Influence of buildings on the urban atmosphere: need to couple CFD simulations with a building model

Noëlie Daviau[1], Maya Milliez[2], Gilles Plessis[2],
Jean-François Sini[3], Jean-Michel Rosant[3], Bertrand Carissimo[1]
(1) CEREA; (2) Enerbat, EDF R&D; (3) École Centrale Nantes
noelie.daviau@cerea.enpc.fr

Context

- Important impacts of urban phenomena such as air pollution or urban heat island.
- CFD : anticipate these phenomena for the populations and the environment.
- Difficulty to model the urban atmosphere, especially the building thermal influence.

Wall models in *Code_Saturne*

Two current wall models in **Code_Saturne** :

- " Force Restore " model

$$\frac{\partial T_{se}}{\partial t} = \frac{\sqrt{2\omega}}{\mu}(L^* + S^* + h_{ext}(T_{ext} - T_{se}))$$
$$- \omega(T_{se} - T_{int}) \quad (1)$$

ω: Earth angular frequency (Hz); μ: thermal admittance ($J.m^{-2}.s^{-0.5}.K^{-1}$); T_{int}: indoor temperature (K).

- " Wall Thermal " model

$$\frac{\lambda}{e}(T_{se} - T_{int}) + h_{ext}(T_{se} - T_{ext}) = L_* + S_* \quad (2)$$

λ: mean thermal conductivity of the wall ($W.m^{-1}.K^{-1}$); e: wall thickness (m); T_{int}: indoor temperature; h_{ext}: outdoor convection coefficient ($W.K^{-1}.m^{-2}$).

BuildSysPro

- Objective: use it as a wall model in **Code_Saturne** (coupling).
- Building modelling software developed by EDF R&D EnerBat in Modelica language.
- Can return the matrices A, B, C and D containing the building informations:

