FORECASTS OF MESOSCALE CYCLOGENETIC EVENTS OVER THE ANTARCTIC PENINSULA AND ITS IMPACT IN MARITIME OPERATIONS

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1. INTRODUCTION

The logistics operations in Antarctica are extremely dependent on the prevailing weather conditions - in particular depending on the wind variable - and this is due to the fact that cargo and personnel movements, from and to the ships that act as a logistic bridge, are made through small boats and/ or helicopters. Currently in Antarctica there are more than 40 permanent bases and dame number of transitory bases or camps that are occupied during the austral summer for scientific research purposes.

In the interior of the Antarctic continent surface winds show almost constant direction indicating that the flow is mostly controlled by the local topography from the katabatic forcing instead of the synoptic scale contribution. While in the Antarctic Peninsula, particularly in the northern portion, is one of the areas with the highest number of cyclogenetic events in this continent, being these events the most severe and damaging to logistic and scientific activities. In particular, the north of the Antarctic Peninsula is a region where permanent and transitory bases are concentrated, as well as summer shelters and camps, and of course it must be considered the increasingly growing tourist activity (Simmonds et al, 2002).

According to Carrasco et al (2003), the highest percentage of deep cyclonic systems occurs in the Bellingshausen Sea, associated with frequent convective instability and coinciding with the regions of more intense katabatic winds that bring cold air and the consequent thermal contrast over the sea. Furthermore, the authors establish that sub-synoptic scale cyclonic activity can occur throughout the year at all latitudes and longitudes around the Antarctic continent.

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They can form and develop near the continental coastline, on ice shelves, on and near the northern edge of the sea ice zone, and over ice-free Southern Ocean.

Mesoscale cyclogenesis is associated with areas of warm and/or cold air advection, low-level baroclinicity, and cyclonic vorticity as a result of the stretching mechanism. Subsequent enhancement depends on support from this structure at higher levels (Carrasco and Bromwich 1993; Turner et al. 1993; Heinemann 1996; Bromwich et al. 2003).

Regarding the extension of these mesoscale systems, most authors agree that, near the Antarctic Peninsula, the average diameter is about 370 km on the Bellingshausen and Weddell Seas (Carrasco et al 2003); dominant diameter range from 300 to 399 km (Turner et al 1996); average diameter of 354 km from examination of IR satellite images in the Peninsula region (Carleton and Song 1997); and according to Turner and Thomas (1994), the vast majority of vortices have a diameter of less than 500 km, with very few observed systems in the 500-1000 km range.

Hines et al (2000) state that obtaining accurate representations of synoptic structure in the high latitudes of the Southern Hemisphere is limited by a variety of obstacles, including data gaps and communication problems associated with long distances, auroral effects and satellite coverage. Extreme weather events and strong topographic and thermal contrasts also create unique difficulties in building reliable analyzes in the Antarctic region.

Forecasts produced for Antarctica are not as accurate as in the rest of the world (Bourke 1996), despite the increasing amount of data available from networks of Automatic Weather Stations and satellite observation systems. All this since the amount of data observed in the Antarctic continent is still limited and there are communication problems for these data to be supplied to the analysis centers during operational times.

Likewise, the inconveniences of the models in fully representing the complex topography of Antarctica and the effect and variability in its extension of the sea ice field are added (Turner et al 1996).

The main forcing factors are the advection of cold air from the Antarctic continent, the presence of an axis of trough and cyclonic vorticity at different levels of the atmosphere and the topographic effect of the South Shetland Islands.

One of the factors for the generation of mesoscale systems is the zones of thermal contrast that are generated in the coastal region of the Antarctic between a very cold air from the Antarctic continent and the relatively higher maritime temperatures. It's for this reason that the anticyclonic circulation can contain favorable conditions for the development of these cyclones when it advances over the north of the Peninsula.

In this work, is intention to analyze cases of mesoscale cyclogenetic events, the predominant factors for their generation and deepening. The case studies were selected because they had a high impact on logistics activities in the South Shetland Islands, as they were not predicted based on the analysis of the GFS model.

In addition, the comparison of numerical weather models (GFS vs. AMPS WRF) is carried out to establish in each case which one of these bests represents the formation of small-scale cyclones.

2. DATA AND METHODOLOGY

In this paper, cases of mesoscale cyclones and the ability of two numerical weather forecasts models to identify these processes 24 hours in advance are studied. The main difference between the two models used is that one is of a Global scale while the other is a specific Mesoscale Model for Antarctica. The cases mentioned correspond to cyclogenetic events that occurred in the northern region of the Antarctic Peninsula, on the South Shetland Islands and vicinities (Figure 1). This extended abstract shows the case of January 16, 2015.

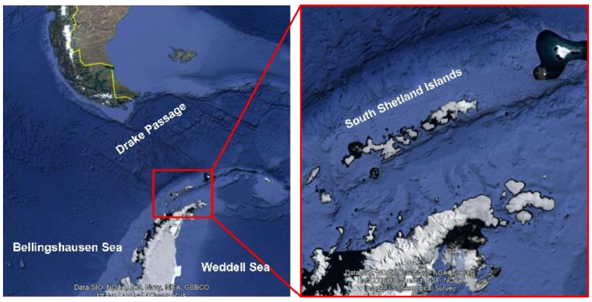

Figure 1: Region of interest in the vicinities of South Shetland Islands.

