Fault Source Model of the 2008 Wenchuan Earthquake (China) estimated from PALSAR data

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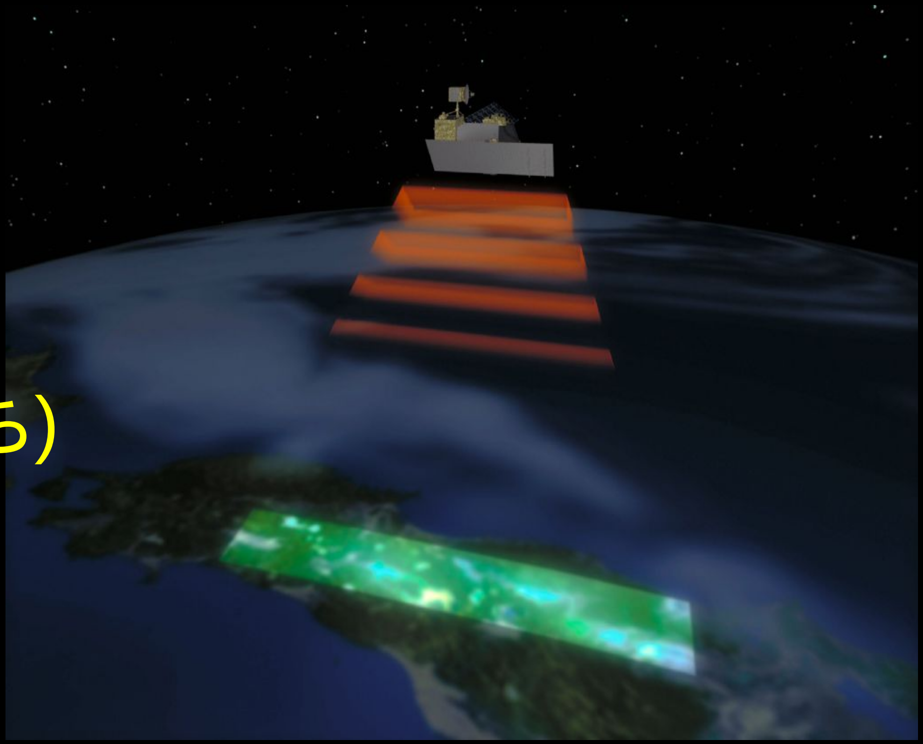
Outline of this talk

- The 2008 Wenchuan eqk. Observed by ALOS/PALSAR - InSAR data, Pixel Offset data –
- Fault Source Modeling
- Summary

PALSAR: L-band SAR sensor on ALOS(だいち)



Koyabashi et al. (2009, GRL)

GEOPHYSICAL RESEARCH LETTERS, VOL. 36, L07302, doi:10.1029/2008GL036907, 2009

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Locations and types of ruptures involved in the 2008 Sichuan earthquake inferred from SAR image matching

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[1] We have detected detailed ground displacements in the proximity of the Longmen Shan fault zone (LMSFZ) by applying a SAR offset-tracking method in the analysis of the 2008 Sichuan earthquake. An elevation-dependent correction is indispensable for achieving sub-meter accuracy. A sharp displacement discontinuity with a relative motion of ~1–2 m appears over a length of 200 km along the LMSFZ, which demonstrates that the main rupture has proceeded on the Beichuan fault (BF) among several active faults composing the LMSFZ, and a new active fault is detected on the northeastward extension of the BF. The rupture on the BF is characterized by a right-lateral motion in the northeast, while in the southwest an oblique right-lateral thrust slip is suggested. In contrast to the northeast where a major rupture proceeded on the BF only, in the southwest multiple thrust ruptures have occurred in the southeastern foot of the Pengguan massif. **Citation:** Kobayashi, T., Y. Takada, M. Furuya, and M. Murakami (2009), Locations and types of ruptures involved in the 2008 Sichuan earthquake inferred from SAR image matching, *Geophys. Res. Lett.*, *36*, L07302,

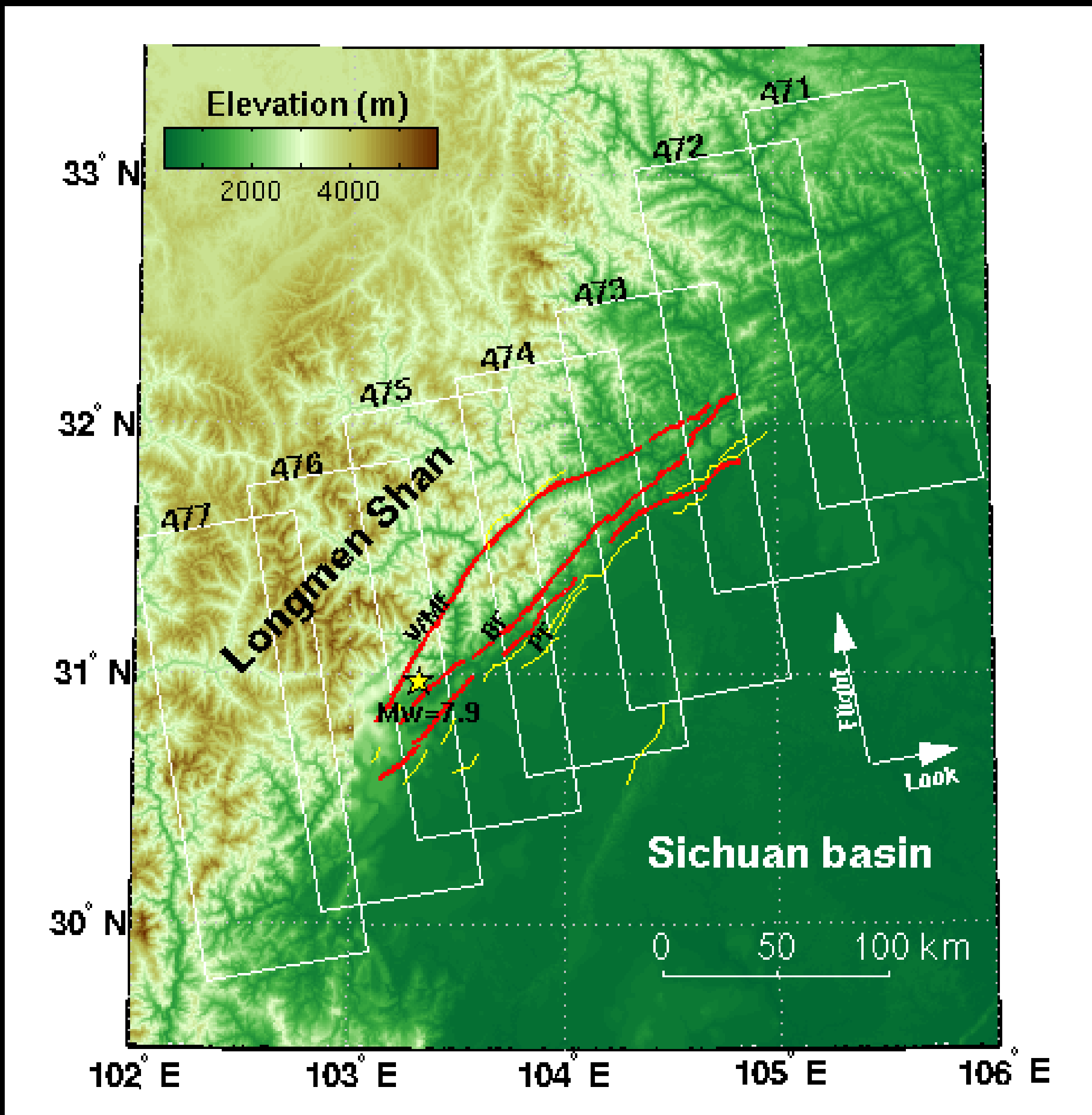
epicentral area certainly plays a key role in answering these questions.

[3] Satellite synthetic aperture radar (SAR) data can provide detailed and spatially comprehensive ground information. Interferometric SAR (InSAR) analysis has an advantage of detecting ground deformation in a vast region with high precision [e.g., *Massonnet and Feigl*, 1998; *Bürgmann et al.*, 2000]. However, for the Sichuan event, the standard InSAR approach is not helpful in knowing the faults directly related to the seismic rupture. This is because the displacement amplitude near the fault zone was too large and a coherent loss area which spreads over an area ~200 km long and ~10–30 km wide prevents us from satisfactorily obtaining the ground deformation in the proximity of the fault zone. Thus, in order to reveal the unknown surface displacements, we conduct an offset-tracking procedure that enables us to robustly detect large ground deformation even in an incoherent area [*Michel et al.*, 1999; *Tobita et al.*, 2001; *Pathier et al.*, 2006]. While similar approaches can be taken with optical images [e.g., *Avouac*

