Merging GPS and InSAR for uniform velocity

- LOS Velocity
  - GPS provides long wavelengths (> 40 km) and InSAR provides short wavelengths
  - L-band ALOS-1 provides only one LOS direction but complete coverage.
  - C-band (ERS and Envisat) provides 2 look directions but incomplete coverage.
  - Contributions to CGM - have standard format – at UNAVCO – need more contributions

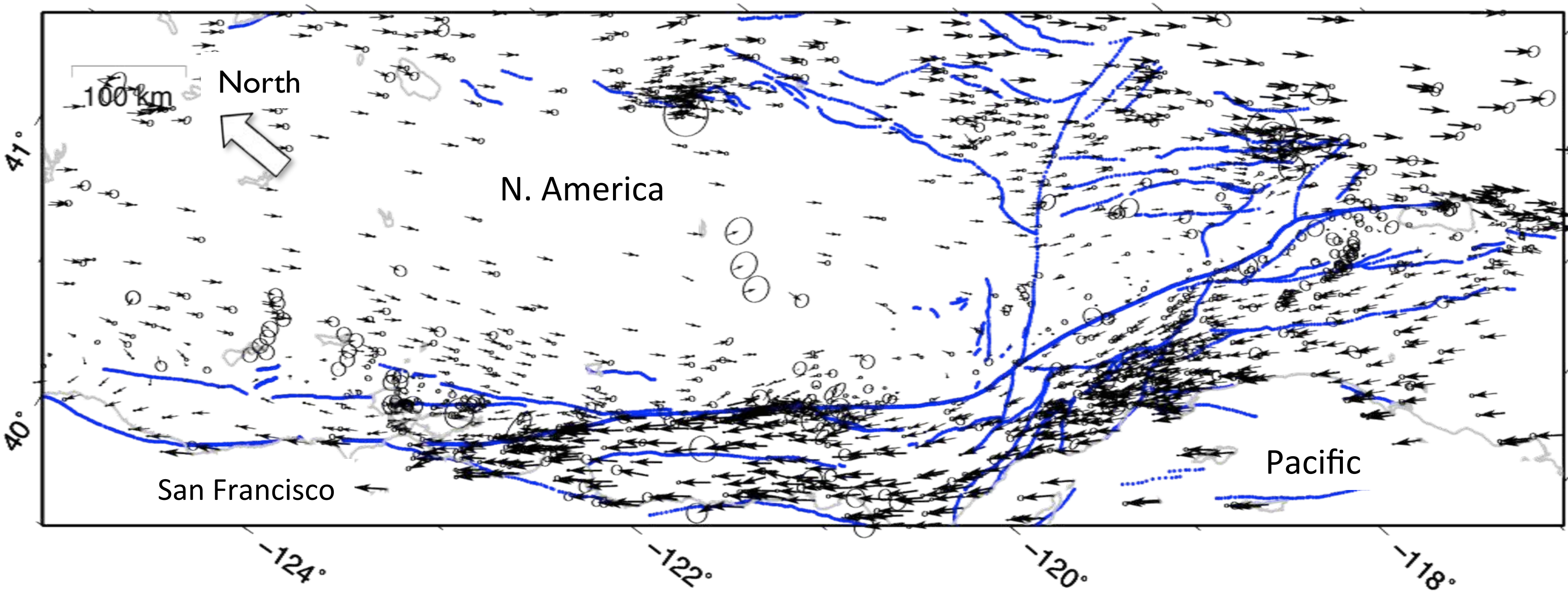
GPS/InSAR Community Geodetic Models

Velocity model based on campaign and continuous (CGPS) plus line-of-sight (LOS) displacement-rate data from stacks of interferograms. Current SoCAL examples:

Tong, X., D. T. Sandwell, and B. Smith-Konter, High-resolution interseismic velocity data along the San Andreas Fault from GPS and InSAR, J. Geophys. Res.; Solid Earth, 118, doi: 10.1029/2012JB009442, 2013.

Lindsey, E. O., Y. Fialko, Y. Bock, D. T. Sandwell, and R. Bilham, Localized and distributed creep along the southern San Andreas Fault, J. Geophys. Res. Solid Earth, 119, 7909–7922, doi:10.1002/2014JB011275, 2014.

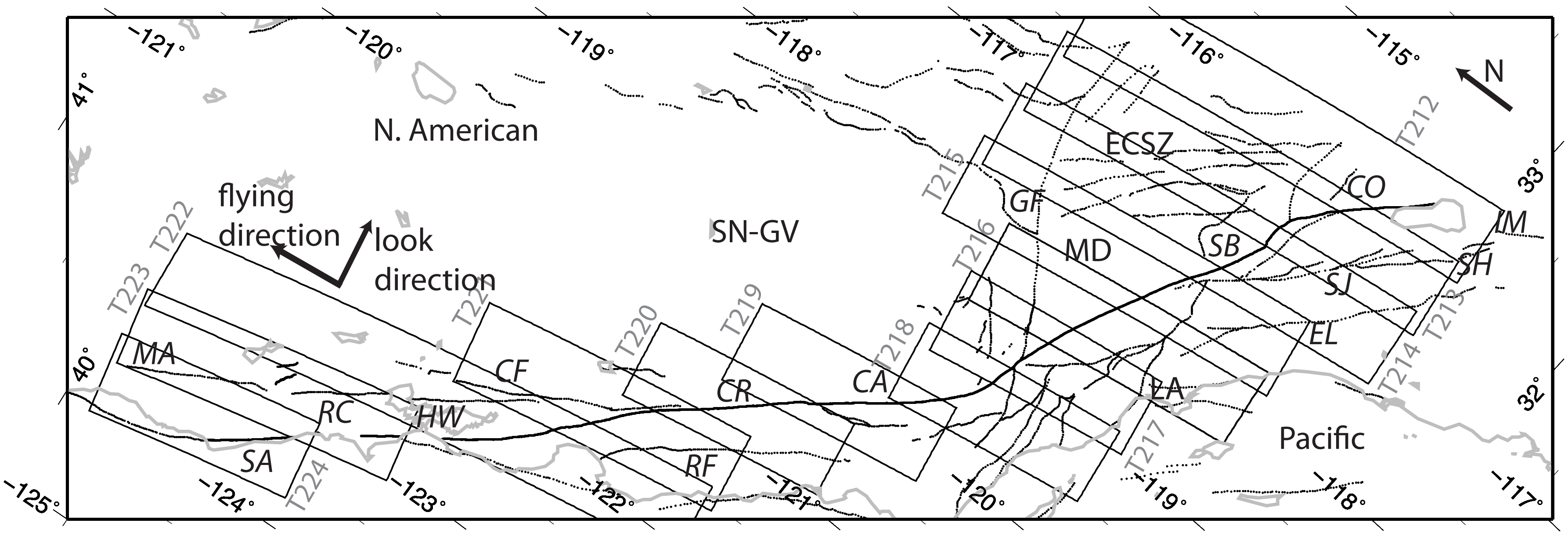
GPS velocity data



- 1989 horizontal velocity measurements from PBO, SCIGN, CMM4
- Combined for UCERF3 exercise [Herring, 2013]
- GPS velocity is initially in North America reference frame, then is rotated and translated [Wdowinski et al., 2007] to be used in the dislocation model

GPS provides high accuracy vector measurements but does not resolve the small-scale (< 20 km).

