Summer Urban Heat Island development in a Coastal Complex Urbanized Terrain using the Enviro-HIRLAM Modelling System

Gonzalez-Aparicio I. (1,2), Hidalgo J(3), Baklanov A.(2), Nuterman R.(2), Mahura A. (2) and Korsholm U (2)

PhD framework: Climate Change projections to assess Meteorological and Air quality fields in Urban Areas

PhD stud. **Iratxe González-Aparicio**

Advisers: Dr. Julia Hidalgo
Prof. Alexander Baklanov

1 - TECNALIA Research and Innovation, Spain
2 - Danish Meteorological Institute, Denmark
3 - Météo France, France

Outline

Numerical Simulation Descriptions

Case Study: The Bilbao metropolitan area

Urban District Classification

Synoptic Conditions: period selected

Validation of the coupling: statistical analysis

Simulations vs. observations: T2, RH2, w10, wdir10

Urban Heat Island quantification

Other example: The Paris metropolitan area

Numerical Simulation Descriptions

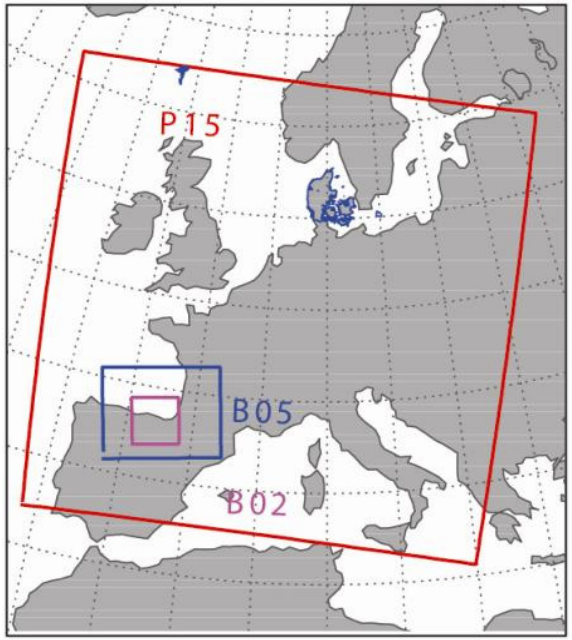
Two high resolution long-term runs for July 2009 using Enviro-HIRLAM NWP-ACT

(1) URB, Urban simulations: Enviro-HIRLAM +
Building Effect Parameterization (*BEP, Martilli et al., 2002*) module
+ anthropogenic heat fluxes (AHF) from the summer 2005 output of the Large scale Urban Consumption of energY model (*LUCY, Allen et al., 2010*).
The natural covers by the Interaction Soil-Biosphere-Atmosphere (ISBA) land surface scheme (*Noilhan and Planton (1989*).

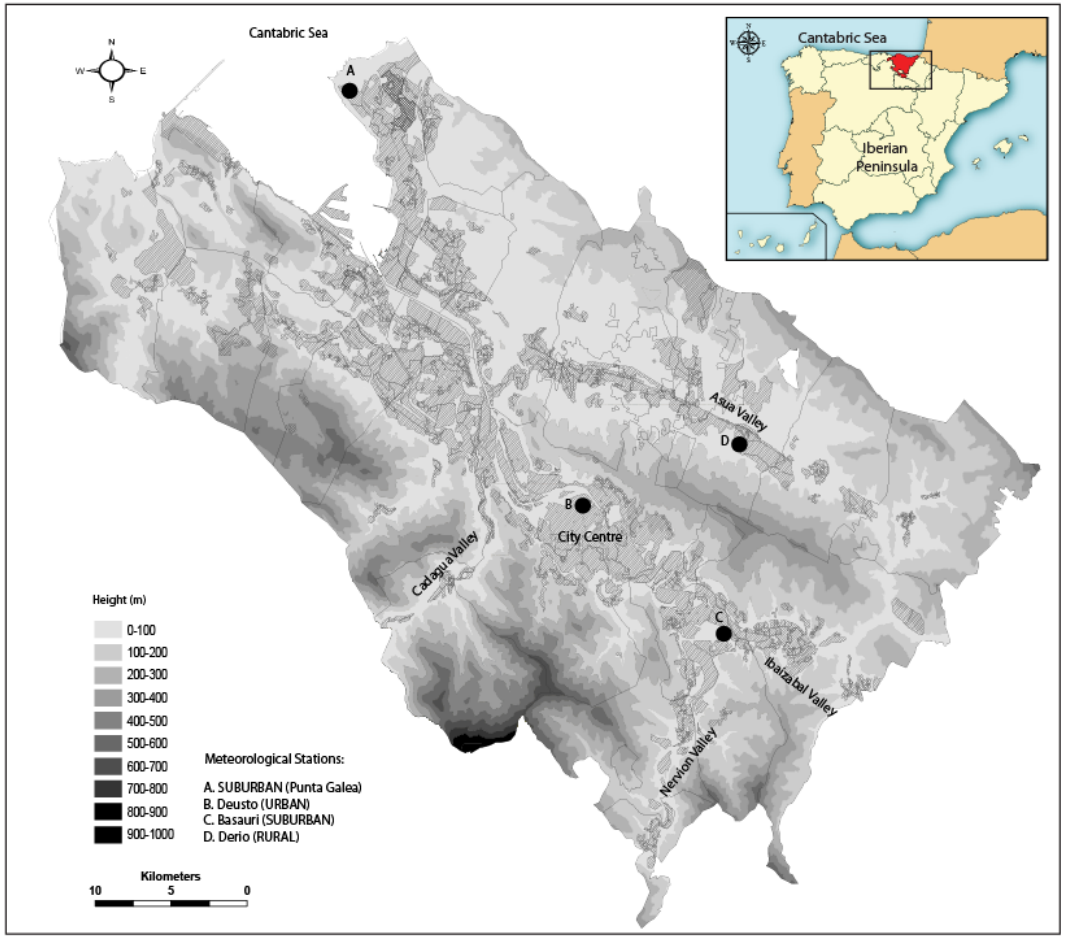
(2) CTRL: Without modification simulations, the urbanized areas removed (the ISBA scheme replaces BEP and LUCY factor in each urban cell)

Impact = URB – CTRL

Show the impact of the urbanisation on the meteorological variables within the mixing layer



