The influence of Atlantic High on seasonal rainfall in Argentina

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Abstract

The objective of this work is to quantify the influence of the position and intensity of the Atlantic High (AH) on seasonal rainfall in Argentina. Monthly precipitation data in 68 stations from the National Meteorological Service of Argentina, the Secretariat of Water Resource and the Territorial Authority of the Limay, Neuquén, and Negro rivers basins (AIC) were used. Correlation was the methodology used to identify the link between seasonal rainfall and some indices especially defined to detect the position and intensity of the anticyclone. Precipitation composites of the years when the value of these indices was extremely high (greater than their second tercile) and extremely low (lower than their first tercile) were built for every season. They were analyzed and compared with humidity

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anomaly transport composites for the same sets of years in order to study circulation patterns associated with seasonal rainfall anomalies. Results indicate that when the AH is intensified, winter rainfall increases in central Argentina and spring rainfall increases in northern Cuyo region. When the AH is displaced towards the north of its mean position, autumn rainfall is favored in the northeast and central and south Patagonia, meanwhile winter and spring rainfall decreases in central Argentina. When the AH is displaced towards the east of its mean position, summer rainfall decreases in Central Andes. Finally, AH indices were used to detect the influence on rainfall in advance. Correlations between seasonal rainfall and the defined indices that characterize the anticyclone in the previous month suggest that there is some rainfall predictability, especially during spring in almost every region in Argentina.

Key words: Atlantic High, seasonal rainfall, predictability, rainfall variability

1. Introduction

Argentina is located in southeastern South America and occupies a total area of 2,791,810 km^2. Because of its extensive territory, there are areas with different climate features and rainfall can be linked to many different factors. The predictability of seasonal rainfall variability in Argentina and subtropical South America seems to result primarily from the influence of remote forcing like the El Niño–Southern Oscillation (ENSO). Barros et al. (2008) analyzed rainfall trends in subtropical South America for the period 1960-1999 in connection with ENSO and the low-level atmospheric circulation using monthly mean sea level pressure (SLP). They found that in most of subtropical South America, most annual rainfall trends took place during the warm semester and in a neutral phase of the ENSO. After applying a Principal Component Analysis (PCA) to the monthly SLP fields, they established that positive rainfall trends south of 32ºS were related to the trends of the first two SLP leading modes. The second mode, whose influence has been growing in time and at expense of the first one, was associated with a low-level circulation advectating water vapor from the Atlantic Ocean towards the country, which shows the importance of studying how the Atlantic High (AH) can influence circulation and, consequently, precipitation. According to Cabos et al. (2017) the prescription of the AH south of 20°S improves the simulation of the seasonal cycle over the tropical Atlantic, revealing the fundamental role of this anticyclone in shaping the climate over this region. Sun et al. (2017) analyzed the annual cycle of the South AH and its interannual variability in connection with regional and large-scale climate variability. They found that the AH has an annual cycle of two peaks in intensity and size, being farthest poleward and in the centre of the South Atlantic basin during austral summer and less intense and closest to the Equator and the western side of the basin in winter. In addition to this, they found that AH is strongest and largest during the solstitial months.

Di Luca et al. (2006) applied a T-mode of PCA to monthly mean sea surface pressure and determined three predominant patterns. The fist pattern represents the summer surface circulation with the South Atlantic and South Pacific Highs in their southernmost positions. The second and third modes represent the winter circulation with the South Atlantic and South Pacific in the northernmost position and a surface pattern that characterizes the frontal activity during that season, respectively.

Moreover, some results show a southward shift of the South AH (Camilloni, 1999; Camilloni et al. 2005) and a displacement to the south of the regional atmospheric circulation over Southeastern South America (Barros et al. 2000). Several authors have studied rainfall in this region according to different forcings, mainly the sea surface temperature, showing strong signals of ENSO, which in turn shows a strong influence on the Atlantic Ocean and its circulation (Doyle and Barros 2002, Barreiro 2009). Some other authors have studied the physical mechanisms responsible for the dominant patterns of coupled mean sea level pressure and sea surface temperature variability (Haarsma et al, 2005) as well as the sensitivity of the atmospheric circulation to sea surface temperature anomalies in the tropical and subtropical South Atlantic Ocean (Robertson, et al. 2003). In addition, Venegas et al. (1997) studied the atmosphere-ocean coupled variability in the south Atlantic and found three leading modes of coupled variability of sea surface temperature and sea level pressure on interannual and interdecadal timescales. However, there are only few works that address the behavior of the South AH connected to rainfall.

The aim of this work is to quantify the influence of the position and intensity of the AH on seasonal rainfall in Argentina and evaluate the predictive capability of the system. For this purpose, this paper is structured in 6 sections. Section 2 shows the rainfall dataset as well as several indices used to describe the intensity and position of the AH and the methodology employed for the subsequent analysis. Section 3.1 describes the climatology of the AH in terms of intensity and location and Section 3.2 explores the incidence of AH in precipitation with non-lagged correlations. Section 4 analyzes different circulation patterns associated with extreme latitudinal and longitudinal displacements and intensity values of the AH. Section 5 explores the ability of the indices to predict rainfall one month ahead using lagged correlations. Finally, Section 6 summarizes the main results and conclusions.

2. Data and Methodology

Seasonal accumulated precipitation series in 68 meteorological stations in Argentina over the period 1979-2012 were used to perform this study. Data comes from different sources such as the National Meteorological Service of Argentina (SMN), the Secretariat of

Hydrology of Argentina (SRH), and Territorial Authority of the Limay, Neuquén, and Negro rivers basins (AIC). Figure 1 shows the meteorological stations used in the study and nine homogeneous regions. They were derived applying Lund (1963) methodology to monthly rainfall data, using a threshold of 0,6 for the correlation coefficient (Gonzalez et al., 2016). The aim is to use these regions only to depict how the country could be regionalized and to address these regions later on for an easier understanding.

Data from ERA-Interim reanalysis from the European Centre for Medium Range Weather Forecasts (ECMWF) were also used to perform the study. ERA-Interim is a global atmospheric reanalysis from 1979, continuously updated in real time with a spatial resolution of approximately 80 km (T255 spectral) on 60 vertical levels from the surface up to 0.1 hPa. For this study, the monthly mean 1000 hPa geopotential height was used as a good approximation of surface pressure data for the period 1979-2012.

The AH is a semi permanent pattern in the subtropical South Atlantic Ocean. However, its intensity and position have a relevant interannual variability. In order to analyze this variability, the AH was identified as the gridded point of the data with maximum value of geopotential height in 1000hPa over the South Atlantic Ocean between the Equator and 40°S. Therefore we defined three monthly indices for the AH: AHINT index (gpm) as the intensity anomaly from the monthly mean value for the period 1979-2012; AHLAT index (°) as the latitude anomalies from the monthly mean position; and the AHLON index (°) as the longitude anomalies from the monthly mean position. A positive value of the AHINT index indicates an intensification of the anticyclonic system whereas a negative value shows that the system is weaker than its mean value. When analysing the AHLAT index, a positive value implies a shift of the system to the north while a negative value means a shift to the south of its mean position. Finally, a positive value of the AHLON index shows a shift to the east whereas a negative value indicates a shift to the west.

