



**Analysis of the Sulphur Dioxide levels  
measured at the Erie Street,  
Victoria, British Columbia, Canada  
monitoring site during the  
2014 cruise ship season**

*GVHA acknowledged, on February 23<sup>rd</sup> 2015, that there had been errors in the wind directions recorded by their breakwater anemometer during the 2014 season and committed to advising JBNA on how the data was affected. This information is still outstanding*

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**James Bay Neighbourhood Association**

[www.jbna.org](http://www.jbna.org)

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Note: A revision to this report will be issued once the results of the anemometer calibration check are known

## 1.0 SUMMARY

This report analyses the available data for wind conditions, sulphur dioxide (SO<sub>2</sub>) levels and cruise ship times to determine the extent of cruise ship pollution within the James Bay neighbourhood of Victoria, BC during the 2014 cruise ship season.

Occasions when the monitor detected levels in excess of health guidelines are detailed in this report. Both the maximum 1-hour and 24-hour SO<sub>2</sub> levels were the highest recorded since the Erie Street monitor was installed in 2011.

It will be shown that the single monitor, located at Erie St., only obtains samples representative of the actual ship emissions when the wind direction is within a narrow band and the wind speed is high. *Therefore, the exceedances identified in this report are only a small sample of those which occurred within the James Bay area.* Additional monitors would have enabled the full extent of the pollution levels within James Bay to be determined.

Combinations of ships which were in port when the highest and lowest levels of SO<sub>2</sub> were detected are identified.

Regulations, which will come into effect on 1<sup>st</sup> January, 2015, will lower the maximum allowable sulphur content of fuel to 0.1% from the current 1%. However, alternatives, such as the use of scrubbers, may be permitted if they result in ship emissions equivalent to that of the low sulphur fuel. Additionally, exemptions may be granted which will allow the continued use of higher sulphur fuel until the alternative becomes operational.

With the expectation of improved air quality it is unlikely that funding for additional monitoring stations will be forthcoming. We will therefore continue to be vigilant during the 2015 season with cautious hope for an environmental improvement and will request that Greater Victoria Harbour Authority (GVHA) use its contractual power to ensure that the intent of the 0.1% fuel legislation is followed by all cruise ships it allows to dock at Ogden Point. This could be accomplished by requiring all cruise ships, which have been granted an exemption, to switch to 0.1% sulphur as they enter Canadian waters on their approach to Ogden Point or, as a minimum, before entering the GVHA water lot.

## 2.0 KEY POINTS

- This is the first season we are able to report under the current North American Emission Control Area (ECA) regulations. These came into effect in mid-2012 and reduced the permitted sulphur content of the fuel from 3.5% to 1%. In 2013 the GVHA anemometer malfunctioned and, as a result, we were unable to make the essential data link between the SO<sub>2</sub> level detected at the single monitor and the wind direction.
- The single sulphur dioxide (SO<sub>2</sub>) monitoring site is located at Erie Street. This site is mostly in the SW sector relative to the Ogden Point piers (page 7).
- The wind direction (ships in port, ≥ 2m/s) was mainly from the SW (23%), WSW (19%), and SSW (19%). However, there are significant differences between;
  - the September wind direction frequency when compared to 2012 data (p 6);
  - the S and W wind frequency when compared to 2012 data (p 7); and
  - the wind direction when the peak level of SO<sub>2</sub> is detected and the monitor bearing (p 13).Confirmation that the anemometer was calibrated following the 2013 malfunction has been requested (Appendix 3).
- The James Bay residential neighbourhood is unique amongst the North American west coast cruise ship ports due to:
  - its closeness to the berthed ships; the nearest residences are within 250m; and
  - the high percentage of the time, 65%, that the winds blow the ship emissions over the neighbourhood (p 6).
- The single monitoring station only obtains the most representative samples of the actual cruise ship emissions under a very narrow range of wind conditions. These are:
  - wind direction between 195° and 205°; and
  - wind speed ≥10 knots.

**These conditions only occur for 6% of the time that ships are in port (p 14).**

- At the single monitoring station:
  - the Island Health (formerly Vancouver Island Health Authority) 1-hour 35 ppb guideline was exceeded 14 times (p 9). The highest recorded level was 131 ppb; **this is higher than levels previously detected when the use of 3.5% sulphur fuel was permitted;**
  - the Island Health 1-hour 75 ppb guideline was exceeded three times (p 9); and
  - the World Health Organization (WHO) 24-hour guideline (20 µg/m<sup>3</sup>, 7.6 ppb) was exceeded four times for periods ranging from 24 to 48 hours. The highest recorded 24-hour level was 11.4 ppb (p 10).

Both the 1-hour and 24-hour maximum detected SO<sub>2</sub> levels are the highest recorded since the Erie St. monitor was installed in 2011 (p 10 & Appendix 1).

- **High levels are not only detected during ship manoeuvring.** The highest 10-minute level was recorded when cruise ships were in port (p 10).
- The ship combinations (p 16 to 18) in port when the greatest number of high SO<sub>2</sub> measurements occurred were:
  - Amsterdam, Grand Princess, Norwegian Pearl.
  - Golden Princess, Norwegian Jewel, Westerdam.
  - Golden Princess, Westerdam, Zuiderdam.

- The single ship in port when the lowest levels of SO<sub>2</sub> (p 19) were detected was Rhapsody of the Seas.
- The two single ships in port when the highest levels of SO<sub>2</sub> (p 19) were detected were Star Princess and Norwegian Jewel.
- We have been informed by Transport Canada that the majority of cruise ships arriving at Ogden Point will use scrubbers as an alternative to the use of 0.1% sulphur content fuel. We also understand that exemptions have been, or will be, granted which may permit the continued use of higher sulphur fuel until the end of the 2016 cruise ship season or beyond (p 4, 5).

### 3.0 BACKGROUND

#### **3.1 History of the James Bay SO<sub>2</sub> studies**

The earliest studies were sponsored by Vancouver Island Health Authority (now Island Health) in collaboration with others from 2007 through 2008. These studies explored the composition of emissions created by cruise ships docked at Ogden Point and determined that a more detailed evaluation of the SO<sub>2</sub> levels in the James Bay neighbourhood was required

In 2009, the BC Ministry of Environment placed a mobile air monitoring laboratory (MAML) in the James Bay community. Analysis of 2009 data revealed elevated levels of SO<sub>2</sub> and led to the preparation of a risk report issue by the BC Centre for Disease Control. Included in the report were the following points:

- *...SO<sub>2</sub> exposure, especially at the higher levels recorded during the 10 minute intervals could plausibly cause wheezing and difficulty breathing in persons with asthma, and to a lesser degree, mild breathing problems in persons who do not have respiratory disease. These reactions are made more likely to occur during exercise, when deep breathing allows SO<sub>2</sub> to reach deeply into the lungs. Under these circumstances, not actively exercising would be protective*
- *Staying indoors may reduce the effective exposure to peak levels on SO<sub>2</sub>. SO<sub>2</sub> is a reactive gas, and reacts with people and building contents, thereby reducing its concentration in confined spaces such as in a house or apartment.*

An outcome of this report was the installation of a single SO<sub>2</sub> monitor at an Erie St. location in 2011. From 2011 through 2013, Dr. Eleanor Setton, of the University of Victoria Spatial Sciences Research Laboratory, was contracted by the BC Ministry of Environment to analyse the data and prepare a report. In 2013 the analysis was limited due to the absence of wind data as a result of equipment failure. Dr. Setton has not been contracted to undertake an analysis of the 2014 data

JBNA has also analysed the data and produced reports for 2011 and 2012 as well as this report for 2014. These reports agree with the findings of Dr. Setton but also attempt to further define the limitations of a single monitoring station.

All of the above mentioned reports are available on the environment page of the JBNA website at <http://www.jbna.org/environment.htm>.

### **3.2 Health impacts of cruise ship pollution**

Not all James Bay residents experience discomfort and health issues as a result of cruise ship emissions but many do, and they continue to contact our association with complaints:

*“Ogden Point where we live in .... Eyes are watering and my husband and I can feel it in our throats. It is windy and we can still smell it.” (7<sup>th</sup> June, 2014)*

*“This is just such a problem and here we are expected to tough it out. We are in a new world with little or no solutions, all for the love of commerce. Just because “everyone” in James Bay is not affected most don’t support those of us who are. Strange, because when environmental disasters happen here and all over the world “everyone” seemingly on the planet supports those who are affected.....why are we so different!?” (24<sup>th</sup> July, 2014)*

One constituent of cruise ship emissions is SO<sub>2</sub> and its effect on asthma sufferers is well known:

*“Short-term peak exposures to elevated SO<sub>2</sub> are of special concern. In an asthmatic, especially during vigorous exercise such as jogging or hard physical labor, asthma may worsen. SO<sub>2</sub> can also cause the eyes and throat to sting.” (ref 1)*

Over 7% of the BC population (age 12 or older) report that they have been diagnosed as having asthma (ref 2) and over 4% (age 35 or older) with chronic obstructive pulmonary disease (ref 3). The James Bay population is especially at risk due to the high percentage of seniors (37% of residents are over 60 vs. 23% for the rest of Victoria).

### **3.3 The Emission Control Area (ECA) regulations**

The North American ECA is essentially an area extending 200 nautical miles around the coast of North America. Under international agreement regulations are in place to limit the sulphur content of the fuels used by cruise ships, along with ocean going vessels, while within the ECA.

A legal requirement to limit the sulphur content of cruise ship fuel from 3.5% to 1% for ships within the ECA was introduced in mid-2012.