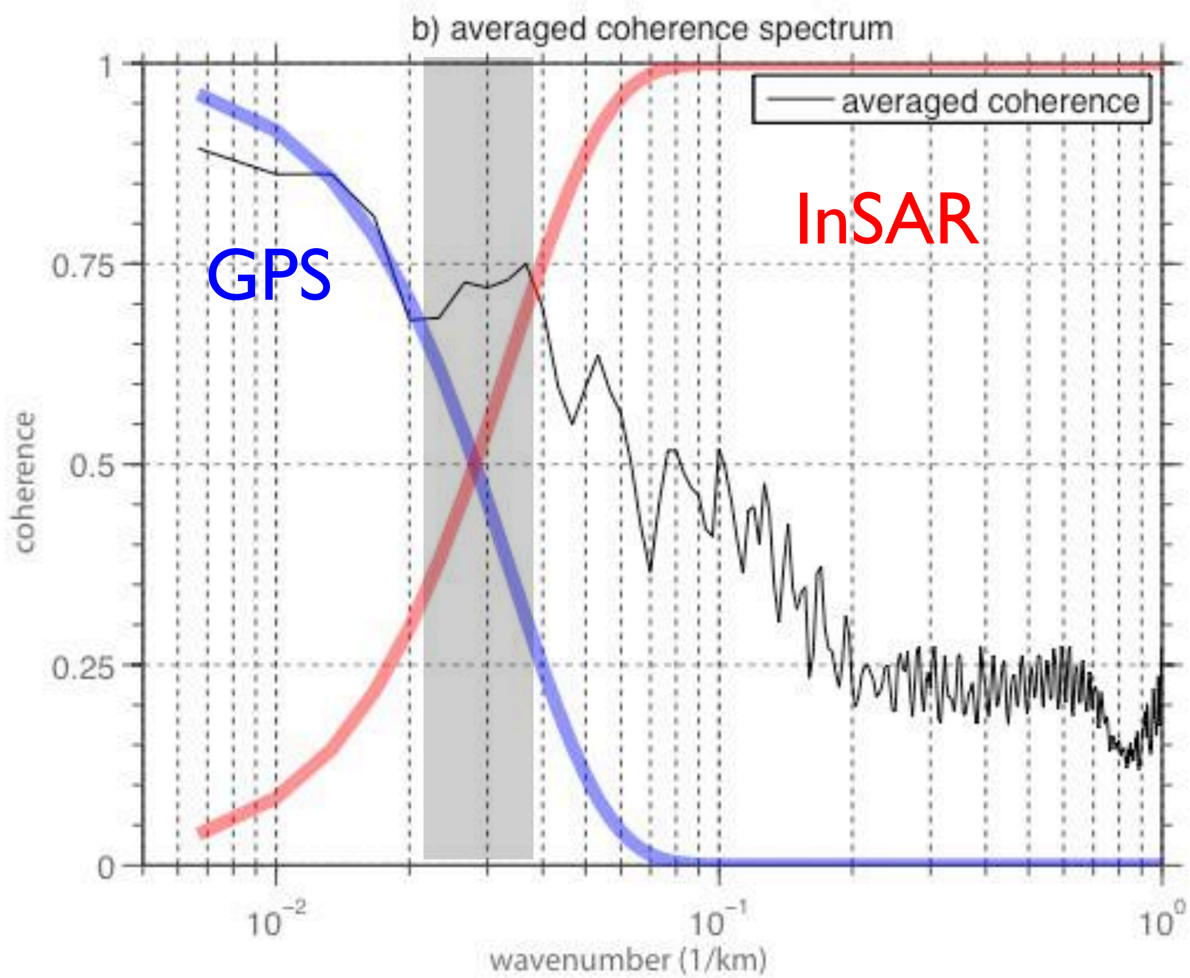
InSAR data from L-band ALOS-1



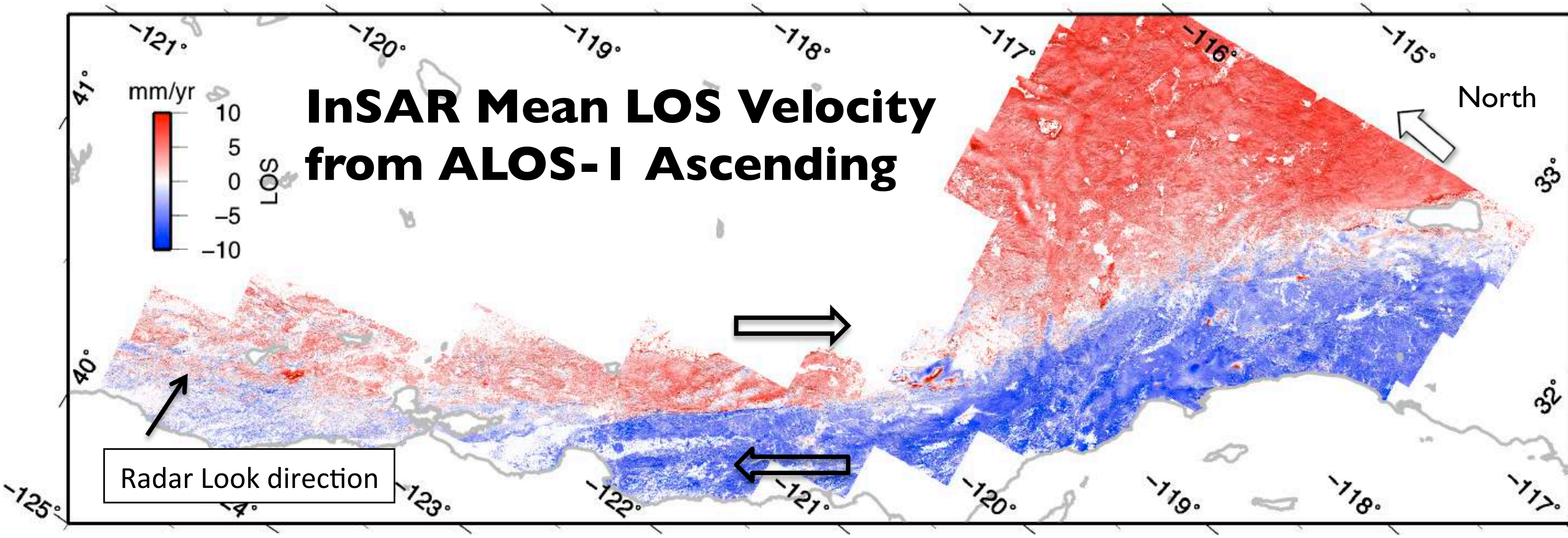
- Time span: middle 2006 to the beginning of 2011
- 14 tracks, 50 frames, 1100 interferograms (~2 TB)
- Data from Alaska Satellite Facility (ASF) and NASA
- Covering the San Andreas Fault system
- Provide Line-of-sight velocity: 35% of plate-boundary deformation

