TAHOE: STATE OF THE LAKE REPORT 2017

PHYSICAL PROPERTIES

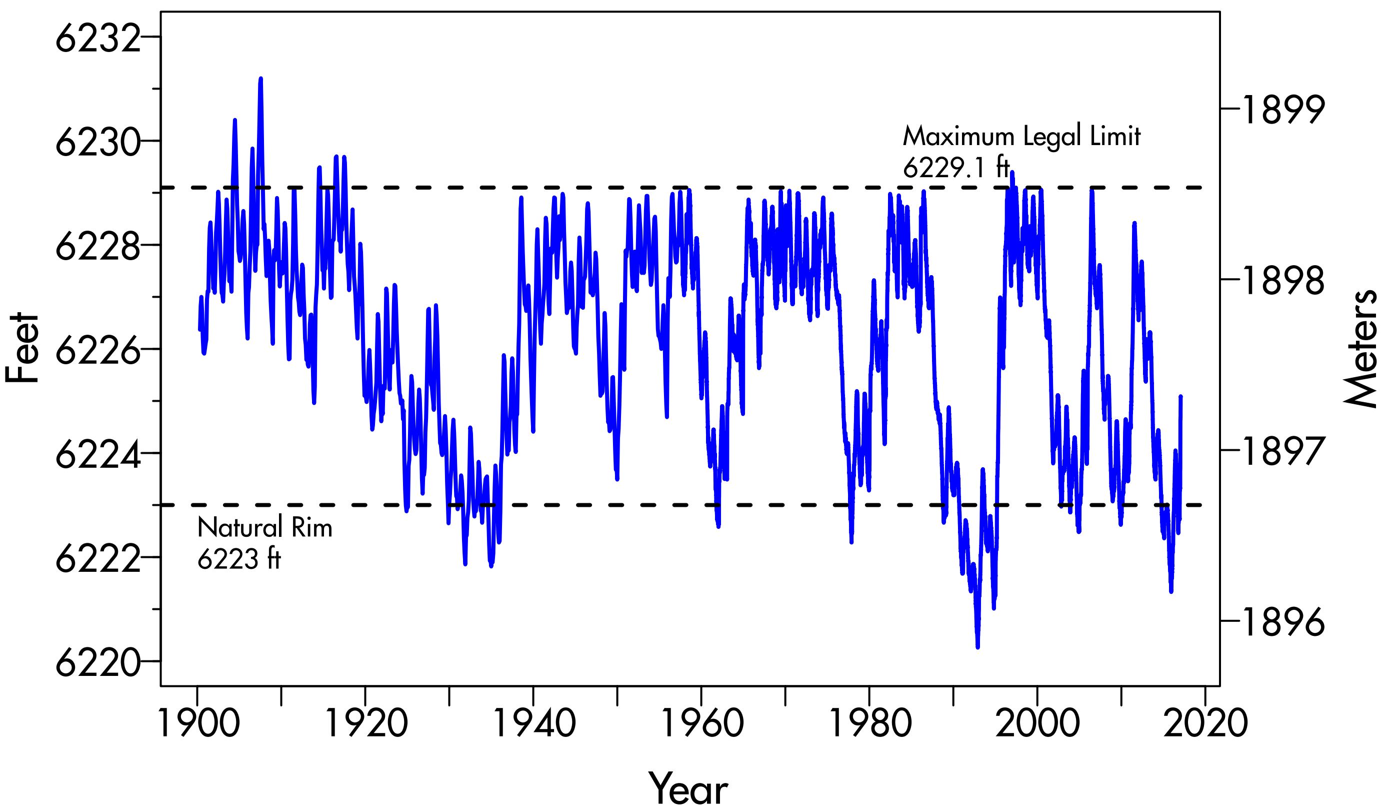
UC DAVIS
TAHOE ENVIRONMENTAL RESEARCH CENTER

PHYSICAL PROPERTIES

Lake surface level

Daily since 1900

Lake surface level varies throughout the year. Lake level rises due to high stream inflow, groundwater inflow and precipitation directly onto the lake surface. It falls due to evaporation, in-basin water withdrawals, groundwater outflows, and outflow via the Truckee River at Tahoe City. Overall, lake level rose over 20 inches during 2016. The highest lake level was 6223.01 feet on June 10, and the lowest was 6221.58 feet on December 9. The natural rim of the lake is at an elevation of 6223 feet. Lake Tahoe was below its rim for almost the entire year, except for one day on January 2, 2016. When the lake is below its rim, outflow via the Truckee River ceases. Several episodes of lake level falling below the natural rim are evident in the last 114 years. The frequency of such episodes appears to be increasing.

