VENUS Ferry Data: Figures & Feedbacks

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Abstract

One year of VENUS Ferry data is analyzed and discussed throughout this document. Among all properties, salinity and seawater temperature look reasonable throughout the whole time period, while wind looks questionable. Dissolved oxygen concentration, chlorophyll-a fluorescence, CDOM fluorescence, turbidity and air temperature look reasonable during most of the times, but still have some problems that need to be solved. For solar radiation, a low radiation gap during noon appears almost every day and cannot be explained at present.

1 Introduction

The VENUS FerryBox system has been installed onto the M.V. Queen of Alberni, for more than 1 year. A simple quality control process was applied by the VENUS data management team, but it has not been verified by a second research team yet. Our goal is to verify the ferry dataset by looking into the recorded data and making plots. The figures are plotted during a long range of time, so the form can be slightly different. Section 1 gives plots of water side properties; Section 2 gives plots of air side properties.

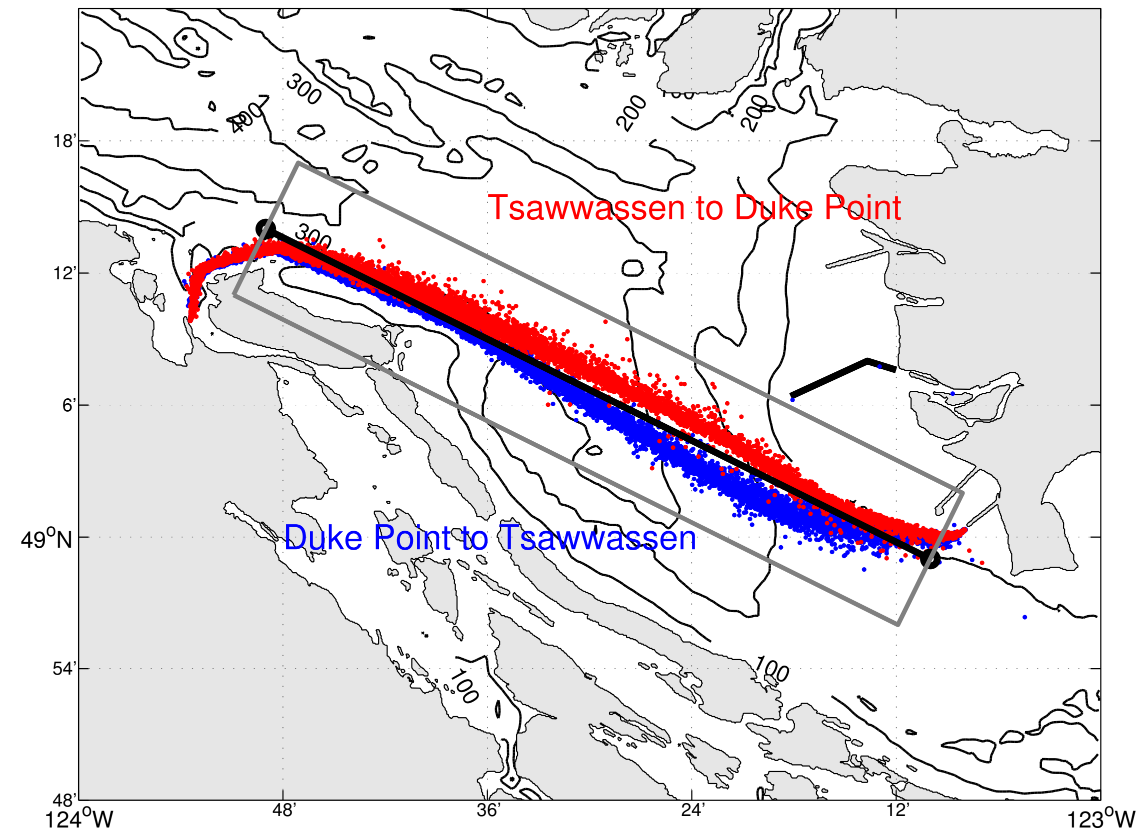

Figure 1: Track of BC Ferry Queen of Alberni. Red and blue dots are coordinates recorded by the Ferry GPS system. Coordinates within the grey box are then projected onto the black line and form a "transect", which has a length of about 55 km.

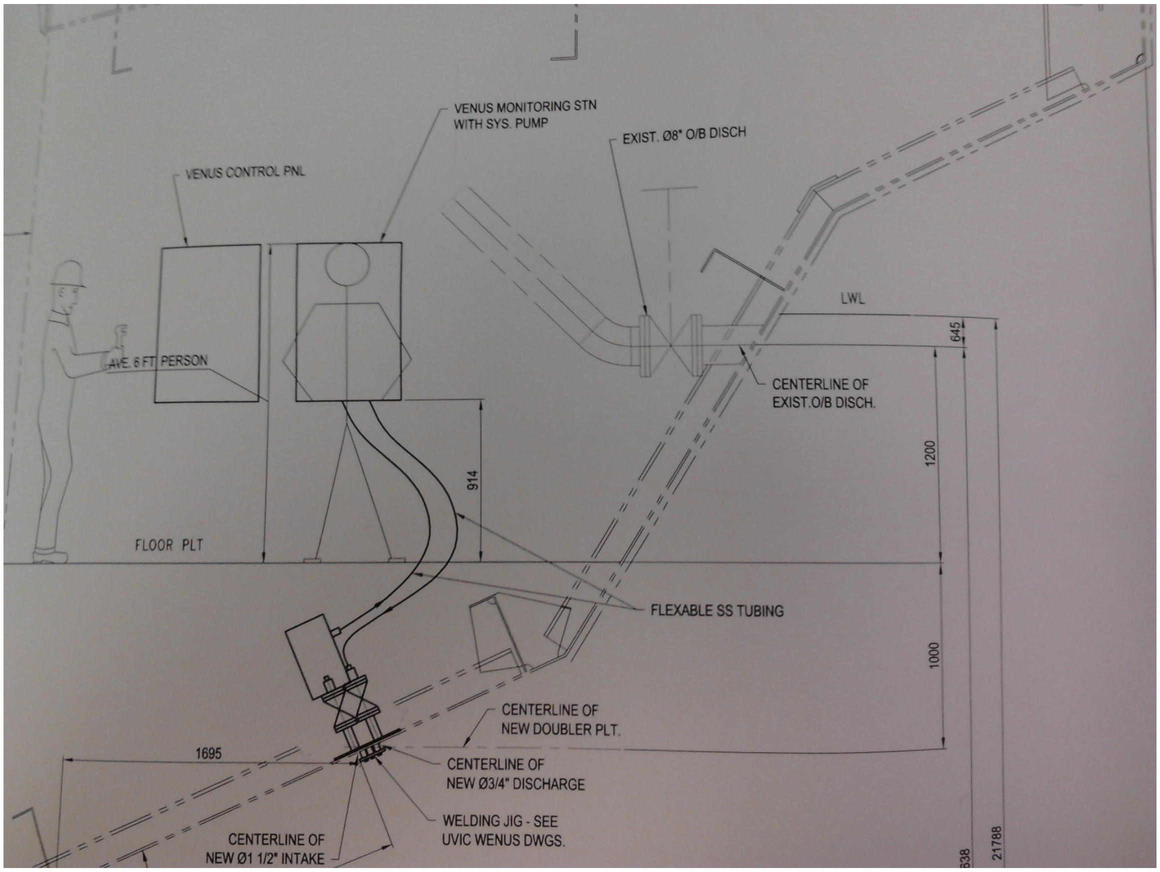

Figure 2: A sketch of FerryBox system provided by Jaklyn Vervynck @ VENUS.

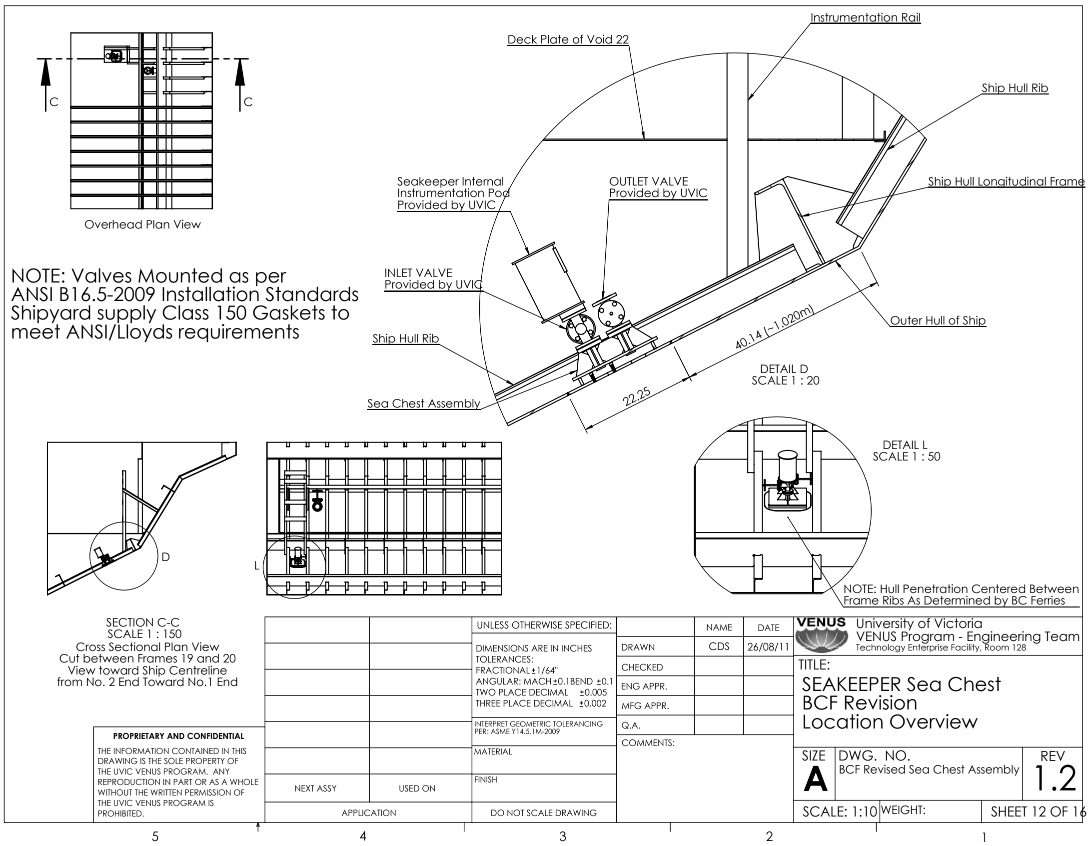

Figure 3: More details about FerryBox and pumping system.

