

Decadal-scale deformation transients in Japan prior to the 2011 Tohoku earthquake

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SCEC Workshop on Ductile Rheology of the Southern California Lithosphere,

1-2 May 2013, USGS Menlo Park, Calif.

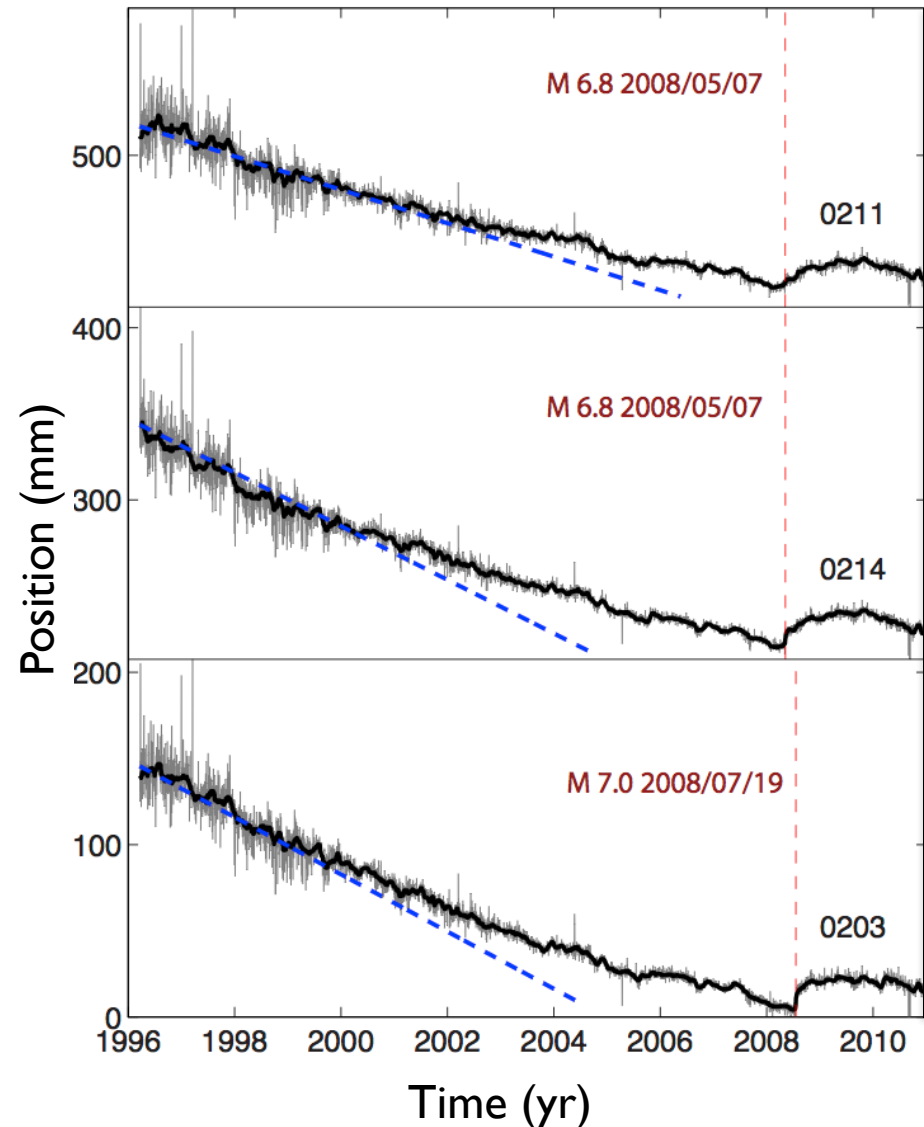
Motivation & Objective

- **Observation:**

Gradual change in deformation rates in southern Tohoku prior to M_w 9.0 earthquake

- **Objective:**

Explore spatial pattern of decadal-scale transients in Japan



Time Series Parameterization

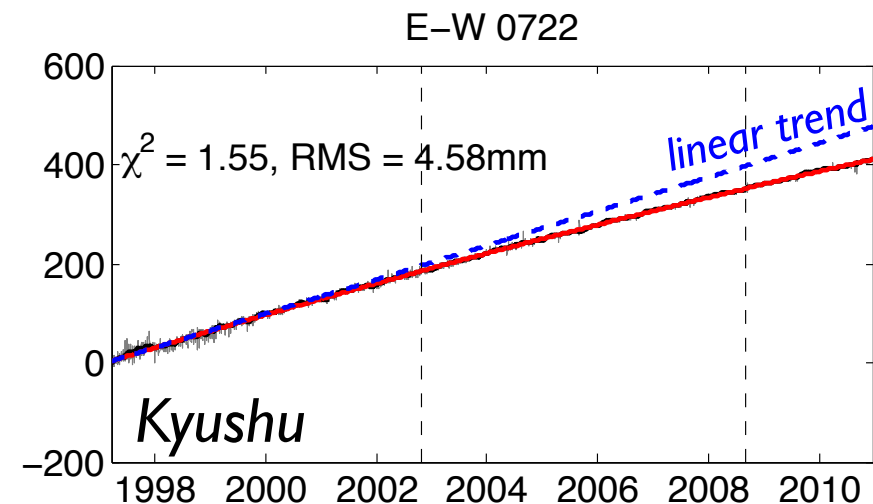
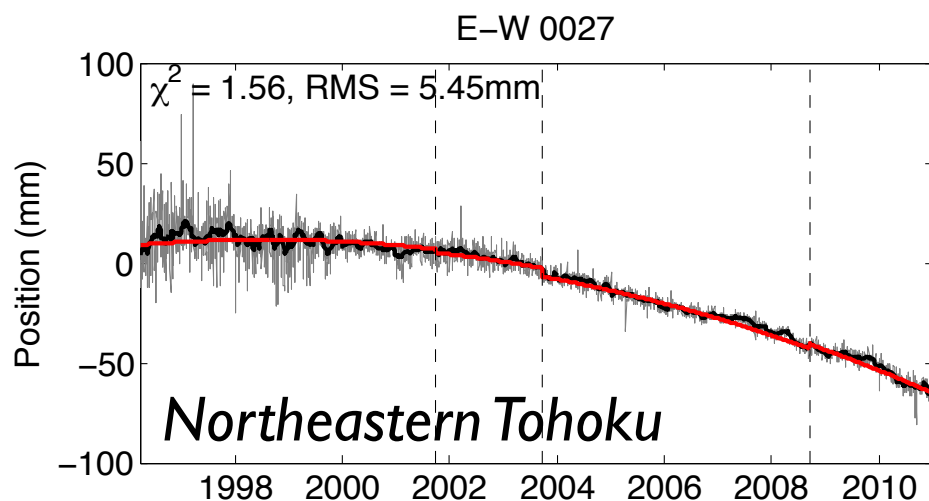
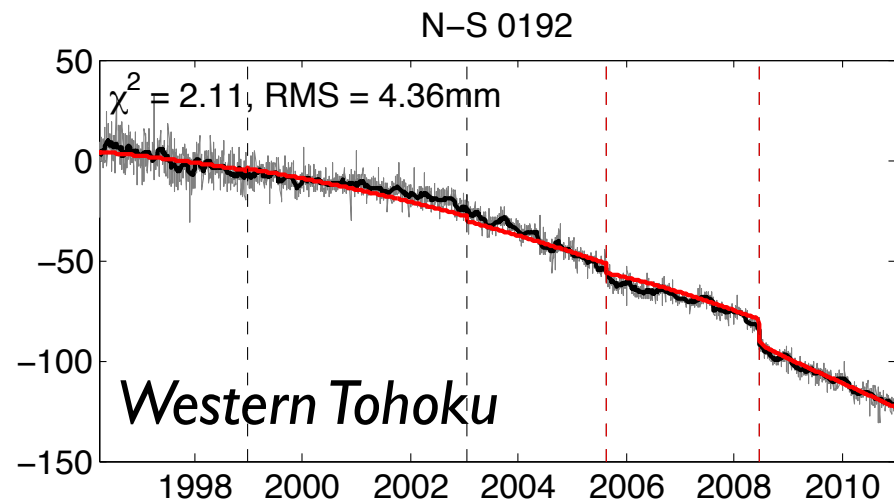
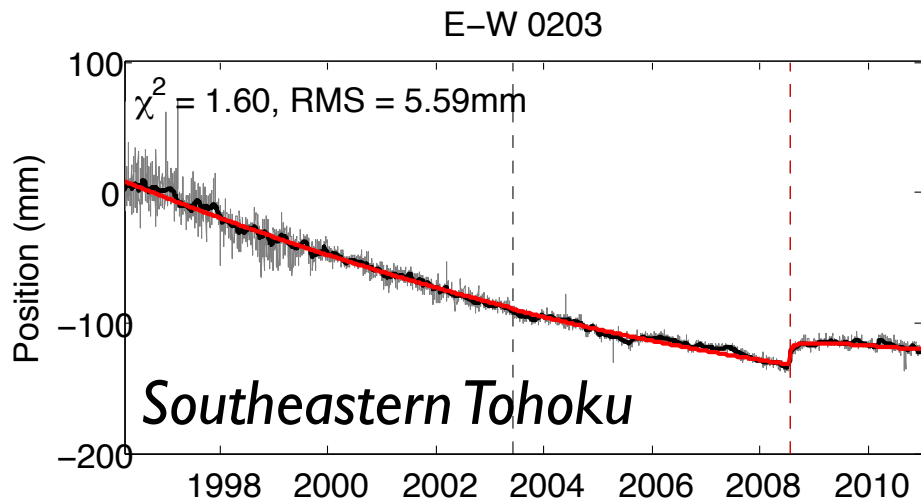
$$1996 < t < 2011$$

