

DYNAMICS OF WAVE PROPAGATION LEADING TO FROST IN THE EXTRATROPICAL LATITUDE VERSUS TROPICAL LATITUDE

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1. INTRODUCTION

This work presents a new vision on the extreme cold events which affect South America considering the dynamics of wave train propagation which rule the systems causing such events. Through the composites analysis of extreme cold events which affected tropical and extratropical latitudes of South America, the differences in the propagation patterns which drive the atmospheric circulation were investigated.

2. DATA AND METHODOLOGY

The daily extreme minimum temperatures from the meteorological station located in a green area in the southern part of Sao Paulo city, are used as representative of tropical latitudes. The cold outbreaks are divided according to the intensity of the minimum temperatures and the occurrence of frost for May to September of the 1950-2000 period following Pezza and Ambrizzi (2005, PA2005). The events are classified into extreme ($T < 0^{\circ}\text{C}$, all cases with frost) and strong ($0 \leq T \leq 2.5^{\circ}\text{C}$). At extratropical latitudes, however, where frosts are frequent mainly during winter months, a criteria based on the intensity of frost would not be representative of cold outbreaks. Therefore, at these latitudes the spatial criteria previously defined by Müller et al. (2000), where each frost day in the period 1961-1990 is identified as an isolated, partial or generalized frost according to the number of meteorological stations with $T < 0^{\circ}\text{C}$ is used. The meteorological stations selected are situated in central-east Argentina, known as Wet Pampa. In particular, generalized frosts (GF) are defined as those where the area with temperatures below or equal to 0°C surpasses 75% of the meteorological stations in the region. In this study GF are taken to represent cold outbreaks in extratropical latitudes, but only those events which took place during years of maximum frequency of GF occurrence are considered. They were selected following the criteria defined by Müller et al. (2005), who selected those periods where the number of frosts is one standard deviation unit below and above the mean value for the period 1961-1990. This criterion is applied to the months between May and September, considering those years above the mean, i.e., years of maximum frequency of occurrence of GF in the Wet Pampa.

A composite analysis of the frost events in tropical (Table I, PA 2005) and extratropical latitudes (Table II, Müller et al., 2005) to study the wave train propagation during the days previous to frigem and GF, respectively, is done using the NCEP reanalysis.

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3. RESULTS

3.1) Tropical latitude events

The composites of the São Paulo frost extremes presented in Table I (PA2005) is depicted in Fig.1 which shows the 250hPa meridional wind field anomalies. From this figure one can see a single wave propagation pattern with significant anomaly values. This configuration is very similar to the cases of less persistent GF events in the Wet Pampa obtained by Müller and Berri (2007) and resembles typical Rossby wave train propagation pattern for cold air irruptions widely studied as shown in the literature.

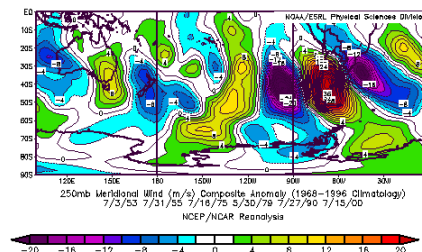


Fig.1: Meridional wind composites anomaly (ms^{-1}) for day -2 at 250 hPa, corresponding to extreme frost events.

Fig.2 depicts the same anomaly field as Fig.1, but for the events defined as strong frost (Table I, PA2005). At first glance it could be said that the propagation pattern is similar to the previous case but with smaller anomaly values. However interesting differences can be pointed out starting in day -5 (not shown) and which will determine the generation of the extreme events in the tropics on day 0. Two negative meridional wind anomalies located southeast and northeast of the continent respectively, only appear in strong frost events. These anomalies become one, strengthened in the following days and together with the other positive anomaly to the west of the former one, generate the event on day 0.

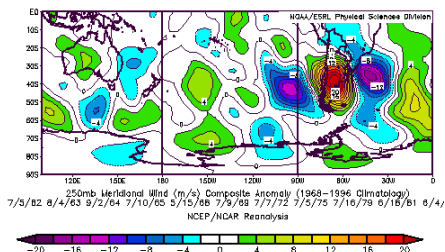


Fig.2: Meridional wind composites anomaly (ms^{-1}) for day -2 at 250 hPa, corresponding to extreme frost events.