2 Water Properties

2.1 Salinity

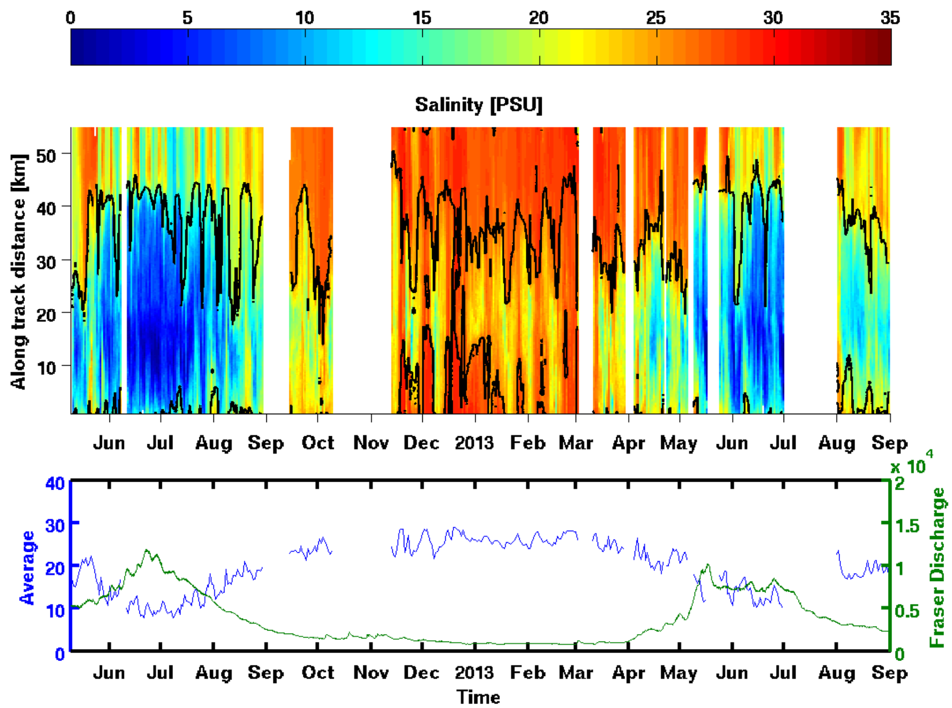

Figure 4: Along track salinity (upper panel) and daily averaged salinity (lower panel, blue) and Fraser River discharge at Hope (green). Data was first projected onto the black line in figure 1 and then interpolated onto a pre-defined grid. In the upper panel, y axis represents along track distance, from 0 km (Tsawwassen) to 55 km (Duke Point, Nanaimo). The black lines in the upper panel (and in subsequent figures) show the edge of Fraser River plume. SoG salinity is closely related to Fraser River discharge - in Jun. 2012 when river discharge reached maximum, averaged salinity dropped to its minimum and vice versa. Also, salinity gradients are large in the plume, and weak to the north of the plume.

2.2 Seawater Temperature

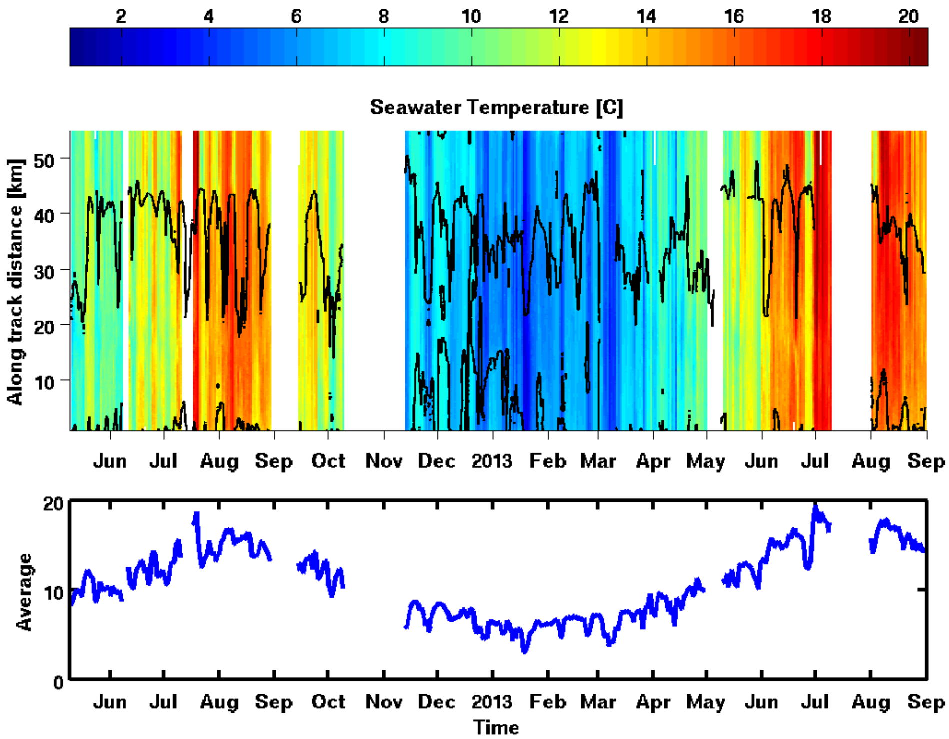

Figure 5: Along track seawater temperature (upper panel) and daily averaged seawater temperature (lower panel). Here seawater temperature is measured by the SBE thermosalinograph. Water temperature inside and outside the plume are usually very similar.

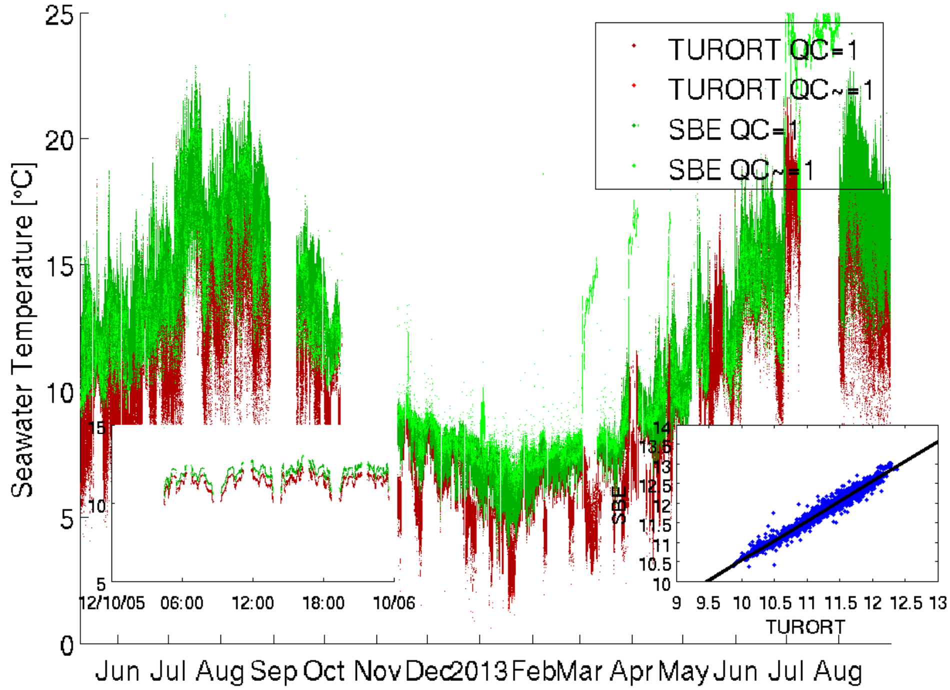

Figure 6: Seawater temperature measured by the TURO Remote Temperature (red) and the SBE (green) thermosalinograph. TURO Remote Temperature is installed closer to the water intake, so the values are a little lower, but the general trend matches (in the left box). In the right box is TURORT temperature versus SBE temperature of the same data in the left box. Black line shows linear regression between the two data fragments. According to the result of regression, the difference between two datasets is around 0.5 $^{\circ}C$.

2.3 Oxygen

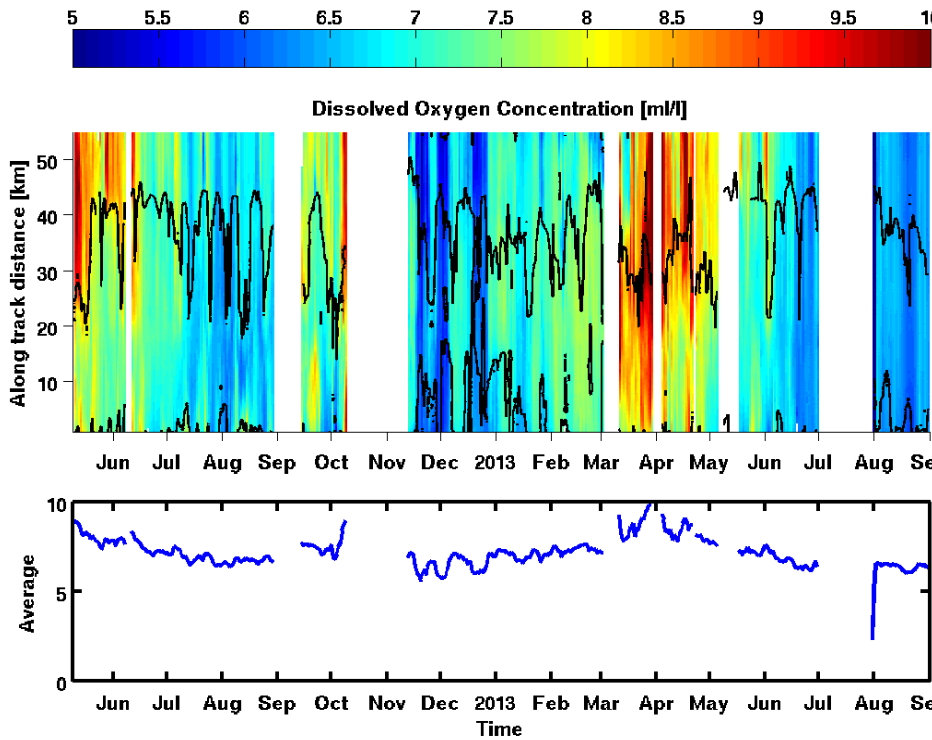

Figure 7: Along track dissolved oxygen (DO) concentration (upper panel) and daily averaged DO concentration (lower panel). DO levels are sometimes different in plume and north of plume areas, but the largest change is related to the spring bloom in March/April. A sharp increase in Oct 2012 and a low value in July 2013 are puzzling.

