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Hurricane Katrina and New Orleans: "I Told You So" Is Not Enough

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There has not been a major natural-hazard-related disaster in modern times that wasn't preceded by warnings from scientists about the potential consequences of the intersection of populations, infrastructure, and extreme natural events. We have taken our understanding of the frequency of these events and the processes associated with them to the table as earthquake-prone cities have contemplated zoning regulations and building standards, floodplain communities and government agencies have sought to improve flood insurance programs, and settlement has moved into wildland fire danger zones.

We have celebrated when we were heeded, but more often we have been frustrated when the impacts of a natural hazard were as we predicted and the opportunity for scientific understanding to have reduced consequences of the event was missed by decision-makers.

The disastrous effects of Hurricane Katrina on New Orleans and the U.S. Gulf Coast communities in adjacent Louisiana and Mississippi provide an unparalleled opportunity for the scientific community to say, "I told you so."

For many years, scientists working in this region have warned about inadequate storm protection, deteriorating levees, the underappreciated effects of the patterns and rates of subsidence on coastal structures, the consequences of the loss of barrier islands and wetlands and their role as storm-effect buffers, the effects of storm surges on near-shore coastal communities, and the multitude of consequences faced by topographically challenged New Orleans should a major hurricane strike the city. It would be easy for those scientists to react with a grim satisfaction in being right, and a sense of helplessness—based on past neglect of their knowledge—in their ability to influence rebuilding efforts.

There has already been public airing of opinions about the rebuilding of New Orleans, ranging from suggestions that it not be put back where it was to advocacy of total restoration of this nationally important economic and cultural asset.

Political, economic, and social realities support a major rebuilding effort. This effort will provide an opportunity to "do it right" on a scale unequaled in U.S. history. It is also a reality that, as in most complex situations, decisions will be based on many values, with scientific understandings among them but not preeminent. Our history of accepting risk in locating communities and infrastructure is not likely to be reversed, and the argument that we should not accept risk is socially and culturally unconvincing.

The opportunity here is for those who treated scientific understanding as a minor ingredient in the planning of neighborhoods, storm protection structures, drainage systems, port facilities, and transportation systems to listen more carefully to scientists and act more responsibly as they seek better protection of lives and property.

The challenge for the scientific community is to be organized, reasonable in its expectations, effective in its communications, and persistent in engaging those responsible for next steps in the recovery and rebuilding of New Orleans and affected Gulf Coast areas.

It would be appropriate and enlightening for an agency or foundation that supports science to take a nontraditional approach and support a well-constructed collaborative effort to maximize the role of science in decisions made about the rebuilding of New Orleans. Supporting the application of interdisciplinary science to such a complex reconstruction effort in real-time would give these organizations a superb opportunity to demonstrate the front-page relevancy of science and their support for it. AGU, in collaboration with other professional organizations, should demonstrate leadership by supporting the development of a proposal for funding this important work.

These actions not only would benefit New Orleans, but also would provide scientists with a major opportunity to broaden and increase the impact of the research to which they have dedicated their careers.

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Mapping Deep-Water Gas Emissions With Sidescan Sonar

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Emissions of methane gas from cold seeps on the seafloor have a strong impact on a number of biogeochemical processes. These processes include the development of deep-sea benthic ecosystems via the process of anaerobic oxidation of methane [*Boetius et al.*, 2000] or the precipitation of carbonates [*Ritger et al.*, 1987]. The fluxes of other chemical species associated with methane emissions may even influence the chemical composition of seawater [*Aloisi et al.*, 2004]. Such gas emissions may have been much more intensive in the past with a strong impact on global climate [*Dickens*, 1999], as suggested by carbon isotope data.

Many international and national research projects, such as the METRO collaborative project (Methane and Methane Hydrates Within the Black Sea: Structural Analyses, Quantification and Impact of a Dynamic Methane Reservoir), part of the German research and development program Geotechnologien, focus on these cold seep sites and stimulate interdisciplinary work between a variety of scientific groups.

However, the proper location of the cold seep sites themselves is the foremost problem in studying the geological, biogeochemical, and ecological processes acting at the sites. Many cold seeps are bound to morphological structures on the seafloor such as mud volcanoes or large pockmarks, and the seeps can be easily identified in detailed bathymetric data. Other seeps, however, do not have significant bathymetric relief and can only be detected using backscatter data.

