Biogeosciences Discuss.,
https://doi.org/10.5194/bg-2018-67-AC1, 2018

Biogeosciences Discussions
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EGU

Interactive comment on "Elevating the biogeosciences within environmental research networks" *by* Daniel D. Richter et al.

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Received and published: 3 July 2018

Authors' responses to review #2. We appreciate the reviews and the editorial work. These comments as a whole pointed to the need for a major rewrite, which we have accomplished. We have taken very seriously both reviews and have substantially rewritten most of the ms. We have internationalized the authorship with scientists from Europe, Mexico, Argentina, Africa, India, and China. The text is internationalized in many ways as well. While we retain much of the historical context of the biogeosciences, which we frankly see as fundamental, we have attempted to make the paper as all encompassing to as many disciplines and audiences as possible. We seem to have been interpreted in our previous version as favoring one environmental network over another. As this was not our message, we have explicitly addressed this fact and have

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adopted a much more positive tone throughout. We are on the side of the biogeosciences, not on the side of any one network. By adding the FLUXNET network to the ILTERs, EONs, and CZOs, we believe we have further defused any possibility of being seen to be partisan for one network over another.

We believe you will see that this is much improved ms. We recruited a number of international co-authors and have substantially re-written the text making it a truly international document.

Below see Author responses (led with an A) to reviewer #2 comments (led with an R).

RGlobally, research networks are key to supporting regional and global science. They have not developed equally across the globe and even the progression of networks within a country can be messy. The authors have done a good job at describing the US based networks and the manuscript is generally well written. Therefore, the authors have provided a great platform for discussion and for this reason I think it is important. I am not from one of those networks and I acknowledge that my comments are partly opinion too but hope that it adds to a useful discussion. I will keep my comments general at this time as I think the paper needs major revision.

AWe appreciate these comments from a person "outside" the environmental network communities. As authors, we'd like to think that these networks are sufficiently open to welcome researchers like the reviewer.

RMy first impression is that this is very American centric with the author list and examples of networks used in the paper. Bringing biogeosciences to LTERs, EONs, and CZOs is necessarily an American focus due to the specific infrastructure programs but should be a global one. Is there a better framework here? Or at least better nomenclature? If, as they propose, we are "interested in addressing questions that motivate the worlds research networks" then this requires a global effort and integration across boundaries is necessary. In addition, submission to Biogeosciences is to a global audience and the paper should be relevant. To stay in Biogeosciences I would recommend

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that the paper should expand globally to be a real interest and engage our global community rather than assuming that the rest of the world is the same as the USA.

AWe have substantially revised the ms in many ways, but one of the most important was to internationalize the coauthors and the topics discussed in the text. We have also added the FLUXNET network which is a profoundly international network. The revised ms is aimed at a global audience across the full range of the biogeosciences.

RThe objective of the paper was to “motivate more collaborators to bring the best of the biogeosciences to the LTERs, EONs, and CZOs”. In my opinion this is a rather odd objective to have for the paper and I don’t think it achieved it. The paper suffers from not having a clear problem statement, so it is never clear what the discussion is trying to achieve and so in the end it achieves nothing. The scope and problem need to be well developed with some specific outcomes in mind. For example, what are the pressing problems and puzzles of the world that you allude to and how can they be addressed by integrating different measurement capabilities or networks. What the important global questions that you refer to in the paper? It would be useful to determine these perhaps as an integrating framework – find synergies first.

AWe thought a lot about the best way to revise the objectives and problem statement and have revised this entirely. We lay this out in the 1st paragraph of the new revision. The paragraph reads: “In this paper, we bring the biogeosciences and environmental research networks together by exploring their origins and by asking a simple question: might on-going environmental research networks benefit from a perspective that more explicitly includes the biogeosciences? The specific objectives of this paper are to consider the historical development of the biogeosciences and of environmental research networks, and to use that history to highlight opportunities for the world’s environmental research networks to use the biogeosciences to benefit network science itself and to broaden their impacts on the wider sciences and society.”

RThere is also no definition of what biogeosciences is and what a is a ‘biogeoscience

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approach'? Are we talking about Earth system Science or Critical Zone Science?

