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Commentary

The opportunities and responsibility for carbon cycle science in the U.S.

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ABSTRACT

Strategies to address climate change increasingly include options to manage the terrestrial and oceanic portions of the carbon cycle, whether as part of national commitments to international treaties, or as elements of entrepreneurial business plans. Carbon cycle science has much to contribute to informing these strategies, but must consider how to organize so as to best provide more "usable science." Experience in other areas of earth systems science demonstrates that for knowledge to be more useful to decision makers and others outside the scientific community, deliberate mechanisms must be created to prioritize, conduct and disseminate research that are informed by the needs of the target audience. Carbon cycle science has not yet explored operating in this more deliberate mode. Carbon management thus presents an opportunity for some portion of carbon cycle research to become more directly relevant to societal decision-making through innovative ways of organizing research and operating programs.

After my Ph.D. in biological oceanography, I spent 6 years at NOAA, the National Oceanic and Atmospheric Administration, a U.S. federal agency that, among other things, issues weather forecasts, manages coastal fisheries, and conducts applied scientific research "to meet our nation's economic, social and environmental needs." I served in the Climate and Global Change Program, a part of the larger, multi-agency U.S. Global Change Research Program from 1996 to 2002. Eventually I became program manager for a relatively small but influential program in carbon cycle science. One day, after a presentation I was particularly proud of on the new, integrated vision for federal carbon cycle science, I was asked a critical question: "how would the information being generated by the program be used in decision making? Where were the "societal implications" included?" In previous decades, such a question might have been acceptably answered by saying, 'eventually someone, somewhere will find it useful for decision making.' In the late 1990s, and early 2000s, however, NOAA's climate programs were being challenged to be relevant, and the results of research in other areas of the climate portfolio indicated that the "loading dock" approach was ineffective at producing useful information (Cash et al., 2006). And so, the questions nagged at me: who was using the information my program produced? Did they have what they needed? Did it help them make better decisions? Was carbon information even a factor in decision making? In the years that followed, I found few sources available to help me even approach answering these questions for the carbon program. In my research today I focus on this issue, and have come to believe that by answering questions such as these, the practice of carbon cycle science will benefit, as will society as a whole, as we come more and more to manage carbon in the environment.

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Societies are already starting to manage carbon deliberately. Internationally, of course, the Kyoto Protocol of the UN Framework Convention on Climate Change is now in force. The Protocol included the possibility of counting emission ''removals by [carbon] sinks'' (such as through forestry or agricultural management practices) and has spawned enormous interest in such activities and projects on the ground, whether or not a nation has ratified the Protocol. In the European Union, whose nations have ratified the Kyoto Protocol, efforts include cross-EU emissions trading, as well as a host of national initiatives to reduce emissions directly. Worldwide, numerous pilot projects in carbon sequestration and capture and storage have been implemented, from the forests of South America, to rock reservoirs in Saskatchewan, the cornfields of Iowa and under the ocean floor in the North Sea.

Policy and economic systems in the United States are beginning to recognize the opportunity to manage carbon as well, despite the fact that the U.S. has not ratified the Kyoto Protocol (Dilling, 2007). For example, a number of states in New England and provinces in northeastern Canada have been working together for several years to develop an emissions trading system known as Regional Greenhouse Gas Initiative (RGGI). The goal of the program is to ''develop a regional cap and trade program covering greenhouse gas emissions.'' Offsets, or carbon sinks, are now being included on a limited basis. California has recently embarked on several historic initiatives, including the regulation of vehicle carbon dioxide emissions, a transnational partnership with the United Kingdom on a host of climate-related actions and technology development, and an agreement to cap greenhouse gas emissions from industry state-wide. In the private sector, the Chicago Climate Exchange has now organized and is trading greenhouse gas emissions allowances, including carbon offsets from agriculture and forestry projects. At the very local scale, cities have been moving ahead to manage their own carbon footprint. Called Cities for Climate Protection, a worldwide network of cities under the International Council for Local Environmental Initiatives (ICLEI) has been working for years to reduce greenhouse gas emissions at the local level. The recent U.S. Mayors Climate Protection Agreement is perhaps yet another sign that other scales of government are interested in moving forward with options to address climate change, including potentially management of carbon. The Western Governors' Association ''Clean and Diversified Energy Initiative,'' launched in 2004, has already received a technical report from a broad group of stakeholders on carbon management and policy considerations. Non-governmental organizations that are brokering carbon, farmers who are deciding whether to change their land management practices, utilities interested in offsetting their emissions, businesses, and states that are developing carbon policies are all part of the trend to manage carbon deliberately.