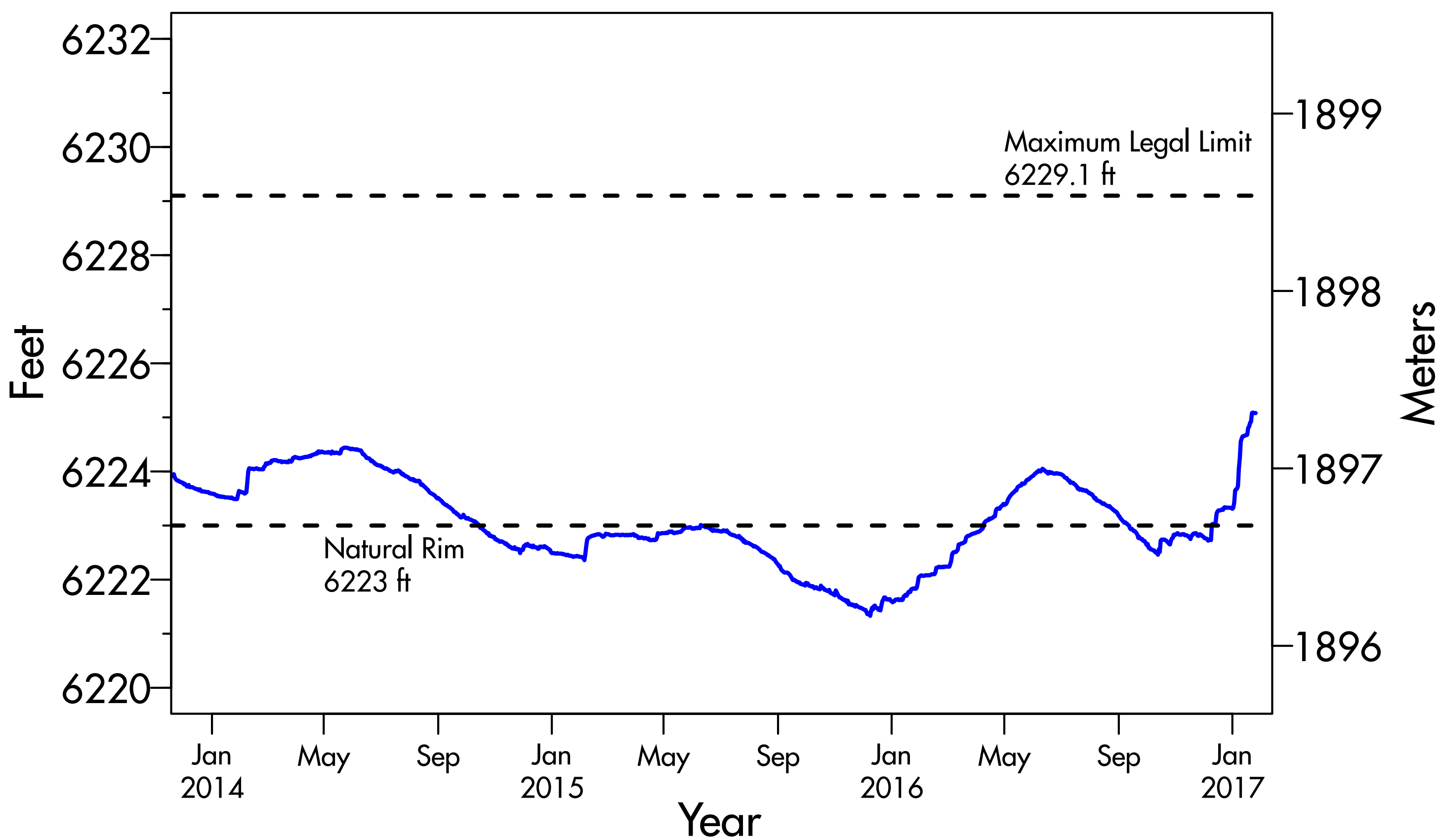


PHYSICAL PROPERTIES

Lake surface level, continued

Daily since 2014

Displayed below is the lake surface data from 2014-2016 extracted from the same data on page 8.1. This more time restricted presentation of recent lake level data allows us to see the annual patterns of rising and falling lake level in greater detail. Data clearly show the lake level falling below the natural rim in October 2014 and its two periods of being below the rim in 2016. The effects of the drought on overall lake water level is evident, as is the beginning of a rapid rise in lake level in 2017.

