PHYS 411 Project

Benjamin Frizzell

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1 Introduction

The temperature and pressure, as measured by several weather stations across Greater Victoria and Vancouver island, was subject to various data analysis methods. Of particular interest was the pressure as measured at the Monterey station, which displayed erratic amplitudes and a sudden drop in atmospheric pressure starting in 2019. Spectral and EOF analysis confirmed that this was caused by an increase in high-frequency pressure oscillations starting at this time and increasing in intensity up to 2022, and this was localized to the climate of Greater Victoria. It is therefore likely that this phenomena was caused by changes in wind flow from the Pacific Ocean, however further understanding of ocean and atmospheric processes would likely be necessary for a complete understanding of this phenomenon.

2 Procedure

Minute-resolution measurements of temperature and pressure were recorded by five stations across Greater Victoria: UVicSci, Monterey, Craigflower, Shawnigan Lake, and Cumberland. Additionally, Hourly-resolution measurements of temperature and pressure were recorded by fifteen stations across The north-eastern coast of Vancouver Island, Victoria, and the Gulf Islands. Recording of data began on 2016-01-01 00:00 UTC and ended on 2022-07-31 00:00 UTC.

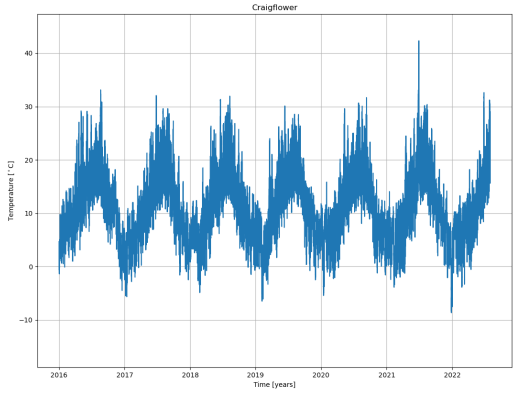
3 Analysis

3.1 Minute-Resolution Data

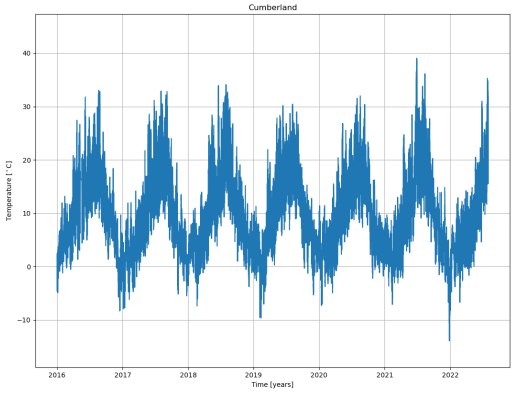
Figure 1 and 2 show the time pressure and temperature time series. Concerning temperature, none of the stations appear significantly distinct from one another: temperature across all stations show seasonal periodicity as would be expected. Interestingly, the Shawnigan Lake and Cumberland stations seem to show a slightly larger seasonal amplitude than the other stations. Since these stations are further inland than the other stations, it is possible that this is due to decreased influence of the pacific ocean as a regulator of climate.

Similar to temperature, the pressure time series also show some seasonal periodicity, although it is much less apparent. Of particular interest is the pressure time series recorded at Monterey, where measurements begin to deviate greatly from the other stations starting in mid-2019, resulting in several cases of high, and mostly very low pressure extremes. Since the Monterey station is one that is particularly low in

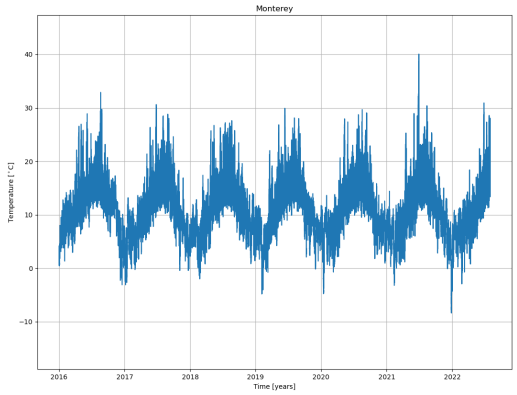
elevation and close to the open ocean, it would not be unreasonable to expect particularly strong winds here. However, it is unclear why this is only observed from 2019 - 2022. Because of this anomaly, the Monterey pressure time series was particularly studied during analysis of minute-resolution data.