Regulations, which will come into effect on 1<sup>st</sup> January, 2015, are to limit the sulphur content of fuel for ships within the ECA to 0.1% but will also allow for alternatives, such as the installation of emission scrubbers, where these reduce the sulphur dioxide levels to the same or lesser extent as that of 0.1% sulphur fuel.

Restrictions for ships which travel within international waters are regulated by an international body, the International Maritime Organization, through the MARPOL treaty, as distinct from Canadian registered ships within Canadian waters which are regulated by Transport Canada. BC Ferries' ships started to use 0.1% sulphur fuel over 10 years ago and had completed the transition by 2011.

This lower level of sulphur content will be 1/35<sup>th</sup> of the pre mid-2012 levels and is the result of long-overdue legislation which recognizes the environmental and health impacts of ship emissions:

*“its benefits are expected to include preventing as many as 14,000 premature deaths and relieving respiratory symptoms for nearly five million people each year in the U.S. and Canada” (ref 4)*

Such a statement, from the US Environmental Protection Agency, vindicates the persistence of JBNA in bringing the concerns of our residents to GVHA and to the City of Victoria.

Many of the cruise ship companies will obtain approval for the use of scrubbers as an alternative to the use of 0.1% fuel. This alternative:

- will allow the ships to burn higher sulphur content fuel (e.g. 3.5% S) when the scrubber is operational. However, if a scrubber is 95% efficient a maximum sulphur content of 2% is required to achieve the same reduction in pollution levels as 0.1 % S fuel; and
- in a situation involving scrubber mechanical failure, may result in pollution levels as high as those experienced in 2009.

Additionally, the cruise ship companies may also apply for an exemption which will allow the cruise ships to continue to burn higher sulphur fuel until the scrubbers become operational. This exemption may extend until the end of the 2016 cruise ship season or, perhaps, even longer:

*“The continued use of residual fuel may be considered, if the vessel is to be fitted with new technology or modified to use of alternative fuels that will result in improved air emissions within 3 years. This would require an exemption issued under Regulation 3 of MARPOL.” (extract from Transport Canada Ship Safety Bulletin No.: 02/2013)*

Although the Transport Canada *Ship Safety Bulletin No.: 08/2014* indicates that use of alternatives to achieve the required emission levels will require Transport Canada approval, it is not apparent that Transport Canada approval is required for the exemption.

In summary we will continue to be vigilant as we enter the 2015 season with cautious hopes for an environmental improvement and will request that GVHA use its contractual power to ensure that the intent of the 0.1% fuel legislation is followed by all cruise ships it permits to dock in Victoria. This could be accomplished by requiring all cruise ships, which have been granted an exemption, to switch to 0.1% sulphur as they enter Canadian waters on their approach to Ogden Point or, as a minimum, before entering the GVHA water lot.

### **3.4 Reasons for analysis**

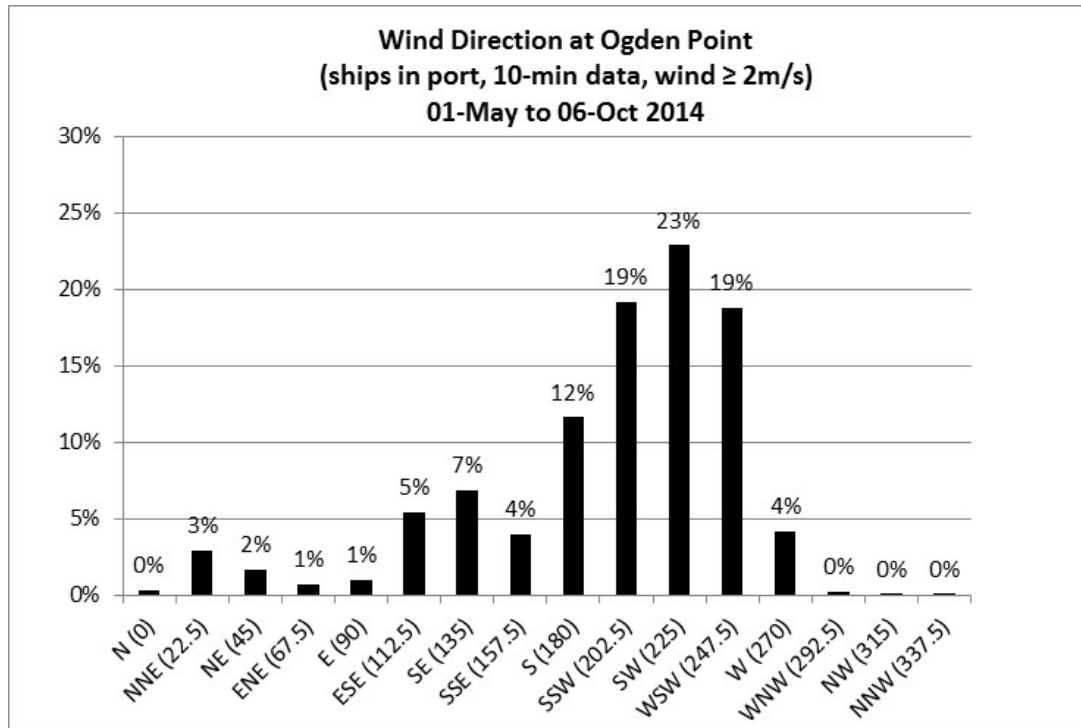
- Residents continue to contact the James Bay Neighbourhood Association (JBNA) with complaints about the effect that the cruise ship emissions have on their health and on their ability to enjoy outdoor activities. James Bay has a high percentage of older residents and our organization has an ethical duty to these residents to analyse and report on the extent of pollution.  
  
Sulphur dioxide (SO<sub>2</sub>) is the emission constituent which, at higher levels, can be harmful to the young, elderly, asthmatics and those with heart and lung disease. SO<sub>2</sub> emissions occur when ships burn sulphur-containing fuel.
- Although regulations, most recently in mid-2012, have reduced the allowable sulphur content of the fuel (from 3.5% to 1%) the SO<sub>2</sub> levels measured at the single James Bay monitor continue to record levels in excess of Island Health and World Health Organization (WHO) guidelines. Our analyses have highlighted these exceedances.
- Statements such as “99 percent of the time ships are in port, the air quality is good” have been made by the Greater Victoria Harbour Authority (GVHA) and have been widely reported in the media. This report, and our previous annual reports, disputes this claim. Only the provision of additional monitoring stations will reveal the full extent of the pollution caused by cruise ship emissions.
- New regulations which come into effect in January 2015 will limit the sulphur content in the fuel to 0.1%. However, exemptions, including a commitment for the future installation of scrubbers, are possible. At this time, it is not known which cruise ships will have operational alternatives in place. Our continuing analysis will provide an early warning if pollution levels in 2015 fail to show an improvement.

## 4.0 2014 ANALYSIS

### 4.1 Wind direction, James Bay map & monitor location

#### 4.1.1 Wind direction

The frequency of wind direction in each of 16 sectors (N, NNE, NE, ENE, E etc.), when cruise ships are in port, is shown in the chart below.



Ogden Point is perhaps a unique North American cruise ship port since:

- the port is located adjacent to a residential area (see map in next section); and
- the majority of the time (65%) the wind blows directly over James Bay.

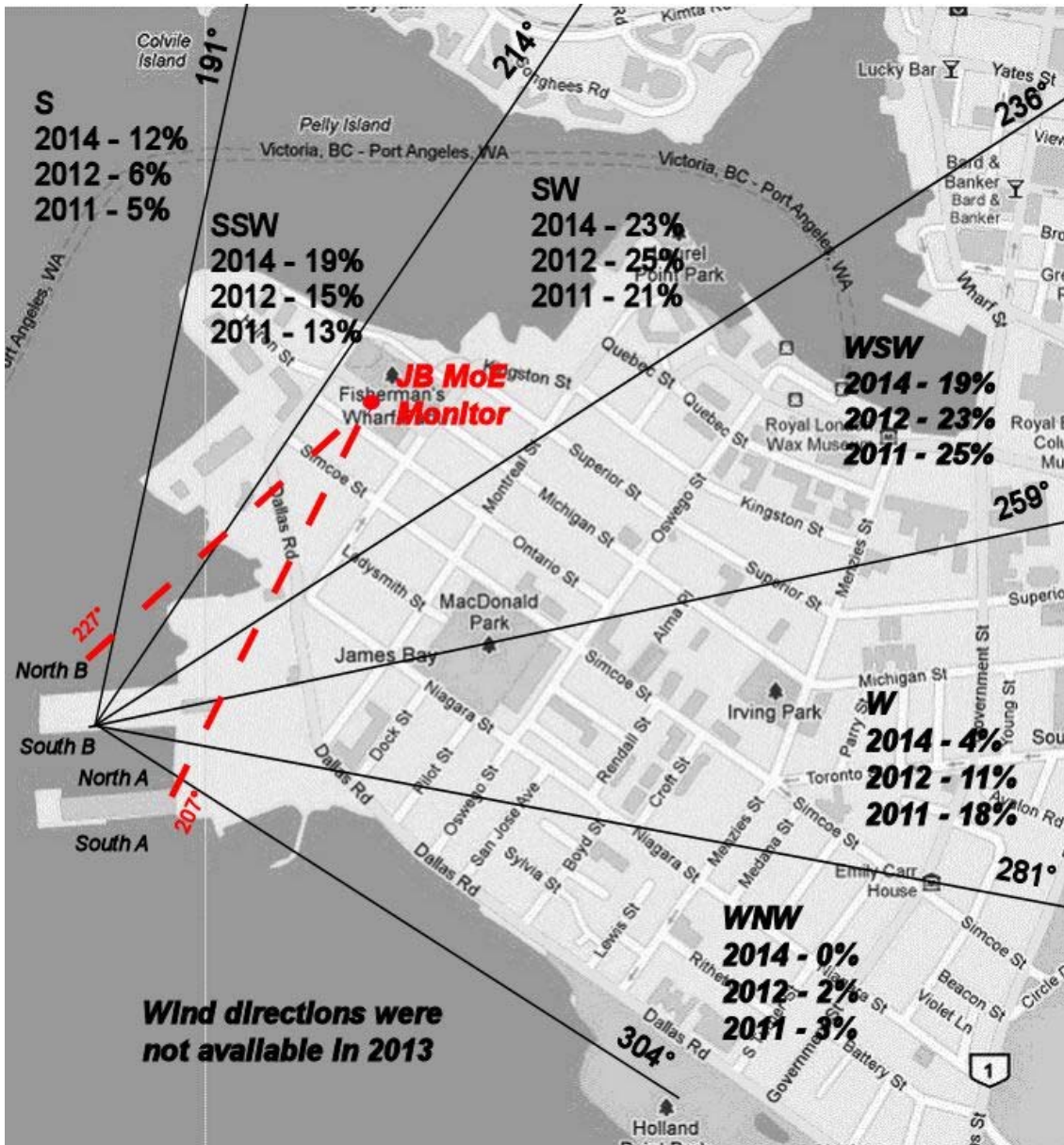
The chart below is for the five (of 16) sectors which affect James Bay (see map on next page).