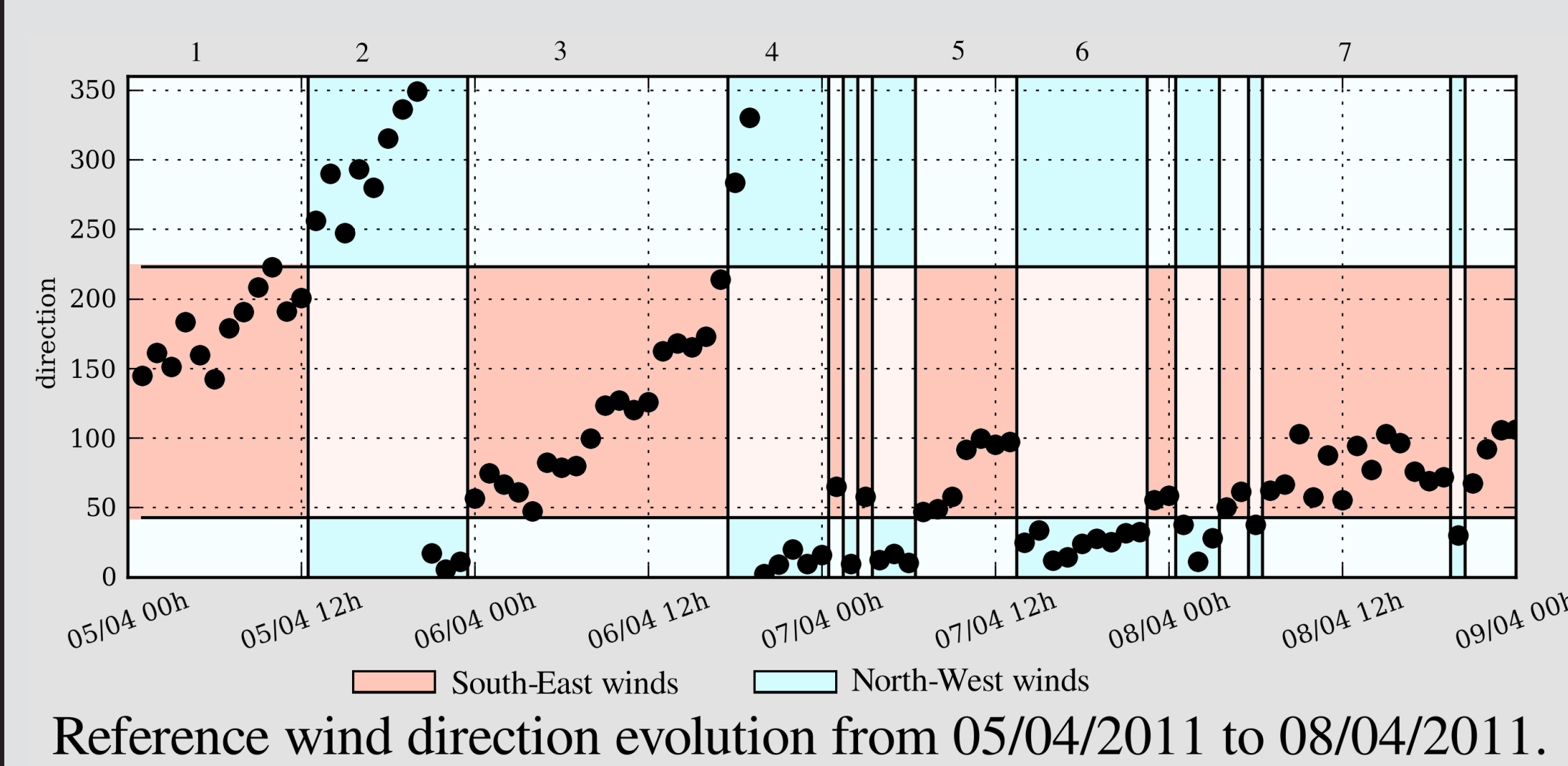$$\begin{cases} \dot{T} = AT + BU \\ Y = CT + DU \end{cases} \quad (3)$$
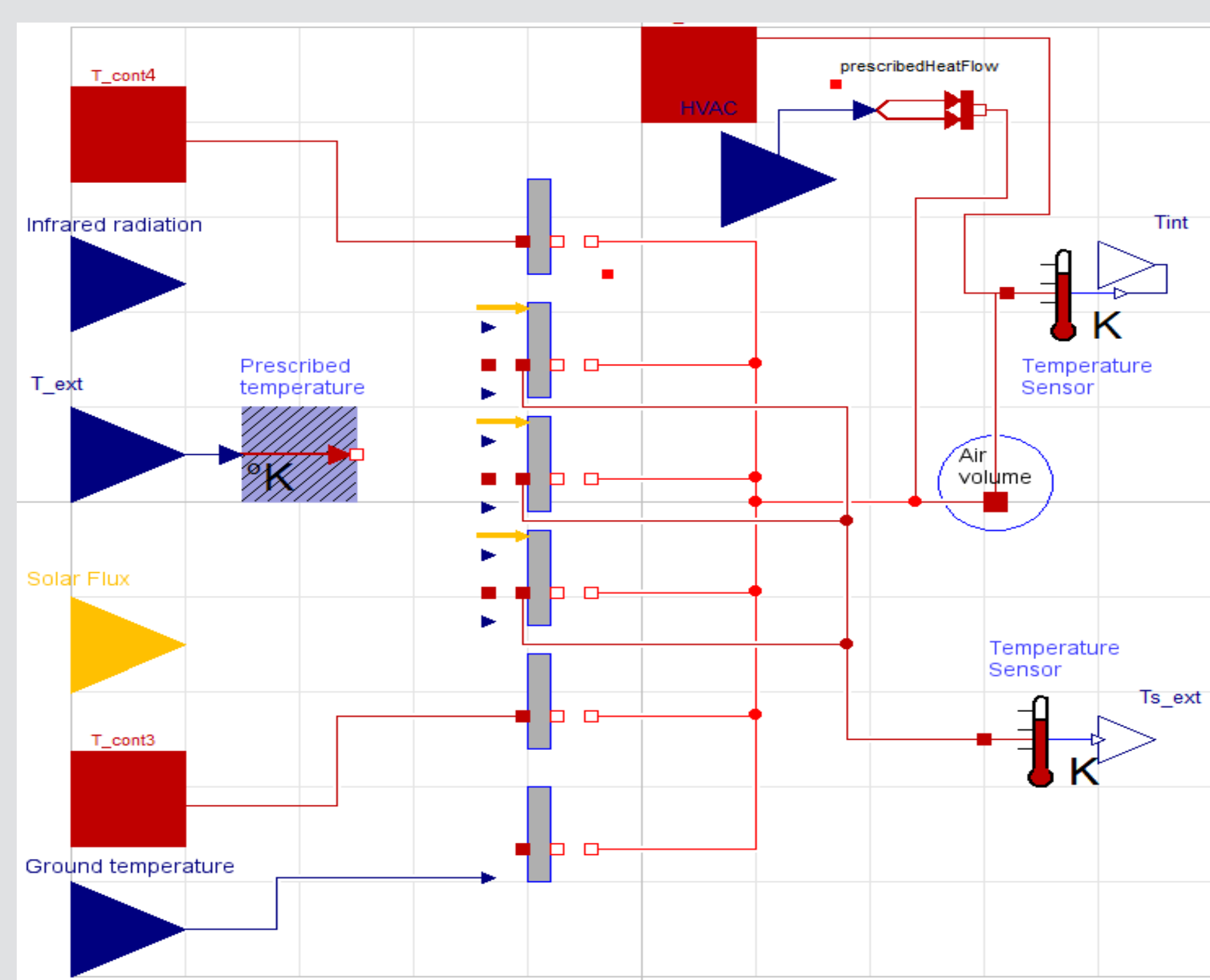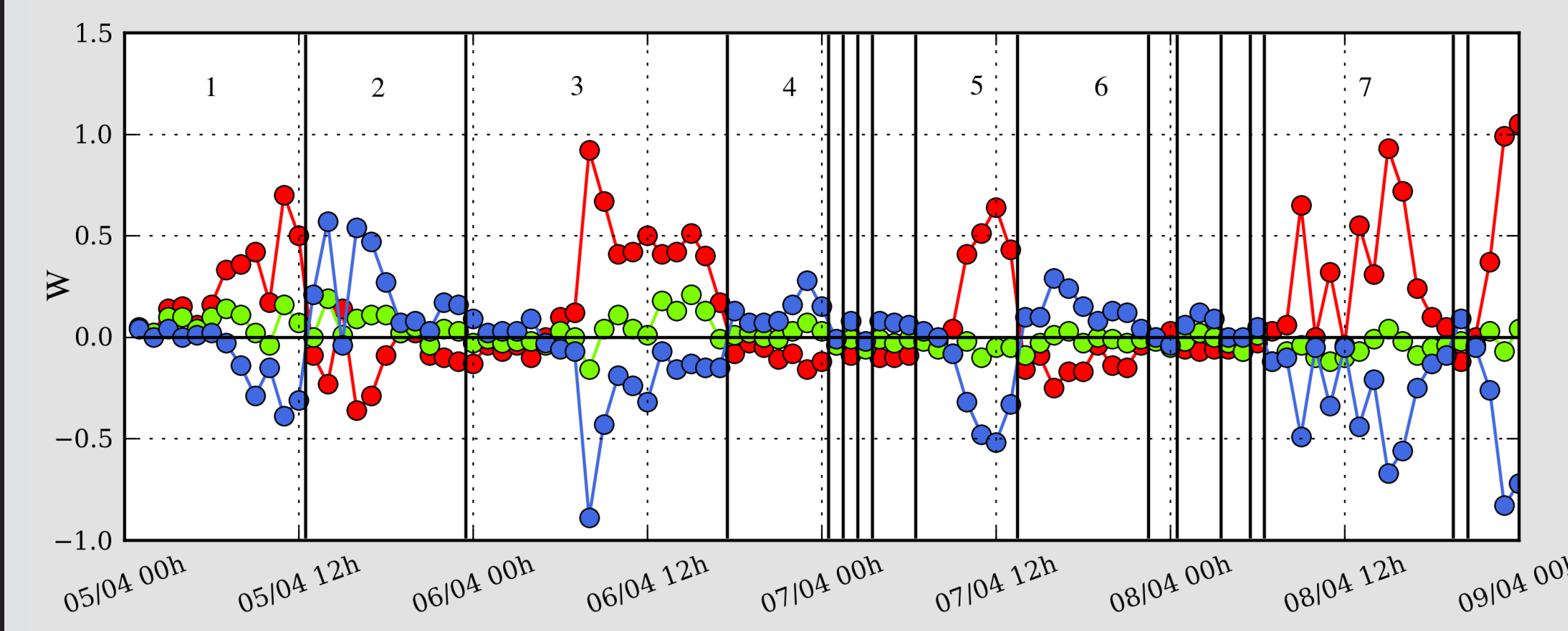

