# Chapter 11
# Climatology of Rapa Nui (Isla de Pascua, Easter Island)

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## 1 Introduction

Rapa Nui (Isla de Pascua, Easter Island) is one of the most remote of the Polynesian islands, lying ~3700 km west northwest of Santiago, Chile, and 2000 km from the nearest inhabited island (Pitcairn) to the west. It is most famous for its iconic statues (moai) that were carved from local volcanic rock by the first settlers on the island who arrived in the twelfth century AD (radiocarbon dating of the initial colonization of Rapa Nui is in the range 1150–1290 cal. AD; Di Napoli et al. 2020). Much has been written about the cultural history of the island, and of the ecological changes that occurred over the following centuries, and these accounts offer widely different interpretations (e.g. Flenley and Bahn 2003; Diamond 2005; Hunt 2007; Rull et

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al. 2018; Rull 2020). Some argue that climate change was an important factor in causing the ecological (and subsequent societal) changes, while others point to the paramount importance of cultural and socio-economic factors. However, current evidence indicates that despite major changes in natural vegetation that followed the arrival of people, the population managed to maintain sufficient agricultural production for their needs. A shift toward drier conditions may have played a role in the cultural upheaval that occurred in the sixteenth to seventeenth centuries (Mann et al. 2008; Rull 2020), but it was the arrival of Europeans in the eighteenth century that brought really catastrophic changes to the island, through the introduction of infectious diseases and the transfer of many indigenous people to South America as slaves.

Despite considerable interest in the past climate of Rapa Nui (Rull 2021), very little attention has been paid to the modern climate of the island. Climate variability is of particular importance to Rapa Nui today, because of the tremendous increase in pressure from tourism. The island is only ~164 $km^2$ in area (about three times the size of Manhattan, New York); the resident population is ~7750 (in 2017) but more than 100,000 tourists visit the island annually, greatly increasing the demand for water, power and local agricultural products. Here, we review the climatology of Rapa Nui, with a particular focus on interannual variability and recent changes in rainfall that have had dramatic effects on the hydrology of the island.

## 2 Large-Scale Circulation

Rapa Nui is situated on the western flank of the Southeastern Pacific sub-tropical high-pressure system (STHP), which defines the descending limb of the southern hemisphere Hadley cell (Chen et al. 2014) (Fig. 11.1). However, the South Pacific Convergence Zone (SPCZ) to the west of Rapa Nui controls moisture flux to the island, as seen in total column precipitable water vapor (Fig. 11.2).

Seasonal variations in the strength and position of the STHP and SPCZ greatly affect rainfall totals in Rapa Nui (Steiger et al. 2022). The island is situated close to the boundary, at which annual evaporation exceeds precipitation, and hence it is sensitive to slight changes in the position of the major circulation features, the SPCZ and the STHP (Fig. 11.3). For example, the eastern Pacific Hadley cell tends to be stronger during El Niño years, which may result in drier conditions on Rapa Nui, though overall there is no significant long-term correlation between rainfall and the phase of ENSO.

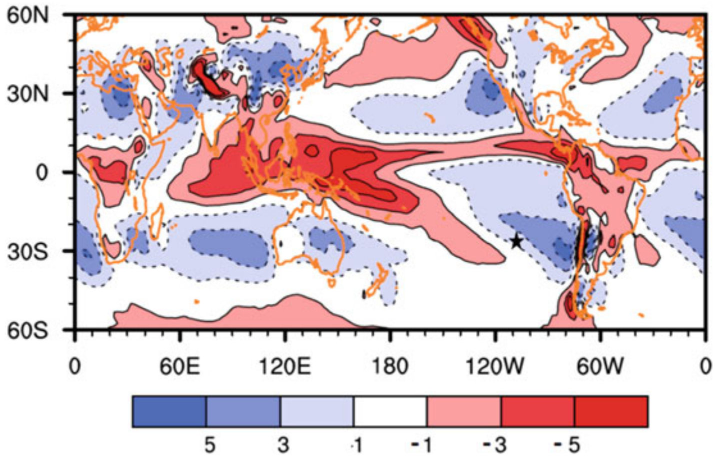


**Fig. 11.1** Mean annual 500 hPa vertical velocity (Pa•s$^{-1}$). Negative values (red) indicate ascending motion. Location of Rapa Nui shown by the red star (from Chen et al. 2014)

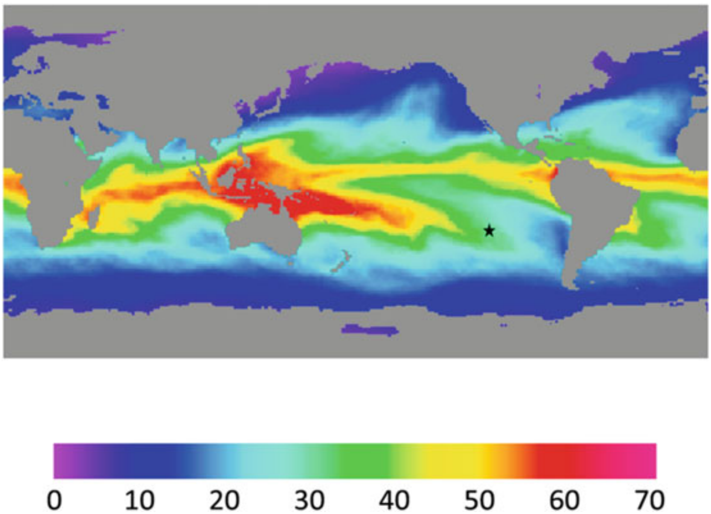


**Fig. 11.2** Mean monthly total precipitable water vapor (kg m$^{-2}$) for 2009. Rapa Nui denoted by the black star. Multi-satellite data from HOAPS (Hamburg Ocean Atmosphere Parameters and Fluxes from Satellite) (Mears et al. 2018)

