The Drought in Chile and La Niña

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La Niña in Chile

Precipitation is one of the climatic elements most affected by the presence of La Niña in Chile. An important precipitation deficit begins during La Niña events, from latitude 45°S to the north. This deficit prevails most of the year, with winter (April–September) being most vulnerable to these anomalies. The central region of Chile (30°S to 40°S) has negative anomalies, with precipitation values 35% to 100% below the climatologic annual average. These rain deficiencies in Chile are determined by the persistence of anomalies of anticyclonal circulation of middle and subtropical latititudes and an area of anomalies of cyclonic circulation in the sub-polar latitudes, from a north–south dipole of positive and negative anomalies of geopotential height in the mid troposphere. In Chile, La Niña usually produces air temperatures lower than normal, with deviations ranging from 0°C to -1°C. The social and economic impacts of La Niña events in Chile are serious. Agriculture, cattle and timber industries, energy, and industrial sectors are the most affected.

Patterns of atmospheric circulation in Chile during La Niña

Normal conditions

The atmospheric circulation in Chile is characterized by the existence of two meteorological occurrences: (1) the subtropical anticyclone of the Pacific southeast and (2) the circulation of the westerlies, where the frontal systems and their associated lows are formed and develop. The former corresponds to a region where high pressures prevail almost year-round. This high is in northern and central Chile and migrates from 30–35°S during winter to 35–40°S during summer.

The second occurrence that defines the seasonal precipitation cycle in central Chile is the displacement of the frontal bands from the west. This displacement is more frequent from April to September, and it contributes more than 70% of the annual precipitation.

La Niña conditions

In the presence of a La Niña event, the subtropical anticyclone of the southwestern Pacific intensifies, and its influence is extended to the south. This shift prevents the frontal systems coming from the western Pacific from being displaced (as they normally are) toward continental mid-latitudes. During La Niña, there is also an intensification of the polar jet stream and a weakening of the subtropical jet stream, favoring greater frontal activity in southern Chile (Figure 1). This condition reduces the frequency of frontal cloudy bands in central and northern Chile, blocks or weakens the passage of active fronts to the continent, and inhibits convective activity, all essential factors for the generation of precipitation.

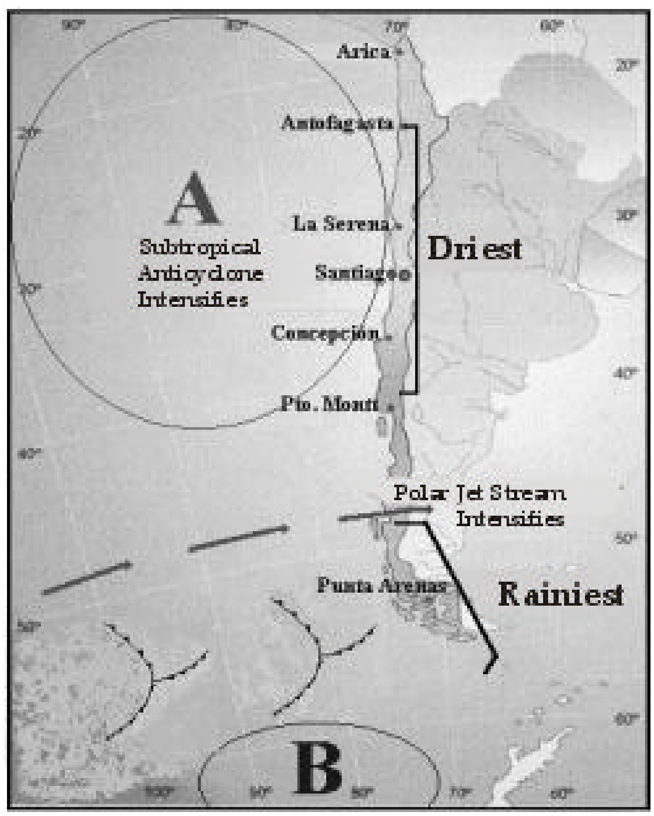

Figure 1. Characteristics of atmospheric circulation observed in Chile during La Niña.

