New Insights on Postseismic Deformation Following the 1999 Chi-Chi Earthquake, Taiwan: Evidence for Viscous Relaxation from Far-Field GPS Time Series

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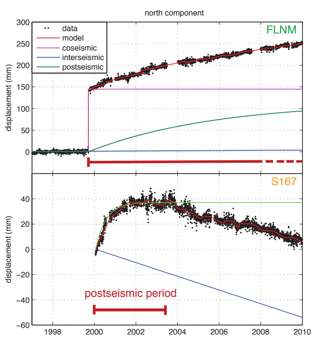
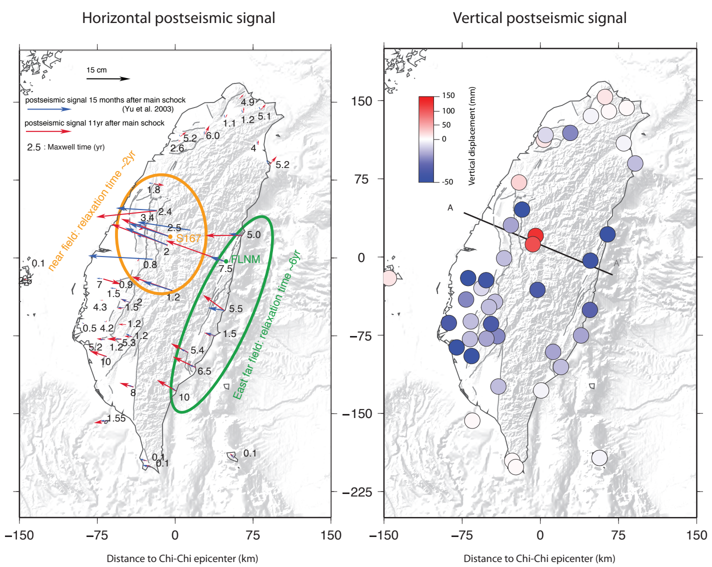
Abstract

With one of the highest convergence rate in the world between the Philipine Sea plate and the Eurasian plate (8.2 cm/yr), all convergence processes are increased in the Taiwan Island. As all vertical displacements (uplift rates , depth advection) induced by underplating are significants , a non-usual thermic structure with high temperatures at shallow depths is observed.After more than 10 years of continuous GPS measurements, the postseismic signal due to the Mw 7.6 Chi-Chi earthquake is remarkable in almost the whole island. Differences between near and far field relaxation times indicate that at least two mechanisms are involved. As suggested in previous studies, the near field postseismic signal can be explained by afterslip on the Chelungpu fault. In our models, we represent the anormally high-temperature structure observed by including a low viscosity block beneath the Central Range. The preliminary results show the importance of a viscous flow to explain the far field posteismic response.

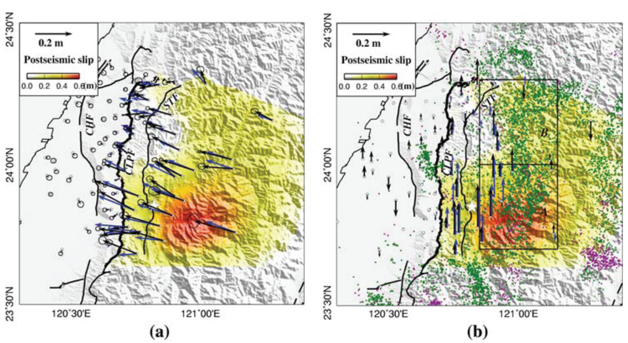
GPS Data Modeling

We have used 11 yrs of continuous measurement in 45 stations of the Taiwan Island to obtain the postseismic signal due to the Chi-Chi earthquake. We decompose the signal as a sum of coseismic, interseismic, postseismic and seasonnal variations signals. The interseismic velocity field is well constrained by numerous campaign data before 1999 for the horizontal component (Hsu et al. 2007), and a leveling campaign in the whole island for the vertical component (Ching et al. 2011). The signal show short relaxation time close to the epicenter and the longest ones in the east far field, which might be due to a different mechanisms.



