# LINEAR AND NONLINEAR ASPECTS PRECURSORS OF THE OCCURRENCE OF GENERALIZED FROSTS IN THE PAMPA HUMEDA REGION

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## ABSTRACT

Frosts are extreme weather events that affect, directly and significantly, human and economic activities, causing impacts and losses in many sectors. The frosts in central-northwest Argentina, a region called Pampa Húmeda, need to be considered because the impacts in this region affects a great number of inhabitants and cause a big impacts in many type of production. This study proposed to identify the Generalized Frost events in the Pampa Húmeda region between 1980 and 2016, after this it will be studied the linear and non-linear interactions (tropics-extratropics, wave-topography and wave-wave) on Rossby waves that are propagated in the Southern Hemisphere and that make synoptic disturbances that cause Generalized Frost in the Pampa Húmeda. The dynamics mechanisms precursors of these events will be analyzed, seeing linear aspects related to the atmospheric circulation and the synoptic characteristics associated with Generalized Frost. This results will be compared with those obtained previously for another period (1961-1990). On the other hand, the nonlinear interactions (wave-basic state, wave-wave and wave-topography) will be analyzed before and during each Generalized Frost event, in order to determine if these mechanisms can be used as precursors. It will be evaluated if the intervening processes can explain the progress / stagnation and / or persistence of the Generalized Frost events in Pampa Húmeda and also it will be analyzed how these non-linear interactions behave in a basic state during warmed state due to global climate changes.

## Background

**Pampa Húmeda:** an extensive region of Southeastern South America of great economic importance for Argentina that are affected by frosts.

**Frost:** a day of frost is defined when the minimum temperature is less than or equal to 0º C and **Generalized Frost (GF)** is a very severe weather condition in which at least 75% of the meteorological station report frost.(Müller et al, 2000).

**Persistence:** Defined as the number of consecutive days that follow the first day of the event and comply with the GF condition. (Müller e Berri, 2007),

**Frequency:** are selected for those winters (June, July, August) in which the number of GF is either one standard deviation (r) below or above the mean value of the period of the study Muller et al (2005).

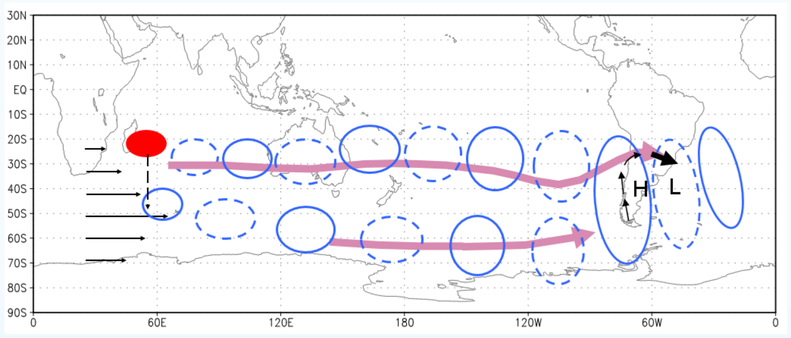


Figure 1: Conceptual diagram on the physical mechanisms that may favor high frequency occurrence of GF over PH.

In order to associate the GF with the Rossby Wave dispersion, the baroclinic vorticity equation (Lau and Lau, 1992;Vera and Vigliarolo,2000) is analysed. The formulation employed made use of the scale splitting i.e. mean basic state and perturbation. Such that the equation reads:

VT = Time rate of the change of perturbation vorticity

VAe = advection of mean absolute vorticity by transient fluctuations

VDe = the stretching effect by the mean absolute vorticity and the divergence of pertubation flow

VDt = the stretching effect by the perturbation vorticity and the perturbation divergence

Includes contributions from all processes not written in the equation

$$\frac{\partial \zeta'}{\partial t} = -\bar{v}\cdot\nabla\zeta' - v'\cdot\nabla(\bar{\zeta}+f) - v'\cdot\nabla\zeta' - (\bar{\zeta}+f)\nabla\cdot v' - \zeta'\nabla\cdot\bar{v} - \zeta'\nabla\cdot v' - \left(\boldsymbol{k}\cdot\nabla\omega\times\frac{\partial v}{\partial p}\right) + VR$$

