# Galapagos (activities for GCSE)

Royal Geographical Society with IBG

Advancing geography and geographical learning

**How can climate variation be used to make predictions on climate change? Investigating El Niño and the Galapagos Islands.**

## Introduction

Global climate patterns are mainly connected to the circulation of air in the atmosphere, but ocean currents can also have a major influence on weather patterns and climate. During El Niño events, when changes in ocean currents occur, effects can be felt not only in the Galapagos, but also the wider world.

## What is El Niño?

El Niño is a phase of a cycle known as the El Niño-Southern Oscillation (ENSO) The ENSO cycle describes fluctuations that occur in temperature between the ocean and atmosphere in the Equatorial Pacific. Usually starting in December, the intensity and duration of El Niño varies, and the frequency is difficult to predict. El Niño events are not an uncommon phenomenon, and can significantly influence both ocean conditions and weather patterns. Strong El Niño events have been known to cause global scale weather disruption; for example, while parts of South America experience heavier rainfall, areas of Australasia may experience drought.

During El Niño, the cold ocean Humboldt Current that flows from the southern tip of Chile to Northern Peru is interrupted. Warm waters, which normally flow west, instead move towards the shores of South America and the Galapagos Islands.
In normal (non-El Niño) years, the current flows northwards along the west coast of South America and then further westwards. As the current flows west, it is warmed by the tropical sun, which results in warm, moist air rising over Indonesia, creating a low pressure area. This leads to the formation of tropical cumulonimbus clouds which cause heavy rain.

