NEWS

Afghanistan Earthquake Hazards Mapped

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As part of efforts to build capacity within Afghanistan for studying, preparing for, and responding to earthquakes, the U.S. Geological Survey has released a map of potential earthquake hazards within the country.

Afghanistan is located in a tectonically active area near where the Indian and Eurasian plates collide, and earthquakes powerful enough to cause significant damage or fatalities occur every few years. However, decades of violence and strife have left the country with few scientists and limited resources to address geohazards. The U.S. Agency for International Development commissioned the USGS to assist in the nation's reconstruction efforts by assessing seismic hazards there.

In developing the hazards map, scientists compiled a catalog of historical earthquakes, mapped the country's geologic regions and fault systems, determined which faults are active, and evaluated how seismic energy would dissipate as it propagates from the source. Four faults were found to hold the greatest hazard.

The most notable of these faults is the Chaman Fault, which runs diagonally through the eastern part of the country and comes within miles of Kabul, the country's capital and largest city. It is a large strike-slip fault system similar in type to the San Andreas Fault in California. However, unlike the San Andreas, for which the hazards and risks are reasonably well understood and modeled, the extent of hazard and risk posed by the Chaman Fault is not yet well known because the geological characteristics have only been identified in general terms from remote sensing, said Harley Benz, scientist in charge at the USGS National Earthquake Information Center in Golden, Colo.

"What we have done is provided a first-order understanding of the hazards," Benz said. Afghan scientists and others can then combine this data with field studies and demographic data to evaluate the risk to important areas, such as Kabul or Kandahar, he added.

The USGS has begun building capacity so that Afghan scientists can take the next steps in geohazards research, including performing field studies. The USGS and British Geological Survey worked together to rebuild the Afghan Geological Survey's building in Kabul. In October 2006, the USGS, along with AGS and Kabul University, reconstituted the Kabul seismic station after two decades of being offline; data is now available in near real time. And the USGS has begun training AGS scientists who will serve as the core of a new geohazards team. Three scientists are currently in the United States being trained on instrumentation; three more will be trained later this summer in geology, active faults, and tectonics.

Ambassador of the Islamic Republic of Afghanistan H.E. Said Tayeb Jawad indicated at a 30 May briefing that the seismic hazard map will help in the design of new roads, much-needed dams and power plants, schools, factories, homes, and villages. In addition, he noted that the reconstituted seismic station will provide crucial information for the entire region.

The hazards map and additional information are available in the USGS Fact Sheet "Earthquakes Pose a Serious Hazard to Afghanistan," which can be found at http://pubs.usgs.gov/fs/2007/3027

—SARAH ZIELINSKI, Staff Writer

MEETINGS

Investigators Share Improved Understanding of the North American Carbon Cycle

U.S. North American Carbon Program Investigators Meeting, Colorado Springs, Colorado, 22–25 January 2007

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The U.S. North American Carbon Program (NACP) sponsored an "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. The meeting participants also addressed the need for better decision support tools for managing the carbon cycle of North America, so that strong science can inform policy as interest in taking action increases across the nation.

Herein we report on themes to integrate the diversity of NACP science and fill significant gaps for understanding and managing the North American carbon cycle: integration among disciplines involving land, atmosphere, and ocean research; strengthening data management infrastructure to support modeling and analysis; identification of study regions that are critical for reducing uncertainties in the North American carbon balance; and integrating biophysical science with the human dimensions of carbon management and decision support.

NACP requires cross-disciplinary integration to evaluate the range of carbon sources and sinks contributing to the carbon balance of North America and adjacent oceans. For example, carbon dynamics in coastal margins are poorly understood, in part because few studies have spanned terrestrial, atmospheric, and ocean reservoirs and disciplinary boundaries. Improved integration would reduce gaps in knowledge of the carbon cycle and how it is changing, and improve attribution of changes to major driving factors such as climate variability, wildfires, insects, and land-use change.

Integrated long-term observation systems are the backbone of the NACP. Some critical observations are "contributed" to the NACP from well-established programs such as land inventories conducted by the U.S. Department of Agriculture. The AmeriFlux observation network can quantify the effects of climate variability on the carbon cycle at seasonal to interannual timescales. An open ocean observing system is being developed as part of the Global Earth Observation System of Systems (GEOSS). Remote sensing observations and analyses have proven critical to supporting biophysical modeling activities within NACP. The meeting participants noted that long-term continuity of these systems is essential.