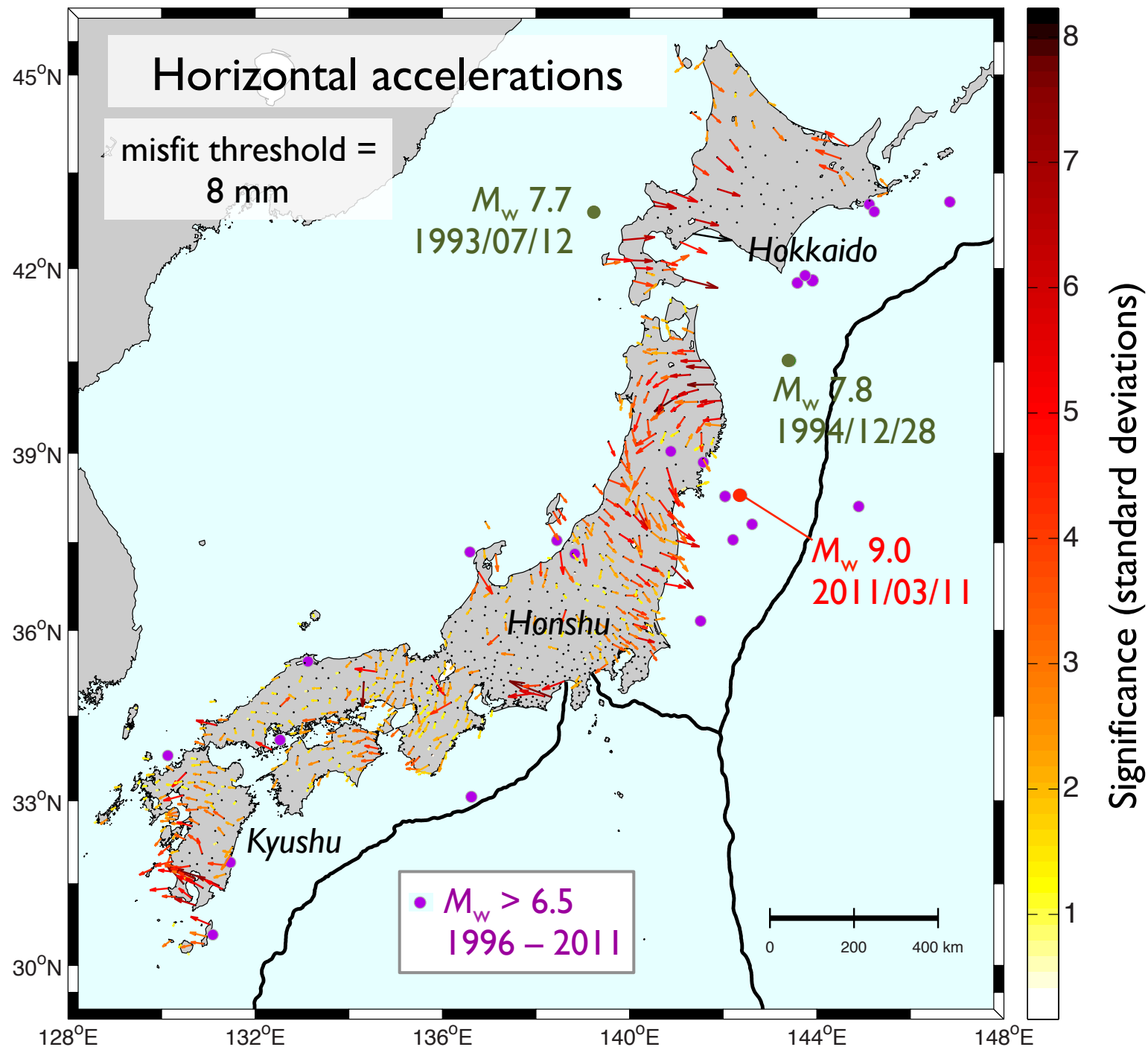
$$\begin{aligned} x(t) = & x_0 + v_0 t + \frac{1}{2} a t^2 \quad \text{secular deformation} \\ & + A_1 \sin \theta + A_2 \cos \theta + B_1 \sin 2\theta + B_2 \cos 2\theta \quad \text{seasonal} \\ & + \sum_{i=1}^{N_{\text{off}}} \Delta x_i \mathcal{H}(t - t_i^{\text{off}}) \quad \text{offsets (earthquakes \& antenna changes)} \\ & + \sum_{j=1}^{N_{\text{eq}}} C_j \ln \left(1 + \frac{t - t_j^{\text{eq}}}{\tau_j} \right) \mathcal{H}(t - t_j^{\text{eq}}) \quad \text{postseismic transients} \end{aligned}$$