InSAR provides high spatial resolution scalar measurements but has large scale errors.

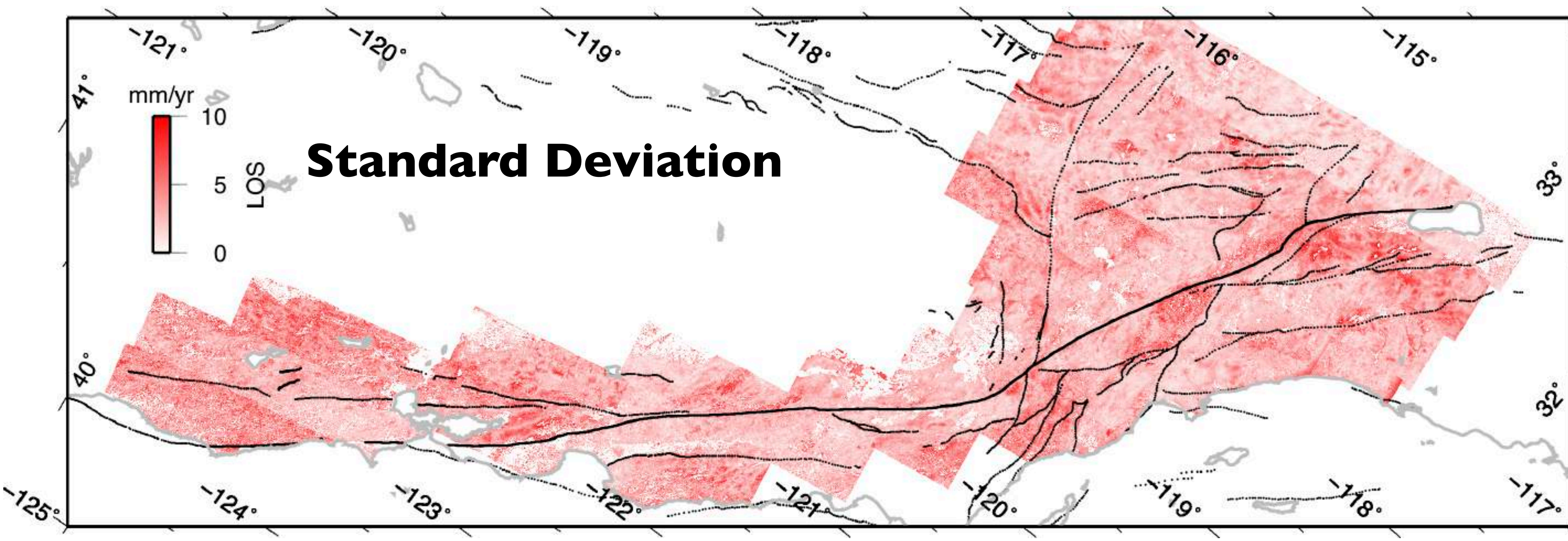
InSAR/GPS Integration Approach



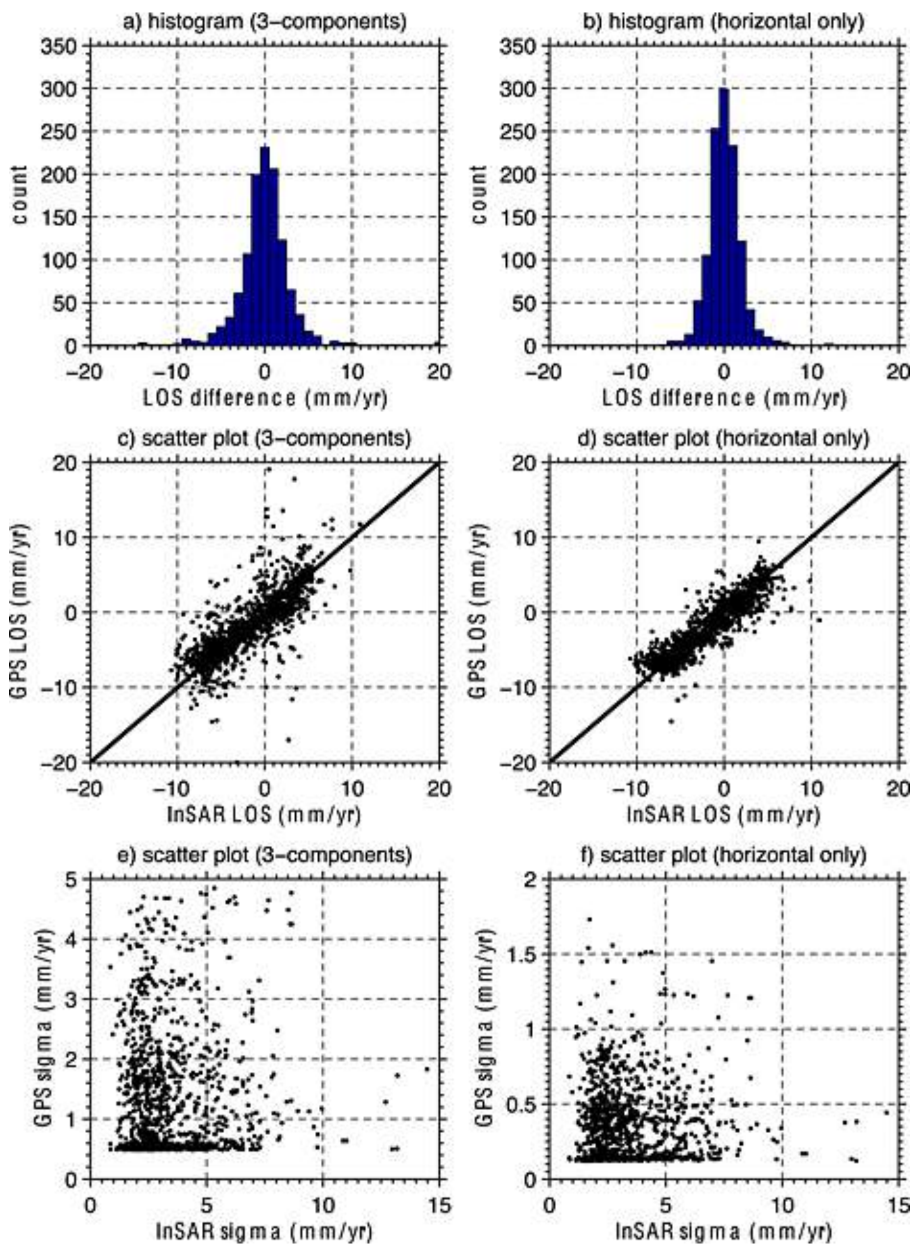
1. Develop a complete surface velocity field based on a kinematic model constrained by GPS secular velocity data.
2. Refine the kinematic model using biharmonic spline correction from GPS misfits.
3. Stack InSAR interferograms to derive an InSAR secular velocity.
4. Remove the GPS model from the InSAR velocity
5. High-pass filter the InSAR residual velocity.
6. Restore the GPS model to the InSAR residual velocity.