The EM2PAU field campaign

- IFSTTAR, LHEEA, CSTB and Université du Maine.
- Street canyon modeled with containers.
- Important data base.
- Radiation, wind and thermal measurements around the modelled street canyon.

Blocks of containers
Mast (height = 10m)
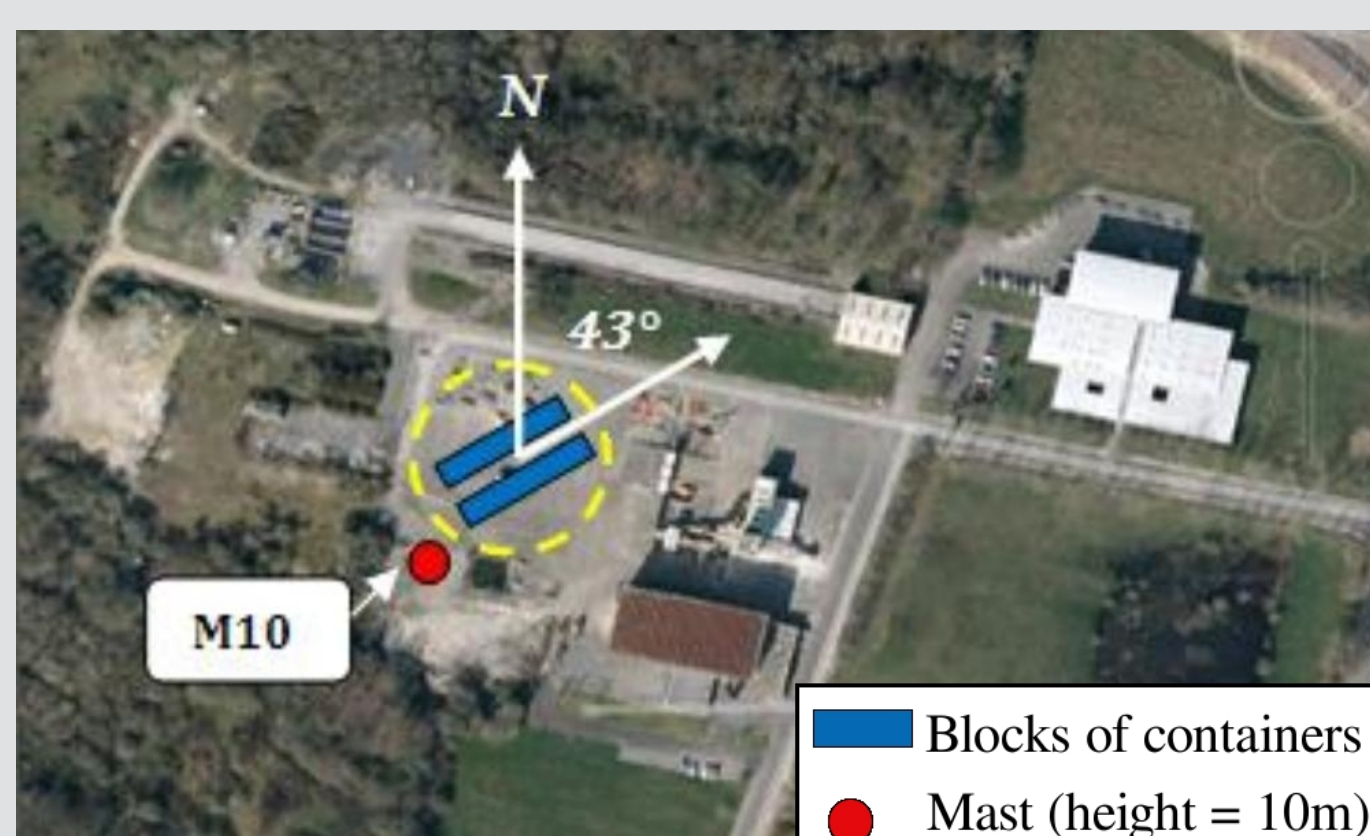
Dynamical effects of the buildings on the airflows

South-East winds
North-West winds

Reference wind direction evolution from 05/04/2011 to 08/04/2011.

SE wind

Wind flows in the canyon with a South-East wind direction.

Vertical wind speed evolution in the canyon from 05/04/2011 to 08/04/2011.