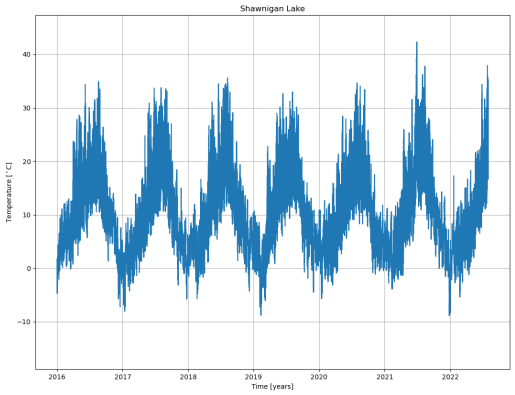
(a) Craigflower



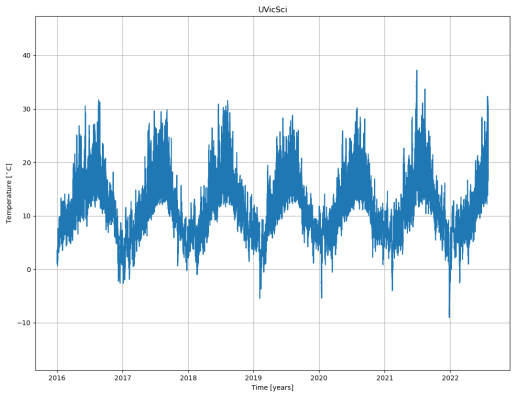
(b) Cumberland



(c) Monterey

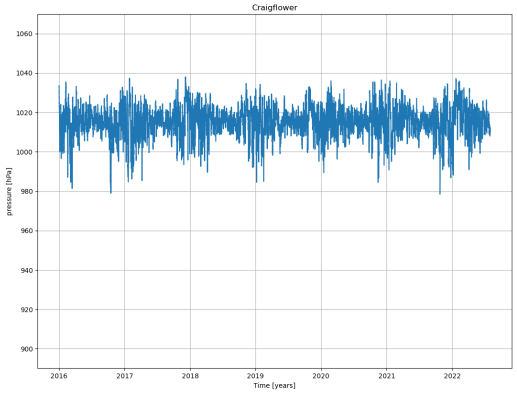


(d) Shawnigan Lake

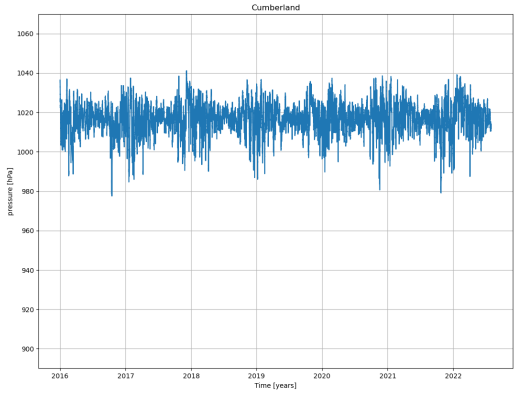


(e) UVicSci

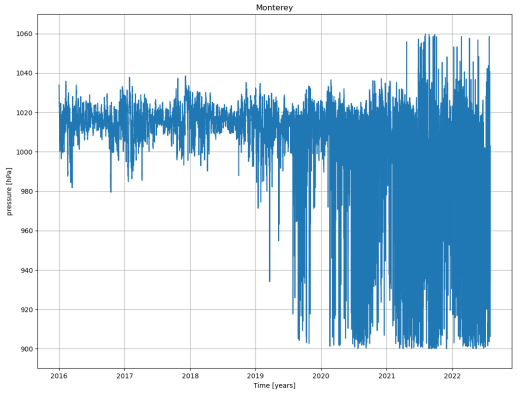
Figure 1: Temperature time series for minute-resolution stations.



