ECOSYSTEM INDICATORS AND TRENDS USED BY FOCI

Fisheries-Oceanography Coordinated Investigations (FOCI) comprises physical and biological oceanographers, atmospheric scientists, and fisheries biologists from federal and academic institutions. FOCI studies the ecosystems of the North Pacific Ocean and Bering Sea with the goals of improving understanding of ecosystem dynamics and applying that understanding to aid management of marine resources.

In their endeavors, FOCI's scientists employ a number of climate, weather, and ocean indices and trends to help describe and ascribe the status of the ecosystem to various patterns or regimes. This document presents some of these with respect to current (2002) conditions. An important finding is that interannual variability can be a dominating portion of ecosystem signals. This means that from year to year, ecosystem characteristics can be very different from those expected during a given climate regime.

NORTH PACIFIC REGION – 2002

El Niño conditions are developing in the tropical Pacific Ocean (Fig. 1) and are forecast to persist for the rest of this year and into 2003. Effects of the still developing El Niño are

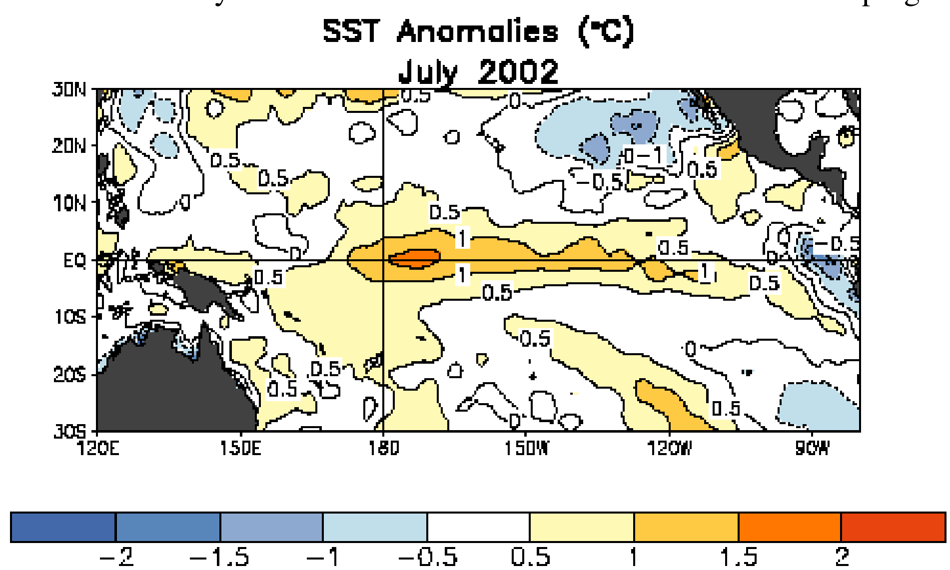


Figure 1. Sea surface temperature (SST) anomalies during July 2002. Departures from average (anomalies) are computed based on the 1971-2000 base period means. Units are °C. (Analysis based on NOAA/PMEL TAO buoy data, NOAA/AVHRR satellite data and ships of opportunity.)

transmitted to the North Pacific Ocean by atmospheric teleconnections and oceanic waves traveling northward along the west coast of North America. Because La Niña conditions in 1998-1999 cooled the coastal waters of the Pacific Northwest and Gulf of Alaska, the massive ocean warming that was associated with the 1997-1998 El Niño may not happen. Compare the sea surface temperature (SST) maps for May 2001 and May 2002 (Fig. 2) to see the persistence of the coastal cooling. For June 2002, the entire North Pacific basin and coastal regions experienced negative SST anomalies. The temporal origin of this cool coastal pattern is shown

