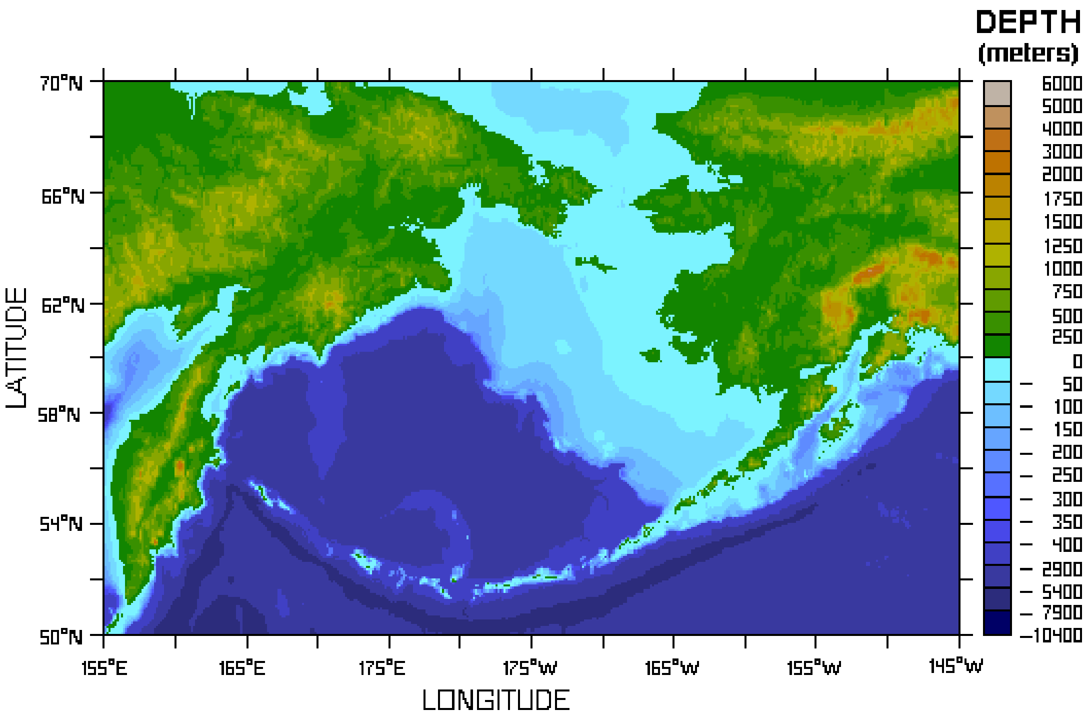
SCIENCE FOCUS: The Bering Sea

Seasons and Cycles of Change



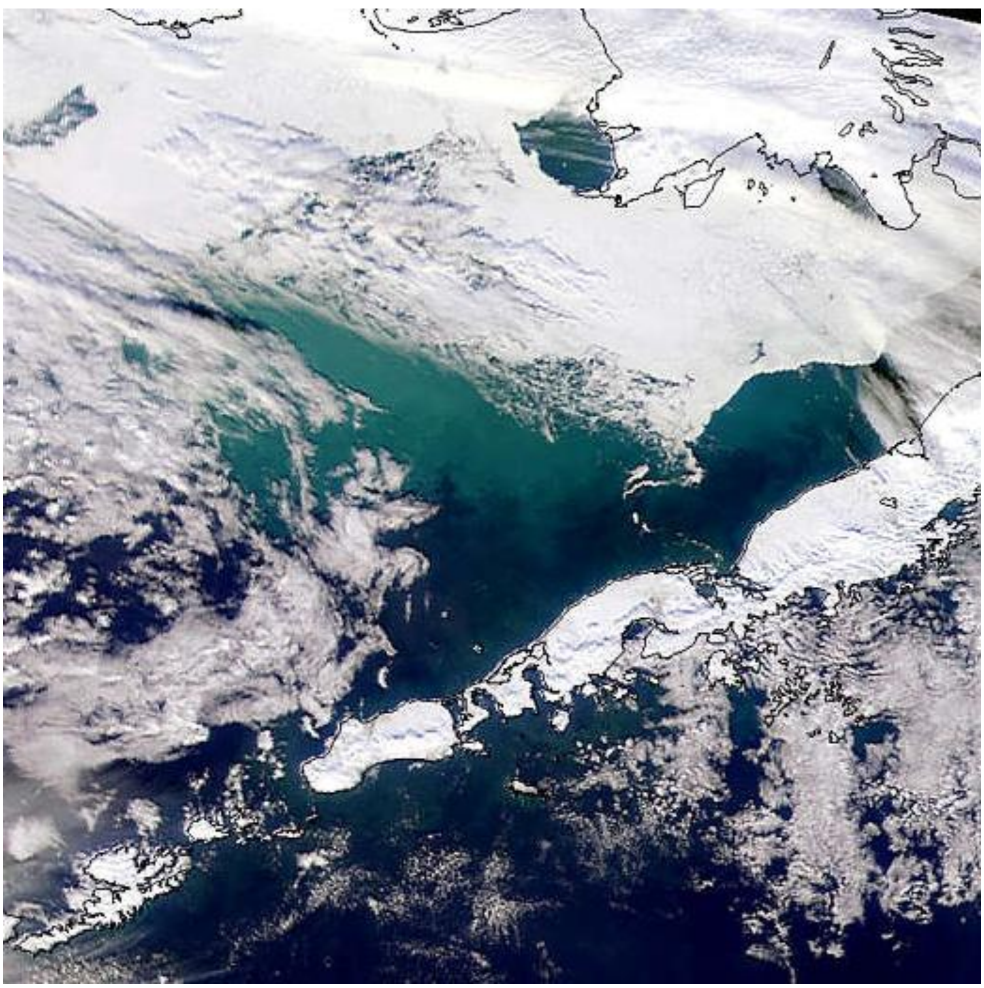
Bathymetric map of the Bering Sea. The Chukchi Sea is the northern part of the Bering Sea, lying north and south of the Bering Strait, the narrow passage of water between Alaska and Siberia. (Image courtesy of NOAA Pacific Marine Environmental Laboratory)

