

1. Introduction

Southeastern South America is one of the major agricultural production regions worldwide. Particularly in Uruguay, in the last 15 years it has seen a significant increase in the area of agricultural production and forestry, considering that frost events are responsible for huge economic losses. Nevertheless, there are few studies about this kind of events. Frosts in Uruguay during winter season are frequent from climatic point of view.

2. Objectives

This study seeks to understand the general aspects about the frost climate in Uruguay and answer some questions like:

- Which is the link between minimum temperatures trends and frost trends?
- Do changes exist in the period of occurrence and distribution of frost?
- Does the intensity and persistence of frost change?
- Are there regions where the occurrence of frosts is spatially homogeneous?

4. Methodology and Results

a) Trends

Observed trends were calculated using the non-parametric Sen method [1] and the statistical significance was assessed at the 5% level.

	# FD year	Tn apr-oct	Tn apr	Tn mar	Tn jun	Tn jul	Tn aug	Tn sep	Tn oct
Artigas	+		+						+
Carrasco		+	+				+		+
Estanzuela			+						
Melo		+	+	+			+		
Mercedes	+								
P. de los Toros			+						+
Paysandú	-	+	+				+		+
Prado		+	+	+			+	+	+
Rivera		+	+		+	+	+	+	+
Rocha	-	+	+						

The color shows the temperature: Red (decrease) and Blue (increase). The long term trend analysis doesn't show a clear spatial behavior.

Only 2 stations show a negative trend and 2 a positive.

c) Intensity and persistence

Fig. 4 (Paysandú) shows the distribution of frost on a daily scale and summarizes the intensity and persistence. Regarding the frost intensity, we analysed the consecutive frost days (CFD) index (fig.5). To study the frost intensity, we discriminated by temperature thresholds: [0, -1], [-1, -2] and below -2°C. Finally, we calculated the thresholds percentage per month and per decade, for each range (fig. 6).

