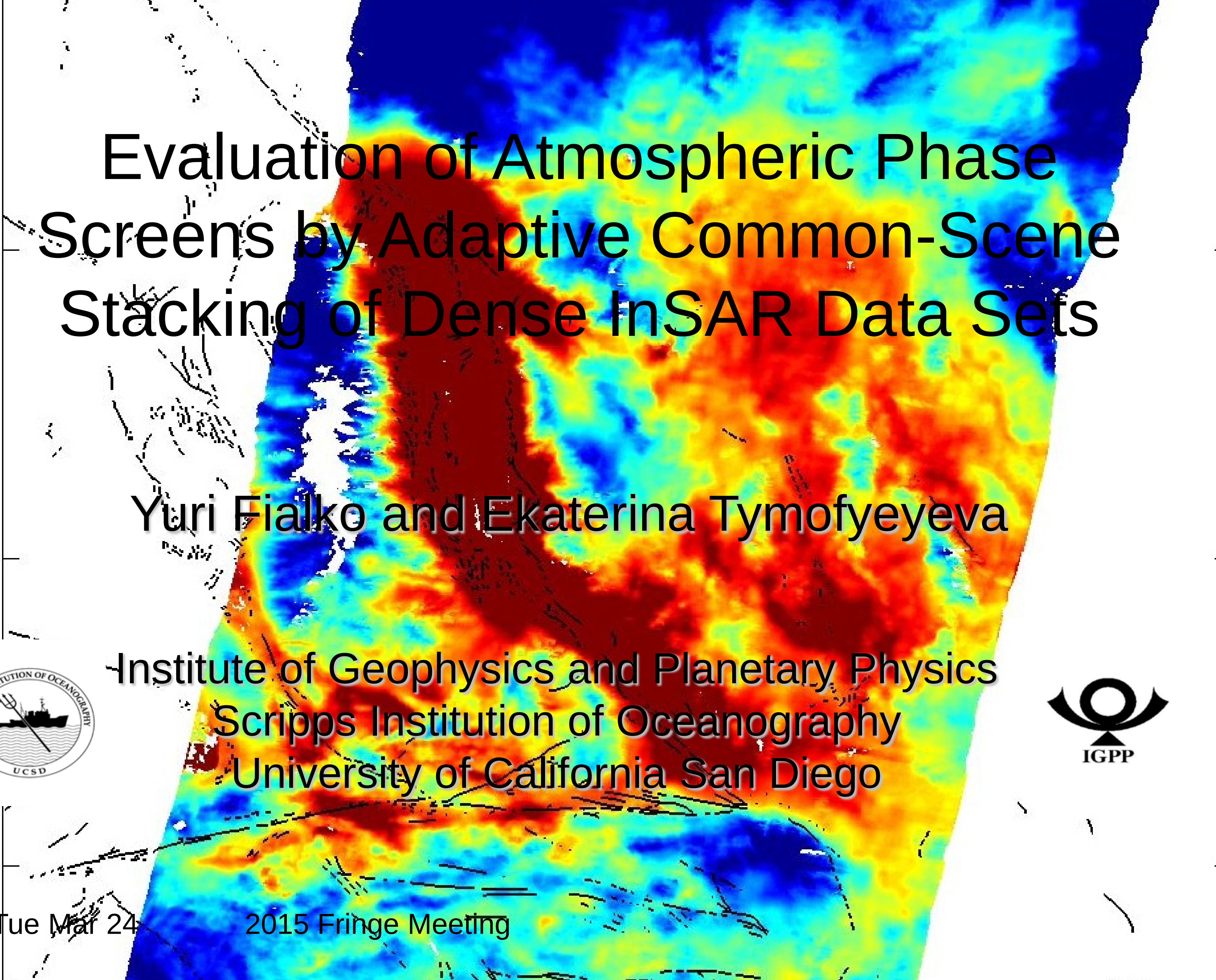
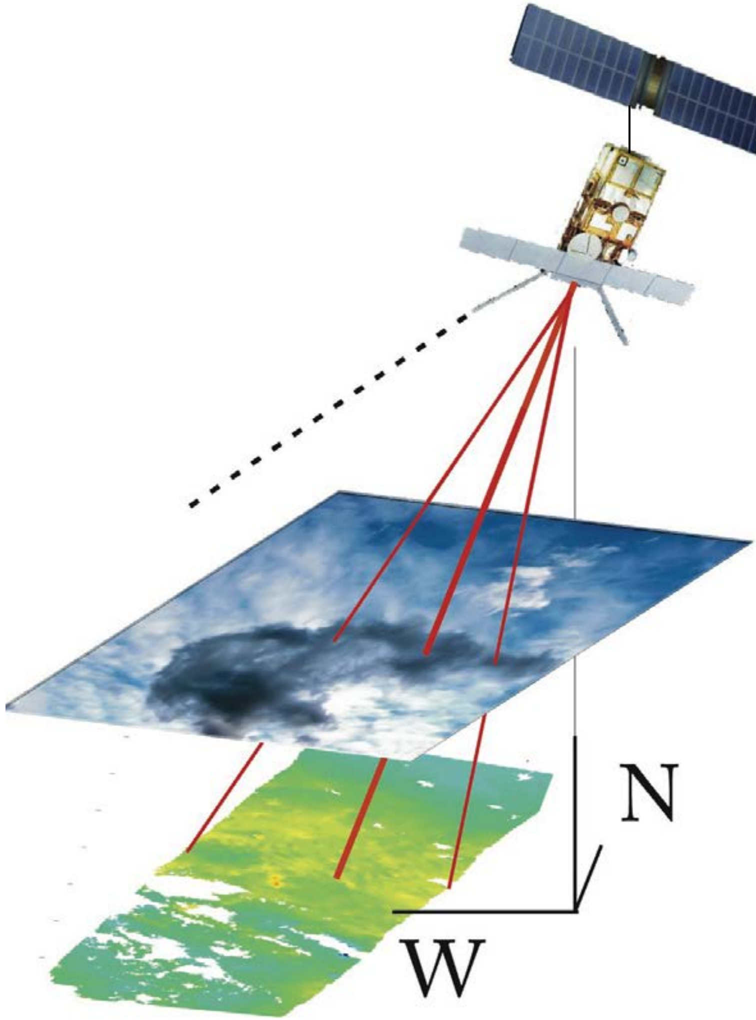


Evaluation of Atmospheric Phase Screens by Adaptive Common-Scene Stacking of Dense InSAR Data Sets

Yuri Fialko and Ekaterina Tymofyeyeva

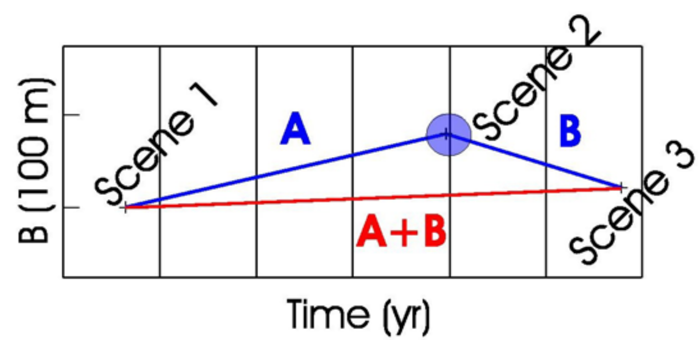
Institute of Geophysics and Planetary Physics
Scripps Institution of Oceanography
University of California San Diego



Mitigation of atmospheric noise:

- Auxiliary data (e.g., maps of atm. vapor) - need to be hi-res in space and time
- Spatiotemporal filtering (e.g., SBAS, StaMPS)
- Stacking of (preferably independent) interferograms

$\phi=\tau+\alpha^{atm}+\varepsilon$: radar phase



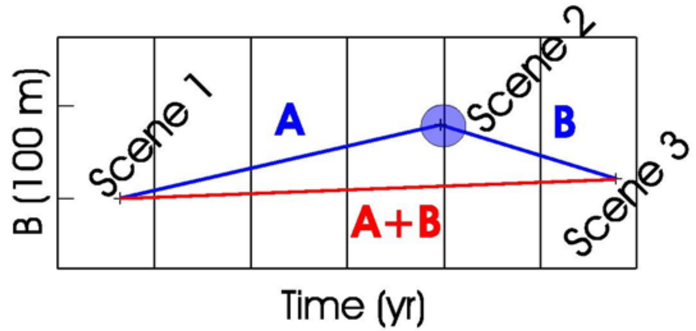
$\Delta\rho_{12} = \phi_2-\phi_1 \sim (+\alpha_2^{atm})$: igram 21 (A)

$\Delta\rho_{23} = \phi_3-\phi_2 \sim (-\alpha_2^{atm})$: igram 32 (B)

$$RMS = \sqrt{\frac{1}{N}\sum_{j=1}^{N}(\Delta\rho(j) - T(j))^2}$$

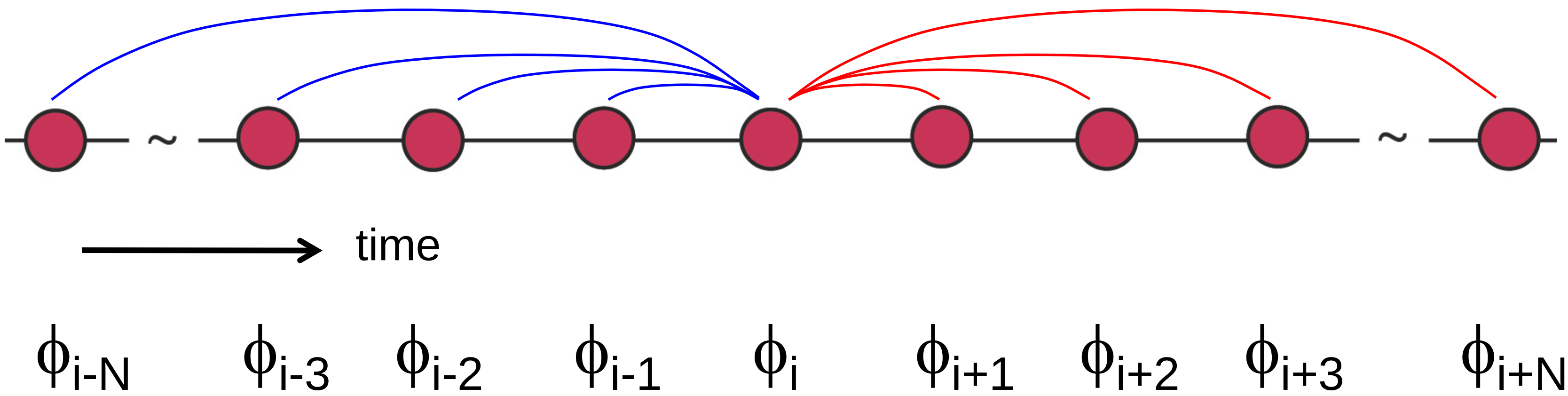
$\Delta\rho(j)$ – range change at pixel j
T - trend (tectonic signal, orbital ramp, etc.)

Atmospheric Noise Coefficient:



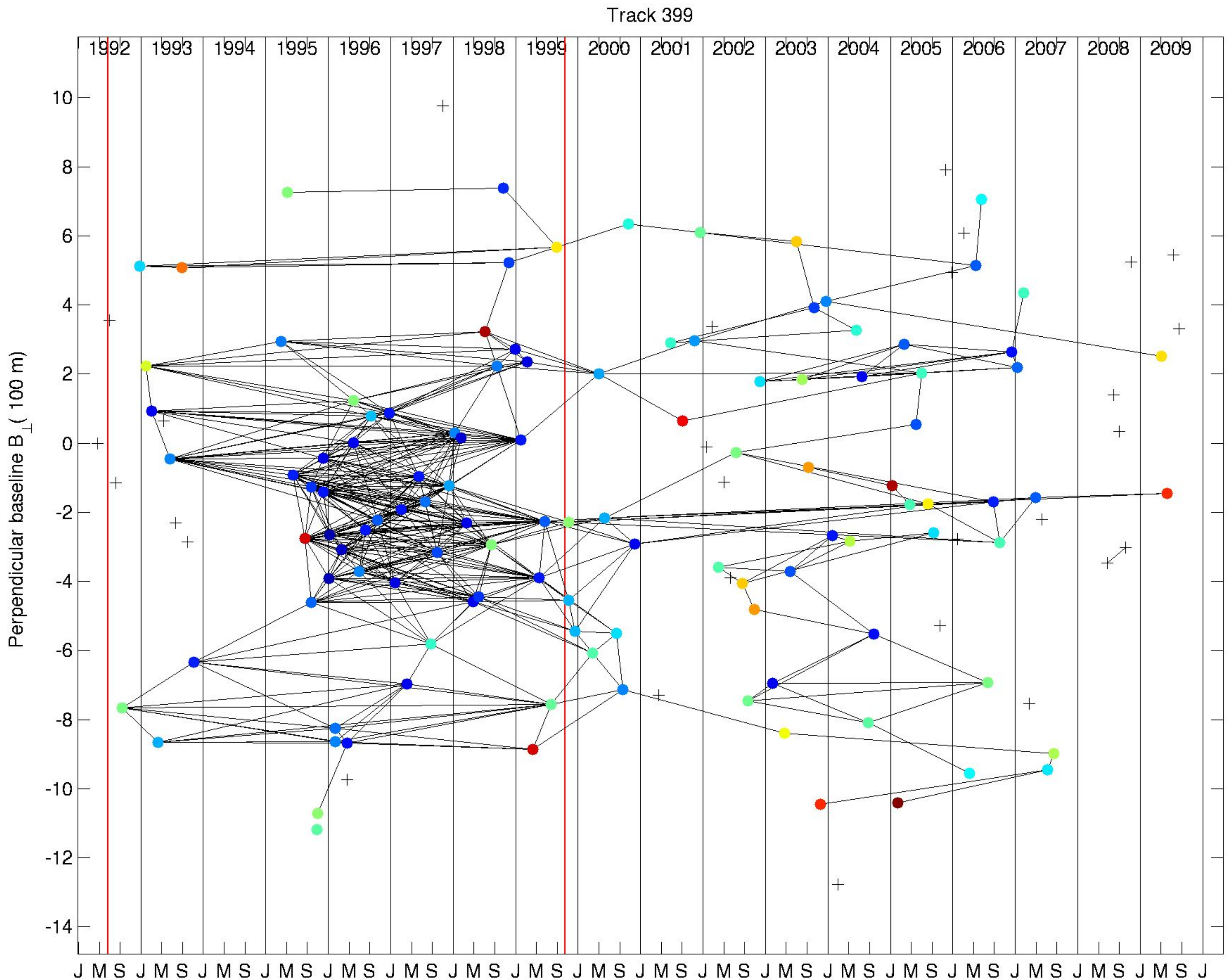
$$ANC_2 = \frac{1}{2}(RMS_A + RMS_B) - RMS_{A+B}.$$

