**Technical report on Temperature Temporal Variability at the Intake and Discharge sites at Ecoelectrica's L.P. Pier. Comparison with six additional locations from Tallaboa and Guayanilla Bay.**

By

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## Introduction

Over the period of January 2017 and December 2019, the department of Marine Sciences conducted monthly monitoring of various water quality variables, including temperature, as part of the EcoElectrica's Biological Monitoring Project Plan (BMPP). This technical document reports on temperature measurements conducted during that period. It provides evidence on the temporal variability observed over the period, and compares results for different locations within the Guayanilla/ Tallaboa Bay complex. A comparison with temperature data collected by the Caribbean Ocean Observing System, operated by the University of Puerto Rico and NOAA is conducted.

## Methods

Eight stations were visited every month from January 2017 through December 2019 (Figure 1). Temperature data collected using a Sontek/YSI CastAway CTD. The instrument was operated from a boat operated by EcoElectrica, LP and stations were visited using a shipboard GPS unit operated by the crew. Sampling at the Discharge point (station Out) was conducted by positioning the boat at the center of the outfall diffuser where its effects are maximized (i.e. increase of temperature of the receiving waters over background level. This instrument collects continuous temperature data through-out the water column at each station and enabling the observer reconstruct temperature vs depth profiles. Duplicate measurements were conducted at each station. For this report, data collected at two depth intervals were binned into two discrete depths, 0-1 and 3.6-4.4 meters since the depth at the discharge fluctuated between 4.5

and 5m. The deeper bin was labelled 4m for simplicity. This way depth was normalized and comparisons among stations were made possible.

## Results and Discussion

The yearly temperature cycles at the discharge (Out) and intake (Int) stations can be observed in Figure 2 for both 0-1 and 4m. This figure shows the striking similarity between both stations and depths. This similarity supports a state of string mixing throughout at these depths sampled as well as no temperature stratification. The figure also shows the temporal changes that are present at the sites with maximum temperatures observed during the months of September/October and minimum temperatures during February-March of each year.

The temperature pattern of the Out and Int stations fitted well within those observed for the rest of the stations (Figure 3). For the purpose of this report, station 12 was selected as an endpoint corresponding to offshore reef conditions and the least affected by the local shallow water environments found in Guayanilla Bay. However, station 12 was found to be slightly warmer than the Out station at occasions related to water temperature maxima. A statistical comparison of the temperatures recorded at stations 12 and Out throughout the sampling period found no significant difference (Figure 4 and Table 1), supporting the similarity between these stations, that is that the temperature patterns observed at station Out are statistically indistinguishable from that of the offshore station during the sampling period. At no time during this period temperatures higher than 32°C were found at neither the Int nor the Out stations. Temperatures higher than 30°C were seldom found, and only during times of the year when temperatures at other stations were similarly high.

Figure 5 includes temperature data from the Caribbean Ocean Observing System (CariCOOS) buoy located farther away from shore to the east of EcoElectrica, in Caja de Muertos Island (CMI), south of Ponce (17.869; -66.532; https://www.ndbc.noaa.gov/station_page.php?station=42085). The buoy provides near real-time data and can be used as an indicator of off-shore patterns more isolated from shallow water regimes than the statins sampled in his study. The CMI data shows lower temperatures than those at the Guayanilla/Tallaboa complex, with a lesser gap during 2017. The difference between both datasets may be attributable to the increase effect of solar insolation on shallow waters. Waters flowing over shallow environments are forced to experience increased exposure to solar irradiation, thus increasing their heat absorption and temperature. Otero (2009)[1] observed an increased range of temperatures in shallow waters of La Parguera than in reefs located in deeper waters. This explain how the observed temperatures at Guayanilla/Tallaboa Bay complex are warmer than the oceanic waters at CMI. If true, the

[1] Otero, E.. 2009. Spatial and temporal patterns of water quality indicators in reef systems of southwestern Puerto Rico. Carib. J. Sci. 45:168-180.

temperature patterns at station 12 indicate that its waters have been exposed to the natural heating occurring in shallow zones. Overall, analysis of data presented at the 2016 Puerto Rico Climate Council Annual Meeting[2] suggests that the trend in temperature for oceanic waters is increasing at a rate of 0.022C/year since 1980, resulting at an average temperature of about 30 °C by 2019 (Figure 6). This agrees with the observations at CMI and suggests that shallow waters of Puerto Rico will potentially have or will reach higher temperatures in the future.