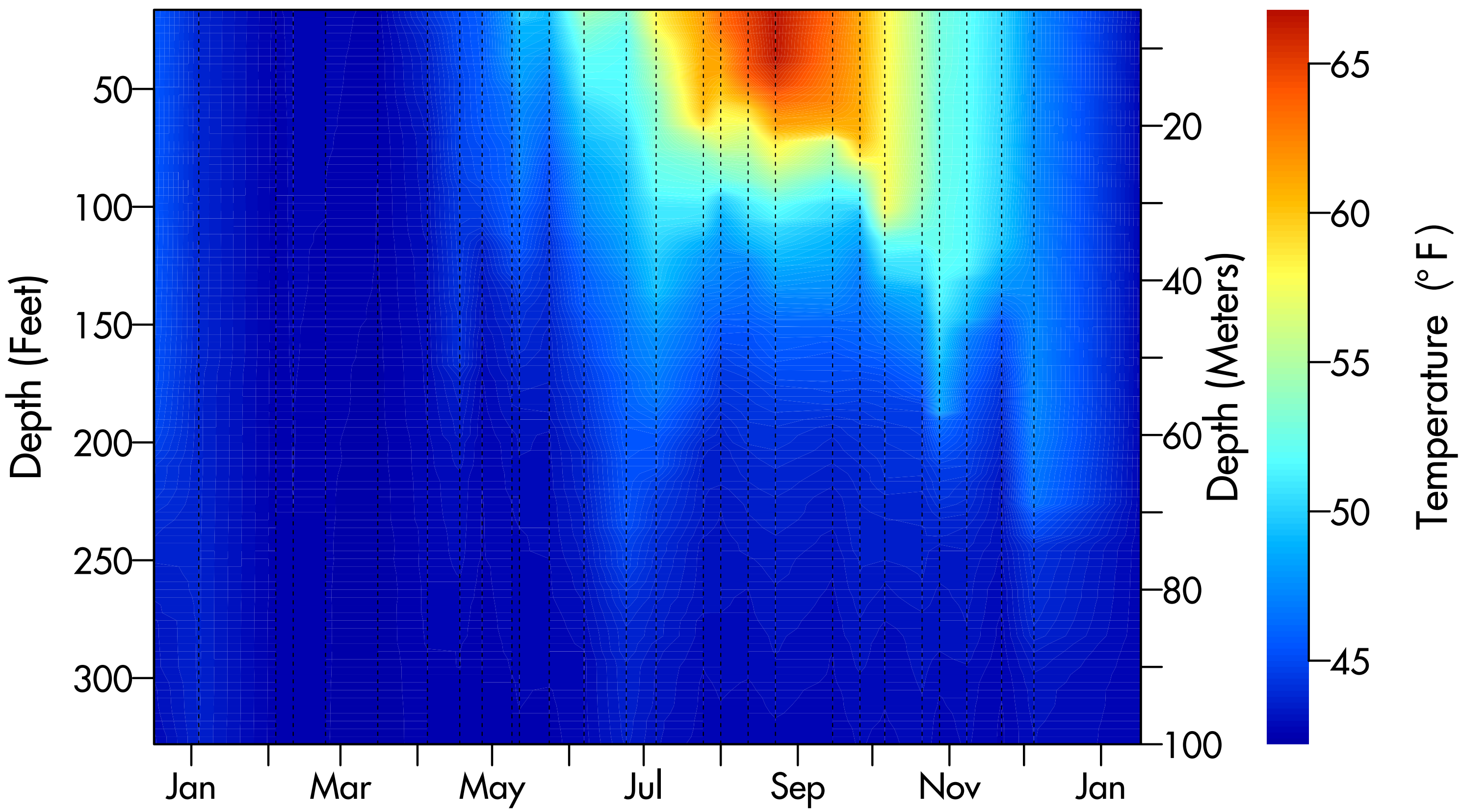


PHYSICAL PROPERTIES

Water temperature profile

In 2016

Water temperature profiles are measured in the lake using a Seabird CTD (conductivity, temperature, depth) profiler at the times indicated by the dashed vertical lines. The temperature is accurate to within 0.005 °F. Here the temperature in the upper 330 feet (100 m) is displayed as a color contour plot. In 2016, the lake temperature followed a typical seasonal pattern. In February-March, the lake surface was at its coldest, while it was at its warmest at the end of August. The deepening of the warm water zone toward the end of the year is the result of winter mixing, a process that is important in bringing oxygen to the deeper parts of the lake.