While carbon management is still in its experimental, toddler stage, these anecdotes suggest that as societies contemplate limiting or reducing carbon emissions to the atmosphere, management of the rest of the carbon cycle is increasingly a part of the picture. Carbon cycle science, it would seem, could play a pivotal role in informing decisions taken for the directions of policies, the actions of the private sector or non-governmental organization arena, and the choices of individuals for effective climate responses. For example, carbon cycle science might be asked to provide insight on issues such as the permanence of various options, tradeoffs with other valued outcomes, options for verification and measurement, and so on. Of course, some nations have already made an explicit connection between carbon science and policy in certain ways and at certain levels (e.g. Sweden, see Lövbrand, 2007).

In order to effectively support decision making, however, science must be timely, relevant and context-sensitive (see McNie, 2007 for a review). There have been many ways that scholars have described these requirements, including ''credible, salient, and legitimate'' (Cash et al., 2003), or ''use-inspired'' (Stokes, 1997). I am partial to the experience of researchers working in the seasonal climate forecasting arena—this topic is close to my heart because of the investments that NOAA has made in openly examining how and why such climate forecasts are used or in many cases, not used. Skilled seasonal climate forecasts have only become possible in the past two decades, because of breakthroughs in understanding and modeling the El Niño-Southern Oscillation (ENSO) and other climate phenomena. Early hopes that these scientific advances would result in better societal outcomes in drought and flooding-prone areas have been somewhat tempered by the complex reality of trying to apply newly-minted knowledge. In some areas, use has greatly improved outcomes, such as in Australian farming and preparation by South Pacific island nations for drought. In other cases, outcomes have been less beneficial. Some of the principles that have emerged from this body of work have been nicely summarized by Lemos and Morehouse (2005). They state that research intended for use by decision makers should ''directly reflect expressed constituent needs, should be understandable to users, should be available at the times and places it is needed, and should be accessible through the media [meaning mechanisms of obtaining information] available to the user community.'' Such requirements can only be met through a deliberate process of interactive research, whether directly by involving potential users in the research (as many of the climate-related Regional Integrated Sciences and Assessment projects of NOAA do) or by proxy through interactions with active boundary organizations or individuals.

Such a process of research is different from what the vast majority of carbon cycle scientists are familiar with. ENSO climate researchers were unfamiliar with this type of work too when they first started down this path 20 years ago. Conducting research with a deliberate use in mind and even involving potential users along the way is a paradigm shift for many scientists. But for those conducting research intended to be useful for societal decision-making, it is a necessary and rewarding shift, as a host of leading scientists involved in ENSO-related research will tell you. Committing some resources to this mode of operating is also beneficial to those carbon cycle scientists who wish to continue doing basic research that does not consider the needs of society. Without a clear distinction between research that is being done with an active strategy to serve decision makers needs and basic research, all research risks being subjected to multiple criteria for evaluation that in the end, frustrates scientists and program managers alike. Establishing a deliberate focus on research that is designed to be useful to decision makers at various scales and evaluating it as such, then allows for more basic research that does not seek to be useful to flourish and be evaluated on its own terms. This is not meant to say that research done to be relevant to society is not fundamental, discovery-oriented research. Scholars in this field will tell you that such research often presents the most challenging, interdisciplinary problems they have had to solve. Stokes (1997) lays out such a premise explicitly in describing this intersection as ''Pasteur's Quadrant,'' where scientific discovery and addressing societal need go hand in hand.