Case Study: The Bilbao metropolitan area

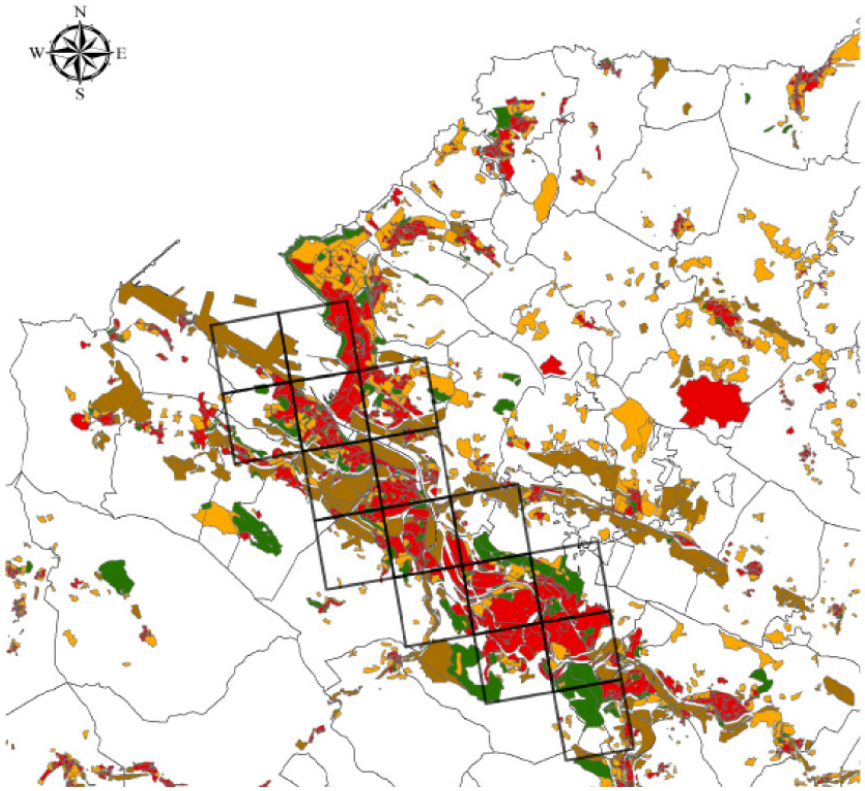


Characteristics:

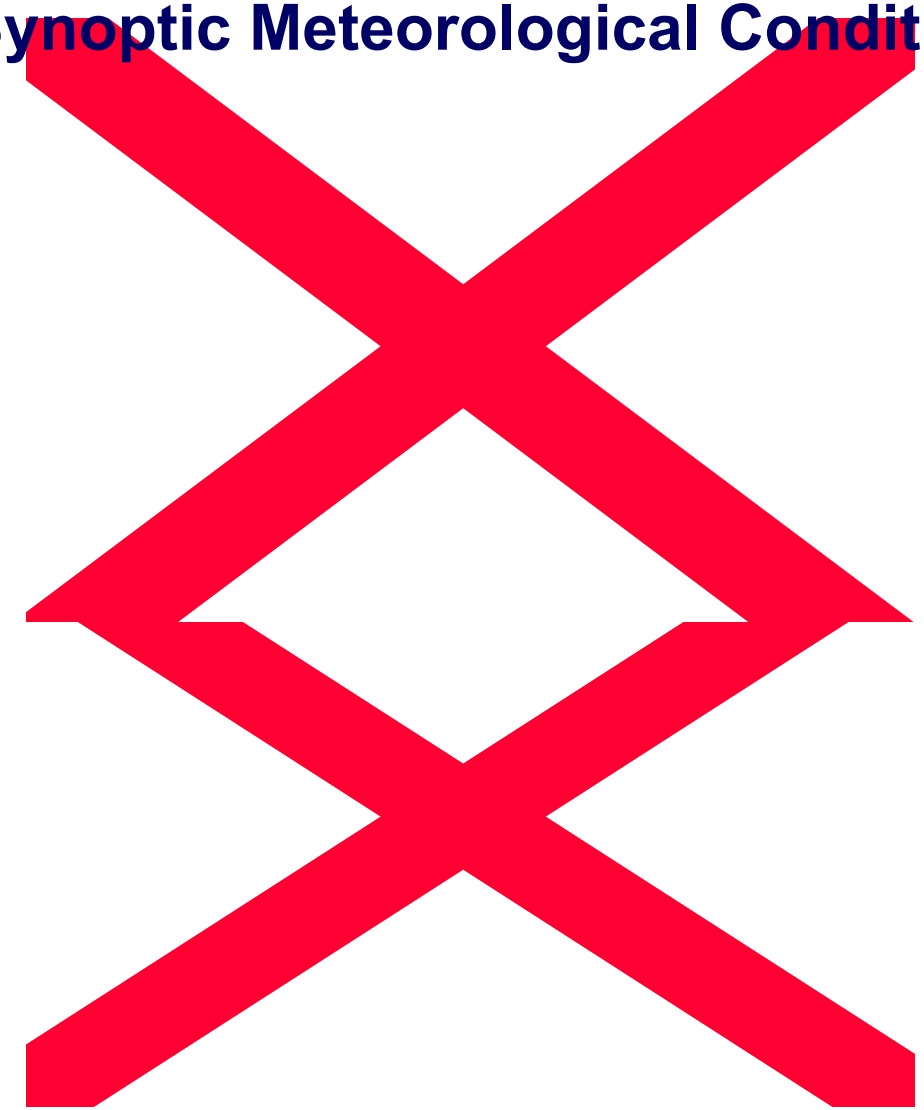
-Coastal city
-Complex terrain
- Placed in a valley sorrounded by two mountain ranges
-16 km length along waterway
- 0.875 million population
- Highly polluted, industrial zone

Urban District Classification

González-Aparicio, I., *et al 2010.*



Synoptic Meteorological Conditions



Validation of the coupling

$$ME = \frac{1}{n}\sum_{k=1}^{n}(y_k - o_k) = \bar{y} - \bar{o} \qquad MSE = \frac{1}{n}\sum_{k=1}^{n}(y_k - o_k)^2$$

$$RMSE = \sqrt{MSE} \qquad RMSE_{UB} = \left\{\frac{1}{n}\sum_{k=1}^{n}\left[\left(y_k - \bar{y}\right) - \left(o_k - \bar{o}\right)\right]^2\right\}^{1/2}$$

+ Pearson`s Linear Correlations

***Pielke 2002 and Freitas et al., 2006*, a simulation has *skill* if the following conditions are met:**

(1) σobs ~ σsimu;

(2) RMSE < σobs;

(3) RMSEub < σobs,

where σobs is the standard deviation of observations and σsimu is the standard deviation of the simulations.

Where y is the modelled variable and o is the observed variable.

K is the position of the time series on the hourly basis.