The study of these cases corresponds to different situations experienced by one of the authors on board the ship A.R.A. "CANAL BEAGLE" (LOCB, by its Call Sign) of the Argentine Navy during the Summer Antarctic Campaigns.

As in situ information, the weather data observed correspond to the meteorological station on board LOCB. The ship has a Vantage Pro2 Wireless Automatic Station of the DAVIS INSTRUMENTS brand, with wind, temperature, humidity and atmospheric pressure sensors. At the time of the measurements, all the instruments were calibrated and verified by the Nautical Enlistment Department of the Argentine Naval Hydrographic Service.

The first of the mentioned models is the Global Forecast System (GFS), which is a numerical global weather prediction system developed by the National Centers for Environmental Prediction (NCEP). The GFS model is a coupled model, made up of four separate models (an atmosphere model, an ocean model, a land/soil model, and a sea ice model), to provide an accurate output of meteorological conditions.

The GFS is a global spectral model (GSM) with spherical harmonic functions whose current horizontal resolution is approximately 13 km. In the vertical, the model is divided into 127 vertical layers. It produces forecast output every hour for the first 120 hours, then every 3 hours for days 5-16 (https://www.emc.ncep.noaa.gov). At the time of the events this paper refers, the horizontal resolution used for GFS forecast was 25 km.

The second numerical weather forecasting model is specific to the Antarctic continent. The Antarctic Mesoscale Prediction System (AMPS) is an experimental numerical weather prediction development whose initial goal was to support the United States Antarctic Program, international Antarctic science and activities. The AMPS model generates its numerical output from the Weather Research and Forecasting model and the Prediction Across Scales (MPAS) model with twice-daily forecasts covering Antarctica.

The AMPS uses the polar version of the Weather Research and Forecasting model, called the Polar WRF, developed and maintained primarily by the Polar Meteorology Group at Ohio University's Byrd Polar and Climate Research Center. (Bromwich et al. 2013).

AMPS model outputs are made at the National Center for Atmospheric Research (NCAR) twice a day, at 0000 and 1200 UTC. AMPS has different domains available with horizontal resolutions ranging from 24 km for the entire southern hemisphere to 0.89 km for Ross Island. In all cases, the model has 60 pressure levels. For this work, the selected domains where those with horizontal resolution of 10 km and 3 km, corresponding to the Antarctic Peninsula.

For the development of this study, the 1200 UTC outputs of the GFS and AMPS models were used for basic variables that allows to identify, or not, the development of mesocyclones systems, at different vertical levels. In this extended abstract only SLP and wind forecast fields are shown. The information from the numerical models corresponds to 24 prior to the occurrence of the events, considering that these are the tools a forecaster could use for the prediction of mesoscale cyclones.

It is also important to notice that access to satellite communications and satellite internet is extremely limited in Antarctica and especially onboard logistics and research ships. This could be because of limited satellite coverage in some austral areas or because the costs of these communications.

3. RESULTS

On January 16, 2015, after 9 a.m. local time, in the vicinity of Half Moon Island (figure 2), there was a rapid increase in the wind intensity, going from average speeds of around 8 kt to sustained intensities of 28 kt with gusts of 35 kt, with heavy snowfall and reduced visibility. This phenomenon developed for a period of 4 to 5 hours, ending completely at 2:00 p.m. with a rapid decrease in the wind to 8 knots, improving general conditions and slightly cloudy skies. The wind direction was from the WSW in the early morning and until 9 a.m. local time, with rotation to the ESE at the time of the abrupt increase in the wind.

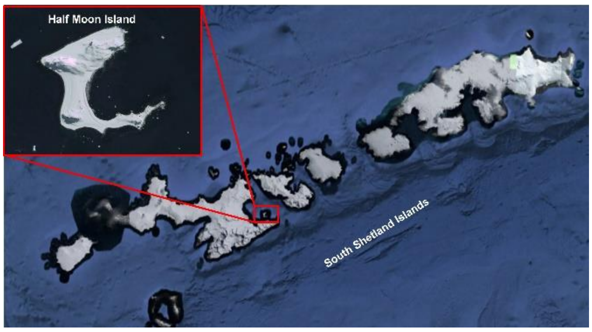

Figure 2: South Shetland Islands and zoom of Half Moon Island.

The main effect of this severe weather event was that the LOCB vessel had to make an emergency departure due to not being able to maintain anchorage; suspending the resupply tasks of Cámara Station and leaving two boats grounded on the beach due to the speed with which the event unfolded. During the navigation of the ship, waiting for better conditions to return to the area of operations, the sea conditions were affected with a significant increase in the waves height due to the effect of the intense wind.

The forecast for the operations of the 16th was made on the 15th with the GFS output of 12Z with a horizontal resolution of 25 km, and the surface charts are shown in Figure 3. It should be noted that the model outputs of 12Z were not updated due to poor internet connection availability.

