University of Victoria

Southern Vancouver Island

Temperature Time Series Analysis

By

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Class:

Time Series Analysis (Phys 411)

South Vancouver Island Temperature Report

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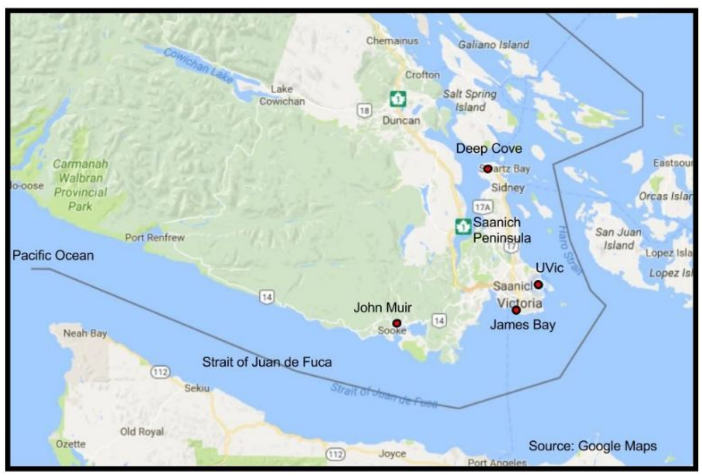
Abstract

Temperature Data over three years, collected hourly at 30 locations around southern Vancouver Island and at a minute resolution for four of the same locations, provides the raw data on which Time Series Analysis techniques were applied to develop an understanding of the dominant weather patterns of the region. Victoria weather is heavily impacted by the water around it, predominantly the Strait of Juan de Fuca, which comes in from the open Pacific Ocean and becomes more sheltered as it swoops up around Vancouver Island to Vancouver and the Gulf Islands. In the winter, storms and other weather patterns come from the open ocean, travel down the Strait, and impact the temperature first at John Muir before arriving at Victoria. In the summer, the calmer waters' heat sink plays a significant role in regulating the temperature of the air. The following sections survey the statistical tools used in analyzing the temperature time series in the region.

Geographic Overview:



Vancouver Island, located on Canada's west coast, is approximately one-quarter of the United Kingdom's size. The southern tip is located near the 49th parallel, 49 degrees north, which makes up most of the Canada and United States border. It is a similar latitude to the south tip of the United Kingdom, northern France, and Germany. The western edge meets the North Pacific ocean, while its eastern edge is separated from North America's main continent by a strait of varying width. Its southern tip is nestled into mainland Washington State, separated by the Strait of Juan de Fuca from the Olympic Peninsula, which juts out into the Pacific ocean.

South Vancouver Island includes Sooke, Greater Victoria, and the Saanich Peninsula. Sooke is located up the southwest coast of Vancouver Island, along the Strait of Juan de Fuca towards the pacific ocean. Greater Victoria makes up the southern tip, with the Saanich Peninsula extending north towards the Gulf Islands.

Station Locations:

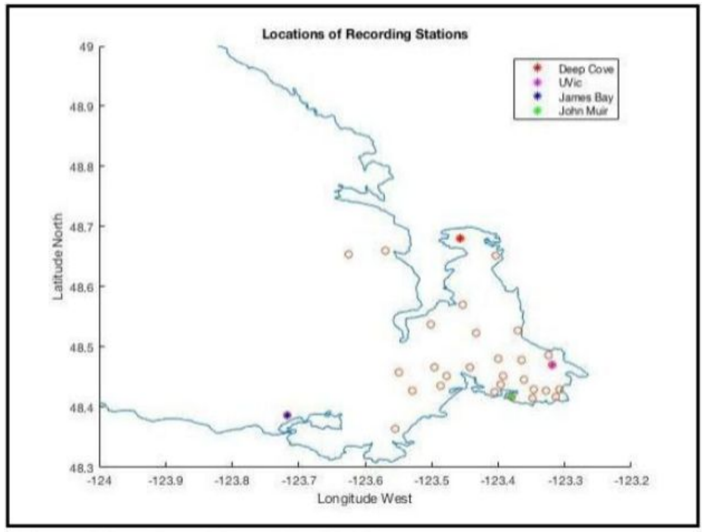


Figure 1: Location of Recording Stations

Temperature data has been collected at 4 locations at a minute resolution for three years, from 2008 to 2010. Locations include; John Muir elementary school in Sooke located along the coast at 40 m above sea level, University of Victoria (UVic) in the northeast corner of Victoria city and 57 m above sea level, James Bay in southwest Victoria and 7 m above sea level, and finally Deep Cove, on the northern tip of Saanich Peninsula at 57 m above sea level. Simultaneously, along with 23 other sites, hour resolution data were collected over the same period.

