Geographic Information Observatories for Supporting Science

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Abstract. In this paper we explore two questions that we feel are important to investigate further if geographic information observatories are to be fruitful research endeavor in GIScience. The first question is simply 'what is a geographic information observatory (and what is it not)?' and the second question is 'what use is a geographic information observatory?'. The construction of large-scale geographic information observatories has the potential to be an exciting development, but it remains unclear what forms they might take. Furthermore, the reasons articulated so far for building these observatories remain largely in the domain of information science and have not been motivated in context to broader scientific problems, such as global climate change. We investigate how geographic information observatories can support science in other fields, focusing on the example of socio-ecological system research. We argue that it is in the application of geographic information observatories toward solving big problems that they can garner community buy-in and demonstrate real impact.

Keywords: geographic information observatory, GIScience, Web Science, socio-ecological systems

1 Introduction

Astronomical and terrestrial observatories have existed since antiquity with perhaps the first state-sponsored observatory as *research institute* having been built in Baghdad in the 9th century CE during the reign of al-Ma'mun [11]. However, it was Galileo and his contemporaries' adoption of the optical telescope for astronomy that led to our modern conceptualization of observatories as houses for observational scientific equipment, such as telescopes. Since that time, advances in observational technology like improvements in telescope design have been undertaken in tandem with changes in science. Observatories have often been built to help find experimental evidence for theoretical advances in physics and astronomy, and as a result technological developments have been made in order to observe phenomena that are not already easy to observe with the existing infrastructure. Equally important, these technological advancements have opened up new avenues of theoretical and applied research in many other fields.

For example, technologies that allowed astronomers to observe the non-visible light spectrum expanded the scope of the observable universe and greatly effected cosmology. Today, observatories are large-scale collaborative infrastructure projects designed to support campaigns that are the outcome of extensive consulting processes and considerable investments of time and money. Examples of modern observatories include the optical Manua Kea observatory, the Very Large Array radio observatory, and the Hubble Space Telescope.

1.1 What are geographic information observatories?

Recently, the analogy of building information and web science observatories has been proposed, though this idea is nascent and remains largely underspecified [13]. Now this idea has been extended to *geographic information observatories* [6]. Although the metaphor of the observatory conjures up many interesting possibilities for what forms geographic information observatories might take, it is important that we work to clarify what geographic information observatories are and what differentiates them from other kinds of observatories. Table 1 presents one simple way of organizing some different types of observatories based on examples. In the case of defining geographic information observatories, we are presented with the question of whether the term *geographic* modifies *information observatory*, or rather do we mean *observatories of geographic information*? In the former case, we have the sense of information observatories that are regional or site-specific in scope–perhaps focusing on the unique characteristics of information in the context of a spatial location and time. The latter interpretation has more to do with understanding the embedding of geographic information in the broader universe of information, for example, examining global patterns in networks of geographic information.

Type of observatory	**Examples**
Geographic observatory [site-specific]	Long-term Ecological Research Network (LTER)[9], Montserrat Volcano Observatory[1]
Geographic observatory [global]	National Ecological Observatory Network (NEON)[7]
Information observatory	Web Science Observatories[13]
Geographic (information observatory) [site-specific]	Urban Observatory (http://www.urbanobservatory.org/)
Observatory of geographic information [global]	(proposed) Portals for spatial, temporal, semantic signatures of place types

Table 1. Different types of geographic and information observatories, with examples.

Both of these interpretations of geographic information observatory can be viewed as distinct from the idea of a geographic observatory (sans information), where the objects of interest–i.e., what are being observed–are terrestrial processes, though the observatory's products are information objects. These information sources and products (from geographic observatories as well as other less-organized and emergent sources) might be the information events that an information observatory observes, however. Even so, since all kinds of observatories perform *information processing*, any line between *geographic observatories* and *geographic information observatories* is quite fuzzy and more exploration of the difference–e.g., in terms of information processing steps subsequent to physical measurement, or in terms of contextual meta-analysis–might help us clarify the form that we would like these observatories to take. For example, depending on the definitions we choose, the Urban Observatory[1] can be considered either a geographic observatory or a geographic information observatory (or perhaps both). As well, although geographic information observatories are in some sense one step removed from the direct process of making observations of the Earth and human behavior, geographic information observatories can still be considered important tools for geographically-related scientific research. Understanding the primary sources of data production, data use, re-use, and integration all fall within the purview of geographic information observatories as we envision them.

