FORECASTING ZONDA WIND OCCURRENCE WITH ERA5 REANALYSIS

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1. INTRODUCCIÓN

The Foehn winds is a strong, warm, and very dry wind associated with adiabatic compression upon descending over the eastern slopes of mountain range. Its spatial extension, intensity, frequency, and effects depend strongly on the topographic characteristics and the regional atmospheric circulation. The synoptic conditions leading to these, sometimes severe, downslope winds commonly vary between mountain ranges in different parts of the world. However, there are some common conditions favoring foehn winds: A cross-barrier pressure gradient, either caused by different air masses or by the dynamic pressure of the incoming flow; crest-level flow with a wind component perpendicular to the crest and a stable stratification of the air masses upstream. Due to their meridional extent and height, the Andes significantly influence the atmospheric circulation (Garreaud, 2009). Zonda is a foehn-like wind that has received much attention in lasts decades. It is characterized by strong, warm and very dry descending air along the eastern slopes of the Andes Mountains in western-central Argentina, with more frequent occurrences during winter and spring seasons (Norte, 2015). The prediction of foehn for a special region with a high temporal and spatial resolution presents an interesting and important challenge in mountainous regions around the globe. The application of statistical techniques, such as the study of Empirical Orthogonal Functions (EOF) or the PCA, allow the objective statistical characterization of vector and scalar variables or other physical variables, like temperature, humidity, wind and stability. In the present work, the PCA is applied to the ERA5 reanalysis data in order to discriminate between Zonda and non-Zonda events using the synoptic fingerprint. Also, a coupled model using reanalysis data and vertical sounding on both sides of the Andes is performed, a new prediction model for Zonda occurrence is found.

2. DATA AND METHODOLOGY

For this study, the ERA5 reanalysis data is used (Hersbach, H. et al., 2020). This dataset is the fifth generation of ECMWF global atmospheric reanalysis. The variables and levels considered are the geopotential height (HGT), the zonal (U) and meridional (V) components of the wind at 1000 hPa, 925 hPa, 850 hPa, 700 hPa, 500 hPa and 400 hPa levels. All reanalysis data are taken at 1200 UTC.

Available daily sounding data at 12 UTC for the 1981-2019 period are taken for both sides of the Andes Mountains (Figure 1, red dots). On the Chilean side (Andes windward) the Santo Domingo surface station (33.65°S; 71.61°W, 75 m.a.s.l) and for the Argentinean side (Andes leeside) the Mendoza Airport surface station (32.83° S, 68.77° W, 704 m.a.s.l.) (Figure 1). The selected variables are; Temperature (*T*), Dewpoint Temperature (*Td*) and the zonal (*U*) and meridional (*V*) wind components. The methodology for the PCA follows that used in Otero et al. (2021). The Zonda/non-Zonda probability index is obtained from a logistic regression between the PCA loading components and a vector of 1 and 0, associated with Zonda/non-Zonda respectively. To detect the patterns capable of discriminating between Zonda and non-Zonda cases, they are compared with random non-Zonda conditions. The probability model (index) is built with the fit coefficients of a logistic regression for a binomial function. So, the logistic regression is transformed into a probability value between 0 and 1.

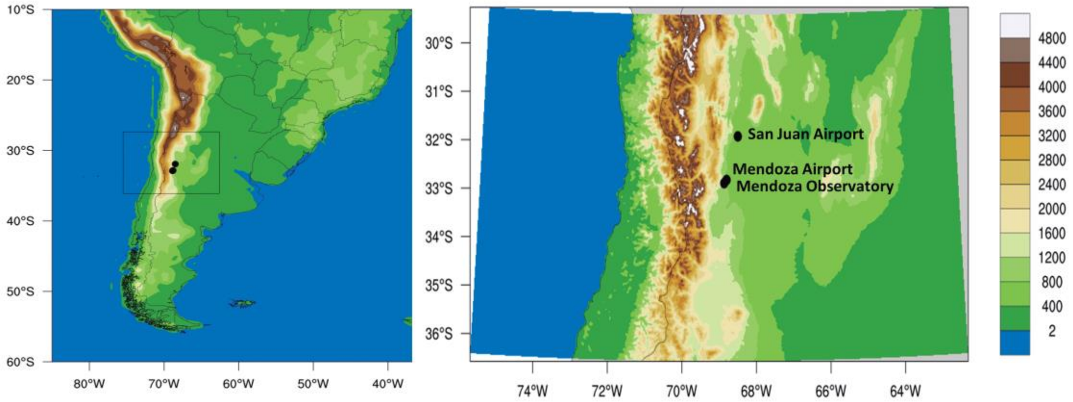

Figure 1. South America region with topographic height (shading) and zoomed-in region over surface weather stations. Black dots and white line correspond to sounding stations and filled black dots correspond to the stations used for Zonda wind classification.

3. RESULTS

The PCA analysis is used to discriminate between the synoptic structure of the atmosphere for a Zonda wind event (and those that are not) and to define a probability index for Zonda occurrence (probabilistic predictive model). Half of these dates correspond to Zonda wind events and the other half to random dates, where the presence of Zonda is not recorded (see their selection in methodologies).