Today; Revise a part of the observation data

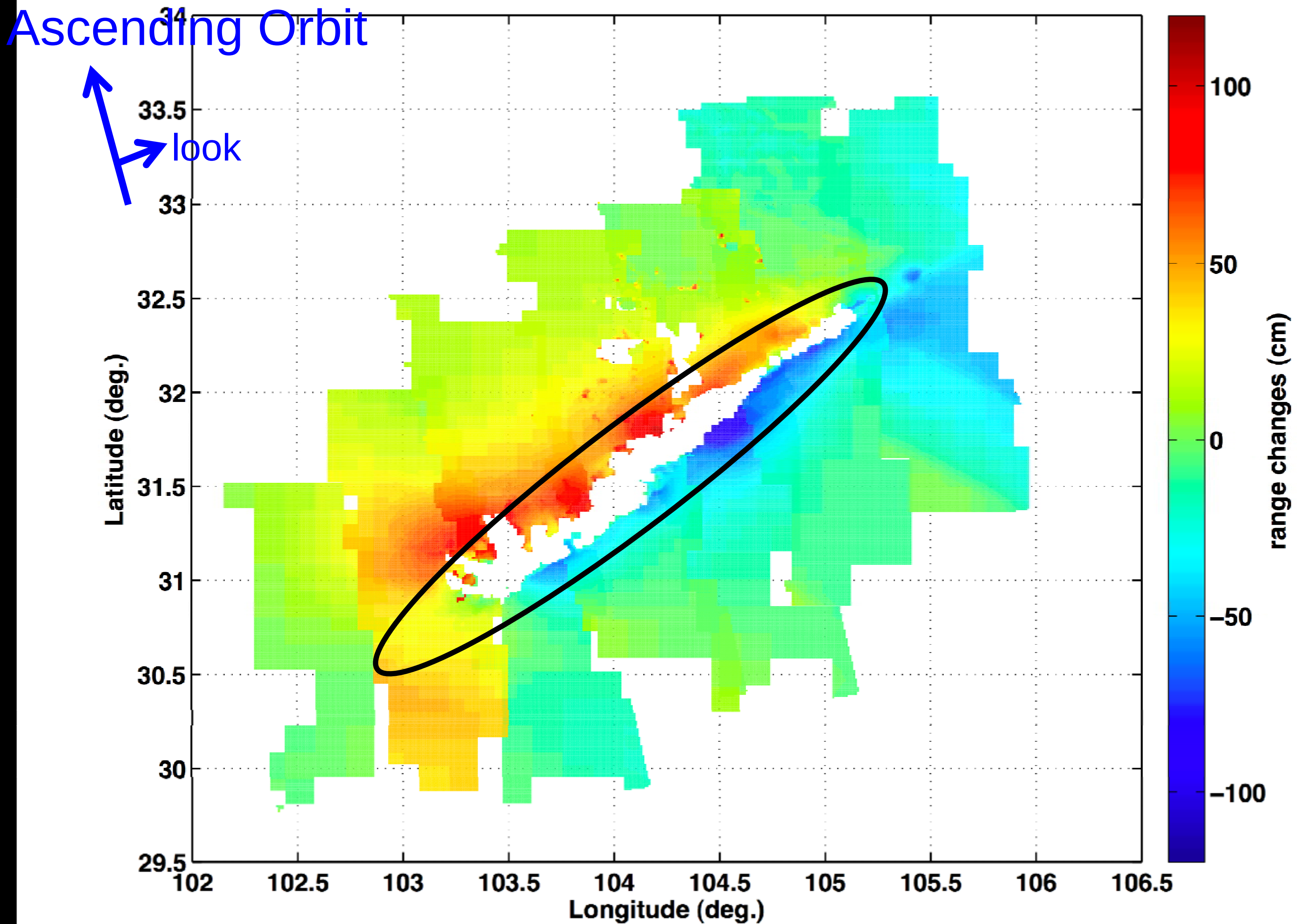
Update the preliminary source model

Longmen Shan Fault Zone and Data Coverage



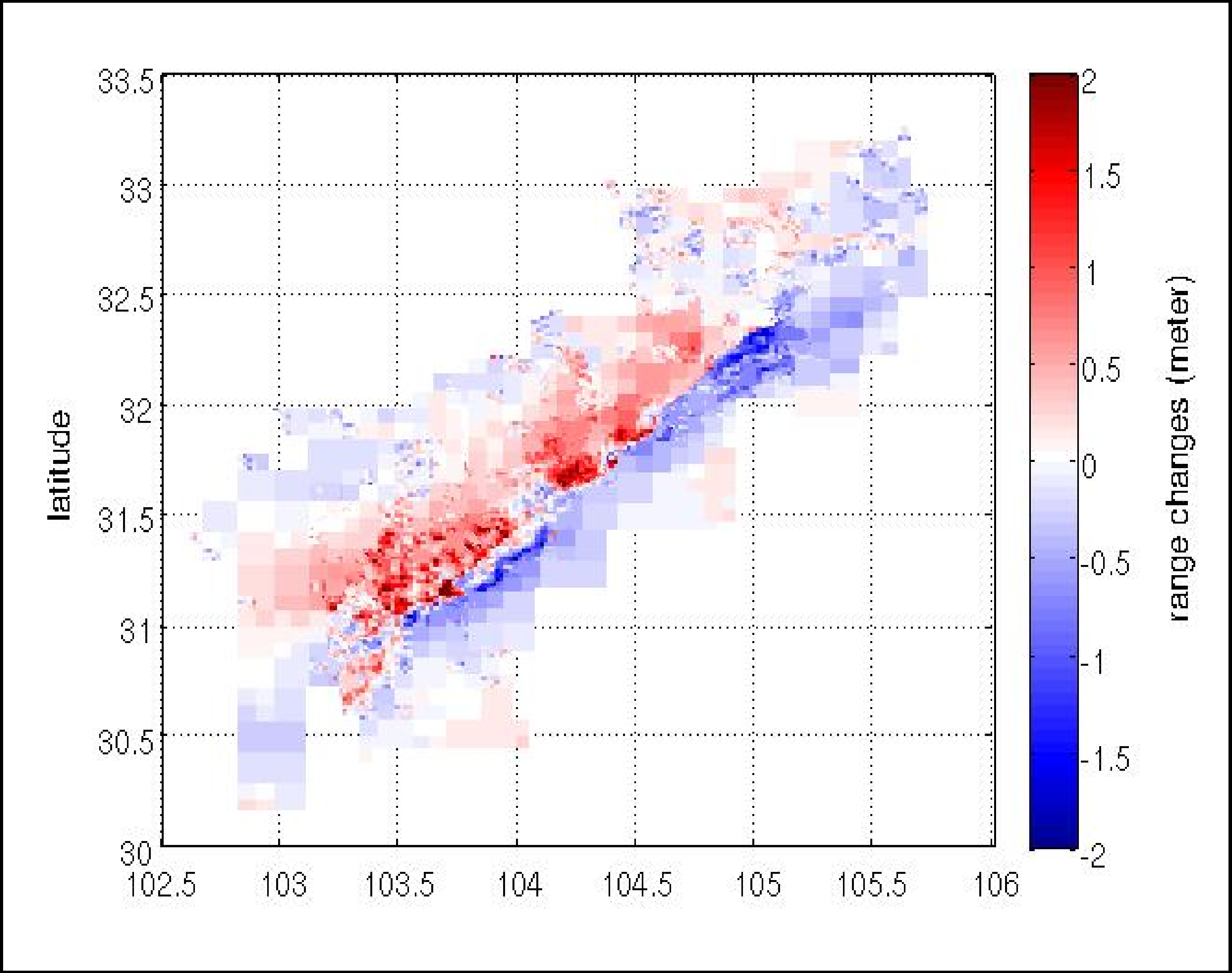
Fault traces by Densmore et al. (2007)

