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Interactive Comment

Interactive comment on "Non-linear power law approach for spatial and temporal pattern analysis of salt marsh evolution" *by* A. Taramelli et al.

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Interactive Discussion

Discussion Paper

Response to Anonymous Referee # 2 comments on "Non-linear power law approach for spatial and temporal pattern analysis of salt marsh evolution"

31 January 2014

The authors analyze the Scheldt estuary salt marsh. In particular, the authors focus on the distribution of vegetation patches, and analyze its deviation from power law behavior and the climatic and hydrodynamic controls on such deviation. The paper is very hard to read to the point that I struggled understanding what was actually done. Many statements are vague, and most need rephrasing. It is not clear what the goals are, and what is achieved with the proposed approach.

We thank the reviewer for his/her valuable comments, which we feel have improved the manuscript substantially. A more detailed description of the changes we made to increase the clarity of the paper are given below.

Some specific comments follow:

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- I suggest rewriting the abstract. It is very hard to understand what the main points of the paper are.

As suggested by the reviewer, we would modify the abstract to better clarify the main points of the paper. We would rewrite it as follows:

“Self-organized pattern formation has been found in an increasing number of ecosystems, among them salt marshes. The mechanisms underlying spatial pattern formation, with implications on ecosystem functioning and degradation, can give rise to scale-invariant patterns, but not much is known on whether the scale invariance can hold over a wider range of environmental variables.

We asked whether the statistical distribution of spatial vegetation patterns could be described by changes in environmental variables acting on salt marshes, and we speculated the conditions under which a shift from a scale-invariant (power law) distribution to patterns characterized by a dominant patch size could be expected.

We quantified the temporal change in patch-size distribution of vegetation patches through satellite images and we developed a fuzzy Bayesian generative algorithm to relate their statistical distributions to the climatic and hydrological drivers acting on them.

The results show that the approach is able to accurately simulate the changes in the statistical distribution of vegetation over time, providing uncertainty ranges that closely fit or fall within the values of the target variable.

Our findings highlight the potential of the fuzzy Bayesian stochastic model, which is able to quantify the uncertainties in the response of salt-marsh vegetation to the short-term environmental drivers used in the simulations. Changes in the distribution of vegetation patches can thus be used to forecast potential deviation from steady states in intertidal systems, taking into account the climatic and hydrological regimes.”

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- Line 11: What does it mean that “For each patch, its area was calculated to test the plausibility of the power law distribution”?

We aimed to assess whether the size-frequency distribution of vegetation patches could be fit by a power law distribution. Thus, we have first calculated the size (areal extent) of each vegetation patch, and then analyzed the data to test whether the power law model was a good fit for the data.

- Line 18: the skeletonization algorithm gives several artifacts particularly when channels are wider than a few pixels. Since the purpose is to analyze channel sinuosity, I would be very careful and would run some test cases to make sure the sinuosity measured corresponds to what observed in nature.

We agree with the reviewer on the caution in using the skeletonization algorithm, due to the fact that such morphological operations can lead to approximations. Nevertheless, this algorithm has been extensively used for analogous measurements in biomedical analysis [Heneghan et al., 2002. Medical Image Analysis, 6:407-429], based on a similar processing procedure of image analysis.

- Moreover, I struggle understanding the physical role channel sinuosity plays within this analysis.

Within this analysis, channel sinuosity has been considered in order to investigate the existence of feedbacks between vegetation colonization and channel network development [Temmerman et al., 2007. Geology, 35:631-634; Vandenbruwaene et al., 2012. Earth Surface Processes and Landforms, 38:122-132]. These scale-dependent feedbacks [van Wesenbeeck et al., 2008. Oikos, 117(1):152-159; Bouma et al., 2009.

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Oikos, 118(2):260-268] have shown that flow deflection caused by the presence of vegetation patches can trigger channel erosion just outside the patches, and over time will lead to the formation of a marsh platform dissected by channels.

