S54C-05 16 Dec 2016

Photo by Dr. Marco Menichetti

Coseismic Fault Slip and Triggered Landslides of the 2016 M_w 6.2 Amatrice Earthquake in Italy

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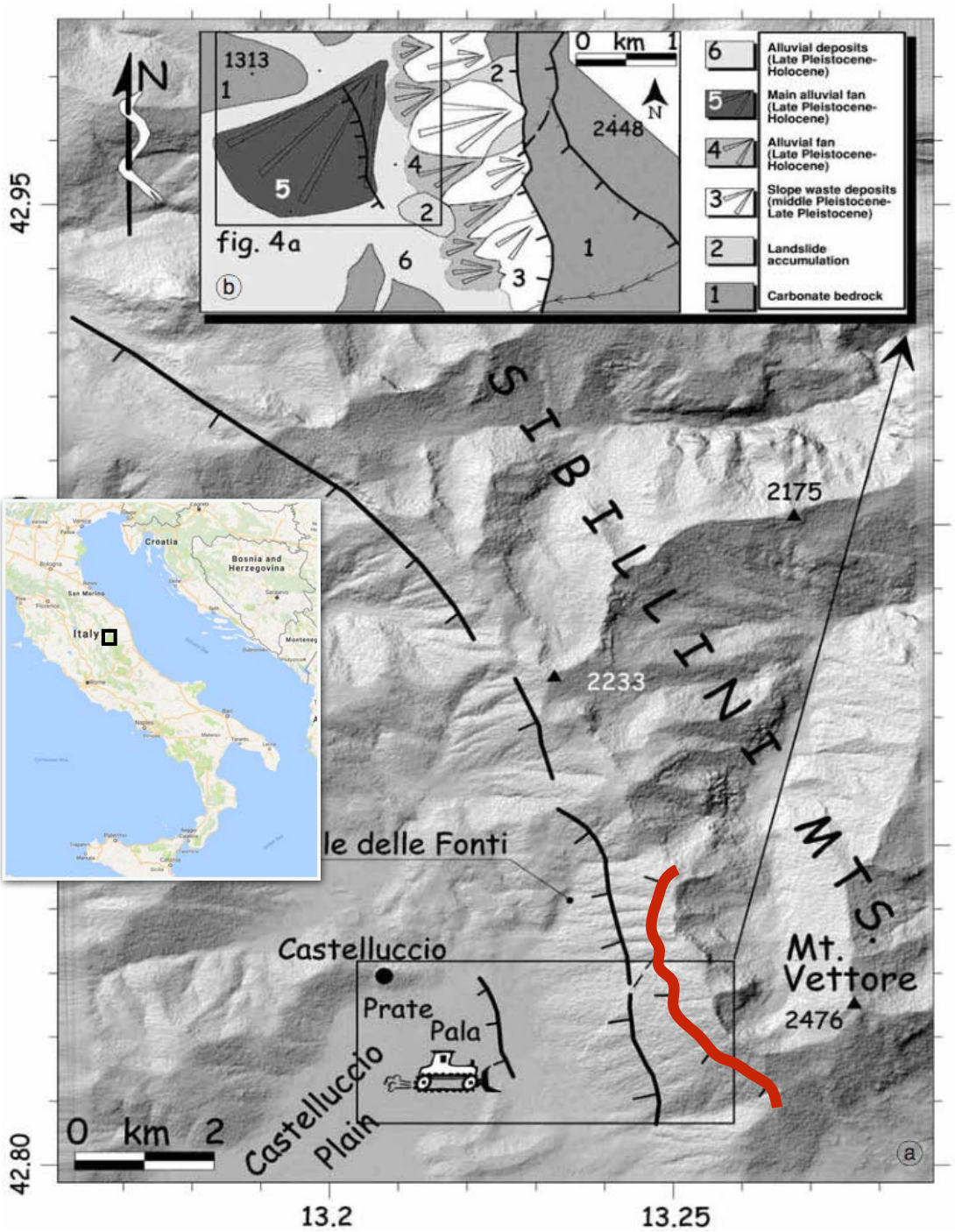
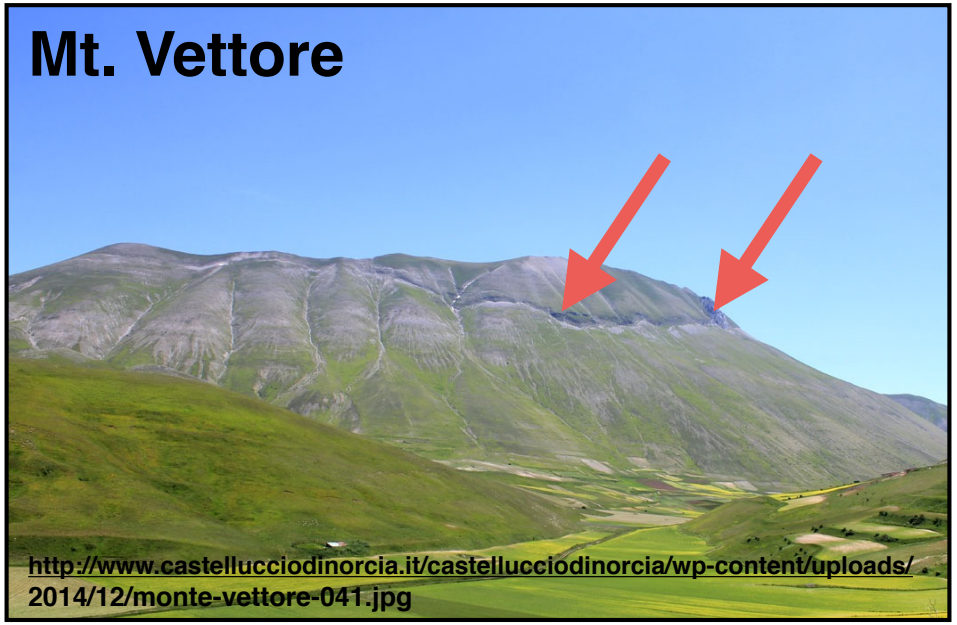
The Mt. Vettore Fault





