Temperature and Precipitation Changes at La Palma, Canary Islands (1971-2000)

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1. Introduction

La Palma is the western-most of the Canary Islands located at a latitude of 26.8N and 17.9W, about 400km off the Moroccan coast of north-west Africa. Its oceanic location ensures that it has a mild and equitable climate throughout the year, with little extremes of temperature between summer and winter. The proximity of the semi-permanent Azores high pressure system means that the usual weather conditions are typically stable and dry, due to a prevalent subsidence inversion layer frequently found at an altitude of around 600-1500 metres (La Palma itself reaches up to 2,400 metres in altitude, well above the inversion). However, rainy conditions can develop when a break in the inversion layer occurs or the synoptic meteorological conditions weaken the Azores high. The island`s steep orography also causes considerable local variation in precipitation.

The prevailing wind in the Canaries is from the north or north-west, and as it flows across the cool Canaries sea current, mist and low-cloud often develops and laps onto north-facing coasts. The top of this low-cloud is usually coincident with the subsidence inversion layer of Azores high, meaning that higher altitude areas can often have increased amounts of sunshine and clearer skies than in northern coastal locations. South facing coasts also have more clear skies than in the north, due to the break-up of the low-cloud layer in the lee of the steep orography. A large drop in absolute humidity also occurs above subsidence layer, meaning that visibility conditions also improve with height. Very occasionally, visibility is reduced on a more widespread scale by large dust storm clouds moving east from the Saharan interior, which also brings the hottest weather.

2. Temperature

The mean annual air temperature at La Palma for the period from 1971-2000 is 20.3C with a mean daily range of temperature of just 4.9C around this mean. However, looking closely at figure 1, we can see that some marked variability in mean annual temperatures has occurred during the 30-yr period from 1971-2000. A rise of about +1.0C occurred during early 1970s, after which the mean annual temperature stayed more or less steady until 1987 (it is difficult to conclude at this stage what might have caused this initial temperature rise). Another jump of about +0.5C occurs between 1987-1992, followed by a rapid drop during 1993 and 1994 to below 20.0C (1994 being the coolest year during the entire record at 19.4C, apart from 1971/1972). This large drop may appear somewhat surprising at first, especially considering the fact that global temperatures have been rising rapidly during the 1990s. However, a quick glance at figure 3 confirms that the probable cause of this significant drop in temperature was due to a marked increase in the frequency of positive North Atlantic Oscillation (NAO) indices during the period 1992-1996. Temperatures recover again to rather warm values during the late 1990s, as the influence of positive NAO indices wanes (the NAO represents the normalised mean difference in pressure between Iceland and the Azores. Thus, increased positive values indicate enhanced zonal (westerly) flow, whereas negative values indicate more blocking or anomalous meridonial flow). Meanwhile, superimposed on all of these changes may be a global warming trend, with a simple linear regression model indicating a rise of about 0.9C over 30 years, although the R^2 coefficient is low (0.26). Incidentally, this warming rate is 4 times the global average during the 20th century (0.7C over 100 years).

3. Precipitation

La Palma is the wettest of the Canary islands, with mean annual precipitation (MAP) values approaching 1000mm in the wetter mountainous districts. At the weather station however, the MAP is just 351.5mm for the period 1971-2000. Precipitation is also highly variable throughout the thirty year period, varying from a maximum of 732.0mm in 1999 to as low as only 94.6mm in 1994 (see figure 2). Typically, however, annual precipitation is in the range 200mm to 400mm. Most of the precipitation falls during the winter-half of the year from October-April, with the summer months being dry everywhere. Over the thirty year period analysed, a simple regression line suggests that there has been little general increase or decrease in the absolute amount of precipitation each year, although the linear

regression coefficient is extremely poor (R^2 = 0.001). Instead, the precipitation regime at La Palma is probably acting in response to stronger outside or cyclical variables, such as the NAO, which may be varying on scales of several years to decades in length (see below).