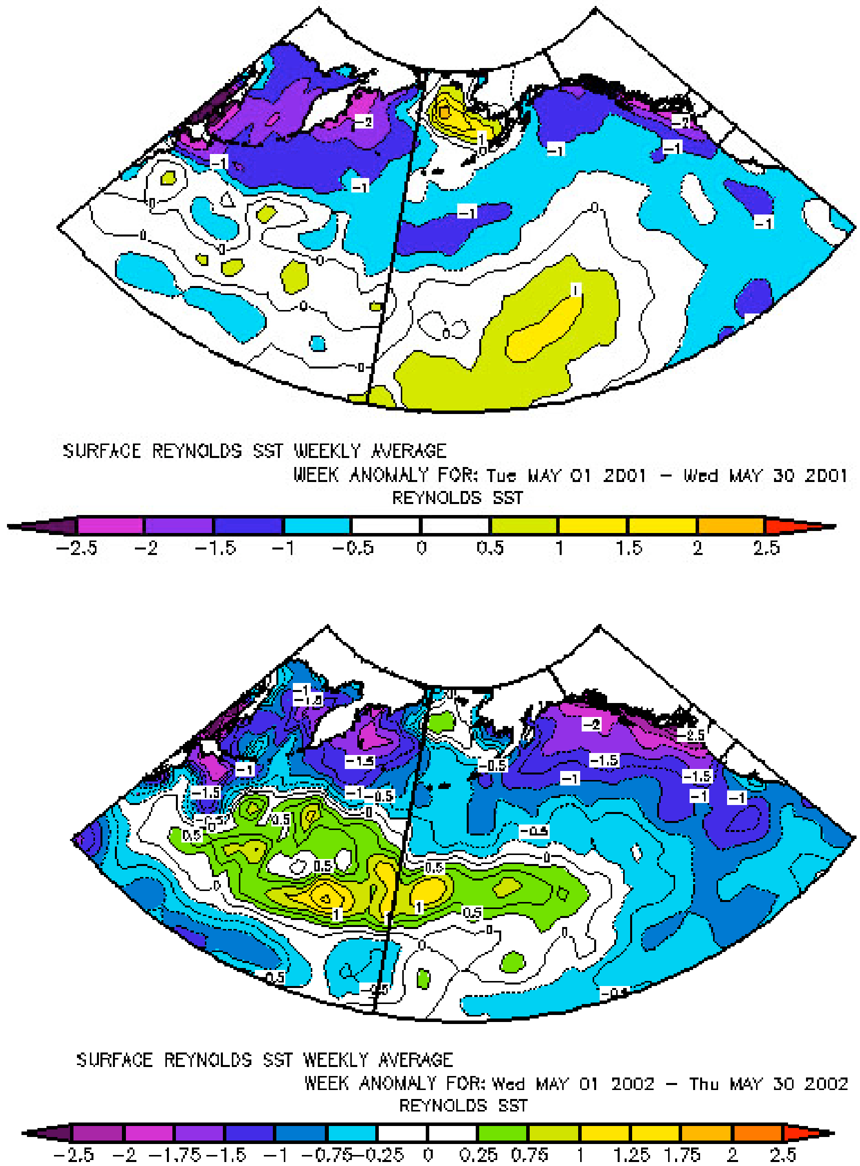
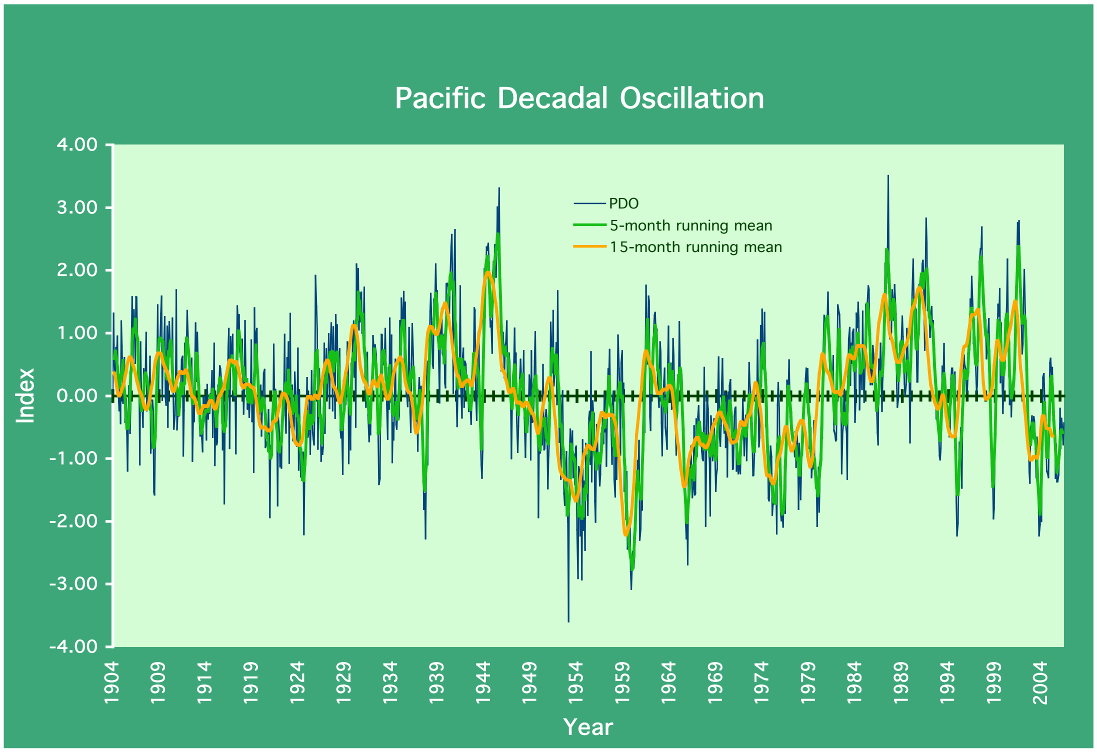


