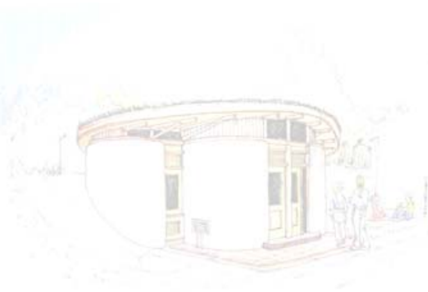
NATURAL VENTILATION THROUGH BURIED PIPES IN A SMALL SCHOOL AT VIAMÃO (BRAZIL)



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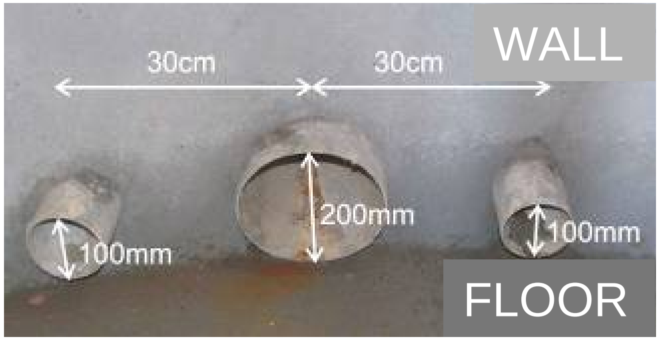
Objective of the study

The objective of the study was to evaluate the thermal performance of a small school construction, in southern Brazil, and to investigate the more influential factors determining the natural convection of air through buried pipes

Vila Ventura

Viamão (Brazil), **30º 01'59"S, 51º13'48"W**

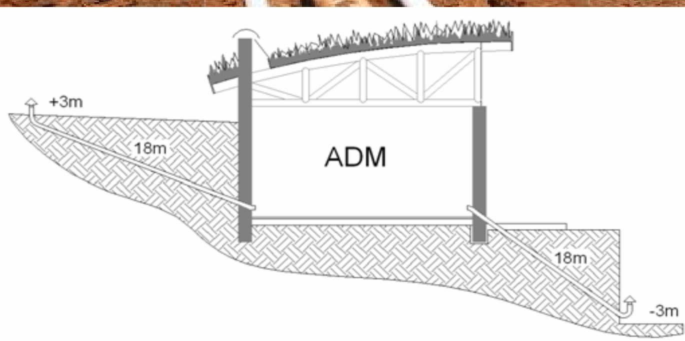
The school



Pipes entering monitoring room (top), burying pipes (left) and during the monitoring (right)

The monitoring

- The prototype was monitored from September 2005 to March 2006;
- Solar radiation data, wind speed (at 10 m) and air velocity in the pipes: controller plate CIO-DAS802/16 + computer routine developed with software HPVEE 6.0;
- Ground temperatures (measured in the depths of 5, 50, 100, 200 and 300 cm) + air temperature in the the pipes (at 1m of each extremity) + temperature of air in solar chimney (bottom and top, in the shade): thermometers NTC linked to TC-Clock900 controllers;
- Air temperature and the relative humidity indoors: thermal-hygrometer linked with TM-530Ri controllers (both controllers stored the data using software Sitrad 4.0. This set of sensors, controllers and software are developed by the company Full Gauge Controls®);
- Long wave radiation + air temperature and relative humidity + air velocity inside the pipes in the building: Indoor Climate Analyzer BABUC/A (Laboratori di Strumentazione Industriale - LSI);
- The equipment was kept in the center of the room, on a tripod, with the sensors at the height of 1.10m approximately and with the hot wire anemometer positioned in mouth of the pipes;
- Nine days of measurements: each pipe was monitored independently – to study factors that influence air flow inside the pipes.
- Solar radiation + wind speed data: collected each 10 seconds with averages integrated each 12 minutes, together with the values of the air temperature and relative humidity.
- The construction was monitored without occupation, with the internal and external doors kept closed and with no internal heat source (except the equipment of measurement).