Whether seeps are currently active cannot be determined with these methods. That deter-

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mination requires either direct video observation of the seafloor or acoustic detection of a gas plume (a so-called flare) in the water column. Both methods have obvious drawbacks. Video observation is restricted to very small areas of the seafloor, and flare detection with shipboard acoustic echo sounders does not allow precise location of the origin of the flares on the seafloor unless many closely spaced profiles are collected. Nevertheless, the use of shipboard echo sounders during numerous routine transits on Ukrainian research vessels has allowed the identification of many gas flares in the Black Sea [*Egorov et al.*, 2003].

Imaging of Gas Flares

These problems can be overcome by using digital, high-resolution, deep-towed sidescan sonar systems, as a recent (14 October to 5 November 2004) METRO cruise to the eastern Black Sea shows. The deep-towed chirp (frequency modulated) sidescan sonar system (DTS-1) of the Leibniz Institute of Marine Sciences (IFM-GEOMAR) operates with a 14-millisecond pulse of 7.5-kHz bandwidth centered at 75 kHz, and the system allows detecting bubble streams in the water column when looking at unprocessed data (Figure 1a).

The detection of these gas bubbles depends on the resonance frequency of the bubbles, which increases with water depth [*Greinert and Nützel,* 2004]. The DTS-1 side-scan sonar (75 kHz) detects bubbles greater than 0.4 millimeter diameter in 750-meter water depth while conventional fish or sediment echo sounders (38 and 3.5 kHz, respectively) only detect bubbles in excess of 0.8 and 10 millimeter diameter, respectively [*De Beukelaer et al.*, 2003]. The combination of the high frequency and the wide vertical opening angle (70°) of the acoustic signal together with a towing depth of only 100 meters above the seafloor favors the detection of gas flares in deep water.

Until *Merewether et al.* [1985], such gas bubbles in deep water were not known, and they were considered unlikely because it was assumed that high pressures would hinder the formation of gas bubbles. Also, the deeper parts of the oceans are within the zone of gas hydrate stability, and it was thought that free gas required to form bubbles should not be available.

Gas seeps detected with the DTS-1 sidescan sonar system range in water depth from 600 to 1800 meters, and they lie within the depth of gas hydrate stability. It is not yet known whether these bubbles could be detected because of a coating of gas hydrate around the bubbles protecting them from dissolution, as first suggested by *Merewether et al.* [1985], because bubbles are oily and better detected by sonar systems [*De Beukelaer et al.*, 2003], or simply because the 75-kHz signal allows the detection of smaller bubbles than do conventional echo sounder systems.

Distribution of Gas Seeps

The use of sidescan sonar for the detection of gas flares has the added advantage of showing the spatial distribution of such flares when processing the data. Seventy-five kilohertz sidescan sonar data in the Black Sea have been obtained for swaths of 1500 meters during the recent METRO cruise. Towing speed was 2.5 knots, allowing data processing with a pixel size of one meter (Figure 1).

