Joint Analysis of InSAR and Geodetic Time Series from a Principal Component Analysis-Based Inversion Method

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PCAIM available on-line at:
http://www.tectonics.caltech.edu/resources/pcaim
Q: How do we join InSAR and geodetic time series?
Principal Component Analysis-based Inversion Method (PCAIM)

Surface Displacement \xrightarrow{\text{PCA Decomposition}} \sum_{i=1}^{r} \text{Principal Component}(i)

\begin{align*}
\text{Inversion} & \quad \text{Elastic Dislocation} \\
\downarrow & \quad \uparrow \\
\text{Forward Model} & \quad \text{Slip at Depth} \\
\downarrow & \quad \uparrow \\
\text{Elastic Dislocation} & \quad \text{Forward Model} \\
\text{Inversion} & \quad \sum_{i=1}^{r} \text{Principal Slip Distribution}(i)
\end{align*}

[Kositsky and Avouac, 2009]
Long Valley Caldara 1997-1998 Inflation Episode

- multiple inflation events since 1980's
- ~10 cm uplift near the resurgent dome during 1997-98 episode
- 8 EDM time series
  [Langbein, 2003]
- 24 ERS scene and 65 interferograms
**PCAIM Nonlinear Solver**

- Sparse matrix $\rightarrow$ weighting matrix and nonlinear solver  
  [Srebro and Jaakkola, 2003]
- Iterative decomposition to maintain temporal continuity of the signals
PCA Decomposition

> Time function

▼ Spatial function
PCA Reconstruction (4 components)

Electronic Distance Measurements

- **hot**
- **krak**
- **saw**
- **sherwin**
- **knolls**
- **miner**
- **shark**
- **tilla**
PCA Reconstruction (4 components)

InSAR SBAS Time Series

Observed

Modeled

19920604 19920917 19921126 19930902 19931111 19950722 19950826 19950930 19951104 19960801 19960802 19970622
19970727 19971109 19980712 19980816 19980920 19981025 19990801 19990905 19991114 20000820 20030801 20050605
19920604 19920917 19921126 19930902 19931111 19950722 19950826 19950930 19951104 19960601 19960602 19970622
19970727 19971109 19980712 19980816 19980920 19981025 19990801 19990905 19991114 20000820 20030801 20050605

Scale: -10 -8 -6 -4 -2 0 2 4 6 8 10 (cm)
Displacement Field 9 Components

Displacement Field 4 Components
PCA Joint Inversion

- Gridded Mogi Model  [Masterlark and Lu, 2004]

- Apply Laplacian operator and cross validation

Residuals between inversion result and observed data
PCA Joint Inversion

2 Components

- hot
- knolls
- k rak
- miner
- saw
- shark
- sherwin
- tilla
PCA Joint Inversion -- Discussion

- We can get better source mapping in time and in space through combining InSAR and EDM

- Some (local) tectonic signals are mixed with noises in higher components

- We may need another source (such as South Moat Fault) to improve the fitting to EDM data

- Noises such as atmospheric signals in InSAR data can be filtered out into higher components

- Atmospheric correction will improve joint inversion by reducing the magnitude of noises
Summary

• PCAIM can produce a detail mapping of the source both in time and in space when combining InSAR and other time series data

• PCA decomposition may filter the unwanted atmospheric signals from InSAR data, but some local low-amplitude signals can also be excluded