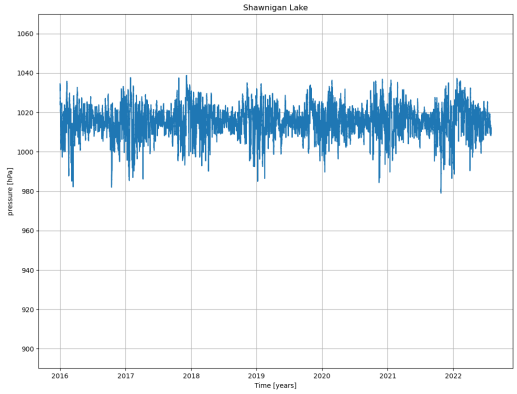
(a) Craigflower



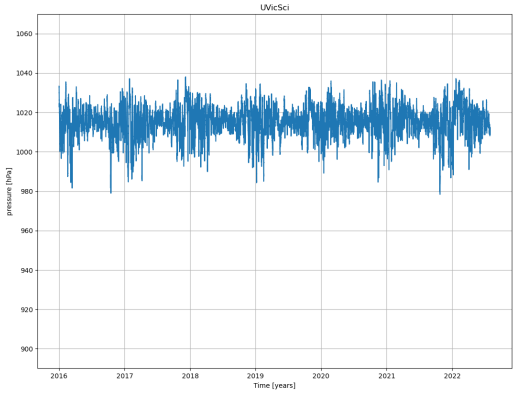
(b) Cumberland



(c) Monterey

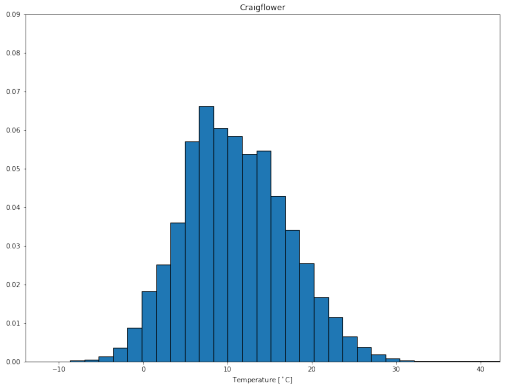


(d) Shawnigan Lake

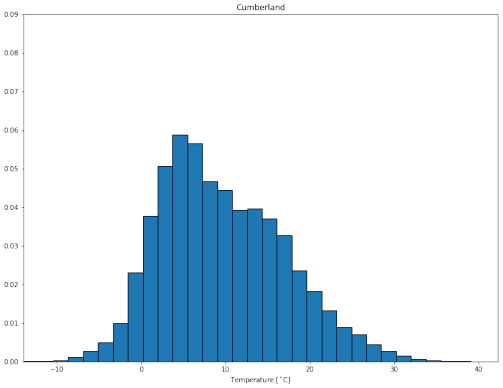


(e) UVicSci

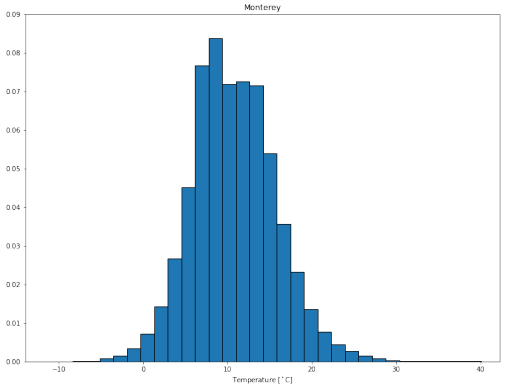
Figure 2: Pressure time series for minute-resolution stations.



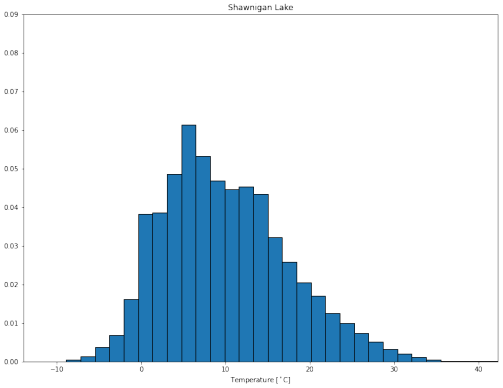
(a) Craigflower



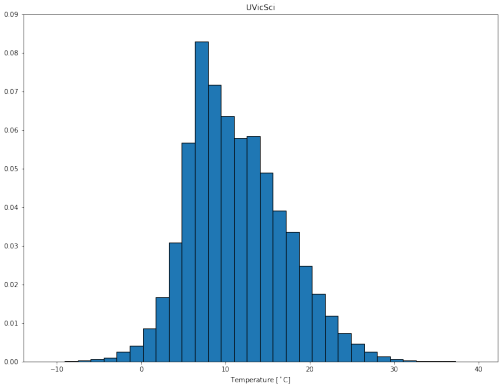
(b) Cumberland



(c) Monterey

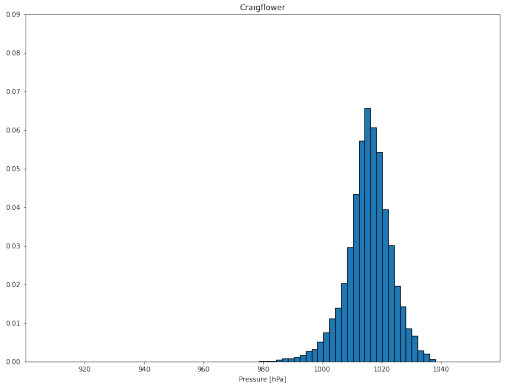


(d) Shawnigan Lake

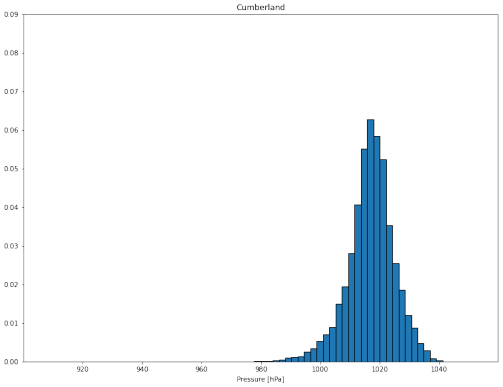


(e) UVicSci

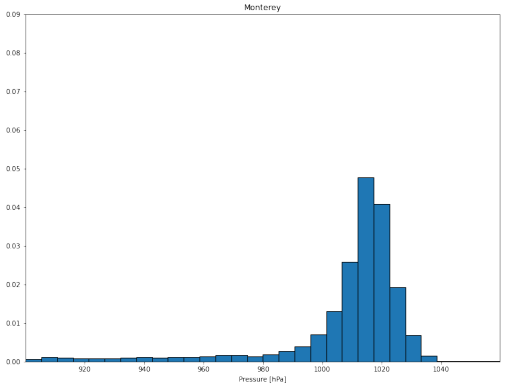
Figure 3: Temperature PMFs for each station. Measurements are separated into 30 centered bins.



