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Predicted Surface Displacements for Scenario Earthquakes in the San Francisco Bay Region

By Jessica R. Murray-Moraleda

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Conversion Factors

Inch/Pound to SI

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
yard (yd)	0.9144	meter (m)
	Force	
dyne (dyn)	10^{-5}	Newton (N)

Predicted Surface Displacements for Scenario Earthquakes in the San Francisco Bay Area

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Introduction

In the immediate aftermath of a major earthquake, the U.S. Geological Survey (USGS) will be called upon to provide information on the characteristics of the event to emergency responders and the media. One such piece of information is the expected surface displacement due to the earthquake. In conducting probabilistic hazard analyses for the San Francisco Bay Region, the Working Group on California Earthquake Probabilities (WGCEP) identified a series of scenario earthquakes involving the major faults of the region, and these were used in their 2003 report (hereafter referred to as WG03) and the recently released 2008 Uniform California Earthquake Rupture Forecast (UCERF). Here I present a collection of maps depicting the expected surface displacement resulting from those scenario earthquakes.

The USGS has conducted frequent Global Positioning System (GPS) surveys throughout northern California for nearly two decades, generating a solid baseline of interseismic measurements. Following an earthquake, temporary GPS deployments at these sites will be important to augment the spatial coverage provided by continuous GPS sites for recording postseismic deformation, as will the acquisition of Interferometric Synthetic Aperture Radar (InSAR) scenes. The information provided in this report allows one to anticipate, for a given event, where the largest displacements are likely to occur. This information is valuable both for assessing the need for further spatial densification of GPS coverage before an event and prioritizing sites to resurvey and InSAR data to acquire in the immediate aftermath of the earthquake. In addition, these maps are envisioned to be a resource for scientists in communicating with emergency responders and members of the press, particularly during the time immediately after a major earthquake before displacements recorded by continuous GPS stations are available.

Method

The source geometries for the scenario earthquakes are those in the California Reference Geologic Fault Parameter Database (*http://gravity.usc.edu/WGCEP/resources/data/refFaultParams/index.html*, last accessed February 11, 2009) compiled by the USGS, California Geological Survey, and the Southern California Earthquake Center and used in the 2008 Uniform California Earthquake Rupture Forecast (UCERF) report produced by the 2007 WGCEP. These source geometries are provided as an input file with the Coulomb 3 software (Lin and Stein, 2004; Toda and others, 2005), and this software (version 3.1.09, May 2008) was used to calculate and plot the surface displacements.

To produce the displacement maps I first developed a slip distribution for each scenario earthquake as follows. The magnitude assigned to the scenario by WG03 was used to calculate the

moment using equation 9.156 of Sleep and Fujita, 1997, $M_w = (\log M_o + 7) / 1.5 - 10.7$, where M_w is the moment magnitude and M_o is the moment in Newton meters.

The slip was assumed to taper toward the edges of the fault rupture using three slip values in the ratio 0.1:0.5:1.0, as shown in figure 1. The smaller dimension of each part of the fault with an intermediate or lower slip value is approximately 1 km. For a given scenario earthquake, these initial slip magnitudes were multiplied by a scalar in order to produce the moment obtained from the magnitude. Using the fault geometries discussed above and these slip values, I then created Coulomb 3 input files for each scenario event. These input files are provided in ASCII form in a supplement to this report to enable others to generate more detailed plots or to modify source parameters (for instance to allow for greater near-surface slip). Finally, Coulomb 3 was used to calculate the predicted displacements for each scenario and to generate plots. These calculations assume a homogeneous elastic half space with a Poisson's ratio of 0.25 and use the expressions of Okada (1985).

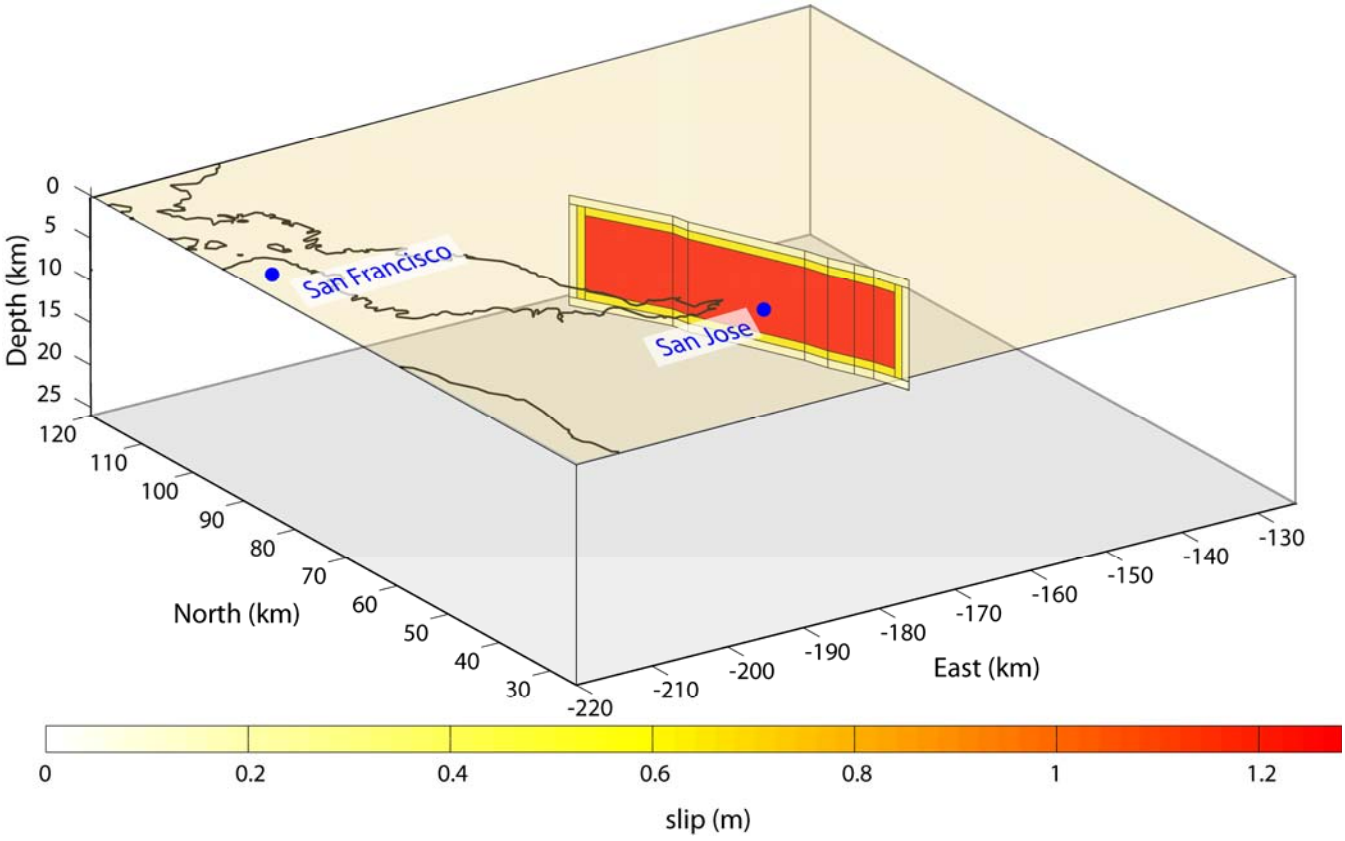


Figure 1. Example slip distribution for the Northern Calaveras *M* 6.78 scenario earthquake. The slip increases from 0.1282 m at the edges to 0.6412 m and then to 1.282 m in the center, giving a moment of 1.66 1019 N m.

Displacement Maps

Figures 2 through 36 show the predicted displacements for scenario events. To provide displacement information throughout the geographic region of interest, the displacements were calculated on a grid rather than at existing GPS site locations. Blue circles indicate the locations of existing continuous GPS sites for reference. Using the input files provided with this report, one can calculate displacements for any location. Horizontal displacements are given by vectors, and the

background color shading shows vertical displacement. Contours of vertical displacement are shown in grey and coastlines in black. For vertical strike slip faults (all sources except the Mount Diablo thrust), the rupture is assumed to reach the Earth's surface, and the surface trace of the source fault is shown in green. In the case of the Mount Diablo thrust the vertical projection of the fault plane onto the Earth's surface is shown in white, and the up-dip projection of the upper edge is shown in green.

The predicted displacements presented here are a reasonable approximation to the displacements that would occur in a real event. However, assumptions made by this study (for example, the spatial distribution of slip and use of an elastic half-space approximation), as well as assumptions made in generating the scenario events (for example, fault geometry, rupture length, and magnitude), will no doubt give rise to differences between the predicted displacements and those observed following an actual earthquake, particularly for locations near the fault rupture.

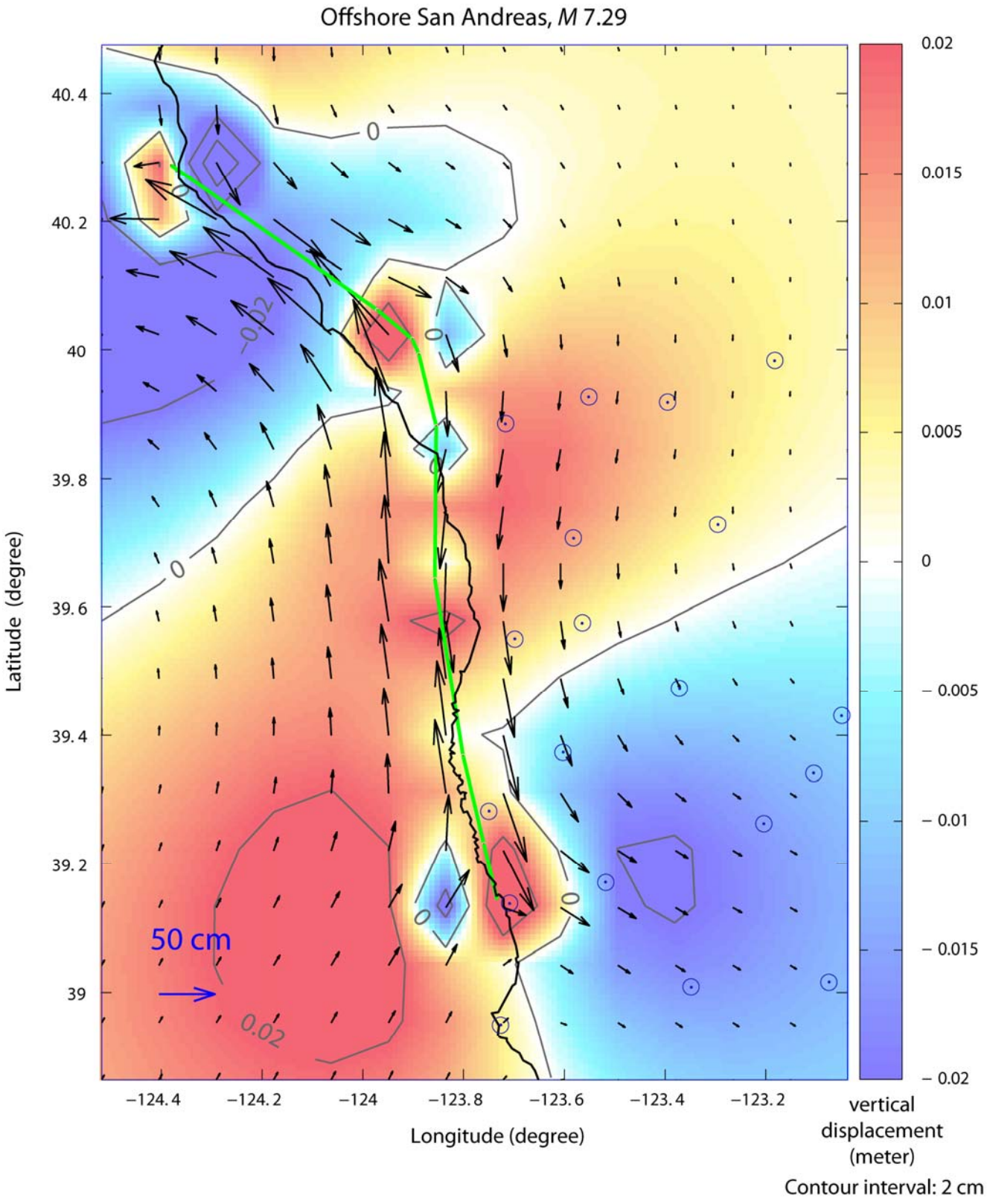


Figure 2. Predicted displacements for scenario offshore San Andreas fault earthquake.

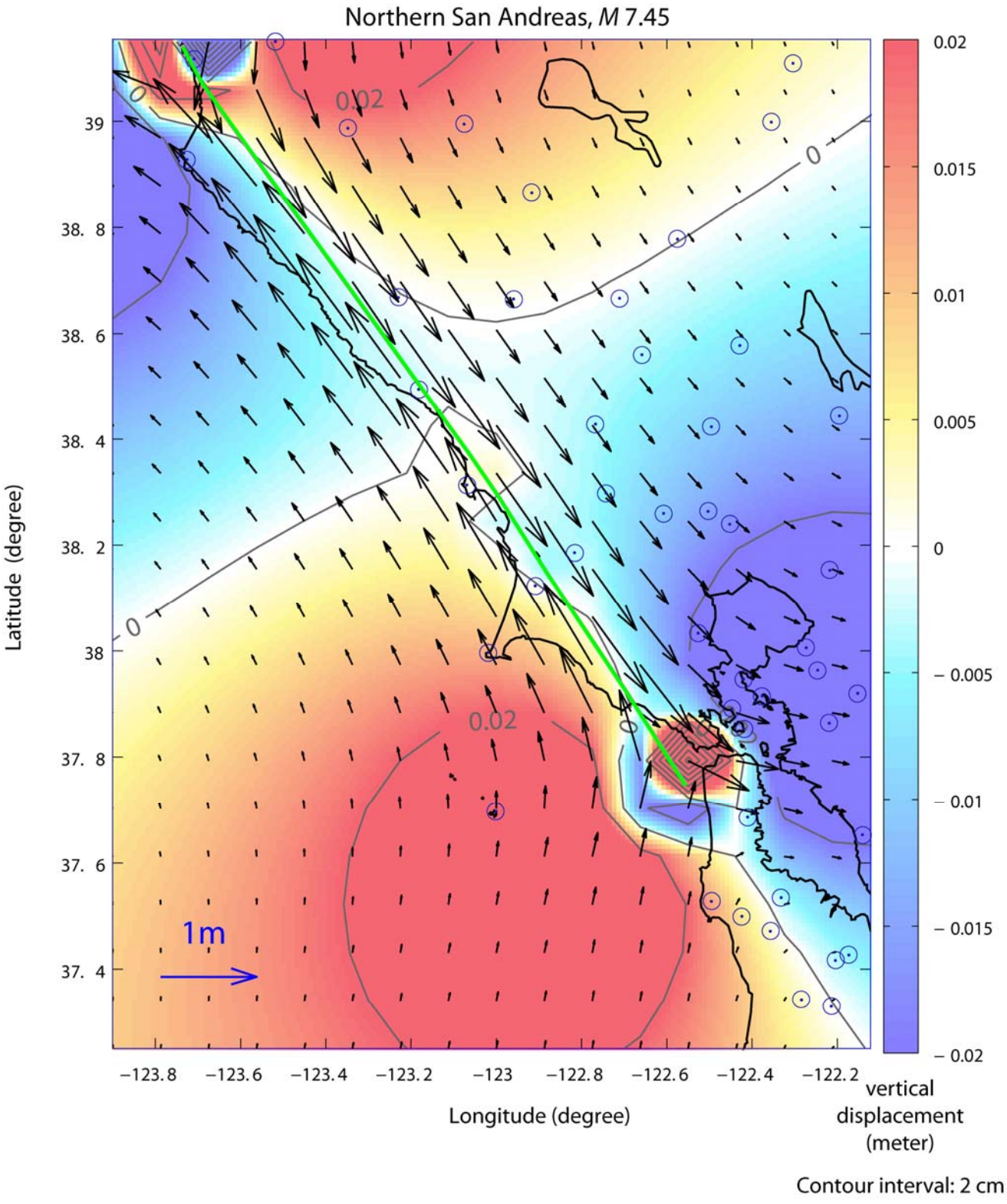


Figure 3. Predicted displacements for scenario northern San Andreas fault earthquake.

