Co-, pre- and postseismic deformation of the 2011 M_w9.0 Tohoku-Oki Earthquake: Preliminary results from PCAIM inversions

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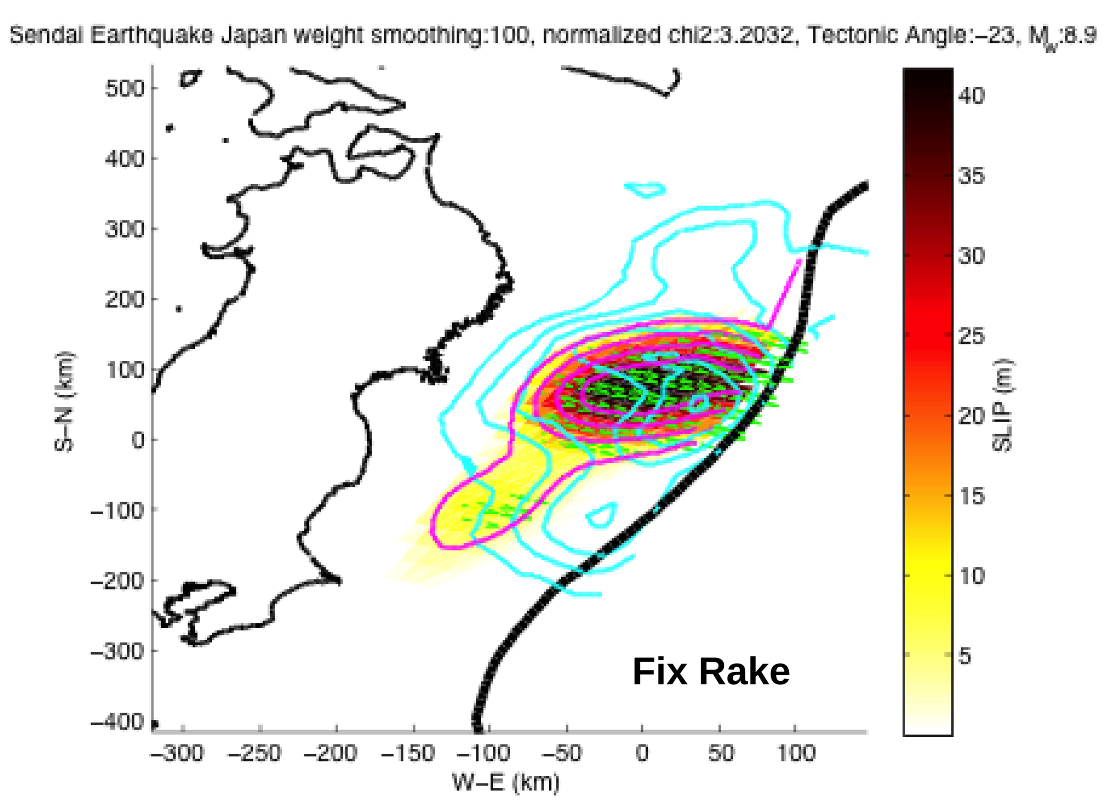
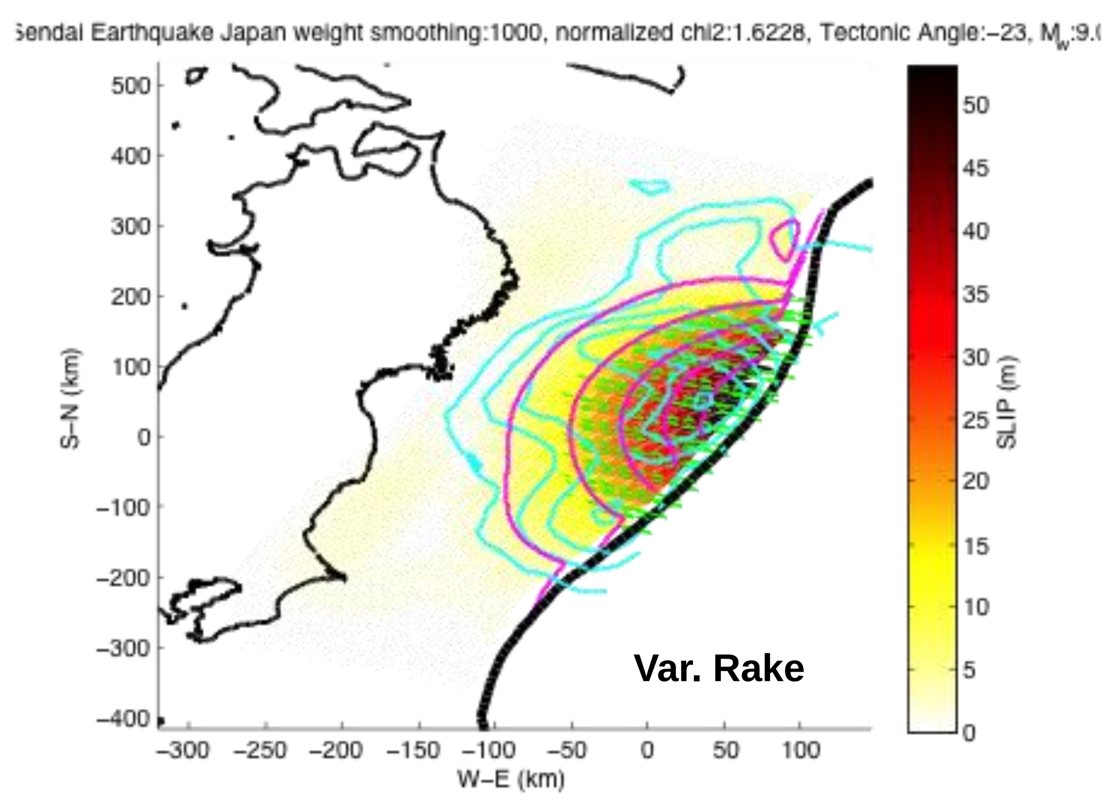
Abstract

