Plastic bottles solar collector

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Introduction:

In the Andean region of Southern Peru, poverty and climate are extreme: at 4000mt asl, insolation is among the highest in the world but temperatures vary more than 30 degrees between day and night.

In the community of Livitaca, the associa-tion "Ingegneria Senza Frontiere" is working on a project of bioclimatic archi-tecture.

Figure 1. "Inti Wasi" project, Livitaca (Cuzco)

It is devised a low cost drainback solar heating system, which can accumulate the heat picked up during the day by a rudimentary solar collector within a system of thermal activation of the floor mass. Due to area high irradiation, it is possible to construct the solar collectors with materials available locally and largely recycled, such as low-density polyethylene pipes for irrigation, empty plastic bottles and used tetrapak, broken plastic bags, according to the model proposed by J.A. Alano (1).
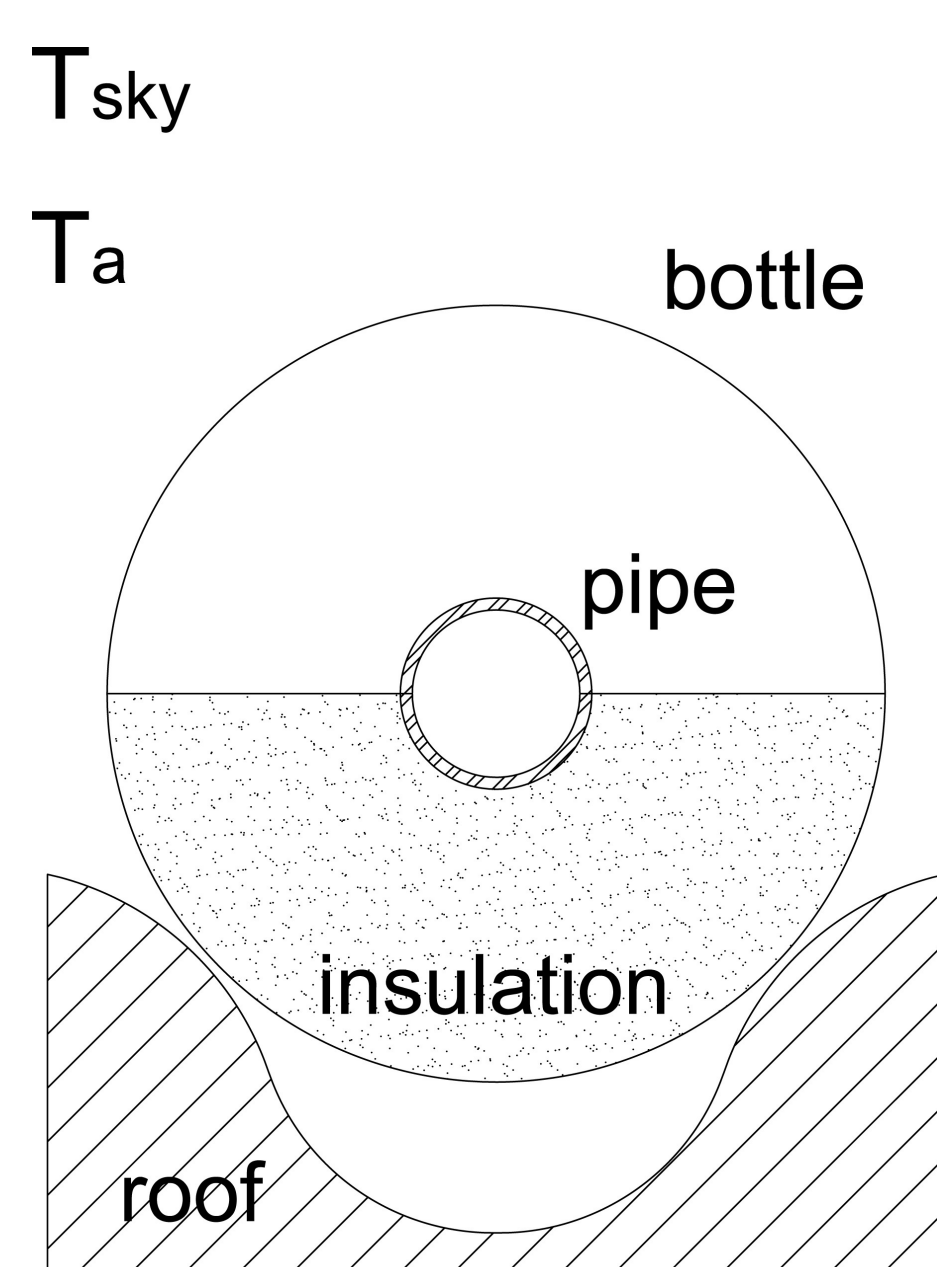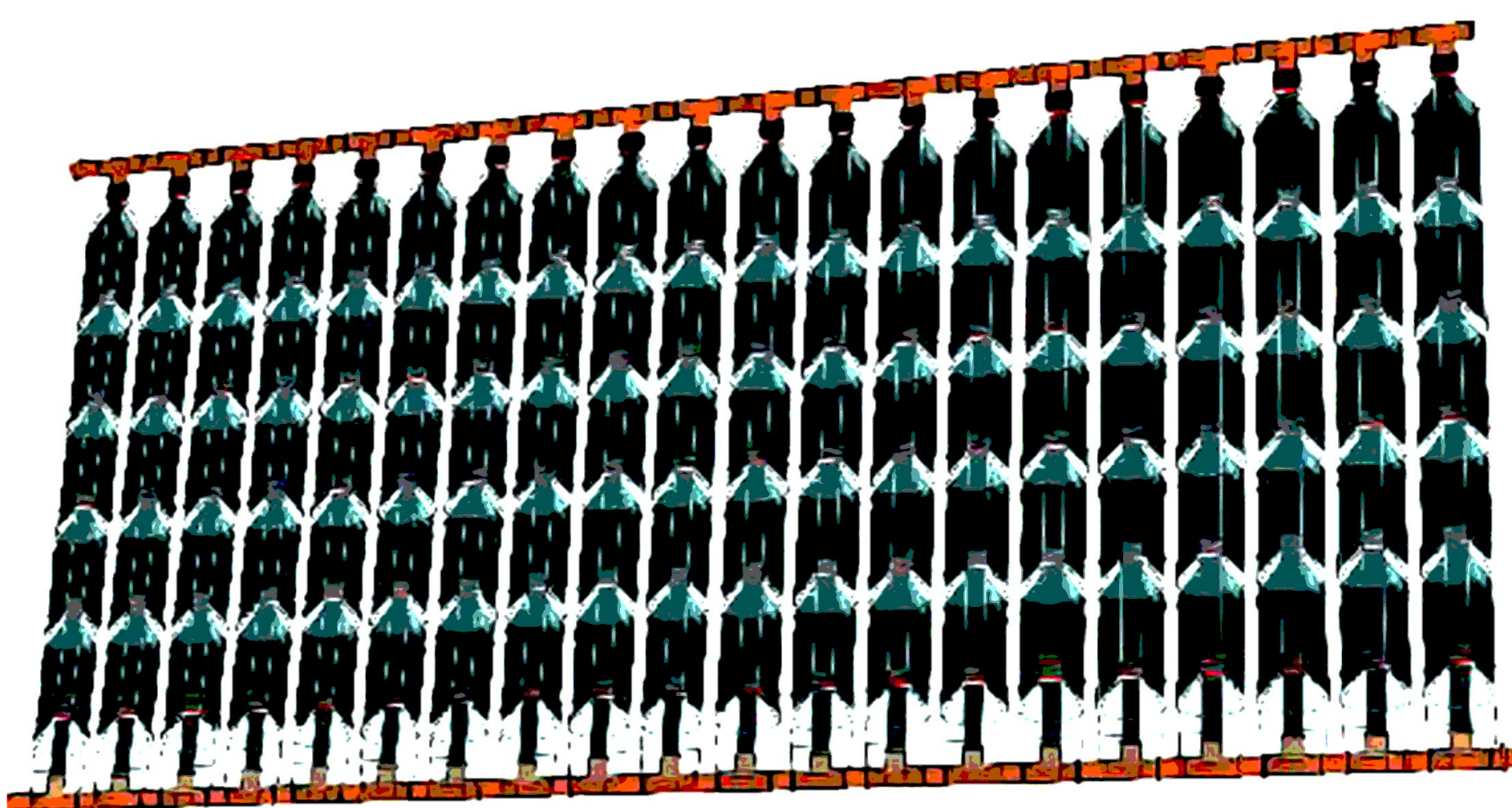