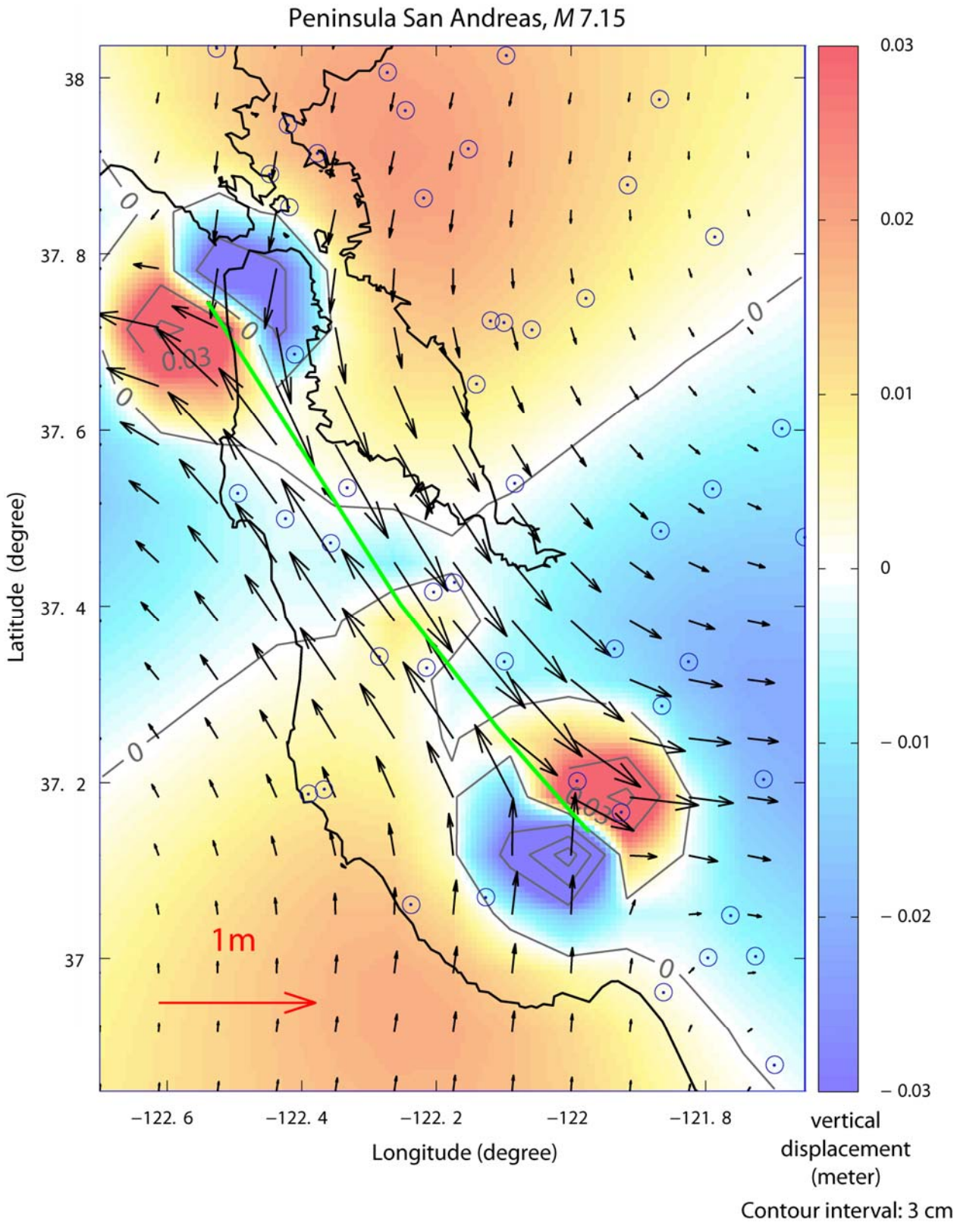


Figure 4. Predicted displacements for scenario peninsula San Andreas fault earthquake.

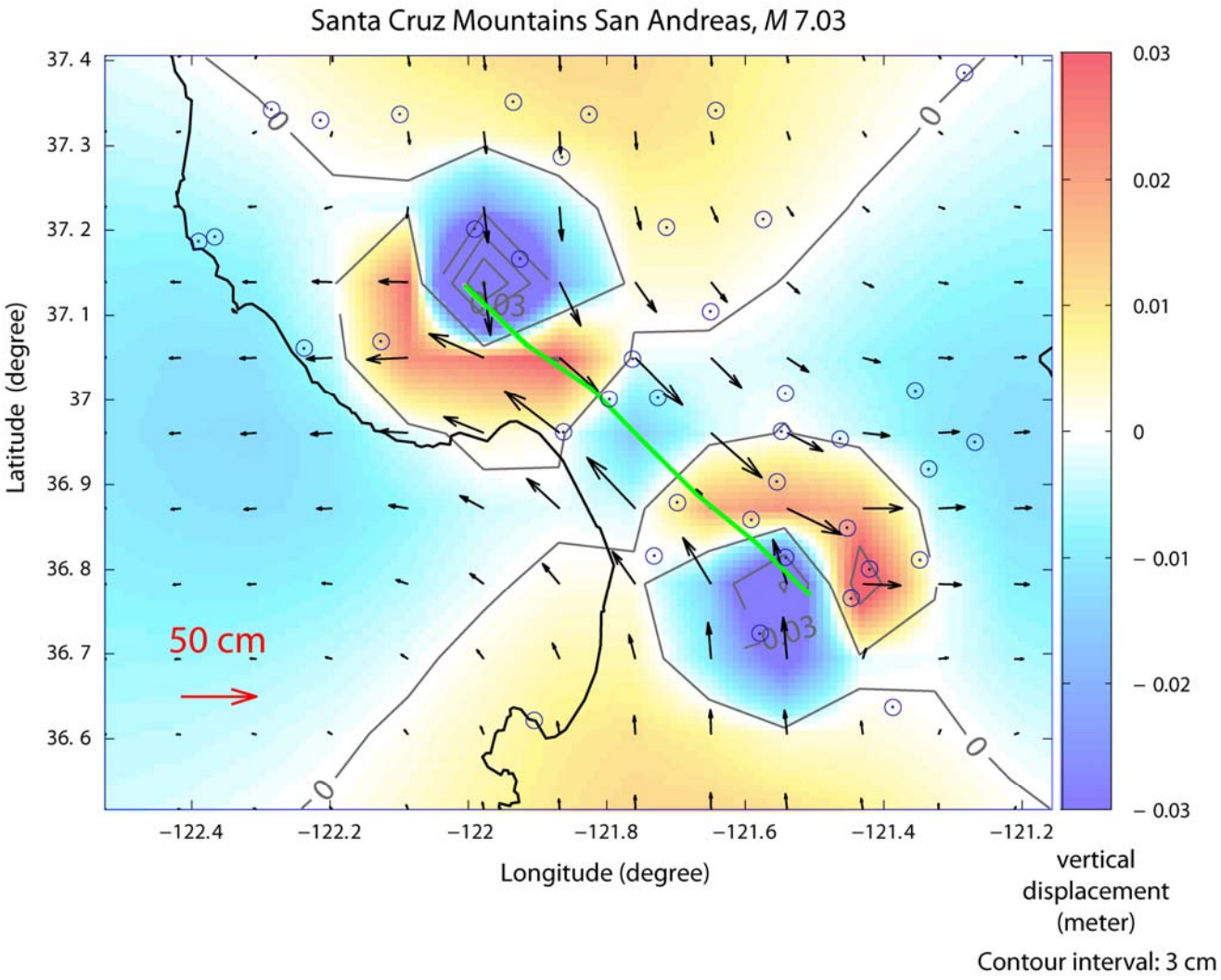


Figure 5. Predicted displacements for scenario Santa Cruz mountains San Andreas fault earthquake.

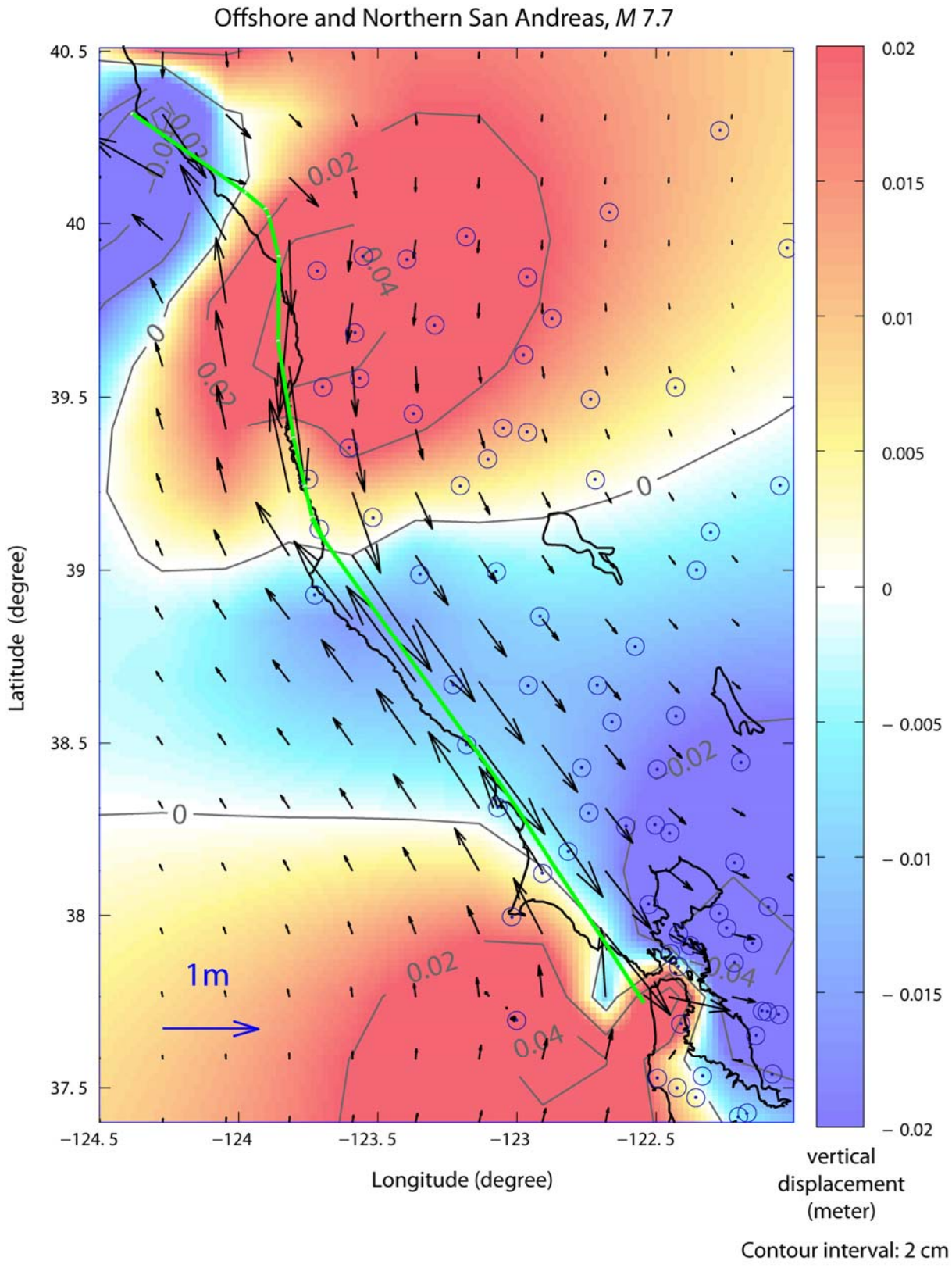


Figure 6. Predicted displacements for scenario offshore and northern San Andreas fault earthquake.

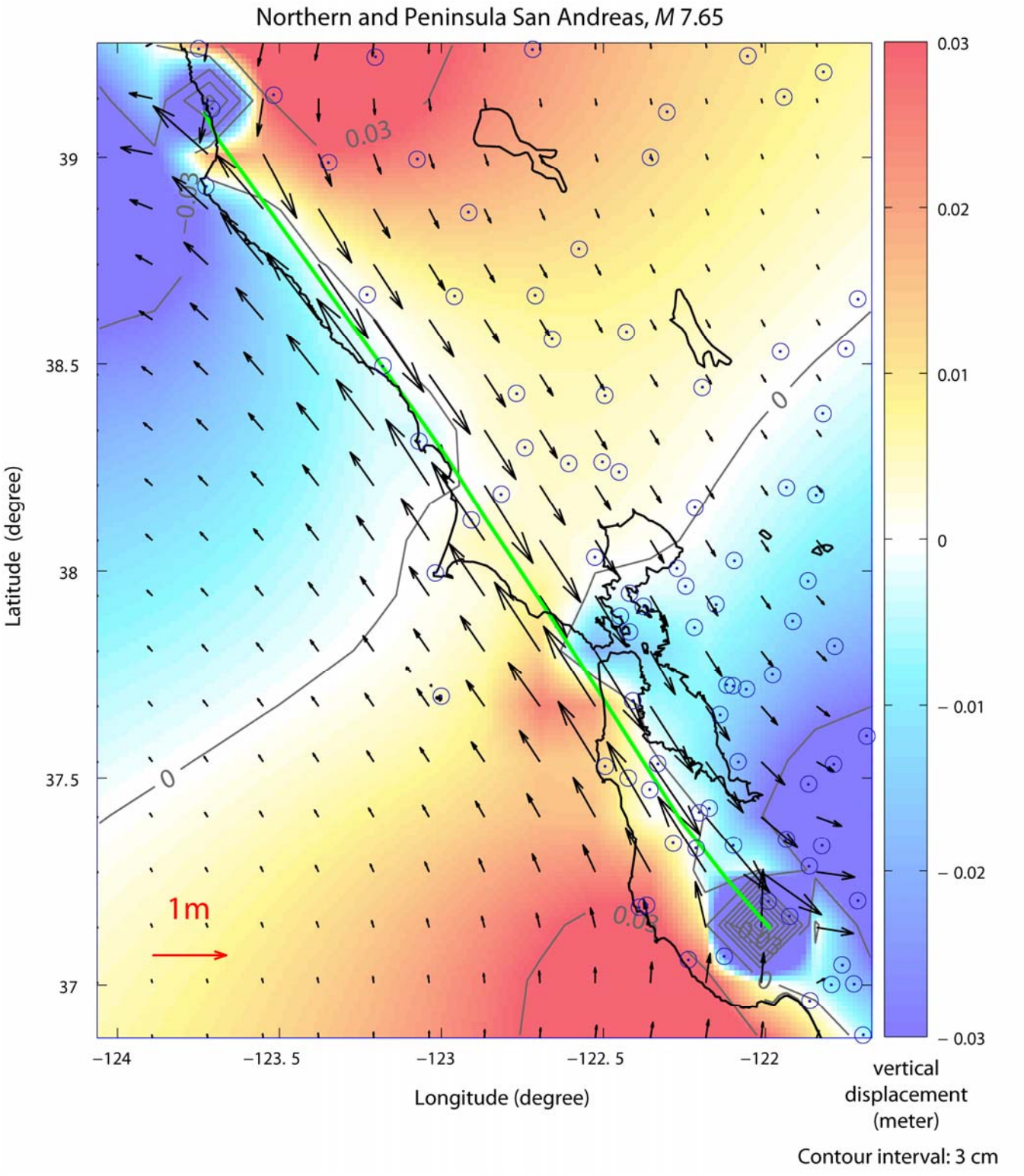
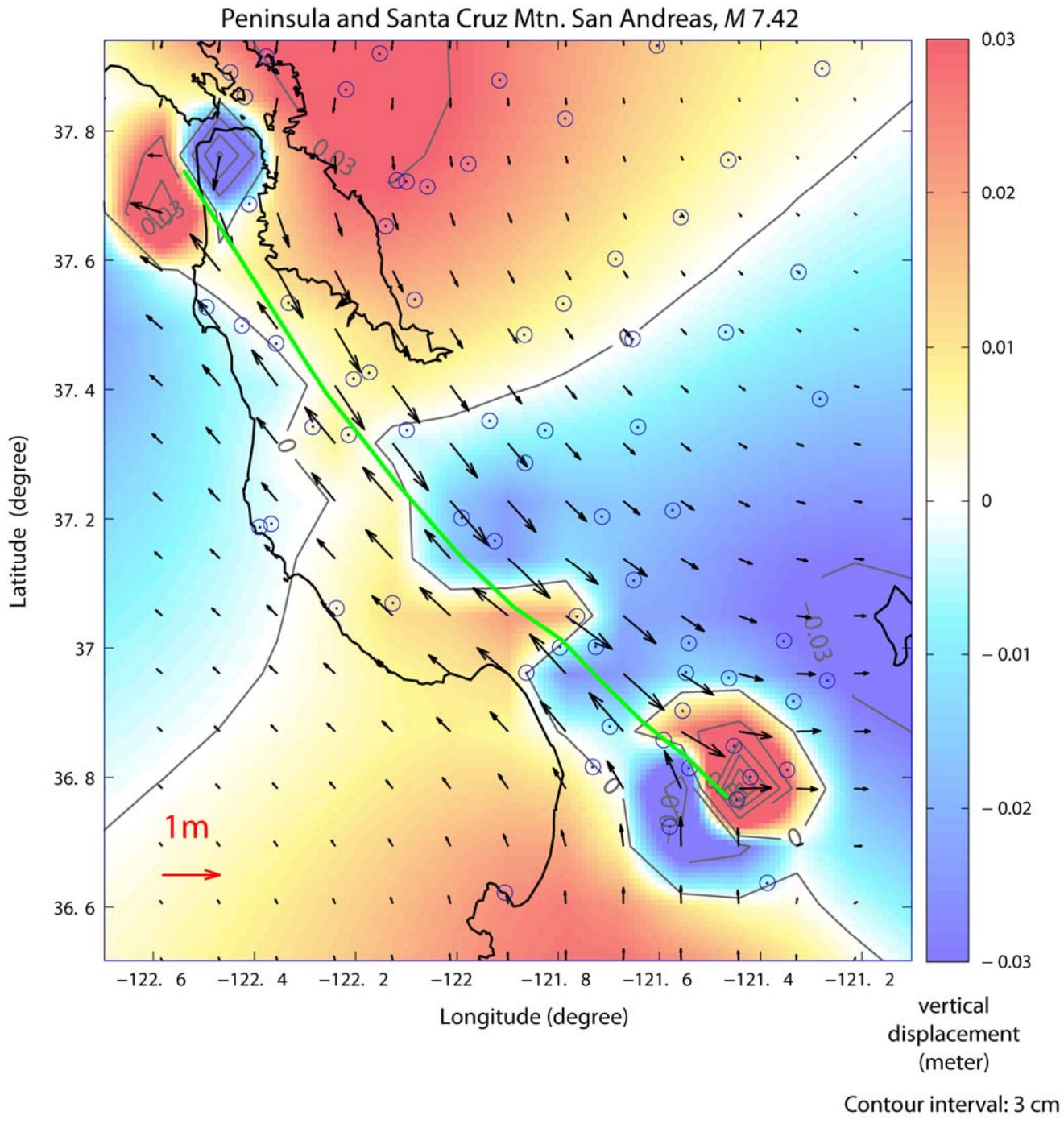


Figure 7. Predicted displacements for scenario northern and peninsula San Andreas fault earthquake.