The monitoring

- Two indirect geothermal systems were installed in the construction: the first (PhD thesis, not presented here - see LEFT, TOP) pumps water (pipes) into the building from a 200m^3 cistern + heat exchanger;
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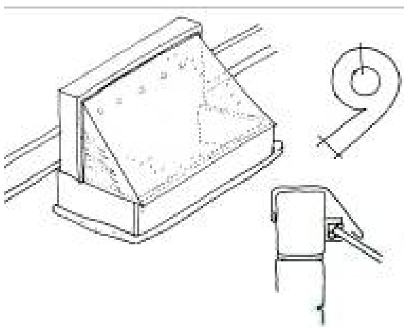
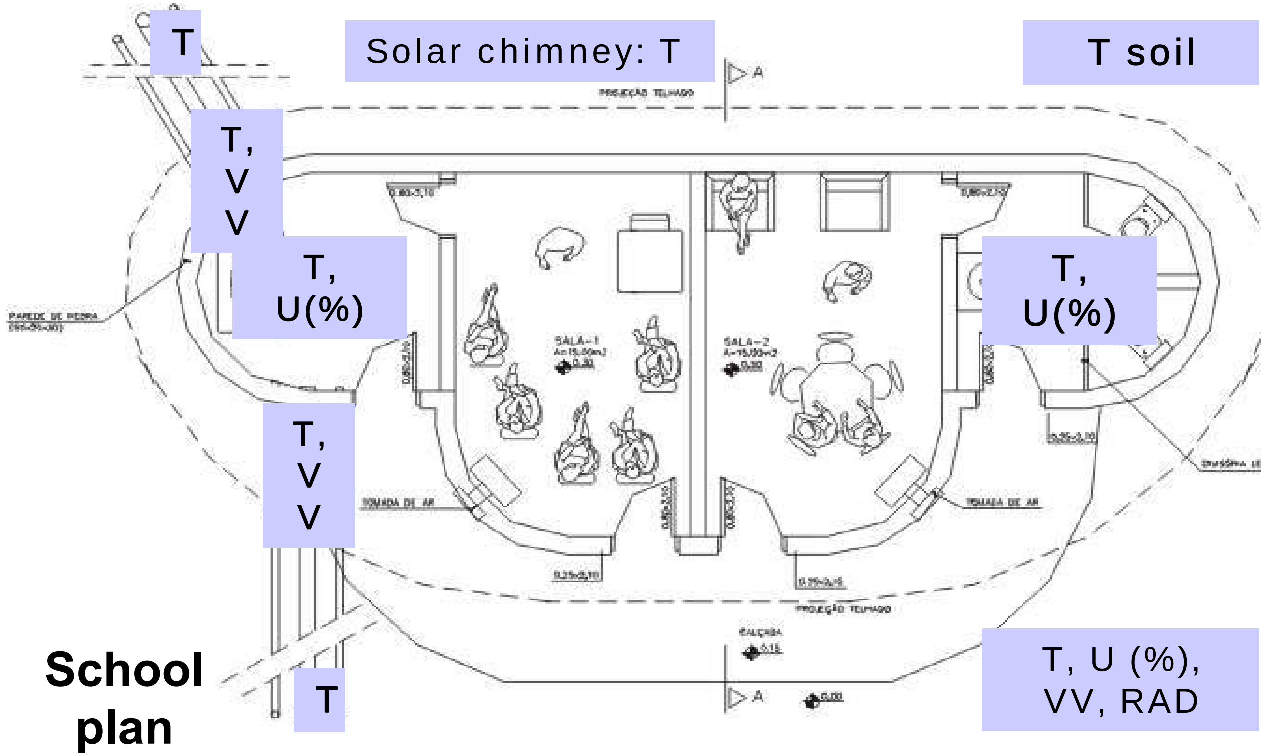
- The second: (focus of this presentation) natural convection drives air into a room (4.5m^2);
- Both studies intend to soften air temperature swings inside the building with low energy use;
- Six pipes were used in this experiment: four Ø100mm (two ascending and two descending pipes), and two Ø200mm;
- The 18m recicled PVC pipes were buried at a variable depth (that goes from zero to three meters in both positions). The outdoor air that circulates in the ducts flows from the room into the ascending pipes through the basis of the south wall and into the descending pipes through the base of the north wall;
- The pipes can be closed with drain plugs, in such a way to be assessed independently

Buried pipes systems: forced convection (top) + natural convection (middle)