For strong frost composites (Fig.2), a wave train propagates following the subtropical jet and joins a second less intense wave train which propagates along the polar jet in the western Atlantic. They have a zonal propagation and on the lee side of the Andes they merge into a wave and due to its meridional orientation will favor polar air advection affecting the

oriental coast of South America. These conditions contribute to cooling the air and the later entrance of the anticyclone from the west-southwest, driven by the observed wave train, enhances radiative loss, temperature descent and the observed frosts.

3.2) Extratropical Latitude Events

The composites of meridional wind anomalies in Fig.3, show a double Rossby wave train that driven by the zonal flow it reaches the continent in subtropical latitudes, and at polar latitudes it only gets close to it. The waves propagate independently along both jets and merge in a single perturbation extending meridionally, previously to the GF events. The anomaly circulation pattern produced contributes to the advection of polar air over the continent. This pattern is similar to that observed prior to the most frequent winter events (JJA) (Müller et al., 2005) and the most persistent ones (Müller and Berri, 2007). In other words, the most frequent events and those of greatest persistence during winter are caused by a propagation wave pattern which does not follow the classical behaviour of Rossby wave trains of a single train, rather they are generated by a double wave train which coincides in phase before its entrance into the continent prior to the event. These results were confirmed through numerical experiments and linear wave theory done by Müller and Ambrizzi (2007).

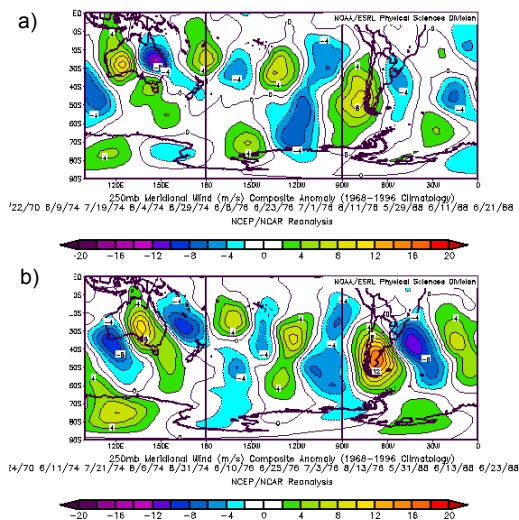


Fig.3: Meridional wind composites anomaly (ms^{-1}) from day 0 (a) to day 1 (b) at 250 hPa, corresponding to GF events.

4. CONCLUSIONS

There are two types of wave propagation which define the extreme cold events in South America and drive synoptic systems at low levels. At extratropical latitudes a double wave train is observed which propagates along the subtropical and subpolar jets in the south Pacific and prior to a GF event in the Wet Pampa, show phase coincide to the west of the continent causing an extended and intense advection of polar air over the whole south cone. For the frost extreme at tropical latitudes the events are associated with a single wave pattern with propagation starting in the Pacific Ocean and extending towards South America forming an arc-like trajectory which ends in the Atlantic Ocean. This is the classical trajectory to

which the most intense events reaching these latitudes follow and which has largely been documented. However, this is not the only type of propagation which can lead to frosts. Sometimes strong frost events are associated to a subtropical wave pattern which propagates along the Pacific Ocean with it merges with another wave train coming from polar latitudes in the western Atlantic, and eventually it continues to the east in a zonal propagation.

The differences in the wave propagation patterns between the tropical and extratropical cases analysed here may explain the observed intensity of them. Strong frost is associated to zonal patterns which rapidly move the low level anticyclone from the southwest of the continent to tropical latitudes. This anticyclone is strengthened together with the meridionally extended cyclone located upstream. This configuration causes southerly wind advection over all the central-southeast Brazil, and consequently the observed temperature decrease at tropical latitudes. This system is less intense than in the case of extreme frosts, which is consistent with the results presented by PA2005 showing that wind at low levels of the atmosphere for the strong frost cases is half the intensity over the continent than that to the composites of extreme frost.

In summary, the results suggest that the phase coincide of the waves propagating along the subtropical and polar jets is an important prior condition to favour extreme events. If this coincidence is observed in the southeast Pacific it will contribute to generate GF events at extratropical latitudes and it will not affect tropical latitudes given the zonal propagation of the wave train. However, if the phase coincidence takes place in the southwest Atlantic, strong frost will occur at tropical latitudes, with no impacts on extratropical latitudes. Instead, extreme frost needs air irruptions which usually follow continental tracks and they are related to a single wave train.

5. Acknowledgements

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6. References

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