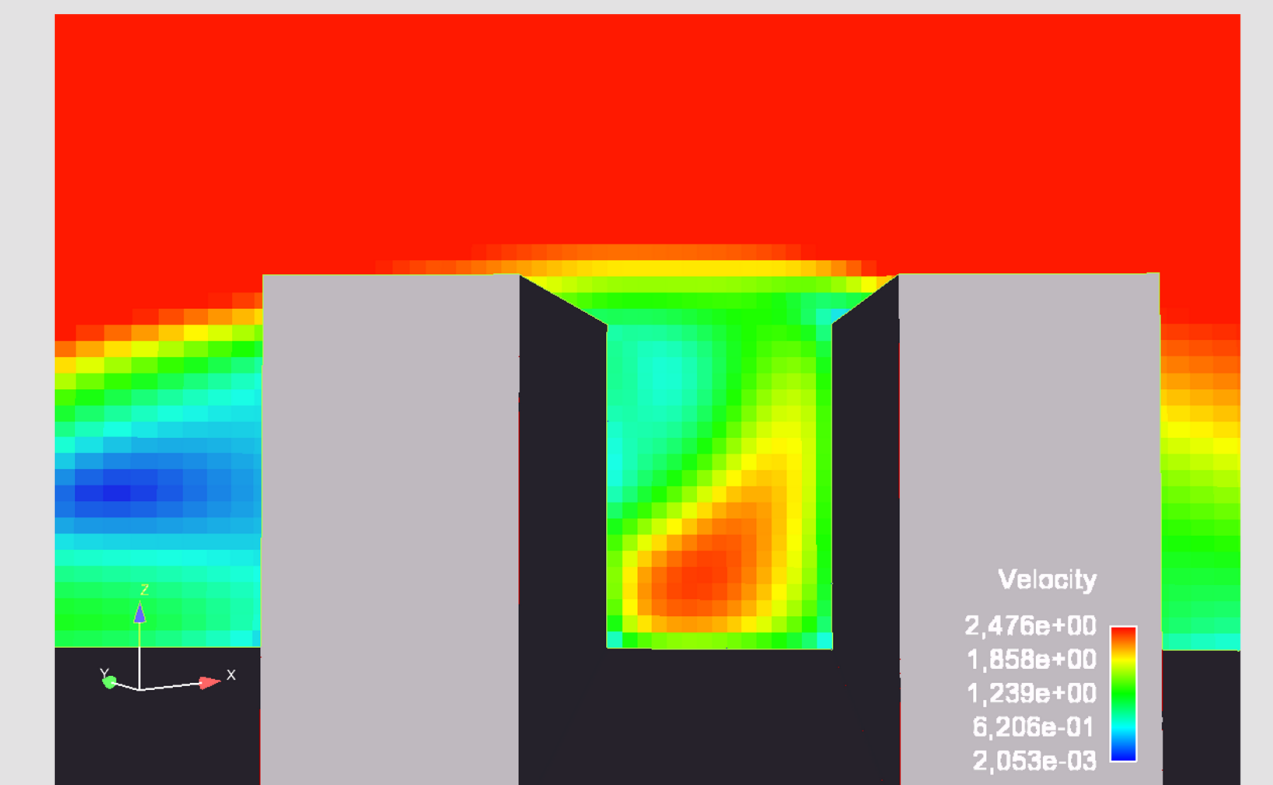Wind speed simulated in the canyon at 7am, 06/04/2011.

Observation: positive values of vertical wind speed component for S1 and negative values for S3 for winds from the South-East, and inversely for North-West winds.

