Cave and Karst Science

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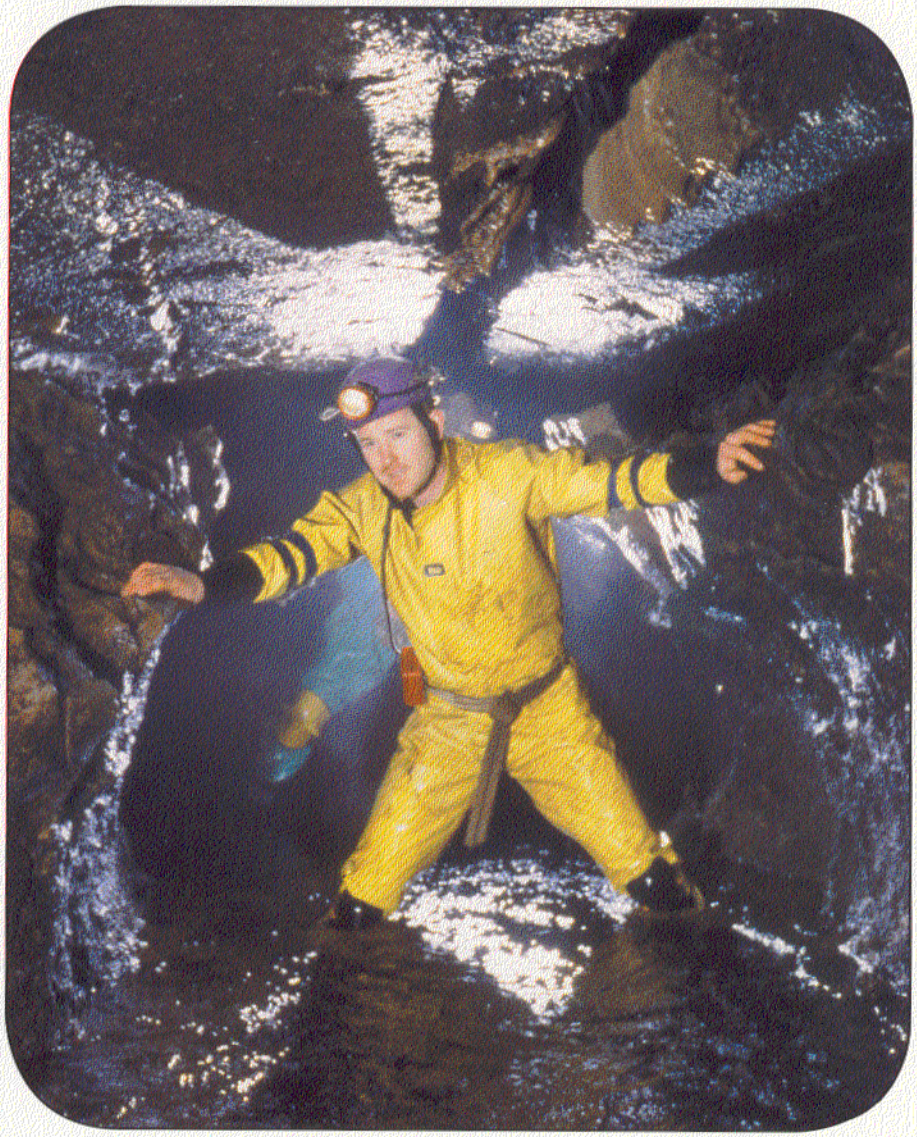

Trickle midges in Peak Cavern, Derbyshire, UK
Low-cost telemetry, Sorbas karst, Spain
Ingleborough Cave, Yorkshire, UK
Gypsum karst, Sivas, Turkey
Caves in Myanmar
Forum

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Cover photo:

Adrian Hall straddles the joint-guided fissure at the head of Lake Avernus in Ingleborough Cave, North Yorkshire. This spot, which provides a somewhat aqueous dive base for the submerged connection with Beck Head Stream Cave, is reached by crawling in the stream (Fell Beck) in a dangerously flood-liable area below Giant's Hall. The first explorers arrived here almost 167 years ago with little better equipment than old clothes and a few candles: a remarkable achievement [see also the paper by Stephen Craven in this Issue].