In September of 1997, SeaWiFS began its remote-sensing mission. As the first images were returned, one of the initial remarkable images was of a bright blue light emanating from the Bering Sea. The SeaWiFS Project realized quickly that they were observing from space a phenomenon that had just been noted earlier that summer: a strangely persistent and widespread bloom of the coccolithophorid species *Emiliania huxleyi (E. hux.).* (The *Science Focus*! article "More than Meets the Eye" also mentions these particular phytoplankton species.)

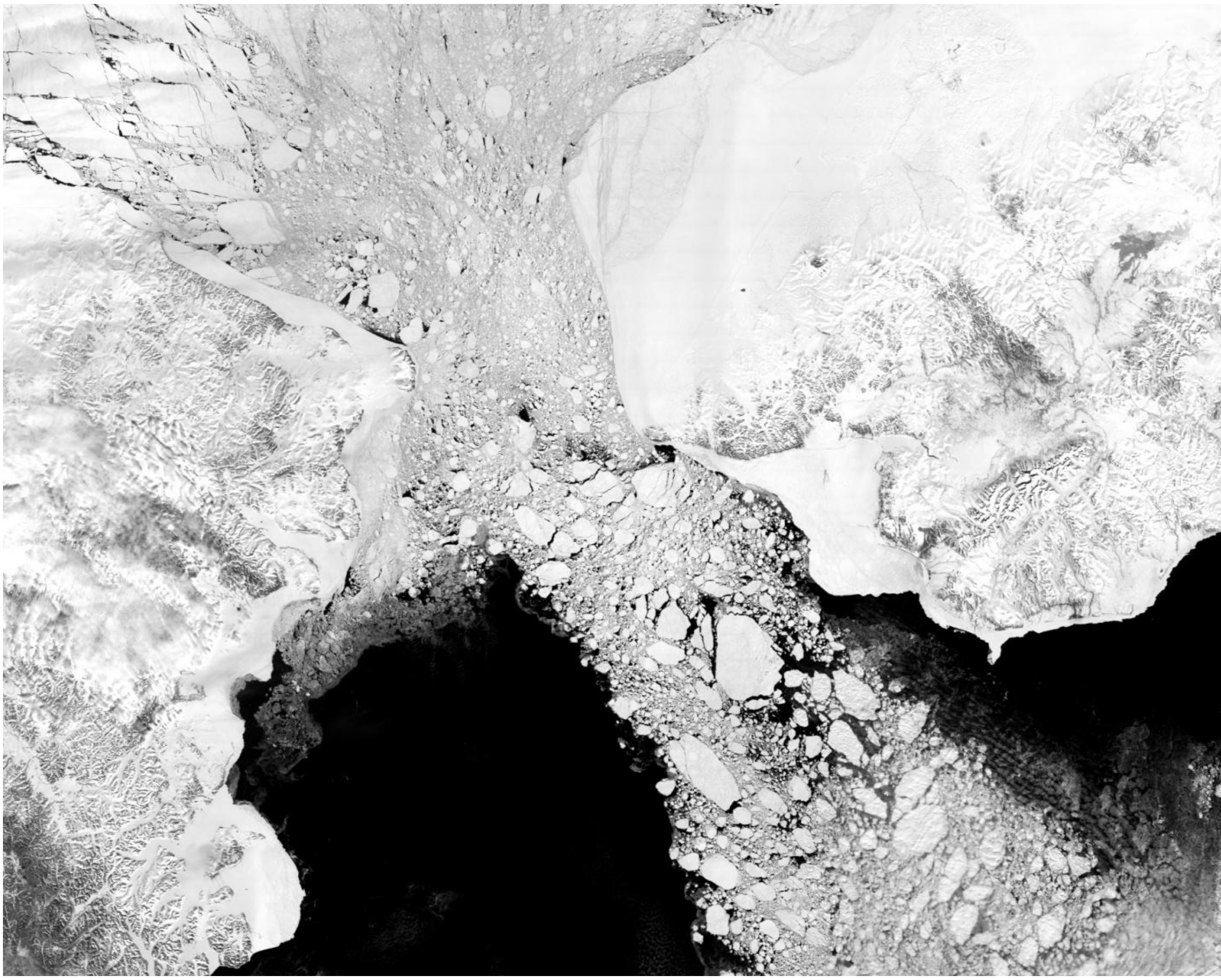
E. hux. blooms are usually short-lived, but the bloom in the Bering Sea had first been observed that summer, and it persisted into October. It reappeared the following spring and summer. This phenomenon indicated that significant changes were occurring in the Bering Sea – changes that were related to larger alterations in the Pacific Ocean and the global climate.