Figure 2. Plastic bottles solar collector (on the right: section over the roof)

Computational Methods:

Using Comsol, we study the behaviour of a single pipe of the collector in order to determine, with fixed diameter and dimensions of the bottles, the combination of the internal water speed and the pipe length that represents the best compromise for the system.   We also investigate the temperature pattern in the thickness of the pipe at the more critical location, to verify that it remains below the threshold of softening of the polyethylene, condition beyond which it would not be able to withstand the pressure of the system in regime of operation.   Moreover we analyse the temperature trend in the condition of absence of water and simultaneous irradiation, which occurs in case of failure of the pumping system.

Some simplifying assumptions are taken for the heat exchange:

-the bottle is completely opaque to infrared radiation (despite the fact that plastic is not)
-exchange between the pipe and the bottle is considered as a radiative and conductive in air's layer, assuming that natural convection is suppressed in the enclosure between bottle and inner pipe (verified by a 2D model)
-the radiation between the outer surface of the bottle and the environment is neglected

The problem, symmetrical with respect to the plane passing through the pipe axis and containing the direction of the solar radiation, is covered in a 3D stationary model in the operating condition and in a 2D stationary to investigate the accuracy of the assumption of convection suppression and the performance of the temperatures in absence of water.

Through a 2D axisymmetric model it is possible to calculate the velocity field of the fluid inside the tube: this is used in the 3D model responsible of the heat exchanges' calculation.
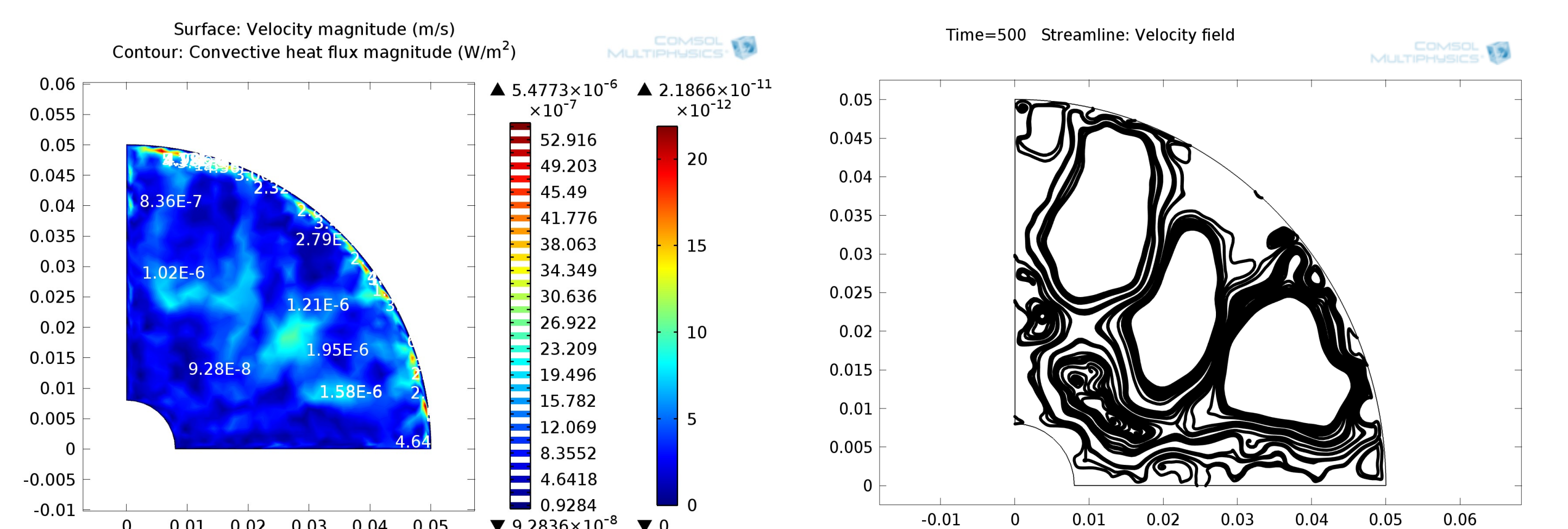

Figure 3. Convection suppression, 2D model with Boussinesq approx.