Basic Weather:

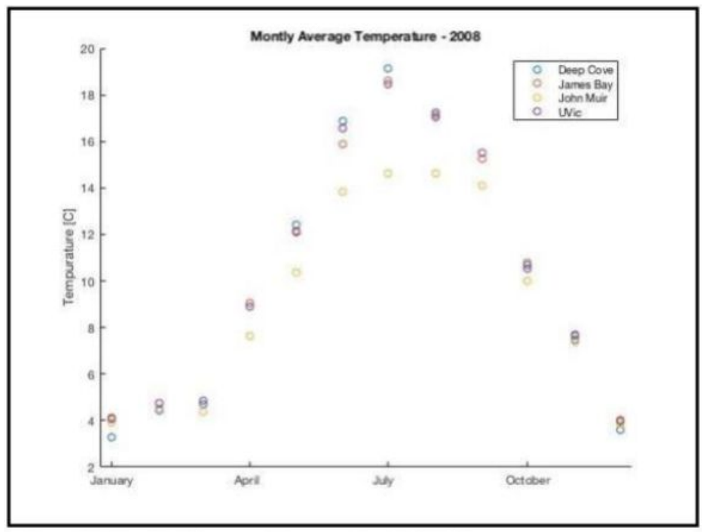


Figure 2: Monthly Average Temperature in 2008

The Greater Victoria area is well known for having the mildest winters in Canada. While it is at a lower latitude than most of the southern border, the primary factor influencing its temperature is the ocean. Large bodies of water and the open ocean are dominant factors influencing the weather through their heat capacity. Winds and pressure zones from the open Pacific can be funneled up the Strait of Juan de Fuca by the Olympic mountain range that climbs steeply from sea level to 2000 meters. Currents from the ocean also sweep up this strait; the Pacific Ocean's dominant current patterns are clockwise and sweep down the west coast of Canada.

Air can both lose energy to the water when the air temperature is much greater than the water, and gain energy when the air temperature is less than or comparable to the water. In the heat of the summer day, energy is stored in the water and then released at night.

Each month's average temperature at each of the four primary locations (Figure 4) shows how the temperature from December through March stays between 2 and 6 degrees Celsius. Between April and November, the average temperature steadily grows to a peak between 14 and 19 degrees in July and then lowers back down. One characteristic of note is that John Muir, located closer to the open ocean, has a lower maximum temperature than the other stations in the summer. Figure 4 combines the temperature data for both day and night and gives each station's total average in each month of 2008. The other years are very similar, but not identical. A full plot of the time series at one location, with a running boxcar average applied to reduce noise, shows how the temperature goes through a series of peaks and troughs. The variance characterizes how much the temperature changes in the day-night cycle throughout the year. Higher variance in the summer shows how the maximum midday temperature differs from the warm but relatively low night temperature. In the winter, the maximum and minimum temperatures are lower but differ from the mean less.