4. Discussion

Puyol et al (2002) show that precipitation in the Canary Islands is strongly correlated with negative NAO indices during the period 1955 to 1998. They also show that there is a slight correlation between precipitation and positive El Nino / Southern Oscillation (ENSO) indices on a few of the Canary Islands during particular synoptic precipitation regimes (but unfortunately not at La Palma). In this study, we also found significant negative correlations between the NAO and La Palma precipitation during the precipitation months of October, November and January (see table 1(a) below). When the data is smoothed using 5-year running averages of both datasets, the respective coefficients for October, November and January become highly significant. This is best displayed during January, where the correlation coefficient is as high as -0.91 (see table 1(b) and figure 3(b); January is often the month when the NAO is most conspicuous). It is not absolutely clear why the remaining precipitation months of September, December, February, March and April have much lower correlation values, although it is possible extreme wet or dry "outlier" months may be influencing the statistical analysis procedure in these cases.

Table 1: The linear correlation coefficients between (a) monthly precipitation values at La Palma and the same month`s NAO index for the period 1971-2000, and (b) the same data, but using 5-year running averages

Month	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
(a) Correlation Coefficient between monthly precipitation at La Palma and the NAO	-0.23	-0.49	-0.39	0.06	-0.51	-0.17	-0.14	0.09
(b) same as above, but using 5-yr running means	0.55	-0.53	-0.71	0.15	-0.91	-0.14	0.44	-0.54

With regards to temperature, it is worth noting that the warmest year of the period was 1987 with a mean annual temperature of 21.3C. Interestingly, this was also the 2nd wettest year with a total of 682.6mm of precipitation. In addition, the marked drop in temperatures between 1992-1994 also coincides with some notably dry years (1994 was the driest year with only 94.6mm).

Also, 5-yr running mean of standard deviations show significantly greater variabilities in standard deviation since 1987 in both the temperature and precipitation parameters (figures 1 and 2). This suggests that some sort of fundamental change in climate occurred around 1987. Such a "step-change" is confirmed by figure 3(a), which shows a marked increase in NAO index variability from approximately 1987 onwards, with very high values during the early 1990s, and much lower ones during the late 1980s and late 1990s. Thus, we can conclude that negative NAO indices usually mean wetter conditions, whilst a positive index can lead to cooler and drier years. It is also worth noting that recent articles by Langenberg (2000) and Palmer & Raisanen (2002) both conclude that increasing greenhouse gas concentrations during the 21st century will result in an increased frequency of wetter, warmer winters across Europe (due to an increase in positive NAO conditions), which would undoubtably have both a temperature and precipitation effect on the Canary islands.

5. Conclusions

Temperatures have increased at La Palma by almost 1.0C over the past 30 years, although there is considerable variability over periods of several years or more. The coolest years occur during spells of highly positive NAO indices and vice versa.

Annual precipitation has been highly variable during the 30-yr period also, but there is no long term trend towards drier or wetter conditions. Some very dry years during the 1990s coincided with strongly positive phases of the NAO. Similarly, monthly precipitation totals show strong negative correlation with the NAO, especially in January. There appears to have been a notable increase in the variability of annual precipitation from year-to-year since about 1987, coinciding with a similar increase in the variability of NAO index.

6. References

Langenberg, H. (2000), Meteorology: Oscillating Phenomenon, Nature, 408, 924-925.

Palmer, T.N., and Raisanen, J. (2002), Quantifying the risk of extreme seasonal precipitation events in a changing climate, Nature, 415, 512-514.

Puyol, D.G, Herrera, R.G., Martin, E.H., Presa, L.G., Rodriguez, P.R. (2002), Major influences on precipitation in the Canary Islands, in M. Beniston (ed.), Climatic Change: Implications for the Hydrological Cycle and for Water Management, 57-73, Kluwer Academic Publishers.