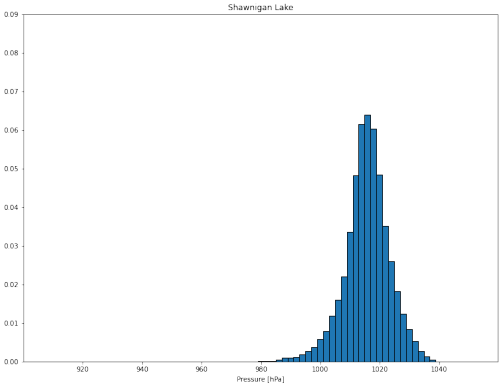
(a) Craigflower



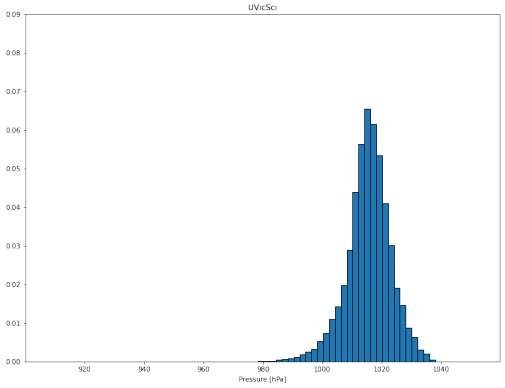
(b) Cumberland



(c) Monterey



(d) Shawnigan Lake



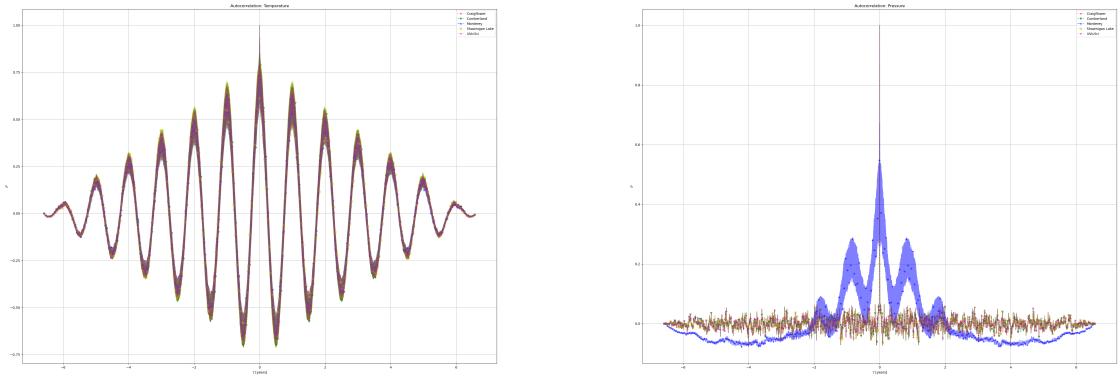
(e) UVicSci

Figure 4: Pressure PMFs for each station.

	Temperature [$^{\circ}C$]				Pressure [hPa]			
Station	Mean	Variance	Skewness	Kurtosis	Mean	Variance	Skewness	Kurtosis
Craigflower	10.88	6.11	0.25	2.90	1015.57	7.41	-0.43	4.12
Cumberland	9.62	7.33	0.46	2.84	1017.00	7.73	-0.44	4.07
Monterey	10.75	4.93	0.28	3.48	1008.31	22.81	-2.57	10.14
Shawnigan Lake	9.97	7.36	0.52	2.95	1015.65	7.44	-0.40	4.10
UVicSci	11.30	5.67	0.41	3.09	1015.53	7.40	-0.44	4.13

Table 1: Statistics and moments of temperature and pressure for each station.

Figures 3 and 4 give the probability distributions of the temperature and pressure for each station, discretized into 30 bins. Table 1 gives the associated statistics and moments. As was the case for the time series, the temperature distributions do not seem to display any significant variation from one another. However, it can be noticed that the previously mentioned "inland" stations, Cumberland and Shawnigan Lake, have the lowest mean temperatures, highest variance, and rightmost skewness of the distributions, which may further support the possibility that these regions are less influenced by the coastal climate and experience more extreme temperature variations as a result. Additionally, the anomalous low-pressure readings obtained at the Monterey station are further illustrated.