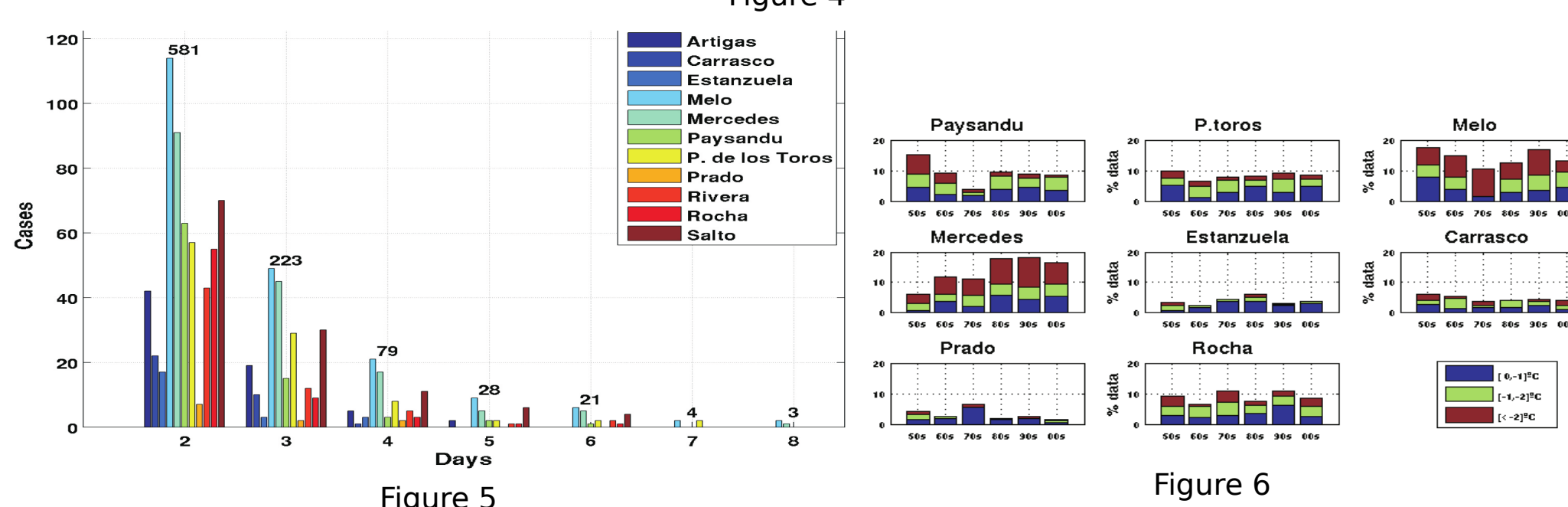
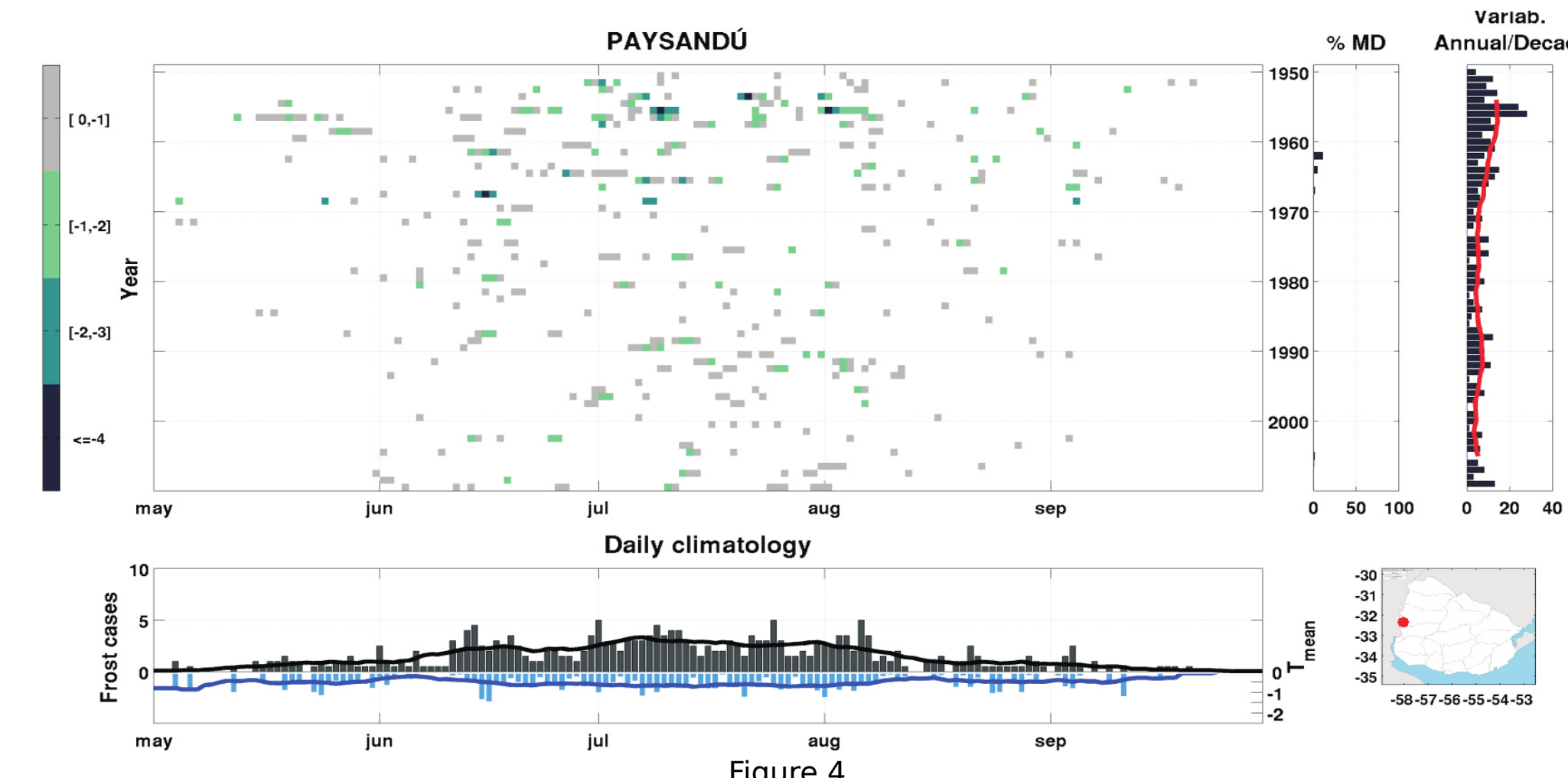


Figure 6

Considering the intensity, no changes were detected in the persistence, but some stations presents more events with T below -2°C during the last decade.

3. Data and Definitions

We used a high quality daily minimum temperature (Tn) database from 11 meteorological stations in Uruguay, covering the period 1950-2009. Figure 1 shows the location of the analyzed stations.