In order to study the AH as a climate forcing to seasonal rainfall, a correlation method was applied to previously detrended data series. This correlation was calculated for the common period 1979-2012 between accumulated seasonal rainfall anomalies and the indices representing the AH for each season: summer (December, January, February), autumn (March, April, May), winter (June, July, August) and spring (September, October, November). Given the time record, a correlation coefficient higher than 0.27 was considered significant with a 95% level of confidence.

In addition to this, as hemispherical and regional circulation influence precipitation through the intensity of vertical velocity, the advection of humidity, the shift of the systems and therefore the location of precipitation areas; we intended to study the circulation patterns associated with the strongest anomalies of every index. To do this, we calculated the first and second tercile for every index in every season and then classified the years in the period of time as *SP Years* if the index was greater than its second tercile and *SUB Years* if the index value was lower than its first tercile. Using these two sets of years for every season, we constructed the moisture anomalies transport composites as the product of specific humidity and wind integrated into the whole column atmosphere (1000 to 300 hPa). This was evaluated in order to determine circulation patterns associated with the strongest anomalies of every index.

Finally, to study how the AH can be used to estimate in advance seasonal rainfall in different regions of the country, it was implemented a linear correlation method to the time series whose linear tendency was previously filtrated in cases when this was statistically significant. This method was applied between accumulated seasonal rainfall for every season and a AH index value a month before the start of the season to predict. Our hypothesis is that what happened a month before in the atmosphere can influence our meteorological variables more than what occurred a few months before. This is why one-month lag was used in this study. Therefore, this methodology helps to analyse the predictability of seasonal rainfall anomalies, and hence the capacity of every index to show future behaviour of seasonal rainfall. These correlations between the time indices series and accumulated seasonal rainfall were calculated for the period 1979-2012. Due to this time record, correlation coefficients higher than 0.27 were significant with 95% of confidence. The obtained results were plotted in spatial correlations fields for every season and every index.

3. Results

3.1. Climatology

Taking into account the AH behaviour in terms of intensity, longitude and latitude, Figure 2 shows the evolution of geopotential height in 1000 hPa over the South Atlantic Ocean.

Results have shown that the AH increases its intensity during winter. In fact, maximum intensity is detected in July and August with values over 2000 gpm. It moves south of its mean position towards south of 30ºS during summer. From winter onwards, the AH is located north of 30ºS until November when its southern shift starts. On the other hand, the AH moves to the east of its mean position during winter reaching the Greenwich parallel and starting in October its shift towards the American continent. These results are consistent with earlier results from Sun et al. (2017) and Camilloni et al. (2005).

In order to analyze the time evolution of this system, a linear trend method of minimum squares was applied to every index time series. The statistical significance was tested with a normal distribution test using a 95% level of confidence. From these results it can be seen that the AHINT shows a significant positive tendency (tendency=0.009, r=0.35), indicating that the AH has been intensifying slowly but still significantly over time. It also shows a tendency of moving to the south and the west of its mean position, although these trends are not significant with a 95% level of confidence.

3.2. INFLUENCE ON PRECIPITATION

The behaviour of AH was analyzed in Figure 3 using linear correlation as explained in Section 2. It can be seen that when the AH is intensified (Fig. 3 AHINT panels), there is a significant rise in winter rainfall in the centre-east of the country (regions 8 and 3) and in spring rainfall in the Cuyo region (region 4). Meanwhile, when the AH is weak there is an increase in autumn rainfall in central-east Argentina (regions 8 and 3) and Cuyo region (region 4) and in summer rainfall in the northwest of Argentina (region 1). In cases where the AH moves north of its mean position(Fig. 3 AHLAT panels), autumn rainfall is favoured in the Litoral region, centre of the country and south Patagonia (regions 3, 9, 8, 6 and 7). On the other hand, there is a decrease in winter rainfall in the north-eastern and central region of Argentina (regions 8 and 3) and in spring rainfall all over the country, especially in regions 2, 4 and 8. In addition to this, when the AH moves east of its mean position (Fig. 3 AHLON panels), summer rainfall shows a decrease in the central Andes (region 5) and in region 8. Autumn rainfall shows a decrease in central and north-eastern Argentina (regions 8 and 3).

Table 1 summarizes the results: AHINT and AHLAT are the factors that mainly affect precipitation in some regions during transition seasons (spring and autumn) and winter; meanwhile AHLON only affects summer and autumn rainfall. Regions 8 and 3 (eastern and north eastern Argentina) are the areas most influenced by AH variability.

4. CIRCULATION PATTERNS

Calculating the first and second tercile for every index lead to the classification of years as *SP Years* and *SUB Years* for every season which can be seen from Table 2 to Table 5. Using these sets of years, the precipitation composites for every season are shown in Figure 4 to Figure 7. Each season will be analyzed in detail.

4.1 SPRING

Analyzing Figure 4a it can be seen that when AH registers its most intense geopotential height values in spring (Fig. 4a upper left panel), positive rainfall anomalies are detected in central-eastern Argentina, including northern Buenos Aires province (regions 2 and 8) which can reach 35 mm. Simultaneously, in the Comahue region (region 5) there are negative rainfall anomalies of up to 25 mm. On the other hand, when AH registers its lowest spring values (Fig. 4a lower left panel), positive rainfall anomalies prevail in most areas of the country (regions 3, 5, 8 and 9), especially in the Litoral region where they reach values between 55 mm and 75 mm and even 85 mm in very local regions. Central Argentina registers slightly lower than normal precipitation in this same scenario. When comparing this factor to the humidity anomalies transport fields (Fig. 4b left panels) the transport from the Brazilian's rainforest towards the northeast region of Argentina increases during the years in which the AH is weakest, therefore indicating that this mechanism could contribute to the increase in precipitation. In the rest of the area analyzed, the general circulation when the AH is intensified is contrary to the one present when the AH is weakened.

As regards the latitudinal factor, there are negative rainfall anomalies in most of the country when the AH is in its northernmost position during austral spring (Fig. 4a upper middle panel), especially in Buenos Aires and the Litoral (regions 8 and 3). On the other hand, a rather opposite pattern can be seen during the years when AH is furthest south (Fig. 4a lower middle panel), although these anomalies are not as intense as during the SP years. When observing the humidity anomalies transport fields (Fig. 4b middle panels), there is more transport from central Brazil towards the Litoral region in Argentina during the SUB Years than during the SP Years when these anomalies come from the south. In addition, an increase of the humidity transport in the eastern south Pacific that could be associated with positive rainfall anomalies in the Comahue region in the SP Years is observed. The opposite humidity transport pattern is present during the SUB Years.