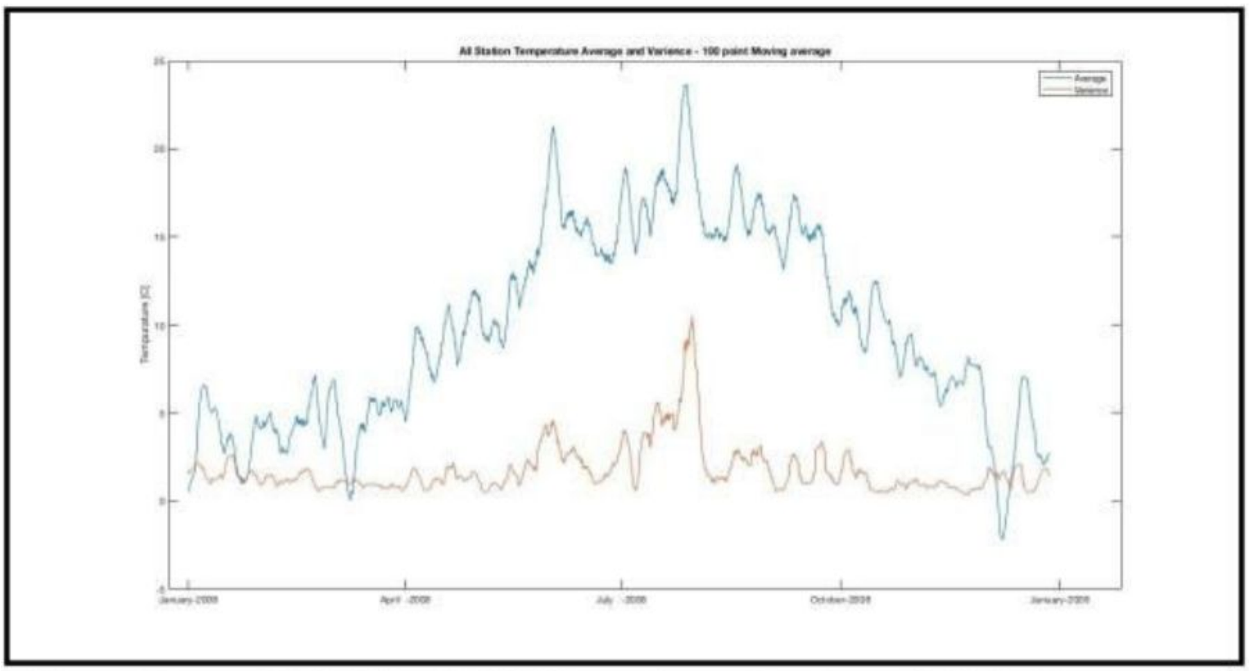


Figure 4: Average of all stations for 2008, temperature and variance with 100 point running boxcar average

Diurnal Cycle:

The Diurnal (day-night) cycle is the temperature variation caused by the sun's angle of incidence increasing to a maximum at midday and then decreasing as the sun sets. In the summer, the sun's path is higher in the sky, and therefore the intensity of its rays higher on a given area of the earth's surface. In the winter, the sun's path is lower along the southern horizon, and its rays are less intense on the same area.

The Power Spectrum of one location characterizes the power in different frequency bands of the time series. A clear peak is noticeable at one cycle per day and smaller peaks at 2 and 3 cycles per day. These are present in both winter and summer, but there is more power in the summer's daily cycle. A filter can be applied that isolates this Diurnal cycle and shows how this force dominates the temperature each day.

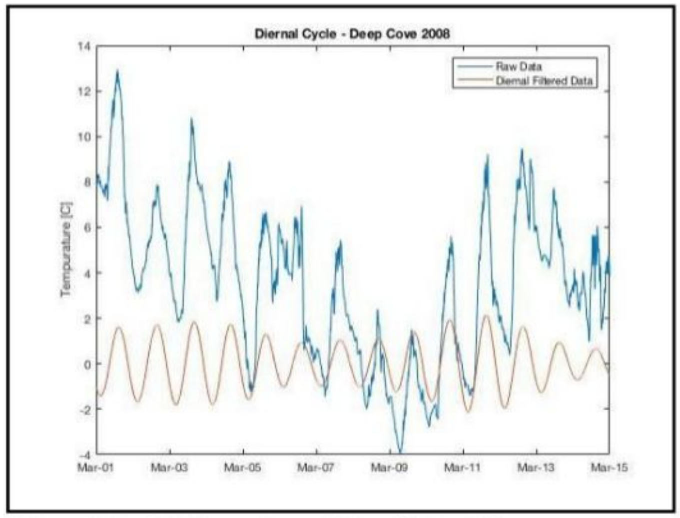


Figure 5: Raw data time series and Diurnal filtered data.