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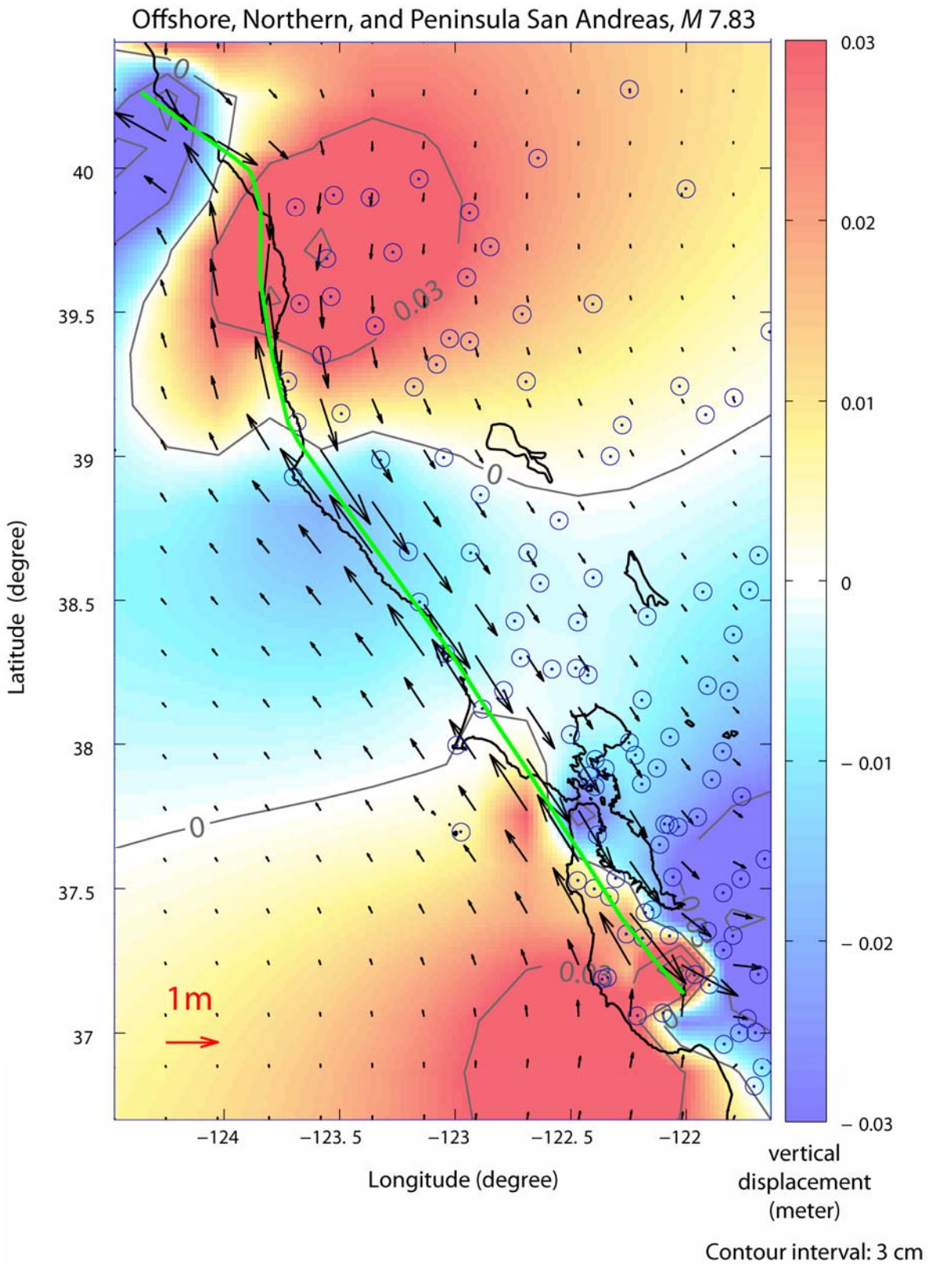
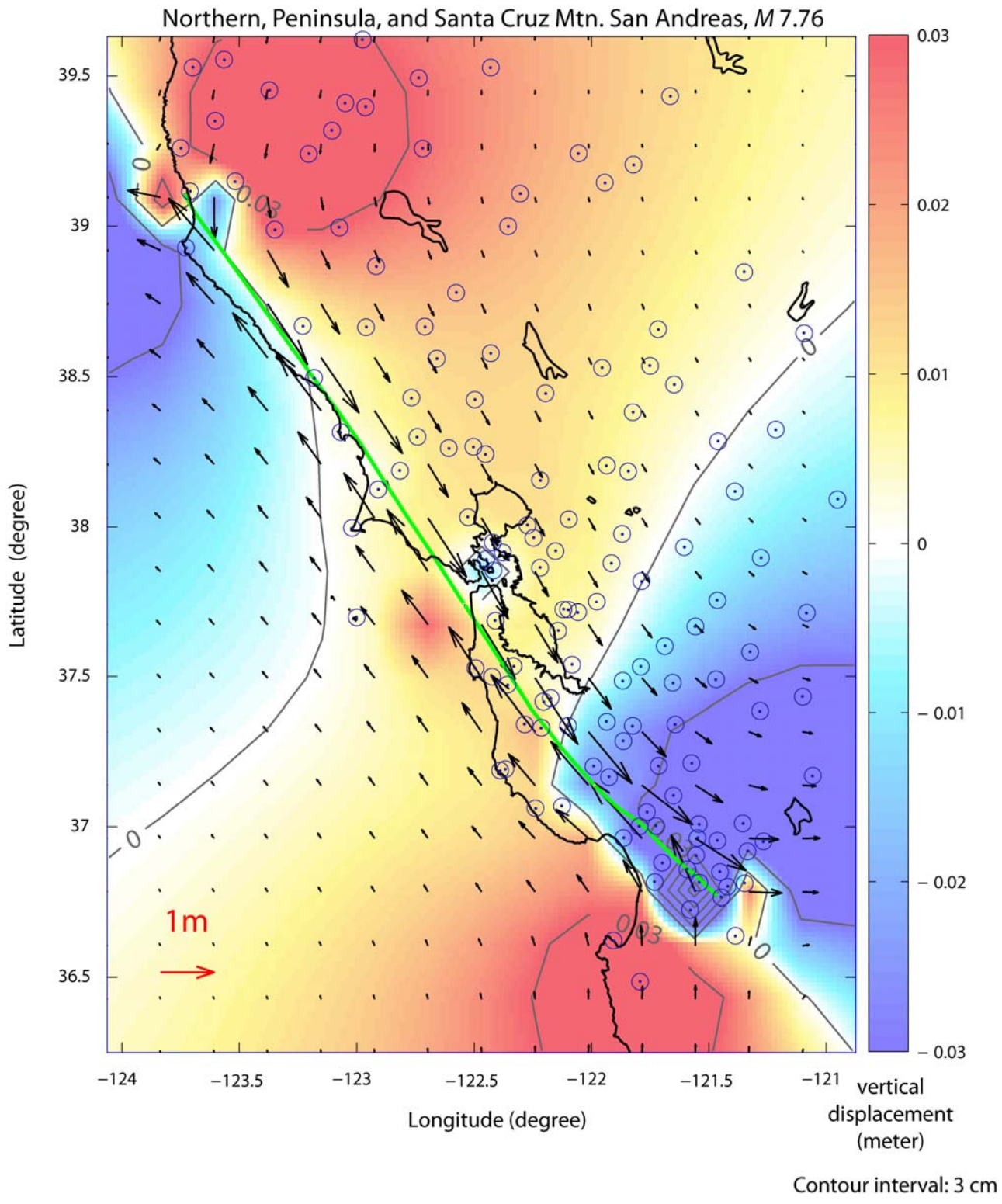


Figure 9. Predicted displacements for scenario offshore, northern, and peninsula San Andreas fault earthquake.



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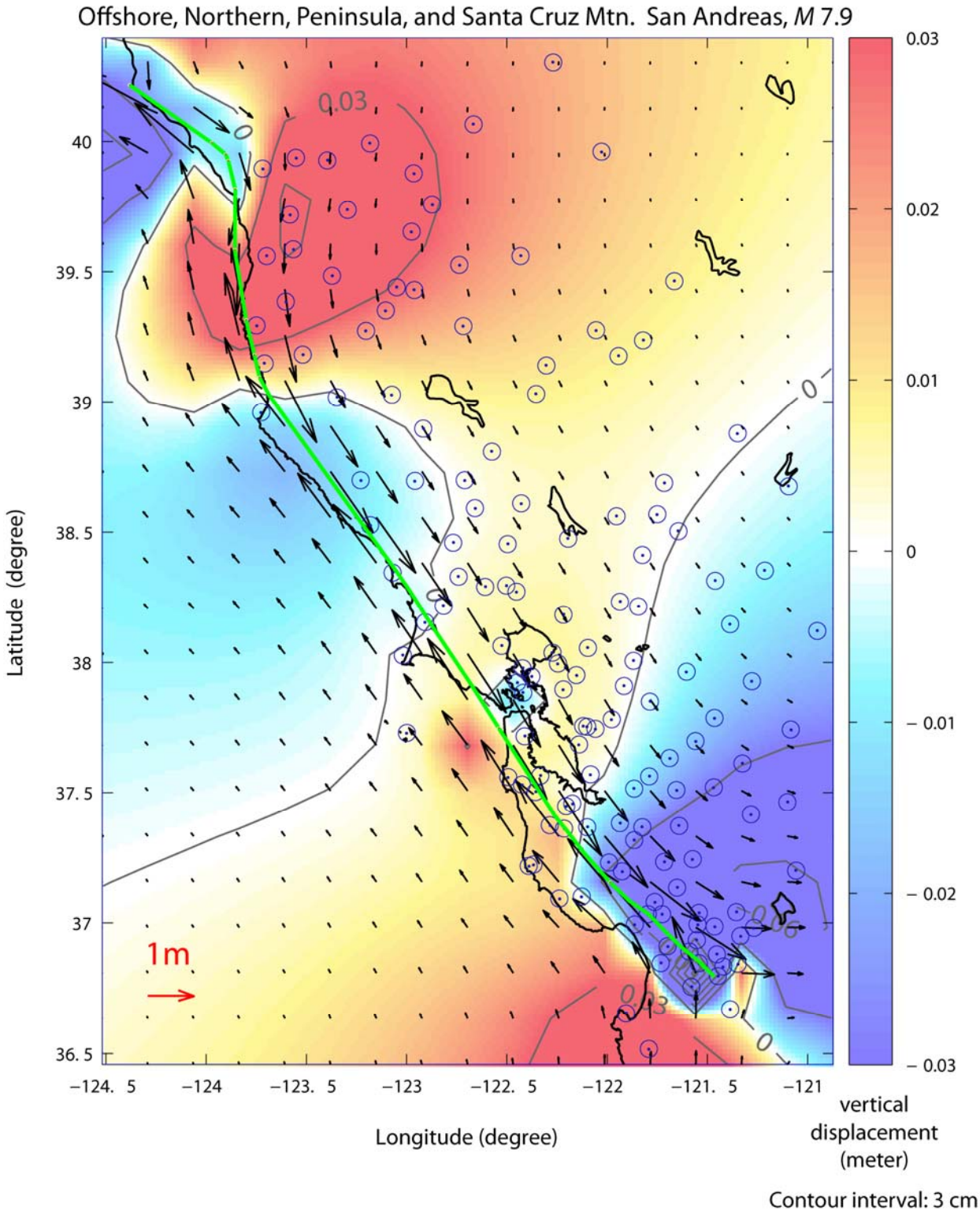


Figure 11. Predicted displacements for scenario offshore, northern, peninsula, and Santa Cruz mountains San Andreas fault earthquake.

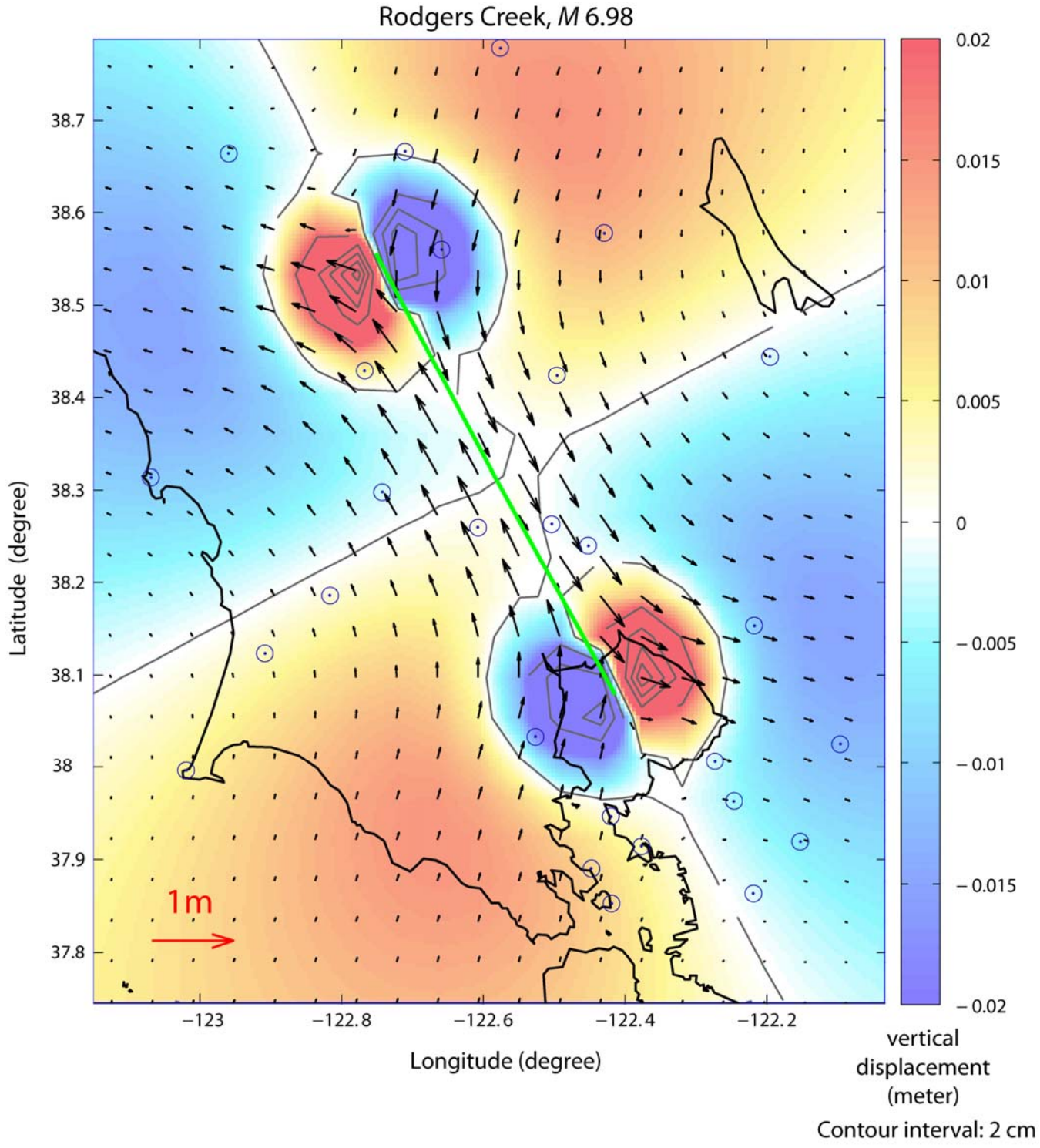


Figure 12. Predicted displacements for scenario Rodgers Creek fault earthquake.