We have studied the seismic cycle in the area of the 2011 M_w9.0 Tohoku-Oki earthquake considering GPS data and the PCAIM inversion software (Kositsky and Avouac, 2010; Perfettini et al., 2010).
We used GPS time series provided by the Geospatial Information Authority of Japan (GSI) which cover preseismic and co-seismic deformation and up to 1 hour after the mainshock. We also included measurements of seafloor displacements at five sites in the epicentral area and near the trench (Sato et al., 2011). Due to the large tsunami observed during this event, suggesting a significant amount of slip near the trench, we have pinned the points that were on the edges of the fault but the upper part of the fault (near the trench) has been left free to move.
The fault model is composed of triangular mesh adjusted to the geometry of the slabs given by USGS (http://earthquake.usgs.gov/research/data/slab). The roughness of our slip models is controlled by a parameter γ that characterizes the strength of the Laplacian operator used to smooth the slip distribution. Two type of slip models are considered: (i) Variable rake models where the rake is free to vary (although the higher the smoothing parameter, the smaller the rake variations), and (ii) Fix rake models. In this case, the rake is fixed to be perpendicular to the mean strike of the fault (203º) corresponding to a pure reverse slip.
Several meters of postseismic slip is observed to have occurred in the 1st hour following the main shock both North and South of the co-seismic rupture. The corresponding postseismic moment released is equivalent to a M_w8.2 event. Aftershocks have released 57 % of the postseismic moment, mostly through the occurrence of a M_w7.9 and a 7.7 aftershock.
The return period of earthquakes similar to Tohoku Oki is estimated to about 200 years given the pattern of interseismic locking required to fit fit interseismic strain measured on land.

Coseismic Model





Our coseismic models (color scale and pink contour) were obtained considering the final (static) GPS displacements considering 346 stations inland stations (Simons et al, 2011) and displacement of the sea floor at 5 sites (Sato et al., 2011).
Our preferred fix rake model predicts a seismic moment M_0=3.6 10^{22} N.m (M_w=8.97) with a peak slip of nearly 44 m mean slip of about 2.4 m.
Our preferred variable rake model predicts a seismic moment M_0=5.5 10^{22} N.m (M_w=9.09) with a peak slip of nearly 56 m mean slip of about 2.8 m. Both of our 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.