In order to determine what was happening in the Bering Sea in 1997, researchers first had to examine the characteristics and dynamics of this important body of water. The Bering Sea is a vital region for numerous organisms and is extraordinarily productive. The persistent coccolithophorid bloom affected almost every level of the Bering Sea ecosystem in some way.

The basics: The Bering Sea is a polar sea, lying north of the Aleutian Island chain, between the state of Alaska and the northeastern section of Siberia, and bounded to the southwest by the northern Kamchatka Peninsula. The total area of the Bering Sea is approximately three million square kilometers. Despite the fact that it is a polar sea, much of the Bering Sea remains free of ice through the winter. SeaWiFS and MODIS images demonstrate the appearance of the Bering Sea in the winter and early spring (when it can be glimpsed through the clouds).



The image above is a SeaWiFS image of the southeastern Bering Sea acquired on February 8, 2000, showing the sea ice edge north of the Alaska Peninsula and Unimak Island.

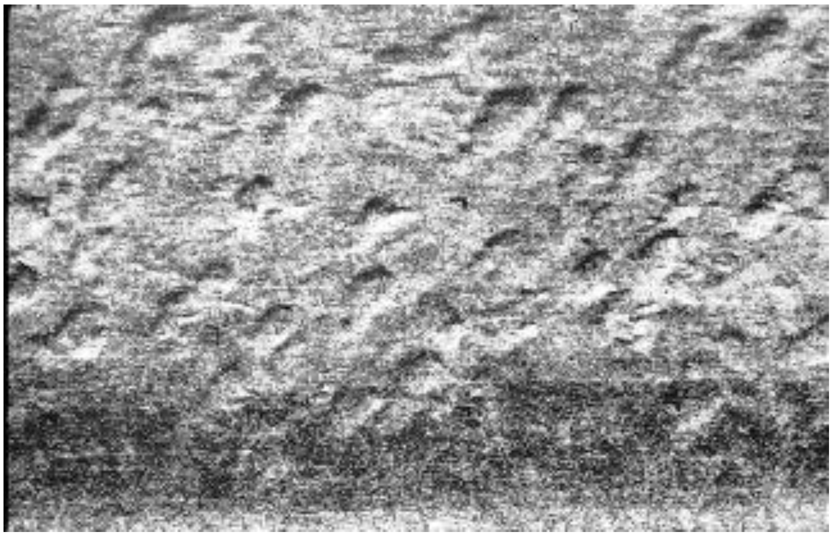


The image above is a MODIS image of sea ice in the Bering Strait, acquired on May 7, 2000.