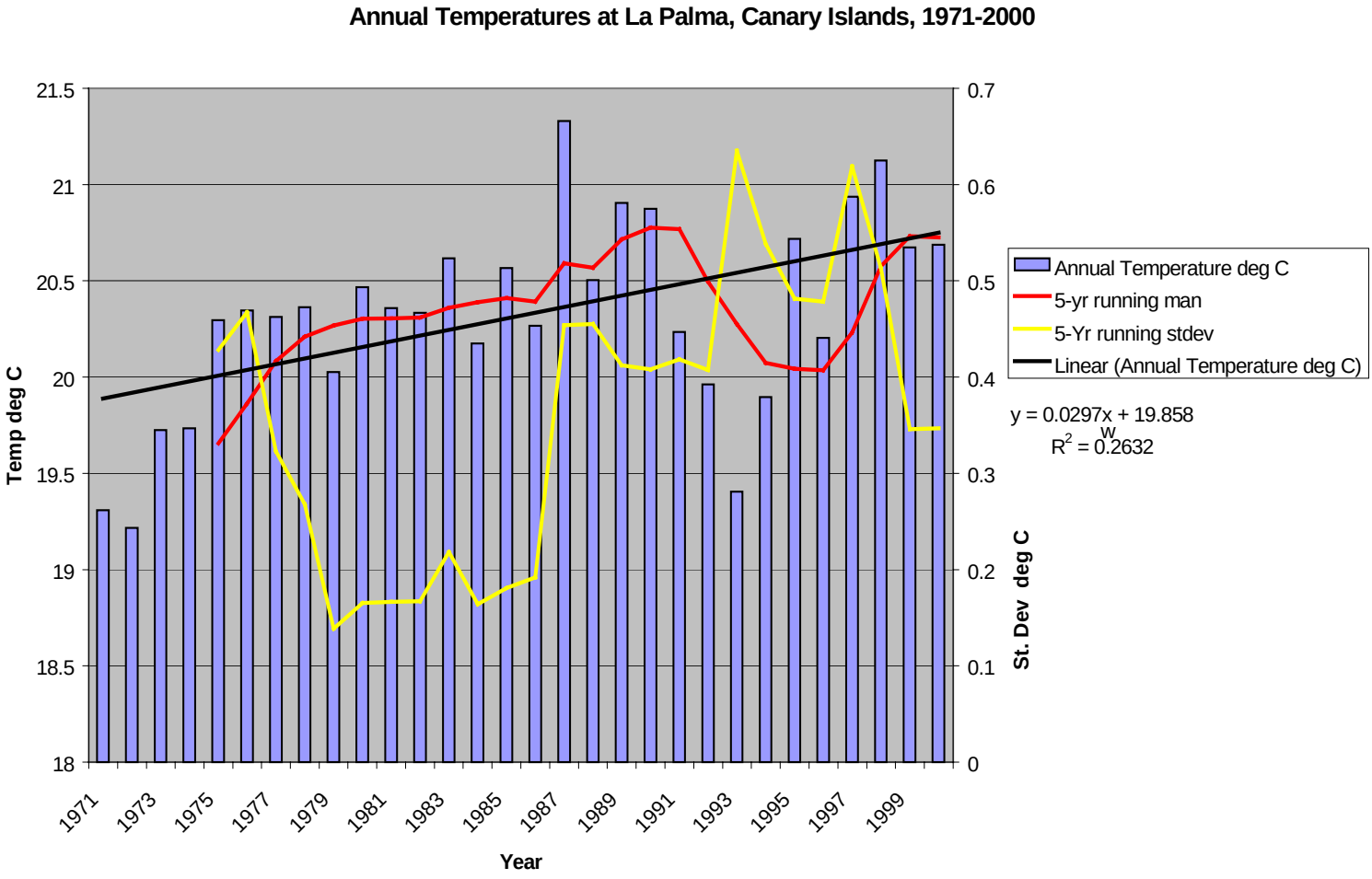