[Tong et al., 2012]



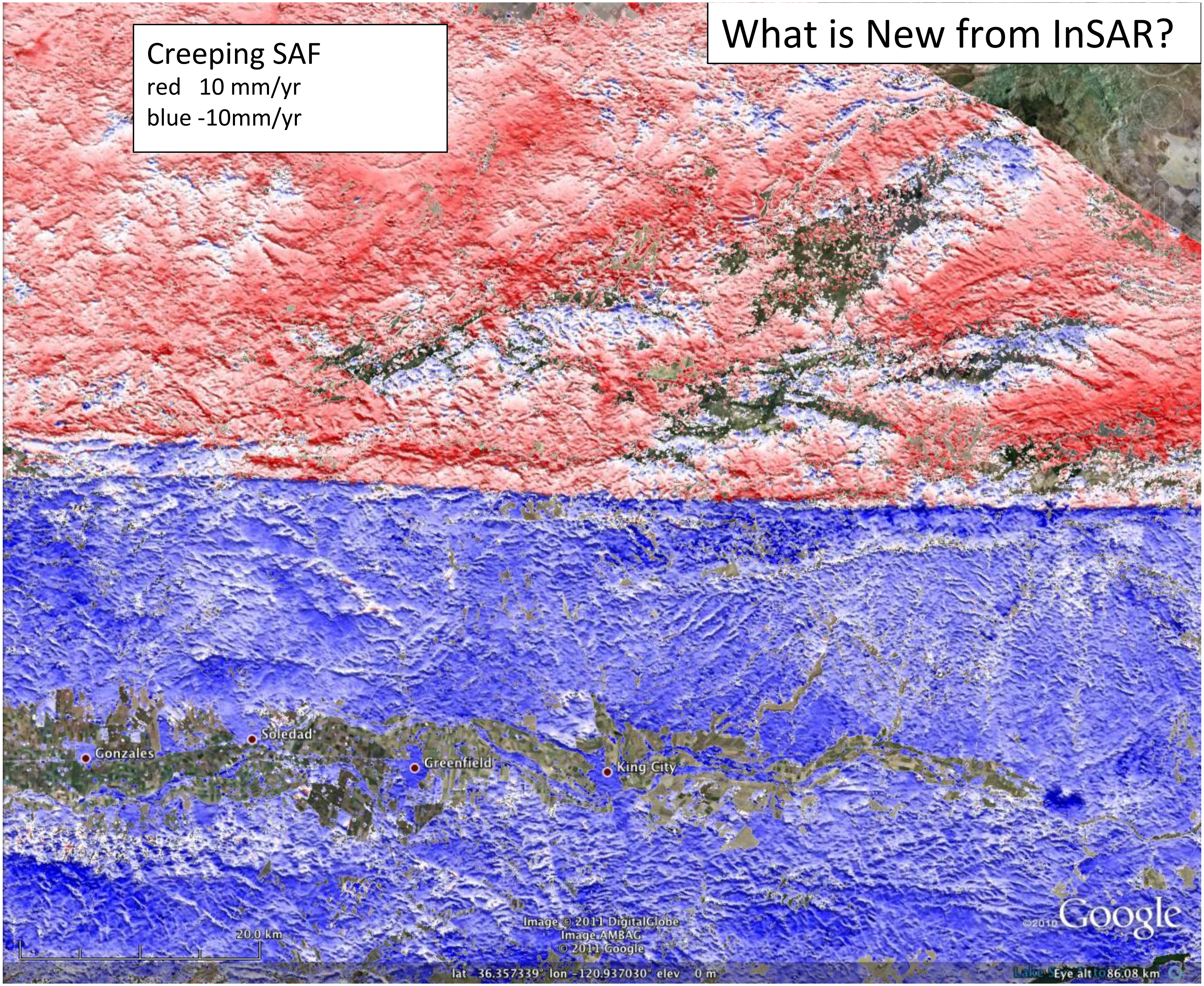
Misfit of InSAR to GPS



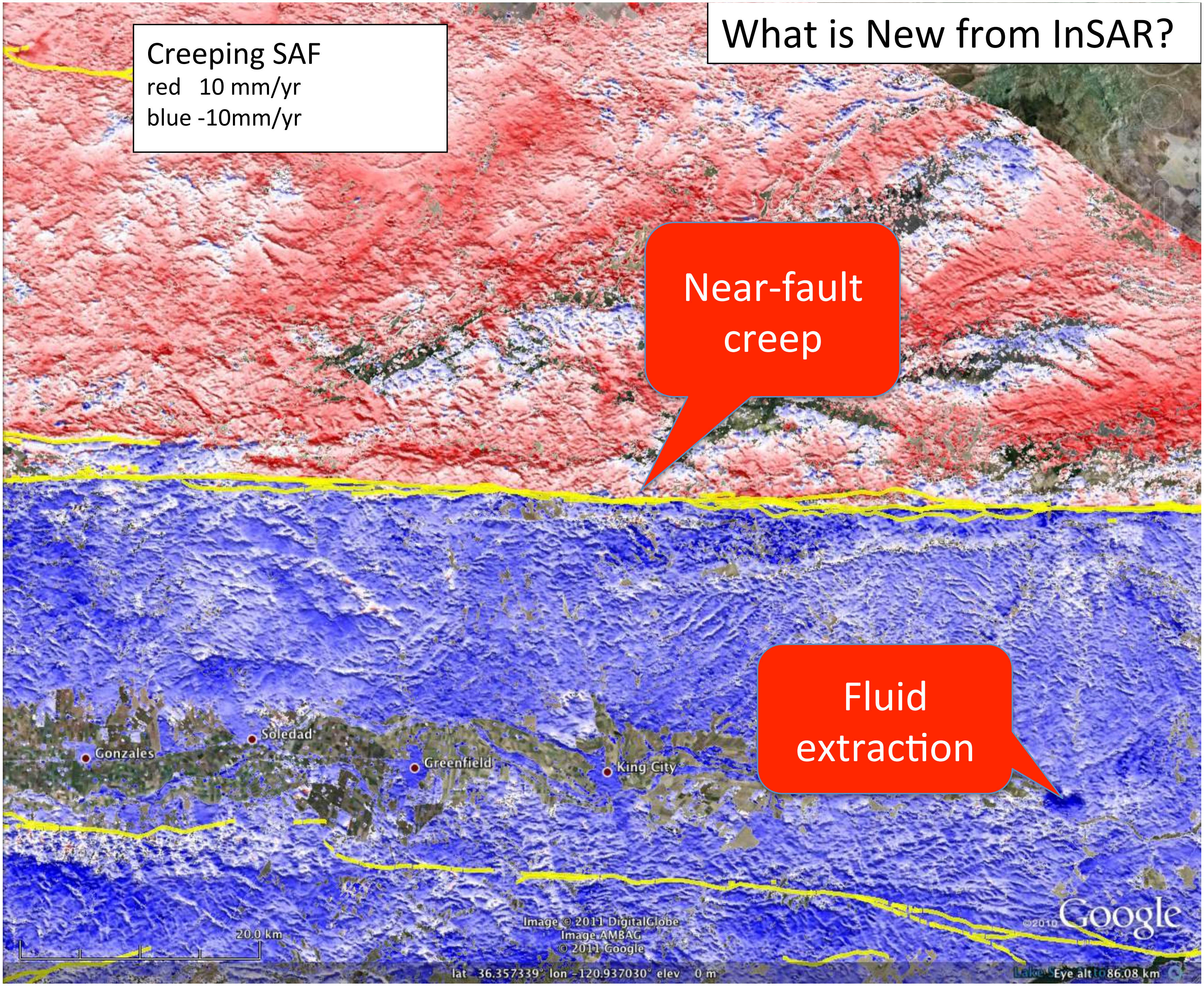
- The misfit between InSAR line-of-sight velocity and the projected point GPS horizontal velocities is 1.5 mm/yr.
