# A methodology to determine the optimum WRF-ARW configuration over Port of Huelva

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**Abstract**

A calibration of the meteorological model WRF for operational forecasting over the city of Huelva (Spain) and its metropolitan area is performed. Weather forecasting will be used to analyze meteorological hazard impacts and to improve the management of the local air quality. A sensitivity analysis is done considering different physics and dynamic options, the use or not of very high resolution physiographic databases (topography and land use), and the assimilation of observations. Experiment results are compared with observations during a representative period of time, focusing on the wind field (the main risk factor in the region), and the best configuration is obtained. Then, simulations for the years 2012 and 2013 are done using this configuration. When comparing with observations, the model has a confidence level of 70% for the temperature, 81% and 66% for the wind speed and wind direction respectively, and 90% for the relative humidity.

## Introduction

This work aims to investigate the optimum configuration of a meteorological model that allows to reduce the uncertainty in Huelva, a region in Southern Spain. It has used WRF model to obtain the meteorological forecasts and it has defined a procedure to calibrate the model in a customized way for Huelva, being replicable to any region.

## Methodology

### Studied area, simulation domains and episodes selected

The regional and mesoscale meteorological model used for the study has been the Weather Research and Forecasting - Advanced Research (WRF-ARW) version 3.7. In Figure 1 we show modeling domains used for operational forecasts over the coastal region of Huelva. The WRF model is built over a mother domain (called d01) with 9 km spatial resolution, centered at 37.14$^o$N 7.38$^o$W.

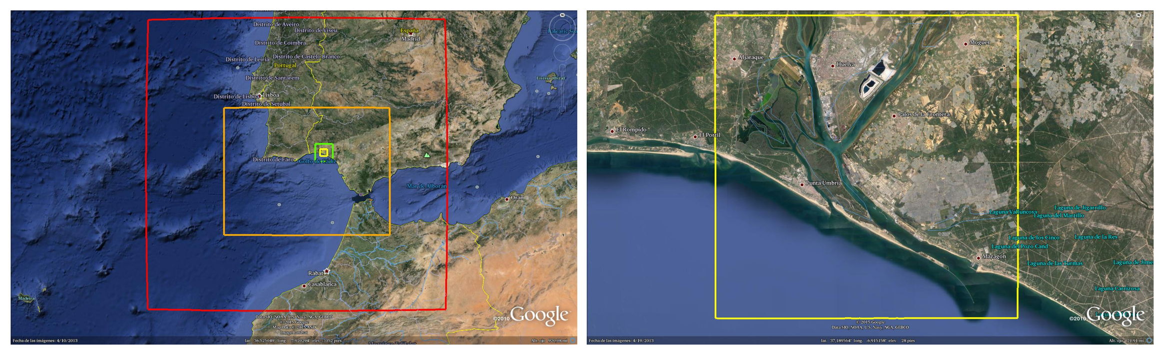

**Figure 1:** Modeling domains used for simulation: d01 (9 km), d02 (3 km), d03 (1 km), d04 (0.333 m) (left) and d04 (0.333 m) (right) spatial resolution.

### Modeling approach

- The initial and boundary conditions for the operational forecast configuration over domain d01 were supplied by the National Centers for Environmental Prediction (NCEP) Global Forecast System (GFS) with an horizontal resolution of 0.25$^o$ and updated every 6 hours.
- To calibrate and validate the model initial and boundary conditions were supplied by the NCEP/NCAR Climate Forecast System Reanalysis v2 (CFSv2, Saha et al., 2013), with 0.5$^o$ of spatial resolution and 6h of temporal sampling.
- Two-way nesting was used for the external domains (d01, d02 and d03) and one-way nesting for d04. On the innermost domain resolution (d04) Large-Eddy-Simulation (LES) technique has been applied [1].