	May	Jun	Jul	Aug	Sep	Oct	May-Oct
SSW	15%	19%	25%	23%	11%	0%	19%
SW	26%	25%	23%	27%	8%	2%	23%
WSW	23%	33%	15%	13%	5%	2%	19%
W	7%	2%	6%	2%	1%	5%	4%
WNW	1%	0%	0%	0%	0%	0%	0%
Other	27%	20%	31%	34%	75%	90%	35%
	100%	100%	100%	100%	100%	100%	100%

The reduction in winds affecting James Bay in September needs further investigation. In 2012 the winds from “other directions” was 27% vs. the 75% in 2014.

Since there were only two ship visits in October the listed wind distribution for this month is not significant.

#### 4.1.2 Wind directions in James Bay while ships were in port



The wind direction (10-minute measurements, ships in port) from **South Pier B** at Ogden Point and the direction frequency have been superimposed on the above James Bay map. The location of the Erie St. SO<sub>2</sub> monitoring site is also indicated. The anemometer is located on the beacon at the Ogden Point breakwater.

Ships dock at the North B (40%), South B (40%) and South A (20%) piers. The location of the monitoring station relative to the piers will therefore range between 207° and 227°; i.e., in the SW sector for Pier B and just inside the SSW sector for most of South Pier A.

## 4.2 The monitor results

The following sections list the occasions where BC Ministry of Environment or WHO 10-minute, 1-hour and 24-hour guidelines for SO<sub>2</sub> levels were exceeded at the monitor. Additionally, the charts included in Appendix 1 clearly demonstrate how the 2014 levels exceeded those of previous years.

### 4.2.1 Occasions where the Island Health 1-hour guidelines were exceeded

The Health Risk Guide below is published on the Island Health website ([www.viha.ca](http://www.viha.ca)) and is for 1-hour SO<sub>2</sub> levels:

#### Protecting Your Health from Sulphur Dioxide

Sulphur Dioxide Concentration (ppb*)	Air Quality	At-Risk Populations**	General Population
0 - 35 Good	Air quality is satisfactory, SO <sub>2</sub> concentrations pose little or no risk	Enjoy your usual outdoor activities. Follow Dr's advice for exercise regime and condition management.	No need to modify usual outdoor activities.
36 - 75 Moderate	There may be a moderate health risk for a very small number of people who are unusually sensitive to SO <sub>2</sub> .	A small number of persons with asthma who are very sensitive to SO <sub>2</sub> may experience symptoms. Follow Dr's advice for managing condition.	No need to modify usual outdoor activities.
76 - 185 Unhealthy for Sensitive Groups	Members of sensitive groups may experience health effects. The general public is not likely to be affected.	Increasing likelihood of respiratory symptoms such as chest tightness and breathing discomfort in people with asthma. People with asthma should consider limiting outdoor exertion or reschedule when SO <sub>2</sub> concentrations are lower. Follow Dr's advice for managing condition.	No need to modify usual outdoor activities unless you experience symptoms of cough or wheeze when exercising.
more than 185 Unhealthy	Everyone may begin to experience health effects; members of sensitive groups may experience more serious health effects.	Children, the elderly, asthmatics and people with heart and lung disease should limit exertion outdoors or reschedule when SO <sub>2</sub> concentrations are lower. Follow Dr's advice for managing condition.	At elevated SO <sub>2</sub> concentrations, chest tightness and wheezing can occur, even with very brief exposures (minutes) in healthy people without asthma. Reschedule outdoor activity when SO <sub>2</sub> levels are lower.

The table below lists the occasions when either the 35 ppb or 75 ppb 1-hour guideline, defined above, were exceeded.

Date	Ships	1st Hour begins	last hour ends	Total Hours	SO <sub>2</sub> (ppb)			1-hour ("on the hour")
					Max 10 min	A, P or D	Max 1-hour ("rolling")	
9-May	Golden Princess, Westerdam, Zuiderdam	19:10	22:30	3h 20m	188	P	131	131 & 50
18-May	Norwegian Sun	17:30	18:40	1h 10m	91	D <sub>b</sub>	41	-
24-May	Grand Princess, Norwegian Pearl	18:10	20:00	1h 50m	95	A <sub>a</sub> P	61	42
30-May	Golden Princess, Norwegian Jewel, Westerdam	17:50	19:10	1h 20m	96	A <sub>a</sub> P	39	37
31-May	Amsterdam, Grand Princess, Norwegian Pearl	17:20	18:50	1h 30m	68	A <sub>ba</sub> P	50	-
3-Jul	Celebrity Solstice, Rhapsody Of The Seas, Star Princess	17:20	18:50	1h 30m	69	PD <sub>a</sub>	40	-
11-Jul	Golden Princess, Norwegian Jewel, Westerdam	18:00	20:00	2h 0m	172	P	76	46 & 58
12-Jul	Amsterdam, Grand Princess, Norwegian Pearl	17:40	20:40	3h 0m	109	A <sub>ba</sub> P	86	76 & 51
26-Jul	Star Princess	13:20	15:10	1h 50m	180	D <sub>b</sub>	69	63
26-Jul	Amsterdam, Grand Princess, Norwegian Pearl	18:10	19:50	1h 40m	79	A <sub>a</sub> P	57	-
26-Jul	Amsterdam, Grand Princess, Norwegian Pearl	20:00	21:30	1h 30m	58	P	48	40
15-Aug	Golden Princess, Norwegian Jewel, Westerdam	17:50	19:30	1h 40m	126	A <sub>a</sub> P	49	49
29-Aug	Golden Princess, Norwegian Jewel, Westerdam	18:10	21:10	3h 0m	124	P	89	78 & 56
9-Sep	Carnival Miracle	21:20	23:20	2h 0m	113	D <sub>b</sub>	66	62
				27h 20m				14 h
A, P & D denote the activity when the maximum 10-minute SO <sub>2</sub> level occurred:								
A= Ship arriving, covers period 30 min. before (A <sub>b</sub> ) and 30 min. after (A <sub>a</sub> )the ship docks								
P= Ship in Port								
D= Ship departing. covers period 30 min. before (D <sub>b</sub> ) and 30 min. after (D <sub>a</sub> )								

The “on the hour” figures are the figures published on the BC Ministry of Environment (MoE) website and cover whole hour periods, e.g., 6 pm to 7 pm; whereas the “rolling hour” figures will capture exceedances that occur at other times, e.g., from 6:30 pm to 7:30 pm. There will therefore be cases where a “rolling hour” exceedance occurs without an “on the hour” exceedance. The 26<sup>th</sup> July data from the table provides an example; the peak of 57 ppb occurred for the hour between 6:30 and 7:30 pm. The website value for the 6:00 to 7:00 pm is 34 ppb and for 7:00 to 8:00 pm is 32 ppb.

From the “A, P or D” column it can be seen that peaks can occur **during arrival, while in port, or during departure.**

At this one location, using the published “on the hour” basis, the 1-hour Island Health SO<sub>2</sub> 35 ppb guideline was exceeded 14 times and the 75 ppb guideline was exceeded three times (see the table on page 8 for the guideline details).

Using the “rolling hour” basis the 35 ppb level was also exceeded 14 times with a total duration of 27 hours and the 75 ppb level four times with a total duration of six hours

The highest SO<sub>2</sub> 1-hour level detected at Erie St. during 2014 was 131 ppb on 9<sup>th</sup> May and is the highest level since the Erie St. monitor was installed in 2011. The highest level previously detected at Erie St., in July 2012 when the use of 3.5% sulphur fuel was permitted, was 101 ppb.

At the GVHA public board meeting held on 15<sup>th</sup> May, 2014, Greg Wirtz, President of Cruise Lines International Association - North West and Canada (CLIA), recognized the unique situation existing in James Bay (closeness of residences, prevailing wind direction) and apologized for the unacceptable SO<sub>2</sub> level experienced by residents; also, Greg Wirtz committed to determine the cause; we do not know if GVHA received, or have requested, the results of this inquiry.

The highest SO<sub>2</sub> 1-hour level detected at Topaz, 3.5 km from Ogden Point, was 49.2 ppb for the 6 pm to 7 pm period on 12<sup>th</sup> July; i.e., the level, in the greater part of the City of Victoria, exceeded the Island Health 35 ppb guideline. This is the highest level detected at Topaz since 2009. The corresponding peak 10-minute (6:30 pm) and 1-hour (7 pm) levels detected at Erie St. were 109 ppb and 76 ppb.