- The misfit increases to 2.1 mm/yr when considering the vertical component of GPS velocities.

(Note for wavelength > 40 km the InSAR LOS data are constrained to agree with the GPS data.)

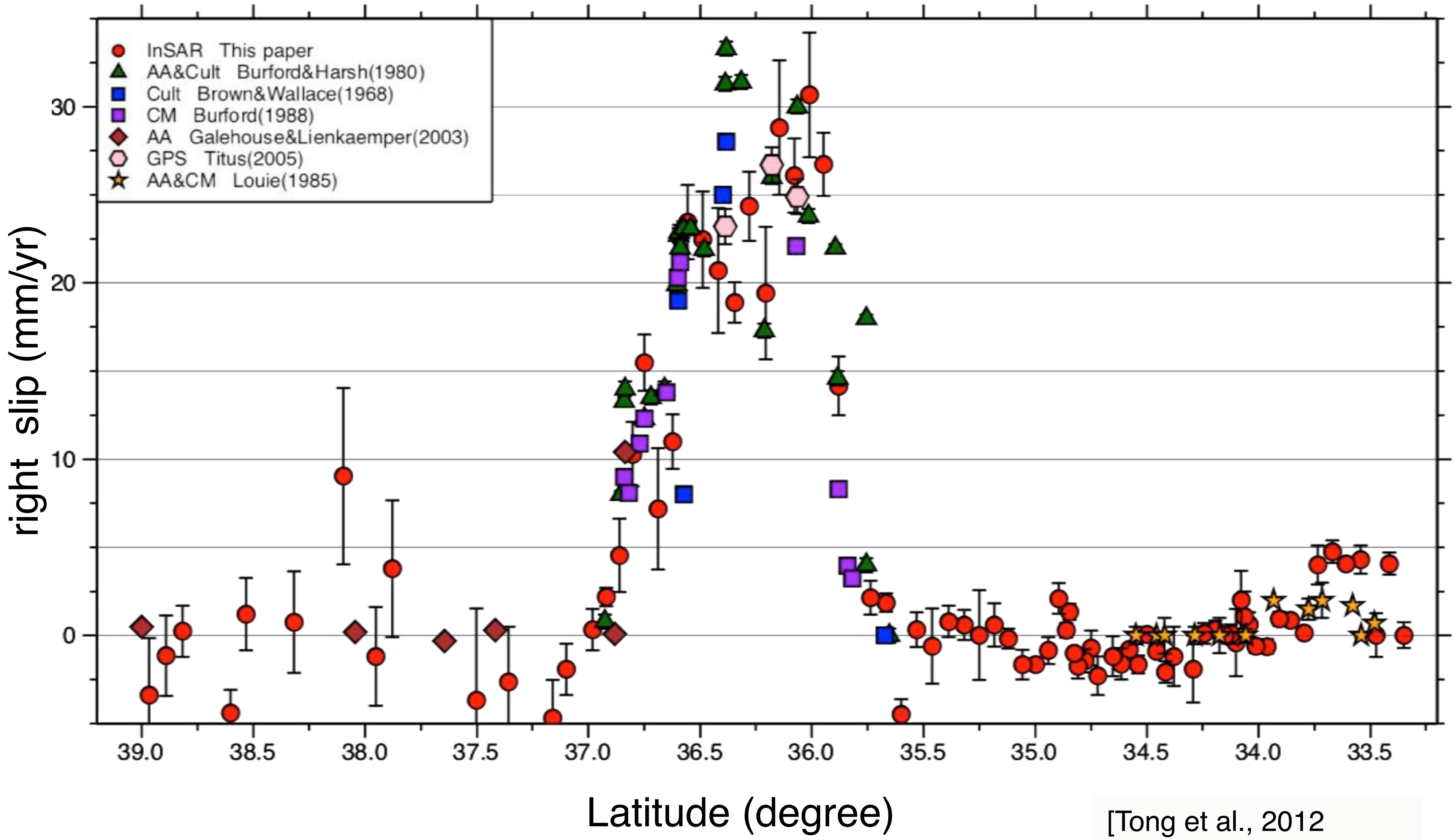
What is New from InSAR?



