

## ***Global Observations: One perspective on the future***

### ***Berrien Moore III***

The world faces significant environmental challenges: shortages of clean and accessible freshwater, degradation of terrestrial and aquatic ecosystems, increases in soil erosion, changes in the chemistry of the atmosphere, declines in fisheries, and the likelihood of substantial changes in climate. These changes are not isolated; they interact with each other and with natural variability in complex ways that cascade through the environment across local, regional, and global scales. Addressing these societal challenges requires that we confront key science questions related to ice sheets and sea level change, large-scale and persistent shifts in precipitation and water availability, transcontinental air pollution, patterns of greenhouse gases, shifts in ecosystem structure and function in response to climate change, impacts of climate change on human health threats, and occurrence of extreme events such as severe storms, heat waves and earthquakes and volcanoes.

Key questions include:

- Will there be catastrophic collapse of the major ice sheets, including Greenland and West Antarctic and, if so, how rapidly will this occur? What will be the time patterns of sea level rise as a result?
- Will droughts become more widespread in the western U.S., Australia, and Sub Saharan Africa? How will this affect the patterns of wildfires? How will reduced amounts of snowfall change the needs for water storage?
- How will continuing economic development affect the production of air pollutants and how will these pollutants be transported across oceans and continents? How are these pollutants transformed during the transport process?
- What are the sources and sinks of greenhouse gases? What are the processes that control these fluxes? Can they be managed? How will they respond to climate change?
- How will coastal and ocean ecosystems respond to changes in physical forcing, particularly those subject to intense human harvesting? How will the boreal forest shift as temperature and precipitation change at high latitudes? What will be the impacts on animal migration patterns and invasive species?
- Will previously rare diseases become common? How will mosquito-borne viruses spread with changes in rainfall and drought? Can we better predict the outbreak of avian flu? What are the health impacts of an expanded "Ozone Hole" that could result from a cooling of the stratosphere, which would be associated with climate change?
- Will tropical cyclones and heat waves become more frequent and more intense? Are major fault systems nearing release of stress via strong earthquakes?

The required observing system is one that builds upon the current international fleet of space-based instruments and brings us to a new level of integration in our understanding of the Earth system.

In the USA, the National Research Council released in early 2007 its first Earth science "Decadal Survey" focused on identifying the needed space-based measurements to address the issues of global environmental change.<sup>1</sup> The primary work in developing the decadal observing strategy took place within the survey's seven thematically organized science panels. Six of the panels were organized to address multi-discipline issues in the general areas of climate change, water resources, ecosystem health, human health, solid-Earth natural hazards, and weather. This

---

<sup>1</sup> <http://www.nap.edu/catalog/11820.html>

categorization is quite similar to the organizing structure used in the GEOSS process. The assessment and subsequent prioritization were based on an overall analysis as to how well each mission satisfied the criteria and high-level community objectives. Recommendations from previous community-based reports such as those from the World Meteorological Organization were also considered.

In establishing this set of missions, it was recognized that a successful program is more than the sum of its parts. As a set, the recommended missions were designed to achieve a robust, integrated program—one that does not crumble if one or several missions in the prioritized list are removed or delayed or if the mission list must evolve to accommodate changing needs. Robustness is thus measured by the strength of the overall program, not by the particular missions on the list. It is the range of observations that must be protected rather than the individual missions themselves. In addition to robustness, there is a formal recognition in the importance of international cooperation and an open flow of data.

The issues associated with the global carbon cycle and climate offers an important example of the integrated nature of the recommended program.<sup>2</sup> Fossil fuel combustion and land-use change are the primary causes for the 35+% rise in atmospheric CO<sub>2</sub> since 1750. Recently, the rate of CO<sub>2</sub> emissions growth has increased significantly, and it appears that the fraction of emissions that remain in the atmosphere has increased. Neither the current state of the science nor our observational systems can account for the growth rate and inter-annual variations of atmospheric CO<sub>2</sub>. The variability of the year-to-year growth in atmospheric CO<sub>2</sub> cannot be explained by the variability in fossil fuel use; rather it appears to reflect primarily changes in terrestrial ecosystems that are connected with large-scale weather and climate modes. The overall pattern is important, and we do not understand it. It is one of several central questions about our changing planet.

In summary, on Earth, there is much change afoot. The changes are many and rapid, perhaps more rapid than at any time in human history; perhaps more rapid than at any time in Earth's history. The human-induced changes are over and above the stresses imposed by the natural variability of a dynamic planet. The accumulation and interaction of these changes may well threaten our well-being and our planet's well-being.

The linked challenges of confronting and coping with global environmental change and addressing and securing a sustainable future are daunting and immediate, but they are not insurmountable. The challenges can be met, but only with a more vigorous and visionary approach to understanding our changing planet. It requires a new stage in the Exploration of the Earth from space.

This paper addresses some of the challenges of developing integrated Earth observations and models with sufficient credibility and robustness to address these challenging issues.

## Refs.

- 2 Dilling L, Doney SC, Edmonds J, Gurney KR, Harriss R, Schimel D, Stephens B, Stokes G. 2003. The role of carbon cycle observations and knowledge in carbon management. *Annual Review of Environment and Resources* 28: 521-558 2003.
- Integrated Global Carbon Observing Strategy (IGOS): Carbon Theme Report, International Geosphere-Biosphere Programme (IGBP). US Climate Change Science Program (CCSP), 2003, available at <http://www.climatescience.gov/>;
- US Carbon Cycle Science Program (CCSP), 2004, available at <http://www.carboncyclescience.gov/>;
- Tans PP, Fung IY, Takahashi T. 1990. Observational Constraints on the Global Atmospheric CO<sub>2</sub> Budget. *Science* 247 (4949): 1431-1438;
- Monitoring Carbon From Space, *Eos*, Vol. 86, No. 41, 11 October 2005, pages 384-385;
-

Baker, D.F., S. Doney, and D.S. Schimel, Variational data assimilation for atmospheric CO<sub>2</sub>,  
*Tellus-B* (in press);

Crisp D, Atlas RM, Breon FM, Brown LR, Burrows JP, Ciais P, Connor BJ, Doney SC, Fung IY,  
Jacob DJ, Miller CE, O'Brien D, Pawson S, Randerson JT, Rayner P, Salawitch RJ, Sander  
SP, Sen B, Stephens GL, Tans PP, Toon GC, Wennberg PO, Wofsy SC, Yung YL, Kuang  
Z, Chudasama B, Sprague G, Weiss B, Pollock R, Kenyon D, Schroll S 2004 The Orbiting  
Carbon Observatory (OCO) Mission. *Advances in Space Research* 34 (4)700-709