Photograph by John Cordingley, assisted by Adrian Hall and Gerald Benn.

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Low-cost telemetry monitoring of the cave environment: Sorbas gypsum karst, Spain.

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Abstract: A cave environment monitoring system installed in the Sorbas gypsum caves (Almería, Spain) is described. The system was initially designed to study the anthropogenic changes within a cave, brought about by the beginning of tourism activities. Data of carbon dioxide concentration, temperature, relative humidity and the presence of visitors are sent by radio, in real time, to the University of Almería base station. The microclimatic information is published on the Internet (http://karst-yeso.ual.es), so that anybody can check the microclimatic conditions of the cave and recognize the influence and environmental recovery after an actual visit in real time. The combination of a remote location and the need to alter dynamically how readings are taken led to the development of custom hardware and software for a cave monitoring system. The system could be a very interesting tool for the management of a show cave.

Keywords: show cave, environment monitoring system, telemetry.

Note: the authors have published additional information, specifically technical details of the hardware and some results, in the *IEE Electronics Systems and Software Journal* (2003, 1(3), 24-27) and *The Cave Radio and Electronics Group Journal* (2003, 53, 6-8).

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ENVIRONMENTAL SIGNIFICANCE OF THE SORBAS GYPSUM KARST: SOME REASONS FOR CONSERVING THE CAVES

The Sorbas Karst (Almería) is a small gypsum outcrop, 12km^2 in extent, which contains almost 1000 sinkholes and caves (Calaforra, 1998; Calaforra and Pulido-Bosch, 1997; Calaforra, 2003.). The high concentration and variety of surface and subterranean karstic forms (Calaforra and Pulido-Bosch, 1999, 2003) make it one of the most important gypsum karst environments in the world. On the other hand, some special environmental conditions, like a semi-arid climate and high levels of soil salinity, turn it into a biodiversity hot-spot area. With respect to the caves, research into the cave arthropod fauna of Sorbas, carried out by the University of Almería, has so far discovered six new species: *Pseudosinella sp. nov.*, *Chthonius sp . nov.*, *Coletinia sp. nov.* and *Tychobythinus sp. nov.* (Ruiz-Portero *et al.*, 2000, 2002), *Palliduphantes cortesi sp. nov*, and *Palliduphantes gypsi sp. nov.* (Ribera *et al.*, 2003).

In addition, the gypsum comprises a mineral resource that has been exploited since the middle of the last century. The mining sector has played an important part in the development of the region and has formed the socio-economic base of the area. The annual production in 1998 was close to 23.5 million € (Euro), generating an employment quota of about 400 direct and indirect jobs (Contreras and Calaforra, 2002). Lack of diversification of economic activities, together with the impact of mining on the environment, has brought this karstic area to an unsustainable environmental situation. The absence of a Natural Resources Ordination Project to plan the use and management of this natural area is the main problem nowadays. Historically, development based around the mineral resources has obviated all other functions and values of the natural heritage.

In 1988 the Spanish Administration recognized the area's rich environmental value and declared it a Protected Natural Space. An area of 23.75 hectares was protected using existing linear structures, especially highways and other roads, to define the limits of