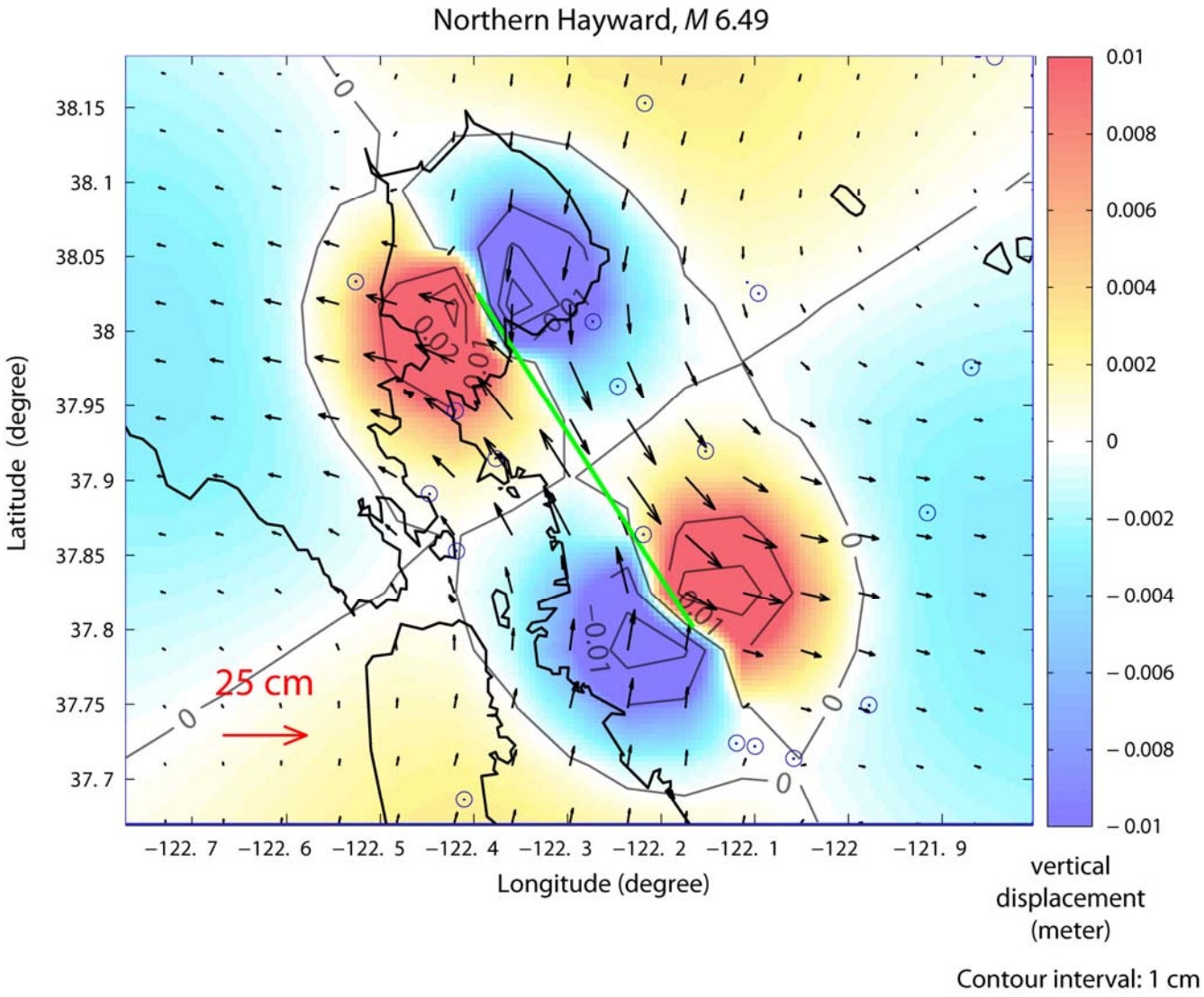
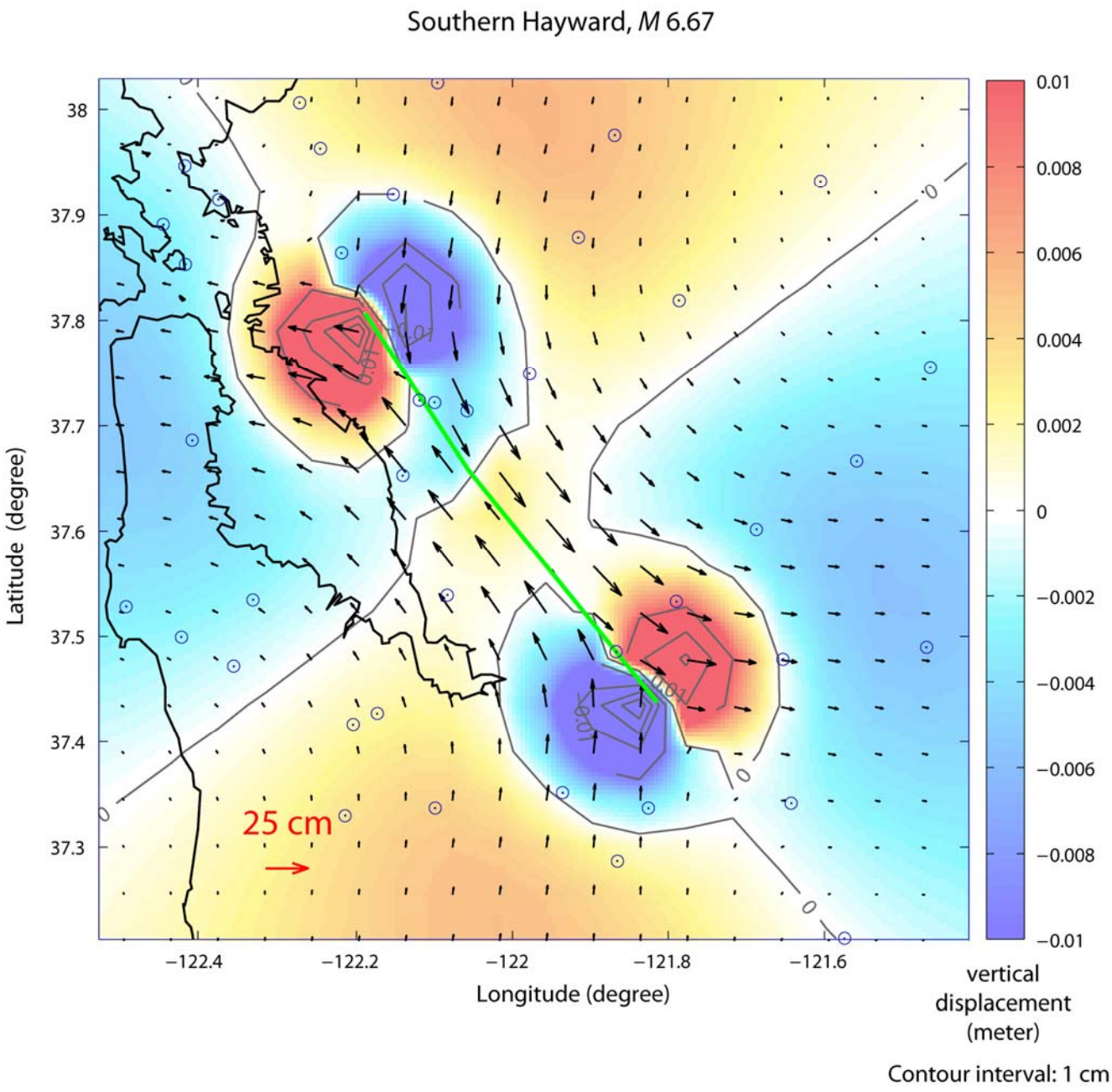


Figure 13. Predicted displacements for scenario northern Hayward fault earthquake.



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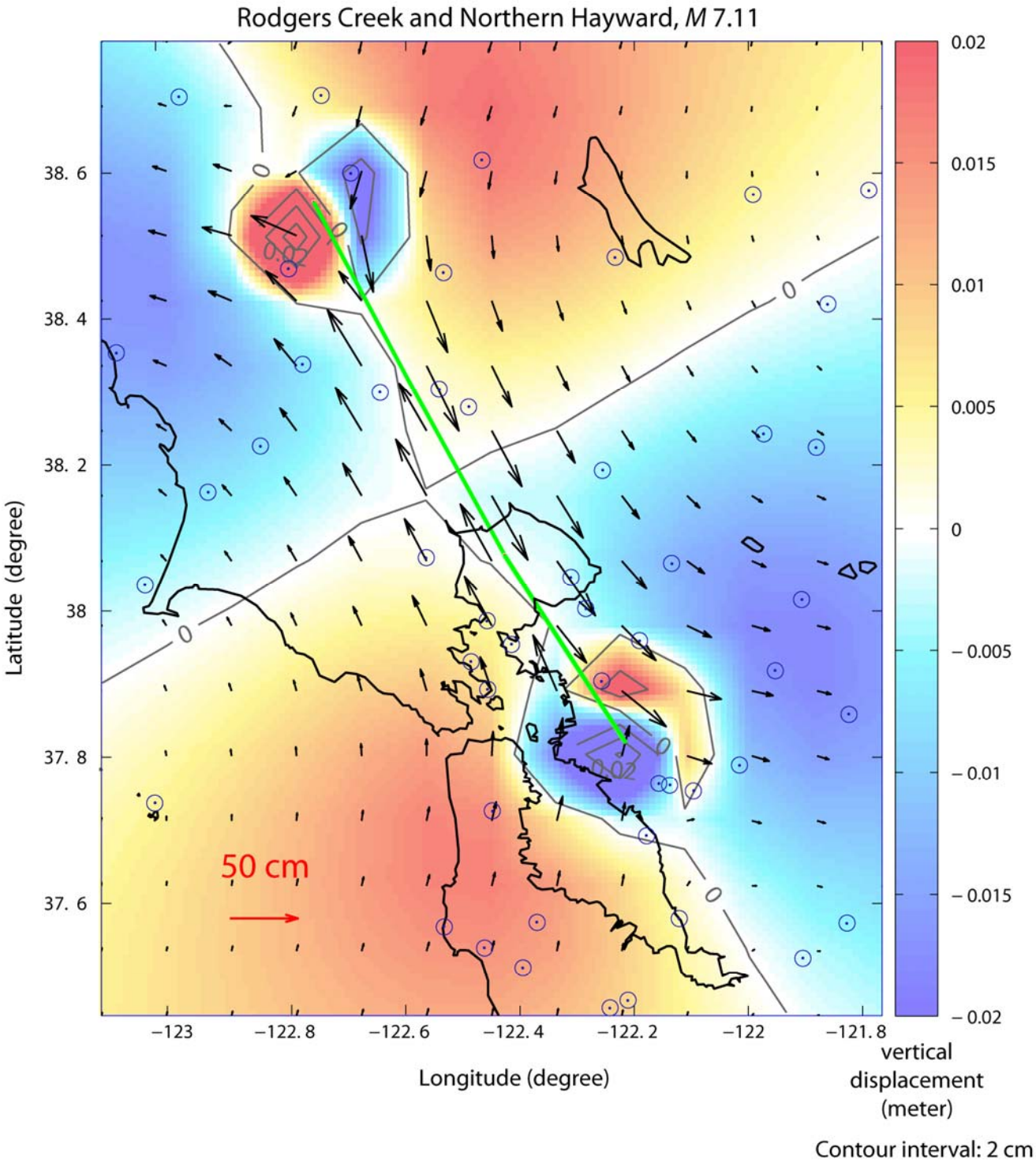
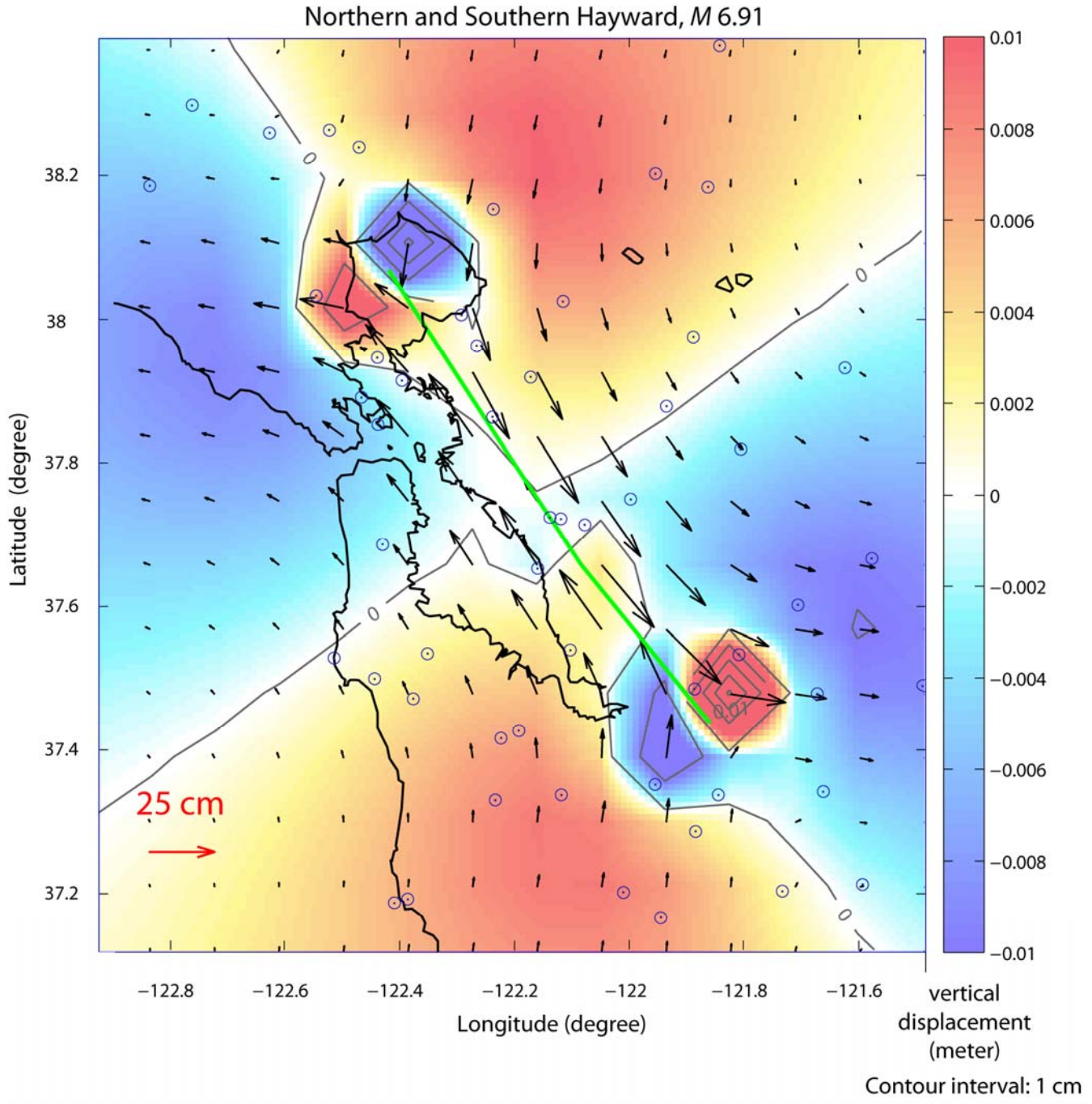


Figure 15. Predicted displacements for scenario Rodgers Creek and northern Hayward fault earthquake.



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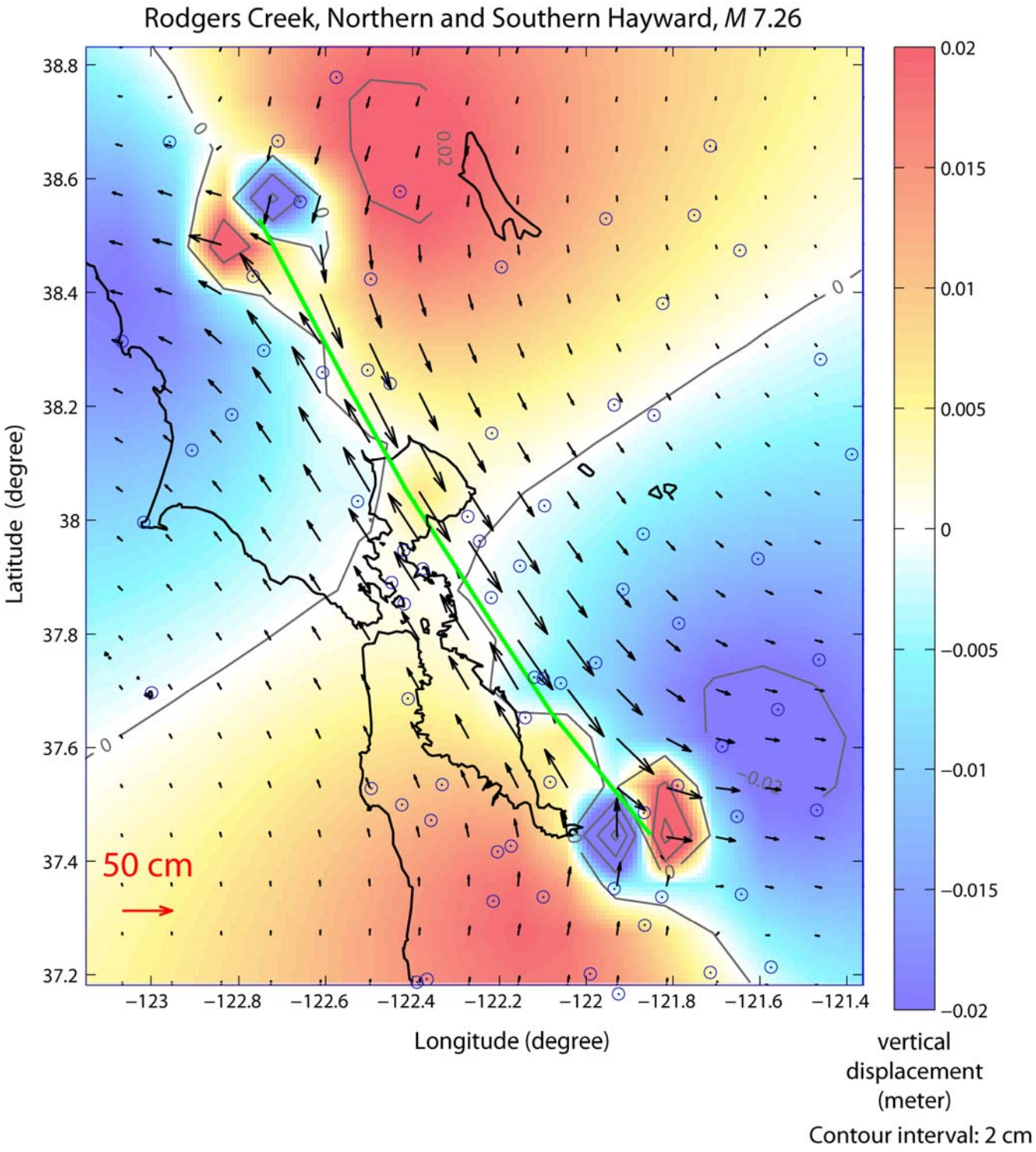