3 major faults

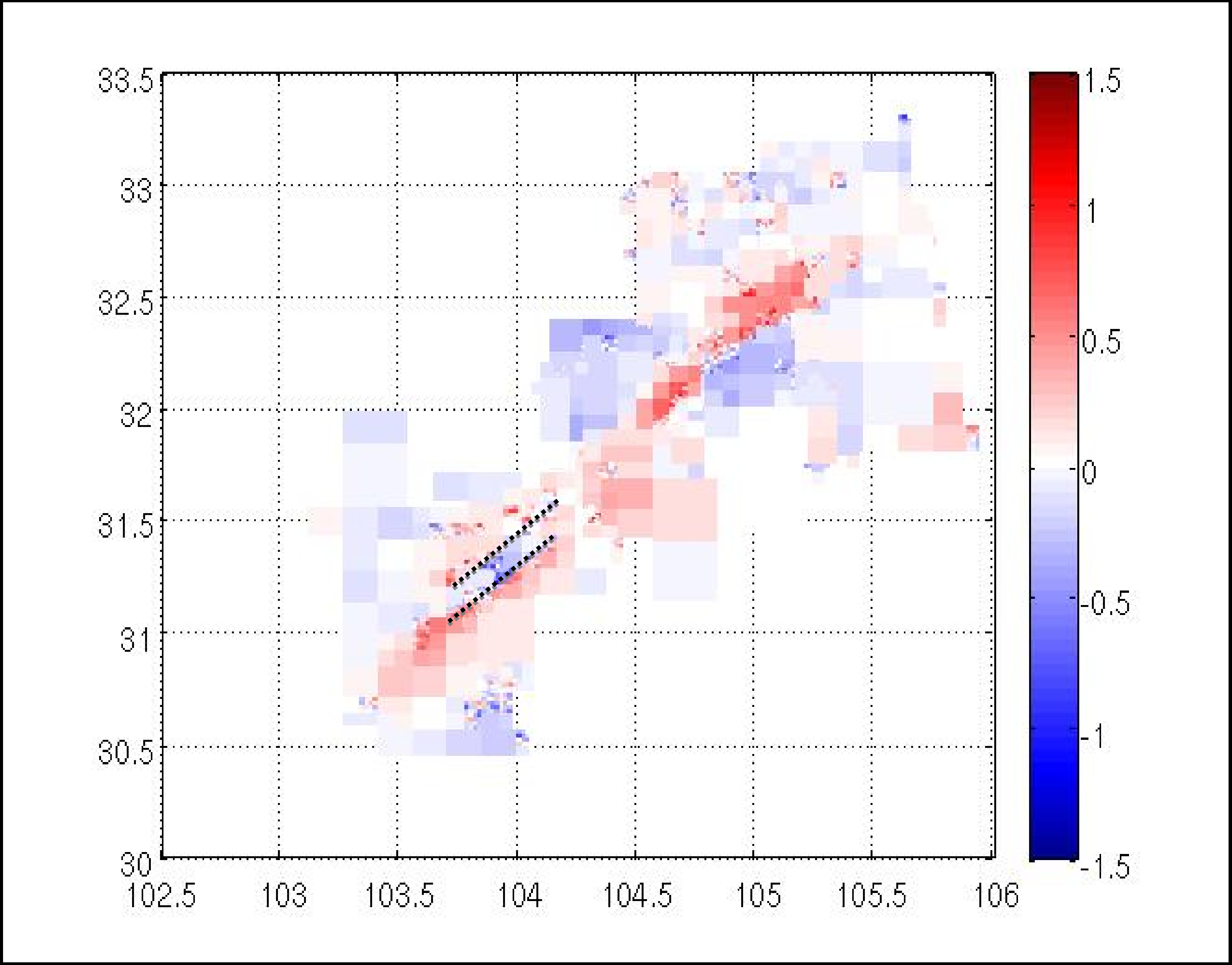


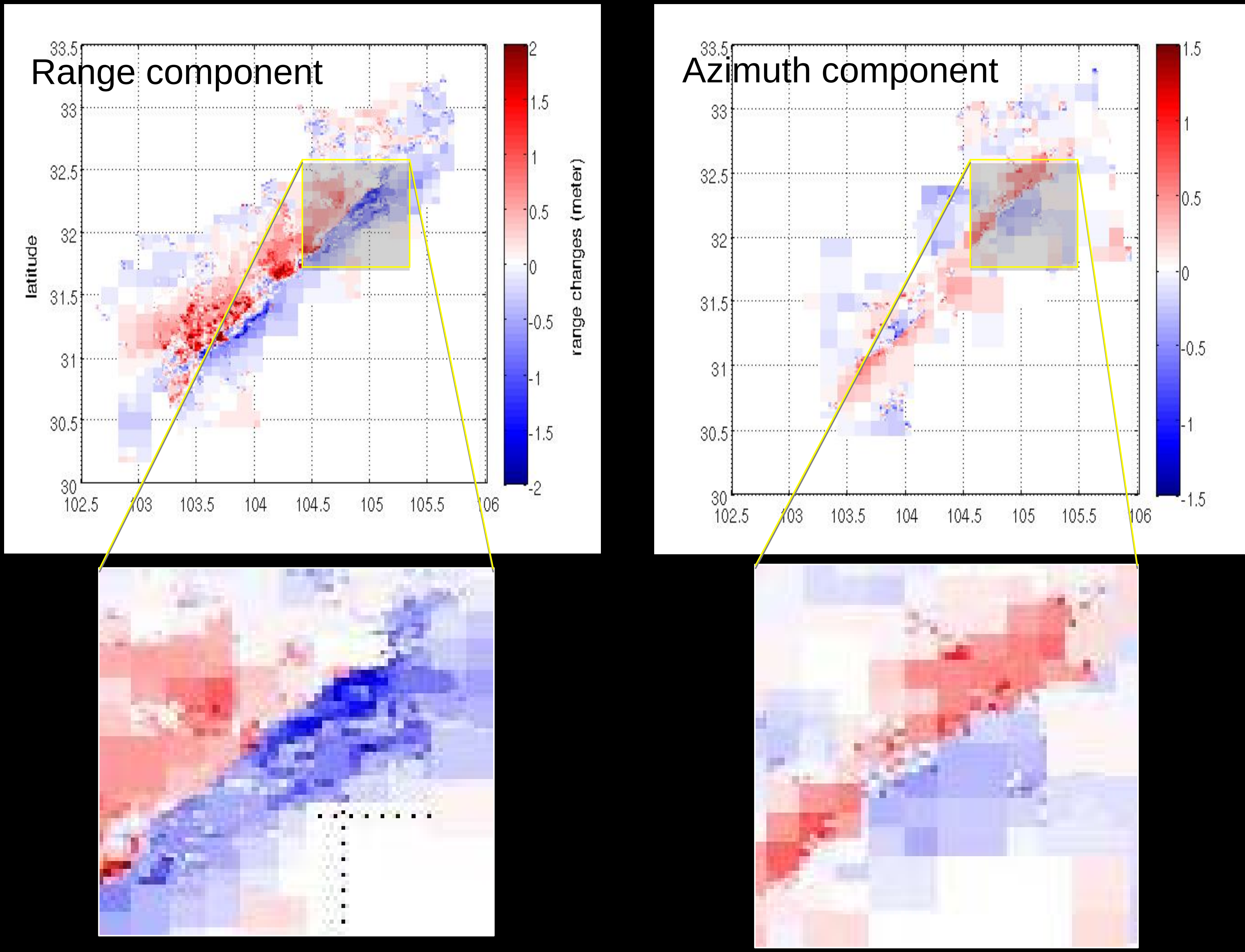
Ascending Orbit
look
Latitude (deg.)
Longitude (deg.)
range changes (cm)
34
33.5
33
32.5
32
31.5
31
30.5
30
29.5
102
102.5
103
103.5
104
104.5
105
105.5
106
106.5
100
50
0
−50
−100

