

Hyper-local extreme temperature and wind modeling in the Basque Country

Abstract

In this paper, we present some results of the implementation of operational high-resolution tools (down to 100m) for temperature and wind analysis at local level. Here we focus on different systems we have developed for its applications at local level in the Basque Country based on WRF and CALMET but we also include a brief descriptive analysis of some others available tools for thermal and wind analysis at high spatial resolution.

1. Introduction

In order to test their operational capabilities, the behavior of the different systems is analyzed in diverse experiments corresponding to high impact weather scenarios, affecting the three largest metropolitan areas of the Basque Country, i.e. the metropolitan areas of Bilbao, Donostia-San Sebastián and Vitoria-Gasteiz, where more than half of the Basque population lives. The aim of this study is to evaluate and provide plausible tools and methodologies for very high resolution meteo-climatic

analysis in the Basque Country area, focusing on wind and extreme temperature. With the final objective of identifying the benefit of hyperlocal modelling, finding under which conditions and spatio-temporal resolutions these highly computation demanding tools for wind and thermal characterization are fully useful and provide sufficient added value. It is important to note that some results and main conclusions are of a general nature and could be extrapolated to other areas.

2. Data and Methodology

Two approaches have been made based on the application of local area numerical models applied to high resolution modelling. WRF is a weather forecasting system developed by NCAR, and NCEP, flexible and computationally efficient, serves a wide range of meteorological applications across scales from tens of meters to thousands of kilometres and suitable for complex terrain simulations. For this work, implemented WRF V4.2 have three 2-way nested domains are used (Figure 2). The grids resolutions are 5 km (91x87), 1 km (170x155) and 100 m (200x200), with 33 vertical levels. The finer domain is focus on Donostia-San Sebastián metropolitan area (DSS), one of the most populated areas in the Basque Country. Orography data derived from own data with 3s resolution and land uses data is extracted from CORINE data (100m resolution) (Figure 3). Meteorology forcing dataset come from ERA5 archive (approx. 31 km resolution). The set of physics parameterizations are Mellor-Yamada-Janjic planetary boundary layer, RRTM/Dudhia radiation, WSM6 microphysics, Grell 3D cumulus (for the two coarser domains) and Noah land surface model. CALMET is a meteorological model, component of the CALPUFF air quality modelling system. Includes a diagnostic wind field

generator containing objective analysis and parameterized treatments of slope flows, kinematic terrain effects, terrain blocking effects and divergence minimization procedure, and a micro-meteorological model for overland an overwater boundary layers useful for modelling domains from tens of meters to hundreds of kilometres and applicable in rough or complex terrain situations. For CALMET system three 100-m horizontal resolution domains have been implemented, one for each metropolitan area, with 10 vertical levels (20, 40, 80, 160, 300, 600, 1000, 1500, 2200 and 3000 m). Topography data come from an elevation digital model and land use data are derived from CORINE archive. The grid sizes are: Bilbao 218x241 points, Donostia-San Sebastián 221x159 points and Vitoria-Gasteiz 159x129 points. The CALMET system generates hourly forecast with a 24-hour forecast horizon. Meteorology forcing data come from 1-km resolution WRF running in operational basis at Basque meteorology Agency (EUSKALMET). CALMET runs daily in an operational basis, to be used as meteorological forcing in a chemical accidents tool developed at TECNALIA to forecast trajectories and concentrations of emitted pollutants.

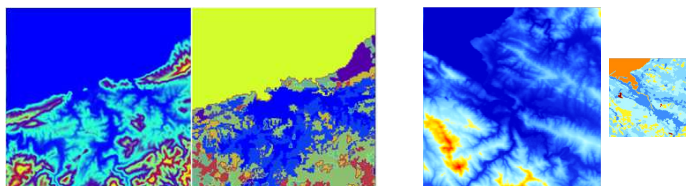


Fig. 3: Topography and land use for 100m resolution WRF for Donostia-San Sebastián metropolitan area

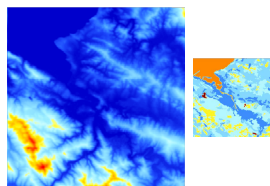


Fig. 4: Topography and land use for 100m resolution CALMET for Bilbao metropolitan area

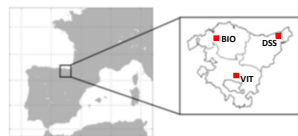


Fig. 1: Basque country and city location



Fig. 2: WRF three nested domain configuration

3. Results and Discussion

The two implementations were built to test the ability of high-resolution forecasting systems in severe weather situations prediction (strong winds, heavy precipitations, extreme temperatures) or have detailed meteorological information with high spatial and temporal granularity that supports decision making facing of accidents or environmental catastrophes. These systems were used in the most widely populated areas of the Basque country, the metropolitan areas of Bilbao (~ 900,000 inh.), Donostia-San Sebastián (~ 390,000 inh.) and Vitoria-Gasteiz (~ 260,000 inh.). We worked simulating the response of both systems in the case of extreme maximum temperature events, focusing on the Donostia-San Sebastián metropolitan area. The selected meteorological events were days corresponding to the