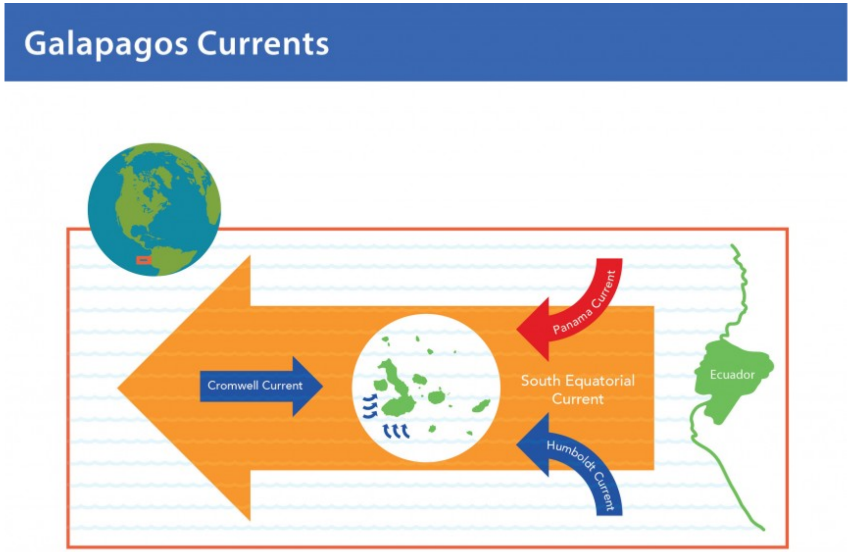


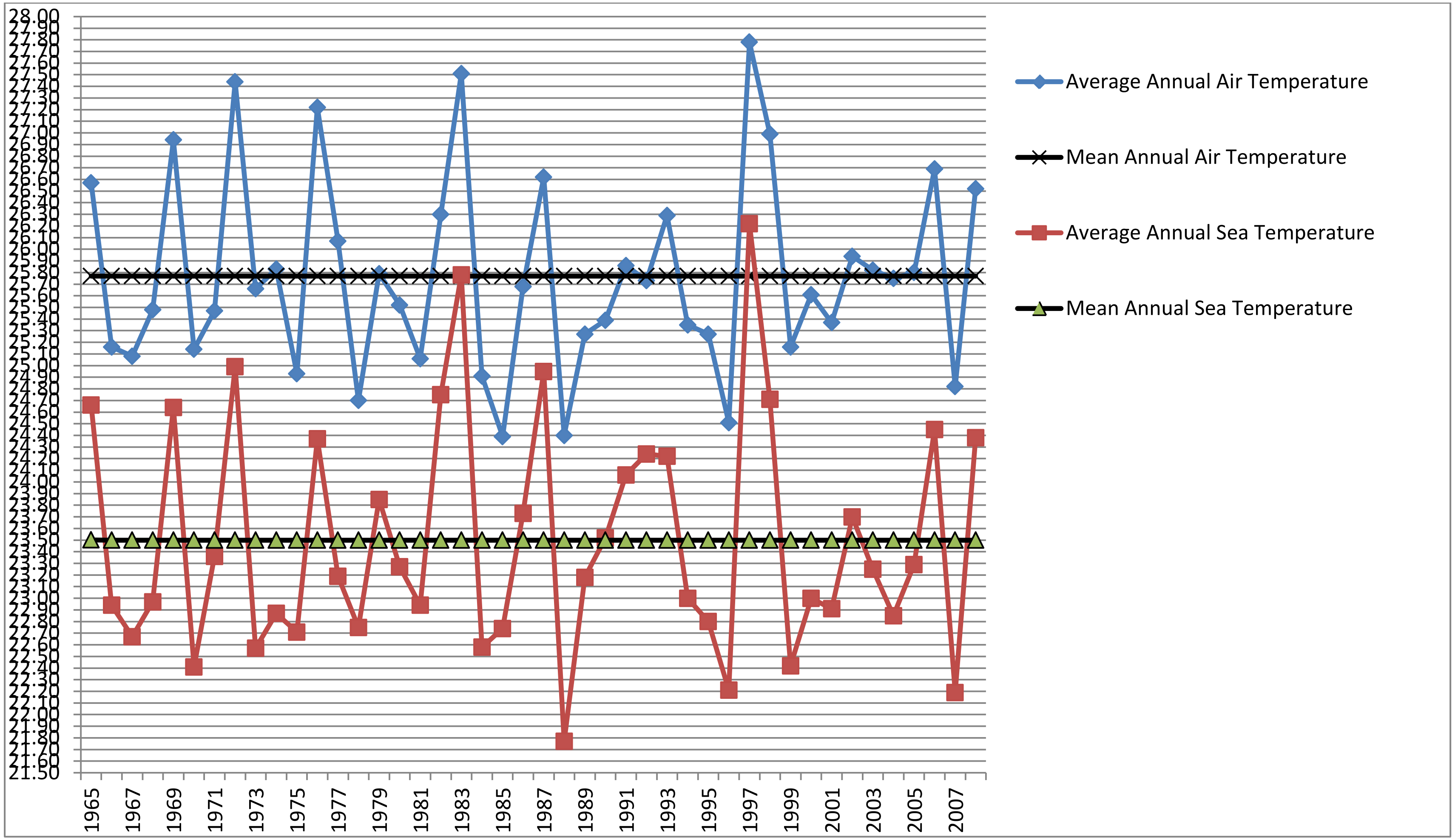

Image showing the flow of the Humboldt Current during normal years around Galapagos

High above in the upper atmosphere, the air circulates east and then sinks into the cooler high pressure area over the west coast of South America. The dry conditions caused by this air flow were instrumental in creating the Atacama Desert in Peru.
During El Niño years, pressure systems and weather patterns reverse. Warmer waters develop in the eastern Pacific, with temperatures rising by up to 8°C. Low pressure systems form over the area, drawing in westerly winds from across the Pacific.
Warm, moist air rises, creating heavy rainfall over the Eastern Pacific region (around Peru). The air circulates west in the upper atmosphere. Around northern Australia and Indonesia the descending air gives drier conditions than usual and can cause drought.
Air currents move eastwards across the Pacific, bringing moist air to South America and the eastern Pacific. The Californian coast is also affected by this current, which brings torrential rains that often causes flooding and landslides.
Available online - http://www.discoveringgalapagos.org.uk/discover/geographical-processes/weather-climate/el-nino/

**How are El Niño events identified?**
Scientists use the Oceanic Niño Index (ONI) to measure the changes in sea-surface temperatures. El Niño events are defined as 5 consecutive months at or above the +0.5o anomaly (deviations from normal temperatures.)
Events are further categorised into Weak (0.5 – 0.9 anomaly), Moderate (1.0 – 1.4), Strong (1.5 – 1.9) and Very Strong (≥ 2.0) events.
(from http://ggweather.com/enso/oni.htm )
El Niño events typically extend into two calendar years.

**Activity 1 / Data set 1**

Graph showing mean coastal air temperature and sea surface temperature (SST) on Santa Cruz, Galapagos, from 1965 – 2008.



Questions:
Part 1:

1. What information is presented on each axis.
2. What is the mean and how is it calculated for the air and sea surface temperatures? What information does it provide?
3. Identify and explain the correlation between air and sea surface temperatures.

Part 2:

Remember El Niño's are categorised according to their deviation from 'normal' sea surface temperatures (SST) for that region. Events usually overlap 2 calendar years; for example, 1976-1977.
The average sea temperature for the whole period shown is 23.5 °C.
During this time, two 'Very Strong' El Niño events were categorised; that is, 5 or more consecutive months of an anomaly of ≥ 2.0° above average.

1. Using the graph, identify these two events and the years they took place. Draw a circle around them. Remember to look at both the air and sea surface temperatures together.

2. Calculate the anomaly for a 'Very Strong' El Niño event.
Now using the SST data set below, identify and highlight the months where they were categorised as being 'Very Strong.' Hint - remember which month of the year El Niño usually begins.