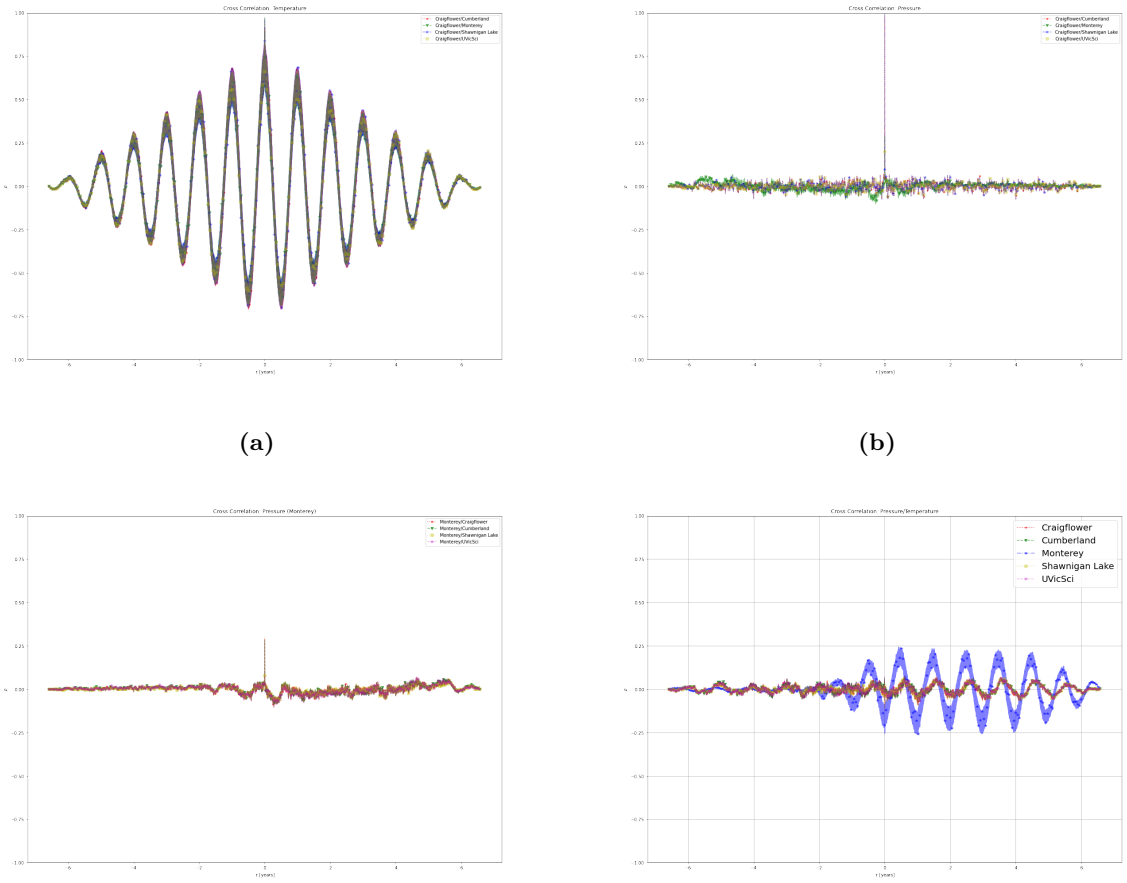


(a) **(b)**

Figure 5: Autocorrelation of temperature and pressure per station.

Figure 5 shows the auto-correlation of temperature and pressure for each station. As expected, Figure 5 a) shows correlation with periodicity of one year, confirming what was expected given Figure 1. Pressure auto-correlation appears to be much weaker over all stations, and only the Monterey station seems to show annual periodicity. This will be further investigated via spectral analysis in the following analyses.

To determine the degree to which temperature and pressure were independent, as well as the degree to which each station was independent of the others, Several samples of the cross correlation between stations and their variables was determined.



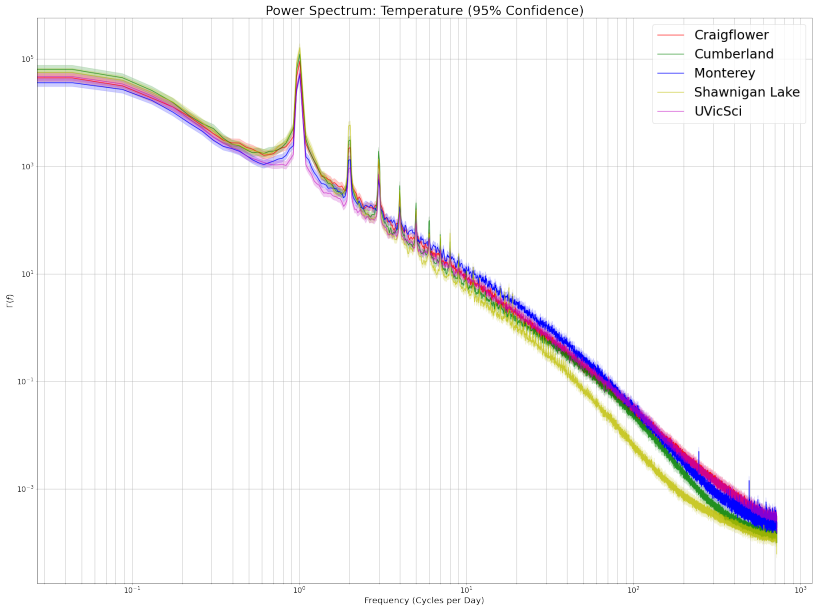
(a) **(b)**

(c) **(d)**

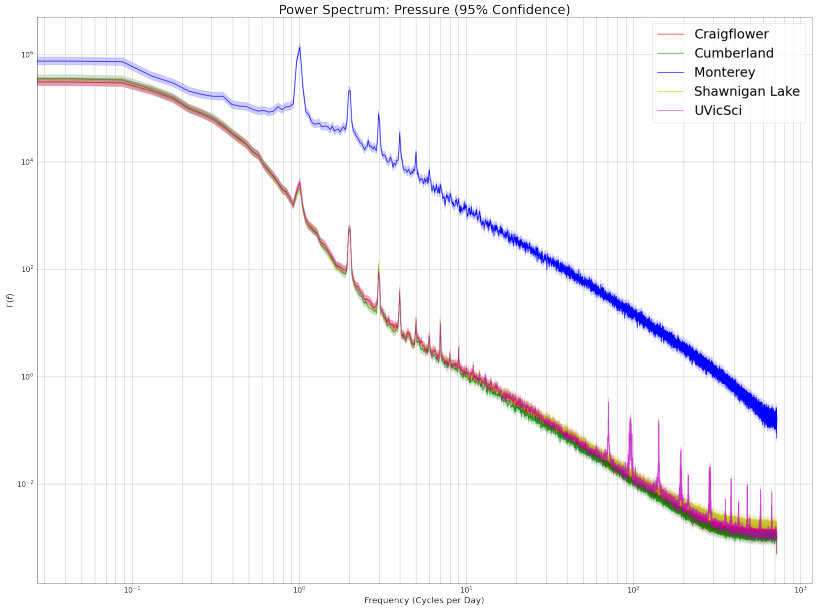
Figure 6: Cross correlation of (a) temperature of Craigflower and temperature of all other stations, (b) pressure of Craigflower and pressure of all other stations, c) pressure of Monterey and pressure of all other stations, d) Cross-correlation of temperature and pressure per station.