European heat wave of 2003, which affected various European countries. For this area, the highest maximum temperatures for this century were recorded in this event. In the qualitative aspect, the implementation of the high resolution WRF notably solves the daily evolution of temperature, and the spatial distribution of temperatures, observing the marine influence on the coast, the thermal differences due to the orography, in urban and rural areas, the greater warming in leeward areas of the mountains, while in areas affected by the sea breeze temperatures moderate their values (see figure 4 and 5), maximum temperatures values reached are well simulated too, better in flat areas (Oiarzun, Lasarte-Oria, Ereñozu) than in stations located in higher areas (Jaizkibel) (Figure 6 and 7).

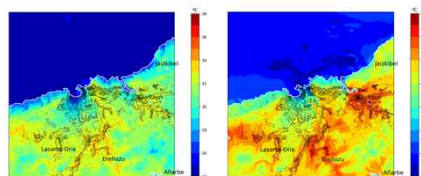


Fig. 5: WRF 2-m temperature for the Donostia-San Sebastián metropolitan area for 2003/08/08. 10:00 UTC (left) and 15:00 UTC (right).

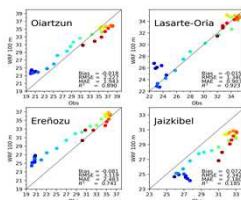


Fig. 6: WRF 2m temperature scatterplots. For station located at Donostia-San Sebastián metropolitan area for 2003/08/08

The CALMET-based system has been executed daily in an operational manner for the areas of interest, due to its integration in the chemical accident tool. The behaviour of the temperature, wind speed and wind direction is shown for the three metropolitan areas, during July 2021. Donostia-San

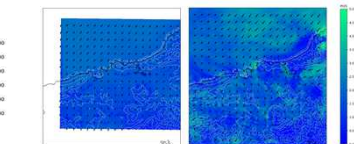


Fig. 7: CALMET (left) and WRF (right). Wind Surface. 2003/08/09 UTC

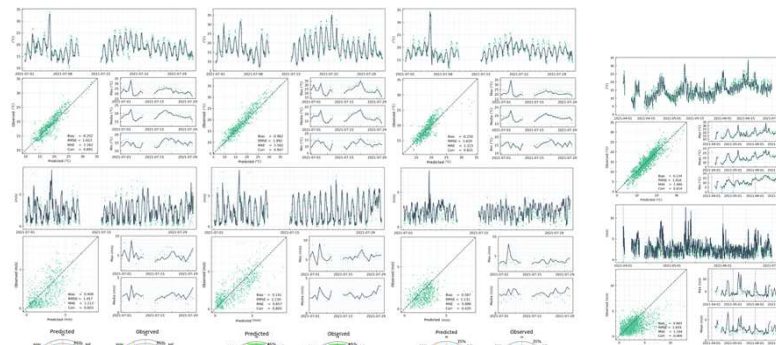


Figure 8: CALMET time series evolution, scatterplots and wind roses for 2m-temperature (top), wind speed (middle) and wind direction (bottom) for Bilbao (left), Vitoria-Gasteiz (centre) and Donostia San Sebastián (right), for July 2021

Good behaviour is observed in the simulation of temperature time evolution in all metropolitan areas. In all three cases there is a slight tendency to underestimate, except in the case of the maximum values, which is significantly overestimated in DSS. Highs are best forecast in BIO and lows in VIT. The calculated errors (RMSE) are less than 2°, and good correlation values, around 0.9 and even widely exceeding it (Figure 9). The correlation is high and the dispersion of the data is lower for VIT, in that area the topography is flat and much less complex than in the case of DSS and BIO. In DSS the wind speed is overestimated in general, with low correlation. BIO is simulated better than DSS but does not reach the behaviour for VIT. For the wind speed forecast, in the 3 cities the errors are

less than 1.5 m/s. The wind direction is remarkably resolved in the case of VIT, mostly for BIO and with obvious discrepancies for DSS (Figure 8). In the case of DSS, data are also available for a period of three months from April to June. A very similar behaviour is observed for the case of the month of July in the case of wind speed, overestimation and low correlation. In the case of temperature, the correlation increases, being corrected the general underestimation and the maximum values overestimation (Figure 9).

4. Remarks and conclusions

CALMET shows good behaviour in high resolution extreme temperatures and wind modelling, better in flat terrain than in complex orography. CALMET is strongly influenced by the meteorological forcing, it is important to ensure the accuracy and quality of the meteorological input data used. Implementation of WRF with high resolution grid,

correctly solves the daily thermal evolution in the area of application. It notably solves the spatial distribution of the wind, its dynamics, and local events such as sea breezes. WRF is computationally very expensive for routine operational use over wide areas of interest.

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