Pixel offset: Range component

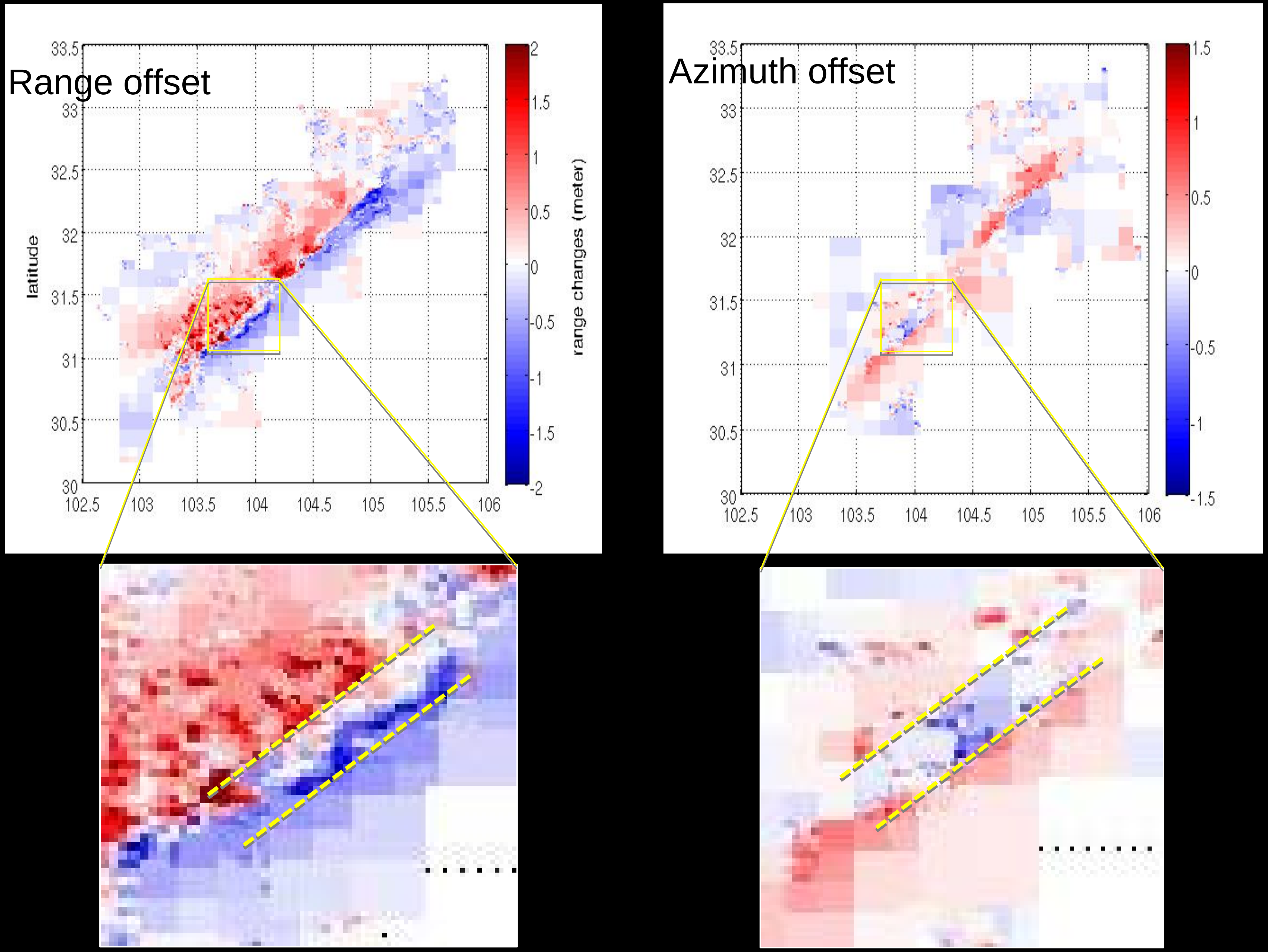


Pixel offset: Azimuth component



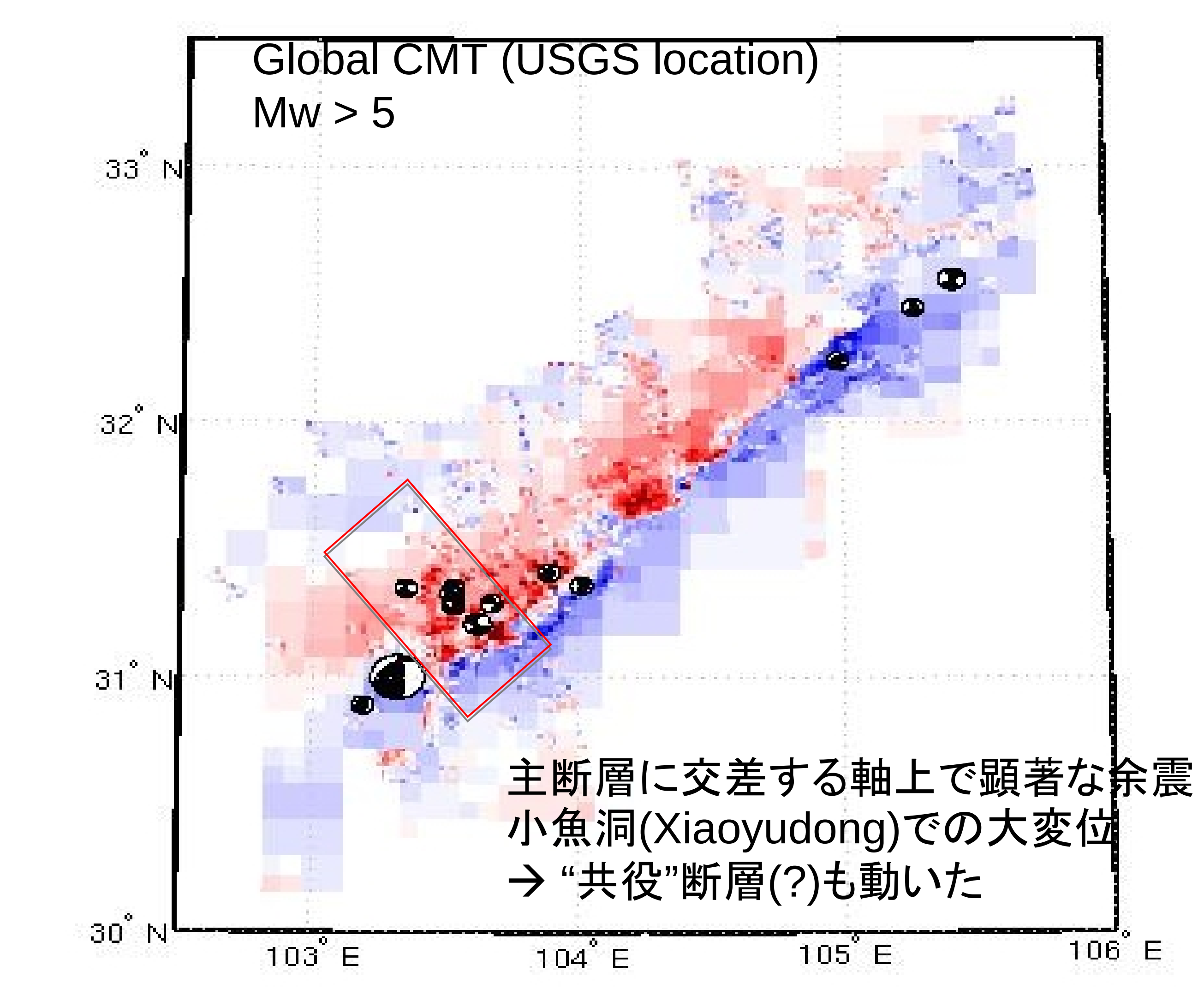


Simpler fault motion to the NE

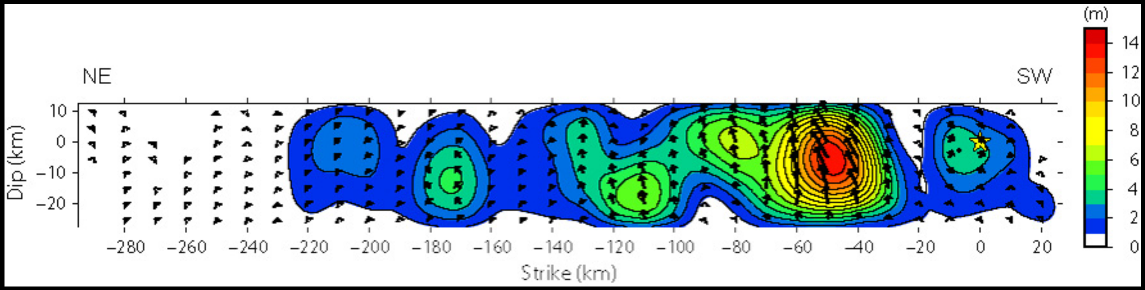


Two faults are necessary to the SW

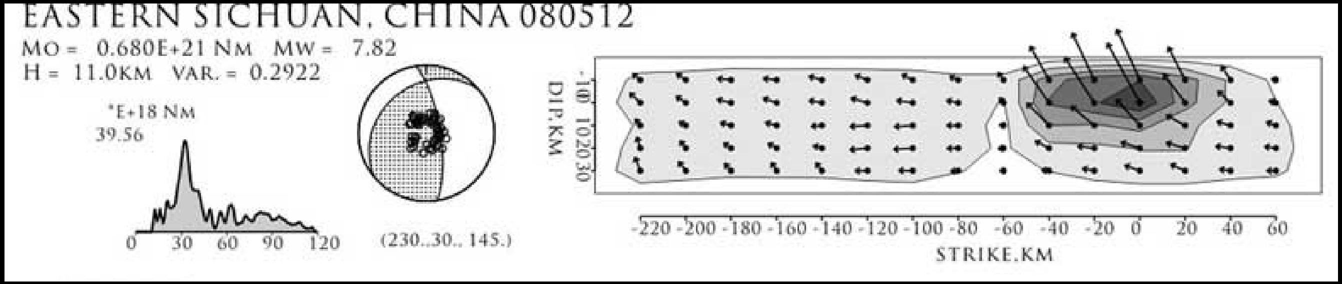
Conjugate fault to the SW suggested from aftershocks



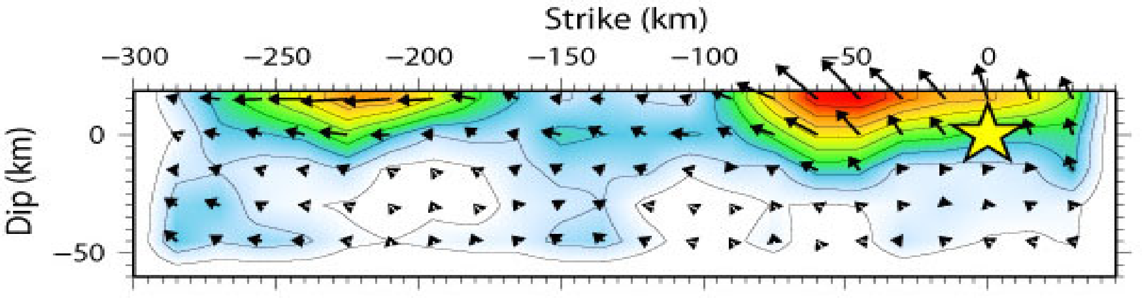
Fault Models from Waveform Inversion



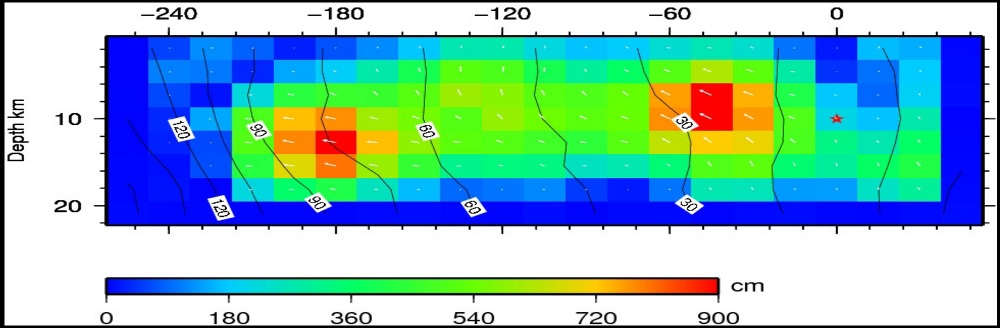
Hikima, 2008
(ERI)



Yamanaka, 2008
(NGY)