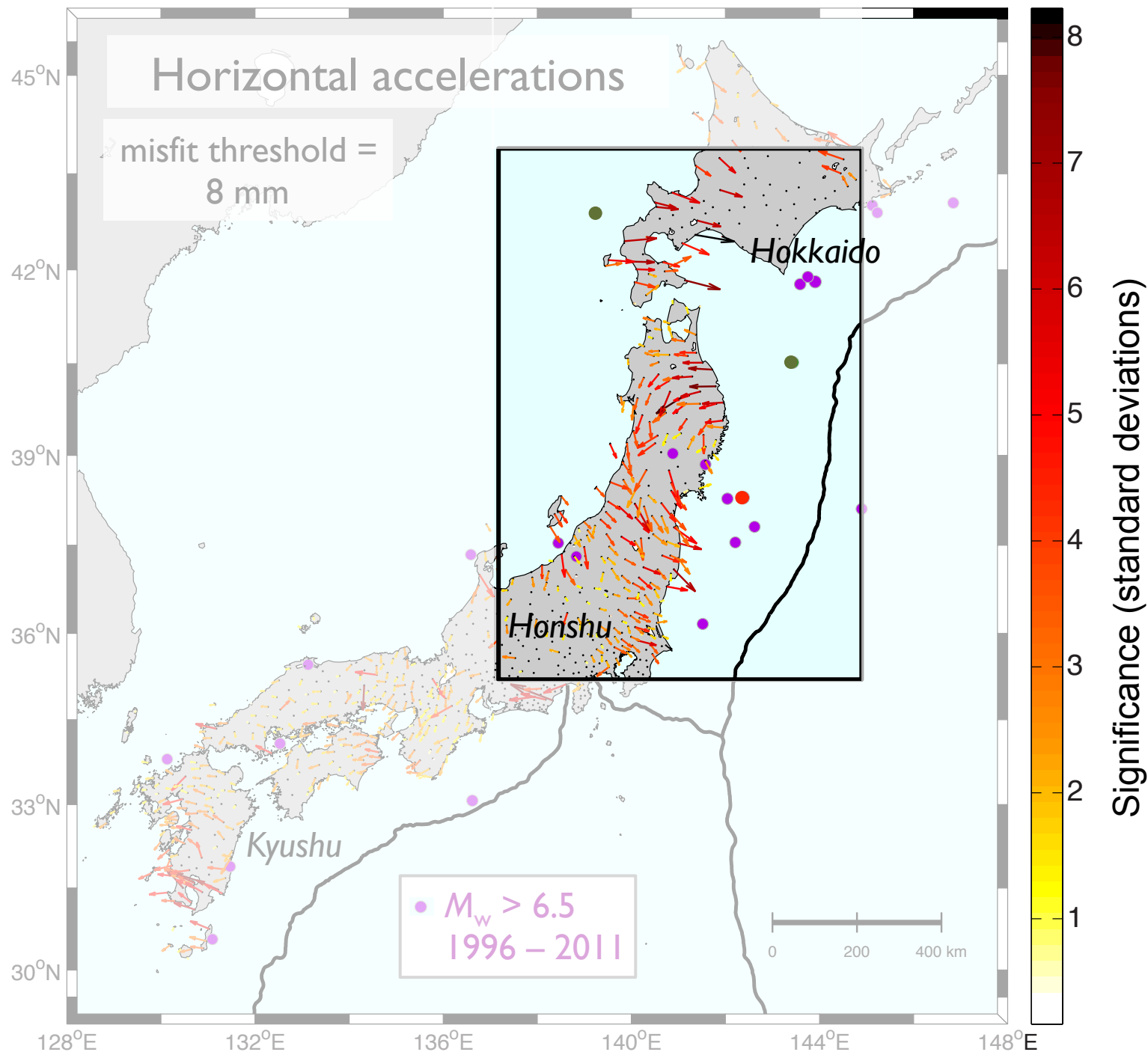
Noise: *observed = white + colored*

$$\Sigma = \sigma^2 \mathbf{I} + \tau^2 \mathbf{J}_n$$

Sample Time Series

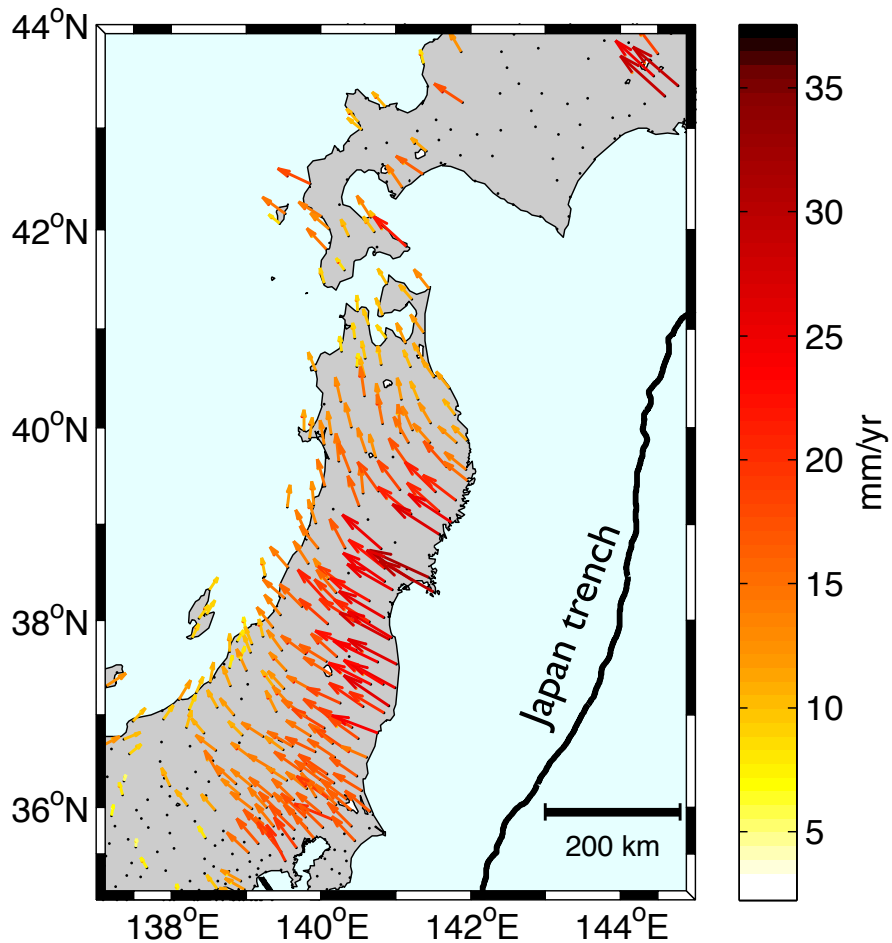




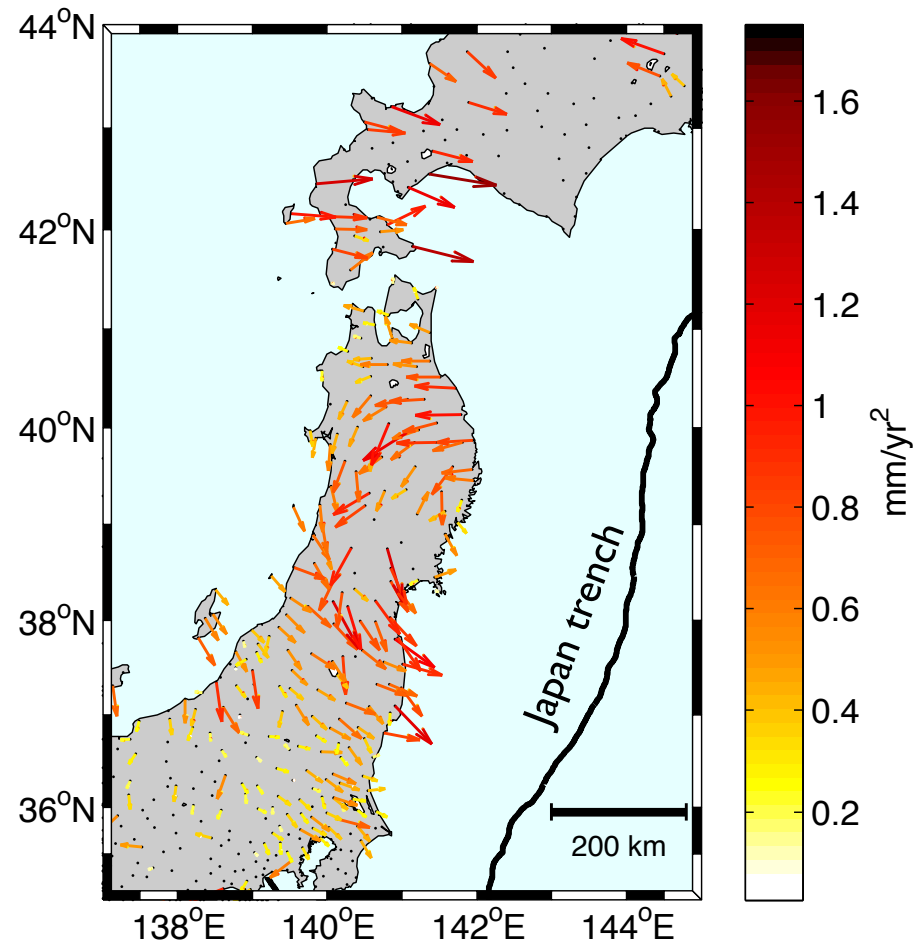


Focus in NE Japan

Velocities (1996, ref. NA)