## Table showing mean coastal sea surface temperatures (SST) on Santa Cruz, Galapagos, from 1965 – 2008.

**Sea Temperature data (Celsius, 0600h)**

| Year | Jan | Feb | Mar | Apr | May | June | July | Aug | Sept | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1965** | 23.67 | 25.77 | 26.39 | 26.72 | 26.89 | 25.45 | 23.58 | 23.03 | 23.05 | 23.18 | 23.81 | 24.39 |
| **1966** | 25.93 | 25.95 | 24.44 | 23.62 | 22.54 | 22.17 | 21.75 | 20.93 | 21.54 | 21.57 | 22.41 | 22.37 |
| **1967** | 24.26 | 24.84 | 24.58 | 24.39 | 23.24 | 22.94 | 21.79 | 20.82 | 20.00 | 21.25 | 22.05 | 21.93 |
| **1968** | 22.96 | 24.13 | 23.49 | 23.24 | 22.45 | 21.43 | 22.26 | 22.65 | 23.02 | 23.11 | 23.08 | 23.79 |
| **1969** | 24.48 | 25.59 | 27.22 | 27.56 | 26.80 | 25.56 | 22.59 | 21.99 | 22.29 | 23.31 | 23.66 | 24.65 |
| **1970** | 24.75 | 24.63 | 24.04 | 24.34 | 22.95 | 21.02 | 19.98 | 19.95 | 20.83 | 21.27 | 22.72 | 22.43 |
| **1971** | 23.66 | 24.58 | 25.52 | 26.35 | 24.04 | 22.93 | 22.46 | 21.61 | 21.32 | 22.50 | 22.93 | 22.40 |
| **1972** | 24.12 | 25.87 | 26.06 | 27.71 | 26.31 | 24.75 | 24.27 | 23.97 | 23.52 | 23.52 | 24.13 | 25.61 |
| **1973** | 26.99 | 25.96 | 25.33 | 23.46 | 21.87 | 20.71 | 20.83 | 20.43 | 20.61 | 20.52 | 21.71 | 22.37 |
| **1974** | 23.09 | 25.13 | 24.28 | 25.82 | 25.02 | 23.89 | 21.95 | 21.03 | 21.17 | 20.92 | 21.34 | 20.78 |
| **1975** | 22.96 | 25.55 | 26.19 | 26.36 | 23.53 | 22.30 | 21.66 | 20.94 | 20.70 | 20.40 | 20.53 | 21.34 |
| **1976** | 23.30 | 24.20 | 25.01 | 26.12 | 26.50 | 25.41 | 24.61 | 23.98 | 22.81 | 22.63 | 23.62 | 24.25 |
| **1977** | 25.62 | 25.48 | 24.53 | 24.12 | 23.76 | 22.90 | 21.94 | 20.85 | 20.54 | 22.00 | 22.89 | 23.59 |
| **1978** | 25.06 | 25.96 | 25.42 | 23.76 | 22.93 | 20.93 | 21.32 | 20.48 | 20.14 | 21.55 | 22.25 | 23.23 |
| **1979** | 25.37 | 25.26 | 25.24 | 26.59 | 24.46 | 23.36 | 22.55 | 21.93 | 22.47 | 22.46 | 23.06 | 23.41 |
| **1980** | 24.70 | 25.43 | 24.96 | 25.42 | 24.38 | 22.93 | 22.45 | 21.14 | 20.99 | 21.62 | 22.61 | 22.58 |
| **1981** | 23.11 | 24.46 | 24.87 | 25.48 | 24.59 | 23.28 | 22.08 | 20.26 | 21.10 | 21.27 | 21.51 | 23.31 |
| **1982** | 24.28 | 25.39 | 25.40 | 24.95 | 25.29 | 24.24 | 23.82 | 23.17 | 23.40 | 24.18 | 25.94 | 26.92 |
| **1983** | 27.57 | 27.89 | 28.56 | 28.54 | 27.94 | 27.50 | 26.75 | 24.31 | 22.28 | 22.41 | 22.44 | 23.11 |
| **1984** | | | | 24.82 | 23.13 | 22.09 | 21.98 | 21.47 | 21.76 | 22.21 | 22.62 | 23.16 |
| **1985** | 23.66 | 23.58 | 24.11 | 25.02 | 22.65 | 22.48 | 22.34 | 21.43 | 21.13 | 21.44 | 22.39 | 22.70 |
| **1986** | 24.14 | 25.62 | 25.47 | 24.79 | 24.75 | 22.96 | 22.81 | 22.55 | 21.84 | 22.25 | 23.47 | 24.15 |
| **1987** | 25.84 | 27.37 | 27.48 | 27.95 | 26.59 | 24.42 | 22.89 | 23.00 | 23.31 | 23.09 | 23.60 | 23.89 |
| **1988** | 24.15 | 24.56 | 24.54 | 22.68 | 21.58 | 19.96 | 18.96 | 19.83 | 20.98 | 20.25 | 21.60 | 22.09 |
| **1989** | 23.41 | 25.23 | 24.52 | 25.82 | 24.59 | 23.03 | 21.81 | 22.16 | 21.50 | 21.83 | 22.08 | 22.22 |
| **1990** | 23.94 | 26.25 | 25.07 | 26.16 | 25.22 | 23.31 | 21.78 | 21.39 | 21.47 | 21.43 | 23.01 | 23.25 |
| **1991** | 23.85 | 26.37 | 26.82 | 23.44 | 25.21 | 24.69 | 23.50 | 22.35 | 22.28 | 22.55 | 23.23 | 24.43 |
| **1992** | 25.81 | 27.52 | 27.78 | 28.38 | 26.82 | 23.65 | 21.65 | 21.45 | 21.11 | 21.53 | 22.03 | 23.19 |
| **1993** | 24.15 | 26.14 | 26.37 | 27.40 | 26.52 | 24.88 | 23.47 | 21.64 | 21.66 | 22.10 | 22.96 | 23.32 |
| **1994** | 24.61 | 25.20 | 23.51 | 22.32 | 22.50 | 23.13 | 22.16 | 21.35 | 21.08 | 22.11 | 23.51 | 24.56 |
| **1995** | 26.28 | 25.78 | 25.30 | 22.43 | 22.44 | 22.11 | 21.70 | 20.69 | 21.20 | 21.56 | 22.13 | 21.97 |
| **1996** | 23.44 | 24.84 | 25.59 | 23.22 | 22.37 | 21.35 | 21.24 | 20.71 | 20.09 | 20.97 | 21.45 | 21.27 |
| **1997** | 23.05 | 25.36 | 26.71 | 27.13 | 27.03 | 26.71 | 26.48 | 25.91 | 25.83 | 25.98 | 26.65 | 27.75 |
| **1998** | 27.87 | 27.85 | 28.47 | 28.46 | 26.89 | 25.80 | 23.09 | 21.99 | 20.98 | 21.05 | 22.45 | 21.63 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1999** | 22.87 | 23.57 | 24.94 | 24.15 | 23.93 | 22.24 | 21.24 | 20.76 | 20.55 | 21.61 | 21.14 | 22.09 |
| **2000** | 23.28 | 24.19 | 24.08 | 25.64 | 24.97 | 23.99 | 22.16 | 21.43 | 21.18 | 21.72 | 21.88 | 21.50 |
| **2001** | 23.11 | 24.64 | 25.67 | 25.46 | 24.69 | 22.68 | 21.97 | 20.81 | 20.94 | 20.50 | 21.60 | 22.80 |
| **2002** | 24.00 | 25.31 | 26.41 | 26.74 | 24.43 | 22.67 | 21.35 | 21.60 | 21.63 | 21.95 | 23.73 | 24.60 |
| **2003** | 25.90 | 25.70 | 25.83 | 23.50 | 21.31 | 21.63 | 21.78 | 21.60 | 21.44 | 23.21 | 22.99 | 24.09 |
| **2004** | 24.53 | 24.47 | 24.67 | 24.52 | 22.68 | 22.23 | 21.53 | 20.49 | 21.03 | 21.66 | 22.46 | 23.98 |
| **2005** | 24.53 | 23.86 | 25.60 | 24.87 | 24.75 | 23.77 | 23.00 | 21.89 | 21.07 | 20.93 | 22.38 | 22.83 |
| **2006** | 24.73 | 26.03 | 25.31 | 24.71 | 25.20 | 24.52 | 23.56 | 22.82 | 23.62 | 23.66 | 24.29 | 24.93 |
| **2007** | 26.18 | 26.21 | 24.64 | 22.51 | 21.83 | 21.34 | 21.25 | 19.93 | 19.85 | 19.43 | 21.45 | 21.67 |
| **2008** | 23.28 | 25.34 | 26.21 | 26.81 | 26.13 | 25.43 | 24.46 | 23.26 | 23.12 | 23.06 | 23.09 | 22.39 |

