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SUMMARY <p>The Marine Icing Monitoring System (MIMS) is a system used to collect image data to monitor ice accumulation on offshore rigs and vessels. MIMS collected from two vessels, the Marine Atlantic ferry Caribou and Petro-Canada's Atlantic Kingfisher. This report describes how the image data was analyzed for icing events. It also describes the documentation of these events as well as a description and analysis concerning ice accumulation measurements. From these measurements, graphs were created, indicating the ice growth on various parts of the vessel.</p>				
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**MARINE ICING EVENTS AN ANALYSIS OF IMAGES
COLLECTED FROM THE MARINE ICING MONITORING
SYSTEM (MIMS)**

SR-2007-07

Leah Gibling

April 2007

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Marine Icing Events

An Analysis of Images Collected from the Marine Icing Monitoring System (MIMS)

Marine Icing Monitoring System (MIMS) Background

The Marine Icing Monitoring System (MIMS) is a system used to collect image data to monitor ice accumulation on offshore rigs and vessels. By using this technology to monitor ice build up, one can monitor situations where ice accumulation could cause operation problems or safety hazards.

MIMS consists of two cameras. One camera is set up on the port side of the vessel while the other is set up on the starboard side, both facing the bow. A computer controls the cameras and is programmed so that each camera takes a picture every twelve minutes. The cameras do not capture images at the same time, but instead one camera's picture capture time is offset by 6 minutes from that of the other camera. This results in alternating images from the port and starboard side every six minutes.

Once a picture is taken, it is automatically downloaded to the computer's hard drive. Data can later be retrieved from the hard drive when the vessel is in port. The system also possesses a satellite phone. With the satellite phone, MIMS can be controlled from IOT. This allows one to control the cameras, as well as download thumbnail images. MIMS is a weatherproofed system designed to withstand the marine environmental conditions of Canada's east coast.

MIMS has been employed on two vessels, the Marine Atlantic's ferry Caribou and Petro-Canada's Atlantic Kingfisher. Its employment on the Caribou allowed the researchers to gain an understanding of how the system would perform in a marine environment. The deployment also presented an opportunity to debug problems in the system and improve MIMS's overall performance. The necessary improvements were made before MIMS was employed on the Atlantic Kingfisher. The Atlantic Kingfisher is a vessel that operates in the oil industry, the industry at which MIMS technology was designed for.

Analysis of MIMS Images and Documenting Procedures

MIMS data was collected on the Caribou from November 30, 2004 to May 5, 2005, and on the Atlantic Kingfisher from December 22, 2006 to February 26, 2007. The data was analyzed picture by picture in order to detect potential icing events.

Marine icing can be caused by various events such as wave induced deck spray, water sloshing on the deck, and wetted snow. During the initial review of the data, each image was individually checked for a number of items that would indicate a potential icing event. These items included looking for water droplets, snow, or ice on the camera window, visible water sloshing around the deck, wet snow on the deck, as well as ice visible on the deck, rail, poles, or ropes of the vessel. Incidences of such events can be seen in Figures 1a to 1e.



Figure 1a. Wave induced deck spray



Figure 1b. Water on the deck



Figure 1c. Wet snow on deck



Figure 1d. Partial camera coverage



Figure 1e. Ice on the vessel

Once one of the above events was identified, it was documented in MIMS observation table. To properly document each event, details concerning the date and time of the event, the event type, a description of the event, the condition of the camera, and key images were recorded.

The tables of MIMS observations for each vessel can be viewed in immediately following the conclusion.

Observations From Analysis of MIMS Images

After analyzing the images from both the Caribou and the Atlantic Kingfisher, some differences between the two sets of data were noticed.

From the Caribou, the night images were very dark, but with editing done through Microsoft Office Picture Manager, features on the vessel were distinguishable. However, it was difficult to determine whether or not there was any ice or water on the vessel. Although it was difficult to detect ice and water on the vessel, it was fairly easy to indicate whether the camera was covered by ice. During the night one of the portholes on the vessel was illuminated. When the lighted porthole in the images became blurry, or disappeared completely, it was in indication that there was water or ice on the camera. Unfortunately, with the Atlantic Kingfisher data the night images were not clear. The vessel's features were indistinguishable, and the majority of the images were completely black. Editing the images did not improve their condition.

The Atlantic Kingfisher data possessed more images with water droplets on the camera than the Caribou data. The Caribou however, had more incidents of the cameras being covered with ice. Frequently, the period of time that there was ice coverage on the Caribou cameras was longer than the period of ice coverage on the Atlantic Kingfisher cameras. Also, the ice covered the entire camera window on the Caribou, where on the Atlantic Kingfisher it was also only partial coverage.

Some of the images in the Atlantic Kingfisher data were blank, either nearly all white, or black. These blank images occurred both at night, and during the day. The reason why these blank images occurred is unknown.

Ice Accumulation Measurements

After all of the MIMS images were reviewed and the icing events documented, information concerning the amount and rate of ice accumulation on the vessel was desired.

While MIMS was employed on the Caribou, the cameras were consistently covered with ice during major icing events. This made it impossible to track the growth of ice on the vessel, thus no measurement of ice accumulation on the Caribou could be performed. As a result, more effective heaters were installed before MIMS was deployed on the Atlantic

Kingfisher. With new heated compartments for the cameras, there was considerably less ice on the cameras, and ice growth could be detected and the ice accumulation could be measured.

To gain an understanding of the rate of ice build up on the Atlantic Kingfisher, various parts of the vessel including rails, ropes, and poles were selected. The points of selected interest on the vessel are shown in Figure 2. The thickness of these points was measured through the duration of major icing events.

For the icing events on December 29, 2006, and January 15, 2007 pictures were selected that were taken approximately thirty minutes apart. Measurements were taken for each consecutive image in precisely the same location.



Figure 2. Points selected for measurement of ice thickness

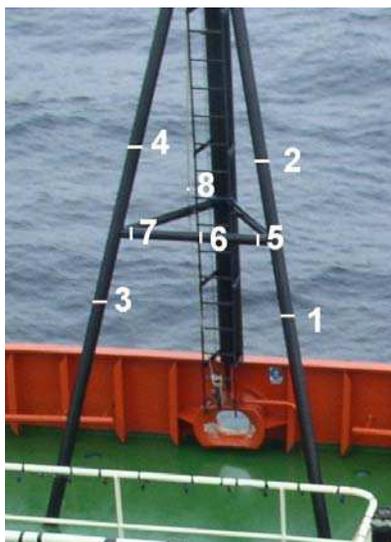


Figure 3. Larger image of points selected on the black structure

To perform measurements, a computer program was required that showed each individual pixel in the image, and displayed the pixels' coordinates in the image. Paint was found to be a simple and effective program that met these requirements. The measurements were taken manually. The measurer used her own interpretation of where the ice began and ended for each of the numbered points (as seen in Figure 2) on the vessel. The ice was measured in units of pixel length because the MIMS images gave no indication as to what an actual length would be in standard units of measurement.

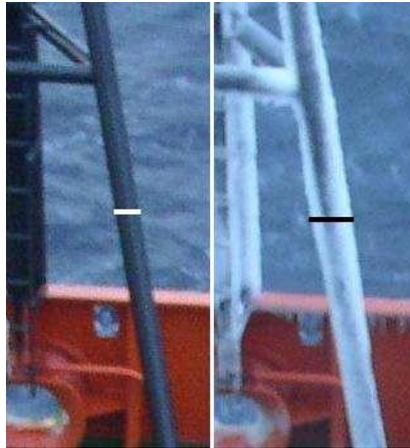


Figure 4. Measurements of Point 1 before and during an icing event

Once a measurement was taken, it was entered into a Microsoft Excel spreadsheet. The original length, before the icing event was also measured for each point. The original length was then divided into each icing event measurement, and the quotient was then documented in a different spreadsheet. The second spreadsheet represented the fractional growth of each point. Each quotient indicated how many times larger the ice-covered structure was compared to the original length (which had a fractional value of 1). The fractional growth values were then displayed in a linear graph that showed the fractional growth over time.

