Reliability of weather services in the Southern part of South America & Antarctic region

Research Report

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Mentor:	J.J.M. van Berlo
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Illustration cover page: Postcards from Antarctica (Holland America Blog, 2014)

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Abstract

The reason why this research was conducted is that the current used weather forecast stations were not accurate enough in the Southern part of South America and the Antarctic region, therefore this research has been conducted to find additional weather services which are more accurate. The objective is to optimize the weather procedures on board of the ships of Holland America Line and Seabourn Cruises which have been operating in the area of South America and the Antarctic region. This lead to the main question; *How can the weather procedures be optimized and displayed using the most accurate weather service in the Southern part of South-America and the Antarctic region?* This research is a quantitative research by collecting data of various meteorological stations and comparing them with the actual measured weather conditions. To answer the question weather forecast data have been collected over a period of 19 days in the entire area. After this period the actual weather, observations, which were made on board have been collected. With all the collected weather forecasts and weather observations an analysis has been made using the method of standard deviation. By using the standard deviation method extreme values (forecasts) have been taken out, this lead to a reliability of 68%.

The results showed that newly found weather services can be used on board of the ships which are cruising in the Southern part of South America and the Antarctic region, the easiest way to show the results is dividing the weather forecasts by the different regions and which sort of weather information are the most accurate. The conclusion is made that in different areas, different weather services are the most accurate therefore a map has been created to find as easy as possible the most accurate weather service for wind information, sea information or any other additional weather information. (see appendix II) The recommendation resulting out of this research is that this research can also be applied on any part in the world where weather forecasts are not reliable enough to use.

Preface

This research is conducted to finalise the last part of the study for Maritime Officer. The subject came from Holland America Line where they had some issues to collect accurate weather information in the Southern part of South America and the Antarctic region. I had to choose between two subjects and chose this subject because weather forecasts are always an interesting topic. As well known: Nothing is as changeable as the weather.

During the study for maritime officer I have conducted other researches as well, these were only much smaller compared to this final research. During this research I have found many things which were hard to work with or to find out. Therefore I found it difficult to find the right direction and answers because a lot can be found but not everything is useful. Unfortunately I had some problems with medical conditions and I am very grateful for the help given by all persons who gave their advice to finalize this research. I can hardly wait to use my knowledge on board of the ships of Holland America Line after I receive my license and certificates.

Niels de Nobel

Vlissingen, May 2018

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1. Introduction

Most of the imported and exported products (cargo) are transported by sea. These products are transported by various types of ships, which are sailing all over the world. Transportation of cargo is the most important trade, in this sector the goods should be delivered in the same state as they came in to the vessels. The cruise industry provides vacations all over the world. The goal in this type of transport is to keep the passengers as safe and comfortable as possible. Holland America Line (HAL) is one of the biggest cruise companies, part of Carnival Cooperation, in the cruise industry. It manages in total 14 ships. (Holland America Line, 2018) Each ship is sailing its own scheduled itinerary which is made well in advance. It is depending on the local seasons. Choosing the best route at a safe speed is not the only solution to keep the cargo or passengers safe and comfortable. Another way of keeping the cargo, vessels and passengers safe is by receiving, monitoring and comparing the weather information on board in various ways.

The officers on board of Holland America Line and Seabourn ships are collecting weather forecasts and information from two different weather services, these are the programs provided by Meteogroup, Ship Performance Optimisation System (SPOS) and a web-based program Dolphin Fleet Management, product of Weather Routing Inc. This is their only procedure to collect forecasts and is used for navigational route planning and to provide weather forecasts for passengers and crew. However the experience of the officers on board the ships in the Southern part of South-America and Antarctic region is that these weather services (SPOS and Dolphin Fleet Management) are not complete nor accurate compared to the actual weather observations.

The objective of this research is to find weather services for the Southern part of South-America and Antarctic region which provide more accurate and reliable weather information. These additional weather services have the preference to be more complete and accurate compared to the programs that are already used. The newly found weather station / services can be compared with the other weather services which are already used on board. This results directly in improving the safety of the ships and passengers by adapting the current weather forecasts. To avoid uncomfortable weather, routes can be adjusted or the stability of the ship improved if necessary.

For this research the following main question has been drafted:
How can the weather procedures be optimized and displayed using the most accurate weather service in the Southern part of South-America and the Antarctic region?

Finding new weather services is done by searching for local weather services and well known services which are not used on board. Weather forecasts of all the different services have been collected for 19 days. All these forecasts have been analysed and compared to the actual weather observations on board.

In the next chapter the ships and regions will be further discussed.

2. Theoretical framework

Seabourn Cruises has at the moment four ships and Holland America Line, 14 ships sailing around the world. During the research only two ships, ms Zaandam and Seabourn Quest, have been used because they were the only two ships visiting this specified region.

ms Zaandam

Tonnage:	61.396 GT
Length:	238 meters
Breadth:	32,3 meters
Draught:	7,9 meters
Speed:	23 knots
Class:	Ice Class 1D, Lloyd's Register, Passenger Ship (Holland America Line, 2000)

Seabourn Quest:

Tonnage:	32.000 GT
Length:	198,1 meters
Breadth:	25,6 meters
Draught:	6,5 meters
Speed:	19 knots
Class:	Ice Class 1C, RINA Classification Society, Passenger Ship (Seabourn Cruises, 2011)

Those two ships had an itinerary starting from Buenos Aires (Argentina) to Valparaíso, Santiago (Chile) and backwards. During this cruise the ships also passed the Falkland Islands, Antarctica, Drake Passage and ports and scenic areas on the coast of Chile.

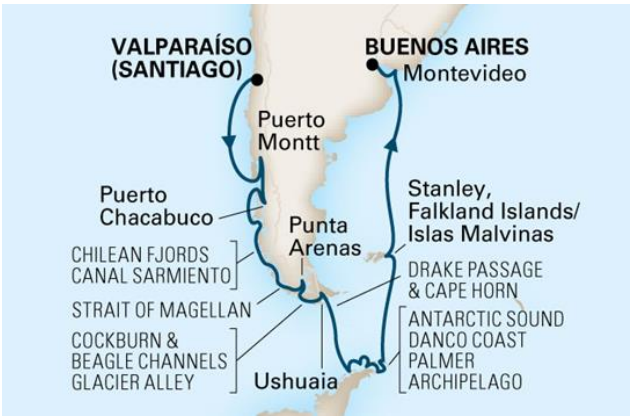

Figure 1: Cruise itinerary Zaandam

Figure 2: Cruise itinerary Seabourn Quest

2.1 Weather in South America

South America is extending 7.640 kilometres from Colombia, south to the most Southern tip of Chile and Argentina. However the large size of the continent makes the climate of South America varied with each region having its own characteristic weather conditions and climate. The variety is ranging from the Antarctic conditions to the tropical conditions near the Amazon basin. The factors influencing the climate of South America are the geographical locations, ocean currents and winds. The westerly winds carrying moisture shed their moisture on the western parts of the Andes, thus the eastern portions of the mountains receive very little rainfall. The driest part of South America are the desert regions of Chile (Maps of World, 2016).

The East coast of Argentina, including Buenos Aires, has a moderate climate with mild winters and warm summers with more rainfall during the summer months. Extreme heat or cold does not often happen in this part of Argentina. In the Southern part of Argentina the summers are cooler, cloudy and have pleasant weather. The winters in this part have long periods of frost and snow but with the influence of the ocean weather can change fast (Met Office, 2013).

Chile is a big country which is part of the west coast of South America. Chile is located between the Pacific Ocean and the west of the Andes mountains. The climate in Chile does not fit into one category, particularly because the country is so long and narrow; in fact Chile has seven climate types, however the easiest way to determine the weather in Chile is to divide the country into three sections, North-, Central- and Southern Chile. The weather in the central section of Chile is a sort of Mediterranean climate. The summers (November-March) are warm and dry and the winters are cooler and wetter. The average temperature in Valparaiso during the year is around 14°C. The weather further south, near Punta Arenas, is a sub-polar oceanic climate which is mild with no dry seasons. The summers are cool and short with an average annual temperature of 6° Celsius. In general the weather in South America is hot, wet and humid. The areas near the Amazon basin are known as a rainforest and have consistently hot and humid weather around the year with heavy rainfall. There are four parts of South America which experience heavy rainfall; these are the Amazon River Basin, the coastal parts of French Guiana, Guyana and Suriname, Ecuador coasts and the southwestern parts of Chile (Climate and Weather, 2016).

