Short -Term Wind Forecast for Generation of Electric Power using Wind Turbines in Qollpana, Cochabamba—Bolivia

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1. Context and objective

Driven by the imperative need to reduce risks of anthropogenic climate change the worldwide demand for renewable energy sources as alternative to fossil sources is constantly growing.

Bolivia that is now a fossil-fuel dependent economy, aspires to change its energy matrix significantly by 2025, expanding its renewable energy capacities, which includes wind farms.

Effective renewable energy planning requires a strong meteorological basis because accurate wind power forecasts heavily rely on accurate modeling of atmospheric dynamics, especially boundary layer winds and atmospheric stability.

The present study seeks to contribute to the national wind energy planning focusing on forecasting wind conditions with the mesoscale WRF model for the first wind park in Bolivia implemented in 2009 and located in the region of Qollpana – Cochabamba (CORANI Wind Proyect) (Fig.1).

Figure 1. First phase of Wind Farm of Qollpana - Cochabamba, Win Turbines (1.5 MW nominal power each one).

2. Model configuration, data and bias correction

In order to perform wind forecast (0-72 hours) over the Qollpana's wind farm, a configuration of the Weather Research and Forecasting Model *(*WRF, v. 3.2) with three nested domains at resolutions 9km, 3km and 1km (Fig.2), respectively, is used.

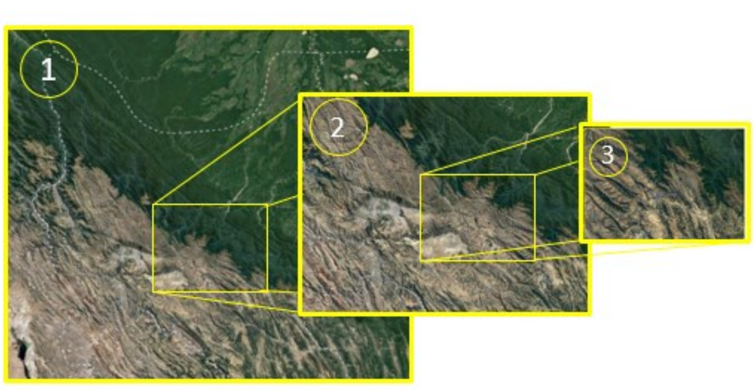


Figure 2. Schematic nesting three domains used in the WRF simulation of WRF, (9,3 and 1 km). (1) Parent Domain—Cochabamba Department of Bolivia, (2) Pocona -Cochabamba municipality, (3) Qollpana—Pocona Region.

The number of vertical sigma levels is 27, with a top at 5000Pa. The initial and lateral boundary conditions were derived from GFS dataset with 0.5 x 0.5°resolution every 6h. The following physical parametrizations were used: *Lin et. al. scheme* for microphysics, *rrtmg scheme* for longwave radiation, *Dudhia scheme* for shortwave radiation, *Grell 3D ensemble scheme* for cumulus, *MM5 Monin-Obukhov scheme* for surface layer and *thermal diffusion scheme* for land surface.

5 sensitivity experiments were carried out in order to choose the *PBL* parametrization. The validation against the observations from the meteorological stations installed at the wind turbines at 80m at 17.6294°S y 65.2841°W over July 2012 – June 2013 showed that the *YSU scheme* produced more realistic wind speed, relative humidity and temperature among the 5 tested PBL schemes.

A statistical bias correction was applied in order to improve the mean and standard deviation of the simulated diurnal cycle of wind speed, Relative Humidity and temperature (Fig.3)

$$x^{corr}_{clt(i,j)} = \bar{x}_{obs(i)} + \left(x_{ctl(i,j)} - \bar{x}_{ctl(i)}\right)\frac{\sigma_{obs(i)}}{\sigma_{clt(i)}}, \qquad i = 1:24 \quad hour \qquad j = 1:365 \quad day \qquad \text{(Eq. 1)}$$

Where x are the value of meteorological variable (wind speed, Relative Humidity and Temperature), subscripts obs corresponds to the observation values, ctl subscript corresponds to the WRF simulation outputs and the super superscript $corr$ corresponds to the bias corrected value, i are hours of diurnal cycle and j are days of year.