VAm = advection of the perturbation vorticity by the mean flow

VAt = the fluctuating part of the nonlinear advection of pertubation vorticity by transient fluctuations

VDm = the stretching effect by the perturbation vorticity and the divergence of the mean flow

VC = the net vorticity tendency associated with tilting effects

## The very strong 1988 GF case

The configuration of the weather system (cyclone/anticyclone pairs) favors a persistent anomalous cool air over the PH region (see Figure 1). Although not shown in the figure this case is Persistence 7 (i.e. 8 days under GF conditions). Some weakening in GF conditions are noted at lags +4 and +5.

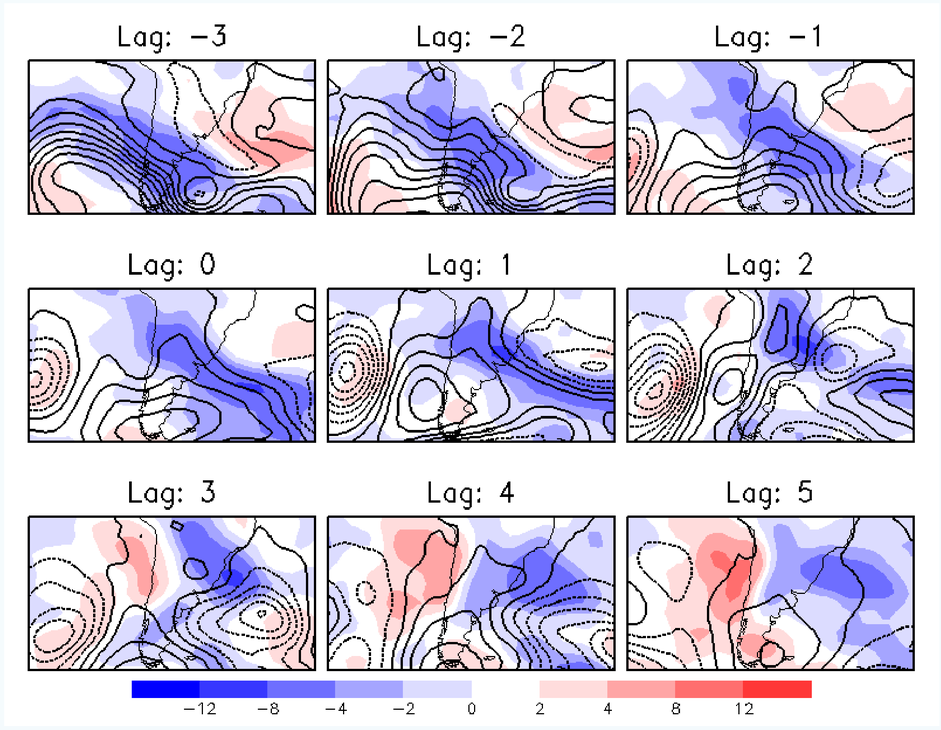


Figure 2: Geopotencial height perturbations (contour) and temperature pertubations (shaded) at 850 hPa. Contour interval is 20 m.

The perturbation-vorticity equation used contains scale separation between mean ($\bar{V},\zeta$) and perturbations ($V',\zeta'$). By definition, this kind of scale separation requieres a relationship between their magnitudes:

$$\mathcal{O}[\bar{V}] \gg \mathcal{O}[V'] \quad (1a)$$
$$\mathcal{O}[\bar{\zeta}] \gg \mathcal{O}[\zeta'] \quad (1b)$$

Resulting that:

$$\bar{V}^2 \gg \bar{V}V' \gg V'V' \quad (2a)$$
$$\bar{\zeta}^2 \gg \bar{\zeta}\zeta' \gg \zeta'\zeta' \quad (2b)$$

Thus, in the perturbation vorticity equation, terms like $-V'\cdot\nabla(\bar{\zeta}+f)$and $-\bar{V}\cdot\nabla\zeta'$should be larger than terms like $-(V'\cdot\nabla\zeta')'$.. The above mentioned terms are advective terms, that relates different forms of scale interactions, however the only one relating product of perturbations is that related to perturbation-vorticity tendency due to perturbation interactions, i.e. $-(V'\cdot\nabla\zeta')'$ .

