SEMAPHORE

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THE EFFECTS OF WEATHER ON RAN OPERATIONS IN THE SOUTHERN OCEAN

Over the last ten years, the Royal Australian Navy (RAN) has been required to deploy into or near the Southern Ocean in support of fisheries patrols and the rescue of yachtsmen taking part in round the world yacht races.[1] Present trends indicate a further increase in the prevalence of illegal fishing of Patagonian Toothfish, with the potential for continued illegal fishing within the Heard Island and MacDonald Island Exclusive Economic Zones (EEZ).

Operations in or near the Southern Ocean present RAN personnel with the challenge of operating in some of the most severe weather conditions in the world. To mitigate the risk associated with these conditions, RAN Meteorological and Oceanographic (METOC) personnel provide weather forecasting advice to the command during such operations. Furthermore, when warships deploy in or near the Southern Ocean a METOC officer is embarked to provide meteorological advice.

The climatology of the Southern Ocean changes seasonally due to the annual heating and cooling cycle of sub-Antarctic waters. These temperature variations give rise to two distinct seasons. Winter extends from June to October and summer from December to May, with short transition periods between. Figure 1 shows the relevant synoptic pressure patterns.

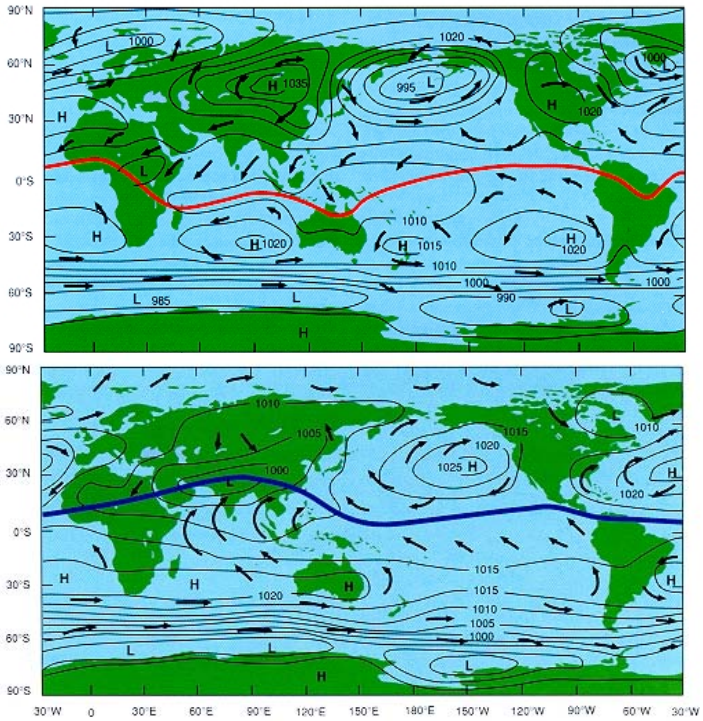

Figure 1: Summer (top) and winter (bottom) mean positions of pressure systems (RAN)

An area of low pressure known as the Antarctic Circumpolar Trough lies between 55°S and 70°S. This system tends to generate particularly violent weather events because, unlike the Northern Hemisphere, there is a continuous corridor of open ocean, which allows circumpolar winds to create very high sea states. Frequent depressions, which vary in intensity and track, move generally west to east at 20 to 30 knots in the vicinity of this trough. They transit with their associated fronts at a frequency of three to five days with a twelve to twenty four hour gap between systems when a weak ridge of relatively high pressure affects the weather. In general, the weather is highly variable and frequently wet and stormy, with cloudy skies and poor visibility for much of the time. Consistent strong to gale force southwest to northwest winds blow year round causing high seas with wave swell heights of 3.5 metres or more for 50 percent of the time, particularly in the band between 45°S and 60°S. The most noticeable seasonal change in the Southern Ocean is sea ice, which extends to between 55°S and 60°S in September or October, before retreating towards the coast of Antarctica in February and March.