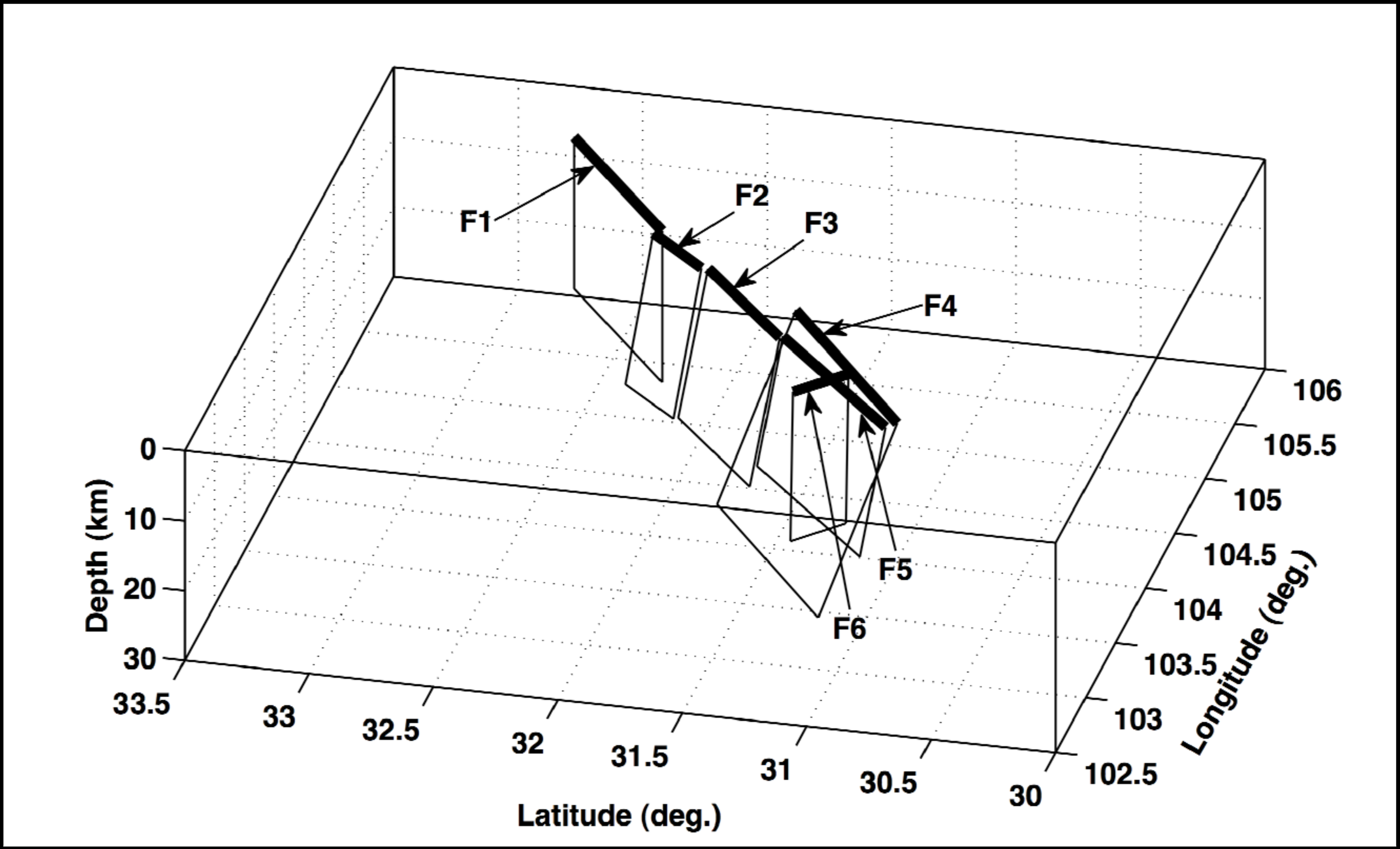


Nishimura & Yagi, 2008
(Tsukuba)



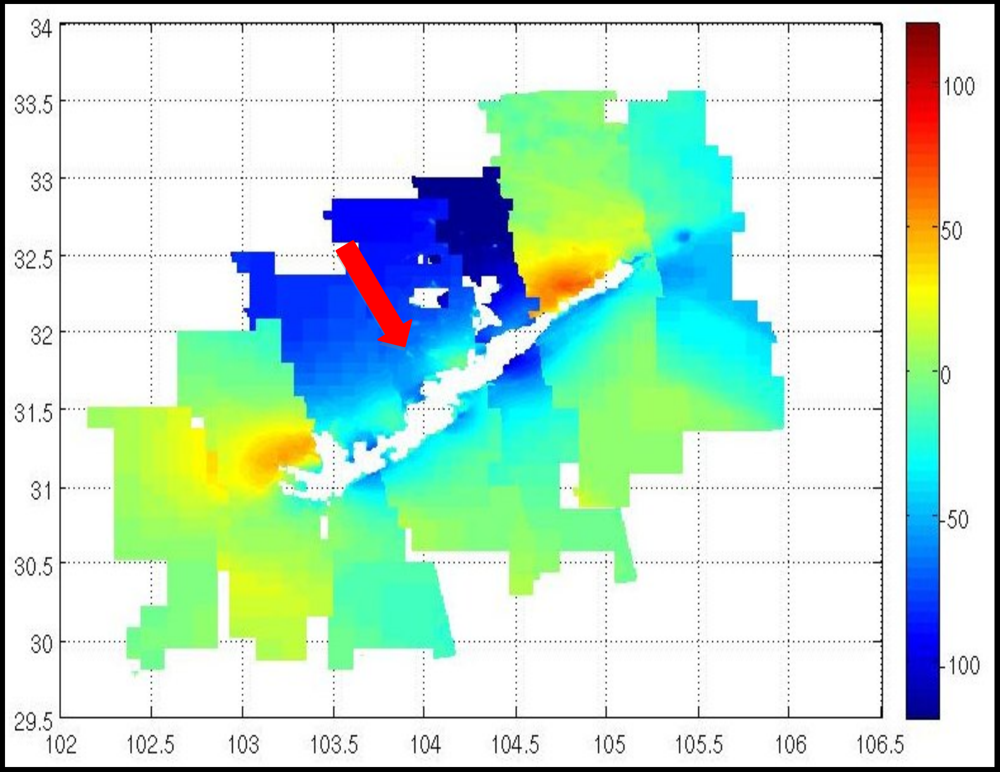
Ji, 2008
(UCSB)

Fault Source Model



Fixing the location and geometry, we let slip distributions to be the unknowns.

"Original" Unwrapped InSAR data



Derived from
Minimum-Cost-Flow approach
…unwrap the entire image
"smoothly" across the fault

Obvious jumps across the
fault trace !

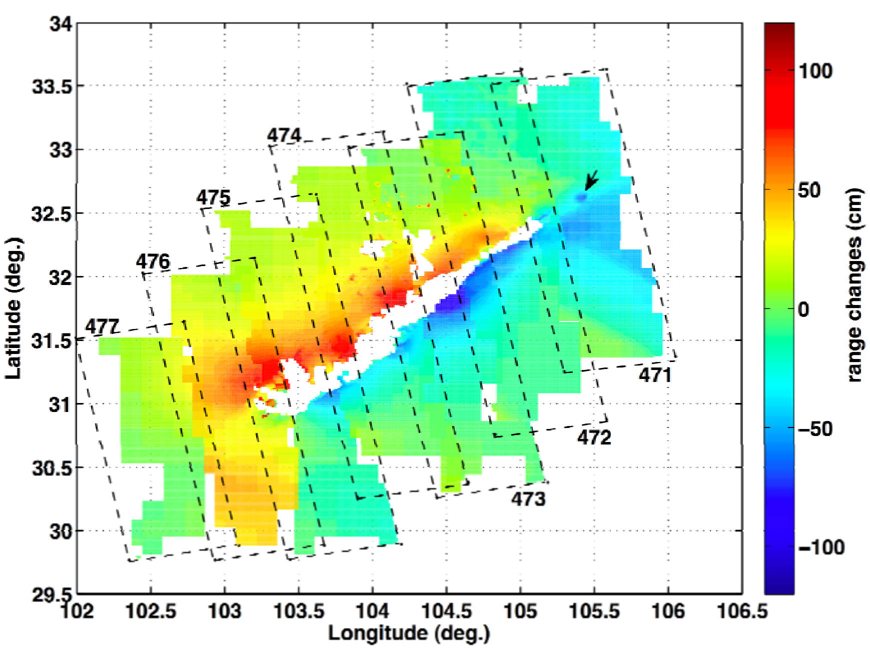
We let the amount of jumps the other unknowns
that are solved together with the slip distribution.

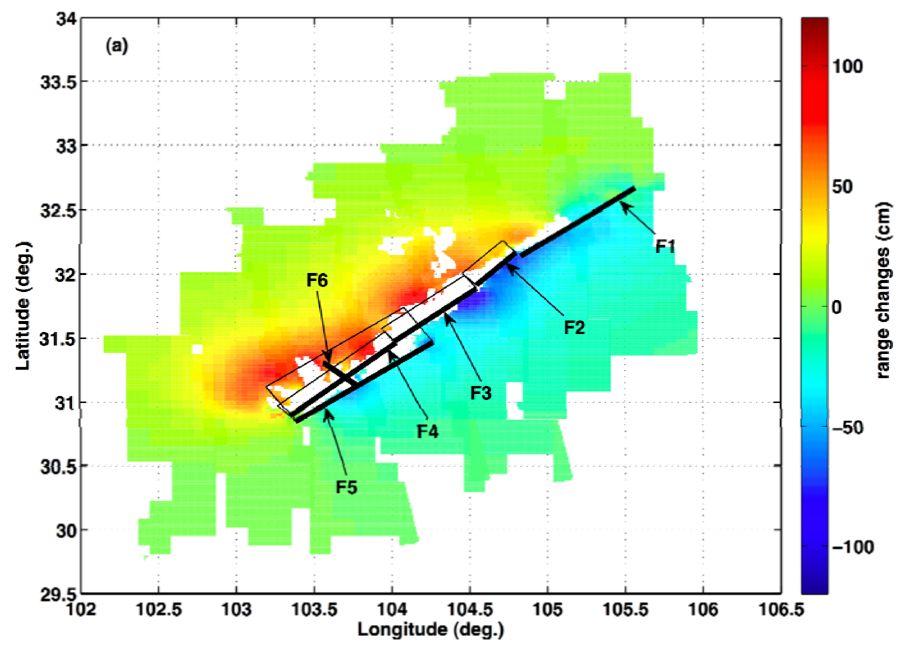
The solved equation

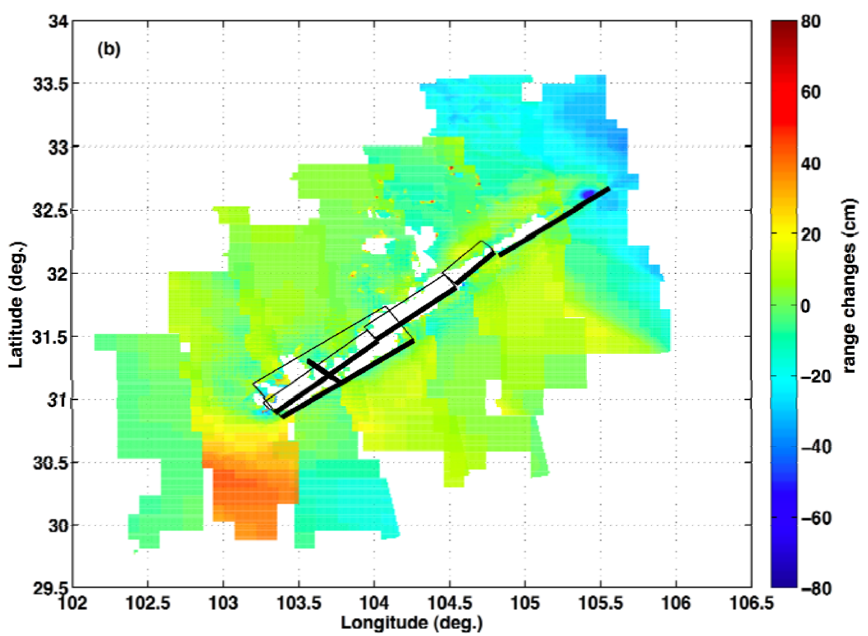
$$\begin{pmatrix} \vec{d} \\ 0 \end{pmatrix} = \begin{pmatrix} G \\ \kappa^2 D \end{pmatrix} \vec{m} + \begin{pmatrix} I_o \\ 0 \end{pmatrix} \vec{m}_o$$

$$G^t \cdot \vec{d} = \left(\left(G^t \cdot G + \kappa^2 D^t \cdot D \right) \quad G^t \cdot \begin{pmatrix} I_o \\ 0 \end{pmatrix} \right) \begin{pmatrix} \vec{m} \\ \vec{m}_o \end{pmatrix}$$