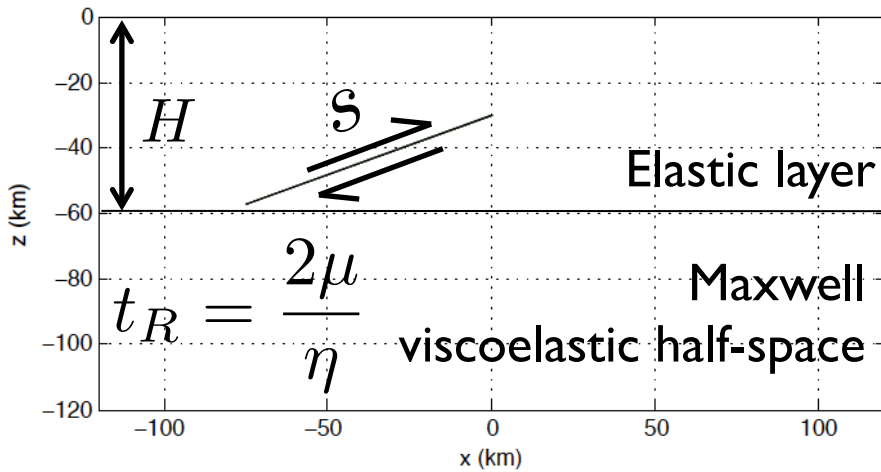


Accelerations

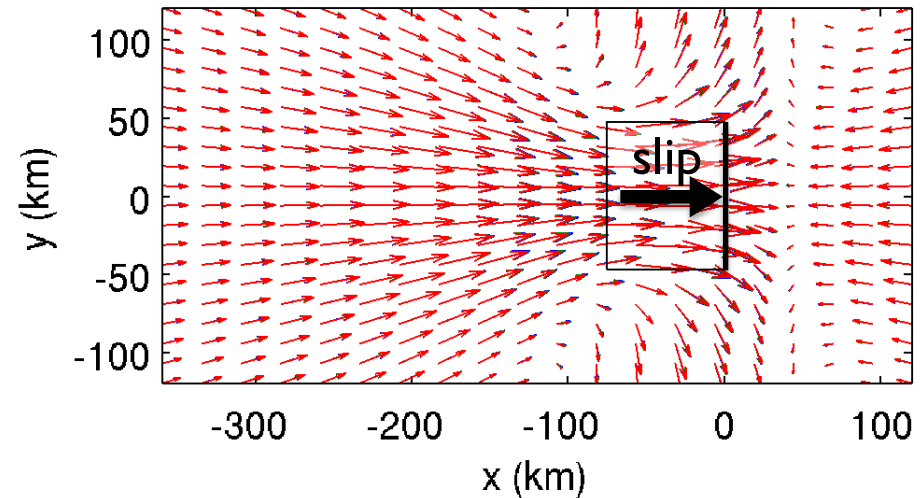


Viscoelastic Modeling

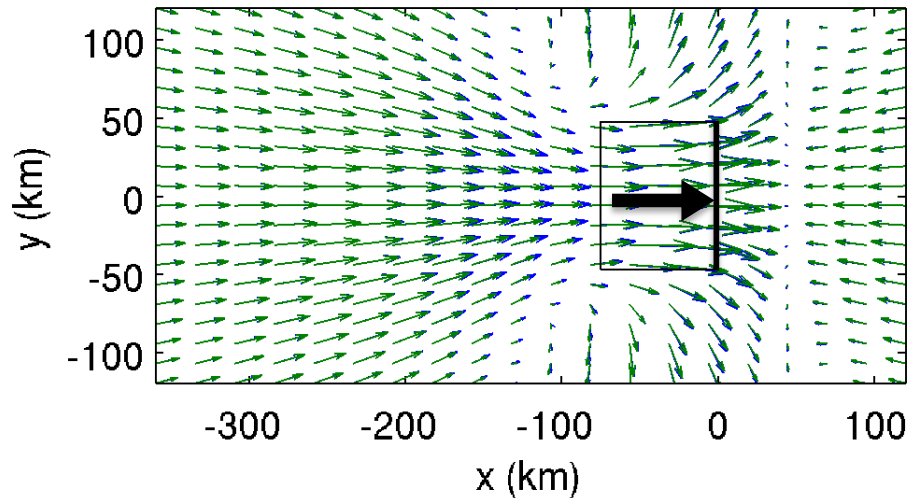
Model cross-section



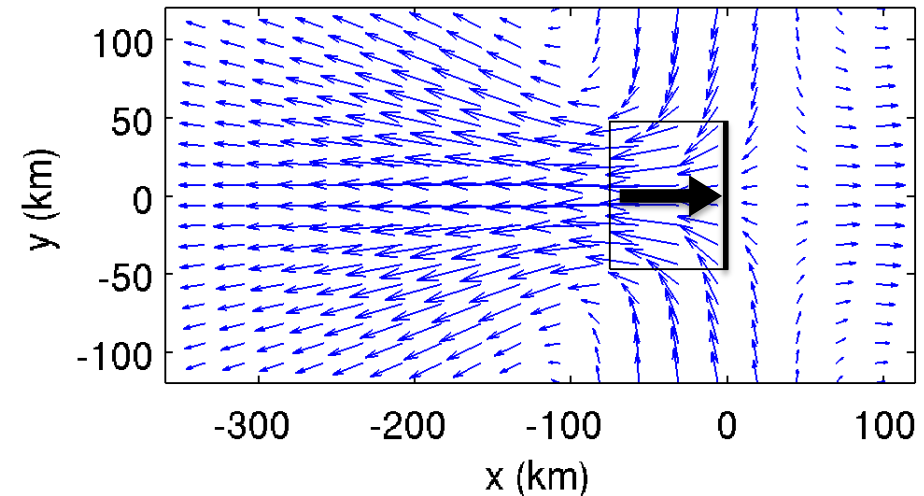
Displacements