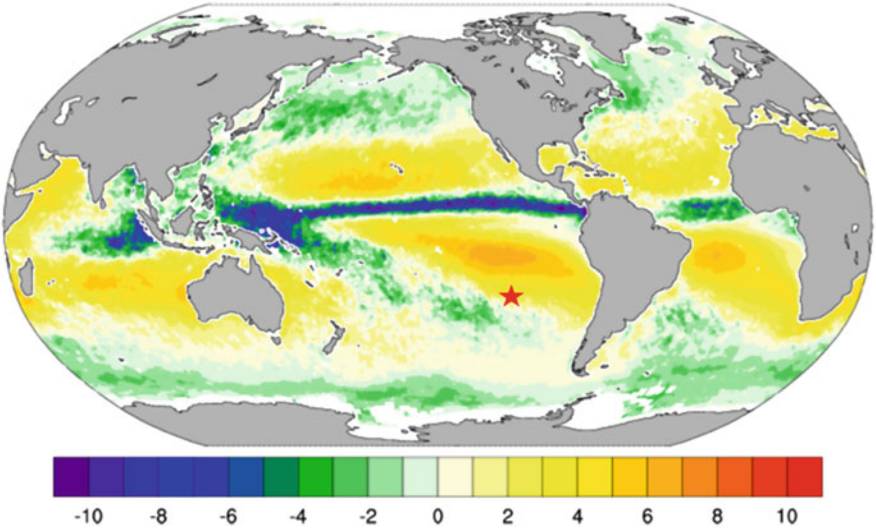


**Fig. 11.3** Evaporation minus precipitation (in mm day$^{-1}$) for 2005, based on HOAPS-3 data (Hamburg Ocean Atmosphere Parameters and Fluxes from Satellite). Variables are derived from SSM/I passive microwave radiometers

## 3 The Climate of Rapa Nui

Meteorological observations have been recorded in Mataveri (27.1606°S, 109.427°W; 48 m above sea level) since 1955 (for rainfall) and 1970 (for temperature). Figure 11.4 shows daily mean temperatures and daily rainfall totals. Because of the oceanic setting of Rapa Nui, the mean annual temperature has a small seasonal range (~6 °C), from ~24 °C in mid-February to ~18 °C in late July and August.

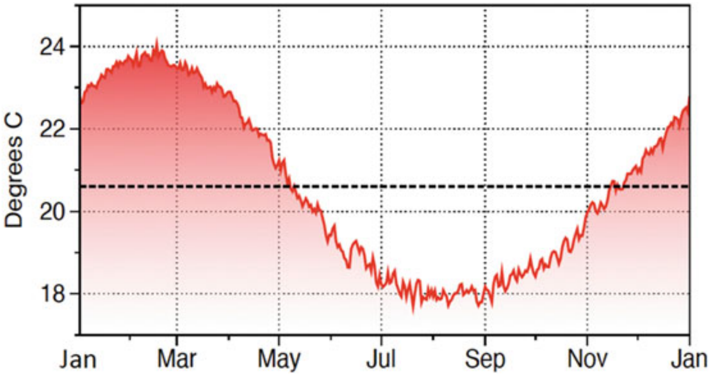


**Fig. 11.4** Mean daily temperature at Mataveri, Rapa Nui (27.16° S, 109.43° W) from 1970–2020. Black dashed line is mean annual temperature