AWe are writing for a premier journal of the biogeosciences, so there should be good understanding of the important overlap of what we conventionally consider biology and geology. We reiterate our objectives by making a statement about that overlap. "While these networks were founded and grown by remarkably interdisciplinary scientists, the preponderance of expertise and funding streams have tended to gravitate to different networks by discipline: ILTERs and EONs toward ecology and biology, CZOs toward the geosciences, and FLUXNET toward ecophysiology and micrometeorology. While our paper's interest and objective is not to homogenize environmental research networks, we do assert that biogeoscience presents special opportunities for integrating diverse disciplines in ways that will benefit the research networks in advancing science and disseminating their science narratives among scientific communities and the public."

RI agree that these networks are underutilised. Many networks globally struggle with minimal (or no) funding to keep the lights on and funds do not support scientific research. This is a problem particularly for investigators who spend a lot of time running things. Perhaps you could discuss this? The authors ague that "In fact, the core concepts that motivate these networks' operation clearly and substantially overlap (Figure 4), that is, ecology's ecosystem is entirely congruent with Earth science's critical zone". I find this is a cursory observation and the figure simply shows different schematics for each network and does nothing to synthesis the information. There needs much more development of these ideas here. This would be more beneficial if it were a systematic analysis of the operational and conceptual frameworks associated with each. Maybe a table or synthetic diagram. Same with the differences, make a systematic review of the difference and/or gaps. What are the challenges they face?

AWe discuss much more this "congruence" of the core concepts of ecology and Earth science, as ecosystem and critical zone. The FLUXNET's ecosystem is often the aboveground ecosystem and its exchanges with the atmosphere. The ILTER/EON

ecosystem is somewhat deeper, perhaps to 2 m with NEON. However the critical zone ecosystem includes the full depth of biological and weathering influence and water's penetration. The text makes the point that many of the biogeoscience opportunity's are in belowground ecosystems.

R"EONs are surveillance facilities" I don't truly understand the distinctions you are trying to make here. All facilities are surveillance really.

AWe have reworked the descriptive paragraphs (in Section 4) of each network; in fact, these are almost completely revised. Survellance is used in a special way, as in to survele with passive instrumentation that continuously logs environmental data.

RAt the end of the day the networks (or what they provide) are just tools. They are constantly evolving and being reinvented to attract and maintain funding. Really what we want is a scientific framework that is capable of answering these questions BUT then utilises tools in its toolkit. These would include surface observational capability (LTER, NEON, CZO), atmospheric tools, remote sensing and modelling. Shouldn't we also include the humanities? If that is the case don't we already have this is Earth System Science (relevant programs are iLEAPS, GLP, Future Earth). How do the networks help address the big societal questions that they are posing? Are we reinventing the wheel in biogeosciences because we already have ESS? This needs discussion and thought.

AYes, these networks ARE tools, though tools at locations where information is builtup over time, so that we begin to learn a lot about each of the sites. The diversity of each ecosystem and critical zone is quite impressive. And what we learn includes many sciences and yes, even the social sciences and humanities. There is important overlap with iLEAPS, GLP, and Future Earth. We do not think that these projects make the four environmental research networks redundant. It may well be that the approach to science may be quite different in that it might be argued that the iLEAPS-GLP-Future Earth approach starts with the environmental problems and brings science to

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find resolutions. Much of the environmental research networks activities focus on the basic science and the environmental dimensions of the science.

RAlso the observational facilities you mention are very specific in the US and are quite different elsewhere in the world so there is a huge need to think about this in terms of CAPABILTIES rather than specific entities like (LTER, NEON, CZO). For example, in Australia there is a Terrestrial Ecosystem Research Network (TERN) that has only a single platform with different capabilities. It is important to document these across the globe to be truly an internationally relevant discussion. Regional questions will be answered very differently depending on capabilities, access and funding. To solve global problems we need to go beyond borders. How is this achieved? Needs discussion.

AThe revision completely opens up this kind of discussion, and we now add FLUXNET with all of its 100s of international flux measurement towers. The capabilities are really incredible, all things considered and by referring to ILTER, EONs, CZOs, and FLUXNET, one hardly has four sets of capabilities. Each of these is diverse with regard to capabilities. Thus CZOs in particular have not protocol for how to design a CZO. The lesson is that each of these systems has inherent diversity in capabilities and that is a fundamental lesson of the paper. We are not after homogenizing the capabilities, just trying to identify the biogeoscience opportunities that might exist across the networks and at particular sites.

