High spatiotemporal resolution study of the Great Basin active deformation (Western US): New methodology and geodynamic challenges

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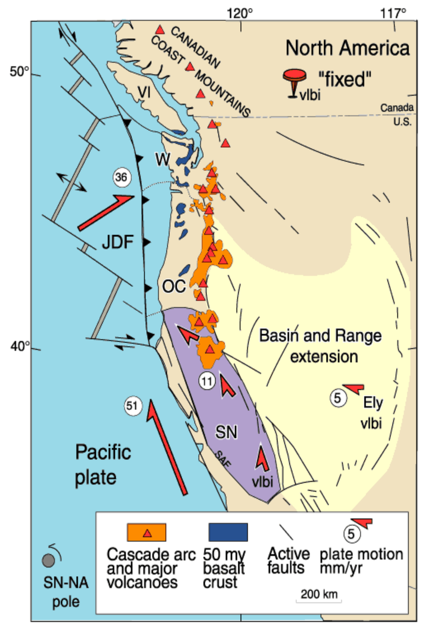
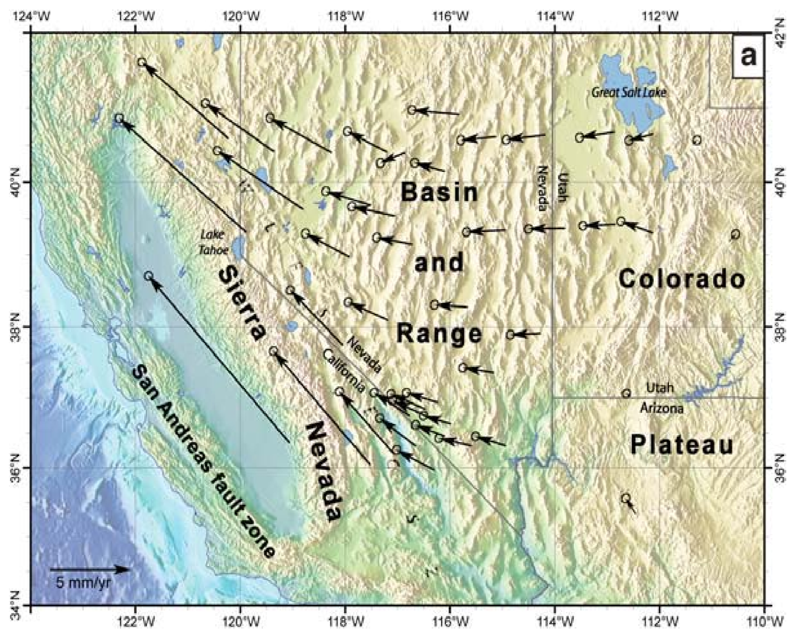
1. Introduction and objectives

The Great Basin is an **800-km**-wide region of high heat flow, thin crust, thin lithosphere and active deformation in both extension and right-lateral shear, accommodating about 25% of the total Pacific-North America relative plate motion (e.g. *Lachebruch and Sass* 1978; *Bennet et al.*, 1999).
Average horizontal velocities (relative to North America) rise from near zero on the Colorado Plateau to 3 mm/yr. oriented due west near the Nevada-Utah border (e.g., *Bennett et al.*, 2003; *Wernicke et al.*, 2000; *Hammond and Thatcher*, 2005, 2007). The velocities remain relatively constant across eastern Nevada, and rotate northwestward and progressively increase up to 12 mm/yr. across the Walker Lane fault system, with the highest strain rates near the western margin.