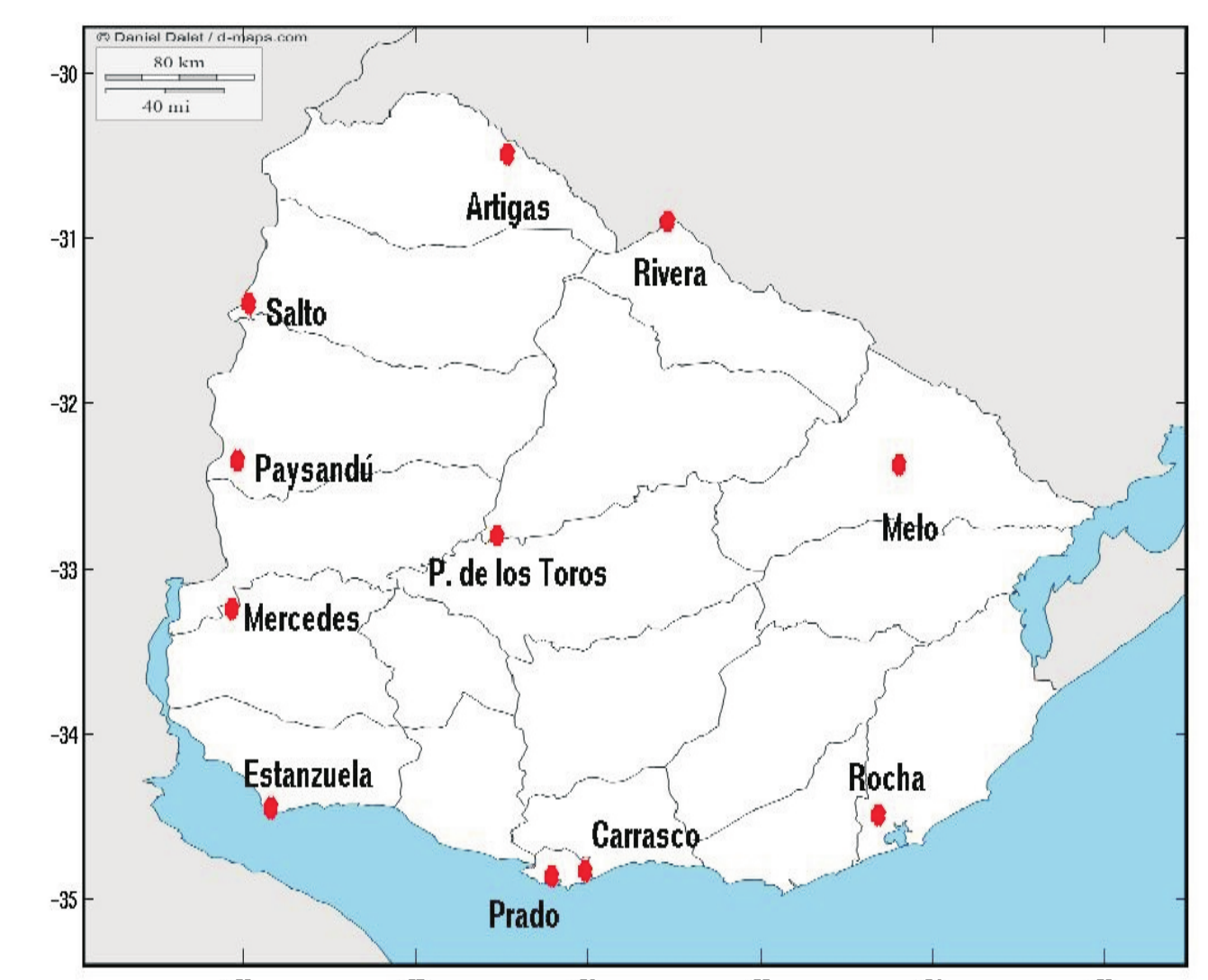


Figure 1: Location

FROST DAY(FD): When the daily minimum temperature is below 0°C.

FROST PERIOD (FP): Covers from the first to the last frost day recorded for each time series. Covers from the first to the last frost day recorded for each time series.

b) Period and distribution

The frost period was analyzed using 2 methodologies. First, we have analyzed the frost period on an annual scale, period of occurrence and size (fig 2). Second, we have analyzed the variation on a decadal scale, percentile 10, 50 and 90 of the date of occurrence. Finally, Gaussian fit was made in the frost occurrence per decade (Rocha, fig 3).