The climate in the Antarctic region is characterized by bitterly cold temperatures and little precipitation. This continent has snow and ice throughout the year with very long and cold winters. There is little precipitation in the cold and stable air. The largest amounts are on the coastal margins. This results often in a cyclone in the region, which brings snow and ice with strong winds (Climate and Weather, 2016).

2.2 Regions

Out of the very different climates in the Southern part of South-America and Antarctic region the complete region has been divided into five different areas. (See Appendix I)

Area A: West coast of Chile, south of Valparaíso up to 50° South

Area B: West coast of Chile, southerly of 50° South until 56° South, this also includes west of the meridian of 68° West (west of Ushuaia)

Area C: Complete area south of 56° South, including the complete Antarctic region

Area D: East coast of Argentina, between 50° South and 56° South and East of 68° West (east of Ushuaia)

Area E: East coast of Argentina, South of Buenos Aires up to 50° South

2.3 Weather information

This chapter describes all kind of information obtained by weather stations. Weather information consists of weather procedures, weather stations, weather data, accurate weather data and displaying the newly found weather stations. The current weather procedure on board is to collect weather forecasts in the best available way possible. Most of the crew on board use SPOS as their weather information service. The obtained weather information is used to make a voyage planning for a few days ahead, so decisions can be made in time to make route adjustments or alter the ports of call. For optimizing the current weather procedure additional weather stations and services must be added to SPOS and Dolphin Fleet Management.

Weather stations
During this research various weather stations have been consulted to find the best, complete and accurate weather forecasts. Out of these weather forecasts an analysis has been made. All of the used weather stations have been asked by email, how they collect weather data and how they make and display the weather forecasts. Most of them are using the Global Forecast System (GFS), this weather forecast model is produced by the National Centers for Environmental Prediction (NCEP). The NCEP is part of the National Oceanic and Atmospheric Administration (NOAA), one of the world leading weather services. Dozens of atmospheric and land variables are available through this dataset, from temperatures, winds, and precipitation to moisture and atmospheric ozone concentration. The entire globe is covered by the GFS model, by this GFS model weather can we predicated up to 16 days ahead. The GFS model is a coupled model, composed of four separate models (an atmosphere model, an ocean model, a land model, and a sea ice model), which work together to provide an accurate picture of weather conditions.

Changes are regularly made to the GFS model to improve its performance and forecast accuracy. It is a constantly evolving and improving weather model. Most of the weather services displays GFS forecasts, the forecast data is displayed with an average of three hours (National Oceanic and Atmospheric Administration, 2018).

All weather services provide forecasts and information in their own way. This results in different type of charts and different measuring units. The chosen weather services provide weather information in the on board standard values and preferably as easily as possible.

All weather services can provide a lot of weather information with lots of details depending on the selection of the user. The most important information for cruise ships in open waters are the wind speed, wind directions, sea / swell heights and sea / swell directions. (Wind information and swell information) By selecting weather services for this research, weather services needs to comply with the minimum amount of information, the so called “must information”. Other information is additional to the must information which less important in this area. Additional weather information can be air / sea temperature, visibility, barometric pressure (World Meteorological Organization (WMO)).

Requirements of weather information	
Must information	Additional information
Wind speed	Visibility
Wind direction	Air / Sea temperature
Sea direction	Barometric pressure
Swell height / period	Humidity

Figure 3: Weather forecasts requirements

The used scale for visibility is slightly different compared to the other data, all other data are set in numbers for example with speed and direction. This visibility scale is used on board of the two ships of Holland America Line and Seabourn Cruises and is part of the standard to fill in the measured weather observations (Administration, 2010).

Code explanation visibility		
Logbook code	Explanation	Visibility
9	Exceptional visibility	Over 30 nM
8	Very good visibility	10 - 30 nM
7	Good visibility	5 - 10 nM
6	Moderate visibility	2 - 5 nM
5	Poor visibility	1-2 nM
4	Mist of thin fog	0,5 - 1 nM
3	Fog	500 meters - 0,5 nM
2	Moderate fog	200 - 500 meters
1	Dense fog	50 - 200 meters
0	Thick fog	Less than 50 meters

Figure 4: Code explanation visibility

To determine the most accurate weather service they have been divided by the five different areas. In these parts the weather is slightly different compared to the other parts. Standard deviation has been applied to all the various data. Statistic programs, for example Statistical Package for the Social Sciences (SPSS), have not been used for analysis.
Standard deviation is a mathematical formula to spread the numbers around the average (μ) data. The formula calculates a deviation (σ) which is called the standard error. Using the standard error a reliability can be determined which is 68%, 95% or 99,7%. Calculating the reliability also eliminates the extreme deviation of data (van der Zee, 2017).

$$Reliablity\ 68\ \%\ =\ (\mu - 1\sigma)\ \&\ (\mu + 1\sigma)$$

$$Reliablity\ 95\ \%\ =\ (\mu - 2\sigma)\ \&\ (\mu + 2\sigma)$$

$$Reliablity\ 99{,}7\ \%\ =\ (\mu - 3\sigma)\ \&\ (\mu + 3\sigma)$$

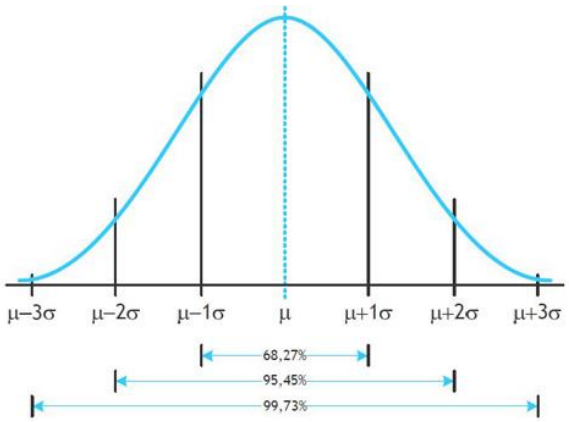

Figure 5: Standard deviation graph

The most accurate weather services found by using the standard deviation can be displayed in different ways which should be as easy as possible to use. This can be done by showing which weather service is the most accurate in a specific area. The region chart made, as in the appendix, weather services can be added.

2.4 Conceptual model

How can the weather procedures be optimized and displayed using the most accurate weather service in the Southern part of South-America and the Antarctic region?