MIMS has two cameras, each on an opposing side of the vessel. Each camera gives a different perspective of the vessel in its images. Because of this, the ice accumulation for each event was documented twice, once using only port camera images, and once using only starboard camera images.

Observations from Ice Accumulation Measurements

Certain areas on the vessel experienced greater ice accumulation than others. The area labelled point 8, which was located on a rope in Figure 3 experienced a significantly larger fractional growth than all other points of measurements. The rope was the only object selected for measurements that was not made of metal. This could indicate why it had a larger fractional growth. The two points that experienced the second and third highest fractional growth were points 5 and 7. These points were located on the black structure at the front of the bow, at each end of the horizontal pole. Significant ice build

up here could have been caused by water running off the vertical poles, pooling, and freezing on the ends of the horizontal bar. The points 9, 10, and 11 (the posts along the deck of the vessel) experienced the least fractional growth.

It was also determined that the perspective of each camera gave different results concerning ice accumulation. Generally, the fractional growth in the starboard images was greater than in the port images. Despite the differences, overall the two graphs had very similar shapes.

Ice Accumulation Measurements and Meteorological Data

One final task performed with the Atlantic Kingfisher MIMS image data was to compare the ice accumulation to meteorological data. The data was recorded in the Atlantic Kingfisher's daily logbook, and provided by Petro-Canada. The logbook is updated every two hours. Information that is logged includes the position of the vessel, the daily activities performed on the vessel, and meteorological data such as wind direction and force as well as the air temperature.

Graphs concerning the change in wind speed, and air temperature were created the dates of the icing events, and compared to the graphs of ice accumulation on the vessel.

Observations of Ice Accumulation Measurements compared to Meteorological Data

For the duration of the icing events, neither the wind speed nor direction changed. Hence, it could not be determined whether or not the wind affects ice accumulation. The temperature however did fluctuate.

Graphs were made comparing the air temperature to the ice growth rate. It was observed that during periods where the temperature remained constant, the ice growth increased gradually. However when the temperature dropped, the growth rate increased more rapidly. This suggests that there is a correlation between the air temperature and the ice growth rate.

Conclusions

The deployment of MIMS on the Caribou and the Atlantic Kingfisher has provided a large amount of marine icing image data. The data contained many examples of the events that could potentially cause marine icing, as well as actual occurrences of marine icing. With this data, an understanding of where ice accumulates on the Atlantic Kingfisher and at what rate was established.

The results obtained from MIMS's first two deployments prove that the system has the ability to detect icing events, as well as monitor ice growth. These results indicate that in the future MIMS technology could be a helpful tool in monitoring icing events on marine structures.

Table 1. Summary of MIMS observations during winter of 2004/2005 deployment on Caribou ferry.

Date	Start Time (on file) GMT + 1hr	End Time	Event Type	Camera Condition	Comments	Key Image(s)
12/06/2004 Port/Starboard Cameras	3:25am	12/07/04 3:36pm	Snow on window	Windows covered by snow, possibly ice; clear by 12/07/04 at 3:36pm		
12/14/2004 Port Camera	4:48pm	8:00pm	Deck spray	Clear, with a few images showing spray on window	Spray wetting deck	6:36pm Image of water on deck
12/21/2004 Starboard Camera	12:34pm		Snow on window Snow on deck	Camera covered by snow at 12:34pm, clear again at 2:06pm	Vessel in port. Snowfall on deck, majority melted by 8:42 pm. Snow that remains becomes ice on 12/22/04. Ice melted by 12/23/04 at 5:54 pm	12/22/04 1:06pm Image of ice on deck
12/24/2004 Port/Starboard Cameras	2:42pm	8:55pm	Deck spray	Clear, with a few images showing spray on window	Spray wetting deck	5:24pm (Port Camera) 3:54pm (Starboard Camera) Spray images
12/25/2004 Starboard Camera	9:55am	12/26/04 4:19 am	Ice on window	Window ices up at 9:55 am; clear again 12/26/04 at 4:19am		
12/28/04 Starboard	12:42pm	3:18pm	Snow on window	Window partially covered with snow	Vessel in port. Snowfall on deck	

Camera						
12/29/04 Port/Starboard Cameras	3:12pm	12/30/04 7:08am	Snow on window	Window covered by snow		
12/30/2004 Starboard Camera	1:06pm		Small amount of ice on deck	Clear	Vessel in port. Snow from a previous snowfall got wet and froze. No apparent deck spray.	1:06pm Image of ice (on Starboard side of deck)
01/02/2005 Port Camera	9:49am		Ice on deck	Camera ices over at 9:49am, is clear by 12:24pm. Camera quickly ices over again at 4:36pm, clear by 5:12pm.	Ice on deck when camera clears at 12:24pm, most likely due to spray (no snow falling beforehand)	4:00pm Image of ice on deck
01/02/2005 Starboard Camera	8:19 am		Ice on window Ice on deck	Camera covered by ice at 8:19am, clear by 01/03/05 at 6:44am	Ice on deck when camera clears on 01/03/05 at 6:44am	01/03/05 6:08am Image of ice on deck
01/03/2005 Starboard Camera	9:07am	2:18pm	Snow on window	Camera covered by snow; clear by 2:18pm		
01/05/2005 Port Camera	4:24pm	9:00pm	Snow on window	Camera covered by snow; clear by 9:00pm		
01/11/2005 Port Camera	4:24pm		Deck spray Ice on window Ice on deck	Camera partially ices over at 5:00pm, fully ices over at 7:00pm	Spray wetting snow at the very front of the deck at 4:24pm. Wet snow starting to freeze	6:48pm Image of ice on deck (at the very front of the bow)

				and is clear by 9:12pm.	on deck at 5:36pm.	
01/11/2005 Starboard Camera	4:18pm		Deck spray Ice on deck	Clear, with a few images showing spray on window	Spray wetting snow at very front of deck at 4:18pm; water from spray starting to freeze on deck 5:42pm	5:30pm Image of spray, and ice forming on deck (at the very front of the bow)
01/15/2005 Port Camera	4:00pm		Deck spray Ice on deck	Camera partially ices over at 5:00pm, is clear by 6:24pm.	Spray wetting deck and ice forms around 4:00pm	6:00pm, 6:36pm Window obscured a little; Spray and ice on deck
01/15/2005 Starboard Camera	4:30pm		Deck spray Ice on deck	Camera partially ices over at 4:54pm, is clear by 5:54pm.	Spray wetting deck and ice forms around 4:30pm	6:54pm Water droplets on window; Image of ice on deck
01/16/2005 Starboard Camera	4:06pm	6:06pm	Snow on window	Snow and water droplets partially cover window		
01/18/2005 Port Camera	5:49am		Ice on window Ice on deck	Camera ices over at 5:49am, clear by 7:36pm	Ice that formed on deck is visible once camera is clear at 7:36pm	8:36pm Image of ice on deck
01/18/2005 Starboard Camera	4:55am		Ice on window Ice on deck	Camera ices over at 4:55am, clear by 1:18pm	Ice that formed on deck is visible once camera is clear at 1:18pm	4:30pm Image of ice on deck
01/22/2005 Port Camera	7:48pm	01/23/05 1:48pm	Ice on window Ice on deck	Camera partially ices over at 7:48pm, fully ices over at 8:24pm and is clear on 01/23/05 around	Ice that formed on deck is visible once camera is partially clear on 01/23/05 at 11:38am.	01/23/05 8:12pm Ice on deck