Figure 3 displays time series of Tmin and of the vorticity equations term.

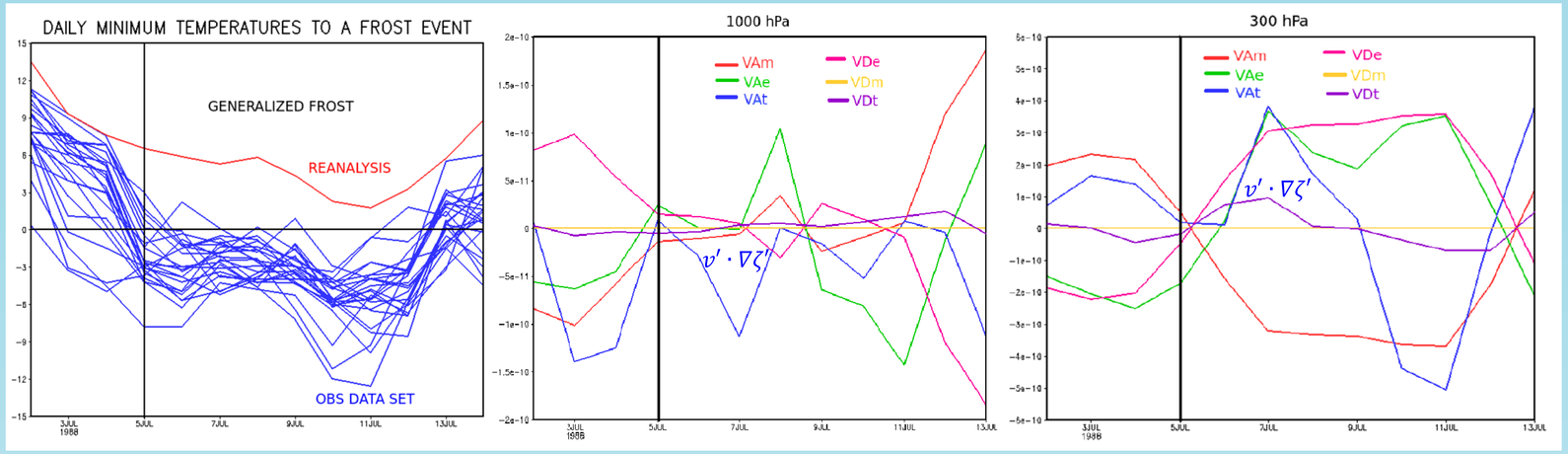


Figure 3: Observed daily minimum temperatures and vorticity equations terms to the very persistent 1988 GF event

**Bibliography**

1. Lau, Kai-Hon, and Ngar-Cheung Lau. "The energetics and propagation dynamics of tropical summertime synoptic-scale disturbances." Monthly weather review 120.11 (1992): 2523-2539.
2. Müller, Gabriela V., Mario N. Nunez, and Marcelo E. Seluchi. "Relationship between ENSO cycles and frost events within the Pampa Humeda region." *International journal of climatology* 20.13 (2000): 1619-1637.
3. Müller, Gabriela V., and Guillermo J. Berri. "Atmospheric circulation associated with persistent generalized frosts in central-southern South America." *Monthly weather review* 135.4 (2007): 1268-1289.
4. Müller, G. V., T. Ambrizzi, and M. N. Núñez. "Mean atmospheric circulation leading to generalized frosts in central southern South America." *Theoretical and Applied climatology*82.1 (2005): 95-112.
5. Vera, Carolina S., and Paula K. Vigliarolo. "A diagnostic study of cold-air outbreaks over South America." Monthly Weather Review 128.1 (2000): 3-24.