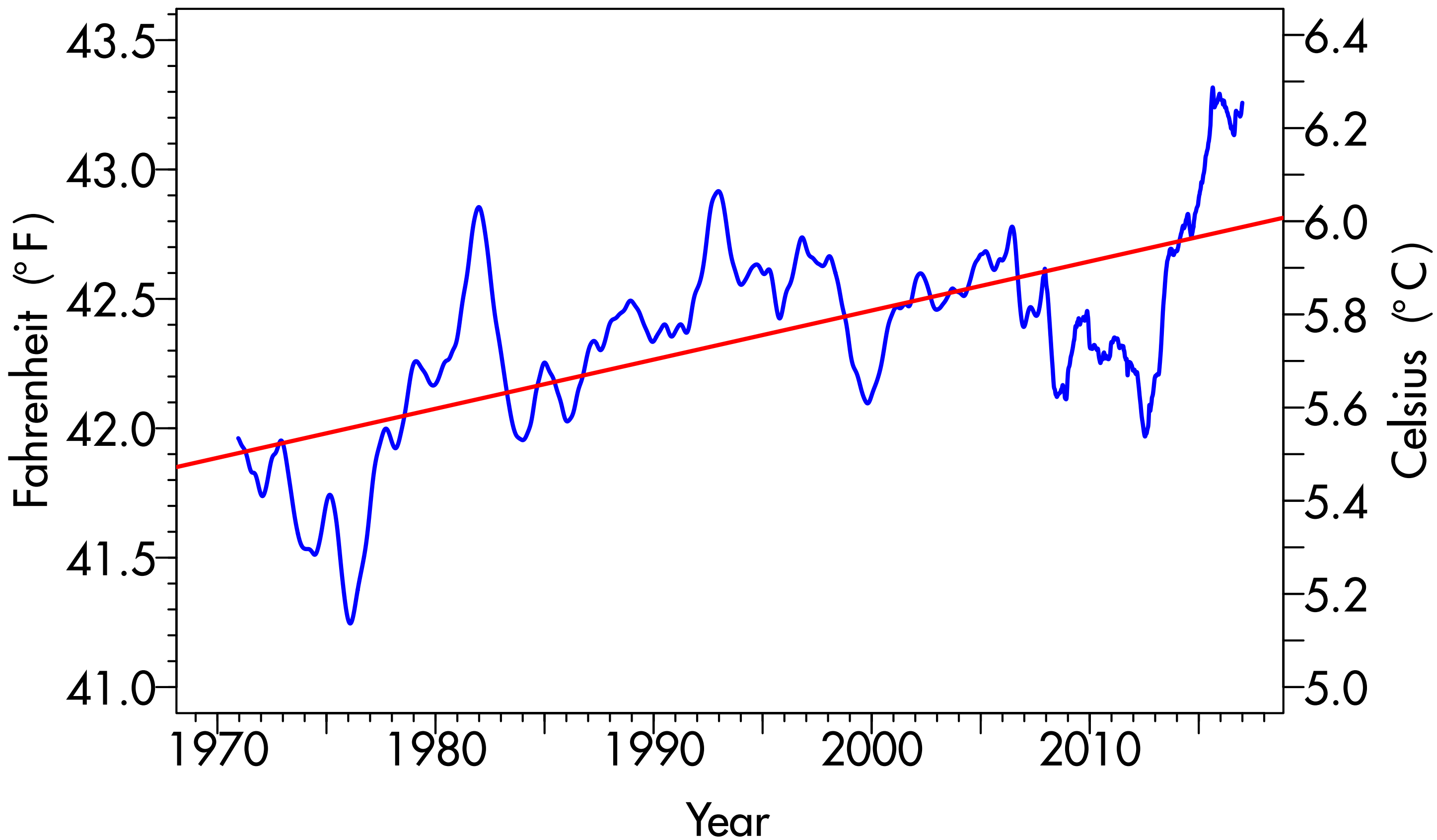


PHYSICAL PROPERTIES

Average water temperature

Since 1970

The trend in the volume-averaged temperature of Lake Tahoe has increased by approximately 0.87 °F since 1970. The annual rate of warming is 0.019 °F/year (0.011 °C/year). The monthly temperature profile data from the top to the bottom of the lake has been smoothed and seasonal influences removed to best show the long-term trend. Up until the late 1990s the warming rate was high, but a high number of deep mixing years between 1997 and 2011 caused the lake temperature to cool. Since that time, warming has accelerated to its highest recorded rate.