				1:48pm.		
01/22/2005 Starboard Camera	6:18pm		Ice on window	Camera partially ices over at 6:18pm, fully ices over at 6:54pm and is clear on 01/24/05 around 9:06pm.	Ice on window caused by spray	5:30pm Spray image
01/28/2005 Port Camera	6:37am		Ice on window Ice on deck	Camera ices over at 6:37am, partially clear on 01/31/05 around 11:13am; and is completely clear on 02/01/05 around 5:24pm.	Ice forms on deck over snow and ice from a previous event. Ice is visible once camera is partially clear on 01/31/05 at 11:13am. Crew clears ice off of deck: 6:36pm-11:12pm on 01/31/05, 1:32pm-8:24pm on 02/01/05, 5:48pm- 11:36pm on 02/03/05, 4:48pm-10:12pm on 02/04/05, 1:24pm- 3:12pm on 02/05/05	01/31/05 3:24pm Image of ice on deck 01/31/05 7:36pm Image of crew clearing ice
01/28/2005 Starboard Camera	6:26am		Ice on window Ice on deck	Camera ices over at 6:26am, clear on 02/03/05 around 7:11am.	Ice forms on deck over snow and ice from a previous event. Ice is visible once camera is clear on 02/03/05 at 7:11am. Crew clears ice off of	02/03/05 5:42pm Image of ice on deck 02/04/05 7:54pm Image of crew clearing ice

					deck: 9:30pm- 11:54pm on 02/03/05, 7:30pm-10:20pm on 02/04/05, 1:18pm- 3:06pm on 02/05/05	
02/06/2005 Port Camera	1:00pm	4:00pm	Ice on deck	Clear	Vessel in port. Thin layer of ice on deck, possibly from spray event	2:24pm Image of ice on deck
02/06/2005 Starboard Camera	11:30am	4:30pm	Ice on deck	Clear	Vessel in port. Thin layer of ice on deck, possibly from spray event	11:54am Image of ice on deck
02/12/2005 Starboard Camera	12:06pm	5:54pm	Ice on deck	Clear	Small amount of ice on Starboard side of deck. Formed from light snow cover that got wet. Ice melted by 5:54pm	12:06pm Image of ice on deck
02/16/2005 Port/Starboard Cameras	12:44am	4:43am	Snow on window	Window partially covered by snow (snowing at the time)	Vessel in port.	
02/18/2005 Port Camera	6:48pm		Ice on deck	Clear, with a few images showing spray on window	Spray wetting deck, then water on deck turning into ice starting at 6:48pm	9:36pm Image of ice on deck
02/18/2005 Starboard Camera	5:54pm		Deck spray Ice on deck	Clear	Spray wetting deck, then water on deck turning into ice starting at 6:42pm	7:18pm Spray image 9:18pm, 02/19/05 12:54am

						Images of ice on deck
02/25/2005 Port/Starboard Cameras	6:18pm		Snow on windows	Cameras covered by snow at 6:18am. Port camera clear at 1:48pm, Starboard camera clear on 02/26/05 at 4:43am	Vessel in port.	
02/26/2005 Port Camera	8:48pm		Deck spray Ice on deck	In some images window partially covered by spray or ice	Water on deck from spray or precipitation turning into ice starting at 8:48pm	8:48pm Spray image 9:36pm Image of ice on deck
02/26/2005 Starboard Camera	9:54pm		Deck spray Ice on deck	Window partially covered by spray or ice at 9:54pm, clear on 02/27/05 at 7:20am	Water on deck from spray or precipitation turning into ice starting at 9:06pm	8:54pm Wave/Spray image 9:30pm Image of spray and ice on deck
02/27/2005 Port Camera	4:00pm	11:01pm	Snow on Window	Window partially covered by ice between 4:00pm-4:48pm and 10:24pm-11:01pm		
02/27/2005 Starboard Camera	3:18pm	10:55pm	Snow on Window	Window partially covered by ice between 3:18pm and 10:55pm		
03/07/2005 Port/Starboard Cameras	11:30am		Snow and ice on windows	Windows initially partially covered in snow (snowing at	Vessel in port.	

				time), then completely covered by ice around 4:00pm. Starboard camera clear at 8:06pm, Port clear at 11:00pm		
03/31/2005 Port Camera	7:36am	2:00pm	Snow on window	Window covered by snow (snow falling at the time). Clear by 2:00pm	Vessel in port.	
03/31/2005 Starboard Camera	8:18am	1:54pm	Snow on window	Window covered by snow (snow falling at the time). Clear by 1:54pm	Vessel in port.	
04/14/2005 Port Camera	6:00pm	10:00pm	Deck Spray Water on deck	In some images window partially covered by water droplets	Spray wetting deck, then water sloshing on deck.	7:24pm Spray image 6:12pm, 7:00pm, 8:00pm Image of water on deck
04/14/2005 Starboard Camera	5:42pm	10:06pm	Deck Spray Water on deck and possible ice on deck	In some images window partially covered by water droplets	Possible ice formation (very small formation) on deck at 8:54pm, melted by 9:42pm	6:30pm Spray image 9:06pm Possible icing event
04/29/2005 Starboard Camera	4:30pm		Deck Spray	In some images window partially covered by water droplets	Spray wetting deck, appears to be water on the very front of the deck at 4:54pm	4:30pm, 7:18pm Spray images 4:54pm

						Image of spray and water on deck (at very front of bow)
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Table 2. Summary of MIMS observations during winter of 2006/2007 deployment on the Atlantic Kingfisher.

Date	Start Time (on file) GMT + 1hr	End Time	Event Type	Camera Condition	Comments	Key Image(s)
12/23/2006 Port Camera	11:30am	1:06pm	Spray on Window Water on Deck	Window partially covered by water droplets from 11:30am to 1:06pm.	Water on deck at 11:30am.	11:30am Image of water on deck
12/23/2006 Starboard Camera	11:36am	2:00pm	Spray on Window Water on Deck	Window partially covered by water droplets from 11:36am to 12:48pm.	Water on deck at 2:00pm.	
12/24/2006 Port Camera	4:06pm	11:43pm	Spray on Window	Window partially covered by water droplets.		
12/24/2006 Starboard Camera	4:00pm	10:00pm	Spray on Window	Window partially covered by water droplets.		
12/25/2006 Port Camera	2:06pm	11:43pm	Spray on Window	Window partially covered by water droplets from 2:06pm to 3:42pm and 8:07pm to 11:43pm		
12/25/2006 Starboard Camera	2:00pm	9:48pm	Spray on Window	Window partially covered by water droplets from 2:00pm to 4:12pm		

				and 8:01pm to 9:48pm		
12/26/2006 Port Camera	11:30am	6:06pm	Water on Deck	Clear	Water on deck at 11:30am, 5:42pm to 6:06pm	
12/26/2006 Starboard Camera	11:12am	5:12pm	Water on Deck	Clear	Water on deck 11:12am to 11:48am, 2:48pm, 3:24pm, 4:36pm to 5:12pm	11:24am Wave/Spray Image
12/27/2006 Port Camera	10:31am	5:30pm	Spray on Window	Window partially covered by water droplets.		
12/27/2006 Starboard Camera	10:37am	5:36pm	Spray on Window	Window partially covered by water droplets from 10:37am to 12:12pm, 1:00pm to 5:36pm		
12/29/2006 Port Camera	10:31am		Spray on Window Ice on deck Water on Deck	Clear, few images with window partially covered with water droplets from 11:06am to 12:18pm, 6:18pm to 7:30pm	Ice visible upper deck at 10:31am. Water on deck 10:54am to 1:30pm, 2:18pm to 6:06pm. Deck water begins to push deck ice around at 12:54pm. Ice begins to form on poles, rails at 10:31am. Crew clear deck ice on 12/30/07 from 11:42pm to 1:06pm	11:30am Water on Deck 1:06pm Spray Image 7:18pm Ice on Vessel