Validation of the coupling

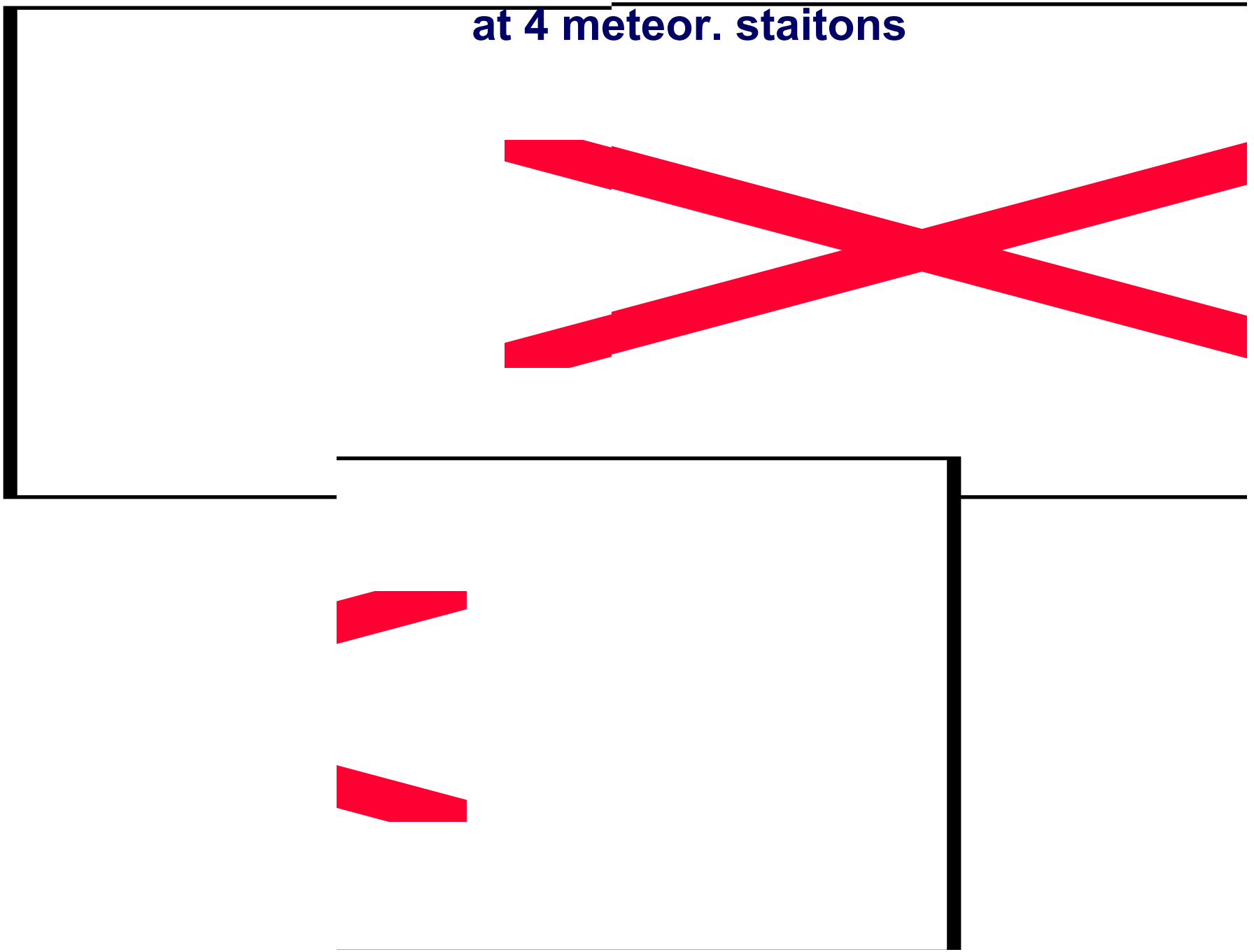
All the simulations compromise the skill of statistics but
tends to slightly underestimate the observations.

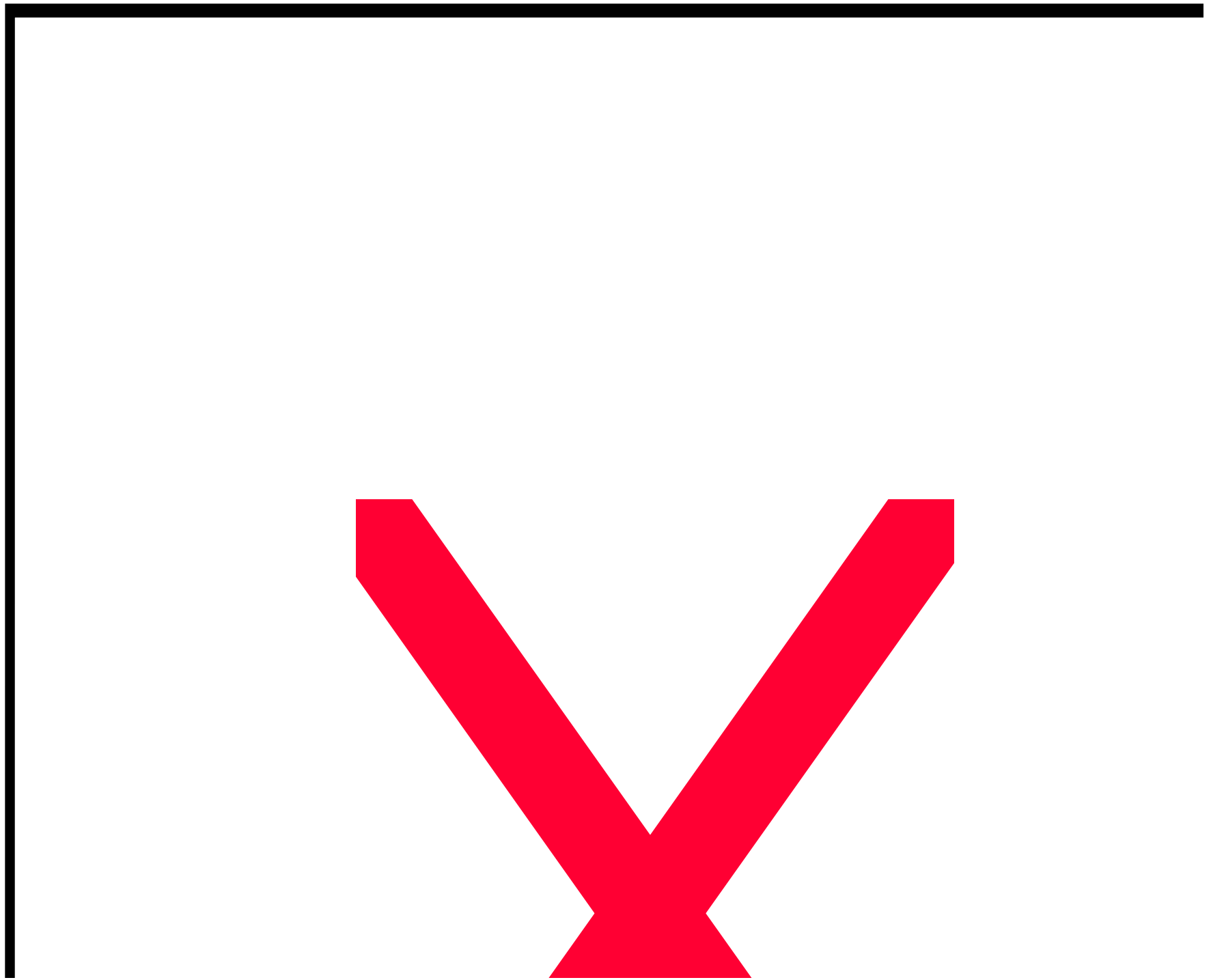
simulations' temperatures (RMSE) errors < 2 ºC.
wind speed at 10 m, errors < -0.9 m/s
relative humidity, errors < -11 %