## Sensitive analysis and calibration

### Physic options

In order to obtain the optimum model configuration over the study area, we have realized a total of 18 experiments modifying physic options as shows Table 1.

| Exp. | PBL | Surface Layer | CU | SW Rad. | LW Rad. | MPh. MPh. |
|---|---|---|---|---|---|---|
| **INI** | YSU | MM5 | KF | Dudhia | RRTM | WMS3 |
| **MPH1** | YSU | MM5 | KF | Dudhia | RRTM | WDM6 |
| **MPH2** | YSU | MM5 | KF | Dudhia | RRTM | SBU-Lin |
| **LWR1** | YSU | MM5 | KF | Dudhia | RRTMG | *MPH* |
| **LWR2** | YSU | MM5 | KF | Dudhia | FLG | *MPH* |
| **SWR1** | YSU | MM5 | KF | RRTMG | *LWR* | *MPH* |
| **SWR2** | YSU | MM5 | KF | FLG | *LWR* | *MPH* |
| **CMS1** | YSU | MM5 | MS KF | *SWR* | *LWR* | *MPH* |
| **CMS2** | YSU | MM5 | Grell 3D | *SWR* | *LWR* | *MPH* |
| **CMS3** | YSU | MM5 | New SAS | *SWR* | *LWR* | *MPH* |
| **PBL1** | MYJ | Eta sim | *CMS* | *SWR* | *LWR* | *MPH* |
| **PBL2** | QNSE | QNSE | *CMS* | *SWR* | *LWR* | *MPH* |
| **PBL3** | ACM2 | MM5 | *CMS* | *SWR* | *LWR* | *MPH* |
| **PBL4** | MYNN2 | MYNN | *CMS* | *SWR* | *LWR* | *MPH* |
| **PBL5** | MYNN3 | MYNN | *CMS* | *SWR* | *LWR* | *MPH* |
| **PBL6** | UW | MM5 | *CMS* | *SWR* | *LWR* | *MPH* |
| **PBL7** | GBM | MM5 | *CMS* | *SWR* | *LWR* | *MPH* |
| **PBL8** | Shin-Hong | MM5 | *CMS* | *SWR* | *LWR* | *MPH* |

**Table 1:** Experiments analyzed corresponding to physic options.

### Dynamic options

We have investigated some dynamical options (Table 2). We have focused on damping and diffusion option. These options could improve model-top reflection of mountain waves, remove poorly resolved structures and reduce noise at model scales similar to grid-spacing.

| Exp. | Turb. mixing | Eddy Coef. | HDif.6 | HDif.6 factor | Damp. | Damp. coef. |
|---|---|---|---|---|---|---|
| **INI** | Dif. 2th | Smagorinsky | No | 0.12 | No | - |
| **DIN1** | Dif. 2th | Smagorinsky | Knievel | 0.12 | No | - |
| **DIN2** | Dif. 2th | Smagorinsky | Knievel | 0.36 (d03) | No | - |
| **DIN3** | Dif. 2th | Smagorinsky | No | 0.12 | Rayleigh | 0.2 |
| **DIN4** | Dif. 2th | Smagorinsky | Knievel | 0.36 (d03) | Rayleigh | 0.2 |

**Table 2:** Experiments analyzed corresponding to dynamic options.

### Number of vertical levels

There are numerous papers which demonstrate that increasing the number of vertical levels is related to an improvement of the accuracy of the forecasts [2].

| Exp. | Vertical levels |
|---|---|
| **INI** | 30 (default configuration) |
| **VER1** | 36 (15 below 1.500 m and first level at 16 m) |
| **VER2** | 42 (21 below 1.500 m and first level at 8 m) |

**Table 3:** Experiments analyzed corresponding to vertical levels.

In Figure 2 we show a comparison between levels for every experiment and their distribution in sigma coordinates.