Winds. Winds north of 60°S flow primarily from the westerly quadrant throughout the year. Due to the mobility of the weather systems, blocking patterns, which bring long periods of constant winds and weather in the lower latitudes, are rare. Mean winds show little variability from month to month, averaging between 19 and 24 knots over open ocean. However, maximum winds in excess of 80 knots are recorded each month. The variation in percentage of gale force winds does vary significantly between winter and summer, however strong winds above 23 knots (Force 6 on the Beaufort Scale) are persistent for more than 50 percent of the time throughout the year. One minor but significant seasonal variation is the increase in much lighter northeasterly winds in summer in the vicinity of Heard Island. Gales are frequent at most of the islands of the Southern Ocean with gusts of gale force being recorded at Kerguelen Island almost daily throughout the year. During the passage of a cold front, the strongest winds blow from the northwest with a heavy overcast sky and a falling barometer, followed by southwest winds, astern the front, as the barometer rises and the sky clears. Near the coasts of Antarctica and Heard Island, katabatic winds generated by sinking cold air over glaciers or radiative cooling can occur suddenly without warning and gust to over 100 knots.

High winds and associated turbulence adversely affect flying operations at winds of near gale force. Small boat operations become very hazardous in strong winds due to the associated sea state. Furthermore, periods of high winds are nearly always associated with periods of poor visibility due to precipitation and blowing spray.

Sea Conditions. Sea conditions in the Southern Ocean average rough to very rough throughout the year, but the swell regime shows some seasonal variation in the more northern latitudes. In this area, mean swells in winter are 4 to 5 metres, reducing to 2 to 3 metres in summer, as the severe swell generating storms become less frequent and the circumpolar trough of low pressure moves further south. Extreme conditions of sea and swell combining to over 12

metres occur in all months, with expected maximum wave heights occurring in most of the westerly wind region. At times extreme wave heights will rise to over 35 metres in the Indian Ocean sector and such waves have been encountered near the Kerguelen Islands in winter. The worst sea conditions are likely to occur between 50°S and 60°S in the Pacific Ocean sector and between 40°S and 50°S in the Indian Ocean and Atlantic Ocean sectors. High sea and swell caused by the persistent and often gale force winds centred around 50°S are a major concern for even large ships.

High combined sea and swell will abort replenishment at sea and small boat operations and the associated pitch and roll may leave flight decks out of limits for helicopter operations. Moreover, ship handling of frigate-sized ships becomes hazardous in waves over 8 metres and a ship's speed of advance and ability to manoeuvre can be reduced significantly in such conditions.

Weather. In the vicinity of 50°S, the weather shows seasonal variability with the summer bringing more rain, snow, cloud and fog due to increased moisture from the higher sea surface temperatures. Days with precipitation increase from near 20 per month during winter to over 25 per month during summer. Precipitation that falls south of 50°S is usually frozen with exceptions to this in northwesterly flows ahead of cold fronts.

Typically, the weather associated with the passage of a cold front includes overcast conditions, with drizzle and rain/sleet ahead, clearing to partly cloudy with scattered snow showers astern. Weather associated with the following weak ridge of high pressure is initially scattered snow showers, whilst in a southwest flow, it changes to fog/mist/sleet/drizzle as the next front approaches. Occasionally, these weak ridges lessen the sea state allowing an opportunity for some naval operations. Warm fronts are generally associated with overcast skies, light continuous rain and areas of fog. Fogs, which are brief and unusual in winter (1 day/month) become more common and longer in summer (3 to 4 days/month). They are most common in a northerly airflow and in the vicinity of the Antarctic Convergence Zone, which separates the very cold, and less saline, Antarctic water to the south from the warmer, more saline ocean to the north.

Operationally, a ship's navigation radar is a valuable tool for detecting approaching squall lines and fronts and for monitoring precipitation in the immediate area. Radar is particularly useful in the final decision-making process for operations such as the launch of an aircraft or small boat.