Results:

Using the model created, it is possible to conclude, for a given irradiation, the average fluid speed and the adequate length to achieve the desired tempe-rature of the mixture at the output.
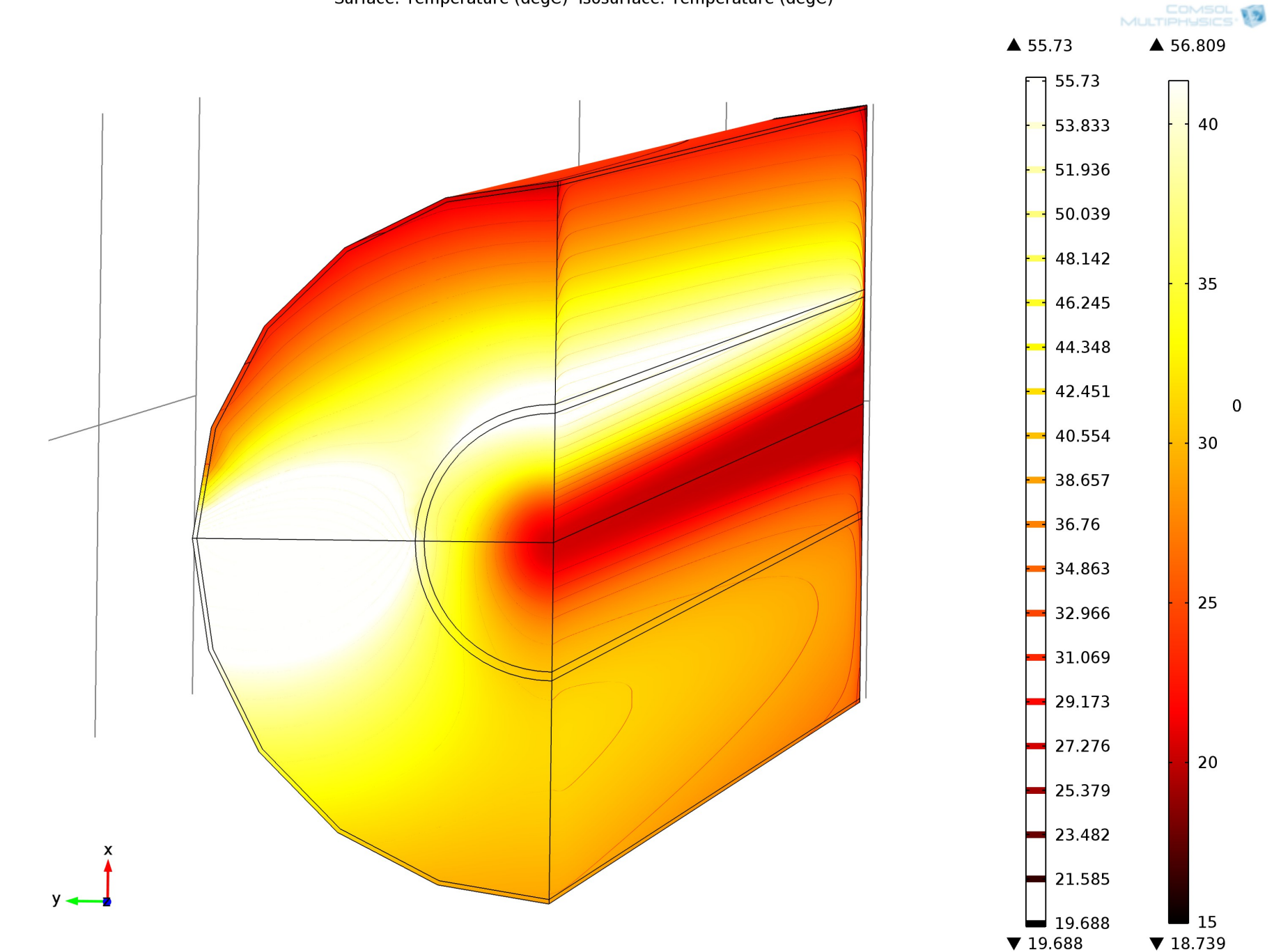