Figure 2. The pattern of sea surface temperature anomalies for May 2001 (top) and May 2002 (bottom) shows persistence of cool coastal water.

as a change in sign of the Pacific Decadal Oscillation (PDO) from positive to negative (Fig. 3, top) after 1998. The negative phase of the PDO is associated with enhanced coastal productivity along Oregon and Washington and inhibited productivity in Alaska. Positive PDO patterns produce the opposite north–south pattern of marine ecosystem productivity. The purported change in phase of the Arctic Oscillation (AO, Fig. 3, bottom) from positive to negative in the last years does not appear to be holding. This implies that the Aleutian Low will be weaker. It is partly the ocean circulation resulting from a strong Aleutian Low that advects relatively warm Pacific basin water to coastal western US, Canada, and Alaska.



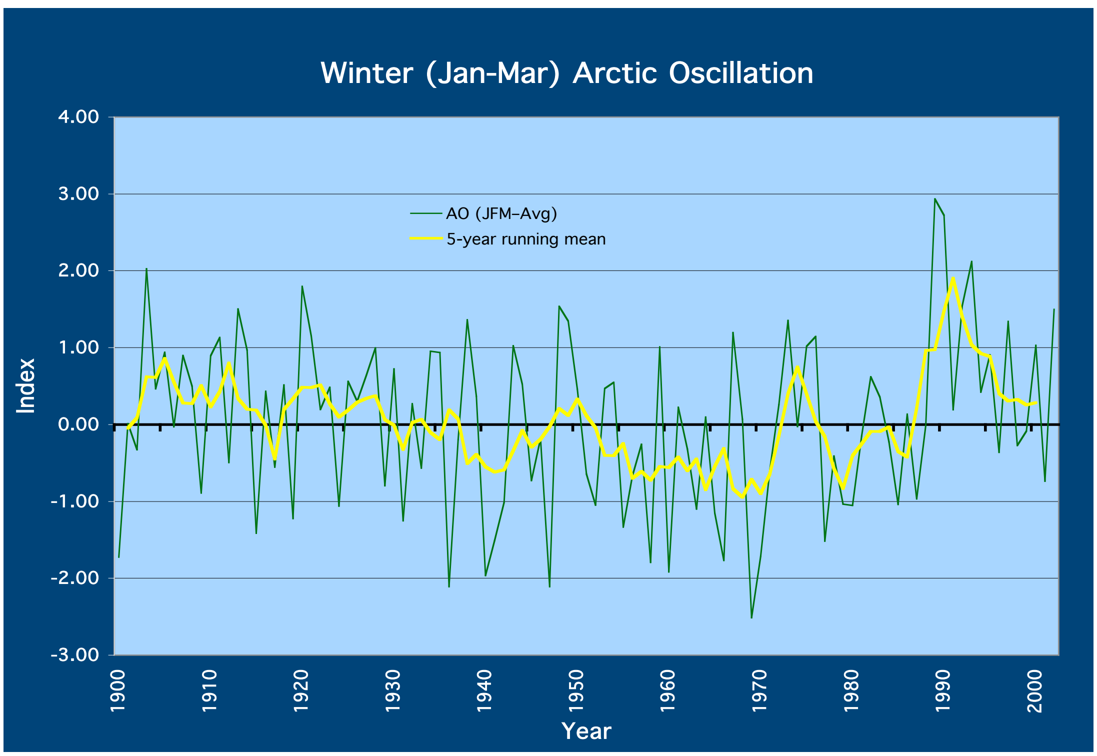


Figure 3. Top: Monthly and smoothed (black line) values of the Pacific Decadal Oscillation (PDO) index, 1900-2001 (updated from Mantua et al. 1997). **Bottom:** Monthly and smoothed (black line) relative values of the Arctic Oscillation (AO) index, 1900-2001.