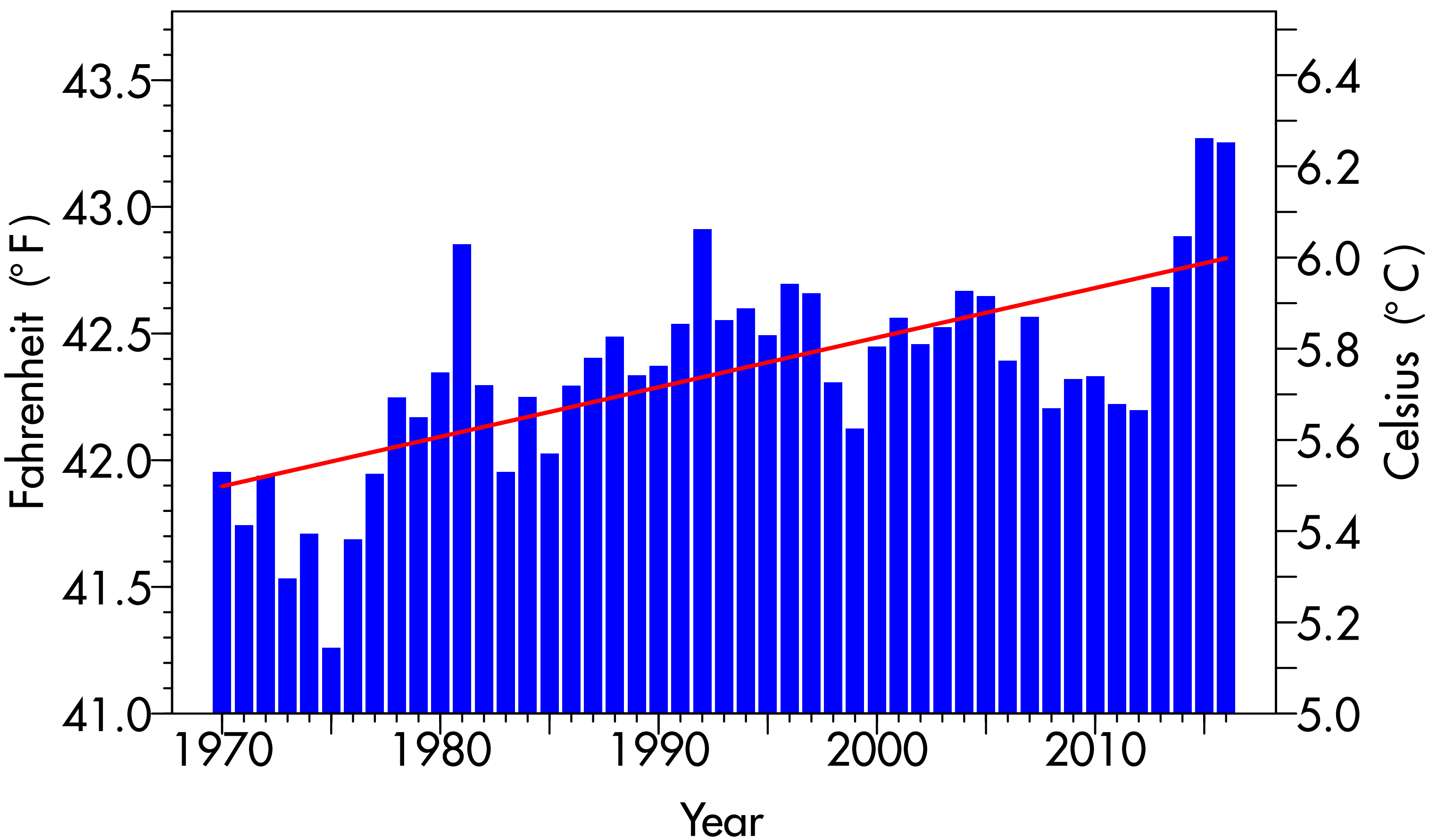


PHYSICAL PROPERTIES

Annual average water temperature

Since 1970

The volume-averaged temperature of the lake for each year since 1970 is shown. In 2016, the volume-averaged temperature decreased by 0.02 °F (0.01 °C) over the previous year. In the last 4 years the lake has warmed at an alarming rate of over 0.26 °F/year, almost ten times faster than the long-term warming rate. Increases in temperature generally correspond to those years in which deep mixing did not occur. In 2016, deep mixing did not occur for the 5th year in a row.



