Co-, post- and inter-seismic models of the 2011 M_w9.0 Tohoku-Oki Earthquake

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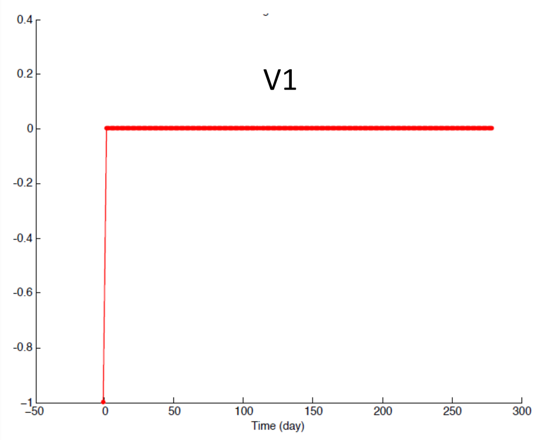
Abstract

We determine the fault-slip history on the Japan megathrust in the area of the 2011 M_w9.0 Tohoku-Oki earthquake from the modeling of the geodetic data using PCAIM (*Kositsky and Avouac [2010]; Perfettini et al. [2010]*). We used the daily solutions of GEONET (http://www.geospatialworld.net) considering 279 days after the mainshock. We also included measurements of seafloor displacements at 5sites in the epicentral area and near the trench (*Sato et al. [2011]*). The technique allows joint inversion of co and post-seismic deformation of continuous and sparse time series. We have considered two boundary conditions: (i) Free trench (FT) models for which slip is permitted near the trench, and (ii) Blocked trench (BT) models where slip is forced to taper to zero near the trench.

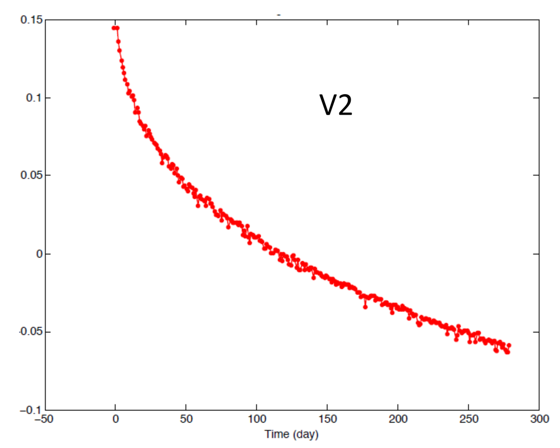
The fault model is composed of triangular mesh adjusted to the geometry of the slab given by Hayes et al. [2012]. The roughness of our slip models is controlled by a parameter γ that characterizes the weight put on the Laplacian operator used to regularize the inversion. Variable rake models show that rake variations are rather modest and that a fix rake approximation is justified.

We also model inter-seismic deformation using the dataset assembled by *Loveless and Meade [2011]*. Various boundary conditions are considered, corresponding to a model where strong coupling is authorized near the trench (FT model) or prohibited (BT model).

