NEON Scope Management Recommendations

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Since the design and scope for the NEON Observatory was initially approved, much has changed. Earth systems have changed, scientific questions and opportunities have changed, methods to quantify the nature and magnitude of ecological change have evolved, and our capacity to do transformational continental-scale science has changed. As a result, some aspects of implementing the NEON Observatory have proved challenging and some sites and deployments have proven to be nonviable for implementation.

A group including representatives from the NEON Board, STEAC, and outside experts were convened July 13-16, 2015 to provide recommendations to steer the final science implementation of the Observatory to ensure that high level science requirements are met. Some sites (mainly relocatables), deployments, and other capabilities whose status is in question due to permitting or other issues were evaluated to determine how their loss would impact the science. The outlined recommendations, based on discussions at the meeting, are intended to ensure that all Level 1 science requirements are met, while eliminating those aspects of the project that are either unviable or no longer of sufficient scientific interest to merit further investment. Some science capability will inevitably be deferred in this process and we identify several areas where unviable solutions must be replaced with innovative alternatives or where seed investment is required to ensure long-term success.

Observations

1) The NEON Observatory as designed and currently being implemented:
    a. Spans the full climate gradient expressed within the US
    b. Includes agricultural and managed forest sites, addressing land use and global change
    c. Includes streams in diverse climate regions of the US
    d. Includes relocatable gradient themes for nitrogen deposition, dust transport, climate change and the water cycle, and (simplified) hydrological transport

2) The human capital and specialized knowledge associated with NEON is invaluable and must be maintained and valued just as much (or more) than sensors, towers, and CI.

3) In this review, we found a number of proposed yet problematic capabilities that make little or limited contribution to meeting Level 1 science requirements.

4) A debt from delayed transition to operations has occurred because of lack of clarity between NEON & NSF about requirements. Technical debt also exists from earlier unsuccessful approaches, further contributing to the delays.

5) Delays and technical debt have also occurred because of an emphasis on following NSF procedure and compliance rather than creative problem solving.

6) As a result, recommendations by NEON project scientists regarding issues such as sites that cannot be permitted or that do not meet science requirements, designs that lead to cost disproportionate to science value, etc have met with unfortunate delays and as a result, there has been an excessive investment in resolving these issues. These issues now need to be dealt with expeditiously by changing tack (i.e., alternate siting or deferral). These issues should be dealt with by science leadership, with NEON project scientists making recommendations to science leadership with review by STEAC in the context of the Observatory's ability to meet science requirements.

7) Lack of clarity about requirements continues to be an issue, especially around two issues that are costing the project time and money: (1) rapid review and approval by NSF of revised protocols based on NEON's staff identifying problems that deviate from the approved science plan and trying to correct for these, and (2) data delivery.

Recommendations

1) We have defined the threshold at which NEON still meets all Level 1 science requirements. If the recommendations outlined here are implemented, the Observatory will still meet these science requirements without a loss of core capability. Reductions below this threshold will mean that the Observatory no longer fully meets all science requirements.

2) There needs to be an aggressive transition to operations. Data production (specific criteria for science quality data) needs to be separated from data publication (availability to the community on the portal), and there should be separate criteria for data publication (X % of data products, Y % of sites, with quantified uncertainty). **The transition to operations should be viewed from an Observatory not site by site perspective.**

3) The cost of carrying field operations on the construction project is unjustified, and these costs should be transitioned to the operations budget immediately.

4) Good cost management by NEON Inc., including standard project management decisions and aggressive transition to operations, can apparently solve ~35% of the $88M problem with no impact on science scope. **It is critical that all measures for management efficiency be taken on both sides to enable this full savings.**

5) Getting control of the "compliance costs" is a non-trivial issue. Focusing more attention on reporting and review against the science requirements rather than details of scope could help both sides concentrate their attention in this end game on the actual deliverable—science capability rather than *how* that science capability is delivered. If NSF funds a group to build a mass spectroscopy laboratory, the peer review and proposal management will focus on metrics like accuracy, precision, throughput and repeatability, and less on the brand purchased, or even the number of units purchased.

6) The scope management plan proposed by NSF, which suggested moving to the "CONUS concept" does not meet the science requirements—exclusion of the Alaska, Hawaii, and

Puerto Rico core sites would greatly reduce the range being sampled of climate and biodiversity expressed within the US since as scoped they cover sites that are the coldest (AK), the hottest (PR) and a hot, wet, island (HI) in the planned observatory (see **Figure 1** below as well as a table with the full list of the Domain numbers, names and mean annual temperatures and precipitation values). These large-scale gradients may lead to the most transformative science, and implementation of the CONUS concept alone does not have a strong scientific rationale. Additionally, it would not have wide community acceptance and could possibly lead to a political firestorm. Finally, we note that substantial investment has been made in AK and PR and so cost savings from this approach are likely to be minimal and disproportionate to the science impact. The suggestion fails the "don't be dumb" test.

