STUDIA UBB GEOGRAPHIA, LXVIII, 1, 2023 (p. 5-15)
(RECOMMENDED CITATION)
DOI:10.24193/subbgeogr.2023.1.01

CLIMATIC DATA COMPARISON BETWEEN MID-LATITUDE AZORES (NORTH ATLANTIC) AND TRISTAN DA CUNHA (SOUTH ATLANTIC) ISLANDS

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ABSTRACT. Climatic data comparison between mid-latitude Azores (North Atlantic) and Tristan da Cunha (South Atlantic) islands. The Azores islands in the North Atlantic and the Tristan da Cunha islands in the South Atlantic are approximately located at the same latitude, stretching between 36 and 41 degrees North and South respectively. Nevertheless, there are important climatic differences between the two archipelagos. The average annual temperature is higher in the Azores by more than 3 degrees, while the amount of precipitation is higher in Tristan da Cunha by about 600 mm/year on average. The warmer climate of the Azores may be explained by several contributing factors, such as: the smaller distance to the nearest continental landmass – less than 1500 km, compared to more than 2700 km in the case of Tristan da Cunha; the land mass of the islands themselves, as the Azores are much larger; the location of the Azores in the area of the North Atlantic High, with more stable weather and a higher amount of sunshine hours compared to the Tristan da Cunha islands, where westerlies prevail; and, not in the least, the influence of the Gulf Stream in the case of the Azores. The larger amount of precipitation in the case of Tristan da Cunha islands is due to their location on the southern flank of the South Atlantic High, which causes a higher degree of cloudiness and therefore more precipitation. The altitude is also a factor, as both archipelagos feature volcanic mountains rising above 2000 metres, providing a barrier for the air masses and determining orographic precipitation, especially on the windward side of the islands. The climate has had an impact on the settlement and human life on the islands. The Azores were settled immediately after their discovery in the 15th century and there is a rich social and economic life ever since. By contrast, the small community on Tristan da Cunha main island was formed only in the 19th century and has endured many hardships.

Keywords*: climatic comparison, Azores, Tristan da Cunha, average temperature, precipitation.*

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Introduction

The Azores Archipelago and the Tristan da Cunha Archipelago are both located in the middle of the Atlantic Ocean and approximately at the same latitude, the former in the North Atlantic and the latter in the South Atlantic. The largest islands, São Miguel (in the Azores) and Tristan da Cunha, are both located between 37 and 38 degrees of latitude, North and South respectively, while all the islands in the two archipelagos lie between 36 and 41 degrees North and South respectively. Given their similar location, the climatic data should be comparable. Nevertheless, there are important climatic differences between the two archipelagos, and this paper aims at identifying the causes for such dissimilarities.

Data, materials and methods

Climatic data from several weather stations in the Azores and the two stations in Tristan da Cunha (one on Tristan da Cunha Island, and the other one on Gough Island) have been collected from public online databases and compared. Data from Observatório Afonso Chaves in Ponta Delgada (São Miguel Island, 37°45' N, 25°40' W, 35 m altitude) and from Edinburgh of the Seven Seas (Tristan da Cunha Island, 37°04' S, 12°19' W, 23 m altitude) were used primarily because their location is most similar, both in terms of latitude and altitude, and because they are located on the main islands.

The comparison reveals a difference in terms of average annual temperature of approximately 3 degrees in favour of the Azores Archipelago, where average annual temperatures are in between 17.5°C and 18°C on all islands, compared to Tristan da Cunha Island (14.8 °C), and up to 6 degrees if compared to Gough Island (11.5°C, located further South, at 40°21' S, 9°53' W, 28 m altitude).

The situation is quite the reverse in terms of precipitation, with about 600 mm more annual precipitation (on average) on Tristan da Cunha (1,681 mm) compared to São Miguel (1,052 mm). However, precipitation values in the Azores stretch from 730 mm/year on Santa María, the southernmost island, to 1,666 mm/year on Flores in the North-West. The difference is much higher if one takes into account the values on Gough Island (more than 3,000 mm/year), while most islands in the Azores account for 1,000 to 1,200 mm/year (table 1).

Data regarding wind speeds could not be collected, but wind speeds on Tristan da Cunha and Gough Islands are notoriously high, compared to those in the Azores.

