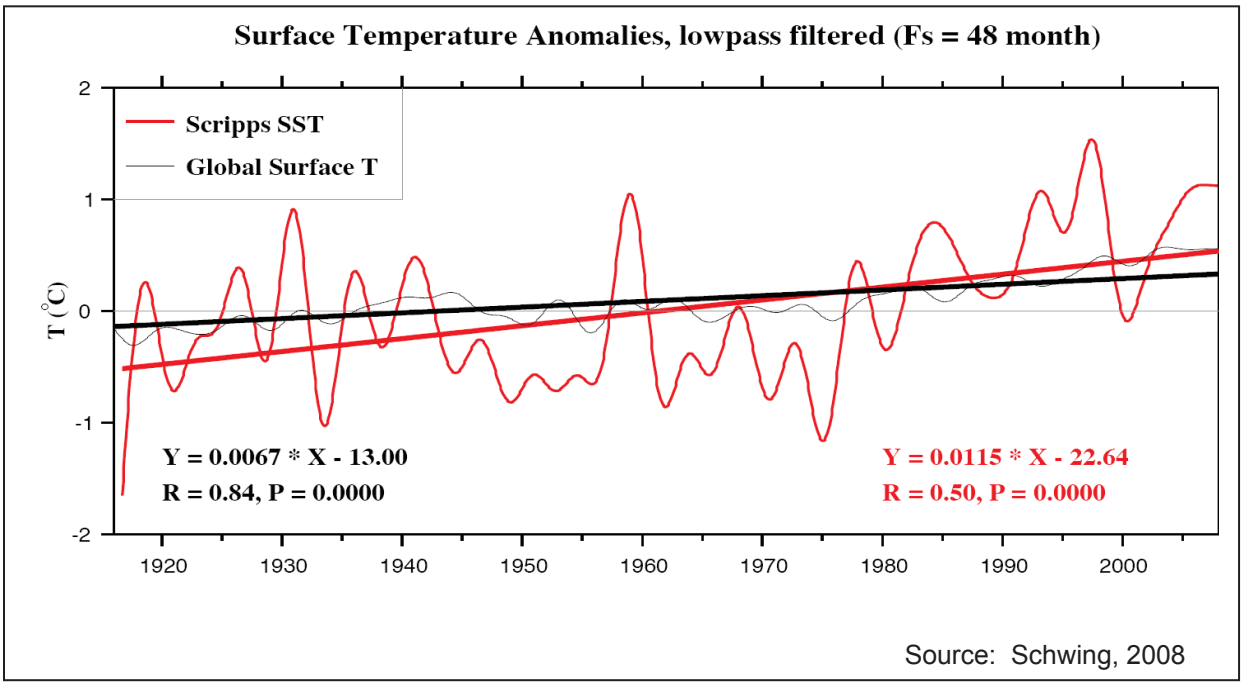
Impacts on physical systems

COASTAL OCEAN TEMPERATURE

California ocean temperatures have warmed over the past century.



What is the indicator showing?

Ocean temperatures along the California coast have risen during the 20th century. Sea surface temperature (SST) measured in La Jolla has increased about 1.1°C since 1916, a rate of approximately 0.0115°C/year. This rate of warming is significantly higher than the global average surface temperature rate of warming (sea and land surface averaged) of 0.0067°C/year (IPCC, 2007).

Why is this indicator important?

Temperature is one of the best-measured, and most reliable, signals of climate change. Global warming is unequivocal; the mean surface has increased by 0.74° C (+/- 0.18) over the last 100 years (IPCC, 2007; NOAA, 2008). The rate of warming has been accelerating; the linear trend over the last 50 years is nearly twice that rate. Coastal ocean warming is consistent with this accelerating trend.

The rate of warming at this location has accelerated over the past 30 years, consistent with the global trend. However the rate of warming locally has been about 70% faster than the global average. Year-to-year variability at Scripps is also much greater than the global mean.

Ocean temperatures contribute to global sea level rise because warming water expands. Warmer waters also play a role in more extreme weather events, by influencing the energy and moisture of the atmosphere. Ecological impacts will include a northward shift in species distributions (Barry et al., 1995). Greater vertical stratification (layers of solar-heated water over layers of denser cold water) of the water column

(Palacios et al., 2004) will reduce upwelling and the movement of nutrients into the photic zone (the depth of the water that is exposed to sufficient sunlight for photosynthesis to occur) reducing biological productivity (Roemmich and McGowan, 1995). Warming in rivers, estuaries, and wetlands could impact reproduction and survival of many species.

Temperature is one of several factors that influence the California marine ecosystem and its populations. It directly affects the range, growth and survival of many species, the location and production of food and predators, and fish catch. SST also represents other factors, including transport and water column structure that affect populations.

Ocean observations (Levitus et al., 2001) and global climate models (IPCC, 2007) confirm that while some of the past variability in surface temperature was due to natural climate fluctuations, global greenhouse gas increases have contributed a significant portion of the observed warming trend. This growing database is an important resource for separating natural from anthropogenic climate changes in our coastal zone. This provides an indication of how future climate change will shape ecosystem structure and productivity, as well as the system's resilience and adaptability to future change.

What factors influence this indicator?

Upper ocean temperatures off California increased by over 1°C during the 20th Century and are projected to rise by another 2-3°C by 2100 (Snyder et al., 2003). Globally, ocean temperatures warm primarily because of the net heat flux from the atmosphere as "greenhouse effect" increases atmospheric temperatures. The world's oceans have warmed to depths of 3000 meters during the past several decades (Levitus et al., 2001). Heat exchange with the atmosphere, which is evidenced by a more rapid rate of warming of near-surface waters, is the source of this trend.