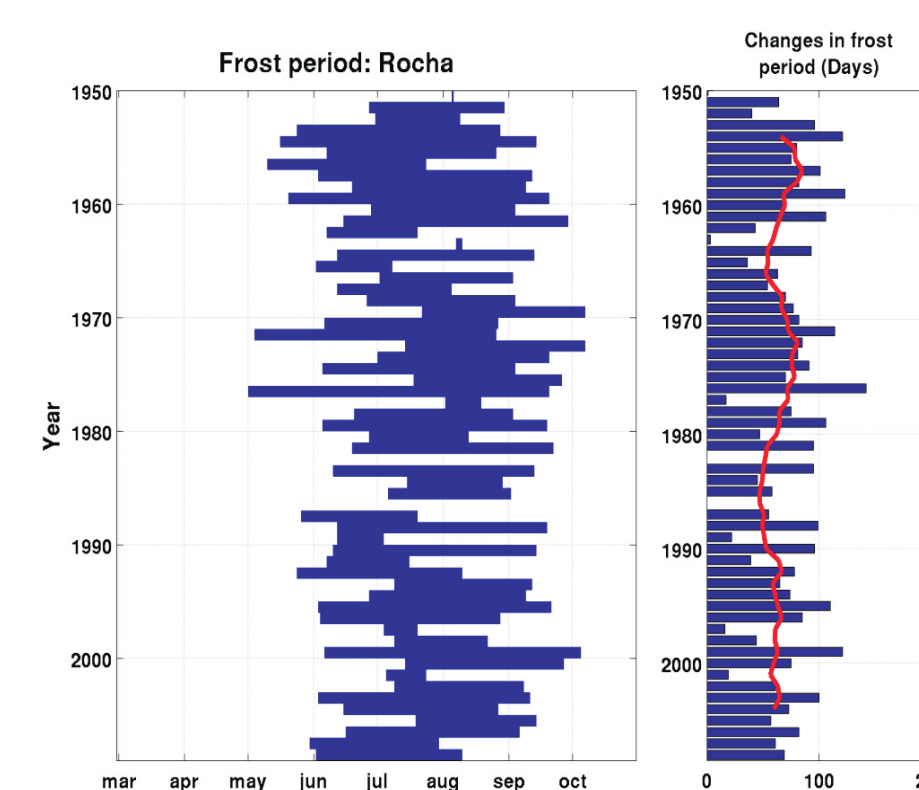


Figure 2

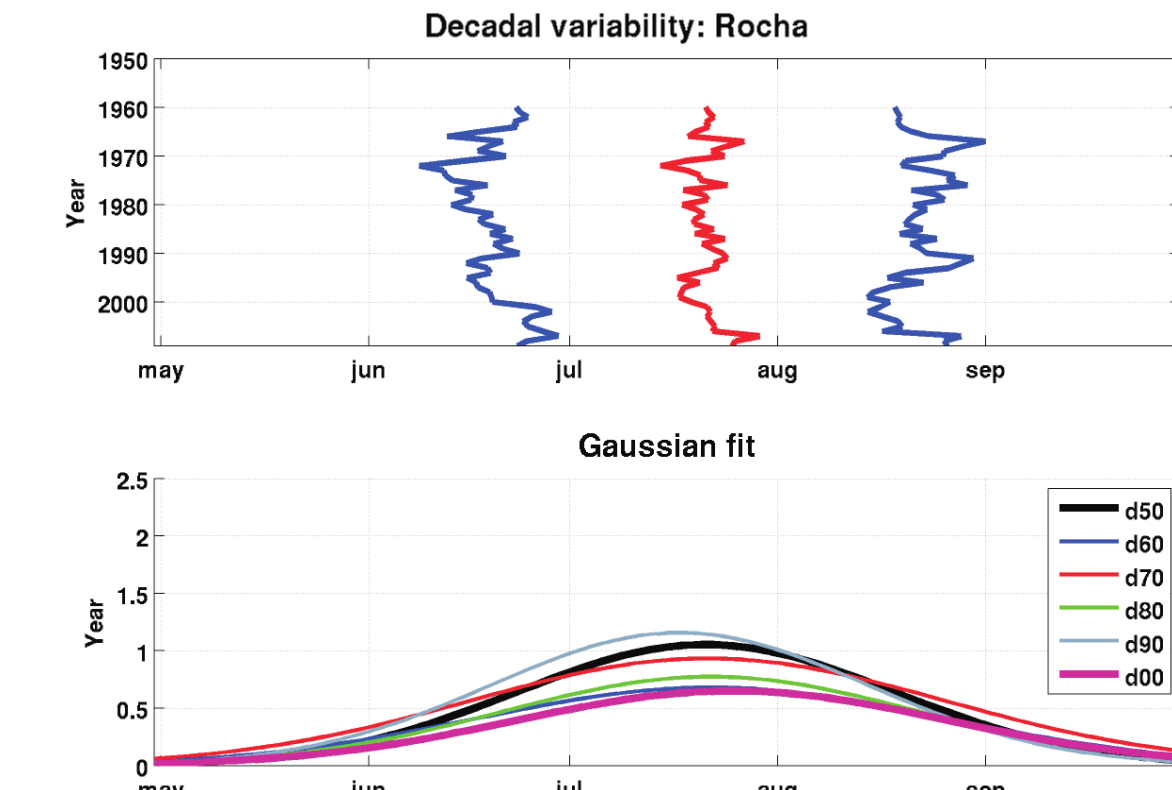


Figure 3

Two of the stations that present a negative trend in FD, were analyzed considering the FP. The most continental station presents a decrease in the FP, while the one located in the coastal region presents a decadal variability.

d) Regionalization

In order to identify regions that are spatially homogeneous across frosts, cluster analysis was used. The chosen variable is the frost quantity per month. Homogeneity or distance is defined by:

$$d(x, y) = \sqrt{\sum w_i (x_i - y_i)^2} \quad \text{where } w_i = \frac{1}{s_{i,j}} \quad \text{and } s: \text{covariance [2]}$$

The clusters are shown by a dendrogram (fig. 7). Our results shows two regions spatially homogeneous. One located in the central-northwestern part of the country and the other one is located in the south along the coast. Mercedes and Melo stations does not fit into any defined cluster. Figure 8 shows the regions obtained.

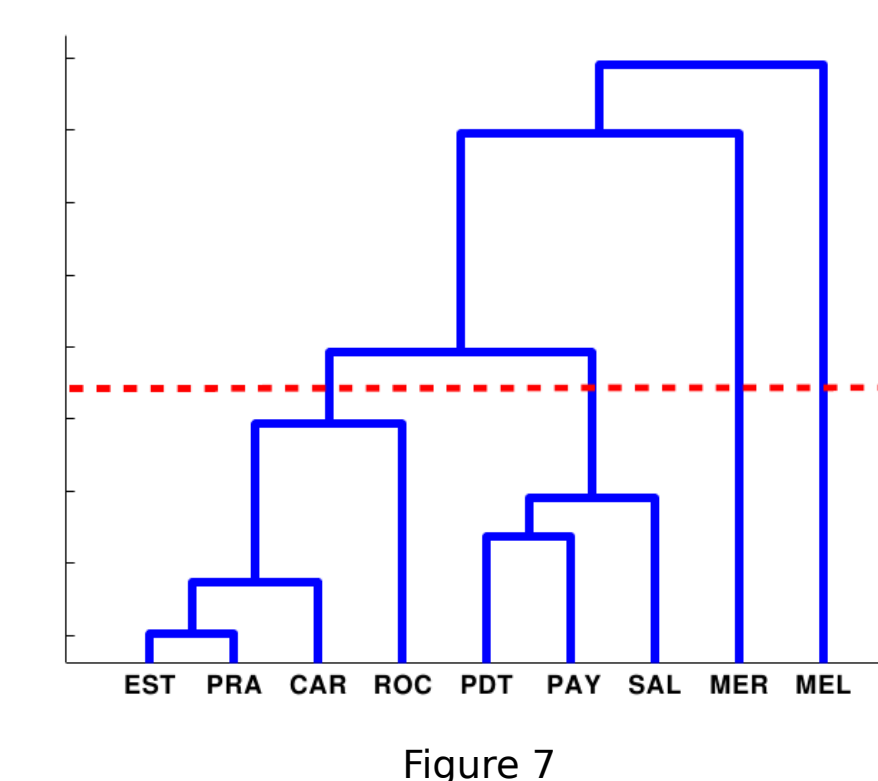


Figure 7



Figure 8

5. Conclusion

- The long term trend analysis doesn't show a clear behavior.
- In general, the frost period decreased about 5 days per decade and had a 7 days shift in the average date of frost occurrence August between the first and last decade.
- The decadal analysis of CDF shows that during the first decades events lasting 4-5 days were common, while in the last decades isolated events were detected.
- The study of the intensity during the 90's evidence more events below -2°C, while during the 2000s, although there were fewer events in coastal stations, the frosts are more intense.

6. Future work

- What atmospheric circulation patterns are linked with frosts in Uruguay?
- What is the frost threshold predictability for different time scales?

7. References

- [1] Sen, P. 1968 - Estimates of the regression coefcient based on Kendall Journalof the American Statistic Association 63: 1379-1389.
- [2] Wilks, D. - 2006: Statistical Methods in the Atmospheric Sciences, Academic Press - 3rd ed. ISBN 978-0-12-3850225