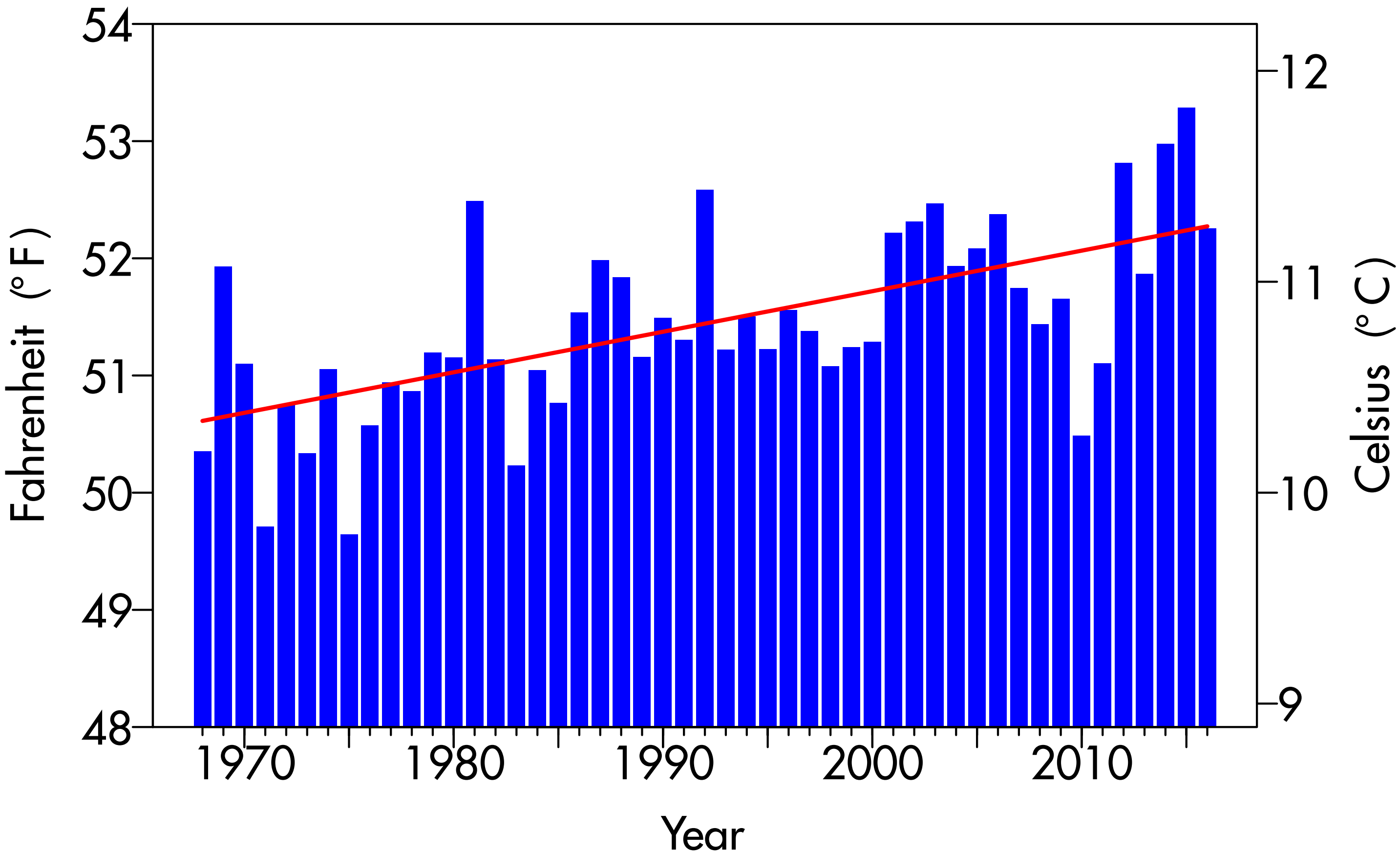
PHYSICAL PROPERTIES

Surface water temperature

Yearly since 1968

Surface water temperatures have been recorded monthly at the Mid-lake and Index stations since 1968 from the R/V John LeConte and the R/V Bob Richards. Despite year-to-year variability, the annual average surface water temperatures show an increasing trend. The average temperature in 1968 was 50.3 °F (10.2 °C). For 2016, the average surface water temperature was 52.3 °F (11.3 °C).

The overall rate of warming of the lake surface is 0.035 °F (0.019 °C) per year.

