

Polynyas Offshore Ellsworth Land, West Antarctica

JORGE F. CARRASCO¹

SUMMARY

In situ collection of one-month meteorological infrared and visible satellite images at Patriot Hills during the 1996 Aurora Austral Campaign, showed the presence of two permanent polynyas offshore from Ellsworth Land. One of them was located in the Bellingshausen Sea area and the other one in the Amundsen Sea area. Their average sizes were $1.4 \times 10^5 \text{ km}^2$ and $2.5 \times 10^5 \text{ km}^2$, respectively. Simulated katabatic airflow reveals that the near surface winds, descending the coastal slope of Ellsworth Land, converge toward Robert English and Walgreen coasts and then continue on across the Bellingshausen and Amundsen Seas, respectively. This indicates that the katabatic drainage plays an important role in the formation and maintenance of the two observed polynyas.

Key word: katabatic winds, polynyas, sea-ice, meteorological satellite images

Polynyas en las costas de la Tierra de Ellsworth, Antártica Occidental

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RESUMEN

Un mes de imágenes infrarrojas y visibles coleccionadas en Patriot Hills durante la Campaña Aurora Austral 1996, mostraron la presencia permanente de dos polynyas en las costas de la Tierra de Ellsworth, una localizada en el Mar de Bellingshausen y la otra en el Mar de Amundsen. El tamaño promedio fue de $1.4 \times 10^5 \text{ km}^2$ y $2.5 \times 10^5 \text{ km}^2$, respectivamente. Simulación del flujo catabático revela que el viento superficial, que desciende por las laderas de la Tierra de Ellsworth, converge hacia las costas de Robert English y Walgreen y luego continúa a través de los mares de Bellingshausen y Amundsen respectivamente. Esto indica que el flujo catabático juega un rol importante en la formación y mantenimiento de las dos polynyas observadas.

Palabras claves: vientos catabáticos, polynyas, hielo marino, imágenes satelitales meteorológicas

INTRODUCTION

Polynyas are areas of combined open water and thin ice surrounded by sea ice and/or land ice, and they can be observed in the coastal areas of Antarctica during all seasons (Jacobs and Comiso 1989, Zwally *et al.* 1985). Their geographic distribution and short-term variability can be seen on infrared satellite images collected by polar/orbiting meteorological satellites. Because these features are much warmer than the adjacent ice, with a brightness temperature contrast of about 7° (Bromwich *et al.* 1993), they appear as dark tones on infrared images being clearly distinguishable during free-cloud days.

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Coastal polynyas interact with the atmosphere, ocean and sea ice playing important roles in the sea ice zone that surrounds Antarctica. Thus, the very large amount of ice that can form contributes to the growth of the ice further north from the coastal areas, while the rejected brine plays an important role in the formation of dense shelf water (Jacobs *et al.* 1985, Budd 1991). Also, because the ice surface insulates the ocean from the atmosphere, the sensible and latent heat fluxes between them primarily occur through the polynyas (and leads). Thus, heat losses from the ocean during winter are supplied by the freezing of seawater (Zwally *et al.* 1985). As the first explorers noted and later the satellite data confirmed, polynyas are the nuclei for the spring disintegration of sea ice by absorbing much more solar radiation than the surrounding ice surfaces (Jacobs and Comiso 1989). On the other hand, the excess heat storage in the oceanic surface layer during spring and summer retards sea ice formation during fall.

SATELLITE IMAGES ANALYSIS

The Chilean Air Force and the Chilean Antarctic Institute deployed a summer camp in the vicinity of Patriot Hills (80°18'S, 81°20'W; Fig. 1) between 21 November and 18 December 1996. During 25 days of the campaign a satellite receiver system (WeatherTrac) was collecting satellite images. At least 8 images were analyzed each day for meteorological purposes. Two recurrent polynyas were observed during the 1996 Aurora Austral Campaign (Fig. 1). One offshore Robert English Coast in the Bellingshausen Sea sector (Fig. 2) and the other offshore Walgreen Coast in the Amundsen Sea sector. These two polynyas have already been identified, for example, through the satellite passive-microwave analyses carried out by Gloersen *et al.* (1992, see also Romanov 1991).