However, even if we better define what we mean by *geographic information observatories* that does not necessarily give us a meaningful road map of priorities for how we should proceed toward building the observatories. Instead, what gives us that roadmap is an investigation into *why* geographic information observatories are an important development. One lesson we can take from real-world observatories is that for there to be community buy-in to the investment of time and money necessary to build large-scale observational infrastructure requires clear purpose. In the remainder of this paper we argue that a good strategy is to look deeper into how geographic information observatories can support scientists trying to solve big social and environmental problems.

2 Why do we want to build geographic information observatories?

2.1 The support science argument

Not to ignore our curiosity as information scientists about the nature of the geographic information universe for its own sake, but as we consider the question of *why* we need geographic information *observatories* we feel it is necessary to look to problems that are not restricted solely to the domain of information science. That is, the question of why is driven by the need to solve important problems irrespective of discipline. There is a tendency among geographic information scientists to assert their desire to do GI*Science* (with a big-S on science) and not be simply seen as tool-builders. This perspective focuses on Goodchild's [5] first sense of GIScience (the science of GIS), but ignores the second but equally important sense–that GIScience investigate how GIS can support science. It is

[1] http://www.urbanobservatory.org/

our contention that by linking the outcomes of building geographic information observatories to solving interdisciplinary problems of concern to many (e.g., geographers, Earth scientists, and ecologists)–rather than remaining in the abstract domain of the information universe–there will be much more vested interest in actually building these observatories. Otherwise, we can hardly be surprised if it is considered a niche endeavor, not worthy of large expenditures of research funding and time. Astronomical observatories are no different–even when the research objectives are at the esoteric end of cosmology, there is always an explicit acknowledgement that by building the observatory there will be technological advances that will aid us in other domains as well. For example, the massive computing infrastructure required to store and analyze data from the CERN particle accelerator has driven innovation in distributed grid computing that will be useful in many other fields. Observatories *do* support science and we should not shirk from the idea that although geographic information observatories are in themselves legitimate scientific endeavors, they also support research in multiple domains.

Geographic data is obviously extremely useful in many kinds of research, but in order to get at what we want geographic information *observatories* to look like, we might first start by asking: what are the fields of research where we are severely hampered by a lack of understanding of the kinds, forms, and diversity of geographic data that exist in the information universe? There are likely many answers to this question, but interdisciplinary and transdisciplinary research fields that rely on the synthesis of geographical data from disparate sources are obvious candidates. We would like to highlight one subject of study in particular, **socio-ecological systems**, which we believe would greatly benefit from a better understanding of the geographic information universe, and therefore help justify why we want to build geographic information observatories.

2.2 Exemplar: supporting socio-ecological system research

Socio-ecological systems (also known as social-ecological systems or coupled human-environment systems) concern the holistic study of the complex relations between human social action and biogeochemical and physical systems [2, 17]. The study of socio-ecological systems was borne of the recognition that the artificial division of social systems and environmental systems into discrete research threads does not reflect the actual strong interweaving between human social systems and environmental systems at all spatial and temporal scales. Having a better understanding of socio-ecological systems is at the core of solving many of the very difficult problems (so-called "wicked problems" [10]) that we face in the 21st century, including global climate change, infectious disease pandemics, natural disaster emergency management, sustainable development, resource management, and environmental justice issues.