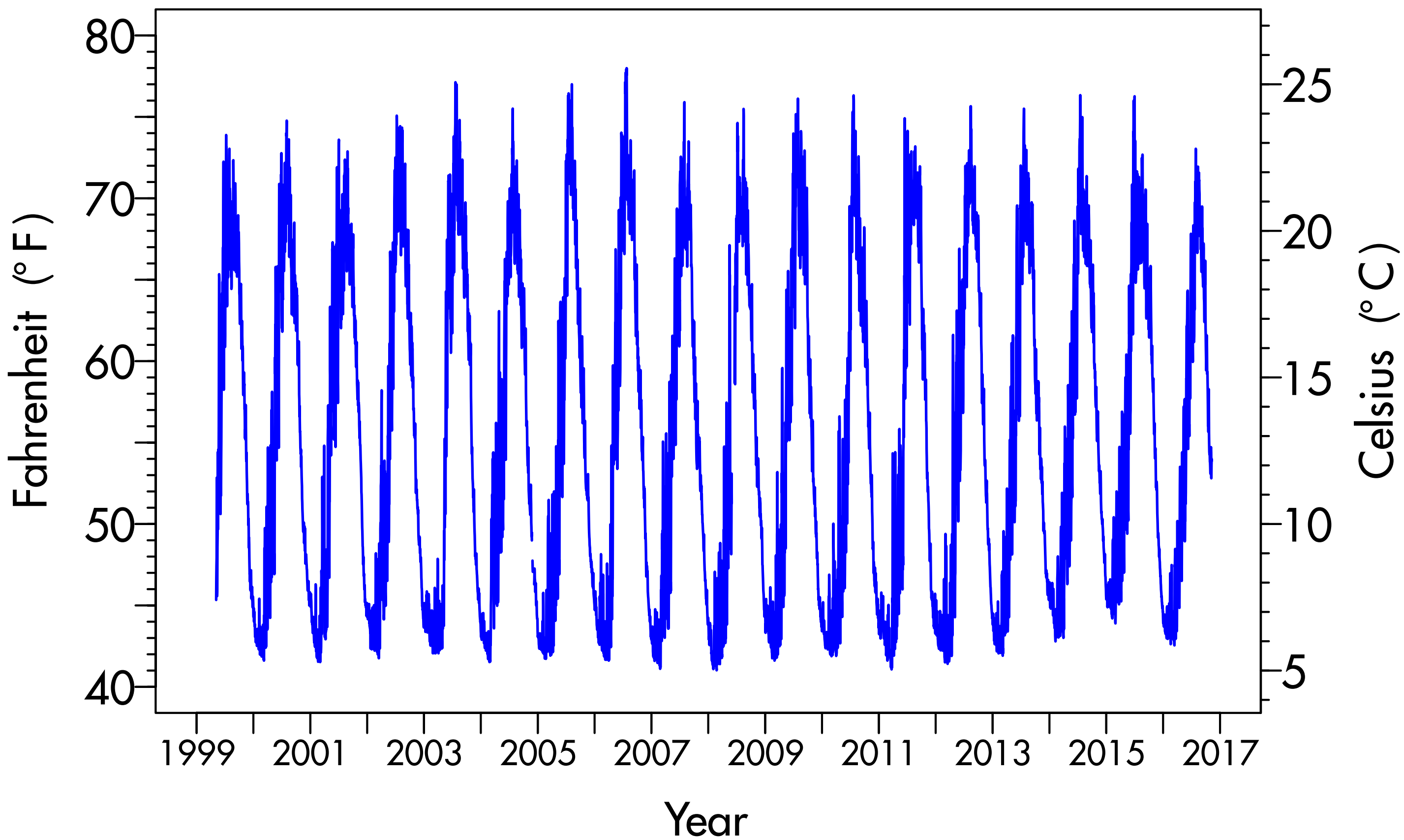


PHYSICAL PROPERTIES

Maximum daily surface water temperature

Surface temperature measured since 1999 every 2 minutes

The maximum daily summer surface water temperature in 2016 was the lowest observed since continuous (every 2 min.) data collection commenced in 1999. The primary reason for the lower temperatures are high winds in June and July. The highest maximum daily surface water temperature (summer) was 73.04 °F, which was recorded on July 29, 2016. The lowest maximum daily surface water temperature (winter) was 42.5 °F, which was recorded on March 14, 2016. These data are collected in real-time by NASA-JPL and UC Davis from 4 buoys located over the deepest parts of the lake.