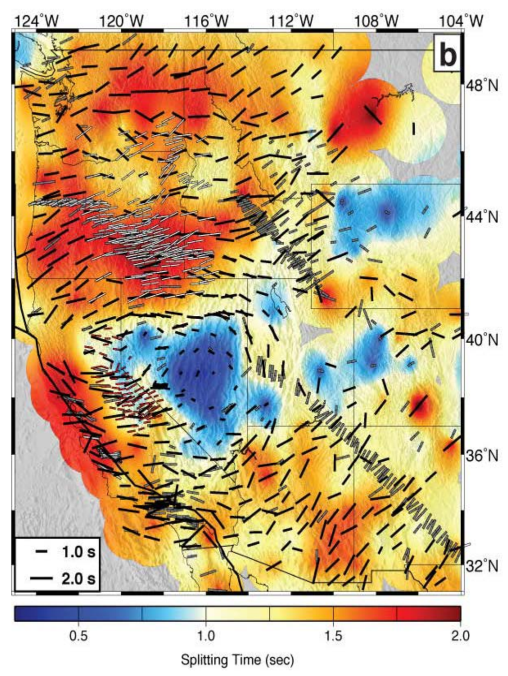
Several regionally coherent, transient velocity anomalies have been observed geodetically in the region, as summarized on the "geodogram" (*Wernicke and Davis*, 2010), and in at least one case shown to be closely linked to microseismicity. In general, these events are far too rapid and aerially extensive to be explained by seismic cycle effects of historic earthquakes.

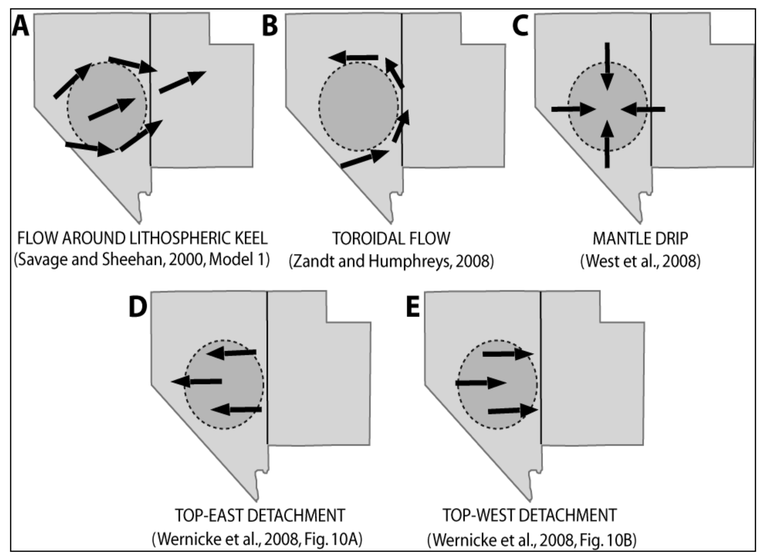


Geodynamic context (Wells et al. 2000).



Velocity field relative to North America, measured by the permanent BARGEN network (Basin and range Geodetic Network).


Shear wave splitting results for the western U.S. (Fouch and West, 2010).
The Great Basin stands out as the only broad region of weak azimuthal anisotropy (blue region). EarthScope project.



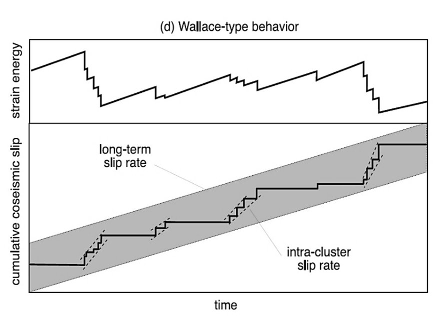
Published hypotheses addressing significant anomalies observed in the mantle, crust and on the surface within the Great Basin region (EarthScope project).

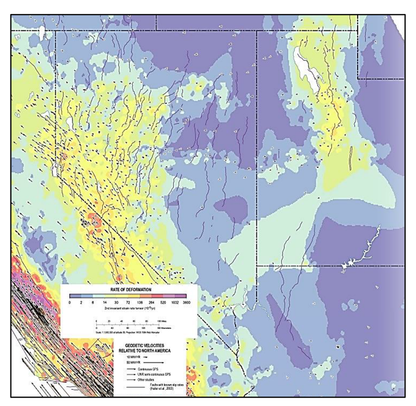
Arrows denote direction of traction exerted either by asthenosphere on lithosphere (lithosphere-asthenosphere coupling) from mantle flow (A, B, C), or by lower lithosphere on upper lithosphere (intralithospheric coupling) (D, E). Models A, B, C address various components of observations that include weak azimuthal mantle seismic anisotropy and high mantle seismic wavespeeds (dark gray circle). Models D, E address several observations suggesting a regional decoupling horizon beneath the whole of the Great Basin.