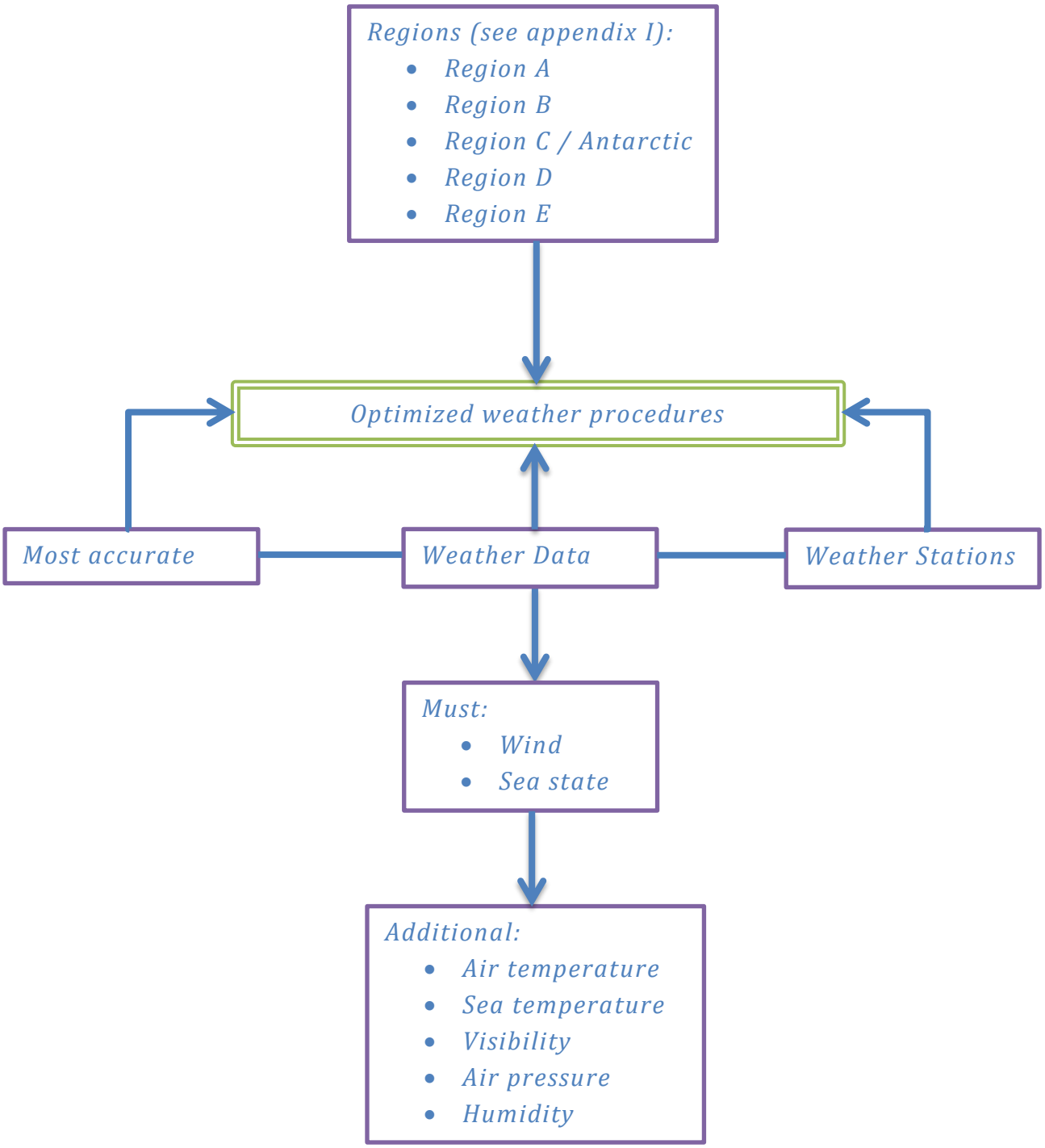

Figure 6: Conceptual model

3. Method

Interviews held on board of the Zaandam and Seabourn Quest show that the weather forecasts in the Southern part of South-America and the Antarctic region are not accurate enough to rely on. The officers on board would like to use other stations as well which are more accurate compared to SPOS and Dolphin Fleet Management. Therefore this research has been conducted.

This research is a quantitative research by collecting data of various meteorological stations and comparing them to the actual measured weather conditions.

All meteorological data, weather forecasts, have been collected from the internet by various weather services which are accessible with or without registering. Most of the weather services are using the GFS model for their forecasts, this is the most used model for weather services. The stations which did not show how they collect and display the weather forecasts were asked which forecast model they use.
SPOS has not been used in this research because this program is only available on board ships. The program is connected to the Global Positioning System (GPS) and only ships have a licence to use this. Dolphin Fleet Management is used to find in which areas the weather forecasts are inaccurate. The following weather stations have been used to collect data from:

- Dolphin Fleet Management
- Passage Weather
- SailFlow
- Weatherzone
- Weather 365
- Weather Underground
- All Met Sat
- Swell Watch
- Servicio Meteorológíco Nacional (SMN)
- Dirección Meteorológica de Chile

Of the above weather services, weather forecasts have been collected over a total of 19 days. All of the collected forecasts were compared to the actual weather observations and measurements made on board which were recorded in the ships logbooks. In the ships logbooks all weather observations are recorded in relative speed and direction. The results are shown in a graphic diagram in the next chapter. Out of the collected weather data, only the most relevant weather forecasts were used. This means only the weather on the water surface, data on the higher altitudes in the 500 (hPa) hectopascal pressure area, were not used in the analysed data. Weather data can be predicted up to 16 days in this weather forecast model, however the used weather forecasts are only used up to 24 hours in advance. The reason why is to keep all data as accurate as possible.

The exact positions of the ships were not yet known but only the areas where they were operating. Exact positions of the ships are used to start the sorting of all data, this could be done only after collecting the actual weather information recorded on board in the ships logbooks. The weather forecasts / information used to determine the most accurate weather forecasts are:

- Wind information (wind speed and direction)
- Visibility
- Air temperature
- Sea temperature
- Barometric pressure
- Humidity
- Sea direction
- Swell information (swell height and length, period)

Ice information has not been used, the ice information which is provided could not be used because it is every limited. Icebergs were not shown on the forecasts, only expected solid ice thickness. Any ice information, ice state or sightings, have not been recorded in the ships logbooks.

Name	Time (GMT)	Time Zone	Deg/Min/Sec		Deg/Min/Sec		Wind dir (°)	Wind speed (ms)	Visibility	Air Temp (°C)	Baro (mbar)	Sea Temp (°C)	Humidity (%)	Sea Dir	Swell Height (m)	Swell Length		Avg SOG (kts)
Ship																		
Dolphin																		
Passage weather																		
Weather under																		
Sailflow																		
Weather 365																		
All met sat																		
Swell watch																		
Meteo Chile																		

Figure 7: Used weather information

Standard deviation was used as a method to determine the most accurate weather forecasts, any statistic program did not work to determine the most accurate weather forecast. This is done by creating an Excel sheet by collecting, eliminating and analysing all data.

After collecting all weather observations made on board of the Zaandam and Seabourn Quest, the raw data has been sorted by date and time. During the selecting of the data by date and time the entry in the logbook “End of Watch” has been used selecting times. In the ships logbooks, the entry of “end of watch”, other weather observations have to be determined additional to the other hourly observations. All observations made in this entry have to be entered manually. The additional observations are the average sea directions, swell height and period during the watch period.

Ship Name	Entry Template	Entry Time (GMT)	Deg/Min/Sec		Deg/Min/Sec		Wind dir (°)	Wind speed (ms)	Visibility	Air Temp (°C)	Baro (mbar)	Sea Temp (°C)	Humidity (%)	Sea Dir	Swell Height	Swell Height (m)	Swell Length	Swell Length (m)
Seabourn Quest	Hourly observations	3-02-15 2:00	34° 21' 6"	South	72° 28' 18"	West	197.9	10.5	Very Good Visibility	16.4	1012	15	67					
Seabourn Quest	End of watch	3-02-15 2:59	34° 7' 19"	South	72° 21' 15"	West	207.5	8.7	Good Visibility	16.2	1012	15	67	N	Low	0-2m	Short	0-100m
Seabourn Quest	Hourly observations	3-02-15 4:00	33° 53' 38"	South	72° 14' 6"	West	194.5	8.0	Good Visibility	16.0	1012	15	66					
QUE AVG							**200.0**	**9.1**	**Good Visibility**	**16.2**	**1012.0**	**15.0**	**66.7**	**N**	**Low**	**0-2m**	**Short**	**0-100m**
Seabourn Quest	Hourly observations	3-02-15 6:00	33° 27' 14"	South	72° 0' 23"	West	203.8	9.5	Good Visibility	15.6	1011	15	66					
Seabourn Quest	End of watch	3-02-15 7:00	33° 14' 14"	South	71° 53' 41"	West	186.6	8.5	Good Visibility	15.7	1010	15	66	NNE	Low	0-2m	Average	100-200m
Seabourn Quest	Hourly observations	3-02-15 8:00	33° 2' 51"	South	71° 46' 38"	West	220.9	10.3	Good Visibility	15.4	1010	16	66					
QUE AVG							**203.8**	**9.4**	**Good Visibility**	**15.6**	**1010.3**	**15.3**	**66.0**	**NNE**	**Low**	**0-2m**	**Average**	**100-200m**

Figure 8: Average "End of watch" data

The weather services display their forecasts with average data (specific time + & - 2 hours), in the Excel sheet the average data have been used at the time of each end of watch entry. In the used weather information sheet the weather forecasts of the weather services are added, this is done by searching for the forecasts in the collected data by specific time and position. Out of all forecasts at the specific position and time the average (μ) of all the different forecasts have to be determined before the standard deviation is applied.

