

offsets for the epochs they want to stake to escape blame for the shrinking time supply.

The Earth sciences' answer to ecoterrorism, the "deep geochronology movement," will have none of this. Besides an end to magnetic core drilling in the tropical rain forest, it demands geology thesis bonfires to liberate millennia from imprisonment in Eurocentric maps, return overworked eons to unpublished obscurity, and restore to pristine ignorance the stock of geophysical misinformation that is humankind's common heritage.

Conserving deep time means that academics must focus on smaller intervals. Why lavish 100 million years of this limited resource on a single doctoral thesis when it can be thin-sectioned into 100 master's degrees? Moderate geopoliticians and hedge fund operators view this problem as an opportunity. To offset the rising number of science degree days, faculties can divert freshmen into comparative literature to create tradable "humanities permits" for sale to corporations that need to study economic geology. Once this new store of time is converted into tradable derivatives, a market in

G-bills and Geo Maes can be established and the regulation of geochronology can be turned over to the Securities and Exchange Commission

Publishers like AGU can help, too. To minimize the profligate consumption of deep time, politically correct geology journals can impose minimum geological mapping mileage standards. Raising the national average from 22 to 45 miles per inch, less in urban geology, could save megayears—lowering map resolution reduces the number of formations wantonly exposed to public view.

Unfortunately, some want to waste deep time. Encouraged by the Young Earth Movement's 1926 victory in the Scopes trial, today's Floodite extremists seek to bring back the antediluvian good old days by exhausting fossil time reserves once and for all. To abolish supply-side geochronology, these Floodites seek to divide and conquer geological time by having educators replace book reports with weekly field trips. If UNESCO can compel every schoolchild on Earth to produce a sixth-grade thesis on a single year of geological history, a children's crusade unleashed on everything from tombstones of Canadian Bur-

gess Shale to the Triassic slate roofs of Ivy League buildings will soon expose every day in the geological column to real-time scrutiny, leaving no vestige of the geological past unexamined.

Creationists may declare victory if the Floodites' "wedge strategy" prevails, but they know not what they do. Without unscrutinized depths of time for missing transitional fossils to hide in, the "God of the Gaps" may be doomed. Unless, of course, a new generation grateful for its legacy of scientific wonder unites to rescue Him from the prospect of that untimely end while, in James Hutton's words, there is still time for a "vestige of a beginning."

All you have to do to preserve the past for the future is leave one stone unturned.

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## MEETINGS

### Taking the Temperature of Ecological Systems With Fiber Optics

***Fiber Optic Distributed Temperature Sensing for Ecological Characterization; Blue River, Oregon, 10–15 September 2007***

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Fiber-optic distributed temperature sensing (DTS) is emerging as a powerful tool for hydrological and ecological observation over wide spatial and temporal scales. DTS installations allow for the precise observation of temperature at each meter of fiber-optic cables, with a precision of up to 0.01°C. The temperature is computed from the light backscattered following an intense laser pulse, and the location of each reading is determined by the arrival time of the pulse back to the central recording station. Because cables can exceed 10,000 meters in length, DTS holds the potential for transformative observation of diverse Earth processes.

However, the technique involves many nonstandard applications of component technologies that have not been previously used within the Earth science communities, presenting challenges in equipment selection, installation, and data analysis. The Hydrologic Measurement Facility (HMF) of the Consortium of Universities for the Advancement of Hydrologic Science, Inc. (CUAHSI), is presenting a series of workshops to aid successful DTS appli-

cation. Here we report on the first U.S. National Science Foundation (NSF) supported CUAHSI DTS workshop, which took place in the H. J. Andrews Experimental Forest, in Oregon.

Instructors of the new technique were John Selker (Oregon State University, Corvallis), Scott Tyler (University of Nevada, Reno), and Fred Day-Lewis and John Lane (Branch of Geophysics, U.S. Geological Survey Office of Ground Water, Storrs, Conn.). There were 30 enrollees in the workshop. The hands-on instruction included cable and instrument selection, cable deployment, power requirements, fiber repair, data acquisition, measurement calibration, quality assurance/quality control, and data visualization and analysis. Participants designed, installed, and analyzed the data from three field experiments using DTS systems from three leading DTS manufacturers. The workshop included a poster session with 16 contributions presenting a diversity of current and planned deployments.