#### 4.2.2 Occasions where the WHO 10-minute SO<sub>2</sub> guideline of 500 µg/m<sup>3</sup> was exceeded

500 µg/m<sup>3</sup> is equivalent to 191 ppb. The highest level recorded at the single monitor was 188 ppb, on 9<sup>th</sup> May, just short of the WHO guideline and occurred when three ships, Golden Princess, Westerdam and Zuiderdam were in port. **This is the highest 10-minute level since early 2012 when 3.5% sulphur fuel content was permitted.**

The second highest level recorded was 180 ppb, on 26<sup>th</sup> July, and occurred when a single ship, Star Princess, was in port.

#### 4.2.3 Occasions where the WHO 24-hour SO<sub>2</sub> guideline of 20 µg/m<sup>3</sup> was exceeded

24 h periods			24h Periods	24-hour max. SO <sub>2</sub>
First Start	First End	Last end		
08-May 21:20	09-May 21:20	10-May 20:30	2.0	11.4
11-Jul 18:40	12-Jul 18:40	13-Jul 18:20	1.9	8.0
25-Jul 20:50	26-Jul 20:50	27-Jul 14:10	1.7	9.0
28-Aug 20:30	29-Aug 20:30	30-Aug 18:30	1.9	8.3
Total			<b>7.5</b>	

20 µg/m<sup>3</sup> is equivalent to 7.6 ppb. Using the “on the hour” published data there were four occasions when the 24-hour WHO guideline was exceeded. A duration factor of 7.5 days was determined from the 10-minute “rolling” data.

**The 11.4 ppb level of SO<sub>2</sub> is the highest recorded since the Erie St. monitor was installed in 2011.**

**4.3 Only a small number of the SO<sub>2</sub> measurements from the single monitor are representative of the actual ship emissions.**

In this section it will be shown that the **single** monitor captures SO<sub>2</sub> levels which are most representative of the actual ship emissions only when:

- the wind direction is within a very narrow band (195° to 205°) (p 13); and
- the wind speed is high (≥ 10 knots) (p 13,14).

These conditions are met only 6% of the time that ships are in port (p 14)

Additionally,

- residents living in other sectors are subjected to more frequent winds and higher wind speeds may experience higher levels of SO<sub>2</sub> (p 14);
- other locations within James Bay, either lower or higher, or nearer or further from Ogden Point, may experience higher pollution levels (p 15); and

**In summary:**

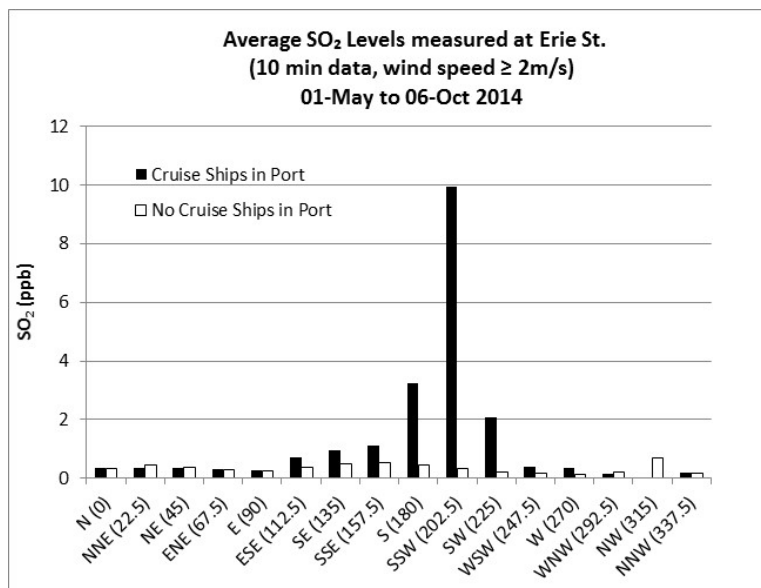
- **The exceedances recorded in the previous section are only a sample of the total exceedances that occurred within the James Bay area in 2014.**
- ***“Additional monitoring is required to better understand the extent and nature of the impact from cruise ship emissions on local air quality.”*** MoE 2011 Air Quality report

**4.3.1 The monitor only detects representative samples when the wind direction is within a narrow band**

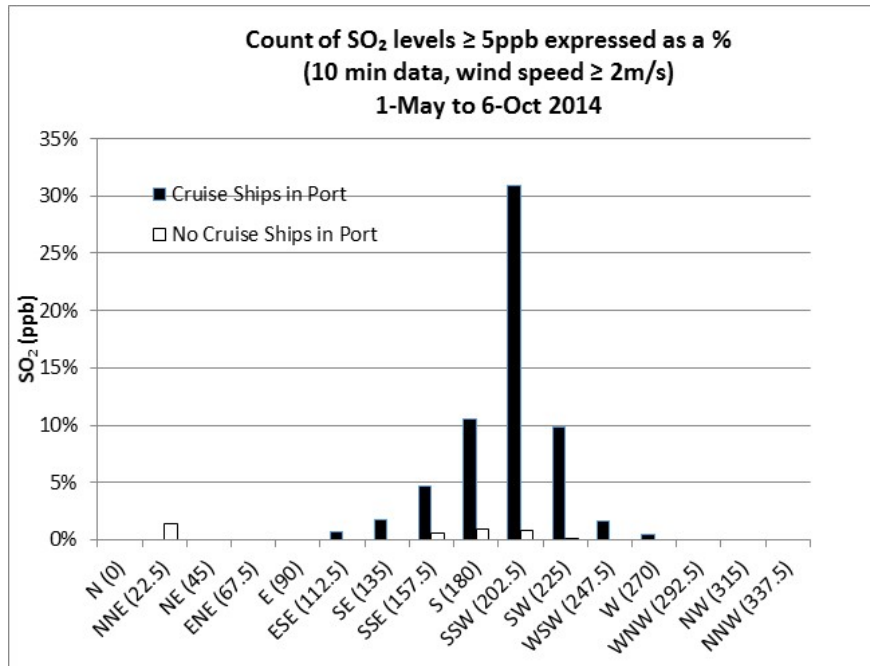
Two methods are used to show the narrow wind range where SO<sub>2</sub> detection occurs:

- **Average** SO<sub>2</sub> level by wind sector – a good guideline but extreme readings may skew the results; and
- **Count** method – the number of records where the SO<sub>2</sub> level exceeds a defined level is expressed as a percentage of the total records.

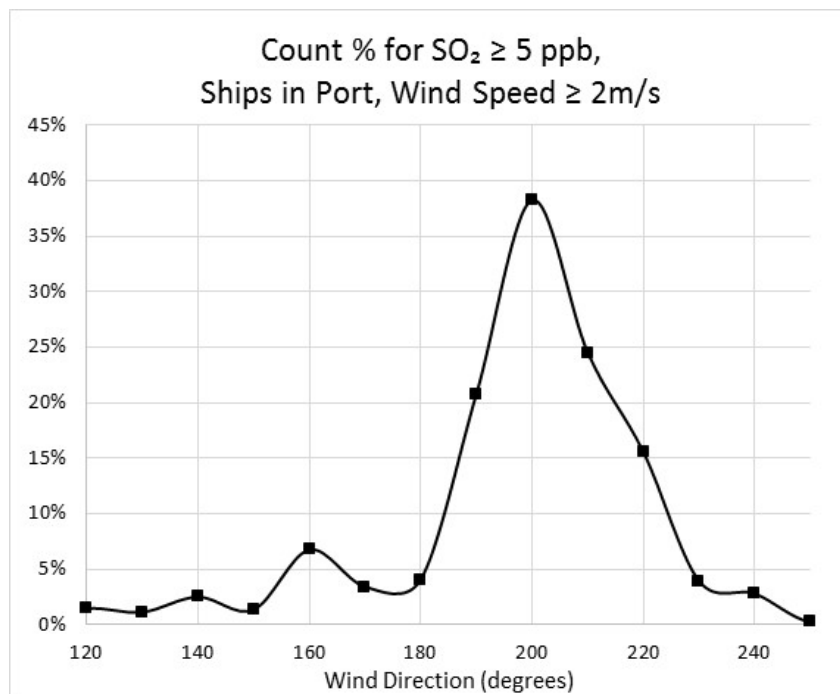
**Average Method**



## Count Method



Both charts show that the most representative samples are only obtained when the wind is from the SSW. When wind is from other directions only a diffused lower level is detected. This is demonstrated more clearly in the next chart:



10 minute records				
		Total	SO <sub>2</sub> ≥ 5	
degrees		Count	Count	%
>=185	<195	376	78	21%
>=195	<205	416	159	38%
>=205	<215	412	101	25%

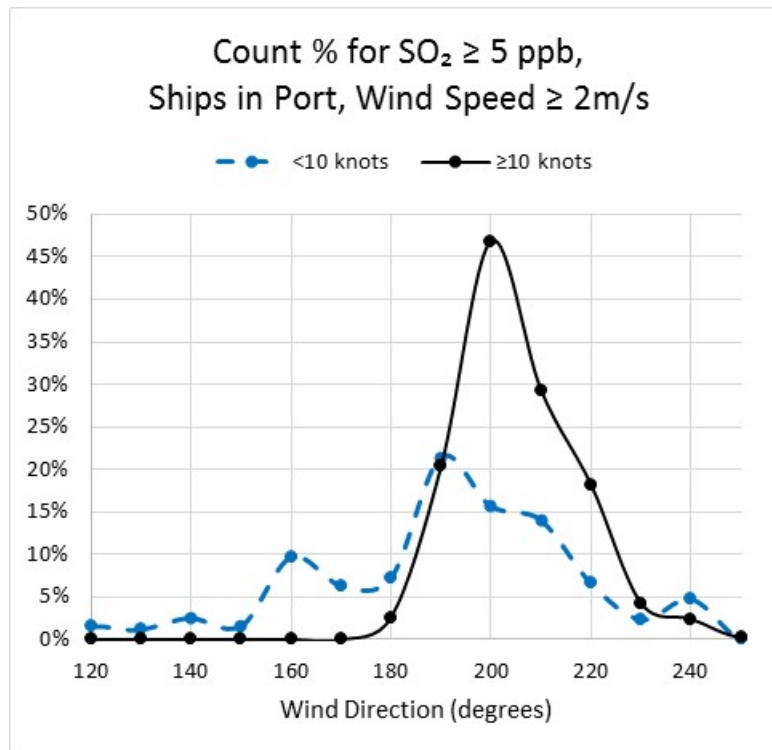
Two zones are apparent from this chart:

- The “**Detectable**” zone between 175° and 235°. Apart from the outlier at 160° only when the wind is blowing between these directions will any significant level of SO<sub>2</sub> be detected
- The “**Representative**” zone between 195° and 205°. Only when the wind is blowing between these directions will levels of SO<sub>2</sub> approaching those of the actual ship emissions be detected.