All these climatic factors have had an impact on human life on the islands. The Azores have been inhabited at least since the 15th century, when they were settled by the Portuguese, and have a total population of about 236,000 inhabitants, with more than half living on the main island, São Miguel. On the other hand, while Tristan da Cunha Island was discovered in the early 16th century, it has been inhabited only since 1810 by a handful of people, reaching about 250 inhabitants nowadays in the only settlement, Edinburgh of the Seven Seas. The other islands in the Tristan da Cunha Archipelago are not inhabited, except for the staff of the weather station on Gough Island, usually including 6 people.

Several hypotheses have been drafted to explain the causes for these climatic dissimilarities. Among the contributing factors to the warmer climate in the Azores, one may list the smaller distance to the nearest continental landmass, the land mass of the islands themselves (as the Azores are much larger than Tristan da Cunha), the location of the Azores in the area of the North Atlantic High, with more stable weather and a higher amount of sunshine hours compared to Tristan da Cunha, where westerlies prevail, and, not in the least, the influence of the Gulf Stream in the case of the Azores. The larger amount of precipitation in the case of the Tristan da Cunha Archipelago may be due to their location on the southern flank of the South Atlantic High, which causes a higher degree of cloudiness and therefore more precipitation. The altitude may also be a factor, as both archipelagos feature volcanic mountains rising above 2000 metres, providing a barrier for the air masses and orographic precipitation, especially on the windward side of the islands.

The paper analysed each of these factors, in an attempt to better explain the existing differences.

Results and discussion

The first factor to be taken into consideration is the distance to the nearest continental landmass. The Azores Archipelago is much closer to both continents, to the East (Europe) and West (North America), compared to Tristan da Cunha, because the Atlantic Ocean is narrower in its northern part. Taking into account the largest island in the Azores, São Miguel, the shortest distance to Europe (Portugal) is 1430 km and the shortest distance to North America (Newfoundland) is 2450 km. By contrast, Tristan da Cunha Island is 2790 km away from the nearest point on a continent, Cape Town in Africa, and 3950 km away from Mar del Plata in South America (Argentina). Therefore, the distance to the nearest continental landmass is almost double in the case of Tristan da Cunha Island, which has an impact on the average temperature. Even more, given the distribution of the landmasses on Earth, predominantly in the northern hemisphere, it is well-known

that average temperatures in the northern hemisphere are higher than those in the southern hemisphere at the same latitudes. In the specific analysed case, it is obvious that Eurasia and North Africa to the East, as well as North and Central America to the West, in the case of the Azores, are much larger in area and have a bigger impact than the southern half of Africa to the East and the southern half of South America to the West, in the case of Tristan da Cunha. Furthermore, the North Atlantic Ocean contains many other islands, such as Greenland or Iceland in the North, Madeira and the Canary Islands to the East and South-East of the Azores, while the South Atlantic has fewer islands, and much smaller, such as Saint Helena to the North of Tristan da Cunha, Bouvet Island to the South-East, Falkland Islands and South Georgia to the West and South-West (fig. 1).

