Title: Simulation of the microclimate in an archaeological cave (Lascaux, France)
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Background

An eulerian/lagrangian method for the numerical simulation of incompressible flows in the complex underground area of the Lascaux cave (France) has been implemented (Lacanette *et al.*, 2009) in the Thetis code, a research code developed by I2M laboratory, TREFLE department, Numerical Fluid Mechanics team. A simulator dedicated to the conservation of the cave emerged.

Methods

Heat transfer through the epikarst (layer of rock between the outside and the cave) implies a modification of the thermal wave. Its intensity decreases and its phase is shifted. For example, in Lascaux, when the thermal wave reaches the shallowest part of the cave, i.e. at 10 m depth, its intensity is only 5,3% of the original one, and the phase shift is 6 months. These figures obviously depend on the nature of the epikarst. Here, we propose a heat transfer model whose diffusion coefficient is settled from the temperatures registered in the monitored cave. Moreover, we define a model dedicated to the projection of the outside temperatures and their consequences on the microclimate of the cave.

Results

The cave is monitored and values of temperature and CO_2 rates are registered in every room. CO_2 rates evolution is interesting to follow the convection currents in the cave.
Simulation provides temperature distributions and convection currents (Figure 1).

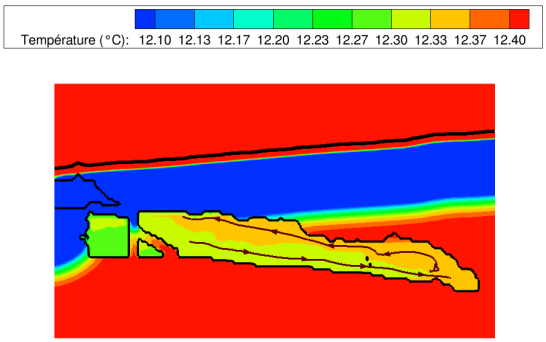

Figure 1: Slice of temperature distributions and stream in the thermal configuration of May 14

When a year is abnormally hot, like 2014 will probably be, simulation can predict the consequences on the microlimate of the cave 6 months later. We will present data of the microclimate of the cave for the first 6 months of 2015, starting from the outside temperatures at the end of 2014.

Conclusions

From a conservation point of view, it is very important to be able to predict unusual events in the cave in order to take measures to prevent them from altering the art.

Numerical simulation of the thermoaeraulic flows in the cave constitutes a tool to improve its conservation.

D. Lacanette, S. Vincent, A. Sarthou, P. Malaurent, J.P. Caltagirone - An Eulerian/Lagrangian method for the numerical simulation of incompressible flows interacting with complex obstacles : application to the natural convection in the cave of Lascaux, *International Journal of Heat and Mass Transfer*, 52, 2528-2542, 2009.