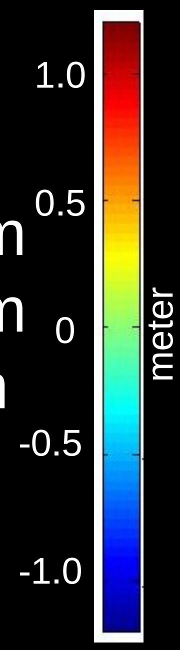
- Data d : InSAR, Range offset, Azimuth offset
- Multiple patch size
- Smoothness constraint on the slip distribution
- Non-negativity constraint on the slip vector

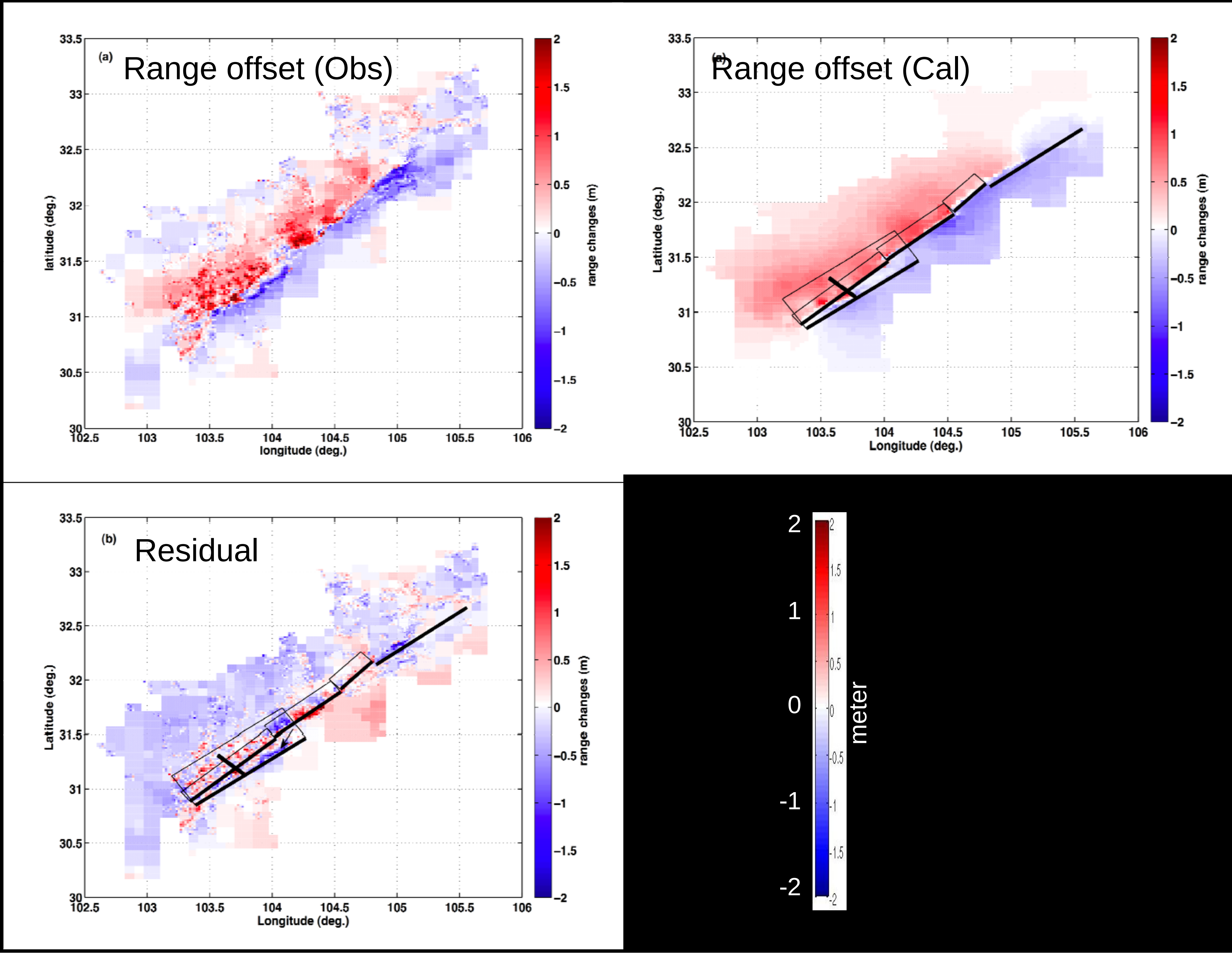




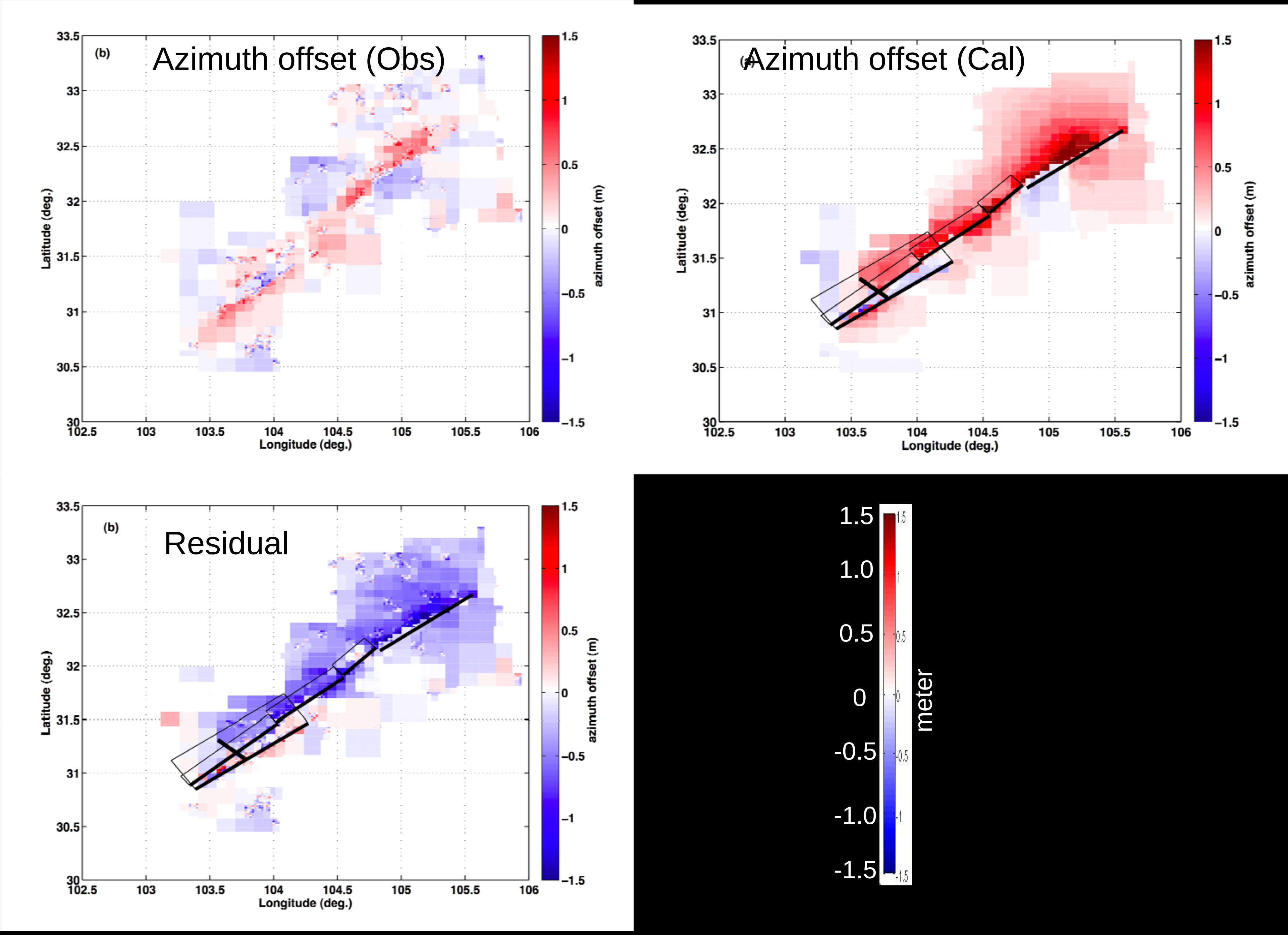


In the "Obs"
Path 473の北側 125.4cm
Path 474の北側 104.1cm
Path 475の北側 96.8 cm
のoffsetが推定された.