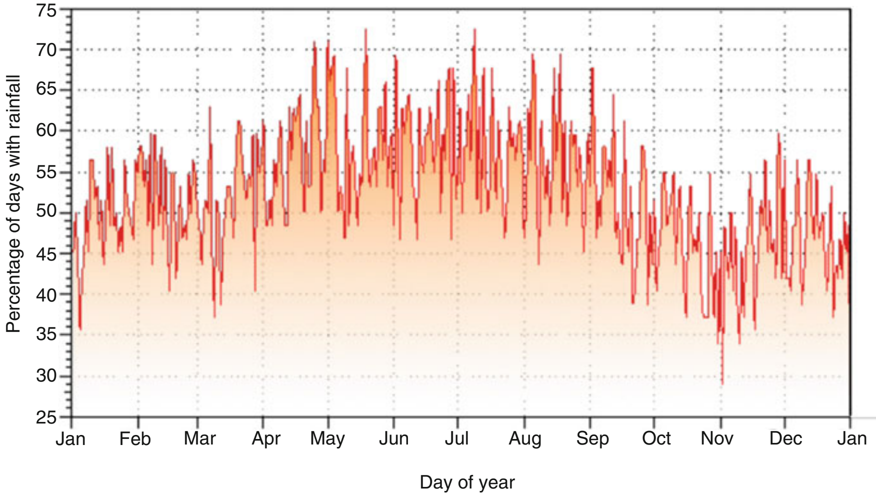


**Fig. 11.5** Percentage of days recording rainfall (mean/median = 52; max = 73; min = 27)

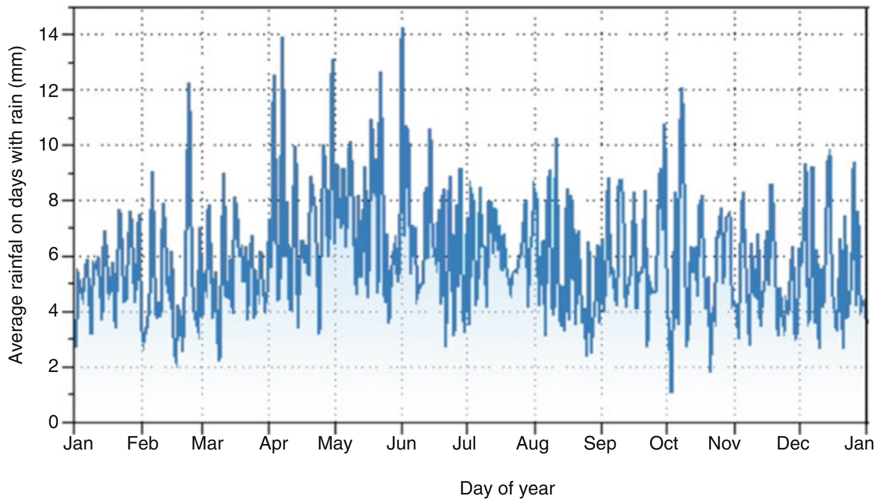


**Fig. 11.6** Mean daily rainfall amount on days with rain (June 1954 to June 2018). Rainfall totals averaged ~1109 mm per year (1955–2019); 42% of annual rainfall is recorded in the months of April–July

Rainfall is quite common, and the probability of it raining on any day of the year is 52%, with maximum probabilities from April to August (Fig. 11.5). Of course, that does not mean rainfall occurs continuously on rainy days; using satellite data, Trenberth and Zhang (2018) estimate that, on average, in the region of Rapa Nui it rains for just a few hours on those days, reflecting the convective nature of most rainfall events. Daily totals on rainy days, are generally low (Fig. 11.6;

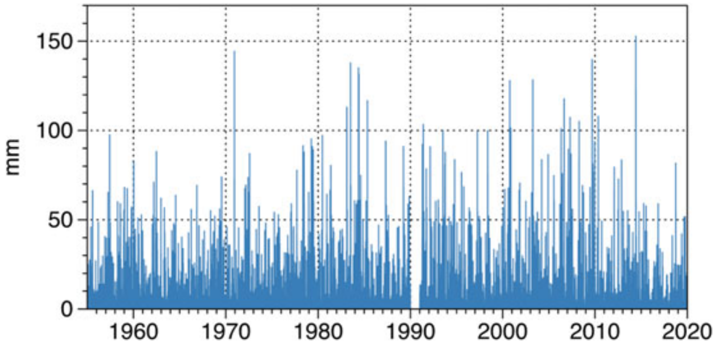


**Fig. 11.7** Daily total rainfall amounts (mm) since 1955; data were not recorded in 1990

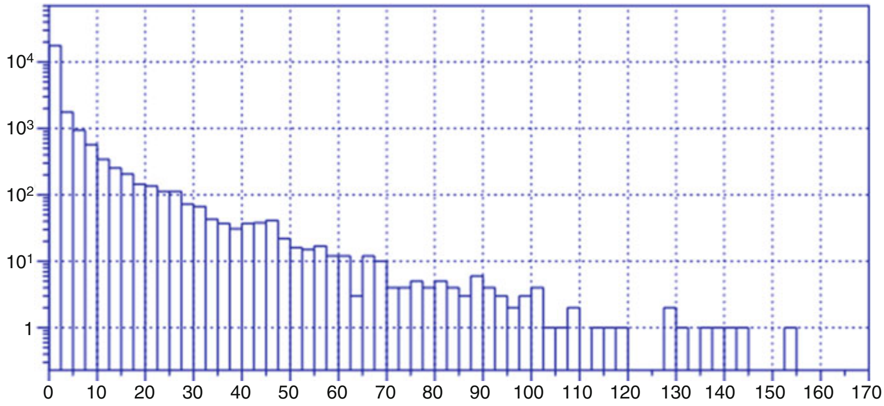


**Fig. 11.8** Histogram of daily rainfall amounts (log scale on y-axis); max daily amount: 153 mm

median = 5.9 mm) with highest daily rainfall totals from early April to mid-June; the maximum daily rainfall amount ever recorded was 153 mm on June 3, 2014, accounting for 15% of that year's annual total rainfall, but in general daily rainfall totals in excess of 100 mm are quite rare (Figs. 11.7 and 11.8). An examination of the rainfall distribution in wet years compared to dry years shows that the difference is mainly due to a higher frequency of occasional days with particularly heavy rainfall (Steiger et al. 2022). For example, in the wettest year on record (1979: 1928 mm of annual rainfall) there were 15 days with daily rainfall amounts >25 mm compared to only 2 days in 2017 (which had only 662 mm in total, the second driest year on record) (Fig. 11.9). Back trajectory air mass analysis for anomalously wet and dry years shows very little difference in the source of moisture, with the prevailing trajectory from the southern Pacific Ocean to the southwest of Rapa Nui bringing moisture to the island (Fig. 11.10).