Limestone scarps

Slip rate: 0.11 - 0.36 mm/yr

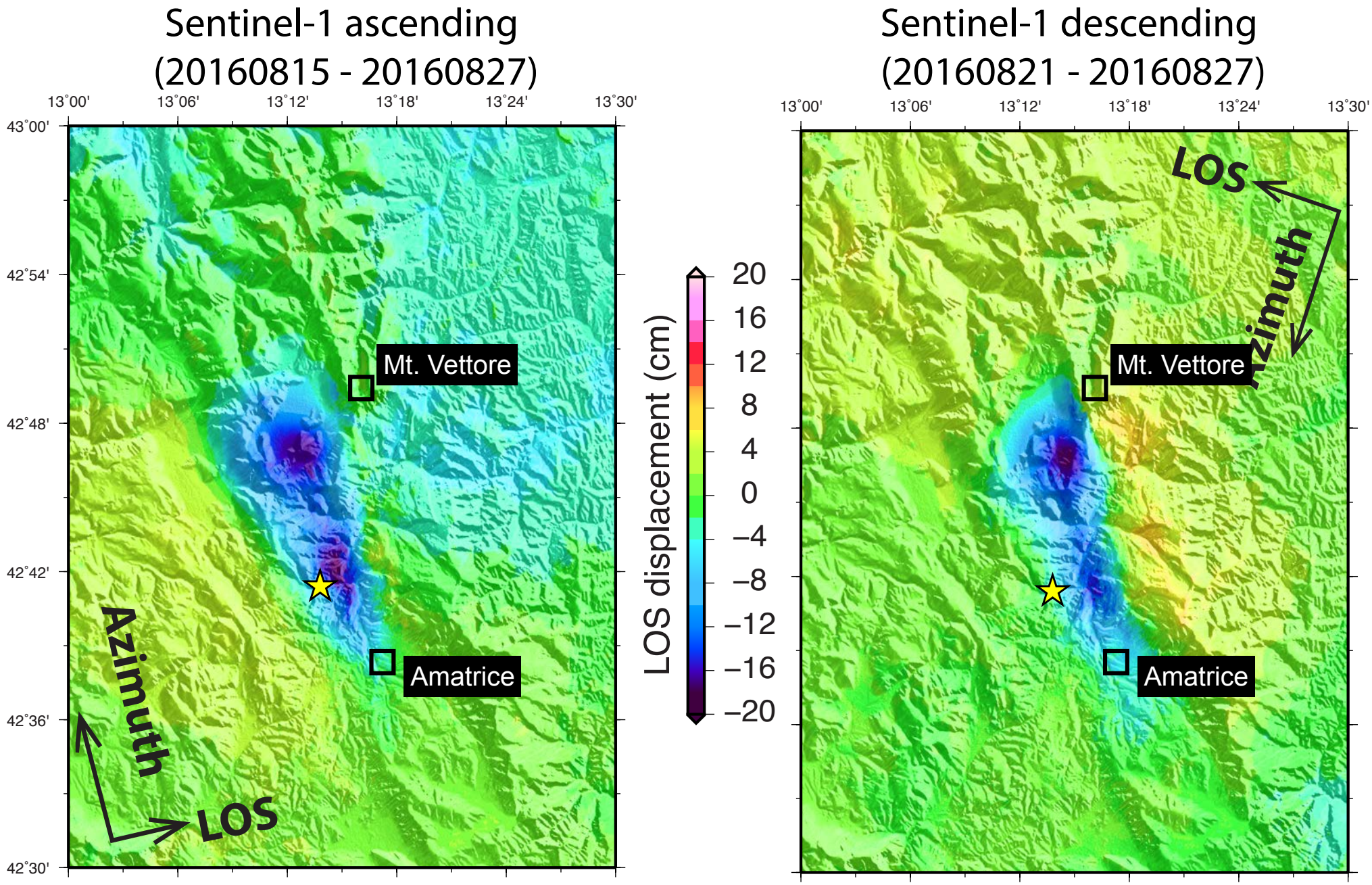
Estimated length: 18 km

M 6.5 - 6.6

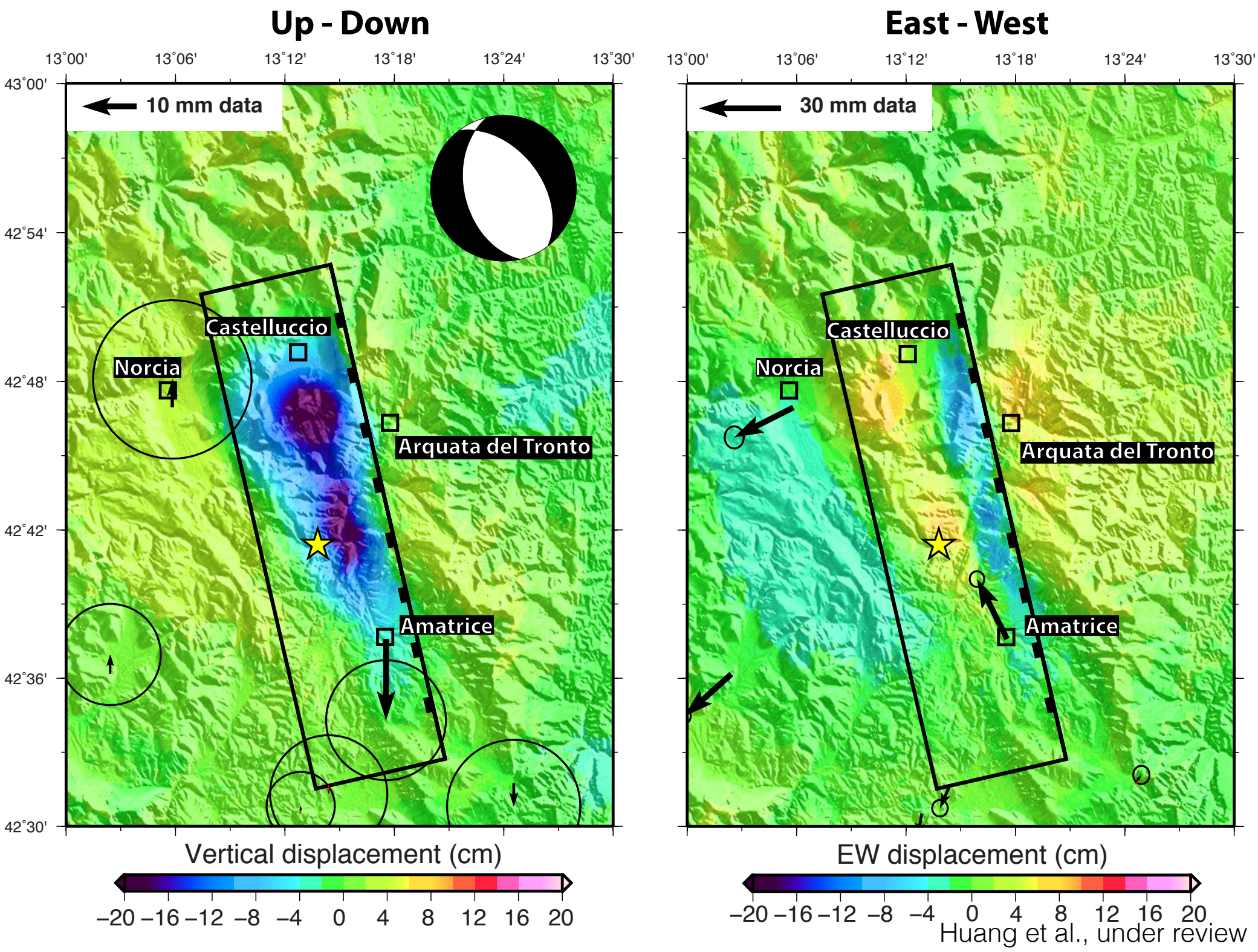
Recurrence interval < ~4700 yr

Galadini and Galli, AG, 2003

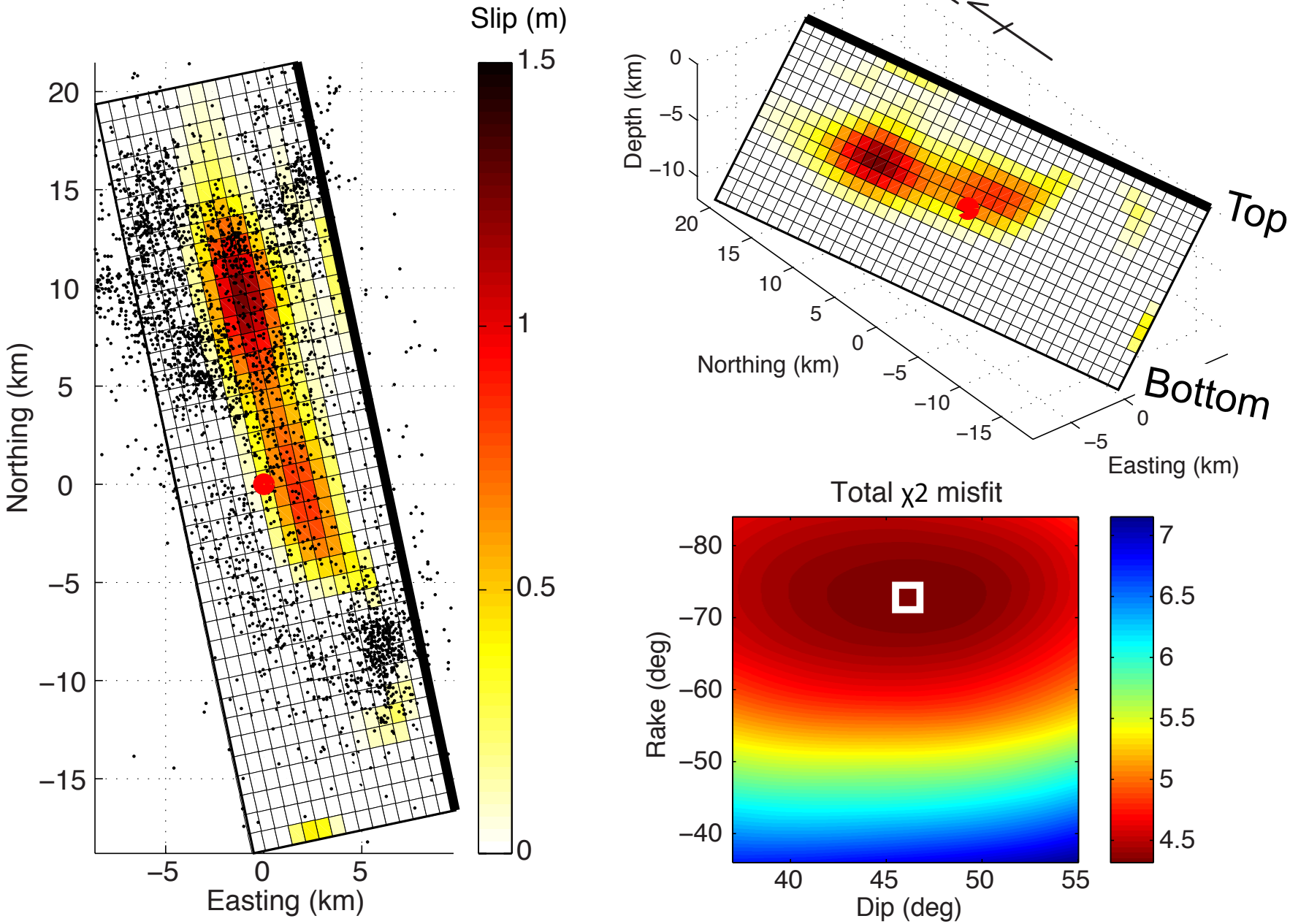
The 24 Aug. 2016 M_w 6.2 Amatrice EQ



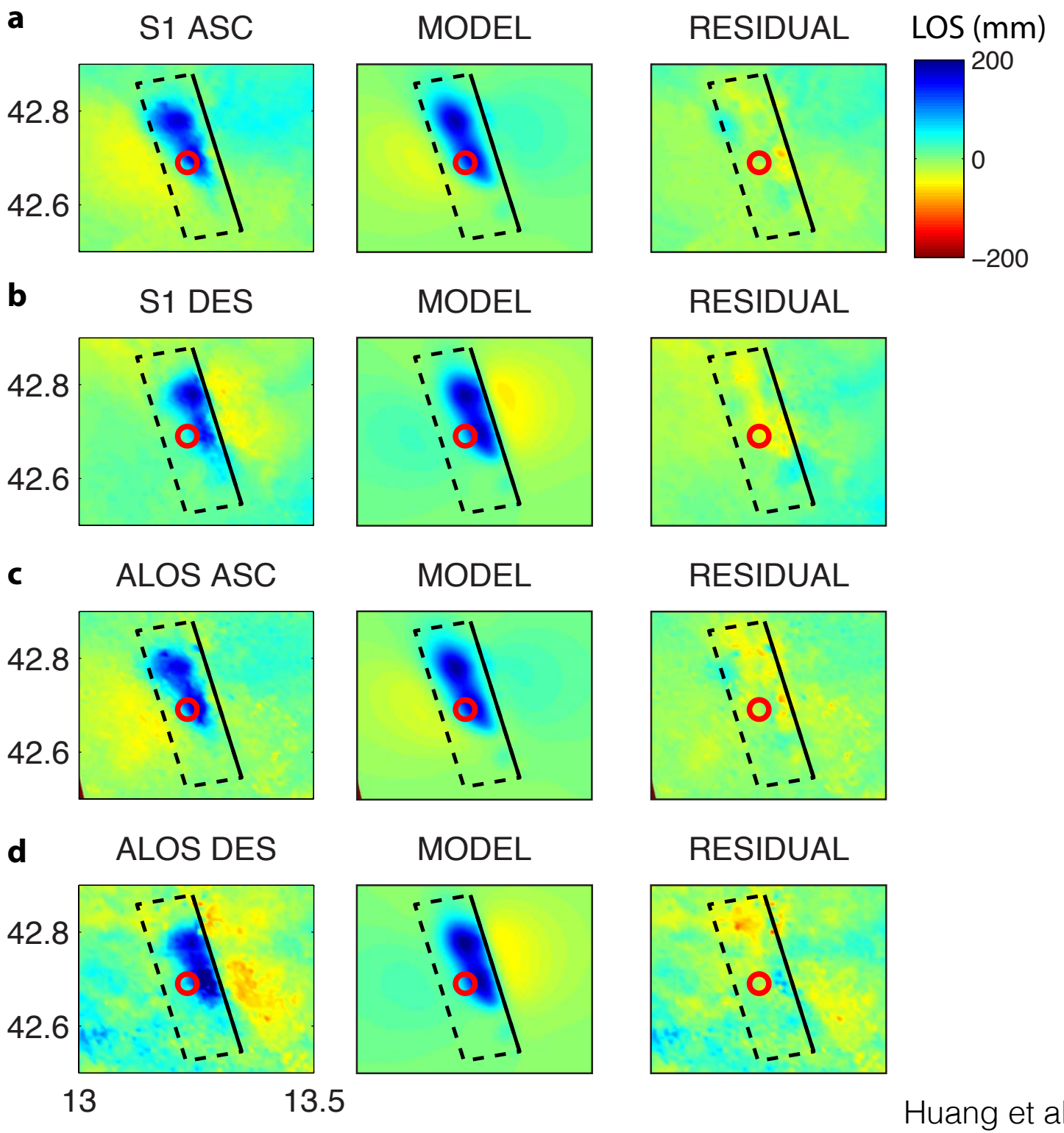
Huang et al., under review


Up - Down
East - West
13°00'
13°06'
13°12'
13°18'
13°24'
13°30'
43°00'
42°54'
42°48'
42°42'
42°36'
42°30'
10 mm data
30 mm data
Castelluccio
Norcia
Arquata del Tronto
Amatrice
Vertical displacement (cm)
EW displacement (cm)
−20 −16 −12 −8 −4 0 4 8 12 16 20
Huang et al., under review