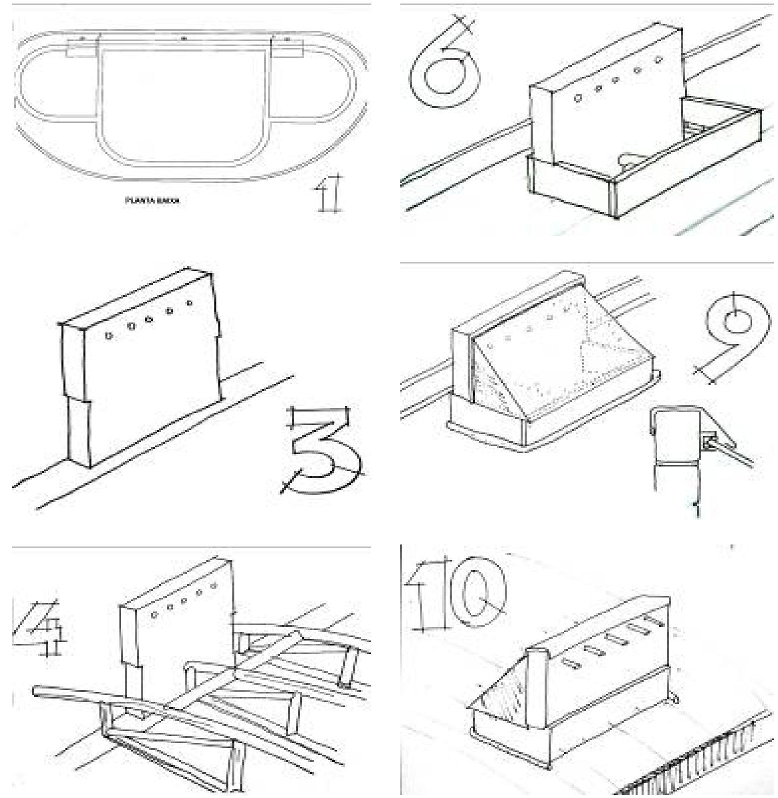
Monitoring

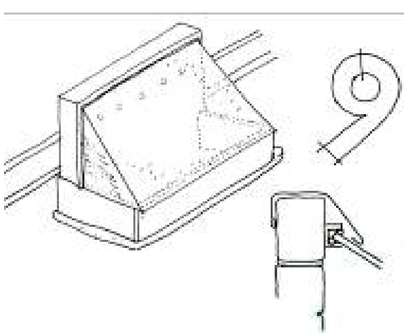


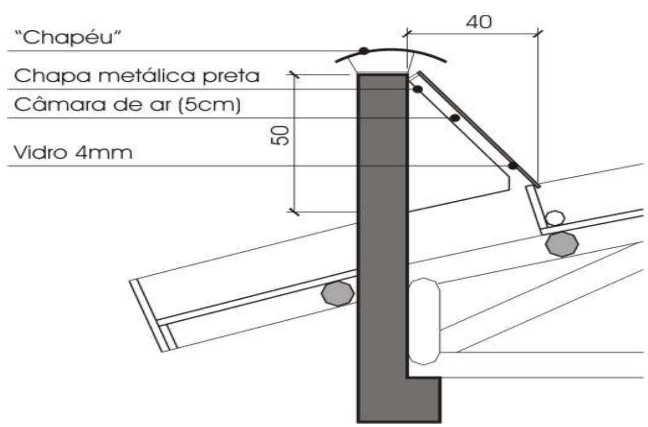


Variables monitored

Solar Chimney







Solar chimney section

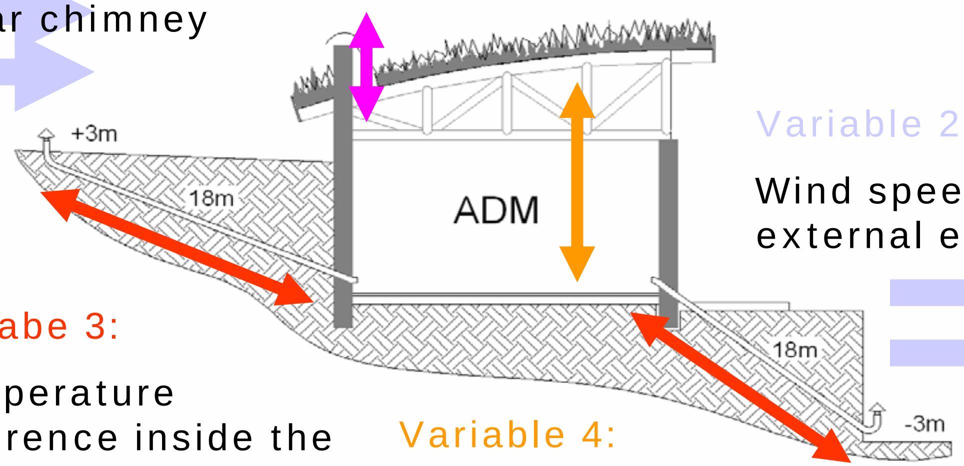
The variables

Variable 5:

Temperature difference inside the solar chimney

Variable 1:

Wind speed at 10m



Variable 2:

Wind speed at the external end of pipe

Variabe 3:

Temperature difference inside the pipes:

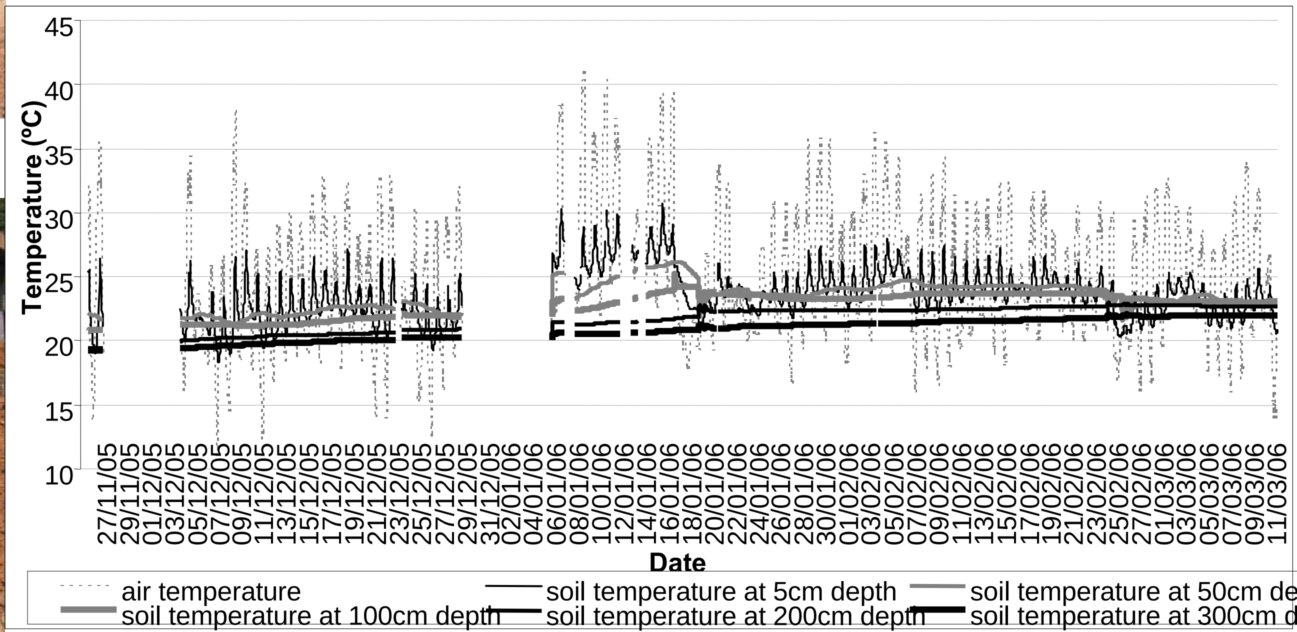
INFER. X SUPER.

Ø100 X Ø200

Variable 4:

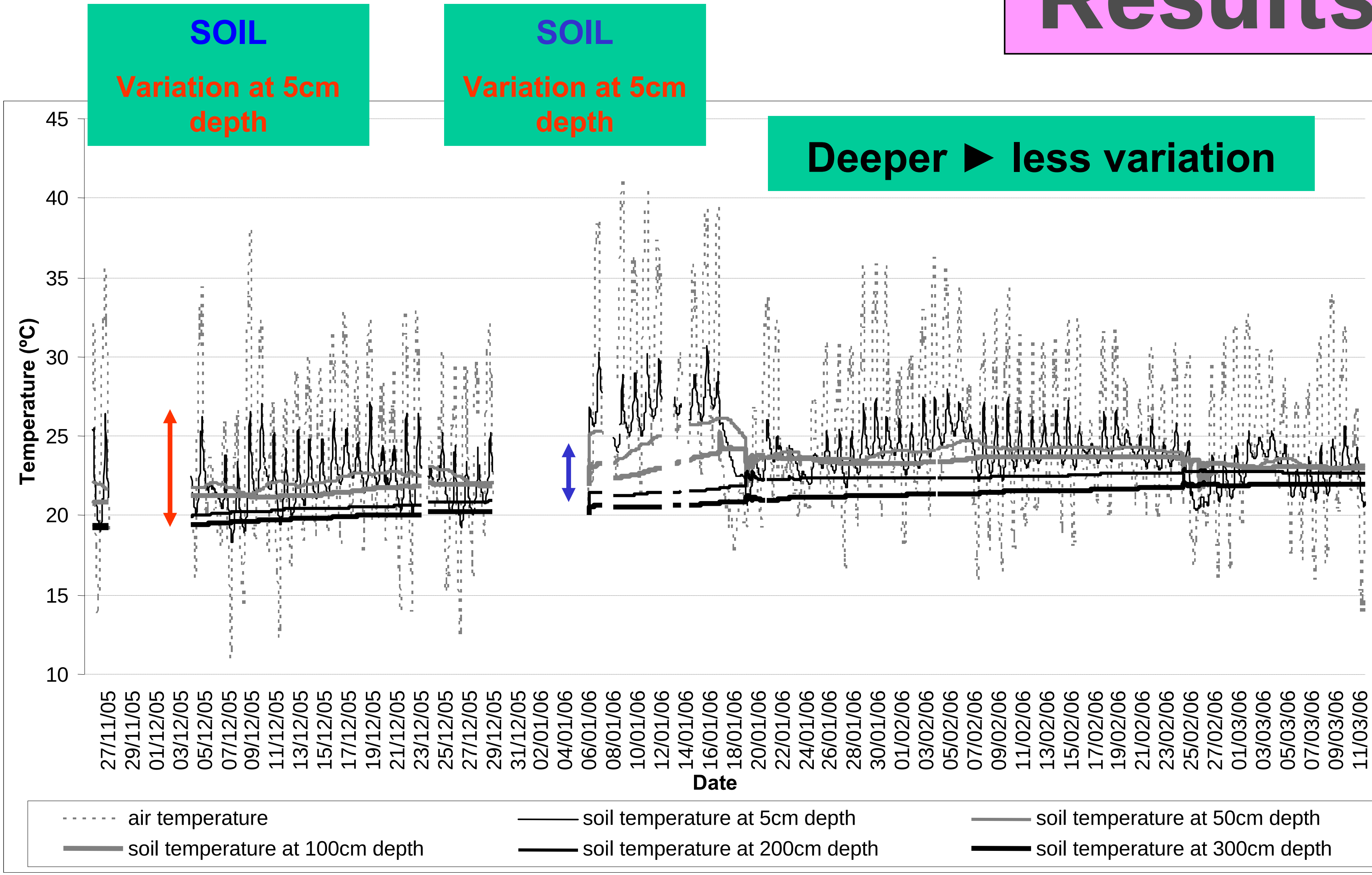
Temperature difference inside the room

Results



Air and soil temperatures:
measurements from 27/11/05 to 11/03/06

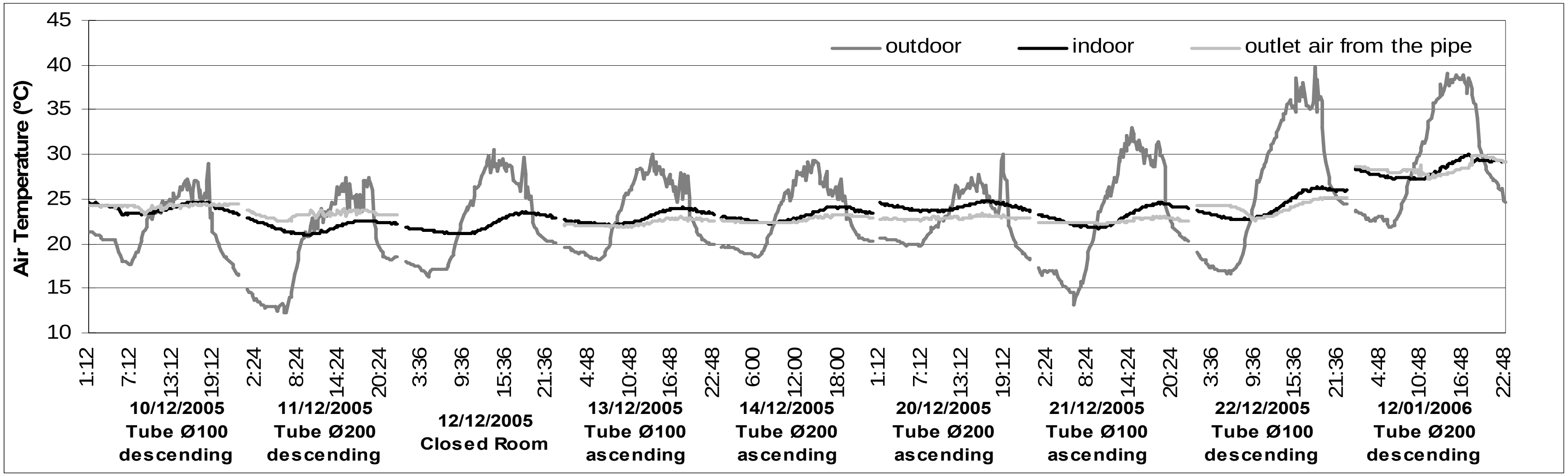
Results



Air and soil temperatures:
measurements from 27/11/05 to 11/03/06

Results analysis

- **Outdoor air temperature: 18ºC - 29.2ºC (maximum of 39.7ºC);**
- **Indoor air temperature: 21.8ºC - 25.7ºC (maximum of 30.0ºC);**
- **In 218 hours, only 8 hours (3.7%) exceeded Givoni´s comfort limit of 29ºC;**
- **Thermal mass > time delay > outdoor maximum air temperature (14:48h);**
  indoor maximum (18:48h);