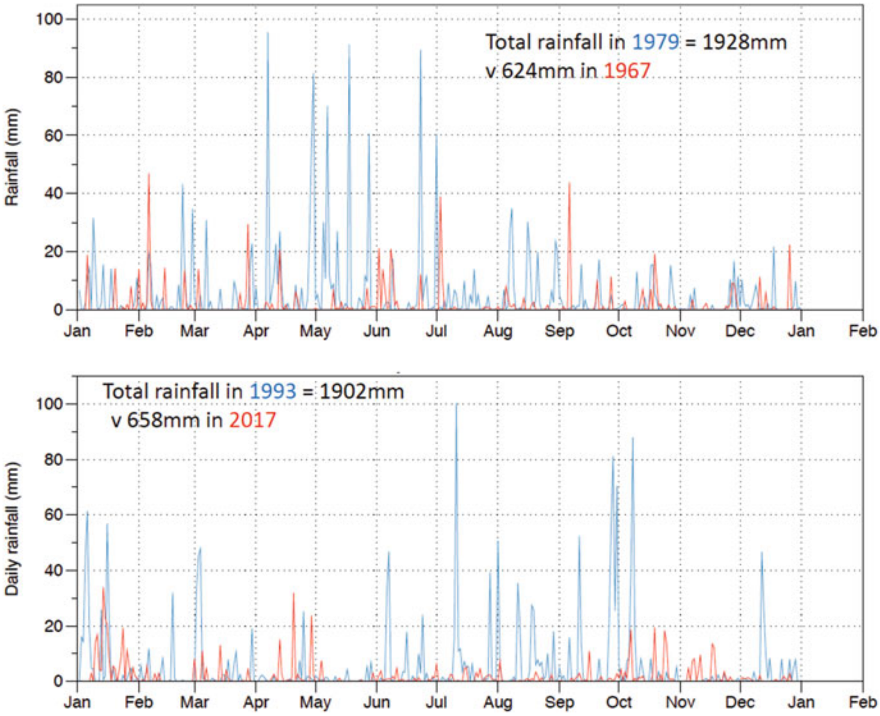


**Fig. 11.9** Daily rainfall distributions in the two wettest years, 1979 and 1993 (blue), compared to two of the driest years, 1967 and 2017 (red)

## 4 Interannual Variations

Over the past 50 years, mean annual temperatures have varied little from year to year (with an overall range of <2 °C) but temperatures were consistently below average for most of the 1980s and 1990s, and have generally been above average since then (Fig. 11.11). There is a slight tendency for days with high amounts of rainfall to be cooler than average. Seasonal temperatures tend to be lower and rainfall amounts higher during El Niño events (indicated by a positive value of the Multivariate ENSO Index, MEI) and the reverse during La Niña events (Negative MEI), but the relationship is inconsistent and not statistically significant (Figs. 11.12 and 11.13) (cf. Genz and Hunt 2003). This reflects the fact that Rapa Nui is located between the regions where, *on average*, air temperatures are positively correlated with ENSO, and the area where the correlation is negative (Fig. 11.14). In any given year, a slight shift in the circulation will likely determine if there is a positive or negative effect from ENSO on temperature, and so overall the pattern is not consistent.