- is a measure of a sign-changing phase contribution
- can be evaluated for every "shared" SAR acquisition
- easy to compute
- trend T should render a zero-mean $\Delta\rho$



$$\alpha_i = \lim_{N \to \infty} \frac{1}{2N} \sum_{j=1}^{N} \left(\Delta\rho_{i(i-j)} - \Delta\rho_{(i+j)i} \right)$$

$$\Delta\rho_{ik} = \phi_i - \phi_k$$



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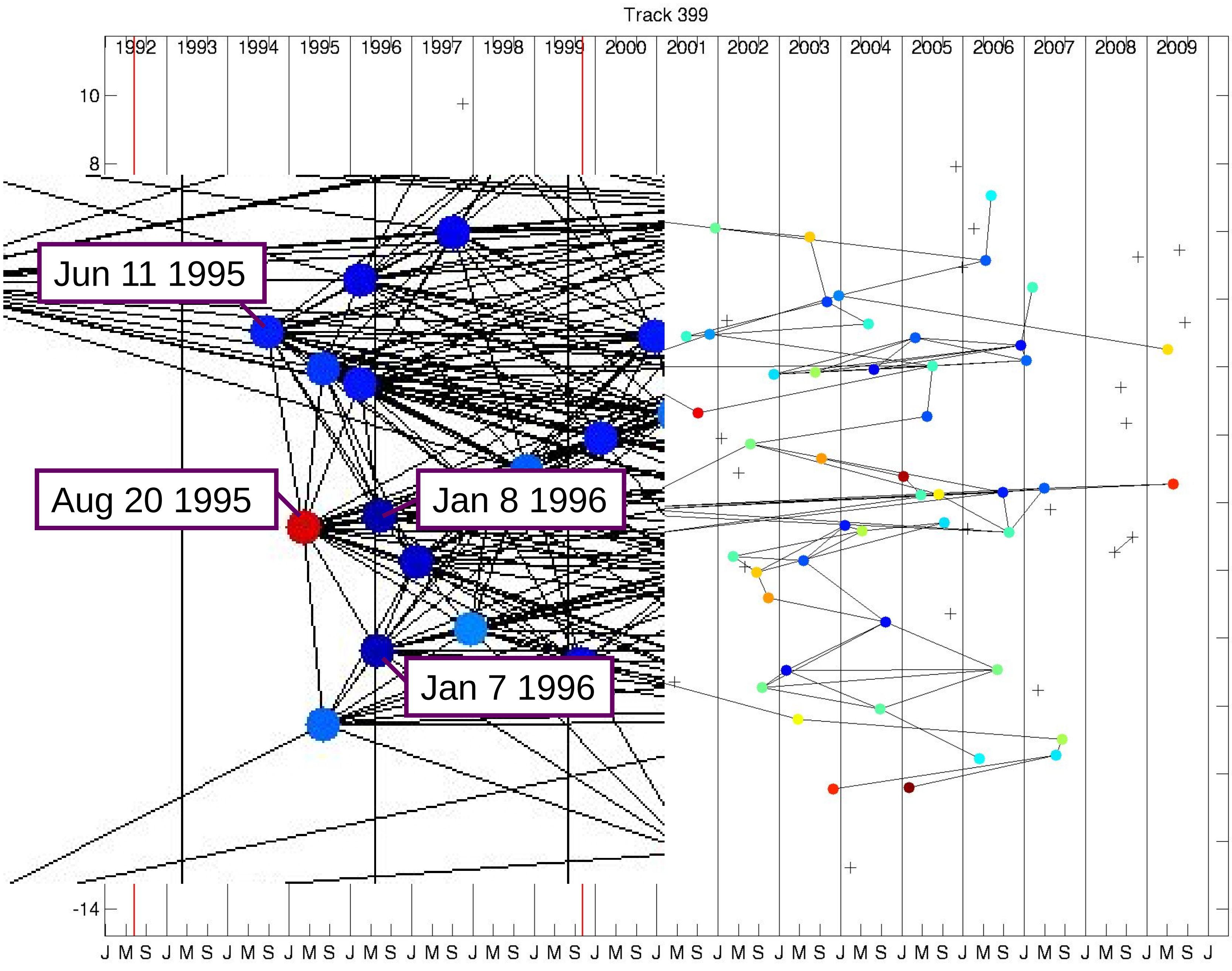
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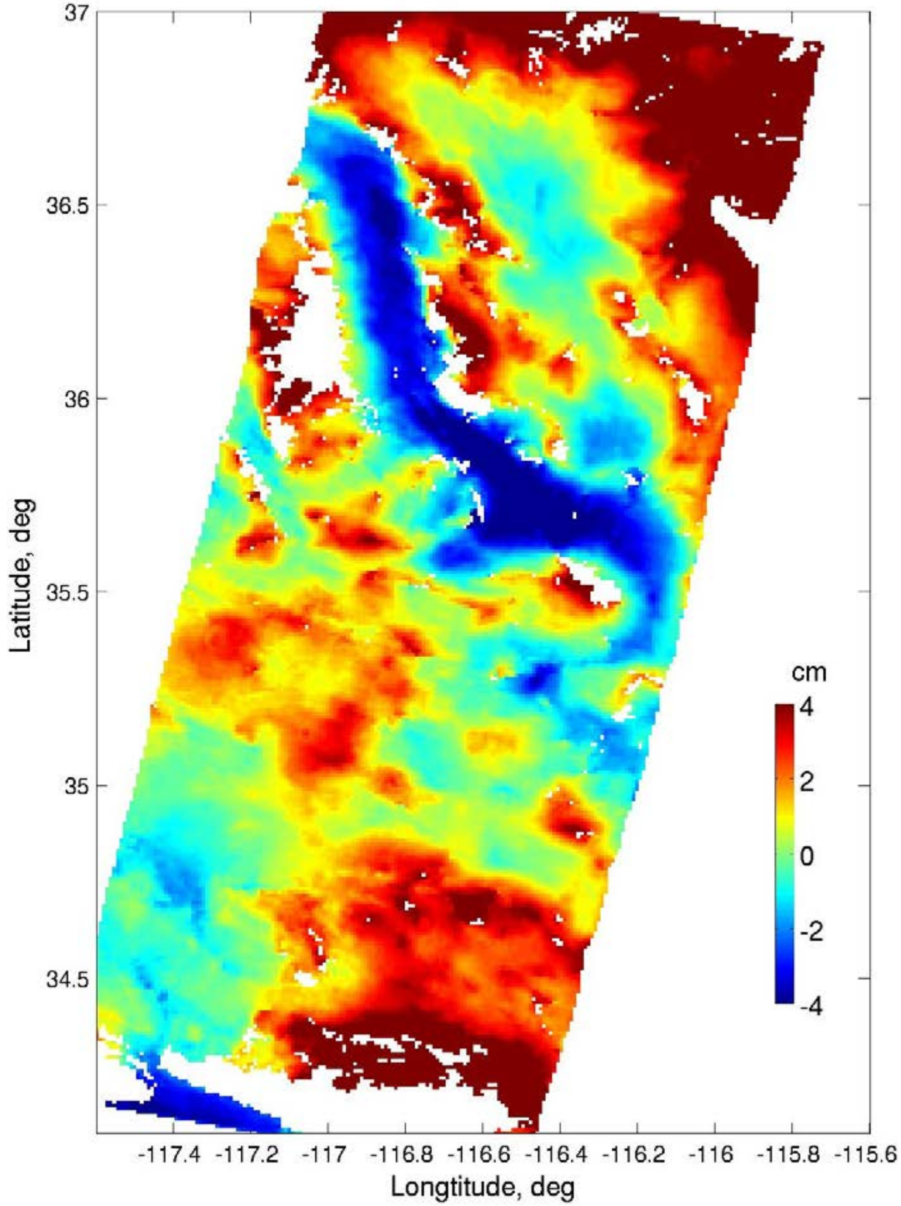
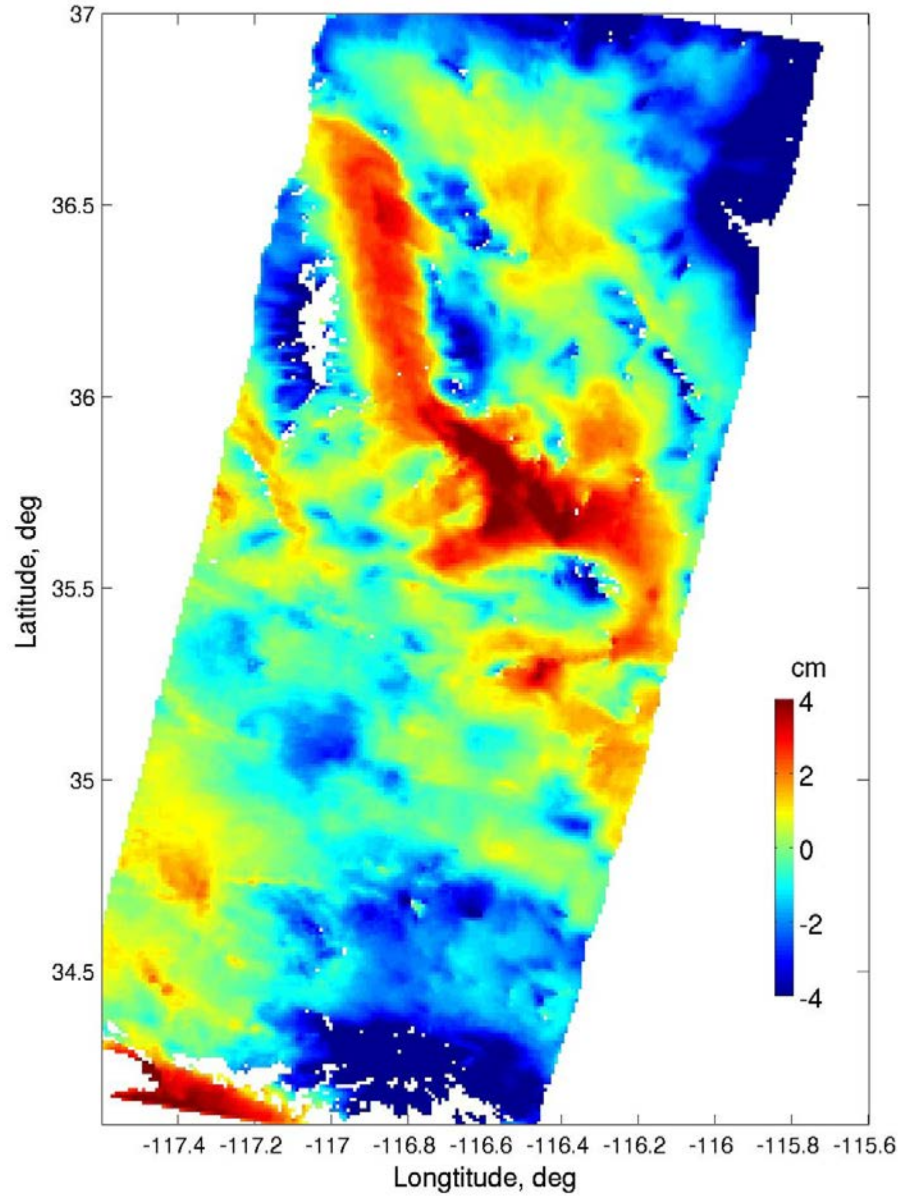
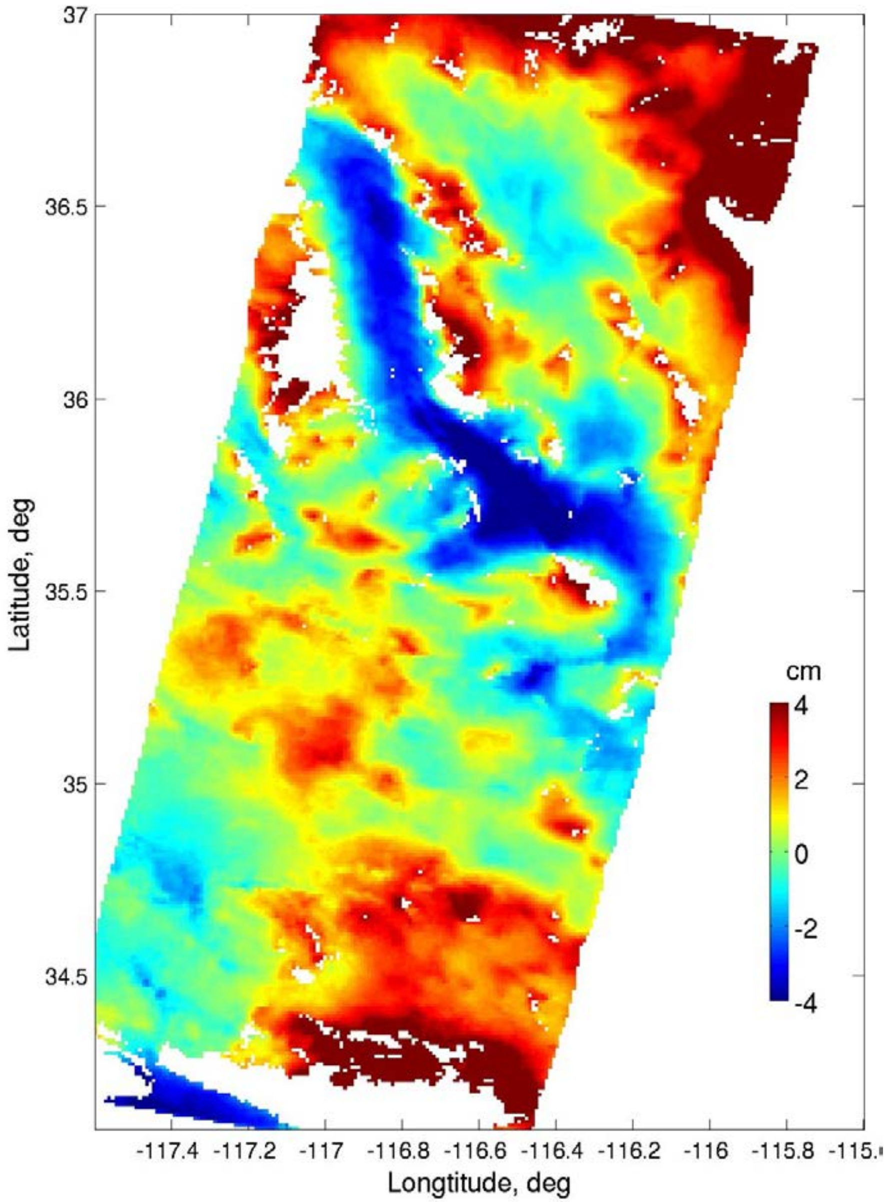
Jun 11 1995 - Aug 20 1995

