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Low level wind forecast over the Uruguay River region nearby Gualeguaychú, using a boundary layer model forced by WRF regional operational forecasts

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Abstract

The mesoscale atmospheric boundary layer model –BLM– is used to run daily low level wind field forecasts over the Uruguay River region nearby Gualeguaychú. BLM runs with a horizontal resolution of 1 km, forced by initial and boundary conditions defined from the operational WRF forecasts of the National Meteorological Service of Argentina at 5 km resolution. The low level wind forecast is validated with the observations of three 42-meter tall meteorological towers located on the coast of the Uruguay River, during the period June 2010 to May 2013. Despite the WRF forecast errors propagate and impact somehow the quality of the final forecast, BLM is able to overcome this situation and produce a forecast with smaller error than WRF at two of the three places.

Key words: boundary layer model coupling, low level wind, forecast validation

Introduction

It is well known that regions of complex topography are subject to significant spatial changes of the atmospheric circulation. The presence of wide rivers and their associated forcing is responsible for local alterations of the low-level atmospheric circulation. For the purpose of meteorological modeling in these conditions, the use of mesoscale models becomes necessary. Several studies have shown, when modeling topographically-induced local circulations, that increasing horizontal resolution is important. High-resolution wind field forecasts can be obtained by model coupling. In particular, Sraibman and Berri (2009) show that coupling a high-resolution boundary layer model to a regional scale operational forecast model improves the quality of the low-level wind predictions. The objective of this paper is to validate low level wind forecasts obtained with the BLM model at 1 km resolution, forced by the WRF operational forecast at 5 km resolution, and compare it with the results of the local WRF wind forecast itself.

Forecast models and data employed

The BLM model is used to produce high-resolution low-level wind forecasts over the Uruguay River region nearby Gualeguaychú, with initial and boundary conditions taken from operational WRF forecasts. The BLM model was specifically developed for



simulating the low-level circulation over coastal regions of complex geometry. The domain of the experiments is the region depicted in Fig. 1, which consists of 76x76 grid points with horizontal resolution of 0.01° . The vertical domain has 12 levels between the surface and the material top at 2000 m, distributed according to a log-linear spacing. The reader is referred to Berri et al. (2010) for the details about the model formulation. The boundary conditions of wind and temperature at the BLM top, as well as the surface temperature that is the BLM lower boundary condition, are taken from the 3-hourly WRF operational forecasts of the National Meteorological Service during the period June 2010 to May 2013. The correct definition of the land-river thermal contrast at the surface is fundamental in high-resolution modeling.



Figure 1. Domain of the model forecasts and observation network.

The temperature of the water surface and the temperature of the air in contact with the water show small changes across a river width of similar dimensions to the Uruguay River. The BLM is initialized at 0600 local standard time (LST) and the first 3 hours of integration are allowed for the model spin-up. The 3-hourly wind forecasts from 0900 LST until 0600 LST of the following day, are compared to the observations at 42 meters of three meteorological towers located along the riverside, namely East Tower (ET), North Tower (NT) and South Tower (ST).

Forecast errors

Scatterplots and correlation coefficients of forecast versus observed u and v wind components are used. An example of the scatterplots is shown in Fig. 2 for the 1500 local standard time (LST) wind components at ET. The y-axis represents the forecast and the x-axis the observed wind component in ms^{-1} . The analysis of scatterplots includes the slope of the regression line and the correlation coefficient between forecast and observed wind components. A slope equal to 1.0 indicates that the forecast wind component matches the observed one. A slope smaller (greater) than 1.0 indicates that the forecast underestimates (overestimates) the observation. We complement the analysis of the slope with the correlation coefficient, since it is desirable to obtain, not only a slope close to 1.0, but a high value of the correlation coefficient as well.

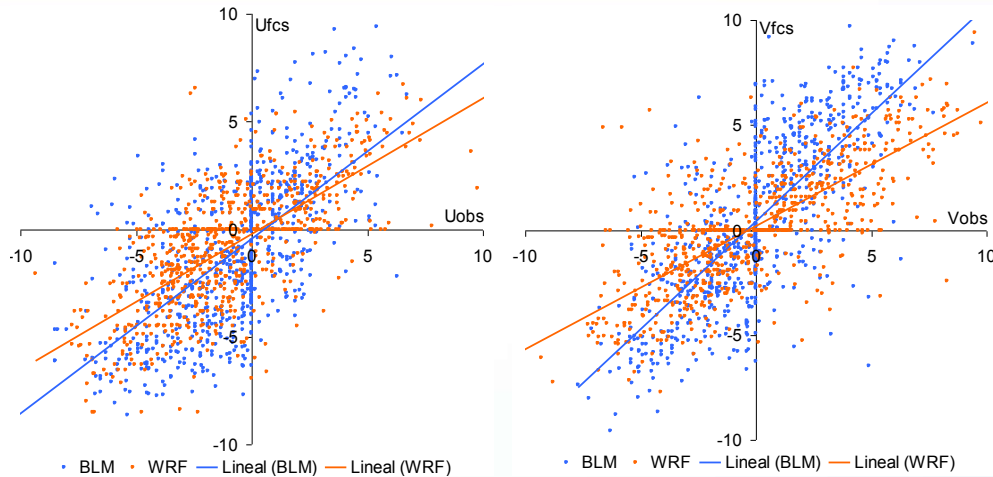


Figure 2. Scatterplot with regression lines of forecast (y -axis) vs. observed (x -axis) wind components (ms^{-1}), at 1500 LST at East Tower (ET). Blue (red) dots and lines correspond to BLM (WRF). The u component is in the left panel and the v component is in the right panel.