Thus, there is conflicting evidence about the state of the North Pacific. An El Niño seems imminent, but its effect on North Pacific and Bering Sea waters may be blunted by the still negative PDO and positive AO.

WESTERN GULF OF ALASKA

Seasonal rainfall at Kodiak

A time series of Kodiak rainfall (inches) is a proxy for baroclinity and thus an index for survival success of species such as walleye pollock that benefit from spending their earliest stages in eddies. Greater than average late winter (January, February, March) precipitation produces a greater snow pack for spring and summer freshwater discharge into the ACC. Similarly, greater than average spring and early summer rainfall also favor increased baroclinity after spawning. Conversely, decreased rainfall is likely detrimental to pollock survival. FOCI's pollock survival index based on precipitation is shown in Figure 4. Although there is large interannual variability, a trend toward increased survival potential is apparent from 1962 (the start of the time series) until the mid-1980s. Over the last 15 years, the survival potential has been more level. Survival potential dropped in 2002 due to the dry spring. During April 2002, the Kodiak NWS station received only 7% of its average monthly rainfall (based on the 30-year average for April from 1962 through 1991).

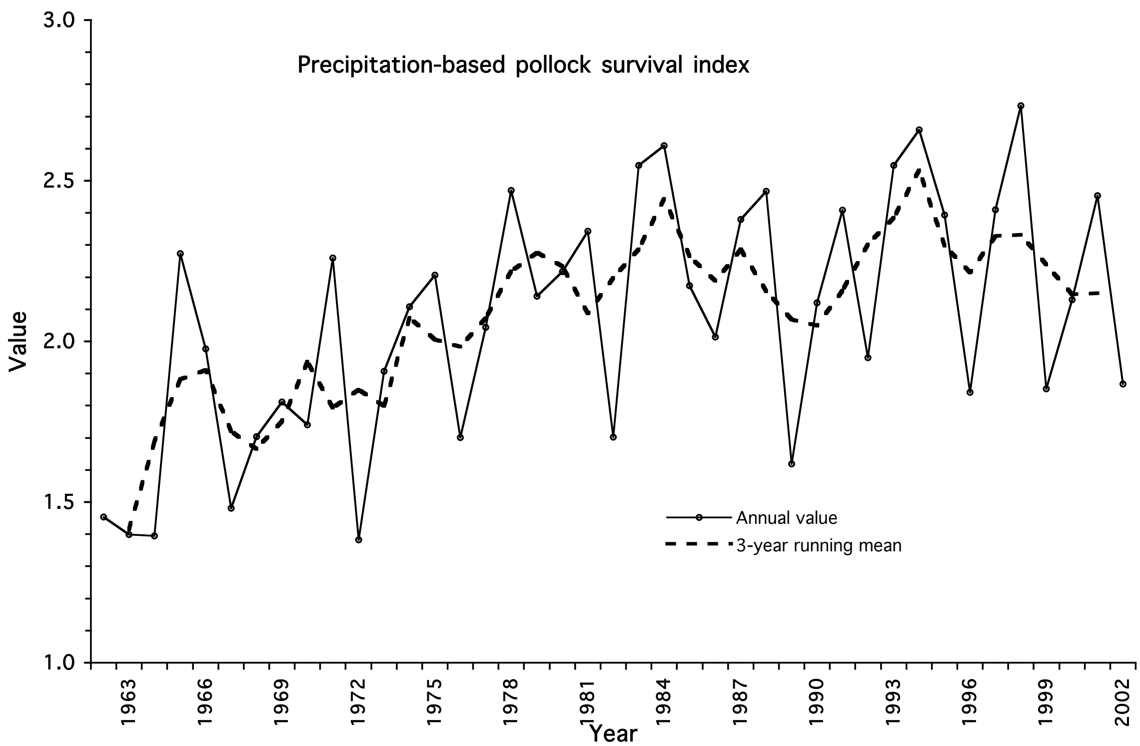


Figure 4. Index of pollock survival potential based on measured precipitation at Kodiak from 1962 through 2002. The solid line shows annual values of the index; the dashed line is the 3-year running mean.

Wind mixing south of Shelikof Strait

A time series of wind mixing energy (W m^{-2}) at [57°N, 156°W] near the southern end of Shelikof Strait is the basis for a survival index (Fig. 5) wherein stronger than average mixing before spawning and weaker than average mixing after spawning favor survival of pollock. As with precipitation at Kodiak, there is wide interannual variability with a less noticeable and shorter trend to increasing survival potential from 1962 to the late 1970s. Recent survival potential has been high. Monthly averaged wind mixing in Shelikof Strait has been below the 30-year (1962-1991) mean for the last five January through June periods (1998-2002). This may be further evidence that the North Pacific climate regime has shifted in the past few years.