**Conclusion**

Temperature patterns at Guayanilla Bay show a general increase during 2018 and 2019, consonant to findings by others in coastal waters of southern Puerto Rico. These natural regime includes maxima that may be >30°C. Trends in general ocean water temperatures derived from nearby oceanographic stations suggest that at present the average temperature maxima is expected to 30 °C or higher. Since ocean water flowing over shallow coastal areas have the potential to be more exposed to solar heating (due to limited mixing to deeper water), it is expected that these will reach higher temperatures than the oceanic norm. Therefore, in the future, temperatures higher than 30 °C should be more frequently expected. The observations of the present study seem to support this view. Under these circumstances, no clear evidence was found of significant temperature effects of EcoElectrica's discharge on the natural temperature regime at station Out.

[2] http://pr-ccc.org/download/MORELL_PRCC__2016_final.pdf

# Figures and Tables


| Station | Latitude decimal degrees | Longitude decimal degrees |
|---|---|---|
| 8 | 17.98810 | -66.78953 |
| 4N | 17.98334 | -66.75203 |
| 11 | 17.97918 | -66.76834 |
| 4 | 17.97844 | -66.75218 |
| Intake | 17.97514 | -66.75924 |
| Outfall | 17.97265 | -66.76152 |
| 5 | 17.97063 | -66.75929 |
| 12 | 17.96189 | -66.76278 |