Seasonal precipitation in central Chile, El Niño–La Niña events, and the Southern Oscillation

Three representative stations were selected from central Chile: La Serena (30°S), Santiago (33°S), and Concepción (37°S). In the central zone, precipitation occurring during April–September represents more than 70% of the annual total. Precipitation totals (April–September) for every year of the period 1950–98 were correlated with (1) anomalies of the sea surface temperature (SST) observed in the area of El Niño 3—the central equatorial Pacific, whose coordinates are 5°N–5°S, 150°W–90°W; and (2) the Southern Oscillation Index (SOI), expressed in standardizing anomalies. The arithmetic averages of the anomalies observed between April and September in both SST and SOI were used in the correlation analysis. The results show a significant statistical relationship ($P < 0.05$) between winter precipitation (April–September) in central Chile and the El Niño–La Niña events and the Southern Oscillation.

Precipitation at Santiago's station responds well ($r = 0.64$) to changes in the thermal condition of the equatorial Pacific (Figure 2). The other two selected stations, although statistically significant, had lower correlation coefficients (Table 1). Precipitation in central Chile and the SOI are inversely correlated, and the highest value (r = 64) was obtained for Santiago (Figure 3). In other words, there is a statistically significant

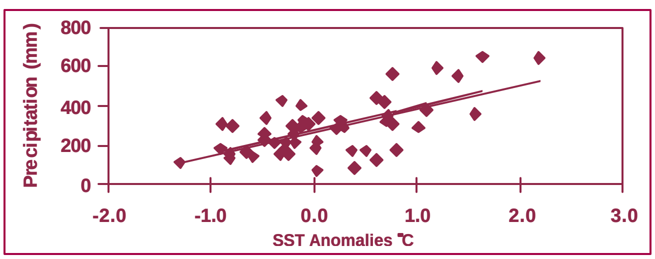

Figure 2. Precipitation for Santiago correlated with anomalies of the SST (Niño 3), April–September 1950–98.

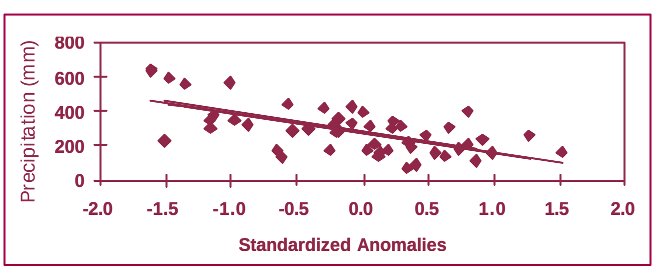

Figure 3. Precipitation for Santiago correlated with anomalies of the SOI, April–September 1950–98.

Station	Precipitation and SST	Precipitation and SOI
La Serena	0.54	-0.41
Santiago	0.64	-0.64
Concepción	0.31	-0.38

Table 1. Linear correlation of precipitation, SST, and SOI values.

phase between the amount of precipitation registered in central Chile and the atmospheric pressure (Tahiti–Darwin) defined by the SOI (Table 1).

In summary, in central Chile, precipitation between April and September correlates with the heating of the sea surface in the central equatorial Pacific (positive anomalies of Niño 3–SST) and the reduction in the surface pressures (negative SOI). When SST surpasses the average by more than 0.5°C and pressures decrease (-1.0 standard deviation), precipitation between La Serena and Concepción tends to increase. Actual precipitation is usually twice the climatologic value. However, if SST is 0.5°C or more below the average and the atmospheric pressure at the surface (SOI) is more than 1.0 standard deviation above average, significant precipitation deficits are more likely to occur during the rainy season. The close relationship between precipitation, SST, and SOI is demonstrated by the results of linear correlation, which reached their greatest magnitude for Santiago at 64% for SST and -64% for the SOI.