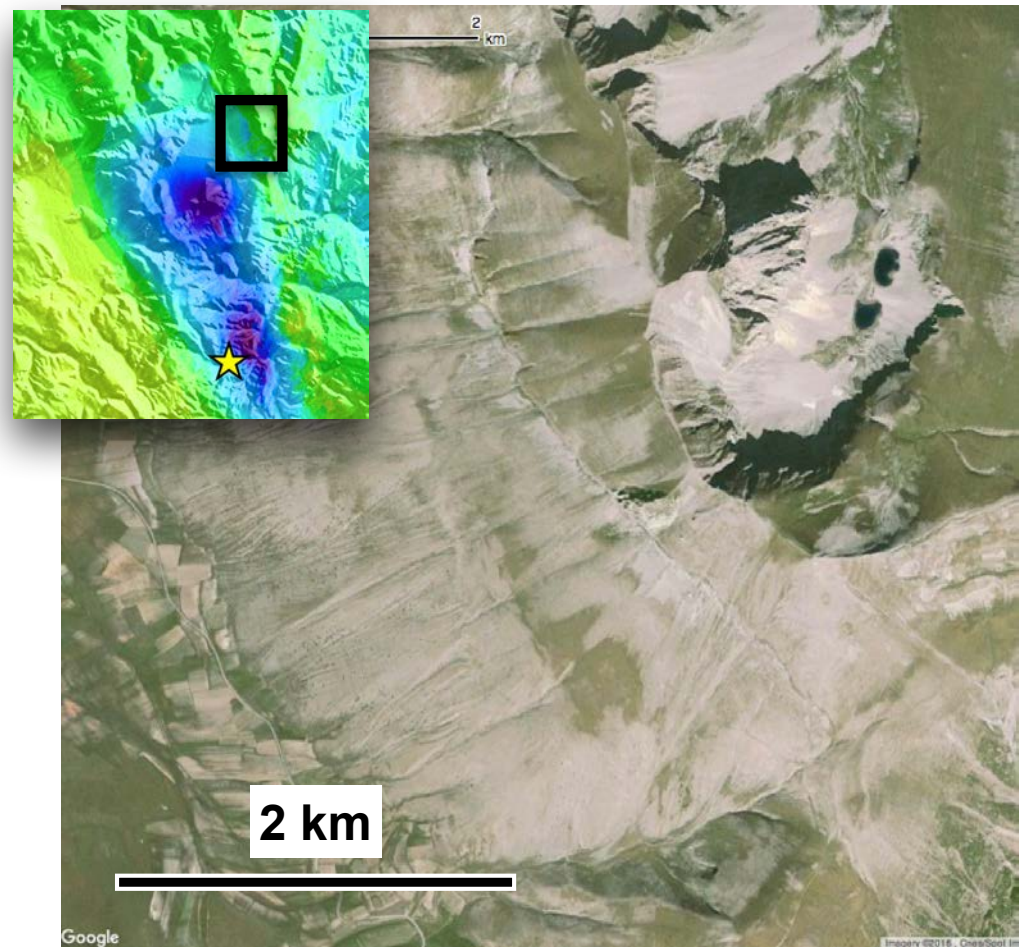
Fault Geometry and Slip based on GPS and InSAR