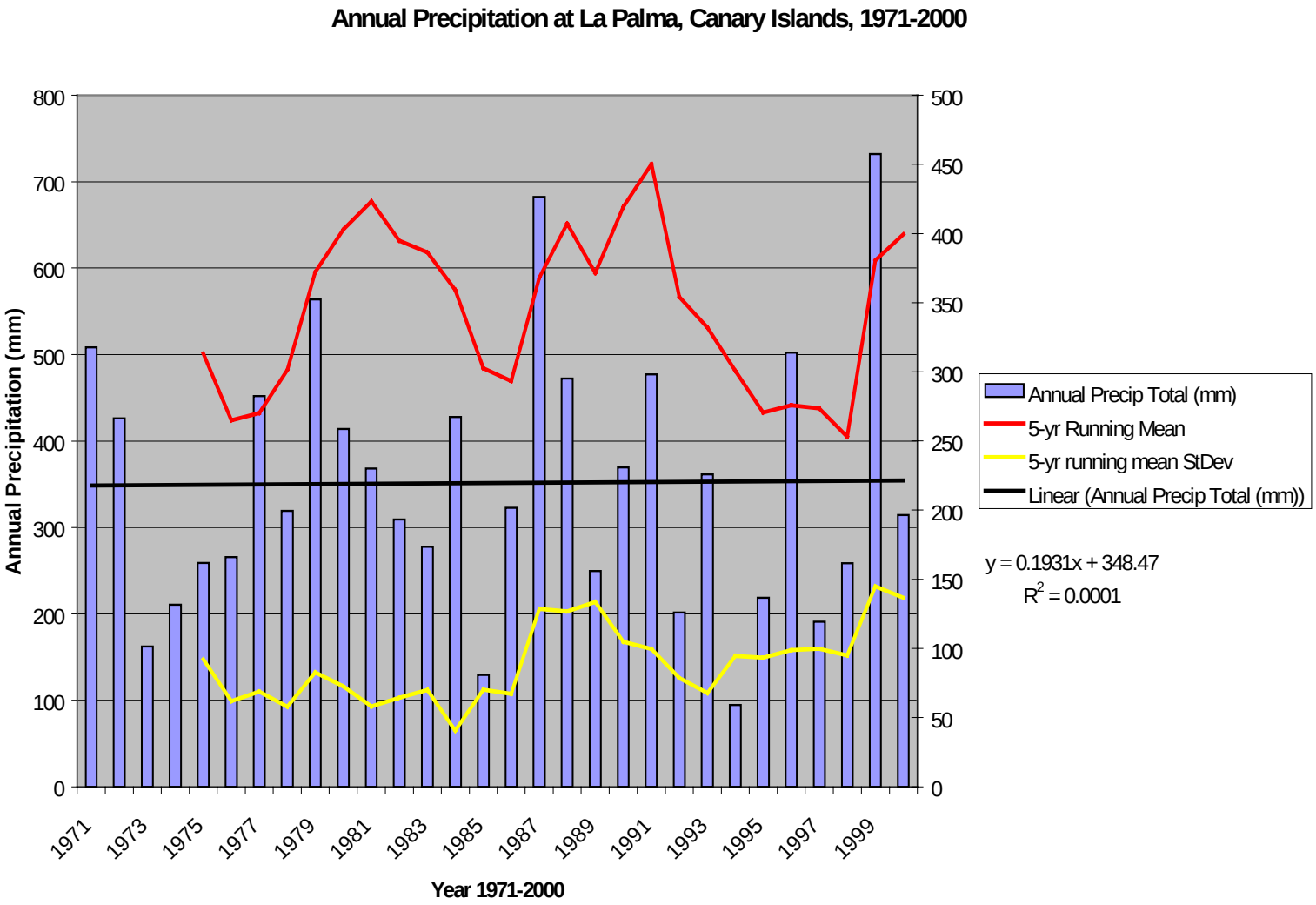