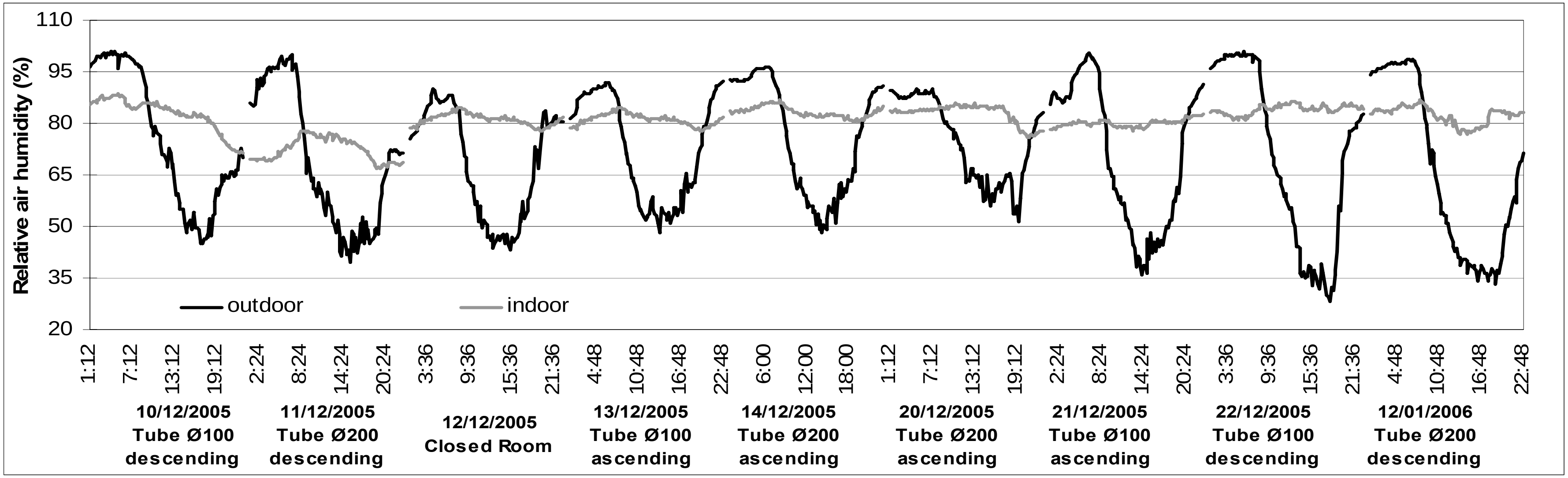


Outdoor and indoor air temperatures (with and without ducts ventilation)

Results analysis

- **Outdoor relative humidity: 51.7 – 91.1% (average 71.4%); more than 70% of variation during a single day;**

- **Indoor relative humidity: 76.9% - 85.2% (average 81.1%)**



Outdoor and indoor relative humidity

Results analysis

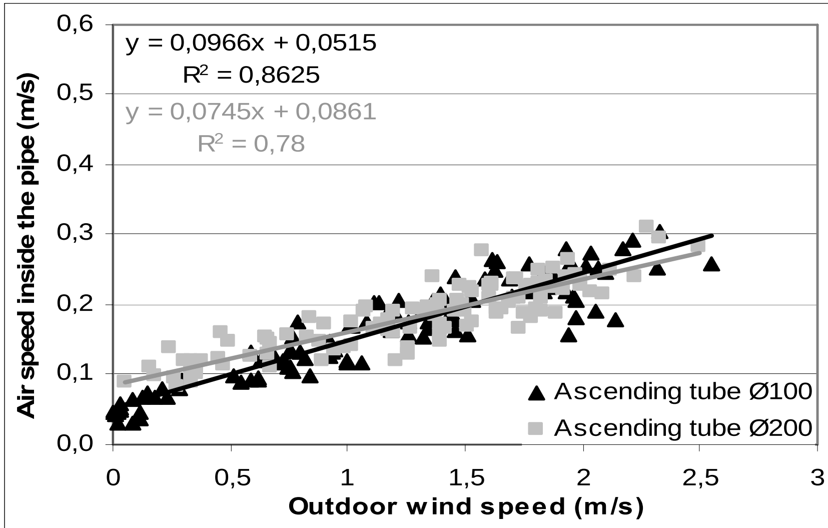
	ΔT of the air in the internal and external ends of the tube.	
	$T_{int} < T_{ext}$	$T_{int} > T_{ext}$
Lowest	-3.0	6.9
Average	3.8	-1.9
Highest	11.8	2.2
Average low	0.4	-3.7
Average high	7.1	-0.1

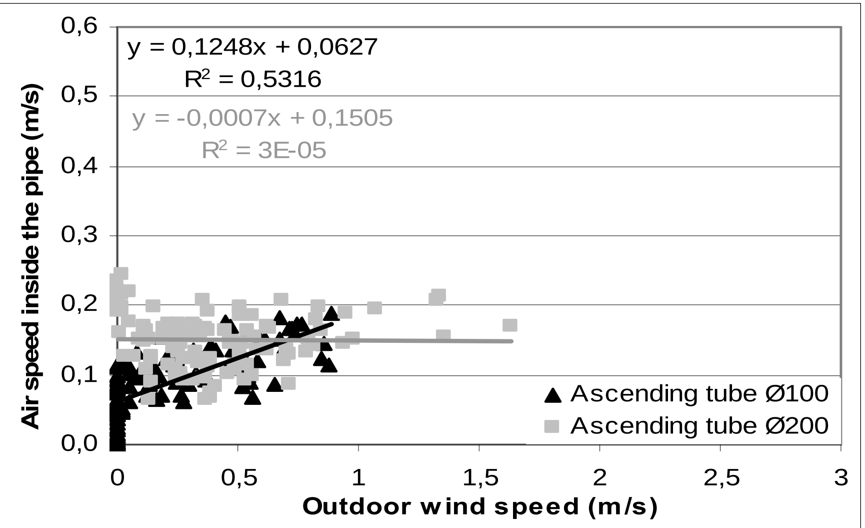
Table shows the temperature variation in the pipes when the indoor temperature is lower and higher than that outdoors;

- **When the room temperature is lower than that outdoors, the air is warmed inside the ducts, raising 3.8ºC on average, while, in the opposite situation, it is cooled 1.9ºC on average;**
- **Thus, the ground cools air in the ducts during the day and it heats it during the night;**
- **On average, the air temperature, when leaving the pipe, presents a smaller thermal amplitude than that of the indoor air**

