was collected from the same instrument and processed using the same algorithm, rather than from a variety of sources, some of which included inaccurate information. Also, the basis for SRTM30 is higher-resolution source data, which provides more inherent topographic detail than is included in the earlier map.

John LaBrecque, manager of NASA's solid Earth and natural hazards program, said SRTM30 is "the first 3-D map of the Earth's surface at a known and uniform accuracy."

Michael Kobrick, SRTM project scientist with NASA's Jet Propulsion Laboratory, said that most scientists working with digital elevation data probably are familiar with GTOPO30 at this point. However, he noted that he has received numerous comments from the user community indicating that SRTM30 is a better product. "If I were a user, I don't think I would go back to GTOPO30 myself," he said.

Kobrick said the digital elevation data is used for a variety of purposes, including hydrology and earthquake research, monitoring volcanoes and glaciers, airplane flight simulation, the placement of communication towers, and even fighting fires. Kobrick explained that fires in the western United States, for instance, are controlled in part by topography and that they tend to burn uphill; an accurate digital elevation map can help to manage them.

Sharper Resolution Global Map On Its Way

Further refinements of elevation data will be included in the release of the global "SRTM3," which provides measurements for every 3 arc seconds, or about every 90 m at the equator. SRTM3 maps for North and South America already have been released. Kobrick said the map for Eurasia will be released in mid-November. The entire globe, again from 60° north to 56° south, will be available in mid-2004, he said.

A global SRTM1 map, which has measurements for every 1 arc second of about 30 m, will be produced nearly simultaneously. An agreement between NASA and NIMA calls for the public release of SRTM3 globally and SRTM1 for the U.S. where 1 arc second data already is available. The agreement also permits NASA internal use of all SRTM data, including the finest resolution SRTM1-level data. NIMA, which has been processing the data, otherwise retains access control to SRTM1.

Robert McCanna, disclosure and release officer at NIMA's internal and policy office, said he expects that there will be some access to the agency's SRTM1-equivalent data for appropriate scientific research purposes that do not conflict with military operations. McCanna, who called the 1 arc second data "the gold standard," said he anticipates that interagency negotiations relating to the potential availability to researchers of some of this global data could be conducted within the next several months.

McCanna said that the 100-fold magnitude improvement in the density of data between SRTM30 and SRTM3 would provide significant utility for researchers.

He said the 9-fold increase to SRTM1 is a more incremental change in terrain data that might be useful in some specific applications such as monitoring tectonic shifts along coastal volcanoes.

Publicly available SRTM30 and SRTM3 data will be archived and distributed by the U.S. Geological Survey's EROS Data Center in South Dakota. Dean Gesch, a USGS contract employee with the center, who works for the Science Applications International Corporation, said SRTM30 in some ways supercedes the agency's GTOPO30, but that the two data sets are complementary. He said SRTM30 attains global coverage because it is "backfilled" with existing GTOPO30 data.

Also, he noted that SRTM30 is a "first return system" which provides elevation based on whatever the radar has bounced off from. While in many instances the elevation may be actual ground level, that is not the case in dense forest, for instance, where the radar signal likely bounced off tree canopy. In such instances, he said, the new map may be more useful for airplane pilots, while GTOPO30 may be better for understanding the hydrology of specific regions.

Gesch said the SRTM30 is a "research-grade data set." He said the real advantage for the scientific community will be the release of the higher-resolution SRTM3. When that product is completed, he said it would make sense to determine how best to merge it with the USGS product.

—RANDY SHOWSTACK, Staff Writer

U.S. Visa Waiver Program Changes

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The U.S. State Department has just announced a change to a new rule affecting citizens from visa waiver program countries. The rule, scheduled to go into effect on 1 October 2003, requires visitors from these countries to obtain non-immigrant visas to enter the United States if they do not have machine-readable passports. The change announced is that a visa waiver country can petition the U.S. government to delay the rule by one year.

The State Department recommends that citizens of visa waiver program countries who are contemplating visiting the United States, and do not have machine-readable passports, contact the nearest U.S. embassy or consulate to find out if implementation of the rule has been temporarily waived for their countries.

As of 11 September, no country had been granted a delay, though a spokesman for the State Department said that the office of the secretary of state is committed to making a decision quickly when petitions are received.

If a government is granted a delay, it will apply only to citizens of that country; not to the citizens of other visa waiver program countries.

Prior to the new rule, citizens of the 27 visa waiver program countries who were planning to visit the United States were not required to obtain visas. AGU advises all non-U.S. citizens planning to attend the 2003 Fall Meeting, and who think they may need a visa, to apply at U.S. consulates immediately.