**Figure 1. Location of Sampling Stations**

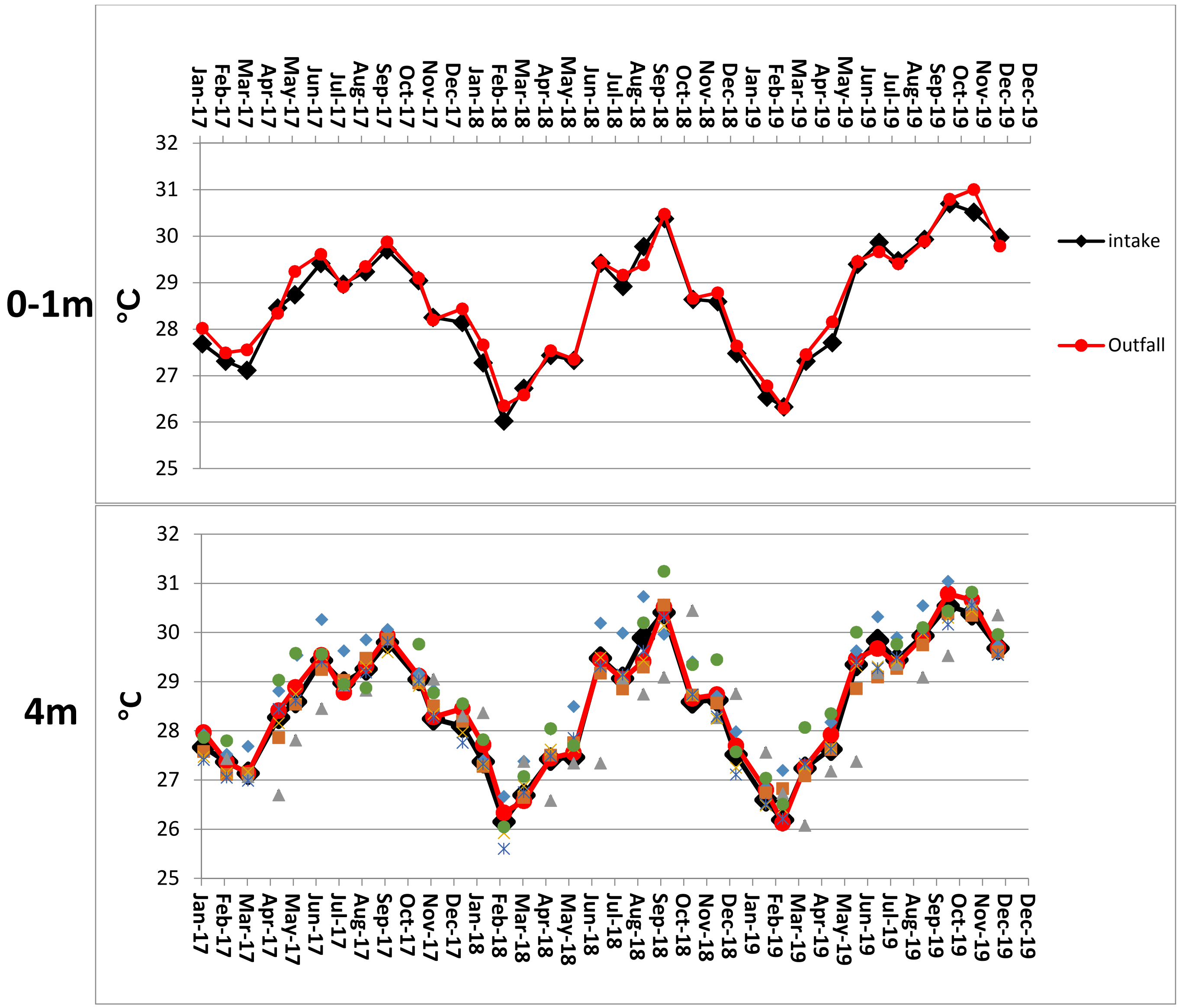


**Figure 2. Time Series Comparison of Temperature at the Intake and Outfall Stations at 0-1m (Top) and 4 m (bottom) depth interval.**