The wind direction is recorded by the meteorological towers as a categorical 16-sector wind rose; so that each sector represents a wind direction within an angle of 22.5° . The agreement between observed and forecast wind direction sector, which means no forecast error, implies in fact an uncertainty of 22.5° . The different error measures are calculated for the BLM and WRF wind forecasts using the 3-hourly observations at the three meteorological towers. In all cases, the forecast errors are calculated at the four grid points surrounding each tower location, and the minimum value is adopted as the result.

Results

The analysis of scatterplots of forecast versus observed wind components (average of all observations), show that the slope of the regression lines is, except in one case, smaller than 1.0 (see Table 1), which means that both models underestimate the observations.



Table 1. Slope of scatterplot regression lines of BLM and WRF u and v wind components forecast versus the observations at North Tower (NT), South Tower (ST) and East Tower (ET). The shaded boxes highlight the better performance

slope	u		v	
	BLM	WRF	BLM	WRF
NT	0.75	0.61	0.76	0.66
ST	0.80	0.64	0.66	0.68
ET	0.99	0.86	1.04	0.87

Table 2. Correlation coefficient between BLM and WRF u and v wind components forecast and observations at North Tower (NT) South Tower (ST) and East Tower (ET). The shaded boxes highlight the better performance

correlation coefficient	u		v	
	BLM	WRF	BLM	WRF
NT	0.73	0.70	0.68	0.66
ST	0.69	0.69	0.69	0.70
ET	0.63	0.65	0.68	0.67

However, the slope of the BLM regression lines is closer to 1.0 compared to WRF winds, except the v component at ST although for a small difference. The analysis of the scatterplots is complemented with the correlation coefficient between forecast and observed wind components. Table 2 shows that BLM forecasts are only marginally better than WRF forecasts. The analysis of wind direction forecast is of particular interest, given the significant changes displayed by the wind direction observations across the region (not shown). For the purpose of air quality studies, wind direction forecast errors have a cumulative effect with traveling distance downwind from the source. Fig. 3 shows that the root mean square error $RMSE_{dir}$ of BLM wind direction forecast (averaged over ET, NT and ST) is, at all validation times of the day, smaller than that of WRF.

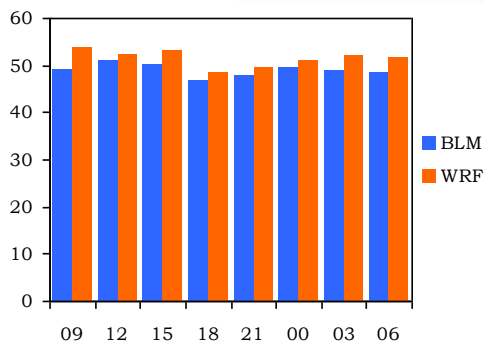


Figure 3. Wind direction $RMSE_{dir}$ (°)

Despite the relatively small differences in favor of BLM, it should be positive for reducing the error in determining the area affected by pollutant plumes when they are away from the source. Fig. 4 shows the percentage of cases in which the wind direction forecast error is greater than 45° , i.e. equivalent to one of the 8-sector wind direction rose, as a function of time of the day. At NT and ST, the BLM wind direction error is smaller than that of WRF, (all times



of the day, while at ET the better performance corresponds to WRF, although for a smaller difference. An interesting aspect is that, in all cases, the errors display almost no dependence on the forecast time. The sites of NT and ST are closer to the river than the ET site, and in particular NT is facing the widest section of the river. The particular formulation of BLM, in which the main forcing at the surface is the land-river temperature contrast, along with its higher horizontal resolution, may explain not only the better performance at those two places, but also the largest difference in the magnitude of the error in favor of BLM at NT. The location of ET is, of the three sites, the most remote one to the river, in the region of the narrowest part of the river whose northern banks may be flooded depending on the water level changes, so that the land-river temperature contrast may not be so well defined.

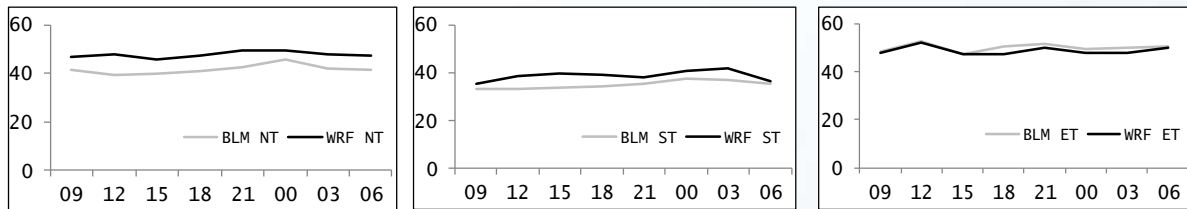


Figure 4. Percentage of cases with wind direction forecast error greater than 45° , as a function of the local standard time. The left panel corresponds to North Tower (NT), center panel to South Tower (ST) and right panel to East Tower (ET).

Conclusions

The initial and boundary conditions of BLM are taken from the WRF forecast outputs so that its errors should propagate and impact somehow the quality of the final forecast. Notwithstanding, BLM is able to overcome this situation and produce a final forecast with smaller error than WRF at NT and ST (but not at ET) at all validation times.

Both models underestimate the observed wind speeds, although the BLM winds have regression line slopes closer to 1.0 compared to WRF winds, except the v component at ST. This means an overall better adjustment of BLM wind components to the observations compared to WRF, although the wind speed of the latter one has less error.

With respect to wind direction forecast, despite the difference in favor of BLM is relatively small, it should have a positive effect in air quality studies by reducing the error in determining the area affected by pollutant plumes as they travel away from the source.

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