12/29/2006 Starboard Camera	11:00am		Spray on Window Ice on deck Water on Deck	Window partially covered by water droplets from 11:12am to 8:00pm	Water on deck 11:00am, 11:36am to 12:36pm, 2:12pm to 3:12pm, 4:12pm. Deck water begins to freeze at 11:24am. Ice begins to form on poles, rails at 11:48am Crew clear deck ice on 12/30/07 at 11:48am	5:48pm Spray Image 6:00pm Ice on Vessel
12/30/2006 Port Camera	10:18am	2:18pm	Ice in Window	Ice partially covers window.		
12/30/2006 Starboard Camera	11:01am	4:48pm	Ice in Window	Ice partially covers window.		
01/02/2007 Port Camera	6:18pm	01/03/07 10:18am	Precipitation on Window	Window partially covered by water droplets	Vessel in Port	
01/02/2007 Starboard Camera	9:49pm	01/03/07 10:48am	Precipitation on Window	Window partially covered by water droplets	Vessel in Port	
01/03/2007 Port Camera	12:06pm	01/04/07 3:30pm	Ice on Deck	Clear	Vessel in Port Water from 01/02/07 precipitation freezes on deck Melted by 3:30pm 01/04/07	7:30pm Ice on deck
01/03/2007 Starboard Camera	1:00pm	01/04/07 1:00pm	Ice on Deck	Clear	Vessel in Port Water from 01/02/07 precipitation freezes on deck. Melted by 1:00pm	1:00pm Ice on Deck

					01/04/07	
01/05/2007 Port Camera	7:30pm	11:30pm	Spray on Window	Window partially covered by water droplets		
01/05/2007 Starboard Camera	7:37pm	11:13pm	Spray on Window	Window partially covered by water droplets		
01/06/2007 Port Camera	11:18am	7:42pm	Spray on Window Water on deck	Window partially covered by water droplets from 11:18am to 12:42pm	Water on deck from 12:18pm to 7:42pm	
01/06/2007 Starboard Camera	10:37am	12:24pm	Spray on Window	Window partially covered by water droplets		
01/07/2007 Port Camera	10:42am	7:54pm	Spray on Window Water on deck	Window partially covered by water droplets from 10:42am to 6:06pm	Water on deck at 11:18am, 12:18pm to 2:54pm, 4:30pm, 5:18pm to 7:54pm	1:42pm Water on Deck 4:18pm Wave/Spray Image
01/07/2007 Starboard Camera	10:25am	7:48pm	Spray on Window Water on deck	Window partially covered by water droplets from 10:25am to 5:36pm	Water on deck at 12:00pm, 1:12pm, 6:24pm, 7:48pm	3:24pm Spray Image 6:24pm Water on Deck
01/08/2007 Port Camera	11:60am	7:30pm	Spray on Window Water on deck	Window partially covered by water droplets from 4:54pm to 5:42pm	Water on deck from 11:06am to 7:30pm	
01/09/2007	9:43am	8:30pm	Spray on	Window partially	Water on deck from	

Port Camera			Window Water on deck	covered by water droplets from 9:43am to 8:30pm	11:18am to 1:30pm	
01/09/2007 Starboard Camera	9:48am	8:24pm	Spray on Window	Window partially covered by water droplets		
01/10/2007 Port Camera	2:30pm	01/11/07 12:42am	Spray on Window Water on deck	Window partially covered by water droplets from 2:30pm to 4:06pm, 11:18pm to 12:42am 01/11/07	Water on deck from 2:30pm to 3:18pm, 5:54pm to 6:30pm	
01/10/2007 Starboard Camera	2:24pm	01/11/07 12:37am	Spray on Window Water on deck	Window partially covered by water droplets from 2:24pm to 3:48pm, 11:13pm to 12:37am 01/11/07	Water on deck from 2:24pm to 2:36pm	
01/11/2007 Port Camera	11:18am	3:54pm	Spray on Window Water on deck	Window partially covered by water droplets from 11:18am to 12:54pm, 2:30pm to 3:54pm	Water on deck at 12:54pm, 2:18pm	
01/11/2007 Starboard Camera	7:37am	3:00pm	Spray on Window	Window partially covered by water droplets from 7:37am to 8:00am, 10:25am to 3:00pm		
01/13/2007 Port Camera	9:30am	6:42pm	Spray on Window	Window partially covered by water	Water on deck from 4:30pm to 4:42pm	

			Water on deck	droplets from 9:30am to 6:42pm		
01/13/2007 Starboard Camera	10:37am	6:24pm	Spray on Window	Window partially covered by water droplets		
01/14/2007 Port Camera	8:19am	11:42am	Spray on Window	Window partially covered by water droplets from 8:19am to 9:07am, 10:42am to 11:42am		
01/14/2007 Starboard Camera	7:49am	10:48am	Spray on Window	Window partially covered by water droplets		
01/15/2007 Port Camera	11:42am		Spray on Window Ice on window Water on deck Ice on Deck	Window partially covered by water droplets from 11:42am to 12:18pm, 1:18pm to 2:06pm, 3:18pm to 8:18pm. Camera partially covered with ice from 11:23am to 11:30am.	Water on deck from 3:30pm to 7:54pm. Deck water begins to freeze at 5:42pm. Ice begins to build up on rope, poles, rails at 5:42pm. Crews clear ice on 01/18/07 at 11:54am, and from 7:06pm to 8:06pm	5:30pm Spray Image 8:18pm Ice on Vessel 11:54pm 01/18/07 Crews clearing Ice
01/15/2007 Starboard Camera	12:12pm		Spray on Window Ice on window	Window partially covered by water droplets from 1:12pm to 4:12pm. Camera partially	Water on deck from 12:12pm to 5:36pm. Deck water begins to freeze at 5:36pm. Ice begins to build up on	4:12pm Water on Deck 5:00pm Spray Image

			Water on deck Ice on Deck	covered with ice from 7:36pm to 8:36pm	rope, poles, rails at 5:24pm. Crews clear ice on 01/18/07 from 6:12pm to 7:13pm.	7:24pm Ice on Vessel
01/16/2007 Port Camera	5:06pm	7:06pm	Snow on window	Window partially covered by snow		
01/16/2007 Starboard Camera	5:12pm	5:48pm	Snow on window	Window partially covered by snow		
01/20/2007 Port Camera	5:06pm	01/21/07 7:54pm	Spray on Window	Window partially covered by water droplets from 5:06pm to 5:30pm, 6:42pm to 7:54pm 01/21/07.		
01/20/2007 Starboard Camera	6:36pm	01/21/07 7:01am	Spray on Window	Window partially covered by water droplets from 6:36pm to 9:48pm, 10:49pm to 7:01am 01/21/07.		
01/21/2007 Starboard Camera	8:25am	01/22/07 10:37am	Spray on Window	Window partially covered by water droplets from 8:25am to 12:36pm, 1:36pm to 7:12pm, 11:37pm to 10:37am 01/22/07.		
01/22/2007	12:00pm	2:12pm	Water on deck	Clear	Water on deck at	

Starboard Camera					12:00pm, and 2:00pm to 2:12pm	
01/23/2007 Port Camera	5:07am	6:31am	Spray on Window	Window partially covered by water droplets		
01/24/2007 Port Camera	8:30am	6:42pm	Spray on Window Water on deck	Window partially covered by water droplets from 8:30am to 6:42pm	Water on deck from 3:18pm to 5:30pm	
01/24/2007 Starboard Camera	10:00am	7:24pm	Spray on Window Water on deck	Window partially covered by water droplets from 10:00 am to 7:24pm	Water on deck at 11:48am and from 12:48pm to 3:24pm	2:36pm Water on deck
01/25/2007 Port Camera	6:06am	8:18pm	Spray on Window Water on deck	Window partially covered by water droplets from 6:06am to 8:18pm	Water on deck at 11:06am and from 11:42am to 6:42pm	11:06am Water on deck 8:30pm Spray Image
01/25/2007 Starboard Camera	3:49am	8:14pm	Spray on Window Water on deck	Window partially covered by water droplets from 3:49am to 10:25am, 12:36pm to 1:36pm, 2:36pm to 8:14pm	Water on deck at 10:48am	3:24pm Wave/Spray Image
01/27/2007 Port Camera	1:18pm	10:54pm	Precipitation on Window	Window partially covered by water droplets from 1:18pm to 10:54pm. Snow falling at the time.	Vessel in Port at 12:30pm	11:54am Spray Image