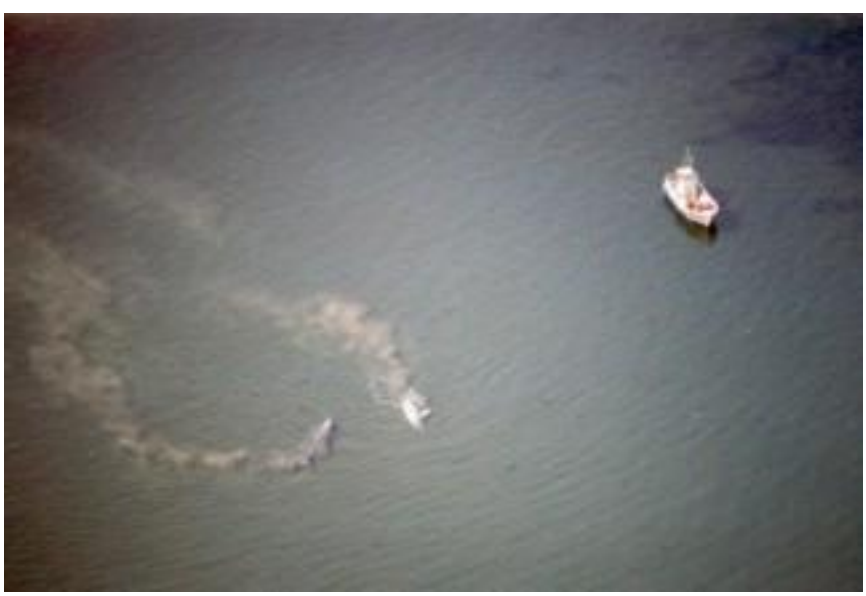
The *bathymetry* (bottom depth) of the Bering Sea is divided into two major regions: the shallow shelf region lying to the eastern side, which is less than 150 meters deep, and the deep region, which reaches to more than 3500 meters. (See the map on the first page.) The shallow shelf region, particularly in the northern Chukchi Sea, is vital to many of the important biological elements of the Bering Sea ecosystem.

The polar nature of the Bering Sea means that its seasonal cycle is simplified compared to the four seasons of the temperate zone: in winter the Bering Sea is minimally productive, due to the cold temperatures and the small amount of daylight. As the length of daylight increases in spring, the Bering Sea explodes in productivity, and numerous animals and birds migrate to the region to gorge on the spring banquet of phytoplankton, zooplankton, and fish. In fact, the Bering Sea supports about 80% of the entire seabird population in the United States.

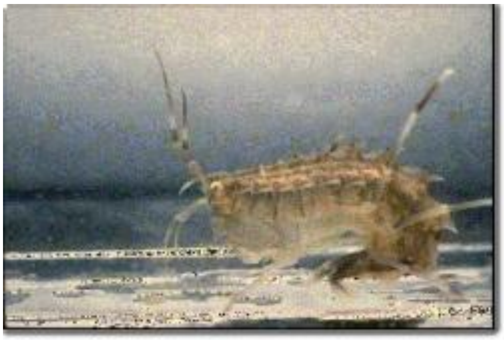
Likely the most noteworthy migrant to the Bering Sea is the California gray whale, which migrates to the Bering Sea from Baja California every spring. The gray whales feed primarily on bottom-dwelling organisms called amphipods, and even ram into the sea bottom to scoop them up. The whales use their baleen to extract the amphipods from the mud and seawater. Feeding in Alaskan waters allows the whales to migrate back to Baja California and provides the females with the nutritional resources to raise calves in their winter habitat.



Sonar image of whale feeding pits in the Chukchi Sea.
Source: United States Geological Survey



Photograph of gray whales during bottom feeding activities.
Source: Erin Carruthers