Objectives of the post-doc :

- Produce an inventory of detailed and updated geologic-geodetic rate comparisons available to the community.
- Defining the location, sense-of-slip and rate of potential decoupling horizons in the lithosphere.
- Deeper and broader investigation of the "geodograms" (generating alternative projections of the data in 3D, test of different references frames).
- Investigation of the crustal deformation at different timescales: transient (annual), geodetic (several decades) and finite geologic deformation (ka to Ma).
- Interpret our results with upper mantle images produced by the EarthScope and DCMC projects to investigate the dynamics of crust-mantle coupling.

2. Comparison of geologic and geodetic strain rate




Geodetic strain rate map, Kreemer et al., (2012).

Active faults mapping of the region is accurate (Fault and Fold Database of the U.S. Geological Survey, *Haller et al., 2004*, http://qfaults.cr.usgs.gov), but deformation rate is time-scale dependent !

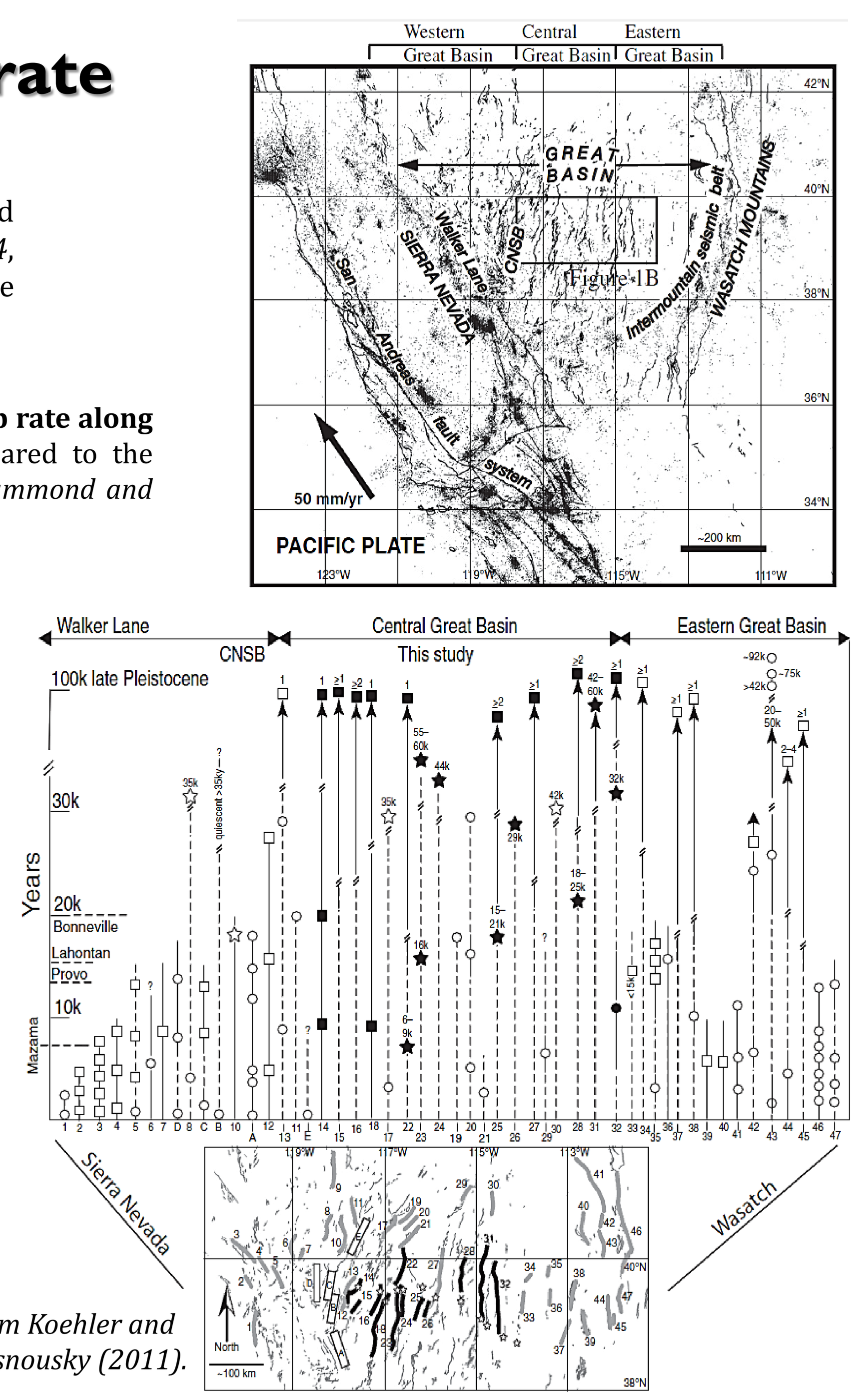
- For the four principal faults of , the total extensional **geological slip rate along a 321° azimuth is 0.59–0.69 mm/yr.** *(Bell et al., 2004)* compared to the **relative difference of 3.13 ±1.88 mm/yr. in GPS velocities** *(Hammond and Thatcher 2004)*, between UPSA and NEWP stations of BARGEN.
- Wasatch fault zone (table of *Friedrich et al. 2003* below).