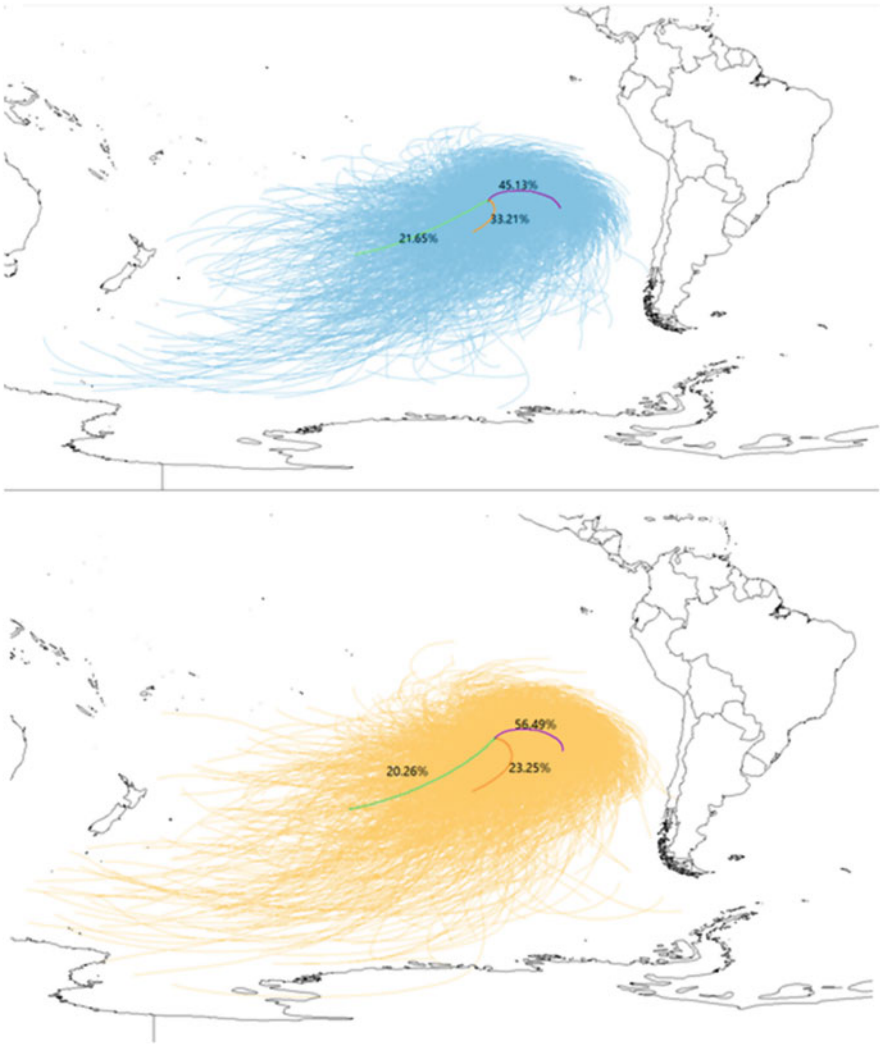


**Fig. 11.10** Annual air parcel back-trajectory (96 h) composites for anomalously wet (upper panel) and dry (lower panel) years. Wet years (>1 standard deviation above the mean): 1959, 1962, 1972, 1979, 1983, 1984, 1993, 2000, 2007, 2009. Dry years (>1 standard deviation below the mean): 1956, 1961, 1965, 1966, 1967, 1971, 2010, 2011, 2016, 2017

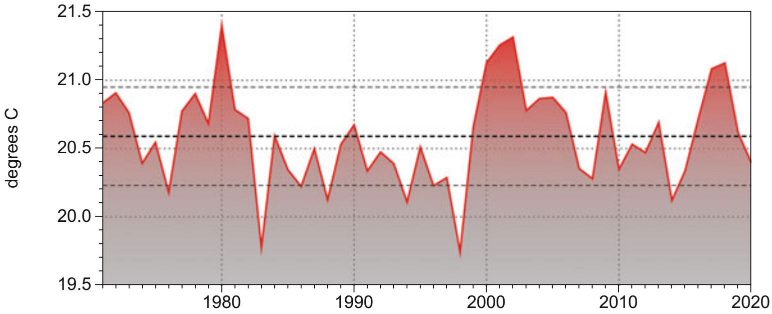


**Fig. 11.11** Mean annual temperature at Mataveri, Rapa Nui for the period 1971–2019. The black dashed lines indicate the mean temperature (20.6 °C) ±1 standard deviation (0.36 °C)

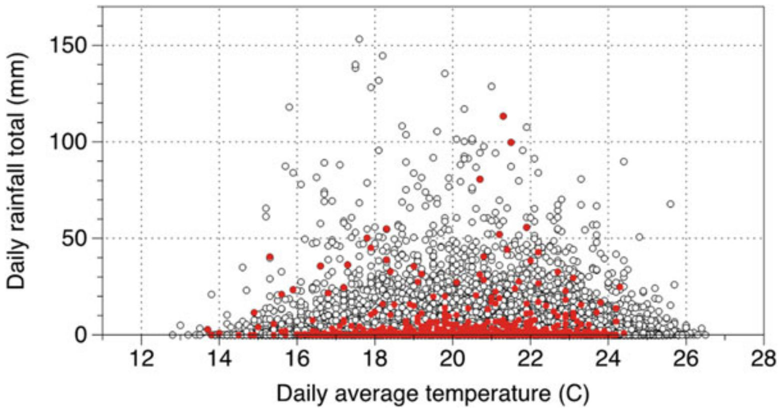


**Fig. 11.12** Daily rainfall amounts versus daily temperatures (1971–2018). Red dots indicate rainfall during the years of 1982–1983 (April–March) and 1997–1998 (April–March, which were both strong El Niño events

Rainfall was above average from ~1977 to 2009 but has been consistently below the long-term mean since then. This period of persistently low rainfall over the last decade is unique in the entire instrumental record (Fig. 11.15) and has shifted the water balance of one of the few lakes on the island (Rano Raraku) to the point, where it is currently almost dry (Fig. 11.16). Annual festivities at this crater lake used to include swimming races on reed mats, but that would be impossible today as the lake has very little water left in it. The decline in water level is not the result of increased water use but of the persistent decline in annual rainfall.