Unexplained is why the peak occurs in the 195° to 205° wind range whereas the monitor is located between 207° & 227°. Is this due to building interference? Or, is an anemometer calibration check required?

#### 4.3.2 The monitor only detects representative samples when the wind speed is high

Again the count method is used to determine the relationship between speed, direction and the SO<sub>2</sub> levels detected at the single monitor.



		10-minute records						
Speed		All	<10 knots			≥10 knots		
SO <sub>2</sub>		All	All	SO <sub>2</sub> ≥ 5		All	SO <sub>2</sub> ≥ 5	
degrees		Count	Count	Count	%		Count	%
>=185	<195	376	145	31	21%	231	47	20%
>=195	<205	416	115	18	16%	301	141	47%
>=205	<215	412	129	18	14%	283	83	29%

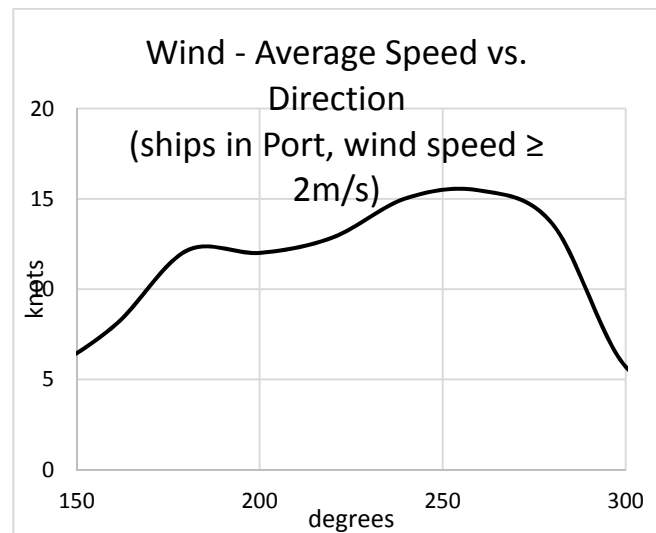
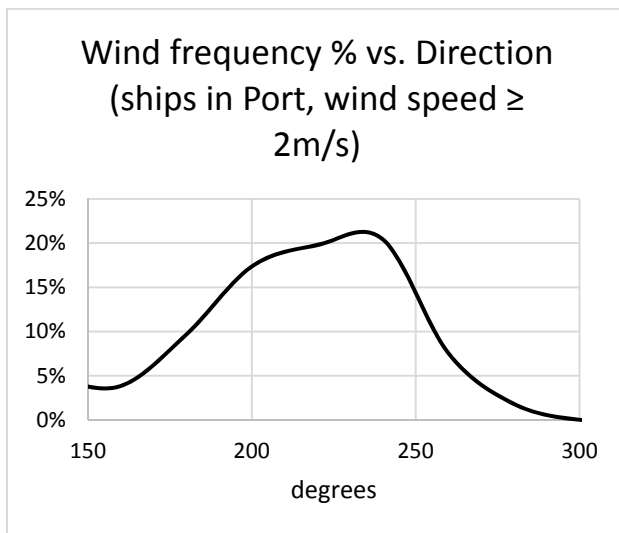
This chart indicates that there is further reduction in the ability of a single monitor to obtain representative samples of the ships' emissions. It would appear to be most effective only when the wind direction is in the 195° to 205° range and the wind speed is greater than 10 knots. These conditions, which occur only 6% (301/4784) of the time that cruise ships are in port, further define the "representative" zone.

**When the wind meets these conditions the 10-minute SO<sub>2</sub> level exceeds 35 ppb for 12% (36/301) of the time (8% for the Island Health 35 ppb 1-hour guideline).**

Wind	All	≥195, <205 & ≥10 knots	
SO <sub>2</sub> (ppb)	All		≥35
	4784	301	36

#### 4.3.3 Locations in other sectors may experience higher SO<sub>2</sub> levels

The two charts below show the frequency and speed of the wind vs. wind direction



Both the frequency and average speed peak at about 240°. The higher wind speeds have been shown to result in higher pollution levels recorded at the monitor.

This direction is within the WSW sector (236° to 259°) and is the sector from which we receive many of the resident complaints. However, the monitor does not detect SO<sub>2</sub> levels for this sector.

Note: if it is shown that the anemometer readings are incorrect the peak would move further into the WSW zone.

#### **4.3.4 Locations closer to Ogden Point may experience higher SO<sub>2</sub> levels**

The monitor is located between 600 and 900 metres from Ogden Point depending on which pier is in use. It is very possible that residences closer to Ogden Point will experience higher levels but, with a single monitor, this cannot be confirmed.

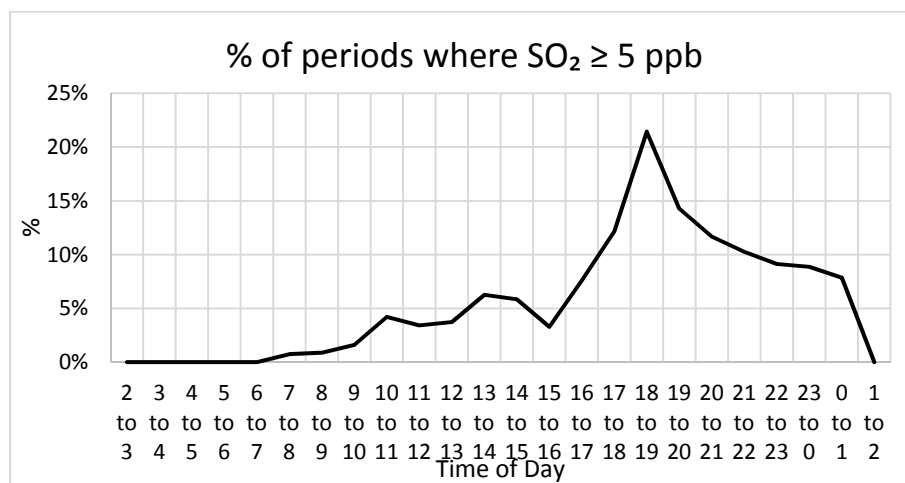
## 4.4 Ship SO<sub>2</sub> Analysis

### 4.4.1 The greater the number of ships the higher the pollution level

The table below shows the effect on the number of cruise ships on the detected SO<sub>2</sub> level. “In-Port” includes ships arriving or departing within 30 minutes of the “first-line” and “last-line” times.

Ships in Port	Total 10-min periods	Using 10-min data			
		SO <sub>2</sub> ≥5 ppb	SO <sub>2</sub> ≥10 ppb	SO <sub>2</sub> ≥35 ppb	Average SO <sub>2</sub> level (ppb)
0	14,746	0%	0%	0%	0
1	4,774	4%	2%	0%	1
2	1,195	12%	6%	1%	2
3	945	24%	17%	8%	8
4	3	67%	33%	33%	18
	6,917	9%	5%	2%	

### 4.4.2 SO<sub>2</sub> level by time of day



Although the peak SO<sub>2</sub> levels were not restricted to arrivals and departures (see p 9) the highest overall levels occur between 6 pm and 7 pm and are associated with the concurrent arrival of three cruise ships.

### 4.4.3 Ships that were present when the highest pollution levels were detected

The table below lists which ships were present when the 10-minute SO<sub>2</sub> levels exceeded 35 ppb. This criterion was chosen on the basis that a 1-hour 35 ppb level will only be recorded if at least one of the 10-minute levels exceeds 35 ppb.

There were 57 distinct ship combinations (the four ship combination at the bottom of the list is a result of a ship arriving as one is leaving within the 30 minute arrival/departure window) and, of these, 18 recorded 10-minute SO<sub>2</sub> levels which exceeded 35 ppb. These are listed in the following table:

	Count of 10-minute periods			
	Total	≥35 ppb		
Amsterdam, Grand Princess, Norwegian Pearl	478	29	6%	63%
Golden Princess, Norwegian Jewel, Westerdam	343	22	6%	
Golden Princess, Westerdam, Zuiderdam	23	14	61%	
Star Princess	782	8	1%	
Carnival Miracle	568	5	1%	
Grand Princess, Norwegian Pearl	152	5	3%	
Norwegian Sun	69	4	6%	
Celebrity Solstice, Rhapsody Of The Seas, Star Princess	9	3	33%	
Celebrity Solstice, Regatta, Rhapsody Of The Seas	11	3	27%	
Norwegian Pearl	152	2	1%	
Regatta	287	2	1%	
Westerdam	181	1	1%	
Silver Shadow	242	1	0%	
Norwegian Jewel, Westerdam	130	1	1%	
Amsterdam, Norwegian Pearl	25	1	4%	
Golden Princess, Westerdam	244	1	0%	
Crown Princess, Westerdam, Zuiderdam	3	1	33%	
Amsterdam, Grand Princess, Norwegian Pearl, Regatta	1	1	100%	
		104		

The top three cruise ship combinations, highlighted in the table, accounted for 63% of the detected 10-minute SO<sub>2</sub> levels in excess of 35 ppb.