When considering the longitudinal effect, the years when AH has a most eastward shift in spring (Fig. 4a upper right panel), there are positive rainfall anomalies in north Argentina and specially the Litoral region (regions 3 and 9) with values of up to 75mm. Changes in the position of the AH lead to changes in the position of the Westerlies, which have an influence on the precipitation field in Patagonia. The Comahue region (region 5) shows positive anomalies during this time of the year, although not as intense as the ones in the

Litoral region. The rest of the country is clearly under the influence of negative rainfall anomalies. On the other hand, when AH is closest to the continent (Fig. 4a lower right panel), negative rainfall anomalies prevail in the country, especially in the Litoral region. Analyzing the moisture transport anomaly in these cases (Fig. 4b right panels), the humidity transport in northern Argentina coming from central Brazil is very intense in the SP Years while during the SUB Years it weakens. The behavior detailed in this section is consistent with results about the warm semester shown in Barros, V. R. et al. (2008).

4.2 SUMMER

From Figure 5, when AH is most intense in summer (Fig. 5 upper left panel), there are higher rainfall than normal in southern Litoral and northern Buenos Aires (regions 3 and 9) and lower than normal in the rest of the country, especially in north-western Argentina. When AH is weakest during summer (Fig. 5 lower left panel), local nucleus of positive rainfall anomalies are found in the central-eastern area and negative in central-western Argentina. When AH is furthest east during summer (Fig. 5 upper right panel), lower than normal rainfall is found in the whole country, especially in the central area. An opposed pattern is registered when AH is closest to the continent (Fig. 5 lower right panel), bringing water vapour from the ocean to the country and producing higher than normal rainfall in Buenos Aires, and a pattern of positive anomalies in the north-western region and Litoral and negative anomalies in Chaco province (region 3). It is important to notice how rainfall anomalies associated to AHLAT are not as important as when AHINT and AHLON are considered. However, there is a tendency to small positive rainfall anomalies in northern Argentina during the years when AH is furthest north (Fig. 5 upper middle panel) and negative anomalies when AH is furthest south (Fig. 5 lower middle panel). Positive rainfall anomalies in regions 8 and south of region 3 when the AH is intensified and displaced southwards, agree with the results about the warm semester shown in Barros, V. R. et al. (2008).

4.3 AUTUMN

Analyzing AH behaviour during autumn, when it is most intense (Fig. 6a upper left panel) there are negative rainfall anomalies in most parts of the country, with maximum values in northern Litoral (region 3). When AH is most weakened (Fig. 6a lower left panel), central Argentina experiences lower than normal precipitation, while Comahue, Buenos Aires province and Litoral (regions 5, 8 and 3) are affected with more autumn rainfall. This behaviour can be related to the humidity transport anomalies (Figure 6b left panels): there is more transport of moisture from central Brazil towards the Litoral region during the SUB Years while during the SP years the humidity transport comes from the south in southern Brazil, Uruguay and northern Argentina. As regards latitudinal displacement, higher than normal rainfall can be found in Argentina when AH is in its northernmost position (Fig. 6a upper middle panel), while the opposite pattern can be seen on the contrary case (Fig. 6a lower middle panel). In this scenario, humidity transport from the Brazilian's rainforest to northern Argentina is intensified during the SP Years while it is weakened during the SUB Years (Fig. 6b middle panels). In addition, when AH is furthest east (Fig. 6a upper right panel), except for some local regions of central Argentina, negative rainfall anomalies prevail specially in Comahue and the northeast region (regions 5 and 3), while the opposite scenario is present when the AH is furthest west (Fig. 6a lower right panel). When compared to Figure 6b (right panels), a humidity transport from the northeast Atlantic Ocean to northern Argentina can be seen during the SUB Years while the opposite behaviour is present during the SP Years. In addition to this, the Comahue region has a similar response during the SUB Years when there is humidity transport in the eastern Pacific Ocean towards the region. During the SP Years, humidity transport anomalies in the eastern Pacific come from the east.

4.4 WINTER

In Figure 7 it can be seen that in the years when AH is most intense during winter (Fig. 7 upper left panel) there is higher than normal rainfall in Buenos Aires province and north-eastern Argentina (regions 3 and 8), and lower than normal precipitation in western Argentina, with a minimum value in Comahue (region 5). In the years when AH is most weakened (Fig. 7 lower left panel), an almost opposite pattern can be seen, where there are positive winter rainfall anomalies in Patagonia, especially in Comahue, and negative anomalies in central and northern Argentina. When studying the latitudinal position, a dipole of positive rainfall anomalies in Comahue and negative anomalies in the Litoral region can be seen when AH is in its northernmost position (Fig. 7 upper middle panel). On the other hand, when AH shows an intense shift southward (Fig. 7 lower middle panel), negative winter rainfall anomalies are registered especially in Comahue (region 5). As regards the longitudinal factor, rainfall anomalies associated to this index are not as intense as the ones previously analyzed, but still it can be seen that when AH is most displaced to the east (Fig. 7 upper right panel), less positive winter precipitation anomalies are found in Buenos Aires, Comahue and Patagonia and the opposite pattern is present when the AH is most displaced to the west (Fig. 7 lower right panel).

5. Lagged correlations – Predictability of seasonal rainfall

In order to study the ability of every index to detect rainfall anomalies with a month ahead, the methodology explained in Section 2 lead to the results shown in Figure 8.

When spring precipitation is considered, it was observed that an intensification of the AH during August (Fig. 8 AHINT SON panel) is associated with positive rainfall anomalies in the central region of the country (regions 2, 3, 4 and 7). When the system is displaced southern than normal during August (Fig. 8 AHLAT SON panel), it allows moist air enter in the country, enhancing the spring precipitation in northern Patagonia and the centre region of Argentina (regions 2, 3 and 6). Also, when the AH shifts east of its mean position in August (Fig. 8 AHLON SON panel), and thus it is further displaced from the continent, spring rainfall is favoured in north-eastern Argentina and central and south regions of the Andes (regions 4, 5, 6 and 3). According to the accumulated summer rainfall (Fig. 8 DJF panels), there has not been significant correlation with the AH indices, indicating that the AH is not a good predictor of summer rainfall with a month ahead. During the autumn months, a significant correlation was found in limited regions when the AHINT and AHLAT indices values in February were considered. The intensification of the AH during February (Fig. 8 AHINT MAM panel) is associated with an increase in autumn rainfall in central Patagonia (region 7), whereas a north shift of this system produces lower than normal rainfall in limited areas of Southern Andes (between 40°S-45°S, region 6) and eastern Buenos Aires province, close to La Plata River, in a region centred in 36°S and 59°W (region 8) (Fig. 8 AHLAT MAM panel). On the other hand, the longitudinal factor shows low correlation values a month ahead (Fig. 8 AHLON MAM panel).

The signal in winter precipitation has proven to be too local. When its intensity in May is increased (Fig. 8 AHINT JJA panel), higher than normal winter precipitation is registered in limited areas of the Andes and central Argentina (regions 6, 3 and 8). A shift east of its mean position (Fig. 8 AHLON JJA panel) is associated with a decrease in rainfall in northern Argentina (regions 1 and 3), whereas a north shift is connected to an increase in winter precipitation in north-eastern Argentina and a decrease in western Patagonia (regions 3 and 6 respectively) (Fig. 8 AHLAT JJA panel).