Velocities

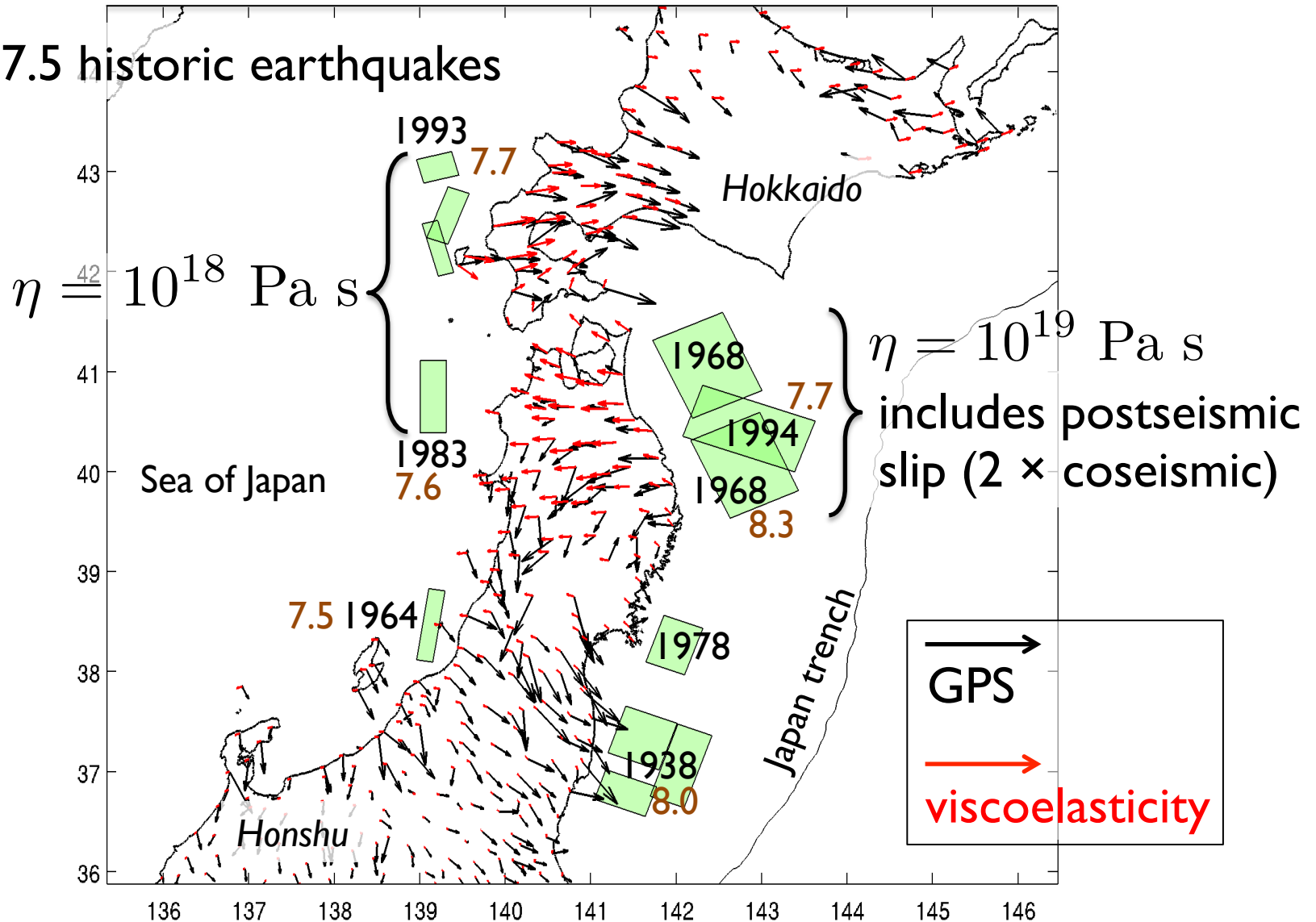


Accelerations



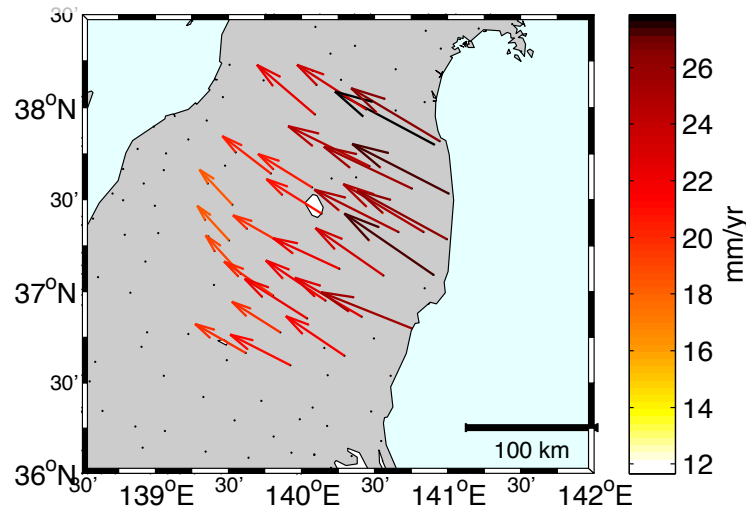
Viscoelastic Modeling

$M > 7.5$ historic earthquakes

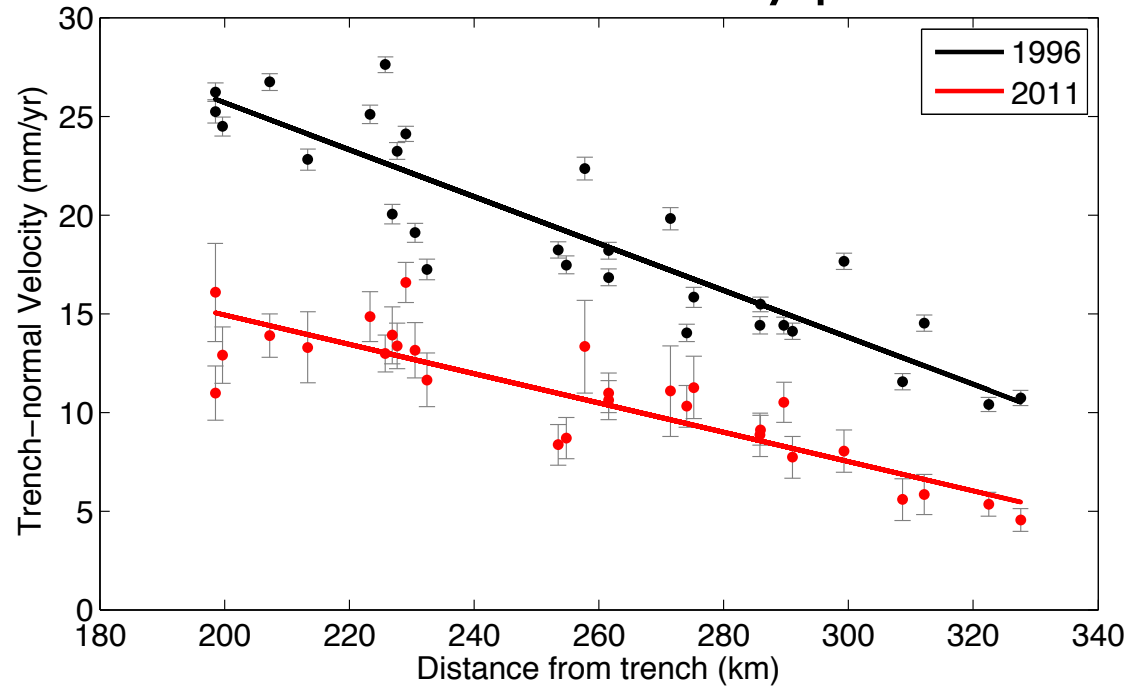


Southern Tohoku: Decreasing Strain Rate