01/27/2007 Starboard Camera	6:48pm	11:31pm	Precipitation on Window	Window partially covered by water droplets from 6:48pm to 11:31pm. Some images blank in this time period.	Vessel in Port at 12:36pm	
01/28/2007 Port Camera	10:54am		Ice on Deck	Clear	Vessel in Port Ice most likely frozen melt from previous day's snowfall	12:06pm Ice on Deck
01/30/2007 Starboard Camera	5:13am	6:24am	Precipitation on Window	Window partially covered by water droplets	Vessel in Port	
01/31/2007 Port Camera	4:30pm		Ice on Deck	Clear	Spray wetting snow on top deck, wet snow freezes. Ice melted by 02/02/07 at 7:54am.	7:54pm Ice on Deck
01/31/2007 Starboard Camera	3:49am	4:48am	Snow on Window	Window partially covered by snow at 3:49am, 4:24am, 4:48am	Vessel in Port until 5:48am. Snowing during the time period.	
02/01/2007 Port Camera	3:34am	02/02/07 9:42am	Ice on Window	Window fully covered by ice from 3:34am to 5:31am, 6:19am to 4:42pm. Window fully clear at 9:42am 02/02/07.		
02/01/2007 Starboard Camera	8:49am	02/02/07	Ice on Window	Window fully covered by ice from 8:49am to 4:48pm.		

				Becomes clear in the period of 4:24am 02/02/07 to 9:48am 02/02/07.		
02/02/2007 Port Camera	10:42am	12:06pm	Ice/Snow on Window	Window partially covered by ice and snow		
02/02/2007 Starboard Camera	11:24am	11:36am	Ice/Snow on Window	Window partially covered by ice and snow		
02/03/2007 Port Camera	3:55am	02/04/07 12:07am	Spray on Window Water on deck	Window partially covered by water droplets from 3:55am to 12:07am 02/04/07	Water on deck from 10:54am to 11:54am, 1:18pm to 3:30pm, and 6:18pm	1:54pm Wave/Spray Image 2:18pm Water on Deck
02/03/2007 Starboard Camera	6:12am	02/04/07 12:01am	Spray on Window Water on deck	Window partially covered by water droplets from 6:12am to 10:13am, 10:48am to 12:01am 02/04/07	Water on deck from 11:36am to 12:24pm, 1:12pm to 7:36pm	12:00pm Water on Deck 2:48pm Wave/Spray Image
02/04/2007 Port Camera	1:47pm	7:30pm	Water on deck	Clear	Water on deck at 1:47pm, 2:52pm, 3:30pm, 4:06pm, 7:30pm	2:30pm Wave/Spray Image
02/04/2007 Starboard Camera	10:12am	8:00pm	Spray on Window Water on deck	Window partially covered by water droplets from 10:12am to 10:36am	Water on deck from 2:48pm to 3:24pm, 4:36pm, 5:12pm to 8:00pm	5:12pm Water on Deck
02/05/2007	10:07am	9:5pm	Spray and	Window partially	Snow falling onto deck at	11:42am

Port Camera			Precipitation on Window Water on deck Ice on deck	covered by water droplets from 10:07am to 11:54am. Window partially covered by snow and water droplets from 5:54pm to 10:07pm. Window fully covered by snow from 9:31pm to 9:55pm	10:30am. Snow wetted at 11:30 and appears to freeze. Melted by 2:54pm. Water on deck from 3:06pm to 3:42pm.	Wetted snow on deck
02/05/2007 Starboard Camera	10:48am	7:12pm	Spray on Window	Window partially covered by water droplets from 10:48am to 12:36pm (some images black in this time period), 6:00pm to 7:12pm		
02/06/2007 Port Camera	12:54am	02/07/07 5:06am	Spray and Snow on Window Ice on deck	Window partially covered by water droplets from 12:54am to 3:07am, 9:07pm to 5:06am 02/07/07. Window covered by snow from 4:43am to 5:19am, 12:06pm to 1:18pm, 1:42pm to 2:18pm, 2:54pm to	Snowfall in early morning becomes wet and freezes. Ice on deck visible at 10:07am. Melted from bottom deck before 2:30pm. Water on deck from 7:06pm to 7:42pm Water on deck freezes at	11:42am Ice on deck (from wetted snow) 8:42pm Ice on Deck (from frozen water that was on the deck)

				3:30pm, 4:18pm to 6:54pm	8:06pm	
02/06/2007 Starboard Camera	4:36am	02/07/07 1:36am	Spray, Snow, and Ice on Window Ice on deck	Window partially covered by snow from 4:36am to 10:12am (some images black in this time period). Window covered by ice from 12:00pm to 3:12pm, 4:12pm to 8:00pm. Window partially covered by snow and water droplets from 10:36pm to 1:36am 02/07/07	Snowfall in early morning becomes wet and freezes. Ice on deck visible at 10:48am. Melted around 8:24pm.	10:48am Ice on Deck
02/07/2007 Port Camera	7:18am		Ice on Window Ice on deck Ice on Vessel	Window partially covered by ice from 7:18am to 8:30am, 9:43am to 11:54am, 6:54pm to 7:42pm, 8:18pm to 8:56pm	Ice on deck, rope, poles, visible at 11:06am. Water on deck from 10:42am to 8:00pm. Water on deck pushing ice on deck around from 12:42pm to 1:06pm.	12:42pm Ice on vessel, water on deck
02/07/2007 Starboard Camera	7:48am		Spray and ice on Window Ice on deck	Window partially covered by ice from 7:48am to 8:12am. Window	Ice on deck, rope, poles visible at 10:24am.	1:00pm 02/08/07 Ice on Vessel

			Ice on Vessel	partially covered by water droplets at 10:13am, 11:24am, and from 5:48pm to 7:24pm		
02/08/2007 Port Camera	6:42am	7:54pm	Spray on Window Water on deck	Window partially covered by water droplets from 6:42am to 7:54am	Water on deck. Pushing ice around from 2:30pm to 5:06pm.	
02/09/2007 Port Camera	1:18pm	02/10/07 12:19am	Snow on window	Window partially covered by snow from 1:18pm to 5:06pm, 11:07pm to 12:19am 02/10/07		
02/09/2007 Starboard Camera	1:24pm	~6:00pm	Ice on window	Window partially covered by ice		
02/10/2007 Port Camera	1:31am	10:55pm	Spray and Snow on Window	Window partially covered by snow from 1:31am to 4:31am. Window partially covered by ice and water droplets from 8:42pm to 10:55pm		
02/11/2007 Port Camera	12:19am	02/12/07 5:06am	Snow on window	Window partially covered by snow from 12:19am to 12:54am, 12:06pm		

				to 12:42pm, 8:55pm to 5:06am 02/12/07		
02/12/2007 Port Camera	4:43am		Ice on Window Ice on deck Ice on Vessel Water on deck	Window partially covered by ice and water droplets from 9:55am to 6:18pm.	Ice starting to build up on poles at 4:43am. Ice on deck, poles, rails, ropes, becomes visible at 10:30am. Water on deck, pushing ice around from 10:42am to 2:18pm. Some water on deck freezes at 2:30pm. Crews clear some ice at 4:30pm.	1:54pm Spray Image 3:42pm Ice on vessel, deck water frozen 4:30pm Crews clearing Ice
02/12/2007 Starboard Camera	10:24am		Ice on Window Ice on deck Ice on Vessel	Window partially covered by ice from 10:24am to 3:24pm	Ice on deck, poles, rails, ropes, becomes visible at 10:36am. Crews clear some ice from 4:24pm to 4:36pm. Ice fully melted on 02/16/07 at 10:24am	2:48pm Ice on Vessel 4:36pm Crews clearing Ice
02/14/2007 Port Camera	1:06pm	8:18pm	Water on deck	Clear	Water on deck, pushing ice around upper deck from 1:06pm to 8:18pm	4:42pm, 7:42pm Water on deck 7:30pm Wave/Spray Image
02/14/2007	2:24pm	8:12pm	Water on deck	Clear	Water on deck, pushing	4:00pm

