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Earth System Dynamics
Discussions

Interactive comment on "ESD Ideas: Structures dominate the functioning of Earth systems, but their dynamics are not well represented" *by* Axel Kleidon et al.

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This paper presents the idea to describe the dynamics of flow structures by considering the work required to build and maintain the structures. This is an interesting idea, and I agree that it could be particularly attractive to explore its relation to optimality principles as suggested at the end of the paper. However, I wonder if the different types of structures discussed by the authors actually fit into one approach or at least whether it is helpful to address such different phenomena by one approach. It seems to me that the meaning of the term "structure" is quite different in the given examples, e.g. with regard to the source of the energy, which in some cases (e.g. drainage structures) may be

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related to the flow itself (thus potentially leading to self-organized flow patterns), while it is external in other cases (plants, human-mad structures – the degree of coupling between the external source of energy and the flow structure appears to be very different in these cases). Thus, I wonder if the development stages proposed by the authors are actually applicable to all of these structures. In summary, I think the concept needs further thought and explanation.

Specific comments:

1) Line 47: Is it actually "the work done to build the structure"? As I understand, the energetic costs due to dissipative processes are subtracted from the work done to build the structure. Thus, U seems to represent the work that would be needed to build the structure in the absence of decay.

2) Lines 34 and 56: I wonder if a "turbulent structure" is a structure in the sense of the structure of e.g. river channels. Flow in the river channel also can be turbulent, but still the channel itself is considered to be the structure (whereas turbulence would be considered a state of the flow). Unlike a river channel or plant structures, turbulence does not appear to meet the requirement (line 34) that it "efficiently " conducts water, as laminar flow is more efficient (in that frictional losses are lower). Examples of structures that appear to be similar to river channels are preferential pathways in soils or solution conduits in carbonate (or gypsum) aquifers (see Hergarten et al., Hydrol. Earth Syst. Sci. , 2014, doi:10.5194/hess-18-4277-2014). With regard to the latter, it is interesting that Howard and Groves (Water Resources Research, 1995, doi:10.1029/94WR01964) found highly selective development of solution conduits under laminar flow, whereas "the transition to turbulent flow results in more general passage enlargement ", i.e. turbulence does not seem to favor flow concentration in localized structures. I guess convection cells, jet stream etc. might be considered structures (i.e. the corresponding pressure distribution resulting from temperature/density differences) that efficiently conduct atmospheric flows.

3) Lines 95-97: "...positive feedback ... more work can be derived from the flow to grow and develop the structure" – this applies e.g. to the river channels and also to the above mentioned solution conduits, where the flow creates the structure. I am not sure if it applies to plant structures – this might seem reasonable if plant growth is water limited but what if growth is e.g. energy limited, why should there be a feedback with flow? Even more so in the case of human-made structures, why would "more work derived from the flow" enhance the development of the structure? Whether a human-made structure is further developed, maintained or decays will likely depend on socioeconomic conditions or more generally the development of the human-environment system. Perhaps there are cases where the feedback of the structure on other components of the human-environment system is sufficient to create a feedback loop, but it seems unlikely that this can be generalized.

4) Lines 98-101: Similarly, this may not apply to all structures considered here.

5) Line 128 – "dissipation ... maximized" vs. line 140 "minimum dissipation": Line 128 suggests that the structure develops to a stage where dissipation is maximized, whereas line 140 suggests that "a more explicit description of the dynamics of structures would ... advance our understanding ... how they relate to optimality principles such as ... minimum energy dissipation" – this might appear contradictory and thus it should be further explained how the development of the structure towards maximum dissipation is consistent with the concept of minimum dissipation. Is it because the first refers to the localized structure only, whereas the second refers to the entire system? If so, again (as discussed in comment no. 3) the relationship between the structure and the entire system (catchment, plant, human-environment system, etc.) needs to be addressed, in particular, the feedbacks between the two, which might be very different for the various structures mentioned in the paper.

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