10 February 2004

At the bottom of the globe, darkness permeates the harsh landscape for months at a time. Just a glimpse of this quiet desolation makes one wonder what could possibly survive there. But as summer slowly approaches and the sun brings light and warmth to the sea around Antarctica, the vast expanse of winter ice that blanketed the sea slowly weakens. Long, ragged cracks wind their way through the ice, revealing areas of open water.

At first glance these open water areas, known as polynyas, might seem too bleak to harbor life. But during brief periods each year the biological productivity increases, meaning that organisms within the polynya produce organic matter at a higher rate. More nutrients in the water means a greater ability to support a variety of organisms.

This image of the Oates and Pennell Coasts of Antarctica, acquired by MODIS on December 3, 2002, shows several large polynyas. Click here for more information.

"When you think of polynyas as a concentrated food source for larger organisms, then it becomes clear how important they are."

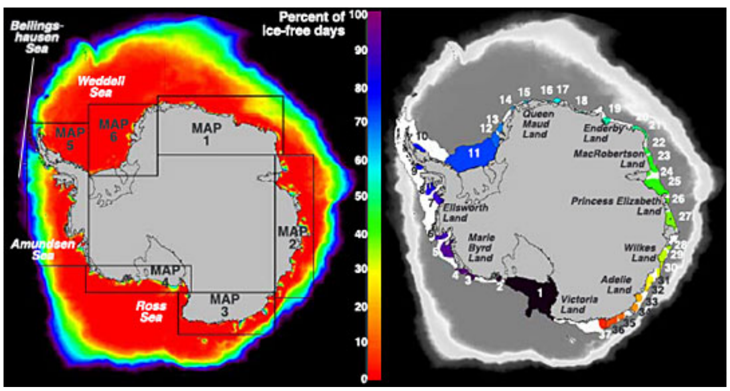
Few studies have looked at the biology of these open water patches until recently. Aided by high-resolution satellite data, Kevin Arrigo conducted a comprehensive inventory of the polynyas surrounding the coast of Antarctica. The five-year study showed that during a typical year, many polynyas are not very productive, while others are teeming with life for just a few short months, providing a feeding ground for larger animals like the Adéile penguin.

“We didn’t have any information about how productive these polynyas were, so our motivation was to find out what fraction of the Southern Ocean production the polynyas are responsible for,” said Arrigo, biologist and assistant professor of geophysics at Stanford University. Arrigo also hoped to learn more about the relationship between polynya productivity and the overall food chain.

Polynyas support the growth and accumulation of plantlike organisms, called phytoplankton, which consist mostly of algae and bacteria and are the foundation of the marine food chain. Ocean surface waters where polynyas occur are the first areas in polar regions to be exposed to increasing springtime solar radiation, either because they lack ice cover or because their weak ice cover is more susceptible to early breakup. This exposure to the sun, in turn, promotes the livelihood of phytoplankton and other marine organisms.

Understanding the distribution of polynyas around Antarctica is one of the first steps toward identifying biological habitats in the region, according to Arrigo. “We knew there were quite a few polynyas, but no one has ever tried to quantify their productivity before,” he said.

To locate the Antarctic polynyas, Arrigo and a team of researchers analyzed data from the Special Sensor Microwave/Imager (SSM/I), a passive microwave sensor that measures the amount of radiation emitted by the Earth’s surface, known as brightness temperatures. Brightness temperatures are a gauge of emissivity, or the ability of water or ice to emit radiation at microwave frequencies. The data, archived at the National Snow and Ice Data Center (NSIDC) DAAC, were collected from June 1997 to May 2002.