(a) Range offset (Obs)
latitude (deg.)
longitude (deg.)
range changes (m)
Range offset (Cal)
Latitude (deg.)
Longitude (deg.)
range changes (m)
(b) Residual
Latitude (deg.)
Longitude (deg.)
range changes (m)
meter



(b)
Azimuth offset (Obs)
Latitude (deg.)
Longitude (deg.)
azimuth offset (m)
Azimuth offset (Cal)
Latitude (deg.)
Longitude (deg.)
azimuth offset (m)
(b)
Residual
Latitude (deg.)
Longitude (deg.)
azimuth offset (m)
1.5
1.0
0.5
0
-0.5
-1.0
-1.5
meter

Predicted Pixel offset depending on the assumed dip angle of F1 (NE)

Range offset

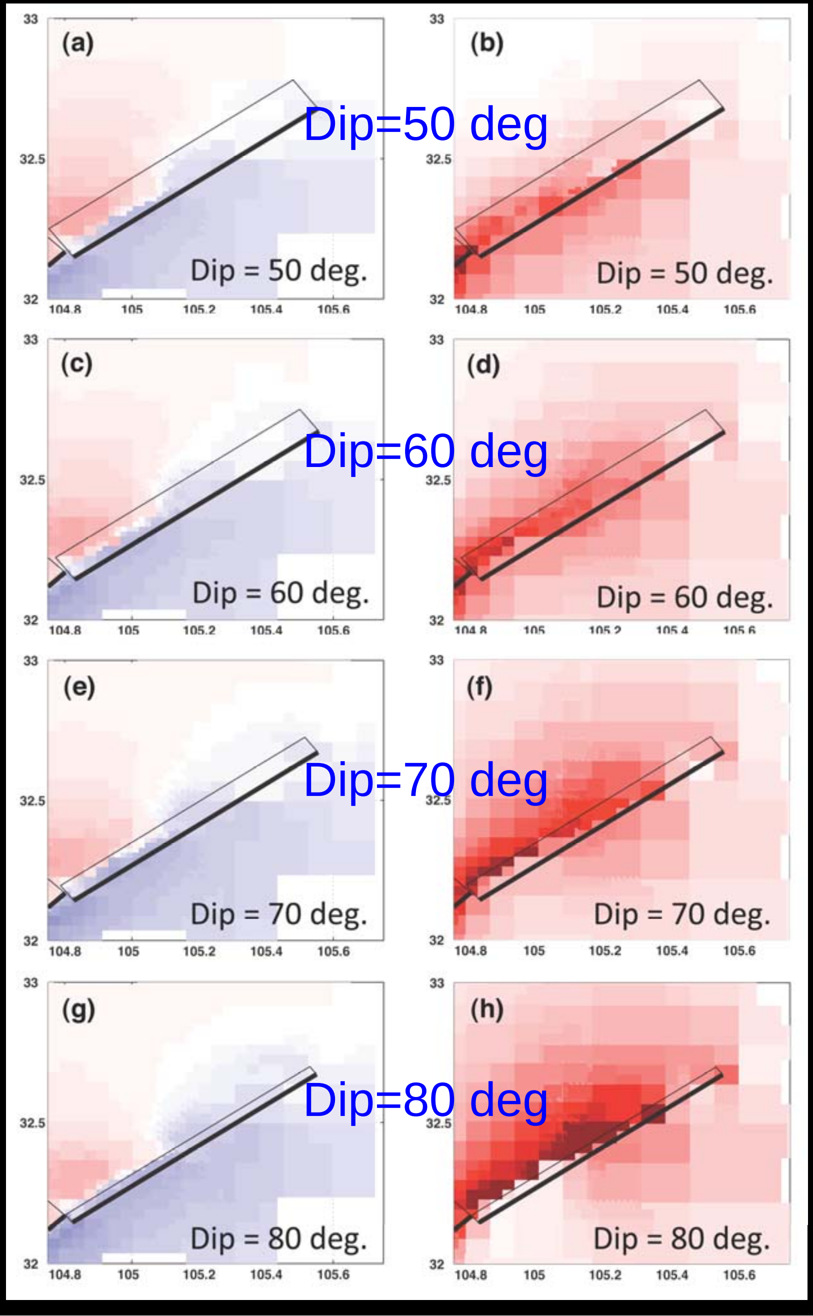
Insensitive to the dip

Azimuth offset

Sensitive to the dip

Near vertical dip angle

Range offset   Azimuth offset



Predicted Pixel offset depending on the assumed dip angle of F5 (SW)