The formula of the standard deviation (σ) has been applied on all the different weather forecasts. The result of using the standard deviation is that the extreme values are eliminated. The data eliminated in this format were the average end of watch data and the weather forecasts of all the different weather services. By eliminating these extreme values it results that the data which were used provides a reliability of 68%. $Reliablity\ 68\ \% = (\mu - 1\sigma)\ \&\ (\mu + 1\sigma)$

Name	Time (GMT)	Time Zone	Deg/Min/Sec		Deg/Min/Sec		Wind dir (°)	Wind speed (ms)	Visibility	Air Temp (°C)	Baro (mbar)	Sea Temp (°C)	Humidity (%)	Sea Dir	Swell Height (m)	Swell Length
Zaandam	13-02-15 2:00	-3	53° 38' 4"	South	57° 32' 9"	West	231.6	22.3	Good Visibility	6.2	997	10	83	NE	2-4m	Long
ZADM AVG							**225.3**	**20.5**	**Good Visibility**	**6.2**	**996.7**	**9.1**	**84.3**	**NE**	**2-4m**	**Long**
Dolphin							230.0	19.0	9	5.0	998	9		50	3.7	10
Passage weather							225.0	18.0	>10		1002	9		50	4	
Weather under							210.0	13.9		6.0	1001					
Sailflow							230.0	15.4		8.0	998			50	3.1	8
Weather 365							220.0	18.0		6.0	1001		75	50	4.5	8
All met sat							245.0	19.0								
Swell watch							220.0	14.4						45	3.1	10
SMN							220.0	21.6		7.0	999		75	60	2.5	
Average							225.0	17.4	9.5	6.4	999.8	9.0	75.0	50.8	3.5	9.0
Standard dev							10.4	2.6	0.5	1.1	1.7	0.0	0.0	4.9	0.7	1.2

Figure 9: Analysed model

In the figure above an analysed model is shown. In the Excel sheets standard formulas were used such as the calculation for the average (μ) and the standard deviation (σ). For applying the reliability of cells in the above were marked as green. This means the data in for the specific weather station is accurate enough within the limited of the reliability.

The used standard deviation calculates an average at a specific time. Weather data can be selected which are reliable and were used further in the analysed model. This was calculated in the percentage (%) of all data on a specific date which complied by the standard deviation, extreme values were not used. The percentage which met the above requirements were divided by all the different regions. The weather information with the highest percentage is the most reliable weather service in a specific region with a reliability of 68%.

Analysed regions	
Regions	Number of days
Region A	9 days
Region B	4 days
Region C / Antarctic	13 days
Region D	6 days
Region E	5 days

Figure 10: Analysed regions by number of days

Area B	Wind Direction (%)	Wind Speed (%)	**Wind (%)**	Sea Direction (%)	Swell Height (%)	Swell length (%)	**Sea State (%)**	Visibility (%)	Barometer (%)	Air Temperature (%)	Sea Temperature (%)	Humdity (%)	**Additional information**
Dolphin	54	46	**50**	25	50	33	**36**	46	29	58	67	0	**40**
Passage Weather	46	54	**50**	38	46	17	**33**	88	38	50	56	0	**46**
Weather Under	50	54	**52**	0	0	0	**0**	0	42	58	0	0	**20**
Sailflow	63	58	**60**	33	58	56	**49**	0	50	50	0	0	**20**
Weather zone	0	0	**0**	0	0	0	**0**	0	0	0	0	0	**0**
Weather 365	63	50	**56**	33	44	56	**44**	0	46	71	0	54	**34**
All met sat	25	63	**44**	0	0	0	**0**	0	0	0	0	0	**0**
Swell Watch	67	67	**67**	33	25	33	**31**	0	0	0	0	0	**0**
SMN	50	33	**42**	50	0	0	**25**	0	50	83	0	50	**37**
Meteo Chile	25	8	**17**	0	33	0	**33**	83	0	0	0	0	**17**

Figure 11: Percentage sheet region B

4. Results

The results of this research were analysed in the created Excel sheet by using the method of standard deviation and calculated to the percentage of which forecasts were reliable enough compared to the actual weather observations on board. All the results were divided by the corresponding regions and divided by must information and additional information. The two must information, wind information and sea information, have been displayed separate because of the fact these are the most important weather information. Wind information consists of wind direction and wind speed. Sea information consists of sea direction, swell height and swell period. The additional information consists of visibility, barometric pressure, air temperature, sea temperature and humidity. The columns which present the reliability given in percentages are shown in the figures divided by the different areas.

4.1 Region A

In the region of the west coast of Chile, region A, data have been collected and analysed over a period of nine days.

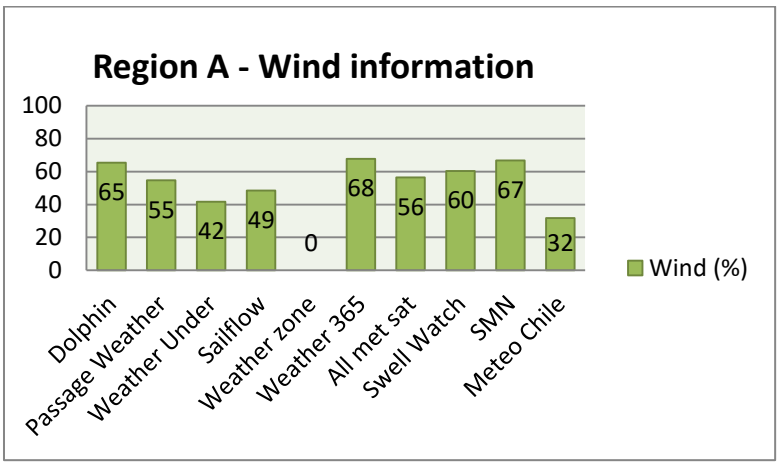

Figure 12: Region A, wind information

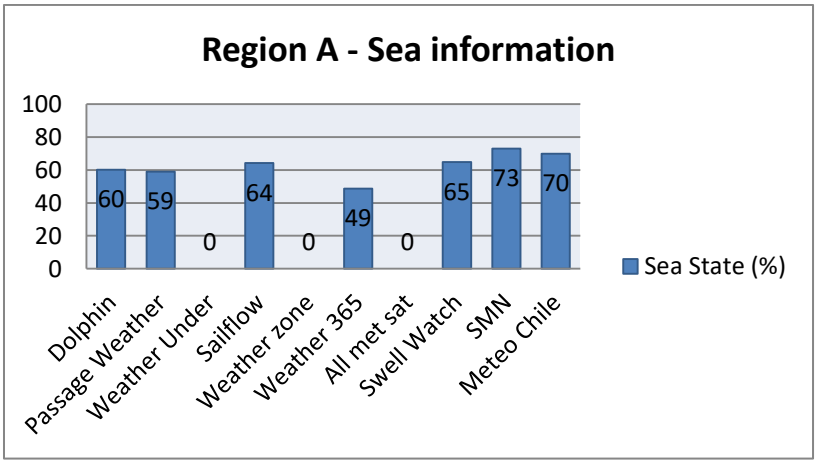

Figure 13: Region A, sea information

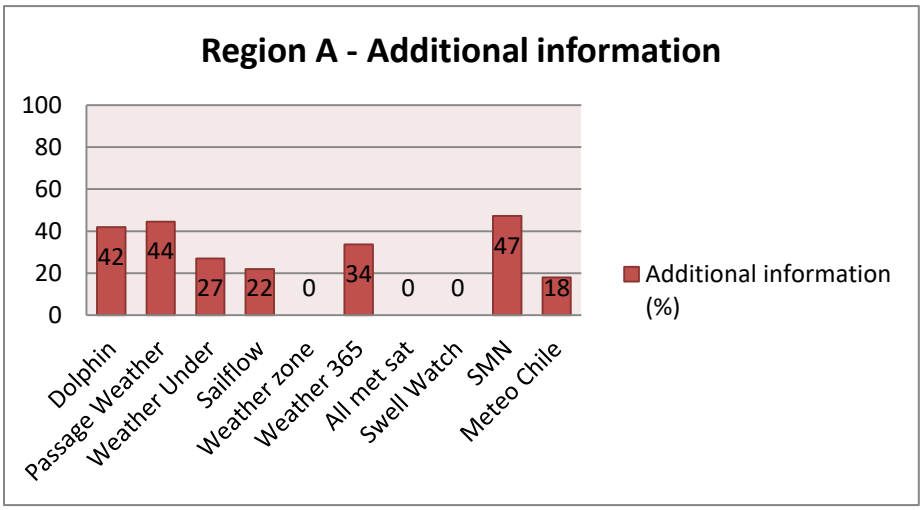

Figure 14: Region A, additional information

4.2 Region B

In the Southern part of the west coast of Chile, region B, data have been collected and analysed over a period of four days.