Equally important is the need to support integrated modeling with robust data management. Large investments in individual projects were not matched by data system infrastructure to enable storage, search, and access of data.

Meeting participants identified a number of regions where intensive studies can fruitfully address NACP goals. In addition to the ongoing midcontinent intensive study, these regions include coastal margins, the interior West region of mixed grasslands and woodlands, and the boreal/Arctic region. Lack of systematic monitoring and comprehensive modeling across all of North America represents a critical shortcoming of carbon cycle science.

To achieve its objectives, the NACP must integrate 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 emergence of the carbon/climate/human modeling needed to provide science and analytical tools for climate action programs at various levels of government. Decision support integrated with basic research would ensure that outcomes are as intended.

A companion meeting followed that involved the carbon programs of Canada, Mexico, and the United States, offering the intriguing possibility of better understanding and management of the carbon cycle by considering a broader array of data sources, models, and management opportunities in the context of diverse national goals, policies, and land-use histories within North America.

The full text of this meeting report can be found in the supplement to this *Eos* edition.

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FORUM

Pattern Informatics and Cellular Seismology: A Comparison of Methods

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The recent article in *Eos* by *Kafka and Ebel* [2007] is a criticism of a NASA press release issued on 4 October 2004 describing an earthquake forecast (http://quakesim.jpl.nasa.gov/scorecard.html) based on a pattern informatics (PI) method [*Rundle et al.*, 2002]. This 2002 forecast was a map indicating the probable locations of earthquakes having magnitude $m \geq 5.0$ that would occur over the period of 1 January 2000 to 31 December 2009. *Kafka and Ebel* [2007] compare the *Rundle et al.* [2002] forecast to a retrospective analysis using a cellular seismology (CS) method. Here we analyze the performance of the *Rundle et al.* [2002] forecast using the first 15 of the $m \geq 5.0$ earthquakes that occurred in the area covered by the forecasts.

Twelve of these $m \geq 5.0$ earthquakes occurred after publication of the *Rundle et al.* [2002] forecast, but all 15 occurred prior to publication of the criticism by *Kafka and Ebel* [2007]. The observed success of the *Rundle et al.* [2002] method was substantially greater than could have been expected based on any previously published work, either in 2002 or on 4 October 2004, when the NASA press release appeared.

NASA issued the press release to document the greatly increased resolution and specificity in predictions of future earthquake locations that have become possible, particularly when compared with other then-current forecast products such as the National Seismic Hazard Map (http://earthquake.usgs.gov/research/hazmaps/products_data/images/nshm_us02.gif), which is a forecast of ground shaking over a 50-year period. Since the NASA press release was issued, there has been a significant expansion of interest [*Field*, 2007] in time-dependent forecasts of future earthquake locations of the type first published by *Rundle et al.* [2002].

The *Kafka and Ebel* [2007] article argues that a CS forecast method published by *Kafka* [2002] is superior to the PI method as published by *Rundle et al.* [2002], so the Rundle et al. results should have been anticipated and were not surprising. However, systematic examination reveals major differences between the method published by *Kafka* [2002] and the *Kafka and Ebel* [2007] implementation: *Kafka* [2002] did not decluster the small earthquake catalog, whereas *Kafka and Ebel* [2007] did. Also, *Kafka* [2002] used small earthquakes having $m \geq 3.0$ to define the forecast area, whereas *Kafka and Ebel* [2007] changed the magnitude of the declustered small earthquakes to $m \geq 4.2$ to optimize performance of the method. The method used by *Kafka and Ebel* [2007] is therefore not the same method described by *Kafka* [2002].