SST in the central equatorial Pacific, atmospheric pressure in Antofagasta, and rainfall in Santiago

The rain regime in central Chile in 1997 and 1998 shows sharp contrasts (Figure 4). In Santiago, precipitation in 1997 surpassed the climatological mean (312.5 mm) by 403 mm (positive anomaly). June was the rainiest month, with 188.6 mm above normal for the month. But during May–October 1998, a deficit or negative anomaly was registered—less than 234.1 mm below normal (286.4 mm). July 1998 was one of the driest months of the 20th century, with only 0.2 mm of rainfall (normal rainfall is 86.6 mm). This rainfall deficit persisted during 1999. Santiago displayed a negative anomaly of -117 mm below the cumulative normal value between January 1 and July 27, a deficit of more

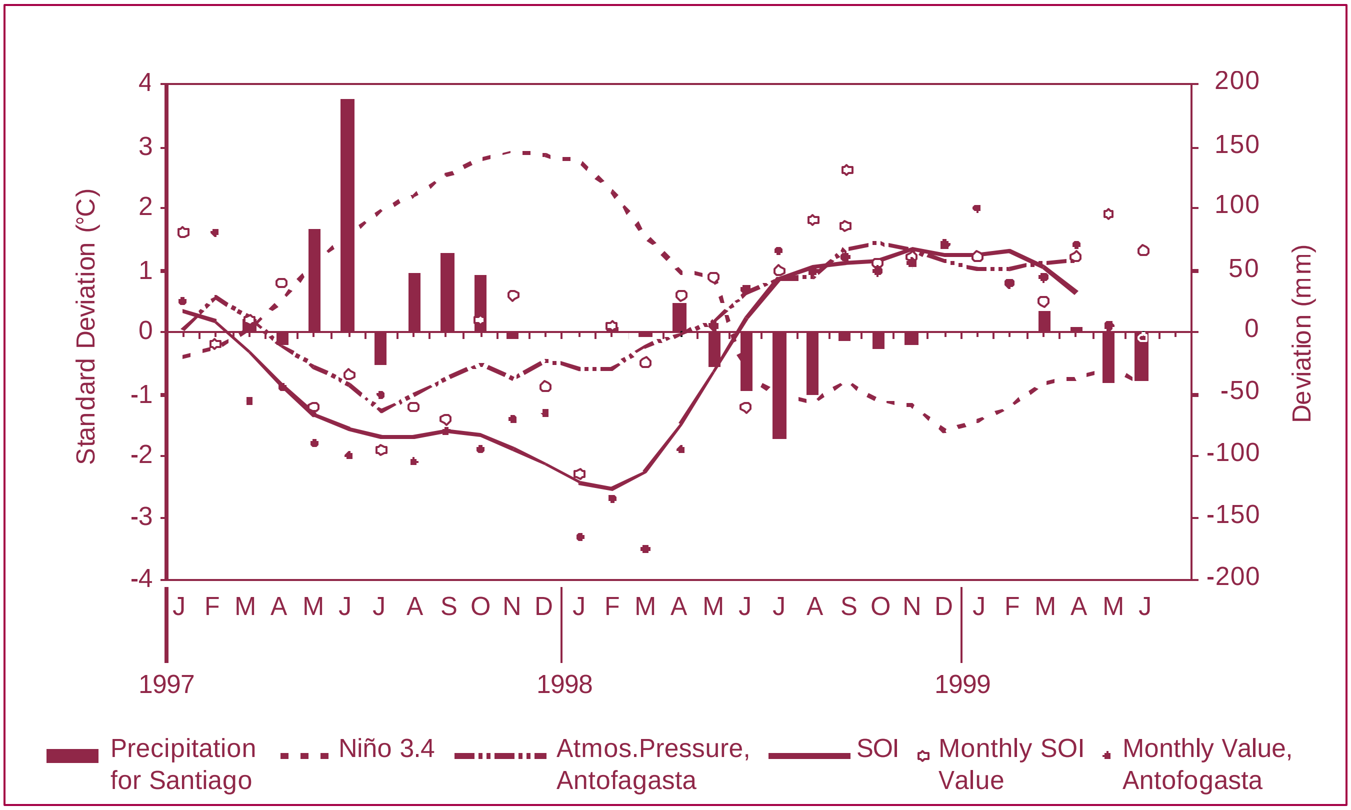

Figure 4. Sea surface temperature in the central equatorial Pacific, atmospheric pressure in Antofagasta, and precipitation in Santiago, January 1997–July 1999.

than 50%. The first half of winter 1999 was characterized by a low frequency of frontal systems in central Chile (30°S to 36°S), with precipitation below normal.

The standardized anomalies of the Southern Oscillation represent the atmospheric component of this cycle. In Chile, the most prominent of these anomalies are observed in the atmospheric pressure at sea level in Antofagasta (23°S), with negative anomalies during 1997 and positive anomalies in 1998, a product of the weakening and later intensification of the semipermanent anticyclone of the eastern South Pacific. The increase in precipitation during the rainy season (April–September) in 1997, and significant deficits in 1998 and part of 1999, are another clear signal.