According to this available information, the conditions on Half Moon Island would be winds of variable direction with intensity around 5 kt, with dominance of an area with large opening of isobars and entry of an anticyclonic cell from the west with an expected increase in atmospheric pressure.

By analyzing the outputs for the same day from the AMPS model in the 10 km (not shown in this extended abstract) and 3 km resolution domains, it can be determined what forecast might been the best option for forecasting with the most accurate and available information.

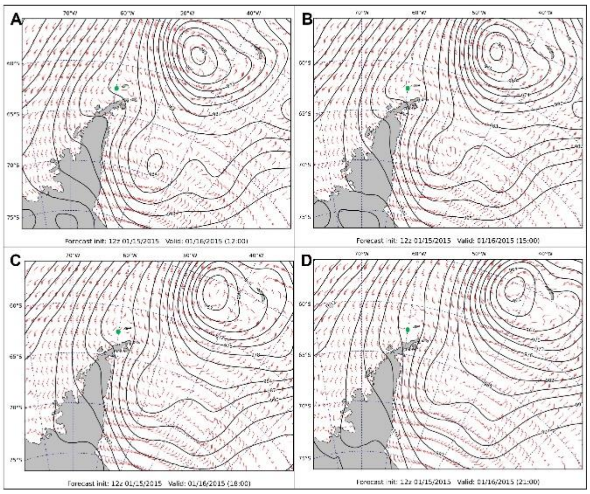

Figure 3: Sea level pressure and wind for January 16, 2015. GFS 25 km Forecast issued at 12Z of January 15, valid for 0900 local time (A), 1200 local time (B) 1500 local time (C) and 1800 local time (D). The green dot represents the approximate position of Half Moon Island.

Figure 4 shows the sea level pressure and wind fields for the AMPS model with 3 km resolution for the Antarctic Peninsula. While in the AMPS 10 km forecast charts no significant differences are observed with the GFS charts, with the 3 km resolution maps it can be seen that the isobars close from 9 a.m. local time and this closed low pressure system is sustained until 6 p.m. local time.

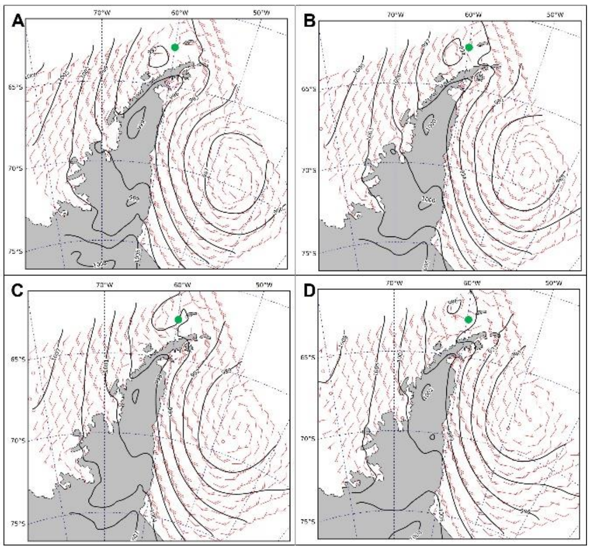

Figure 4: Sea level pressure and wind for January 16, 2015. AMPS 3 km Forecast issued at 12Z of January 15, valid for 0900 local time (A), 1200 local time (B) 1500 local time (C) and 1800 local time (D). The green dot represents the approximate position of Half Moon Island.

In any case, the intensity of the wind remains at low intensity values, but the direction of the wind in the area of Half Moon Island is coincident with that measured by LOCB.

4. DISCUSSION

Fast-developing, high-severity mesoscale events obstruct ship logistics and scientific operations in Antarctica. Being able to count on an accurate forecast for these cases is of fundamental importance since it allows tasks to be diagrammed and accidents to be avoided.

The tools for forecasters on ships are limited because access to information sources on the Internet is only through satellite communications, which are expensive and often have poor coverage depending on the region.

The motivation to study these cases where the forecasts were made with a global model such as GFS instead of one with mesoscale characteristics such as AMPS, with better horizontal resolution and with response to this type of cyclogenetic events, is based on the fact that it is essential give the AMPS model greater visibility, not only among forecasters but also in the maritime community.

Each year the entry of tourist ships to the Antarctic Peninsula is greater, with cruises that must overcome the difficulties that weather faces them and with tight schedules to comply. Most of these vessels do not have forecasters on board and purchase forecast chart through automatic delivery services. These products do not have the benefits offered by the best resolutions of the AMPS and can generate cases like the ones presented here.

It is important to note that the ways of accessing the AMPS charts are not entirely friendly for observation and analysis, particularly when the internet connection is limited and intermittent.

This sort of studies will allow Antarctic meteorologists to use the best possible tools in the elaboration of their forecasts, in an environment where meteorological factors are fundamental for the development of logistic and scientific activities and the information available - both due to the low density of weather stations as well as the difficulty of accessing satellite information from ships.

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