During the workshop, participants conducted two field installations, which focused on stream temperatures at research watersheds within the Long Term Ecologi-

cal Research (LTER) Network. In one installation, cable was laid over contrasting bedrock and alluvial reaches, demonstrating how such a technique can collect data on the dynamics between groundwater and surface water beneath and lateral to the streambed. Cable for a unique air-shed fiber-optic array, designed to monitor nocturnal cold-air valley drainage (see supplementary material, at [http://www.agu.org/eos\\_elec](http://www.agu.org/eos_elec)), was also established. The greatest logistical challenge for this deployment was threading 11 cable crossings through the dense forest canopy. This was achieved by emplacing guide strings using biodegradable potatoes launched from a high-pressure device fitted with bow-fishing line. Notably, there were no field injuries through the course of the workshop.

Many technical issues were discussed during the course of the workshop, including whether and why to use DTS, comparisons between different types of fiber-optic cable, the need for additional test and repair tools (e.g., optical time domain reflectometers and fusion splicers), and the cost-benefit comparison of fiber-optic and conventional point measurements. Cable selection received special attention, as costs (from less than \$0.20 to more than \$10 per meter), loss rate, flexibility, tensile strength, resistance to crushing, resistance to animals (e.g., squirrels, beavers, muskrats), weight, and even the durability of meter marks along the cable vary greatly between products.

DTS has great promise for efficiently gathering precise, high-resolution environmental temperature data. The workshop provided participants with practical on-the-

ground fiber-optic handling and deployment experience through an interactive and efficient venue for dissemination of this technology. The substantial knowledge base required to successfully design, deploy, and troubleshoot a DTS installation continues to be a significant obstacle to

the broad adoption of DTS in Earth sciences. The CUAHSI HMF has identified DTS as a transformative technology that it intends to vigorously support. A follow-on workshop will take place 2–7 June 2008 and is open to all interested parties (<http://www.cuahsi.org>).

The full text of this meeting report can be found in the electronic supplement to this *Eos* issue ([http://www.agu.org/eos\\_elec](http://www.agu.org/eos_elec)).

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## Ocean Monitoring Collaborations Between Europe and China

***DRAGONESS Project Kickoff Meeting; Beijing, China, 11–12 October 2007***

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A coordinated, concerted action between Europe and China in ocean monitoring kicked off with its first meeting, held in Beijing.

The project, named DRAGONESS (DRAGON in support of harmonizing European and Chinese marine monitoring for Environment and Security System), is funded by the European Union's (EU) Framework Programme for 3 years. Researchers from the two continents will establish an inventory of Chinese and European capacities in marine monitoring for environment and security in the framework of challenges identified within international programs such as Global Ocean Observing System, Global Earth Observing System of Systems, and Global Monitoring for Environment and Security. In particular, the DRAGONESS aims to (1) assess existing Chinese and European information products and services arising from integrated use of remote-sensing, in situ observations, models, and data assimilation methods; (2) identify monitoring gaps and barriers (e.g., restrictive data availability); and (3) stimulate

exchange and initiation of a new European-Chinese partnership in Earth observation science and technology in support of global environmental monitoring.

The DRAGONESS project is both benefiting from and complementing the joint European Space Agency (ESA) and China's Ministry of Science and Technology (MOST) DRAGON collaboration, with a focus on Earth observations from satellites. DRAGON will run until 2012.

More than 30 participants from five European research institutes and eight Chinese institutes attended the kickoff meeting, which was hosted by MOST and the Ocean University of China. An official welcome was provided by the director of the National Remote Sensing Center of China, Guocheng Zhang. A detailed revision and discussion of the project background, objectives, tasks, and milestones followed (see <http://dragoness.nersc.no>).

In particular, meeting participants agreed that monitoring the marine environment is urgently needed to advance understanding of mesoscale and submesoscale processes and physical and biogeochemical interaction. Monitoring the marine environment is

also crucial to tracking pollution, forecasting and tracking extreme events, understanding climate change, and aiding operational oceanography. Because of the myriad of important applications, sustainable monitoring of the ocean is necessary, speakers stressed. In this context, the five work packages in the project (review of in situ observing systems, review of spaceborne observing systems, specification of data integration and information management, specification of ocean and coastal information products and services, and capacity building) are therefore highly relevant.

The project is now evolving around these work packages, with the first progress report delivered in April 2008. This will be followed by the first annual meeting, to be held in Bergen, Norway, in the autumn of 2008. The second and third annual meetings and a final symposium will be coordinated with the DRAGON program to secure a wider promotion of the DRAGONESS achievements.

For more information, contact the program coordinator, Johnny Johannessen ([johnny.johannessen@nersc.no](mailto:johnny.johannessen@nersc.no)), and the Chinese coordinator, Ming-Xia He ([mxhe@orsi.ouc.edu.cn](mailto:mxhe@orsi.ouc.edu.cn)).