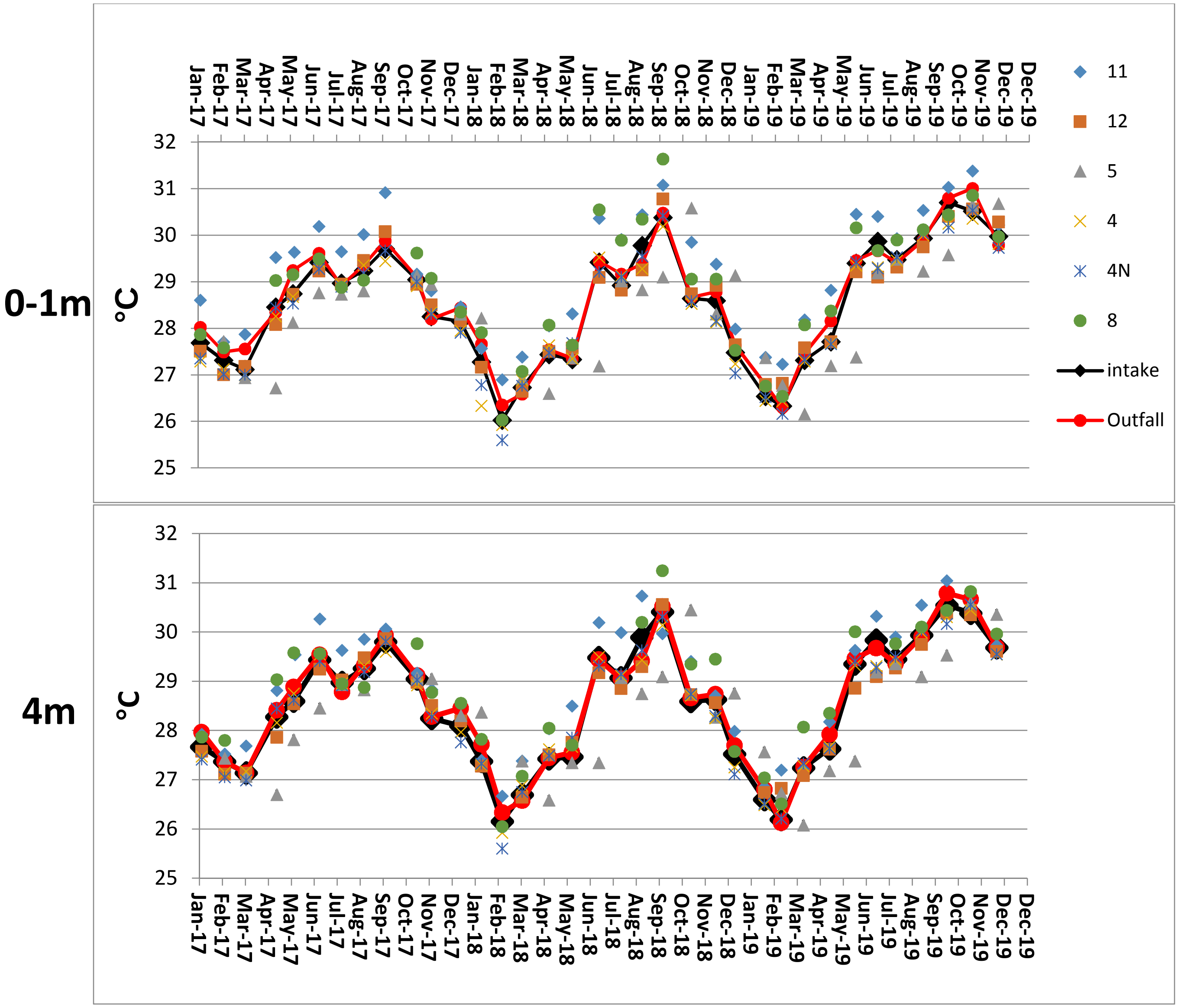


**Figure 3. Comparison of temperature time series of the Intake and Outfall stations with that of other stations at Guayanilla and Tallaboa Bay. The other stations include various endpoints outside the influence of EcoElectrica's operation and are included as reference of natural or background environmental regimes.**