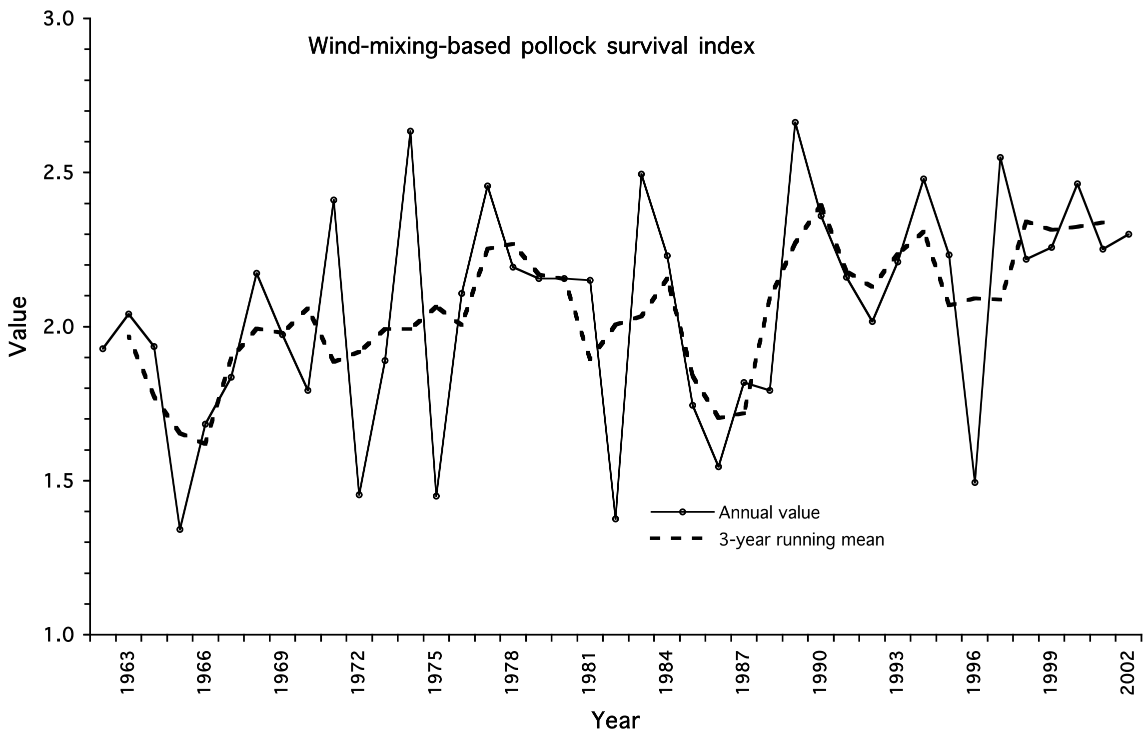


Figure 5. Index of pollock survival potential based on estimated wind mixing energy at a location south of Shelikof Strait from 1962 through 2002. The solid line shows annual values of the index; the dashed line is the 3-year running mean.

Ocean transport in the western Gulf of Alaska

The seasonal strength of the Alaskan Stream and Alaska Coastal Current (ACC) is an important factor for overall productivity on the shelf of the Gulf of Alaska. FOCI uses satellite-tracked drift buoys, drogued at mid mixed-layer depths (~40 m), to measure ocean currents as a function of time and space.

The drifter trajectories shown in Figure 6 are from October 18, 2001. Each red line represents the track of the drift buoy for the past five days. There is strong flow down Shelikof Strait, but outside this region, the flow is convoluted with many small meanders. The complete movies can be downloaded from http://www.pmel.noaa.gov/foci/visualizations/drifter/shel2001.html or http://www.pmel.noaa.gov/foci/visualizations/drifter/aleu2001.html for the Aleutian passes.

In general, the flow of the ACC down Shelikof Strait was weaker than usual from May 15-September 10, 2001. This was caused by weak alongshore winds. Weak flow through Kennedy and Stevenson Entrances results in less vertical mixing and limits the amount of nutrients available in the Shelikof Sea valley. After September 10, a series of strong storms spun up the ACC and resulted in strong flow down Shelikof Strait.

In contrast the Alaskan Stream was well defined, with strong transport from May onward. Flow through the Aleutian Passes was intermittent which is typical. When water flows through the passes, it is vertically mixed, introducing nutrient rich water into the euphotic zone.