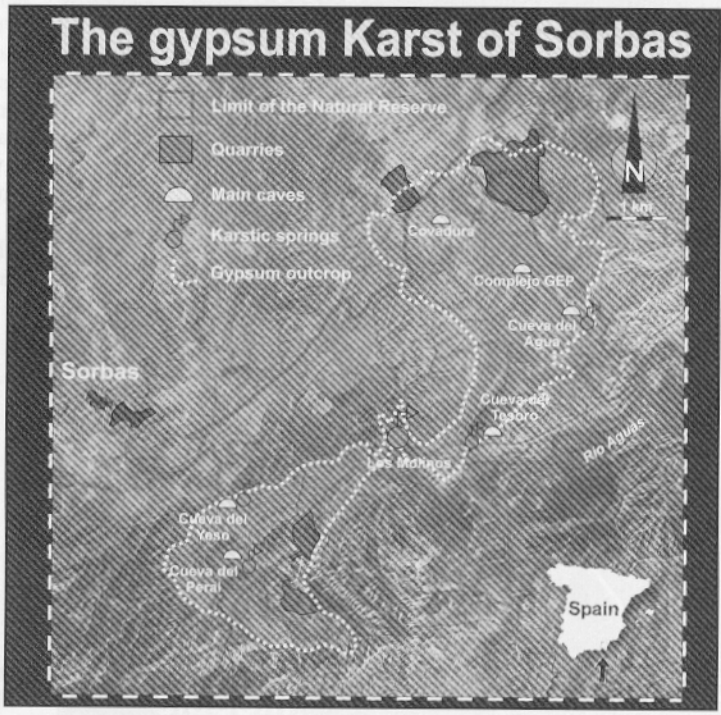

Figure 1: The gypsum outcrop and Natural Space of the Karst of Sorbas, main caves, karstic springs and quarries (Calaforra, 2003).

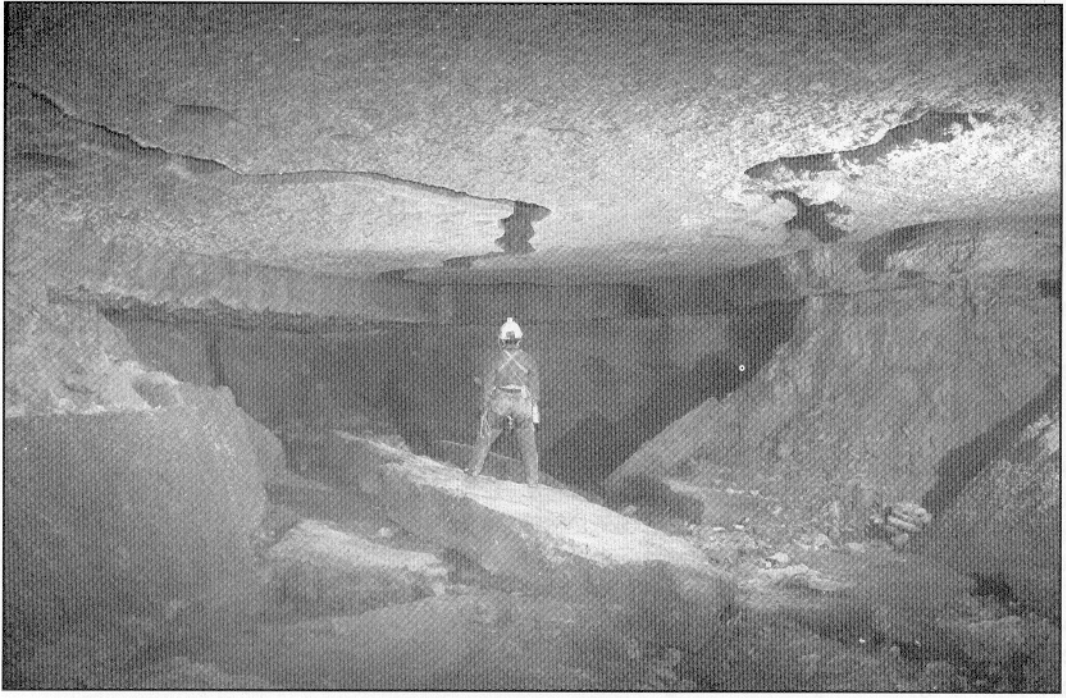

Figure 2: Main gallery of the Covadura Cave system (Sorbas gypsum karst). Photo by Jabier Les.

protection. For this reason not all of the gypsum outcrop is totally protected. Karstic areas to the north and south, and where the gypsum mines are located, are outside the limits of the Natural Space (Fig.1). Note that mining activity and exploitation licenses pre-date the declaration of the Natural Space. Nowadays the karst outcrop and the mining activity are in a delicate environmental equilibrium. Mining activity is located at the limits of the protected area without any policed perimeter control existing between them.