Most important, the *Kafka and Ebel* [2007] analysis was published after all of the 15 earthquakes $m \geq 5.0$ had occurred, thereby allowing the authors the opportunity to change their forecast model to produce optimal results, an

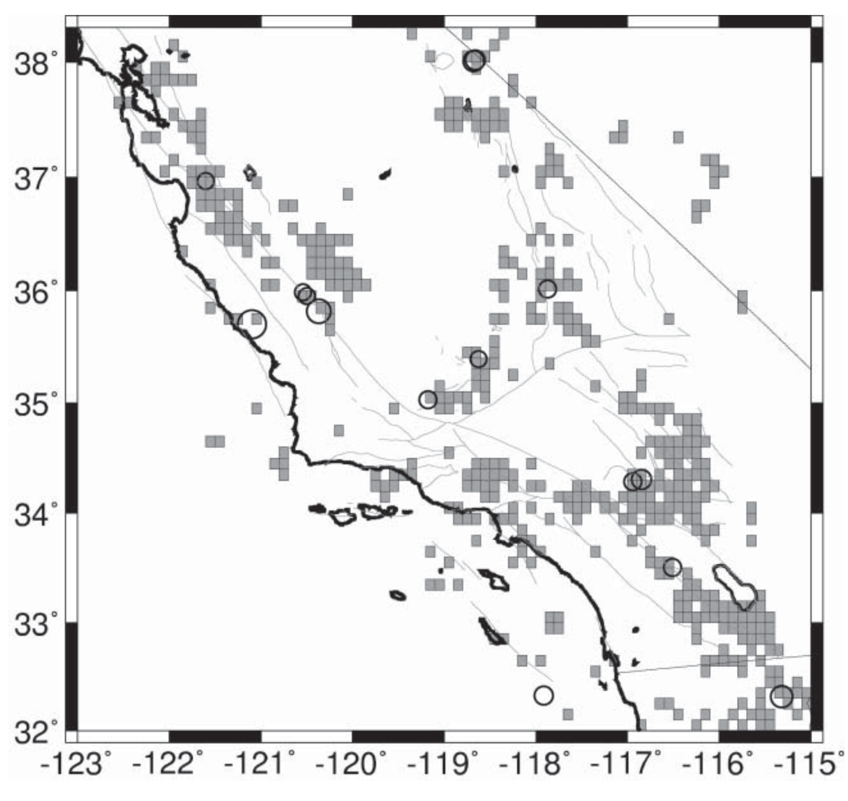

Fig. 1. Individual hot spot pixels and earthquakes corresponding to the original color-contoured map of Rundle et al. *[2002, Figure 4] for a hit rate of 14 out of 15, or 93%. Original map also reproduced as Figure 1 of* Holliday et al. *[2005] with corresponding pixel plots in Figure 4 there.* Kafka *[2002] normalizes forecast area to land (map) area, a practice that we follow here. The shading covers 476 (13.9%) of the 3427 total land pixels on the map and forecasts the locations of 14 of 15 large earthquakes. To be counted as a hit, the epicenter of the large earthquake must fall directly on a gray hot spot pixel. There is no margin of error allowed.*

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Supplementary material to "Investigators Share Improved Understanding of the North American Carbon Cycle"

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The U.S. North American Carbon Program (NACP) sponsored an "all-scientist" meeting, 22–24 January 2007, in Colorado Springs, Colorado, 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. The meeting participants also addressed the need for better decision support tools for managing the carbon cycle of North America, so that strong science capability can better inform policy as interest in taking action increases across the nation.

Herein we report on major themes that will help integrate the diversity of NACP science and fill significant knowledge gaps for understanding and managing the North American carbon cycle: integration among disciplines involving land, atmosphere, and ocean research; strengthening data management infrastructure to support modeling and analysis; identification of study regions that are critical for reducing uncertainties in the North American carbon balance; and integrating biophysical science with the human dimensions of carbon management and decision support.

The North American Carbon Program

The NACP Science Plan (Wofsy and Harris, 2002) and Science Implementation Strategy (Denning et al. 2005) lay the foundation for a program of interagency research to address several globally-important questions about the carbon cycle. The NACP is organized around the following questions: What is the carbon balance of North America and adjacent oceans? What are the geographic patterns of carbon fluxes and how is the balance changing over time? What processes control the sources and sinks, and how are they changing over time? Are there potential “surprises” where sources could increase or sinks disappear? How can we enhance and manage long-lived carbon sinks to sequester carbon, and provide resources to support decision makers? Participating agencies and scientists have initiated an integrated program of research to answer these questions, involving atmospheric, terrestrial, and marine studies with activities ranging from intensive field campaigns to long-term monitoring and modeling over a range of time and space domains. NACP goals, planning documents, and project profiles, as well as the abstracts and posters from this science meeting, may be found at http://www.nacarbon.org/.