Aug 20 1995 - Jan 7, 1996

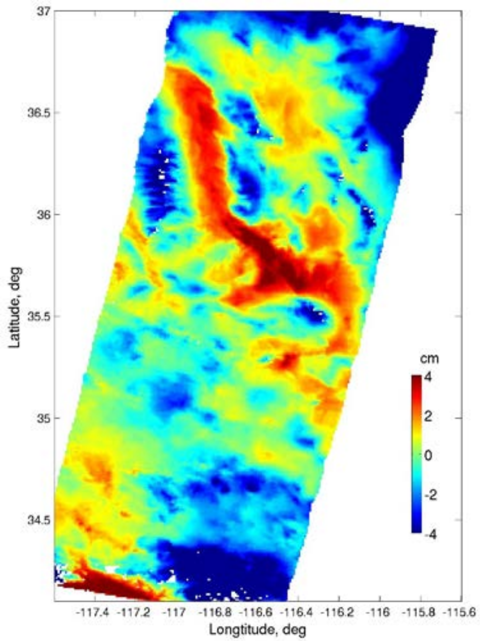


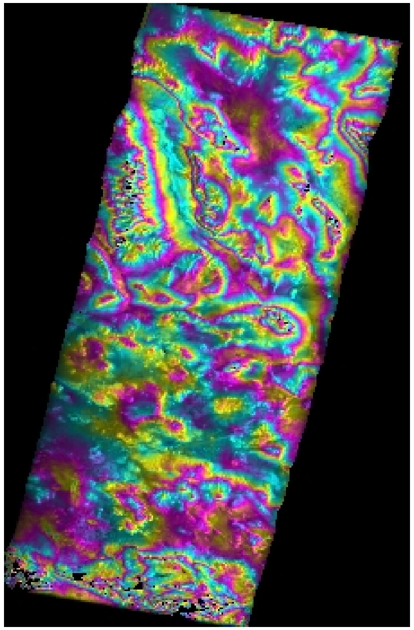


Estimated atmospheric phase on Aug 20 1995



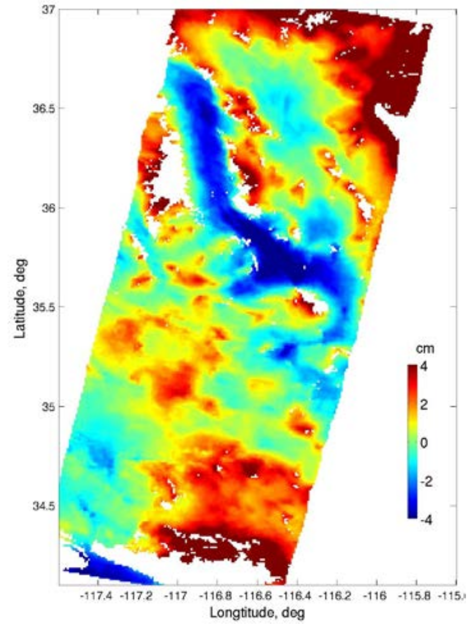
observed





+

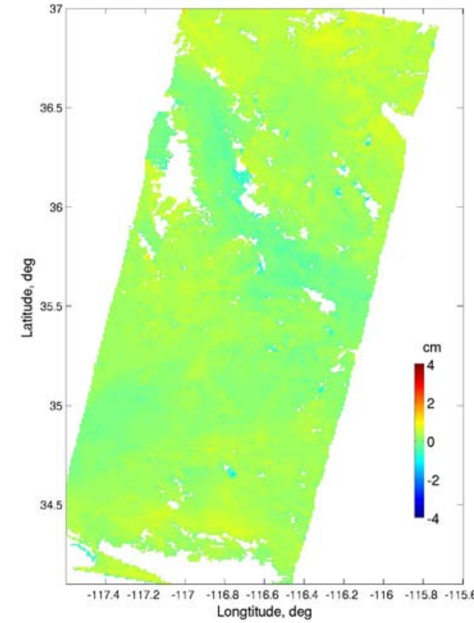
est. atm. on 8/20/95

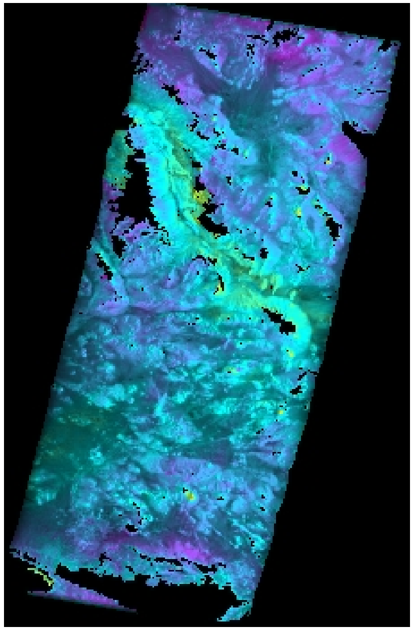


Aug 20 1995 – Jan 8, 1996

=

corrected igram



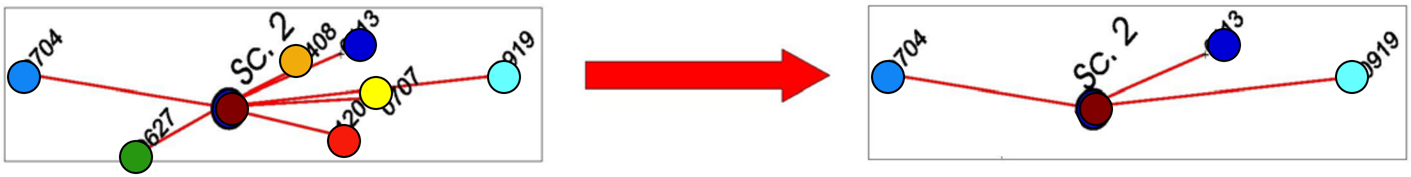


Refined evaluation of Atmospheric Noise Coefficients :

- use computed atmospheric phase screens to update ANCs as

$$ANC = \sqrt{\frac{1}{N}\sum_{i=1}^{N}\left(a_i - \overline{a}\right)^2}$$

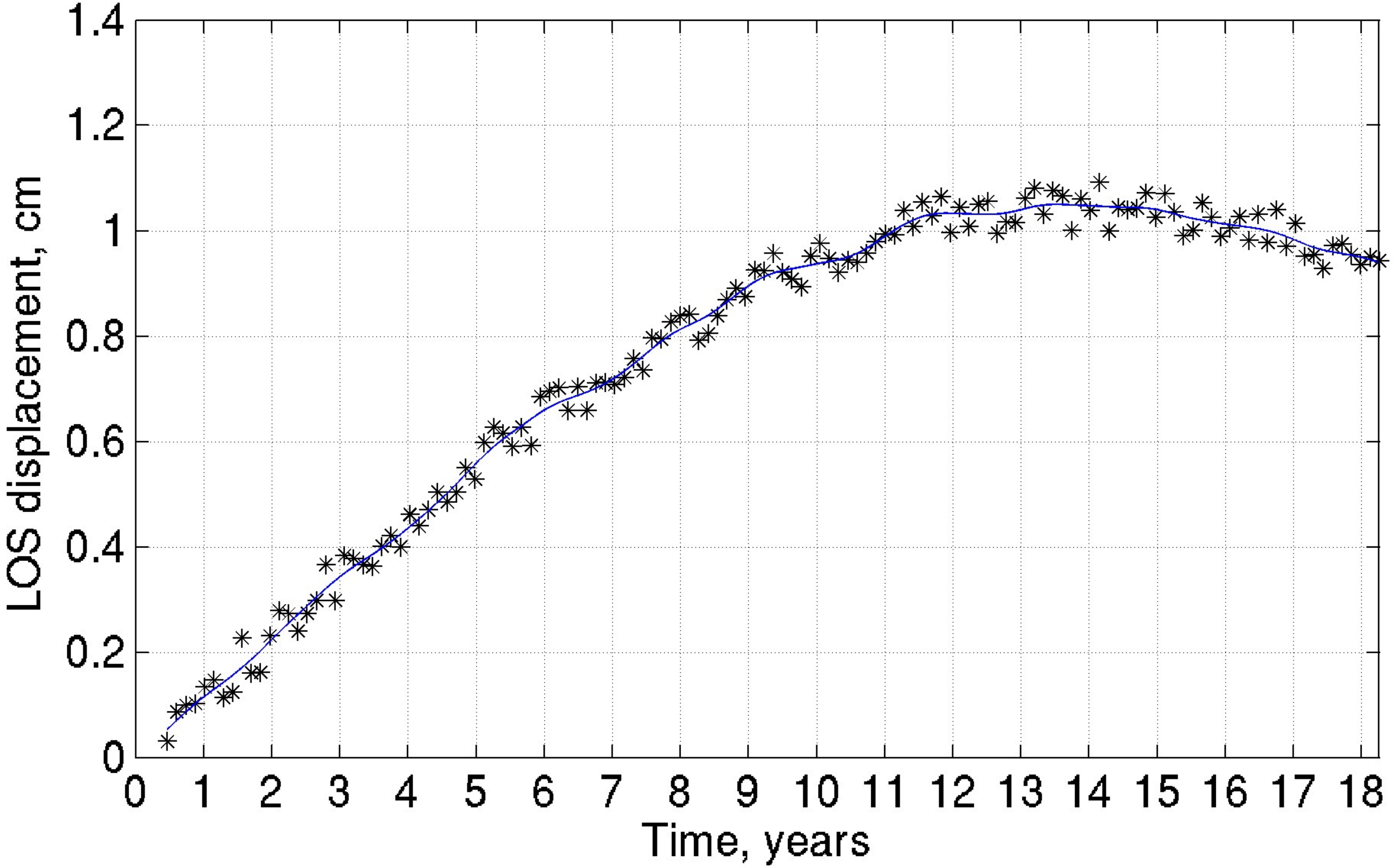
- use updated ANCs to optimize the “stacking tree”



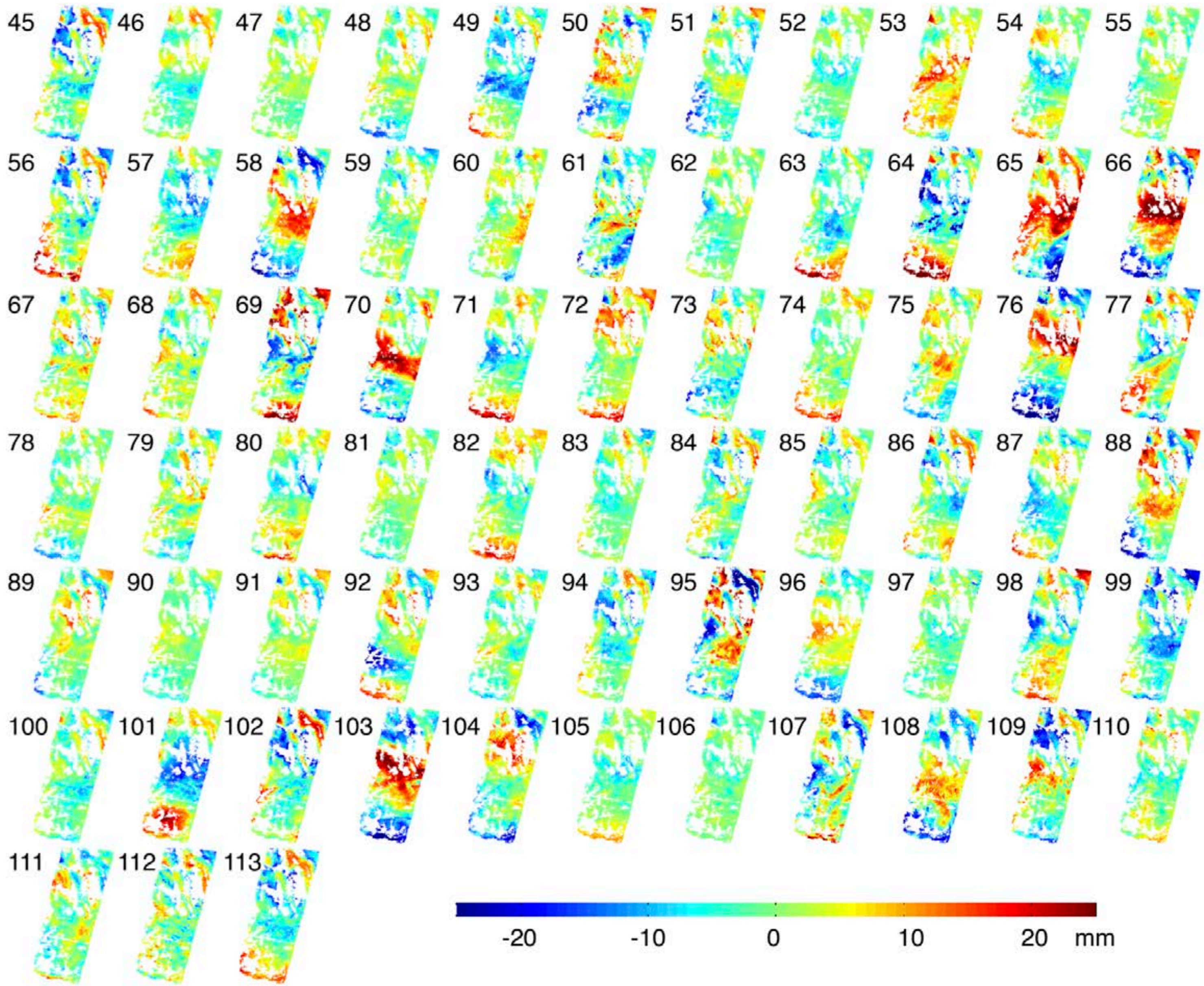
-update the mean LOS velocity
-iterate until convergence
-subtract atmospheric phase screens from all interferograms before the time series analysis