Temperature amplitude in the pipes

Results analysis





Measurements of air velocity in two pipes with different diameters, having the same inclination and position

High wind speed

- **Straight relationship between air velocity in the tubes an external wind speed, measured at 10m above the ground;**
- **Lines show similar trend: pipe diameter has little influence.**

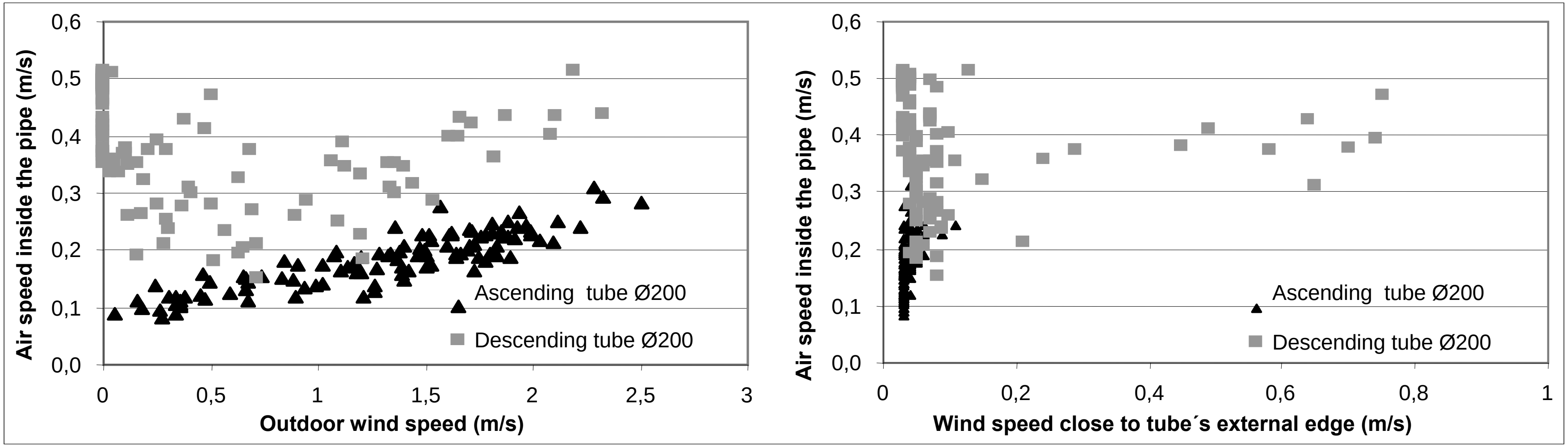
Low wind speed;

- **Even when the wind speed is less than 0.2m/s there is still air circulation in duct's interior, demonstrating that natural convection is occurring**

Noticeable relationship exists only for days where the average wind speed is higher than 1.5m/s

Relationship between the wind speed and the air velocity inside the pipe

Results analysis

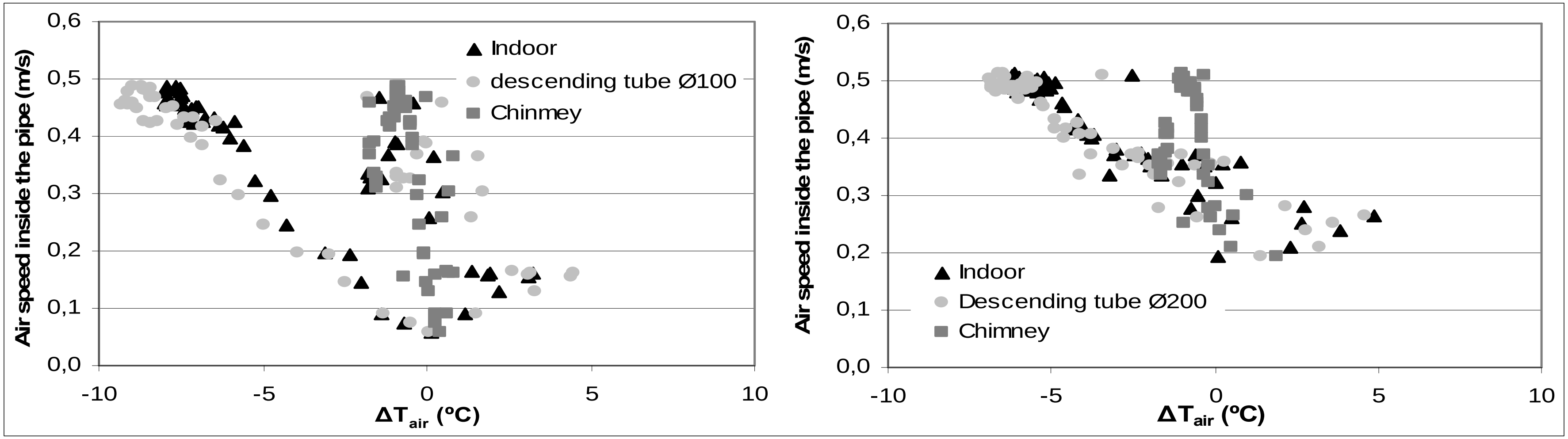


Ascending pipe presented higher and more dispersed results of average air velocity than the descending pipe.

