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:


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.
Standard Deviation

InSAR

Mean LOS Velocity
from ALOS-1 Ascending

[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.)
Creeping SAF
red  10 mm/yr
blue -10mm/yr

What is New from InSAR?
Creeping SAF
red 10 mm/yr
blue -10 mm/yr

What is New from InSAR?

Near-fault creep
Fluid extraction
Fault Creep from ALOS vs. creep meters

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

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

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

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

Fault-parallel velocity

Vertical velocity

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.