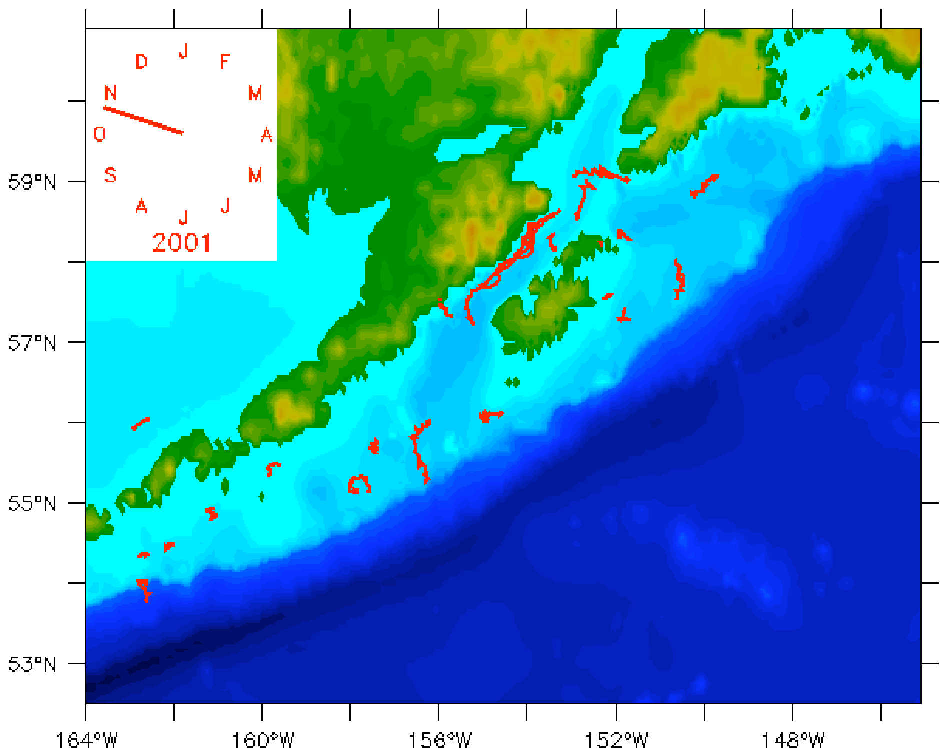


Figure 6. Tracks of satellite-tracked drifters for the period October 14-18, 2001, show sluggish flow on the shelf, except for within Shelikof Strait.

During 2002, flow was again weak in the western Gulf of Alaska. This section will be updated in fall 2002.

EASTERN BERING SEA

Sea ice extent and timing

The extent and timing of seasonal sea ice over the Bering Sea shelf plays an important, if not the determining, role in the timing of the spring bloom and modifies the temperature and salinity of the water column. Sea ice is formed in polynyas and advected southward across the shelf. The leading edge continues to melt as it encounters above freezing waters. The ice pack acts as a conveyor belt with more saline waters occurring as a result of brine rejection in the polynyas and freshening occurring at the leading edge as the ice melts. Over the southern shelf, the timing of the spring bloom is directly related to the presence of ice. If ice is present in mid-March or later, a phytoplankton bloom will be triggered that consumes the available nutrients. If ice is not present during this time, the bloom occurs later, typically during May, after the water column has stratified.

The presence of ice will cool the water column to -1.7°C. Usually spring heating results in a warm upper mixed layer that caps the water column. This insulates the bottom water, and the cold water (<2°C) will persist through the summer as the "cold pool." Fish, particularly pollock, appear to avoid the very cold temperatures of the cold pool. In addition the cold temperatures delay the maturing of fish eggs and hence affect their survival.

The amount of ice cover over the Bering Sea shelf exhibits decadal behavior similar to other climate features. The 1970s were cold, extensive ice years for the Bering. Following the regime shift at the end of the 1970s, the Bering experienced a decade or so of warmer temperatures and less ice. During the 1990s, sea ice coverage has been more extensive, but not as much as in the 1970s. In any of the regimes, strong interannual variability is the norm with sea ice as well as with many other ecosystem responses to physical forcing.