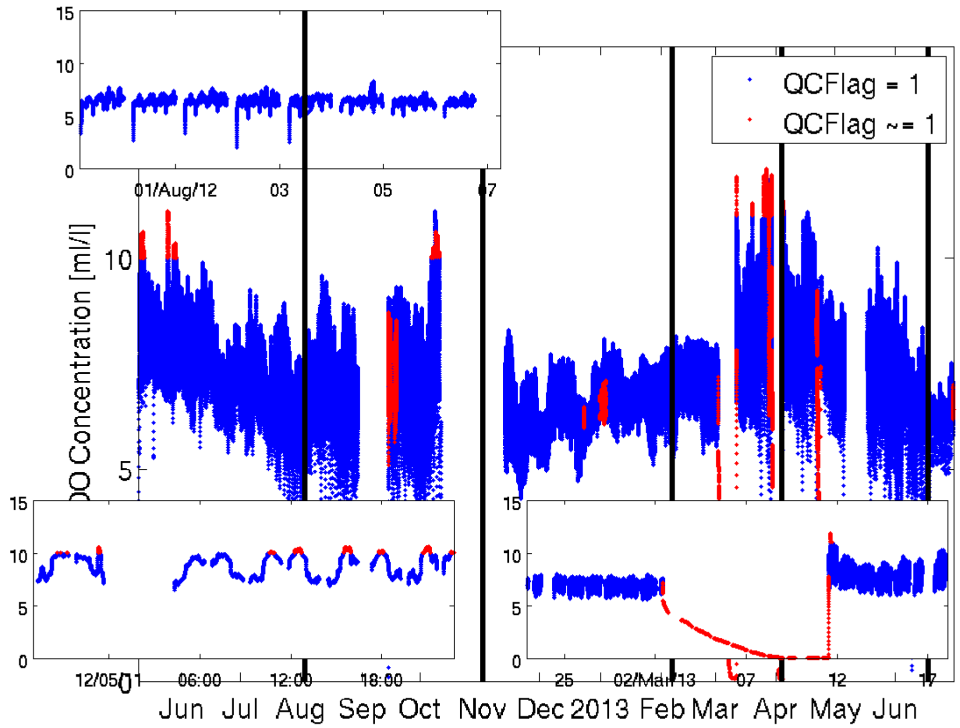

Figure 8: DO concentration over one year. Data passed quality control is plotted as blue while data didn't pass quality control is plotted as red. Black lines indicate the time when the instruments are cleaned. 3 short time periods were choosen and plotted in the 3 boxes.

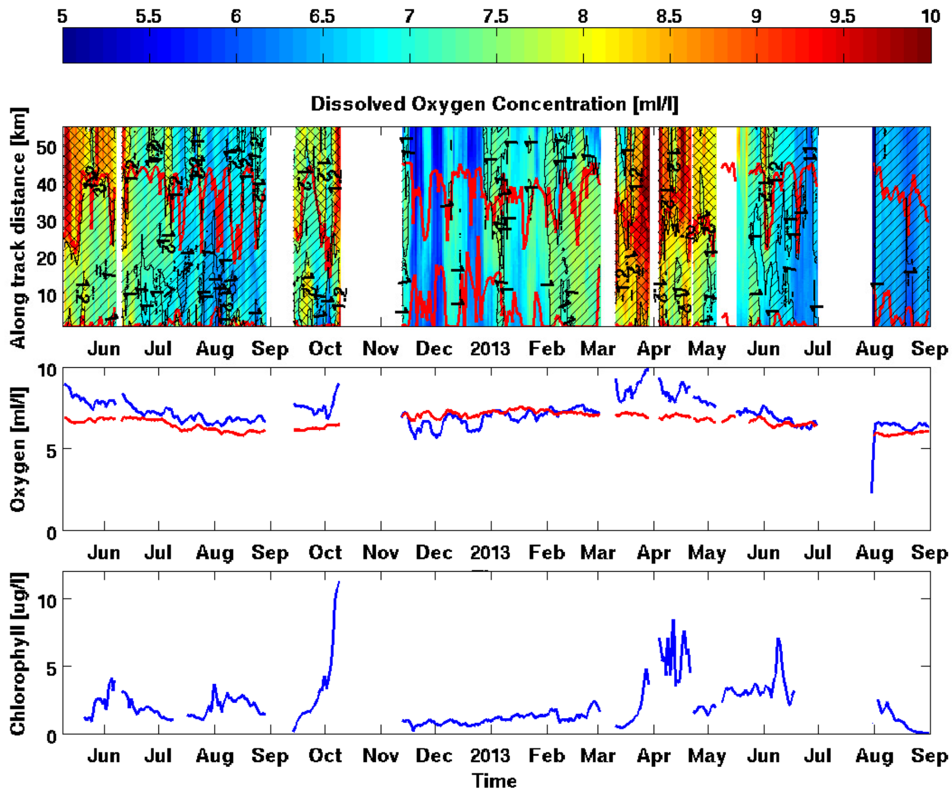

Figure 9: Upper panel: Along track DO concentration. Percentage saturation level is indicated with single line (over saturated, 100% $-$ 120%) and cross line (supersaturated, $>$ 120%). Red line is the boundary that divides plume water from non-plume water. Middle panel: Daily averaged DO concentration (blue) and saturation concentration (Red). Lower panel: Daily averaged chlorophyll-a fluorescence. The Apr 2013 supersaturation is clearly linked to high chlorophyll-a levels. The Oct 2012 increase of oxygen also correlated with extremely high chlorophyll-a level, but the drop of chlorophyll-a level in Aug 2013 is not reflected by DO level.

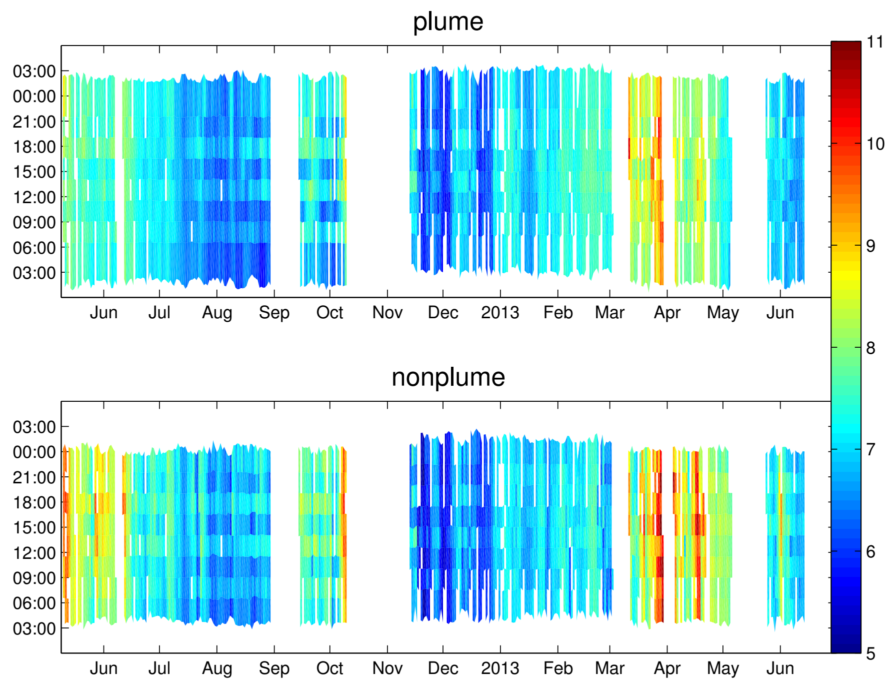

Figure 10: DO concentration at different times during a day. Each day 8 transects or less were made, by averaging over plume or non-plume area we can get 8 or less DO concentration data points per day. Strangely these data points show a very regular pattern, forming these dark and light 'strips' in both upper (plume) and lower (nonplume) panel, there correspond to northward and southward tracks. Possibly the water intake characteristics are different depending on which end of the "double-ender" is currently the "bow".

Figure 7 to Figure 10 shows DO concentration data across the year. In Figure 8, 3 short time periods were chosen and plotted in the 3 boxes. In the lower box on left side, it seems that 10 is set to be a threshold - all values larger than 10 ml/l didn't pass quality control. but the threshold is not constant through the year, Later in Mar. 2013 the threshold has apparently been changed to 11 ml/l. Also, not all values larger than 11 are considered bad - for some transect they pass quality control. That makes quality control process a little confusing.

In the lower box on right side, we believe that the pump stopped working from Mar. 2^{rd}, 2013 (quality control successfully recognized this). In the upper box, we want to show the difference before and after the instruments are cleaned. On the left side of the black line, every cluster of data (corresponding to one day length of sampling) has a "tail" of low values at the beginning, but on the right side we cannot find such "tail"s. We believe that this is due to bio-fouling - before cleaning was carried out, planktons get accumulated on the sensor, and because the pump is turned off every night, oxygen gets slowly consumed; so every day in the morning we will pick up a very low signal for a short period of time. I suggest that every day in the morning the first 20 - 30 data points should not pass quality control.