Corrections for transient deformation:

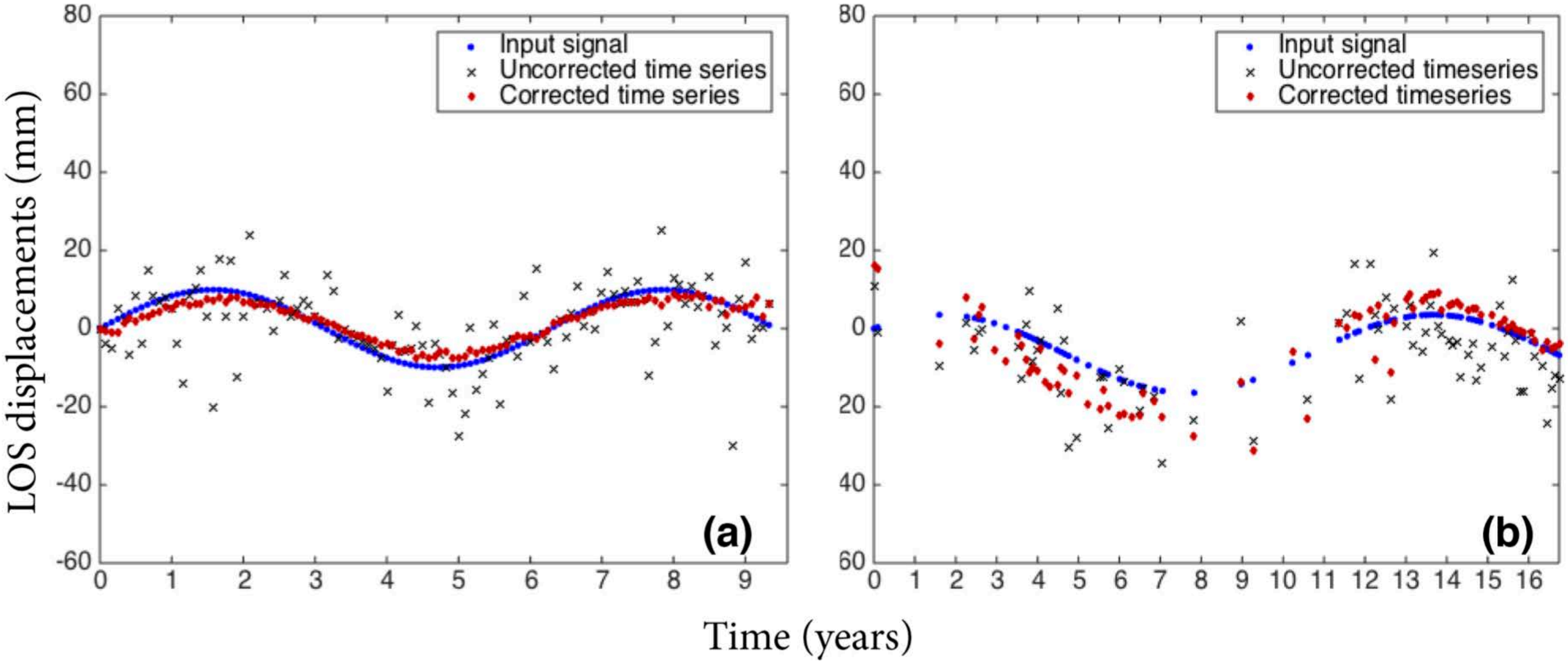
- use a spline fit to the time series to evaluate a local rate of deformation, and subtract it from the ANC estimates



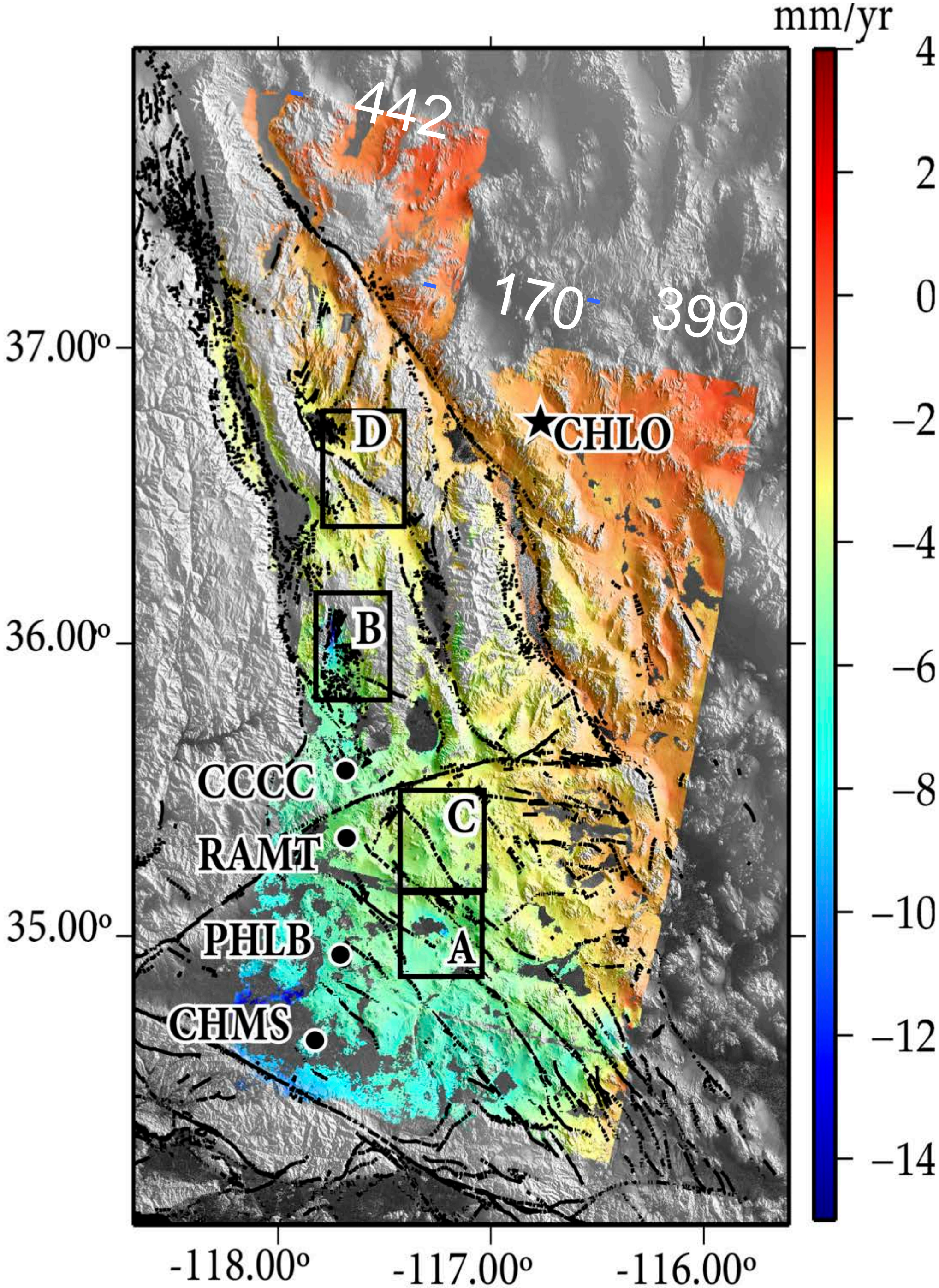
Estimated Atmospheric Phase Screens (track 170)



Tests using synthetic data

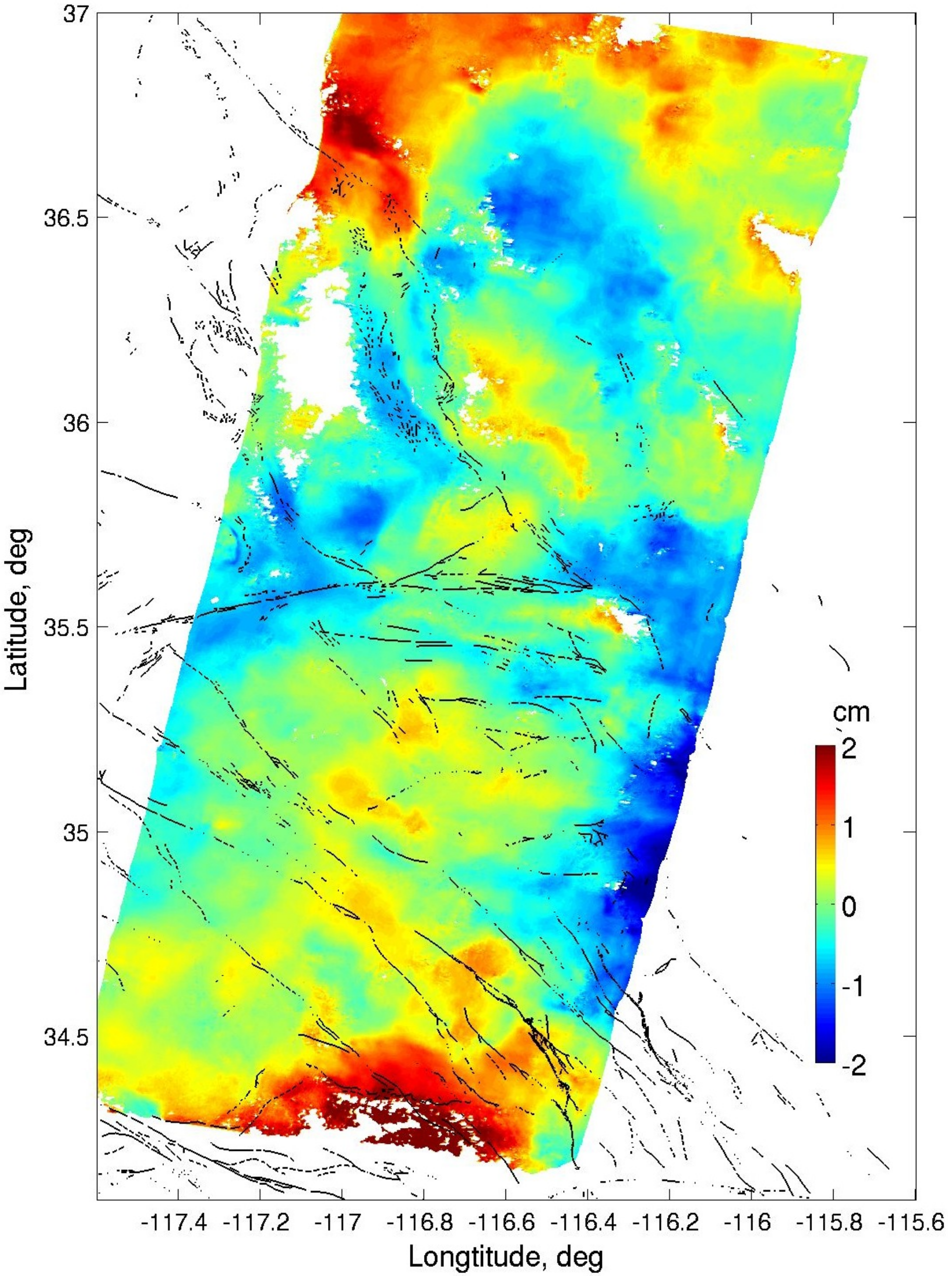


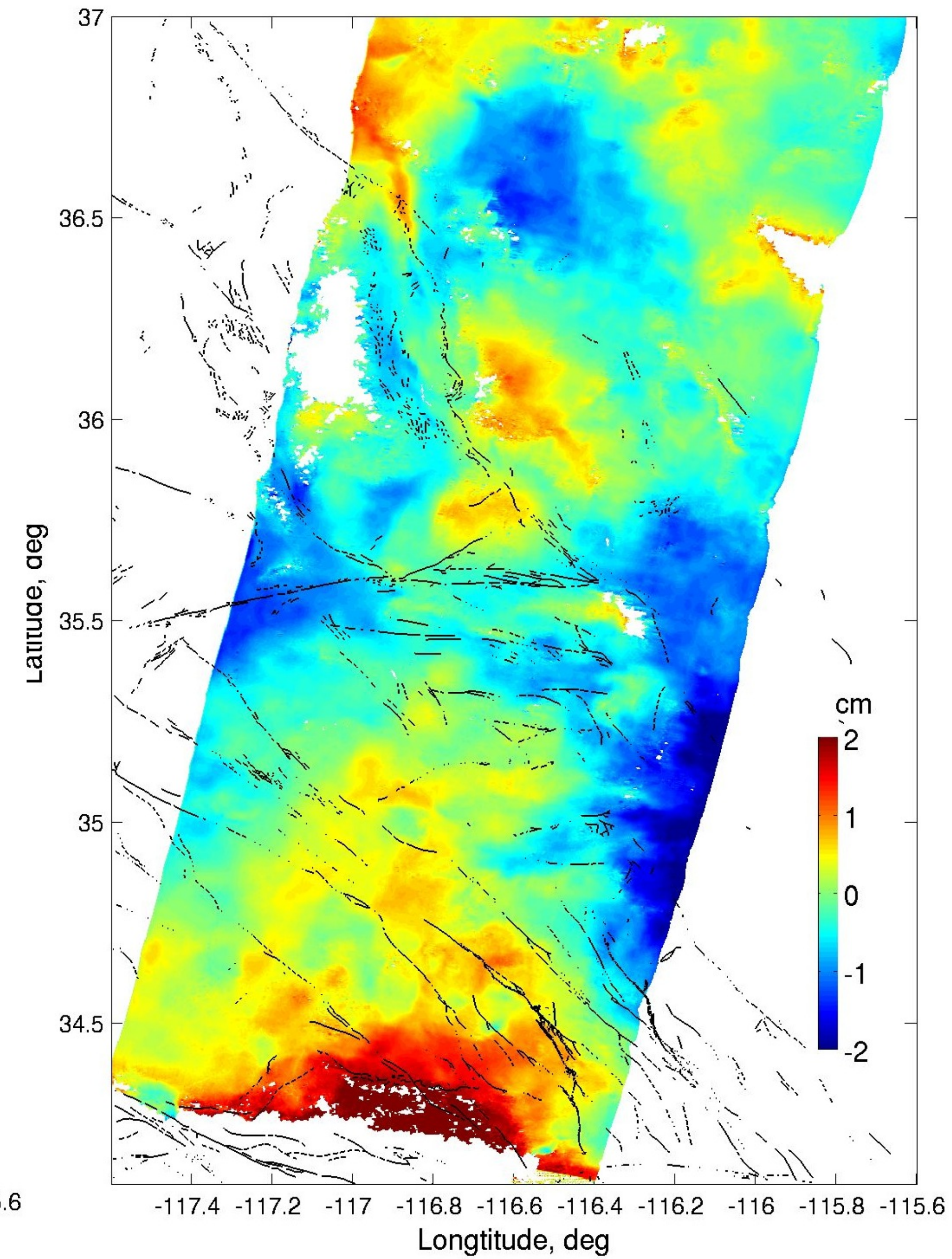
- recover 95% of atmospheric noise in synthetic data
- recover up to 65% of atmospheric noise in synthetic data