3. What were the maximum sea surface temperatures reached during the identified events? Calculate the difference between the maximum and mean temperatures for each.

Using the mean or average data to produce graphs is useful as it considers all data, and can help identify patterns and trends over longer periods of time, such as in the graphs studied here.

4. What disadvantages do you think there are in using average data in this case study?

## Activity 2 – Data set 2

**Table showing coastal rainfall on Santa Cruz, Galapagos, from 1965 – 2008.**

**Coastal Rainfall data (mm)**

| Year | Jan | Feb | Mar | Apr | May | June | July | Aug | Sept | Oct | Nov | Dec | Total | Total Inc Previous Yr |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1965** | 31.50 | 8.93 | 0.00 | 223.55 | 224.15 | 6.30 | 12.70 | 8.80 | 16.20 | 40.20 | 11.70 | 16.00 | **600.03** | |
| **1966** | 69.70 | 41.80 | 0.00 | 0.00 | 0.00 | 9.00 | 13.80 | 10.40 | 15.60 | 19.10 | 14.00 | 10.40 | **203.80** | **803.83** |
| **1967** | 34.60 | 112.00 | 26.90 | 13.80 | 7.90 | 3.80 | 10.60 | 10.90 | 13.25 | 13.70 | 16.50 | 13.30 | **277.25** | **481.05** |
| **1968** | 5.70 | 32.91 | 30.20 | 0.00 | 0.10 | 1.00 | 18.80 | 19.10 | 23.50 | 14.10 | 11.80 | 6.60 | **163.81** | **441.06** |
| **1969** | 23.00 | 16.80 | 249.00 | 68.50 | 31.40 | 16.80 | 12.00 | 3.80 | 18.60 | 3.20 | 11.00 | 15.70 | **469.80** | **633.61** |
| **1970** | 20.40 | 0.00 | 1.20 | 0.70 | 4.60 | 8.10 | 8.70 | 10.20 | 6.20 | 10.20 | 9.60 | 5.65 | **85.55** | **555.35** |
| **1971** | 12.30 | 1.50 | 141.90 | 41.20 | 0.40 | 11.50 | 10.00 | 19.70 | 12.30 | 0.50 | 4.70 | 13.50 | **269.50** | **355.05** |
| **1972** | 46.90 | 70.80 | 49.10 | 241.90 | 31.20 | 123.50 | 7.20 | 8.00 | 5.50 | 8.10 | 1.70 | 75.20 | **669.10** | **938.60** |
| **1973** | 399.00 | 11.70 | 10.90 | 0.00 | 1.60 | 0.50 | 0.80 | 6.30 | 6.50 | 8.90 | 8.90 | 14.30 | **469.40** | **1,138.50** |
| **1974** | 7.20 | 54.45 | 16.20 | 15.20 | 19.70 | 14.35 | 6.00 | 12.10 | 9.55 | 6.10 | 6.10 | 7.40 | **174.35** | **643.75** |
| **1975** | 2.60 | 335.10 | 417.60 | 108.20 | 0.20 | 6.00 | 4.80 | 16.00 | 8.50 | 14.80 | 3.10 | 12.20 | **929.10** | **1,103.45** |
| **1976** | 45.20 | 81.80 | 0.00 | 43.40 | 239.20 | 10.40 | 30.90 | 22.10 | 10.00 | 3.90 | 10.20 | 8.90 | **506.00** | **1,435.10** |
| **1977** | 116.30 | 29.00 | 13.80 | 0.00 | 31.80 | 7.00 | 22.50 | 5.20 | 2.50 | 18.60 | 9.40 | 12.30 | **268.40** | **774.40** |
| **1978** | 158.30 | 63.40 | 99.60 | 0.00 | 0.00 | 0.00 | 4.70 | 7.90 | 2.30 | 7.30 | 9.90 | 64.80 | **418.20** | **686.60** |
| **1979** | 44.30 | 31.50 | 0.00 | 44.40 | 1.90 | 12.70 | 8.00 | 3.80 | 14.80 | 3.10 | 0.60 | 4.60 | **169.70** | **587.90** |
| **1980** | 23.40 | 69.20 | 0.00 | 139.40 | 0.00 | 1.20 | 4.70 | 3.00 | 3.60 | 5.80 | 4.50 | 1.00 | **255.80** | **425.50** |
| **1981** | 1.50 | 4.40 | 275.30 | 21.00 | 1.00 | 2.10 | 4.50 | 1.20 | 12.20 | 5.90 | 3.20 | 37.50 | **369.80** | **625.60** |
| **1982** | 13.20 | 22.20 | 11.50 | 6.80 | 8.50 | 4.20 | 9.00 | 5.70 | 6.10 | 8.93 | 34.70 | 508.62 | **639.45** | **1,009.25** |
| **1983** | 315.90 | 91.90 | 298.90 | 434.20 | 660.20 | 635.50 | 278.20 | 5.40 | 3.10 | 28.30 | 3.00 | 14.10 | **2,768.70** | **3,408.15** |
| **1984** | 3.50 | 38.00 | 77.10 | 0.40 | 0.00 | 4.00 | 5.70 | 5.40 | 6.20 | 12.60 | 3.50 | 0.50 | **156.90** | **2,925.60** |