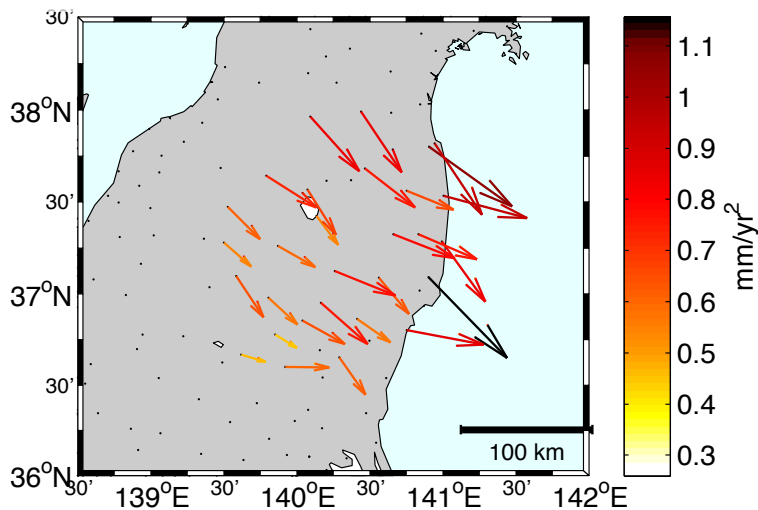
Velocities



Trench-normal velocity profile



Accelerations

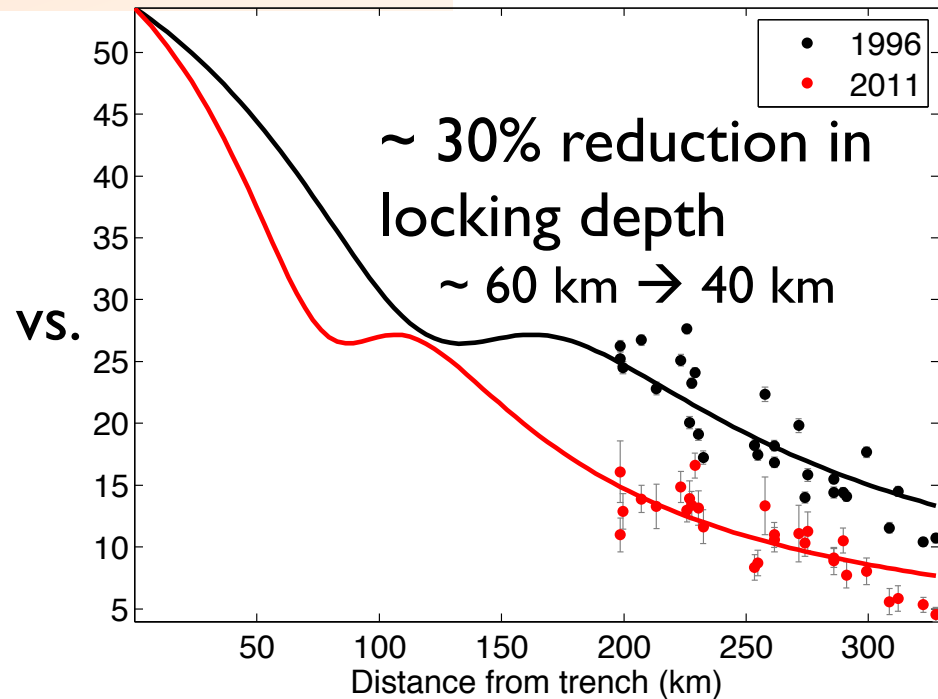
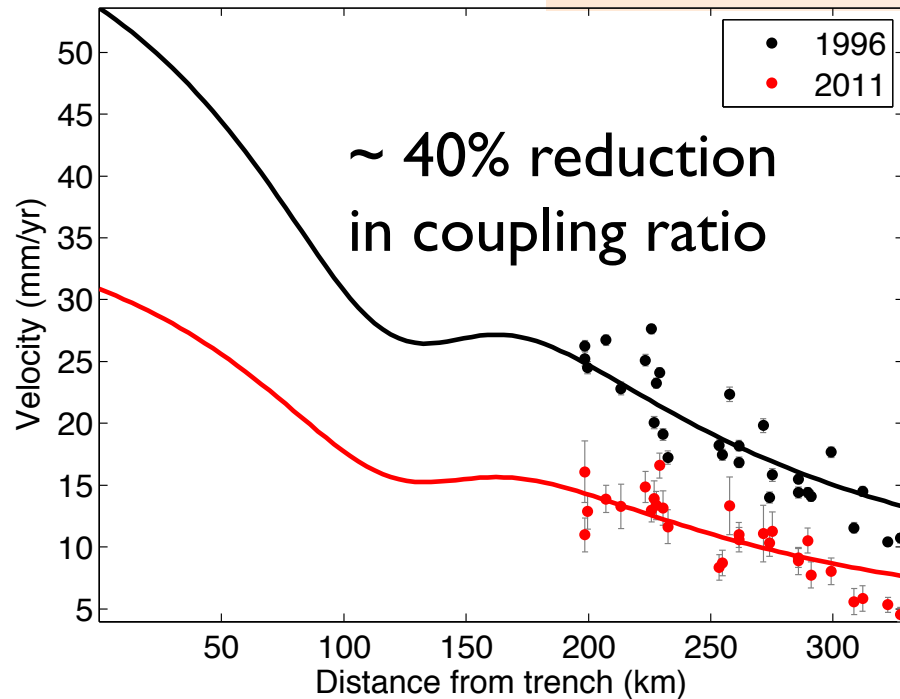
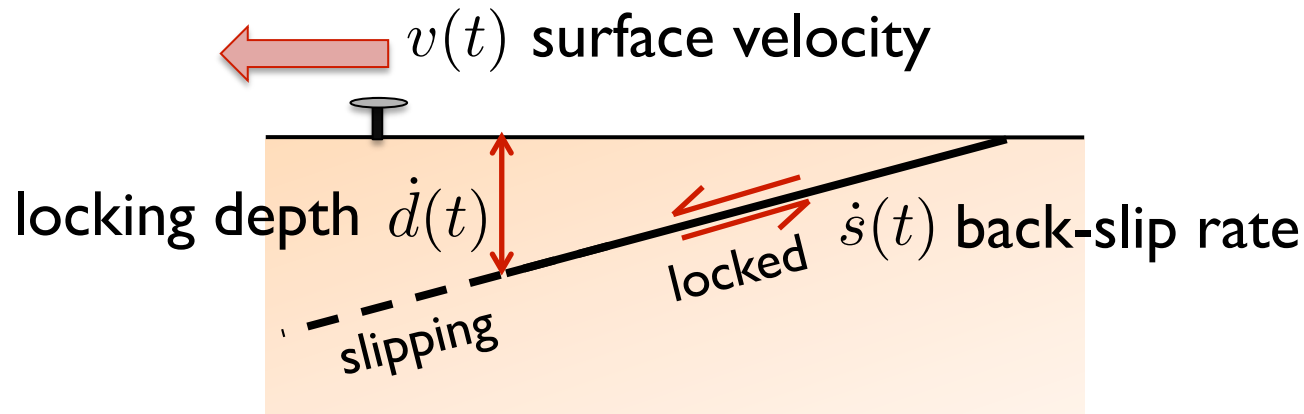