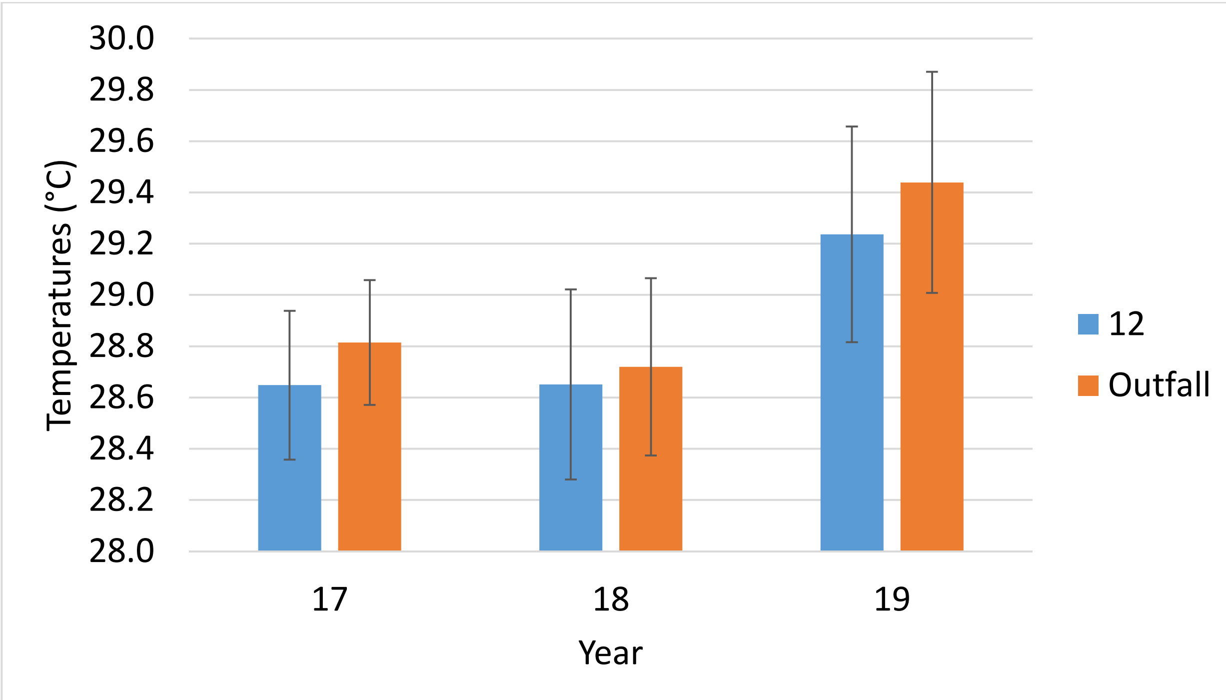


**Figure 4. Summary of statistical comparison of temperature (Average± 1SE) for station Outfall and 12 (offshore station). Analysis was conducted using monthly averages shown on previous figures. Months where records were missing were deleted from all years. The ANOVA Table (Full Factorial: year and Stations uses as Classification Factors) is shown below.**

# Table 1. Full Factorial ANOVA Table (StatistiXL Ver.2.0)

**A. Overall test of model for between stations (P≤0.05 means statistically significant differences)**

| Source | Type III SS | Df | Mean Sq. | F | Prob. |
|---|---|---|---|---|---|
| Model | 5.188 | 5 | 1.038 | 0.902 | 0.487 |
| Error | 57.520 | 50 | 1.150 | | |
| Total | 62.707 | 55 | | | |

**B. Tests of effects for Temperature by year and an a dependency between differences between years and stations. (P≤0.05 means statistically significant differences)**

| Source | Type III SS | Df | Mean Sq. | F | Prob. |
|---|---|---|---|---|---|
| Station | 0.298 | 1 | 0.298 | 0.259 | 0.613 |
| Year | 4.843 | 2 | 2.421 | 2.105 | 0.133 |
| Station*Year | 0.043 | 2 | 0.022 | 0.019 | 0.981 |