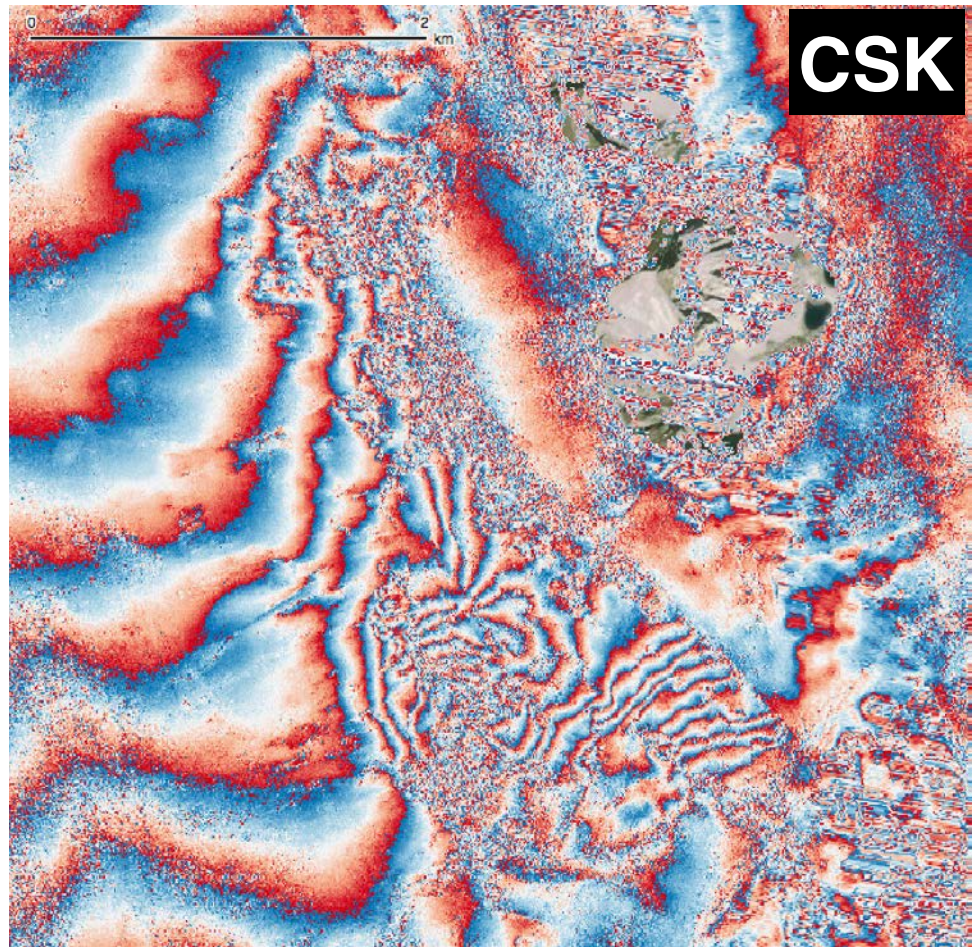


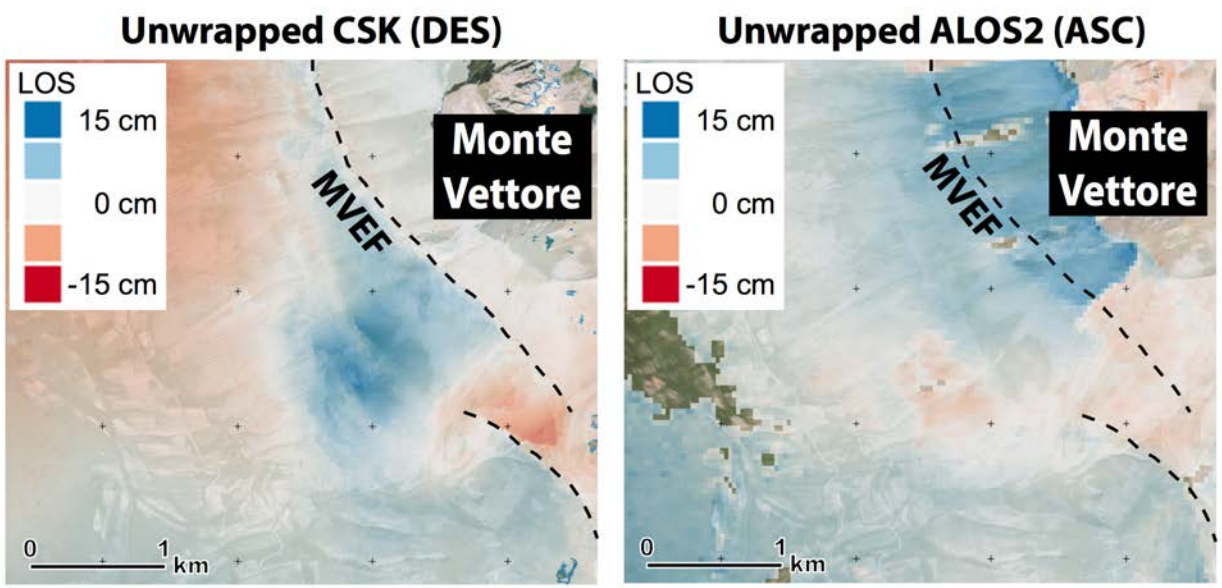
Huang et al., under review



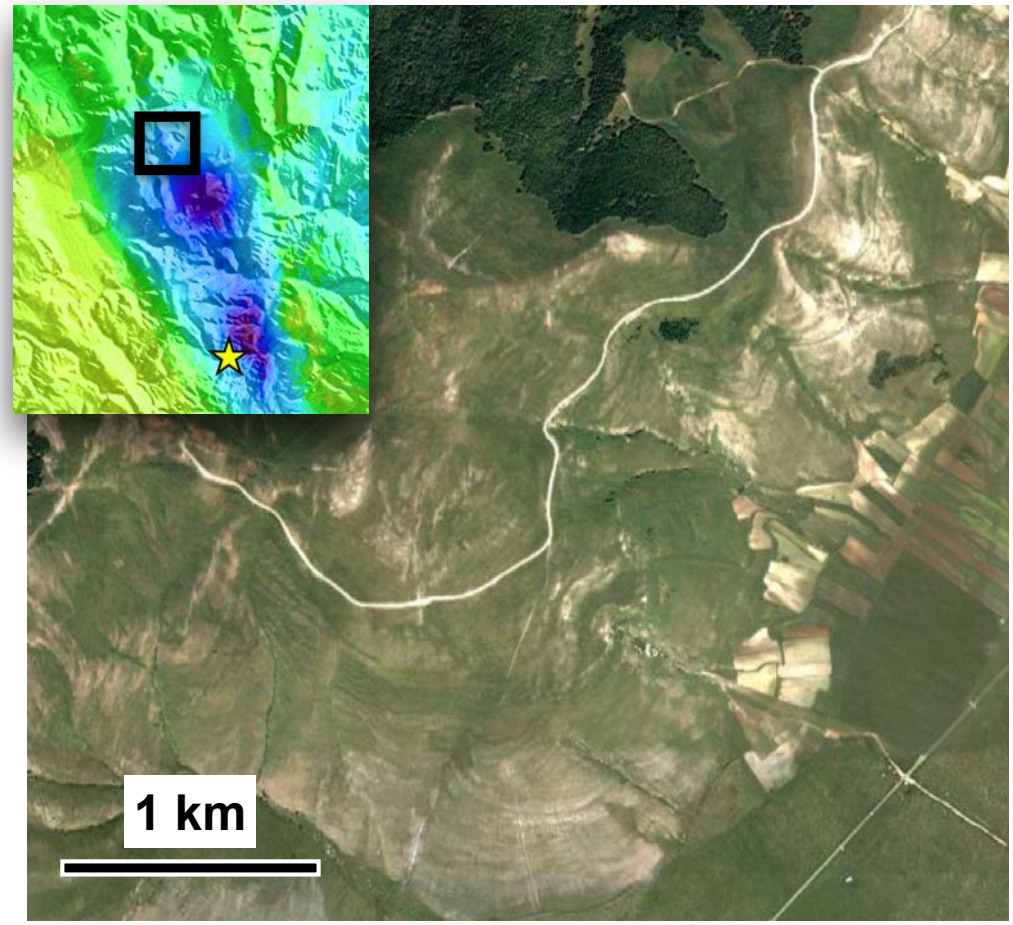
Huang et al., under review

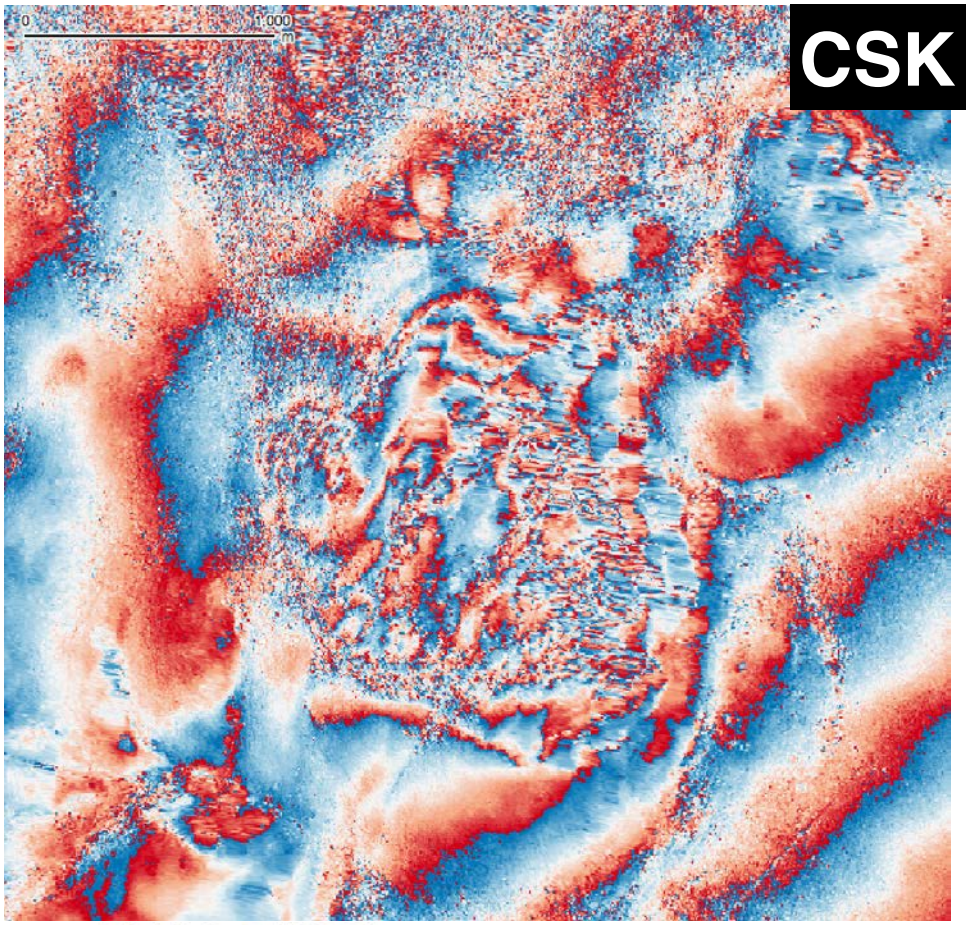




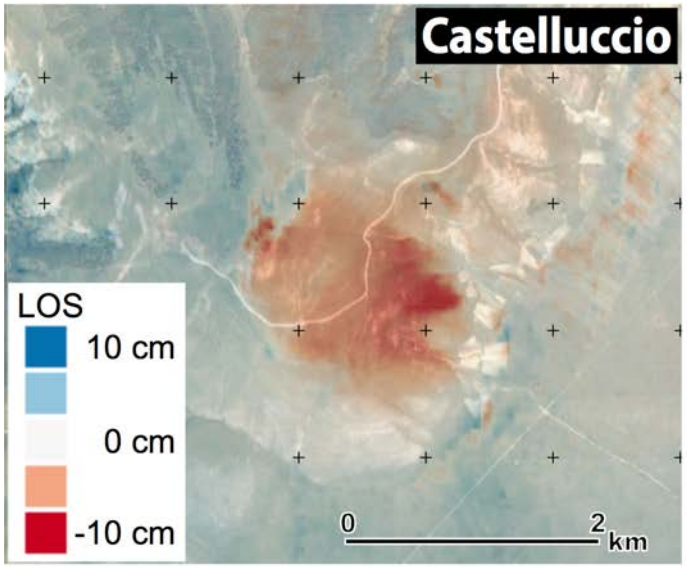


Huang et al., under review

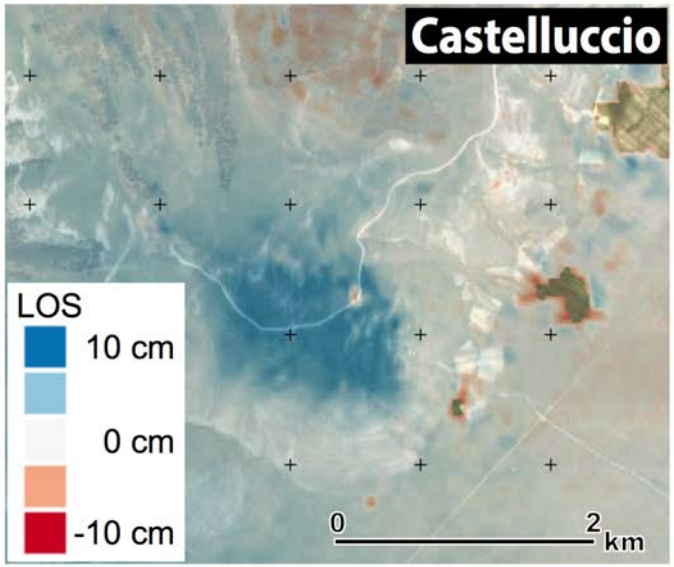




Unwrapped ALOS-2 (DES)

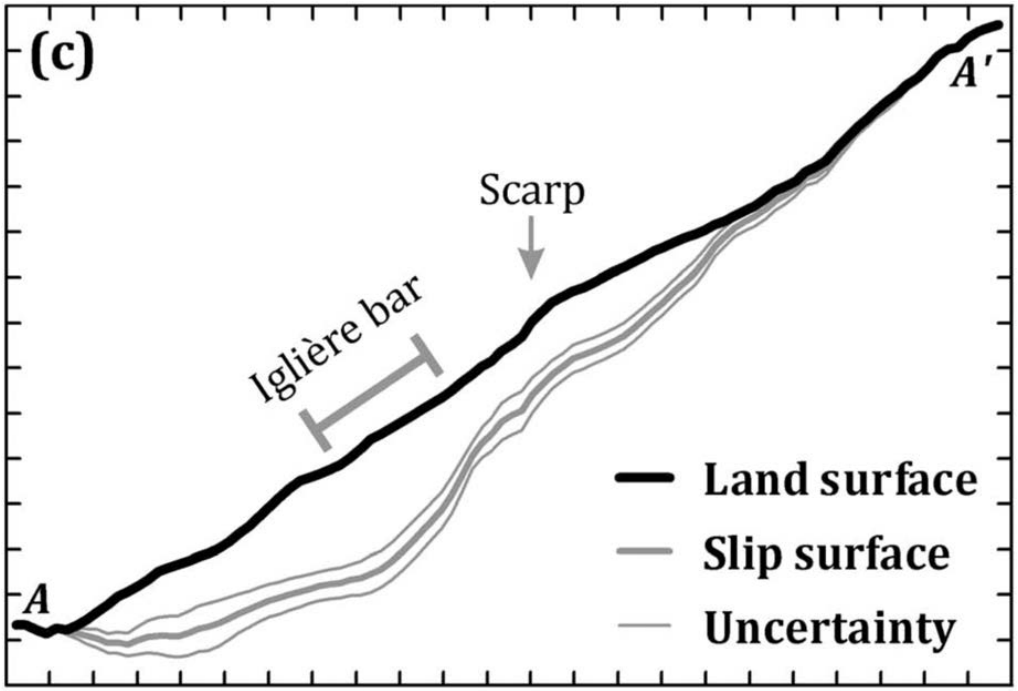


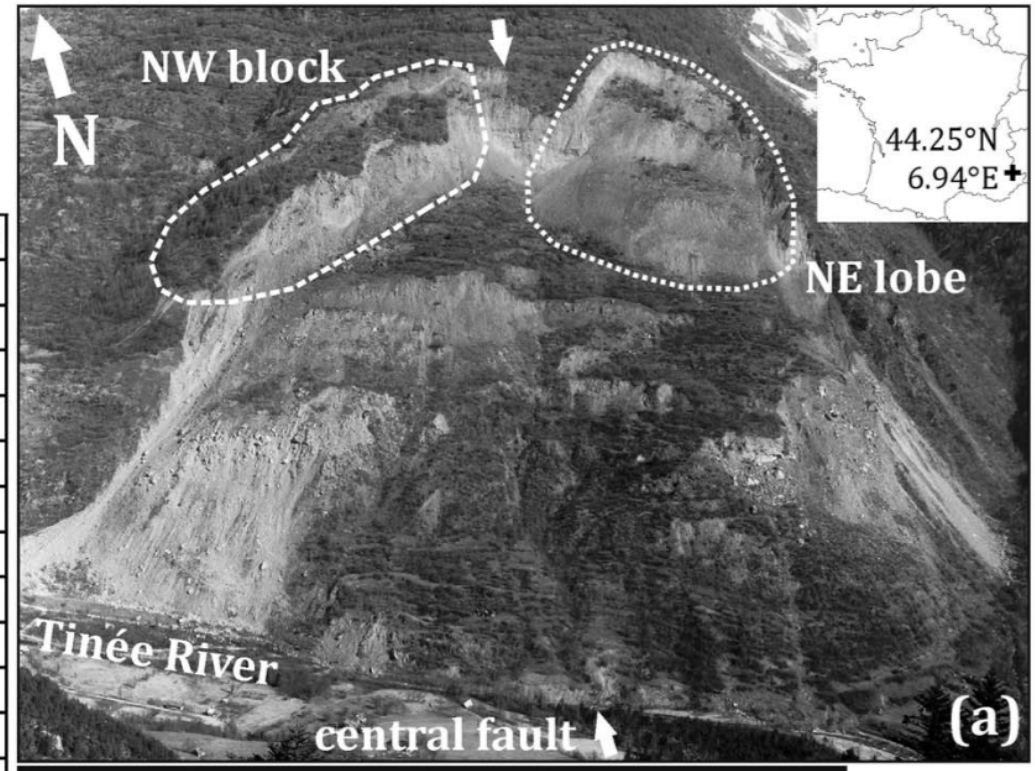
Unwrapped ALOS-2 (ASC)