Decrease in shear strain rate

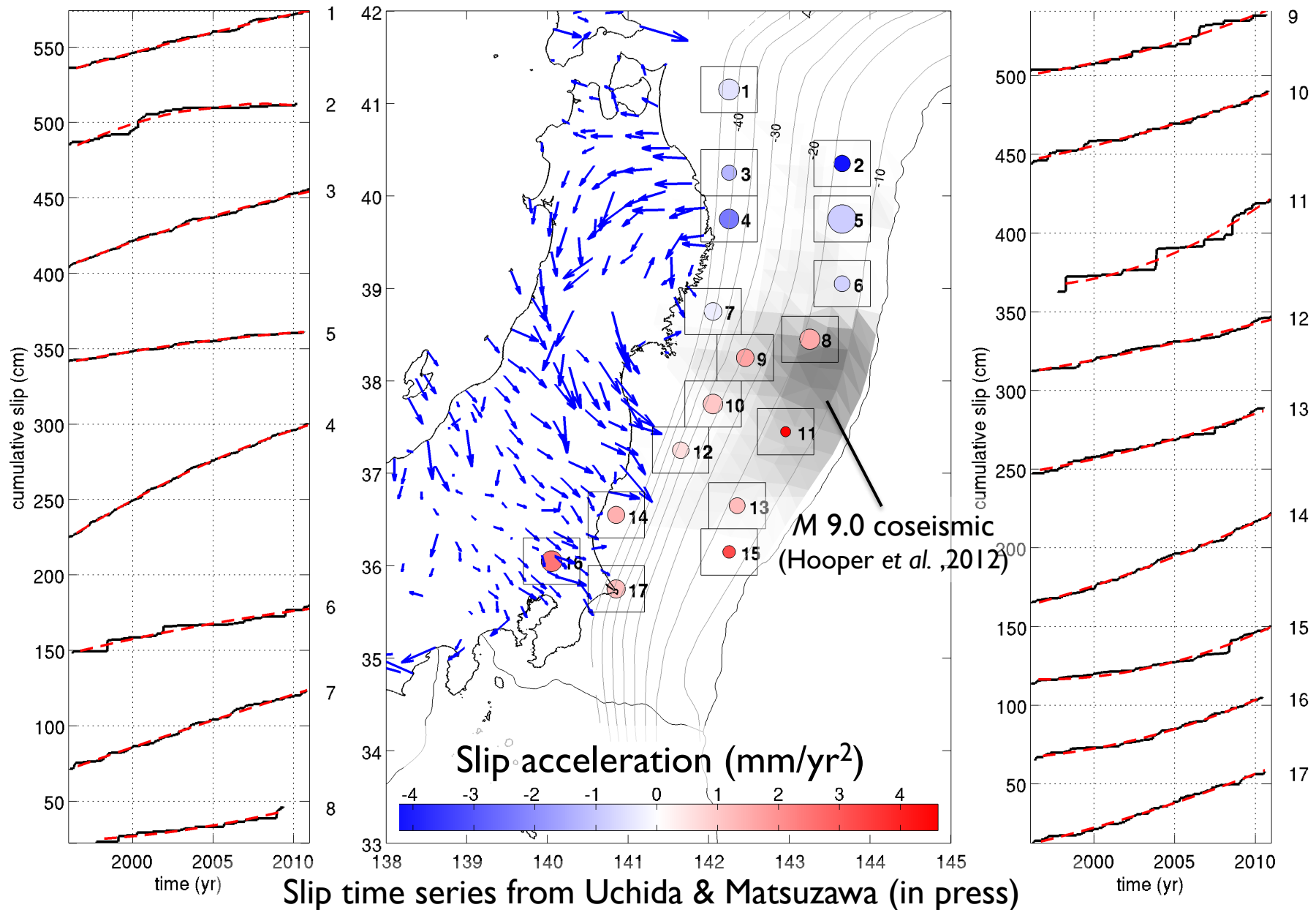
$$\dot{\gamma}_1 = \dot{\epsilon}_{11} - \dot{\epsilon}_{22}$$