Table 6 summarizes these results: there is virtually no signal in summer and the best signal is detected during spring. In addition to this, region 3 (northeastern Argentina) is the area of the country where the best signal was found.

6. Conclusions

The aim of this work was to determine the influence of the Atlantic High on seasonal precipitation anomalies in Argentina. The simultaneous correlation between the AH indices and seasonal precipitation was carried out in order to study the influence of this forcing on seasonal rainfall. This allowed us to conclude that signals strongly depend on the region and the season analysed, being spring the season which presents the strongest signal, especially in the north-western area and the Comahue region. Summer constitutes the season with the weakest signal, particularly in the central-western region of Argentina. In addition, Buenos Aires area, north-eastern region of the country and central and northern Patagonia are the most influenced areas by AH as they present the most significant correlations with the largest number of indices.

When evaluating the relation between seasonal precipitation and the indices a month prior to the beginning of the season, the strongest signal was obtained in spring rainfall. It can be concluded that almost all regions have at least one index that helps foretell spring precipitation a month ahead. For autumn and winter, the amount of useful indices per region diminishes. Summer presented the weakest signal a month ahead, showing that summer rainfall is not affected by AH variability.

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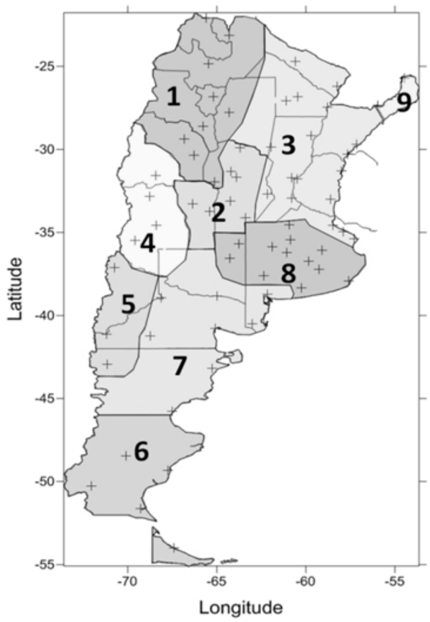

Region	Name
1	Northwestern Argentina
2	Central Argentina
3	Litoral
4	Cuyo
5	Comahue
6	South Patagonia
7	Central and northern Patagonia
8	Buenos Aires province
9	Misiones province

Figure 1 – Map and names of different regions in Argentina. Meteorological stations used in this study are marked with a cross.

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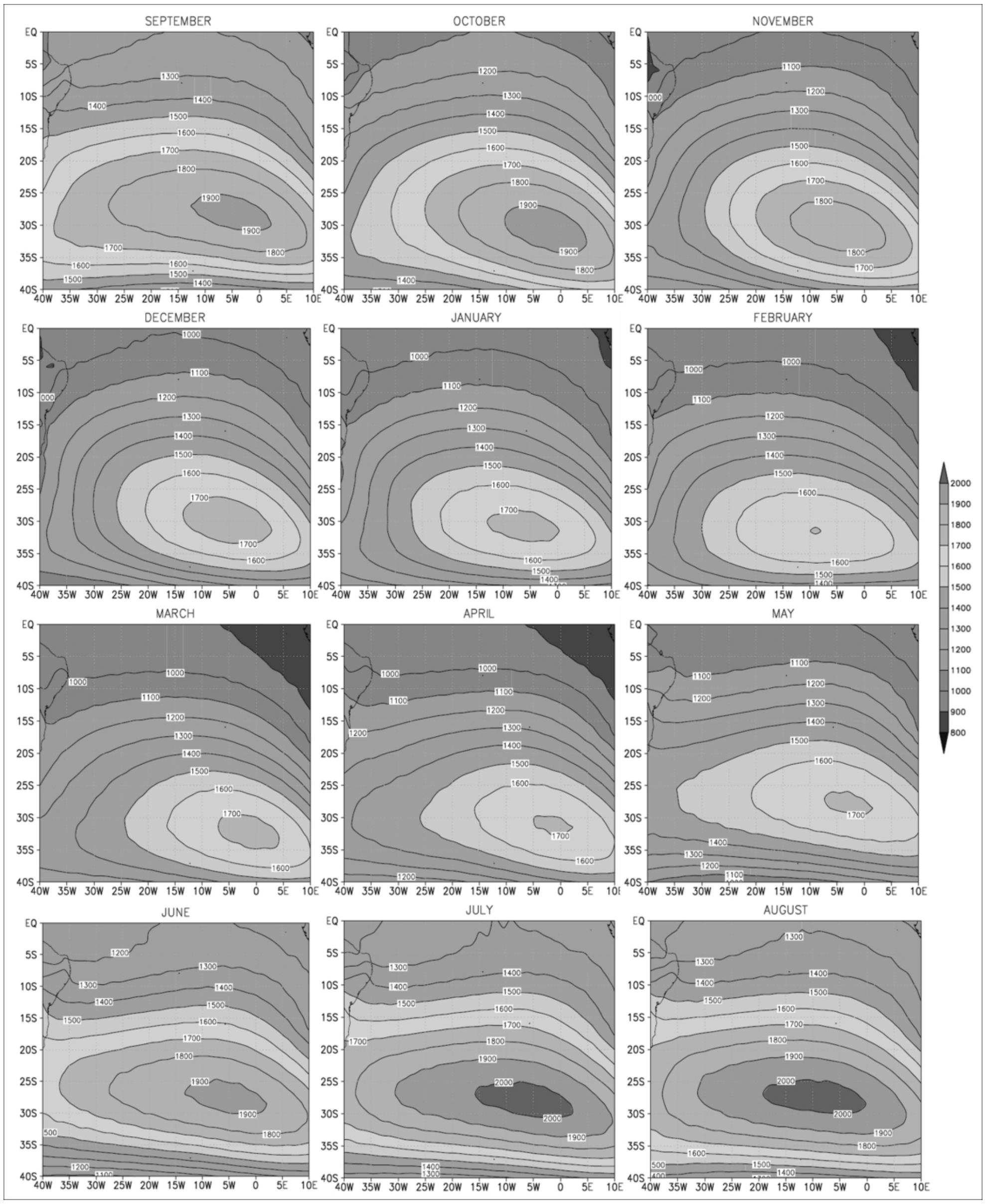

Figure 2 – Semi permanent AH monthly mean values of intensity in gpm for the 1979-2012 period.