Figure 6 a) shows reasonably strong temperature correlation across all stations on annual cycles, suggesting that temperature does not vary significantly across Greater Victoria and the surrounding regions for given times of the year. Concerning pressure, Figures 6 b) through c) show the contrary; wind pressure shows little to no correlation between other locations in Greater Victoria or with temperature. The one exception to this trend appears to be Monterey, where pressure and temperature show weak but non-negligible correlation in a yearly cycle and with a time delay of approximately 2.5-3 years. Since the anomalous low-pressure readings appear to also begin about 3 years after data collection begins, it is likely that the cross correlation might somehow explain this.

Following this, the spectra of temperature and pressure was determined for each station, using Welch's method.



(a)

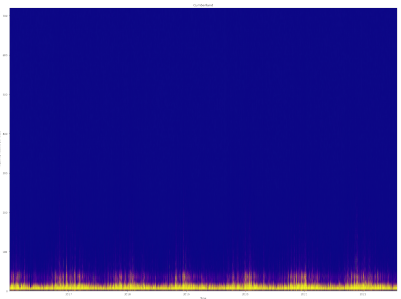


(b)

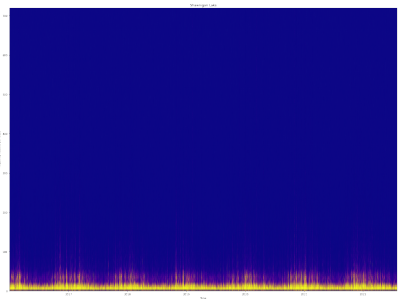
Figure 7: Temperature and Pressure Spectra

All spectra share a common dominant peak at 1 cycle per day, with diminishing peaks at integer multiples of 1 cycle per day. Closer inspection of the temperature spectra reveals very similar results for all stations, as is expected given all previous results. Upon inspection of the pressure spectra, it is revealed that the Monterey pressure spectrum station is quite similar in shape to the other stations, differing only in an overall higher energy across all frequencies.

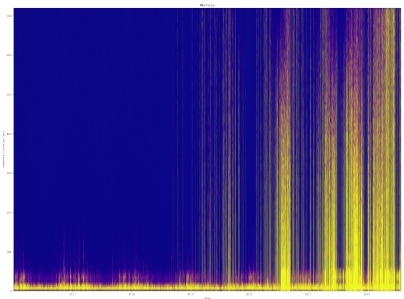
Because of this results, several pressure spectrograms were produced to further pinpoint the source of deviation in pressure between the Monterey station and the other stations. Figure 8 shows the results:



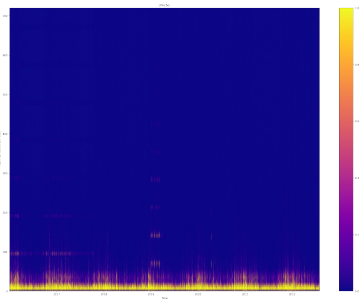
(a) Cumberland



(b) Shawnigan Lake



(c) Monterey



(d) UVicSci

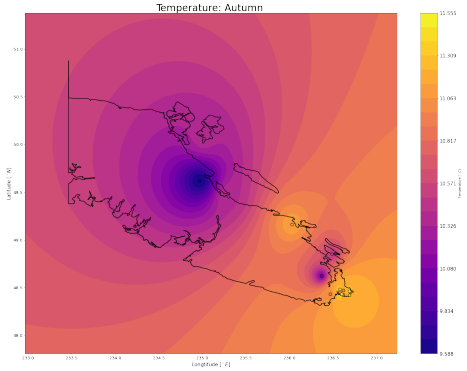
Figure 8: Pressure Spectrograms

The Figures above allow for a clearer understanding of the results shown for Monterey in Figure 2. While pressure spectra remain fairly regular across time for all other stations, Monterey specifically seems

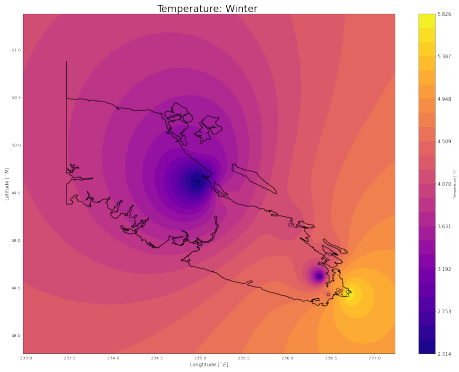
to obtain additionally energy in the higher frequencies starting in 2019 and increasing in intensity across all frequencies through 2022. It appears that the spectrum begins to decrease in upper-frequency energy towards the end of the time series, however the data is insufficient to make a proper conclusion. The exact cause of this phenomena is unknown and would likely require a more thorough understanding of pacific coastal climate processes.