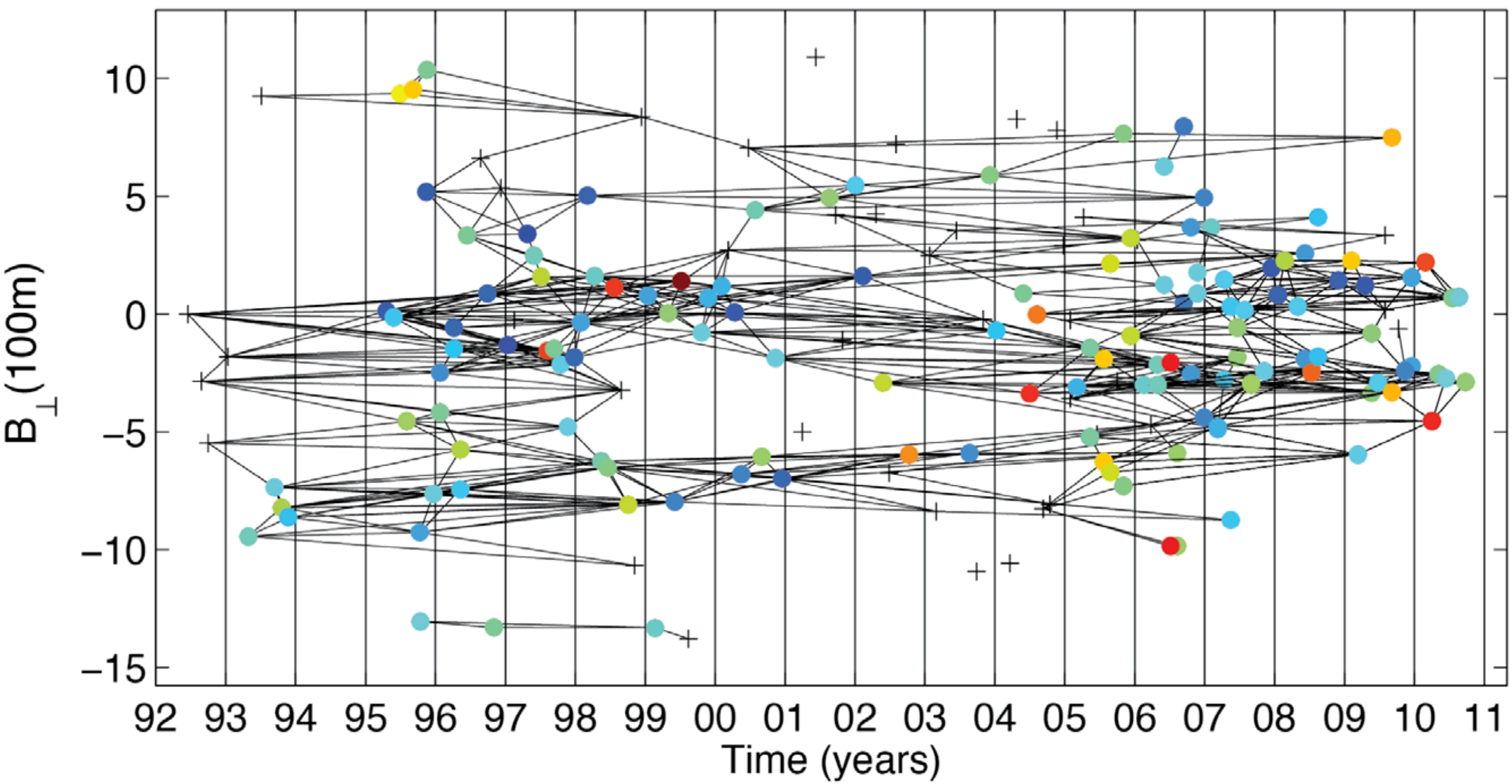
- Eastern California Shear Zone
- 3 descending tracks (ERS-1/2, ENVISAT)
- 1992-2010
- ~500 SAR acquisitions
- computed APS, mean LOS velocities, and time series corrected for the atmospheric artifacts
- validation: comparison of LOS velocities from different tracks (in areas of overlap); comparison between InSAR and cGPS
- 4 focus areas where anomalous deformation has been suggested by previous studies

ERS-2 Dec 11 2006 – Feb 19 2007 ENVISAT

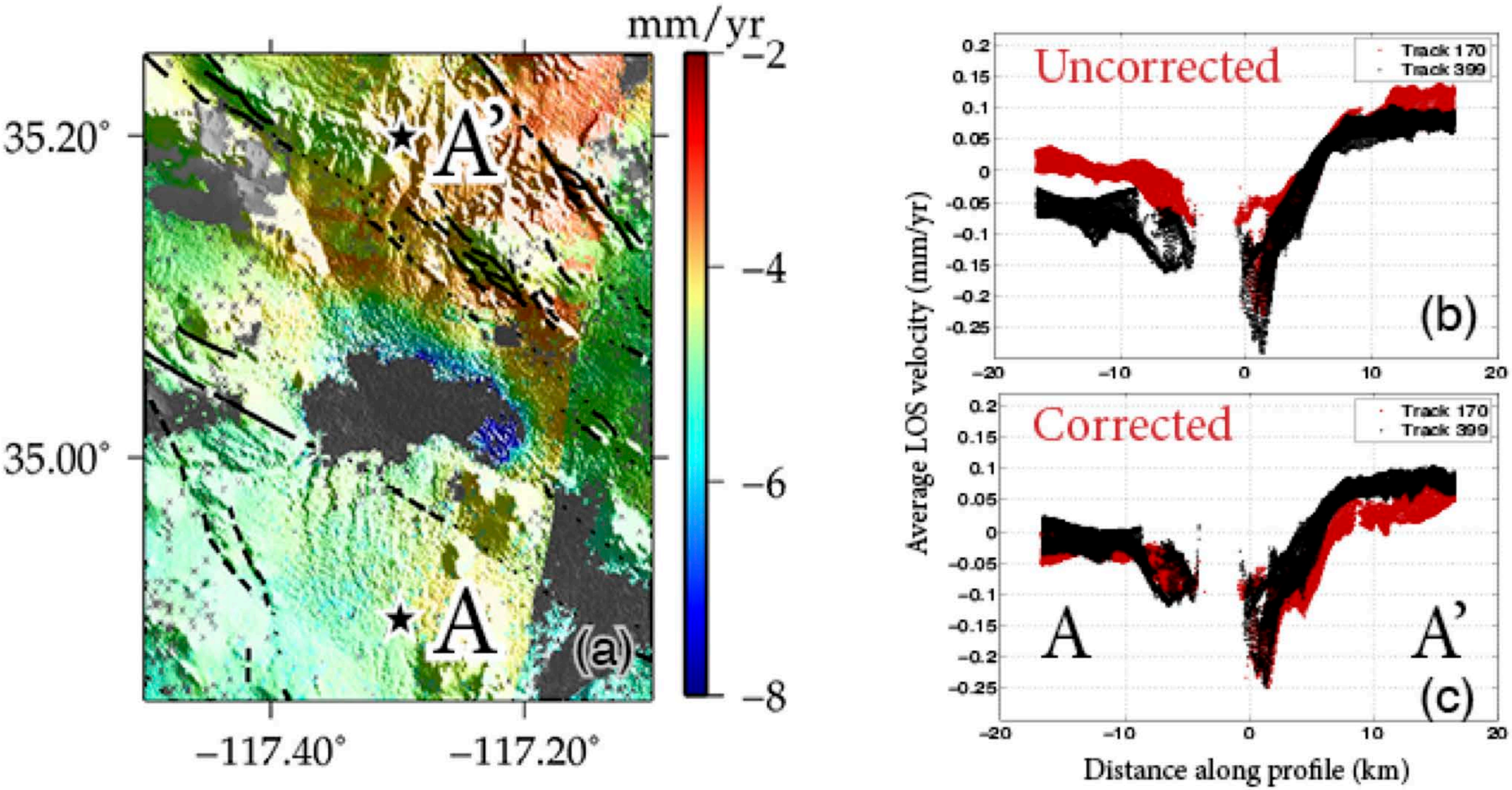




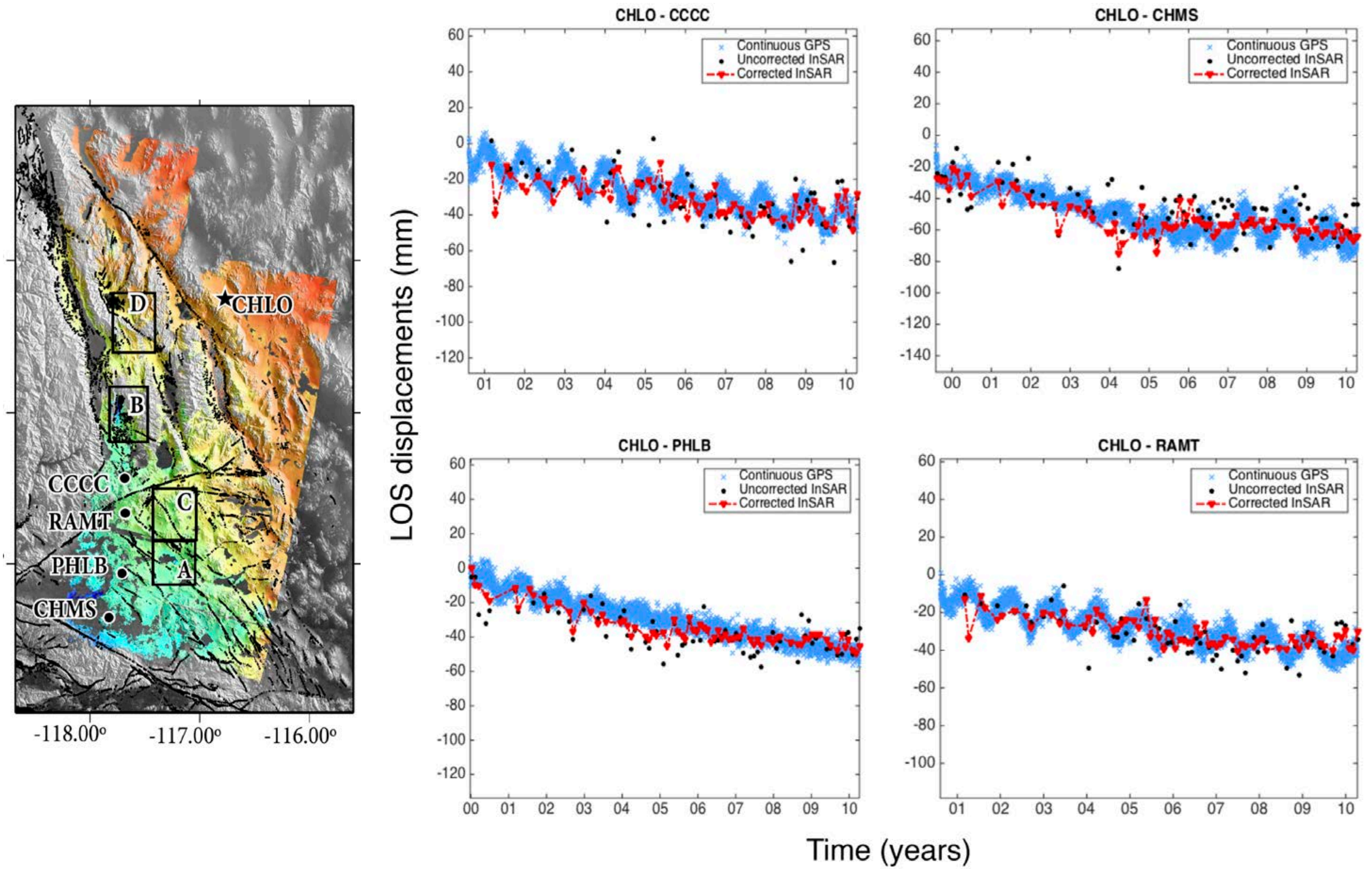
ERS/ENVISAT baselines and estimated ANCs