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## Supplementary material to “Taking the Temperature of Ecological Systems With Fiber Optics”

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Fiber-optic distributed temperature sensing (DTS) is emerging as a powerful tool for observation of hydrological and ecological processes over a wide range of spatial and temporal scales. Several studies published over the last year suggest a broad range of applications (e.g., Selker et al., 2006a, b, Westhoff et al., 2007, Lowry et al., 2007, Moffett et al., 2008). DTS uses standard fiber-optic communication cables and can report the temperature of each meter of cable for distances exceeding 10 kilometers as frequently as every 3 seconds. With careful calibration, long integration times (>1 hour), and short cables (<4 kilometer), precision approaching 0.01°C can be achieved at 1-meter spatial resolution. With the ability to precisely observe temperature at tens of thousands of locations, DTS holds potential for transformative observation of diverse processes throughout earth and ecological science. The technique involves many non-standard applications of component technologies that have not previously been employed within these communities, presenting challenges with respect to equipment selection, installation, and data analysis. A series of workshops is being put on by the Consortium for the Advancement of Hydrologic Sciences Incorporated (CUAHSI) Hydrologic Measurement Facility (HMF) to aid the successful application of DTS methods. Here we report on the first workshop, “Fiber Optic Distributed Temperature Sensing for Ecological Characterization,” held 10–15 September 2007, and announce the next

workshop, to be held 2–7 June 2008.

The 2007 workshop was supported by the NSF, in cooperation with the USGS Ground-Water Resources Program. The event was held at the H J Andrews Long-term Ecological Research (LTER) site in Blue River, Oregon. The instructors for the workshop were John Selker (Oregon State University), Scott Tyler (University of Nevada, Reno), and Fred Day-Lewis and John Lane (USGS, Office of Ground Water, Branch of Geophysics). There were 30 enrollees in the workshop, with a supporting field crew of 6 graduate students, for a total of 40 full-time participants. The participants received a hands-on introduction to DTS, which included coverage of cable and instrument selection, cable deployment, power requirements, fiber repair, data acquisition, measurement calibration, QA/QC, and data visualization and analysis. The participants took part in the design, installation, and analysis of three field experiments using DTS systems from leading DTS manufacturers:

Agilent, Sensornet, and SensorTran<sup>1</sup>. These active-learning exercises sought to measure surface-water/ground-water interactions and airshed thermal processes using DTS methods. The workshop included a poster session with 16 contributions that presented a diversity of current and planned deployments.

Two of the three field installations were focused on stream temperatures at research watersheds within the LTER: Watershed 3 (WS3) was chosen for its contrasting bedrock and alluvial reaches, its considerable history of data collection, and as a test case for deployment in steep, challenging terrain. Fiber-optic cable was laid along the stream thalweg, with coils placed in larger pools to better constrain temperatures at those locations. The large number of boulder steps and log jams as well as occasional subterranean reaches in WS3 made cable deployment particularly challenging and required the exposure of many sections of cable to the air in order to negotiate such obstacles. These sections were used opportunistically by suspending the cable to measure variations in air temperature. As expected, the influence of hyporheic exchange was pronounced between the bedrock and alluvial reaches of the stream. Daytime water-bottom temperatures rose as the water flowed downstream over the bedrock, which represents an area of little or no hyporheic exchange, and fell in the alluvial reach, where surface-water interaction with the sediment is more pronounced; at night the reverse was true (Figure 1). Notably, the downstream end of the alluvial reach maintains the same temperature to within 0.1°C throughout the period of observation. These processes were further explored using ice-pulses and chemical tracers, and will be the subject of upcoming publications.

The airshed fiber-optic array was installed in Watershed 1 with the goal of understanding the daily cycle of air movement in the valley, with particular interest in nocturnal cold-air drainage from higher elevations (e.g., Pypker et al., 2007). The experiment entailed installations of four different types of cable. One armored cable was set in the stream bed. A second cable was helically wrapped in a machined groove of a 3-inch, Schedule 80 PVC pipe so that there was 1 meter of fiber length per 0.0254 meter of pipe height, thus providing a high-resolution vertical profile of temperature immediately above the stream. A third 700-meter long cable crossed the width of the valley at elevations of 2.5, 5.0, 7.5, 10, 12.5, 15, 17.5, 20, 25, 30 and 37 meters perpendicular to the stream (Figure 2). The greatest logistical challenge for this deployment was threading the cable through the dense forest canopy, which was achieved by first positioning guide strings into place using a 8-bar 50-centimeter barrel PVC potato launcher fitted with a bow-fishing line (Gurstelle, 2001). The final cable was deployed by a Helium-filled blimp to a height in excess of 120 meters, providing continuous monitoring of the vertical temperature profile (data not shown).