3.2 Hour-Resolution Data

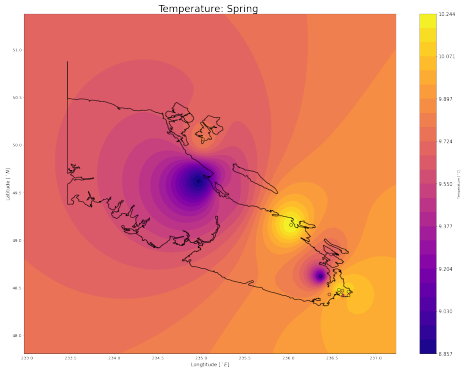
Using the hourly data-set, a coastal weather map of Vancouver Island was produced. To do so, temperature and pressure across the 15 stations was averaged according to seasons: autumn temperature and pressure was averaged over the months of September to November for all years in the data-set. For winter, data from December to February was selected, March to May for spring, and June to August for summer. Using global $\frac{1}{r^2}$ gridding, the following pressure and temperature maps were produced:



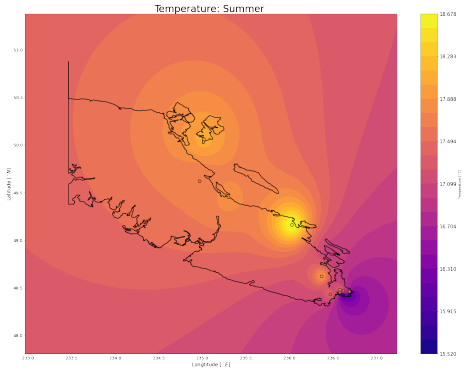
(a) Autumn



(b) Winter

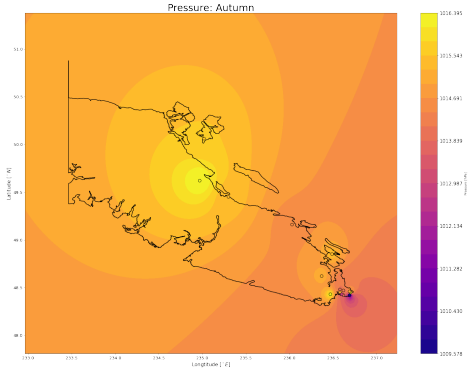


(c) Spring

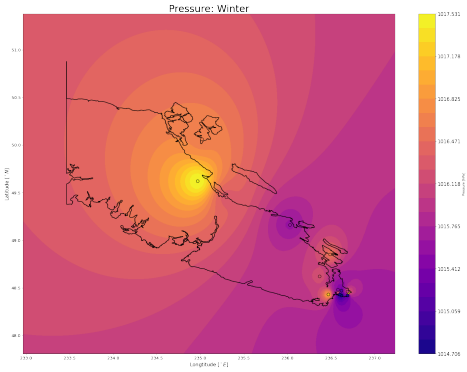


(d) Summer

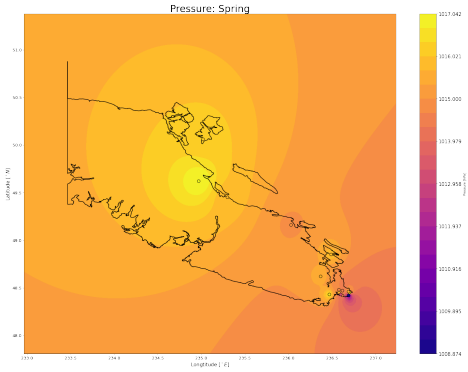
Figure 9: Global Gridding: Temperature



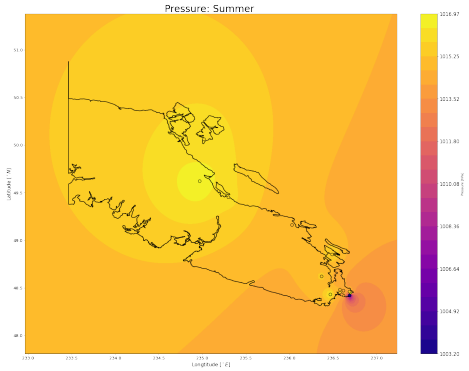
(a) Autumn



(b) Winter



(c) Spring



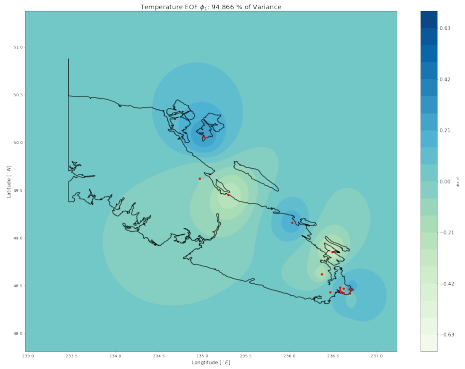
(d) Summer

Figure 10: Global Gridding: Pressure

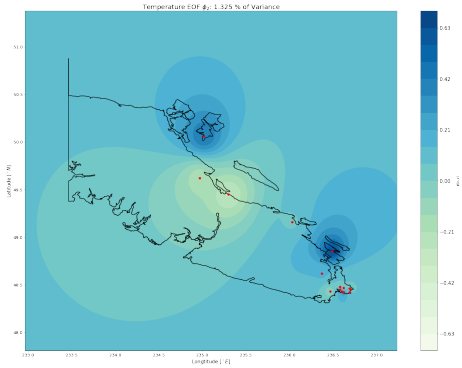
A general observation that can be made observing Figure 9 is that the southeast pacific coastal temperature is much less extreme than temperatures found inland: average temperatures on the southeastern point of the island appear to range from approximately 5 $^{\circ}C$ in the winter to 15 $^{\circ}C$ in the summer, whereas temperatures inland and northwest range from approximately 2 $^{\circ}C$ to 18 $^{\circ}C$. Since the pacific ocean acts