The socio-ecological system perspective advocates an integrative approach. However, although there is conceivably a vast amount of geographic data that can shed light on understanding socio-ecological systems, most of the data is not integrated, nor even accessible to a scientist in any useful form. In fact, in many cases even when the data is available, it is unclear what data is useful for answering a specific question. In part, this is due to the fact that social data and environmental data are collected and stored using very different procedures and formats, and for different purposes. Furthermore, the study of socio-ecological systems is fundamentally the study of equilibrium, resilience, robustness, adaptability, and vulnerability [14, 4]. But the scale at which we observe geographic processes fundamentally biases our conclusions about these dynamics in socio-ecological systems [8]. Thus, epistemologically we must have a better handle on the scale of the environmental and social processes that are being represented in geographic information [12]. An example of this in climate science is the problem of downscaling [16]. Arguably, getting a better understanding of the scale of the processes represented in geographic information and "scaling effects" on different interpretations of that information is one of the most critical research areas for geographic information observatories.

Socio-ecological systems are adaptive, complex systems operating at multiple spatial and temporal scales, and our sensors of the geographic world are also operating at several spatial, temporal, and thematic scales. Ideally, there is great potential to exploit the increasing availability of multi-resolution and multi-thematic geographic data to model socio-ecological systems. However, because we do not have a good picture of the geographic information universe, it is extremely difficult to match and integrate the relevant data that might be scattered across the information universe to specific socio-ecological research problems. For many socio-ecological analyses, it is often the case that in order to get at a composite social-environmental picture requires using heterogeneous information artifacts that people "leave behind," e.g., through social media, GPS tracking, etc., in combination with environmental sensor data of varying resolutions and themes, such as metagenomic analysis and spatio-temporal microparticle measurements. The investigation of exposure over the life-course of an individual (exposome) is a prime example of this kind of analysis [15].

2.3 What makes up a geographic information observatory?

In the context of answering what form we want geographic information observatories to take we might also identify some of the various aspects geographic information that we want to be able to observe in order to support the scientific process.

Finding what we need. We need observatories that specialize in finding and ingesting geographical data from a multitude of sources. Along many fronts these are already being developed in the context of spatial data infrastructures, linked geo-data repositories, and the like. For the example of socio-ecological research this entails mapping the vast variety of environmental and social geographically-referenced data that are available.

Understanding what we find. We must also understand what kinds of data are useful for what purposes, which is in many ways a much more difficult research problem [3]. In part this is because the information event representing the use of a data set is not transparent in many cases. The observation of this information might not be something for which there is primarily a technological solution. Instead, we might need deep research effort into the sociological study of how scientists use their data. Observatories can attract researchers because they offer functionality to observe (and data about) data use, and thus create the opportunity to look through the lens in the other direction at the research community.

Watching the detectives. We want to measure the change of geographical information, both in terms of content and related conceptual framing and interpretation. For example, in order to recognize that data from a source is used for one purpose by the originating community but has been re-purposed by an unrelated community. We want to be able to observe these differences and their patterns through space and time. Also, at the community-level scientific knowledge is in flux and interpretation of data recorded in the past through a present-day lens will often be distorted.

Studying the use of geographic information. Perhaps of particular importance to *geographic* information observatories, we want to be able to observe the myriad relationships between attributes of geographic information and its use. For example, exploring the relationships between scale and process, and the implications of those relationships for specific scientific research questions, which could also entail observing methodological differences in how scale is conceptualized by different users of geographic information. We could also study the geographic footprint of data in terms of **where** (**when**) it is used as opposed to where (when) it depicts, or **what** it was used for as opposed to what it was made for.

3 Outro

More often than not, geographic information scientists interested in organizing information about socio-environmental and other complex geographic systems are limited to using their "table-top telescopes" that are only pointed in one direction and which collect data that are easy to get, but biased and of limited interest (e.g., Twitter API). Or worse yet, they are information astrologers designing ontologies with no basis in observation! Information observatories (both geographic and non-geographic) do already exist–companies like Google and Facebook and governmental organizations like the United States National Security Agency have developed information observatories that are designed to answer the needs of commercial industry and the intelligence community. Where do we as academic information scientists position our information observatories in this environment? The observatories these organizations have built are powerful, but they are not designed to support scientists working to solve the many difficult problems of the next century. We have an opportunity (and imperative) to build similarly powerful observatories that will support critical research questions in climate change, health care, environmental science, social sciences, and the like.

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