Comparison of Geodetic (BARGEN) Rates With Geologic Rates Across the Wasatch Fault and the Transect Region

	Horizontal Geodetic Rate,[a,b] mm/yr (1996–2000)	Vertical Geologic Displacement Rates,[c,d] mm/yr				Horizontal Geologic Rate, mm/yr: Effective Fault Dip of 30°		Horizontal Geologic Rate, mm/yr: Effective Fault Dip of 60°	
		Holocene (0–10 ka)	Pleistocene (0–130 ka)	Plio-Q (0–5 Ma)	Miocene (5–15 Ma)	Holocene	Pleistocene	Holocene	Pleistocene
Wasatch fault	1.9 ± 0.2	1.7 ± 0.5	0.1 – 0.6	0.2 – 0.7	0.5 – 1.4	2.9 ± 0.5	0.2 – 1.0	1.0 ± 0.5	0.1 – 0.4
Regional transect[c]	2.7 ± 0.2	1.9 – 3.5	0.4 – 1.3	0.4 – 1.2	n/a	3.3 – 6.1	0.7 – 2.3	1.1 – 2.0	0.2 – 0.8

[a]Horizontally measured geodetic rates for baseline HEBE-COON across the Wasatch fault, and HEBE-CEDA across the regional transect.
[b]Including the Wasatch, West Valley, Oquirrh, and Stansbury faults.
[c]For effective fault dips of 45°, the vertical rates reported in these columns equal to the horizontal displacement components.

From Friedrich et al., (2003).

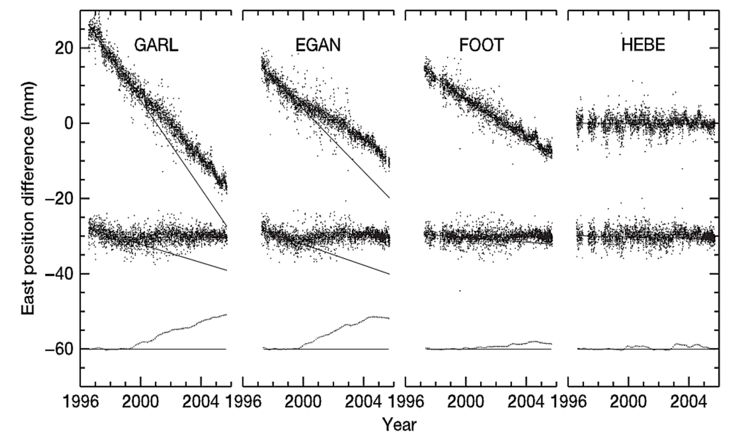


From Koehler and Wesnousky (2011).