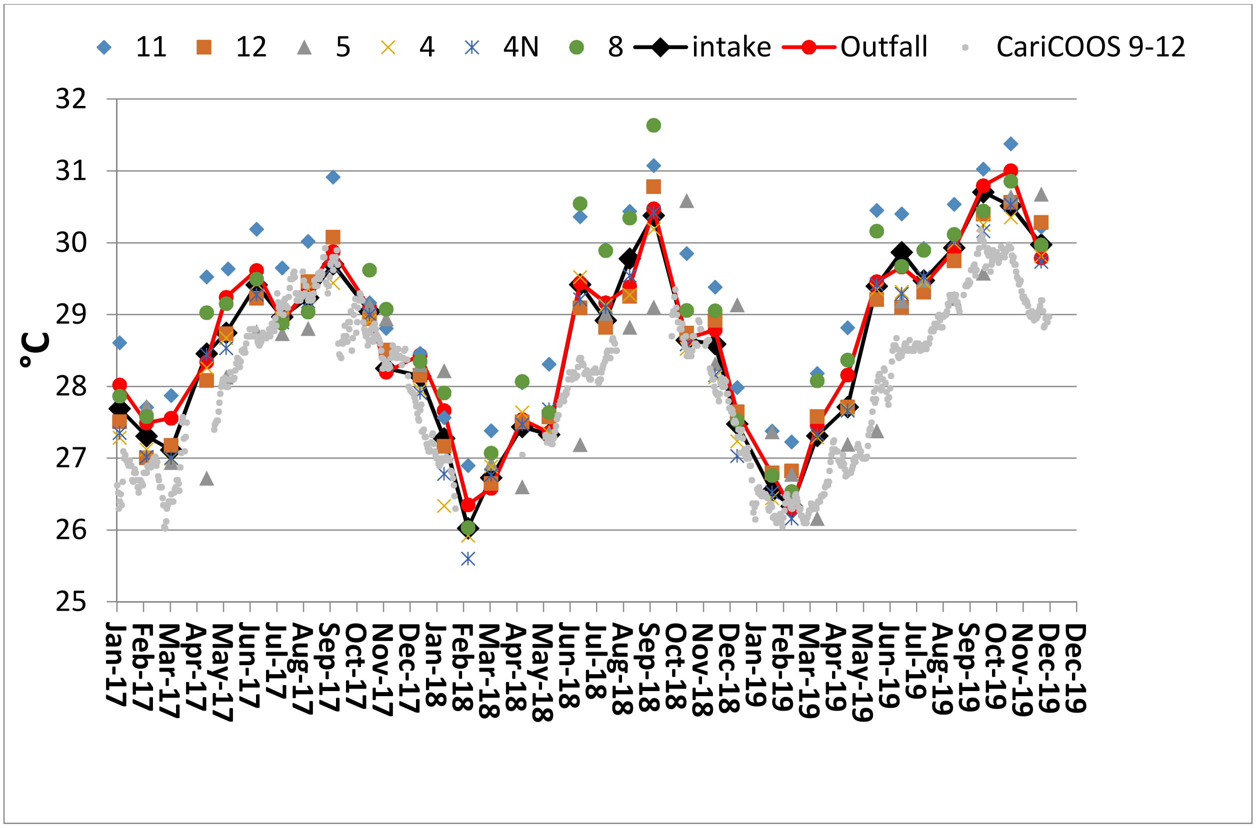


**Figure 5. Comparison of average temperatures measured at the Guayanilla/ Tallaboa Bay Complex and data collected in Offshore waters at Caja de Muertos Island [3]. Data from Caja de Muertos Island shows data only for the 9AM to mid-day hours which is the same period where data was collected for this study.**

[3] https://www.ndbc.noaa.gov/station_page.php?station=42085

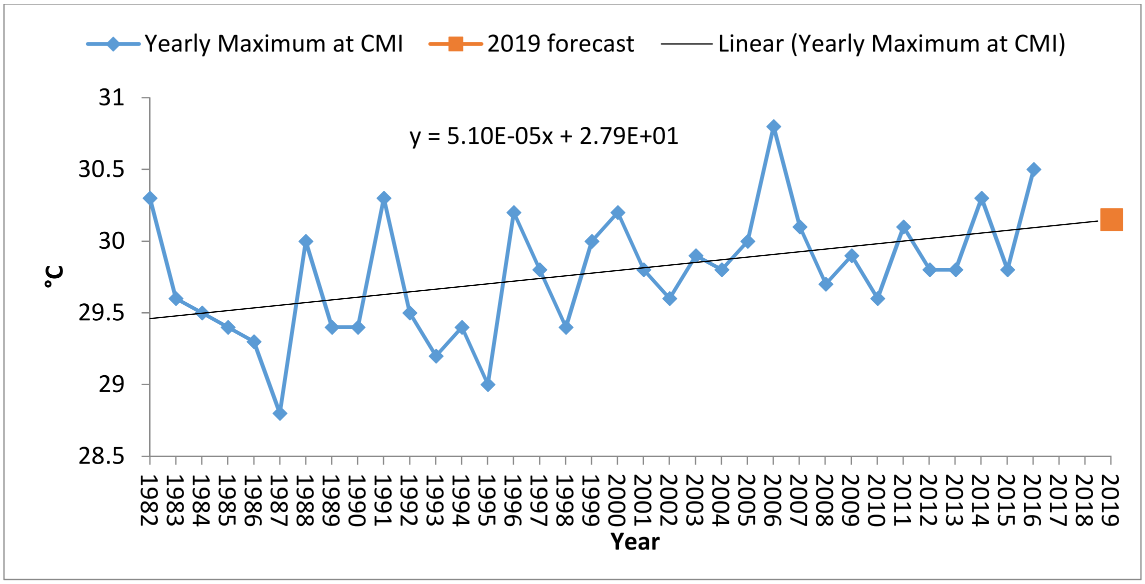


**Figure 6. Yearly temperature maximum at the Caribbean Time Series Station from 1982 to 2016. Data digitized from Morell (2016)[4]. The 2019 forecast was calculated using the regression derived from the data.**

[4] http://pr-ccc.org/download/MORELL_PRCC__2016_final.pdf