(a) (b) (c)

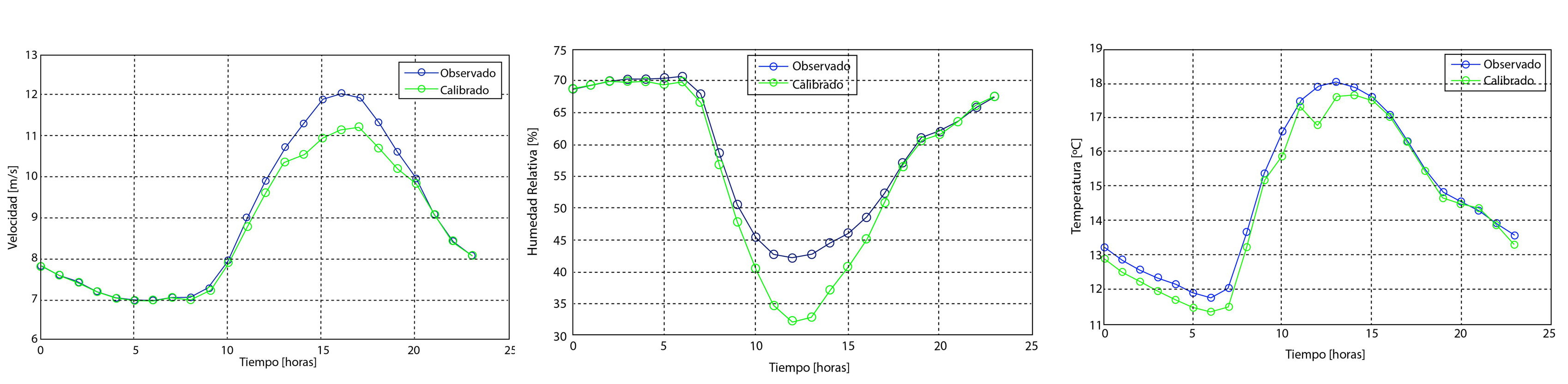


Figure 3. Mean diurnal cycle of (a) wind speed (m/s), (b) relative humidity (%) and (c) temperature (ºC) at 80 m above surface level, at the wind turbine location over the validation period (July 2012- June 2013): WRF simulation with bias correction (green) and observations from the meteorological station (blue).

3. Results: forecast of the meteorological fields

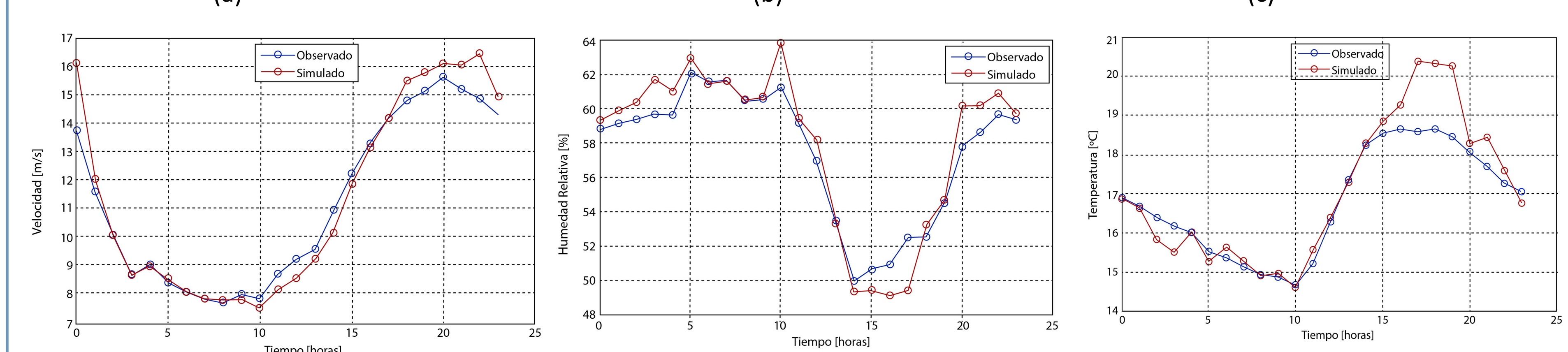
The WRF model was then applied to perform the forecast of the wind, relative humidity and temperature at the wind turbine location for 16-19 October 2015. The bias correction was done respective to the bias-corrected control simulation (cf. Eq.1) as follows:

$$x^{corr}_{for(i,j)} = \bar{x}^{corr}_{ctl(i)} + \left(x_{for(i,j)} - \bar{x}_{for(i)}\right)\frac{\sigma_{ctl(i)}}{\sigma_{for(i)}}, \qquad i = 1:24 \quad hour \qquad j = 1:3 \quad day \qquad \text{(Eq.2)}$$