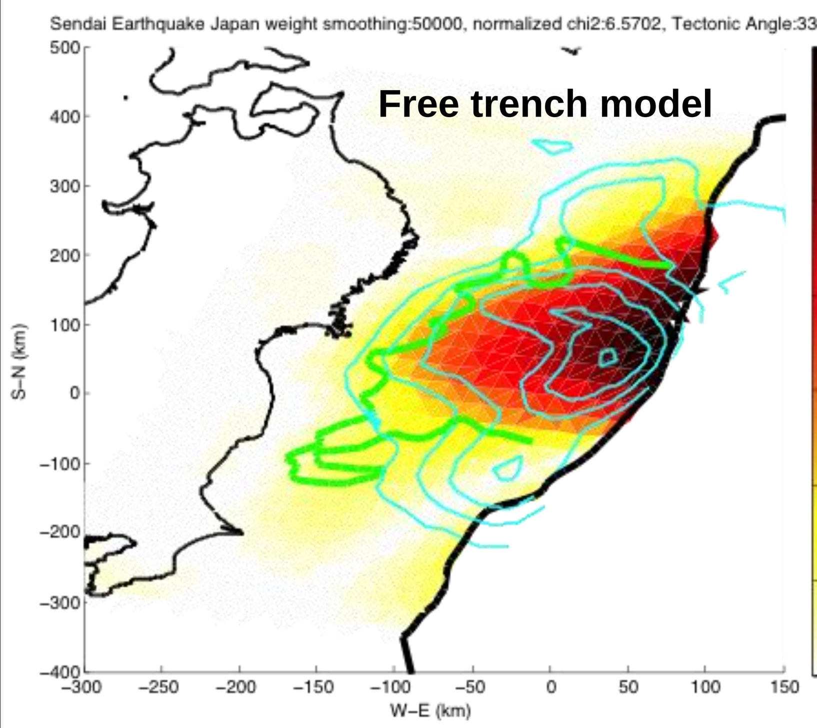
PCAIM decomposition

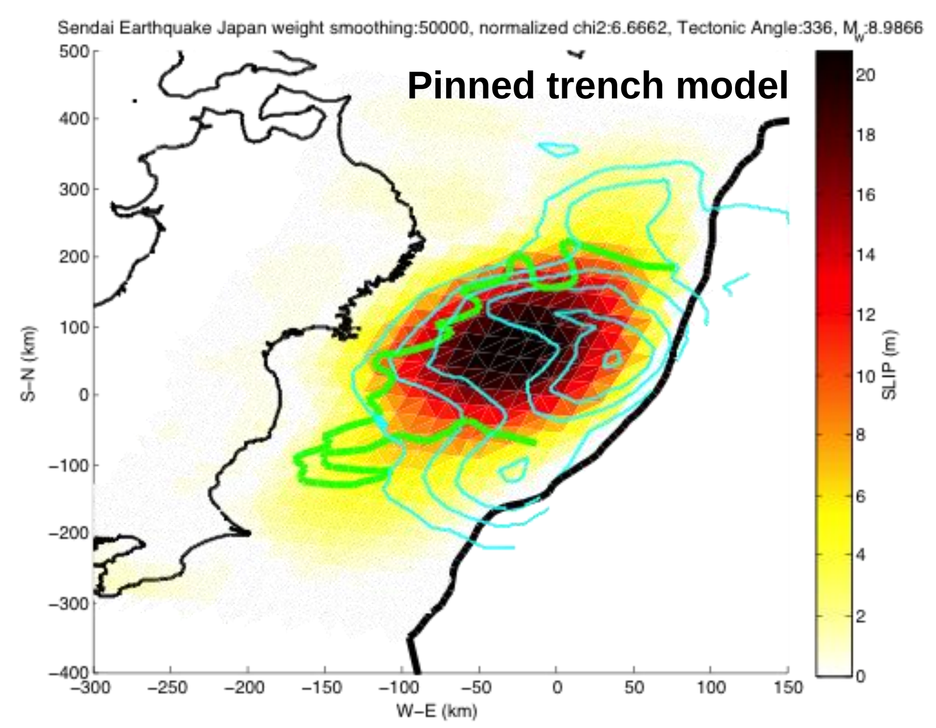


We start by decomposing the data using the PCAIM method. We impose the 1st temporal eigenvector V_1 to be a step function centered on the mainshock, while the 2nd temporal eigenvector V_2 is left free. V_2 shows a log(time) evolution, characteristic of afterslip. By imposing the first component to mimic the coseismic offset, we force the 1st component to describe the co-seismic phase and the 2nd component the post-seismic contribution. These 2 components account for most of the data variance.