In Figure 9 both oxygen and chlorophyll-a fluorescence are plotted. During the spring bloom, oxygen went supersaturated in and out of the plume, and correspondingly, chlorophyll-a fluorescence also went up. Notice that during Oct. 2012, both DO concentration and chlorophyll-a fluorescence went up, indicating a very late plume. The existence of this plume is suspicious and still needs to be verified by other observation.

2.4 Chlorophyll-a

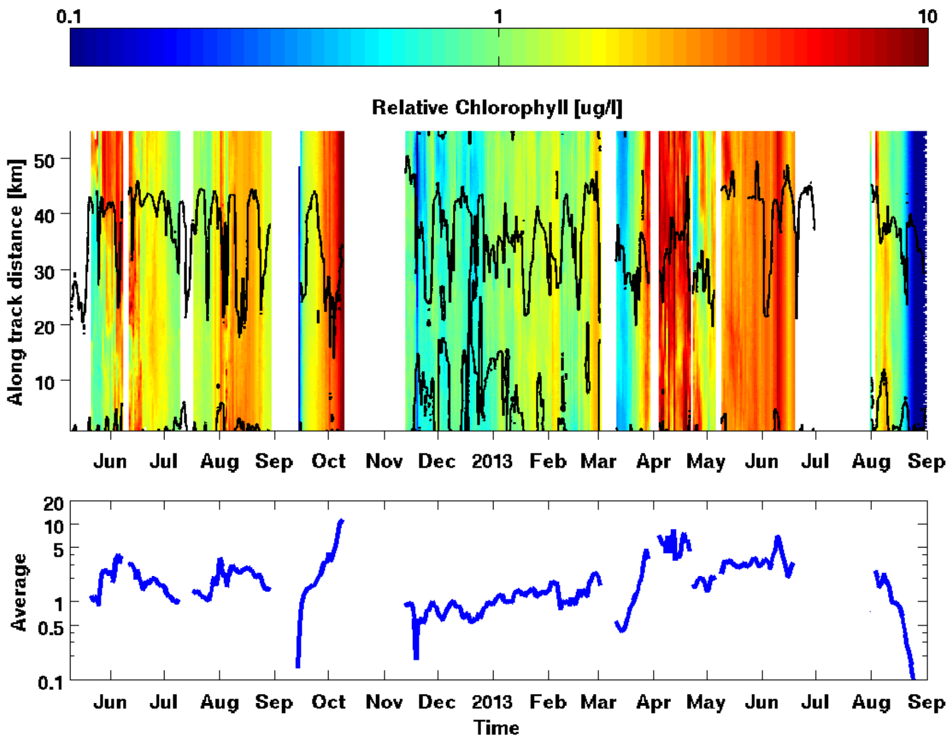

Figure 11: Along track chlorophyll-a fluorescence (upper panel) and daily averaged chlorophyll-a fluorescence (lower panel). Chlorophyll levels are not particularly related to the plume although at times levels do differ inside and outside the plume. Notice abnormally high Chlorophyll-a fluorescence in Oct 2012, indicating a very late bloom. Very low values in late Aug 2013 are suspicious.

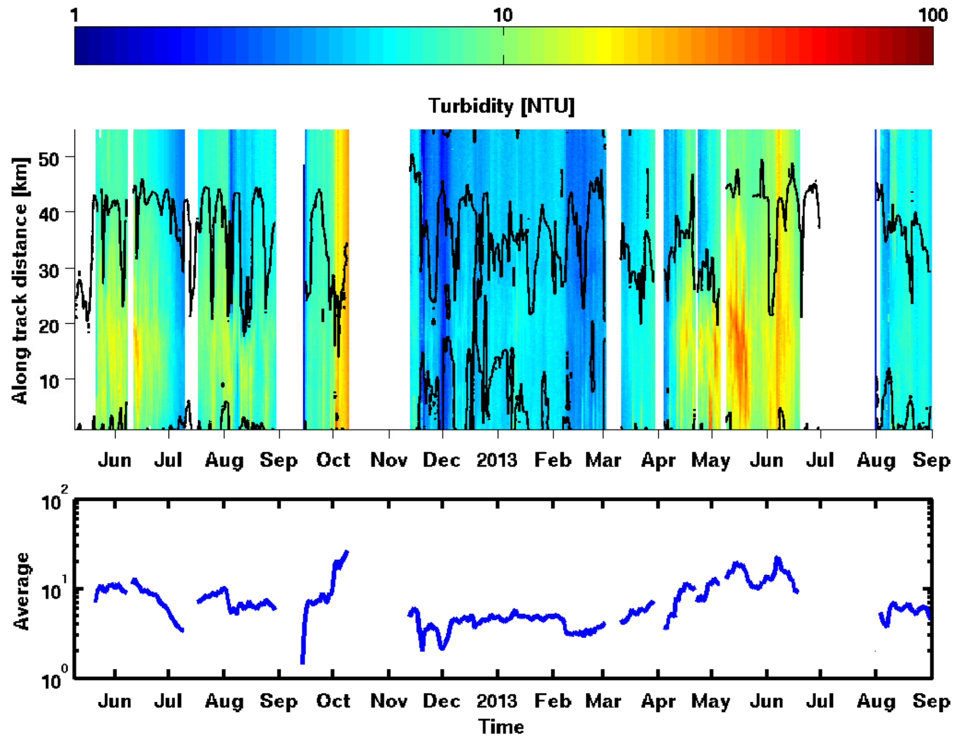

Figure 12: Along track turbidity (upper panel) and daily averaged turbidity (lower panel). Turbidity levels are clearly higher in plume waters, especially in summer.

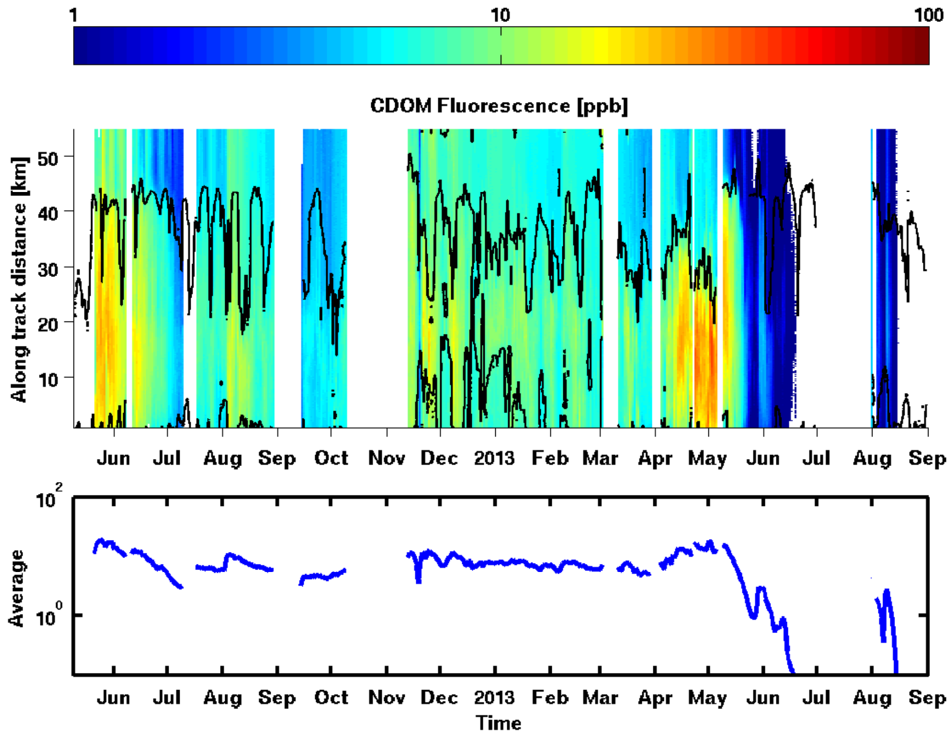

Figure 13: Along track CDOM fluorescence (upper panel) and daily averaged CDOM fluorescence (lower panel). CDOM fluorescence went down quickly after Jun 2013, possibly indicating sensor malfunction.

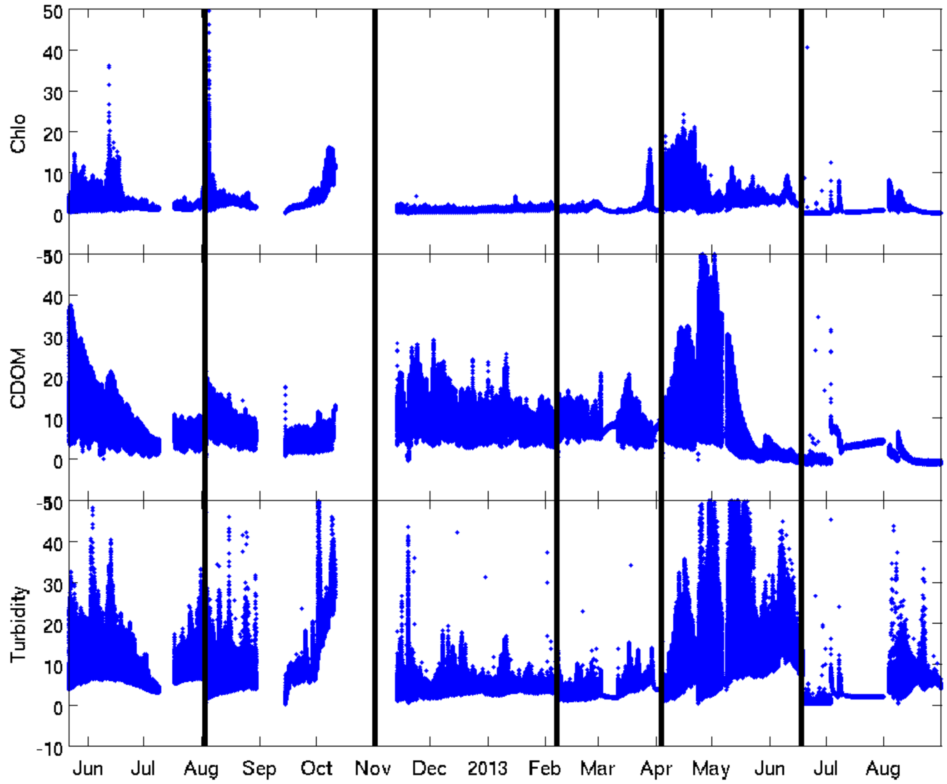

Figure 14: Chlorophyll-a fluorescence, CDOM fluorescence, and Turbidity raw time series. Black lines are the recorded times when the instruments are maintained and cleaned. Notice that almost everytime the instruments were cleaned, turbidity dropped immediately, but CDOM rose. For example, in Aug 2012, turbidity dropped by about 5 NTU, while CDOM fluorescence increased by about 5 ppb. It is hard to see clearly here but chlorophyll-a fluorescence drops a little bit just as turbidity. This indicates that as time passes by, bio-fouling becomes an issue, and more calibration is needed. During late Apr 2013, a drop in turbidity and an increase in CDOM was observed, just like what was observed after the instruments are cleaned. Was there another clean up that is not in maintenance reports?