Tourism and caves in the Sorbas gypsum karst

Currently the tourist development of the Sorbas gypsum karst is based around an "adventure-visit" scheme, which is used in several caves. Tourism represents the main sustainable economic alternative to the gypsum quarries. Some private companies have collaborated with the Administration to provide visits of small groups (up to 20 visitors per group) to the Cueva del Yeso and most of the subsurface galleries of the Covadura Cave system (Fig.2). "Adventure tourism" is based on speleology-type visits, with individual electric lamps and with no paths or artificial structures. Tourist exploitation of these caves has increased considerably during recent years (up to 25,000 visitors per year).

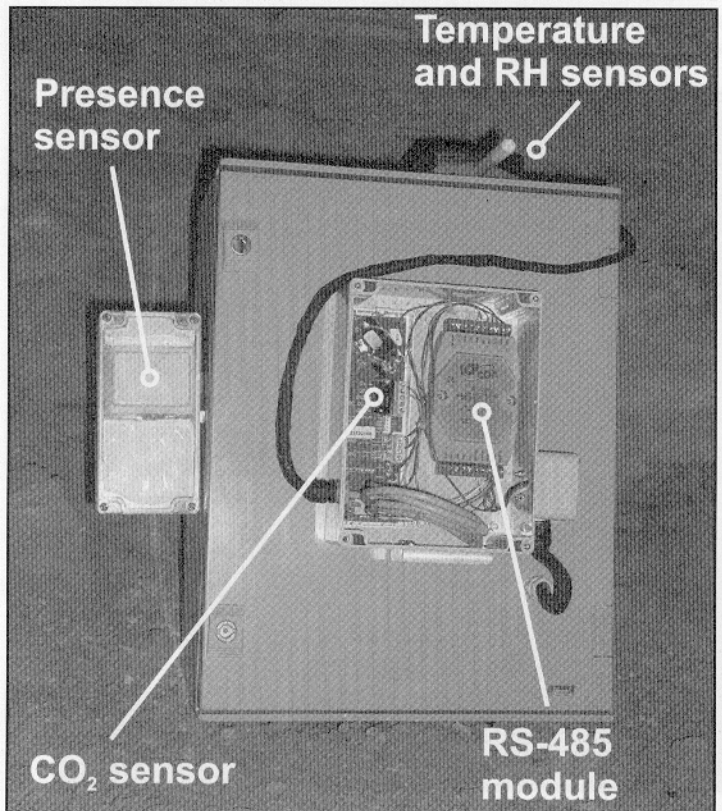

Figure 3: View of a remote microclimatic control station in the Covadura Cave System.

The "FEDER-SORBAS" research project: a framework for sustainable management of show caves

Show cave management should be able to preserve the cave environment within risk limits, and support a sustainable visitor capacity (Cigna, 1993; Calaforra et al., 2003). It is advisable to have some environmental management tools that facilitate and characterize the main parameters of the cave, and to obtain some environmental indicators under natural conditions. This database will be used as a reference for objective evaluation of the human impact during tourist exploitation of the cave. In this sense, the FEDER-SORBAS Research Project (Spanish Commission of Science and European Union Funds - FEDER, Project number: 1FD97-1577) constitutes the first phase of the cave tourist potential possibilities of the Sorbas gypsum karst. On the other hand, many cases of exploitation of the environmental heritage have assured conservation, because added economic and cultural value are factors that can be used to help develop their protection. Correct environmental management of a show cave can impact favourably when encouraging the environmental education of the visitors.

Objectives of the FEDER-SORBAS research project

The main objectives of this research project are:

- to understand the environments of the most significant caves within the Sorbas gypsum karst;
- to determine the inter-annual variation, inside and outside the caves, of environmental parameters: temperature (air/water/rock), relative humidity, natural ventilation, carbon dioxide concentration, relationship between rainfall and cave drip-water rate, etc;
- to compare the microclimatic stability of each cave and the inertia of their recovery after different types of human presence (mass visits, sporadic visits);
- to determine the caves that are susceptible to tourist use, evaluating the environmental impact upon them.