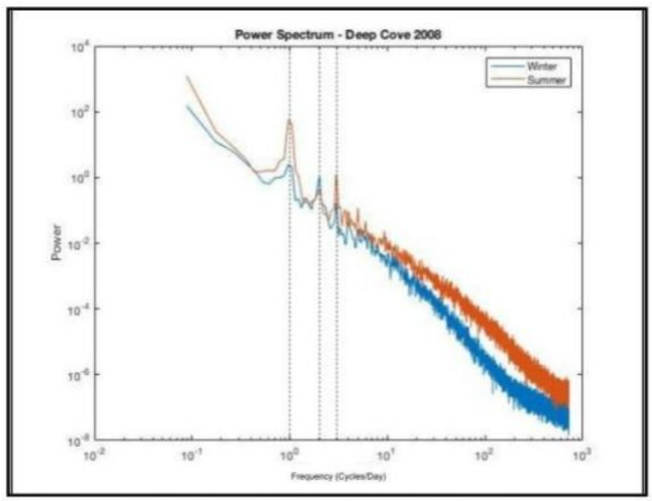


Figure 6: Power Spectrum of Deep Cove 2008, winter and summer.

Cross Lag Correlation:

Data can be compared to itself (Auto-Correlation), with another time series (Cross-Correlation), or to itself with some lag (Lag-Correlation). The Correlation Coefficient is a number between -1 and 1, where 1 is perfectly correlated, -1 is inversely correlated, and zero is uncorrelated. Lag is the time offset between two compared time series. Thus a plot of the lag on the x-axis and Correlation Coefficient on the y-axis shows how strongly time series correlate at different values of lag. Using James bay as the base time series, the other three are compared to it with either the month of December or August.
In the summer, each day is very similar to the previous and has a healthy diurnal cycle, with a high correlation at one day lag and low correlation at a half-day lag. The correlation coefficient value is never more than 0.05, which is only 5% of a perfectly correlated series.

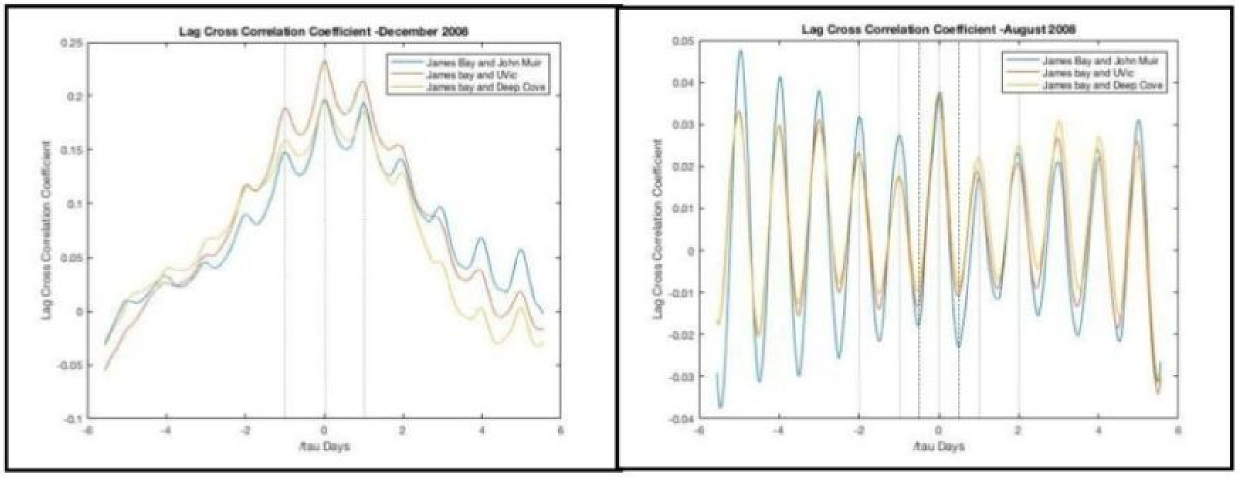


Figure 7: Lag Cross-Correlation Coefficient, August and December 2008.

Interestingly John Muir is more strongly correlated with James bay than either UVic or Deep Cove to James Bay.

In the winter, there is a correlation at one day lag, which quickly drops off as the lag grows. The correlation coefficient value at 1 day is nearly 0.2, which is much higher than the summer at 0.05. There is also a strong correlation between each of the pairs of stations at zero lag, with James Bay and UVic at the highest zero-lag correlation.

Dominant Patterns:

The temperature at hour resolution is recorded at 23 discrete locations with a higher concentration in Greater Victoria, and a few along the strait towards Sooke, up island, and up the Saanich Peninsula. To estimate the temperature between locations, different interpolation methods can be applied to spread the temperature data onto a regular grid map. These are sensitive operations and only use each station's relative location and the value recorded there at a discrete time. It is insensitive to altitude changes, bodies of water, and other contributing factors.