Co-seismic Model

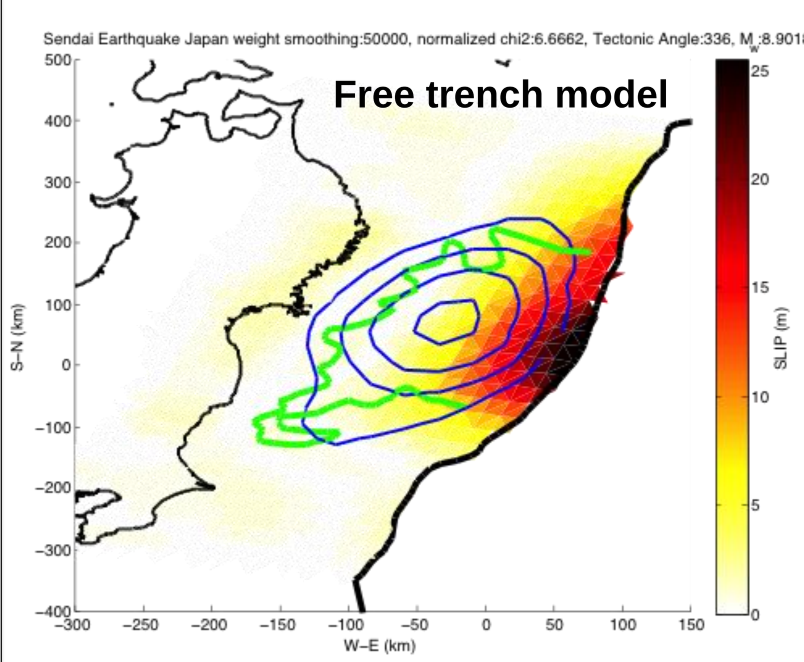




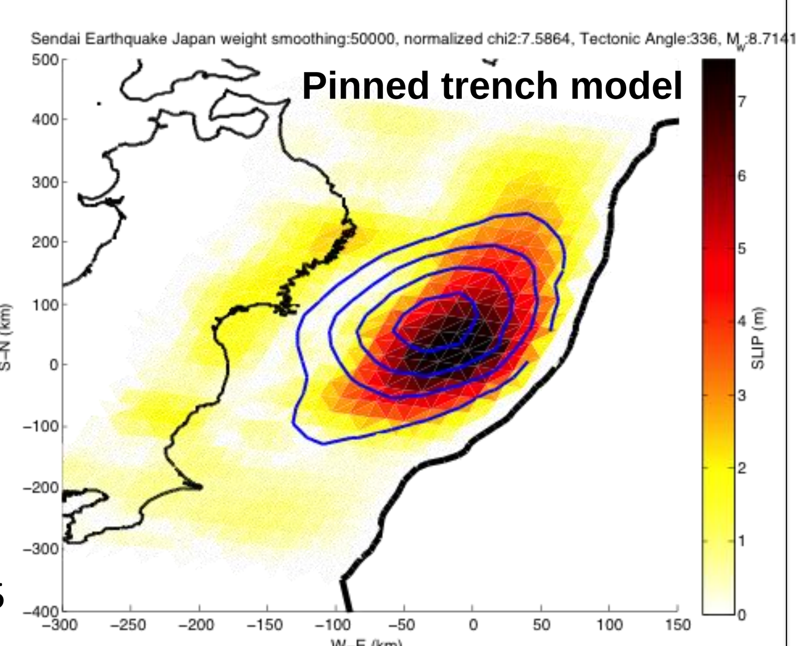
Our co-seismic models were obtained considering the final (static) GPS displacements considering 400 inland stations inland stations and displacement of the sea floor at 5 sites (*Sato et al. [2011]*). The PCAIM code simultaneously invert the co- and post-seismic distribution, insuring consistency between those two distributions.

Depending on the boundary conditions considered, the seismic moment vary from 3.4 10^{22} to 5 10^{22} N.m (M_w≈9.0-9.1) with a peak slip ranging from 20 to 35 m. Both types of models are consistent to first order with published models (e.g., *Ito et al. [2011]; Simons et al. [2011]*), in particular with the model of *Wei et al. [2011]* showed with cyan contour. Most aftershocks are located outside of the area delimited by the green contour (*Kato and Igarashi [2012]*), demonstrating that most aftershocks ly outside of the rupture area.

