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Social network and content analysis of the North American Carbon Program as a scientific community of practice

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ABSTRACT

The North American Carbon Program (NACP) was formed to further the scientific understanding of sources, sinks, and stocks of carbon in Earth's environment. Carbon cycle science integrates multidisciplinary research, providing decision-support information for managing climate and carbon-related change across multiple sectors of society. This investigation uses the conceptual framework of communities of practice (CoP) to explore the role that the NACP has played in connecting researchers into a carbon cycle knowledge network, and in enabling them to conduct physical science that includes ideas from social science. A CoP describes the communities formed when people consistently engage in shared communication and activities toward a common passion or learning goal. We apply the CoP model by using keyword analysis of abstracts from scientific publications to analyze the research outputs of the NACP in terms of its knowledge domain. We also construct a co-authorship network from the publications of core NACP members, describe the structure and social pathways within the community. Results of the content analysis indicate that the NACP community of practice has substantially expanded its research on human and social impacts on the carbon cycle, contributing to a better understanding of how human and physical processes interact with one another. Results of the co-authorship social network analysis demonstrate that the NACP has formed a tightly connected community with many social pathways through which knowledge may flow, and that it has also expanded its network of institutions involved in carbon cycle research over the past seven years.

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1. Introduction

Climate change has emerged as a significant scientific, social and economic challenge to society (IPCC, 2014). Understanding how climate change may evolve over the coming decades requires significant investment in research about carbon and how it cycles, through both living and nonliving states (Smil, 1996). Scientists frequently study these biogeochemical cycles in the context of subsystems such as the terrestrial biosphere (land-based living systems), oceanic systems (both organic and inorganic forms of carbon), and the atmosphere (Falkowski et al., 2000). These investigations may also include the specific role humans play in the carbon cycle, such as the impact of human-generated emissions or the consequences of climate change to agriculture and food systems (Berthelot et al., 2002; Bradbear and Friel, 2013; Dempewolf et al., 2014; Shindell et al., 2012). Carbon cycle science is relevant to a great many aspects of life as we know it: the condition of our environment, the quality of air we breathe, water resources, the food that we eat, and the energy we consume.

Engaging across the social and physical sciences to embrace all aspects of the carbon cycle is very challenging, particularly when the implications of the research are both political and economic. The North American Carbon Program (NACP) is one of the few programs on this topic to host collaborative activities cutting across all carbon cycle science disciplines, and promoting opportunities to foster interdisciplinary and intramural collaboration whose objective it is to do interdisciplinary research that results in information that can be directly relevant to critical social decision making (Michalak et al., 2011). Central to the program's science agenda is the engagement of social, economic and policy-relevant research in order to improve how carbon cycle science is conducted to ensure policy-relevant findings. This paper uses communities of practice

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as a conceptual model for exploring how the NACP has fared in creating such a knowledge network, both in terms of measuring the connectivity among program participants, and in terms of incorporating measuring social, economic and policy-relevant topics into carbon cycle science research.

1.1. History of the NACP

The NACP was formally recognized by the United States in 2002 under the mantle of the nation's overall climate change management strategy (Wofsy and Harriss, 2002). The first implementation plan for the NACP put forward a research agenda that was centered on quantifying and understanding carbon sinks and sources in North America and surrounding oceans, and the integration of such information into socially, economically, and politically relevant decision-support systems (Sarmiento and Wofsy, 1999; Wofsy and Harriss, 2002). The *State of the Carbon Cycle Report* established that North America is a net source of CO_2 to the atmosphere, due to fossil-fuel emissions and that there are globally important carbon sinks whose future is highly uncertain (King et al., 2007). Understanding how humans both experience and influence the carbon cycle and climate change is critical to the interests of decision makers (Bernabo, 1995; Feldman and Ingram, 2009), such as those who confer support upon the member agencies of the NACP through funding and other resources.