The next table shows the three ship combinations which had the highest number of 10-minute SO<sub>2</sub> levels exceeding 35 ppb when the winds were optimal for SO<sub>2</sub> detection (“representative” zone, wind direction ≥195°, <205° and speed ≥10 knots). All except the Zuiderdam return in 2015.

	10-minute periods		
	≥195°, <205° & ≥10 knots		
	All	≥ 35 ppb	
	Count	Count	%
Golden Princess, Norwegian Jewel, Westerdam	19	13	68%
Golden Princess, Westerdam, Zuiderdam	12	10	83%
Amsterdam, Grand Princess, Norwegian Pearl	44	7	16%
	75	30	40%

There were 14 hours (“on the hour” basis) where the Island Health SO<sub>2</sub> guideline of 35 ppb was exceeded. The ships in port at these times were:

	Count
Golden Princess, Norwegian Jewel, Westerdam	6
Amsterdam, Grand Princess, Norwegian Pearl	3
Golden Princess, Westerdam, Zuiderdam	2
Carnival Miracle	1
Grand Princess, Norwegian Pearl	1
Star Princess	1
	14

The maximum SO<sub>2</sub> levels detected were 188 ppb (10-minute measurement) and 131 ppb (1-hour measurement) both for the Golden Princess, Westerdam, Zuiderdam combination on May 9<sup>th</sup>.

**Both of these were detected when the winds and speeds were in the narrow range (195° to 205°, ≥10 knots) where the most representative samples of the actual ship emissions are obtained. These conditions only occur 6% of the time that ships are in port.**

#### 4.4.4 The single ships present when highest and lowest SO<sub>2</sub> levels were detected

This table lists three measures of SO<sub>2</sub> levels; average, maximum and count but limited to the detectable zone (175° to 235°) zone. To ensure a reasonable calculated average only ships with more than 100 10-minute records within this zone are included.

The lowest single ship level of SO<sub>2</sub>, by a large margin, was recorded when the Rhapsody of the Seas was in port (not returning in 2015). The highest single ship SO<sub>2</sub> levels were detected when the Star Princess (13 vs. 1 visit 2014/2015) and the Norwegian Jewel were singly in port (18 vs. 22 visits 2014/2015).

	10-min SO <sub>2</sub>				10 min periods
	ppb		≥5 ppb	≥10 ppb	
	Average	Maximum	%		Count
Rhapsody Of The Seas	0.5	6	1%	0%	285
Celebrity Solstice	1.4	29	8%	3%	253
Carnival Miracle	2.6	113	7%	4%	275
All single ships	2.6	180	10%	6%	
Star Princess	4.3	180	12%	8%	225
Norwegian Jewel	2.5	16	14%	8%	114

The table for three ships in port is included below for comparison.

	10-min SO <sub>2</sub>				10 min periods
	ppb		≥5 ppb	≥10 ppb	
	Average	Maximum	%		Count
All 3 ship combinations	16.6	188	45%	31%	
Amsterdam, Grand Princess, Norwegian Pearl	13.5	109	50%	32%	211
Golden Princess, Norwegian Jewel, Westerdam	18.6	172	42%	28%	113

All these ships return in 2015.

## 5.0 SHIP STATISTICS

### 5.1 Ship counts and scheduled durations by year

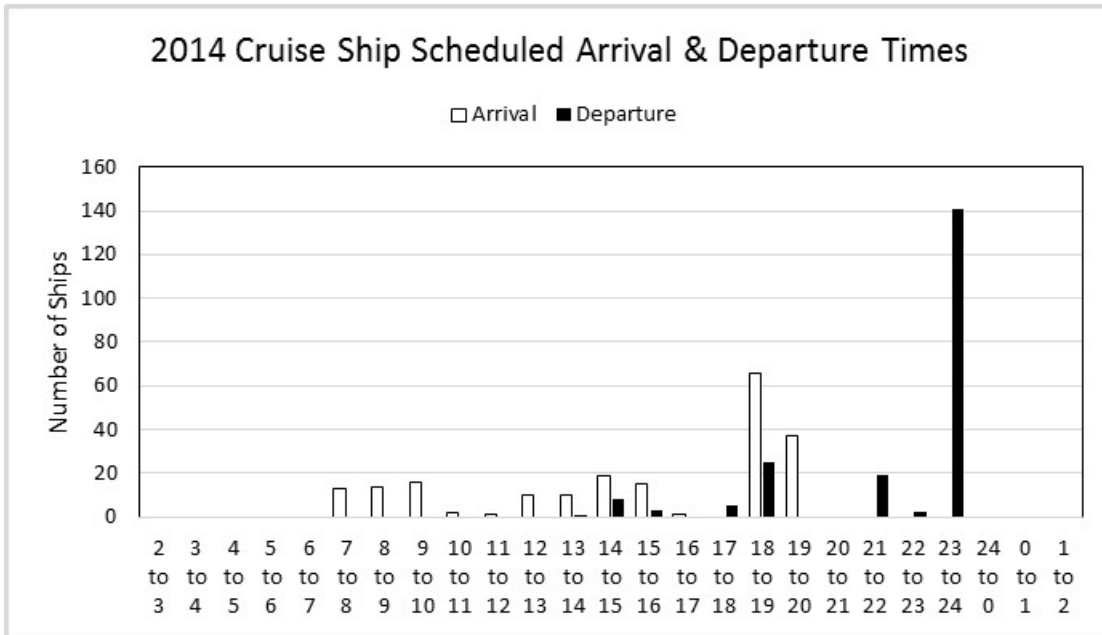
	2011	2012	2013	2014	2015
Ships	208	229	203	204	230
Passengers	414,388	476,916	449,668	442,044	526,112
Passengers/Ship	1,992	2,083	2,215	2,167	2,287
Days in Port	104	108	96	102	113
Hours in Port	1,502	1,488	1,377	1,475	1,644
Passenger time on Shore	5.3	4.8	5.0	5.5	5.4

### 5.2 Average and median durations of port visits

		2014			
		Scheduled		Actual	
	Ships - time in Port (hours)	Count	%	Count	%
	≥0, <6	103	51%	81	40%
	≥6, <9	51	25%	72	35%
	≥9, <13	46	23%	43	21%
	≥13, <18	4	2%	7	3%
		204	100%	203	100%
Ships in port - average (hours)		7.2		7.5	
Ships in port - median (hours)		6.0		6.8	
Passengers in port - Average (hours)		7.0		7.3	
Passengers on shore - average (hours)		5.5		5.8	

The Star Princess had an unscheduled overnight stop on 5<sup>th</sup> August and that visit is excluded from the "Actual" counts in the above table.

**5.3 Ship arrivals and departures by time of day**

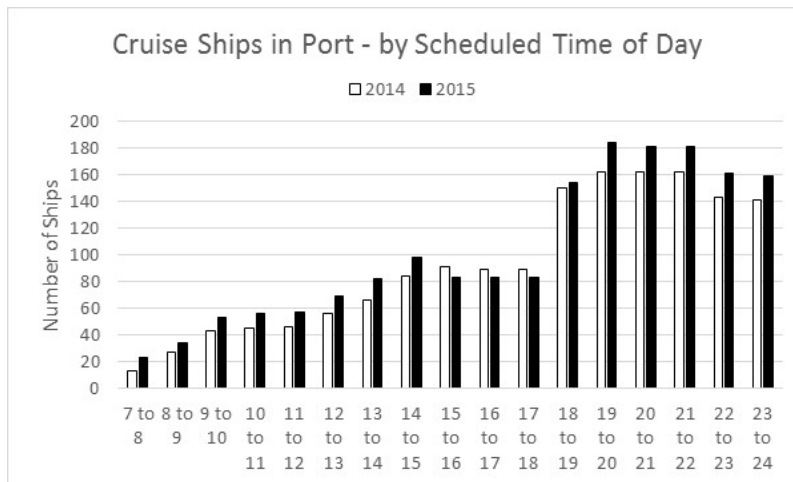


Average passenger hours are less than average ship hours due to shorter stays by larger ships.

A total of 1-½ hours have been allowed for passenger disembarking and embarking.

The Star Princess had an unscheduled overnight stop on 5<sup>th</sup> August and that visit is excluded from the above table.