Figure 2 shows the index distribution for Zonda (blue) and for non-Zonda (red) classes using the geopotential height for all considered levels. For example, for the 1000 hPa model, if an index cut-off value of 0.5 is chosen, the number of hits for Zonda events is 94.83%, while the non-Zonda events hits represent 91.37%, and the total efficiency is above 93%. The total efficiency reveals for this particular model, that the best cut-off point is located at 0.68, giving a total efficiency of 95.68% (93.1% hits of Zonda events and 98.27% for non-Zonda).

The discriminant fields between Zonda and non-Zonda classes obtained from the PCA are shown in Figure 3. At low levels, the HGT discriminant field present a center of negative anomalies between 35°S – 40°S over the Pacific. This center extends to the east over the Argentinian Patagonia and to the north near the mountain leeside. At mid and high levels, the center is located further west to the respective low-levels indicating the baroclinicity of the system.

The combination of different variables and levels does not lead to a net increase in the total efficiency for all models presented here. However, produces very similar values using fewer eigenvalues required for the discrimination between Zonda and non-Zonda events. It is in this sense that the combination of variables and levels, without losing a lot of efficiency, can contribute to a greater amount of information to the structure of the atmosphere for the discrimination of Zonda events. It is observed that, in general, the highest efficiency is produced for the combination of variables at mid and low-levels particularly. A notable feature is the presence of the variable V in all those best models. Following this idea, different variables and levels from reanalysis data are put together in a unique model by adding the vertical sounding data on both sides of the Andes at the same moment (both at 12 UTC). It is shown that the efficiency of these new models results as great as those obtained for the single or combined variables/levels models showed previously. Regarding the total efficiency, the best

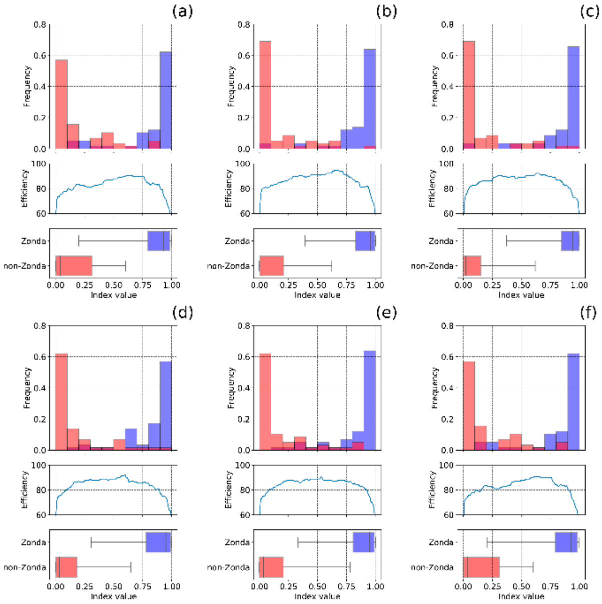

Figure 2. Model for geopotential height for all pressure levels. Index values distribution for Zonda (blue) and for non-Zonda (red) events, model efficiency according to each cut-off value and index boxplot, whiskers are [3%-97%].

models contain two reanalysis fields and one, two or three vertical sounding variables. This leeside discriminant sounding represents an unstable sounding, especially at mid-levels due to strong heating at low levels and cooling in the upper-levels.

CONCLUSION AND DISCUSSION

Throughout this work it was demonstrated that an accurate discrimination of Zonda events is possible by using reanalysis data as well as vertical sounding data. Using these models, a Zonda wind forecast with high efficiency values was possible, representing a useful tool when it comes to operational forecasting of this type of wind. The synoptic fingerprint is a fundamental tool for the general understanding of these events, which are also strongly related to the vertical structure of the atmosphere.

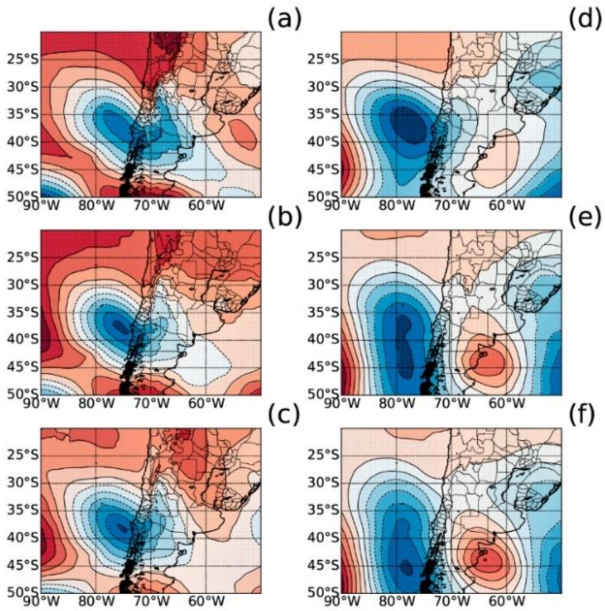

Figure 4. Geopotential height discriminant fields for 1 variable/level models. (a) to (f) Only the significant components are retained for 1000 hPa, 925 hPa, 850 hPa, 700 hPa, 500 hPa and 400 hPa.

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