| **1985** | 1.80 | 0.00 | 0.00 | 2.70 | 0.00 | 13.80 | 9.80 | 11.00 | 10.80 | 7.60 | 3.20 | 2.90 | **63.60** | **220.50** |
| **1986** | 12.00 | 67.70 | 39.00 | 63.60 | 5.90 | 8.70 | 7.60 | 17.50 | 7.30 | 5.60 | 29.90 | 12.80 | **277.60** | **341.20** |
| **1987** | 124.70 | 379.70 | 310.00 | 170.80 | 191.20 | 3.90 | 20.10 | 22.30 | 14.80 | 5.30 | 5.00 | 5.80 | **1,253.60** | **1,531.20** |
| **1988** | 14.30 | 8.30 | 0.00 | 0.00 | 2.00 | 1.60 | 9.80 | 7.40 | 13.90 | 9.90 | 7.60 | 3.70 | **78.50** | **1,332.10** |
| **1989** | 10.60 | 7.10 | 0.20 | 2.10 | 11.20 | 1.20 | 8.90 | 13.70 | 5.40 | 9.00 | 9.90 | 3.20 | **82.50** | **161.00** |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1990** | 8.90 | 176.20 | 17.40 | 1.00 | 4.30 | 6.90 | 4.90 | 8.90 | 14.30 | 7.60 | 18.10 | 9.00 | **277.50** | **360.00** |
| **1991** | 17.50 | 118.10 | 256.20 | 0.00 | 0.80 | 12.30 | 17.40 | 8.90 | 13.40 | 15.70 | 15.70 | 27.30 | **503.30** | **780.80** |
| **1992** | 105.70 | 109.30 | 113.80 | 313.60 | 154.40 | 8.70 | 3.10 | 14.60 | 7.70 | 10.50 | 14.10 | 0.80 | **856.30** | **1,359.60** |
| **1993** | 61.60 | 144.40 | 162.20 | 65.60 | 230.00 | 9.90 | 17.20 | 22.00 | 3.91 | 8.35 | 9.15 | 12.95 | **747.26** | **1,603.56** |
| **1994** | 33.20 | 7.05 | 0.00 | 0.00 | 1.50 | 6.50 | 11.00 | 6.70 | 10.10 | 1.90 | 2.90 | 106.31 | **187.16** | **934.42** |
| **1995** | 183.20 | 8.50 | 40.00 | 0.30 | 1.30 | 4.10 | 13.60 | 9.90 | 25.70 | 15.70 | 4.80 | 9.70 | **316.80** | **503.96** |
| **1996** | 53.60 | 43.80 | 20.50 | 0.00 | 0.30 | 4.90 | 13.50 | 14.60 | 11.00 | 6.00 | 6.60 | 11.80 | **186.60** | **503.40** |
| **1997** | 4.30 | 97.80 | 253.20 | 401.20 | 137.20 | 247.60 | 24.30 | 12.10 | 4.90 | 7.90 | 146.90 | 317.80 | **1,655.20** | **1,841.80** |
| **1998** | 396.30 | 342.90 | 221.30 | 448.30 | 245.60 | 53.50 | 5.10 | 15.90 | 3.60 | 3.10 | 13.30 | 3.50 | **1,752.40** | **3,407.60** |
| **1999** | 6.50 | 11.40 | 47.00 | 8.10 | 3.00 | 3.80 | 6.10 | 13.70 | 6.90 | 20.98 | 3.70 | 12.90 | **144.08** | **1,896.48** |
| **2000** | 40.40 | 23.50 | 12.00 | 33.40 | 7.45 | 9.85 | 18.80 | 7.70 | 7.20 | 17.50 | 3.00 | 7.20 | **188.00** | **332.08** |
| **2001** | 0.90 | 78.40 | 8.90 | 32.70 | 84.80 | 8.65 | 18.95 | 21.50 | 11.10 | 8.70 | 12.30 | 6.00 | **292.90** | **480.90** |
| **2002** | 23.30 | 101.00 | 172.10 | 162.50 | 2.40 | 3.50 | 11.40 | 16.80 | 12.40 | 13.90 | 24.60 | 33.80 | **577.70** | **870.60** |
| **2003** | 15.30 | 39.70 | 28.30 | 0.20 | 0.00 | 3.70 | 11.10 | 11.20 | 11.50 | 12.00 | 20.20 | 37.00 | **190.20** | **767.90** |
| **2004** | 18.80 | 9.90 | 19.10 | 0.50 | 2.80 | 22.40 | 14.70 | 11.80 | 14.20 | 18.00 | 12.20 | 16.80 | **161.20** | **351.40** |
| **2005** | 13.30 | 0.20 | 109.20 | 0.80 | 0.30 | 5.00 | 15.90 | 14.70 | 5.00 | 7.70 | 9.10 | 4.70 | **185.90** | **347.10** |
| **2006** | 1.00 | 50.80 | 0.50 | 0.00 | 2.80 | 12.40 | 15.10 | 13.80 | 12.10 | 29.60 | 9.10 | 17.90 | **165.10** | **351.00** |
| **2007** | 87.50 | 42.10 | 4.90 | 0.30 | 0.00 | 6.00 | 14.40 | 7.90 | 16.30 | 7.60 | 11.70 | 10.00 | **208.70** | **373.80** |
| **2008** | 31.50 | 165.30 | 170.90 | 262.70 | 34.50 | 10.80 | 33.00 | 13.10 | 19.00 | 10.70 | 11.60 | 5.90 | **769.00** | **977.70** |
| **Mean** | **60.02** | **71.60** | **84.68** | **76.66** | **54.26** | **30.63** | **18.17** | **11.43** | **10.43** | **11.23** | **13.24** | **34.60** | | |