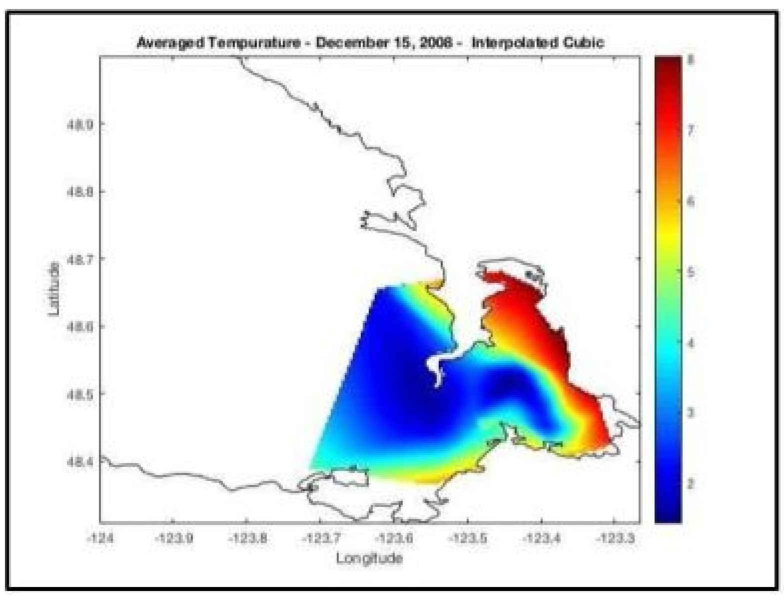


Figure 8: December Map - An interpolated map using the average over december for each station.

Taking a collection of these maps over time and analyzing the covariance between these maps, the patterns that underlie the system are pursued using Empirical Orthogonal Functions or Principle Component Analysis. The most powerful modes are plotted for both November 4th-16th and August 4th-15th. They display what might be the underlying temperature patterns over those periods, with Mode 1 being the most powerful. In the winter month, Mode 1 shows that temperatures towards Sooke and up island are colder than Greater Victoria, and there is a warm spot in the center of the Saanich Peninsula. In the summer, the roles are slightly reversed, with up island being hot, central Saanich being warm, and colder in Sooke and around the coast.

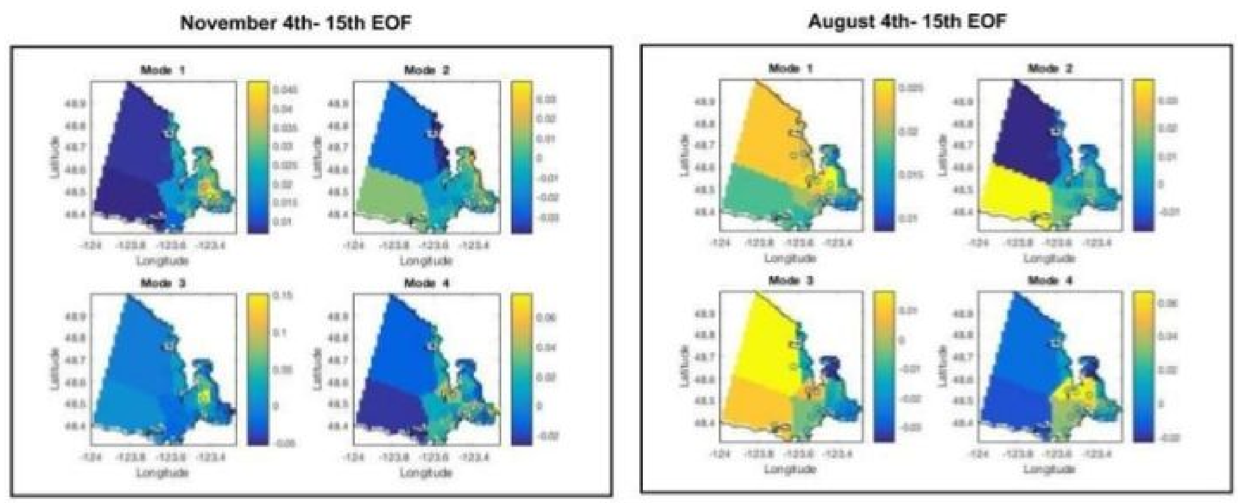


Figure 9: EOF Analysis for November and August