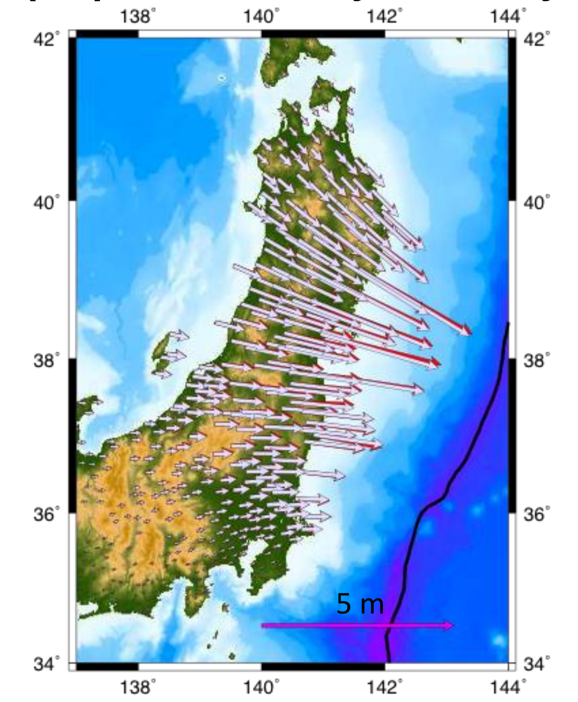
Post-seismic Model



Post-seismic models were determined using GPS displacements at 400 inland stations and 5 ocean bottom stations. Blue and show co-seismic model with pinned trench and green contour lines show the aftershocks-based co-seismic model of *Kato and Igarashi [2012]*. Depending on the boundary conditions, the seismic moment varies from 1.3 10^{22} to 2.5 10^{22} N.m (M_w≈8.7-8.9) with a peak slip ranging from 7 to 25 m. During the first 279 days, post-seismic slip has released between 26 and 75 % of the co-seismic moment.

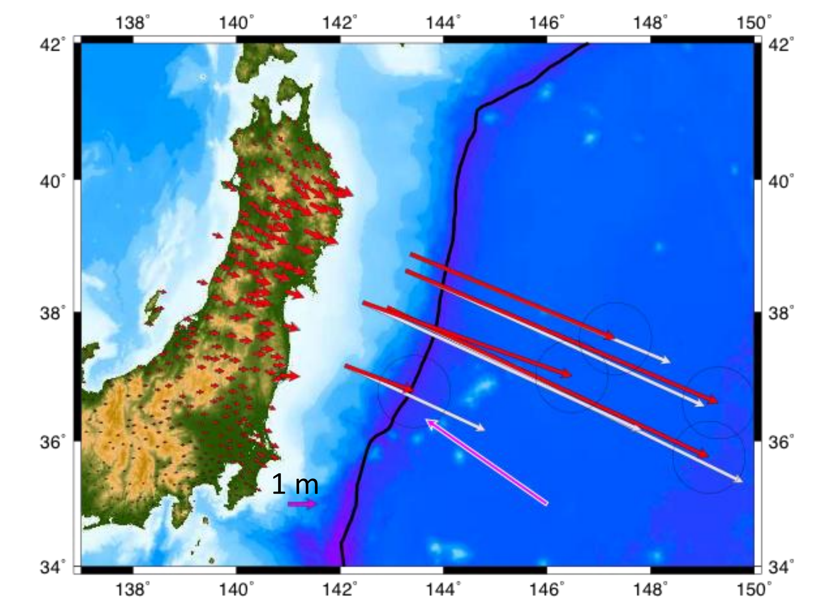


Co-seismic displacements (disp. Between day 0 and day 1)

