Authors' response: Esurf-2017-36

We appreciate the comments on our paper reviewing the arc of CZ research and proposing a strategy for the future design of an observatory network. We found the reviewers' comments thoughtful and helpful as discussed below. We also appreciated the comments from outside the U.S.A., specifically reviewers from Sweden (K. Bishop) and Australia (E. Bui), who attest to the importance of the CZ concept.

Both E-Surf reviewers suggested we improve the structure of the manuscript. As pointed out by Tunnicliffe, we brought Section 3 forward in the article. This brings the discussion of the intellectual heritage ahead of the discussion of funding strategies to provide a more logical sequence that emphasizes the evolution of scientific thinking. We also now emphasize the four common elements of CZOs earlier in the paper in the new section incorporating Section 3. We have also revised paragraphs 3 and 4 as suggested by Reviewer #2, so that they describe, in order, the research initiatives and evolution followed by the limits of those research programs and the potential to go beyond those achievements. As requested by Reviewer #2, we also call out Tables 2, 3, and 4 in the manuscript.

Tunnicliffe points out that this re-organization allows the article to better live up to its title. We agree that perhaps the article as initially written and the title were a bit out of sync. After re-organizing and re-emphasizing, we returned to the title of the manuscript to see if a different title was warranted and we decided to keep the title. Tunnicliffe also requested elimination of the use of the word "experiment" to describe the CZ science venture. We have edited out that word and now used a more precise term (enterprise), as suggested.

Another set of words were also the focus of a few more of Tunnicliffe's comments – paradigm and transformative. "Paradigm" is defined by Merriam Webster as "a philosophical and theoretical framework of a scientific school or discipline within which theories, laws, and generalizations and the experiments performed in support of them are formulated" (accessed at https://www.merriam-webster.com/ on 9-7-17). Scientific paradigms include definitions of what should be studied, the questions of interest, and the broad approach of study. We argue that CZ science is at least a paradigm shift in that it emphasizes that the CZ is one entity and must be investigated in its entirety. Reviewer E. Bui agrees. Therefore, we have included a more complete discussion of why CZ science is a paradigm shift, and we qualify our assertions appropriately. We do respond to Tunnicliffe by using the term paradigm only for the overall CZ science initiative and not for the emergent hypotheses in Section 6, and we emphasize use of the word "transformative" for the CZ enterprise rather than the individual hypotheses in Table 4.

The reviewers had comments on figures that have now been addressed. For example, Tunnicliffe suggested changing Figure 1 to emphasize biological aspects. We have considered possible revisions for Figure 1 and have selected one to replace the earlier version of that figure, because it more clearly integrates biology with the weathering profile and it has been commonly used by the CZ science community to highlight these interactions. Given that both reviewers

questioned Figure 3, we have modified the caption by pointing out in our revision that the figure includes sites associated as CZOs and that all the sites shown derive from networks within the U.S.A., Germany, France, and China, noting that some sites in China are co-funded and studied by scientists from the United Kingdom. The sites included are also ones that are registered on SiteSeeker. The RBV and Critex networks (France) include sites outside of Europe. We added this information to the caption: RBV stands for the Réseau des Bassins Versants (Network of Drainage Basins), CRITEX is not an acronym, and TERENO stands for the Terrestrial Environmental Observatories.

We agree completely with the comments about models by Tunnicliffe and Bui. As Table 3 indicates, the initial CZ modeling efforts may be characterized into four groups. The first includes modifications and adoption of existing models to incorporate new couplings between hydrology and biogeochemistry, ecology and biogeochemistry, etc. The second includes identifying and filling critical gaps or knowledge of new processes such as hyporheic exchange, weathering, etc. The third includes development of a new generation of models that takes advantage of emerging streams of high resolution data such as airborne and UAV (unmanned aerial vehicle) based LiDAR and hyperspectral data. The fourth includes coupling between fast and slow processes across many time scales. Slow processes provide the template for the fast response variable, while the accumulative effect of the latter results in the evolution of the former. Both mathematical frameworks and data to support such modeling are still in their infancy. We discuss this in the paper but we do not separate the table explicitly because of the complexity of real distinctions along these lines for many of the models.

Tunnicliffe also writes, “Table 4 is missing any mention of hypotheses related to the social science aspects of the CZ…It would be good to see how this strand of the research fits in!” Likewise, reviewer E. Bui emphasizes that the future NSF network should “address current ‘wicked’ societal problems and help formulate better land development environmental management policies.” We could not agree more. However, the CZO enterprise in the U.S.A. so far has not emphasized social science and no such hypothesis has yet emerged from the community. We emphasize in the revised manuscript that such hypotheses are needed and should be part of the future of the network. For example, in the revision we specifically mention the idea proposed by reviewers P. Shroeder and E. Bui that an urban CZO would be of great interest.

Reviewer #2 points out that “paragraph 7 mentions briefly the publication of numerous datasets (p. 7, l.1) sometimes spanning several decades of measurements…the creation of this repository as well as the website …should be highlighted in the text.” We agree with the reviewer. Tunnicliffe noted that “Table 2 does not back up your point about long-term measurements. It would be more helpful to see the length of these records, rather than a smattering of similar measurements that may or may not relate to broader hypotheses being tested across CZOs.” This reviewer also noted that, “Pg 9, ln 307 makes reference to the ‘extremely long’ duration of the datasets - this could use some quantification.”

We have clarified these points in the revision. In short, the time-series datasets (sensor and sampler arrays, eddy covariance, hydrometeorology, vadose zone and saturated zone aqueous chemistry, etc.) have durations that are roughly equivalent to the age of the CZO sites, determined by the initiation of NSF funding, with the caveat that CZOs have often added new study locations that were not among the original set. Three sites (SSCZO, BCCZO and SSHCZO) have been in operation since 2007, and so their longer-term observational datasets extend roughly over that duration. Three other sites (CJCZO, LQCZO and CRCZO) that initiated operations two years later have measurements dating to 2009, and four newer sites (IMLCZO, CHCZO, RCCZO and ERCZO) have datasets dating to 2013. Therefore, at present, continuous time series datasets range in duration from ca. 4 to 10 years. In addition, however, several of the CZOs are located in sites that provide longer datasets through previous measurement programs. The question of duration of dataset is thus somewhat complex, but we have tried to make this information more transparent in the revision.