Ocean currents redistribute heat, resulting in a greater warming rate at higher latitudes. Regionally, ocean temperatures can show much different trends, even local cooling (Mendelssohn and Schwing, 2002). On paleo-time scales, oceans have undergone extremes in warming and cooling coinciding with glacial cycles and the varying concentration of atmospheric CO_2 and other greenhouse gases.

The Scripps SST time series is significantly correlated with SST records throughout the north Pacific (McGowan et al., 1998). This means the Scripps SST time series is correlated with time series throughout most of the Pacific, so the interannual variability as well as long-term trend at Scripps is seen throughout the test of the ocean. It also reflects the trend in California upper ocean temperature over the past several decades (Mendelssohn and Schwing, 2002). SST variability relates to fluctuations in many California coastal marine populations as well (Goericke, 2007).

Technical Considerations:

Data Characteristics

Daily SST is measured from the end of the Scripps Institution of Oceanography Pier in La Jolla CA. The proximity of Scripps Pier to the deep waters at the head of La Jolla

submarine canyon results in data quite representative of oceanic conditions along the California coast, and throughout much of the California Current marine ecosystem (Roemmich, 1992).

Temperature readings are collected in a Shore Stations Program which provides access to current and historical data records of SST and salinity observed along the west coast of the United States (http://shorestation.ucsd.edu/). Long-term records of ocean temperature are uncommon; the SST time series maintained at Scripps Institution of Oceanography, in La Jolla, extends back to 1916, making this the longest continuous record of its kind on the United States west coast and the Pacific Rim.

For this indicator, the daily temperatures were averaged by month and smoothed by computer with a 48-month low pass filter. A linear trend was computed for each series. The global-averaged surface (sea and land surface temperatures combined), from the NOAA National Climate Data Center (NOAA, 2006), based on Smith and Reynolds (2005), was processed likewise for comparison.

Strengths and Limitations of the Data

Like many climate records, Scripps SST displays considerable interannual variability. El Niño-Southern Oscillation (ENSO) is responsible for anomalously warm (cool) ocean temperatures during El Niño (La Niña) events, with major El Niño events occurring every 5-10 years (UCAR, 1994). The west coast also is affected by multi-decadal variability in temperature, characterized by patterns such as the Pacific Decadal Oscillation, or PDO (Mantua et al., 1997), and the North Pacific Gyre Oscillation, or NPGO. Natural fluctuations in temperature and other physical factors that characterize ocean conditions and affect the marine ecosystem, make it difficult to isolate the magnitude of anthropogenic climate change. However, they also provide an indication of the ecosystem's sensitivity to extremes in temperature and other factors.

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For more information, contact:

Franklin B. Schwing
Southwest Fisheries Science Center/Environmental Research Division
NOAA Fisheries Service
1352 Lighthouse Avenue
Pacific Grove, CA 93950-2097
(831) 648-8515
Franklin.schwing@noaa.gov




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Arnold Schwarzenegger
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Joan E. Denton, Ph. D.
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Compiled and Edited by:
Linda Mazur
Carmen Milanes
California Environmental Protection Agency
Office of Environmental Health Hazard Assessment
Integrated Risk Assessment Branch (IRAB)

Reviewers:
Karen Randles, IRAB
William Dean, Cal/EPA Office of the Secretary
David Siegel, Ph.D., DABT, Chief, IRAB
George Alexeeff, Ph.D., Deputy Director for Scientific Affairs
Allan Hirsch, Chief Deputy Director

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CONTRIBUTORS

John Abatzoglou, San Jose State University
Michael Anderson, Department of Water Resources
Dennis Baldocchi, University of California Berkeley
Hassan Basagic, Portland State University
Rupa Basu, Office of Environmental Health Hazard Assessment
Steven Bograd, NOAA/NMFS, Southwest Fisheries Science Center
Russell W. Bradley, PRBO Conservation Science
Kim Nichols Cahill, Stanford University
Dan Cayan, Scripps Institution of Oceanography
Robert Coats, Hydroikos Ltd.
Michael Dettinger, Scripps Institution of Oceanography
Laura Edwards, Desert Research Institute/Western Regional Climate Center
Marc Fischer, Lawrence Berkeley National Laboratory
Matthew Forister, University of Nevada Reno
Andrew Fountain, Portland State University
Guido Franco, California Energy Commission
Alexander Gershunov, Scripps Institution of Oceanography
Mark Herzog, PRBO Conservation Science
Diana Humple, PRBO Conservation Science
Jaime Jahncke, PRBO Conservation Science
Karen Lutter, California Air Resources Board
Connie Millar, US Forest Service, Pacific Southwest Research Station
Craig Moritz, Museum of Vertebrate Zoology
Bill Peterson, NOAA, Hatfield Marine Science Center
Kelly Redmond , Desert Research Institute/Western Regional Climate Center
William Reisen, University of California, Davis
Maurice Roos, Department of Water Resources
Geoffrey Schladow, University of California, Davis
Franklin Schwing, NOAA, Southwest Fisheries Science Center
Arthur Shapiro, University of California, Davis
William Sydeman, Farallon Institute for Advanced Ecosystem Research
Pieter Tans, NOAA, Climate Monitoring and Diagnostics Laboratory
Webster Tasat, California Air Resources Board
James Thorne, University of California, Davis
Mary Tyree, Scripps Institution of Oceanography
Phillip van Mantgem, U.S. Geological Survey
Anthony Westerling, University of California, Merced
John A. Wiens, PRBO Conservation Science

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