Intelligent environmental control system for caves

Monitoring of basic physical variables in show caves is highly recommended because cave lighting and the presence of visitors immediately modify cave environmental conditions. A cave that receives a continuous stream of visitors can suffer changes in

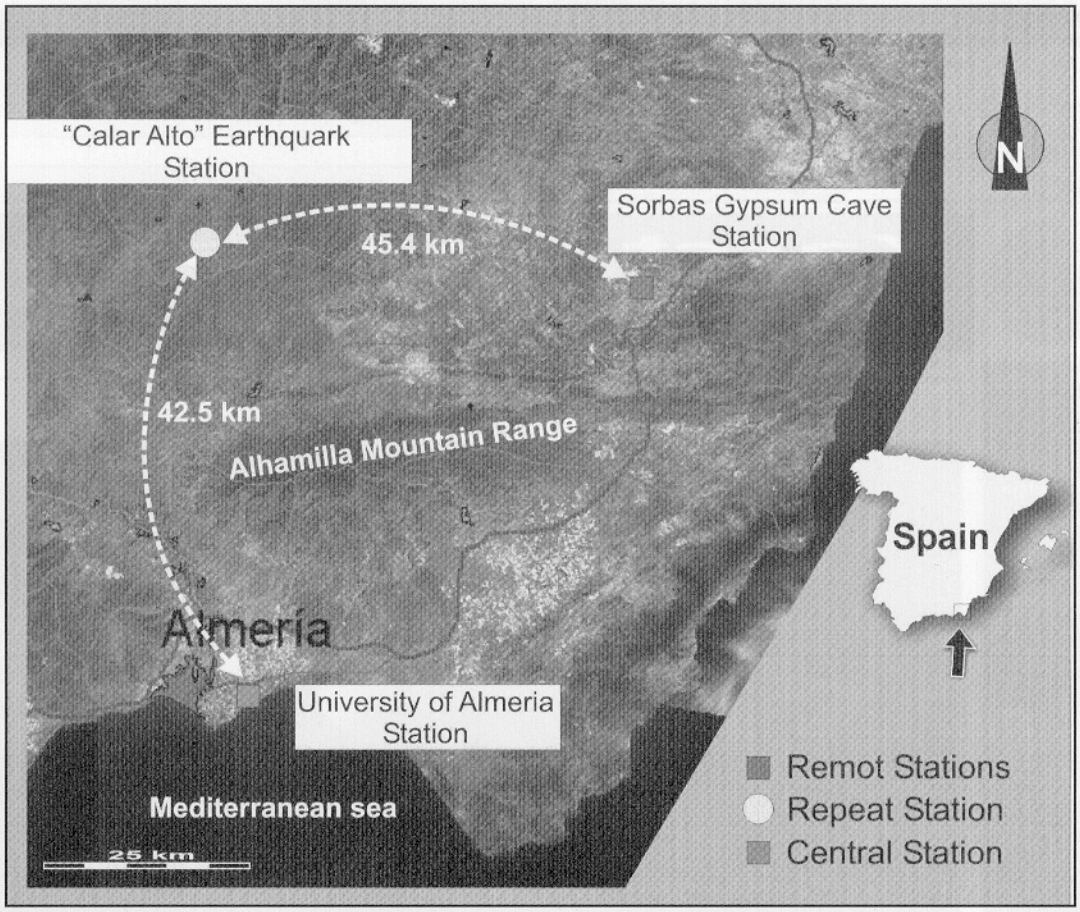

Figure 4: Radio communications between the local station (Covadura Cave system, Sorbas gypsum karst) and the central station (University of Almeria).

relative humidity, air temperature and CO_2 concentration, among other variables, as a result of the presence of visitors. Such variations could mean a change away from the optimal living conditions of any troglobitic fauna, or changes in speleothem growth conditions. Therefore, measuring these variables is of great value in trying to achieve appropriate environmental conservation of the cave.