3. A new technique to investigate transient motions : the "geodograms"

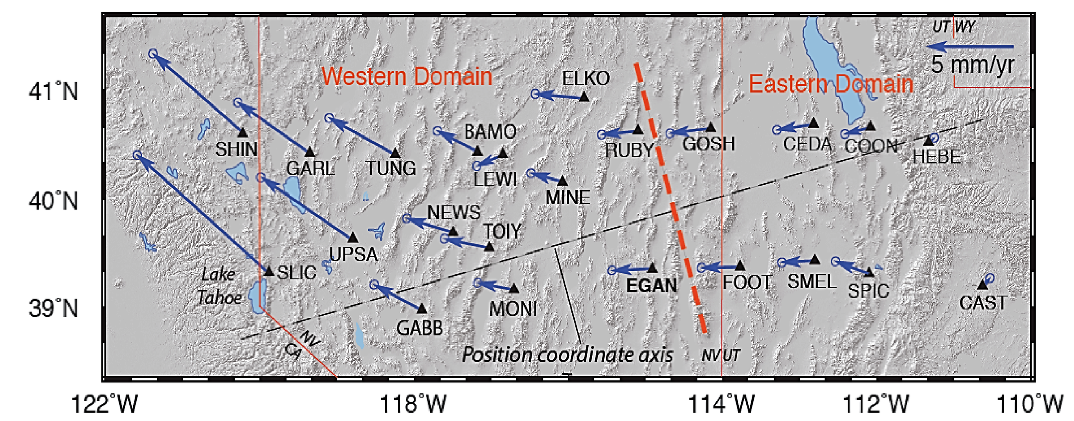
Methodology

1

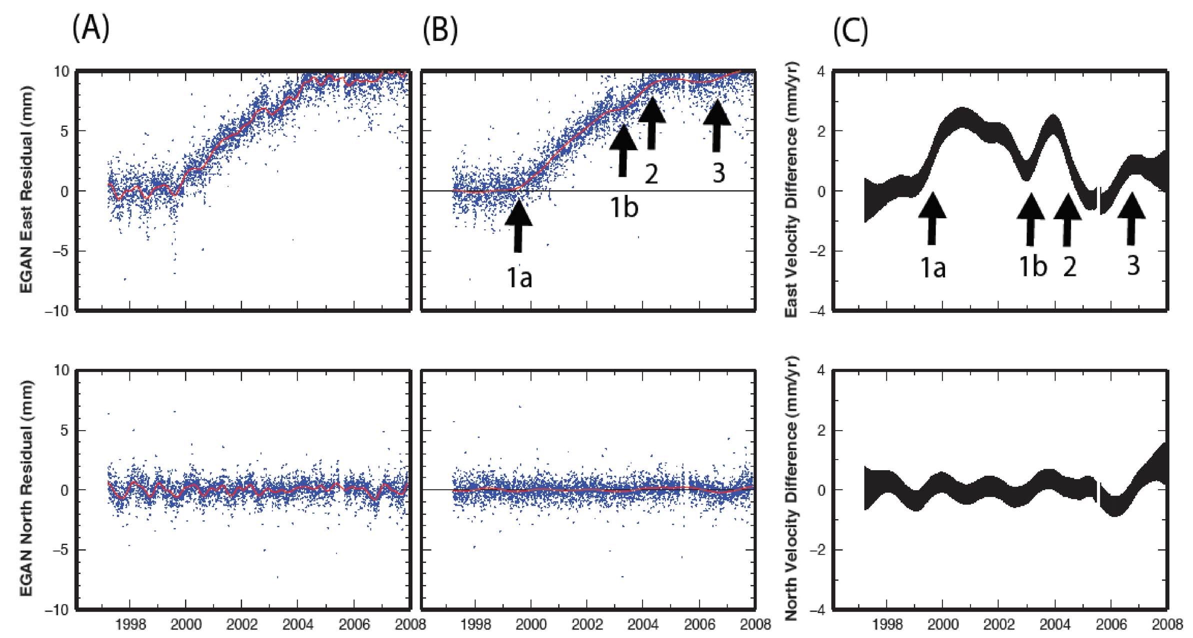


Post-analysis procedure, using time series of east position for four BARGEN sites.