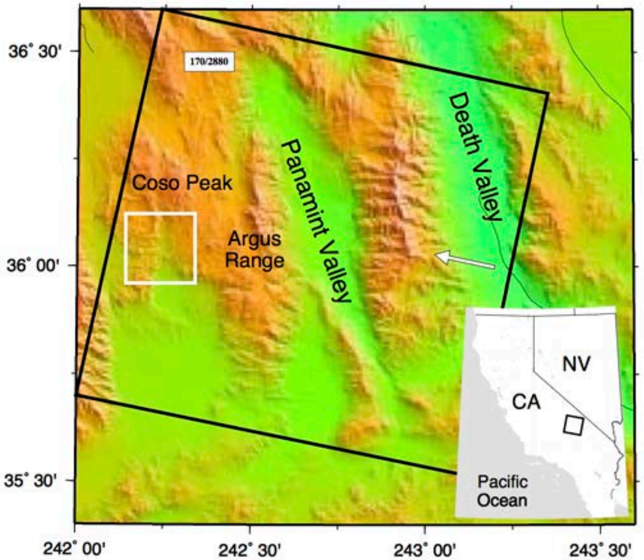
Subsidence around Harper Lake

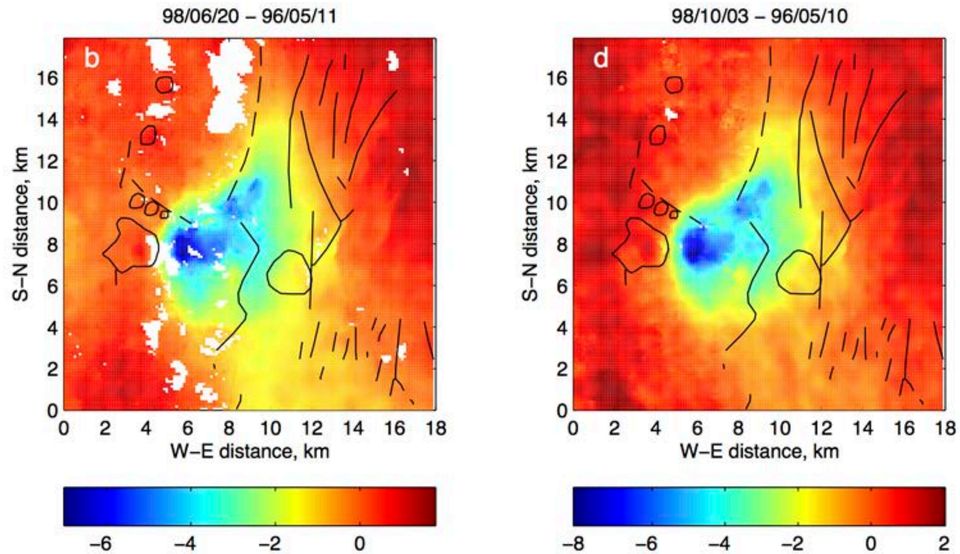


Comparison of InSAR-cGPS timeseries

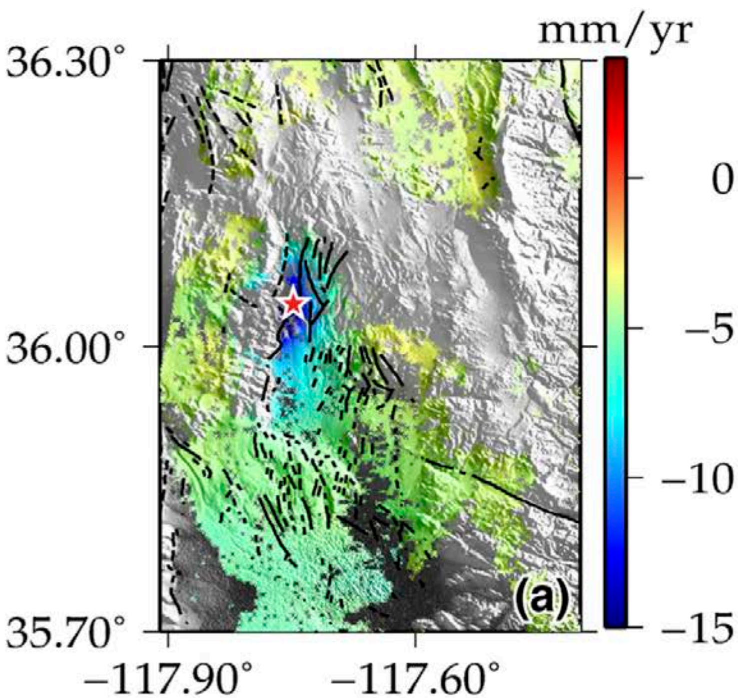


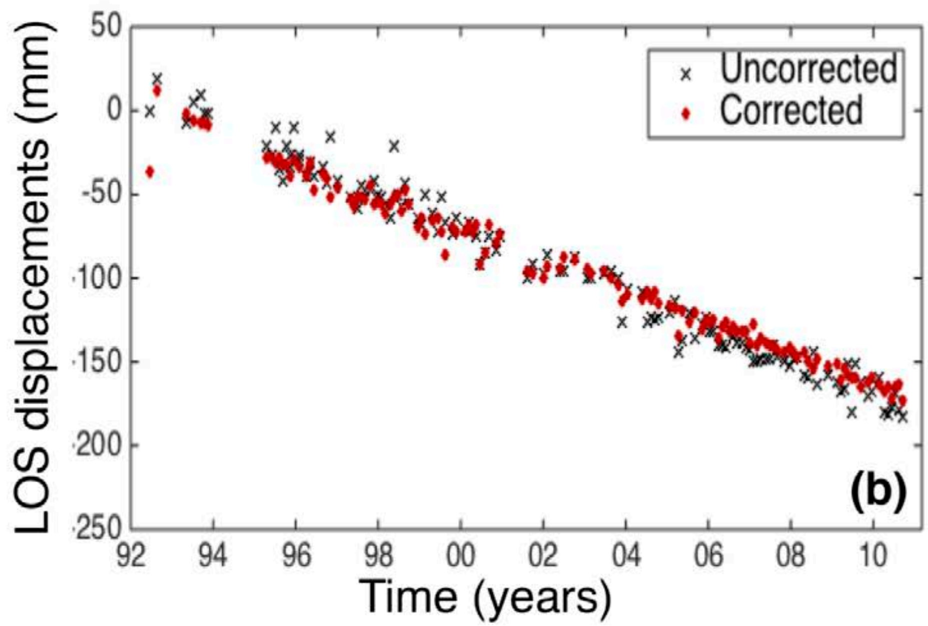
Subsidence due to the Coso geothermal plant



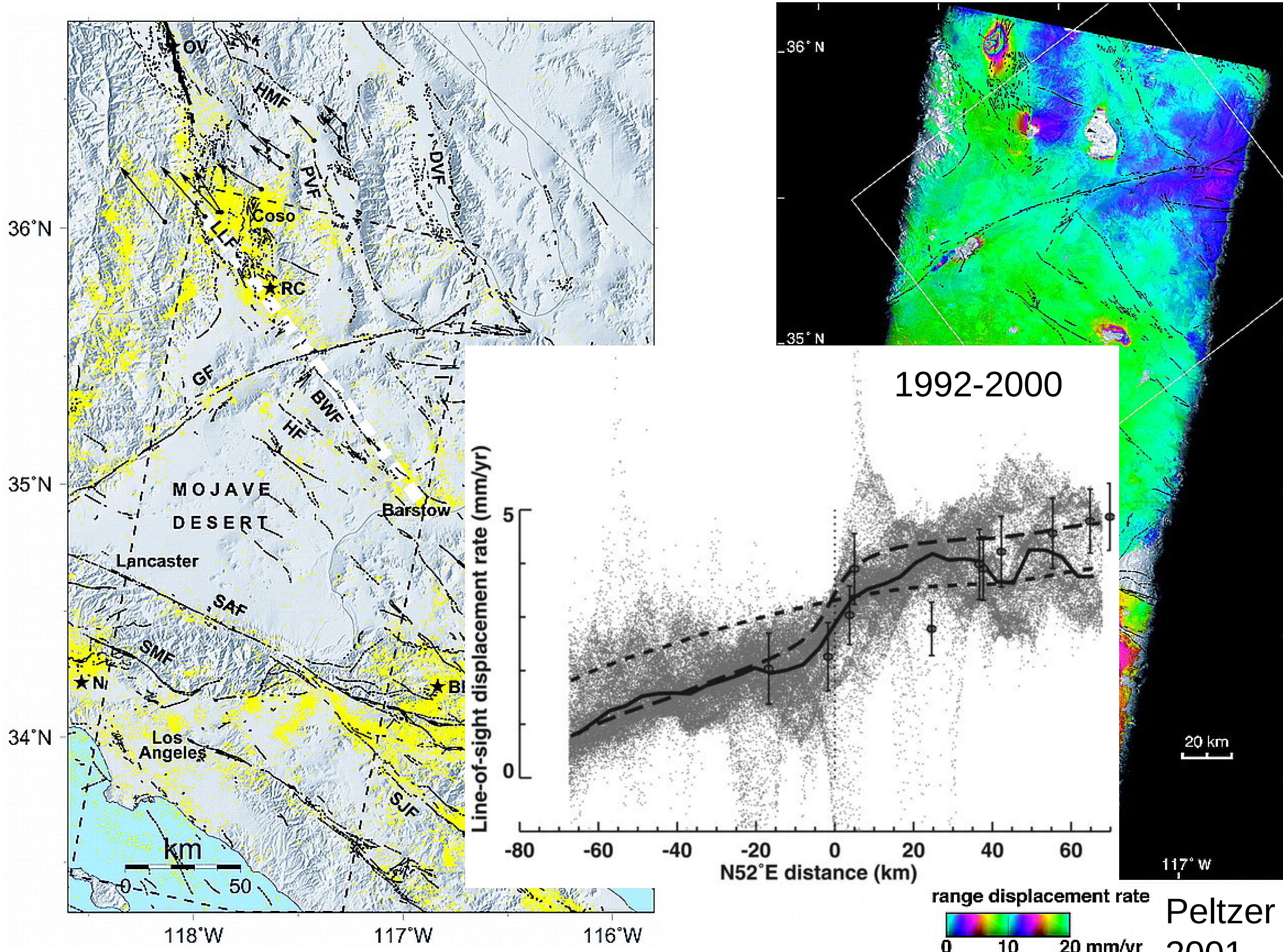


Fialko and Simons, 2000

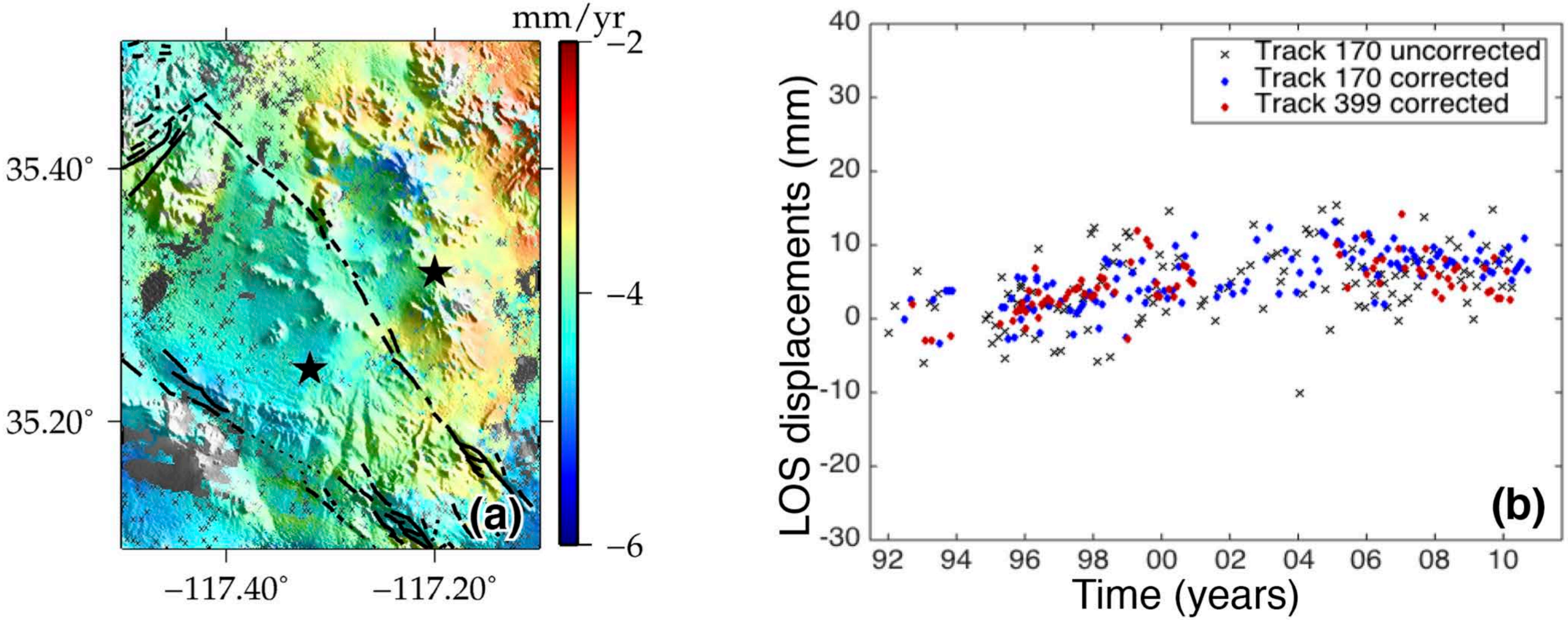




Deformation due to the Blackwater fault



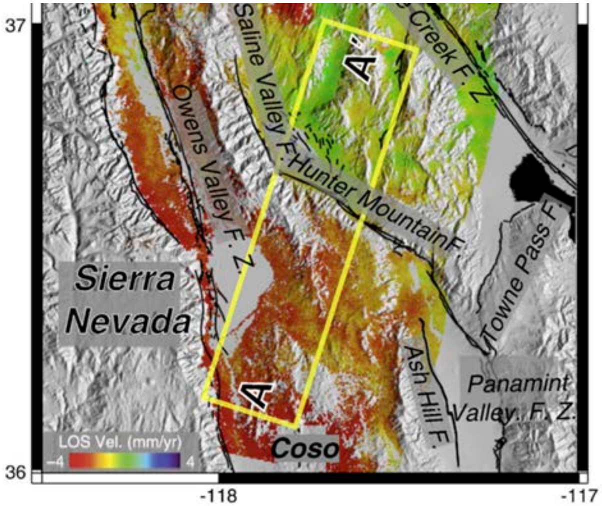
Peltzer et al., 2001

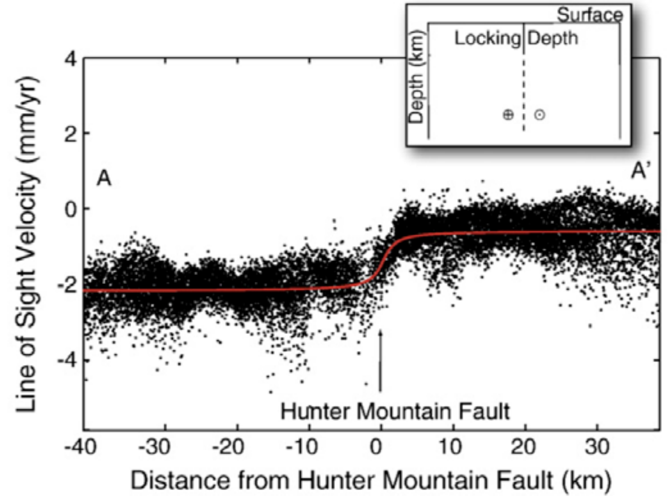


- no obvious near-fault strain localization in the average LOS velocity over 1992-2010
- consistent results from the 2 overlapping tracks (170 and 399)