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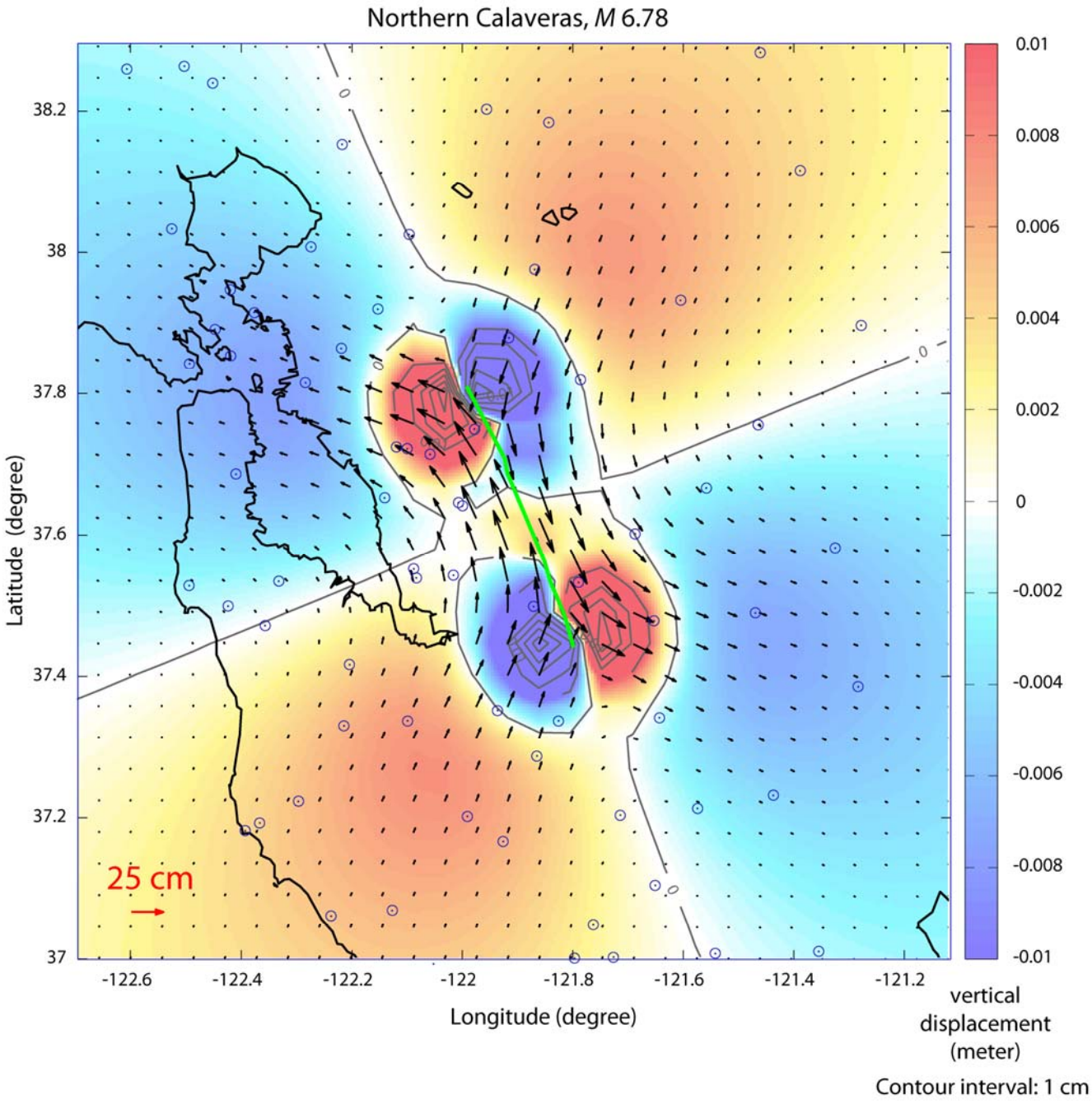

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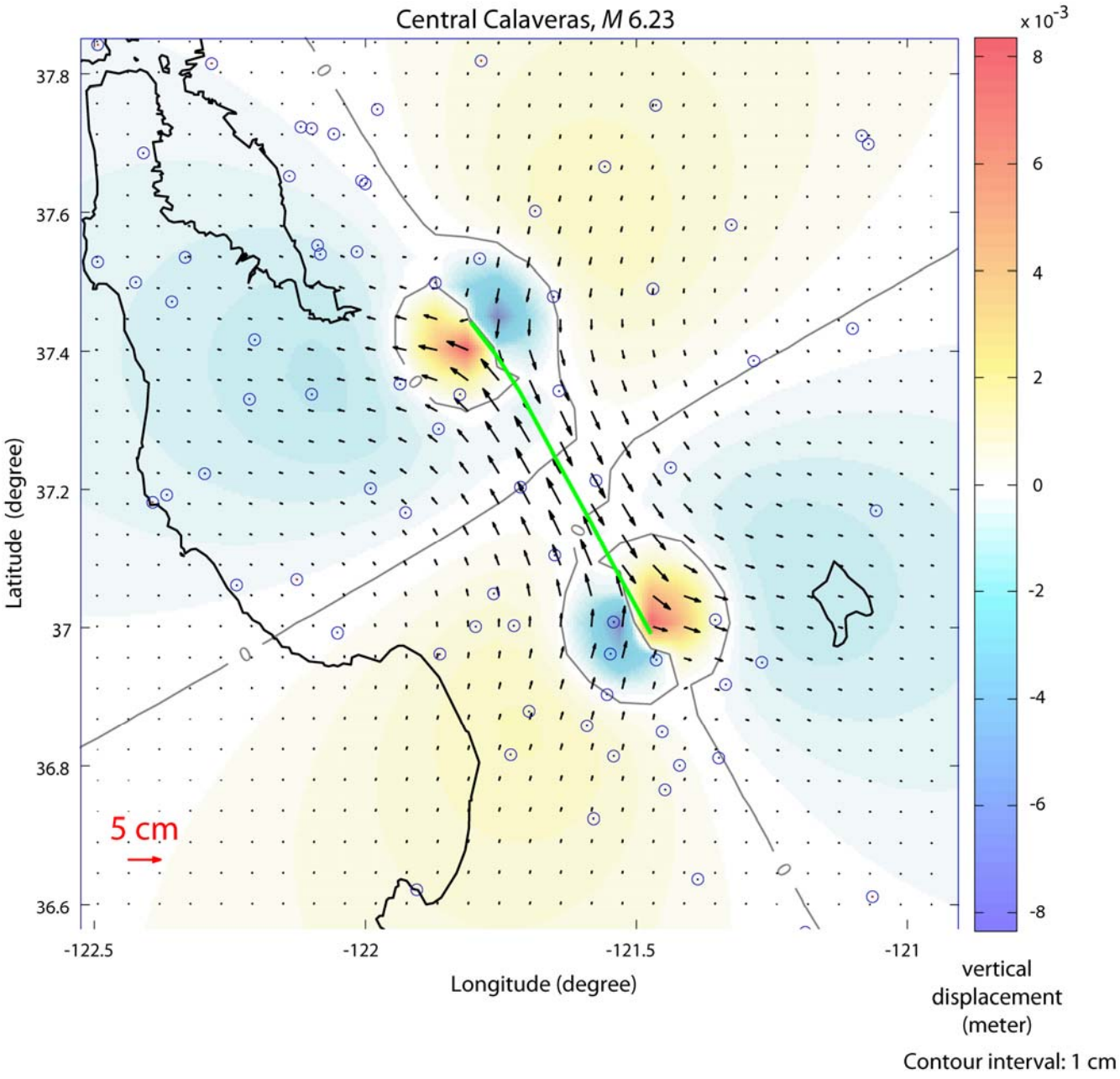

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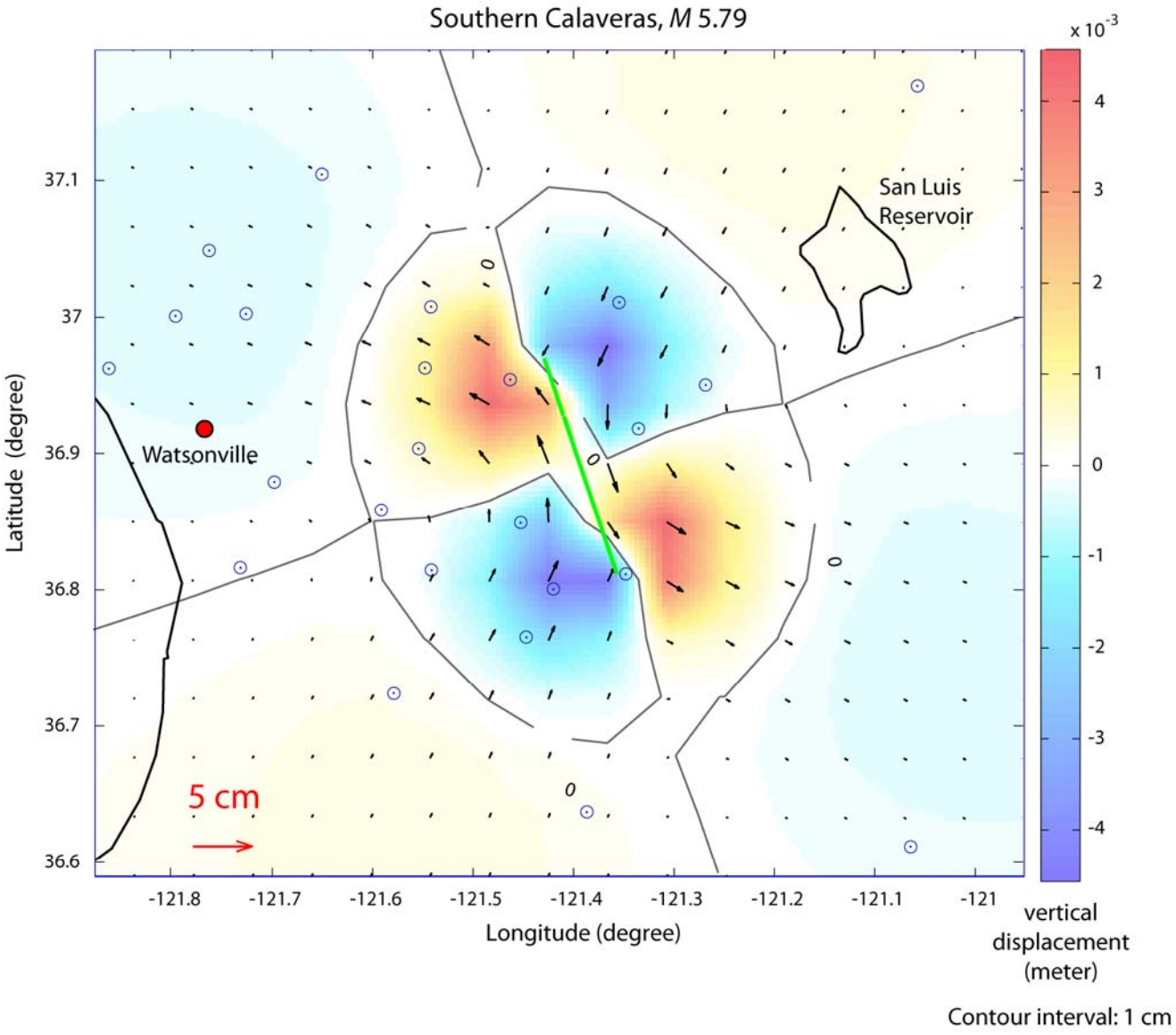

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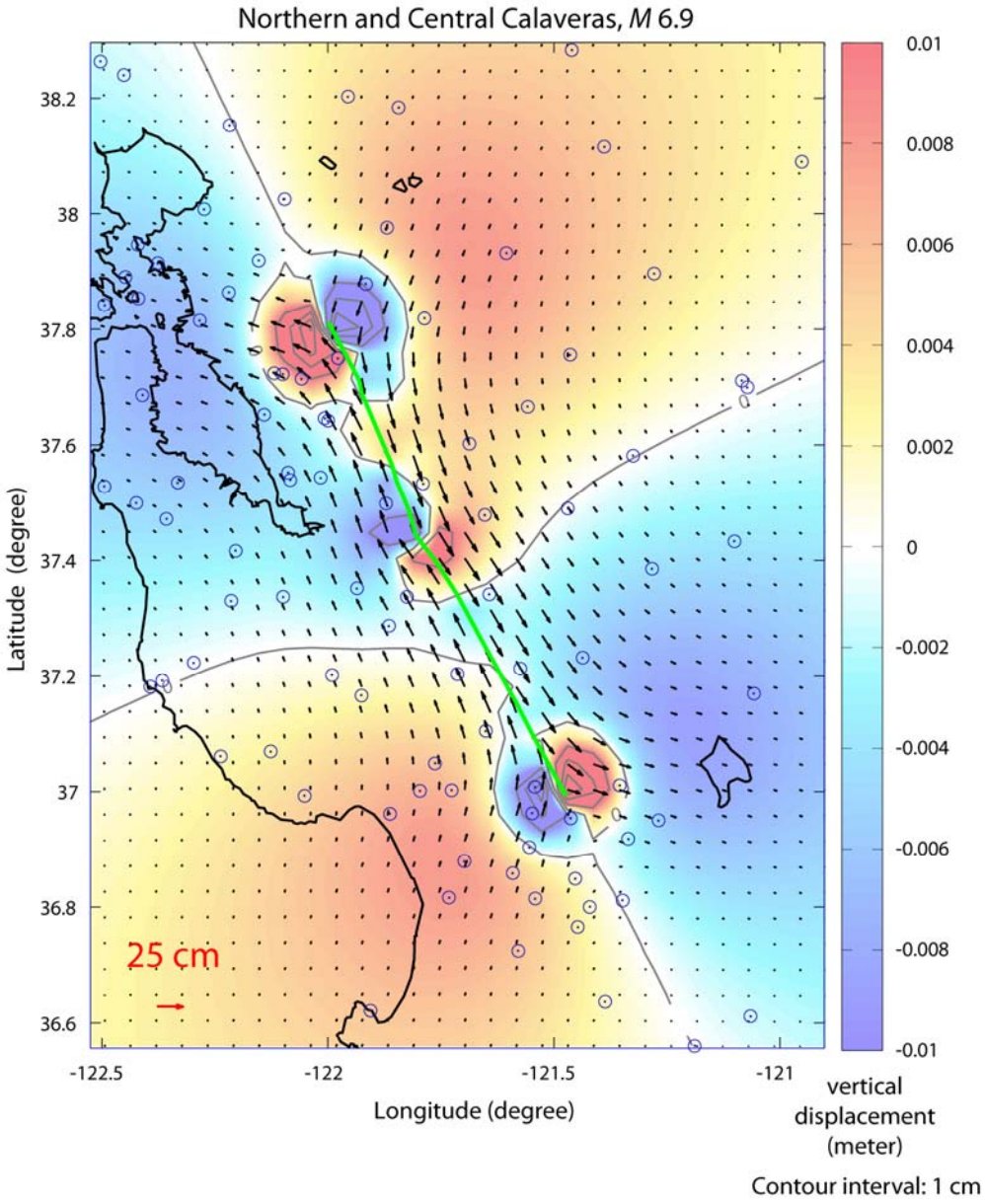


Figure 21. Predicted displacements for scenario northern and central Calaveras fault earthquake.

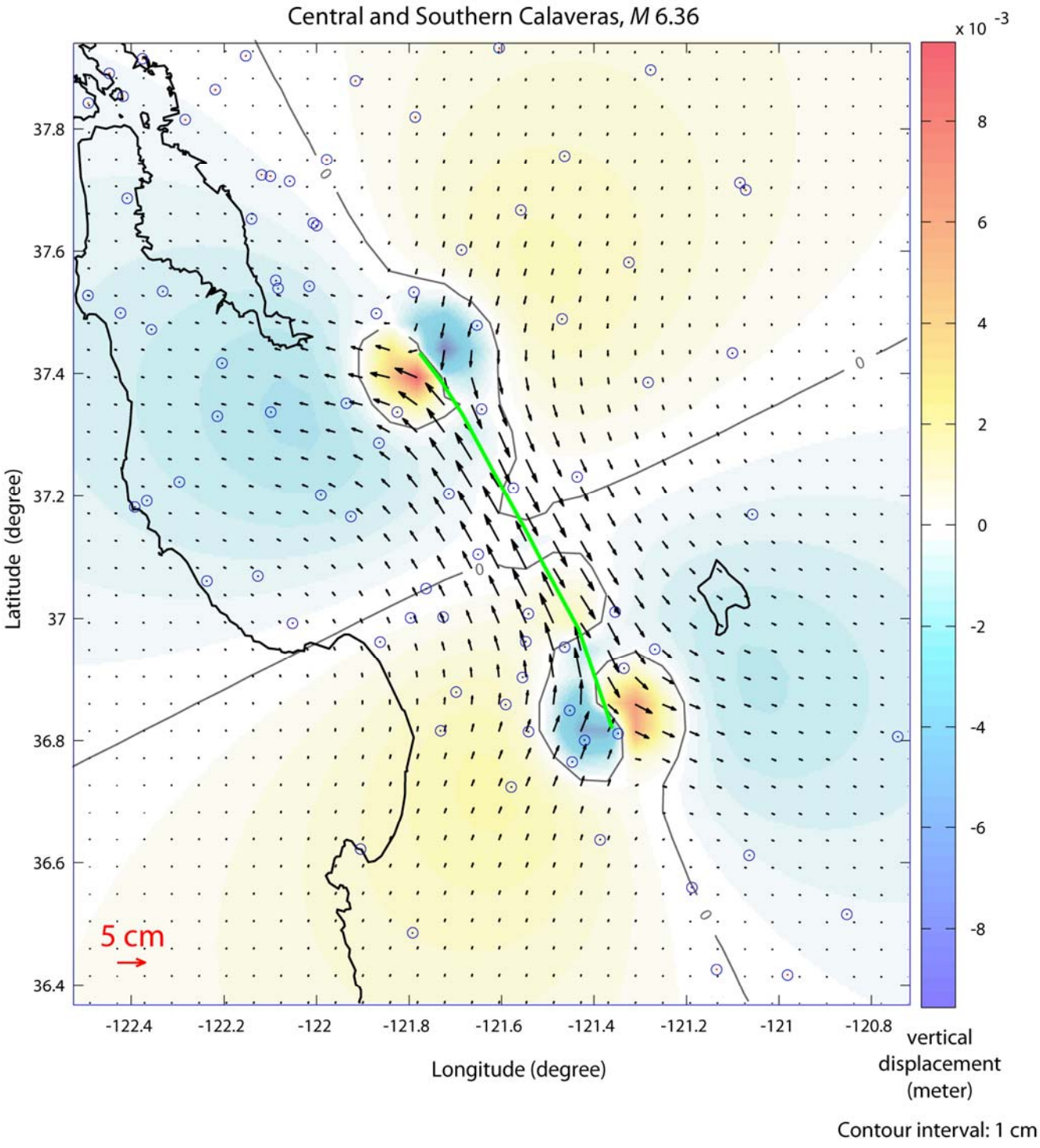


Figure 22. Predicted displacements for scenario central and southern Calaveras fault earthquake.