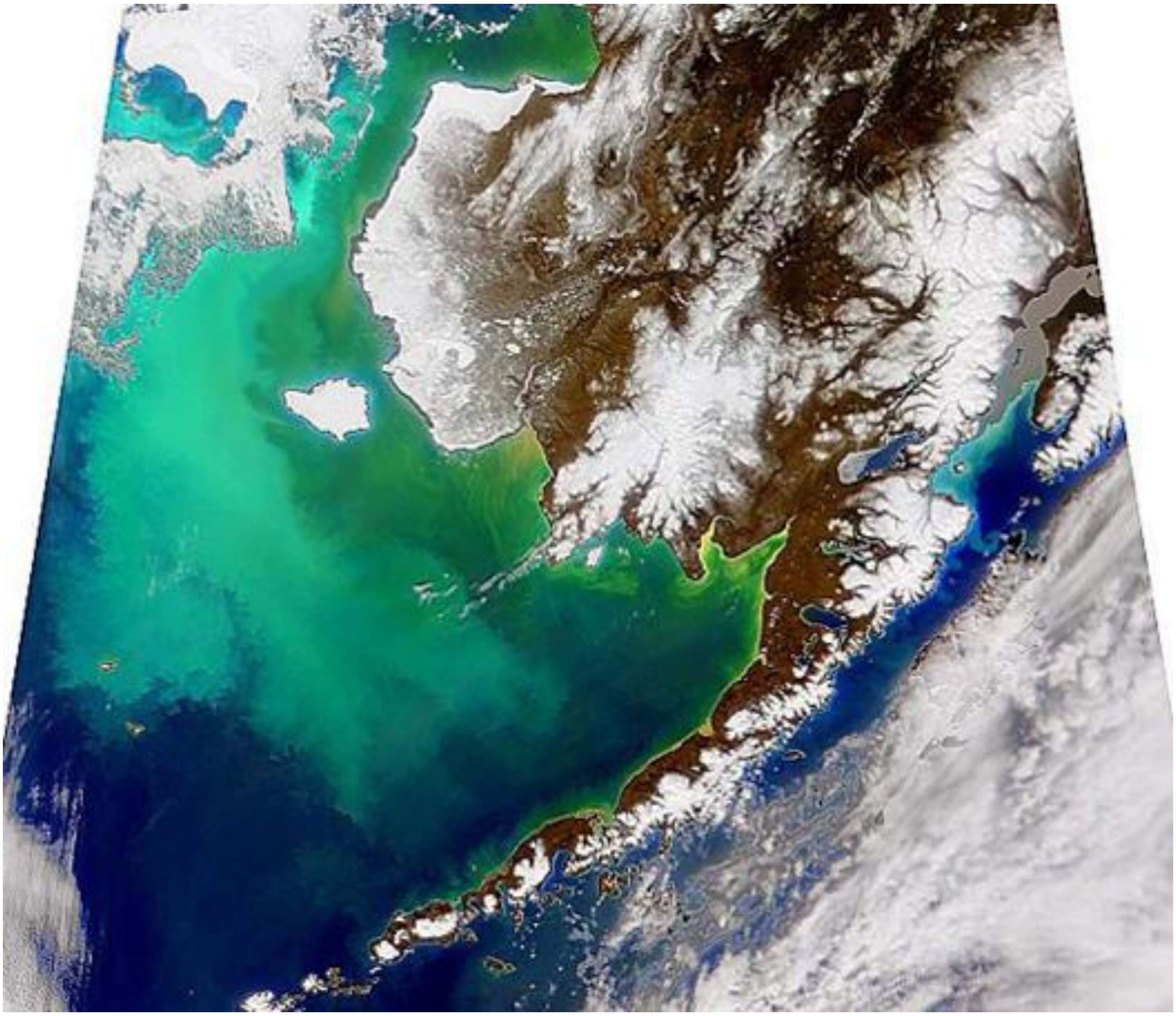


Arctic benthic amphipod *Gammaracanthus loricatus*. Source: Fisheries and Oceans Canada

The changes: In 1977, an event which oceanographers refer to as a *regime shift* took place in the North Pacific Ocean and the Bering Sea. The term refers to the state of the Pacific Decadal Oscillation (PDO), which describes the climate (winds, temperatures, rainfall patterns) of the North Pacific Region. Putting it simply, the PDO can be in either a warm or cold phase. In 1977, there was a fairly abrupt shift from the cold phase to the warm phase, which resulted in warmer sea surface temperatures (SST) in the Gulf of Alaska and the Bering Sea.

One of the main effects of the warmer SST was a suppression of phytoplankton productivity, which led to reductions in shrimp, crab, and populations of smelt fish, such as capelin. (Other fish populations, particularly cod and pollock, increased at the same time.) The reduced numbers of smelt may have led to declines in the numbers of Steller's sea lions and harbor seals, which were one of the main food items for killer whales. The declining numbers of sea lions and seals apparently led to increased predation on sea otters by killer whales, resulting in a drastic reduction in the population of Alaskan sea otters of more than 70%. These low sea otter numbers allowed sea urchins (a major part of the sea otter diet) to proliferate. Sea urchins feed on kelp, so the kelp forests in the Gulf of Alaska and the Bering Sea were overgrazed, which affected all of the organisms associated with the kelp, including seabirds like puffins and kittiwakes. (Note: The Gulf of Alaska and Bering Sea fisheries are the largest in the United States, and some researchers also blame overfishing for the decline in marine mammal populations. Because of the climatic regime shift, it is difficult to conclusively determine the primary cause.)