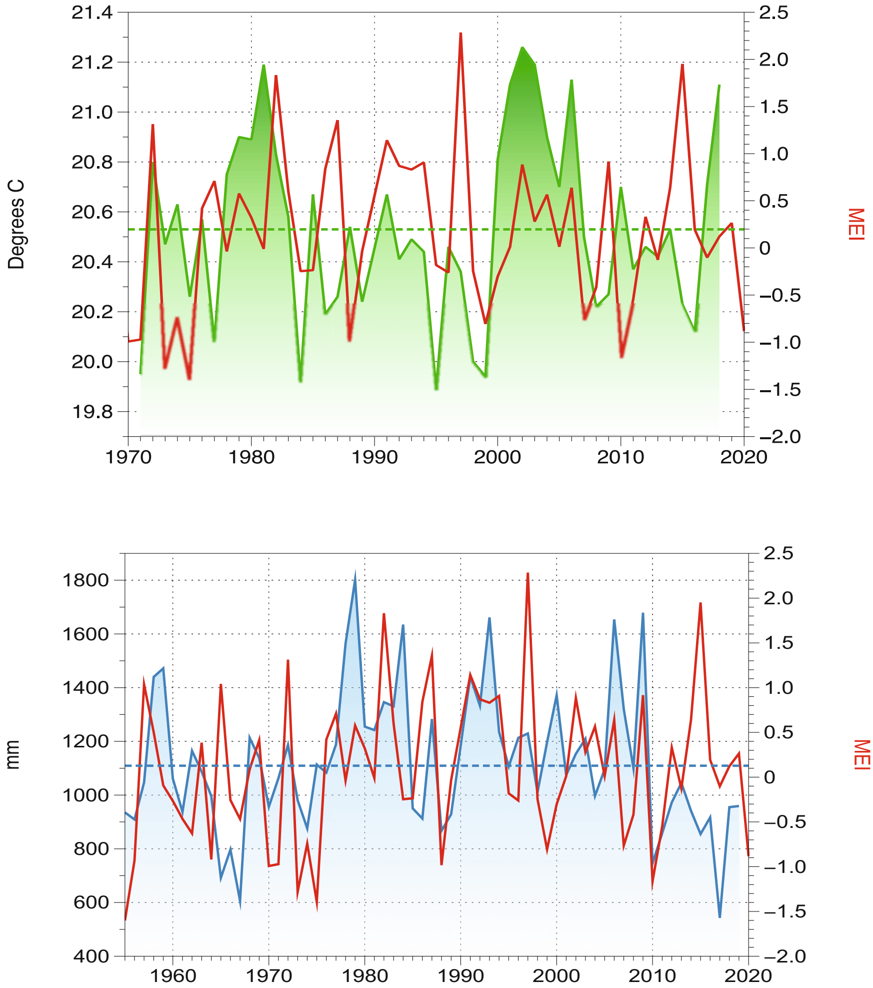


**Fig. 11.13** Multi-ENSO index (red) averaged from April–March, compared to April–March annual temperature, 1971–1972 to 2018–2019 (green, above) and annual precipitation totals, 1955–1956 to 2019–2020 (blue, below). The correlation coefficients between the MEI and rainfall, and MEI and temperature are 0.12, and 0.15, respectively (not significant)