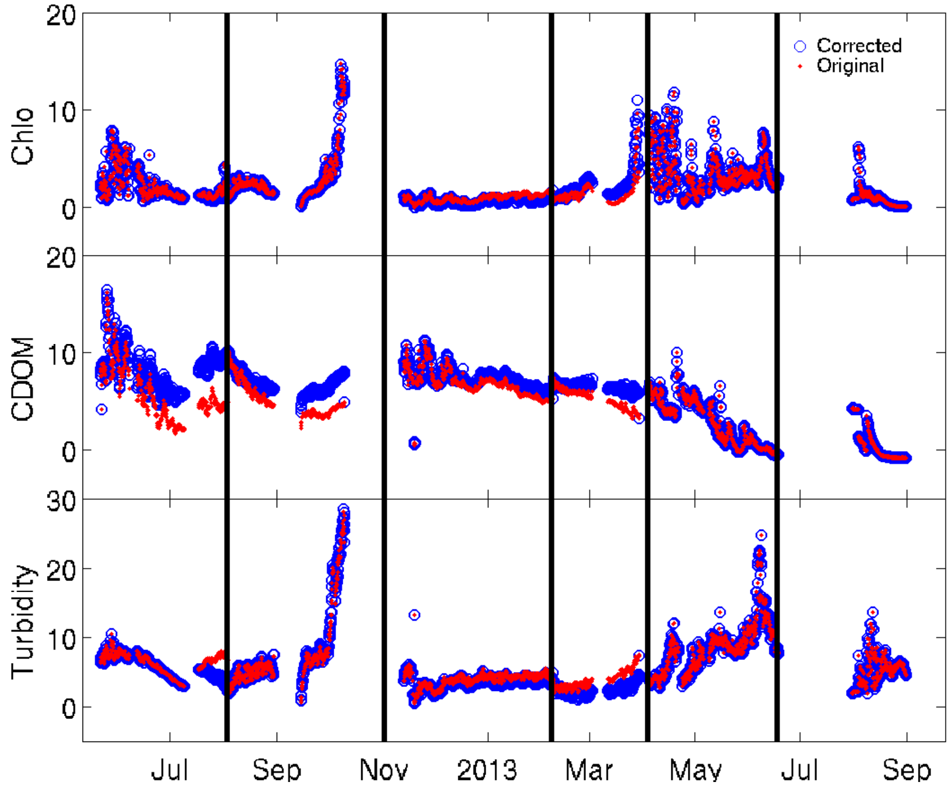

Figure 15: Chlorophyll-a fluorescence, CDOM fluorescence and turbidity near Nanaimo end. Original data is plotted as red dots. To deal with bio-fouling problem, we used a linear correction term: assuming that bio-fouling is a linear function of time since last cleaning. Corrected data is plotted as blue circles.

3 Air Properties

3.1 Air Temperature & Relative Humidity

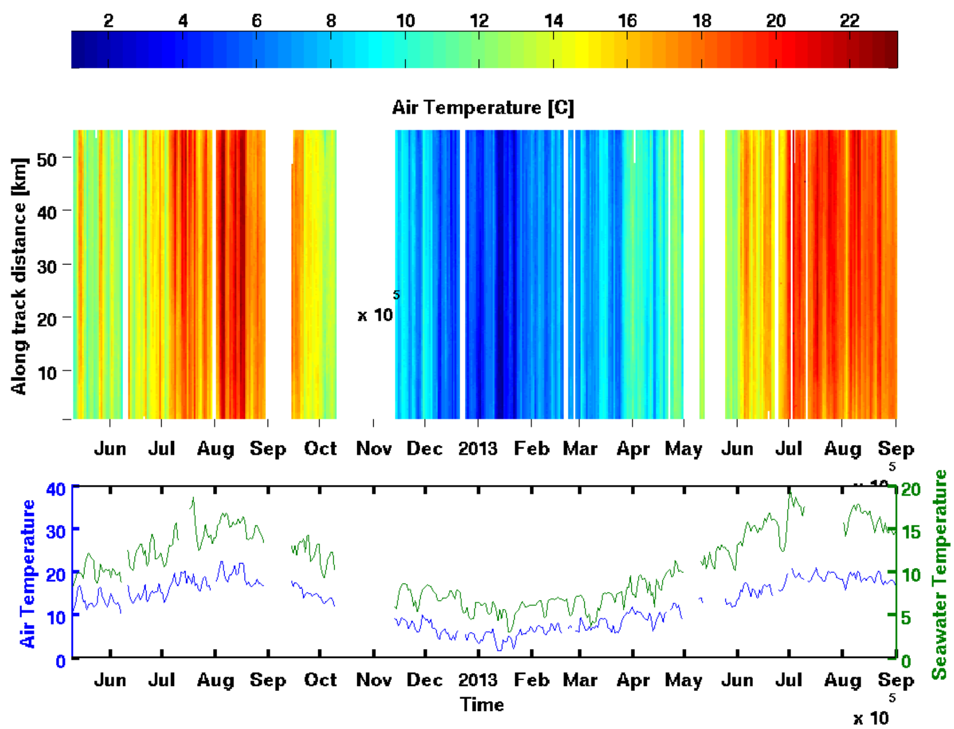

Figure 16: Along track air temperature (upper panel), daily averaged air temperature (blue lower panel) and seawater temperature (green lower panel). Very little spatial variation can be seen, but there is a strong seasonal cycle, corresponding to seawater temperature.

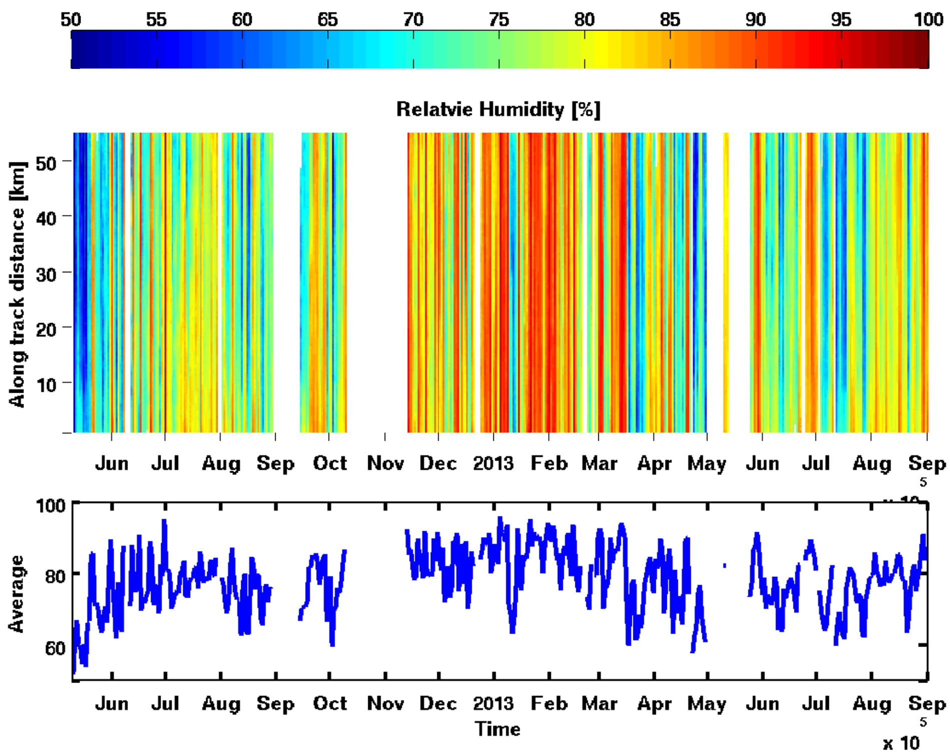

Figure 17: Along track relative humidity (upper panel) and daily averaged relative humidity (lower panel).