1. Plot the total rainfall data for each year. Add labels to the axes.

2. Calculate and draw the median rainfall using the total rainfall figures for each year. Add the ‘median line’ onto your graph. Why is it better in this case to calculate the median rainfall, rather than the mean?

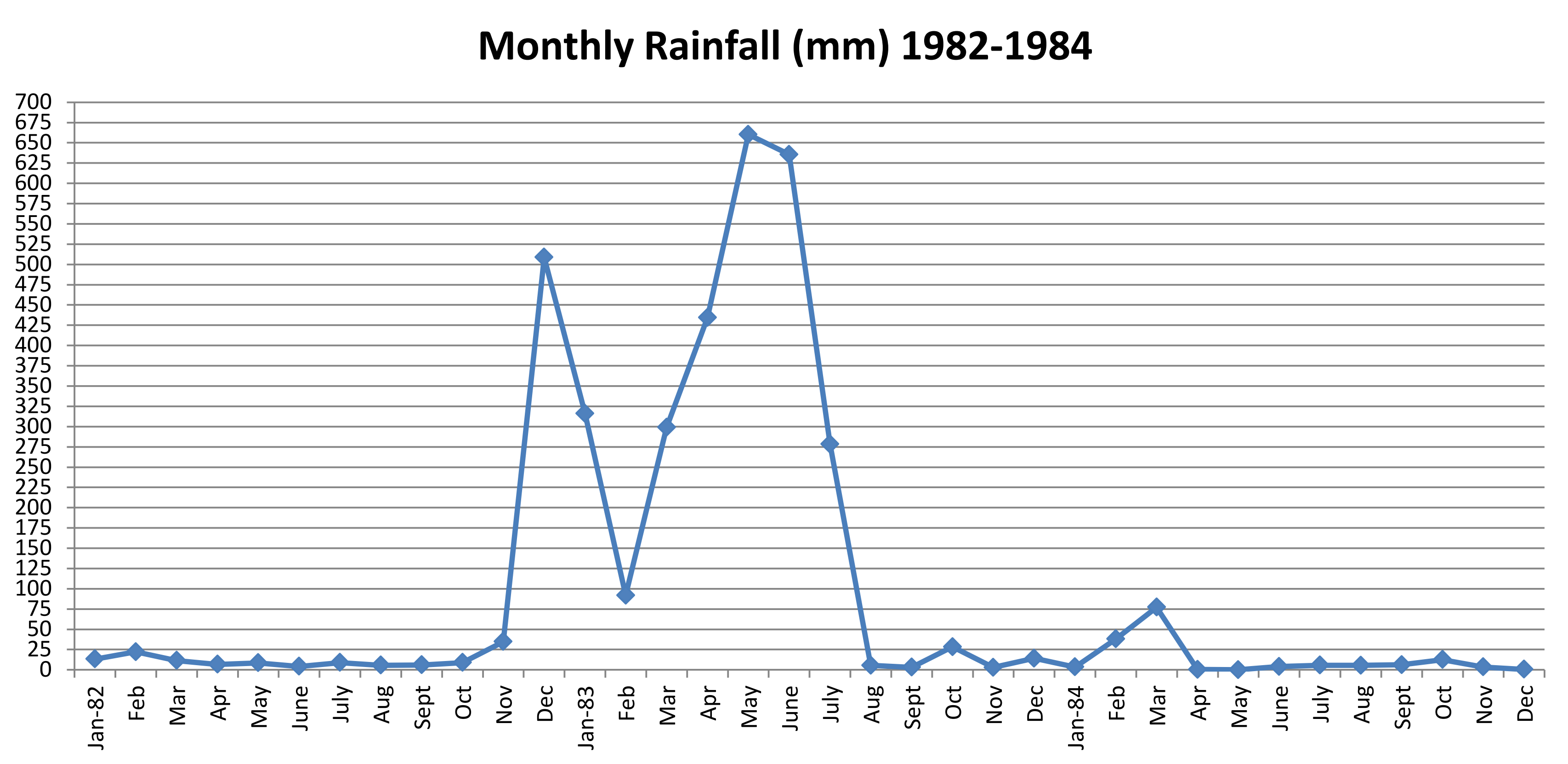
3a. Locate and mark the two ‘Very Strong’ El Niño events you previously identified. Explain the pattern of rainfall in relation to air and sea surface temperatures for the same periods.