What is New from InSAR?

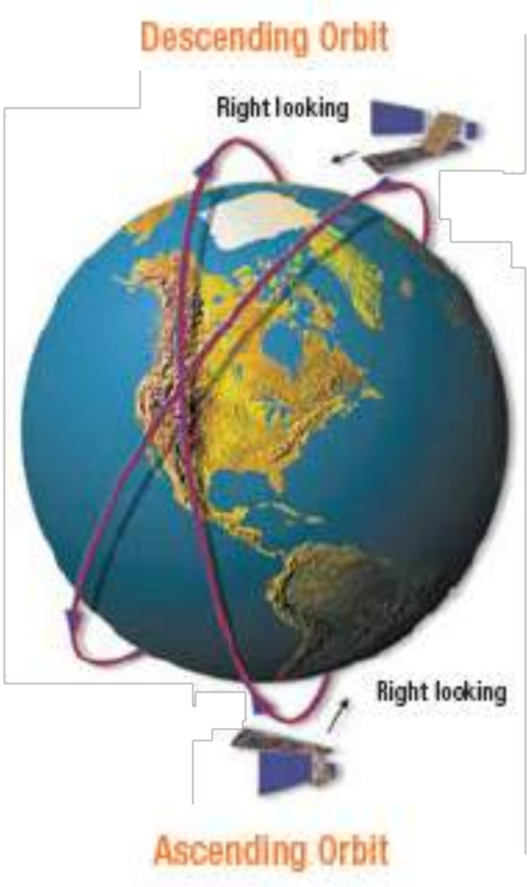


Fault Creep from ALOS vs. creep meters



[Tong et al., 2012
UCERF3 – Appendix D]

ALOS-1 has only one LOS direction
Need 2 or more to separate horizontal from vertical



- We have two independent Line-of-Sight observations
- From GPS, we also know the direction of horizontal motion
- We can use this information to extract two components of motion: **Vertical** and **Fault-Parallel**

$$\mathbf{P} = \begin{pmatrix} e_1 \sin\alpha + n_1 \cos\alpha & u_1 \\ e_2 \sin\alpha + n_2 \cos\alpha & u_2 \end{pmatrix}$$

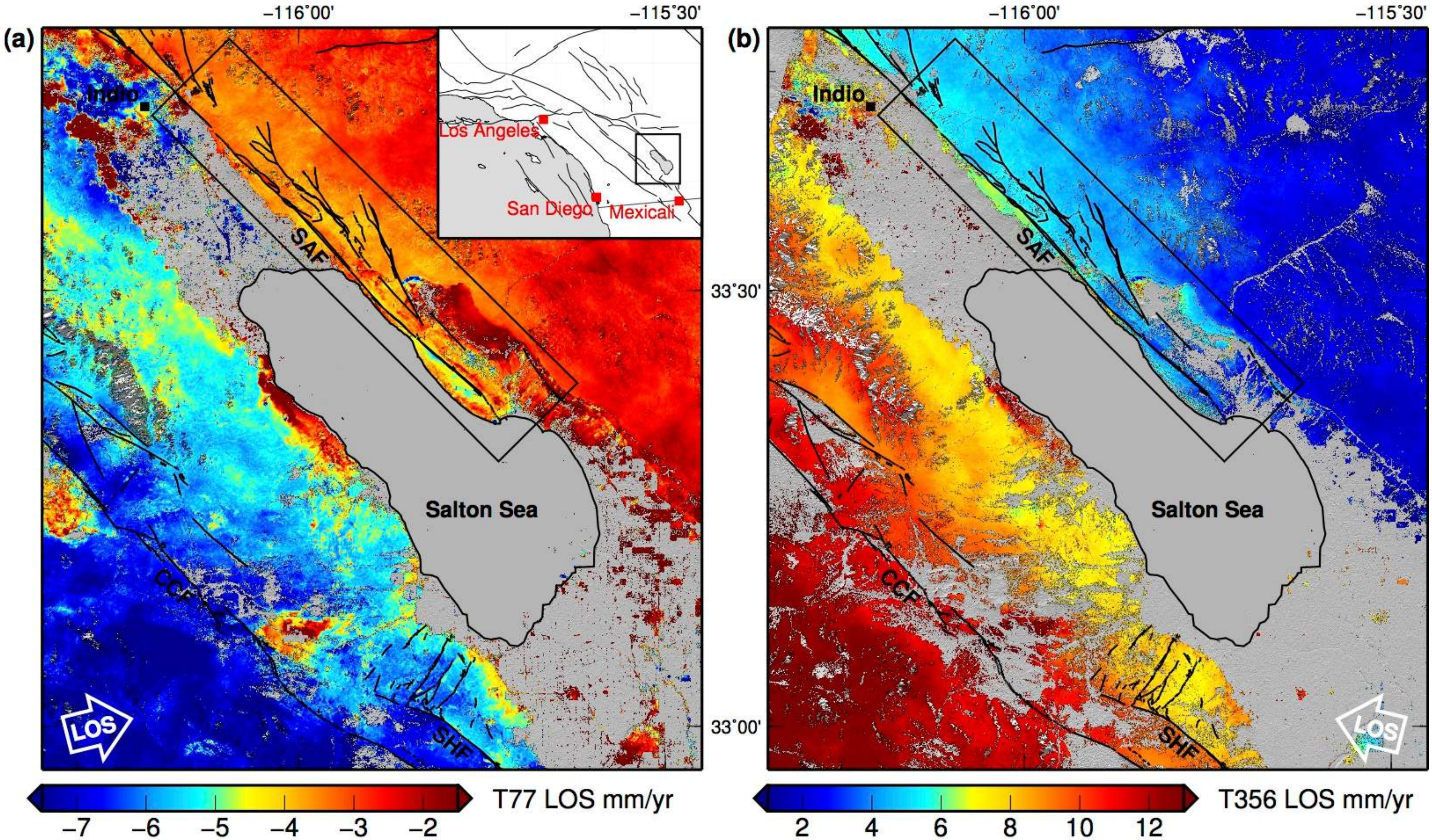
$$\begin{pmatrix} v_f \\ v_z \end{pmatrix} = \mathbf{P}^{-1} \begin{pmatrix} v_1 \\ v_2 \end{pmatrix},$$

Lindsey et al. (JGR, 2014)