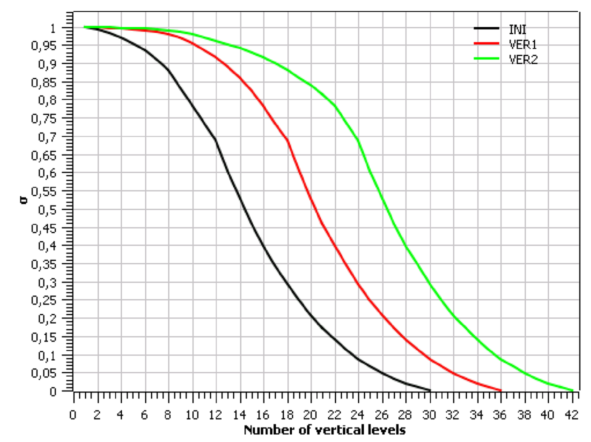


**Figure 2:** Sigma level distribution for every experiment defined.

### Physiographic model database

When very high resolution is required it is necessary to couple higher resolution databases. In this research, we have evaluated different topographical and land use database information (Table 4).

| Exp. | Topography and Land Use database |
|---|---|
| **HRP1** | ASTER and CLC2006 |
| **HRP2** | SRTM and CCI-LC |

**Table 4:** Experiments analyzed corresponding to physiographic model database.

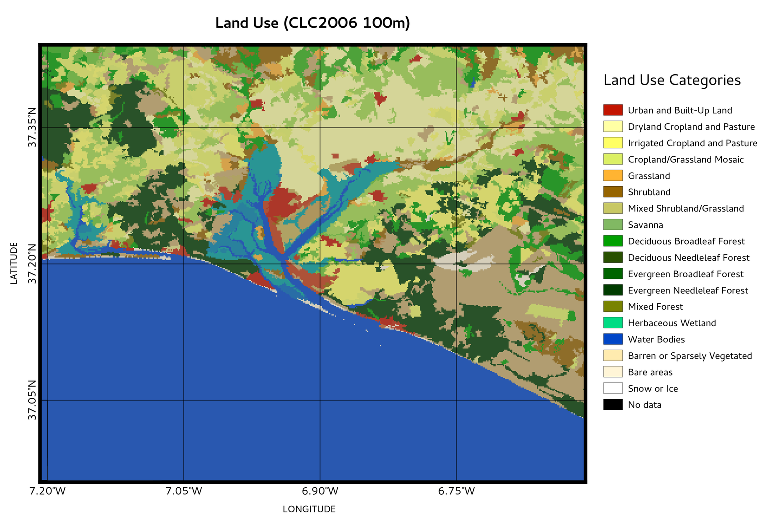


**Figure 3:** Land use information (Corine Land CLass 2006 - 100 m resolution) used over d04.

### Nudging options and data assimilation

Data assimilation system based on the grid-point statistical interpolation (GSI) three-dimensional variational data assimilation (3DVar) system has been applied. We have considered observational nudging and grid nudging using meteorological observations from:

- Metars, radiosoundings and monitoring stations.
- Irradiance information from EUMETSAT satellites.

This information has been coupled and combined into WRF defining different testing experiments as we show in Table 5.

| Exp. | Nudging options d01 (9 km) | d02 (3 km) | d03 (1 km) |
|---|---|---|---|
| **INI** | NO | NO | NO |
| **NUD1** | Grid (global data) | NO | NO |
| **NUD2** | Grid (satellite data) | NO | NO |
| **NUD3** | Grid (global and satellite data) | NO | NO |
| **NUD4** | Grid (satellite data) | Observations | NO |
| **NUD5** | Grid (satellite data) | Observations | Observations |

**Table 5:** Experiments analyzed corresponding to nudging options.

## Results and conclusions

To evaluate the model performance, four statistics have been selected: Mean Bias (MB), Mean Absolute Gross Error (MAGE), Root-Mean-Square Error (RMSE), Index of Agreement (IOA) and Directional Accuracy (DACC) statistics. Table 6 shows the statistical evaluation for the optimum model configuration.