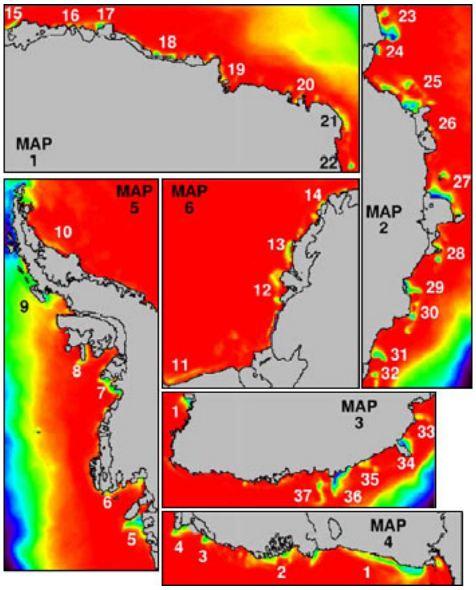


These Antarctica maps show the locations of the 37 polynyas from Arrigo’s study. In the map on the left, the colored region indicates the percentage of days from June to October, 1997 to 2001, that a particular pixel was ice-free. Coastal areas with low winter sea ice were identified as polynyas. In the map on the right, the different colors represent groups of pixels assigned to a particular polynya. (Maps courtesy of Kevin R. Arrigo)

According to Arrigo, the coastal polynyas of Antarctica have never been studied in detail before, largely because of the region’s persistent cloudiness, which prevents satellites from “seeing” the surface. But passive-microwave sensors such as SSM/I measure the Earth’s emitted microwave energy that easily penetrates clouds. The SSM/I data enabled the researchers to study the sea ice in great detail, even in cloudy conditions.

Using these data, Arrigo identified 37 coastal polynyas around Antarctica. The largest, located in the Ross Sea, was 396,500 square kilometers (153,090 square miles), and the smallest, located in the West Lazarev Sea, was 1,040 square kilometers (401 square miles).

The team also obtained Sea-viewing Wide Field-of-view Sensor (SeaWiFS) ocean color data for the same time period from the Goddard Earth Sciences (GES) DAAC. Ocean color data distinguish variations in ocean color caused by chlorophyll and other plant pigments that harvest light for photosynthesis. The SeaWiFS data identify the areas of greatest biological productivity, based on the amount of light absorbed by phytoplankton chlorophyll.



These expanded views of the false-color map, above at left, show in greater detail the sizes and distribution of Antarctic coastal polynyas. At one extreme, red areas were completely covered with ice during the winter months, and at the other extreme, black areas remained ice-free all winter. (Maps courtesy of Kevin R. Arrigo)

"Some of the polynyas were not as productive as I would have expected," said Arrigo. "The Southern Ocean as a whole is not considered a very biologically productive place, and some of the polynyas are even less productive than the average for the Southern Ocean, which surprised me because we tend to think of these areas as little 'hot spots' of productivity."

But, Arrigo explained, polynyas can indeed be hot spots during a short period of time during the Southern Hemisphere summer, typically December to February each year. This is when phytoplankton concentrations are highest, providing nutrients for a wide variety of larger organisms. "Total productivity may not be that high when averaged over an entire year, but when concentrated in a brief time span, it's significant. When you think of polynyas as a concentrated food source for larger organisms, then it becomes clear how important they are," said Arrigo.

In fact, Arrigo found that Adéile penguins depend on these nutrient-rich polynyas throughout much of their life. Besides providing a concentrated food source, the polynyas affect the penguin's reproductive schedule. "The penguins time their cycles with when the food is available," said Arrigo. "Adéile and Emperor penguins have their chicks in the middle of the winter, so when spring comes, they will have food for the chicks."

Adéile (or Adelie) penguins depend on nutrient-rich polynyas. (Image courtesy of NASA)

Arrigo also learned that polynya development is not constant. "We usually think of polynyas as persistent, recurrent features that happen in the same place year after year, but in fact, they are incredibly variable. The amount of open water within the 37 Antarctic polynyas varies by more than two orders of magnitude both during the winter and summer."

Next, Arrigo plans to study the polynyas on an individual basis, with a longer time series of satellite imagery, including data from the Coastal Zone Color Scanner (CZCS) sensor from the 1970s. He hopes to use this detailed information about each polynya to evaluate patterns of Adéile penguin colonies and focus on their food sources, and to learn why some regions are more nutrient-rich than others. "We've looked at polynyas and productivity in a broad sense, so now I'd like to start taking the polynyas apart and study individual colonies of organisms," he said.

References:

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Link:

Antarctic penguins thrive in ocean oases. Accessed January 9, 2003.

For more information:
National Snow and Ice Data Center DAAC
GES Earth Sciences DAAC