NACP is a large and complex program supported by eight federal agencies and conducted by hundreds of scientists at federal, academic and other research institutions. The Carbon Cycle Interagency Working Group (CCIWG), made up of representatives from each of the participating federal agencies, provides overall programmatic direction and direct oversight of the NACP Coordinator. Scientific leadership is provided by a Science Steering Group (SSG) of NACP investigators appointed by the CCIWG. Additionally, U.S. leadership is working with counterparts in Canada and Mexico to develop a joint program that will take advantage of each country’s independent carbon research programs.

Need for Cross-Disciplinary Integration

The NACP, a multi-disciplinary program involving land, atmosphere, and ocean research, requires cross-disciplinary integration to evaluate the range of carbon sources and sinks contributing to the carbon balance of North America and adjacent oceans. For example, carbon dynamics in coastal margins are poorly understood, in part because few studies have integrated across terrestrial, atmospheric and ocean reservoirs and disciplinary boundaries. Opportunities exist within disciplines for investigators from a variety of projects to collaborate in integrative activities, by coordinating efforts that might have otherwise been conducted independently. Such within-discipline coordination is improving with guidance from the CCIWG and SSG, making it more likely that critical integration needs are met. For example, it is likely that NACP can couple diagnostic and prognostic modeling capabilities, and integrate these models with greenhouse gas reporting systems currently relying mostly on inventories (see the first State of the Carbon Cycle Report, SOCCR, 2007). Such integration would reduce gaps in knowledge of the carbon cycle, how it is changing, and why.

Another opportunity is integration of data collected by various investigators across spatial and temporal scales. These activities would benefit U.S. reporting of greenhouse gas inventories by improving our fully-integrated estimates of the interannual variability in land-atmosphere-ocean carbon exchange, and attributing changes to major driving factors such as climate variability, wildfires, insect outbreaks, and land-use change.

Community Effort Needed for Integrated Observations, Modeling and Data Management

Integrated long-term observation systems are the backbone of the NACP. Some critical observations are “contributed” to the NACP from well-established programs such as land inventories conducted by USDA. The AmeriFlux network of temporally intensive observations has demonstrated relevance in quantifying the effects of climate variability on the carbon cycle at seasonal to interannual time scales (Law, 2005). Continuous high-precision CO_2 concentration measurements are made at various locations across the continent for use in inverse modeling and investigation of large-scale patterns of atmospheric transport of CO_2. These observation networks are of great value for understanding and verifying regional and cross-boundary sources and sinks, but face challenges to continuing operations. The open ocean observing system is being developed as a part of the Global Earth Observing System of Systems (GEOSS), but there currently is no established long-term program for the coastal margin component of that effort (http://www.oco.noaa.gov/). Remote sensing data and analyses have proven critical to supporting biophysical modeling activities within NACP. Hence, there is a need to insure that the satellite data required by NACP scientists are readily available and have consistent technical specifications.

The need for coupling different types of models is based on achieving better understanding of feedbacks between earth systems and eliminating boundary problems. There is an emerging effort to fully couple carbon (land and ocean) and climate models; this could be expanded to include emissions models that consider the full range of human drivers in diagnostic and prognostic analyses. Equally important is the need to support integrated modeling with robust data management. The meeting participants noted that large investments in individual projects were not matched by data system infrastructure to enable storage, search and access of data. Data archives do exist for the carbon flux, precision CO_2 concentration data, and biological data collected by the AmeriFlux network (CDIAC; http://public.ornl.gov/ameriflux/), Fluxnet-Canada (http://www.fluxnet-canada.ca/), tree data of the USDA Forest Inventory & Analysis (http://fia.fs.fed.us/), and ocean carbon data (CDIAC: http://cdiac.esd.ornl.gov/oceans/home.html). These databases will serve a critical role in facilitating modeling studies and syntheses, but it will be a challenge to coordinate these diverse data sets into a meaningful synthesis. NASA is supporting a Modeling and Synthesis Thematic Data Center (MAST-DC; (http://nacp.ornl.gov/mast-dc/)) that will provide some data products and data management services. Furthermore, the NACP Office is hosting a searchable database of NACP project profiles that allows investigators to register their data requirements and planned data deliverables. This database is available online to the scientific community at the NACP web site: http://www.nacarbon.org/.

