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EONs (Earth Observation Networks): Finding the Right Balance

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Abstract:	Earth Observation Networks (EONs) are an emerging, surveillance-based approach to environmental monitoring and research that fundamentally differ from traditional question-driven, experimentally-designed approaches. There is an urgent need to find an optimal balance between these approaches and develop new integrated initiatives that take advantage of key features of both.

Forum Article

EONs (Earth Observation Networks): Finding the Right Balance

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Abstract

Earth Observation Networks (EONs) are an emerging, surveillance-based approach to environmental monitoring and research that fundamentally differ from traditional question-driven, experimentally-designed approaches. There is an urgent need to find an optimal balance between these approaches and develop new integrated initiatives that take advantage of key features of both.

The past decade has seen a radical shift in the way environmental science is done, with an increasing focus on the establishment of EONs – Earth Observation Networks and Biodiversity Observation Networks (e.g., [1]). NEON in the USA is the most well-known example, but there are many others including those within the international network – the Global Earth Observation System of Systems (GEOSS). The overarching aim of EONs is to establish built infrastructure that supports data generation, storage and sharing; the focus is not on analyzing data or research (for which there is limited or no funding). The EON model is a surveillance approach to monitoring (*sensu* [2]) underpinned by the collection of large streams of (often real time) data but which is not guided by specific questions or an experimental design. This approach is fundamentally different to traditional question-driven, experimentally-designed environmental monitoring and research based on appropriate data collection to answer key questions [2]. Procurement of extensive infrastructure to develop observation networks can generate larger-scale patterns not visible from smaller datastreams derived from area-focussed, question-driven monitoring (e.g., [3]). Indeed, some important discoveries have been made this way [4]. However, we argue there is an urgent need to find an optimal balance between, and the amount of funding dedicated to, surveillance versus question-driven research and monitoring. Fully integrated monitoring initiatives that take advantage of the key features of both approaches need to be developed.

In the EON approach, data collection can be driven extensively by technology (e.g. satellites, remote sensors) with the resulting, often large, datasets subsequently mined for answers to questions posed post-hoc. Such opportunistic questions can produce important outcomes. However, relative to both true and natural experiments, a post-hoc observational approach is weak because it is not possible to identify causal factors giving rise to observed ecological patterns [5]. It is important to ensure that important environmental problems are not overlooked with the EON approach. The ozone hole discovery over Antarctica is an example of this danger. American researchers using extensive data-generating methods without well-focussed questions missed the ozone hole. British researchers developed good questions and, using relatively simple methods that did not generate enormous volumes of data, discovered the ozone hole [6]. Therefore, a fundamentally important question is: <u>How can the EON approach be best used to detect critical changes in ecological conditions and determine the ways in which those changes impact ecosystems and biodiversity?</u>

A related further challenge with the EON approach is to ensure the scales of data collection (often national or global) interface robustly with: **(1)** local and/or regional scales of, and solutions to, environmental problems; and **(2)** the scales needed for many forms of monitoring such as species movements or invasive species colonization. For example: <u>How might EONs help quantify the effectiveness of management interventions (e.g. vegetation restoration and invasive species control) essential for improving environmental outcomes?</u> Advances in hierarchical statistical theory combined with increasing computational resources have enabled a new generation of methods for integrating data collected across spatial and temporal scales [7]. Initiatives like GEO BON are attempting to connect datasets gathered from *in-situ* observations, airborne sensors and satellites at scales from genes to species and even ecosystems. However, there remains a clear need for on-ground work to calibrate data generated from satellites and remote sensors, including improved environmental management.

In addition to calibrating remotely sensed data, people working in the field often have been the ones to alert society to environmental problems (e.g. acid rain and eggshell thinning in birds). People have been essential 'infrastructure' in most past successful examples of environmental monitoring. Much of the EON approach to science is driven by technology not directly involving people. New kinds of technology-driven surveillance monitoring will require, in addition to data managers and data miners, field-based environmental scientists. Two key questions then are: How can we encourage people to remain working on the ground to ensure environmental changes are not overlooked? How can we ensure remote, technology-driven monitoring continues to make environmental science attractive for young scientists [8]? We note that new generations of scientists raised in a data-rich world are excited by the large data streams generated by EONs.

Funding for environmental science and monitoring is limited. A key question is: Is the EON approach a more efficient and effective way of investing limited resources than researcher-driven and question-based investigations? Given competition for rapidly shrinking resources, EON funding should not trigger the demise of other important programs. Issues associated with major initiatives being less efficient than, and redirecting resources away from, more focussed question-driven studies are not new. For example, some individuals criticized the International Biological Program (IBP) in the 1960s on this basis [9] and such criticisms have been a prominent point of recent contention in marine research and monitoring [10]. However, a congressional add-on to the NSF budget actually funded IBP, which also was an explorative, science-directed research program. The IBP add-on became the basis for establishment in NSF of a question-driven ecosystem science program, which was not common at that time.

Another important question is: In what ways can EONs most effectively convert large data streams into useful scientific knowledge and management relevant understanding? It can be extremely challenging to analyze, and then identify robust insights from, large and complex datasets from multiple sources [8]. In 2012, the Editor of *Nature* noted that massive data streams can produce major errors in data interpretation and conclusions and these are occurring with increasing frequency [11] (see also [12]).