So where do we stand in the carbon cycle science arena? As part of the Climate Change Science Program, carbon cycle science has promised, and is increasingly called upon to be, relevant to society. To date, we only have a few experiments with carbon science programs that take a new approach to creating usable science, i.e. where research has been conducted explicitly to serve current decision making, such as the NASA Applied Sciences program and the Consortium for Agricultural Soils Mitigation of Greenhouse Gases (CASMGS) sponsored by USDA (e.g. Logar and Conant, 2007). As a community, we have not yet embraced the fact that we may have new decision maker interests for carbon cycle science, and that it may require some new offshoots of current research and new modes of operating. The needs of decision makers for carbon information have never been systematically assessed. Sarewitz and Pielke (2007) describe this as the need to ''reconcile supply and demand'' for information. If experience in other scientific realms can serve as any kind of a guide for us, we must invest in projects seeking to deliberately determine how carbon information is being used (or not), to understand the context of decision making and the role of carbon information in that context. To what extent carbon cycle science can be relevant to decisions at the wide variety of scales at which carbon management is occurring is an open question in many contexts. For example, a study of the Large-Scale Biosphere-Atmosphere transnational project in Brazil (Lahsen and Nobre, 2007) suggests that in some cases, carbon information may not in fact be as relevant as other types of knowledge for particular situations.

The guiding policy documents of carbon cycle science at the federal level, whether community visions or those of the U.S. Climate Change Science Program, do not currently demonstrate awareness of the needs of decision makers within the diverse range of households, governments, organizations and businesses for additional information on carbon cycle science. It may very well be that these decision makers are content to manage carbon largely without the benefit of scientific input into their decision process. It may also be the case, however, that information needs for science do exist in the area of carbon management that are being unmet. Without a deliberate strategy to discover which of these scenarios might be true, carbon cycle science will likely miss opportunities to be useful, and will not be able to meet its goal of being a program of scientific research that is ''strategically prioritized to address societal needs'' (Sarmiento and Wofsy, 1999).

The evolution of the carbon cycle science program and its policy context would suggest that carbon cycle science may be moving from a period of identifying and alerting society to a problem, to one of being relevant for solutions. In the 1970s and 1980s, carbon cycle science was focused on finding out how much of the carbon being added to the atmosphere from human activities was being taken up by the land and the ocean in the context of fleshing out knowledge on climate change. In recent decades, effort has focused on refining the spatial description of carbon uptake and release, understanding budgets at finer spatial and temporal scales, and honing in on process understanding of why the carbon cycle functions as it does. Now, as society is indeed embarking on carbon management, we face an opportunity to apply this knowledge and new knowledge still to be developed to the pressing issues of how to intelligently manage the environment in the face of climate change. Again, this is a brave new world for carbon scientists, but one that cannot be avoided. Entering into it brings with it additional challenges of delineating appropriate boundaries, maintaining credibility, and ensuring transparency and access to knowledge. Because of the scales at which carbon will be managed, from the individual farmer to the national policy directive, transparency and openness pose particular challenges (e.g. see Lövbrand, 2007). Whose needs for information will be served by the limited resources that the federal system might provide? Which scales are most important? How do we decide?

If we, the carbon cycle science community, do wish to begin a deliberate process to explore what potential uses of carbon-related science exist, there are a few lessons we should consider from other communities that have tried to venture into this new frontier of creating ''knowledge-action systems'' (NRC, 2005):

- We cannot assume that we know users' needs—they must be investigated and discovered through a deliberate process. In some cases this requires ongoing discovery and dialogue between what might be ''desired'' by users and what is possible from a scientific perspective.
- Such a process might include direct interaction between potential users and decision makers, or it may be brokered through boundary organizations, who mediate between the worlds of science and practice.
- Attention must be paid to the question of which users, which needs, and with what resources. Some needs may be appropriately met by research in the private sector, while others might be fruitfully addressed by federal research funds, state funds or non-profits.
- In some cases, meeting users' needs may require new research. In others, it may be a matter of synthesizing, translating, assessing, or otherwise communicating existing knowledge in a way that is accessible to decision makers.

In 2007, it will have been 50 years since Keeling began his pioneering measurements on top of a volcanic mountain in Hawaii. It will have been 30 years since the U.S. National Academy of Sciences wrote that ''the prospect of damaging climatic changes'' justified further research into the carbon cycle and launched what was to become a US$ 2 billion a year climate and global change research program. As carbon management becomes a reality, now is the time for that program to a focus on delivering usable carbon science. The opportunity and responsibility await.

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