Nonlinear Processes
in Geophysics
Discussions

NPGD

Interactive
comment

Interactive comment on "An upper limit for slow earthquakes zone: self-oscillatory behavior through the Hopf bifurcation mechanism from a model of spring-block under lubricated surfaces" *by* Valentina Castellanos-Rodríguez et al.

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We thank to Anonymous Referee number 1 for his comments on the article. We believe that his suggestions and recommendations are very timely and very supportive to enrich this document. We take his observations into account and they were attended as follows:

RFC1 (Referee's comments): My chief objection to the paper is that too little space is devoted to the link between the model and real seismogenic regions. The authors should establish a neat correspondence between the values of the model parameters

and real conditions in the Earth. They should provide at least one example, assigning specific values to the parameters and deriving their consequences in terms of dimensional quantities, such as the depth of the border, the thickness of the border zone, the fluid content, the frequency of the perturbation, and so on. This would make the paper more appealing to a wider audience.

AR (author's replay): Our main contribution is more related to the proposals of a formal pattern in the study of SSEs, and a first approximation of the limit of the transition zone in terms of seismic and frictional parameters. We agree that the real example would make the paper more appealing to a wider audience, however the parameters considered for slow earthquakes are still being studied experimentally and by means of simulations, but there is still not something precise, so giving a real example is complicated.

However, an approximation of some of the parameters considered in this article are discussed in Watkins et al. 2015 (See references there in). Their study seek to model observations with a simulator to reproduced reported characteristics of SSEs in Cascadia through variations in (A-B), normal stress, and convergence rate. The estimates of these parameters do not adjust to the SSEs in Cascadia with respect to the recurrence intervals. Fluids and variations in the width transition zone might affect the recurrence times, among other factors.

Estimates of these frictional parameters are given below (Watkins et al., 2015): The slip amounts of SSEs are of order of cm but the average slip amount of smaller events are unknown. The efective normal stress in the range of 3-9 MPa produce fault slip consistent with some observed SSEs., $B - A$ is in the range (0.0015 to 0.003) of the slow slip section. At the top of the slow slip section 0.003 and 0.001 at the base, $A \approx 0.02$, L is in the range 1-50 μm (real L is unknown), the Rate of convergence (10 a 50 mm/year) represents the range of convergence rates of subduction zones where SSEs are observed with GPS. The critical value $K_c = (A - B)\sigma/L$ depend on L. These

parameters could vary depending on the region that SEEs occur.

By other hand, viscosity=0.1 (nondimensional) has been used in earthquake models (Carlson et. Al., Reviews of Modern physics, Vol. 66, No.2, 1994), but the estimation of the real viscosity depends on the region.

RFC1: Secondly, the authors should check definitions and dimensions of the quantities involved in the model. It seems that nondimensional quantities are introduced starting from equation (5). If equation (1) has dimensions, is F_s a force per unit length? According to (3), the quantities A, B and theta have the same dimensions? The variable x is defined as the block displacement at page 4, line 3, but the same symbol is used for the dimensionless state vector at page 6, line 1.

AR: From the equation (1), page 4, the units of F_s are Newtons. The first term is the Coulomb friction (dry or lubricated at the border), the second term (friction effect for mixed lubrication) is the diference between the maximum static force and the Coulomb friction; and the last term is the viscous friction, all the forces have units of Newtons (see Andersson et. al. 2007).

The complete form of the equation (3) is given by

$$F_{dr} = \sigma[\theta + A\ln(v/v_0)], \qquad d\theta/dt = -(v/L)[\theta + B\ln(v/v_0)]. \qquad (1)$$

F_{dr} is the frictional stress, σ is the normal stress (constant) and $[\theta + A\ln(v/v_0)]$ is the coefficient of fault friction which is nondimensional, i.e., $F_{dr}/\sigma = [\theta + A\ln(v/v_0)]$.

Derived from experimental and mathematical approaches, A and B are constants (intrinsec properties of material), " θ is a weighted average of $-\ln(v/v_0)$ over the distance L"(Ruina, 1983, page 10363, paragraph 3).

The variable x assigned for the displacement of the block was replaced by the variable y (page 4, line 3).

RFC1: Some minor corrections are: Page 1, line 2: Ruinas's should be Ruina's. Page 4, line 2: relatives should be relative. Page 4, line 11: velocity function should be velocity dependent. Page 5, lines 4-7: the sentence is not clear and should be rephrased. Page 7, line 15: Descarte's should be Descartes'. Page 16, line 13: longitude should be length. Page 17, line 26: stablished should be established. Figure 1, caption: doted should be dashed. Figure 2, caption: de should be the.

AR: We did the corrections of the misspelling words in the following pages: page 1, line 2; page 4, line2; page 4, line 11; page 7, line 15; page 16, line 13; page 17, line 26; Figure 1, caption; and Figure 2, caption.

Page 5, lines 4-7. We take into account the comment on the need to explain or rewrite this part, in addition we relocate equation (2) and part of the explanation after equation (4), page 5.

From the second equation of the system (4) on page 5, we infer that the block will oscillate with respect to the position of the plate. This equation tells us whether the oscillator is to the right or to the left with respect to the driver plate (v is the oscillator displacement rate and v_0 that of the plate). Although the direction of the displacement of the system is always forward; If $v - v_0 > 0$, i.e., if $v > v_0$, eventually the oscillator will be more advanced than the plate; On the other hand if $v - v_0 < 0$, i.e., $v < v_0$ eventually the oscillator will be to the left of the plate. One of the objectives when introducing the function $sign(v - v_0)$ is indicate this effect; assigning value 1, for the first case, -1 for the second case, and zero if $v = v_0$. We eliminate the sign function because this effect is already considered in the second equation of the system (4).

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