Summary
A primitive equation, dry and hydrostatic mesoscale boundary layer model (BLM) is used to simulate the high-resolution low-level wind field climatology over the La Plata River region in South America. The horizontal model domain (350 km x 316 km) has 79x58 points, with a horizontal resolution of 0.05 degrees; and the vertical domain (2 km) has 12 levels.

The model climatology is the ensemble result of a series of daily forecasts obtained by forcing the model with limited local observations. Each ensemble member produces a daily forecast that participates in the definition of the wind climatology with a probability calculated with the local observations. The upper boundary condition is taken from the local radiosonde observation at Ezeiza airport, and the lower boundary condition consists of a surface heating function calculated with the temperature observations of the surface weather stations in the region.

The study conducted during the period 1960-1990 reveals an overall good agreement between the observed and the modeled surface wind climatology at five weather stations of the region. The BLM model represents very well the differences in the wind speed magnitudes and predominant wind direction sectors throughout a region that displays a strong sea-land breeze daily cycle. The average rms value of the model relative error is 31% for wind direction and 23% for wind speed.

Low-level climatological wind fields with the BLM model
- the low-level wind climatology is the result of a 192-member ensemble (16 wind directions and 12 wind speeds at the upper boundary)
- each member has a probability of occurrence $P_{ij}$ (16 - $\theta$ - wind direction sectors, 12 - $v$ - wind speed classes), which is determined from the 1960-1990 observations
- the upper boundary condition (2 km above the surface), is taken from the 1200 UTC (0900 local time) radiosonde observations
- the lower boundary condition (surface) is a land-river differential heating function defined from the meteorological observations of the region, interpolating 4 daily observations
- each member is a 24-hour forecast, initialized at 0900 local time
- at each grid point, the mean wind direction frequency distribution and mean wind speed by wind sector are calculated by applying the probability matrix $P_{ij}$

Model equations
\[
\begin{align*}
\frac{\partial \theta}{\partial t} + \frac{\partial}{\partial x}(\theta u) + \frac{\partial}{\partial y}(\theta v) &= \frac{\partial}{\partial z} \left( \frac{\partial \theta}{\partial z} + \frac{g}{\rho} \frac{\partial \rho}{\partial z} \right) \\
\frac{\partial u}{\partial t} + \frac{\partial}{\partial x}(u^2) + \frac{\partial}{\partial y}(uv) &= \frac{\partial}{\partial z} \left( \frac{\partial u}{\partial z} + \frac{\partial \rho}{\partial z} \right) \\
\frac{\partial v}{\partial t} + \frac{\partial}{\partial x}(uv) + \frac{\partial}{\partial y}(v^2) &= \frac{\partial}{\partial z} \left( \frac{\partial v}{\partial z} + \frac{\partial \rho}{\partial z} \right) \\
\frac{\partial p}{\partial t} + \frac{\partial}{\partial x}(pu) + \frac{\partial}{\partial y}(pv) &= \frac{\partial}{\partial z} \left( \frac{\partial p}{\partial z} + \rho \frac{\partial \rho}{\partial z} \right) \\
p &= \rho = \rho_0 \quad \theta = \theta_0 \\
p = p_x + p_y \\
\theta = \theta_x + \theta_y
\end{align*}
\]

Mean wind direction frequency

Mean wind speed by wind sector
Model errors

The model errors are calculated as the root mean square value of the relative error in wind direction frequency \( rmsDir \), and mean wind speed per wind sector \( rmsVel \). Both are weighted by the mean observed wind direction frequency.

\[
\begin{align*}
fo &= \text{observed wind direction frequency} \\
fv &= \text{calculated wind direction frequency} \\
e_{o} &= \frac{(fo - fv)}{fo} \text{ relative error in wind direction} \\
e_{v} &= \frac{(fv - fo)}{fo} \text{ relative error in wind speed} \\
rmsDir &= \sqrt{\frac{\sum (e_{o})^2}{\sum fo^2}} \text{ m/s wind direction} \\
rmsVel &= \sqrt{\frac{\sum (e_{v})^2}{\sum fv^2}} \text{ m/s wind speed}
\end{align*}
\]

Comparison of model errors obtained with two different methods

- the simplified method calculates the wind climatology as the mean value of the 192-member ensemble
- the daily method calculates the wind climatology by simply averaging 3248 daily forecasts during the same 1960-1990 period

Climate variability study with the BLM model

The variability of the climatological low-level wind fields during the period 1960-1990 is studied, using the BLM model and the observations from five weather stations.

The observations reveal:
- decrease of the daily amplitude of the land-river surface thermal contrast
- increase of the easterly wind component in the lower levels of the local radiosonde observations, accompanied by a decrease of the mean wind speeds.
- The ensemble method is applied to two subperiods, i.e., 1967-1976 and 1982-1991, in order to calculate wind direction frequency distribution and mean wind speed by sector, with the BLM model

The difference between the climatological wind fields of the two periods is expressed in percentage, and compared to that observed at the five weather stations.

Conclusions

The ensemble method is an appropriate methodology for determining high-resolution, low-level climatological wind fields

This conclusion is based on the fact that the results obtained with the ensemble method are not outperformed by those of the daily method (traditional way of calculating climatology using all available information).

The BLM model is particularly useful for calculating wind fields over regions with strong diurnal cycle of surface thermal contrast.

The proposed methodology is of particular utility for synthesizing wind fields over regions with limited meteorological observations, since the 192-member matrix can be reasonably defined with few observing points, and even in the case of incomplete records.

References


Sraibman, L. and G.J. Barri, 2009, Low-level wind forecast over La Plata River region with a mesoscale boundary layer model forced by regional operational forecasts, Boundary Layer Meteorology, 136, 3, 407-422.

Acknowledgement

This research has received support from grant PICT2008-1417 from the National Agency for the Promotion of Science and Technology (ANPCyT) of Argentina.