In 2007, The US North American Carbon Program (NACP) sponsored its first "all-scientist" meeting to review progress in understanding the dynamics of the carbon cycle of North America and adjacent oceans, and to chart a course for improved integration across scientific disciplines, scales, and Earth system boundaries (Birdsey et al., 2007). Following this meeting, a 2011 US Carbon Cycle Science Plan was published that set forth priorities for research in carbon cycle science for the coming decade (Michalak et al., 2011). In addition to reaffirming the need for basic research and for continuing traditional research in carbon cycle science, the plan recommended substantial expansion in research on the efficacy and environmental consequences of carbon management policies, strategies, and technologies; prioritization of research on human elements of the carbon cycle; an increased exploration of the direct impact of rising greenhouse gas concentrations and carbon-management decisions on ecosystems, species, and natural resources; and research on how to express uncertainty in all aspects of the global carbon cycle as well as improved ways of conveying those uncertainties to policy and decision makers, as well as society at large. To achieve these objectives, the report authors recommended a substantial focus on conducting research that integrates human dimensions with the biologic, atmospheric, and oceanic sciences. Social processes that drive land use and fossil fuel emissions should be quantitatively integrated into land use/cover and emissions modeling to promote the integrated carbon, climate, and social modeling needed to provide science and analytical tools for climate action programs at various levels of government (Michalak et al., 2011).

The challenges facing the North American Carbon Program bring to light the larger issue as to how organizations, agencies, and nations at any level can cultivate the development of inter-organizational and interdisciplinary networks targeted toward creation of specific kinds of knowledge resources. To that effect, this paper seeks to apply a systemic approach for assessing the knowledge creation that takes place within a research program such as the NACP. How might we compare the professed knowledge goals of the NACP, or similar programs, to the actual knowledge created by participants? We also consider how to describe the state of collaborations between participants within such a community. How do collaborations amongst core participants grow and change over time? Are there changes in researchers' tendencies to collaborate across institutional boundaries over the same period of time? These are the questions we seek to answer in analyzing the NACP as a community of practice.

2. Theory and rationale

A *community of practice* is defined as "a group of people who share a common set of problems, or a passion about a topic, and who deepen their knowledge and expertise in this area by interacting on an ongoing basis". Wenger et al. (2002) describe three structural elements to the CoP model: domain, community, and practice. Domain refers to the knowledge concerns and issues around which the CoP is structured. A well-defined knowledge domain translates to a strong sense of purpose, guiding the activities of members. It also implies a shared competence and commitment to the subject matter. Domain manifests as the specific knowledge the community develops, shares, and maintains. The community element references the social environment itself: the people and relationships through which learning, knowledge transfer, and knowledge creation takes place. Practice concerns all of their rituals, systems of meaning, and channels of communication.

The CoP model provides a theoretical foundation upon which to base discussion and analysis of the scientific community and its research. Structural elements of the model aid us in communicating fundamental assumptions as well as limitations of the study (Wenger et al., 2002). Additionally, it aids us in understanding and expressing the relationships and distinctions between a community, individual members, and separate but participatory institutions that provide support to scientists. Other examples of the CoP model being employed to study knowledge networks via shared resources and sustained interaction, including an ethnographic study of climate change adaptation projects at the science-policy interface (Iyalomhe et al., 2013).

2.1. Community of the NACP

There is no a single form of social structure which qualifies as a community of practice, and membership is not by virtue of traditional organizational or departmental boundaries. The size of the community could be less than ten, or it could number into the hundreds. It might be community of individuals who all live or work in close proximity to one another, or it could be distributed across a wide range of geographical locations and organizational boundaries. The CoP model does, however, predict an approximate distribution of member participation which corresponds to three broad levels of investment within the community: (1) a small group of core members who both attend meetings regularly and who also oversee functional tasks, (2) active members who regularly attend meetings, and (3) peripheral members who only occasionally participate in the community (Wenger et al., 2002). As part of conceptualizing the NACP as a community of practice, we will consider if the distribution of participation frequency in meetings shows any agreement to the distribution suggested by the model. We will describe and analyze the community in terms of relationships between core participants using social network analysis methods. As the NACP also seeks to increase collaboration between different institutions studying the carbon cycle, we will furthermore look at how the relationships between individuals translate to connections between the institutions they represent.

2.2. Knowledge domain of the NACP

A domain is "a statement of what knowledge the community will steward" and "a commitment to take responsibility for an area of expertise" (Wenger et al., 2002). We have noted that the knowledge domain of the NACP is codified within the US Carbon Cycle Science

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