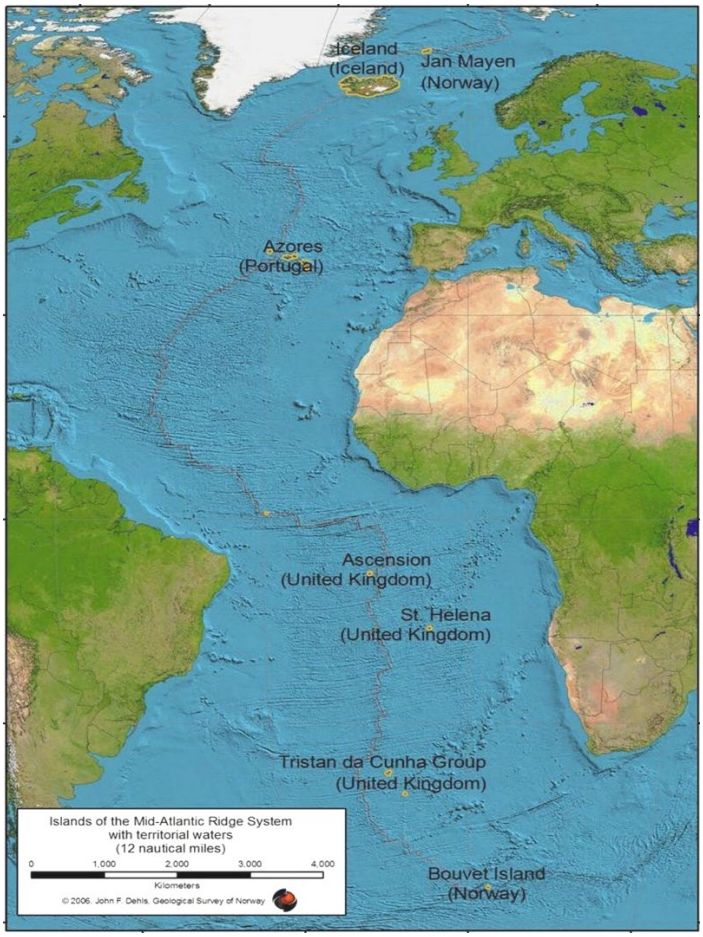

Fig. 1. Location of the Azores and of Tristan da Cunha on the Mid-Atlantic Ridge.
Source: UNESCO (2023)

The second factor to be considered is the land mass of the archipelagos themselves. It is worth noting that the Azores cover a total area of 2,351 km^2, which is more than 11 times the area of Tristan da Cunha Islands, which only cover a total of 207 km^2. In fact, the largest island of the Azores, São Miguel (759 km^2), is almost 8 times larger than Tristan da Cunha Island, which only covers 98 km^2, and almost four times larger than the entire Tristan da Cunha Archipelago (table 1). This is significant for the manner in which the total land area may affect the climatic elements. Tristan da Cunha Islands are very small and therefore their land mass has a low impact on climatic elements, whereas the Azores are larger and their impact is more significant.

Table 1. Area, population, highest points and basic climatic elements of the Azores and Tristan da Cunha islands

Island	Area (km^2)	Population (2021)	Highest point	Height (m)	Average temperature (°C)	Annual precipitation (mm)
Azores						
São Miguel	759	133295	Pico da Vara	1103	17.8	1053
Pico	447	13883	Montanha do Pico	2351	17.5	1109
Terceira	402	53244	Serra da Santa Bárbara	1021	N/A	N/A
São Jorge	238	8373	Pico da Esperança	1053	N/A	1259
Faial	173	14334	Cabeço Gordo	1043	17.4	962
Flores	142	3428	Morro Alto	915	17.7	1666
Santa Maria	97	5408	Pico Alto	587	18.4	730
Graciosa	61	4091	Pico do Coirão	402	17.4	845
Corvo	17	384	Estreitinho	720	17.5	1145
Tristan da Cunha						
Tristan da Cunha	98	238	Queen's Mary Peak	2062	14.8	1681
Gough	91	6	Edinburgh Peak	910	11.5	3069
Inaccessible	13	-	Cairn Peak	449	N/A	N/A
Nightingale	3	-	High Peak	370	N/A	N/A

Data source: Instituto de Meteorologia de Portugal and NOAA for the climatic elements; various web sources for the area, population and highest points.

Another factor taken into account is the location of the islands in relation to the main anticyclones of the Atlantic. The Azores are located in the area of the North Atlantic High (Davis *et al*., 1997), also known as the Azores High (Falarz, 2019; Cresswell-Clay *et al*., 2022) or the Azores-Bermuda High, an area of high pressure over the subtropical North Atlantic which is very important for the climate and weather of the eastern coast of North and Central America

(Chase, 1951), as well as for Europe and North Africa (Rashid, Iqbal and Hussain, 2012; Yadav, 2021; Ummenhofer, 2022). The position and strength of the North Atlantic High varies throughout the year. Especially in summer, it is located in the area of the Azores and its presence is associated with stable weather, more sunshine hours (a total of 1738 sunshine hours annually on São Miguel Island) and higher temperatures as a result. In winter, the Azores are usually North of the North Atlantic High, in the area where the westerlies are predominant, bringing more precipitation (Trewartha and Horn, 1980). By contrast, the South Atlantic High (also known as Saint Helena High) is weaker and has a limited impact on the climate and weather of Tristan da Cunha Islands (Venegas, Mysak and Straub, 1997; Lübbecke *et al*., 2014; Sun, Cook and Vizy, 2017; Reboita *et al*., 2019). In summer, the South Atlantic High is supposed to move southwards, covering the area of Tristan da Cunha Islands, but this seldom happens, and therefore the average number of annual sunshine hours (1498 on Tristan da Cunha Island and only 1429 on Gough Island) is lower than in the case of the Azores. Tristan da Cunha Islands lie most of the year on the southern flank of the South Atlantic High, in the area where westerlies prevail almost all-year round, a feature materialized in the data regarding the total amount of precipitation (which is higher than in the case of the Azores) and the total number of sunshine hours (lower than in the case of the Azores), causing a higher degree of cloudiness and directly affecting the average temperatures as well (Baker *et al*., 1964; Dickson, 1965; Ljung, 2007).

