Comparison of MM5 and WRF forecasts in coastal urban environment: Lisbon case study

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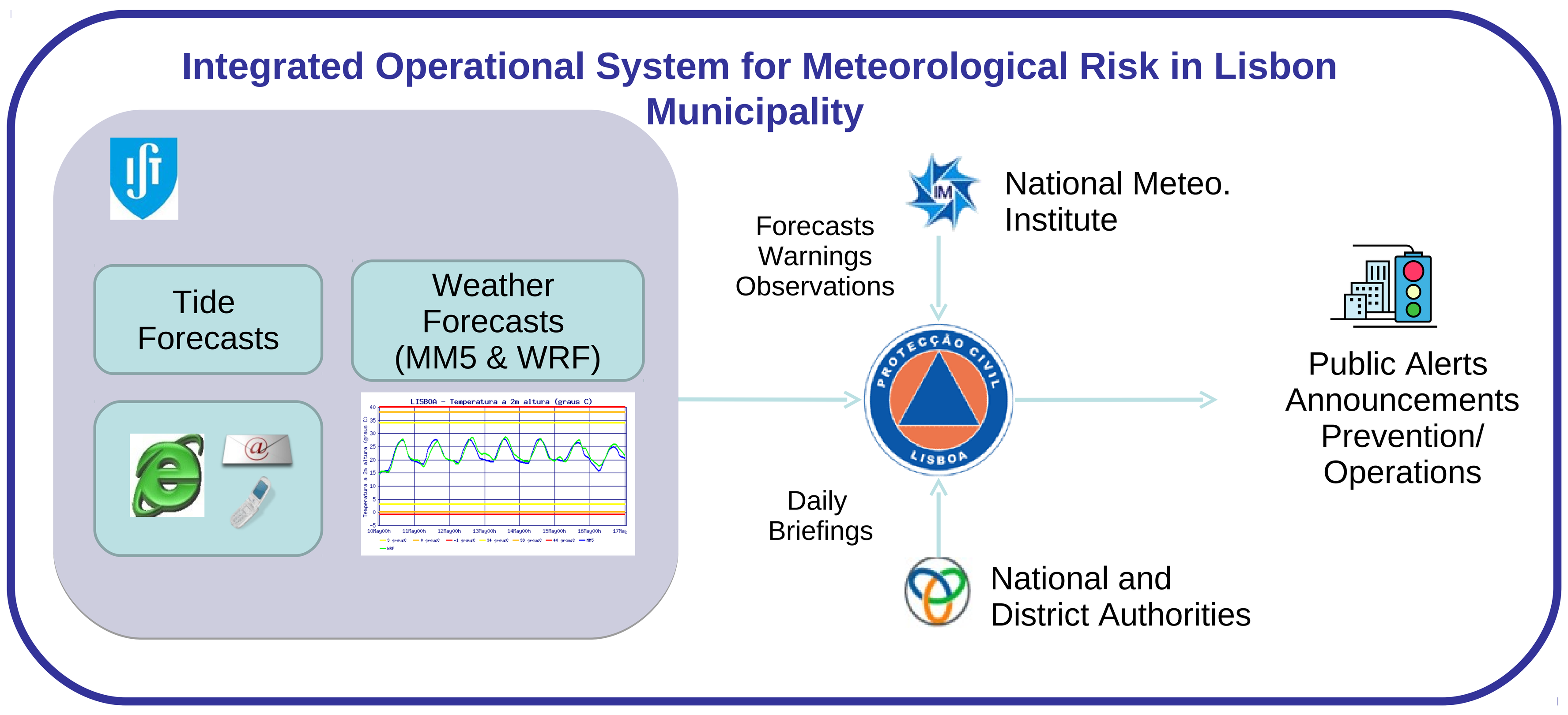
International Workshop Land Atmosphere Interactions at the regional scale
8-10 October 2012 Madrid (Spain)
Madrid 2012 Land atmosphere interactions