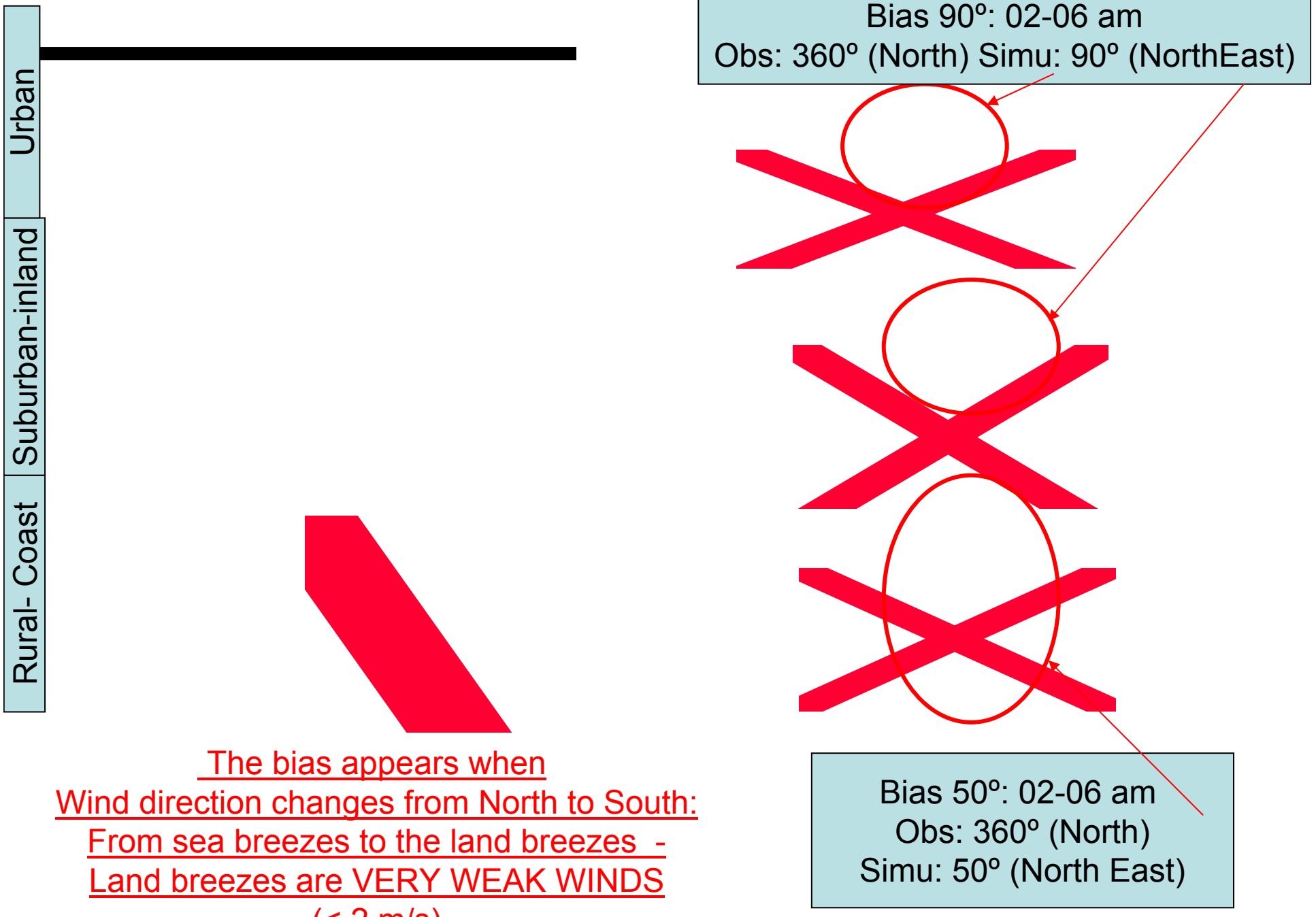
By comparing modelled vs. observed standard deviations :
temperature, wind and relative humidity - it is found to be very similar.

The correlation coefficients show a mean value of 0.75 for the
temperature in the urban and hinterland stations and 0.6 at the coastal site.
For the wind speed, the best correlation is found in the hinterland station (0.7),
at the urban and rural - coastal station is 0.5.
The correlation of the relative humidity fulfils the conditions
(>0.5), but it is less correlated comparing with the other variables.

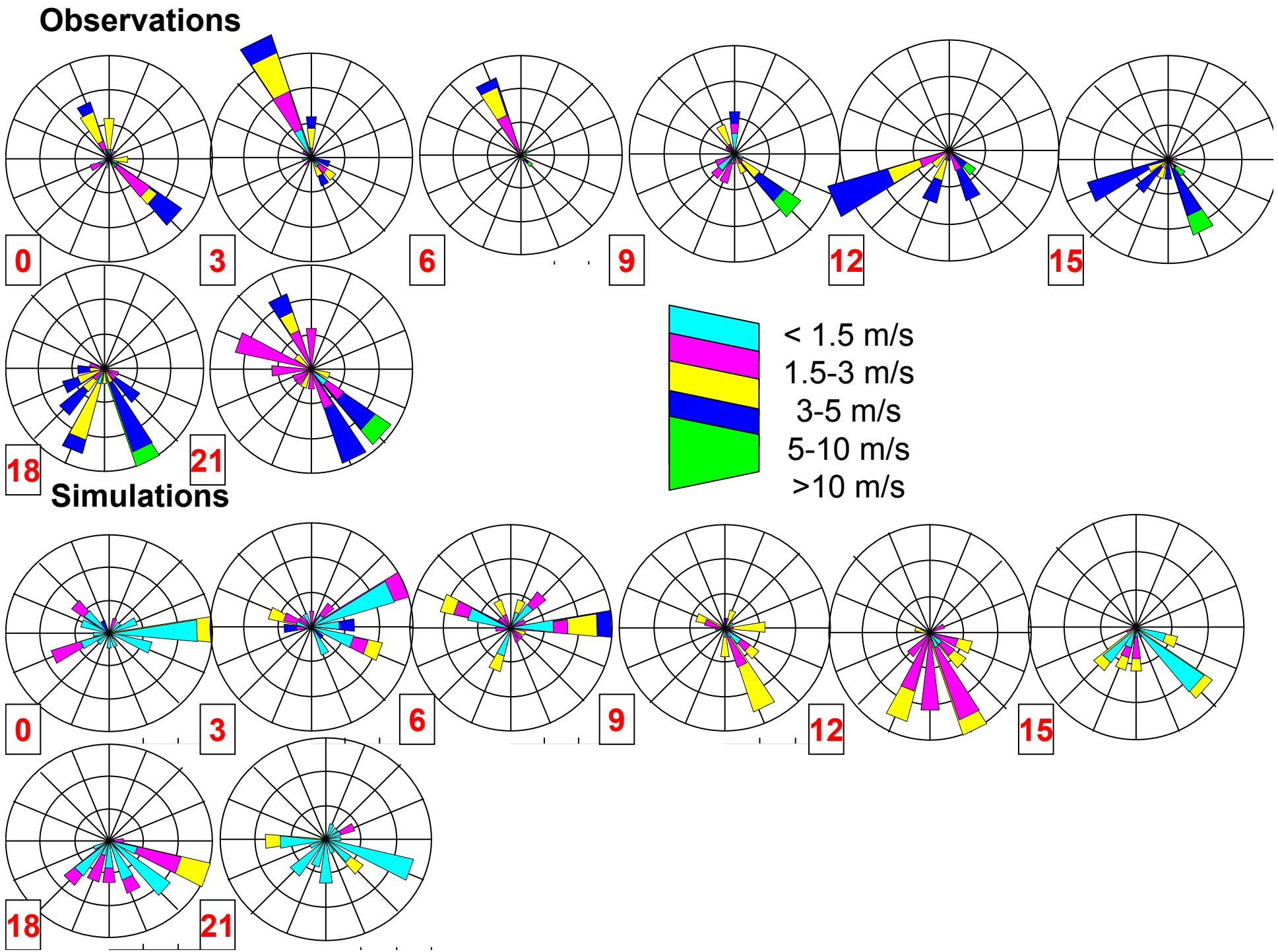
Validation of the coupling (3,4,5 July 2009) at 4 meteor. staitons