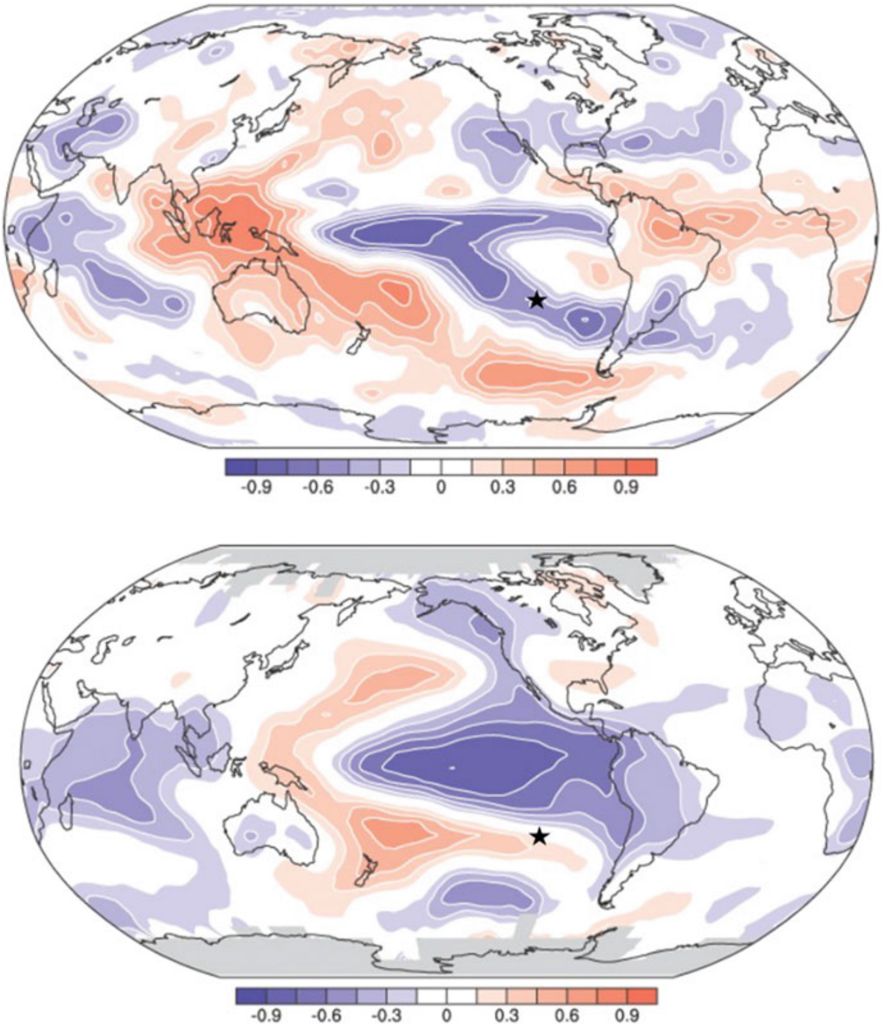


**Fig. 11.14** Correlations with the Southern Oscillation Index (SOI) (based on normalized Tahiti minus Darwin sea level pressures), for annual (May to April) surface temperature averages (bottom) for 1958–2004, and GPCP precipitation amounts for 1979–2003 (top). Location of Rapa Nui indicated by a black star (from Trenberth et al. 2007). Negative values of the SOI correspond to El Niño events (positive values of the MEI in Fig. 11.13). Almost identical patterns are found with other indices such as the Multivariate ENSO Index (MEI), and the Tripole Index for the Interdecadal Pacific Oscillation (see Garreaud et al. 2009; Henley et al. 2015)

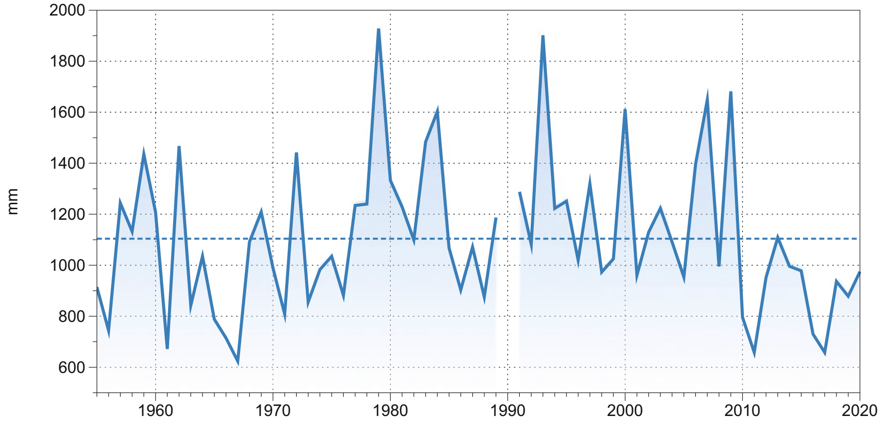


**Fig. 11.15** Annual rainfall totals, 1955–2020 (dashed line = long-term average [1104 mm]; median = 1067 mm). Mean annual temperature and rainfall totals are not significantly correlated (r = 0.08). Rainfall has been well below the long-term mean since 2010

There is little evidence that decadal variability of Pacific circulation patterns, such as the Pacific Decadal Oscillation (PDO) and related indices, can account for the changes in rainfall on Rapa Nui. As with ENSO, Rapa Nui is located at the boundary between areas that are strongly linked to such oscillations (Fig. 11.17) and long-term changes in the PDO cannot explain the remarkable decline in rainfall over the past decade (Fig. 11.18). However, this decline may be linked to large-scale changes in atmospheric conditions in the western Equatorial Pacific: as the Warm Pool in that area has expanded, rainfall along the South Pacific Convergence Zone has increased, but east of that convergence, rainfall has declined (Figs. 11.19 and 11.20) (Roxy et al. 2019). This is the opposite of what appears to have happened from 1000 to 1400 CE when the SPCZ was displaced further to the east (Higgins et al. 2020). How future changes in greenhouse gases will affect the Warm Pool and these large-scale circulation features is unclear, but if the recent shift in the SPCZ persists in the future, it is likely that rainfall on the island will remain well below the average recorded during the instrumental period, with serious implications for water availability. Periods of prolonged drought have occurred in the past (Rull 2020), but given the higher population pressures on the island today, from both permanent residents and the much larger number of tourists, persistent drought would likely be much more consequential.

**Fig. 11.16** Rano Raraku on March 16th 2018, almost completely dried up (photographs by R.S. Bradley)

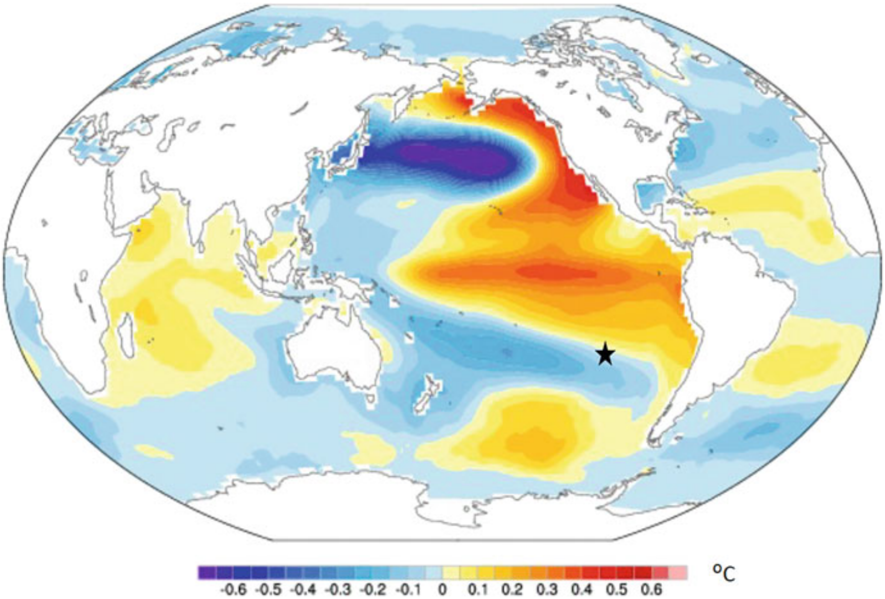


**Fig. 11.17** The sea surface temperature anomaly pattern associated with the positive phase of the Pacific Decadal Oscillation (PDO) (cf. Mantua and Hare 2002), using ERSST v.5, from https://psl.noaa.gov/pdo/. Location of Rapa Nui indicated by a black star