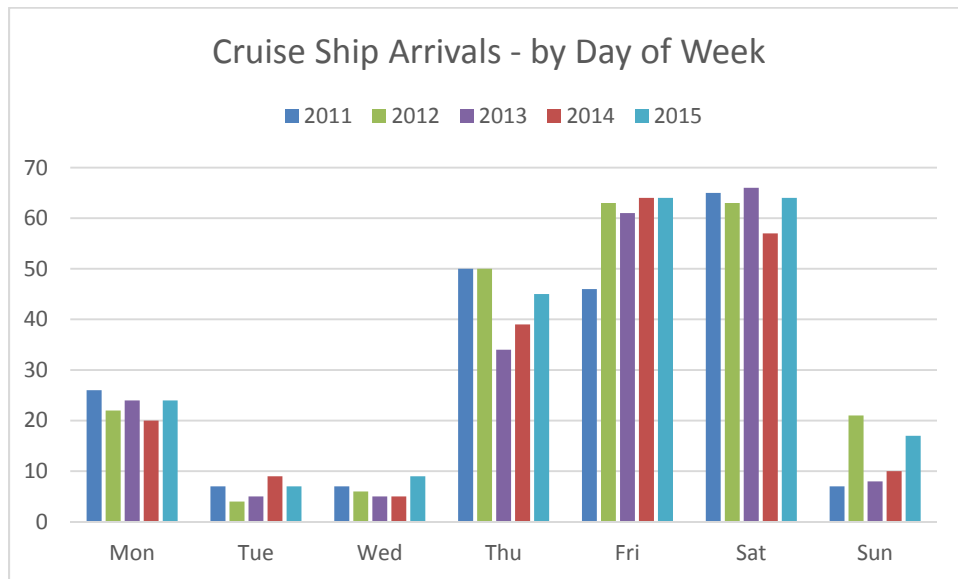
**5.4 Ships in port by time of day**



**5.5 Number of ships in port at one time**

	1	2	3
2015	67%	18%	14%
2014	70%	17%	13%
2013	67%	16%	17%
2012	61%	19%	20%
2011	63%	27%	11%

**5.6 Ship arrivals by day of week**



## 5.7 Ship lists, visit counts and durations

	2014		2015		
	Visits	Average hours (Scheduled)	Returning in 2015?	Visits	Average hours (Scheduled)
WESTERDAM	22	6.3	√	22	6.2
NORWEGIAN PEARL	20	6.4	√	21	6.6
GOLDEN PRINCESS	19	5.0	√	15	7.5
GRAND PRINCESS	19	5.1	√	2	6.5
CELEBRITY SOLSTICE	18	6.2	√	20	6.2
NORWEGIAN JEWEL	18	7.0	√	22	7.7
CARNIVAL MIRACLE	16	8.3			
RHAPSODY OF THE SEAS	15	9.1			
STAR PRINCESS	14	8.9	√	1	7.0
AMSTERDAM	14	7.1	√	17	6.0
REGATTA	7	10.4	√	10	10.6
SILVER SHADOW	4	12.2			
CELEBRITY CENTURY	3	8.7			
ZAANDAM	3	9.0	√	1	8.0
CROWN PRINCESS	2	12.0	√	19	5.6
ISLAND PRINCESS	2	9.0			
SEVEN SEAS NAVIGATOR	2	9.0	√	4	12.2
CORAL PRINCESS	1	10.0	√	2	13.0
DISNEY WONDER	1	8.0	√	1	8.0
NORWEGIAN SUN	1	10.0	√	3	10.0
RADIANCE OF THE SEAS	1	9.0			
ZUIDERDAM	1	7.0			
	203	7.2			
2015 - did not visit in 2014					
CARNIVAL LEGEND				15	4
CELEBRITY INFINITY				3	10
CELEBRITY MILLENNIUM				1	9.0
CRYSTAL SYMPHONY				1	11.0
JEWEL OF THE SEAS				19	9.1
NOORDAM				2	12.0
PACIFIC PRINCESS				1	12.0
RUBY PRINCESS				19	5.0
STATENDAM				9	10.0
				230	7.1

The Star Princess had an unscheduled overnight stop on 5<sup>th</sup> August, 2014 and that visit is excluded from the above table.

## 6.0 COMPARISON WITH PREVIOUS YEARS

### 6.1 SO<sub>2</sub> maximum levels

		1% fuel		3.5% fuel				
		2014	2013	2012		2011	Guidelines (ppb)	
				Post Aug	Pre Aug			
Max. SO <sub>2</sub> levels (ppb)	10-min	188	98	69	243	167	WHO	191
	1-hour	131	60	51	102	90	Island Health	35
	24-hour	11	10	5	10	10	WHO	7.6

The 2014 maximum levels for the detected levels for both the 1-hour and 24-hour are the highest since the Erie St. monitors were installed in 2011.

The 2014 detected 10-minute level is the highest since the ECA 1% sulphur content fuel regulation was implemented in mid-2012.

### 6.2 SO<sub>2</sub> average levels

	2014	2013	2012		2011
			Post Aug	Pre Aug	
Average SO <sub>2</sub> (ppb)	2.6	2.7	2.6	3.6	3.8

This table displays the average levels detected at the single monitor; it does not provide any pertinent information on the actual ship emission levels; i.e., unless the wind meets specific direction and speed conditions the level recorded will be far below the actual emitted levels. The chart does, however, provide an indication of the slight improvements that have occurred since the mid-2012 1% sulphur fuel requirement and will be useful in determining the effectiveness of 2015 ECA legislation.

### 6.3 SO<sub>2</sub> counts by ppb level

	Count of 10-min SO <sub>2</sub> expressed as a % of total				
SO <sub>2</sub> level (ppb)	2014	2013	2012		2011
			Post Aug	Pre Aug	
≥0, <5	91.5%	88.4%	89.7%	85.7%	86.6%
≥5, <15	5.1%	6.3%	6.3%	9.1%	7.9%
≥15, <35	1.9%	4.0%	2.7%	3.2%	3.3%
≥35	1.5%	1.3%	1.3%	2.0%	2.2%
	100%	100%	100%	100%	100%

Comments same as above

## APPENDIX 1 – 2014 PEAKS

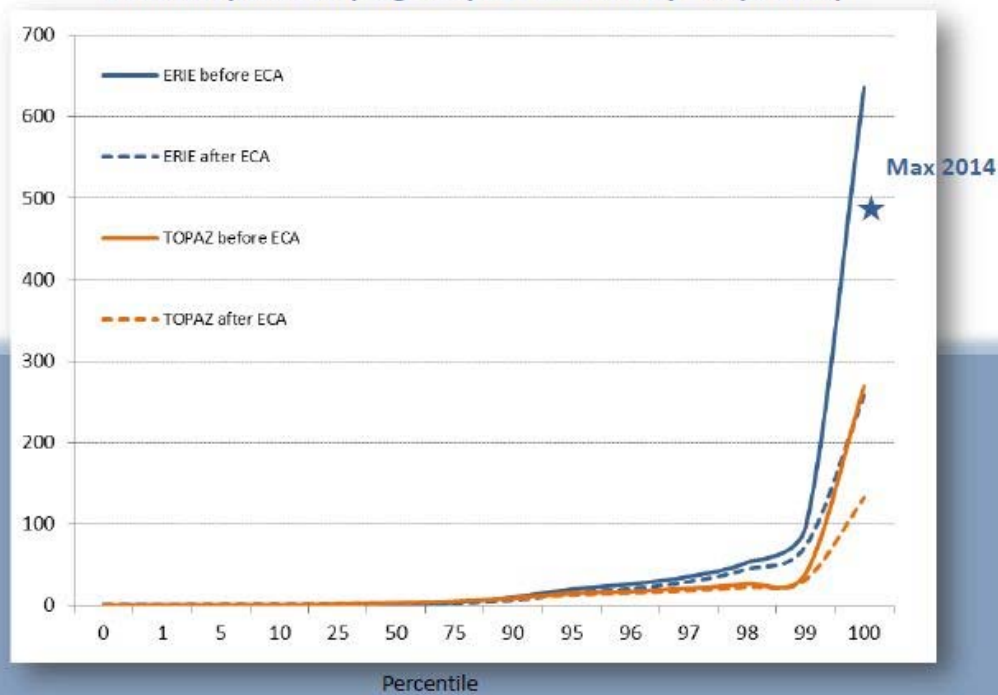
The following slides were part of a presentation to the GVHA Board meeting on 20th November, 2014 by Eleanor Setton, PhD of the University of Victoria Spacial Sciences Research Laboratory. The complete presentation is available on the environment page of the JBNA website at <http://www.jbna.org/environment.htm>.

The three slides show the 2014 peak superimposed on charts showing the 10-minute, 1-hour and 24-hour SO<sub>2</sub> levels recorded at both the Erie St. and Topaz sites both pre and post the 2012 ECA sulphur content reduction.

The 2014 peaks for both the 1-hour and 24-hour levels are higher than the pre-ECA peak levels and the 10-minute peak is at the highest level since the 1% sulphur content fuel was introduced in mid-2012.

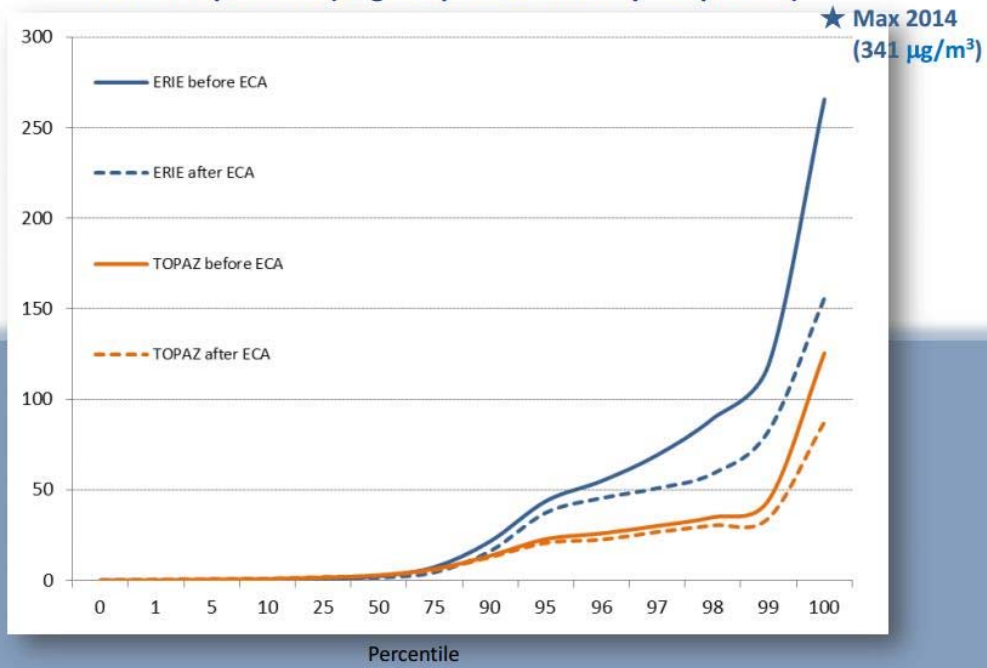
### 10 minute average when ships present: SO<sub>2</sub> (µg/m<sup>3</sup>)