7) Relocatables in HI, AK, PR could be deferred (but the core sites must be retained per #4 above). The HI sites no longer represent an invasion gradient. One PR relocatable is urban (and is already decommissioned), while one Alaskan relocatable is unfeasible for permitting reasons.

8) The urban sites should be deferred due to issues with 1) permitting, 2) the inability to implement the standard protocols, and 3) no clear alternative design. The urban sites should be deferred to the first round of relocatable moves and in the meantime, a viable science plan, feasible protocols and an appropriate sampling design should be developed.

9) BGMS can be deferred and implemented by PI-led investigations where CH_4 and N_2O instruments can be placed on NEON towers. A guest investigator program with scientists in this area could accomplish most of the science at lower cost and with additional benefits through the likely involvement of students, postdocs, etc and the knowledge of NEON technology these PIs would gain. That does imply waiting until 1-2 years post commissioning to allow NEON assignable asset procedures to stabilize; however, this would be a good area to use in prototyping assignable asset use of towers as this is a tech-savvy subcommunity.

    a. What is the question or questions to be answered by BGMS? It could address process-level controls over N_2O and CH_4 at a set of research sites where these gases are relevant. But the NEON towers were not micro-sited to be optimized for trace gas biogeochemistry. The response of CH_4 at high latitudes to climate change is interesting and important, but significant analysis of the recent CARVE experiment and other studies would need to be done to determine if any of the Alaskan NEON sites are well-suited to monitoring long term change. In any case, the NEON sites cannot provide an estimate of statewide change (for example the Yukon, Yukon Delta, Copper River Delta and other inland wetland areas are the major sources).

    b. A key source for N_2O is from agriculture, and especially from heavily fertilized corn and soybeans. NEON could support process studies, but the basic biogeochemistry of N_2O is relatively well-known. NEON cannot update the national estimate with its coverage of agriculture, so again while it can support process studies, it adds relatively little to continental estimates of flux.

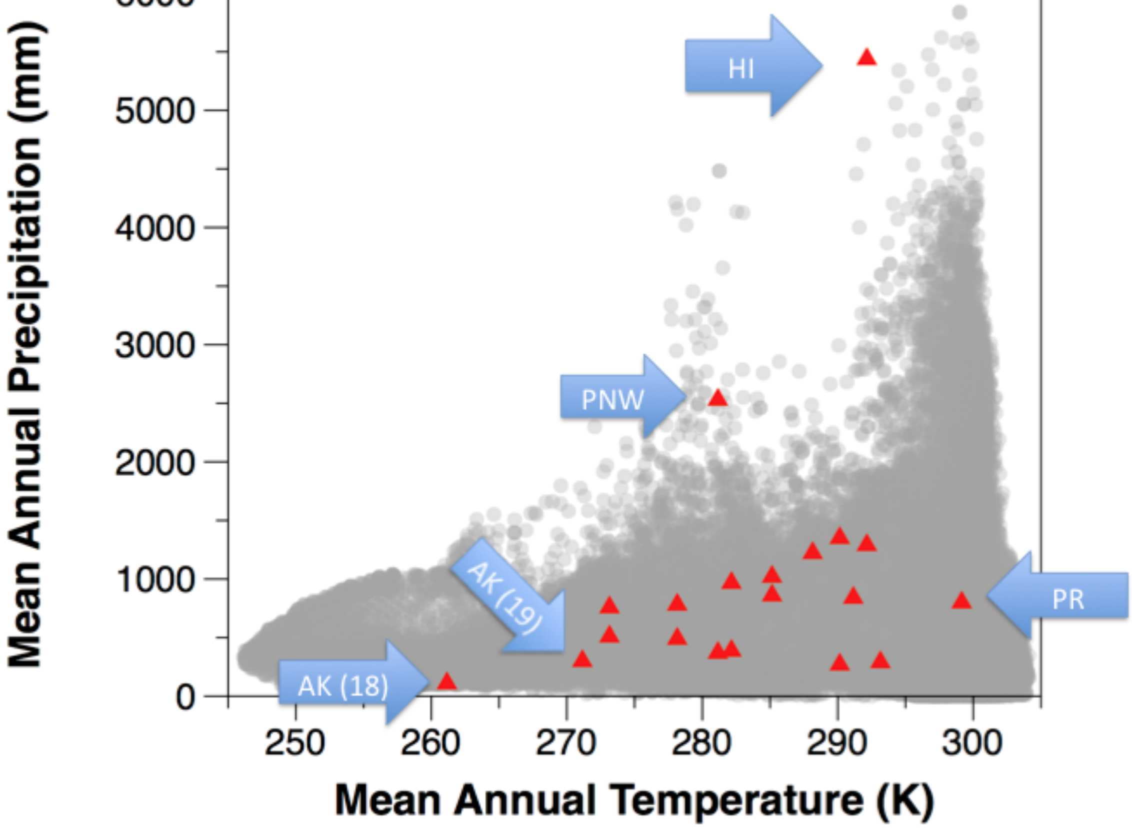
c. Since NEON's sampling design cannot support continental scale integrals for CH_4 and N_2O, rigorous standardization is less important for this than for other measurements, leaving scope for associated PI investigations rather than experiments following standard, NEON managed protocols.