Southern San Andreas fault

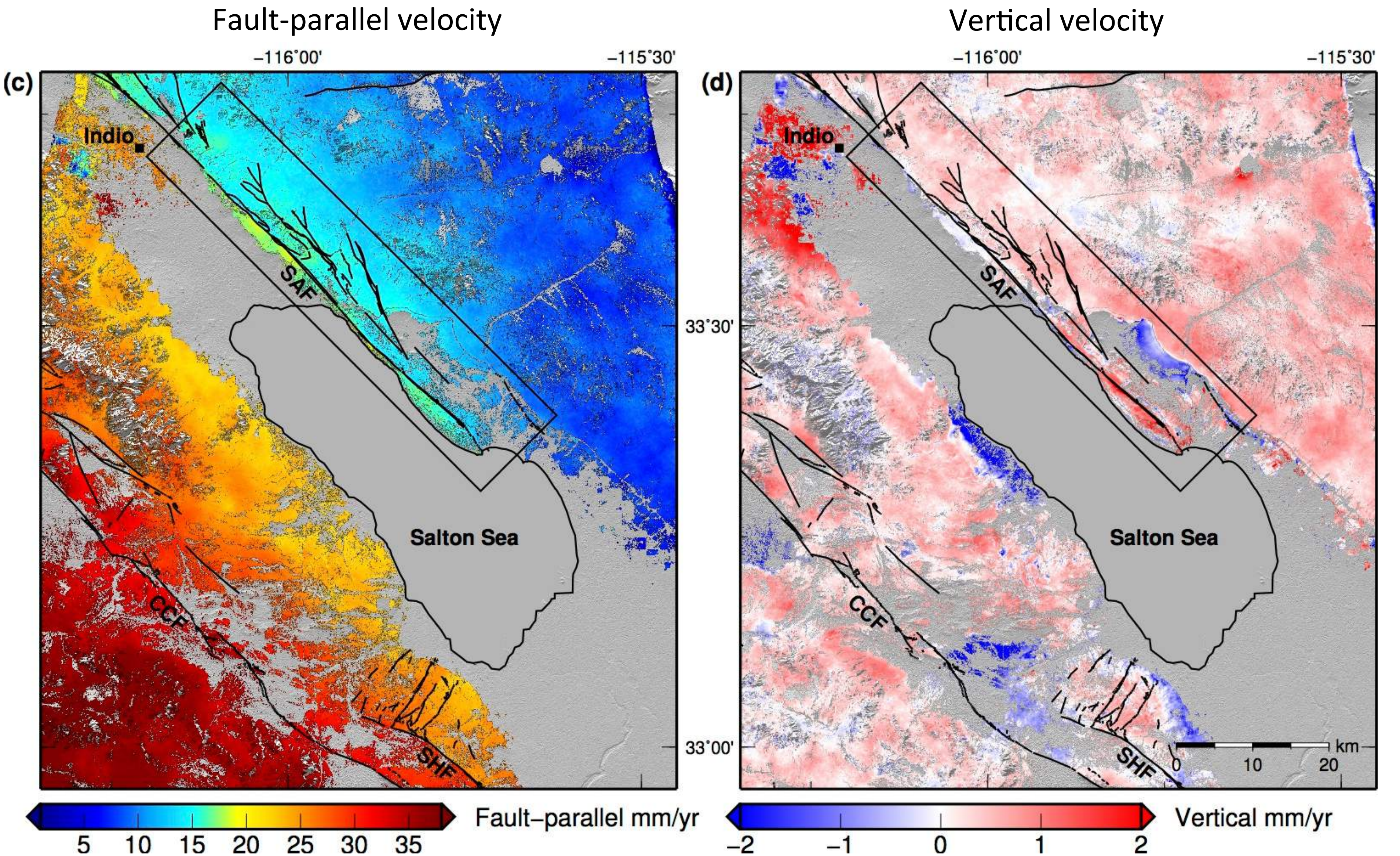
Envisat Track 77 (Ascending)

Track 356 (Descending)



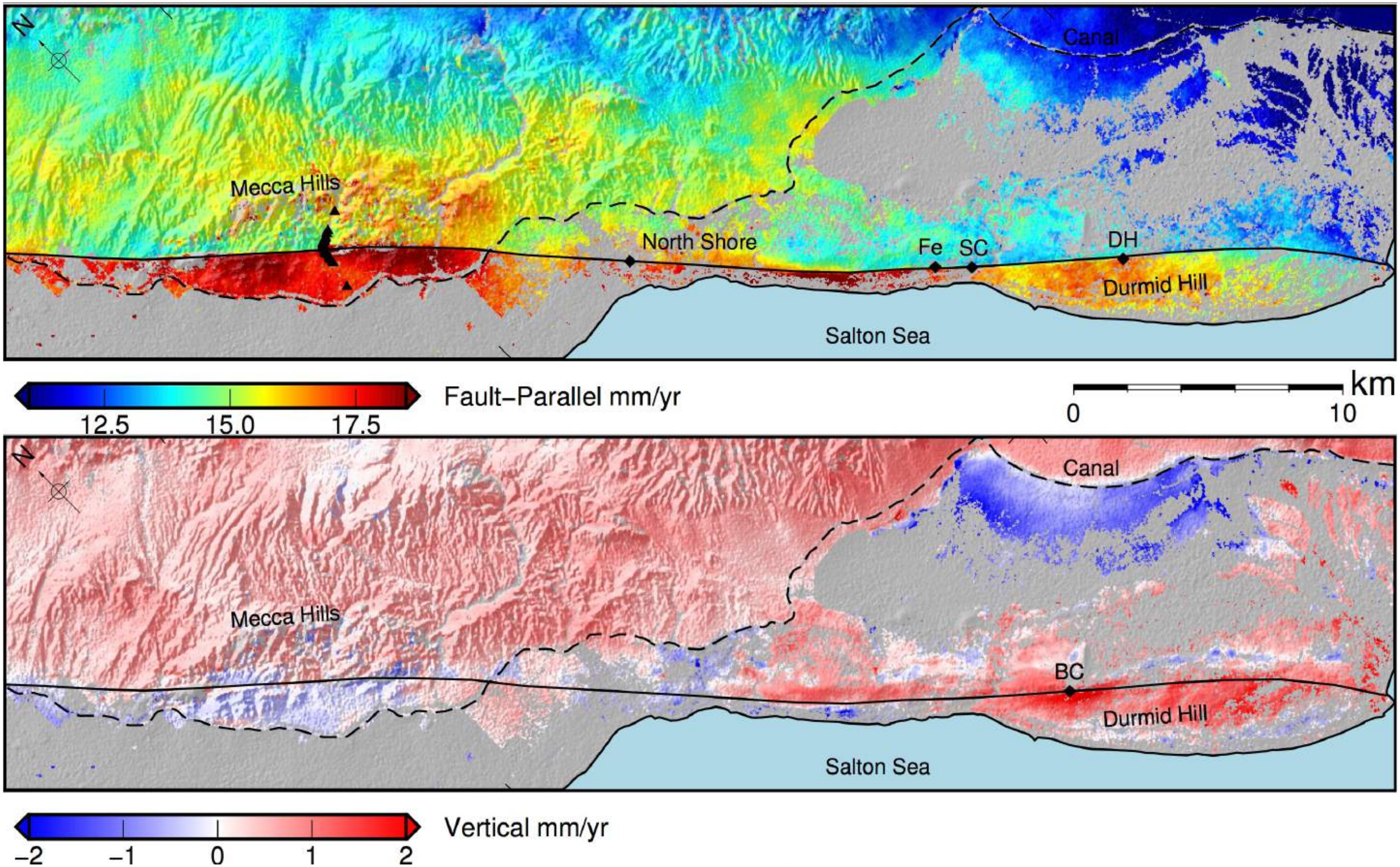
Lindsey et al. (JGR, 2014)