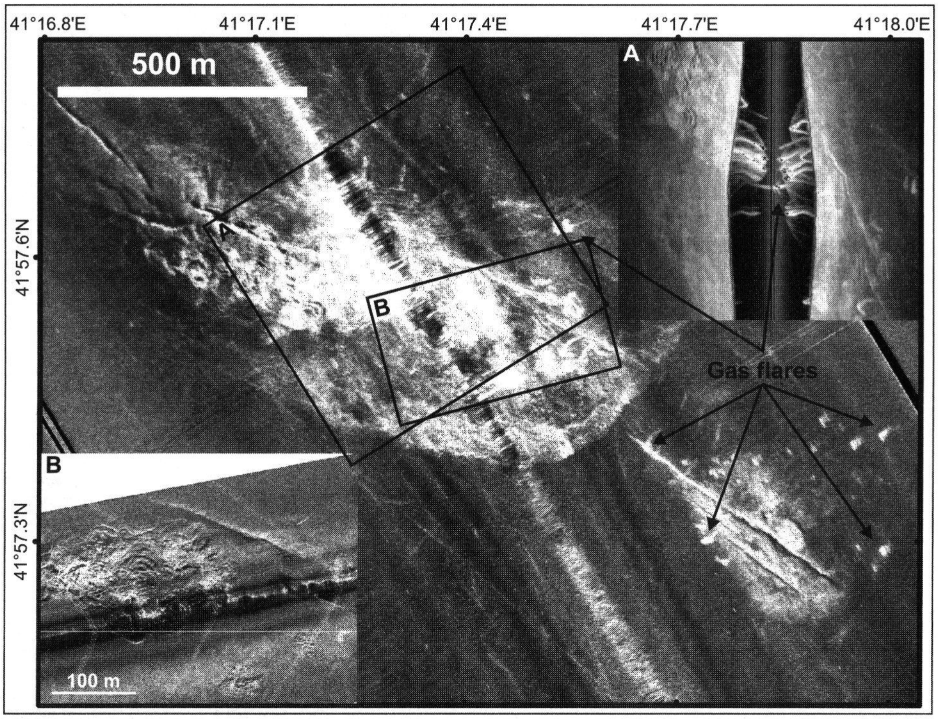

Fig. 1. Mosaic of 75-kHz DTS-1 sidescan sonar data showing a cold seep area offshore Georgia including many gas flares. (a) Unprocessed 75-kHz sidescan sonar data indicating several acoustic anomalies in the water column (gas flares). (b) Sonograph of 410-kHz sidescan sonar data possibly showing fluidized upper sediments around individual gas seeps. High backscatter is shown as light tones.

Processed data of a previously known cold seep site offshore Georgia [*Egorov et al.*, 2003] indicate a large number of gas flares over an area of less than one square kilometer. These flares are well imaged in the water column of raw sidescan data (Figure 1a). Small isolated spots of high backscatter intensity in the processed side-scan data are also interpreted as gas flares (Figure 1).

Whether these high backscatter spots are related to changes in the composition of the seafloor such as carbonate precipitates, rather than related to gas flares, cannot be excluded, because both features return a strong backscatter signal. If the interpretation as gas flares is accepted, spacing between individual gas flares is not uniform, and there exist clusters of flares as well as isolated flares.

Geoacoustic data do not allow determining individual centers of the formation of bubbles, because those are mostly only a few centimeters across. However, very high resolution sidescan sonar data (410-kHz center-frequency chirp signal, 0.25-meter pixel size, Figure 1b) indicate the probable area of influence of isolated gas emissions.

These data have been acquired with a towing altitude of only 25 meters, and the data show concentric rings of fluidized upper sediments around the flares. The rings have a diameter of up to 40 meters around the flare, and they are partially overlapping at the center of the seep area, suggesting a strong spatial variability of the gas emissions.

Control of Gas Flares

Many of the flares are aligned along fractures or discontinuities on the seafloor (Figure 1). Some are evenly distributed along the fractures, while others cluster in specific locations. However, isolated flares unrelated to fractures are also present. The flares are generally concentrated along bathymetric highs, and they are not found at the bottoms of canyons or other erosional depressions (Figure 2). This is a common pattern for cold seeps, and it possibly indicates that hydrostatic pressure plays a role in controlling the gas emissions. In all cases, however, the seep sites are probably related to gas reservoirs at depth, though the exact source of the gas and the pathways are not known.

Improved Sampling and Budgeting

The potential for detailed investigations of cold seeps in deep water is greatly enhanced through the use of high-resolution (75 kHz), deep-towed sidescan sonar data. Such data allow detecting gas flares in the water column and relating the flares to specific seep locations on the seafloor. In addition, the distribution of different backscatter facies on the seafloor can be related to the presence of carbonate precipitates and/or gas hydrates, and their distribution consequently allows mapping of the entire seep environment at high resolution.

Selecting sites for detailed biogeochemical investigations within the METRO project is much improved, and the data can ultimately be integrated in regional geological and ecological studies of deep-sea environments. Within the METRO project, the methane concentrations and fluxes in the sediments and into the ocean from such sites through controlled degassing studies of autoclave cores, through gas desorption experiments, and through geochemical flux measurements will be studied in future cruises. These findings can then be integrated with the results of geoacoustic mapping of the cold seep sites in order to derive better regional methane flux estimates.