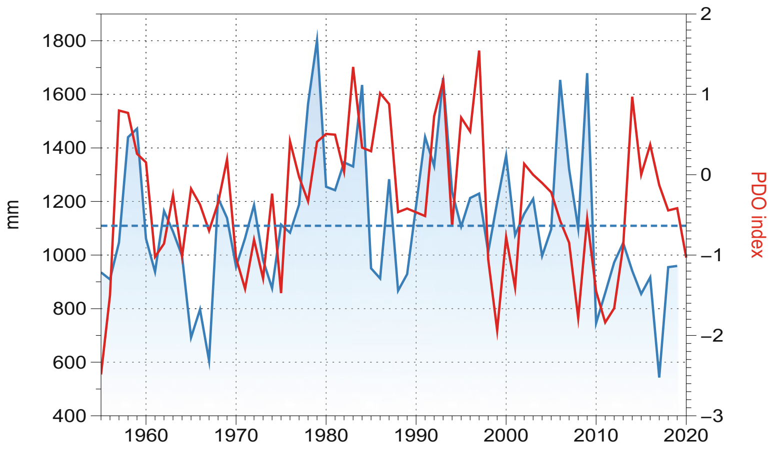


**Fig. 11.18** April–March rainfall totals at Mataveri, Rapa Nui (blue) 1955–1956 to 1920–1921, compared to the April–March Pacific Decadal Oscillation Index (red); r = 0.3 (not significant). Mean rainfall total indicated by dashed line. PDO values are from the National Center for Environmental Information, NOAA

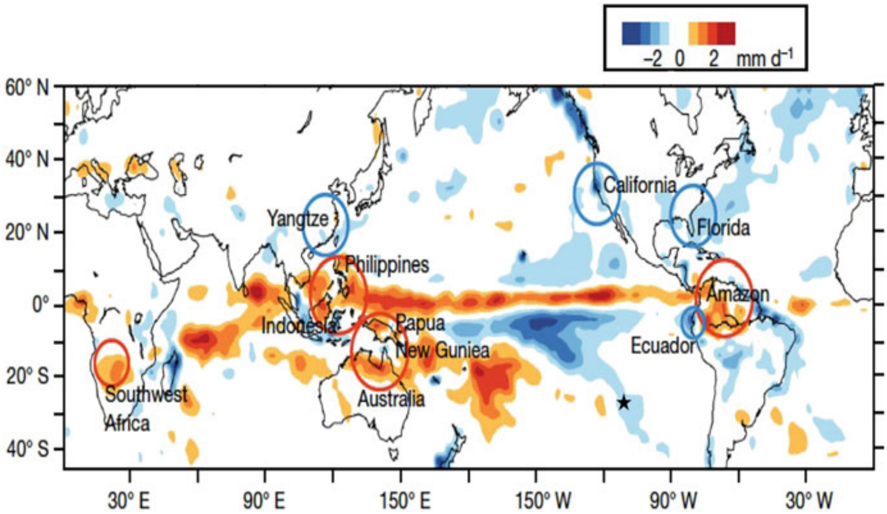


**Fig. 11.19** Observed trend in rainfall (mm day$^{-1}$, per 38 years). As the West Pacific Warm Pool has expanded, rainfall along the South Pacific Convergence Zone has increased, but decreased to the east of it (from Roxy et al. 2019). The position of Rapa Nui is shown by the black star

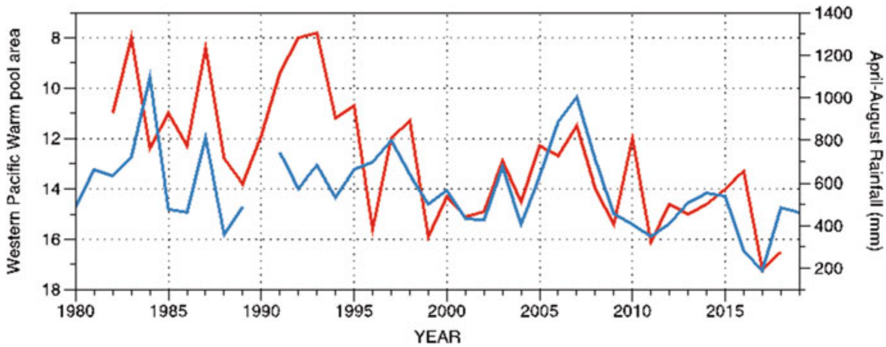


**Fig. 11.20** Relationship between April–August rainfall at Rapa Nui (blue) and area of the West Pacific Warm Pool (red: plotted inversely, in $10^6$ km$^2$); ($r = -0.49$). As the Warm Pool has expanded, rainfall in Rapa Nui has declined (Warm Pool area data from Roxy et al. 2019)

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