A list of visa waiver countries and other information is available at: www.travel.state.gov/vwp.html.

MEETINGS

Identifying Future Directions for Subsurface Hydrocarbon Migration Research

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Subsurface hydrocarbon migration is important for understanding the input and impacts of natural hydrocarbon seepage on the environment. Great uncertainties remain in most aspects of hydrocarbon migration, including some basic mechanisms of this four-phase flow of tar, oil, water, and gas through the complex fracture-network geometry, particularly since the phases span a wide range of properties. Academic, government, and industry representatives recently attended a workshop to identify the areas of greatest need for future research in shallow hydrocarbon migration.

Novel approaches such as studying temporal and spatial seepage variations and analogous geofluid systems (e.g., geysers and trickle beds) allow deductions of subsurface processes and structures that remain largely unclear. Unique complexities exist in hydrocarbon migration due to its multiphase flow and complex geometry, including in-situ biological weathering. Furthermore, many aspects of the role of hydrocarbons (positive and negative) in the environment are poorly understood, including how they enter the food chain (respiration, consumption, etc.) and "percolate" to higher trophic levels. But understanding these ecological impacts requires knowledge of the emissions' temporal and spatial variability and trajectories.

Subsurface hydrocarbon migration is of great interest to petroleum geologists and engineers, and is important for understanding the input and impacts of natural hydrocarbon seepage on the environment. However, non-destructive, in-situ studies of hydrocarbon migration pose enormous challenges. Great uncertainties remain in most aspects of hydrocarbon migration, including basic mechanisms of this four-phase flow through the complex fracture-network geometry, particularly since the phases span a wide range of properties.

To address these issues, the "Shallow Hydrocarbon Migration Workshop" was held to review what is understood about this complex seep system and its impacts on the environment. To identify current frontiers of understanding and research directions, other analogous, geophysical systems, such as geysers, were considered. All contributed to the discussion. The workshop included oral, video, and poster presentations, roundtable discussions, and a field trip to the Wind-Wave Channel in the Ocean Engineering Laboratory at the University of California, Santa Barbara, where recent seep instruments, including turbine seep-flux tents, a video-based bubble measurement system, and a catamaran-based, rotating-drum slick sampler were demonstrated with artificial seeps.

Workshop participants reached several major conclusions:

- Research is needed to elucidate hydrocarbon migration processes, including multiphase flow and conceptual model development.
- Temporal and spatial seepage variations allow deductions of subsurface processes and structure.
- Analogous geofluid systems (e.g., geysers, trickle beds) aid interpretation of hydrocarbon migration observations.
- Most details of how hydrocarbon components enter the food chain (respiration, consumption, etc.) and "percolate" to higher trophic levels are unclear.
- In-situ biological processes, including microbial degradation, may impact hydrocarbon migration and should be characterized further.
- Understanding the ecological (and pollution) impacts of seepage requires knowledge of the emissions' temporal and spatial variability and trajectories.

Migration

The Earth leaks hydrocarbons and other geofluids, but few rates are quantified. As a result, marine seepage contributions to the global atmospheric methane budget (540 Tg yr^{-1}) are often assumed negligible, although recent estimates suggest they contribute ~5.5% (20 Tg yr^{-1}; *Kvenvolden et al.* [2002]) and represent a fraction of global geological gas emissions. These estimates are based on steady-state emissions, though observations [*Boles et al.*, 2001] show temporal variations ranging from several percent to orders of magnitudes on time scales from seconds to decades. Marine seeps are advantageous for studying hydrocarbon migration in a fracture network, since the sea bed transects the network, and locating seepage is simpler in the marine environment, where bubbles visibly identify seeps.

Thus, the workshop participants first considered the importance of quantifying temporal variations, both to assess overall budgets and as an information source (i.e., response to perturbations) for subsurface processes. Given the complexity of hydrocarbon seeps, learning from other, simpler multiphase flows (engineering and geophysical) is a logical first step.

An analogous, two-phase system is a geyser, which exhibits both similarities and differences. Two similarities are their eruptive or transient nature and their subsurface interconnectedness, up to 1.5 km [*Ingebritsen and Rojstaczer*, 1996]. A network of flux-measuring, turbine-seep tents at Shane Seep, an active seepage area in the Coal Oil Point (COP) Seep Field in the Santa Barbara Channel, California (34° 24.370'N, 119° 24.370'W), recently quantified an intense gas ejection (500 l in 10 s). Both immediately before and after the ejection, the flux virtually stopped. After the latter quiescent period, the flux increased above pre-eruption levels. Meanwhile, 90 s after the ejection, the flux at a tent 5 m distant decreased significantly, suggesting subsurface interconnectedness. Sea bed video of a separate blowout showed tar ejection as well. Tar provides a potential mechanism to block fractures, allowing pressure behind the blockage to grow until an ejection blows it clear. Ejections may "flush the pipes," thus increasing flux.