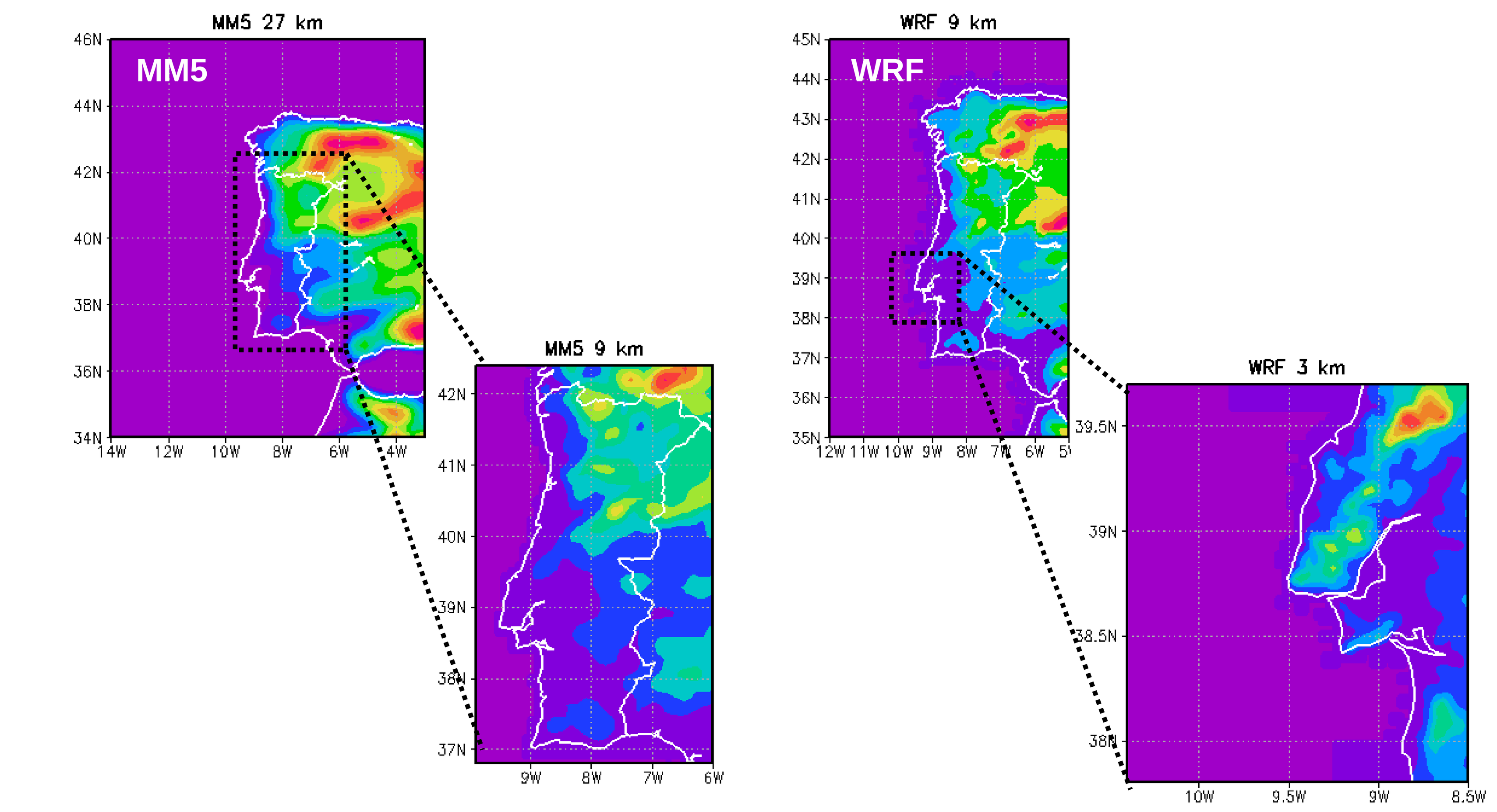
INTRODUCTION

The urban environment presents unique challenges due to increased vulnerability and meteorological events that are influenced by local effects. Lisbon is a costal dense urban city under the influence of sea breezes and tide level and the Civil Protection Authorities need to have not only accurate and reliable forecasts but also some confidence measure of forecast errors [1].