by a factor of 1.6 ± 0.3 in 15 years

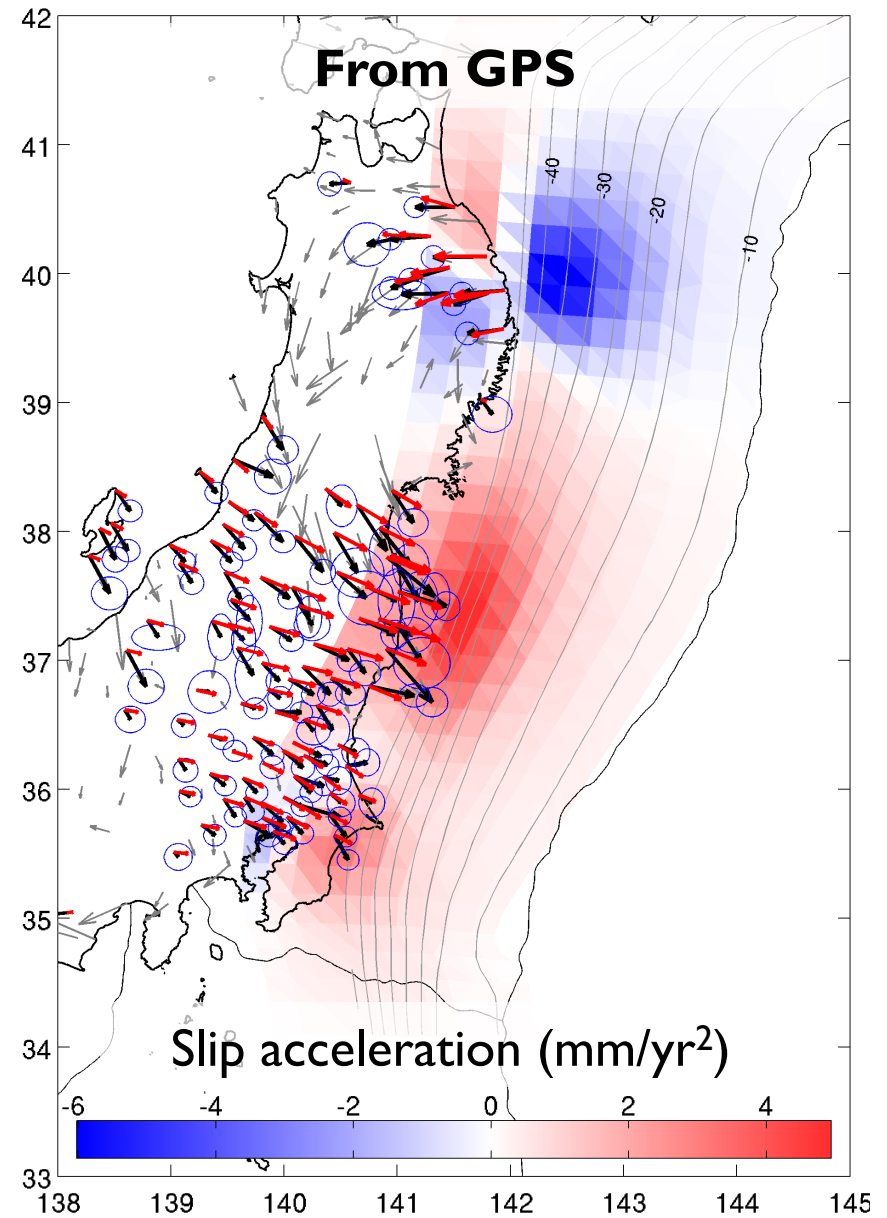
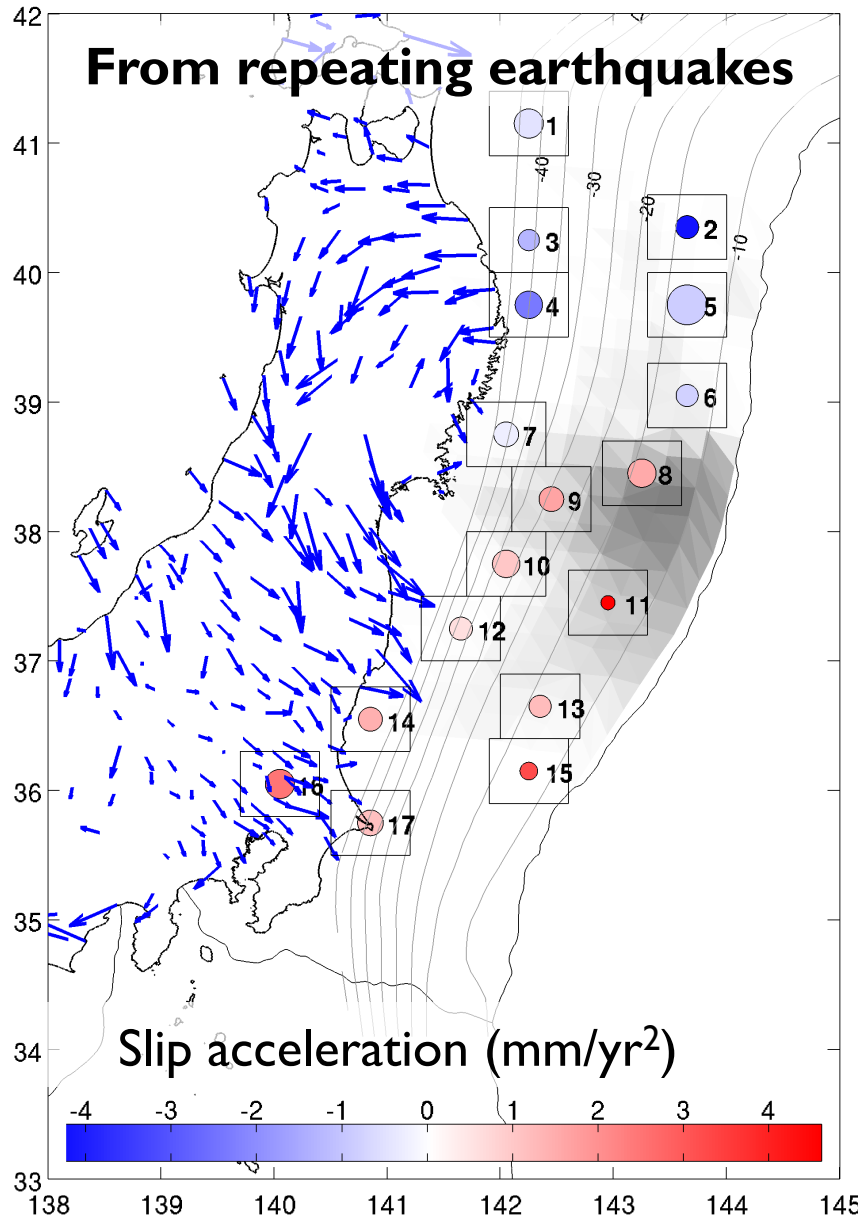
Southern Tohoku: Kinematic Interpretations



Repeating Earthquakes on the Japan Trench



Accelerating Slip on the Japan Trench



Summary

- **Northern Tohoku & Western Hokkaido:**
 - Transients consistent with postseismic effects
- **Southern Tohoku:**
 - Decreasing strain rate in the 15 years before the Tohoku earthquake
 - Evidence for change in slip rate
 - Other interpretations?