Precipitation in Santiago during La Niña events

Between 1877 and 1999, twenty-six years show negative anomalies equal to or smaller than -0.5°C for three or more consecutive months in the central equatorial Pacific during April to September. These years are shown in Table 2, with their respective annual precipitation values for Santiago. The annual average precipitation in Santiago during La Niña years was 210 mm.

The analysis selected 25 years as El Niño years. For these years, Santiago had an annual mean of 494 mm. In 71 years considered as normal (an absence of La Niña or El Niño), the annual precipitation mean was 340 mm.

Figure 5 shows the histogram of relative frequencies of annual precipitation for Santiago for the period 1877–1998. The impact of La Niña on the annual cycle of precipitation in Santiago is clear, with a distri-

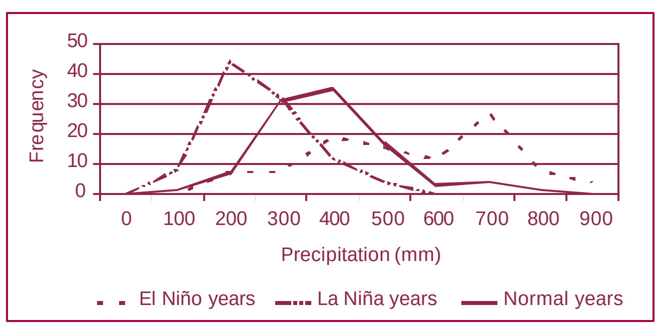

Figure 5. Relative frequencies of annual precipitation for Santiago, 1877–1998.

Year	Total (mm)	Year	Total (mm)
1879	166.0	1938	202.0
1886	126.0	1942	402.7
1889	230.0	1950	292.7
1890	222.0	1954	316.2
1892	123.0	1955	193.8
1893	238.0	1964	186.4
1903	194.0	1970	327.7
1908	202.0	1973	172.1
1909	184.0	1975	184.3
1910	270.0	1985	186.2
1916	225.3	1988	139.6
1924	66.3	1998	89.7
1933	316.4		

Table 2. Precipitation in Santiago during La Niña years during the period 1877–1999.

bution centered on the 200 mm annual precipitation and a frequency of 43%. For El Niño years, the annual distribution of precipitation in Santiago shows a greater variability (700 mm) and a smaller frequency (28%).