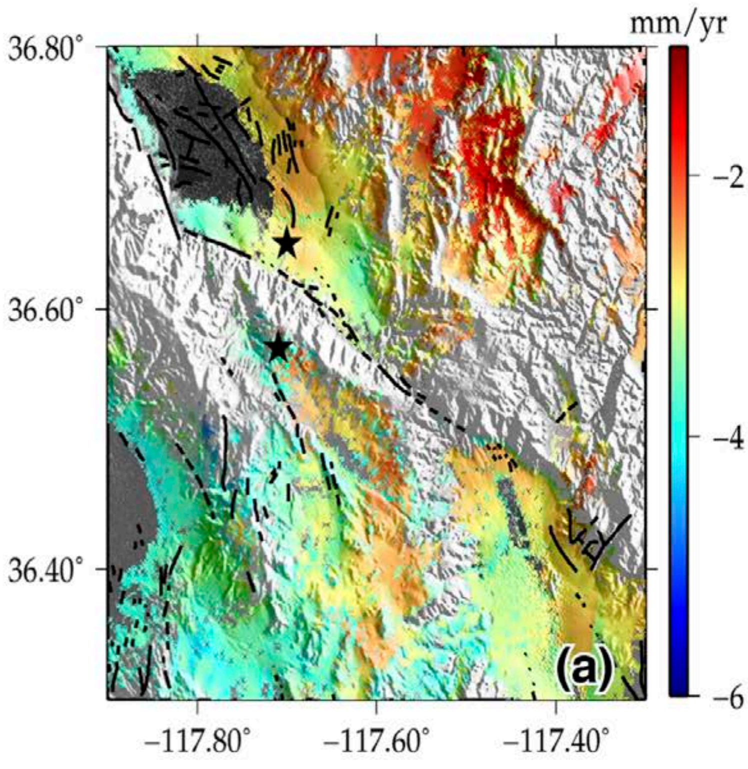
- time series show elevated LOS velocity (1-1.5 mm/yr) across the fault in 1992-2000
- after 2000, deformation slowed down and possibly even reversed

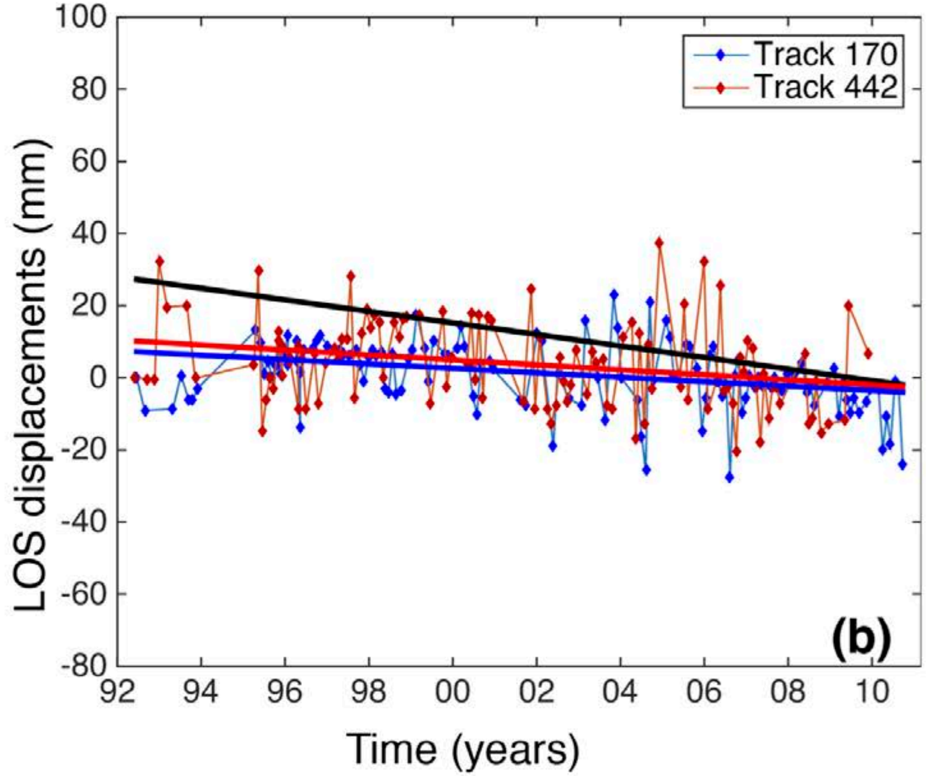
Deformation due to the Hunter Mountain fault





Gourmelen et al., 2010; 2011



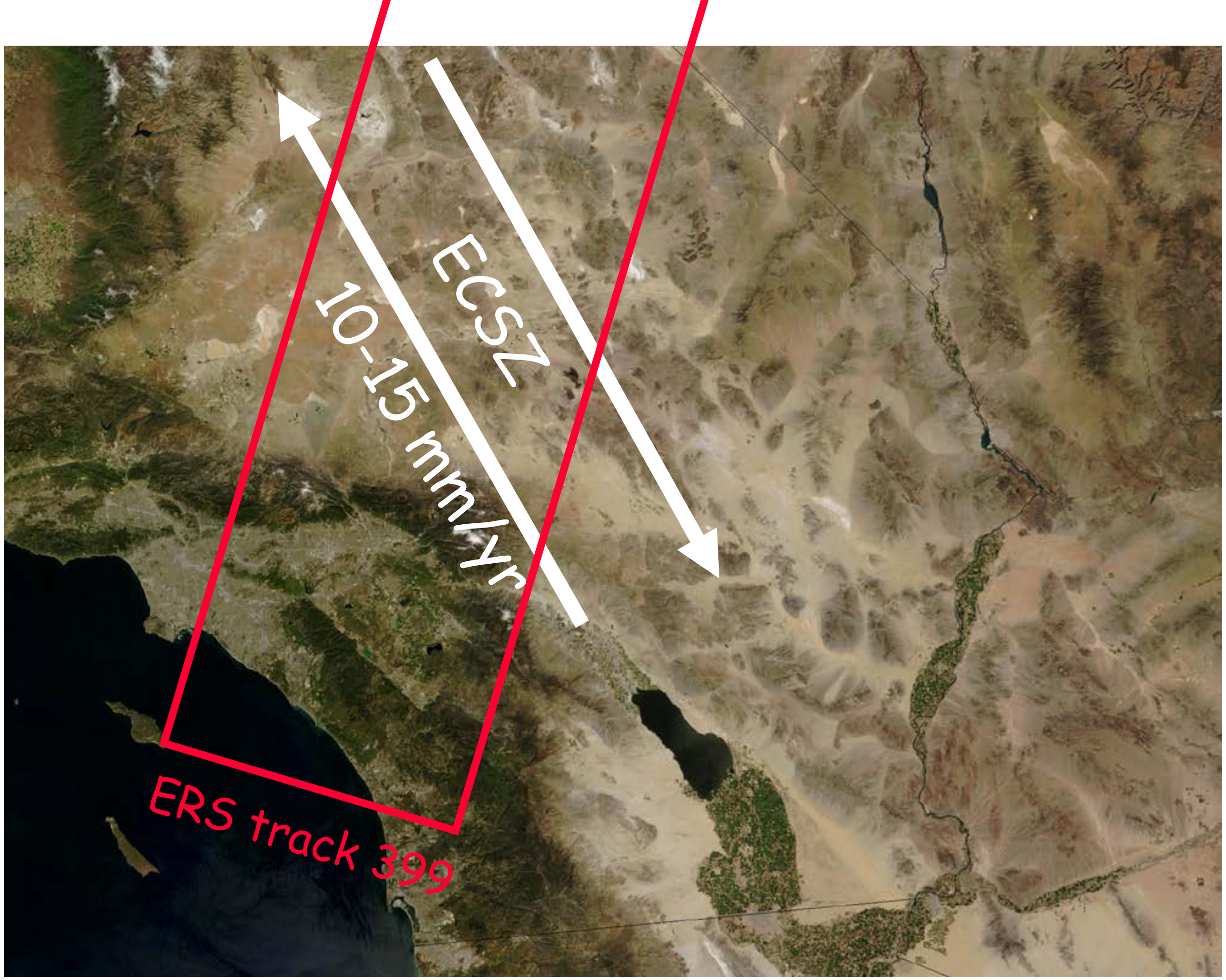


Conclusions: method

- Common-point stacking can be applied iteratively to estimate path delays in every data take
- Easy to implement and execute, computationally efficient
- Relies on frequent acquisitions with small baselines
- Validated by comparisons of data from different tracks, and cGPS
- Efficiency can be improved by using more sophisticated signal enhancement techniques (image cross-correlation, pattern recognition, etc.)
- Method can be used to estimate not only the tropospheric contributions, but also those due to ionosphere and imprecise orbits

Conclusions: ECSZ

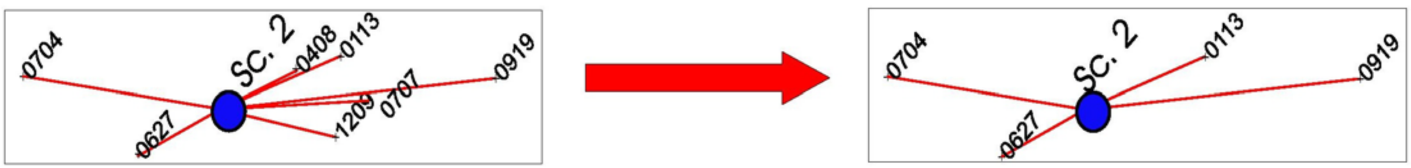
- Subsidence due to the Coso geothermal plant has occurred at a constant (and significant! – centimeters per year) rate over the last 20 years
- The data do not require that the Black Water fault and the Hunter Mountain fault have anomalously high slip rates and small locking depths.
- The Black Water fault may have experienced an accelerated deformation following the 1992 Landers earthquake; however, this deformation could involve either horizontal or vertical motion (or both) – little ascending data exist to address this issue
- [ms in review in JGR – available for anyone interested]



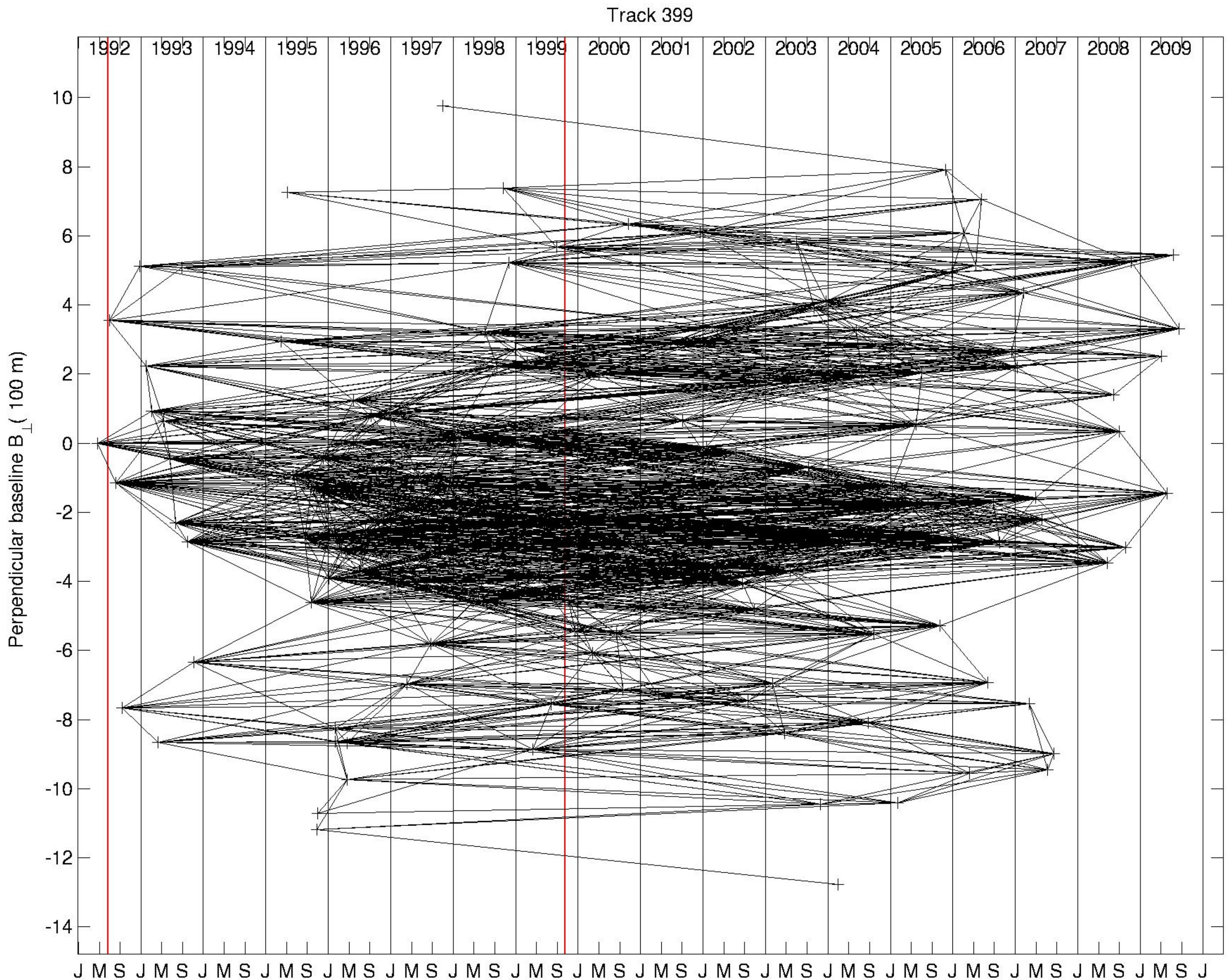
1992 M7.3 Landers earthquake
1999 M7.1 Hector Mine earthquake

Initial evaluation of Atmospheric Noise Coefficients :

- generate a set of interferometric pairs for a given range of baselines and timespans
- calculate ANC for all shared scenes
- calculate ANC for all "endpoint" scenes using scaling between ANC and $\Delta\rho$, $(ANC_i+ANC_j)/2 \sim RMS(\Delta\rho_{ij})$
- reorganize the stack to eliminate or reduce the contribution of most noisy scenes:



- calculate the mean LOS velocity by averaging the optimized set of interferograms