References

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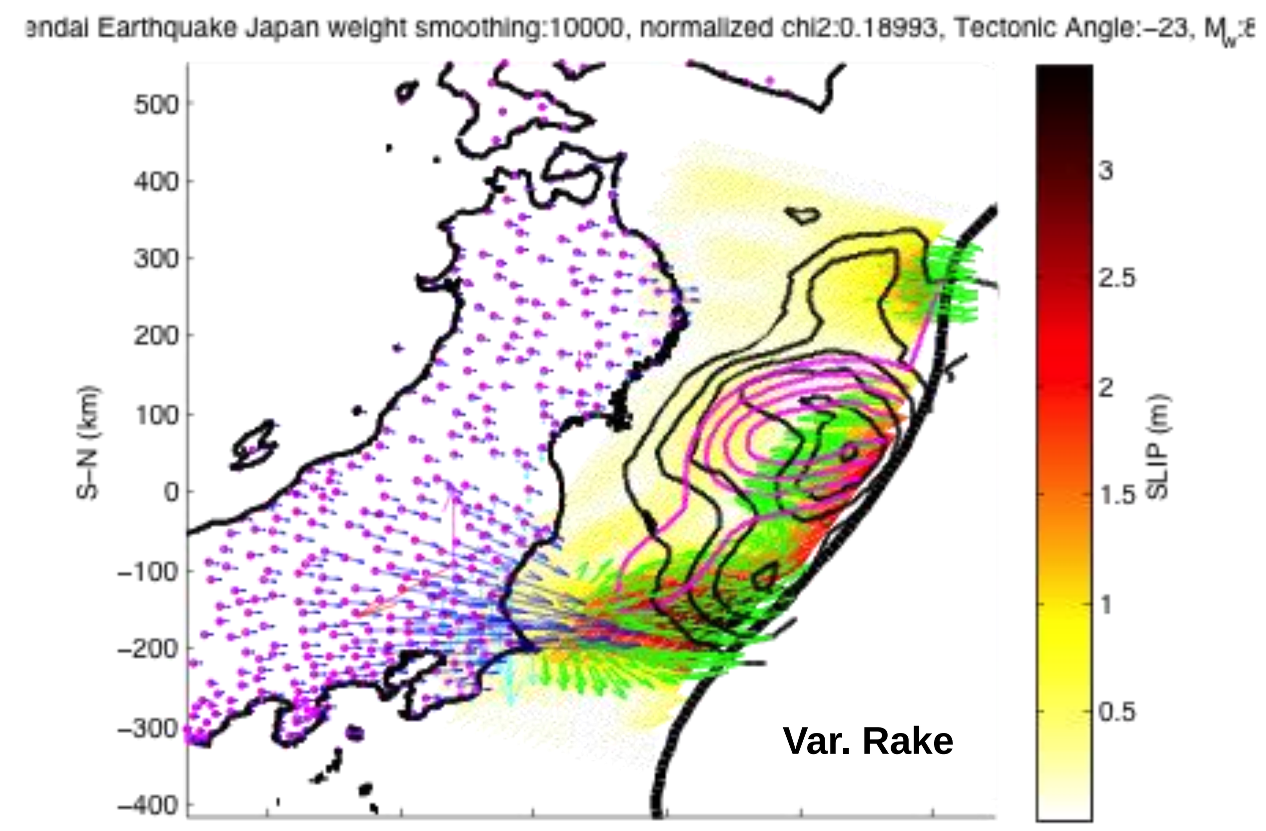