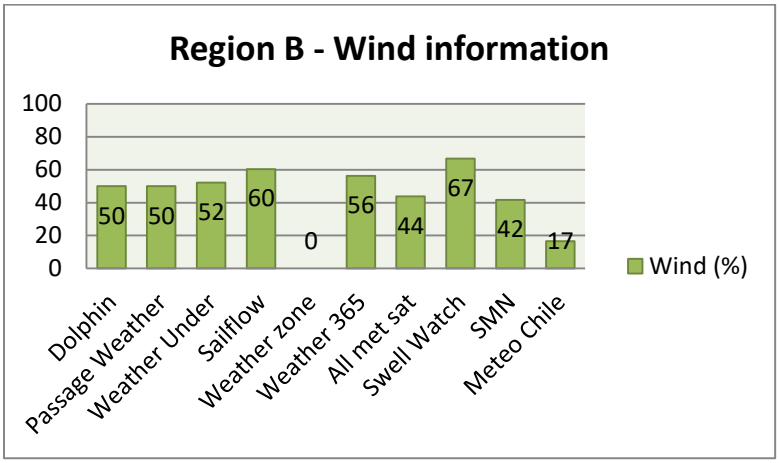

Figure 15: Region B, wind information

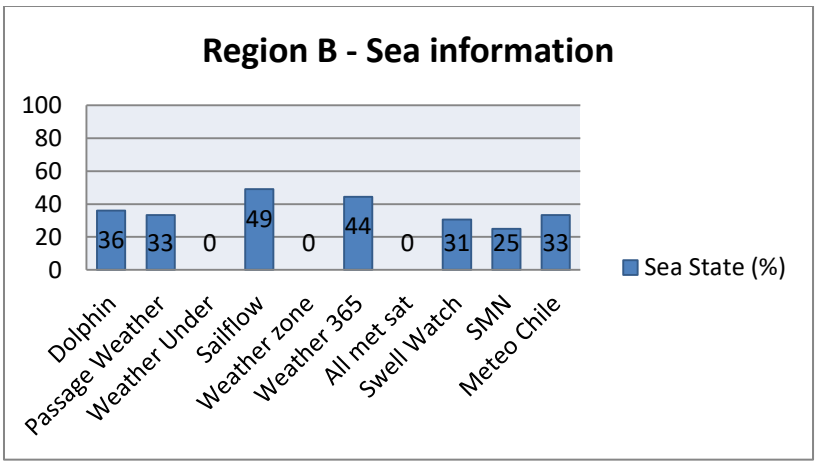

Figure 16: Region B, sea information

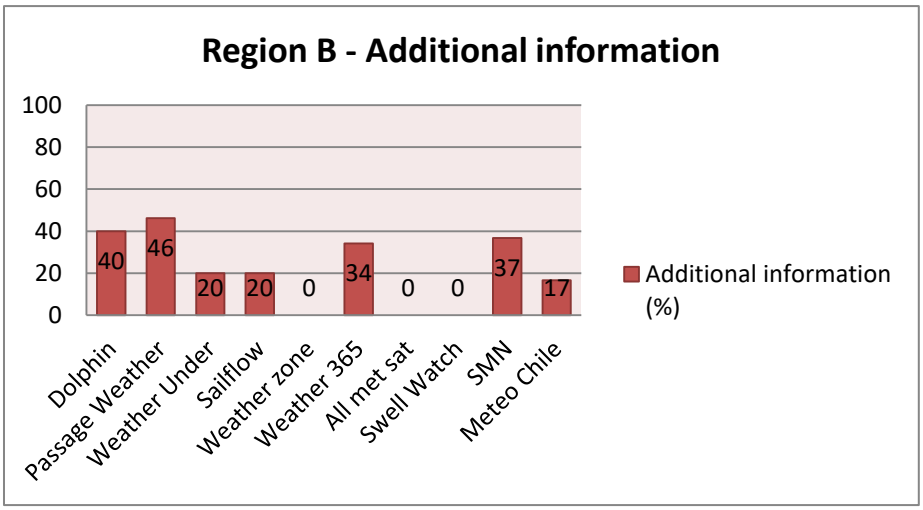

Figure 17: Region B, additional information

4.3 Region C

South of the Southern part of South America region C is located, this includes the Antarctic area where the ships will visit. Data have been collected and analysed over a period of 13 days.

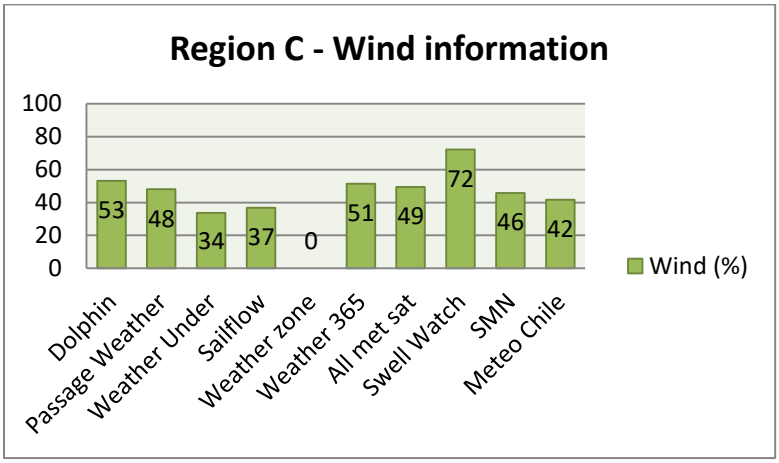

Figure 18: Region C, wind information

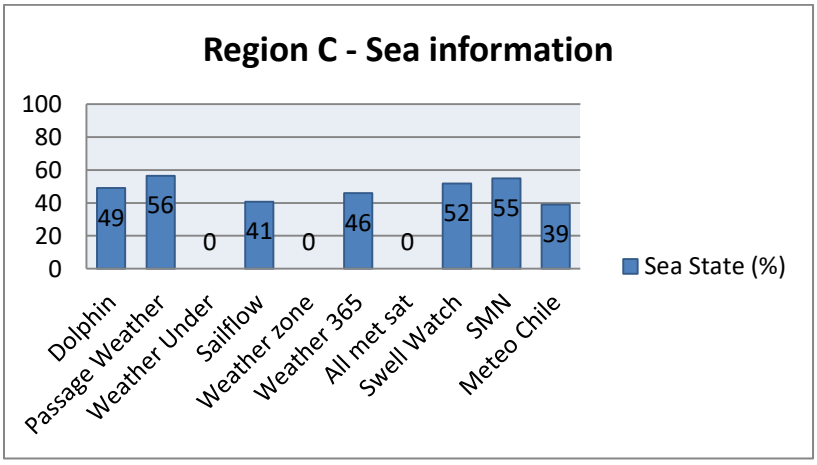

Figure 19: Region C, sea information

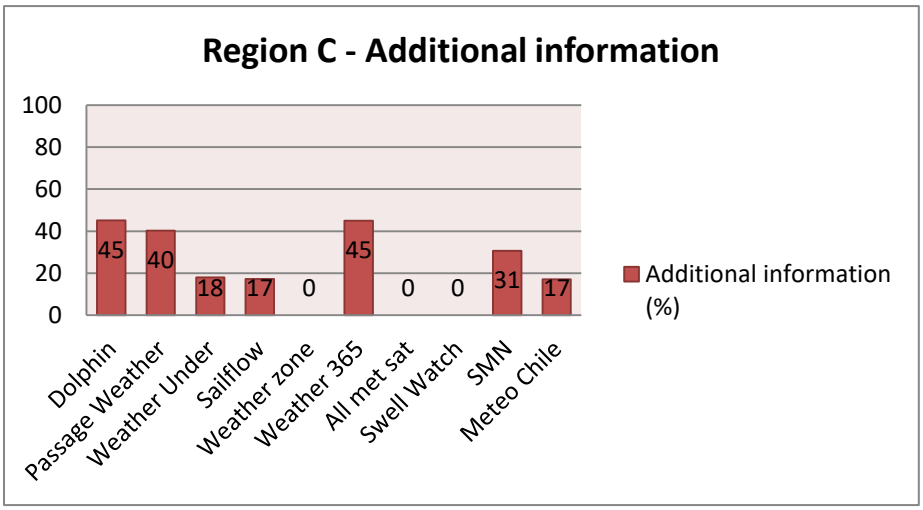

Figure 20: Region C, additional information

4.4 Region D

In the Southern part of the East coast of Argentina, region D, data have been collected and analysed over a period of six days.

