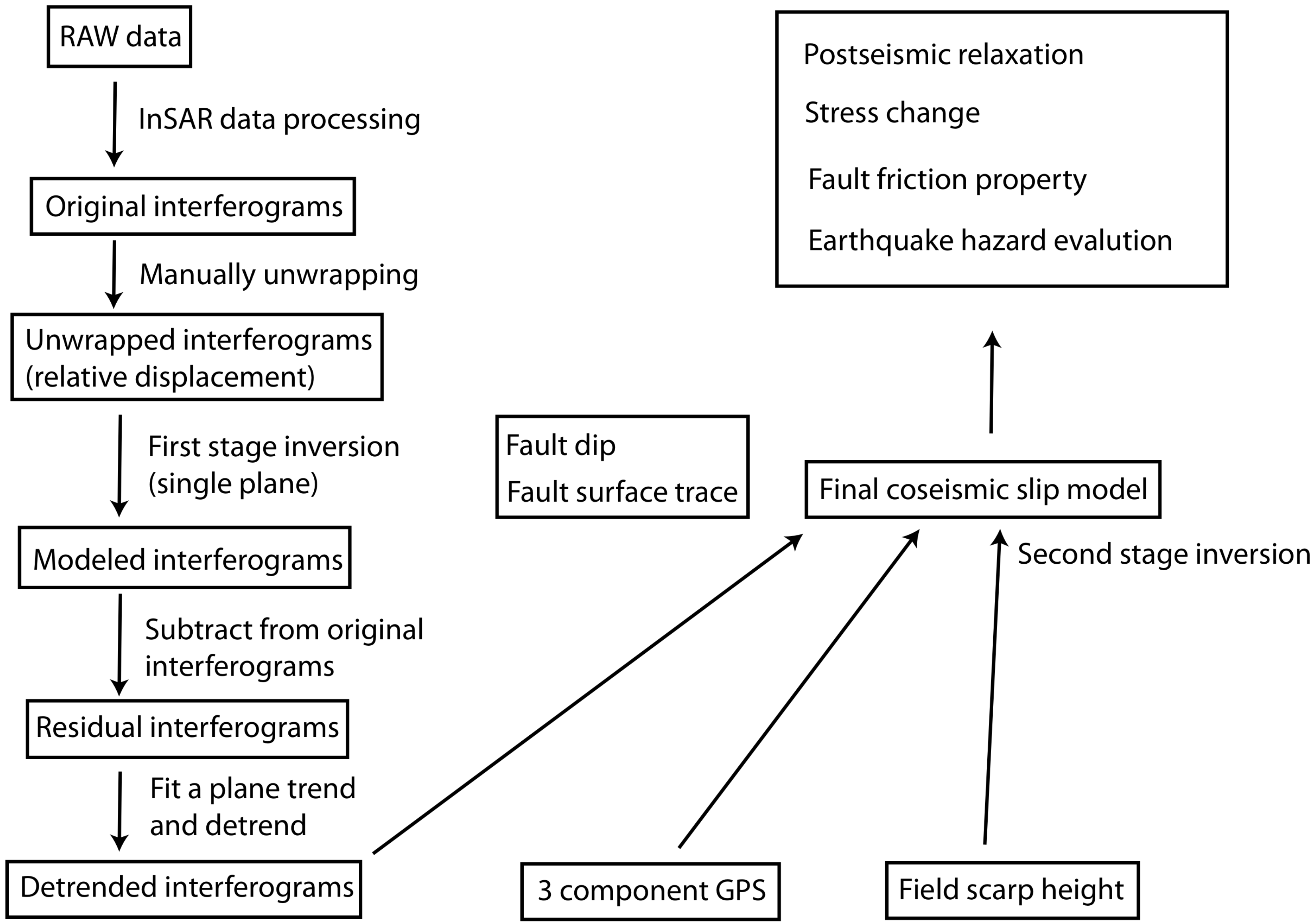
[Working Group of the Crustal Motion Observation Network of China project, 2008]



[Working Group of the Crustal Motion Observation Network of China project, 2008]


Checkerboard test
Synthetic model
Recovered model
Strike slip (cm)
Dip slip (cm)
0
100
200
300
400
500

Flow chart of how we derive this slip model



What’s special about ALOS PALSAR data ?

- Complete spatial coverage:
  - Ascending: swath mode, 6 tracks, 78 scenes.
  - Descending: ScanSAR mode, 1 tracks, 2 scenes, providing second look direction.

- L-band makes mapping possible in mountains.

- Background mission provide excellent pre-earthquake database.

- Comparison with ERS :
  - Spatial resolution 1.3x better.
  - LOS accuracy 1.6x worse.

[Sandwell et al., 2008]