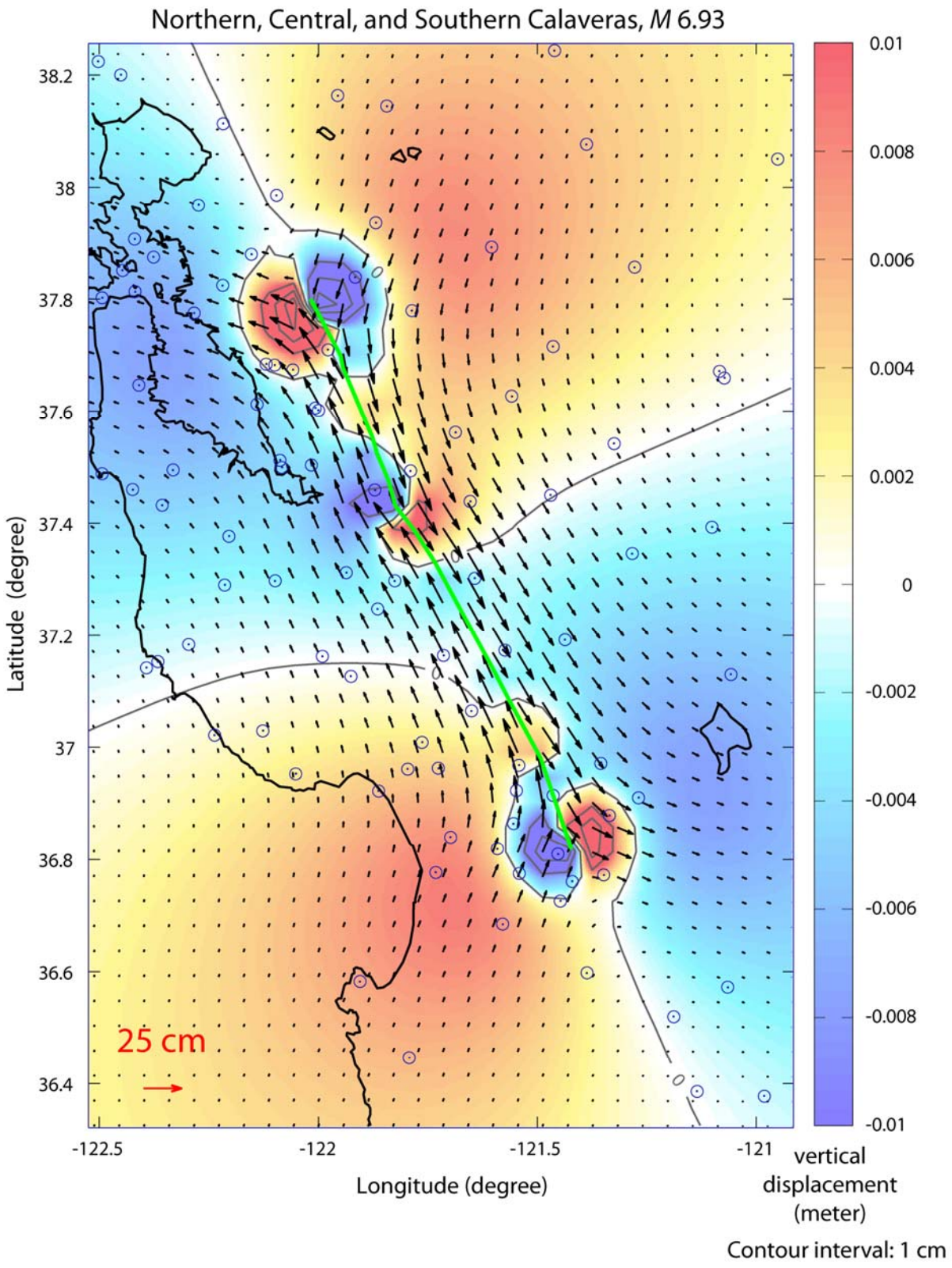
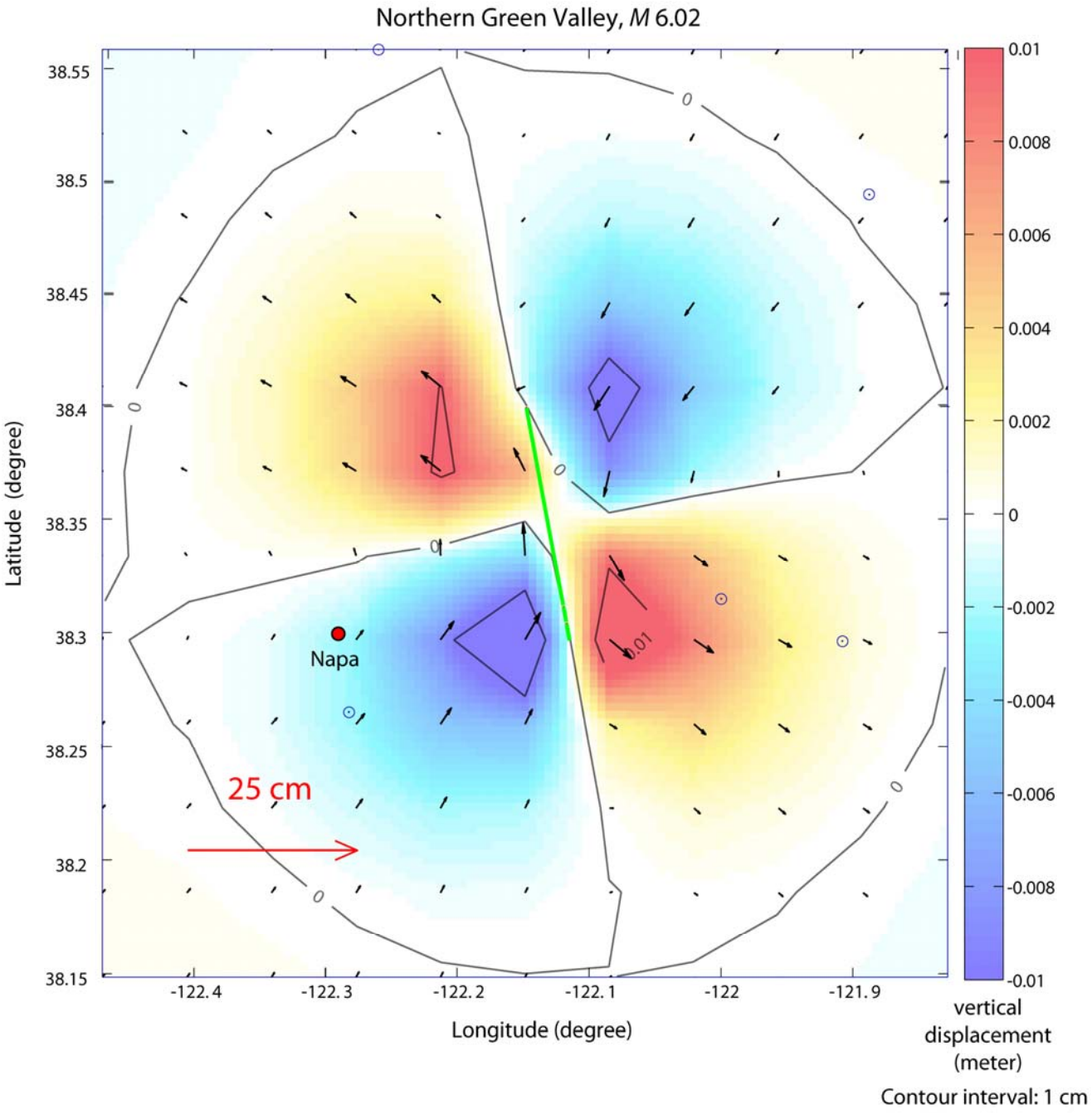


Figure 23. Predicted displacements for scenario northern, central, and southern Calaveras fault earthquake.



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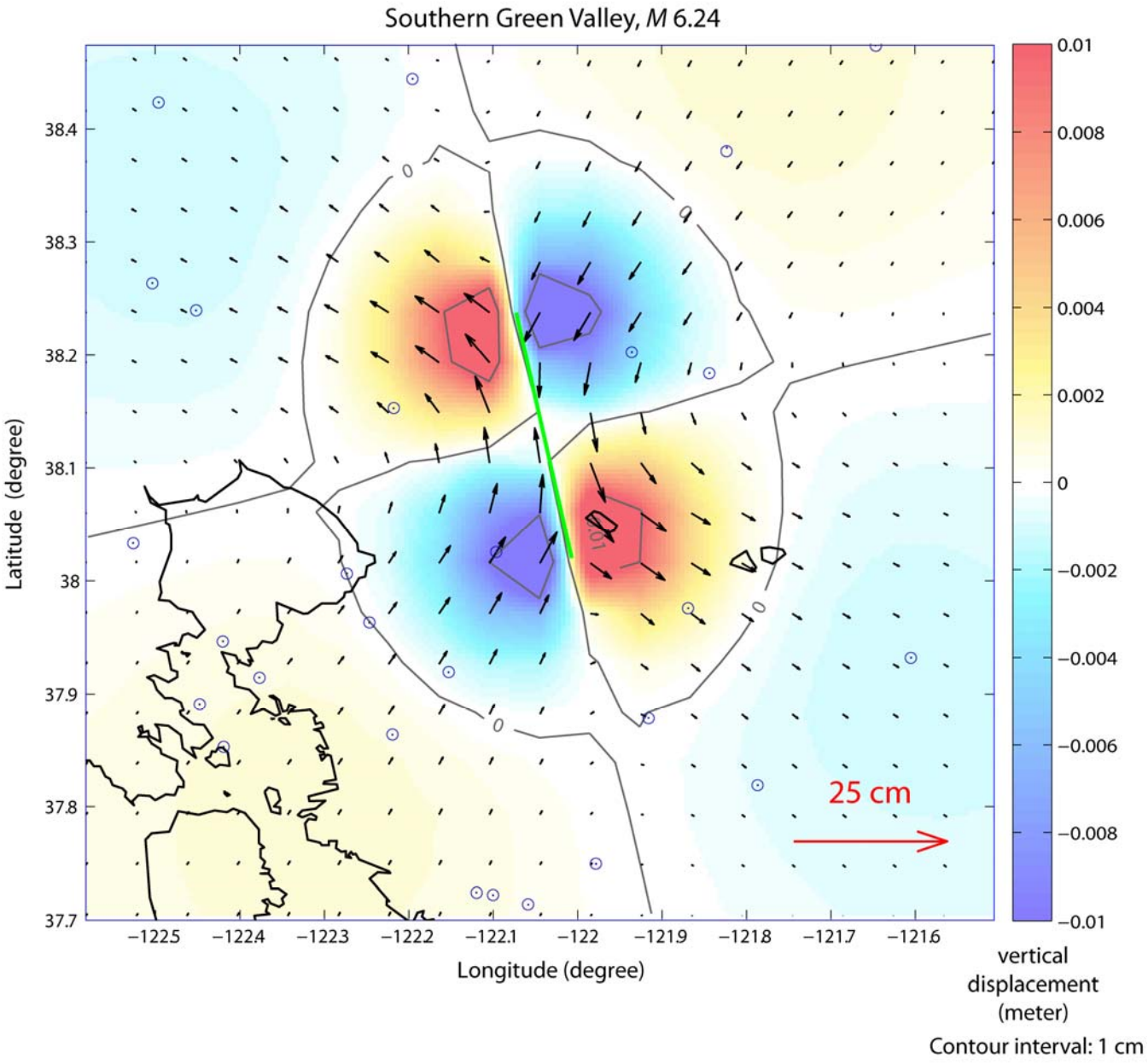

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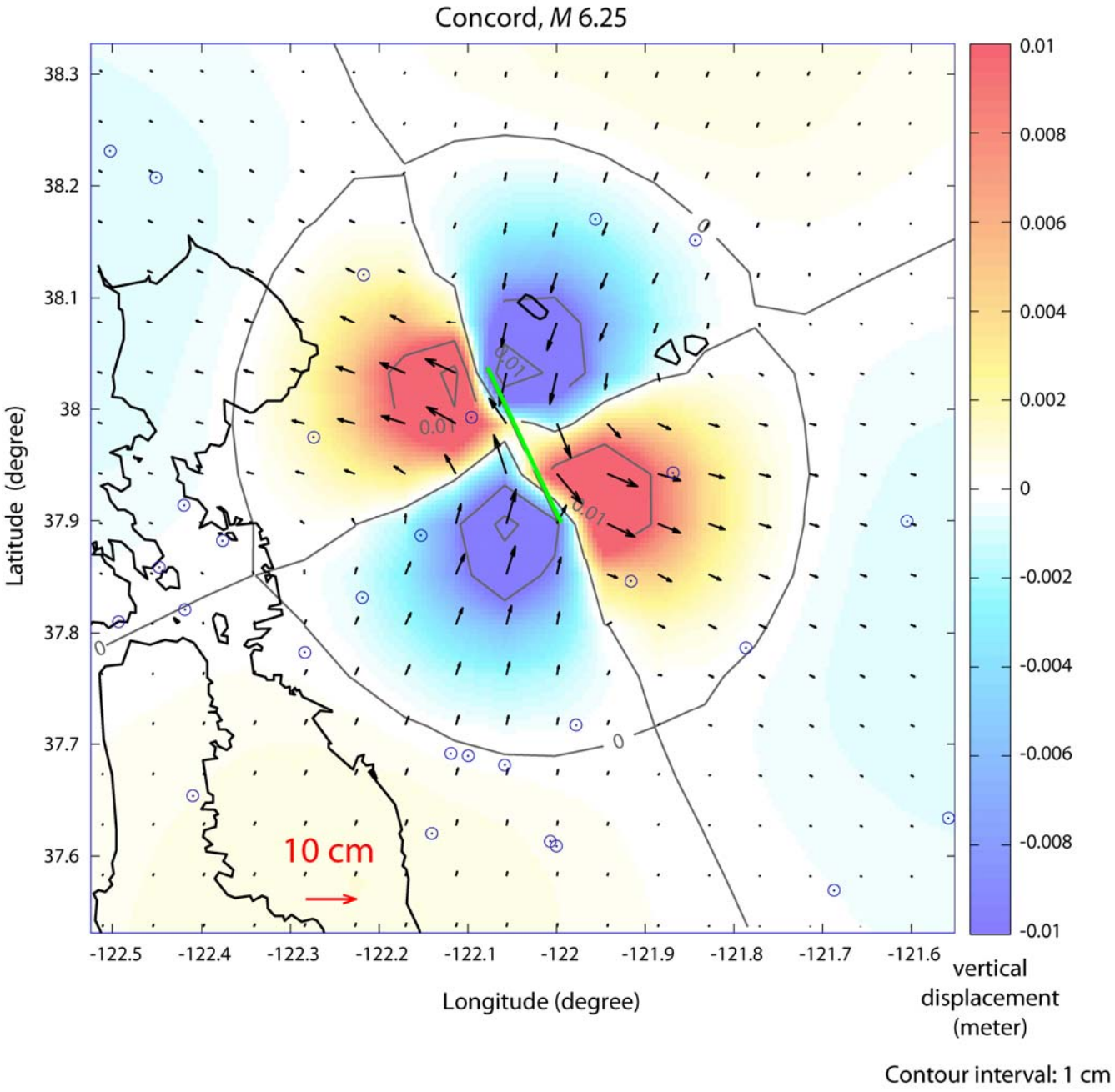

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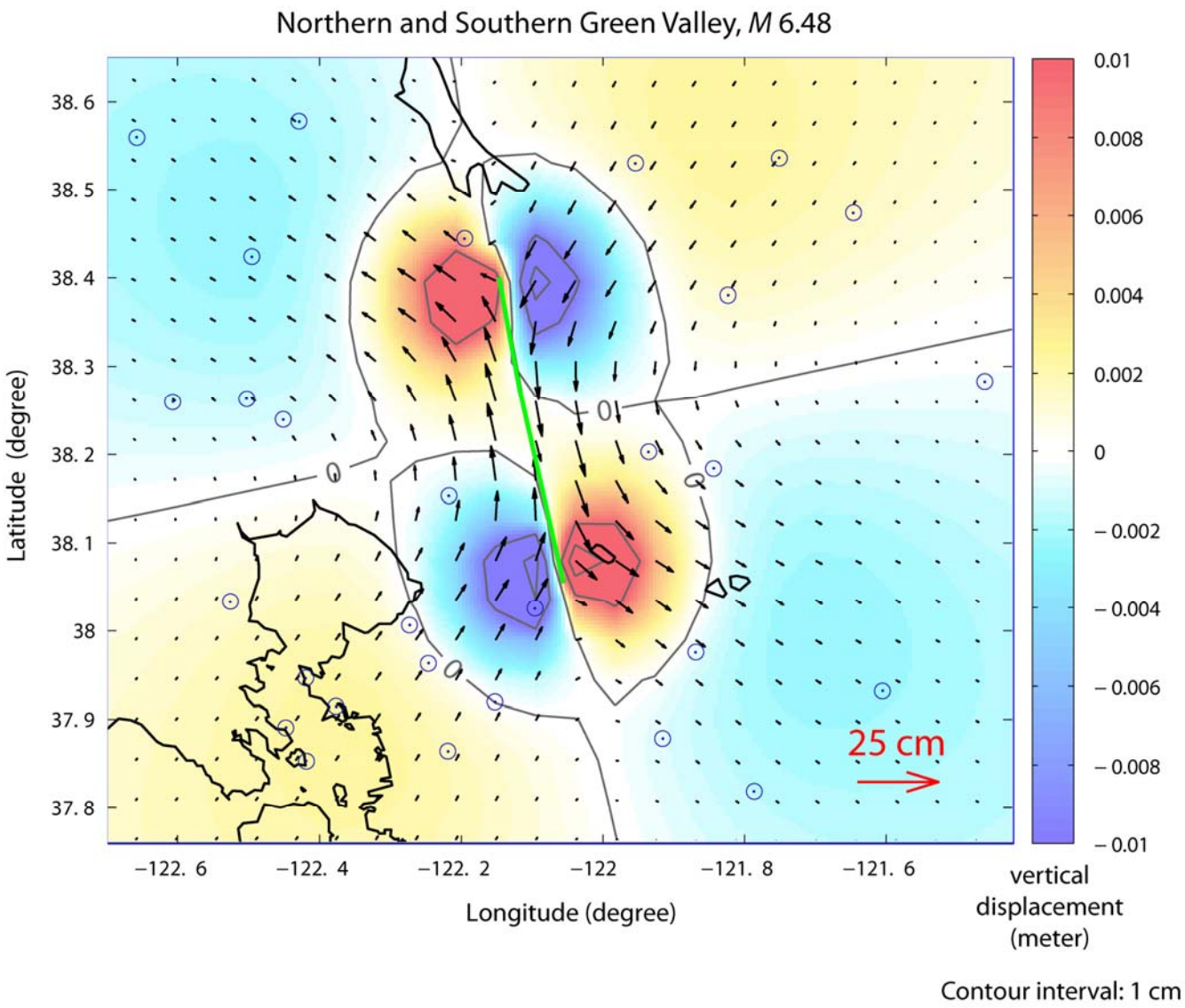


Figure 27. Predicted displacements for scenario northern and southern Green Valley fault earthquake.