Extremity of ascending pipe is more exposed to the outdoor wind, increasing the air velocity in the duct.

Relationship between the wind speed and the air velocity inside tubes with the same diameter, but with different inclination and under a similar wind speed

Results analysis

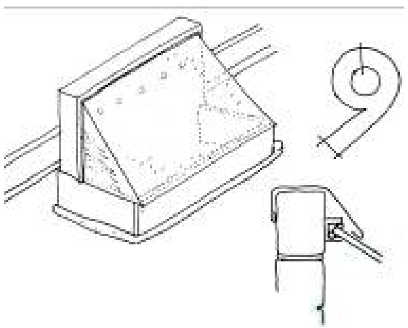


Differences of temperature in the interior of the (a) descending duct, (b) room and (c) chimney

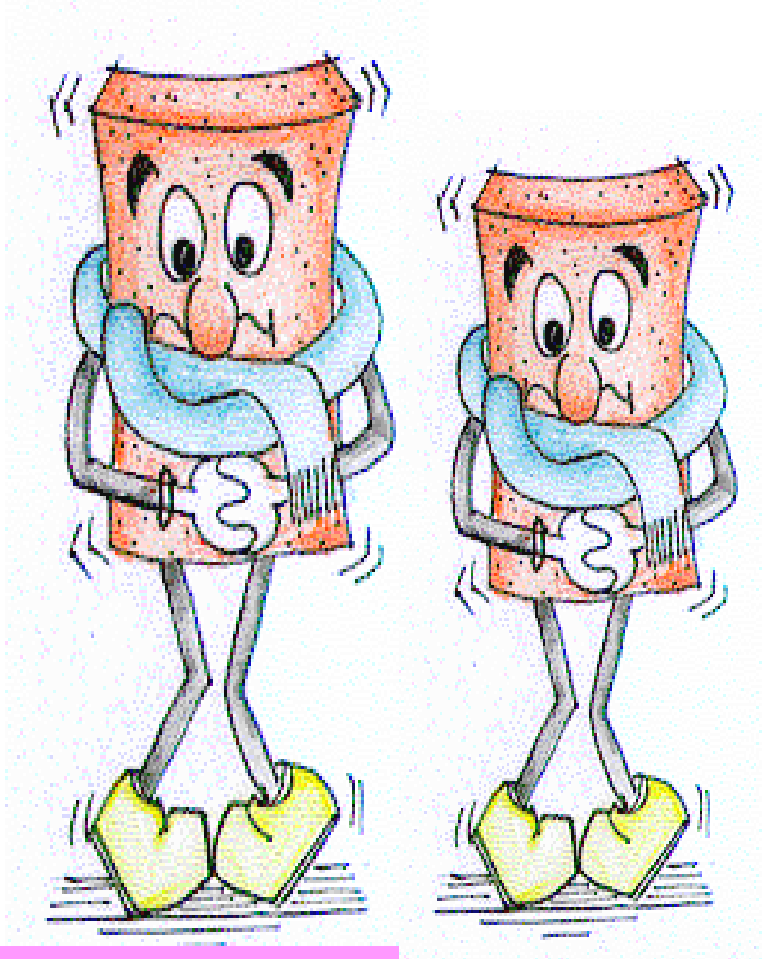
- **a trend of increasing the air velocity inside the pipe exists when the temperature difference increases;**
- **The larger dispersion of points for the negative values of temperature difference happens because the majority of the calmness moments were observed at night, when the indoor temperature is higher than that outdoors.**
- **This fact also explains why the temperature difference in the solar chimney demonstrated itself irrelevant.**

Relationship between the temperature difference and the air velocity inside the tube in different days, when wind speed is low (Va<0.5m/s e Vb<0.5m/s).

CONCLUSIONS



- The external wind speed presented a regular cyclical behavior during the day, with calmness predominating during the night time, with some highest values occurring during the day time;
- The average local wind speed was of 0.8m/s, presenting a maximum of 4.8m/s;
- The indoor measurements showed that the air temperature varied mostly between 21.8ºC and 25.7ºC, reducing the outdoor temperature swings by nearly 11°C;
- The average air velocity inside the pipes did not vary with the diameter or with time (night or day).
- The average air velocity flowing into the room was of 0.22m/s. The pipes total area is of 0.08m², resulting in 62.17m³/h of air, or in 3.87 renewals per hour;
- On average, the air leaving the pipe, presents a much smaller thermal amplitude than that of the outdoor air;
- This can be explained by the fact that the ground presents a much larger thermal mass than the construction and demonstrates that the heat exchange between the air and the ground is effective.



Thank you for your attention!

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