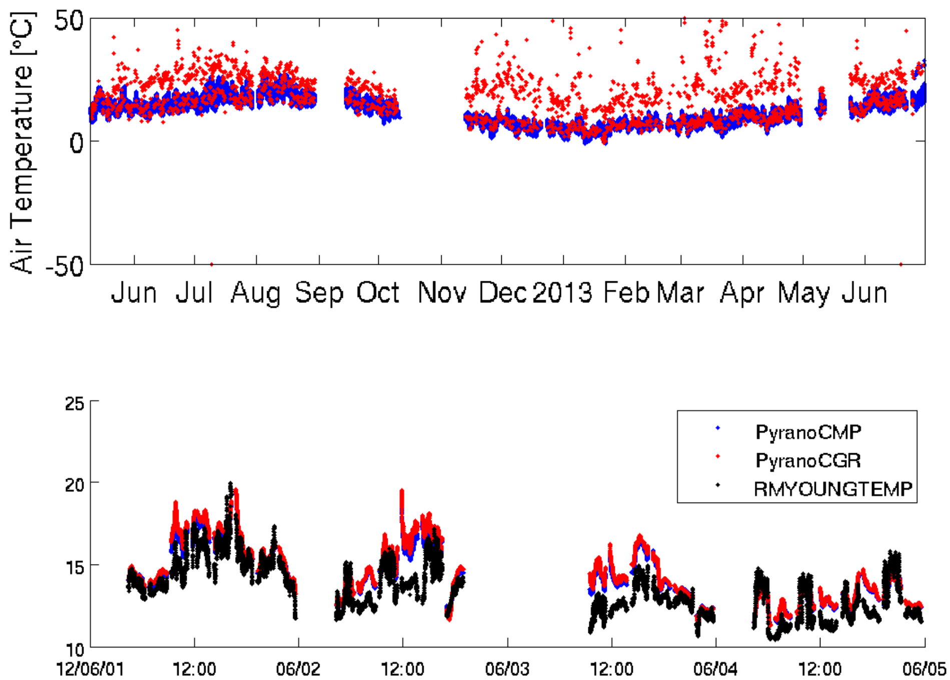

Figure 18: Upper panel: Air temperature time series with data that has passed quality control (Blue) and data did not pass quality control (Red). Most data away from the main trend is red, indicating a successful quality control process. Lower panel: Air temperature measurements from 3 different instruments during a small period of time (Jun 1 to Jun 5, 2012). Only data from RMYOUNG Temperature went through quality control process. Temperature measurements from PyranoCMP and PyranoCMP looks almost the same, but they are slightly different from that of RMYOUNG Temperature. PyranoCMP and PyranoCGR probably measure temperature inside the sensors, which are warmed a little by radiation from the environment and instrument. Hence temperature measured by PyranoCMP and PyranoCGR is a little higher than that of RMYOUNG Temperature, especially in sunlight.

3.2 Solar Radiation & Long Wave Radiation

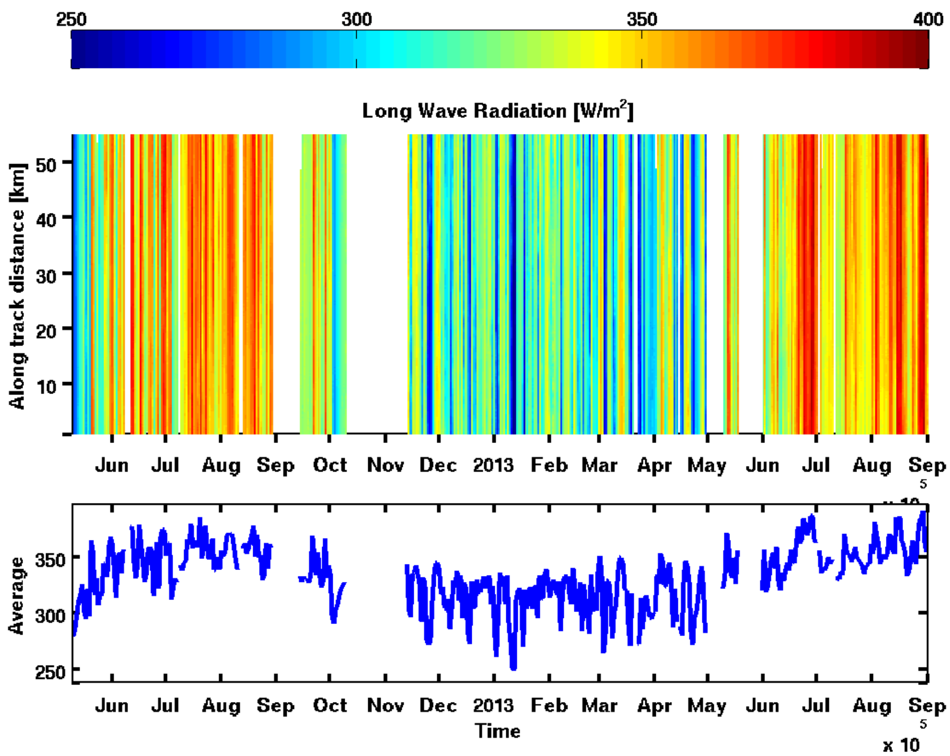

Figure 19: Along track long wave radiation (upper panel) and daily averaged long wave radiation (lower panel).

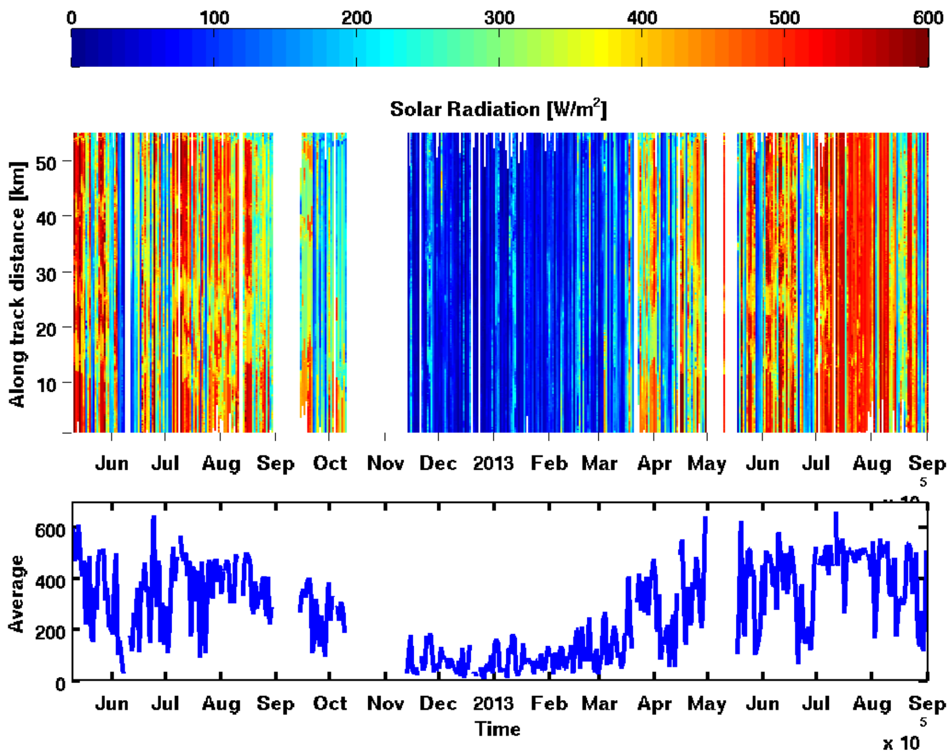

Figure 20: Along track solar radiation (upper panel) and daily averaged solar radiation (lower panel).

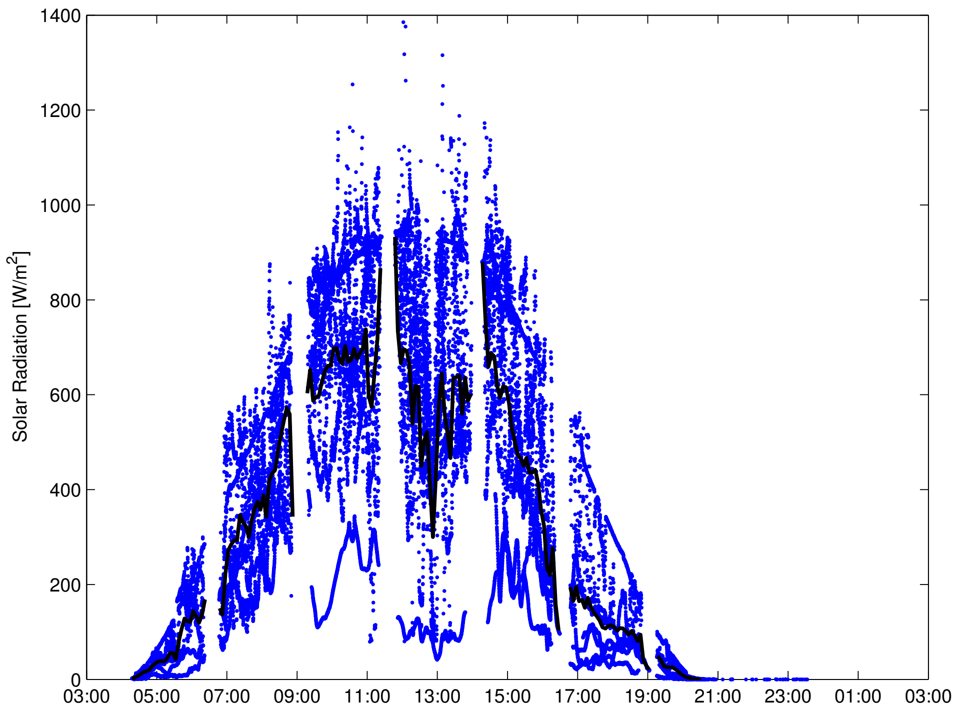

Figure 21: Day time solar radiation from 2012/06/18 to 2012/06/24. Black line is the average over the week. As we can see solar radiation is not consistent over the week, in summer time it can be up to 1000 W/m^2, at other days it can be as low as 200 W/m^2 on average. One strange feature is that every day around 13:00, solar radiation drops to a very low level (less than half of its normal value), and this is probably an artifact of some kind. This can be verified by comparing with solar radiation data from UBC climate station in the following figures.