Figure 7 shows the maximum southward extent of ice over the southeastern shelf during the last half-decade (top) and the weekly percent of ice cover between 57° and 58° N during the same period (bottom). Excluding 2001, the maximum ice cover did not differ radically between years. However, the timing of maximum ice extent did. In 2001, as a result of strong southerly winds, ice was not advected southward over the shelf beyond about 60° N. Thus, ice coverage varies immensely on temporal and spatial scales despite the climate regime that characterizes the ecosystem. Again in 2002 (not shown), ice built up rapidly during December and retreated early in the spring. This section will be updated in fall 2002.

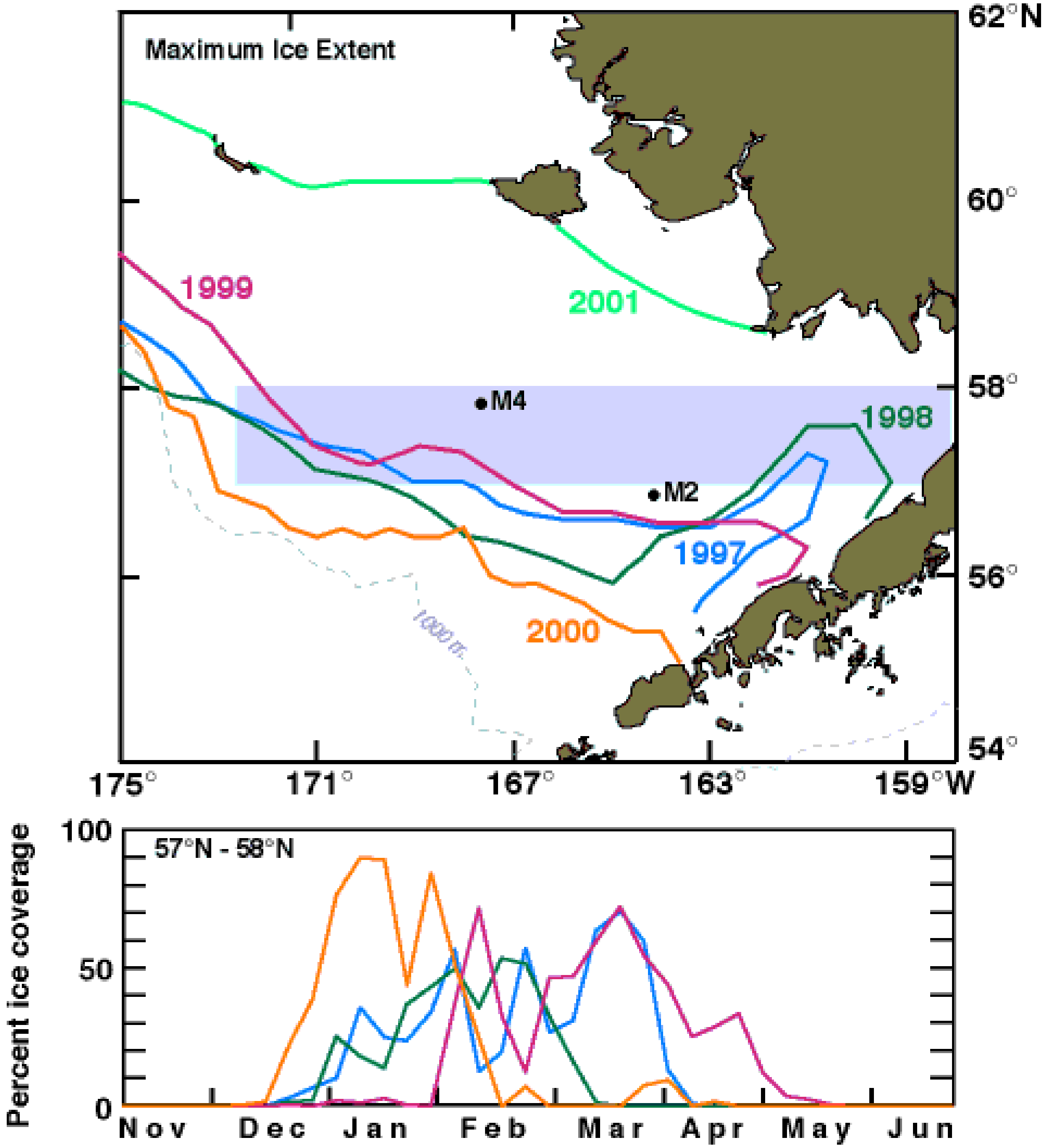


Figure 7. Top: Maximum ice extent during the period 1997-2001. **Bottom:** Weekly percent ice cover of the area indicated by the shaded box in the top figure (57° N – 58°N) for the same 5-year period.