Starboard Camera					ice around from 2:24pm to 8:12pm	
02/15/2007 Port Camera	11:06pm	02/16/07 12:31am	Spray on Window	Window partially covered by water droplets		
02/16/2007 Port Camera	10:31pm	02/17/07 1:19am	Snow on window	Window partially covered by snow		
02/16/2007 Starboard Camera	11:36pm	11:49pm	Snow on window	Window partially covered by snow		
02/17/2007 Port Camera	10:54am	4:18pm	Spray and Precipitation on Window	Window partially covered by snow and water droplets from 10:54am to 12:18pm, 3:18pm to 4:18pm		
02/17/2007 Starboard Camera	12:00pm		Spray and Precipitation on Window Water on deck Ice on deck	Window partially covered by snow and water droplets from 12:00pm to 12:24pm	Water on deck wetting snow from morning's snowfall. Pushing snow around lower deck from 4:00pm to 6:12pm. Wet snow freezing on upper deck at 1:37pm	4:12pm Ice on upper deck, wet snow on lower deck
02/18/2007 Port Camera	12:07am		Spray and Ice on Window Ice on deck Ice on Vessel	Window partially covered by water droplets from 12:07am to 3:32am, 4:55am to 7:55am, 5:54pm to 8:30pm. Window partially covered by ice	Ice starting to build up on poles at 5:19am. Water on deck at 12:18pm, 1:18pm, 2:06pm to 4:48 pm, 7:18pm to 8:06pm.	3:18pm, 4:06pm Spray Image 7:30pm Ice on Vessel

				from 8:06am to 5:42pm	Crews clear some ice from 7:42pm to 7:54pm. Ice fully melted on 02/19/07 at 7:06pm.	
02/18/2007 Starboard Camera	6:36am		Ice on Window Ice on deck Ice on Vessel	Window partially covered by ice from 6:36am to 8:00am, 10:12am to 8:36pm	Ice on deck, poles, rails, ropes, becomes visible at 11:36am. Crews clear some ice from 7:36pm to 8:24pm. Ice fully melted on 02/19/07 at 7:36pm.	1:48pm Spray Image, Window partially covered by Ice 6:36pm Ice on Vessel
02/19/2007 Port Camera	9:42am	9:55pm	Spray and Precipitation on Window	Window fully covered by snow/ice from 9:42am to 11:42am, partially covered from 11:54am to 12:06pm. Window partially covered by water droplets from 12:18pm to 9:55pm.	Water on deck, pushing ice around from 12:18pm to 8:18pm.	
02/19/2007 Starboard Camera	10:24am	9:00pm	Spray and Precipitation on Window	Window fully covered by snow/ice from 10:24am to 11:24am, partially covered from 11:36am to 12:12pm. Window		

				partially covered by water droplets from 12:24pm to 9:00pm.		
02/20/2007 Port Camera	9:43am	9:19pm	Spray and Ice on Window Water on deck	Window partially covered by water droplets from 9:43am to 11:30am, 1:30pm to 3:18pm, 6:06pm to 9:19pm. Window fully covered by ice from 3:30pm to 5:54pm.	Water on deck from 10:06am to 12:54pm, 2:06pm to 3:54pm, 4:42pm, 7:30pm to 8:54pm	10:06am Water on Deck
02/20/2007 Starboard Camera	6:25am	9:01pm	Spray and Ice on Window Water on deck	Window partially covered by water droplets from 6:25am to 7:25am, 9:49am to 3:12pm, 6:00pm to 9:01pm. Window fully covered by ice from 3:24pm to 5:48pm	Water on deck from 10:01am to 11:12am, 1:00pm, 4:48pm, 6:00pm, 7:12pm to 8:48pm	9:49am Spray Image
02/21/2007 Port Camera	1:19am	6:42pm	Spray on Window Ice on deck Water on deck	Window partially covered by water droplets from 1:19am to 7:18am, 11:06am to 12:42pm, 3:54pm to 4:06pm.	Ice on deck visible at 10:38am. Melted by 12:42pm. Water on deck from 11:18am to 1:06pm, 2:18pm to 2:42pm, 5:30pm, 6:30pm, 6:42pm	10:42am Ice on deck 11:06am Wave/Spray Image

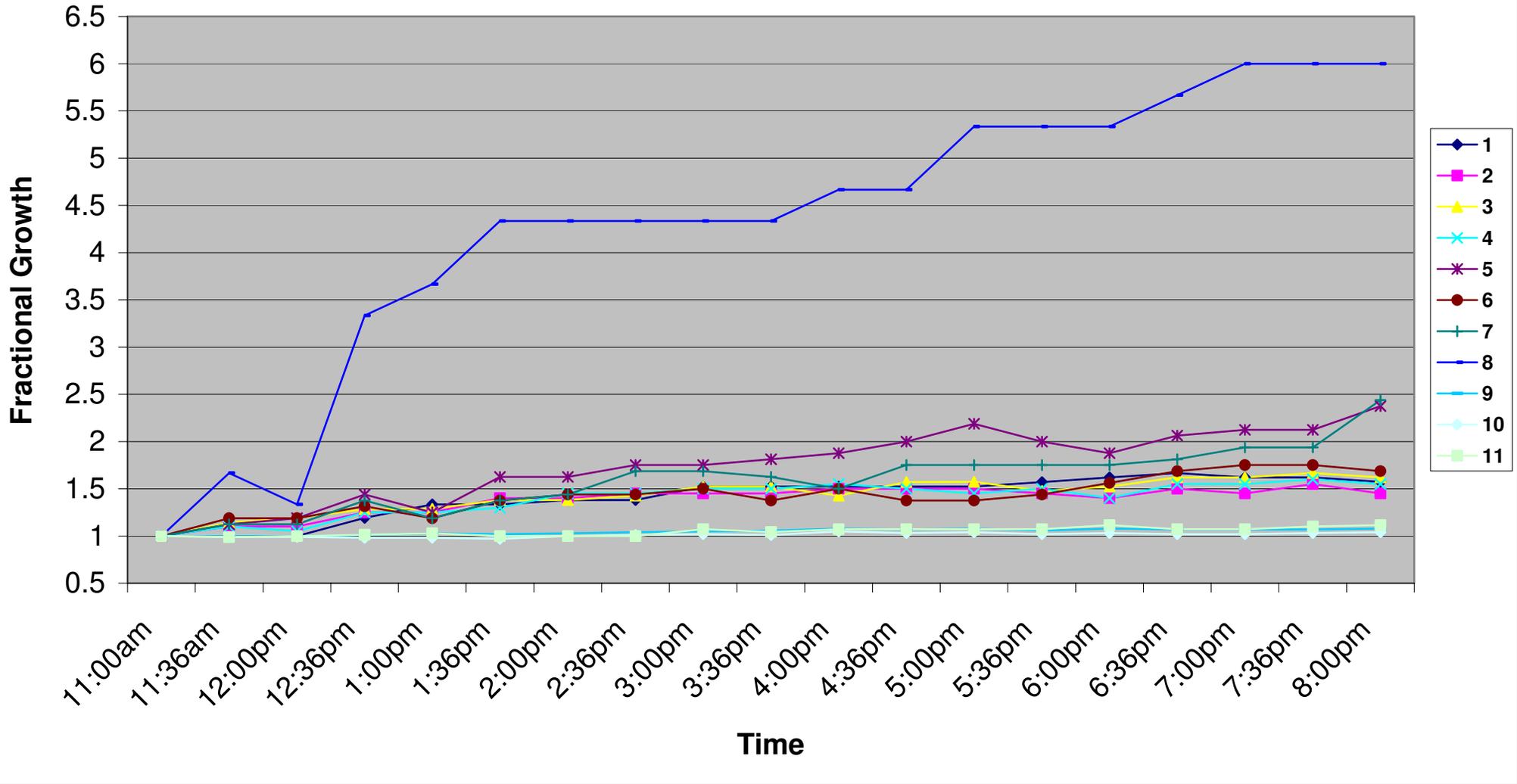
02/21/2007 Starboard Camera	1:13am	3:12pm	Spray on Window Ice on deck Water on deck	Window partially covered by water droplets from 1:13am to 2:48am, 3:39am to 6:24am, 10:38am to 1:24pm, 2:12pm to 2:36pm.	Ice on deck visible at 10:38am. Melted by 1:24pm. Water on deck from 11:12am to 11:48am, 12:24pm, 12:48pm, 2:12pm, 3:12pm	10:48am Ice on deck
02/22/2007 Port Camera	12:06pm		Spray on Window Water on deck Ice on deck	Window partially covered by water droplets from 12:06pm to 7:54pm.	Water on deck at 12:54pm. Water begins to freeze at 1:18pm.	6:54pm Ice on deck
02/22/2007 Starboard Camera	12:00pm	5:48pm	Spray and Ice on Window	Window partially covered by water droplets from 12:00pm to 3:12pm, 5:24pm to 5:48pm. Window partially covered by ice from 3:48pm to 4:36pm.		
02/23/2007 Port Camera	2:42pm		Water on deck Ice on deck	Clear	Water on deck, pushing ice around from 2:42pm to 3:54pm. Water begins to freeze at 7:18pm.	8:18pm Ice on deck
02/23/2007 Starboard	3:12pm	3:24pm	Ice on Window	Top left corner of window partially		