Top, 'raw' time series, in a North America-fixed reference frame (Davis et al. 2006). Error bars are omitted for clarity, but are generally 1 mm. The straight line is the best-fit straight line using position estimates from the first 2.5 years. Middle, residuals of the raw time series from a best-fit model consisting of a straight line and seasonal (annual and semi-annual sinusoids) terms. A statistical approach that allowed these terms to change with time in a constrained manner was used (see Methods). Bottom, residuals smoothed with a Gaussian filter with a full-width at half-maximum (FWHM) of 8 months. A model based on a linear fit to the first 2.5 years of data has been removed. The evolution of these final time series thus indicates deviation from temporally linear motion.

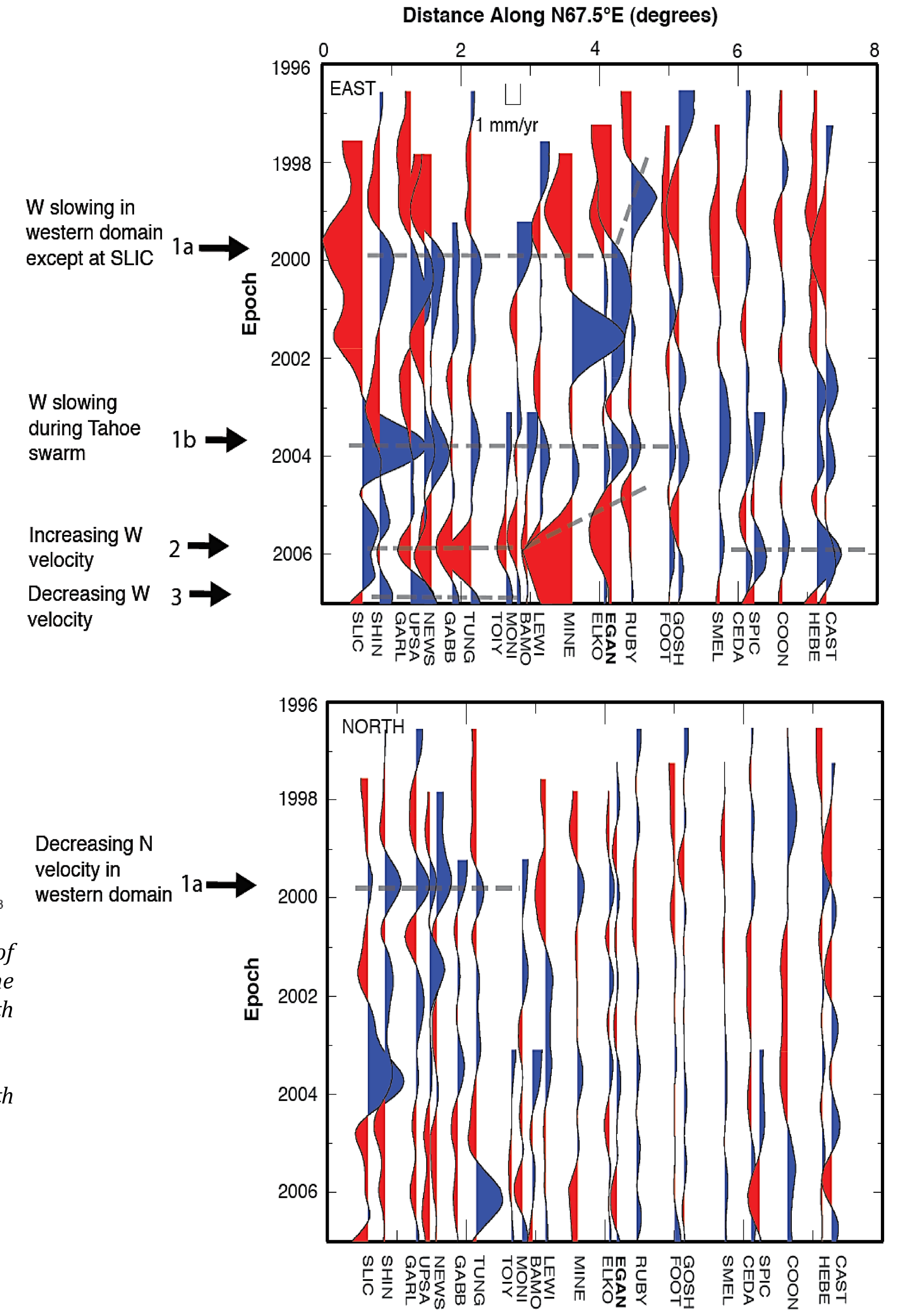


Average velocity field (ca. 1997–2007) with 1σ error ellipses of BARGEN GPS sites near latitude 40°N, after Wernicke et al., (2008).



2

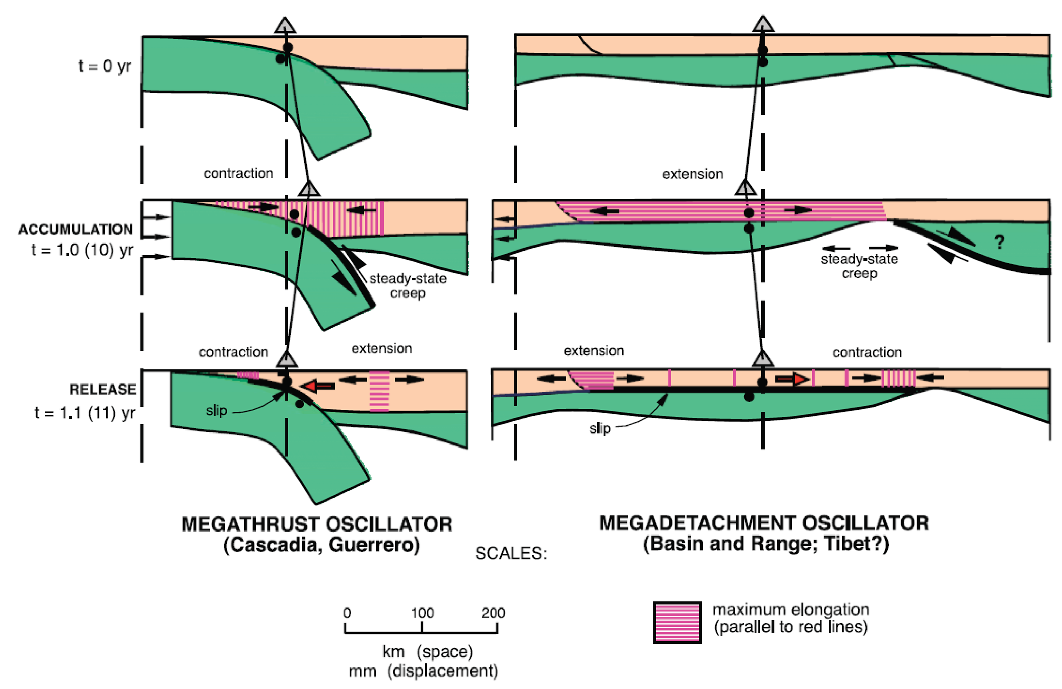
A) Unfiltered time series of east (upper) and north (lower) components of position of site EGAN, relative to its average position prior to 2000.0. The model determined using the Kalman filter described in the text is shown with a red line.
B) Same as A, with seasonal signals removed from the data and model.
***C) Velocity time series derived from the filter analysis for site EGAN;** width of curve reflects 1σ error limits. From Davis and Wernicke (2010).*



3 ***Velocity "geodogram" for BARGEN sites, with site position projected onto the azimuth N67.5E.***

Red regions denote westward velocity anomalies; blue regions denote eastward velocity anomalies. Dashed lines show regionally coherent events. From Davis and Wernicke (2010).

Proposed interpretation



*Schematic cross-sectional models drawing analogy between top-to the-east displacement and associated strain patterns on the **megadetachment** and the **slow slip events (SSE)** in subduction zones. From Wernicke et al., (2008).*