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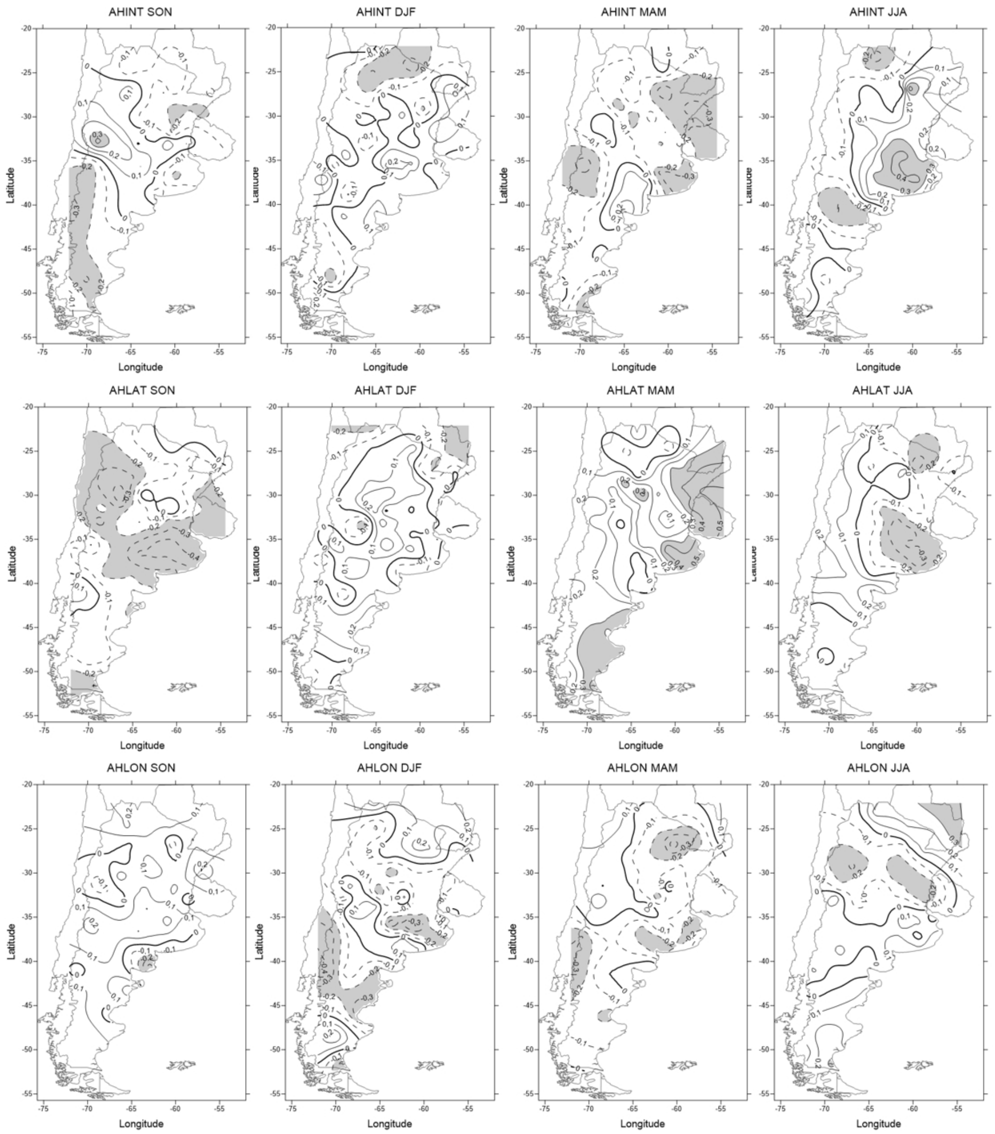

Figure 3 – Correlation fields between the AH indices and seasonal rainfall for the time period 1979-2012. Dotted lines represent negative correlations.

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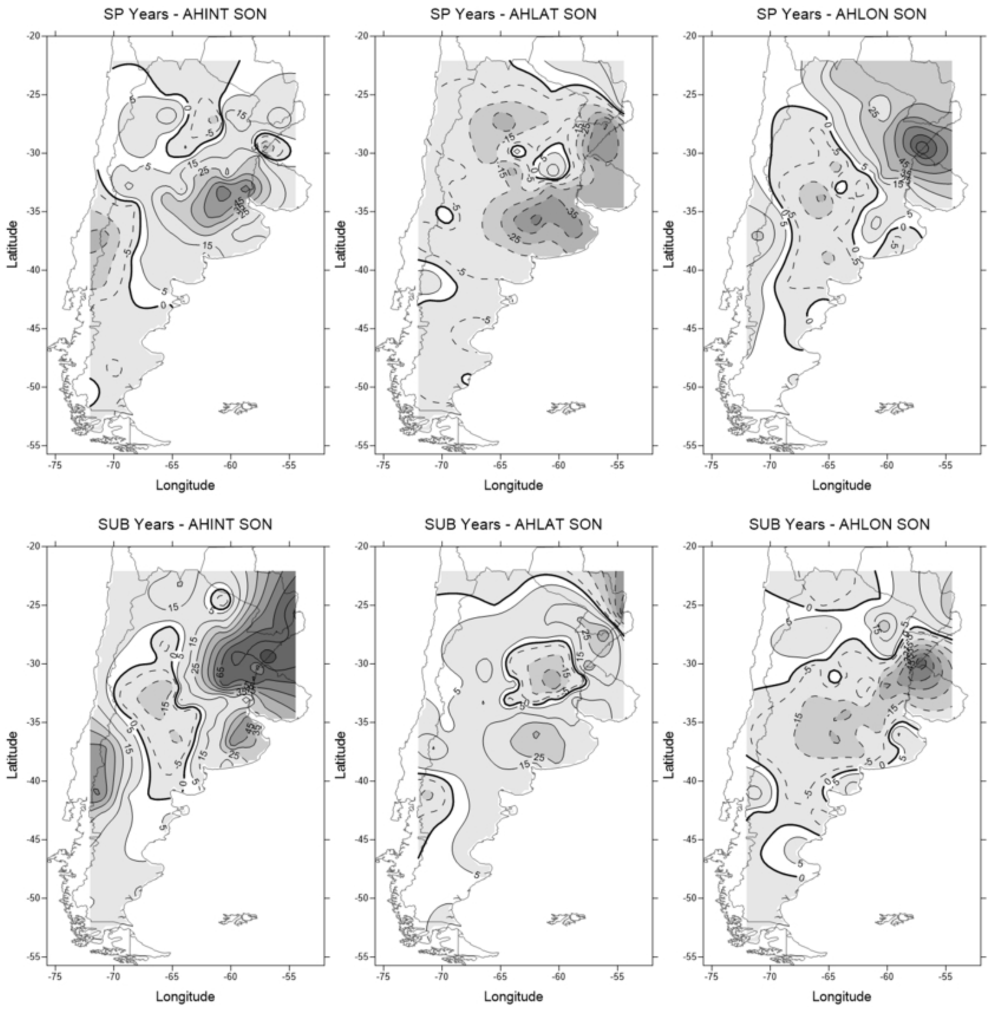

Figure 4a – Spring rainfall anomalies composites for SP and SUB Years for AH (mm).