La Niña 1998/99's impact on Chile's precipitation

The rapid change of SSTs in the equatorial Pacific altered atmospheric circulation patterns worldwide. Conditions went from very warm in the first months of 1998 (January–April)—associated with El Niño—to a characteristic cold condition of La Niña during the second quarter of 1998. In Chile, the subtropical high was an almost permanent feature that reached 40°S to 45°S during May and July 1998, reducing precipitation during the rainy season in the central part of the country in both 1998 and 1999.

The atmospheric blocking observed during most of the period between May 1998 and July 1999 prevented the normal displacement and development of frontal systems in central and northern Chile. This blocking caused the driest year of the 20th century between 30°S and 36°S. Between 37°S and 45°S, the precipitation deficit reached 30–50%. Only the austral region (Punta Arenas) had a surplus (near 40%).

During the first half of 1999, meteorological conditions in Chile were similar to those of the previous year, with a precipitation deficit in almost the entire country, but of a lesser magnitude than in 1998. Up to July

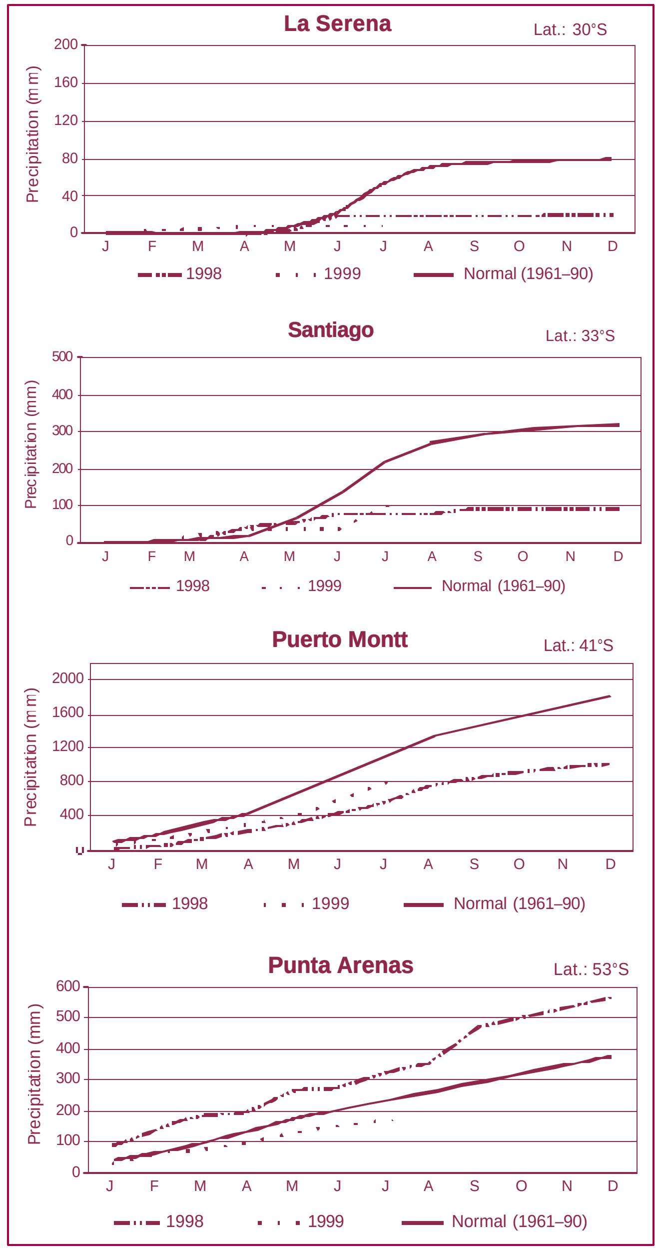

Figure 6. Accumulated precipitation for 1998 and 1999, compared to the normal, for four locations in Chile.

1999, the region with the greatest deficits was the central zone, from 36°S to the north, with values oscillating between 0% and 80% lower than average. Figure 6 shows accumulated precipitation for 1998 and 1999 versus the climatologic value for four locations in Chile.

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