3b. Using the data explain why these two events were the wettest events on record.

4. Identify the years of the 3 other ‘strong’ El Niño events.

5. Consider the rainfall data you have just plotted. Your graph shows the total amount of rainfall each year. It does not show rainfall from month to month. Why might this be a useful source of information?

Look at the following graph showing monthly rainfall on Santa Cruz, Galapagos, during the El Niño event of 1982-1983.

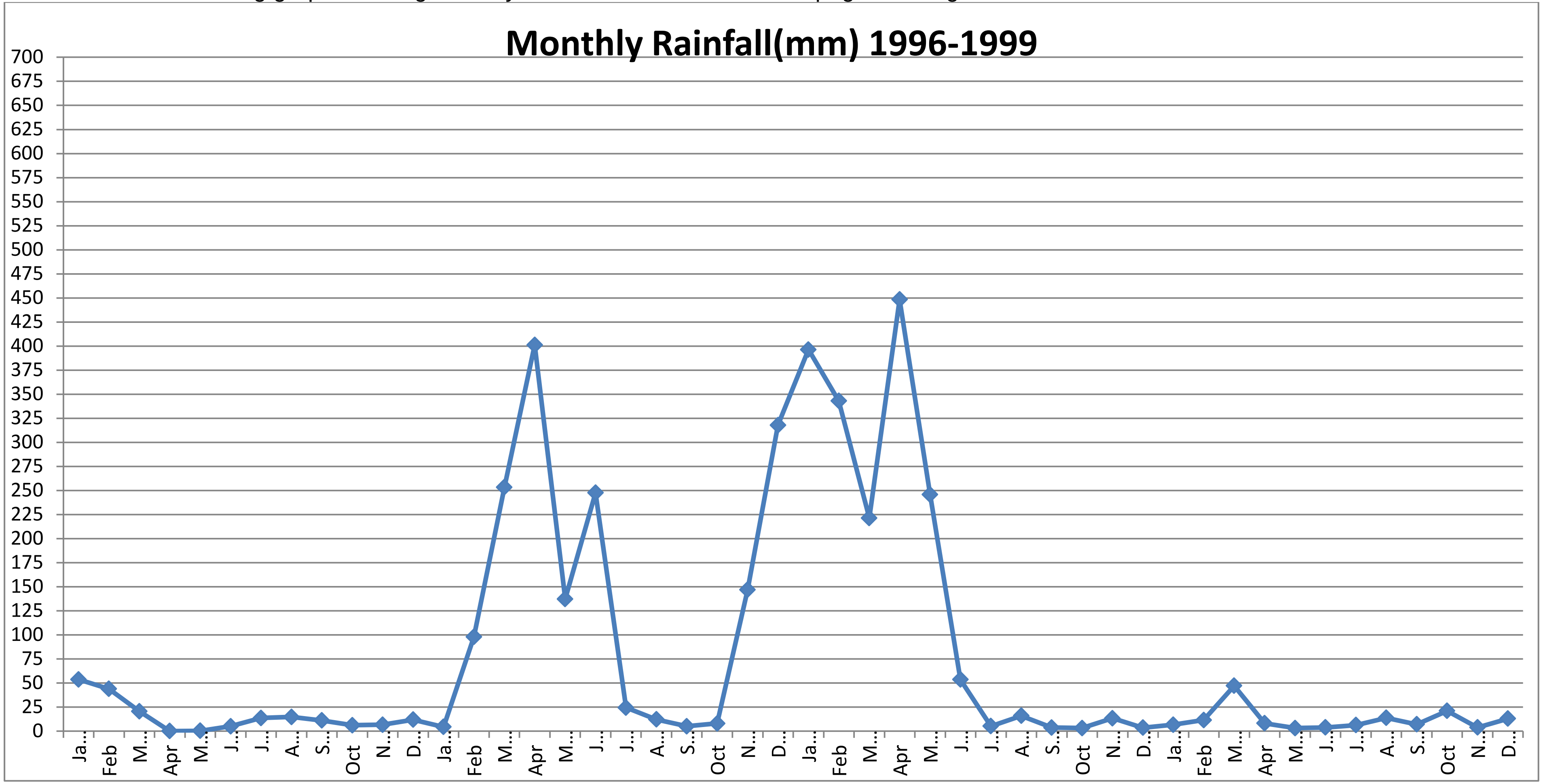



6. From this graph we can clearly identify which months received the most and least amounts of rainfall. Identify which months received the heaviest rainfall.