Figure 1: Annual temperatures in degrees Celsius (bar-graph) at La Palma, Canary Islands from 1971-2000. Also shown is the 5-yr running mean temperature (smooth red-line). The straight black line represents the best linear fit to the data, with a positive slope (temperature increase) of about 0.3 deg C per decade. The jagged yellow line is a plot of the 5-yr running mean of standard deviation in temperature, thus showing a much greater variability in temperatures since about 1987.

Figure 2: Annual precipitation in millimetres (bar-graph) at La Palma, Canary Islands from 1971-2000. Also shown is the 5-yr running mean precipitation (smooth red-line). The straight black line is the best linear fit to the data, but it represents a very poor fit. The jagged yellow line is a plot of the 5-yr running mean of standard deviation in precipitation, thus showing the a slighter greater variability in precipitation since about 1987.



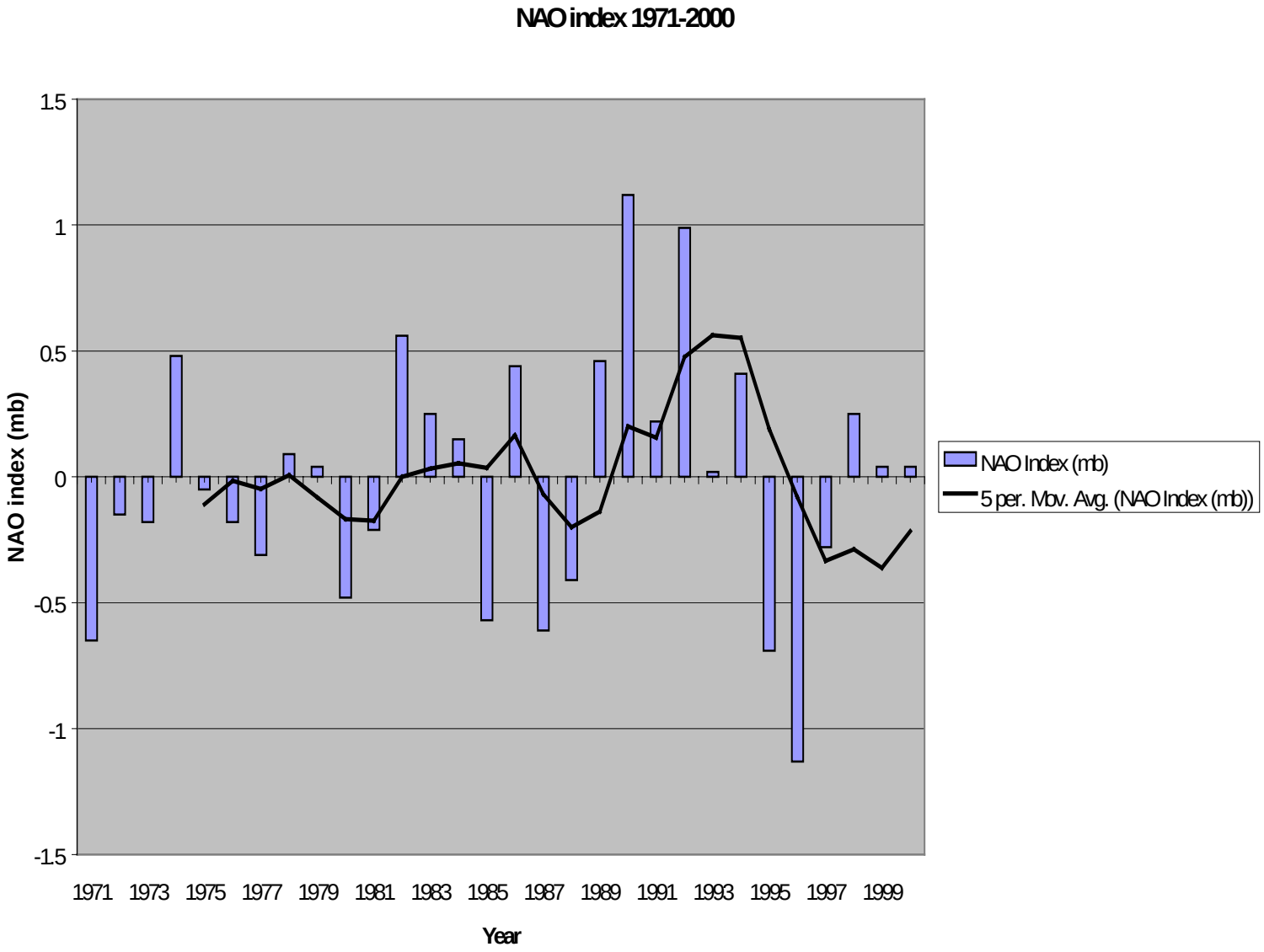


Figure 3(a): The North Atlantic Oscillation (NAO) index for each year from 1971-2000, in millibars. Also shown is the 5-yr moving average (smooth black-line). Note the much greater variability since about 1987, and the period of significantly enhanced positive NAO activity during the early 1990s, which may be linked to lower temperatures (figure 1) and drier years (figure 2) during the same period.