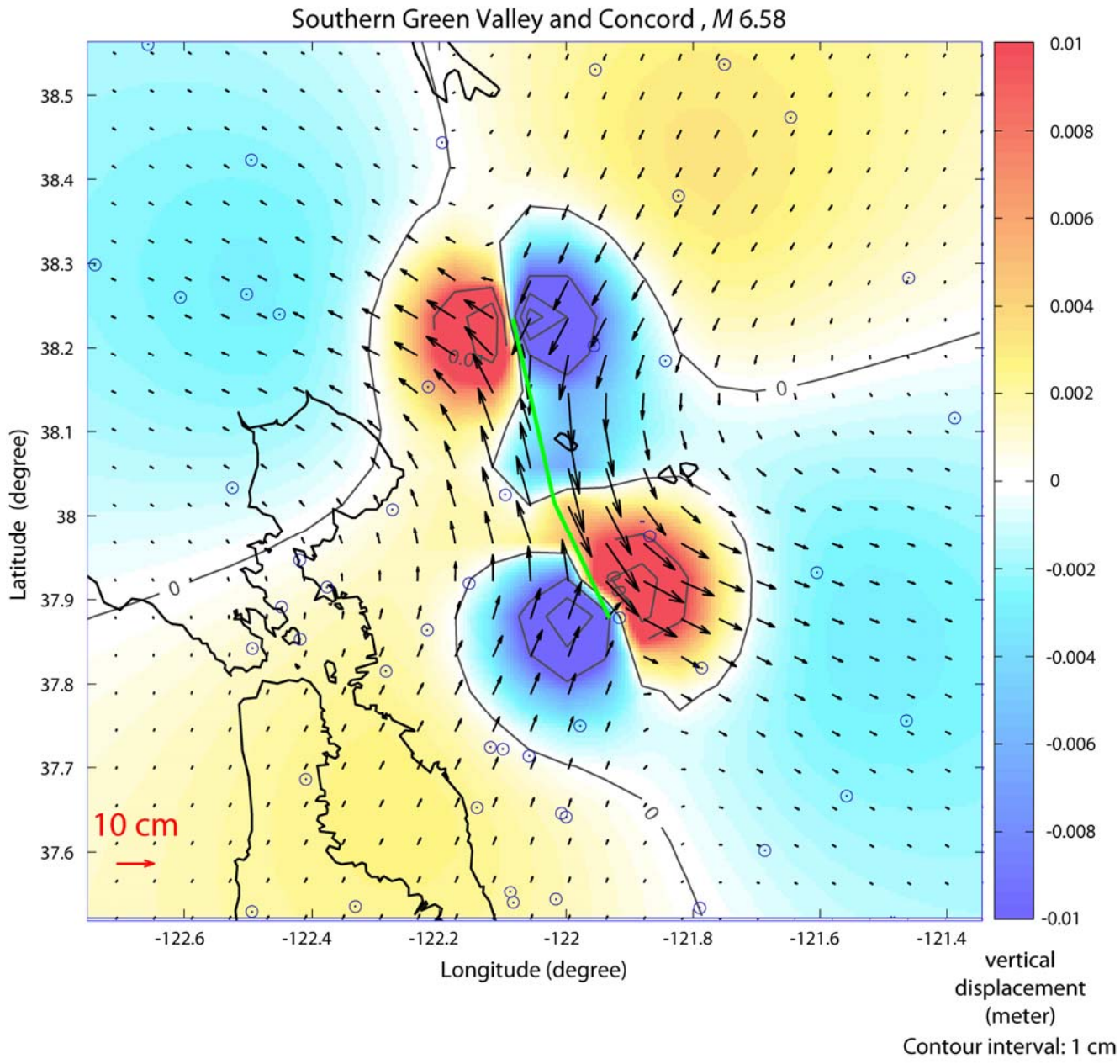


Figure 28. Predicted displacements for scenario southern Green Valley and Concord fault earthquake.

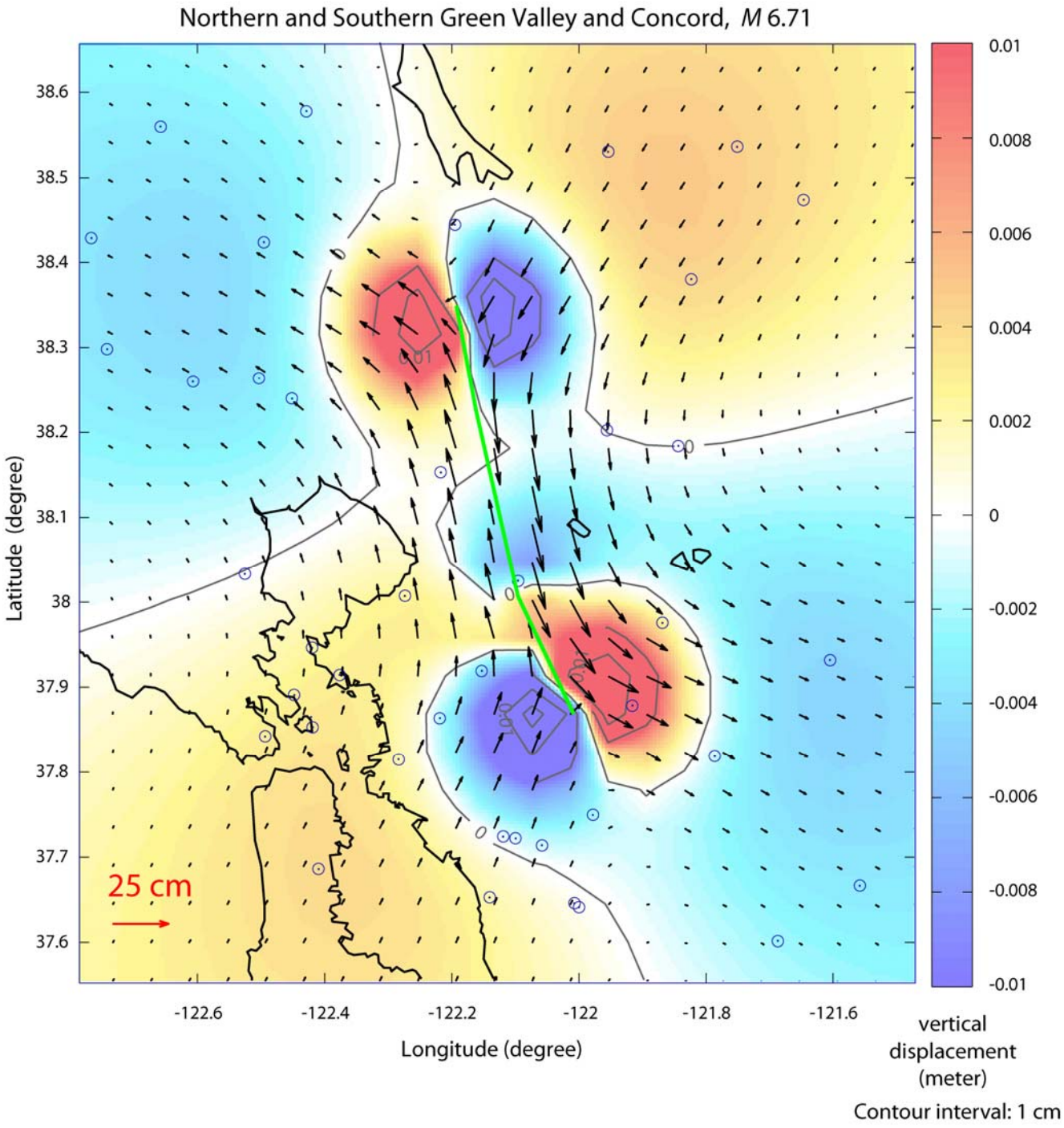


Figure 29. Predicted displacements for scenario northern and southern Green Valley and Concord fault earthquake.

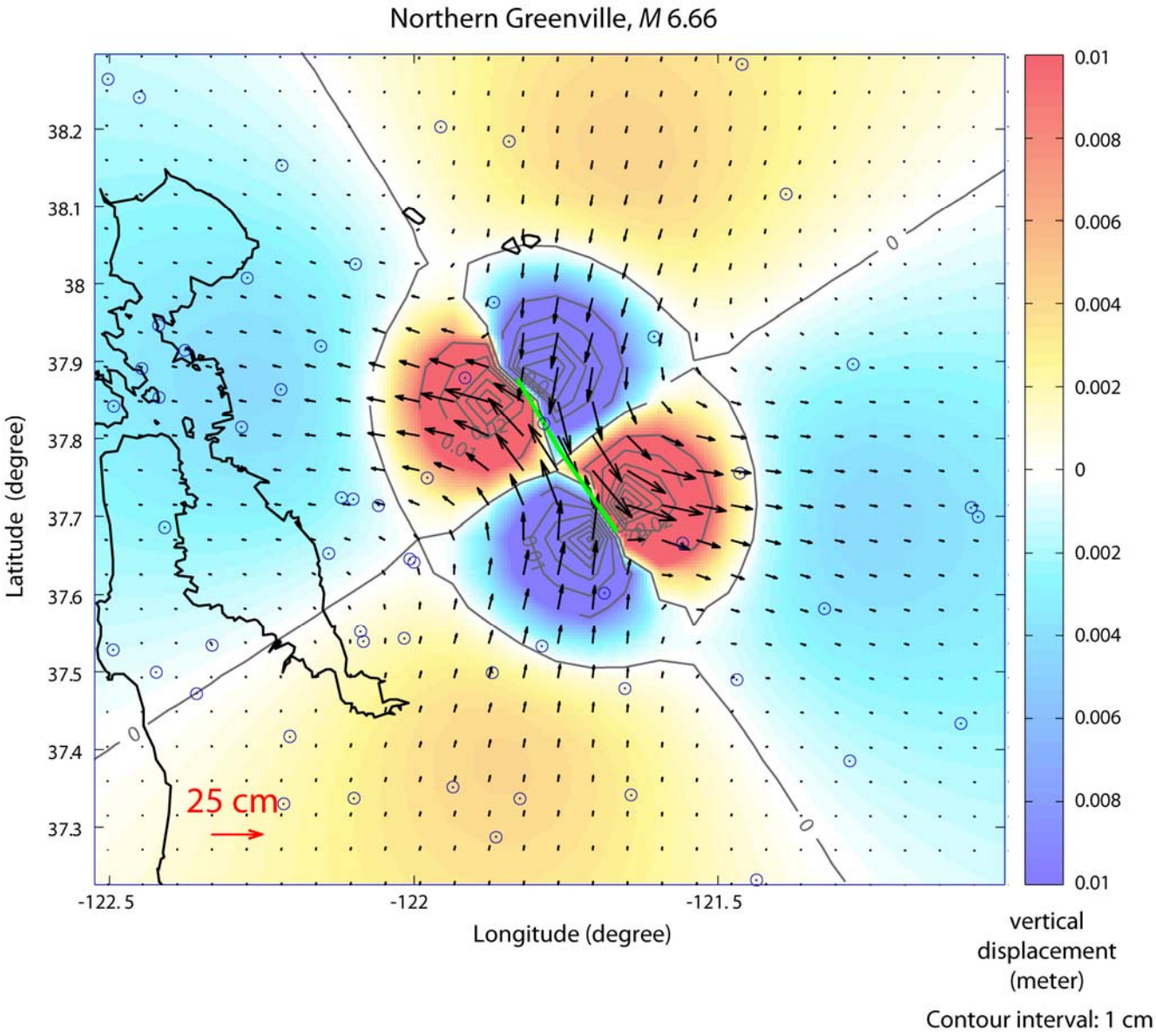
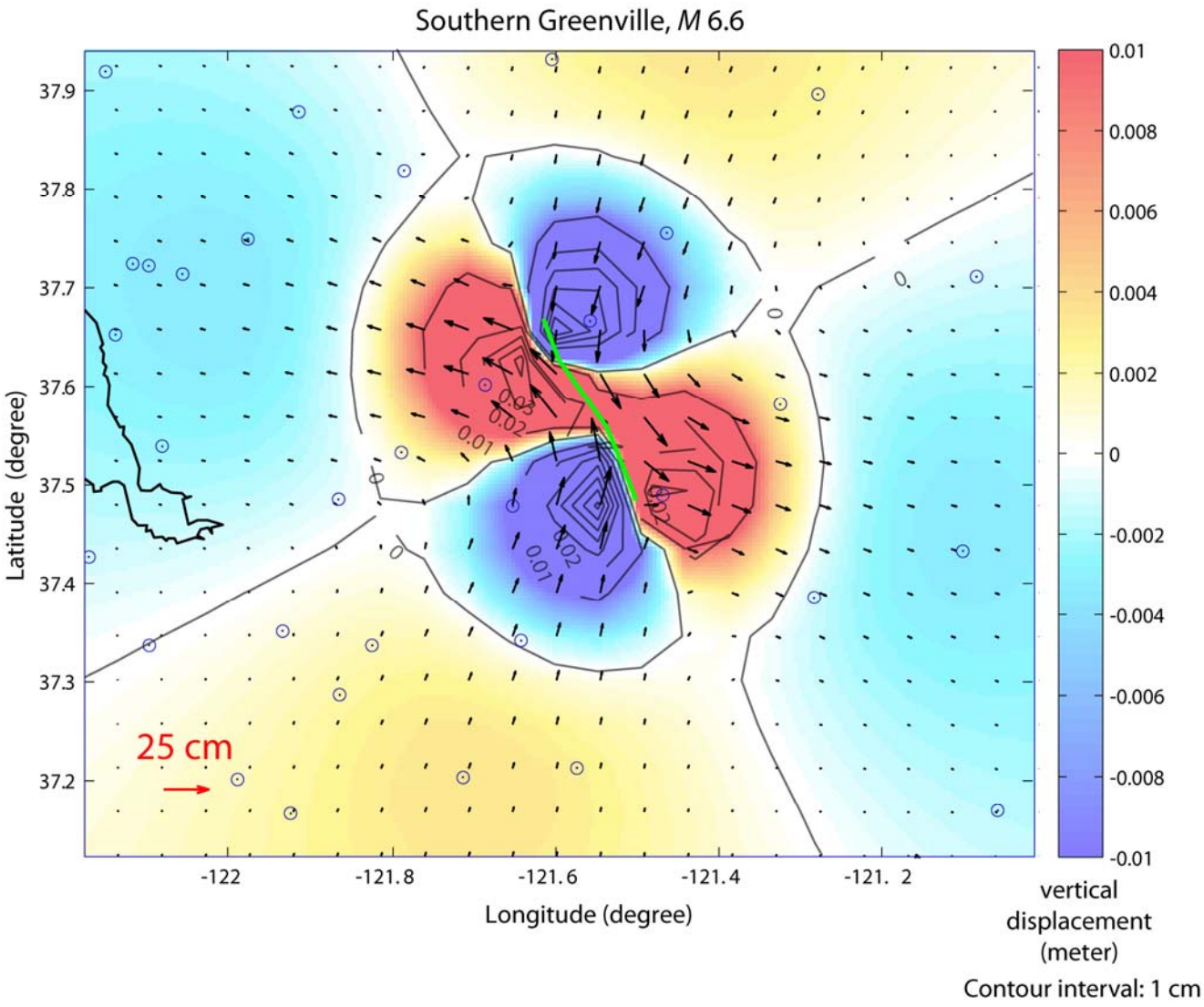


Figure 30. Predicted displacements for scenario northern Greenville fault earthquake.