The bias appears when
Wind direction changes from North to South:
From sea breezes to the land breezes -
Land breezes are VERY WEAK WINDS
(< 2 m/s)


Observations
0
3
6
9
12
15
18
21
< 1.5 m/s
1.5-3 m/s
3-5 m/s
5-10 m/s
>10 m/s
Simulations
0
3
6
9
12
15
18
21

**At night a ground-based inversion is formed (from 0 to 3 UTC)
in the bottom of the valleys by a combination of radiation cooling
and the accumulation of cold down-slope drainage wind.**

**At the early hours, solar heating initiated fumigation
and the sea and up-valley breezes penetrates
into the city starting around 9 UTC.**

**A blocking of the stabilized air mass could occur
over the surroundings of Bilbao
due to the roughness and the heat island and
the generation of upward motions in the urban zone.**

**During the early day hours the temperature gradient between the slopes
of the surrounded mountains and
the Bilbao area is larger and the anabatic plus up-valley winds increase over
The city. A convection winds appears increasing in the city and decreasing in the
Surroundings.**

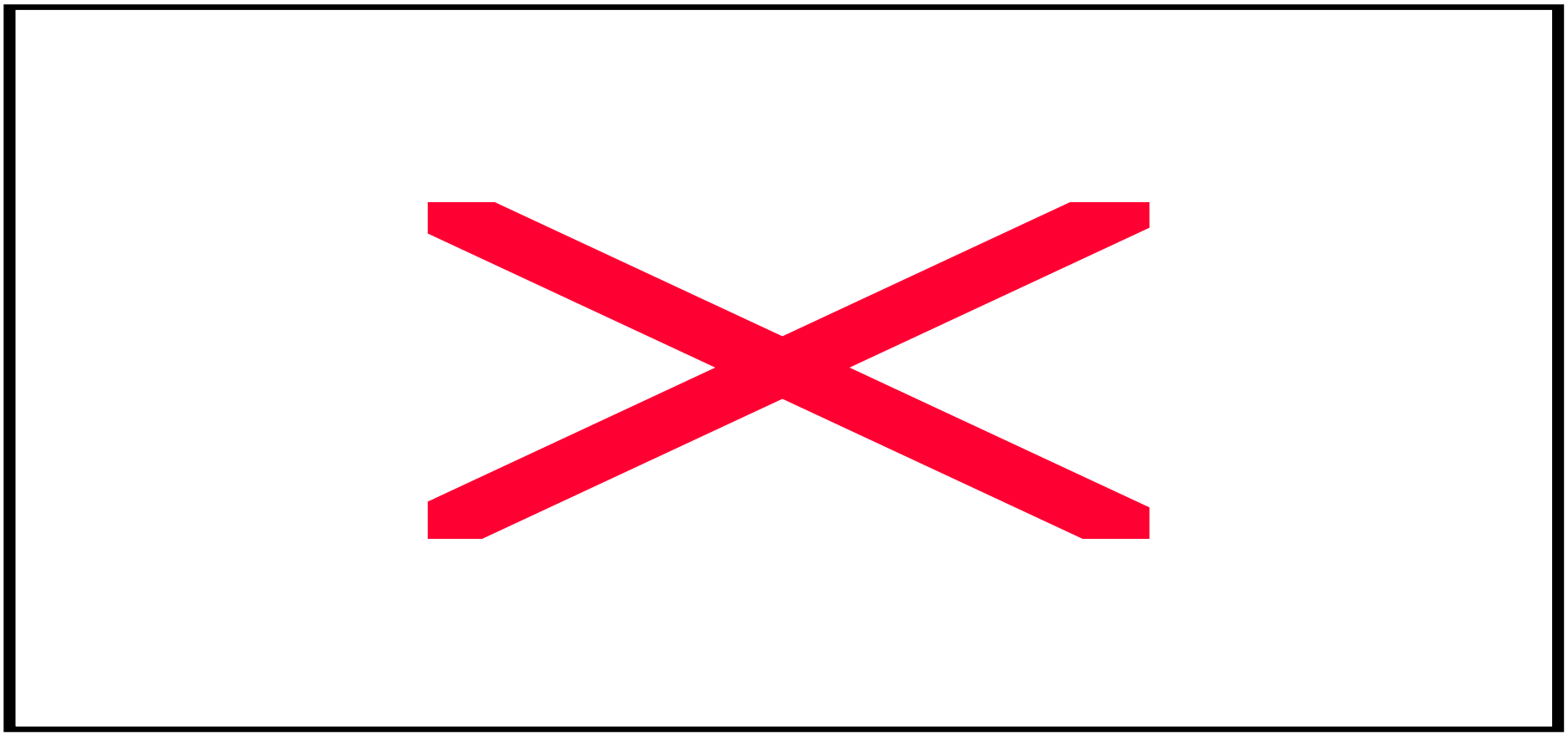
**During the late afternoon to the night-time (15 to 00 UTC)
process of the development of the UHI starts again
when the land breeze regime moves out from the city to the sea:**

Urban Heat Island Quantification

Turb-Tctrl
Urb = 0.82 ºC at 3 UTC
Sub-urb = 0.6 ºC at 4 UTC
Rurals = 0.1 ºC T 3 UTC
During daytime urb = 0ºC and suburb
UHI > -1.3ºC !!

Wurb – Wctrl
Urb = + 1 m/s at 3 UTC
Sub-urban = - 0.7 m/s at 3 UTC
Rural = -0.3 m/s at 3 UTC
The difference tends to increase (+)
During day hours due to the sea breeze

RHurb – RHctrl
Urb = - 12% at 3 UTC
Sub-urban = -2 % at 3 UTC
Rurals = 0% at 3 UTC
The diference increase during day
Hours due to the sea breeze



Difference plots for the (a) air temperature at 2 m and (b) wind speed at 10 m between the outputs of the urbanized (BEP + AHF) and control runs of the Enviro-HIRLAM model on 5th of July 2009 at 6 UTC

NUMERICAL SIMULATIONS

- CONTROL RUNS; i.e. without any modifications
- URBAN RUNS; including (BEP + AHF)
- URBAN AND FEEDBACKS OF SULPHATE AEROSOLS
- FEEDBACKS OF SULPHATE AEROSOLS

Long – term runs:
Summer: 2-31 July 2009
Winter: 15 January -15 February 2010

Selection of four days under Low Wind Conditions:
5th, 11th, 21st, 28th of July 2009