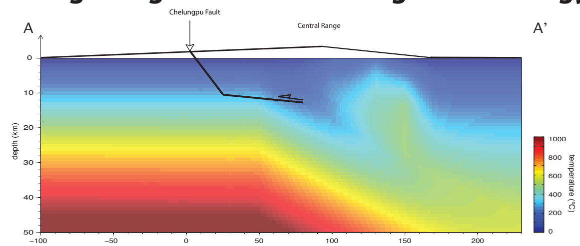


The 1999 Mw 7.6 Chi-Chi earthquake: state of knowledge



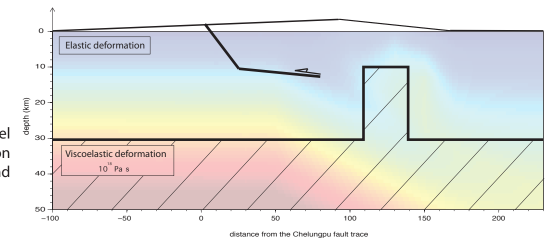
Previous studies, 15 months of GPS measurements after the main shock show that all postseismic displacements are due to afterslip on the Chelungpu fault (Hsu et al. 2009). After such a period, this mechanism was dominant in the near field and the postseismic displacement was still insignifiant in the far field. However, 10 years after the signal looks different and afterslip on the Chelungpu could still be almost sufficient to explain the signal close to the epicenter, because the whole signal was relaxed after ~3 yrs. However an other mechanism with a longer relaxation time must be taken into account for the far field.

Integrating constraints from geochronology



To model the viscous flow favored by the high temperatures, we build a 3D model with a stress change imposed by a coseismic model (Hsu et al. 2003). The relaxation is elastic above 30 km depth and viscoelatic beneath. We can also adapt the size and the viscosity of a low viscosity block beneath the central range.

The thermic structure of the Taiwan mountain range is well constrained by thermometric and thermochronological analyses on metamorphic rocks (Simoes et al. 2007). After being underplated beneath the Philipine Sea Plate, some material is exhumed to the surface, which produces a high temperature flux with values of 400ºC at 10 km depth beneath the Central Range.



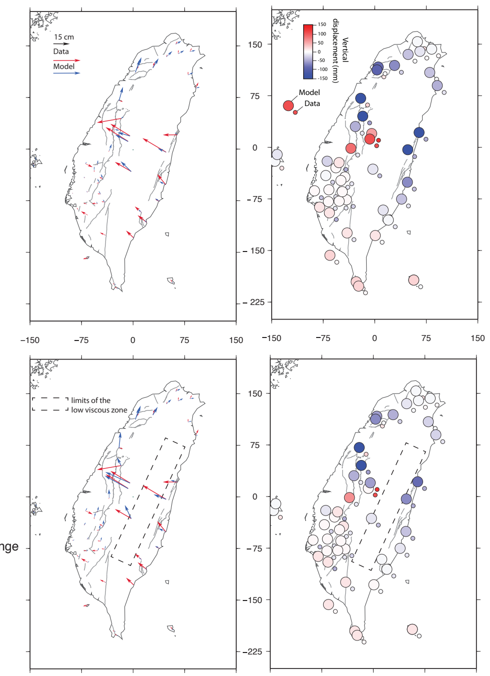
Preliminary results

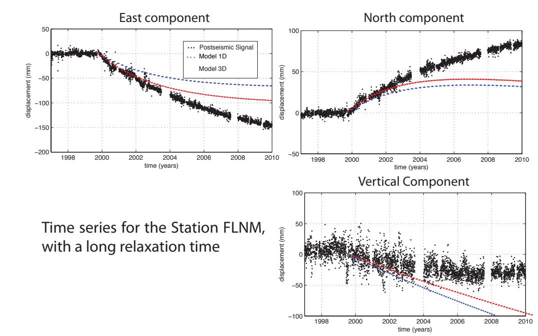
1D Model:

Viscous layer 30 km

3D Model:

Viscous layer 30 km + Low viscosity block beneath the Central Range





Time series for the Station FLNM, with a long relaxation time

Model 1D:

- Direction of displacement coincides with data in the whole island

- All the amplitude of the signal is well fit by this model for the northern part of Taiwan.

- Horizontal component is underestimated at numerous stations, and vertical component is often overestimated.

Model 3D

- Only the center of Taiwan is affected: preserve a good fit for the northern, far-field, region.

- Increase the amplitude of the horizontal component in the eastern part, and improve the fit for the vertical component. Close to the epicenter, the uplift might be due to after slip, as explain in previous studies.

Perspectives

1 - Improve the geometry of the low velocity block to better explain variations between stations.
2 - Find the optimum viscosity compatible with the rheology in situ.
3 - Do a coupled model of afterslip and viscoelastic flow to explain far and near field displacements together.