Many technical issues were discussed during the course of the workshop, including the choice of DTS, fiber-optic cable, the need for additional test and repair tools (notably the expensive optical time domain reflectometers and fusion splicers) and the cost-benefit between fiber-optic versus conventional point-measurement instruments. The issue of cable selection received special attention, as cables vary greatly in cost (<\$0.20 to >\$10/meter), loss rate, flexibility, tensile strength, resistance to crushing, resistance to animals (e.g., squirrels, beaver, muskrats) and vandalism, weight, and even the durability of meter marks along the cable (a conversation based on painful experience...).

DTS has great promise for efficiently gathering precise, high-resolution environmental temperature data under many circumstances. The installations provided workshop participants with practical on-the-ground fiber-optic handling and deployment experience, as well as exposure to hydrologic and atmospheric applications of the DTS technology. The workshop provided an exciting and efficient venue for dissemination of this technology, but several key challenges remain for broadening its use. First, although costs continue to decrease, purchase and deployment of a DTS and high quality fiber-optic cable costs about \$50,000, which excludes the technology from use in many studies. More importantly, the substantial knowledge base required to successfully design, deploy and troubleshoot a DTS installation commonly requires the involvement of highly experienced users. The participants indicated that expanded use of this innovative technology within the hydrologic community would be greatly facilitated through programs for DTS rental, lease, or cooperative purchase and through on-site support from experienced users. The CUAHSI HMF views DTS as a transformative technology that it intends to support to the greatest degree possible. A follow-on workshop will take place 2–7 June 2008, as described at the CUAHSI website (<http://www.cuahsi.org>).