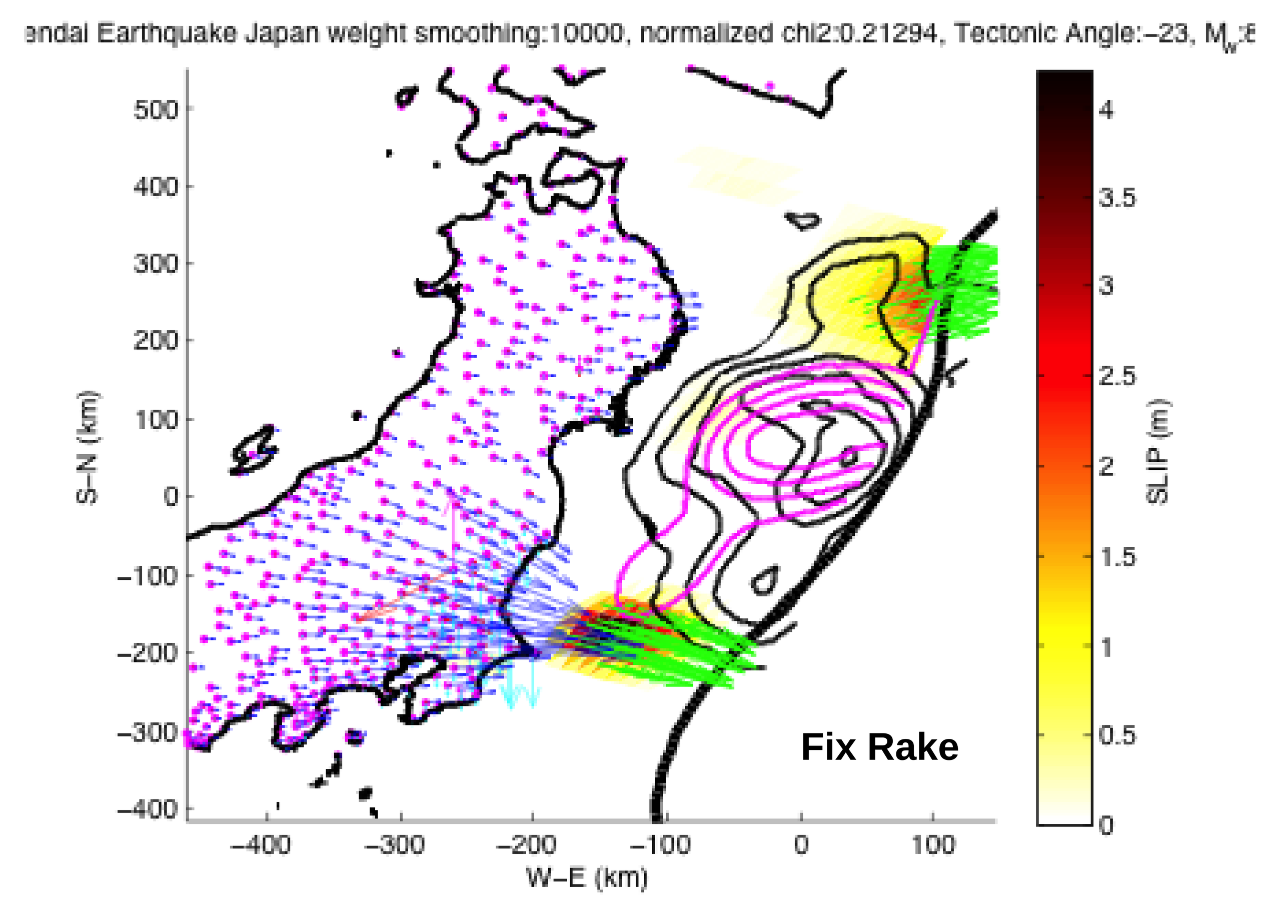
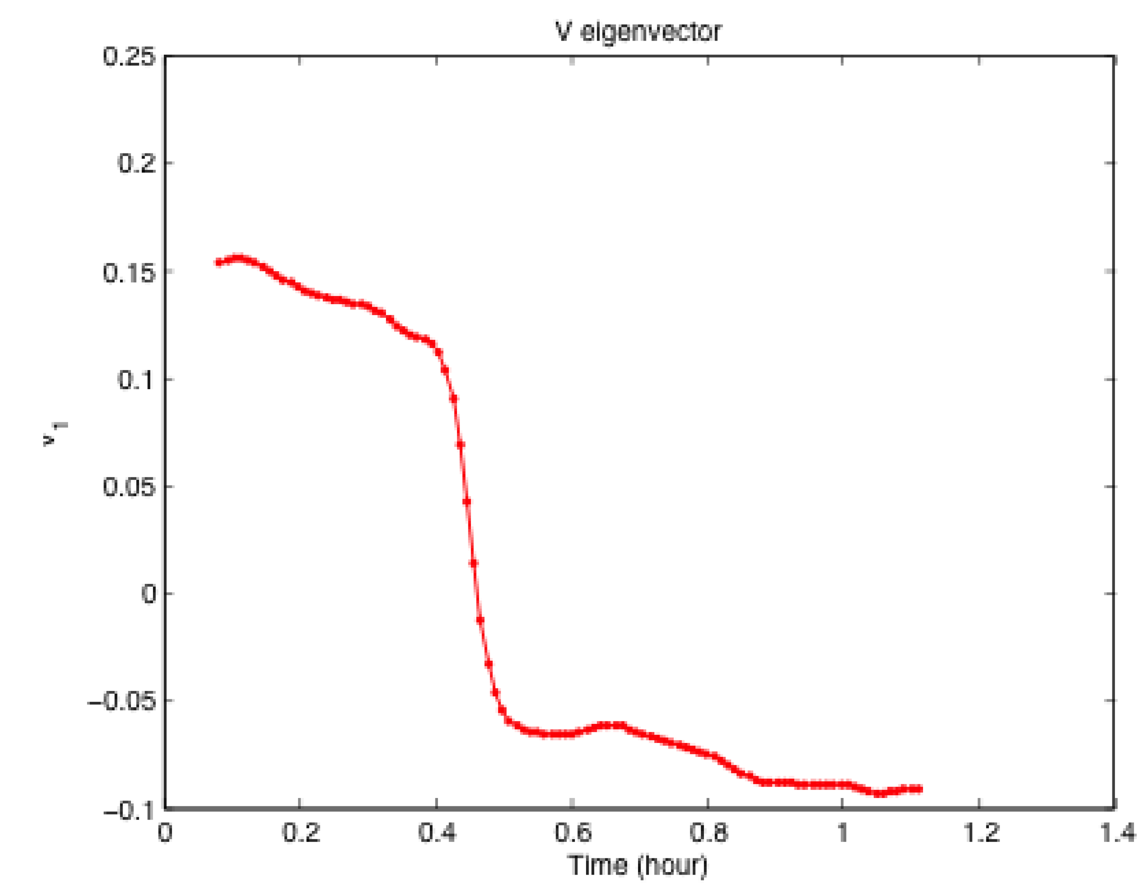
Postseismic Model