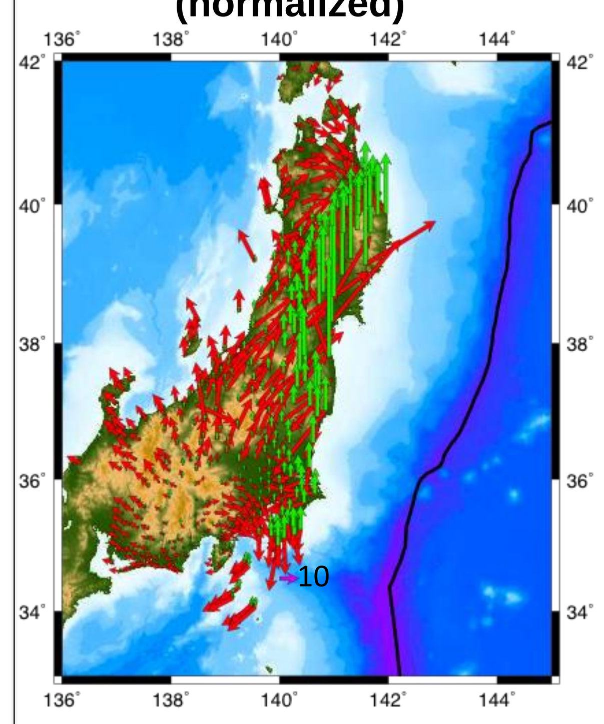


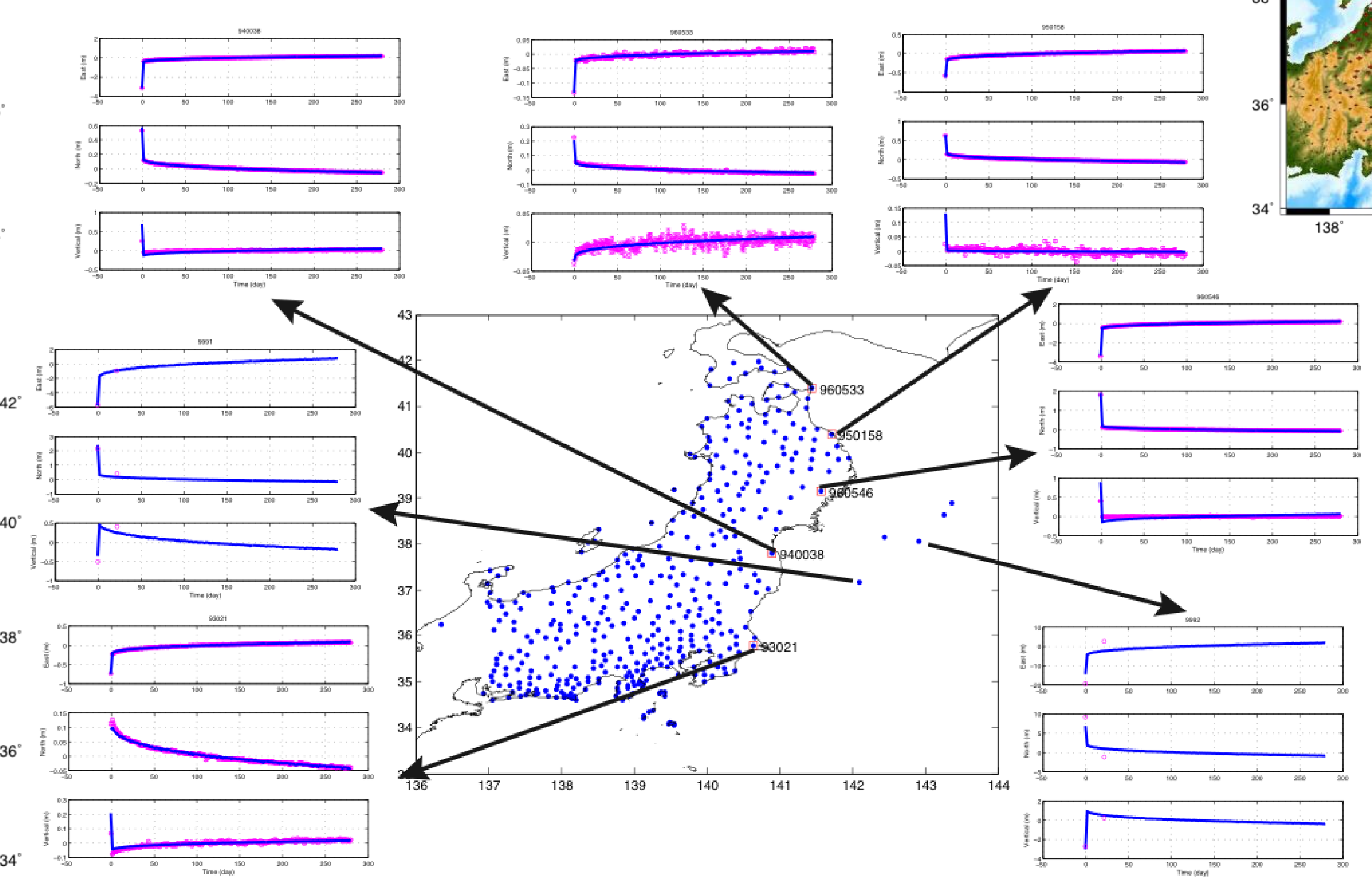
The maps compared modeled (white vectors) and measured (red vectors) displacements at the inland and the off-shore measurements. For both the co- and post-seismic models, the residuals are larger than the assumed nominal errors (2mm horiz., 10 mm vert.) by a factor of 2-3 on average. The residuals do not show any significant regional trend horizontally. Vertical residuals are large as our model systematically under predicts the vertical displacements, suggesting that the geometry we use or the Green functions may not be appropriated below the continent.