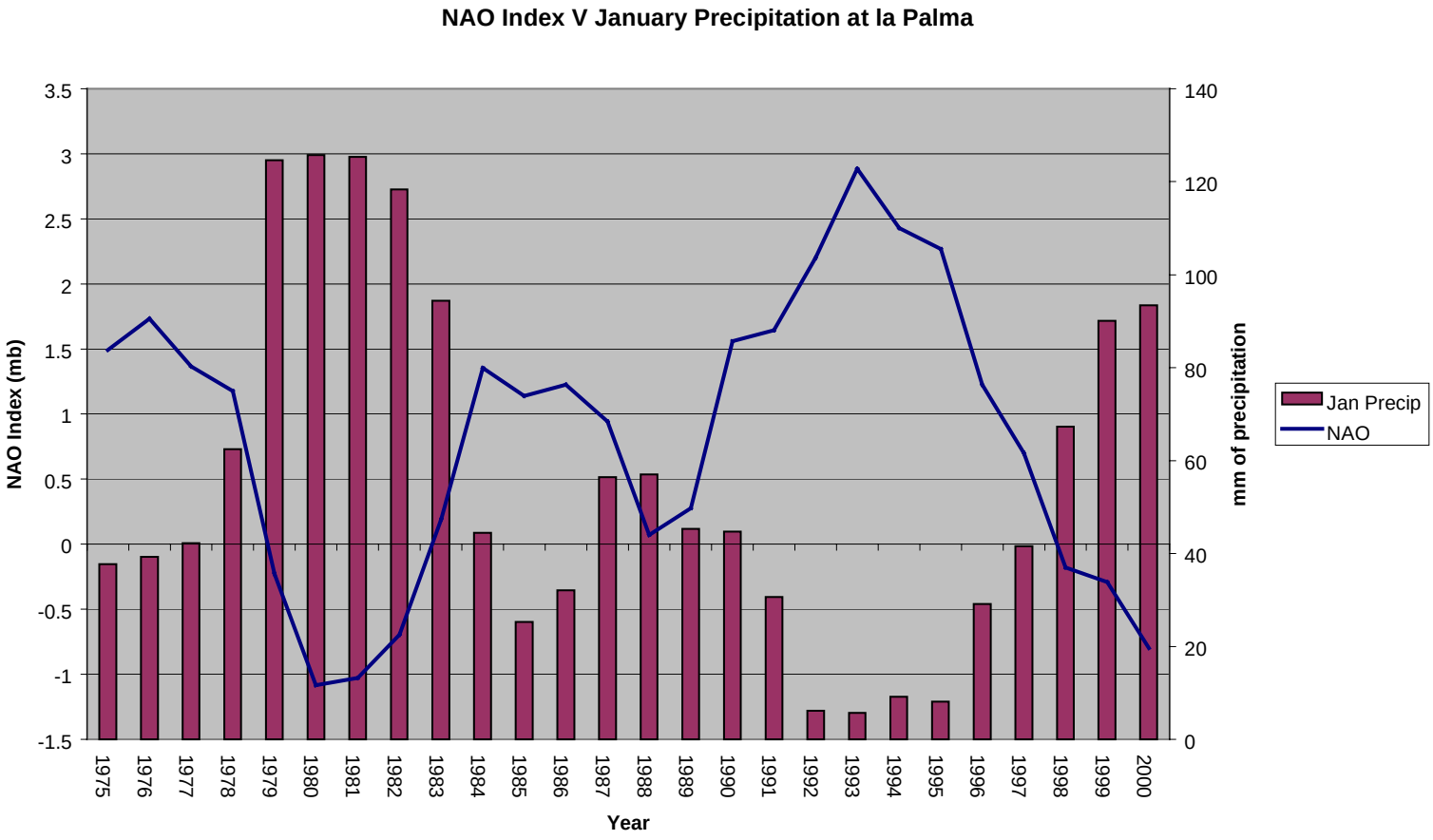


Figure 3(b): The 5-yr moving average of the North Atlantic Oscillation (NAO) index for January from 1971-2000 is shown by the smooth black line. Also shown is the 5-yr moving average (bar graph) of January precipitation for the same period. Note the very strong correlation between positive NAO indices and drier Januarys at La Palma, and vice versa.