| Exp. | Temperature (2m) | | | Wind Speed (10m) | | | Wind Direction (10m) | | | Relative Humidity (2m) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | MB | MAGE | IOA | MB | RMSE | IOA | MB | MAGE | DACC | MB | MAGE | IOA |
| | <±0,5°C | <2°C | ≥0,8 | <±0,5ms$^{-1}$ | <2,0ms$^{-1}$ | ≥0,60 | <±10° | <30° | % | <±10% | <20% | ≥0,6 |
| VER1 | -0,51 | 1,77 | 0,97 | 1,37 | 2,19 | 0,64 | 9,90 | 33,47 | 69,36 | -1,35 | 9,89 | 0,87 |
| MPH2 | -0,21 | 1,78 | 0,97 | 1,39 | 2,30 | 0,63 | 10,61 | 31,06 | 69,54 | -3,62 | 10,60 | 0,85 |
| LWR1 | -0,27 | 1,79 | 0,97 | 1,35 | 2,26 | 0,64 | 10,18 | 30,87 | 69,43 | -3,61 | 10,63 | 0,84 |
| SWR1 | 0,02 | 1,77 | 0,97 | 1,38 | 2,26 | 0,64 | 10,21 | 31,57 | 68,45 | -4,11 | 10,78 | 0,84 |
| CMS1 | -0,25 | 1,79 | 0,97 | 1,28 | 2,22 | 0,64 | 10,56 | 31,41 | 68,67 | -3,47 | 10,71 | 0,84 |
| DIN4 | 0,30 | 1,79 | 0,97 | 1,29 | 2,23 | 0,64 | 10,47 | 31,17 | 69,23 | -3,14 | 10,45 | 0,85 |
| HRP1 | -0,53 | 1,48 | 0,98 | 0,40 | 1,47 | 0,76 | 9,52 | 30,66 | 69,96 | -4,44 | 9,45 | 0,89 |
| NUD5 | -0.56 | 1.75 | 0.89 | 1.11 | 2.04 | 0.65 | 7.20 | 39.19 | 58.87 | -3.42 | 9.91 | 0.83 |

**Table 6:** Statistical evaluation of the different physic-dynamic-physiographic experiments for the temperature, wind speed, wind direction and relative humidity.

We can conclude that optimum model configuration has a confidence level of 70% for the temperature, 81% and 66% for the wind speed and wind direction respectively, and 90% for the relative humidity. Table 7 shows optimum WRF-ARW configuration for the operational forecast over the region of study .

| Scheme or parameterization | Option selected |
|---|---|
| **Initialization** | GFS 0.25° |
| **Microphysics** | SBU-Lin |
| **Longwave radiation** | RRTMG |
| **Shortwave radiation** | Dudhia |
| **Cumulus** | Kain-Fritsch |
| **Surface Layer** | MM5 similarity |
| **Planetary Boundary Layer** | YSU (d01,d02,d03) |
| | LES (d04) |
| **Vertical levels number** | 36 |
| **Diffusion 6th order option** | Knievel |
| **Diffusion 6th order factor** | 0.36 (d03) |
| **Damping** | Rayleigh |
| **Topography** | GTOPO30 (d01 and d02) |
| | ASTER (d03 and d04) |
| **Land Use** | GLC (d01 and d02) |
| | CLC2006 (d03 and d04) |
| **Nudging** | Grid (d01) |
| | Observations (d02 and d03) |

**Table 7:** Configuration option selected as optimum for the region.

### Acknowledgements

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## References

[1] J.C. Wyngaard. Toward numerical modeling in the "terra incognita". *J. Atmos Sci.*, 61:1816–1826, 2004.

[2] Vuille M. Clement A Garreaud, R. The climate of the altiplano: observed current conditions and mechanism of past changes. *Palaeoclimatol*, 194:1–18, 2003.