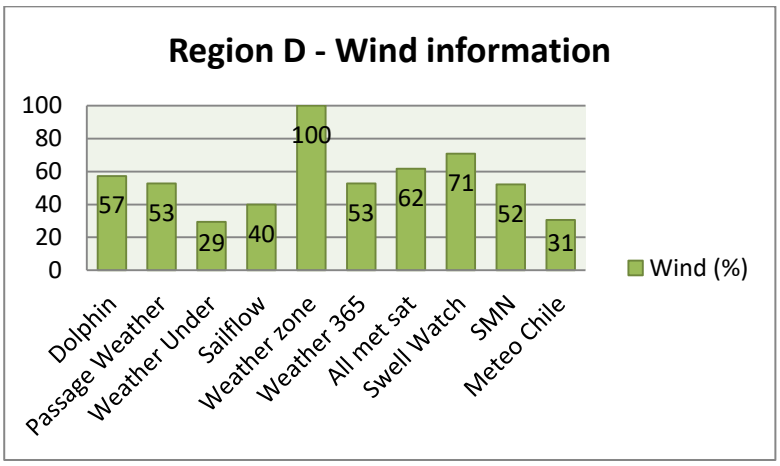

Figure 21: Region D, wind information

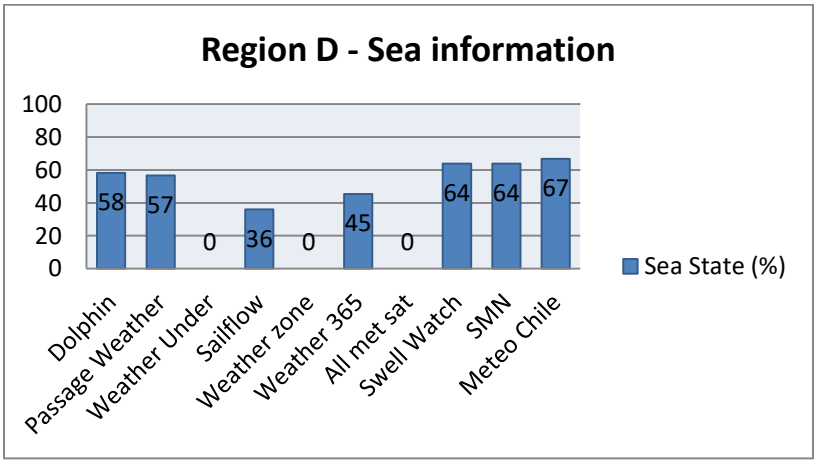

Figure 22: Region D, sea information

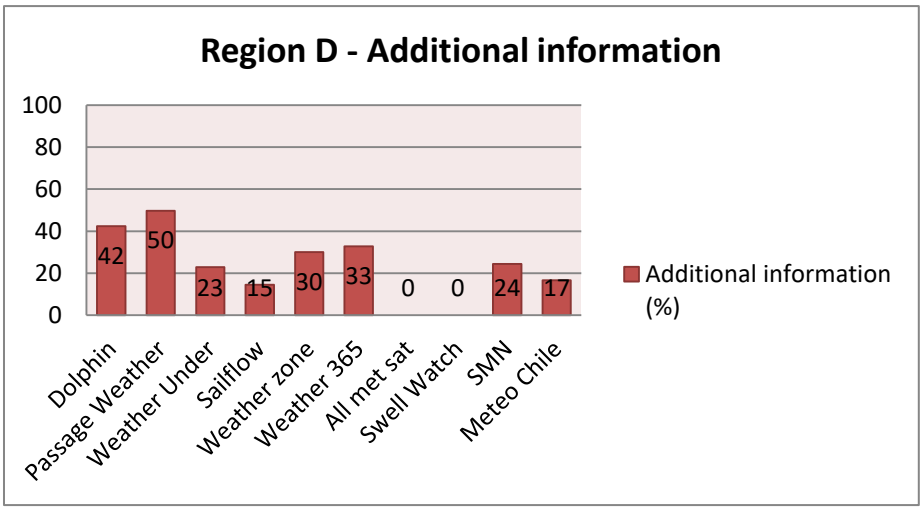

Figure 23: Region D, additional information

4.5 Region E

In the region of the East coast of Argentina, region E, data have been collected and analysed over a period of five days.