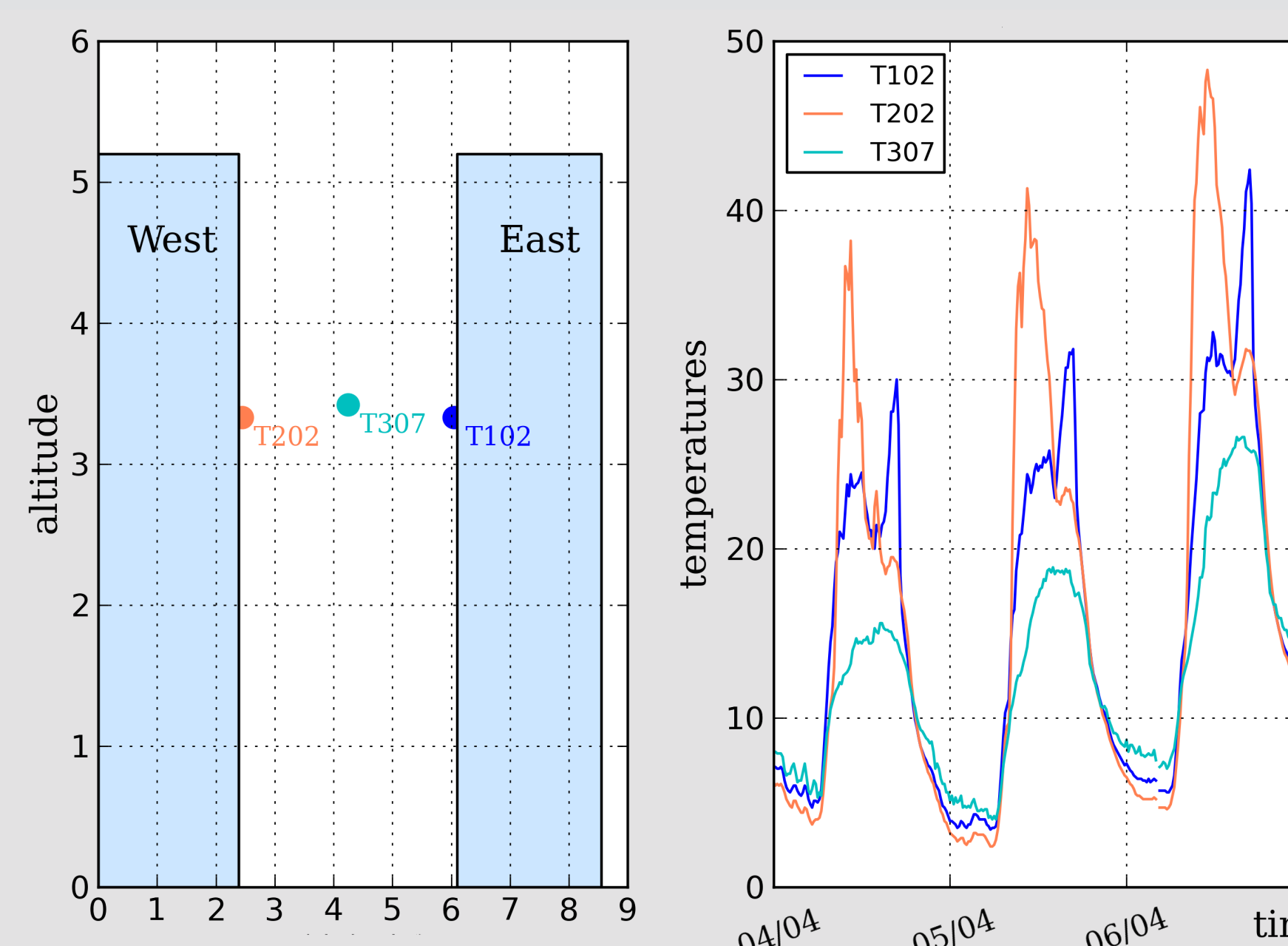Vertical wind speed evolution in the canyon during a sunny day. Dots: measurements; Lines: simulations.