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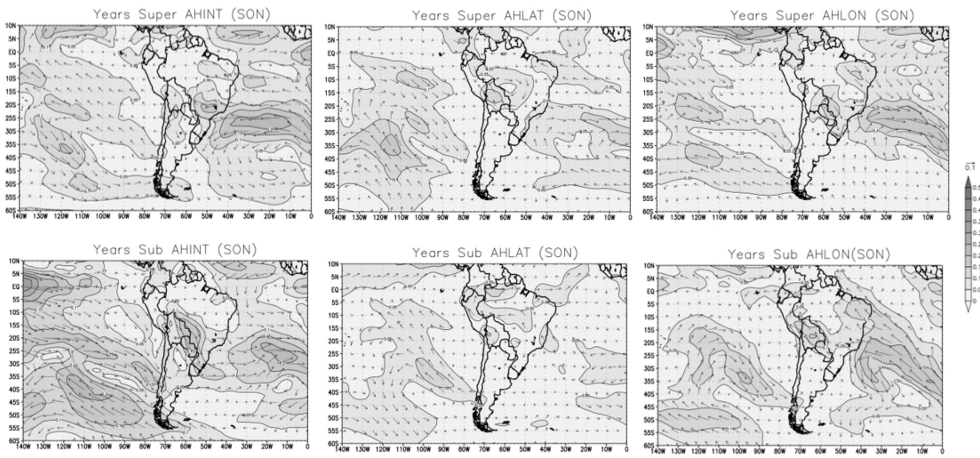

Figure 4b – Humidity transport anomalies field composites for spring. Vectors show the direction of the transport and shaded area shows the intensity of the transport (g/kg m^2/s).

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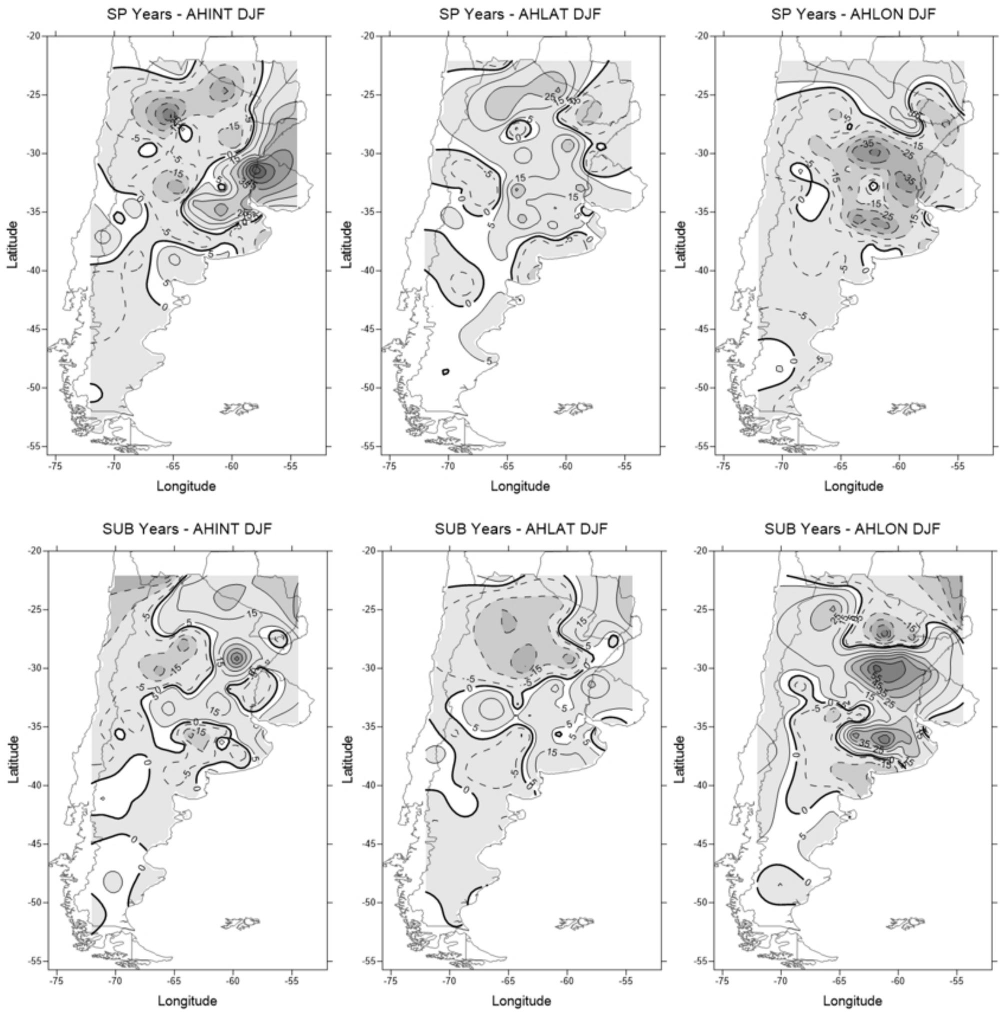

Figure 5 – Summer rainfall anomalies composites for SP and SUB Years for AH (mm).

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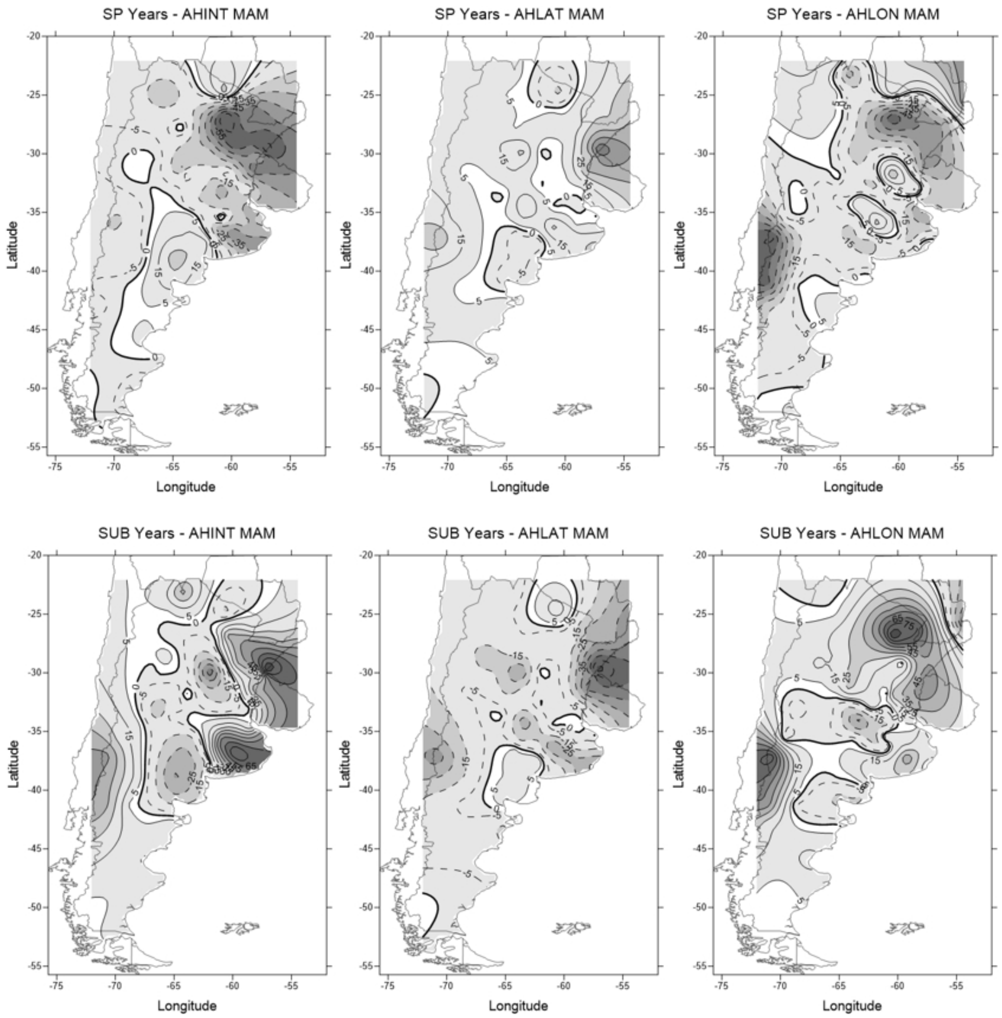

Figure 6a – Autumn rainfall anomalies composites for SP and SUB Years for AH (mm).