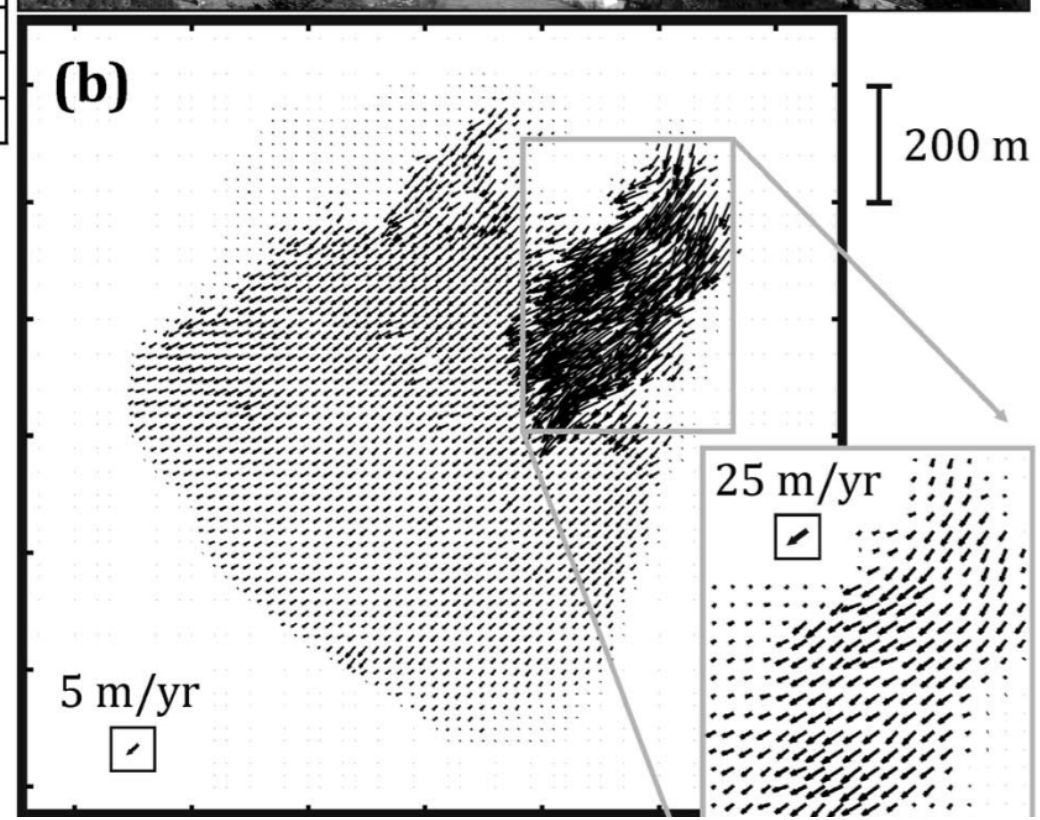


Huang et al., under review

Landslide modeling



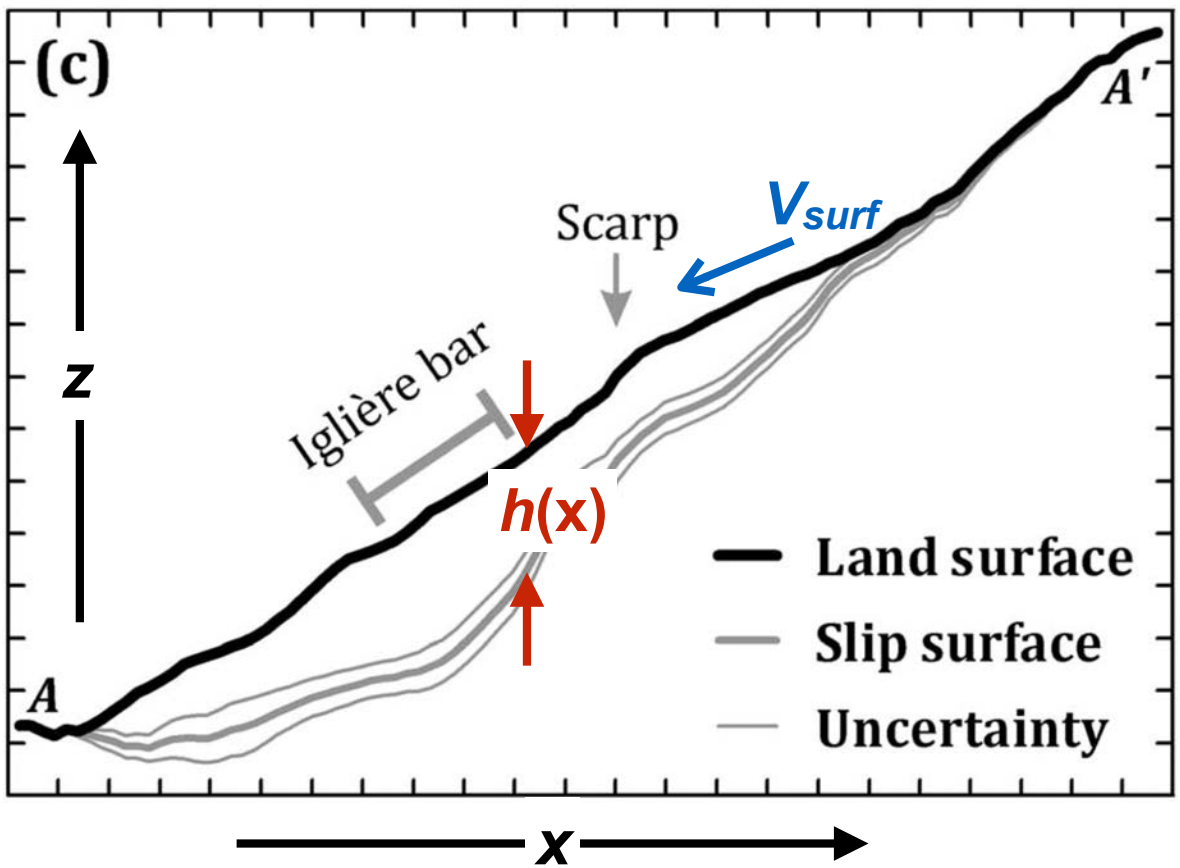




Booth et al., GRL, 2013

$$\frac{\partial z}{\partial t} = -\vec{\nabla} \cdot \left(f \vec{v}_{surf} h \right)$$

$$\Delta z_i = \frac{1}{-2\Delta x} \left[\Delta u_i f \left(h_{i+1} - h_{i-1} \right) + \left(\Delta u_{i+1} - \Delta u_{i-1} \right) f h_i \right],$$



Lowering Thickness

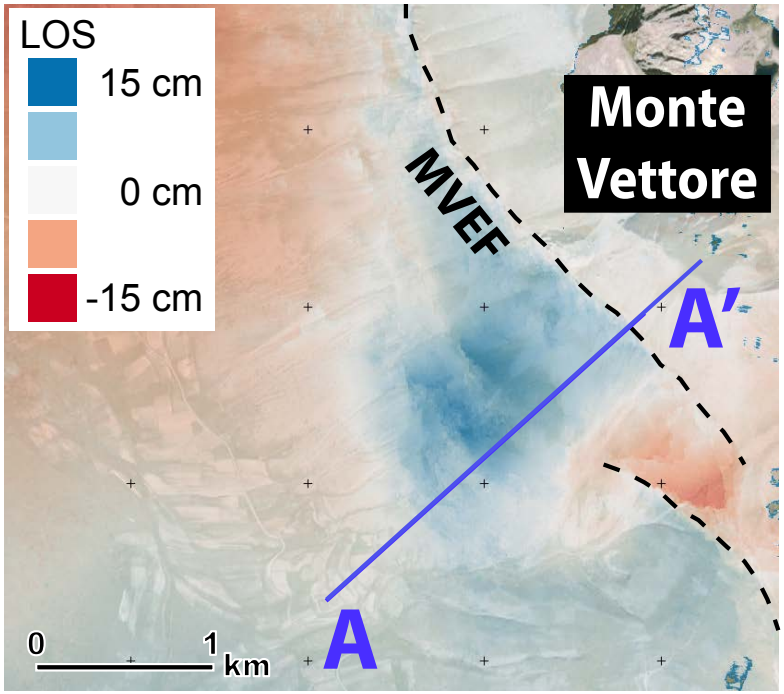
$$\begin{bmatrix} \Delta z_1 \\ \vdots \\ \Delta z_i \\ \vdots \\ \Delta z_N \end{bmatrix} = \boldsymbol{G} \begin{bmatrix} h_1 \\ \vdots \\ h_i \\ \vdots \\ h_N \end{bmatrix},$$

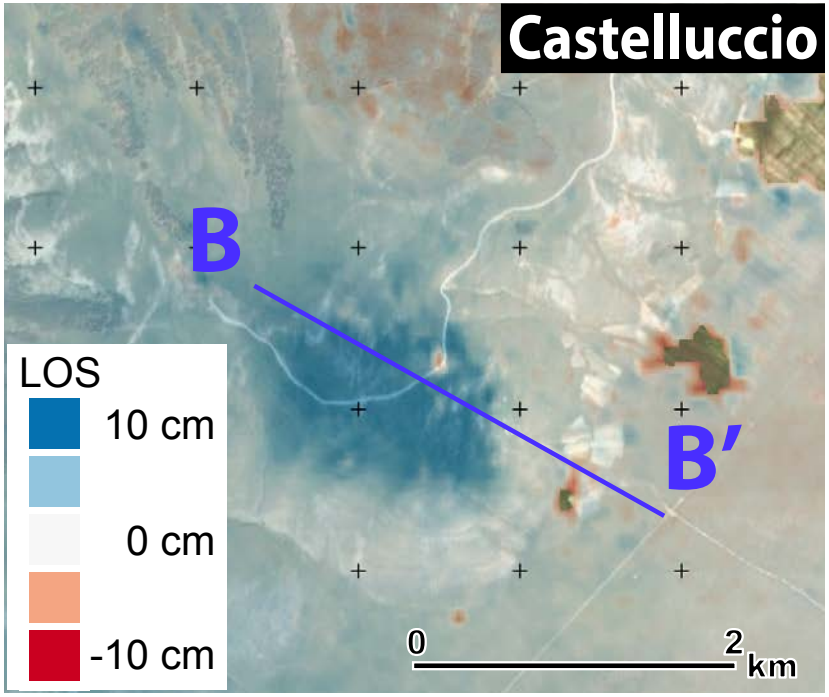
$$\boxed{\boldsymbol{h}^{est} = \left(\boldsymbol{G}^T \boldsymbol{G} + \kappa^2 \boldsymbol{L}^T \boldsymbol{L} \right)^{-1} \boldsymbol{G}^T \Delta \boldsymbol{z}}$$