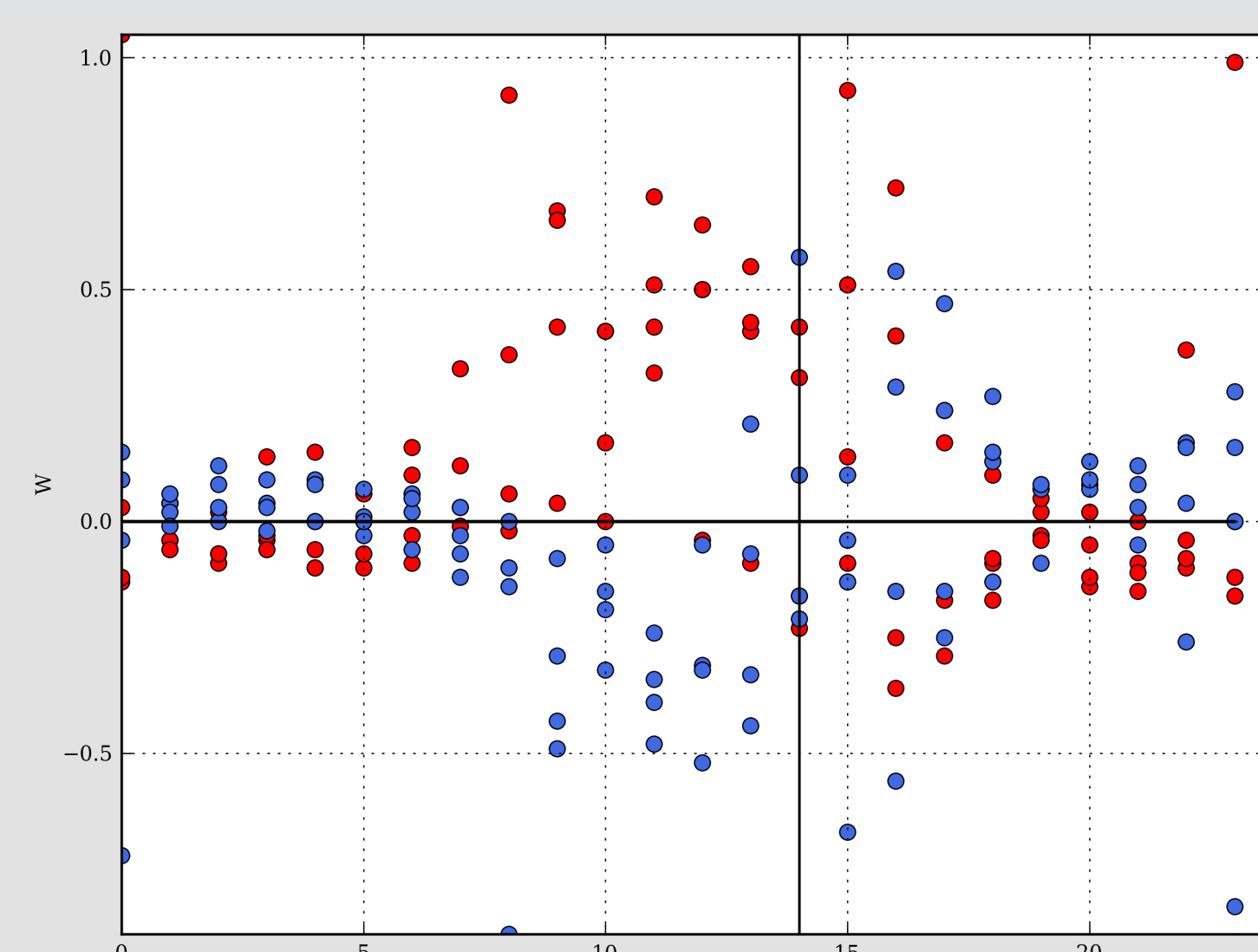
Influence of the temperature in the simulations
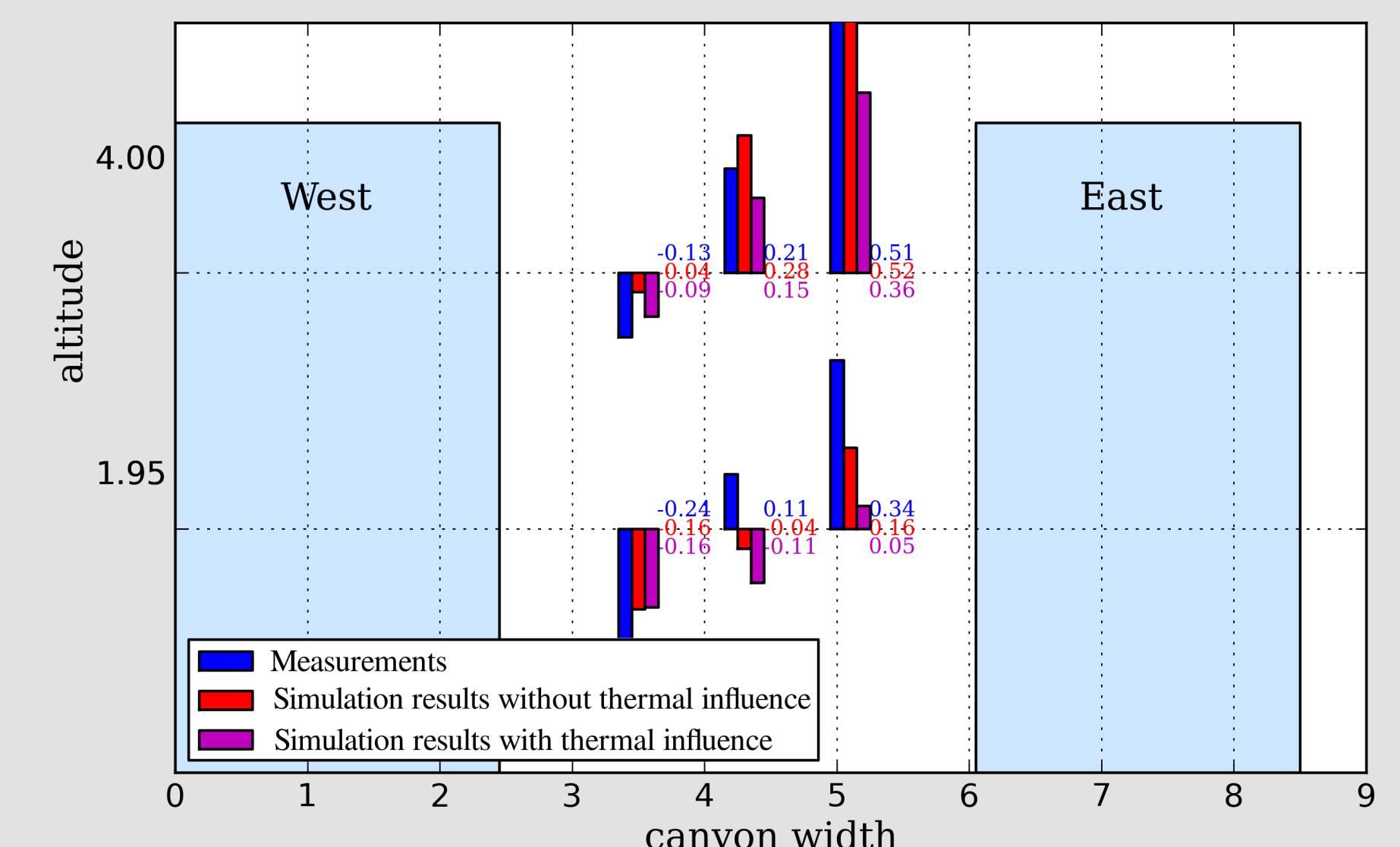