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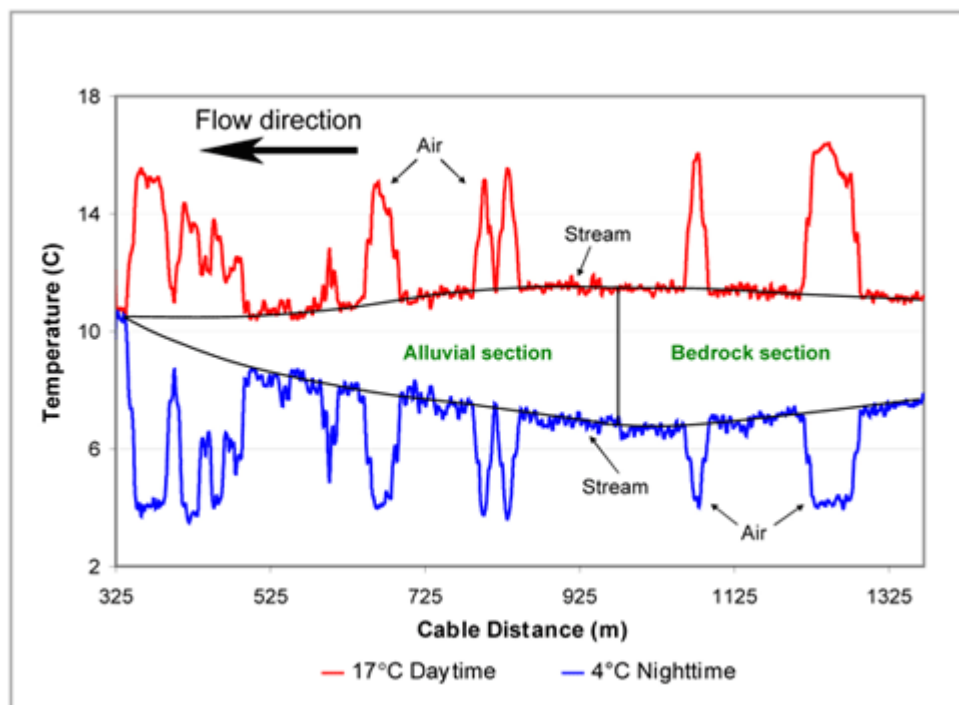
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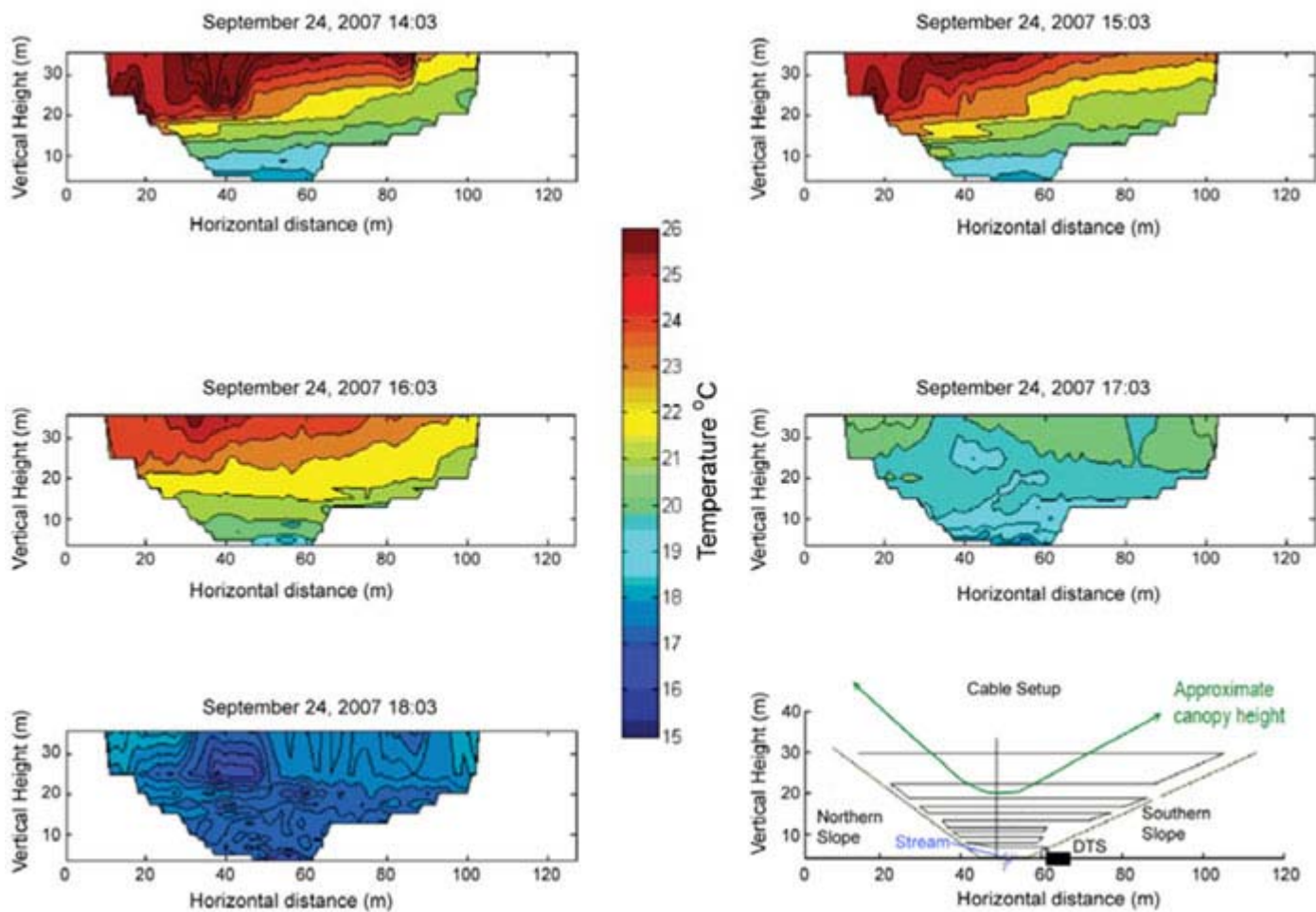
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**Figure 1.** DTS data from coldest and warmest datasets obtained 27 September 2007—at 6 AM (“nighttime” when air temperature was 4°C) and 5 PM (“daytime” when air temperature was 17°C)—in Watershed 3 (Brugg BruSteel cable and Sensonet double-ended Sentinel DTS). Stream flows right to left. Sketched black lines are interpolated stream-bottom temperature along the reach. Data reflecting air deployments of the fiber are those far from the two black lines. The bedrock reach warms in the day and cools at night with distance downstream (towards the left), while the reach with deep alluvial fill has the opposite pattern due to hyporheic exchange with the bed material. Measurements at cable distance 325 meters are where the stream has re-emerged following a >10 meter section where the entire flow was carried sub-surface through a log and debris conglomeration. The cable distance includes air and coil deployments, thus does not directly reflect the stream distance, which was approximately 700 meters.



**Figure 2.** Interpolated temperature from the Airshed study based on 1-hour DTS data, 24 September 2007, from the cable setup shown in lower right panel (obtained with Brugg BruSteel fiber and Agilent double-ended NA4386A DTS) in Watershed 1. Cooling is seen in the late afternoon, with cold air masses immediately above the tree canopy and above the stream.

<sup>1</sup>Use of brand names is for information purposes only and does not constitute endorsement by the U.S. Government or any other organization or individual among the authors.

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