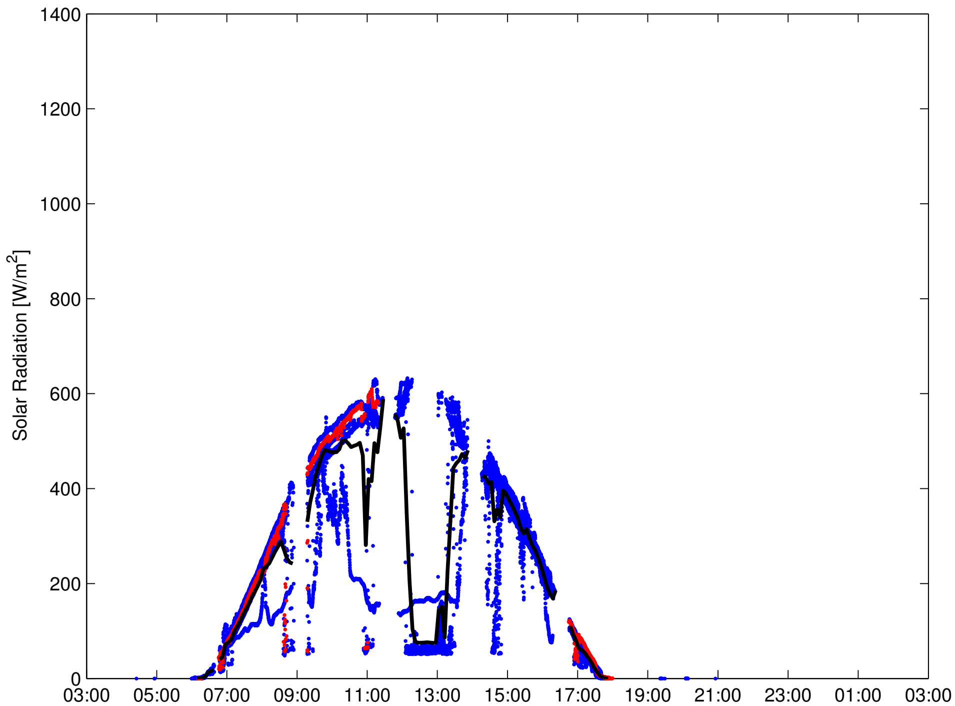

Figure 22: Day time solar radiation from 2012/10/01 to 2012/10/07. Black line is the average over the week. Red dots are data points that didn't pass quality control. During this week, the low radiation at noon problem is even more severe.

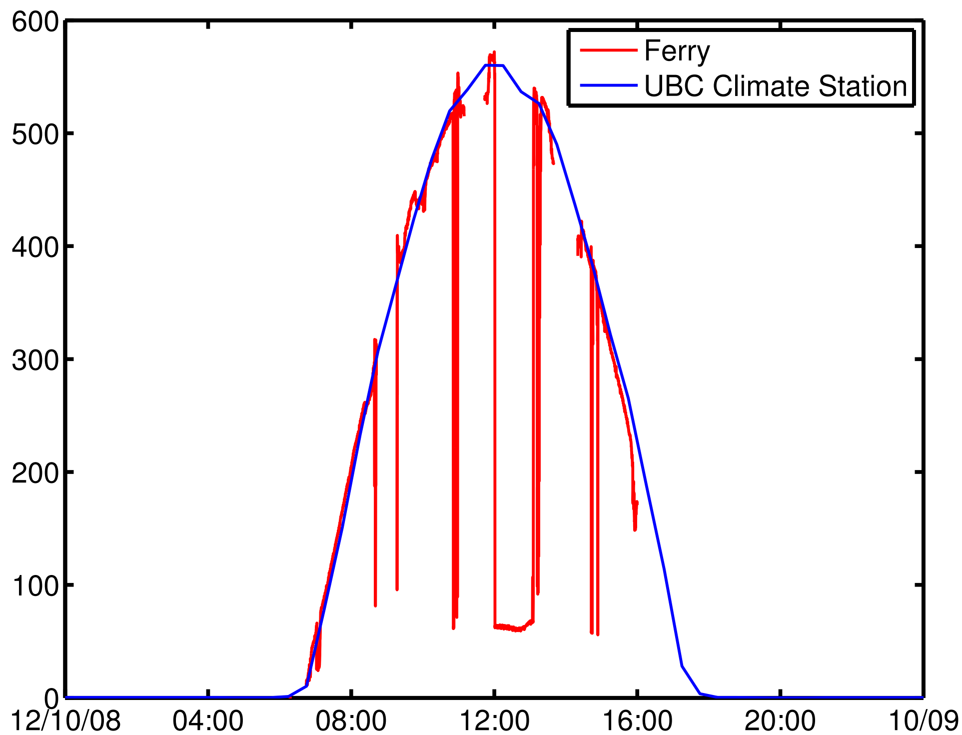

Figure 23: Solar radiation measured by ferry (red) and by UBC climate staion (blue). Low radiation at noon is measured by the ferry, which is not true according to UBC climate station measurements. Aside of that, ferry measurements is consistent with UBC climate station. This day is the best comparison I've found in the dataset. Generally speaking, ferry measurements contain more noisy signals, partly because of higher temporal resolution.

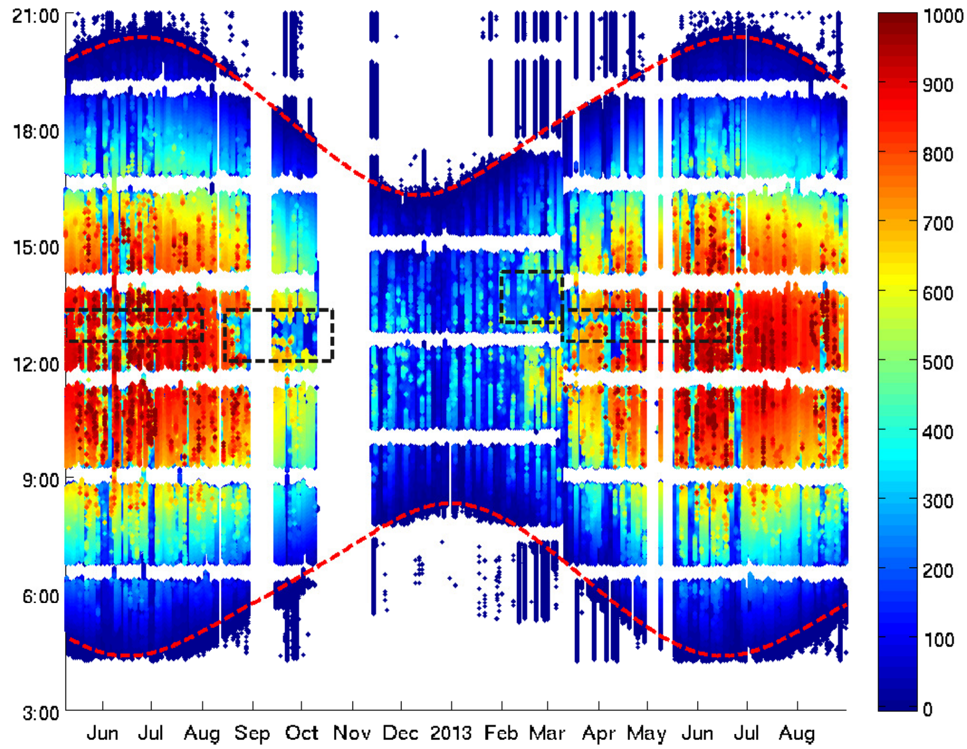

Figure 24: Solar radiation at different time during a day. Red lines are calculated sunrise/sunset time based on the geographical coordinates of the strait. Black boxes show the problem of low radiation level at noon, note that when the ferry schedule shifted due to daylight saving, low radiation problem also shifted one hour accordingly. Is it possible that the problem is related to a specific geographical location?

3.3 Air Pressure

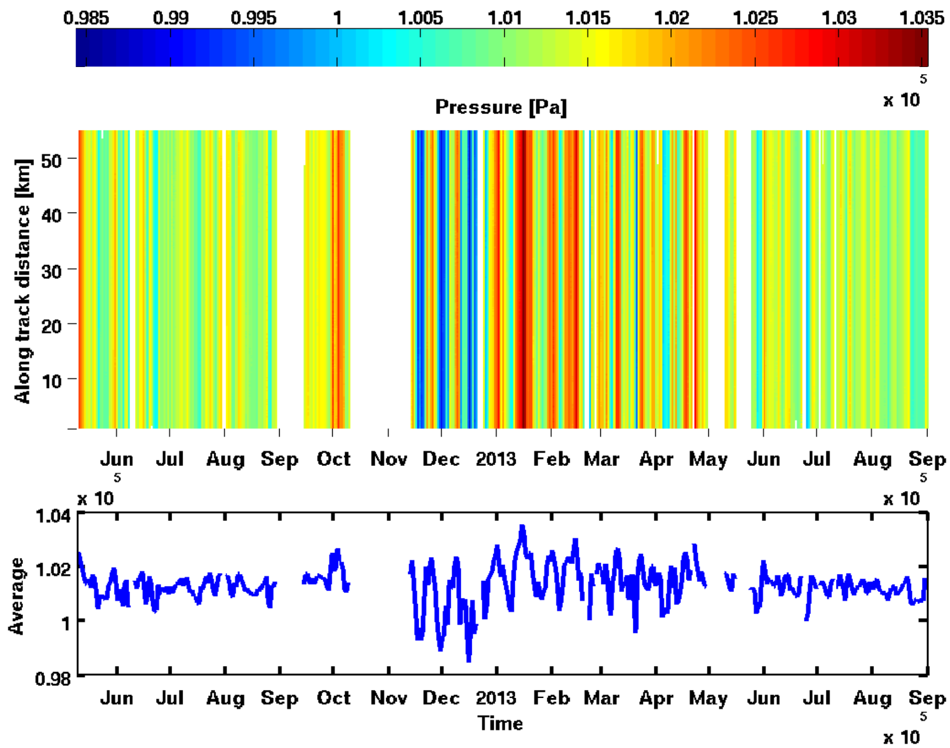

Figure 25: Along track air pressure (upper panel) and daily averaged air pressure (lower panel).