The classical way of measuring and recording variables makes use of data-loggers. This confers the advantages of independence in terms of placement of the instruments, and autonomy in the acquisition and storage of the periodic measurements from the sensors. The limitations of such equipment relate to the battery life and the memory available for data storage. These data acquisition systems require periodic servicing to replace the battery and download the data. In addition, because they are isolated and have no communication to the surface, the frequency of readings cannot easily be modified in accordance with external events.

To determine the influence of cave visits on environmental conditions inside the cave, and to assess the degree of impact in terms of physical and biological conservation, it would be useful to be able to increase the frequency of data acquisition of all the sensors in the cave automatically, for example when people are detected inside. In the Sorbas Karst these requirements have been met by installing a microclimatic control system based on techniques of distributed control and telemetry, to allow intelligent and customized data acquisition (Gázquez *et al.*, 2003a and b). This system supports both measurement and real time transmission to the station located in the University of Almería.

Environmental control stations

The environmental control stations have the function of acquiring the different variables and transmitting these data to a central station, which is responsible of the storage, treatment and diffusion of this information. Each sampling station contains the following set of environmental sensors with an analog output: (1) carbon dioxide concentration, (2) air temperature and (3) relative air humidity. It also incorporates a human presence detector to monitor visitors to the cave (Fig.3). Data are digitized using a commercial data acquisition module.

Data communication network

In the first instance, the information collected digitally by the various data-sensors at the remote stations is transferred to a local computer situated in a small building close to the cave. This computer is responsible for formatting the data received from the sensors. Subsequently, the information is sent to a central computer located at the University de Almería for data processing and storage. To perform these functions, a mixed communications system is required. The first stage (remote stations to local computer) utilizes a 1km-long cable RS-485 communication, whereas the second (local computer to central computer) requires wireless communication via radio.

The data acquisition system has a protocol that allows the local computer to check, every 30 seconds, whether or not there are people present in the cave, and so to establish the counting rate for data acquisition, using the following criteria:

- (1 minute): measurements every minute if human presence was last detected less than one hour ago;
- (1 hour): measurements every hour if human presence was last detected more than one hour ago.

The system permits the sampling frequency to be increased to allow a more detailed study of the impact of a visit on the environmental parameters in the cave. Additionally, the established intervals of 1 minute or 1 hour can be adjusted if necessary.

The second stage of the communications network is the transfer of information from the local computer to the central station at the University of Almería. The Sorbas caves lie in a rather remote area with no telephone lines and so the two options available for data transmission are digital mobile telephone or autonomous communication using a radio-modem. The second option is better suited to the monitoring of ambient conditions inside show caves, because a constant connection is possible and it does not require private operators. In addition, the rugged topography of the province of Almería prohibits a direct link between the local station in the Sorbas Karst (cave) and the central station (University of Almería). Thus, a repeater was needed to cover both stations. This repeater

