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Nonlinear Processes in Geophysics
Discussions
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Interactive comment on "Complex interplay between stress perturbations and viscoelastic relaxation in a two-asperity fault model" *by* Emanuele Lorenzano and Michele Dragoni

Anonymous Referee #1

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This manuscript describes an effort of using a theoretical asperity model (mostly mathematical without much physical mechanism being invoked) to investigate the effects of viscoelastic relaxation on the evolution of the states of a two-asperity fault in response to the stress perturbation induced by another earthquake. The major conclusion is that earth rheology plays an important role in affecting various features of the two-asperity fault and its future rupture, such as the interseismic interval, the amount of slip (seismic moment), the sequence of the failures of the two asperities, etc. The authors then use the 1992 Landers and 1999 Hector Mine earthquakes as an example to study how the stress perturbation induced by the 1999 earthquake and the viscoelastic deformation associated with the 1992 earthquake interact in determining the characteristics of the

future rupture of the Landers fault. While the scientific question discussed by this paper is very interesting and this work does provide some valuable insights, I think this manuscript can be improved in the following two major aspects.

First, the theoretical model used in this work is based on some assumptions that may not establish in the actual world. Based on my understanding, two major assumptions are listed as follows. While I understand that it is crucial to make these assumptions for the subsequent reasoning, I think the authors should at least discuss how the potential violation of these assumptions would affect the model results.

1. This model appears to assume relatively uniform or similar ruptures of the same asperity throughout multiple earthquake cycles. In the actual earth, earthquake cycles can be irregular, i.e. consecutive events may have different degrees of stress drop. Therefore, the "dynamic friction" may end up at quite different values in different events.

2. This model seems to assume that the asperity part of the fault only shows two modes: sticking and slipping seismically, corresponding to the static and dynamic frictions, respectively; and the part of the fault outside of the asperity only shows steady-state creep (at a constant rate). How would episodic slow slip (faster than relative plate motion) affect the model results? What happens if the fault asperity can slip aseismically?

Second, as an observation-based modeling geophysicist, I found many discussions of this paper to be difficult to understand. This is due to two reasons: (1) the details of the model are actually beyond my expertise; (2) the author may not have done an adequate job, either in the Introduction or at the beginning of Section 2, in linking the mathematical or geometrical terms massively used in the paper with geophysical concepts. For example,

Line 4-5 of Page 2: "dynamics of the system", " means of orbits in the phase space", "dynamic modes"

Line 18-19 of Page 2: “the state of the system at the beginning of the event” To have a broader impact, it is important to define these terms when they are brought up. I also wonder if it’s possible to avoid such perplexing terms in the abstract, such as “a vector in the state space” and “state variables of the system”, but try to provide a more geophysically meaningful summary instead.

Also, the meanings of the following statements are not clear to me. For example,

Line 3 of Page 1: “variation of their difference”. Is that temporal or spatial variation?

Line 14 of Page 2: “the impact of viscoelastic relaxation has first been studied by Amendola and Dragoni (2013) . . .”. Do the authors mean "has first been studied in this kind of asperity model"?

Line 30-31 of Page 2: “viscoelastic relaxation on the fault was dealt with by adding a third state variable, the variation in the difference between the slip deficits of the asperities during interseismic intervals.” I do not understand the physical mechanism of the process discussed here, any elaboration on that? What does “viscoelastic relaxation on the fault” mean? Are we still talking about mantle viscoelasticity, or ductile deformation of the fault zone? How would creeping behavior (slow slip) of the fault affect this third state variable?

Line 7-8 of Page 4: “the terms $\pm\alpha Z$ are the contribution of stress transfer between the asperities, in the presence of viscoelastic relaxation. . . The parameter α is a measure of the degree of coupling between the asperities.” I do not fully understand the physical meaning of this α here. Are the authors suggesting treating partial coupling (creep) of the fault also as a type of viscoelastic behavior?

Line 26 of Page 6: “In the particular case in which P1 belongs to the edge CD, the earthquake will be a two-mode event 11-01.” If I understand correctly, this sentence is saying that for an earthquake in which two asperities start to fail at the same time, the weaker asperity would have a longer rupture duration. What are the physical reasons

for that?

Line 16-20 of Page 18: the authors mentioned the effects of stress perturbation on the interseismic intervals of asperities 1 and 2. However, in Line 17-19 of Page 19 (Conclusions), the authors concluded that “the presence of viscoelastic relaxation prevents any prediction about the change in the interseismic time of this fault. . .” Maybe I didn’t understand these, but I found the two discussions contradictory.

Figure 4 is difficult to understand. Can it be clarified?

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