Camera				covered by ice.		
02/24/2007 Port Camera	9:55am	2:54pm	Precipitation on Window Ice on deck	Window partially covered by water droplets from 8:54pm to 02/25/07 at 12:54am.	Snowfall from previous night becomes wet and freezes at 9:55am. Vessel in Port at 12:06pm. Crew clear ice and snow from 2:18pm to 2:54pm.	11:30am Wetted Snow/Ice on deck near the bow
02/24/2007 Starboard Camera	11:36am	9:24pm	Spray and Precipitation on Window	Window partially covered by water droplets at 11:36am, 12:12pm, 12:48pm to 1:00pm, 8:48pm, 9:24pm	Vessel in Port at 12:12pm	
02/25/2007 Starboard Camera	1:12am	3:01am	Precipitation on Window	Window partially covered by water droplets from 1:12am to 1:24am, 2:48am to 3:01am.	Vessel in Port	

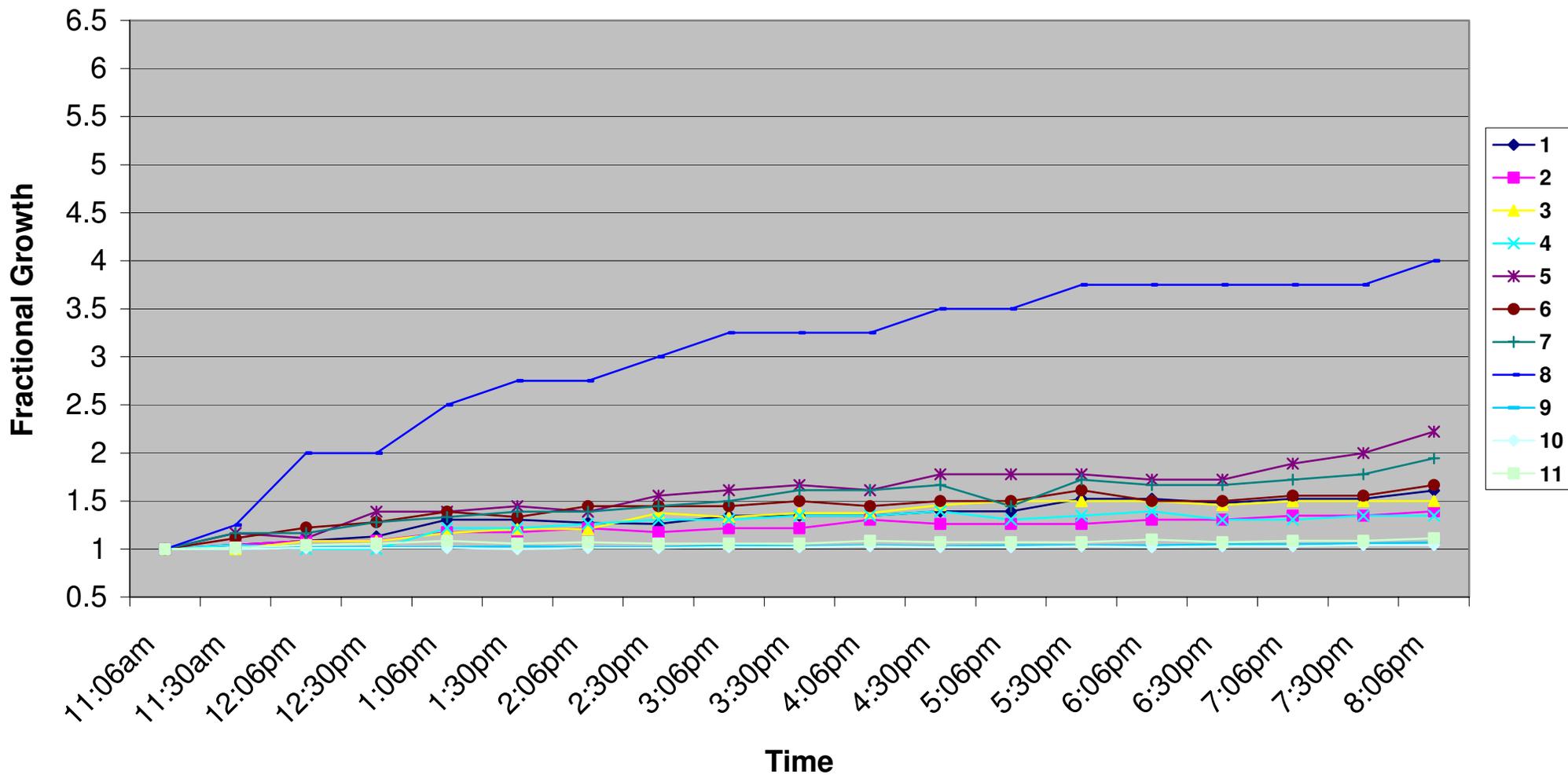
Appendix A

Ice Accumulation Measurements

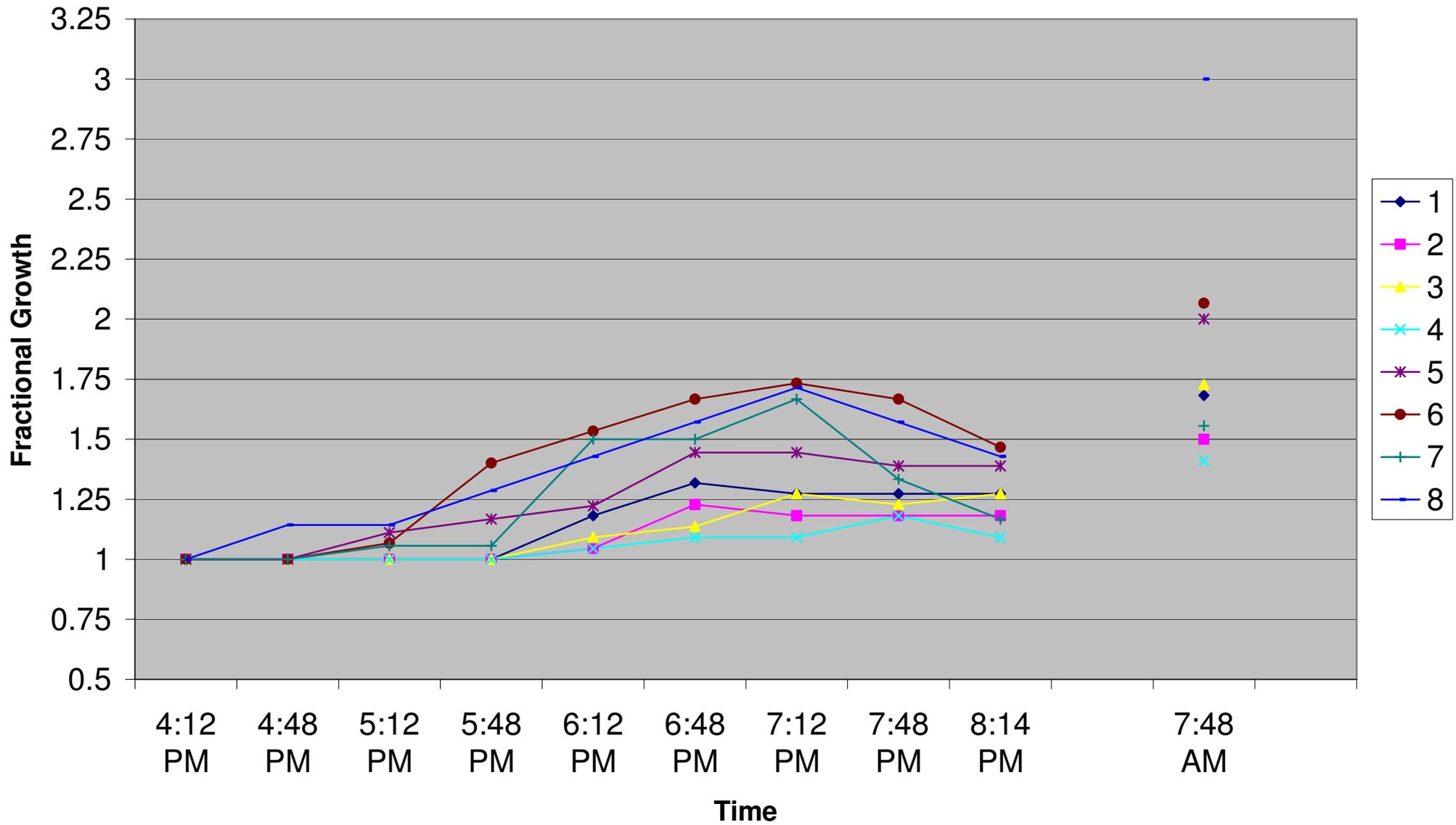