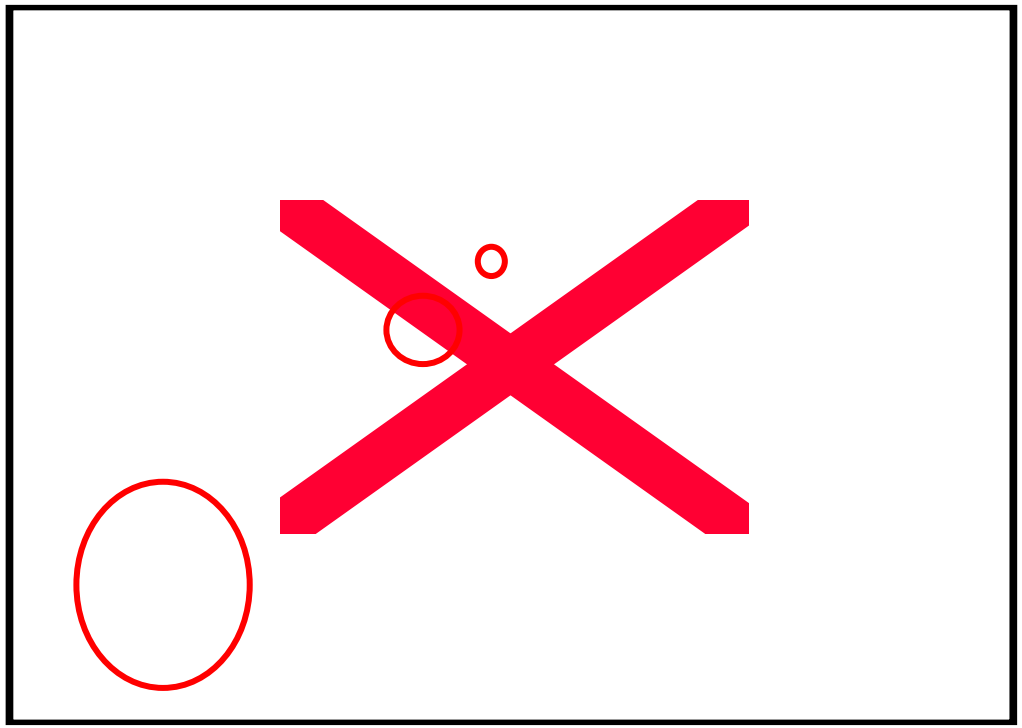
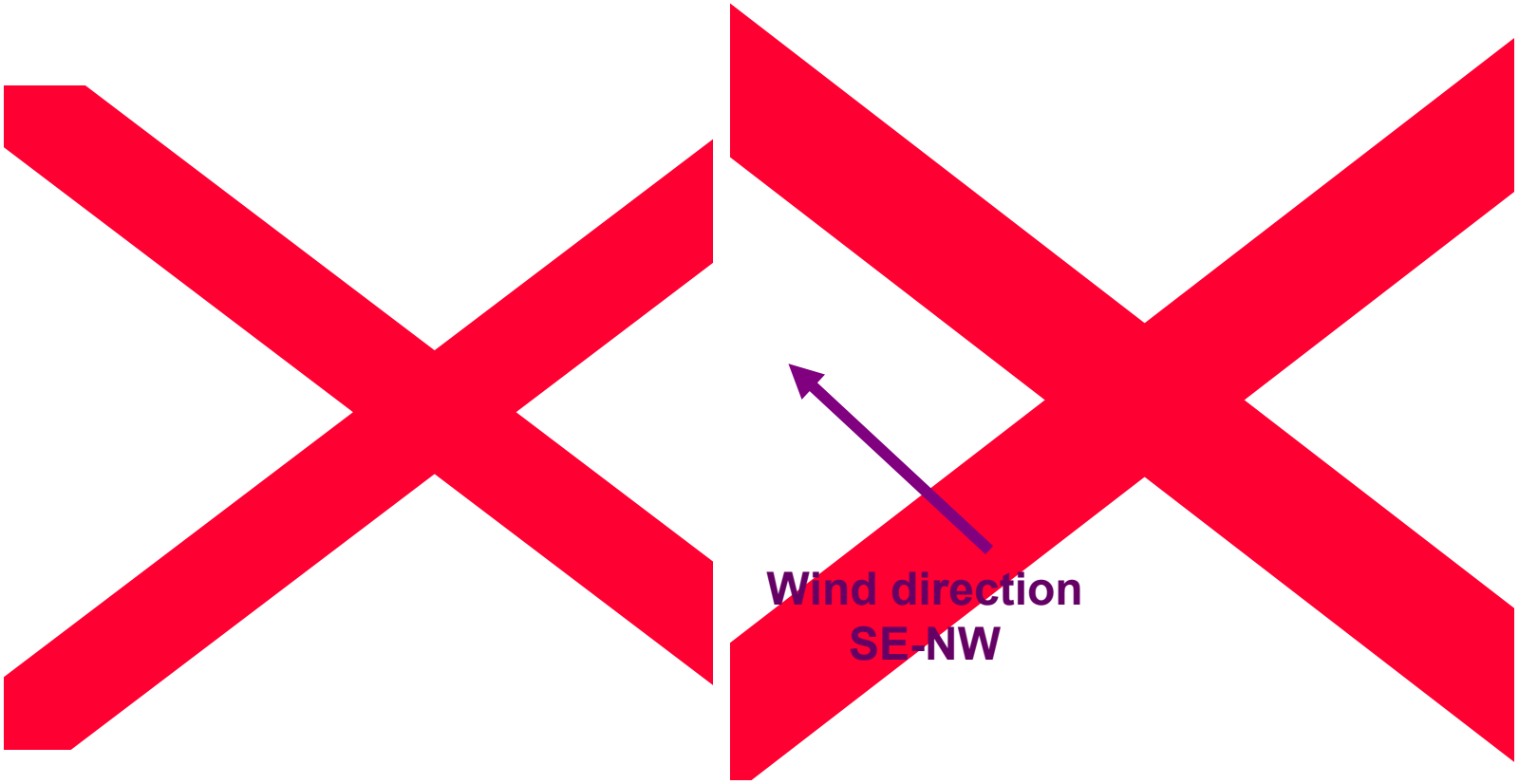
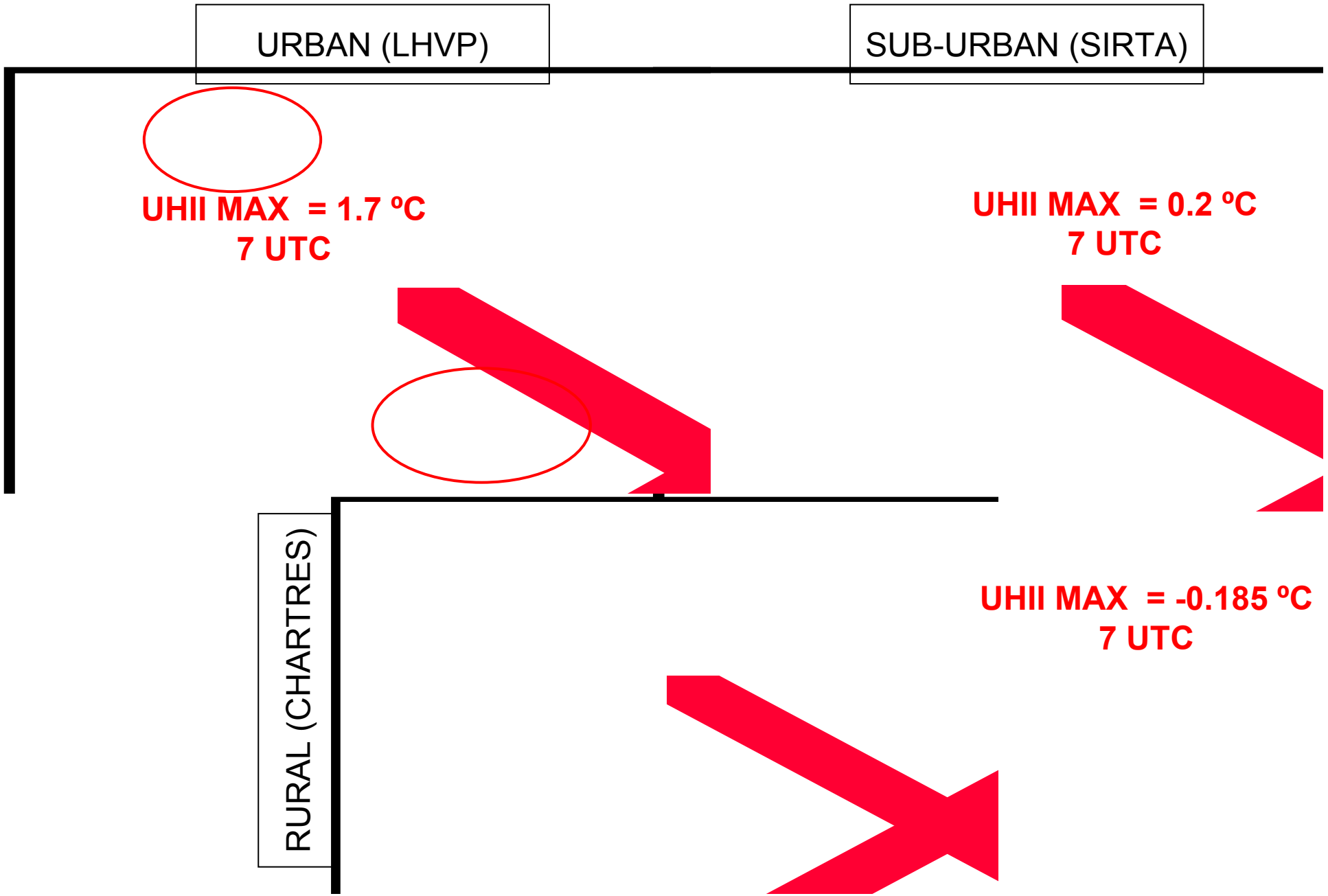