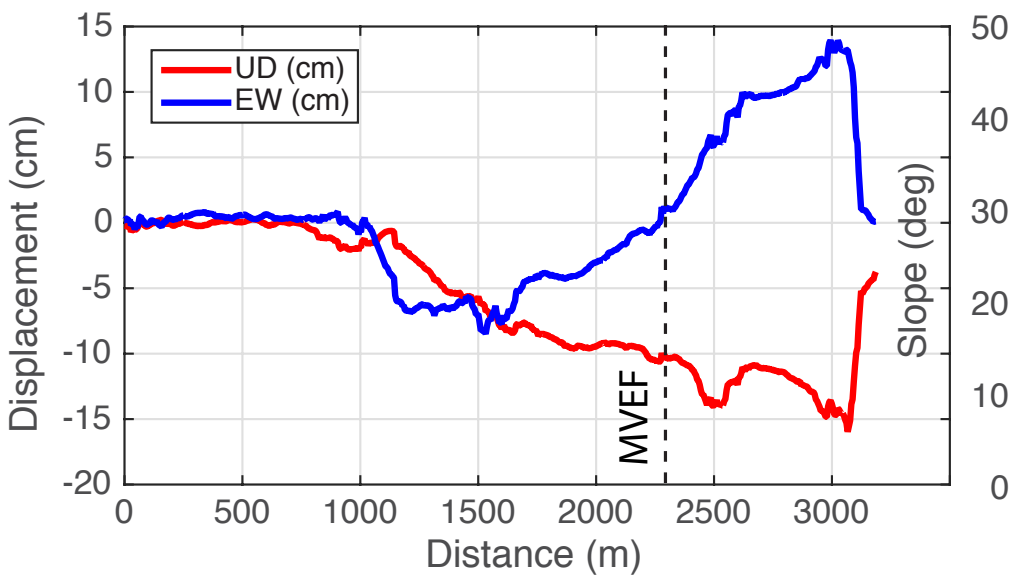
Estimated thickness

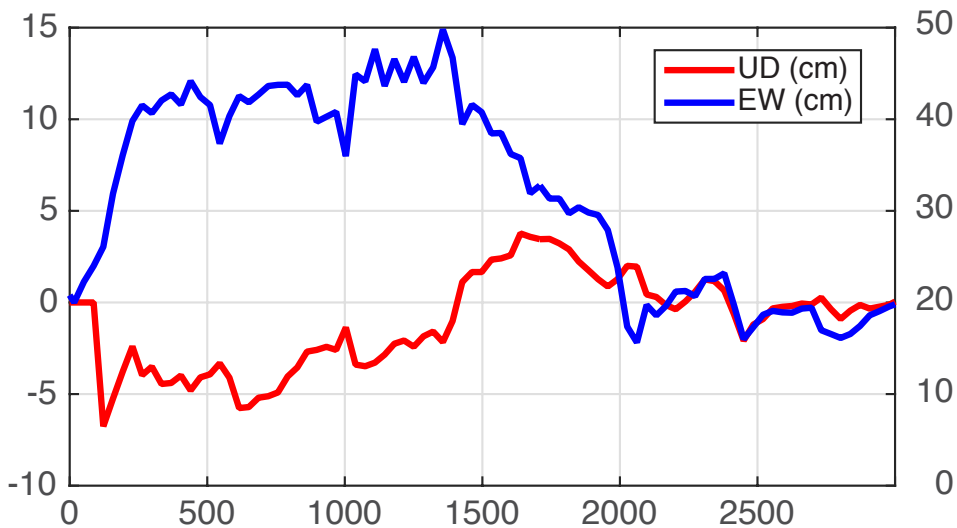
Smoothing

Booth et al., GRL, 2013

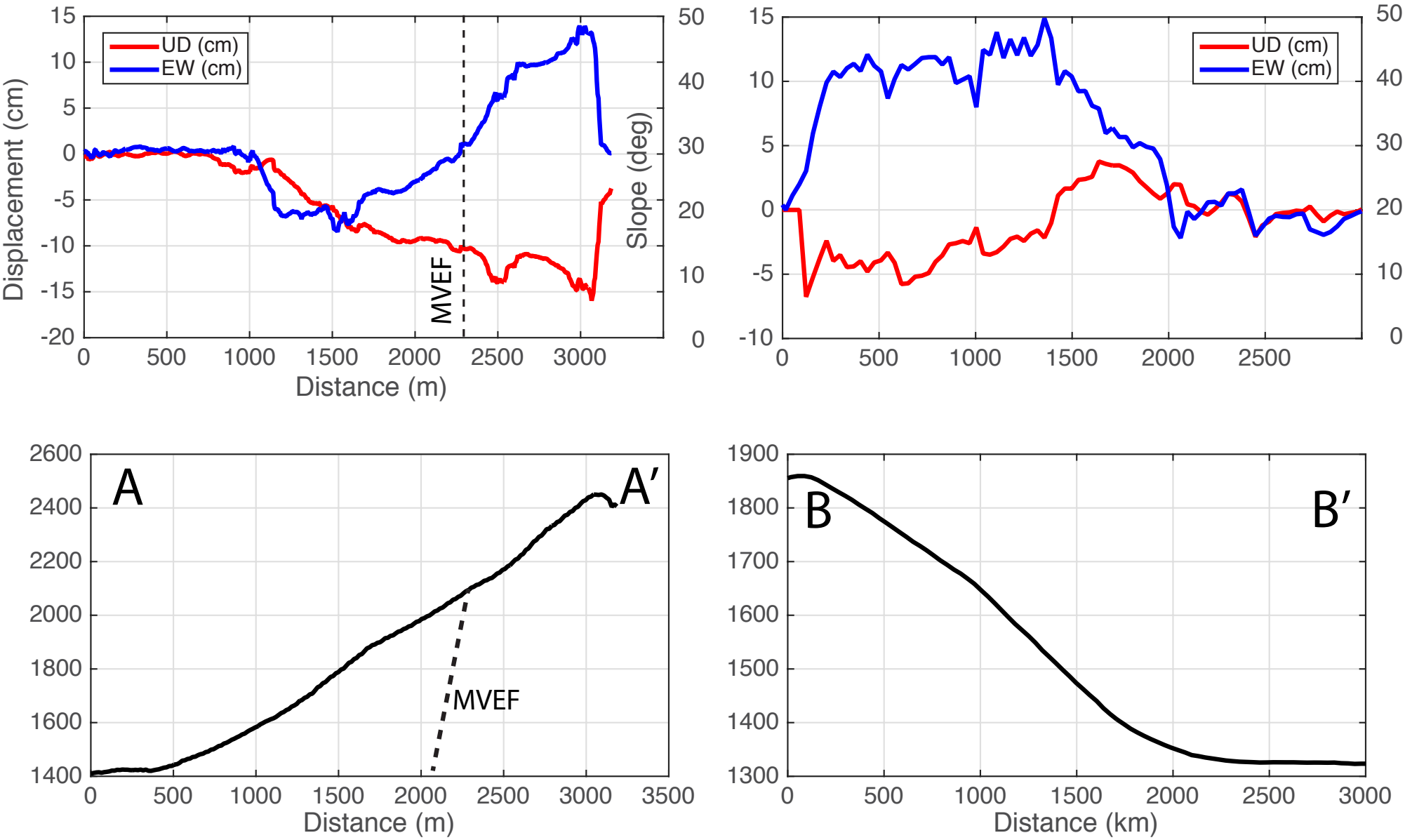




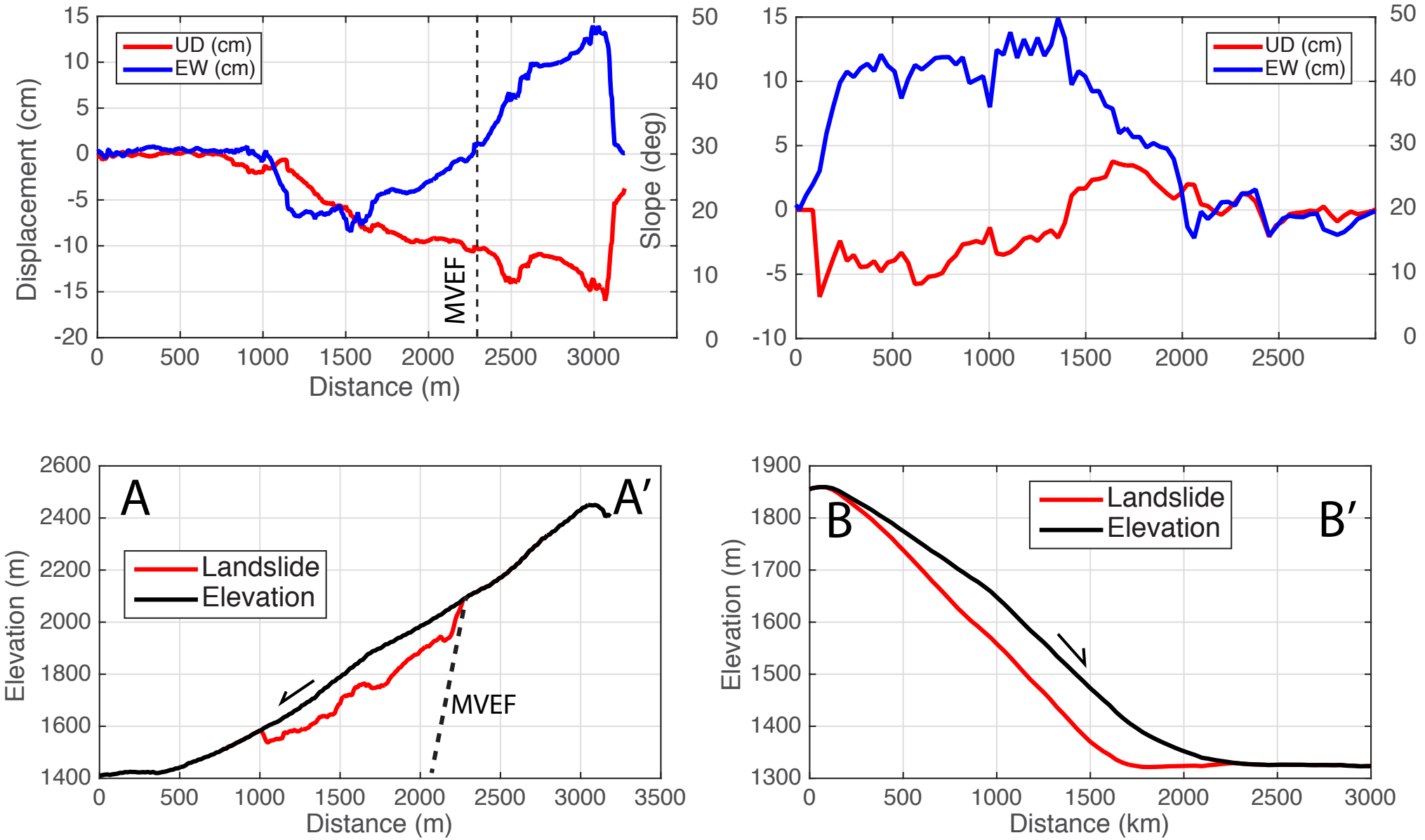




Huang et al., under review

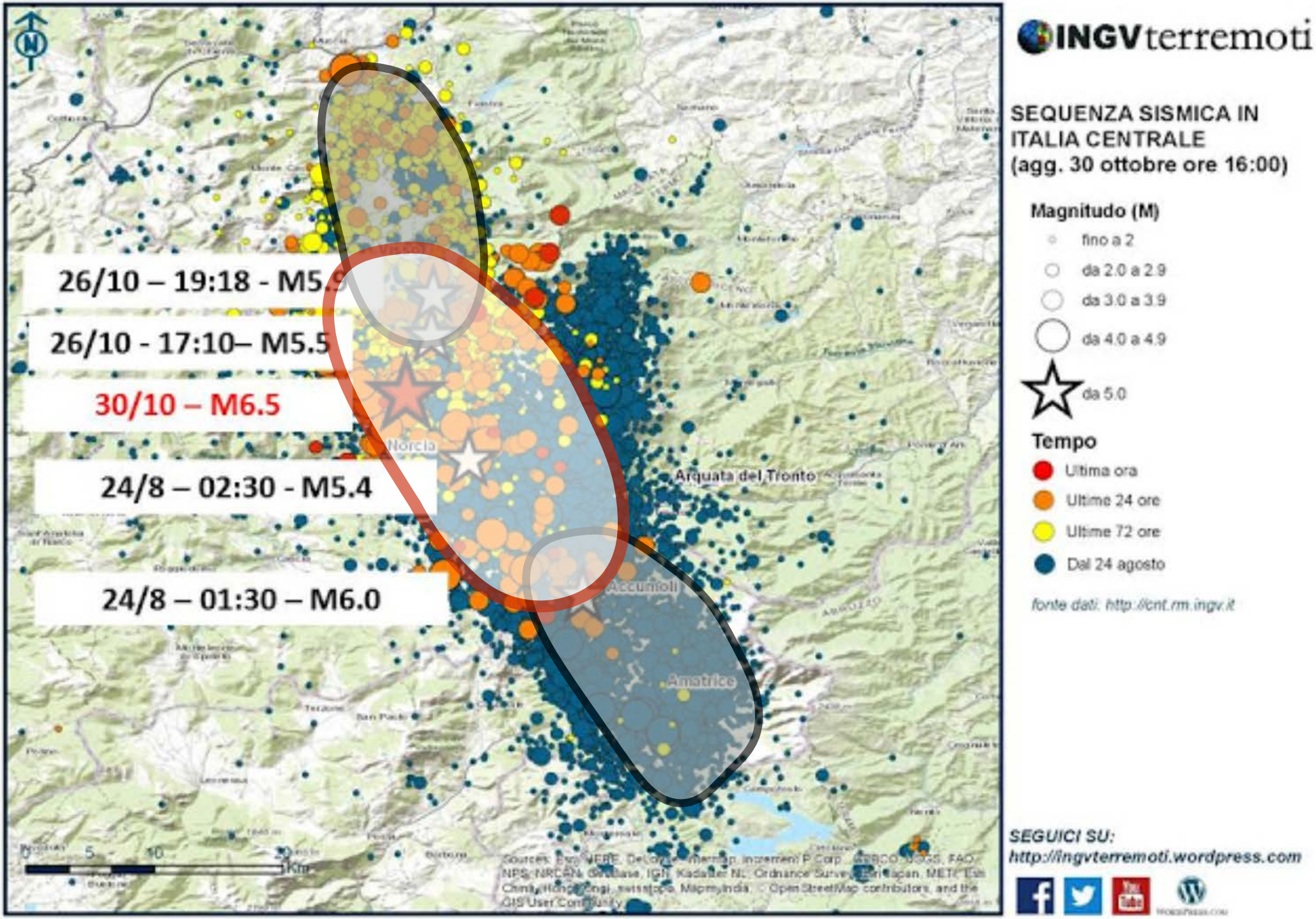


Huang et al., under review



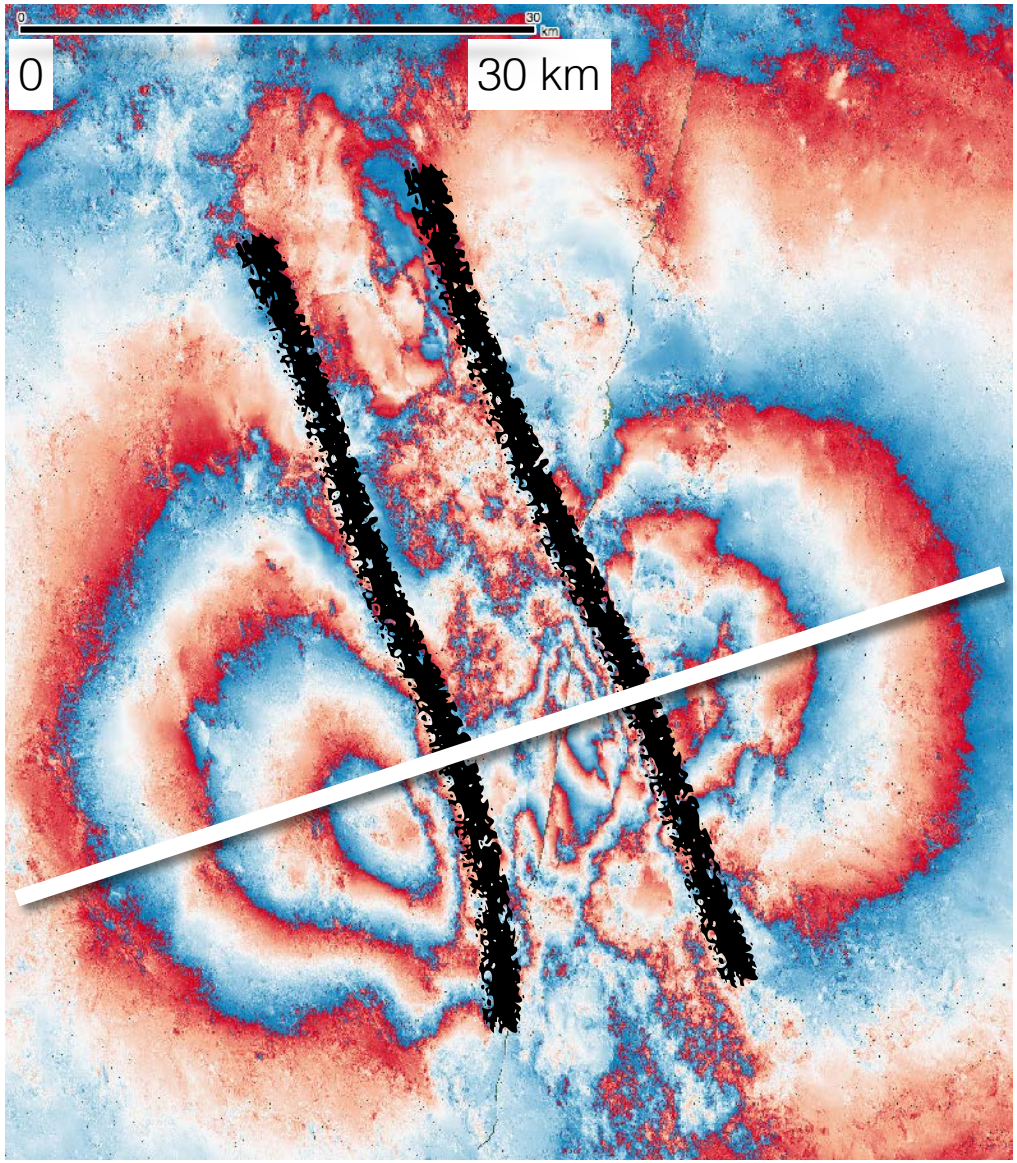
Huang et al., under review

The 30 Nov. 2016 M_w 6.4 Norcia EQ

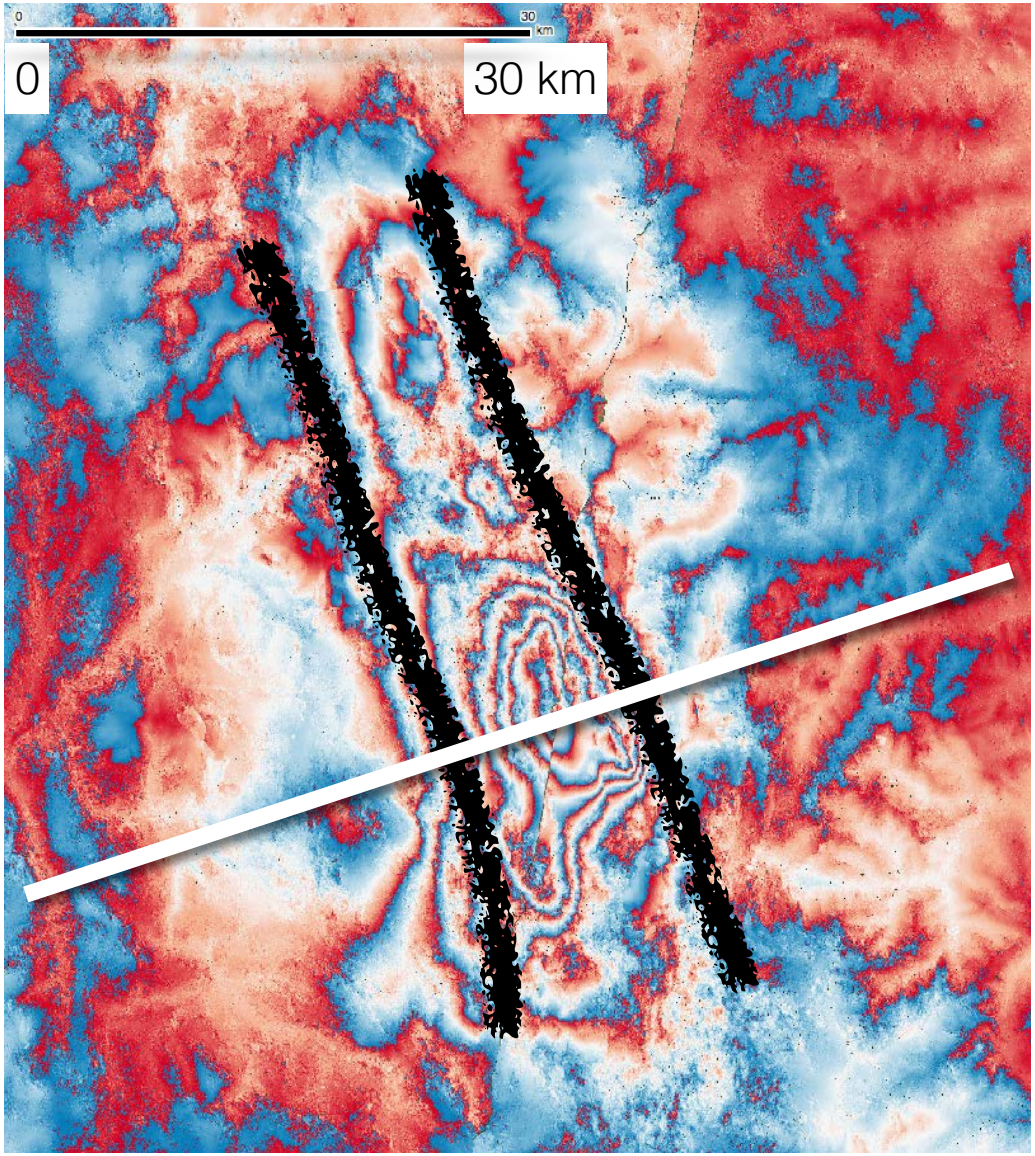


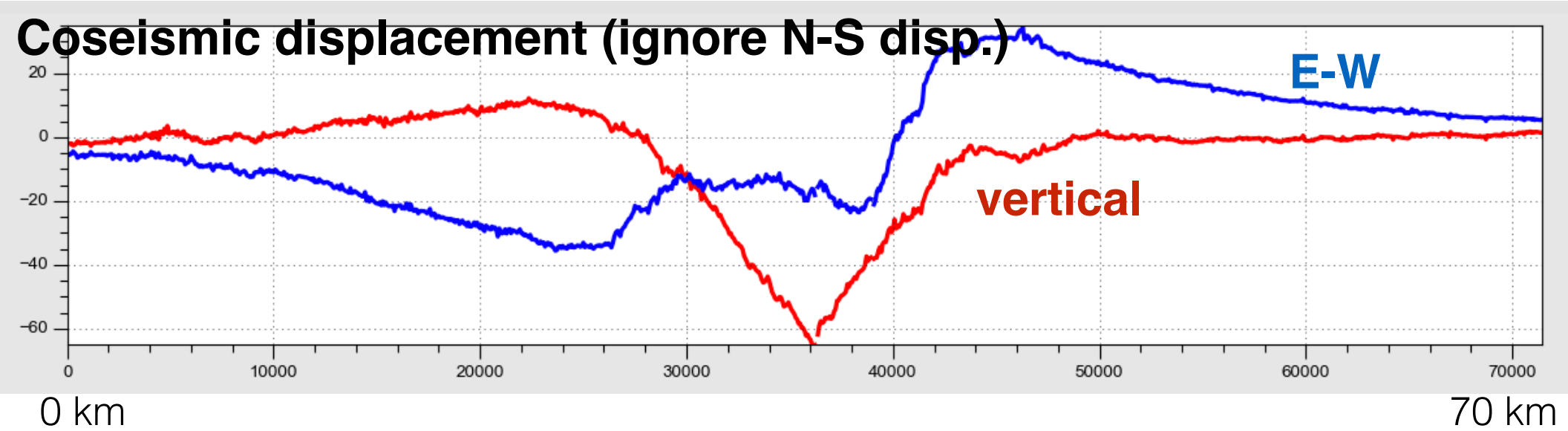
Sentinel-1 InSAR (re-wrapped to 10 cm/fringe)