- Many statements are vague and others need rephrasing. For example, line 19: Any deviation from the steady state can grow to the increases of the sizes": : : of what?

We apologize for the mistake. The sentence will be completed in the revised version of the manuscript.

- Can the authors explain further what the physical meaning of the power law in this context is? Why is it expected? What does a deviation from it mean? I'm also not convinced about the deviation in the tail and what's that telling in terms of salt marshes processes not known otherwise.

Spatial self-organization is the process through which large-scale patterns arise from local interactions between the organisms and their environment [Rietkerk and Van de Koppel, 2008. Trends in Ecology Evolution, 23, 169-175]. One of the mechanisms explaining spatial pattern formation is based on the scale-dependent feedback principle, whereby the interaction between the organisms and the environment leads to a positive feedback on shorter scales, while a negative one inhibits their growth on larger scales. These feedbacks have been found to result in spatial patterns, with a size-frequency distribution that can be described by a power law. The presence of scale-invariant patches, with no characteristic patch size, has been interpreted as a sign of self-organization [Scanlon et al., 2007. Nature, 449, 209-212; Schoelynck et al., 2012. Ecography 35(8): 760-768]. Due to the self-organization and auto-correlative prop-

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erties of salt marsh vegetation, for which plants have a positive feedback by growing together, a power law of scale-invariant patterns is expected. Plants tend to aggregate into patches and are thus able to decrease hydrodynamic forcing and increase sedimentation on local scales, leading to a positive feedback due to improved growth conditions. This strongly auto-correlative process is expected to give rise to scale-invariant patterns, since it is at the same time accompanied by a negative feedback due flow deflection and increased erosion around the patches themselves.

Although a power law is the general model to which self-organized patches can be ascribed, changes in environmental conditions may shift the system towards different states where a variance of scale is observed. In previous works, a progressive truncation in the power-law distributions was observed to be related to increasing environmental and biotic stress [Kéfi et al., 2007. Nature, 449, 213-217]. We argue that, in salt marshes, the auto-correlative process is in general valid but its magnitude is influenced by the environmental conditions: over time, variations in tidal level and rainfall can shift the system towards different states. A deviation in the power law can indicate the shift from a scale-invariant, self-organized vegetation to scale-variant spatial patterns with a dominant patch size.

- "20 The high complexity and uncertainty associated with ecological systems under power law tail, can be then treated using a combination of fuzzy logic and a naïve Bayes compiler." I don't understand what this statement means. Can the authors explain in simple and detailed terms what is the role played by this approach?

We will add the analytical reasons for which we chose a fuzzy naïve Bayes classifier, which lie in the ability of the naïve Bayes to find unobserved equilibria in complex patterns, the reduction of the dimensionality of a complex problem, and the esplicitation of the uncertainty inherent to the result [Störr, H.P., 2002. Pages 172-177 in Proceedings

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InTech/VJFuzzy; Viertl R. and D. Hareter, 2004. ZAMM. Zeitschrift für Angewandte Mathematik und Mechanik 84: 731-739; Zadeh, L. A., 1965. Information and Control 8:338-353; Zadeh, L. A., 1968. Journal of mathematical analysis and applications 23: 421-427; Lewis, D.D. 1998. Lecture Notes in Computer Science 1398: 4-15].

In addition, we will provide a more detailed explanation of the application of a fuzzy naïve Bayes compiler regarding the extent of the fuzzy sets, the fuzzyfication functions we have used and the fuzzy partition of the domains.

In general I feel like a discussion on the physical aspects of the analysis, the meaning of the methods and findings are missing in this manuscript. I don't exclude there is some new element of interest for the community proposed by the authors, but in the current stage it is very hard to assess it.

To investigate possible links between vegetation patterns and environmental forcing, based on the observed evidence highlighted in the paper, we will implement a structured discussion based on the literature and the suggested references, as has also been pointed out by Reviewer #1.

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