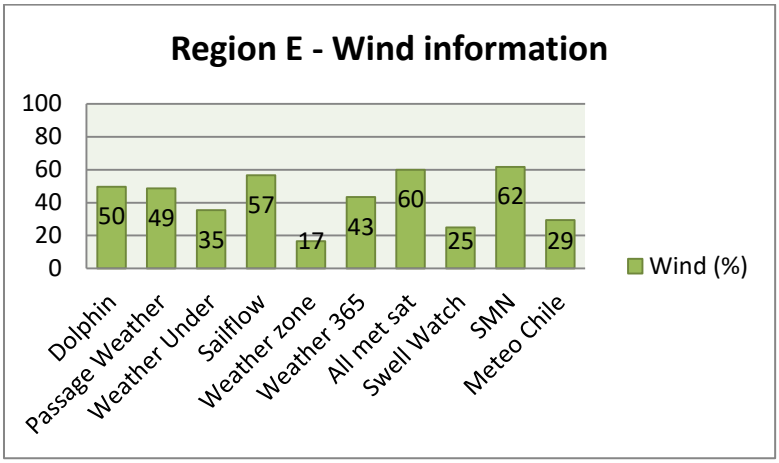

Figure 24: Region E, wind information

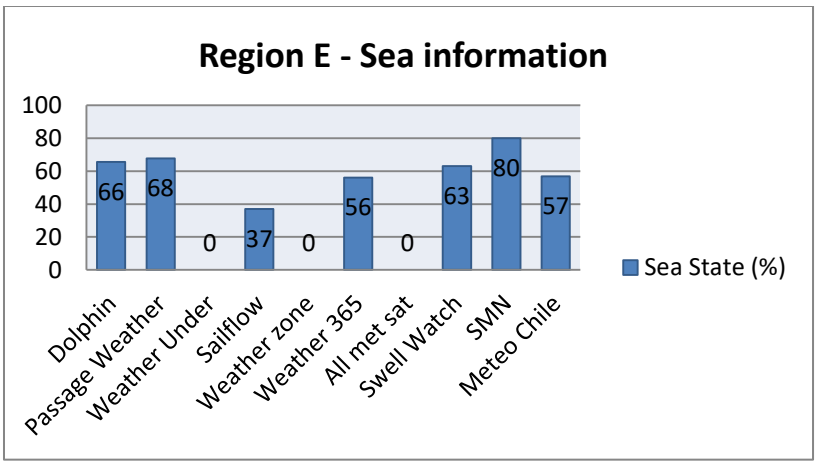

Figure 25: Region E, sea information

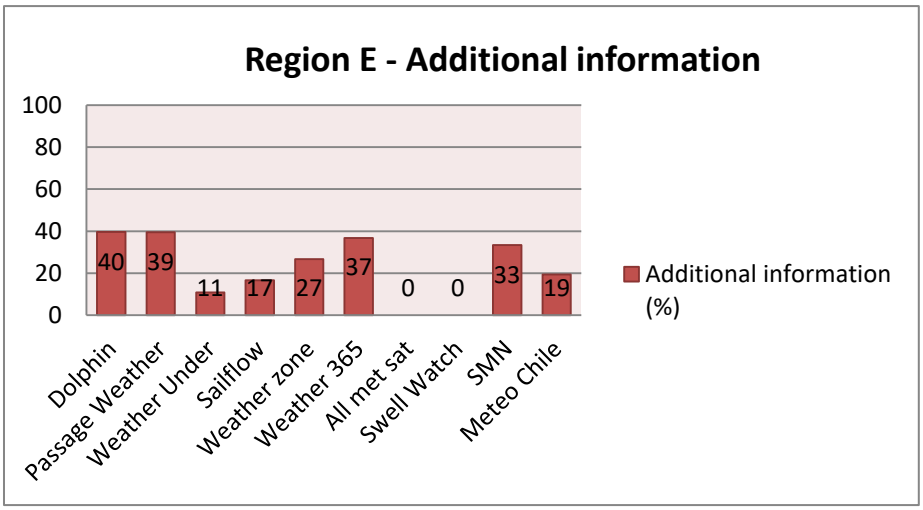

Figure 26: Region E, additional information

5. Discussion

The analysis made of the weather services in this research is only done for cruise ships but can also be applied to any other vessel. The collected weather forecasts and data is a big data set collected over a large area of the Southern area of South America and Antarctic region, this results in possibilities of human errors. The human error can be made in the ships logbooks by the entry which needs an manual input or by the first steps in the analysing model by entering all the different weather forecasts. The used forecasts were only for 24 hours in advance, this can also rely in different data compared to forecasts up to 36 or 48 hours. The reliability of the data was kept in this research at 68%, to use a higher reliability of 95% or higher, more data had to be removed and weather stations which can be accurate in some regions would be eliminated.
Results are only used for data which is forecasted or recorded by the ships, other information which were not recorded or forecasted were not used but can still make changes on the reliability of which weather services is the most accurate.

The expectations were that ice information and forecasts could be used, however this data had not been recorded in the ships logbooks and not enough data could be found on the any sources online or in weather programs. For example the weather service of ArcticWeb, this weather services is created for the arctic regions, but at this time only of the North Arctic Area (ArcticWeb, 2013). This weather services provided all information which is needed for this research; vessel information, route information, ice information, maritime safety information, actual weather, weather forecasts and search and rescue information.

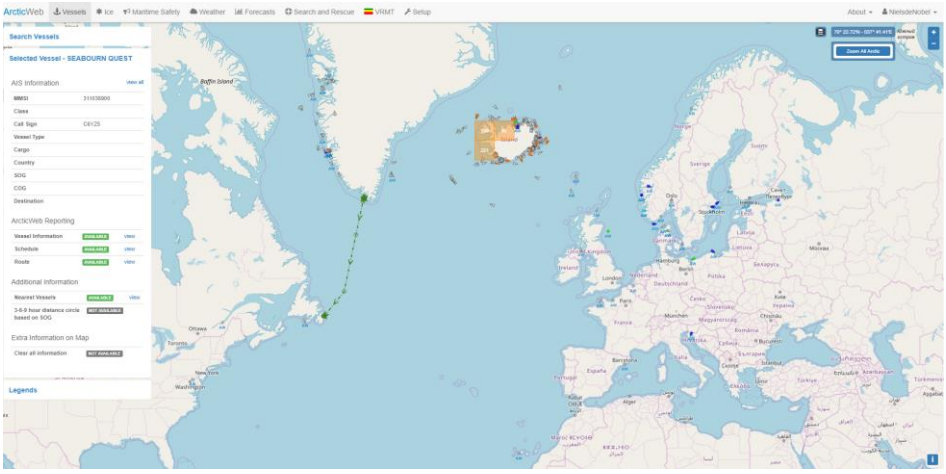

Figure 27: Example of the weather service ArcticWeb

The possibilities for this research are not limited to only the Southern part of South America but can be extended to more and bigger areas where the weather services are not accurate enough. The time period in this research is only limited to the time of year that ships can visit this area and is also depending on the weather around this area. The limitation of the research is that it can only be used for areas that ships actually visit and record their observations and any other important weather information which is needed for a research like this.

6. Conclusion & Recommendations

The results shown in the previous chapter are that some weather services are providing more accurate weather forecasts in the Southern area of South America and the Antarctic region compared to others. Conclusion can be made that in the following regions, the following weather services are providing the most accurate weather forecasts. These are divided by must information and additional information and in order of reliability. For the accurate weather services a map has been created in appendix II.

Conclusion weather services		
Regions	Weather information	Weather service
Region A	Wind information	Weather 365
		Servicio Meteorológíco Nacional (SMN)
		Dolphin Fleet Management
	Sea information	Servicio Meteorológíco Nacional (SMN)
		Dirección Meteorológica de Chile
	Additional information	Servicio Meteorológíco Nacional (SMN)
		Passage Weather
Region B	Wind information	Swell Watch
		Sailflow
	Sea information	Sailflow
		Weather 365
	Additional information	Passage Weather
		Dolphin Fleet Management
Region C	Wind information	Swell Watch
		Dolphin Fleet Management
		Weather 365
	Sea information	Passage Weather
		Servicio Meteorológíco Nacional (SMN)
	Additional information	Dolphin Fleet Management
		Weather 365
Region D	Wind information	Weatherzone
		Swell Watch
	Sea information	Dirección Meteorológica de Chile
		Servicio Meteorológíco Nacional (SMN)
		Swell Watch
	Additional information	Passage Weather
		Dolphin Fleet Management

Conclusion weather services		
Regions	Weather information	Weather service
Region E	Wind information	Servicio Meteorológíco Nacional (SMN)
		All met Sat
	Sea information	Servicio Meteorológíco Nacional (SMN)
		Dolphin Fleet Management
		Passage Weather
	Additional information	Dolphin Fleet Management
		Passage Weather

Figure 28: Conclusion of weather services

How can the weather procedures be optimized and displayed using the most accurate weather service in the Southern part of South-America and the Antarctic region?
In the figure above the most accurate weather services are displayed divided by the selection made of the different regions in the Southern part of South-America and the Antarctic region. The best and easiest way to display the results is to add the above accurate weather services into the same map made in appendix I. By adding the newly found accurate weather services to the map in appendix II, this can be used on board the ships. Optimizing the weather procedure on board can be done by using the map as seen in appendix II, the required weather information services can been seen very easy in just one map.

The recommendations of this research is to use this map and if needed adjust it to other found weather services which are accurate and if needed this could be calculated for any other part in the world where they had the same experience of the inaccuracy of the current used weather services. The recommendations for new areas is also to find and use as much local weather services as possible.