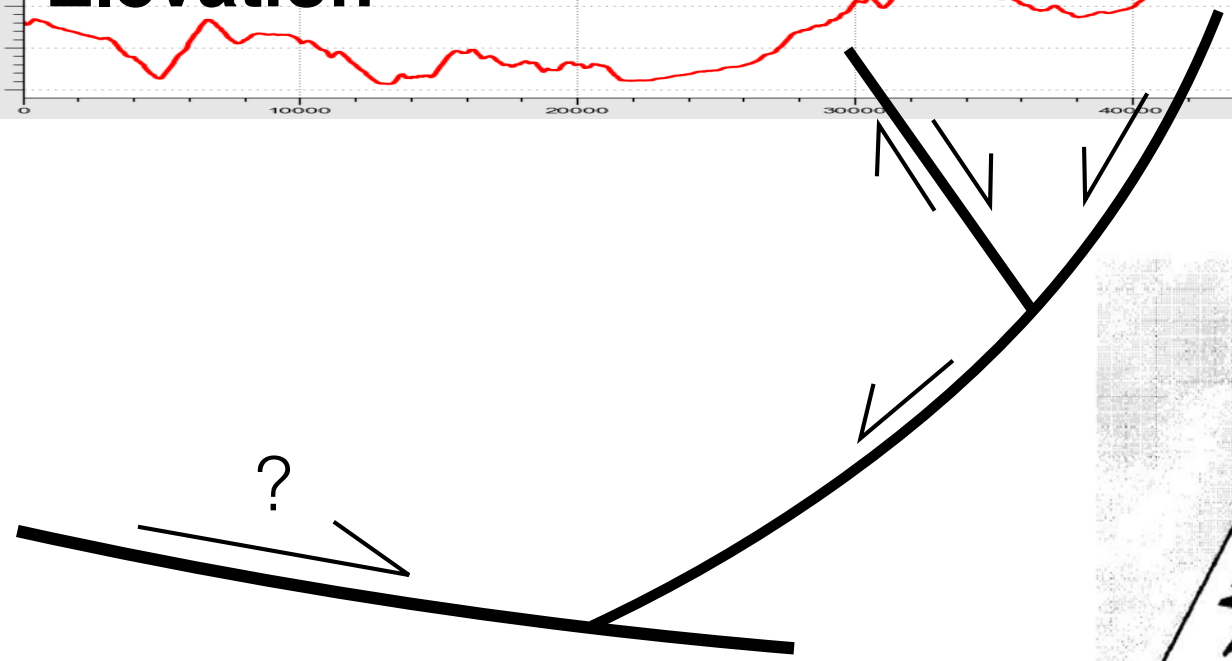
East - West

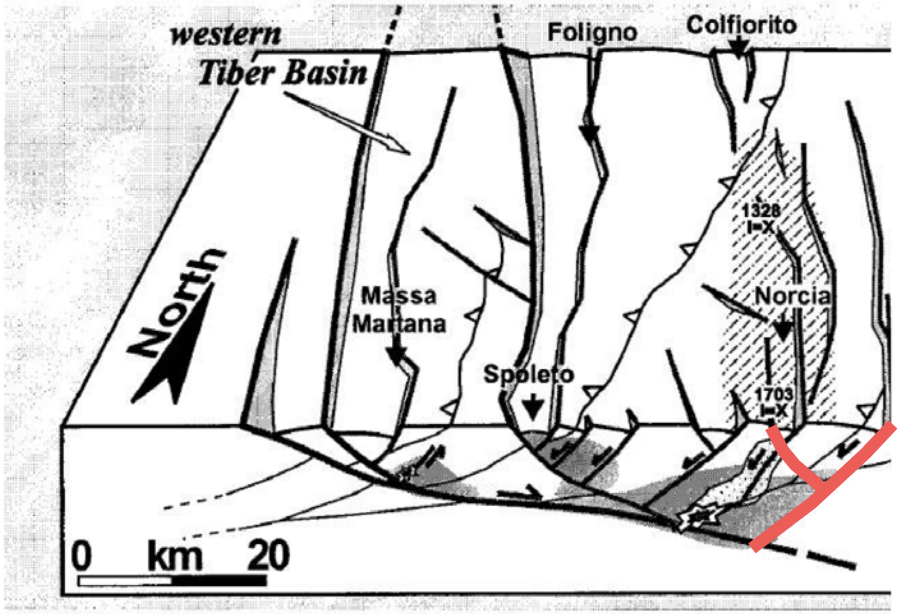


Up - Down

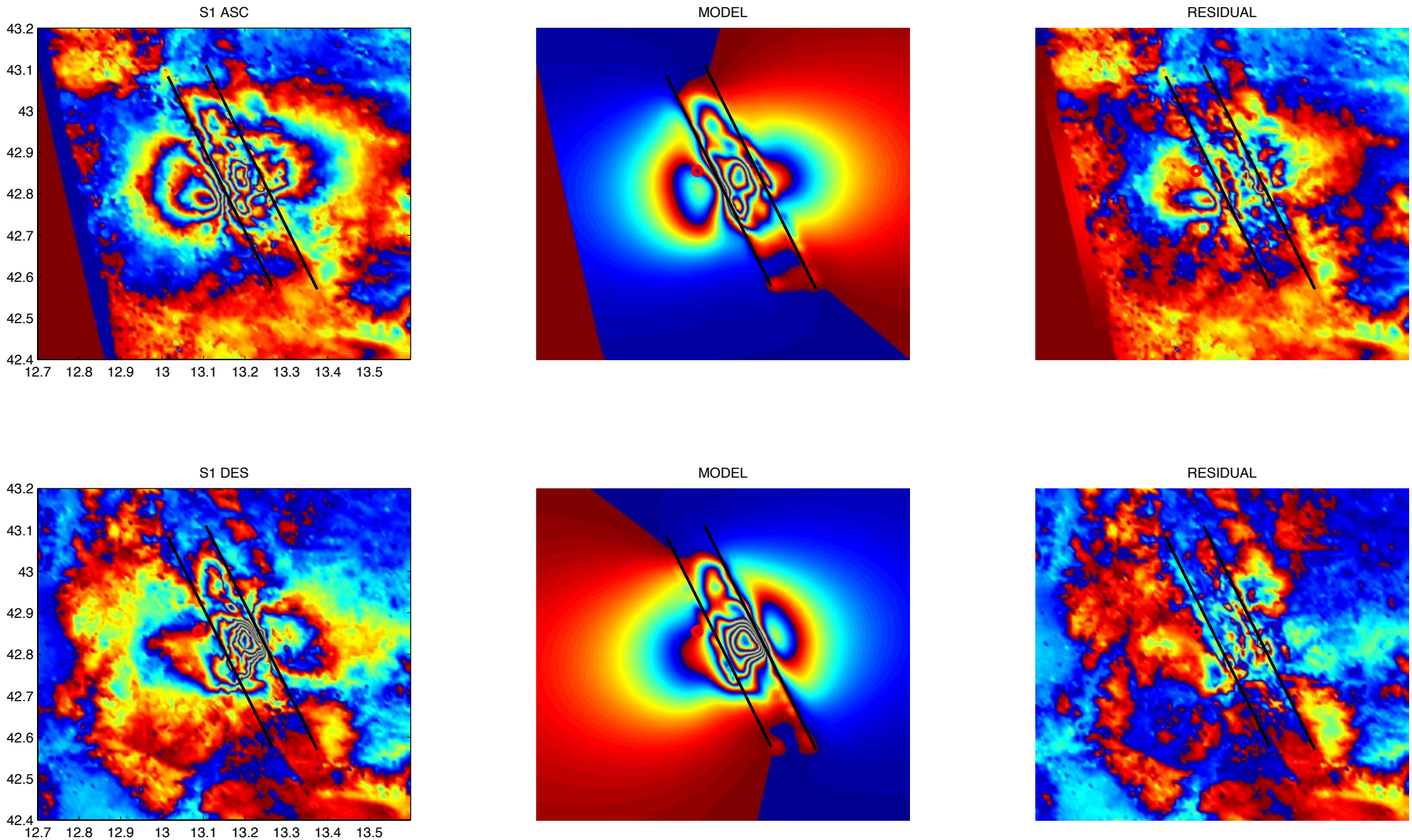



Coseismic displacement (ignore N-S disp.)
E-W
vertical
20
0
-20
-40
-60
0
10000
20000
30000
40000
50000
60000
70000
0 km
70 km
Elevation
2000
1500
1000
500


?


western
Tiber Basin
Foligno
Colfiorito
North
Massa
Martana
Spoleto
1328
I=X
Norcia
1703
I=X
0 km 20

Re-wrap to 10 cm/fringe



Summary-I

1. Nearly all of the slip occurred between 3 and 5 km depth but extends about 20 km along strike with two distinct slip asperities.

2. At least two triggered landslides east and west of a slip asperity.

3. The triggered landslide on the Mt. Vettore fault may contribute additional fault offset and could influence the long-term fault slip rate.

Summary-II

1. The coseismic subsidence is within the graben structure in the Apennines

2. Evidences of a conjugate normal fault system with shallow (~30° - 40°) dip angles.

3. May need a detachment below the normal fault system to explain InSAR measurements.