An early warning system has been developed at IST in collaboration with the Lisbon Municipality Civil Protection Agency, producing 3 and 7 day forecasts for Lisbon city, with MM5 and WRF models, in different resolutions and parameterizations (http://meteo.ist.utl.pt) [2].

A comparison between the models performance and their efficacy in forecasting extreme conditions (precipitation, warm and cold weather, and wind speed) is presented.





METHODOLOGY

MM5 and WRF forecast quality was assessed in terms of issued warnings, during the hydrologic year 2009/2010, for projection times 6 to 180 hours, using contingency tables and categorical performance statistics [3]. Warning thresholds are defined by the Portuguese National Meteorological Institute (http://www.meteo.pt) where each level corresponds to a range of values, and associated with a color representing the degree of warning: Green – not dangerous; Yellow – potentially dangerous (strong but usual weather); Orange – dangerous (strong and unusual weather); Red – very dangerous (exceptionally intense phenomena).

RESULTS

Results are presented in contingency tables for both models (MM5/WRF) and other relevant statistics according to each variable. H is hit rate, FAR is False Alarm Ratio [3], Tmax and Tmin are maximum and minimum temperatures respectively.

6 hours accumulated PCP (mm)

Obs / Fcst	No Rain	> 0.01	> 30	> 40	> 60
No Rain	16 938/16 048 (73/68 %)	**1 151/870 (5/4 %)**	0/0	**4/3**	0/0
> 0.01	**2 484/3 778 (11/16 %)**	2 613/2 937 (11/12 %)	**16/17**	**44/47**	0/0
> 30	**6/4**	**7/9**	0/0	0/1	0/0
> 40	0/2	0/1	0/0	0/0	0/0
> 60	0/1	1/0	0/0	0/0	0/0

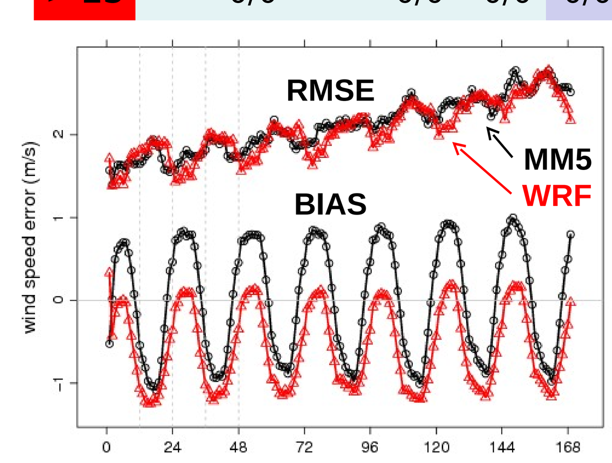
Hourly PCP (mm)

Obs / Fcst	No Rain	>0.01	> 10	> 20	> 40
No Rain	113 246/110 891 (80/77 %)	**9 952/8 807 (7/6 %)**	**41/38**	**12/12**	0/0
> 0.01	**10 036/14 546 (7/10 %)**	7 882/9 245 (6/6 %)	**88/96**	**19/18**	0/0
> 10	**28/33**	**36/25**	1/1	0/0	0/0
> 20	0/0	1/3	0/0	0/0	0/0
> 40	0/0	0/0	0/0	0/0	0/0

As expected, for precipitation, the most frequent categories have high H and low FAR. The forecasts have higher % of missed events than false alarms. Looking at the data, it can be seen that the false alarms correspond to forecasts with more than 4 days lead time.

10 m Wind Speed (m/s)

Obs / Fcst		> 14	> 19	> 25
	135 994/138 650 (100%)	**45/48**	0/0	0/0
> 14	**43/7**	4/1	0/0	0/0
> 19	0/0	0/0	0/0	0/0
> 25	0/0	0/0	0/0	0/0



For wind speed warnings, it can be seen that MM5 has higher H but also higher FAR than WRF. Both models have high % of missed events.

The distribution of data in the bins indicates that the warning thresholds might not be adjusted to the urban characteristics (trees, bridges, etc.).