Southern San Andreas fault



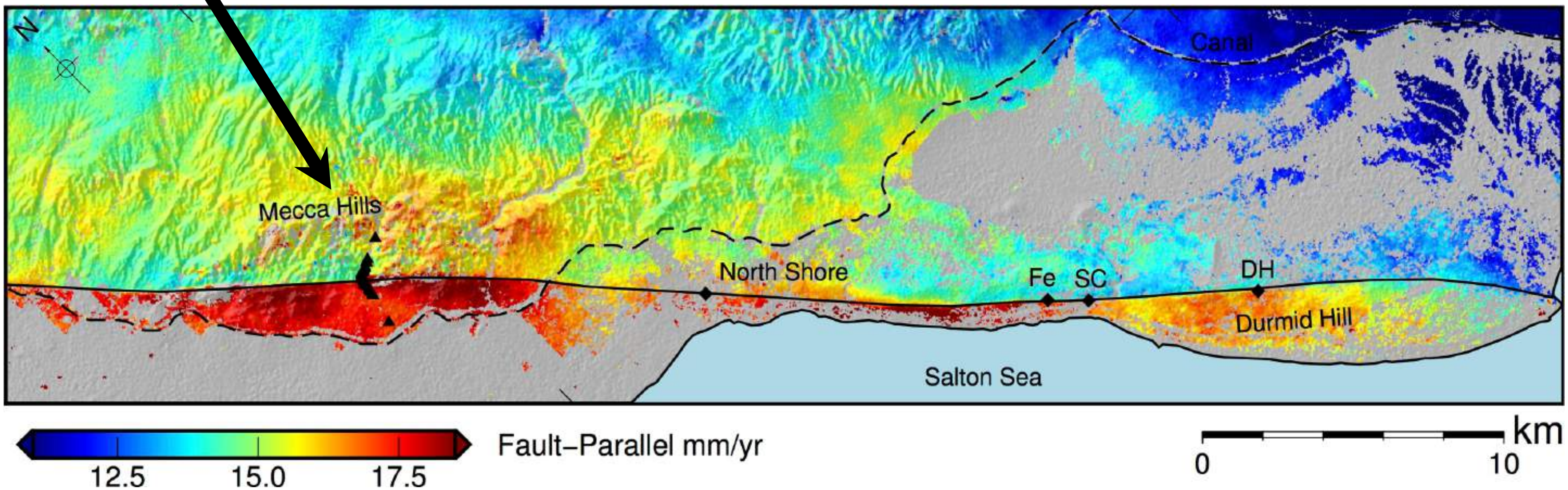
Lindsey et al. (JGR, 2014)

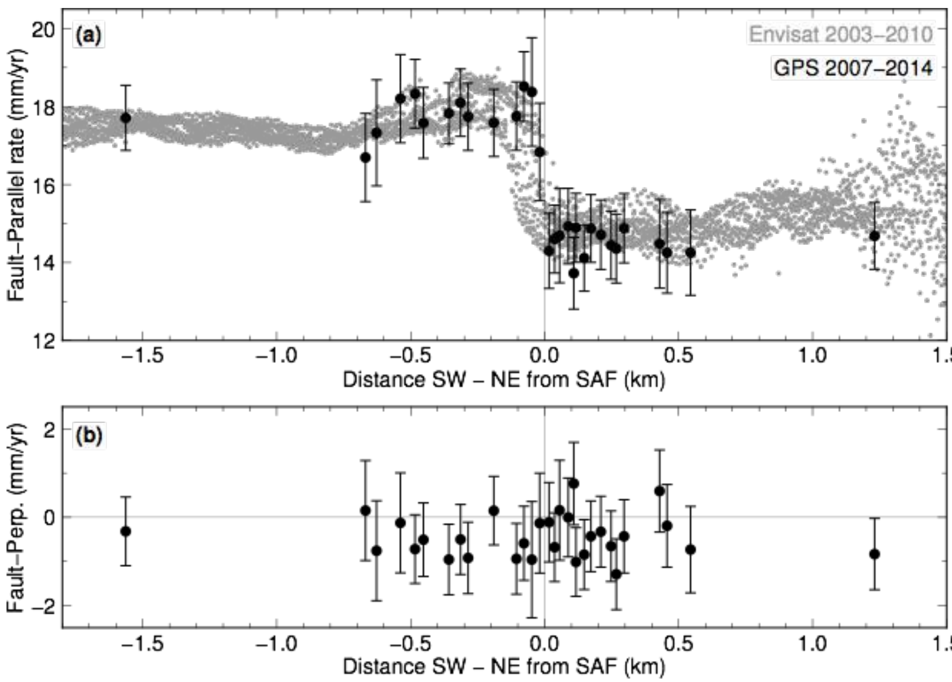
Southern San Andreas fault



Lindsey et al. (JGR, 2014)

Southern San Andreas fault





Lindsey et al. (JGR, 2014)

Data Availability

- **CGM-Velocity Model:**
  - GPS velocity:

    longitude, latitude, velocity in north, east, up (mm/yr), standard deviation in north, east, up (mm/yr)
  - InSAR Line-Of-Sight velocity [*Tong et al*.,2013; *Lindsey et al*, 2014]:

    longitude, latitude, velocity (mm/yr), look vectors in local east, north, up, standard deviation (mm/yr)
  - These are ASCII files.
  - Velocities are transformed into a consistent North America Fixed reference frame.