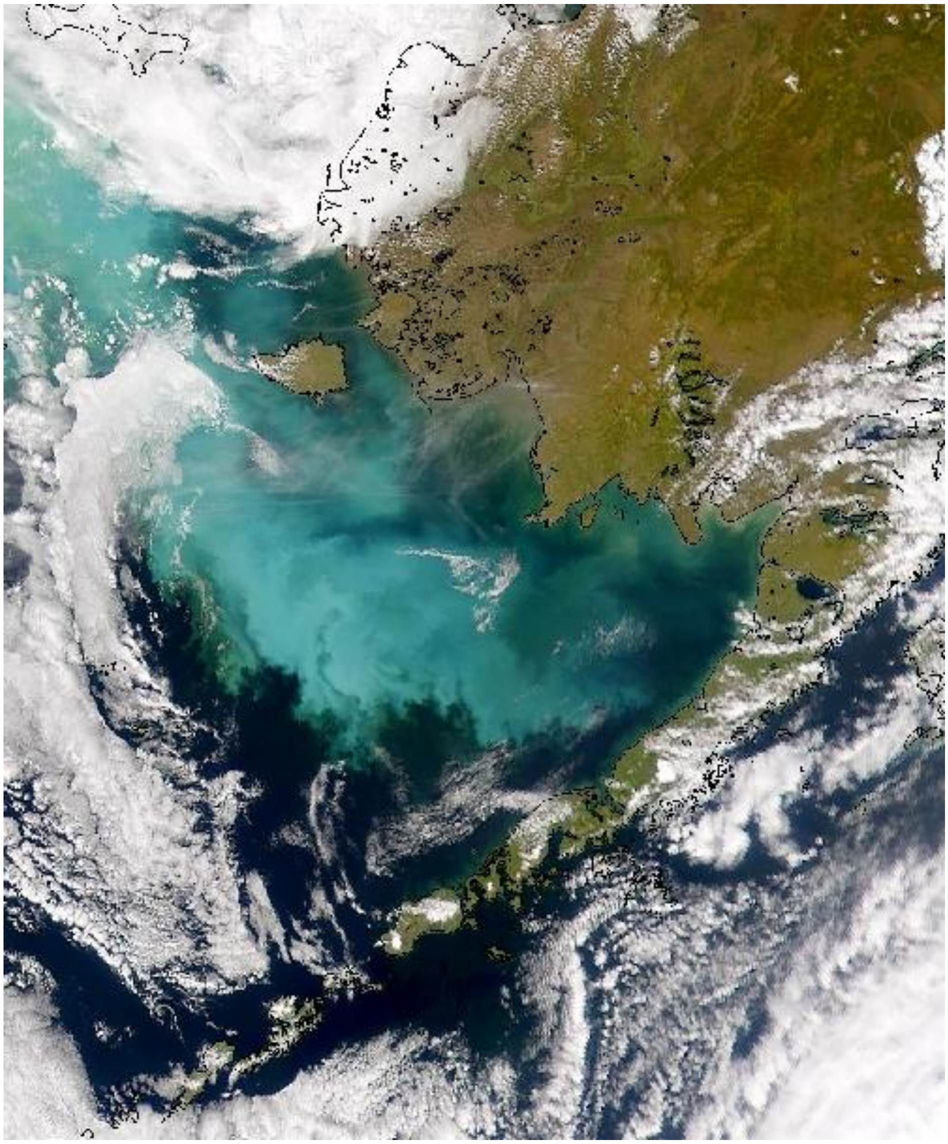
Shift forward to 1997. Due to the combined effects of two other climate cycles, the Arctic Oscillation (AO) and the more familiar El Niño Southern Oscillation (ENSO), winds over the Bering Sea calmed and cloud cover was reduced. The increased amount of sunlight caused the water temperature to rise more than 2 degrees Centigrade above normal, while at the same time the calm wind conditions did not stir the water column sufficiently to bring nutrients to the surface. These conditions stymied the growth of the normal diatom blooms in the Bering Sea and were quite amenable to the growth of *E. hux.*



SeaWiFS image of the Bering Sea acquired on April 25, 1998.