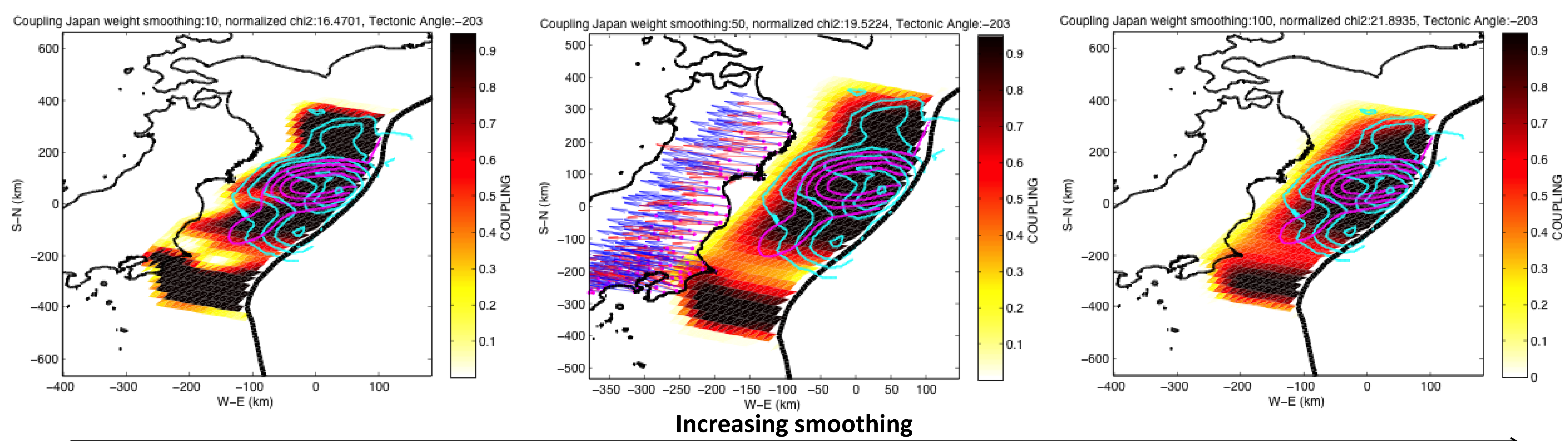


Our postseismic models (color scale and pink contour) were derived from GPS displacements at 398 inland stations. Our (pink contours) and Wei's et al. (black contours) coseismic slip models are shown for reference.
We have considering 1 Hz GPS data covering the first hour following the mainshock.
The data were smoothed temporally using a Gaussian filter an resampled in order to reduce the number of data to 500 measurements.
The GPS time series are affected by the early aftershocks among which are a M_w7.9 and a 7.7 events. The temporal eigenvector V_1 presents a jump related to those events.
The model predicts some back-slip near the trench (as no constraints for positivity was imposed). Patches with large postseismic slip are observed at both ends of the coseismic rupture area. The spatial pattern of afterslip of our model is consistent with the results of Ozawa et al. (2011). The moment released during the first hour is equivalent to M_w8.1 (variable rake) or M_w8.4 (fix rake) for set 1, and M_w8.2 for set 2 (for both the variable and fix rake model). It is comparable to the M_w8.3 found by Ozawa et al. (2011) and released on 25 March 2011.





Interseismic Model



The interseismic model was obtained considering pre-seismic velocities given by GEONET GPS data. No sea bottom measurements data area available. Only a fix rake model is considered due to the homogeneity of the velocity field. The correlation between the coseismic slip model and the areas of high coupling (ISC>0.6) is good and suggests that the magnitude of this event was predictable, assuming slip was not prohibited near the trench. However, we infer a recurrence time of about 200 yr which is shorter than what the historical records suggest (the last great event in this area was in AD 869).
The postseismic slip patch south of rupture corresponds to an area of low ISC, as expected. But the northern postseismic patch falls into an are of high ISC. We believe that this discrepancy will disappear extending the velocity field spatially, after some block corrections (not done here), as done in Loveless and Meade (2011).