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Hydrology and Earth System Sciences Discussions

Interactive comment on "Pattern dynamics, pattern hierarchies, and forecasting in complex multi-scale earth systems" *by* J. B. Rundle et al.

Anonymous Referee #1

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General comments

The paper presents a numerical and mathematical analysis of patterns of seismicity and surface strain (and to some extent to sea surface temperature) in space and time and discusses the application of this pattern analysis to forecast catastrophic events.

The authors conclude from the observed spatial and temporal patterns to a simplified description of the dominant essential physics and use this insight for better predictions.

This work about the mathematical description of patterns and the linkage between observed patterns and essential physics is important and should be published. However, the actual description of the underlying model and mathematics must be improved and extended. I propose that the section 2 and 3 about the mathematical pattern analysis

are combined to give an extended and more illustrative description.

As far as I understood, the numerical model is based on Cellular Automata (and self-organized criticality), but the mechanisms and the geometry of the model are not clear. Unfortunately, the reference with the description of the initial model (cited in the text as Rundle et al. 2000) is missing in the manuscript. I tried to follow the description of the model given in Rundle et al. (2004). I cannot understand how the cells of the models are interconnected because some of the 650 fault segments (shown in Figure 2) seem to be isolated from the whole network.

Specific comments

A) Title / abstract:

The meaning of 'pattern hierarchies' remains unclear and must be explained in the text in more detail. As far as I understood, the hierarchy is just based on the power-law found between the index of the eigenvector (of the matrix describing the modeled dynamics) and its spectrum. I cannot see how this confirms a hierarchic structure of the system. Similarly, the description of the 'multi-scale structures' must be extended. What are these structures at different scales?

B) Introduction

The introduction is easy to read and explains the ideas of this study. But I suggest that the concepts of threshold, state variables and physical variables are explained in more detail using the example of earthquakes/faults. The example of neural networks (page 1048, lines 12 – 14) can be deleted because it does not help to explain the principles used in this study.

Page 1047

line 6: Please specify the size and duration of 'spatial scales' and the 'rapid onset' ?

line 15: 'statistically identical units'; does the system response depend on random

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variation of the physical variables of the units?

line 16: the term ‘fired’ can be avoided because it is not helpful in the context of the discussed applications.

line 17, 19, 26 What is the difference between the state variable ‘s’ and the physical variable ‘sigma’ in case of earthquakes/faults ?

Page 1048

lines 6 to 9: Can you provide any references for the other examples of thresholds ?

lines 12 to 18: The example of neural network is not helping to clarify the state variables and thresholds. Instead, explain the variables in more detail for the following example of the Hurricane Katarina.

C) Patterns in El Nino events

I am not sure if this section is relevant to understand the modeling of fault systems given in the sections 3 to 5. One possibility would be to show the example of El Nino in the introduction. Alternatively, the mathematical framework that can be used for the earthquakes as well can be described in more detail. Perhaps, the sections 2 and 3 can be combined.

Page 1049

line 14: what is the meaning of ’delta t’ ? What are the ‘many time scales’ ?

equation 1: How is this stochastic forcing related to the earthquake model given in sections 3 to 5?

Page 1049 and 1050, equations:

The quantification of spatial and temporal patterns is very important and interesting. However, the description given in section 2 and later on in section 3 is very abstract and not very illustrative. I suggest introducing the theory with a simple example or more

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figures of the modeled behavior.

Is it correct that the fault system can be described with the same equation(s)? If yes, these equations (1 to 3) could be introduced in the context of earthquakes and faults systems.

What is a 'pattern evolution operator'? What is the meaning of the 'alpha' coefficients in equation 2? Specify the dimensions of the terms in the equations.

Page 1050, line 8: the sentence ' . . . initial El Nino anomaly projects strongly onto an optimal initial pattern . . . ' is very difficult to understand.

D) Threshold systems

I suggest combining section 3 with section 2 to introduce and to explain the mathematical tools, the parameters and the variables in more detail. The state vector S and the function psi (and the pattern dynamics operator and correlation operator) should be explained in terms of the fault system (Virtual California) modeled in sections 4 and 5.

Page 1051

lines 24 to 26: Is this related to the subject of self-organized criticality?