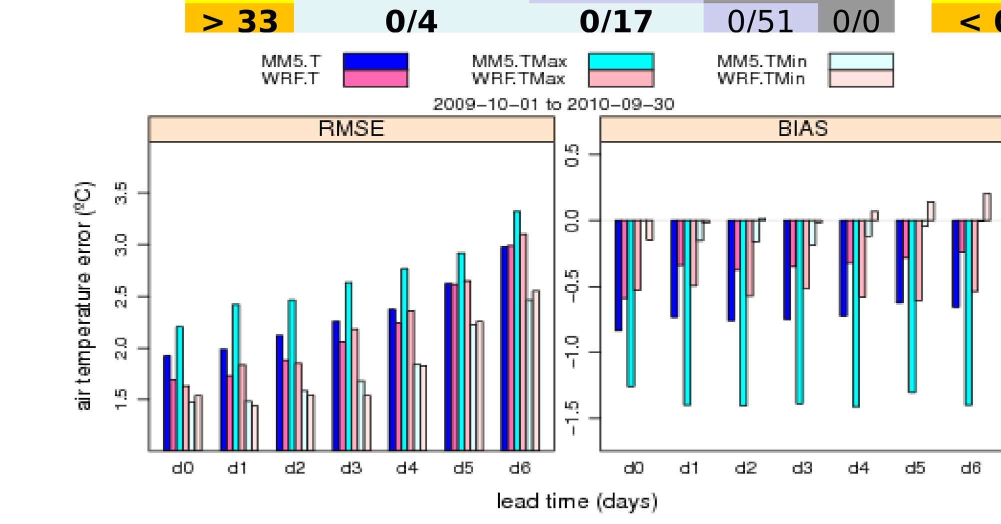
Both models have a RMSE of approx.. 1.5 to 2 m/s in the first 3 days of lead time.

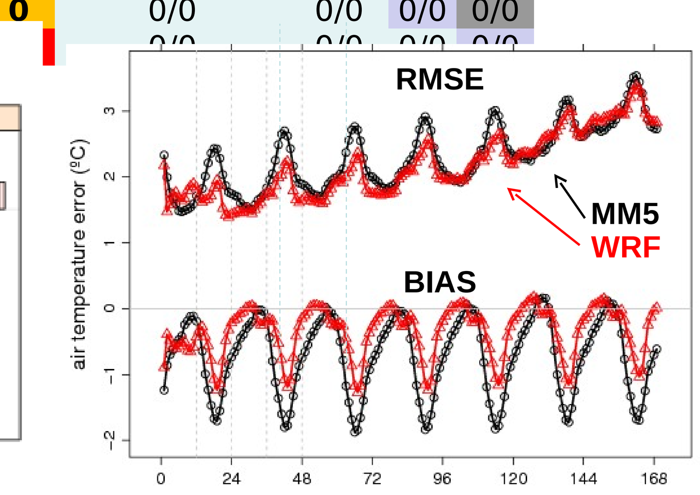
2 m Maximum Temperature (ºC)

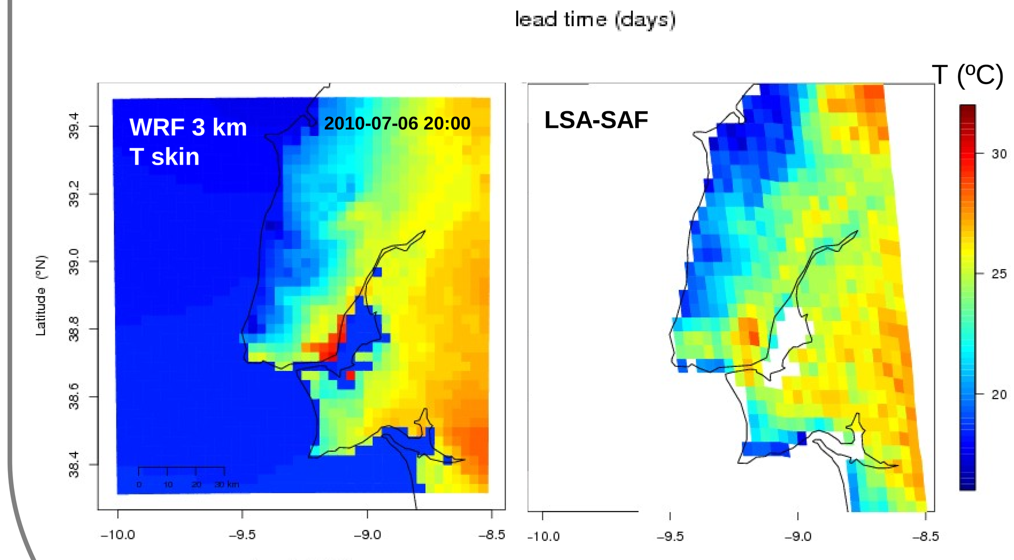
Obs / Fcst		>30	> 33	> 37
	137 250/139 745 (99/99%)	**1 529/1 011 (1/1%)**	**269/99**	0/0
> 30	**9/189**	26/541	**51/170**	0/0
> 33	**0/4**	**0/17**	0/51	0/0