The non-question-driven, surveillance-based approach that underpins EONs is a new way of doing science. All scientific fields tend to grow stale with time and need renewal. However, there are fundamental planks of a given discipline, including environmental science. Answering good questions through a robust experimental design is one such plank. Hence, there will be numerous cases where the question-driven approach is the most effective in terms of cost and for producing new ecological understanding and management-relevant results. There also will be important opportunities for discoveries based on EONs. It is time to think deeply about the optimal balance between, and the amount of funding dedicated to, the EON approach versus question-driven research and monitoring. To date, some initiatives such as SAEON in South Africa have been a ‘hybrid approach’ which encompass elements of both the EON and question-driven approaches. However, because EONs are expanding against a background of highly focussed, often very effective place-based, question-driven monitoring, it is critical to develop fully integrated rather hybrid approaches. That is, new approaches that fully integrate larger-scaled EONs with important place-based, long-term site and landscape studies to capture the advantages of both (Figure 1). This approach demands that key questions and a rigorous experimental design drive multi-scaled data collection. Developing fully integrated approaches will be challenging, especially as attempts to frame tractable questions for initiatives like NEON (and TERN in Australia) have been unsuccessful to date. Yet the quest for effective integrated methods is increasingly critical given environmental problems confronting the planet and the urgent need to address them.

Figure 1. Full integration of EONs and question-driven approaches to monitoring that aims to capture key features of both kinds monitoring.

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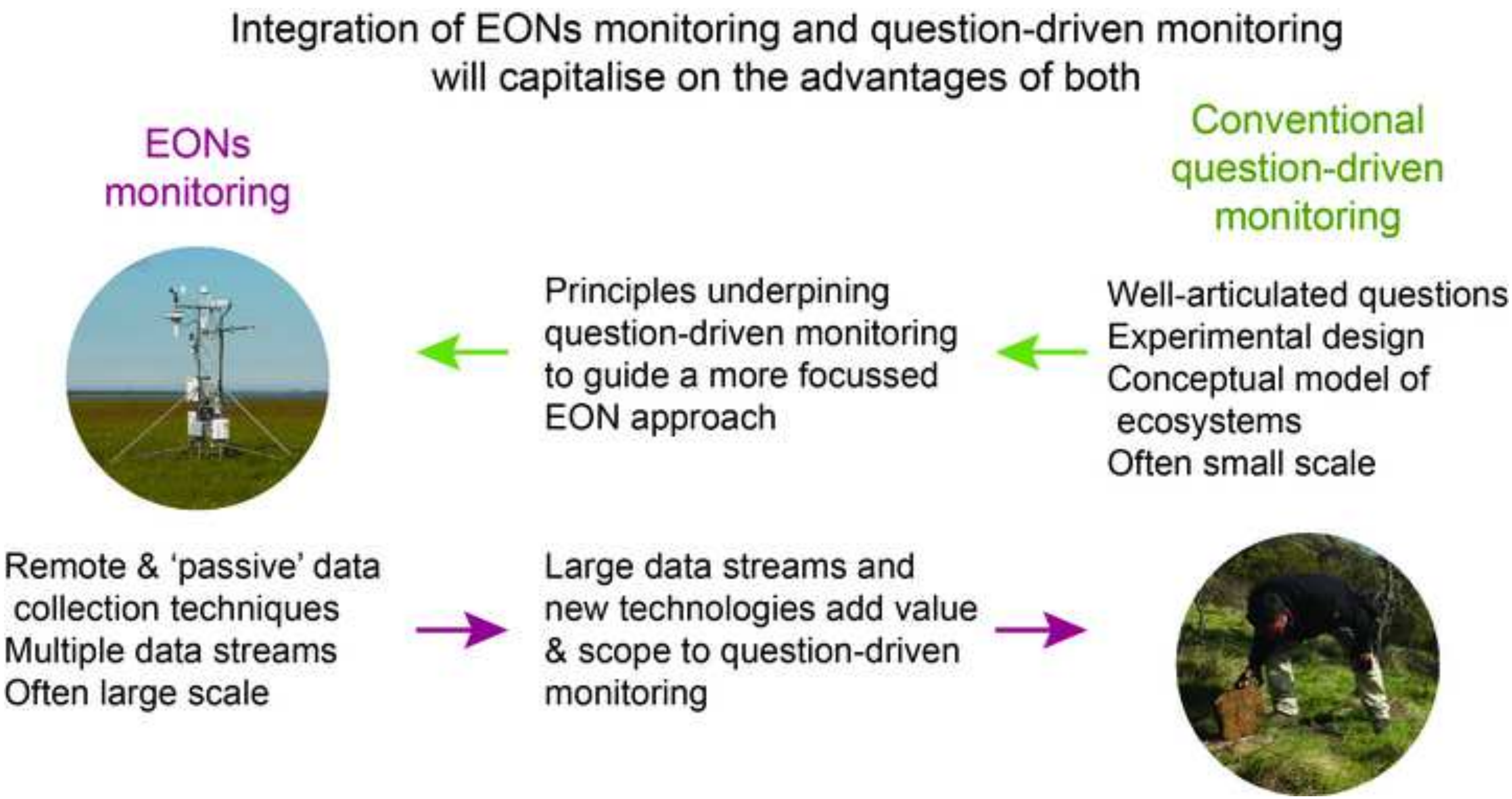
Figure 1


Integration of EONs monitoring and question-driven monitoring
will capitalise on the advantages of both
EONs
monitoring
Conventional
question-driven
monitoring
Principles underpining
question-driven monitoring
to guide a more focussed
EON approach
Well-articulated questions
Experimental design
Conceptual model of
ecosystems
Often small scale
Remote & 'passive' data
collection techniques
Multiple data streams
Often large scale
Large data streams and
new technologies add value
& scope to question-driven
monitoring