RThe authors note that “emphasized, discussions with international colleagues are most important” and I would agree, so much so that really that needs to be done as part of this submission else it is completely biased. This collaboration could/should also come from breakout group or similar at major meetings to enable and capture discussion and debate. It is unclear as to how this has arisen. I suggest that the global community needs to be included now. Also the authors state that “We respond to this request by arguing that NEON can ensure much greater scientific engagement by incorporating more geophysical and biogeophysical aspects of the biogeosciences into their overall design and operations”. Again this is a rather flippant statement. What

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greater engage- ment exactly? What would this look like? How would it add value to NEON? Isn't this just incorporating CZO into NEON?

AMore than anything, we have completely transformed the manuscript into an international document. This has taken a lot of time and effort. But we think we've done it quite well.

RMaybe we should embrace the differences you describe between the networks? I think through the paper you have highlighted the differences between the capabilities but perhaps are the strengths. Rather than trying to make them work "much more closely", perhaps again view these as different tools that have their strengths and weaknesses. It will be through our interdisciplinary science approaches (like ESS or CZO etc.) that becomes the enabling factor.

AIn point of fact, the more we investigated the differences between networks the more we have come to see that as we say, we do not support a homogenization of the environmental research networks. On the other hand, there are different but important biogeoscience research opportunities that exist within sites and within networks that scientists ought to know about. That is an important part of the paper, in addition of course to a critical thinking of how we gravitate on the basis of discipline.

RThere is a strong focus on 'ecological' and 'earth' sciences but there is more to biogeosciences or ESS. Would be useful to have a more wholistic picture of the interdisciplinary nature of the 'biogeosciences' (which by the way is never defined or scope given).

AYes, there is a wider set of opportunities than the interdisciplinary biogeosciences. We decided to write this for EGU's BGS journal as a good first step. One really can't "solve" problems of the environment within a boundary impermeable to social science and the environmental humanities. Environments have histories afterall! We tried to take a step, rather than run the full marathon that will eventually be run.

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RWhat are you really asking people to do?? You state that “We call on scientists to accelerate their production of ideas, papers, and proposals for biogeoscience research and education, and to support such research at place-based research sites and across environmental networks.” Why in an acceleration needed? Don’t we already do this? Not clear on what you are asking from the community and to what end?

AWe have omitted this argumentation in the new version.

RThe authors talk about scientists and students will provide “The information that will reveal the coverage of data and the data gaps in the three networks”. This is a big let-down as I was rather hoping that this paper would tell me this and provide a mechanism to achieve this. What cross-networks hypotheses are needed? What mechanisms can be used to achieve this USA and globally? Very much left wanting more here and there was a lot of description of the networks to reach a one paragraph statement that does nothing. It certainly doesn’t motivate me (which was the aim of the paper). The objective of this paper is to motivate more collaborators to bring the best of the biogeosciences to the LTERs, EONs, and CZOs”

AWe’ve backed away from an ambitious new initiative, etc. We’ve adopted a more subtle approach in encouraging this interdisciplinarity within existing networks.

RWith respect to NEON the authors say that “expanding the scope to include the biogeosciences would involve additional implementation”. I question whether that is what is really needed. What is the evidence that there is a lack of biogeoscience in EON’s. I would argue that most EON’s are lead and driven by biogeoscientists and the community. Again, really what we need here is not biogeosciences injected into everything but rather to utilise the scientific frameworks developed by interdisciplinary science (i.e. ESS and CZS) with appropriate tools to address global problems or answer hypothesis. I can see the attraction of combining CZO’s and NEON but I understand that they come from different program areas (and hence funding streams) and serve different core communities. It would have been nice from a design point of view to integrate

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these right at the start, however, having two capabilities allows independence and the research funds to be distributed not to the usual suspects. There is a danger in having all capabilities rolled into one because then the are operated centrally and you loose buy in from the scientists that need to have a vested interest. Maybe discuss some of these challenges and more systematically?