Page 1053

line 6: I can not understand the expression 'Brownian noise' in this context

E) Numerical simulations and virtual California

It is difficult to understand the model based on the short description in the text and the information in the tables and the figures. Does the model consist of the 650 segments or are the faults embedded in a larger two-dimensional grid?

How does the model differ from the simple 'Burridge-Knopoff' model (1967) with respect to lattice type and connectivity?

Page 1054

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lines 20, 21: Please extend the description of the terms ‘backslip model’, and ‘slip deficit’.

line 28: What is the reason for the 10% overshoot or undershoot? Does each cell receive a random amount of stress? How is this justified?

Table 1 and 2 are very difficult to understand because a geographic map is missing. It is very difficult to follow the description if the locations of the mentioned fault-systems cannot be found in the figures. Perhaps you could add in Figures 1, 2 and 3 the names of the most important faults or regions.

F) Patterns in Virtual California

The authors show that the most frequent patterns of simulated activity correspond to observations made in the past. Was the model initially fitted to reproduce these events?

Page 1058

line 16: It is not obvious how the index of an eigenvector is related to a physical quantity. Please explain in more detail.

G) References:

Several references have no citation in the text:

Bowman et al.

Bufe et al.

Frankel

Garcia and Penland

Goes and Ward

Kagan and Jackson

Keilis-Borok

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Kerr and Bagla

Keilis-Borok et al.

Kossobokov et al.

Sykes and Jaume

Ward (1992)

Two references that have a citation in the text are missing in the list of references

Rundle et al., 2000

Penland, 1989

Technical corrections

Page 1046

line 24: Richter - Magnitude M

line 25: Specify storm categories;

. . . a category 5 storm (winds of more than 155 miles per hour) that weakened . . .

footnote 1: the www-link does not exist

Page 1047

line 3: (Travis, 2005) instead of (J. Travis, 2005)

line 18: time t in italic

footnote 3: the www-link doesn't exist

Page 1048

line 11: No Rundle et al. (2000) is given in the references;

line 12: Is it Rundle et al. 2002a or 2002b ?

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Interactive Comment

Page 1049

line 4: Introduce the abbreviation ENSO

lines 6 - 8: Do all references apply all those methods ?

line 6: The citation Penland 1989 is not given in the references

line 17: warming of . . . (misspelled 'of' ?)

Page 1050

line 3, insert a gap before 'has all the usual . . . '

line 18; misspelled anomaly

Page 1051

line 11, 16 and 22: The citation Rundle et al. (2000) is not given in the references

line 15: the state variable 's' was introduced as a lower case letter in section 1; now the capitol 'S' is used for a state vector. Are these two terms identical?

Page 1052

line 1, 21: The citation Rundle et al. (2000) is not given in the references

Page 1053

line2: The correlation operator was introduced as a lower case letter d, now it is a capitol D.

line 5: delete the gap after D

Page 1054

line 11: Is it Rundle et al. 2002a or 2002b ?

line 19: in the introduction, a capitol (M) was used for magnitude, now it is a lower case

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letter (m)

Page 1055

line 7, use capitol M for magnitude

Page 1056

line 11: I think this sentence is incomplete.

Page 1058

line 4: This sentence is incomplete?

line 25: The ratio of integers is 3/4 and not 3/3

Page 1059

line 7: Please specify the abbreviation ENSO (EL NIÑO/SOUTHERN OSCILLATION)

line 12: delete ‘of’

Page 1061

line 29: the word ’temperatures’ is misspelled

Page 1062

line 8: The reference Rundle et al. (2004) is given twice; delete one.

line 14: The title of the reference is not given:

J. B. Rundle, P. B. Rundle, W. Klein, J. Martins, K. F. Tiampo, A. Donnellan, and L. H. Kellogg, GEM plate boundary simulations for the Plate Boundary Observatory: A program for understanding the physics of earthquakes on complex fault networks via observations, theory and numerical simulation, Pure and Applied Geophysics, 159, 2357-2381, 2002.

Page 1063

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line 14: the word dynamics is misspelled

Page 1064

Table captions: Write 'Virtual California' instead of the abbreviation VC

Page 1067

Figure 2: the epicenter is barely visible; could you indicate it with an arrow? What is the meaning of the given time?

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 3, 1045, 2006.