These observations raise the question of how tar blocks fracture. In the COP field, hydrocarbons migrate from the Miocene Monterey Formation through fractures located along faults. One possible migration mechanism is that tar migrates in "jumps," being blown upwards from fracture construction to constriction. Alternatively, tar may form in the fractures by "deposition" and degradation (aging). Gas forces an upward oil migration, primarily along the walls. Since continuity forces wall flow to zero, oil on the walls could age in place, becoming less mobile, thereby narrowing and eventually blocking fractures. Chromatograms of freshly deposited tar, appearing shortly after a blowout, created a new hydrocarbon volcano, and are almost entirely an unresolved complex mixture (i.e., highly degraded). But they also showed n-alkane peaks typical of fresh oil. One explanation is fresh oil flowing over tar adhered to fracture walls.

Ocean tides affect seeps [*Boles et al.*, 2001], while recent, high-quality time series of geysers do not show a clear Earth-tide response. Geysers do respond to weather system pressure changes and possibly thermal changes. More interesting, the relationship between geyser recharge rate and seismic activity (even remote) is well-established [*Silver and Valette-Silver*, 1992]. Widespread stress re-adjustment after an earthquake may open/close fractures, changing the recharge rate (i.e., migration) or permeability, and thus eruption period. This lends credence to observations linking seismic activity and hydrocarbon seepage.

Geysers and industrial trickle beds show unsteady flow without tar. In chemical engineering trickle beds, gas and liquid flow downward through narrow, millimeter-scale gaps in a catalyst bed. Pressure pulses are observed for just a 10-cm column height, increasing with height. This unsteady flow may arise from the transition between slug and wall flow in the gaps [*Benkrid et al.*, 2002]. Geyser modeling studies also show that eruptions can arise out of porous media or branched-fracture networks without constrictions [*Ingebritsen and Rojstaczer*, 1996].

Offshore COP sea bed surveys show very large but infrequent blowouts that re-arrange sea bed features. Such a blowout occurred in the Santa Barbara Channel in 1978, and the resulting sea surface boil was visible from oil platform Holly, several kilometers distant. Two large seep tents (30 m x 30 m each) were deployed in 1982 to capture gas from this seepage and the captured gas piped onshore [*Boles et al.*, 2002]. Similar processes may occur in gassy geysers; that is, effervescence of a rapidly rising super-saturated fluid. As the fluid rises, hydrostatic pressures decrease, increasing super-saturation and out-gassing, and thus driving pressure; and thus rise rates (positive feedback) as well.

Flow complexities largely arise from interactions between phases. Thus, a clear consensus was the importance of understanding these interactions. Such interactions are partially expressed by concepts such as relative permeability—the effect of multiple phases on permeability—and capillary pressure.

Ecosystem

Hydrocarbons, both oil and gas, are both an energy source and ecosystem stress. For example, chemosynthetic communities at deep-sea seeps depend on hydrocarbons. Methanotrophic and oil-degrading bacteria at the bottom of the food chain metabolize seepage. Benthic organisms consume these bacteria, "percolating" hydrocarbon energy up the food chain. Oil toxicity is also a selective force. This is shown by an inverse correlation between sediment oil content and microbial community diversity at Shane Seep [*Bergmann et al.*, 2002].

The COP seeps provide habitat for or are frequented by a wide array of marine life including, but not limited to, sea anemones, crustaceans, benthic and pelagic fishes, and marine mammals. The COP seeps have existed for millennia and are extensive, covering ~3 km^2 of sea floor and releasing 10,000 m^3 per day of gas and 100 barrels per day of oil [*Hornafius et al.*, 1999]. Estimates are unavailable for hydrocarbon flux deposited to the sediment, but may be highly significant. Extensive oil slicks cover tens of square kilometers, and tar balls continuously wash up on area beaches. So, given the presence of aromatic hydrocarbons, why don't mobile fauna avoid the seeps?