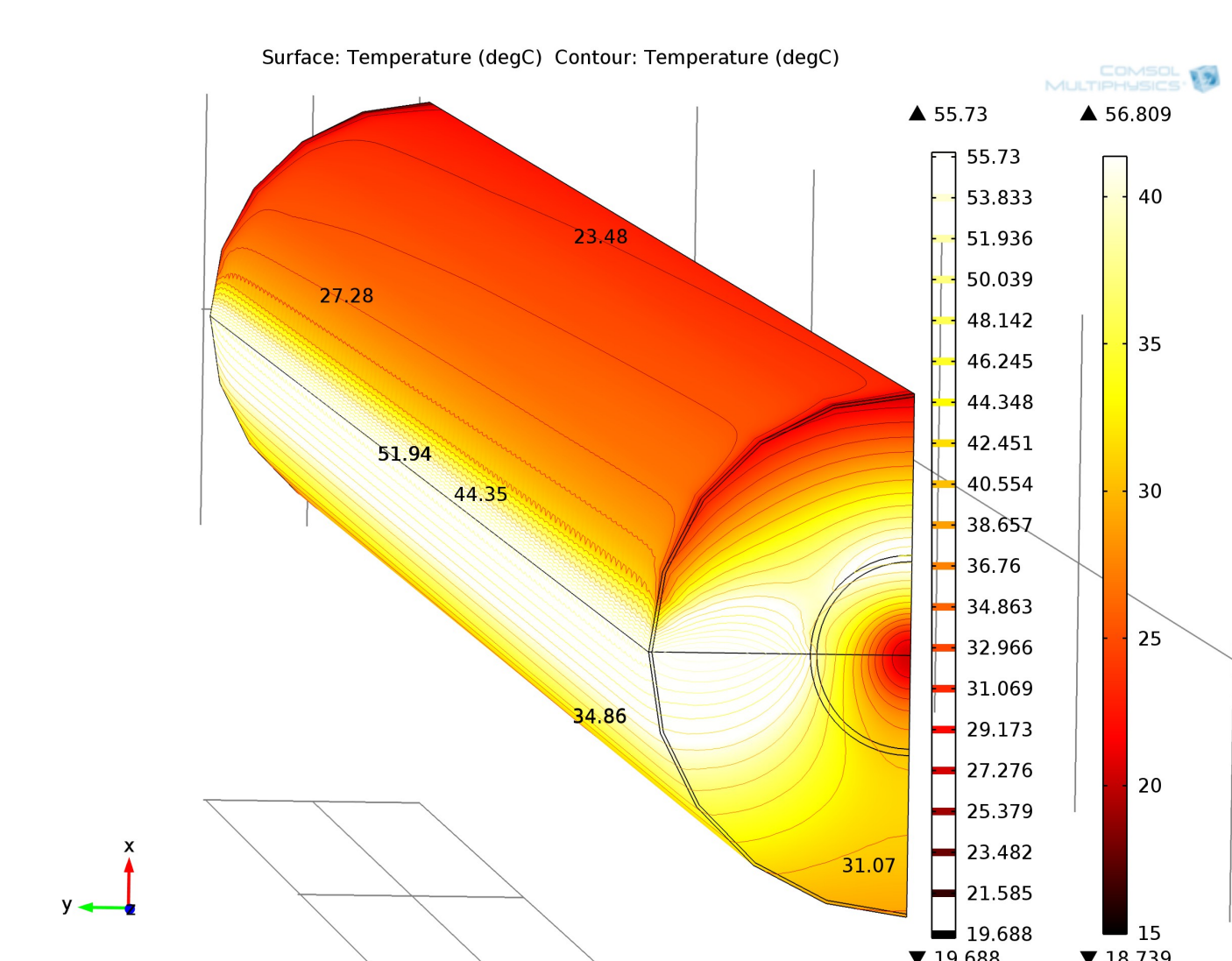**Figure 4**. T distribution, S=1100 W/sq.m, v=0.05 m/s, L=2m
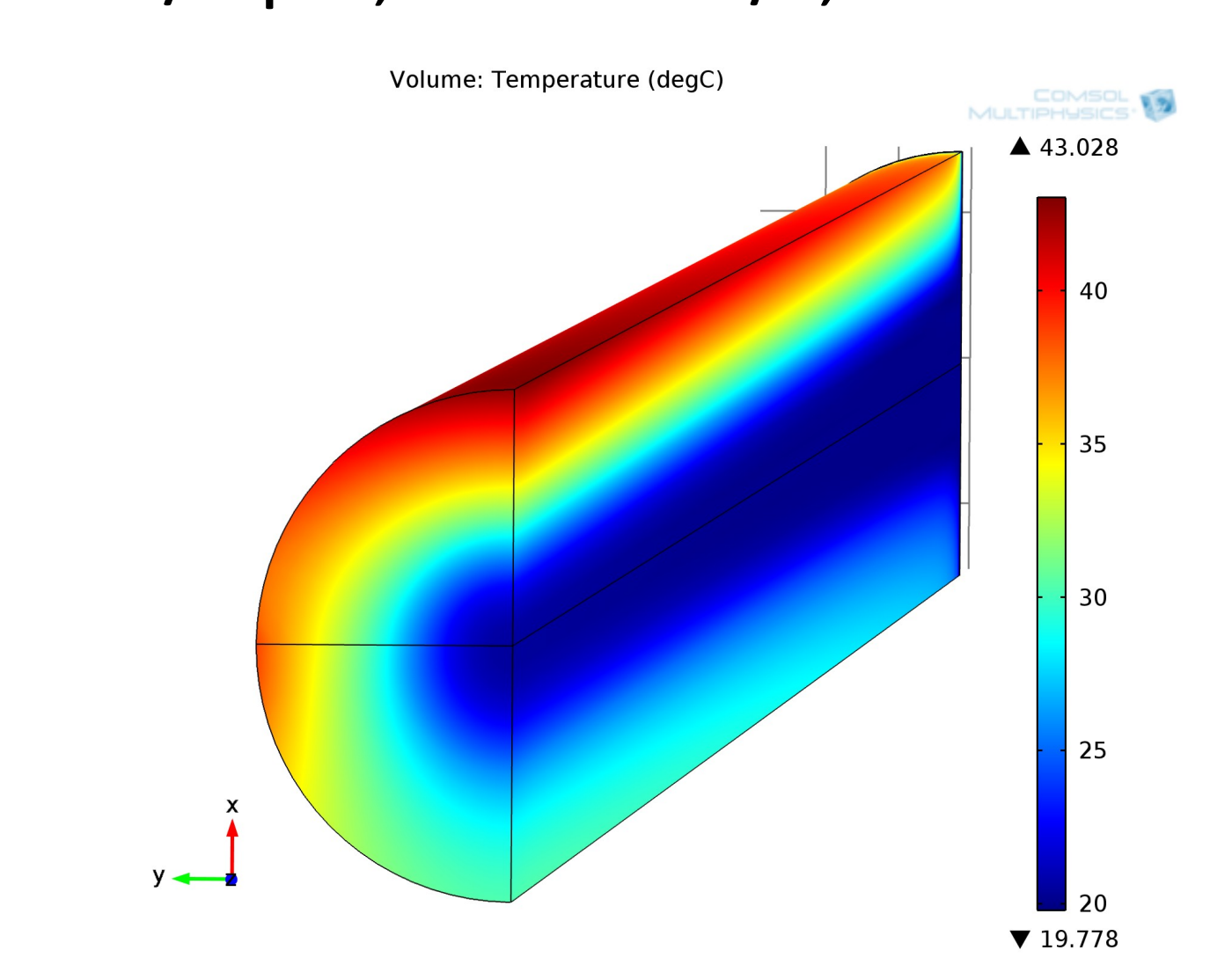

Figure 5. Bottles temperature

Figure 6. Water temperature

Conclusions:

Future model improvement will include a more realistic characterization of the plastic of the bottle, utilizing radiation in participating media.

Using the results of the simulation a prototype of the collector, still in testing phase, was made; subsequently we will proceed with the construction of the collector with the number of tubes necessary to meet the structure's heating needs and then we will carry on with the installation.

References:

1. J.A.Alano, "Manual para la Construcción y Instalación del Calefón Solar Compuesto de Embalajes Descartables", Sema, Paranà (2008)
2. J.A.Duffie, W.A.Beckman, "Solar Engineering of Thermal Processes", J.Wiley & Sons (2006)