Figure extracted from MEGAPOLI SCIENTIFIC Report 10-15

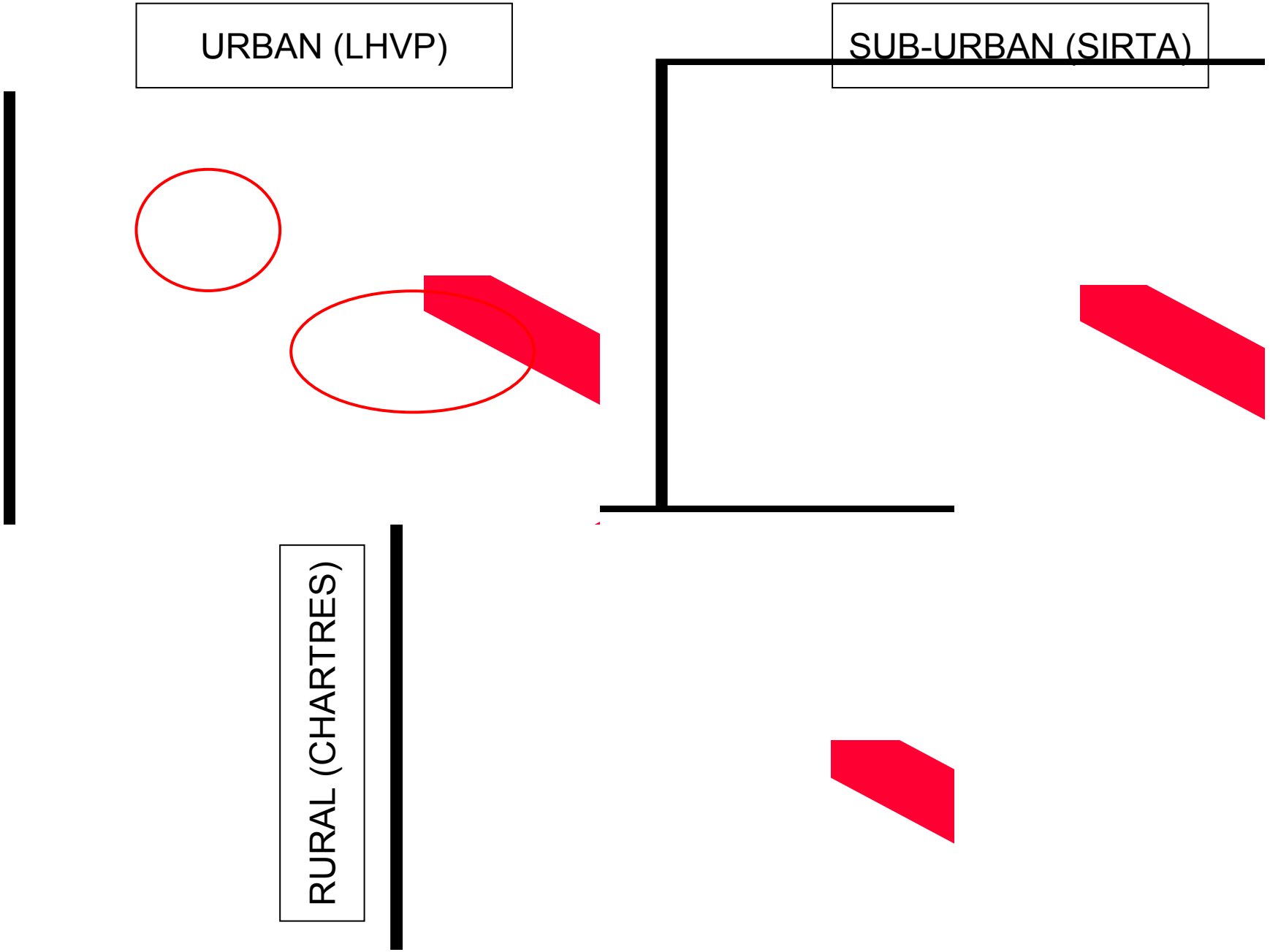


Difference plots for the a) 2 m temperature (ºC) and b) wind speed (m/s) for the Paris metropolitan area between the outputs of the urbanized (BEP+AHF) vs. Control runs for the Enviro-HIRLAM model on the 21st July at 6 UTC.