Mooring 2: The cycle in the middle shelf

The cycle in water column temperatures is similar each year. In January, the water column is well mixed. This condition persists until buoyancy is introduced to the water column either through ice melt or solar heating. The very cold temperatures (shown in black in Fig. 8) that occurred in 1995, 1997, 1998 and 1999, resulted from the arrival and melting of ice. Shelf temperature during 1999 was the coldest, well below 1995 and 1996, and approaching the cold temperatures of the negative PDO phase of the early 1970s. During 1996, ice was present for only a short time in February, however no mooring was in place. A phytoplankton bloom occurs with the arrival of the ice pack in March and April. If ice is not present during this period, the spring bloom does not occur until May or June, as in 1996, 1998, 2000, and 2001. The winter of 2001 was particularly warm, with no ice occurring over the southeastern shelf. This section will be updated for 2002 conditions in the fall of 2002.

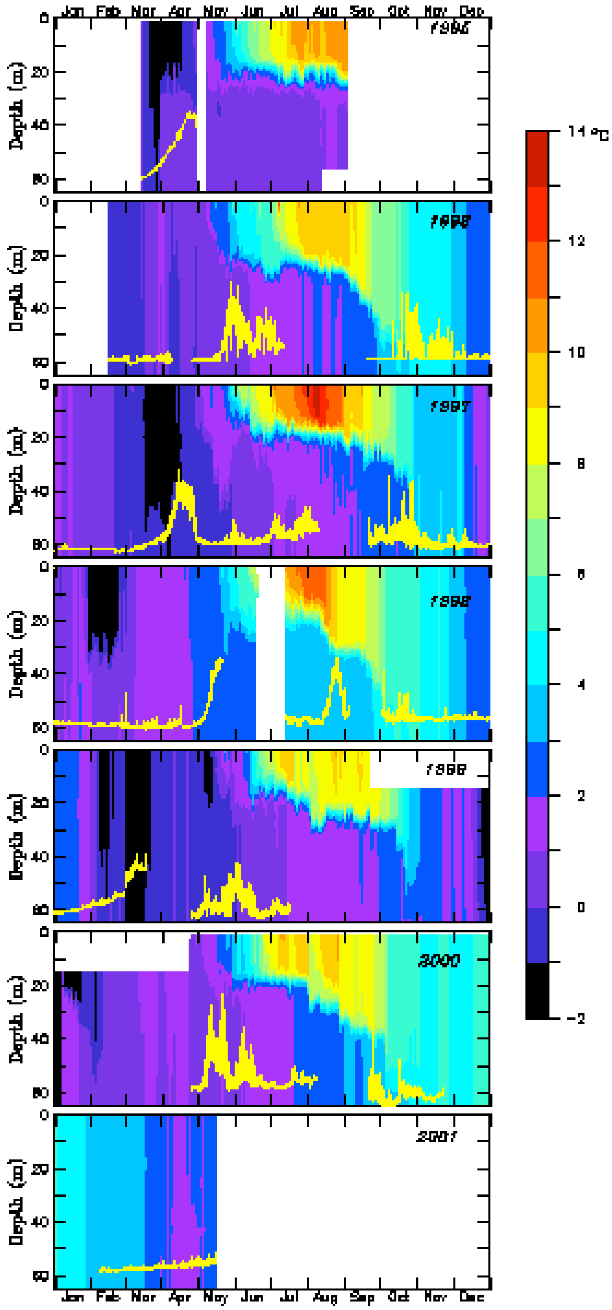


Figure 8. Ocean temperature (°C) as a function of depth (m) and time (month of year) and fluorescence as a function of time measured at mooring site 2 during 1995 through 2001.

Generally, stratification develops during April. The water column exhibits a well defined two-layer structure throughout the summer consisting of a 15 to 25-m wind-mixed layer and a 35 to 40-m tidally mixed bottom layer (the cold pool if temperatures are sufficiently low). Deepening of the mixed layer by strong winds and heat loss begins in August, and by early November the water column is again well mixed.

The depth of the upper mixed layer and the strength of the thermocline contribute to the amount of nutrients available for primary production. A deeper upper mixed layer makes available a greater amount of nutrients. In addition, a weak thermocline (more common with a deeper upper mixed layer) permits more nutrients to be "leaked" into the upper layer photic zone and thus permits prolonged production. The temperature of the upper layer influences the type of phytoplankton that will flourish. For instance, warmer sea surface temperatures (>11°C) during 1997 and 1998 may have supported the establishment of an extensive coccolithophorid bloom that has reappeared each year since, despite a return to colder water temperatures.