Visibility. Visibility outside of precipitation is generally excellent in the cold, dry winter air and poor in the warmer, moister summer air. Heavy rain and thick drizzle with very low clouds reduce visibility quite frequently in the more northern latitudes. Extensive sea spray during periods where winds are stronger than gale force also creates visibility problems. There are many occasions when the visibility falls below the fog limit of 1000 metres in rain, sleet and snow.

Safe navigation, safe aircraft operations and effective air surveillance by land based aircraft all rely on timely and accurate forecasts of visibility. However, at present, visibility can only be inferred from prognostic and forecast charts.

Temperatures. During February there is a gradual decrease of temperature with increasing latitude from 10°C at 45°S to 0°C at 60-65°S. The average August temperature over the same latitudes varies from 8°C to -12°C. For personnel with exposed skin the phenomenon of wind chill can cause severe frostbite. The wind chill factor reduces air temperature substantially, causing significant physical discomfort and greater chances of hypothermia.

Sea Surface Temperatures. Variations of 2°C or 3°C above or below the average may occur at any time of the year. Even greater differences are recorded near the Convergence Zone area where the sea surface temperature drops to zero. Sea survival times are very short for personnel without proper survival suits.

Icing. Though there are a number of types of icing that occur in the Southern Ocean, clear ice, freezing rain and freezing spray are of particular significance to naval operations. **Clear ice** can form when moisture in the air freezes onto either a ship superstructure or an airframe. This maritime version of black ice is difficult to detect and remove. Clear ice is rare and most commonly associated with outbreaks of extremely cold air over relatively warm water. This will be most common in the autumn transition. Ice can also accumulate due to precipitation falling as rain or drizzle and freezing when it hits the deck of a ship or an airframe. Icing due to **freezing rain** is possible in all seasons, with a maximum in summer when moisture levels are higher. It quickly builds up on airframes increasing the all-up weight of aircraft; furthermore, in the absence of anti-icing measures it quickly collects on the leading edge of rotor blades reducing lift and aerodynamic stability. In the Northern Hemisphere, there have been a number of civil and military helicopter crashes associated with this phenomenon and all aircrews operating in such conditions take forecasts of freezing rain very seriously. The final type is ice formed by **freezing spray**. The rate of accretion depends on the water and ambient air temperatures and the wind speed, as they determine the droplet size. Superstructure ice accretion can occur in all seasons, being most common in the south of the area in winter. In extreme winter conditions, icing rates of 4 to 6mm per hour are likely. Ice accumulation on ships' hulls and superstructures can create a significant rise in the vessel's centre of gravity causing the vessel to become top heavy. Ship designs for vessels working south of the Convergence Zone need to account for the possible increase in weight to the superstructure. Most warship designs already have significant weight high in the superstructure due to the need to place radars and communications equipment as high as possible.

Sea Ice. Sea ice occurs in a belt around the Antarctic continent. In winter it extends a considerable distance north into the Southern Ocean, with about 85 percent of the sea ice that surrounds Antarctica melting during the southern summer. The Antarctic sea ice reaches its maximum extent in late September or early October, when its northern limit extends as far north as 54°S in the Atlantic Ocean sector, 56°S in the Indian Ocean sector and 60°S in the Pacific sector of the Southern Ocean. The least extent is reached during late February/early March. At this time ice conditions show considerable variability, however, the sea ice is mostly restricted to the immediate coastline of the continent, with some regions remaining ice-free.

The Directorate of Oceanography and Meteorology provides expertise to mitigate the risks of Southern Ocean operations. The Fleet Weather and Oceanography Centre (FWOC) provides 24 hour forecasting support and routinely supplies numerical weather prediction model output, area wave and wind forecasts and Antarctic composite satellite pictures, which are interpreted by embarked METOC Teams to provide accurate aviation forecasts.

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[1] In 2000 the International Hydrographic Organisation delimited the waters within the Atlantic Convergence to create a fifth world ocean – the Southern Ocean – which extends from the coast of Antarctica north to 60°S, and is a circumpolar body of water encircling Antarctica, encompassing 360° longitude. Not all nations agree with these boundaries.