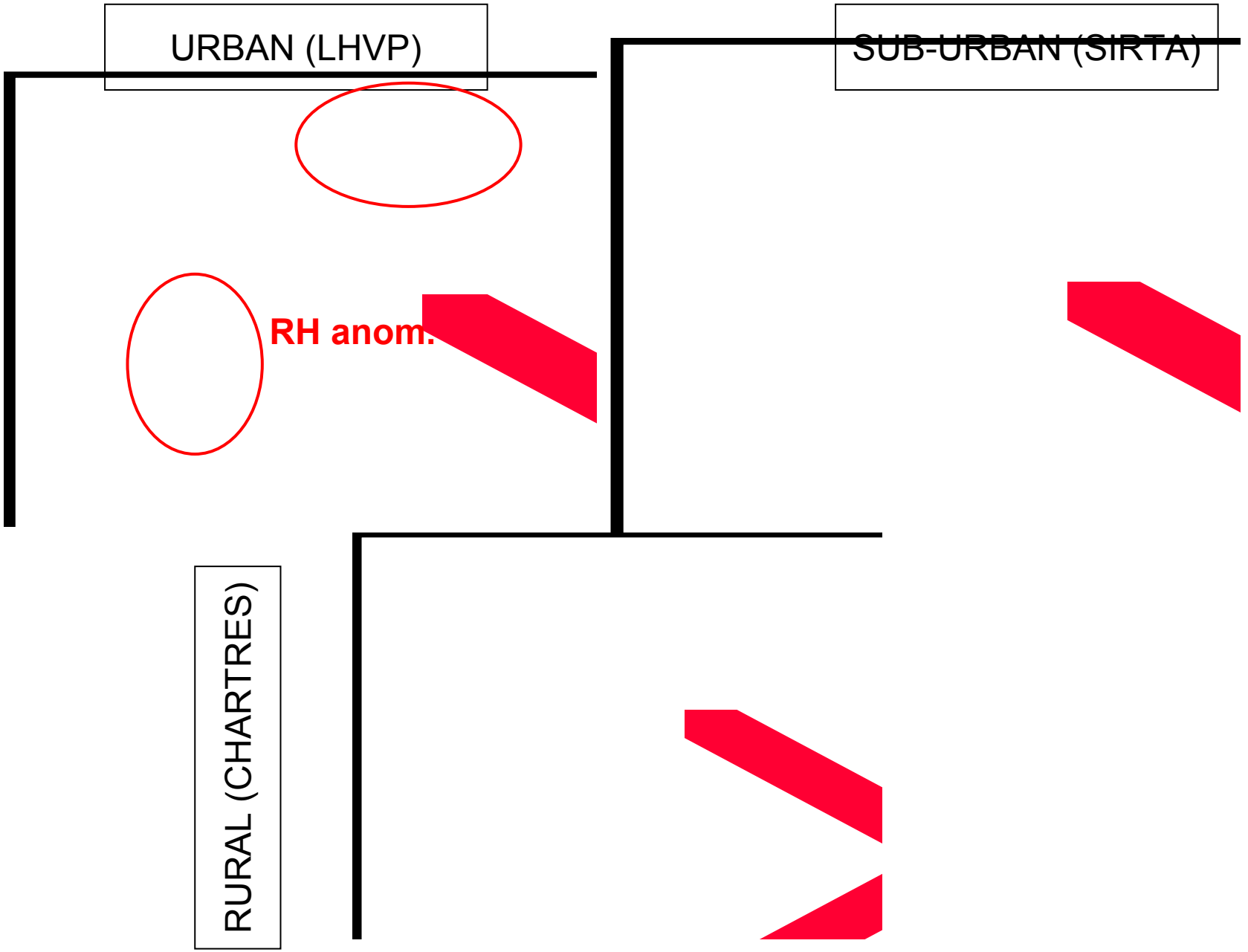
UHII on monthly basis



Wind speed anomaly on monthly basis



Relative humidity anomaly on monthly basis



METEOROLOGICAL AND AIR QUALIY MODELLING

→***González-Aparicio, I.,*** *Nuterman R., Korsholm U.S., Mahura A., Acero J.A., Hidalgo J. and Baklanov A.*
PROCESSING OF LAND-USE DATABASE FOR MESO-SCALE MODEL URBANIZATION
Newsletter 9, NL09-10-12, p.9

→***González-Aparicio, I.,*** *Nuterman R., Korsholm U.S., Mahura A., Acero J.A., Hidalgo J. and Baklanov A.*
LAND-USE DATABASE PROCESSING APPROACH FOR MESO-SCALE URBAN NWP MODEL INITIALIZATION.
DMI Scientific Report 10-02, 34 pages. ISBN: 978-87-7478-593-4, 2010

→*Alexander Mahura, Roman Nuterman,* ***Iratxe Gonzalez-Aparicio****, Claus Petersen, Alexander Baklanov, Ulrik Korsholm.*
ENVIRONMENTAL MODELING IN METROPOLITAN AREAS.
Scientific Report. DMI /In preparation/

→*Nuterman R., Baklanov A., Mahura A., Zakey A., Korsholm U., Bjarne A. and* ***González-Aparicio I.***
MULTI-SCALE AIR QUALITY FORECAST: DOWNSCALING FROM REGIONAL TO STREET SCALE.
Newsletter 9, NL09-10-12, p.10

→***González- Aparicio I.,*** *Nuterman R., Korsholm U., Mahura A., Hidalgo J., Baklanov*
URBAN SCALE MODELLING FOR A MEGACITY AND A MEDIUM SIZE CITY: EVALUATING SULPHATE AEROSOL INDIRECT EFFECT.
European Geoscience Union. General Assembly. AS3.6: Megacities: Air Quality and climate impacts from local to global scales. Vienna 3-8 April 2010.

→ Alexander Baklanov, Ulrik Korsholm, Alexander Mahura, Ashraf Zakey, Roman Nuterman,Bent Sass, Kristian Nielsen, Brian Soerensen, and **Iratxe Gonzalez-Aparicio**
Enviro-HIRLAM online integrated ACT-NWP modeling system with two-way interactions: History and current status.
EGU 2011 session - AS4.25 'Integrated physical and chemical weather modelling'

TEACHER ASSISTANT/Teaching

Integrated modelling of meteorological and transport processes

→ Enviro-HIRLAM Research Training Week, 25-29 Oct, 2010. DMI, Denmark
→ Young Scientist Summer School, July 2011. Odessa, UKRAINE

Acknowledgements

- Thanks to Julia Hidalgo, Alexander Baklanov, Roman Nuterman, Ulrik Korsholm, Alexander Mahura and Juan Angel Acero for advising and scientific discussions

- The authors are thankful to Dr. Maddalen Mendizabal and Urban Climate Team (TECNALIA Research and Innovation) for the constructive discussions related to the GIS processing data.

- Thanks to Oscar Santa Coloma (TECNALIA Reseach and Innovation) for supporting research activities of this study within the framework of the PhD Programme, as well as providing the financial support from TECNALIA Research and Innovation (Bilbao, Spain).

- Thanks to Drs. Xiaohua Yang and Claus Petersen (Danish Meteorological Institute, DMI) for the assistance with technical aspects of the Enviro-HIRLAM model setup

- The research leading to these results has received funding from the European Union's Seventh Framework Programme FP/2007-2011 within the project MEGAPOLI, grant agreement n°212520.

- Iñaki Goenaga foundation (Bilbao, Spain) for research and development.