7. Think about your answer to question 1.4 where we considered disadvantages of using average or mean data. How might the December 1982 and May 1983 figures distort the mean data calculated for each month from 1965-2008?

8. Why could it be more useful to provide yearly sets of data running from December to November, rather that January to December, when considering the effects of El Niño?

Now look at the following graph showing monthly rainfall on Santa Cruz, Galapagos, during the El Niño event of 1997-1998.




9. Calculate the total rainfall from April to June from the 1983 and 1997 data. Then look at the pattern of rainfall shown on both graphs. Read the following statement and explain if you agree or disagree. Use your calculations and the graphs to help explain your answer.
*"A 'typical' El Niño event in Galapagos does not exist"*

**Activity 3 – Identifying trends in data**

1. Refer to your rainfall graph and look at the El Niño events. Explain what happens to levels of rainfall following an El Niño. You may want to focus on the events after the 1982-1983 El Niño as an example.

**What is La Niña?**
After El Niño events, there is often a dry period, or period of drought, where rainfall is considerably lower than average. In Santa Cruz in 1985 for example, there were 3 months where no rainfall was recorded at all! This period of drought is referred to as La Niña and in the Galapagos can last for up to 3 years.

La Niña is part of the natural climatic variation of ENSO (El Niño Southern Oscillation) centred in the equatorial Pacific region. During a La Niña event the low pressure over the western Pacific becomes even lower and high pressure over the eastern Pacific even higher. Because of this, rainfall increases over South East Asia while South America experiences drought. Trade winds become stronger due to the increased pressure between the two areas.

2. Is there a correlation between the strength of El Niño and La Niña events? If so, can you explain it?

**Activity 4 - Analysing trends from data**

1. Using both graphs in this study, explain the approximate frequency of El Niño events.

2. Looking at patterns in the data, predict when the next El Niño will be. Is it possible to predict which category it may belong to? Explain your answer.

3. Looking at rainfall data, explain what is happening to the intensity of El Niño. What do you think future trends of El Niño in Galapagos may look like?

**Concluding activity/ Activity 5 - How can climate variability be used to inform us of future climate change and its impact?**

It is important to realise that El Niño is not the same as climate change. Whilst climate change represents a long term and more substantial change in patterns of weather globally, effects of El Niño are comparatively more short-term, perhaps lasting a year or two. The Galápagos Islands have been experiencing the short-lived climate variations of El Niño for thousands of years.

As the effects of El Niño mirrors many of the changes that climate change is **predicted** to cause, it serves as a useful model to look at its impact on human and environmental factors. With climate models proposing the frequency and intensity of El Niño increasing as our climate changes, information gathered from El Niño in Galapagos can be used in developing management techniques and strategies to reduce the risk to ecosystems and the humans that rely upon them: strategies that could be deployed not only in Galapagos itself but also across the globe.

Scientists have predicted that the following climate change impacts may occur this century:

- Higher average air temperatures: The Intergovernmental Panel on Climate Change (IPCC) estimate that global average temperatures could increase between 2 and 4°c by 2100.
- Higher sea surface temperature: As the ocean absorbs excess heat from the atmosphere, the temperatures of the upper layers of the ocean are likely to increase.
- Increased rainfall: Warming temperatures would likely lead to increased rainfall.
- Sea level rise: Current estimates suggest that sea levels around the Islands have the potential to rise by around 1 metre by 2100. However, the overall effect of global sea level rise on the Galapagos Islands is difficult to predict because volcanic activity on some islands could cause the land to rise (or subside).
- Ocean acidification: The IPCC estimates that by 2100, the oceans average pH will drop between 0.14 and 0.35 units meaning it will become more acidic.

Available online: http://www.discoveringgalapagos.org.uk/discover/geographical-processes/weather-climate/climate-change/

1. Look at the following cards of how climate change may affect the Galapagos both environmentally and economically.
(see attached sheet)
Match each climate change phenomena with its associated impact and adaptation strategy best employed to minimise its effects. Sort into marine, terrestrial and socio-economic impacts.

Discuss the following points with a learning partner:
1. Do any fall into more than one category?
2. Which impacts do you think will affect other countries globally?

**Further investigation and reading can be found here**:

- Full meteorological data sets from The Charles Darwin Foundation http://www.darwinfoundation.org/datazone/climate/
- Weather, Climate and El Niño in Galapagos http://www.discoveringgalapagos.org.uk/discover/geographical-processes/weather-climate/seasons-galapagos/
- On climate change and invasive species (scroll down to second video) https://www.galapagos.org/conservation/conservation/conservationchallenges/climate-change/
- More on El Niño and the Galapagos Islands https://www.climate.gov/news-features/blogs/enso/el-ni%C3%B1o-and-gal%C3%A1pagos