The Gulf Stream also influences the temperatures in the Azores (Carvalho *et al*., 2020; Meirelles *et al.*, 2022). The Gulf Stream brings warm water from the Gulf of Mexico along the eastern coast of North America before crossing the North Atlantic, divided into two branches: the North Atlantic Current, to the North of the Azores, and the Azores Current, to the South (Gould, 1985; Klein and Siedler, 1989). Both currents bring warmer waters in the area of the Azores from West and South-West, which determine higher average temperatures. By contrast, Tristan da Cunha Islands are located in the area of the cold South Atlantic Current, flowing eastwards, that has a negative impact on average temperatures in the area (Höflich, 1984; Barnes *et al*., 2021).

The altitude is also important, as both archipelagos are volcanic in nature and feature high mountains, over 2000 metres above sea level. In the Azores, the only such mountain is Pico (2351 m) on Pico Island, the second largest island in the archipelago. It is more than twice higher than any other summit in the Azores, with most of the other islands having the highest altitude in between 700 m and 1100 m. Pico da Vara (1103 m) on São Miguel Island is the second highest summit in the Azores.

The highest point on Tristan da Cunha Island, Queen Mary's Peak, reaches 2062 m on a much smaller island, involving steep slopes around the island, which make landing difficult. In the same archipelago, the highest elevation on Gough Island is Edinburgh Peak (910 m).

Both in the Azores and in Tristan da Cunha, the mountains provide a morphological barrier to the air masses generally coming from the West, involving orographic precipitation, especially on the windward (western) part of the islands. The amount of precipitation caused by the morphological features of the islands is proportional to the height of the mountains, the length and direction of the mountain range (if there is any) and the gradient of the slopes. However, mountains in the Azores and Tristan da Cunha do not form lengthy ranges, as they are usually single volcanic cones, which may or may not be connected to other volcanic cones on the same island – as it happens, for instance, on São Miguel Island in the Azores. It comes out that the amount of orographic precipitation is therefore determined mainly by the absolute height and the gradient of the slopes. Data regarding precipitation (Instituto de Meteorologia de Portugal, 2001) indicate that the average multiannual amount of precipitation at Lagoa do Caiado, on Pico Mountain (Pico Island) is 4697.8 mm/year, which is more than 4 times the amount of precipitation on the same island at sea level. On São Miguel Island, the same average amount reached 3197.3 mm/year on Monte Escuro, about 3 times higher than the values at sea level on the same island.

Similar, and even higher amounts would be recorded on Queen Mary's Peak on Tristan da Cunha. The steepness of the slopes in the southern archipelago in almost all islands (Tristan da Cunha, Gough and Inaccessible), except for Nightingale Island, also contributes to a higher amount of orographic precipitation than in the Azores. The site of the weather station on Tristan da Cunha Island in the only settlement, Edinburgh of the Seven Seas, in the North-West of the island, involves a location on the windward side of the island, where precipitation is more abundant. The area around Sandy Point, in the East of the island (on the leeward), has higher average temperatures and lower amounts of precipitation. This is also proved by the existence of fruit trees, forming a small orchard near Sandy Point, which would not survive in the harsher conditions around Edinburgh of the Seven Seas, in North-West, as there were several unsuccessful attempts to plant trees closer to the settlement or even within it (Mackay, 1963).