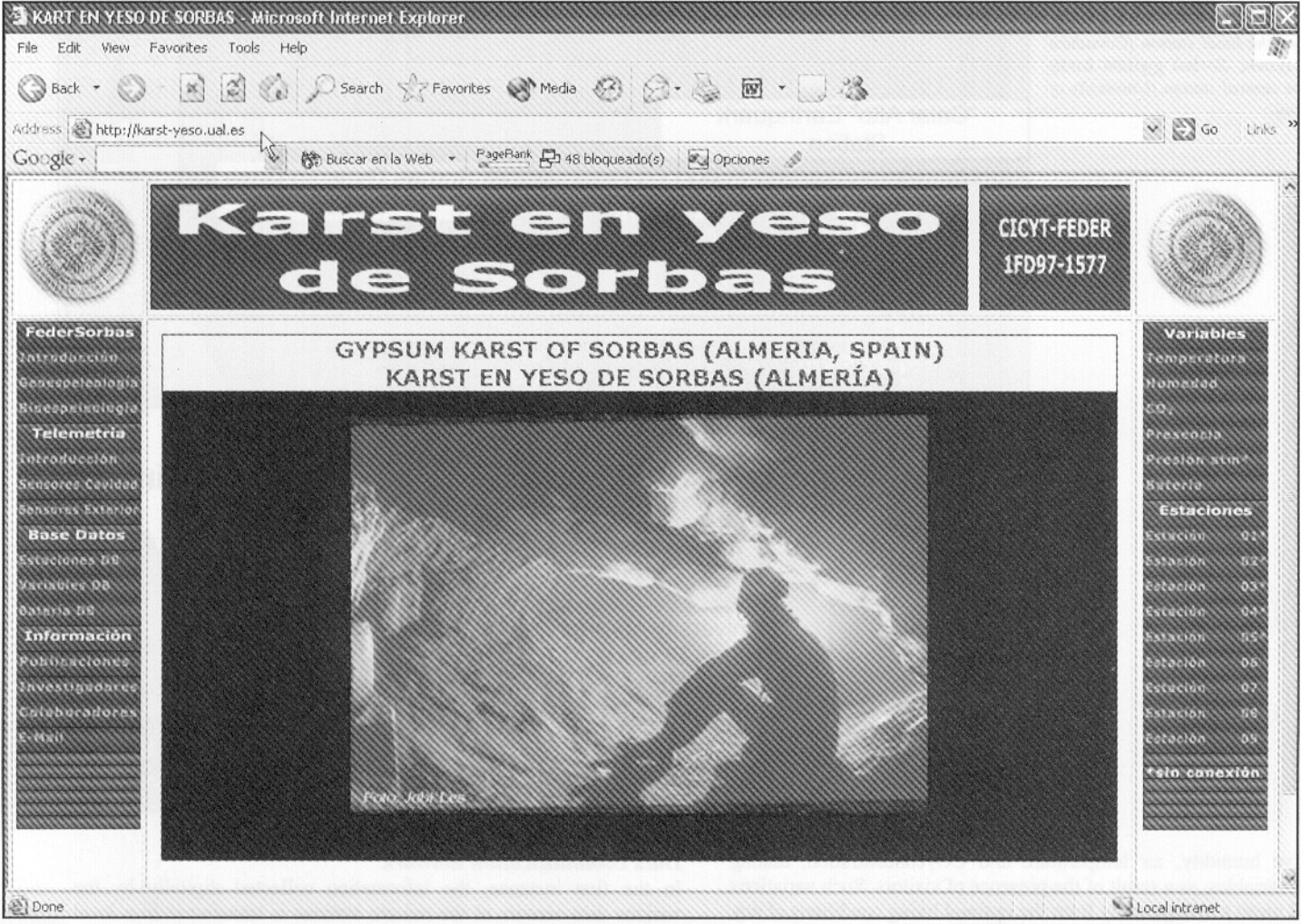

Figure 5: *Main web page of the FEDER-SORBAS research project (http://karst-yeso.ual.es).*

radio-modem was installed at the Seismological Station belonging to the Andalusia Geophysics Institute ("Calar Alto" Earthquake Station). Figure 4 shows the geographical distribution of the data transmission network.

Internet accessibility to the environmental control of caves in the Sorbas gypsum karst

The data acquisition system installed inside the Sorbas caves provides intelligent environmental control, potentially of great interest to the future management agents of shows caves. The system has been in operation for more than a year and there is already a considerable volume of data. What is more, the automatic increase of the data acquisition frequency of the system, according to the presence or absence of visits, offers detailed time series data for the main environmental variables in the cave. This record will facilitate determination of the ideal approach to visits, with respect to the incidence of each parameter in many areas of the cave (9 stations with 36 sensors in total have been installed).

Lastly, transfer of the research results is direct, and these are of immediate use to the Administration responsible for the caves (the Environment and Tourism offices of the Autonomous Government of Andalusia, the City Council of Sorbas and the speleo-adventure companies). With these results promotion of rural tourism in these interior districts can be increased, assuming there is opportunity to change or diversify the economic dependence of this area. The information is published in real time by means of the http://karst-yeso.ual.es (n.b. no "www") web (Figs 5 and 6), so that anybody can access details of the microclimatic conditions in the cave and observe the influence and rate of environmental recovery after an actual visit.