Acknowledgments

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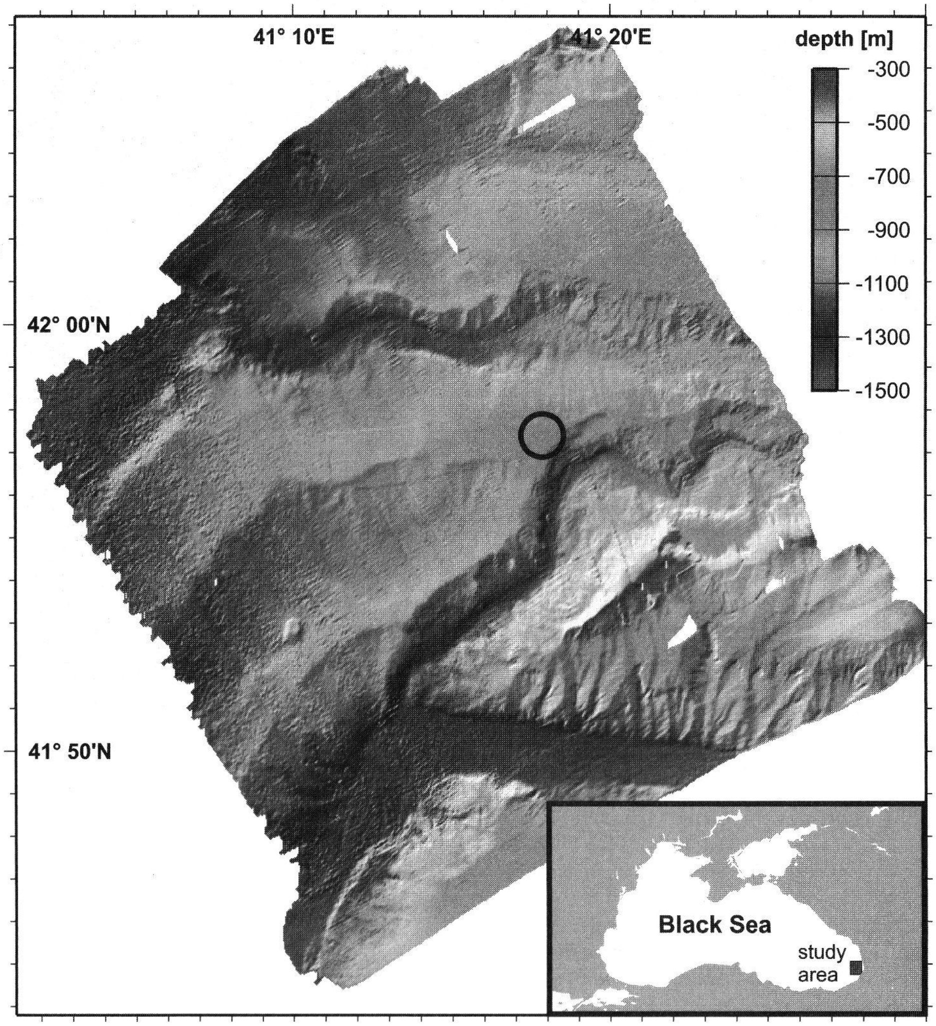

Fig. 2. Bathymetric grid of the area offshore Georgia studied during the METRO project. Data have been acquired with a portable ELAC Bottomchart Mk.II (Mark II) multibeam system working at 50 kHz. Grid cell size is 50 meters. Circle shows the location of seeps shown in Figure 1.

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Modeling Past Atmospheric CO_2: Results of a Challenge

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The models and concepts used to predict future climate are based on physical laws and information obtained from observations of the past. New paleoclimate records are crucial for a test of our current understanding.

The Vostok ice core record [*Petit et al.*, 1999] showed that over the past 420 kyr (1 kyr = 1000 years), Antarctic climate and concentrations of the greenhouse gases carbon dioxide (CO_2) and methane (CH_4) were tightly coupled. In particular, CO_2 seemed to be confined between bounds of about 180 ppmv (parts per million by volume) in glacial periods and 280 ppmv in interglacials; both gases rose and fell with climate as the Earth passed through four glacial/interglacial cycles.