The height of Pico in the Azores and Queen Mary's Peak on Tristan da Cunha allows for snow cover in winter months, on the upper side of the mountains. However, temperatures never reach freezing point at sea level in the Azores or in most islands of Tristan da Cunha. The only island where negative temperatures have been reported in winter is Gough Island (Tristan da Cunha Archipelago),

where there is a record low of -2.7°C. This is due to the southernmost location of this island, beyond 40° S, which also explains the persistence of snow in the higher areas around Edinburgh Peak (910 m) in winter. However, data from the weather station on the island's south-eastern coast indicate average lows above 6.5°C in any month, while negative temperatures occur very rarely.

Conclusions

The climatic comparison between the Azores and Tristan da Cunha archipelagos in the North and South Atlantic respectively shows that the average temperatures in the Azores are between 3°C and 6°C higher than in Tristan da Cunha, while the amount of precipitation is consistently higher in Tristan da Cunha, despite their location at almost the same latitude and in the same ocean. Among the factors that contribute to this situation are the closer and larger continental landmasses in the case of the Azores, the larger area of the Azores as a whole, the stronger and closer North Atlantic High in the case of the Azores, compared to the South Atlantic High for Tristan da Cunha, the stronger impact of the westerlies in the case of Tristan da Cunha, the warm North Atlantic Current and the Azores Current, in contrast to the cold South Atlantic Current. Both groups of islands are volcanic in nature and feature several mountains that act as a barrier to the air masses, generating orographic precipitation as well. However, the number of sunshine hours is much higher in the Azores, which is also consistent with a higher average temperature and a lower degree of cloudiness compared to Tristan da Cunha Islands.

All these climatic characteristics are relevant for human life on these islands. The Azores have been probably inhabited since early medieval times, probably by Norse people, as suggested by recent research (Gabriel, Mathias and Searle, 2015; Raposeiro *et al*., 2021). They also appeared on medieval maps and atlases, before their official discovery and settlement by the Portuguese in the 15th century (Raposeiro *et al*., 2021). Since then, the Azores have had a rich economic and social life, and their population has steadily increased, reaching more than 200,000 inhabitants, spread across the islands. Except for Corvo Island (which is easily reachable by boat), every island of the Azores has an airport and there are many flights connecting the islands with the continent (especially mainland Portugal) and between them, and there are connections by boat as well. Apart from the very strong relations with Portugal, to which they belong, the Azores have also been well connected to other European countries, and to the Americas, especially the USA, Canada and Brazil, with important emigration and immigration flows (Rocha, de Medeiros and Ferreira, 2011; Rocha, Ferreira and Mendes, 2011).

Tristan da Cunha Islands, on the other hand, were only discovered in the 16th century. The isolation due to the large distance from any continent, the lack of any natural harbour, the steep cliffs and rocky shores which made them almost inaccessible for landing parties, as well as the harsh climatic conditions, contributed to the idea that the islands were uninhabitable. Nevertheless, three people settled on the main island in 1810, and one of them survived until 1816 when the British Crown officially annexed Tristan da Cunha and established a military garrison, which only lasted for a year. However, some of the soldiers remained and therefore the small community continued to grow throughout the 19th century, in very difficult conditions. There were several attempts to evacuate the small population from the island, but each time some of the inhabitants refused to go (Mackay, 1963). There was continuous habitation on Tristan da Cunha until 1961, when a volcanic eruption forced the entire population to be evacuated to the United Kingdom, but most of the islanders came back in 1963, when it was safe. Nowadays, there is a community of (only) 238 islanders and a few others who have temporary jobs on Tristan da Cunha. The other islands are uninhabited, except for the weather station crew of (usually) 6 people on Gough Island. None of the islands has an airport or an airstrip, so the only possible access is by boat, which comes once a month or once in two months from Cape Town (South Africa), with a very limited capacity for passengers, no more than 12 in most occasions (Tristan da Cunha Website, 2023). The archipelago is part of Saint Helena, Ascension and Tristan da Cunha Overseas Territory of the United Kingdom, but connections to Saint Helena Island (the governor's seat) or to the United Kingdom are poor, and are available only through Cape Town. The weather conditions, especially very powerful winds, render the construction of an airport impossible on Tristan da Cunha.

As a result, one may conclude that climatic conditions, along with other factors, contributed largely to the social and economic development of the Azores, on one hand, but impeded the same kind of development on Tristan da Cunha, on the other hand. The two archipelagos, while located at the same latitude and in the same ocean, have had a contrasting fate.

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