An evaluation of these two polynyas was carried out during the 25-day period. Because the satellite receiver did not have the capability of making digital analysis, the northward extension and size of the polynya were directly estimated from the computer screen in degrees of latitude and longitude with an accuracy of about 0.3'. Only the above mentioned polynyas were clearly observed through the examination of the satellite images. Figure 3 shows the average size of two polynyas observed all the time that the area was without cloud obscuration during the campaign. Their average sizes were 1.4×10^5 km² in the Bellingshausen Sea sector and 2.5×10^5 km² in the Amundsen Sea sector.

DISCUSSION

Studies indicate that the size of the polynya is related to the surface wind regime and air temperature (Pease 1987, Knapp 1972, Cavalieri and Martin 1985, Kurtz and Bromwich 1985). A significant increment of the wind speed is associated with an enlargement of the polynya (Bromwich and Geer 1991, Bromwich *et al.* 1994). On the other hand, for a given wind speed, colder (warmer) air produces smaller (larger) polynya (Pease 1987). Unfortunately, wind data around the area of interest is not available in order to analyze the windfield and wind behavior and its effect on the polynyas. Only for a few years the Antarctic Program of the U.S. deployed an automatic weather platform at Siple Station (75°90'S, 83°92'W; see Stearns *et al.* 1993). The average wind for November and December shows a prevailing south-southeast direction (constancy ~ 0.73) and wind speed of 3 m s⁻¹, which does not concur with the geostrophic wind direction derived from the climatological sea-level pressure charts for these months. This suggests that the wind regime at Siple Station is the result of an additional force(s) apart from the pressure gradient force.