Table of Figures

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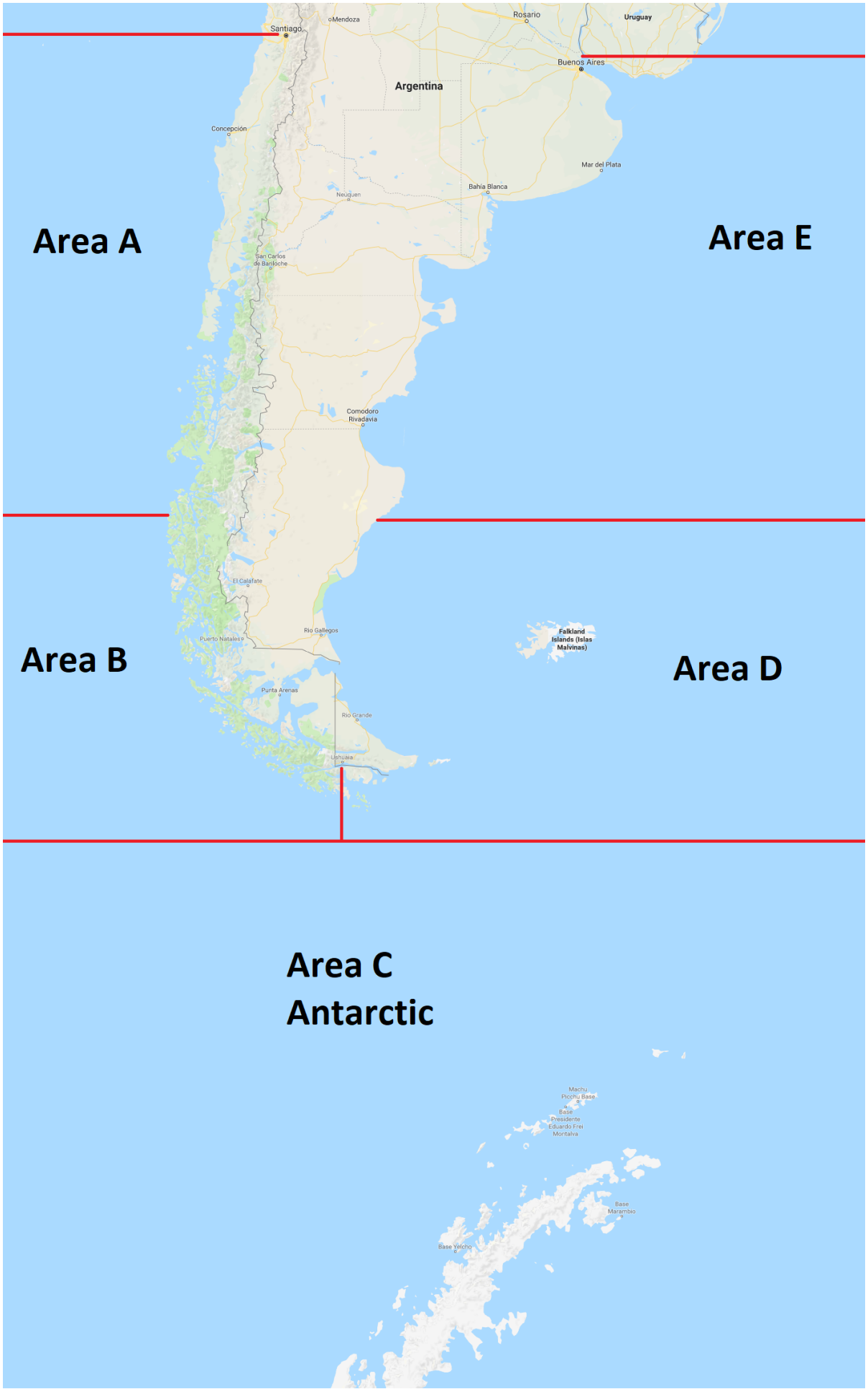
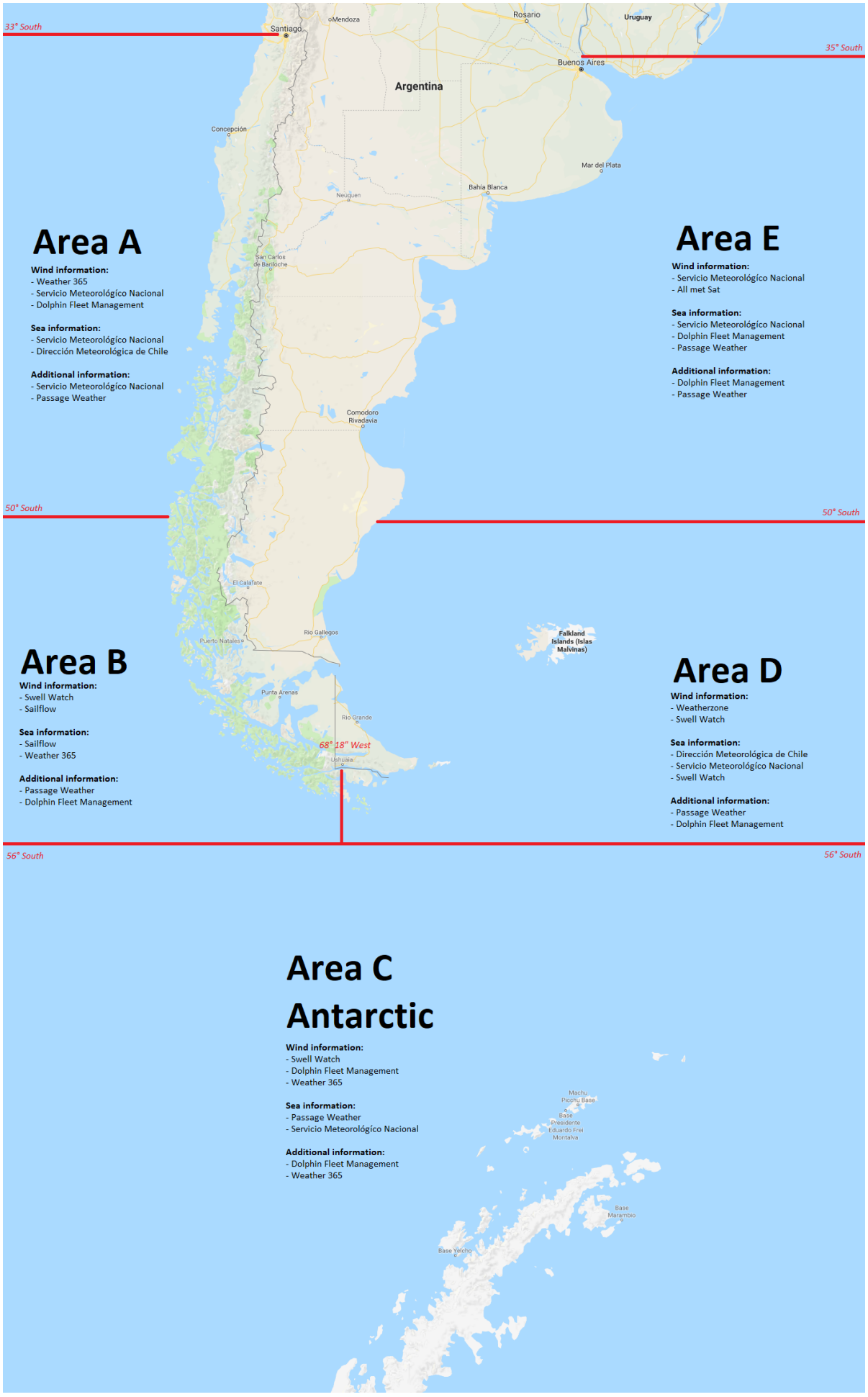
Appendix I:


Area A
Area B
Area C
Antarctic
Area D
Area E
Santiago
Mendoza
Rosario
Uruguay
Buenos Aires
Argentina
Concepción
Mar del Plata
Bahía Blanca
Neuquen
San Carlos de Bariloche
Comodoro Rivadavia
El Calafate
Puerto Natales
Rio Gallegos
Falkland Islands (Islas Malvinas)
Punta Arenas
Rio Grande
Ushuaia
Machu Picchu Base
Base Presidente Eduardo Frei Montalva
Base Marambio
Base Yelcho

Appendix II:


33° South
35° South
50° South
56° South
68° 18" West
Santiago
Mendoza
Rosario
Uruguay
Buenos Aires
Argentina
Concepción
Mar del Plata
Bahía Blanca
Neuquen
San Carlos de Bariloche
Comodoro Rivadavia
El Calafate
Puerto Natales
Rio Gallegos
Punta Arenas
Rio Grande
Ushuaia
Falkland Islands (Islas Malvinas)
Machu Picchu Base
Base Presidente Eduardo Frei Montalva
Base Marambio
Base Yelcho
Area A
Wind information:
- Weather 365
- Servicio Meteorológíco Nacional
- Dolphin Fleet Management
Sea information:
- Servicio Meteorológíco Nacional
- Dirección Meteorológica de Chile
Additional information:
- Servicio Meteorológíco Nacional
- Passage Weather
Area E
Wind information:
- Servicio Meteorológíco Nacional
- All met Sat
Sea information:
- Servicio Meteorológíco Nacional
- Dolphin Fleet Management
- Passage Weather
Additional information:
- Dolphin Fleet Management
- Passage Weather
Area B
Wind information:
- Swell Watch
- Sailflow
Sea information:
- Sailflow
- Weather 365
Additional information:
- Passage Weather
- Dolphin Fleet Management
Area D
Wind information:
- Weatherzone
- Swell Watch
Sea information:
- Dirección Meteorológica de Chile
- Servicio Meteorológíco Nacional
- Swell Watch
Additional information:
- Passage Weather
- Dolphin Fleet Management
Area C
Antarctic
Wind information:
- Swell Watch
- Dolphin Fleet Management
- Weather 365
Sea information:
- Passage Weather
- Servicio Meteorológíco Nacional
Additional information:
- Dolphin Fleet Management
- Weather 365