During 2004, new Antarctic temperature and dust records from the European Programme for Ice Coring in Antarctica (EPICA) Dome C (EDC) ice core were published extending back to 740 kyr [*EPICA Community Members*, 2004]. The early part of the record shows a changed behavior, with much weaker but longer interglacials. The imminent appearance of an ice core record of atmospheric CO_2 covering the same period prompted a challenge issued in an *Eos* article at the end of last year [*Wolff et al.*, 2004] for the modeling community to predict, based on current knowledge, what the greenhouse gas records will look like.

This article describes the submissions to the challenge. Several groups took up this "EPICA challenge," using models, concepts, and correlations; their predictions were presented as posters at the 2004 AGU Fall Meeting.

Although different approaches were used, most of the teams effectively assume that Southern Ocean processes are the main control on atmospheric CO_2. Most of them expect that the CO_2 concentration will look very similar to Antarctic temperature throughout the extended time period, with no overall

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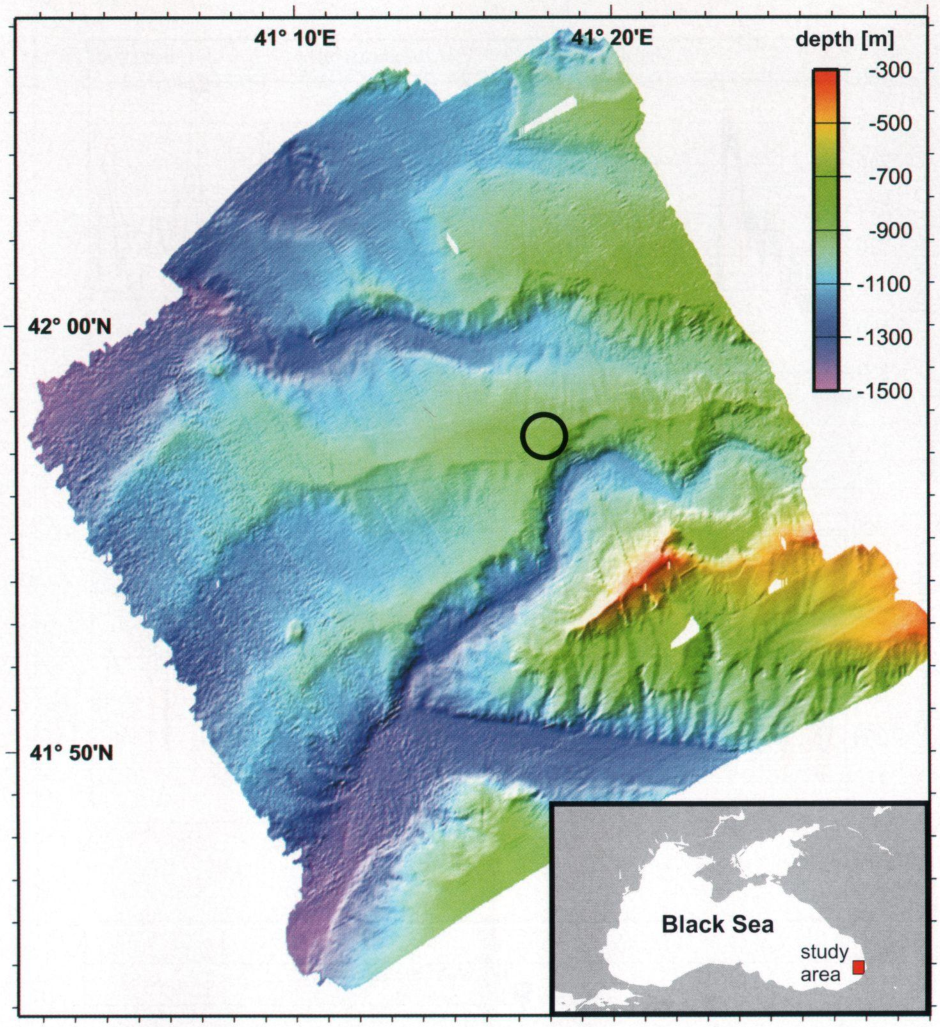

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