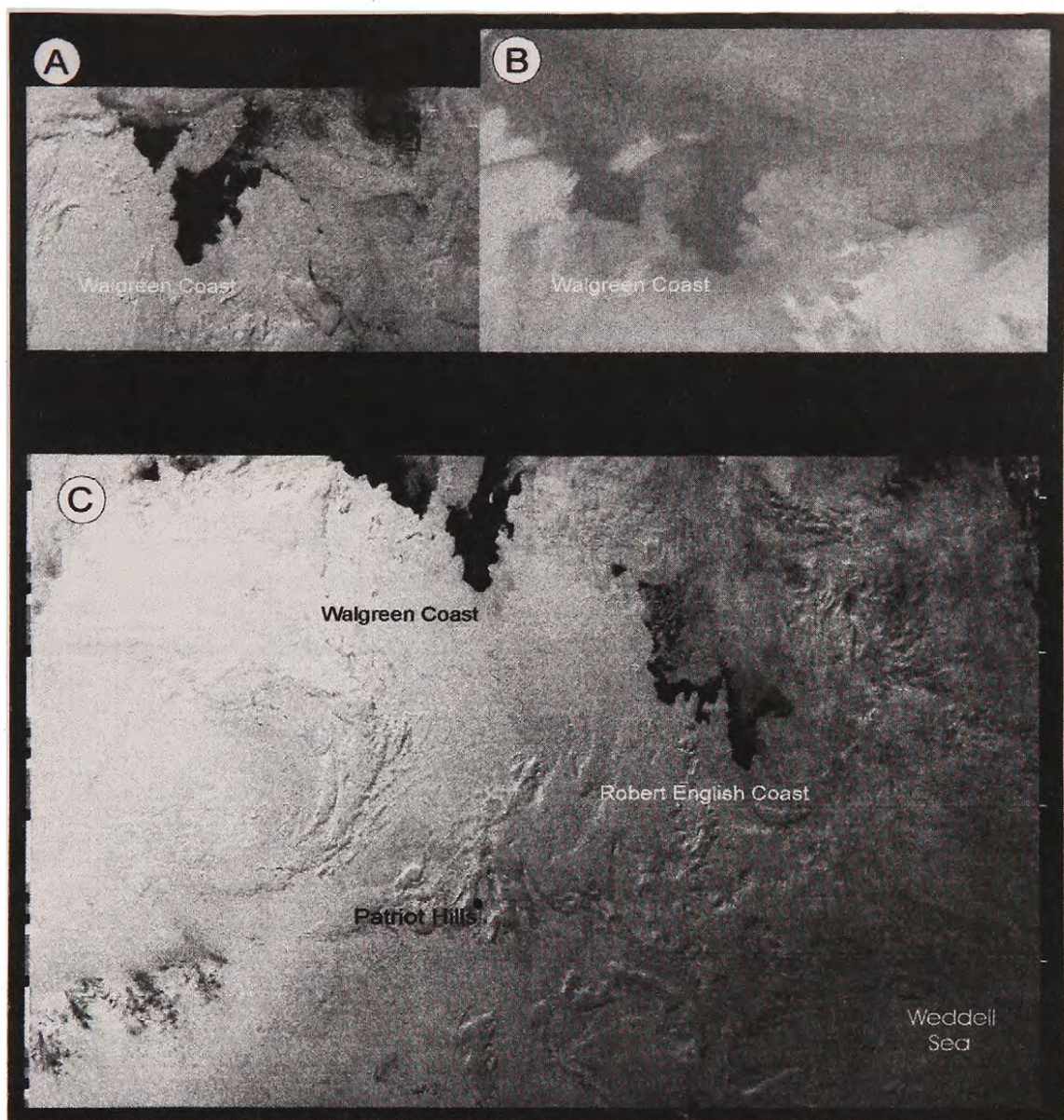


Fig.1.- Example of visible (A and C) and infrared (B) satellite images showing polynyas offshore Robert English and Walgreen coasts.

The monthly mean sea-level pressure analyses for November and December 1996 (Australian Bureau of Meteorology) resolved a low pressure center to the west of the Antarctic Peninsula. The derived geostrophic surface wind circulation from the analyses suggests that the two polynyas observed offshore Ellsworth Land were, on average, affected by northeasterly and easterly winds. This implies that there were not geostrophic winds support for development and maintenance of the two observed polynyas.

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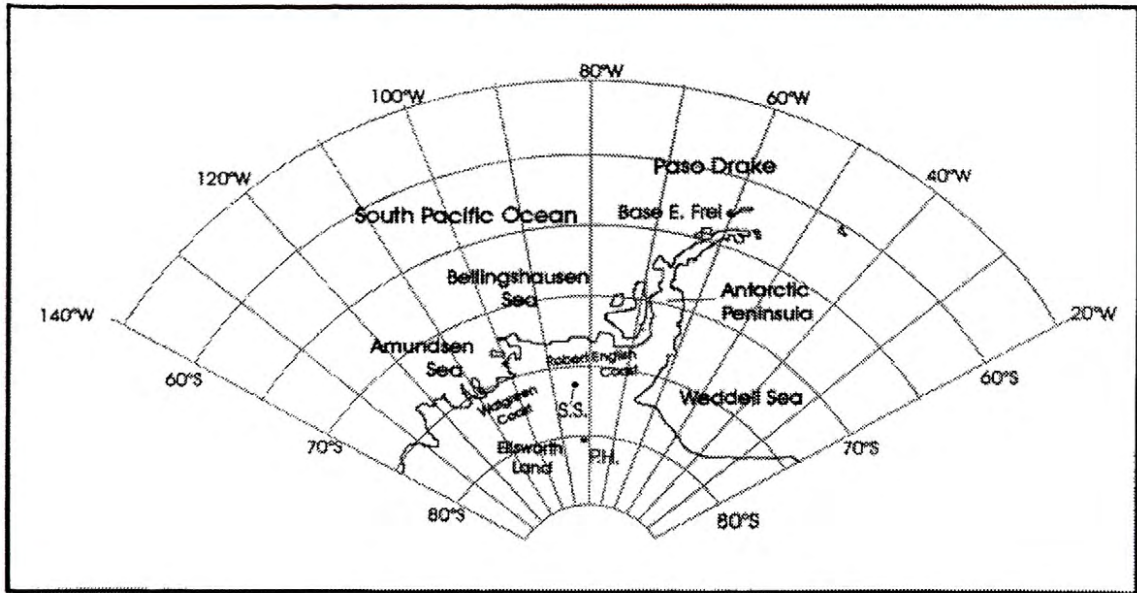


Fig. 2.- Location map of the Ellsworth Land and surrounding areas. SS identifies Siple Station.