2 m Minimum Temperature (ºC)

Obs / Fcst		< 3	< 0	< -1
	138 936/141 723 (100%)	**75/88**	0/0	0/0
< 3	**78/5**	45/11	0/0	0/0
< 0	0/0	0/0	0/0	0/0







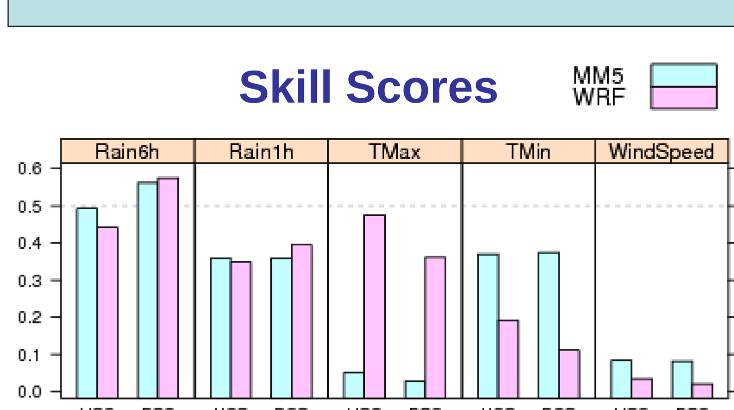
Contingency tables show that WRF performs much better than MM5 for Tmax. This is corroborated by the good simulation of the Urban Heat Island by WRF (maps on the left).

Results show that MM5 is colder than WRF and that the error is Tmax is higher than Tmin error for both models.

The RMSE for Tmax is approx.. 2ºC for MM5 and 1ºC for WRF, while for Tmin is approx.. 1.5ºC in both.

CONCLUSIONS

Skill Scores



MM5 performs better than WRF for precipitation, cold weather and wind forecasts, while WRF is significantly superior in warm weather forecasting, which can be attributed to the higher resolution and different land surface scheme.

Support in decision making:

False Alarms have lead times > 4 days.	• Use the time lagged ensemble forecast
Recent forecasts tend to underestimate observations.	• Correction with real time observations (satellite imagery)
Phase errors are intrinsic to numerical models	• Quantitative and Hourly based forecasts and observations are important

FUTURE WORK

- Inter-annual study to capture more extreme phenomena
- Spatial verification to better identify the forecast error sources
- Understand why WRF doesn't perform as good as MM5 in precipitation, cold weather and wind
- Update topography and land use in model input.

References:

[1] Trancoso, A.R., Domingos, J. D., Telhado, M. J., Corte-Real, J. (2009) *Early Warning System for Meteorological Risk in Lisbon Municipality: Description and Quality Evaluation*. 8th International Conference on Information Systems for Crisis Response and Management, 8-11 May, Lisbon, Portugal

[2] Trancoso, A. R. (2012) *Operational Modelling as a Tool in Wind Power Forecasts and Meteorological Warnings*, PhD in Environmental Engineering, Instituto Superior Técnico, Lisbon Technical University

[3] Jollife, I.T, Stephenson, D.B. (2003) Forecast Verification: A Praticioner's Guide in Atmospheric Science. John Wiley & Sons,UK, 240 pp.

This work was partially funded by QREN POVT-03-0335-FCOES-000102 and a PhD scholarship grant provided by FCT (SFRH/DB/17957/2004)