143x144mm (150 x 150 DPI)

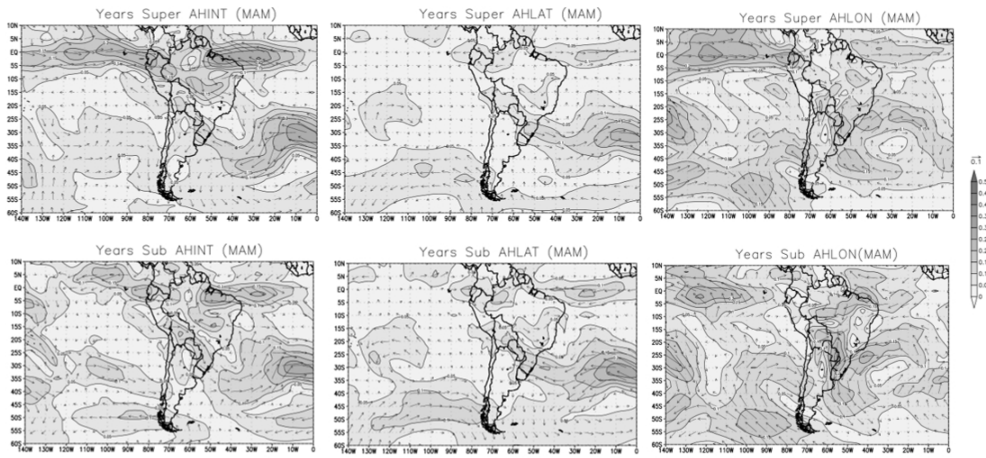

Figure 6b – Humidity transport anomalies field composites for autumn. Vectors show the direction of the transport and shaded area shows the intensity of the transport (g/kg m^2/s).

188x85mm (150 x 150 DPI)

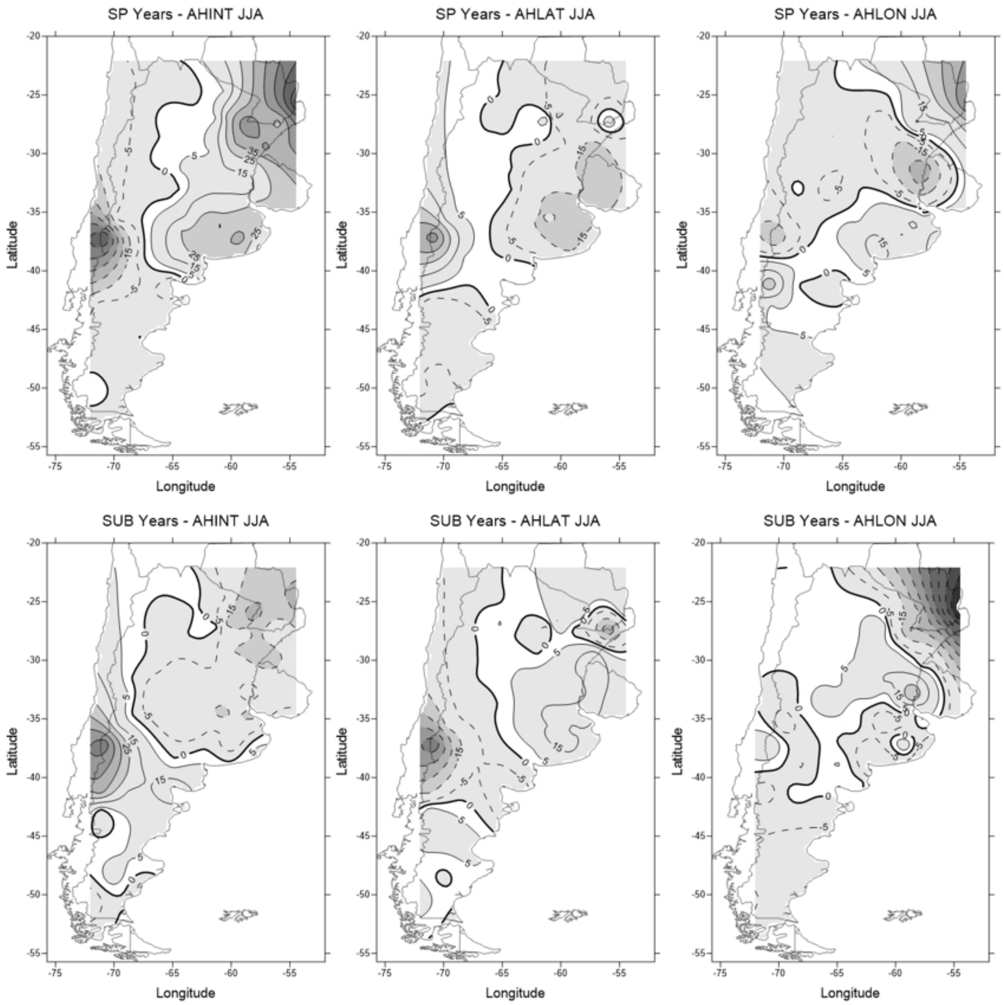

Figure 7 – Winter rainfall anomalies composites for SP and SUB Years for AH (mm).

143x145mm (150 x 150 DPI)