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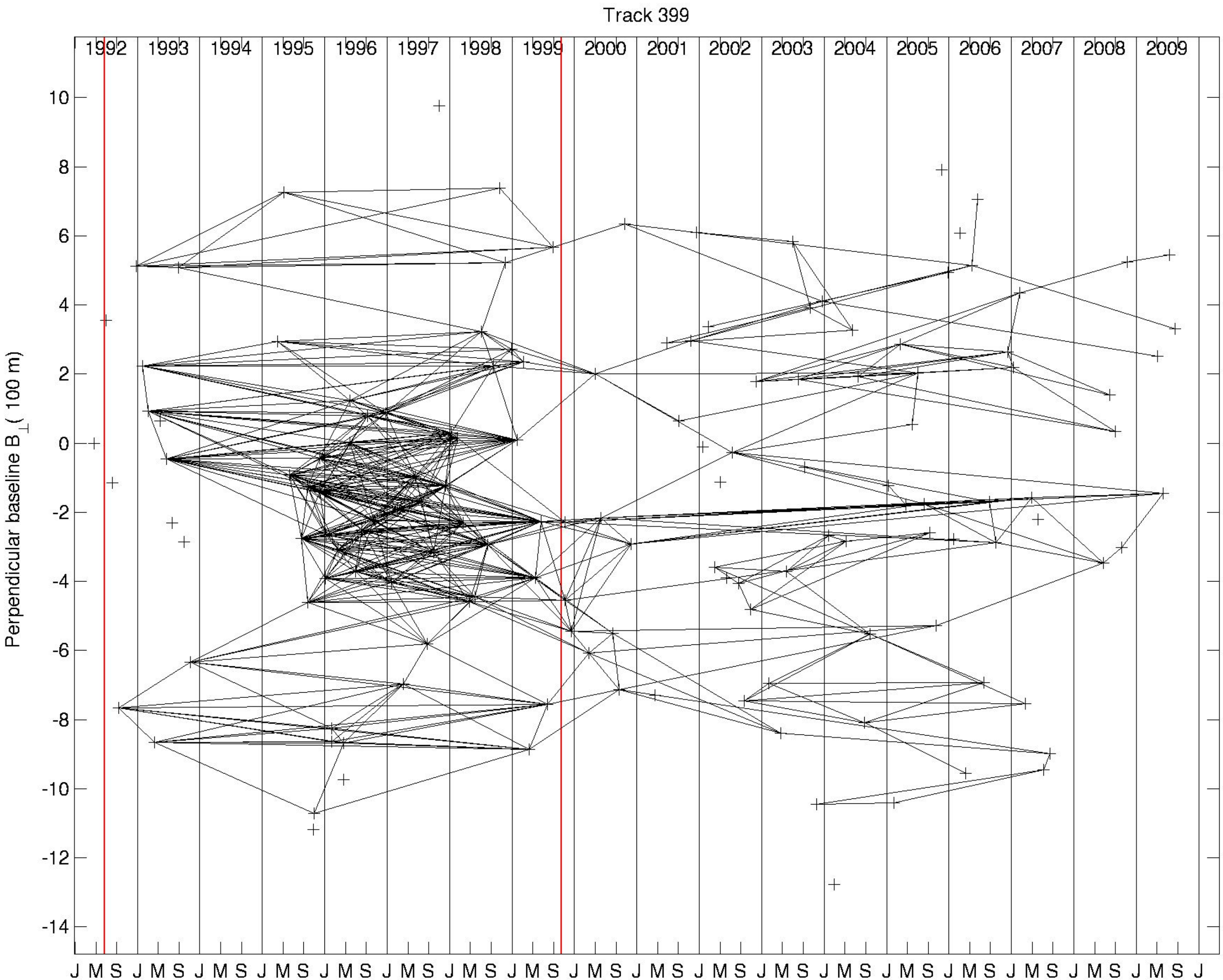

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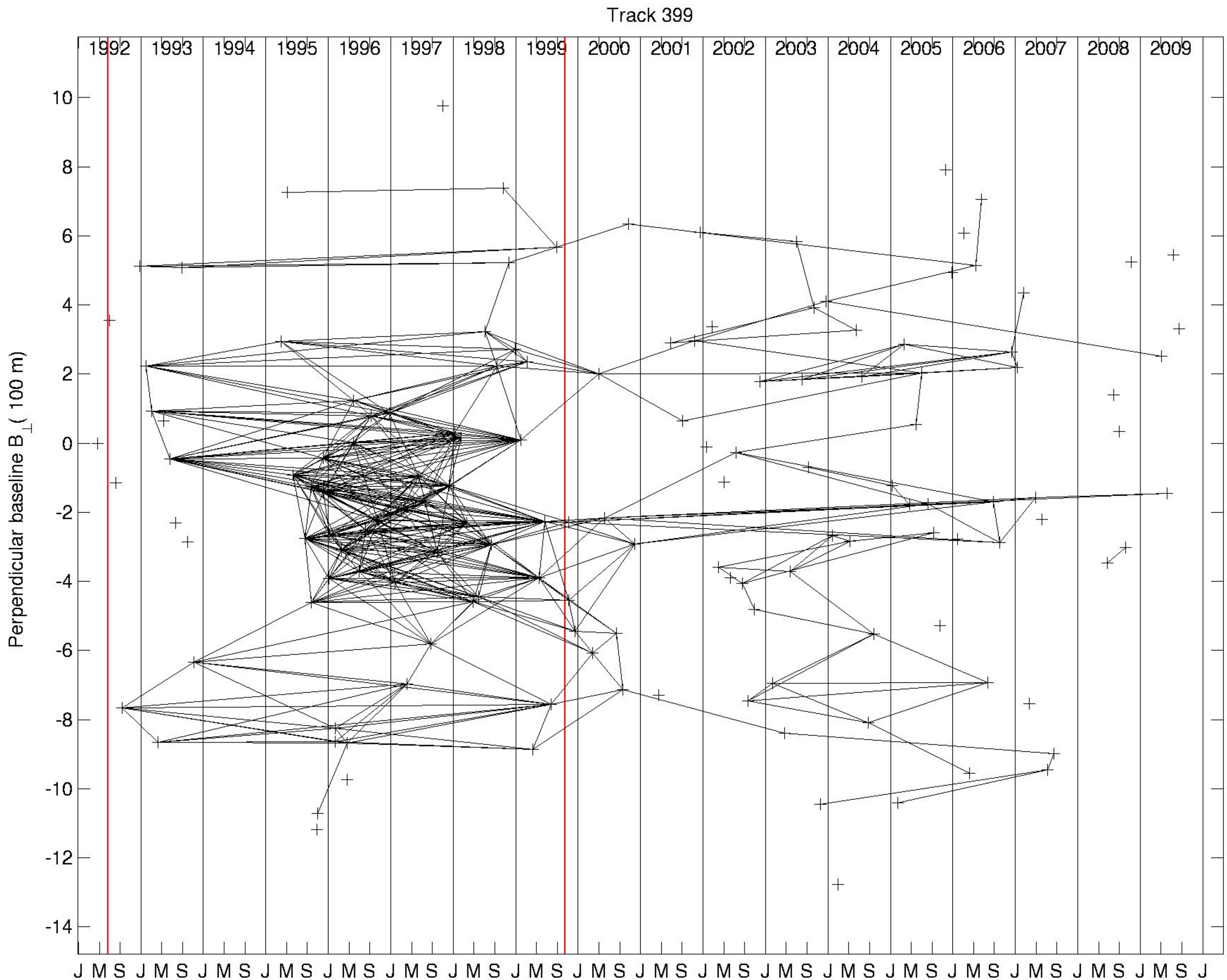
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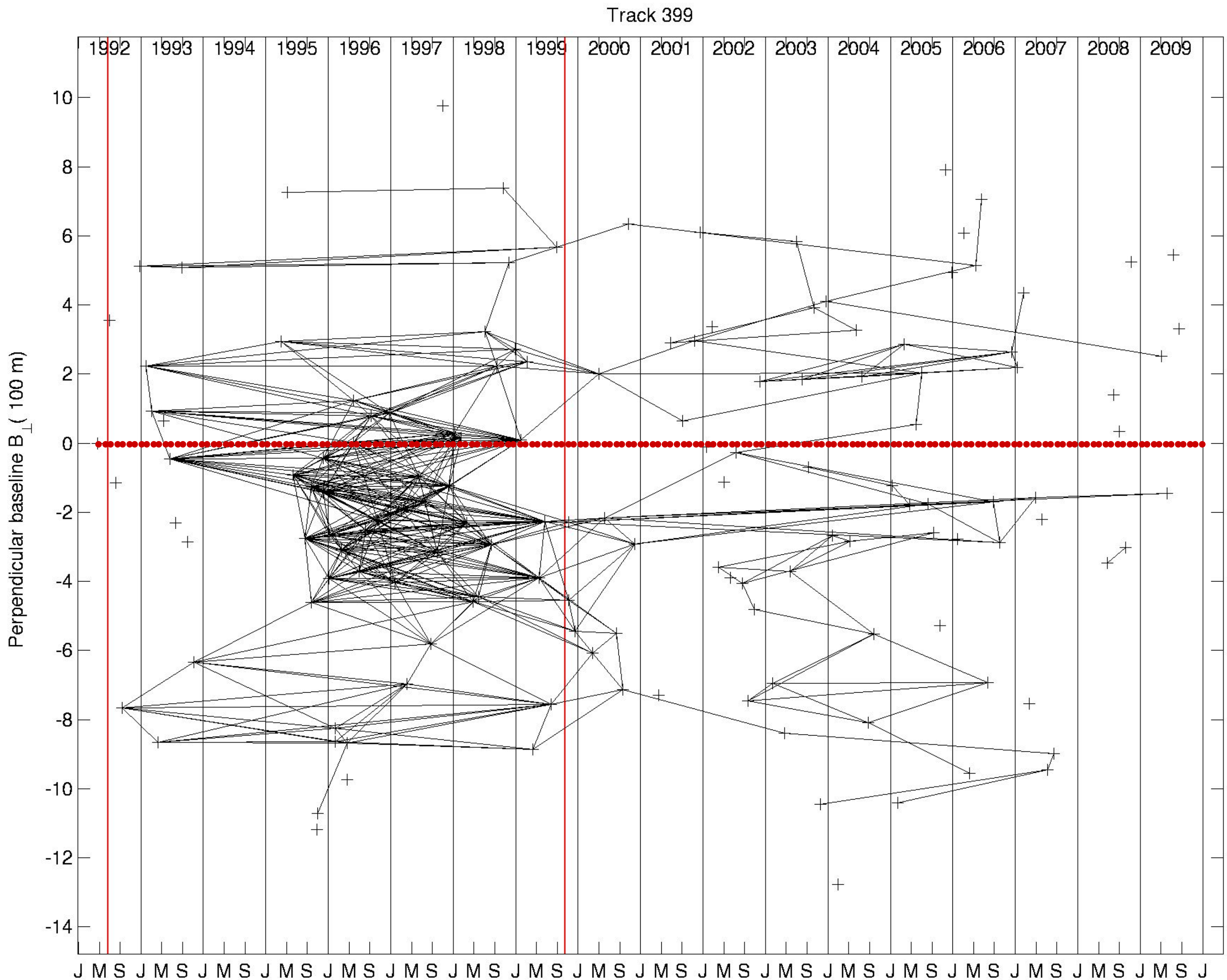
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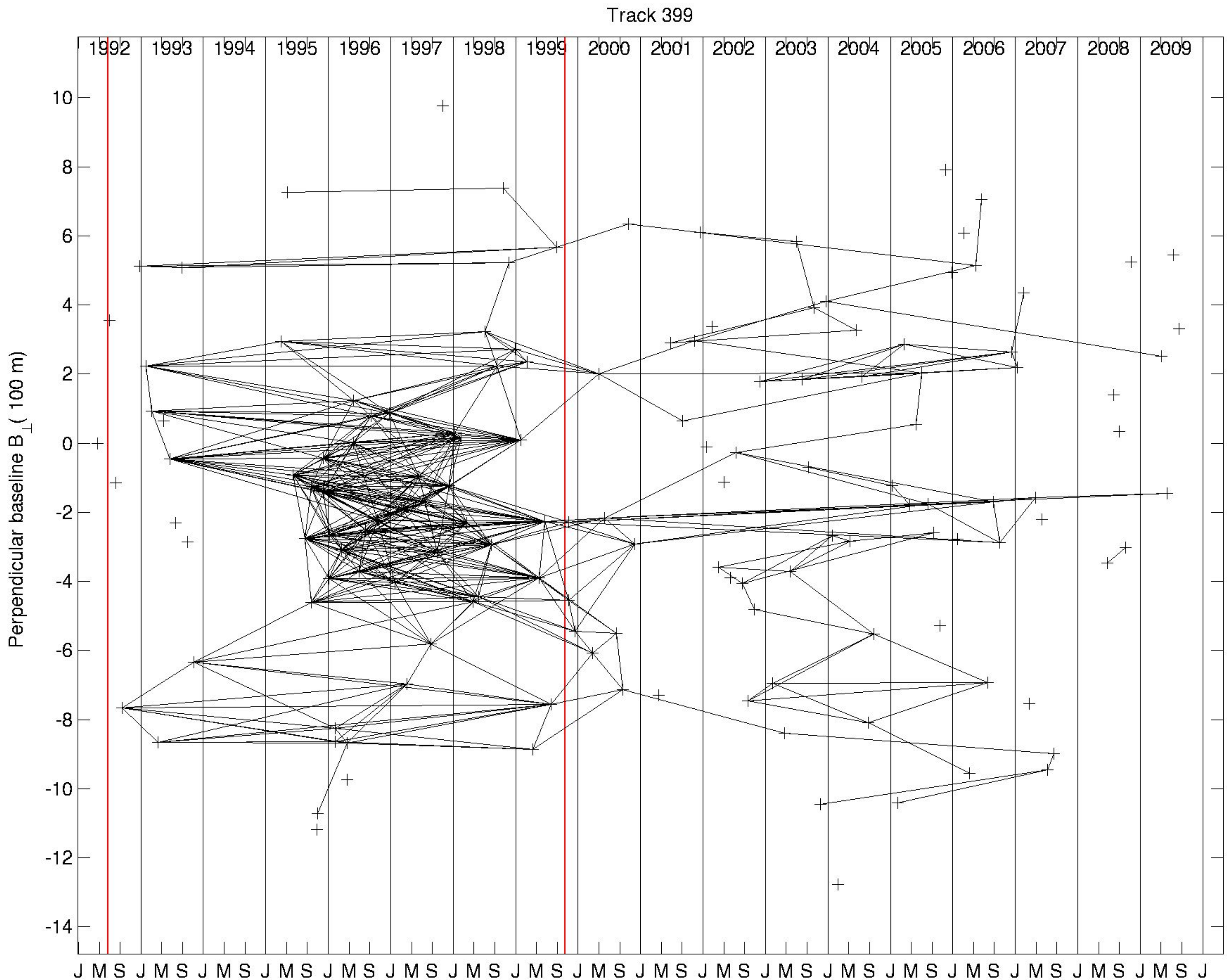
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