Explanations include: elevated seep nutrient levels attract marine organisms [*Leifer and Judd*, 2002]; fish find bubbles attractive; and bubbles or dissolved toxic compounds decrease predation. Bubble-driven upwelling [*Leifer et al.*, 2000] may explain observations of elevated seep nutrient levels while drawing in uncontaminated seawater at the sea bed. Gas may play an important role in hydrocarbon bioavailability. Unlike Shane Seep, where marine life is common, another seep, Ira Seep, located a few hundred meters to the east on the same depth trend, is primarily a tar plain with occasional releases of 10–30-cm diameter bubbles, and is largely devoid of marine life, including bacterial mats. An important exception occurred at Shane Seep after a storm in February 2003 scoured the sea bed and deposited many centimeters of sand, removing bacterial mats. Only on this survey (of ~15 visits) were fish and crustaceans absent.

The positive and negative impacts of hydrocarbon seepage on marine life suggest a complex effect on fisheries. Although fish near the seeps contain hydrocarbon markers [*Spies et al.*, 1996], the hydrocarbon entry pathways—predation, consumption, or adsorption—are unclear. Oil has a strong negative effect on fish embryos, but COP fish may have adapted, particularly if hydrocarbons protect against predation. Sterility may be common. Furthermore, local marine mammals and birds show behavioral adaptations. Birds have been noted to avoid hydrocarbon spills; for example, a spill of red-dye diesel in April 2002 near the Santa Barbara harbor. Mortality for another spill mainly affected baby pelicans; adults avoided the spill.

To conclude, understanding seep impact requires comparisons between marine organisms in and out of seep-impacted areas. This requires data on the spatial and temporal distribution of marine biota and seep emissions and seep-hydrocarbon trajectories. While the COP ecosystem has adapted to "chronic" seepage, large human or natural transient releases will elicit a different response. Since surveys map temporal variations as spatial, they provide only a partial picture. Therefore, an accurate assessment of total emissions requires long-term monitoring to quantify both steady and transient seepage.

The Shallow Hydrocarbon Migration Workshop was held 22 April 2003, in Santa Barbara, California. More details about the workshop can be found at www.bubbleology.com/USHMworkshop.html.

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—I. Leifer, Marine Sciences Institute, University of California, Santa Barbara; and J. F. Clark, B. Luyendyk, and D. Valentine, University of California, Santa Barbara

GEOPHYSICISTS

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In Memoriam

Naoshi Fukushima, 78, 25 June 2003, Retired Life Member and AGU Fellow, Magnetospheric Physics, 1960.

Honors

Francisco P.J. Valero has been elected a full member of the International Academy of Astronautics, an organization—founded in 1960 and first led by Theodore von Karman, one of the most important figures in the evolution of space exploration—that recognizes the global significance of astronautics and space exploration. Among his many accomplishments, Valero is the head of a new, innovative space research mission, the Deep Space Climate Observatory satellite. This NASA-funded mission is designed to test an unprecedented approach to researching the Earth system from deep space, providing a complete, simultaneous view of the sunlit hemisphere of Earth, with high-time resolution observations.

Valero is director of the Atmospheric Research Laboratory at Scripps Institution of Oceanography, University of California, San Diego. He has been an AGU member (Atmospheric Sciences) since 1984.

FORUM

Comment on "Are Noctilucent Clouds Truly a 'Miner's Canary' for Global Change?"

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I noted with interest the article, "Are Noctilucent Clouds Truly a 'Miner's Canary' for Global Change?" by *von Zahn* [2003]. I am in agreement with the argument of this article; namely, that the frequency of noctilucent clouds is well controlled by temperature and water vapor in the mesospheric layers.

Von Zahn used short-term data for 1960–2001 (see his Figure 1), but the long-term observations from Russia [*Astapovic*, 1961] and Germany [*Schröder*, 1966, 1975, 1996, 1999] are also of interest. These observations for the years 1885–1996 show no long-term variability in frequency, but indicate variability in brightness and partial duration of noctilucent clouds (NLC) for different years.

We have had years with brilliant NLC, detailed forms, and colors, and they occurred in years associated with natural atmospheric pollution from volcanoes. Furthermore, we find years with very weak NLC that were not remarkable in either brightness or form. If we understand this morphological aspect as change, then we can note this as a form of long-term change. We must remember that after the Krakatoa eruption in 1883, very intense and bright NLC were observed for several years. This has also been indicated in more recent times, and also during recent volcanic eruptions. It may be possible that anthropogenic effects and human activities in general also stimulate the NLC displays in certain years and time spans.

Another point, also, must be considered. Since the late 19th century, we have had an increase in industrial production and resultant atmospheric pollution, which has increased rapidly over the last few decades. This effect also maintains the anthropogenic effects for the middle and high atmosphere.