as a heat sink to moderate temperature throughout the year, this aligns with expectations. Wind pressure across the island appears to vary more extremely between inland and coast in the colder months, and appears to become more homogeneous across the island in spring and summer. Pressure seems to be consistently lower in Victoria than in all other regions, which is consistent with previous observations made with the minute resolution data.

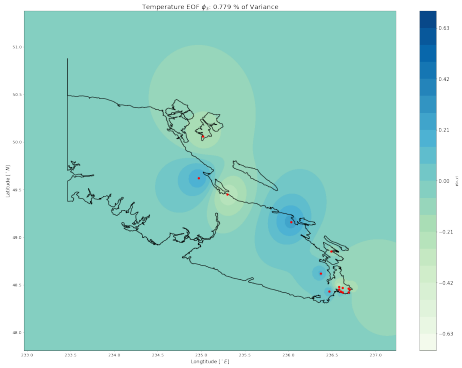
Finally the Empirical Orthogonal Functions were determined for the pressure and temperature, followed by their amplitudes. For the temperature data-set, three orthogonal functions representing 96.7% of the variance were displayed, and for the pressure, two orthogonal functions represnting 98.59% of the variance were selected. The results are displayed below:



(a) ϕ_1 : 94.37% of Variance

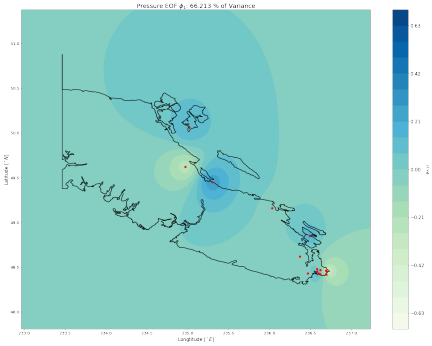


(b) ϕ_2: 1.32% of Variance

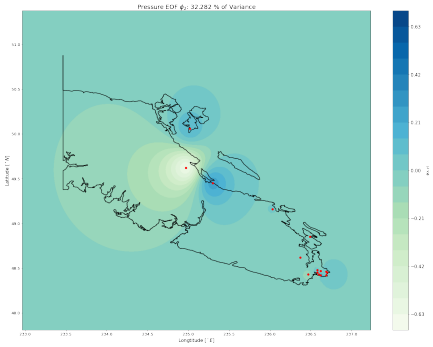


(c) ϕ_3: 0.79% of Variance

Figure 11: Temperature EOFs

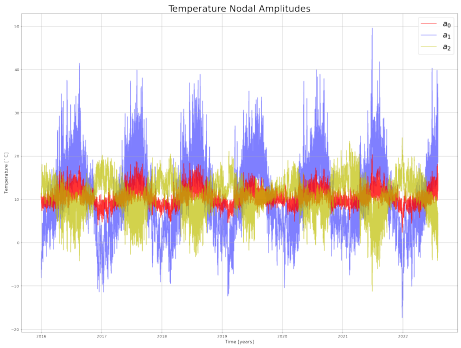


(a) ϕ_1 : 66.21% of Variance

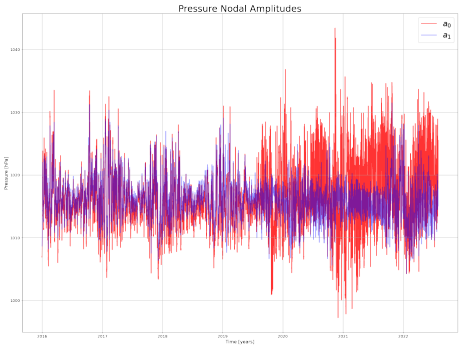


(b) ϕ_2: 32.28% of Variance

Figure 12: Pressure EOFs



(a) Temperature



(b) Pressure

Figure 13: Amplitudes of Fundamental EOFs

The temperature variation across the island is almost entirely dominated by the first EOF, which displays generally similar temperatures across the interior of the island and Saltspring island, Whereas temperatures across Greater Victoria and Cortes Island (and its surrounding islands) generally differ. The corresponding amplitudes show yearly periodicity as is expected.

Unlike the temperature, which is dominated by one EOF, wind pressure across the island is influenced by two EOFs, the first displaying wind flow to the north opposing the wind flow in Victoria. The secondary, less influential EOF displays strong wind flow inland near Courtenay. Interestingly, the amplitude of the first pressure EOF are consistent with the anomalous Monterey pressure readings discussed previously, as the amplitude also seems to increase significantly in mid to late 2019. This further confirms that the cause of the low pressure during these years is likely due to the influence of the ocean climate.