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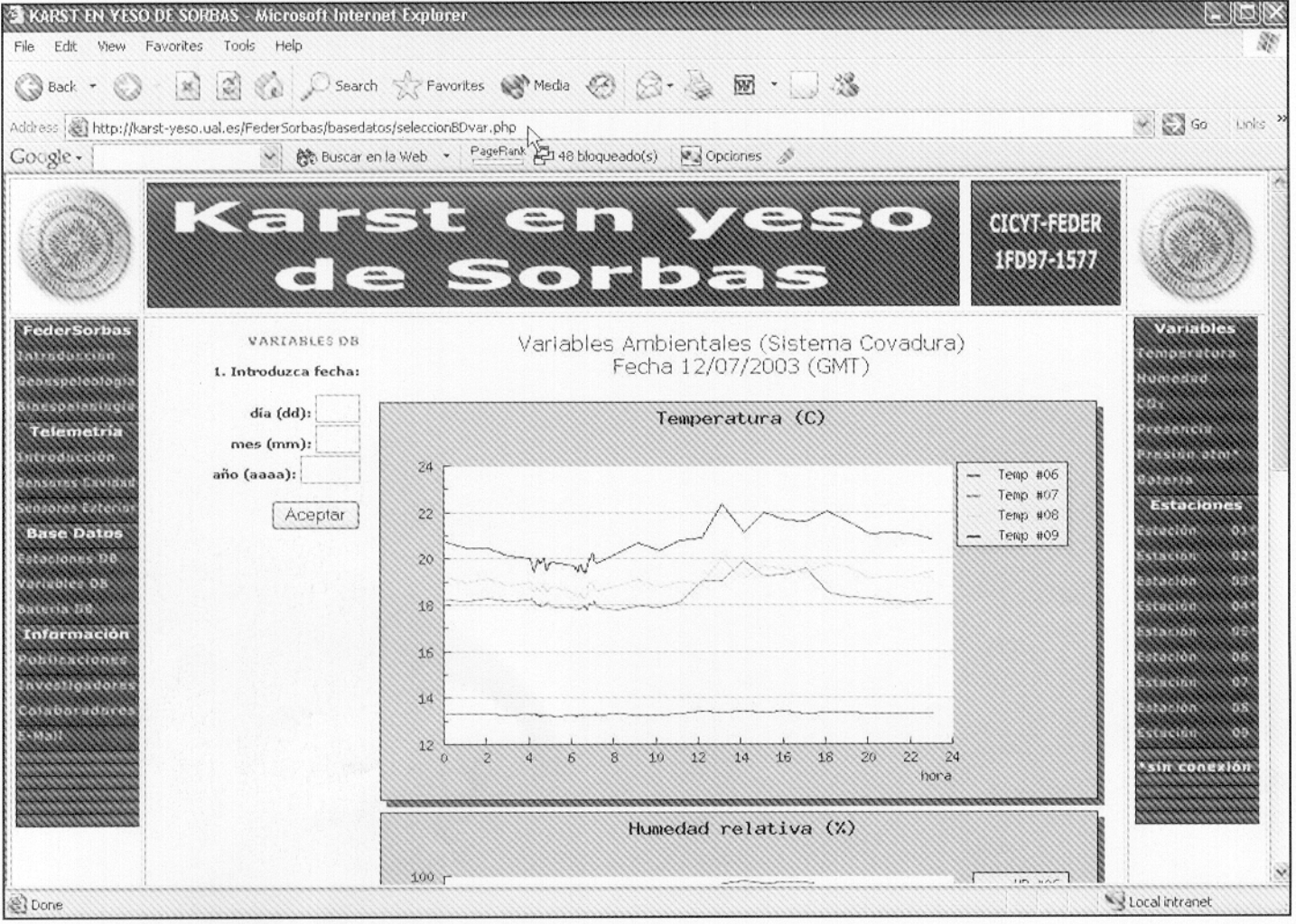

Figure 6: *Real time graph of air temperature inside the Covadura Cave system.*

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