3.4 Wind

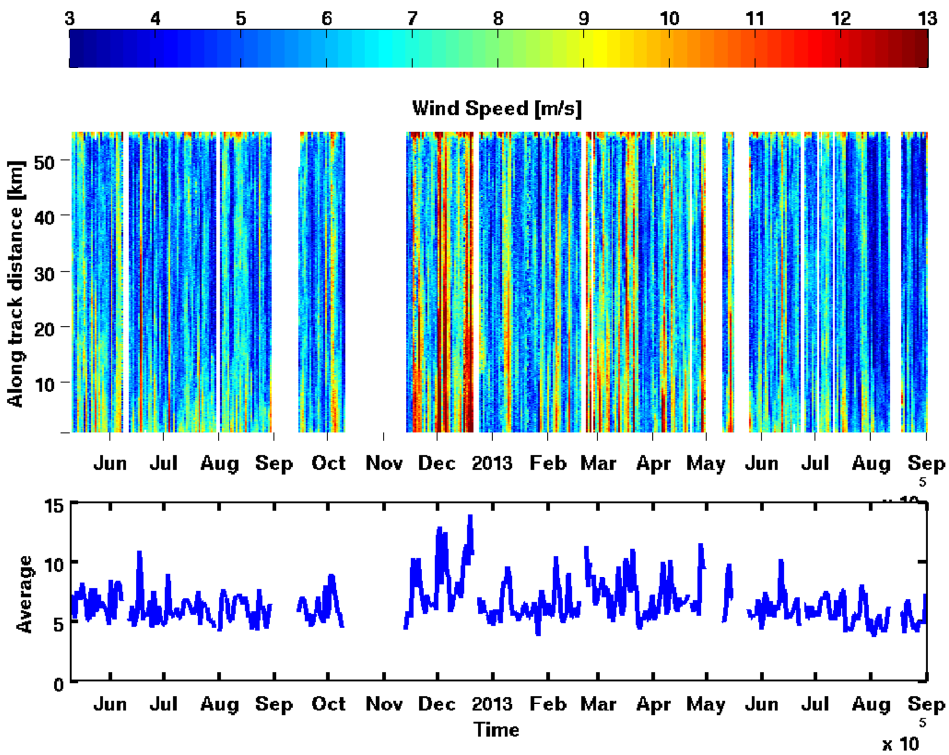

Figure 26: Along track wind speed (upper panel) and daily averaged wind speed (lower panel).

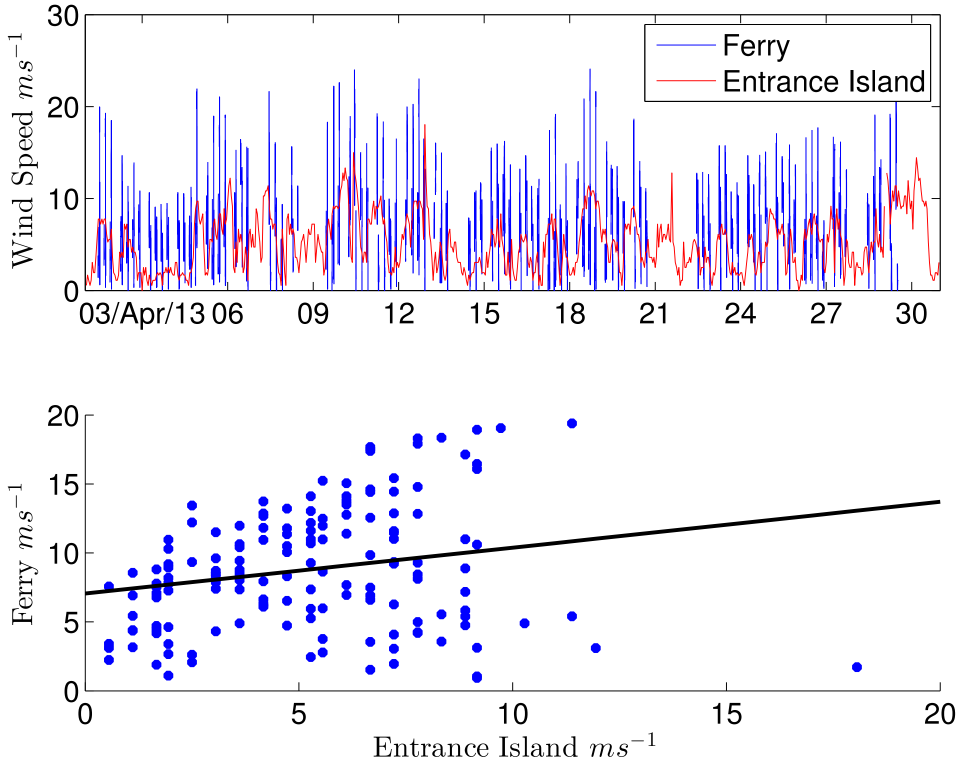

Figure 27: Upper panel: Wind speed measured on ferry (blue) and Entrance Island met station (red). Only one month of data (Apr. 2013) is shown. Ferry data was broke into pieces and only parts near Entrance Island are plotted. The two sets of measurements are of the same magnitude and their trend matches, but the range of ferry measurements is much larger. Lower panel: Ferry measurements vs Entrance Island measurements. Black line shows the linear regression fit. It is obvious that 2 datasets are not highly correlated.

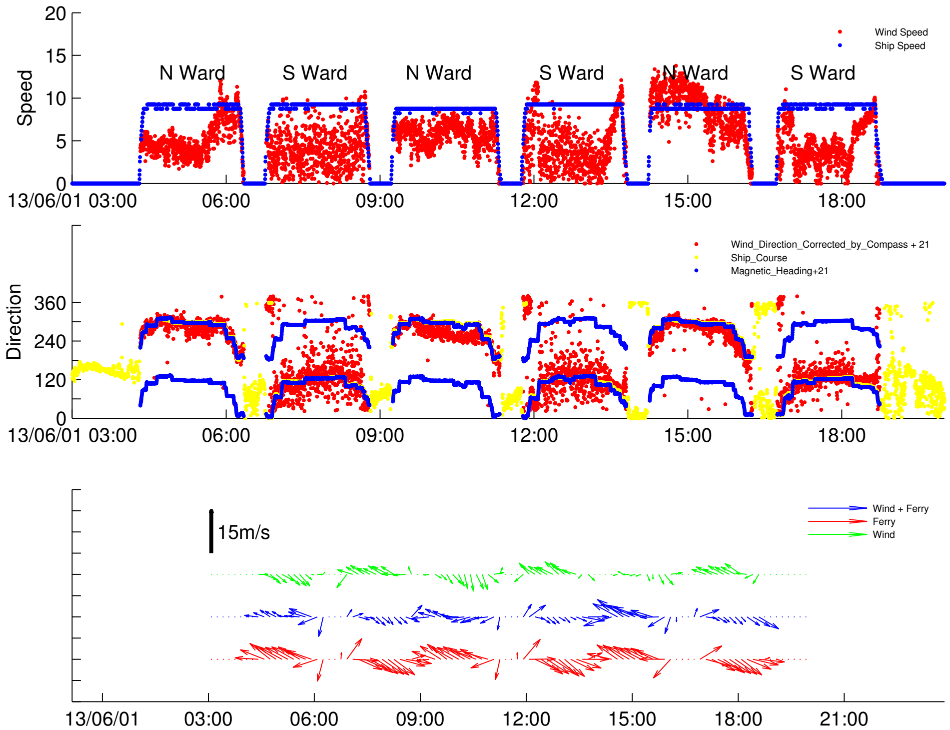

Figure 28: Upper panel: Wind speed (red) and ferry speed(blue). Middle panel: Wind direction corrected by compass + 21° (magnetic deviation), ferry course and magnetic heading + 21° during one single day (13/06/01). Wind direction is similar to ship course, consistent with hypothesis that ferry wind is not corrected with ferry speed. Note that wind speed and heading of southward tracks (2,4,6) are more "noisy" than that of northward tracks (1,3,5). Lower panel: Ferry velocity/300 vs measured wind velocity/30 of the same time period. Both of them are averaged over a span of 10 minutes. Again this figure shows that ferry direction is similar to measured wind direction.

3.5 Recommendation

1. Quality control for DO concentration has 2 major problems:
(1) the upper limit is too low for DO concentration during a bloom environment. During May 2012 and Mar 2013 DO concentration exceeded the upper limit (10 ml/l / 11 ml/l) but it still appears to be reasonable. We suggest to set the upper limit much higher, or do not set the upper limit.
(2) At the beginning of every day optode records a low DO concentration 'tail' for a few minutes (Figure 8 upper box). We think it is because the pump on the ferry box is turned off during the night, when oxygen gets slowly consumed by planktons and other organisms in a "dirty" system - Hence, everyday when ferry box is turned on, optode picks up a low oxygen signal before this small amount of water is pumped out. This 'tail' is a result of bio-fouling and cannot be trusted, hence we suggest that the first 20 data points that optode records everyday should not pass quality control. (Perhaps it can also be used to judge system cleanliness?)
2. As just discovered by VENUS, ferry measured wind speed is off by a factor of 10; After multiplied by a factor of 10, ferry measured wind speed still cannot match up with ferry speed (Figure 27). We guess that the mast near the met station must have some influence on the RMYOUNG Wind Monitor, as wind speed is more "noisy" when the ferry travels southward (when ferry travels southward the Wind Monitor "hides" behind the mast). We suggest to relocate the met station away from the mast, or to the other side of the mast to verify our conjecture.
3. Bio-fouling is an important issue for WetLab fluorometer. As we show in Figure 14, a correction term needs to be added to balance the error caused by bio-fouling.We tried to estimate this correction term and the results are shown in Figure 15, but we cannot get a very good estimate due to lack of information. We suggest that every time before and after the WetLab Fluorometer is cleaned, a few in-situ measurements should be made to establish a reference for data correction and instrument calibration.
4. CDOM Fluorescence dropped to almost 0 in the middle of May, indicating sensor malfunction. We suggest to check and recalibrate the sensor immediately.
5. Almost everyday at noon solar radiation drops to only 50 W/m^2, much less than its normal value. The reason for this decrease is unclear, it can be either (1) a shade caused by the mast or other objects on the ferry, or (2) instrument malfunction. We suggest that the met station should be relocated

to another site on the ferry.
6. If possible, add instrument height into metadata for meteorological datasets. It is a good way to track instrument location and an important parameter for calculation of air-sea interaction.