West   East

Measured temperature evolution and comparison for different spots in the canyon from 04/04/2011 to 06/04/2011.
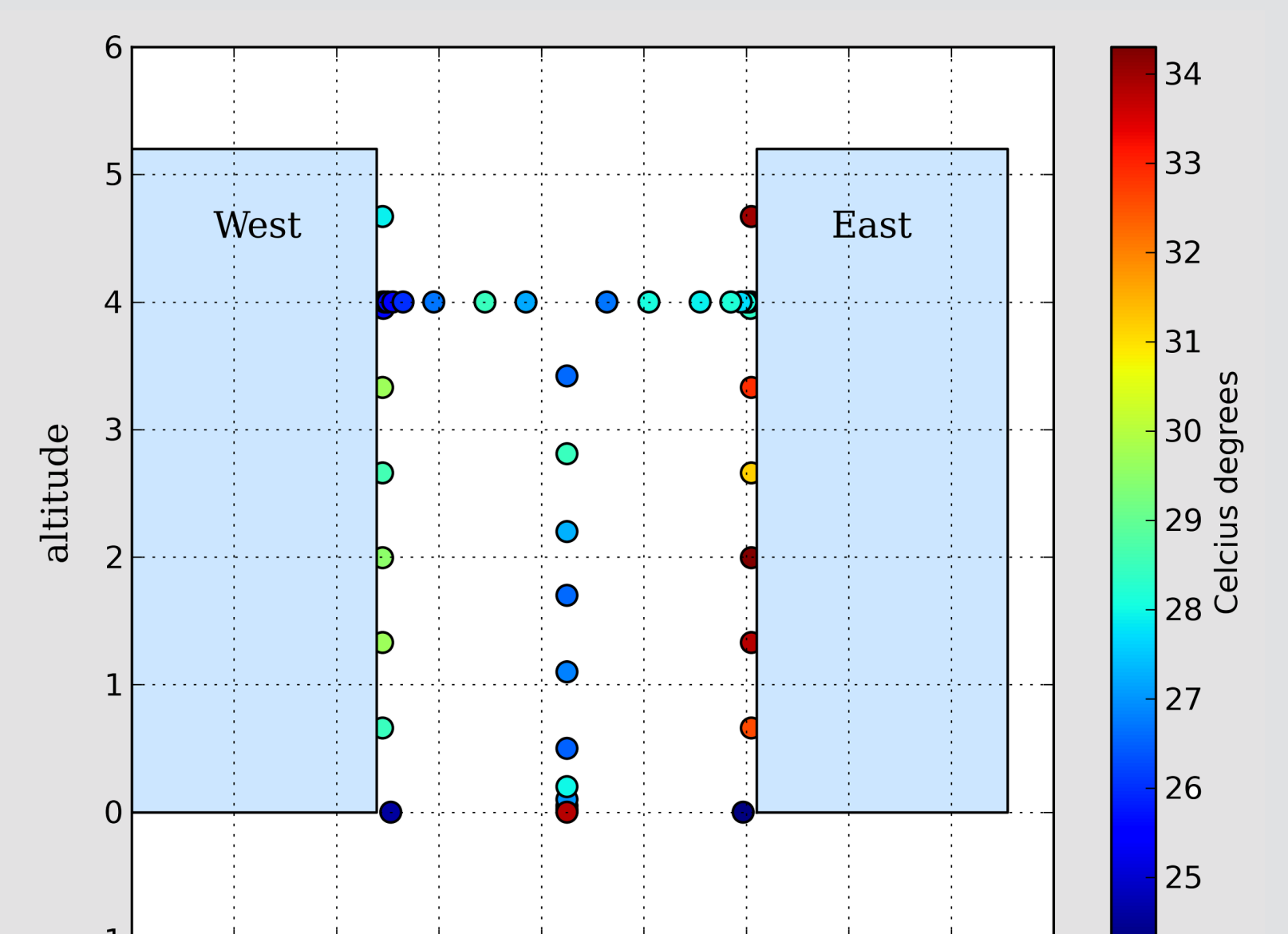
Measured temperatures in the EM2PAU canyon at 3pm, 06/04/2011.

Vertical wind speeds from 05/04 to 08/04/2011 as a function of day time. Observation of a difference between daytime with sun-heated walls and nighttime.

Comparison of measured and simulated vertical wind speed in the EM2PAU canyon at 3pm, 06/04/2011.

Measurements
Simulation results without thermal influence
Simulation results with thermal influence

Conclusion and Acknowledgements

- Influence of temperature in the simulation of winds (with forced surface temperatures according to observed temperatures).
- Noised and weak thermal effects that are, so far, difficult to isolate from the preponderant dynamic effects.
- Next step: implementation of Osmosys building model in **Code_Saturne**.