Post-seismic displacements (between day 1 and day 279 inland, between day 1 and day 22 off-shore)



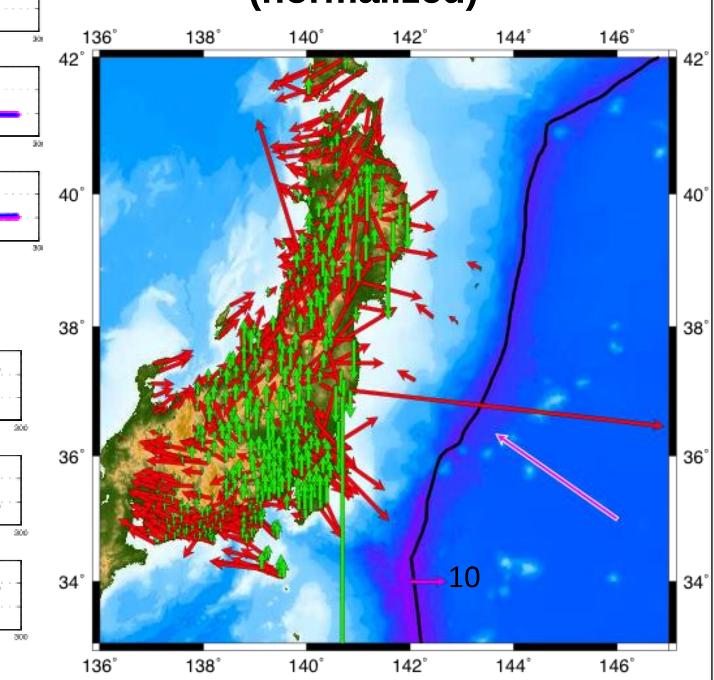
Co-seismic residuals (normalized)





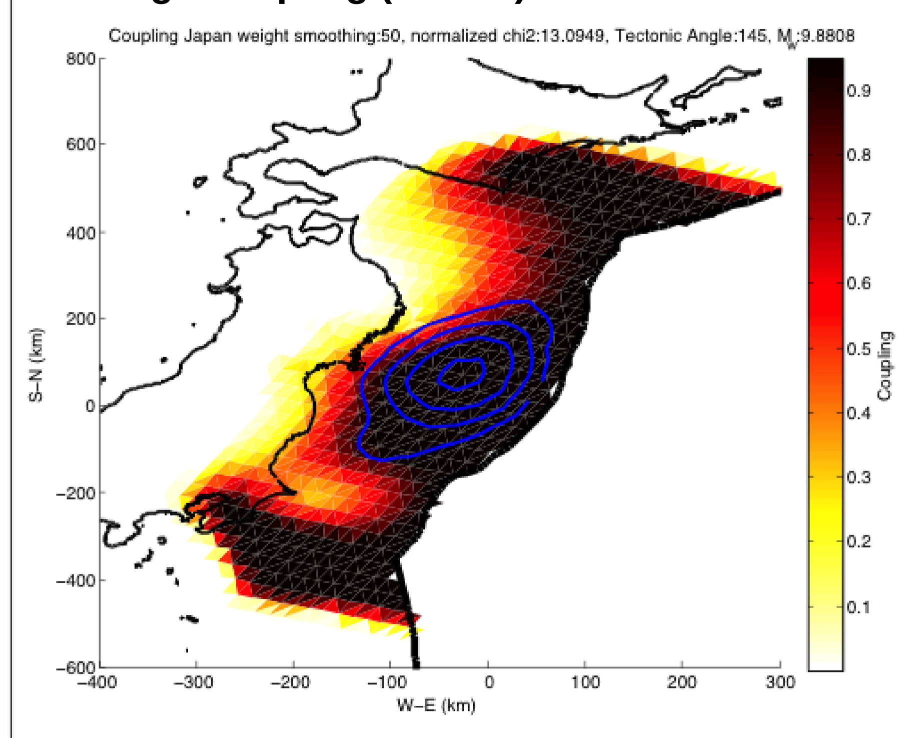
Measured (magenta) and predicted (blue) time series at various location, including two ocean bottom stations.