Ice Growth Starboard Camera Dec. 29, 2006



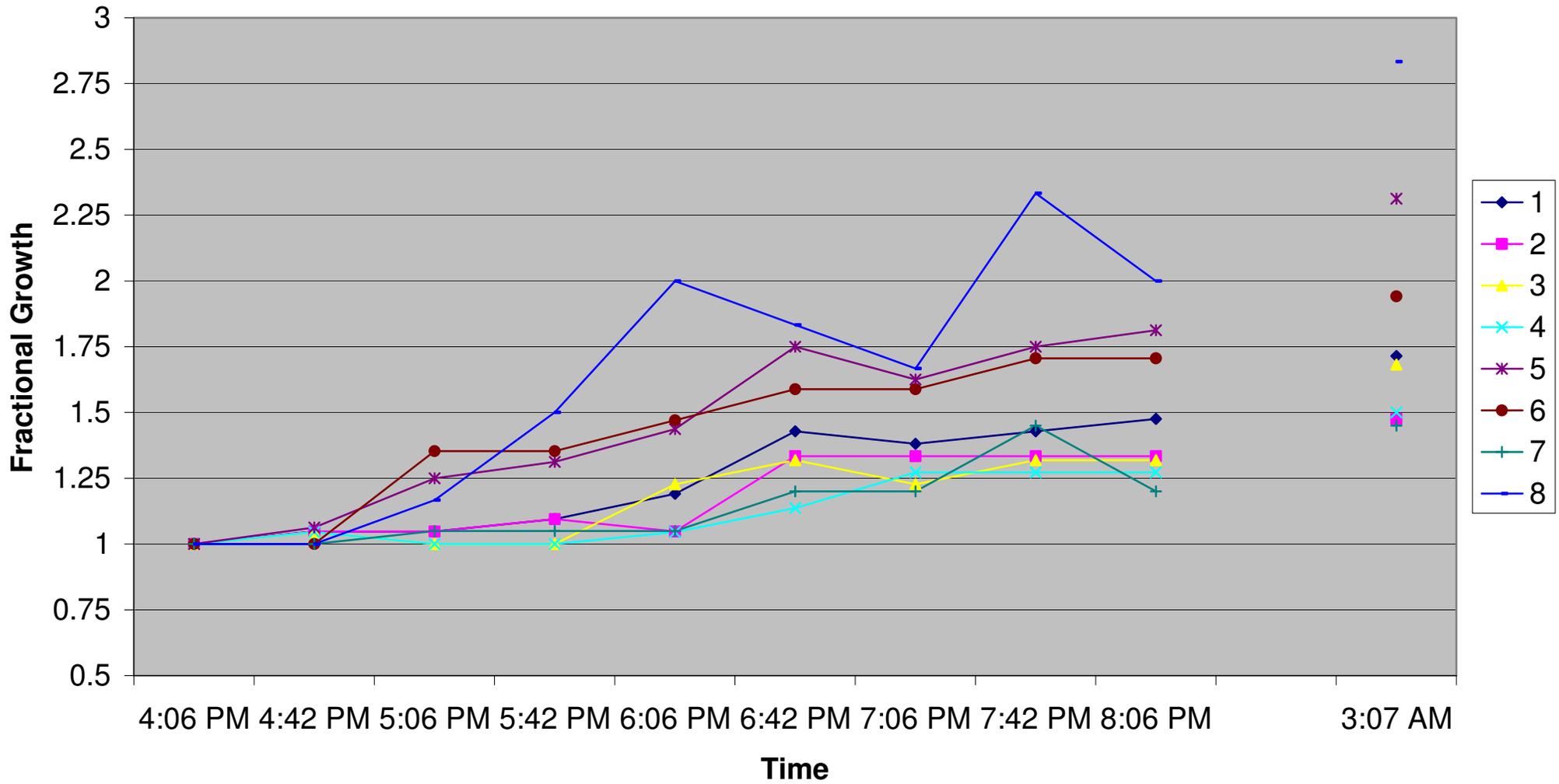
Ice Growth Port Camera December 29, 2006



Ice Growth Starboard Camera January 15, 2007



Ice Growth Port Camera January 15, 2007



Appendix B

Ice Accumulation Measurements compared to Air Temperature

Appendix C

Atlantic Kingfisher Log Book data for December 29, 2006

Time (NST)	Time (GMT)	Position North	Position West	Wind Direction	Wind Force	Air Temperature (°C)
12/29/06 6:00am	12/29/06 9:30am			W		8 -2
12/29/06 8:00am	12/29/06 11:30am	46°31.3' (8:40am NST)	048°36.1' (8:40am NST)	W		8 -3
12/29/06 10:00am	12/29/06 1:30pm	46°37.2'	048°58.1'	W		8 -3
12/29/06 12:00pm	12/29/06 3:30pm	46°41.3'	049°14.4'	W		8 -3
12/29/06 2:00pm	12/29/06 5:30pm	46°45.6'	049°30.8'	W		8 -2
12/29/06 4:00pm	12/29/06 7:30pm	46°49.6'	049°46.2'	W		8 -4
12/29/06 6:00pm	12/29/06 9:30pm	46°54.5'	050°00.0'	WNW		7/8 -5