Where the subscript for corresponds to forecast period value, i is the hour of day and j corresponds to the day from 16 to 18 October 2015.

3.1. Diurnal cycle

(a) (b) (c)



Statistic	Value
Mean BIAS	0.190
RMSE	0.723
R (Correlation)	0.944

Statistic	Value
Mean BIAS	0.269
RMSE	0.696
R (Correlation)	0.917

Statistic	Value
Mean BIAS	0.418
RMSE	1.298
R (Correlation)	0.936

Figure 4. Mean diurnal cycle of (a) wind speed (m/s), (b) relative humidity (%) and (c) temperature (ºC) at the wind turbine location (17.6294°S y 65.2841°W, 80 m above surface level) over the forecast period (16-18 October 2015) : bias-corrected WRF forecast (red) and observations from the meteorological station (blue). The corresponding validation statistics are indicated below each plot.

3.2. Time series 72 — h

(a) (b) (c)

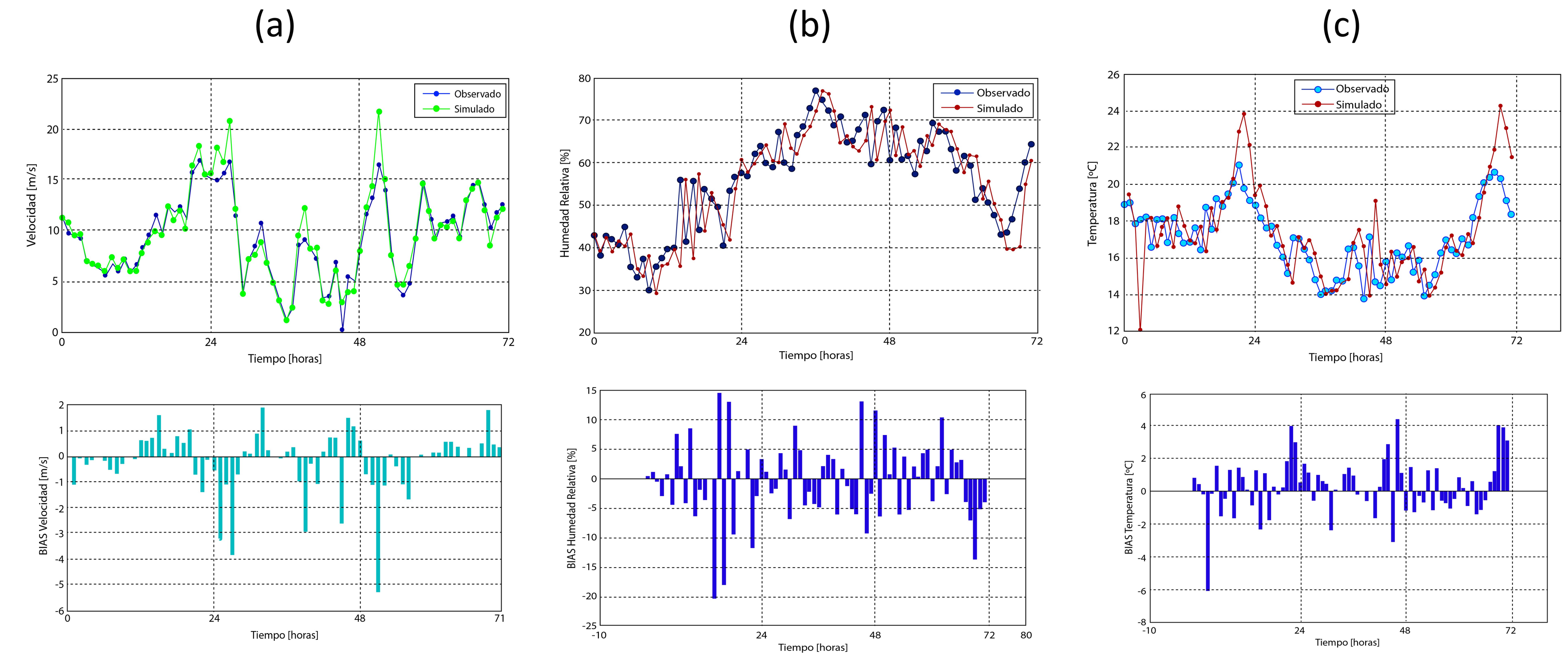


Figure 5. *Upper panel*: Hourly evolution of (a) wind speed (m/s), (b) relative humidity (%) and (c) temperature (ºC) at wind turbine location (17.6294°S y 65.2841°W, 80 m above surface level) over the forecast period (16-18 October 2015) : bias-corrected WRF forecast (green and red) and registered values at the meteorological station (blue). *Lower panel*: Hourly evolution of the corresponding forecast errors.

4. Wind Energy Production

The bias-corrected 72-h WRF forecast of the meteorological fields (cf. Section 3) was used to estimate the energy efficiency based on the characteristics of the installed wind turbine.

The wind turbine power production is a function of velocity. The efficiency C_p (dimensionless) is measured as the ratio of nominal power produced by the real power produced as follow:

$$C_P = \frac{P_{nominal}}{P_{air} A_{swept}}$$

Where C_p is the coefficient of power (dimensionless), $P_{nominal}$ is the nominal power of wind turbine (kw), Pair is the potential power of air (kW/m^2) and A_{swept} is the swept area by the wind turbine blades (m^2).

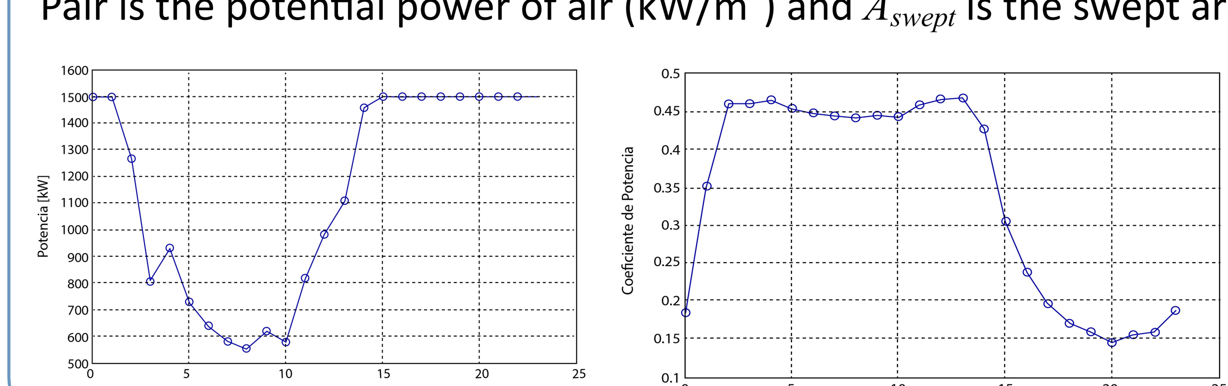


Figure 5. *Left*: Wind energy production ($P_{nominal}$, kW) over the forecast period calculated for the wind turbine power curve model GW77/1500 with maximum nominal power 1.5 MW. *Right:* Corresponding efficiency of wind energy production C_p as coefficient of power (dimensionless unit).

5. Conclusions

In this study wind power forecasting system based on bias-corrected WRF meteorological fields at 80m was implemented for Qollpana's wind farm. The results show that the WRF model is able to provide low-level wind speed 72h forecasts for the study area with reliability to some extent. A simple statistical bias correction further improves the reliability of the forecast in term of representation of the mean wind speed diurnal cycle. Validations of the wind speed output carried out against the observations for the Qollpana's wind farm suggest that the proposed forecasting system can be an effective and practical tool for short-term predictions of wind power. The proposed system can be also potentially used to evaluate the impact of future climate changes on the wind energy production in this particular site based on CORDEX – South America products.