AMethinks in re-thinking and revising the ms, we've come to a similar direction as seems outlined here. That we do not want to homogenize. On the other hand, there are incredible opportunities and what is discussed in the ms is that while NEON has given us instruments to 2-m depth, FLUXNET experience clearly demonstrates that the water balance can't be closed in most places at 2 m. The same goes for nutrients and other resources, and thus it is quite typical that subsurface characterization is quite superficial. Again, we are not arguing to make all networks the same, as you say there is value in different emphases and capabilities. However, this means there are un- and underexplored opportunities.

RI found the discussion rather adhoc and biased. 3.1 talks about "biogeosciences and EON/NEON" and 3.2 "The biogeosciences and LTERs and CZOs". Why have one section for EON and another with LTER and CZO combined? Rather get rid of those sections (which are silos to start with) and come up with an integrative framework to look across biogeosciences and the tools and platforms that support them. In all of the discussion there was a push to get CZO into NEON or CZO into LTER. In 3.1 the discussion was a bit of a wish list of CZO measurements that should be made at NEON sites. In section 3.2 the push was for CZO and drilling at LTER sites. I thought it was an unbalanced discussion and needs to be rewritten. These are all very well and good but why are you asking for all these items for each capability? What specific problem or hypothesis is currently being limited because of the current arrangement? I'd like to see a more systematic review of the measurements required for the biogeosciences and from that the additional tools and measurements that may be needed and where they would be best placed.

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AWe've shifted to a much more practical approach in the new version. We're no longer suggesting there is a big program out there. We've completely revised this Discussion and much more systematically and in a non-siloed fashion opened up some of the opportunities that research managers, researchers, or students might see and find interesting and important.

RAlso, in section 3.2 the authors say that "Ways in which we can promote enhancement of the biogeosciences in the research question-driven LTERs and CZOs can be found in the LTER and CZO literature itself." and proceed to describe some examples. These examples showed the conceptual link of the link of geosciences to LTER but the section did not demonstrate any ways to promote the enhancement of biogeosciences in LTERs.

AWe've upgraded these topics substantialy in the current version. We do not foresee you having this reaction with the revised ms.

RIf we added all the missing pieces from each (as you have identified) then don't we end up with three identical capabilities? Is that what we want? Again, maybe the diversity is important.

ADiversity is good. We are NOT recommending all networks be homogenized. We learn from each other. The networks too often are in their own silos however and it is time to have them start to interact!

RThe last paragraph is really the first and only specific recommendation from the paper. I would like to see a more comprehensive plan for engaging biogeoscientists. Overall paper could have outlined the challenges better and what the opportunities are?

AWe have advanced this paragraph to the front end of the ms, so that it makes clear from the start what we are doing. Again, this is not a big NSF project, capital P, but rather a big decentralized effort on the part of biogeoscientists.

RThere are some throw away statements about societal issues such as "Such a biogeo-

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science initiative could help better address a variety of pressing human needs as well. There are growing numbers of biologists and geologists working together on societally important issues." What are these? Cant just say this and leave it you must demontrate this. These issues can perhaps be a uniting umbrella for biogeoscientists but these need to be articulated.

AWe've edited the ms very closely.

RLast paragraph in the conclusion "good reasons to bring an explicitly biogeosciences initiative to the world's LTERs, EONs, and CZOs". Despite this sounding like a good thing I don't think the authors have outlined what a 'biogeosciences initiative' is? Again I would argue that 'biogeosciences' is just a name for multidisciplinary research and the principles and frameworks for LTERs, EONs, and CZOs have been developed by communities that have been multidisciplinary. The development of ecosystem ecology, earth system science over the past 2-3 decades have driven these networks so again at the end not sure what the real purpose of this paper was.

AWell that is our challenge, I can see. To convince readers like you that there are major scientific opportunities in these networks!

RDo the Geophysical Unions play a key role in biogeosciences? Discuss?

AThis is far more than the Biogeoscience Section of AGU or EGU. Formal sections are more symptoms than causal determinants which are much more scientific.

RI found the figures not so relevant, particularly figures 1, 2 and 5 do not add value to the text and I suggest you remove.

AThis critique guided our presentation of the six figures to ensure that they really contributed to the ms.

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