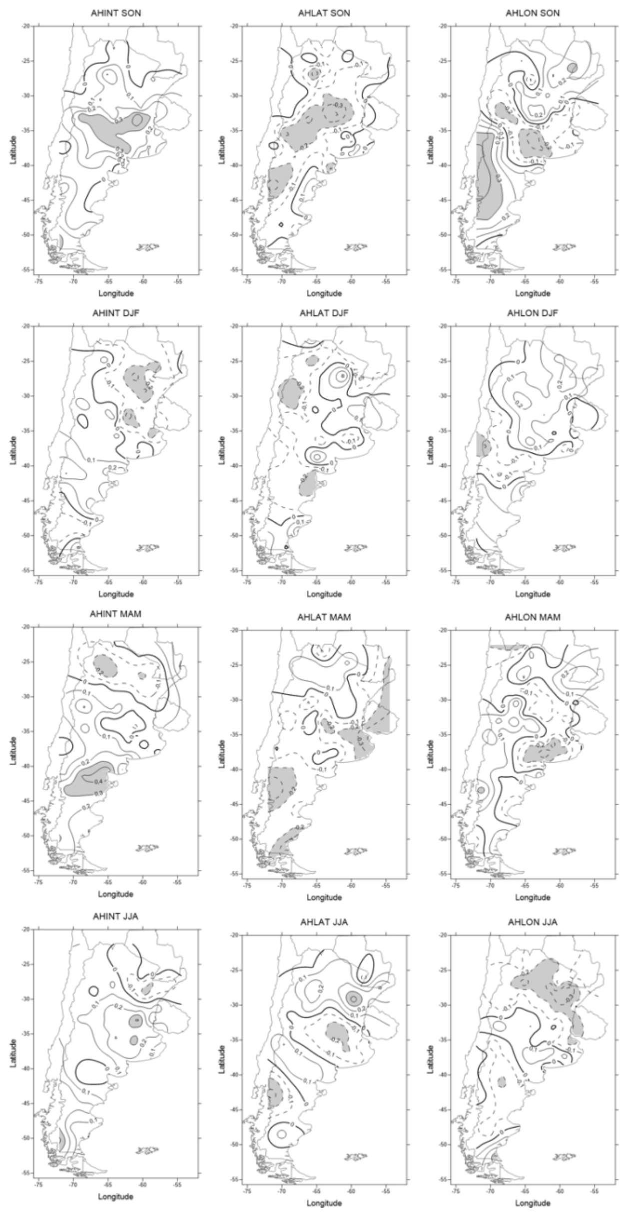

Figure 8 – Correlation field between seasonal precipitation and AH indices values a month prior to the beginning of the season analyzed. Dotted lines represent negative correlations.

127x247mm (150 x 150 DPI)

INDEX	SPRING	SUMMER	AUTUMN	WINTER
AHINT	**4**	*1*	*3,8,4*	**8, 3**
AHLAT	*2, 4, 8*		**3, 9, 8, 6, 7**	*3, 8*
AHLON		*5,8*	*8, 3*	

Table 1 *– Regions representing significant simultaneous correlations between seasonal precipitation and time series of the AH indices for the 1979-2012 period. Bold (italic) numbers corresponds to positive (negative) correlations between both variables. Empty cells represent non significant signals with a 95% level of confidence.*

INDEX	First tercile	Second tercile	Units	SPRING SP Years	SUB Years
AAINT	-0,548	0,478	gpm	1986, 1990, 1992, 1995, 1996, 1998, 2000, 2001, 2006, 2007, 2011, 2012	1979, 1981, 1982,1984, 1985, 1993, 1994, 1997, 2002, 2003, 2009
AALAT	-0,569	0,481	°	1979, 1981, 1984, 1989, 1991, 1993, 1994, 1995, 2003, 2005, 2008, 2009, 2011	1980, 1982, 1985, 1986, 1988, 1990, 1997, 1998, 1999, 2000, 2001, 2004, 2006, 2007, 2010
AALON	-0,289	0,529	°	1979, 1980, 1982, 1985, 1987, 1989, 1991, 1993, 1997, 2002, 2004, 2006, 2008, 2009	1981, 1983, 1986, 1992, 1994, 1996, 2000, 2003, 2007, 2010, 2011

Table 2 *– SP and SUB Years along with the value of the first and second tercile for every index for spring.*

INDEX	First tercile	Second tercile	Units	SUMMER SP Years	 SUB Years
AAINT	-0,152	0,297	gpm	1979, 1981, 1982, 1994, 1997, 1998, 2000, 2002, 2004, 2007, 2009, 2012	1984, 1985, 1986, 1988, 1989, 1993, 1995, 2003, 2006, 2010, 2011
AALAT	-0,273	0,569	°	1980, 1983, 1984, 1986, 1987, 1991, 1992, 1993, 1995, 2003, 2007, 2010, 2012	1981, 1988, 1990, 1994, 1996, 1997, 1999, 2000, 2001, 2002, 2004, 2006, 2008, 2009, 2011
AALON	-0,259	0,559	°	1984, 1985, 1986, 1989, 1990, 1994, 1995, 1996, 1998, 2000, 2001, 2004, 2006, 2008, 2009	1979, 1980, 1982, 1983, 1988, 1991, 1992, 1993, 2002, 2011, 2012

Table 3– *SP and SUB Years along with the value of the first and second tercile for every index for summer.*

INDEX	First tercile	Second tercile	Units	AUTUMN SP Years	AUTUMN SUB Years
AAINT	-0,554	0,507	gpm	1981, 1982, 1983, 1992, 1995, 1997, 2000, 2004, 2005, 2006, 2011, 2012	1980, 1984, 1986, 1987, 1988, 1993, 1996, 1998, 2002, 2008, 2009
AALAT	-0,306	0,071	°	1979, 1980, 1984, 1986, 1987, 1988, 1990, 1991, 1992, 1996, 1997, 1998, 1999, 2001, 2002, 2003, 2007, 2008, 2009	1981, 1982, 1983, 1985, 1989, 1993, 1994, 1995, 2000, 2004, 2005, 2006, 2010, 2011, 2012
AALON	-0,269	0,366	°	1979, 1983, 1988, 1995, 1996, 1998, 1999, 2000, 2003, 2007, 2008, 2009, 2012	1980, 1981, 1982, 1984, 1986, 1991, 1992, 2002, 2005, 2010, 2011

Table 4– *SP and SUB Years along with the value of the first and second tercile for every index for autumn.*

INDEX	First tercile	Secondtercile	Units	WINTER SP Years	SUB Years
AAINT	-0,608	0,192	gpm	1982, 1989, 1990, 1991, 1992, 1994, 1998, 2001, 2002, 2004, 2011, 2012	1984, 1986, 1987, 1988, 1993, 1996, 1997, 1999, 2000, 2006, 2008
AALAT	-0,487	0,412	°	1982, 1983, 1985, 1986, 1993, 1995, 1996, 1997, 1999, 2002, 2006, 2007, 2008, 2009, 2010	1979, 1980, 1981, 1984, 1990, 1991, 1992, 1994, 1998, 2001, 2003, 2004, 2005, 2011, 2012
AALON	-0,481	0,355	°	1979, 1980, 1984, 1987, 1988, 1989, 1990, 1992, 1993, 1994, 1997, 2000, 2004, 2008, 2011	1985, 1986, 1991, 1995, 1996, 1999, 2001, 2006, 2007, 2010, 2012

Table 5 – *SP and SUB Years along with the value of the first and second tercile for every index for winter.*

INDEX	SPRING	SUMMER	AUTUMN	WINTER
AHINT	**2, 3, 4, 7**		**7**	**6, 3, 8**
AHLAT	*2, 3, 6*		*6, 8*	**3** *6*
AHLON	**4, 5, 6, 3** *7*			*3*

***Table 6–** Regions with significant correlations between seasonal precipitation and the indices value a month prior to the beginning of the season to predict for the 1979-2012 period. Bold (italic) numbers corresponds to positive (negative) correlations between both variables. Empty cells represent non significant signals with a 95% level of confidence.*