Resource constraints have delayed the implementation of some elements of the NACP infrastructure as originally planned (Wofsy and Harris, 2002). For example, the NACP has not yet fully implemented intermediate-tier field sampling needed to link intensive sites, such as AmeriFlux observations, to extensive inventories. Adjustments to the implementation plan that match program needs with resource availability are a major activity of the CCIWG and SSG.

Identifying Critical Regions for Understanding the Changing Carbon Cycle

The NACP has made some very good progress in a few areas. Assimilation of remote sensing data and atmospheric observations in a geostatistical framework is revealing some of the key uncertainties in understanding and managing the North American carbon budget (Michalak et al., 2006, Law et al. 2004, Chen et al. 2003). An intensive field campaign in the Mid-continental region is a test-bed of methods with goals of reconciling carbon flux estimates from “top-down” and “bottom-up” approaches to integrating models and data, in addition to revealing changes in sources and sinks within this largely agricultural region (http://www.nacarbon.org/nacp/mci.html). This campaign is an example of integrative activities occurring within the NACP that will eventually lead to improved diagnosis, prediction and attribution of carbon sources and sinks at the continental scale.

Meeting participants identified a number of other regions where intensive studies can fruitfully address NACP goals. The coastal margins (ranging from head-of-tide in rivers to the edge of the continental shelf) are a “hotspot” of carbon cycle activity. Carbon flows between the land, ocean, and atmosphere in these regions are complex and dynamic, especially during events such as hurricanes, El Niño, and floods. Likewise, the Interior West region of mixed grasslands and woodlands has been poorly inventoried and sparsely monitored by intensive study sites, so that SOCCR identifies this area as having the most uncertain estimate of periodic change in carbon flux. Finally, the fate of “heritage carbon” under changing climate, particularly carbon stored in permafrost, bogs, and soil carbon in the Boreal/Arctic region, remains poorly understood. Lack of systematic monitoring and comprehensive modeling of carbon dynamics in these regions represents a critical shortcoming of carbon cycle science in North America.

Integrating Human Dimensions

Most of the NACP focus has been on the natural sciences, but to achieve its objectives, the NACP must integrate human dimensions with the biologic, atmospheric, and oceanic sciences. Human decisions influence the carbon cycle in North America through interactions between social and economic systems with the biological, chemical and physical processes leading to carbon transfers between lands, oceans and atmosphere. Two broad categories of human dimensions are in need of consideration. The first is to expand research on social processes that drive land use and fossil fuel emissions, quantitatively integrating them into diagnostic and prognostic land use/cover and emissions modeling. This will allow for the emergence of the carbon/climate/human modeling urgently needed to provide the science and analytical support tools for climate action programs at various levels of government.

This leads to the second area of human dimensions research, decision support for national, state, and local stakeholders in the public and private sectors. While there are emerging tools to support strategies for land management, there needs to be more attention to decision support for managing fossil fuel emissions, including independent monitoring and verification from atmospheric measurements, and a consideration of carbon consequences in coastal management decisions. Decision support should be more fully integrated with basic research to ensure that outcomes are as intended. It is critical to understand interactions between the industrial and biological aspects of the carbon cycle. An emerging decision-support need is to understand and quantify the combined effects of management actions on net radiative forcing rather than solely on atmospheric chemistry. This coupling of biogeochemical and biophysical knowledge is required to improve the understanding of, and accounting for, the effects of management and policy on warming potential.

Next Steps

The NACP Office and SSG are summarizing the specific recommendations that emerged from the meeting, and will present that summary to the CCIWG for consideration. We expect that, within the constraints of very tight budgets, NACP sponsoring agencies will take some of the recommended steps to more fully integrate the organization, infrastructure, and science. Immediately following the NACP meeting was a companion meeting of the Joint NACP involving Canada, Mexico, and the United States. The Joint NACP offers the intriguing possibility of much better understanding and management of the carbon cycle by considering a broader array of data sources, models, and management opportunities in the context of diverse national goals, policies, and land-use histories within North America.

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