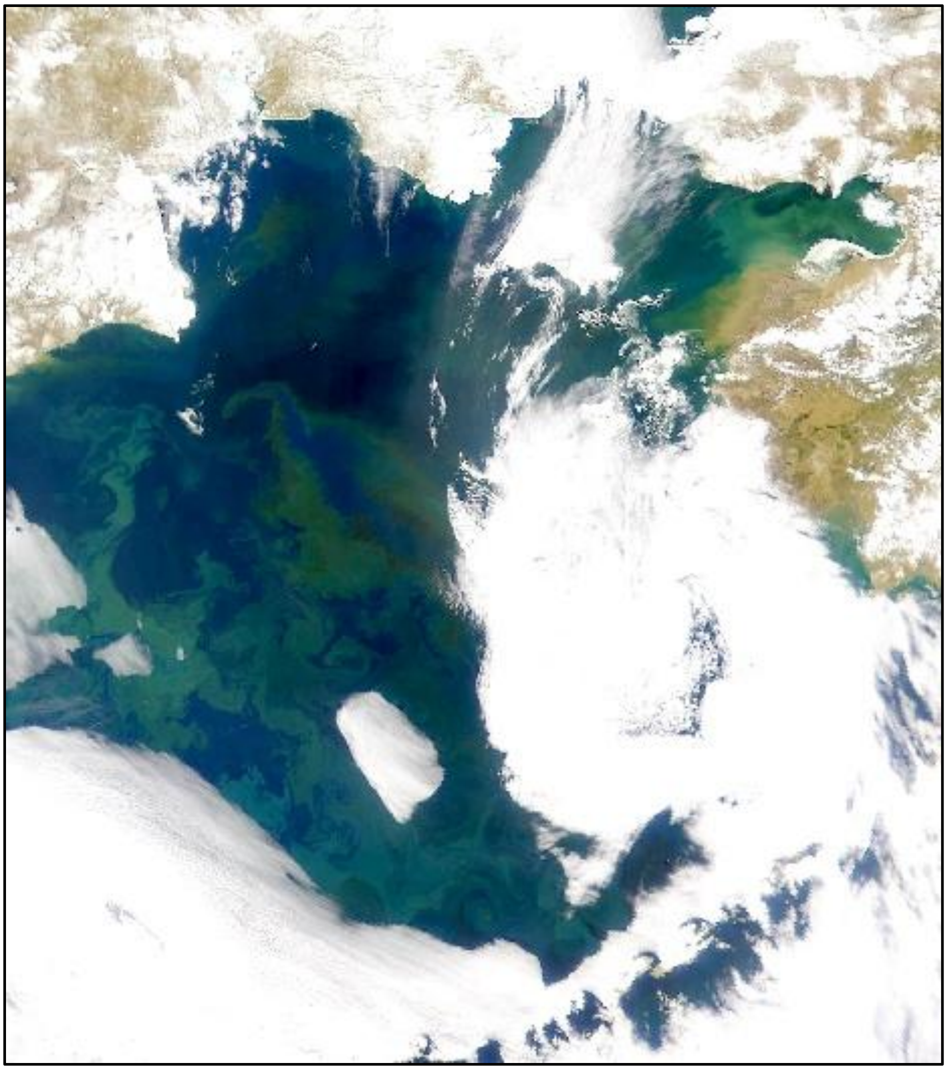
The turquoise waters of a coccolithophore bloom are highly visible from space, and they can appear in patterns that are remarkably beautiful to the human eye. But for fish and birds, the situation is markedly different. Because the coccolithophore bloom reflects light, primary production is suppressed. The effects move up the food chain, reducing the populations of zooplankton, particularly euphausiids (closely related to the krill found in Antarctic waters). Birds accustomed to gorging on euphausiids, notably shearwaters, starved to death in enormous numbers.

Observations indicated that the birds avoided the bright turquoise waters of the coccolithophore bloom, perhaps because they could not see their accustomed prey in the water. Other observations indicate that salmon migration patterns were also altered by the presence of the bloom.