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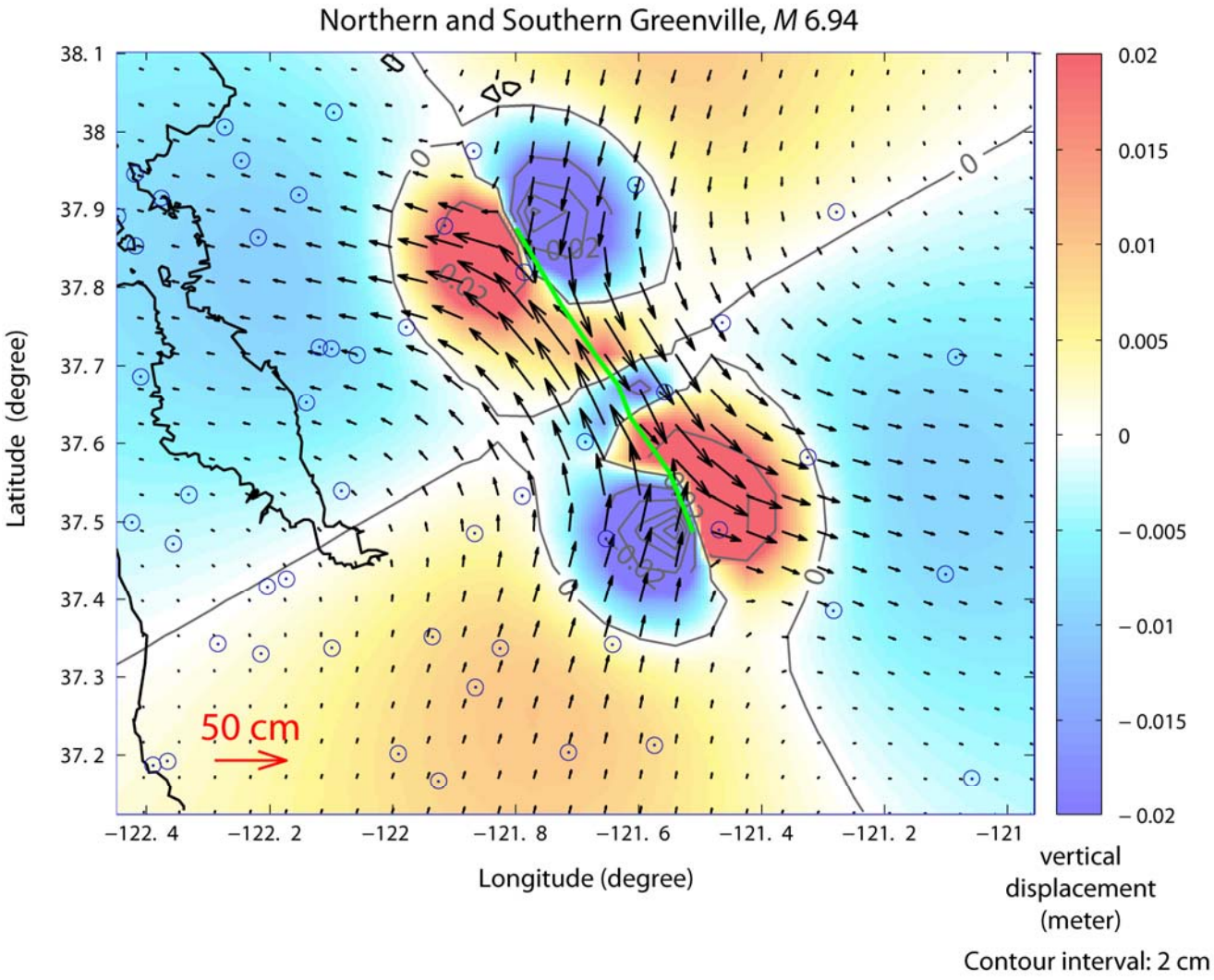


Figure 32. Predicted displacements for scenario northern and southern Greenville fault earthquake.

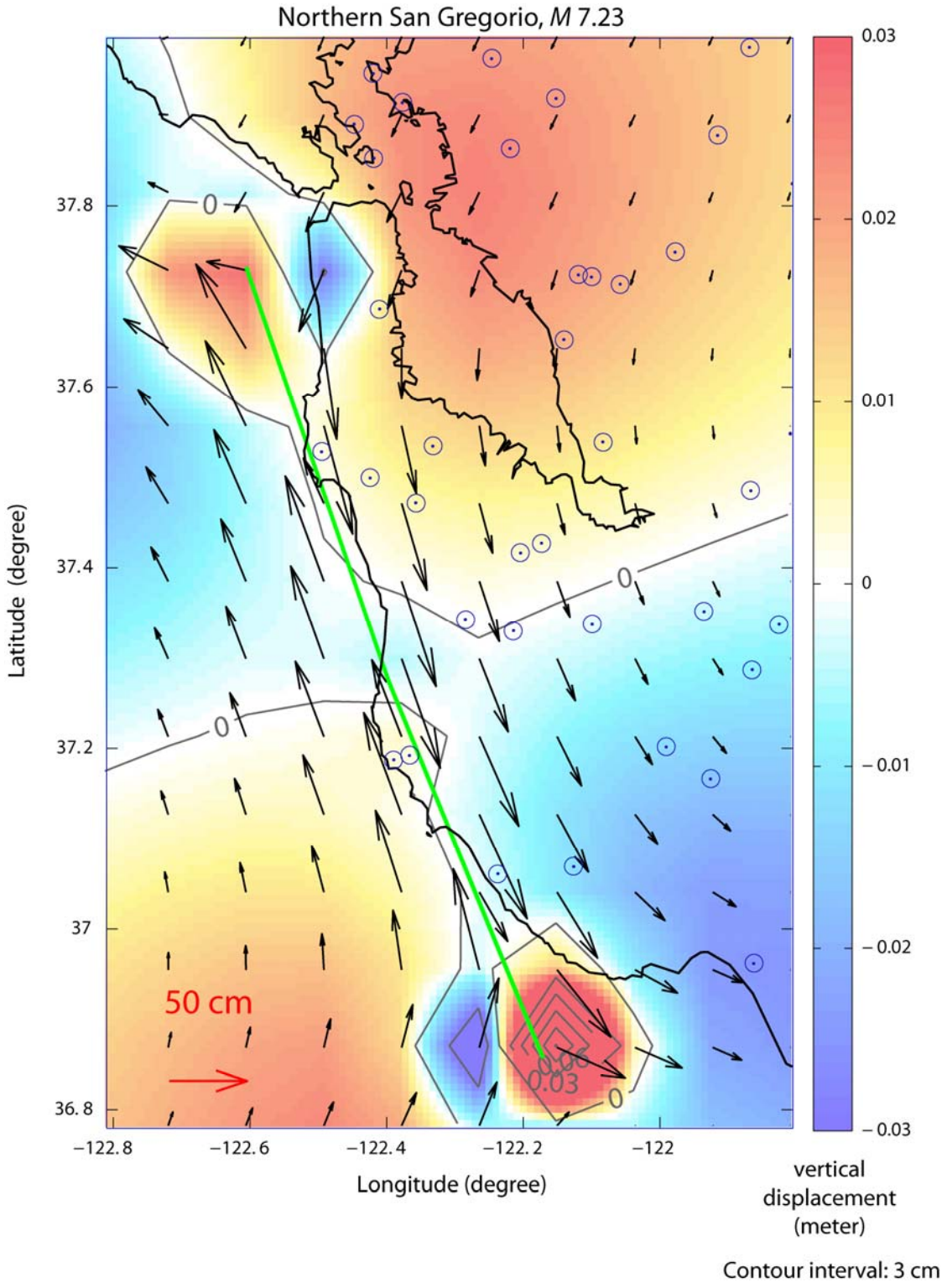
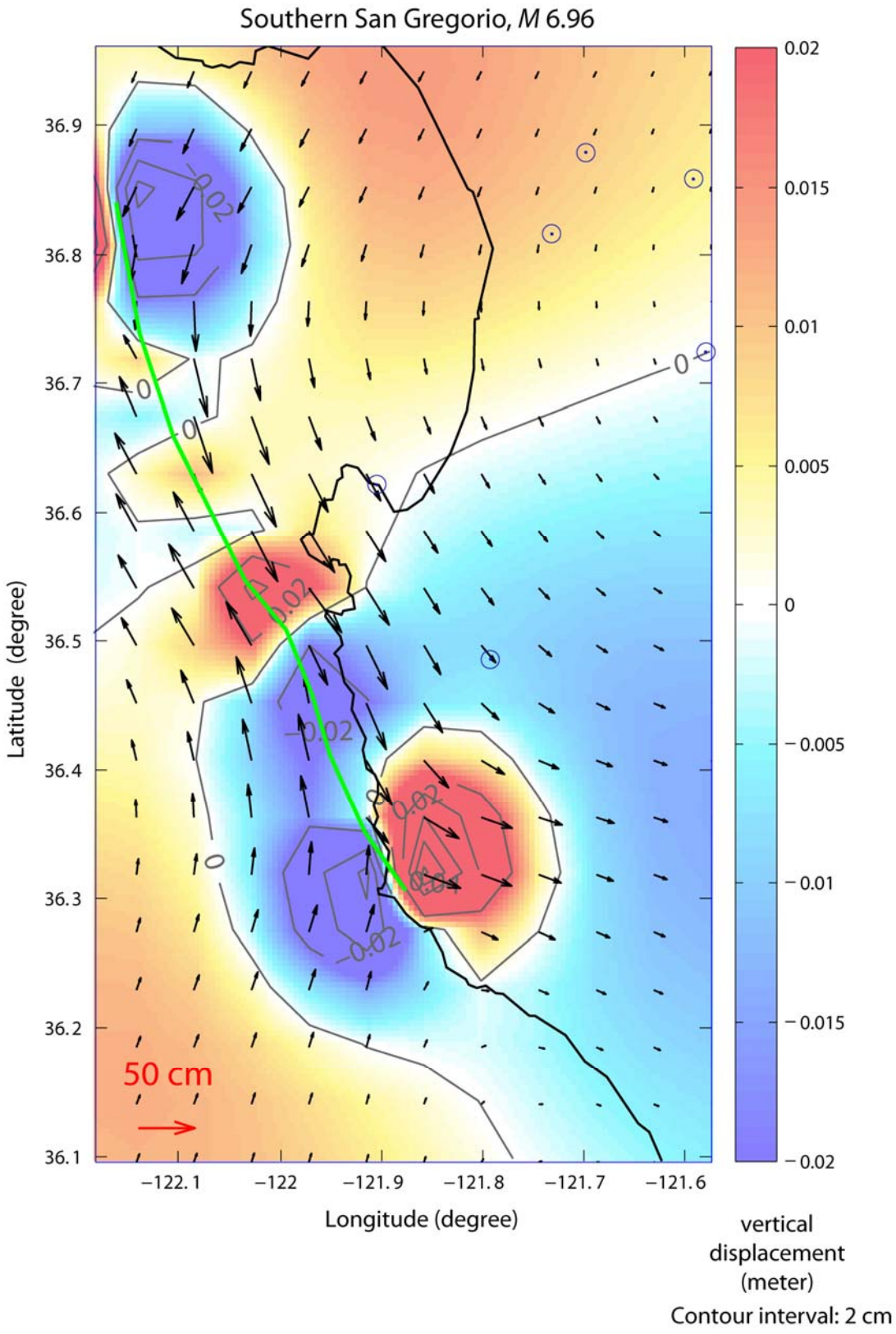


Figure 33. Predicted displacements for scenario northern San Gregorio fault earthquake.



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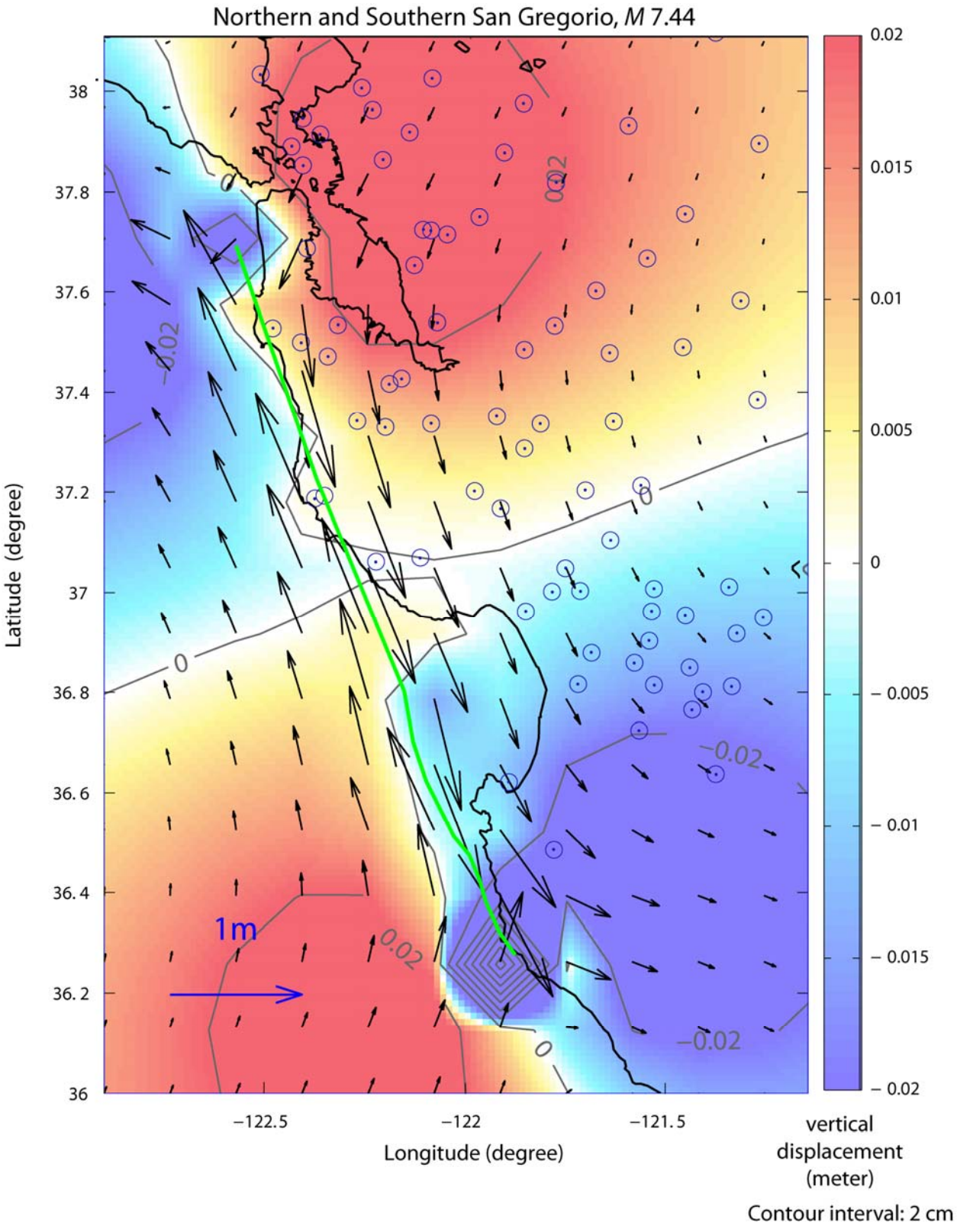

Figure 35. Predicted displacements for scenario northern and southern San Gregorio fault earthquake.

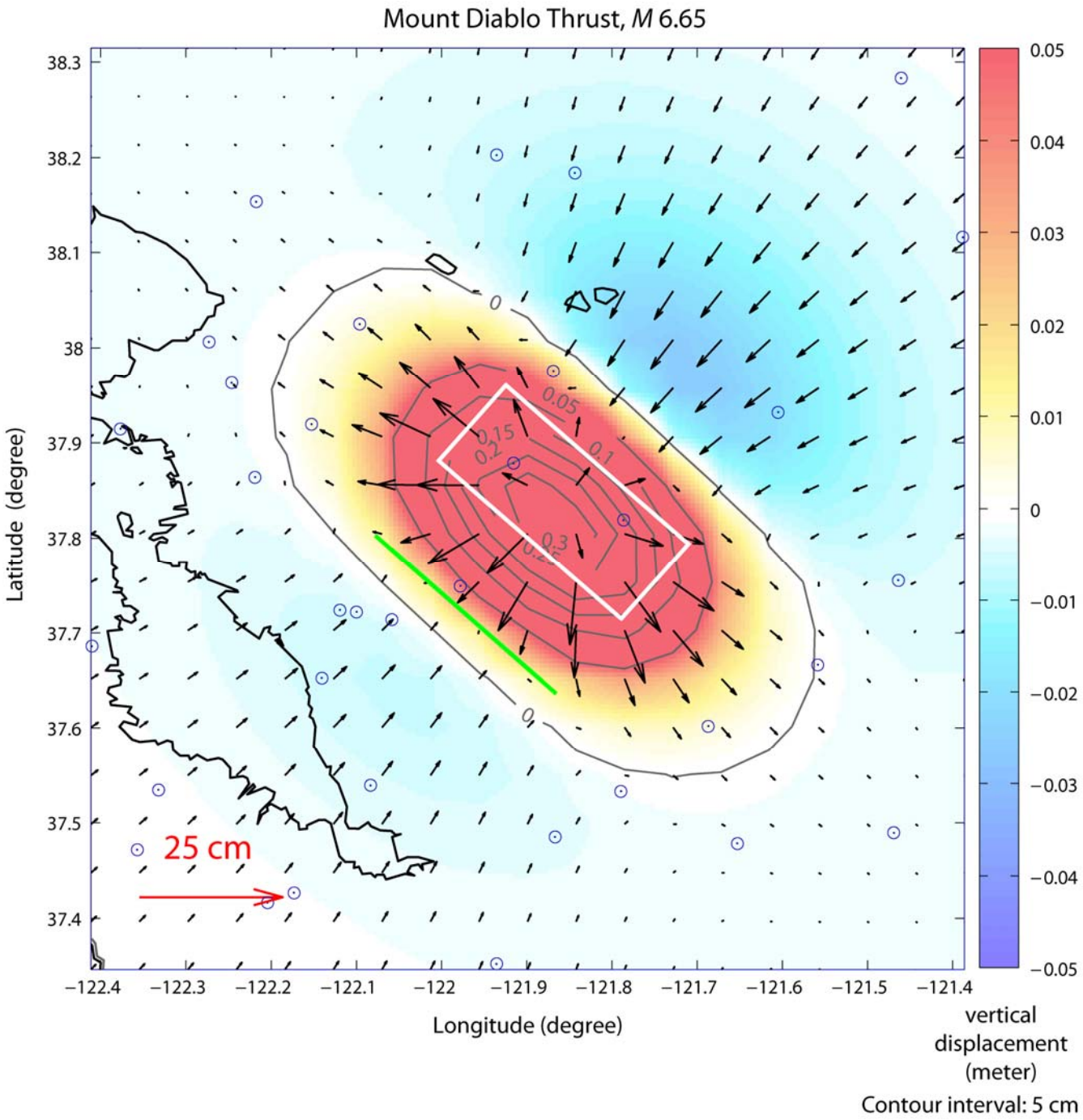

Figure 36. Predicted displacements for scenario Mount Diablo thrust fault earthquake.

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