8 months pre-ECA (May – Sept 2011 and May - July 2012)  
7 months post-ECA (Aug – Sept 2012 and May – Sept 2013)



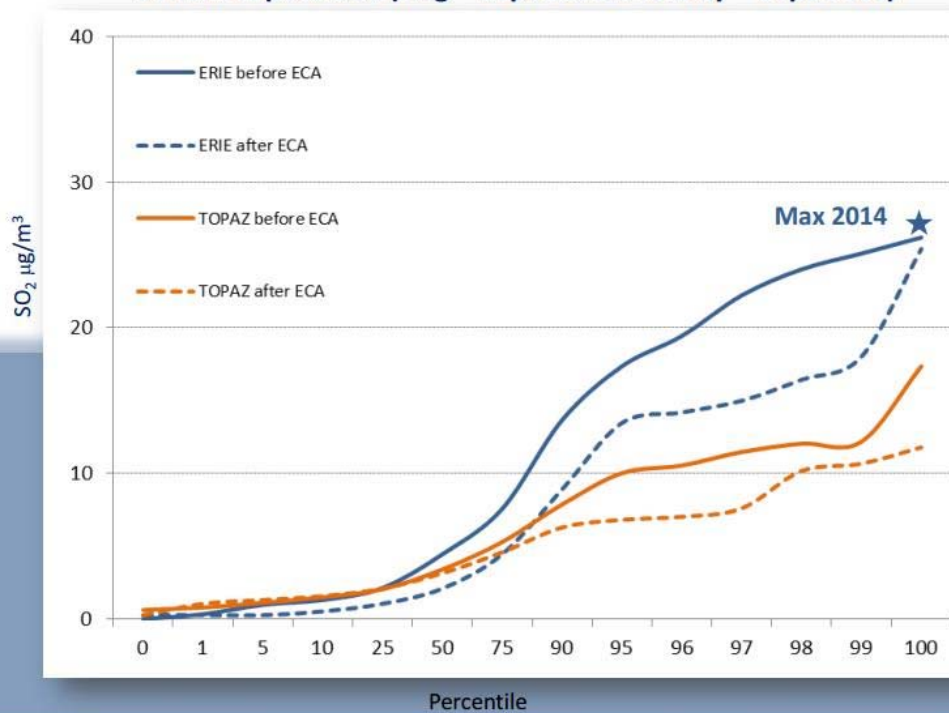
## Hourly average when ships present: SO<sub>2</sub> (µg/m<sup>3</sup>)

8 months pre-ECA (May – Sept 2011 and May - July 2012)  
7 months post-ECA (Aug – Sept 2012 and May – Sept 2013)



## 24 hour average when ships present: SO<sub>2</sub> (µg/m<sup>3</sup>)

8 months pre-ECA (May – Sept 2011 and May - July 2012)  
7 months post-ECA (Aug – Sept 2012 and May – Sept 2013)



## APPENDIX 2 – DATA SOURCES AND REFERENCES

### A2.1 Wind speed & direction

- Obtained from the GVHA website: <http://www.victoriaharbour.org/weather.php>
- These measurements are at 10 minute intervals and are used to create hourly averages, i.e., the wind measurements used for “10 am” is the average of all the 10-minute measurements between 9 am and 10 am.
- Only data associated with wind speeds > 2m/s (3.9 knots) have been included where tables or charts display directional information. At wind speeds <2m/s eddying occurs and the measured direction may not be accurate.

### A2.2 SO<sub>2</sub> data

- Raw hourly data has been obtained from BC Ministry of Environment website <http://www.bcairquality.ca/readings/index.html>.
- A “10 am” measurement is the average of the measurements between 9 am and 10 am.
- Ten minute data has been supplied by the BC Ministry of Environment.

### A2.3 Ship arrivals and departures

- Actual ship arrival and departure times have been used in this report and were supplied by GVHA.
- For ship arrivals and departures the following are examples of the times used for linking the ship times to the hourly SO<sub>2</sub> and wind data:

Arrival	Leave	Data Link (arrival)	Data link (departure)
1:50 pm	11:59 pm	2 pm	1 am next day
6:15 pm	11:19 pm	7 pm	12 midnight

Thus, in general, all arrival times are rounded up to the next hour above and departure times are rounded to the nearest hour and then one hour is added. This ensures the correlation of ship arrival and departure emissions with the hourly SO<sub>2</sub> data (the 7 am measurement is for the 6 am to 7am period).

For the **10-minute results** – 30 minutes have been deducted from the arrival time and 30 minutes added to the departure times.

### A2.4 References

- ref 1, page 4: [www.viha.ca/mho/james\\_bay\\_sulphur\\_dioxide\\_monitoring.htm#health%20affects](http://www.viha.ca/mho/james_bay_sulphur_dioxide_monitoring.htm#health%20affects)
- ref 2, page 4: [www.statcan.gc.ca/tables-tableaux/sum-som/l01/cst01/health50b-eng.htm](http://www.statcan.gc.ca/tables-tableaux/sum-som/l01/cst01/health50b-eng.htm)
- ref 3, page 4: [www.statcan.gc.ca/tables-tableaux/sum-som/l01/cst01/health105b-eng.htm](http://www.statcan.gc.ca/tables-tableaux/sum-som/l01/cst01/health105b-eng.htm)
- ref 4, page 4: [www.epa.gov/otaq/regq/nonroad/marine/ci/420f10015.pdf](http://www.epa.gov/otaq/regq/nonroad/marine/ci/420f10015.pdf)

### APPENDIX 3 – CONFIRMATION OF ANEMOMETER REQUIRED

Differences between wind directions measured in 2014 and those of other years are apparent. These may be due to natural fluctuations but there is sufficient concern to warrant a check of the anemometer calibration. This has been requested from GVHA by the BC Ministry of Environment.

Differences include:

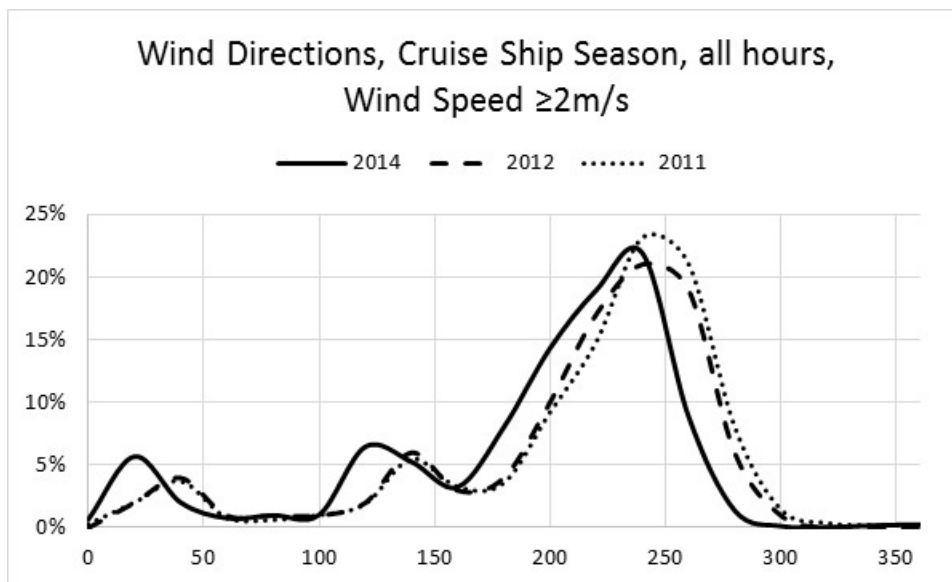
#### **A3.1 Comparison of 2012 & 2014 wind direction by sector**

The 2014 wind directions appear to have shifted one sector anti-clockwise. This year's "S" is closer to the 2012 "SSW" and this year's "W" is closer to the 2012 "WNW".

Wind direction %			
2014		2012	
S	12%	SSW	15%
SSW	19%	SW	25%
SW	23%	WSW	23%
WSW	19%	W	11%
W	4%	WNW	2%
WNW	0%	NW	0%
NW	0%	NNW	0%
NNW	0%	N	0%
N	0%	NNE	2%
NNE	3%	NE	2%
NE	2%	ENE	1%
ENE	1%	E	1%
E	1%	ESE	2%
ESE	5%	SE	6%
SE	7%	SSE	4%
SSE	4%	S	6%

### A3.2 Wind directions by degrees – 2011, 2012 & 2014

The peaks and troughs for 2014 are shifted to the left compared to 2011 & 2012



### A3.3 Other differences noted within the report

- The “wind direction by month” table in section 4.1.1 shows an unusual wind distribution for September.
- The peak  $\text{SO}_2$  is shown to occur with a wind direction of  $200^\circ$  (section 4.3.1). This is unexpected since the monitor is located between  $207^\circ$  and  $227^\circ$  depending on which pier is in use. In previous years the direction associated with the peak  $\text{SO}_2$  level has more directly corresponded with the monitor location.

#### APPENDIX 4 – REVISION LIST

Date	Section	Description
January 18, 2014	-	Report first issued