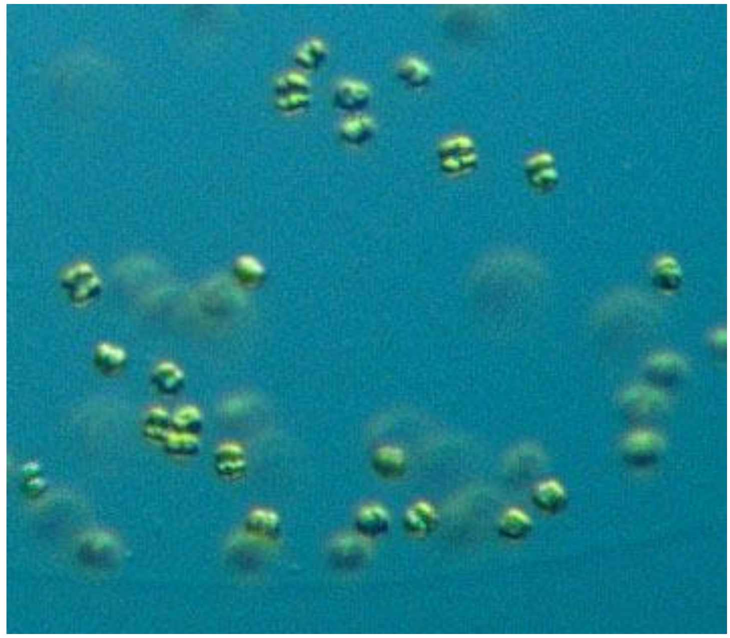
SeaWiFS image acquired on September 15, 2000. It is not clear if the blue-white waters seen here represent living or dead cells of *E. hux*., as their reflective properties do not change significantly when the cells die.

What happened next: SeaWiFS images, such as the one shown above, recorded the return of the turquoise waters characteristic of coccolithophore blooms to the Bering Sea in the spring of 1998, 1999, and 2000. The bloom was clearly active in 1998, but the situation was not as clear in 1999, and the blooms in 2000 were not as intense or widespread, though they were seen into September. There were also alarming reports about increased numbers of gray whale carcasses washing up on the shores of California and Baja California. Some researchers speculated that the gray whales may have been dying during their southern migration due to reduced feeding success in the Bering Sea.



SeaWiFS image acquired on June 7, 2001, showing several blooms in the Bering Sea. The brightness and contrast of this image have been altered to emphasize the bloom features.

In the spring of 2001, SeaWiFS saw different colors in the Bering Sea (above): swirls of dark green and reddish green, indicating that something other than coccolithophores was blooming. A report from John Cullen of Dalhousie University (Halifax, Nova Scotia) described the results of a research cruise on the NOAA R/V *Ronald H. Brown*, which sampled the blooms and found the species *Phaeocystis*, as well as chain diatom species, and surface chlorophyll concentrations ranging from 3 to 15 milligrams per cubic meter of seawater (which is a high concentration). This report, and the absence of a coccolithophore bloom, indicated that the anomalous conditions that fostered the explosion of *E. hux.* were likely subsiding. There are other possible indicators that the PDO may have shifted back to a cold phase in 1998, which was one potential cause of reduced rainfall in the Pacific Northwest at this time.



(Left) Microphotograph of chain diatoms, courtesy of F.J.R. Taylor.

(Right) *Phaeocystis*. Image from The mystery of the foam on the sea shore by Wim van Egmond.

Large blooms of *Phaeocystis* can lead to the formation of noxious foams which can accumulate on nearby coastal areas, such as the one shown here. Source: European Commission.

ACKNOWLEDGMENT
The National Oceanic and Atmospheric Administration's Pacific Marine Environmental Laboratory (PMEL) "North Pacific Ocean Theme Page" (see link below) provided an invaluable starting point for Bering Sea information. We thank the late Dr. Glenn Cota of Old Dominion University for a review of this article.

Links

Bering Sea General
- NOAA/PMEL North Pacific Ocean Theme Page
- North Pacific Ecosystem Metadatabase
- The Bering Sea Ecosystem (National Academy Press) This book is available as a PDF document.

Bering Sea, Arctic sea ice, climate change
- 20th Century Changes of the Arctic Sea Ice Cover (2003)
- Arctic Sea Ice Decline (Weather Underground)

Bering Sea ecosystem changes
- Aleutian Islands: A Wilderness Ecosystem in Collapse
- Bering Climate (NOAA)

Pacific Decadal Oscillation
- NASA Jet Propulsion Laboratory Pacific Decadal Oscillation Page
- The Pacific Decadal Oscillation (PDO) (JISAO, University of Washington)
- A Pacific interdecadal climate oscillation with impacts on salmon production (paper discusses reversals and their impacts)
- Senate testimony regarding salmon stocks and ocean conditions