

Earth Syst. Dynam. Discuss., author comment AC2  
<https://doi.org/10.5194/esd-2021-26-AC2>, 2021  
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## Reply on CC2

Oliver López-Corona et al.

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Author comment on "ESD Ideas: planetary antifragility: a new dimension in the definition of the safe operating space for humanity" by Oliver López-Corona et al., Earth Syst. Dynam. Discuss., <https://doi.org/10.5194/esd-2021-26-AC2>, 2021

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Dear Richard Rosen (RR),

We appreciate all your comments and the clear amount of time and effort you have invested in.

What is a complex system is an open question? Yes, please read (<https://www.researchgate.net/publication/260868740>) where Carlos Gershenson has compiled dozens and dozens of definitions. As happens with other important concepts everywhere in Science, take "Forest" or "Life", nevertheless we can and have done a lot of things in turn of those concepts.

In that sense you may like this work:  
<https://www.frontiersin.org/articles/10.3389/frobt.2017.00010/full>

Or other references:

<https://www.springer.com/gp/book/9783642040832> or the following  
<https://www.hindawi.com/journals/complexity/2019/1403829/> where a lot of applications are cited, so it is not only possible to measure complexity (in a specific context) but people have done it extensively, take for example all the work done in network theory (i.e. <https://www.sciencedirect.com/science/article/abs/pii/S0378437119306429>)

Talking specifically about Ecosystems, including the Earth system:

<https://www.sciencedirect.com/science/article/abs/pii/S1470160X10000567>

<https://esajournals.onlinelibrary.wiley.com/doi/full/10.1890/ES13-00182.1>

<https://www.mdpi.com/1099-4300/12/3/613>

<https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2005GL025373>

<https://royalsocietypublishing.org/doi/full/10.1098/rstb.2010.0018>

<https://royalsocietypublishing.org/doi/abs/10.1098/rsta.2009.0188>

<https://royalsocietypublishing.org/doi/abs/10.1098/rstb.2009.0310>

And even on this Journal: <https://esd.copernicus.org/articles/2/179/2011/>

**RR:** How would you even define what the entropy is of such a complex system? Entropy can only be measured in theory for very simple systems.

**Response:** First part of the comment is responded to in the references above. I hope you are not suggesting the only scientifically valid results are those that can be derived analytically.

**RR:** And how does entropy relate to resilience?

**Response:** please read our previous work: <https://peerj.com/articles/8533/> In short, one way to measure complexity under information theory is as a quadratic form of perturbation (the product of emergence and self organization). Once you construct complexity it may be used as a payoff function to assess system's Fragility-Antifragility (see reference of Pineda and co-workers inside our work). Resilience is merely a particular case of Fragility-Antifragility.

**RR:** And you don't even connect the type of reflected radiation you measure and analyze to climate change in theory.

**Response:** we are not making any claim about Climate Change *per se*, we are not interested (in this work) about specific prediction of temperature or similar but in terms of changes in the type of dynamics Earth systems have been going through because of anthropic perturbations. Please see:  
<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5180148/>

**RR:** The reverse is true -- reductions of entropy for small sub-systems are "good", because that means that such sub-systems can be more organized and, perhaps, resilient.

**Response:** No, this is not the case, nor too much entropy or too less is "good" for ecosystems (or any system under an evolutionary type of process). Please read: <https://www.pnas.org/content/pnas/111/28/10095.full.pdf> where authors make very clear why ecosystems tend to criticality. We recommend also read about so called "Criticality Hypothesis" maybe in our own previous work: <https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0200382>