10) STREON is one of the most important and visionary components of NEON. The STREON design, focused on establishing meta-parameters for tipping point or threshold behavior as a function of climate/hydroperiod conditions adds an otherwise missing element to NEON and responds to the requirement for experiments that accelerate conditions towards anticipated future states. However, the current STREON design, tied to NEON's siting is unviable for permitting reasons. NSF should fund a study of optimal and permittable sites for STREON, while NEON continues to develop the requisite technology. When a complete and satisfactory solution is available (mature technology and permittable sites in a scientifically optimal design), NSF should identify a funding path for this visionary study. We recognize this is unsatisfactory and places crucial science at risk. However, proceeding down the current path will lead to failure, at the cost of funds that could be reserved to support an optimized study.

11) Minirhizotrons—The STEAC has recommended that these be deleted and brought back as PI projects to mature the technology. If the technology matures and the science is still compelling, this is a future opportunity for enhancement of the observatory. Alternatively there may be some other technology option for assessing belowground biomass turnover.

In conclusion, aggressive transition to operations will require agile project management and effort related to oversight (reporting, review) that enhances project execution, since further delays will potentially destroy the ability of the proposed deferral and minor scope changes outlined above to control budget problems.

Figure 1. The 20 Core NEON sites, plotted in climate space (adapted from Schimel *et al.* 2015*). The figure shows where the Alaska (AK), Hawaii (HI), and Puerto Rico core sites are placed in climate space for all 20 NEON domains. The table that follows below shows the full list of the Domain numbers, names and mean annual temperatures and precipitation values. This information is relevant to recommendation #6 above.



*Schimel, D., Pavlick, R., Fisher, J. B., Asner, G. P., Saatchi, S., Townsend, P., ... & Cox, P. (2015). Observing terrestrial ecosystems and the carbon cycle from space. *Global change biology*, *21(5),* 1762-1776.

Full list of the NEON Observatory Domain numbers, names and mean annual temperatures and precipitation values.

Domain ID	Domain Name	Core Site	MAT °K	MAP mm
1	Northeast	Harvard Forest	282	967
2	Mid-Atlantic	Smithsonian Conservation Biology Institute	274	851020
3	Southeast	Ordway-Swisher Biological Station	282	1290
4	Atlantic Neotropical	Guanica Forest	299	800
5	Great Lakes	UNDERC	278	781
6	Prairie Peninsula	Konza Prairie Biological Station	285	860
7	Appalachians & Cumberland Plateau	Oak Ridge	288	1222
8	Ozarks Complex	Talladega National Forest	290	1350
9	Northern Plains	Woodworth	278	490
10	Central Plains	Central Plains Experimental Range	281	370
11	Southern Plains	LBJ National Grassland	291	840
12	Northern Rockies	Yellowstone Northern Range (Frog Rock)	273	509

13	Southern Rockies	Niwot Ridge Mountain Research Station	273	758
14	Desert Southwest	Santa Rita Experimental Range	293	290
15	Great Basin	Onaqui-Ault	282	388
16	Pacific Northwest	Wind River Experimental Forest	281	2530
17	Pacific Southwest	San Joaquin	290	270
18	Tundra	Toolik Lake	261	110
19	Taiga	Caribou Creek - Poker Flats Watershed	271	300
20	Pacific Tropical	Upper Waiakea Forest Reserve	292	5438