Range offset

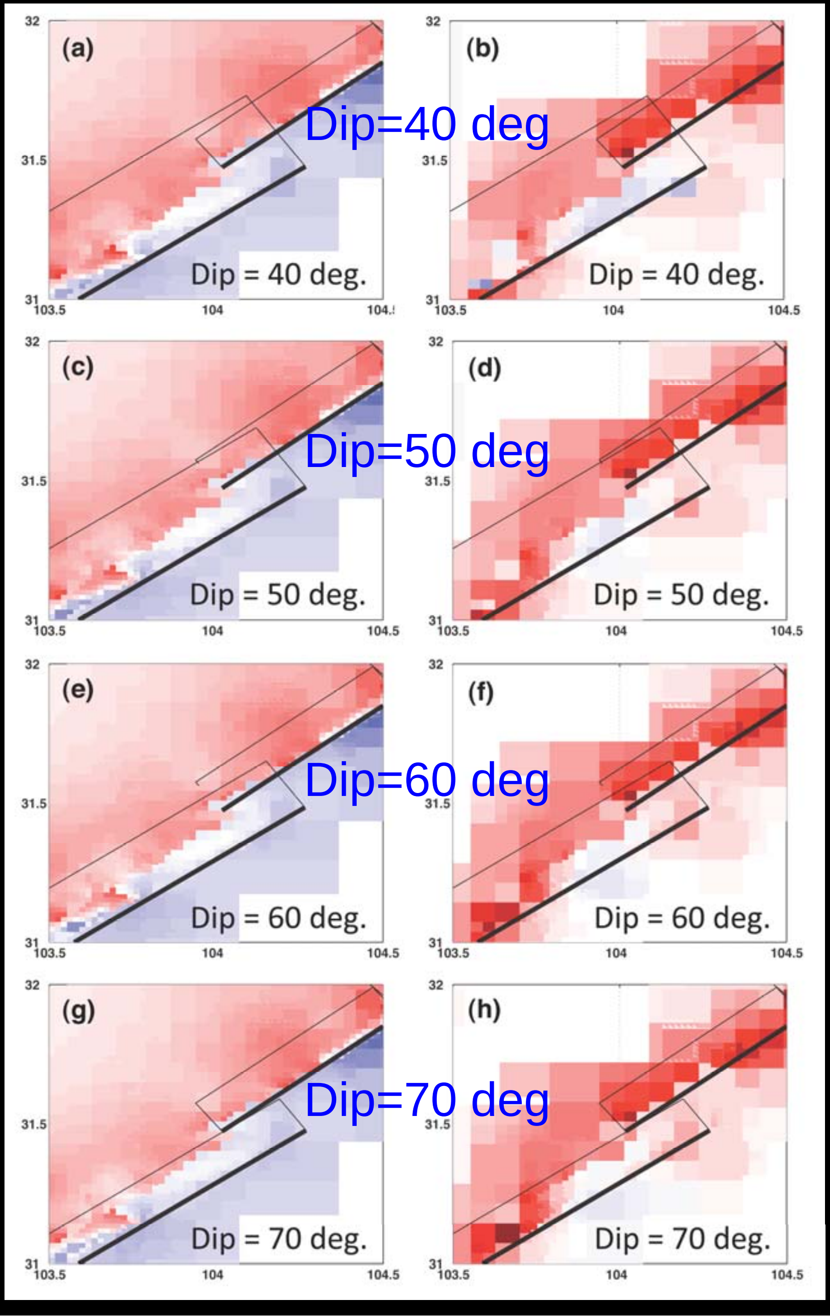
Insensitive to the dip

Azimuth offset

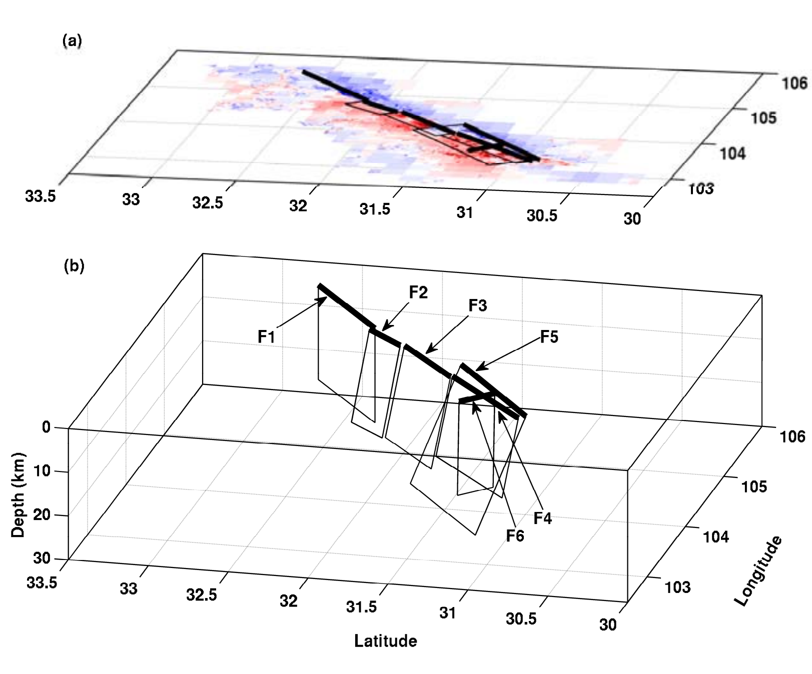
Sensitive to the dip

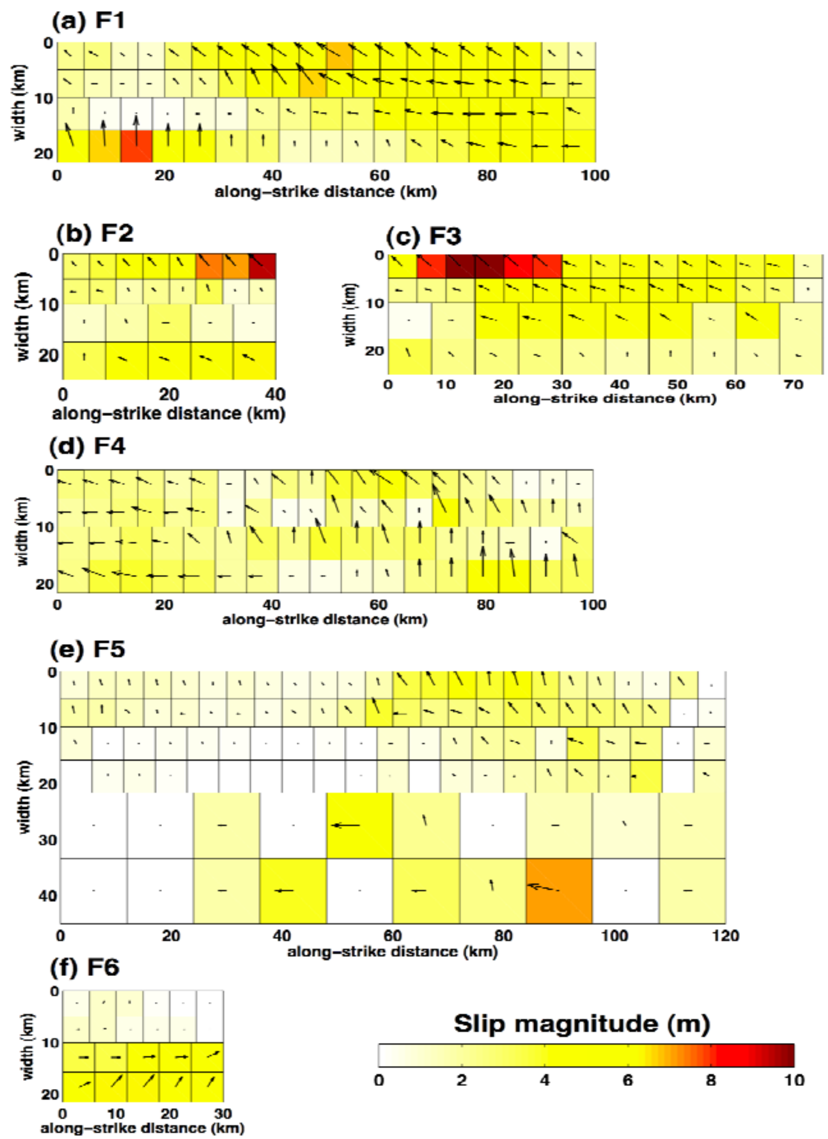
Shallower dip angle

Range offset Azimuth offset

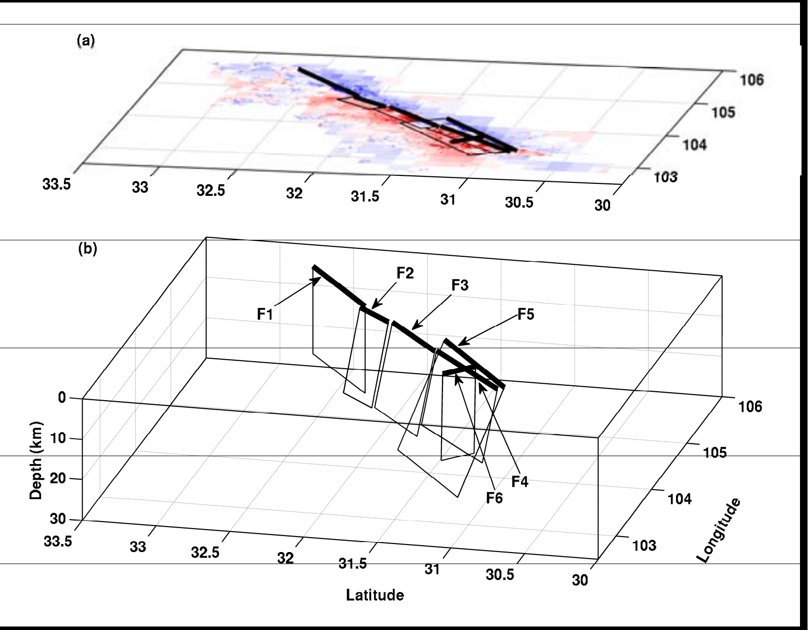


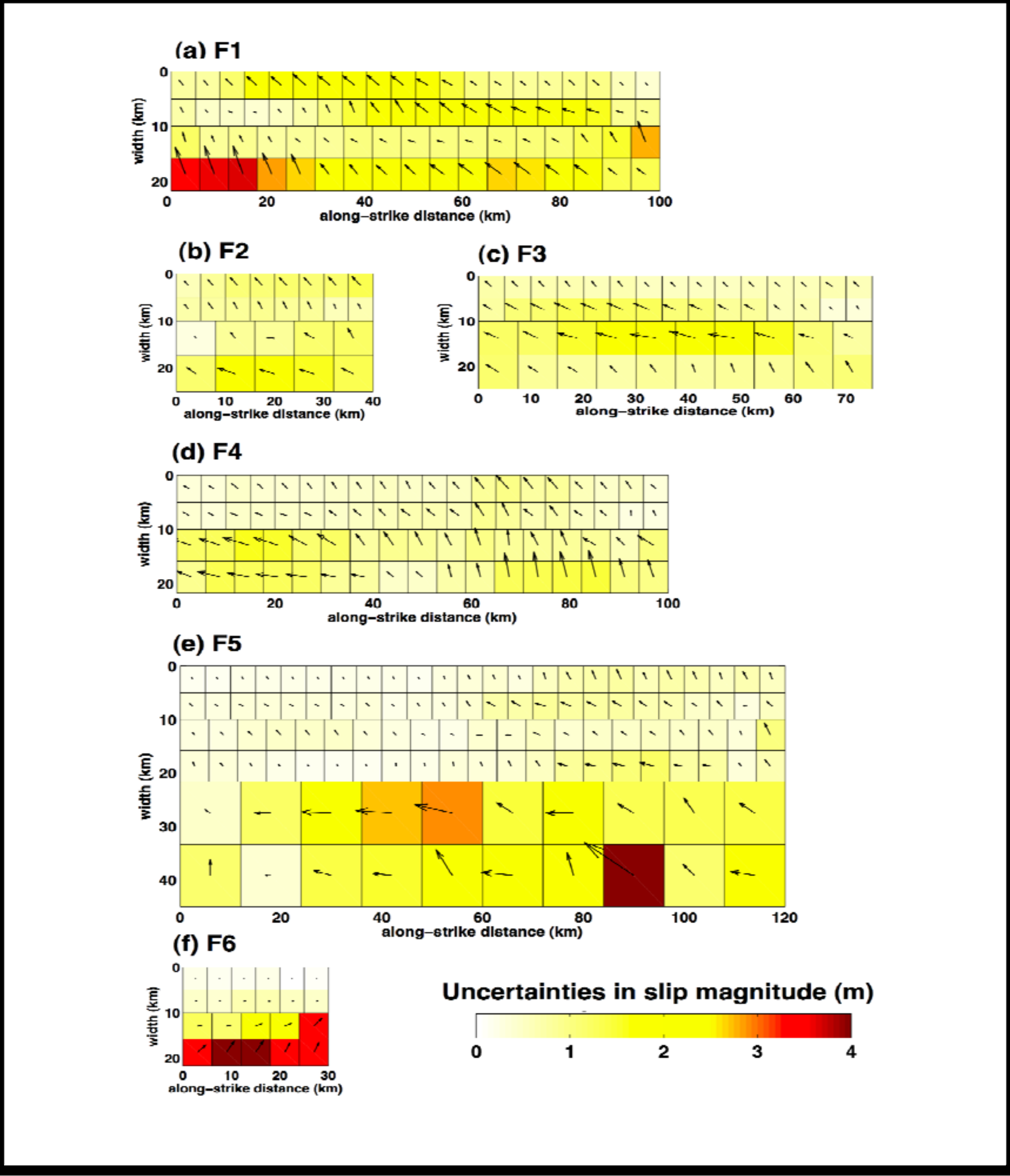
Estimated slip distribution





Estimate of errors in the slip distribution





Summary

- Pixel offset data revealed detailed image of the fault motion responsile for the 2008 Wenchuan earthquake at Longmen Shan Fault Zone.
- Yingxu-Beichuan fault and Anxian-Guanxuan (Pengguan) fault to the SW were involved.
- No evidence for the active motion at Wenchuan-Maowen fault.
- Geodetic Moment Magnitude Mw = 7.9
- Characteristics of the inferred fault motion:

  (1) Right lateral slip to the NE

  (2) Near vertical dip angle to the NE

  (3) Two fault planes to the SW, including thrust components

  (4) Shallower dip angle (~35deg) to the SW

  (5) Maximum slip to the NE (~10 m at shallower depth)

  (6) Conjugate fault to the SW

Acknowledgement

- PALSAR level 1.0 data were provided from the Earthquake Working Group and PIXEL (PALSAR Interferometry Consortium to Study our Evolving Land surface) under a cooperative research contract with JAXA (Japan Aerospace Exploration Agency).
- The PALSAR data belongs to METI (Ministry of Economy, Trade and Industry) and JAXA.
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