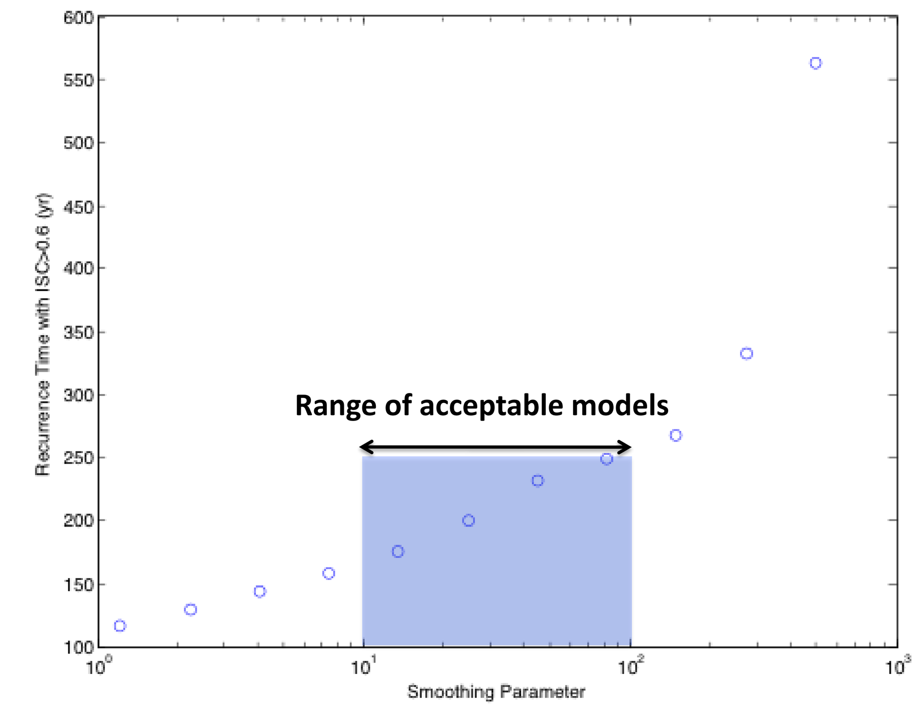
Post-seismic residuals (normalized)



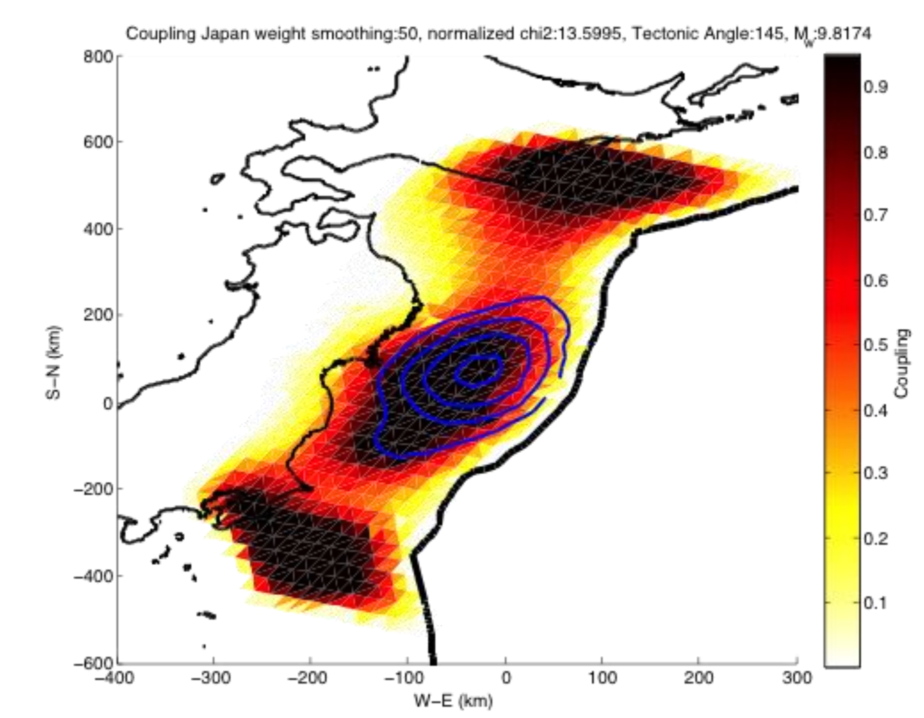
Inter-seismic Model

High coupling (locked) near the trench





Low coupling (creep) near the trench



The inter-seismic model was obtained considering pre-seismic velocities from the GEONET GPS network compiled by *Loveless and Meade [2011]*. Two sea bottom measurements data are included (*Matsumoto et al. [2008]*). Block corrections considering the NE Honshu and Okhotsk blocks have been applied. Only a fix rake model is considered due to the homogeneity of the velocity field. The correlation between the co-seismic slip model and the areas of high coupling (ISC>0.6) is really good for both the high (left figure) and low coupling near the trench (right figure) cases. We infer a recurrence time between 150 and 250 yr (center figure).

References

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