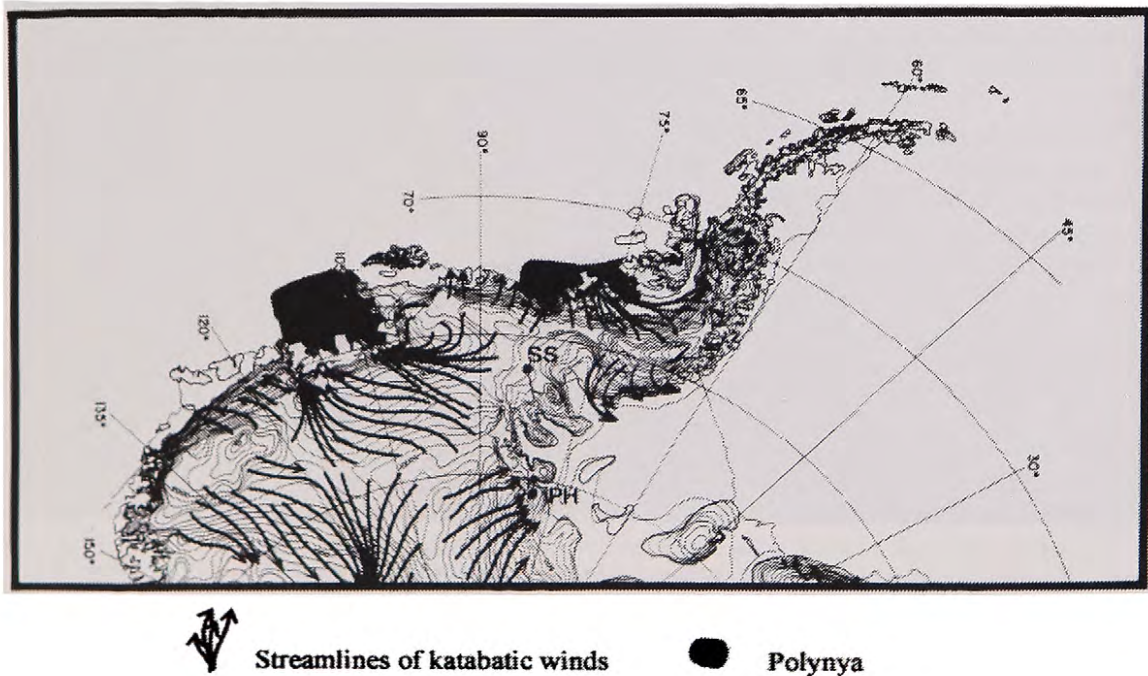


Fig. 3.- Integrated depiction of the katabatic streamlines and the prominent polynyas observed offshore Ellsworth Land (Partial reproduction from Parish and Bromwich 1987). Streamlines in Robert English Coast were obtained from the 20-km numerical model result. PH and SS denote Patriot Hills and Siple Station, respectively. Thin lines are elevation contours in 100-m increments.

A numerical model that simulates the winter (and summer) katabatic wind drainage over Antarctica (for details of the model see Parish and Waight 1987) showed that the katabatic near-surface airflow converge toward several coastal areas around the continent (Parish and Bromwich 1987, 1991). One of the confluence zone was resolved in the Walgreen Coast area (Fig. 3). This was confirmed by a subsequent 3-dimensional numerical model with 20-km horizontal resolution, which in addition revealed another confluence zone located offshore Robert English Coast in the Bellingshausen Sea area (see Fig. 3). These two confluence zones concur with the location of the two permanent polynyas identified near these areas and that were observed during the campaign. Therefore, it is suggested that offshore katabatic airflow is an important forcing mechanism, rather than geostrophic winds, to form and maintain the above polynyas by preventing sea ice from consolidating in the bays. Blocking action by the surrounding topography can be an additional factor that prevents existing sea ice to move toward the Robert English and Walgreen coasts.

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