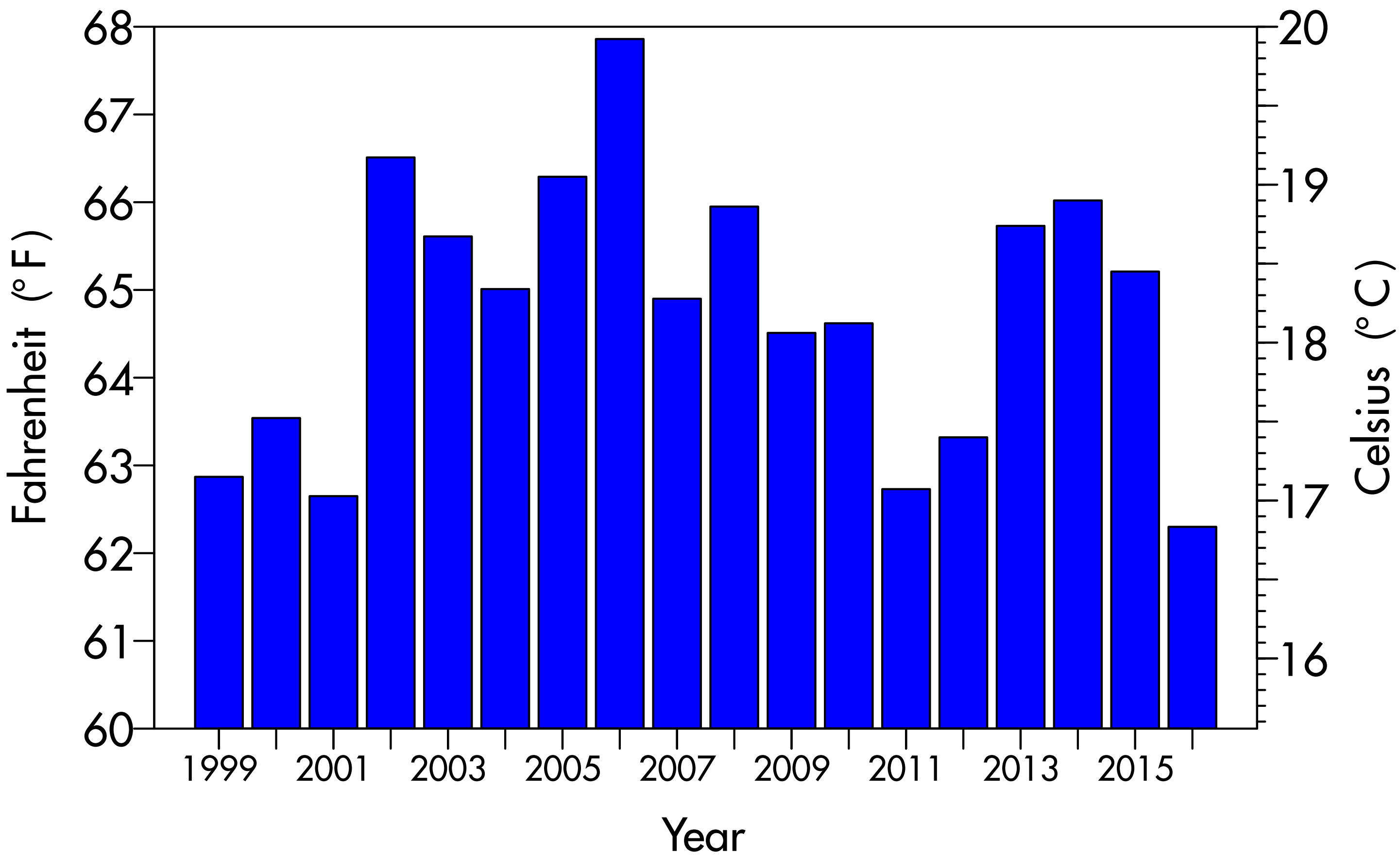


PHYSICAL PROPERTIES

July average surface water temperature

Measured since 1999 every 2 minutes

Since 1999, surface water temperature has been recorded every two minutes from four NASA/UC Davis buoys. Shown here are 18 years of average surface water temperatures in the month of July when water temperatures are typically warmest. In 2016, July surface water temperature averaged 62.3 °F. High winds in June and July were responsible for the cold July water temperatures. The warmest July temperatures were 67.9 °F in 2006. The average July surface water temperature for the 18 year period is 64.8 °F.

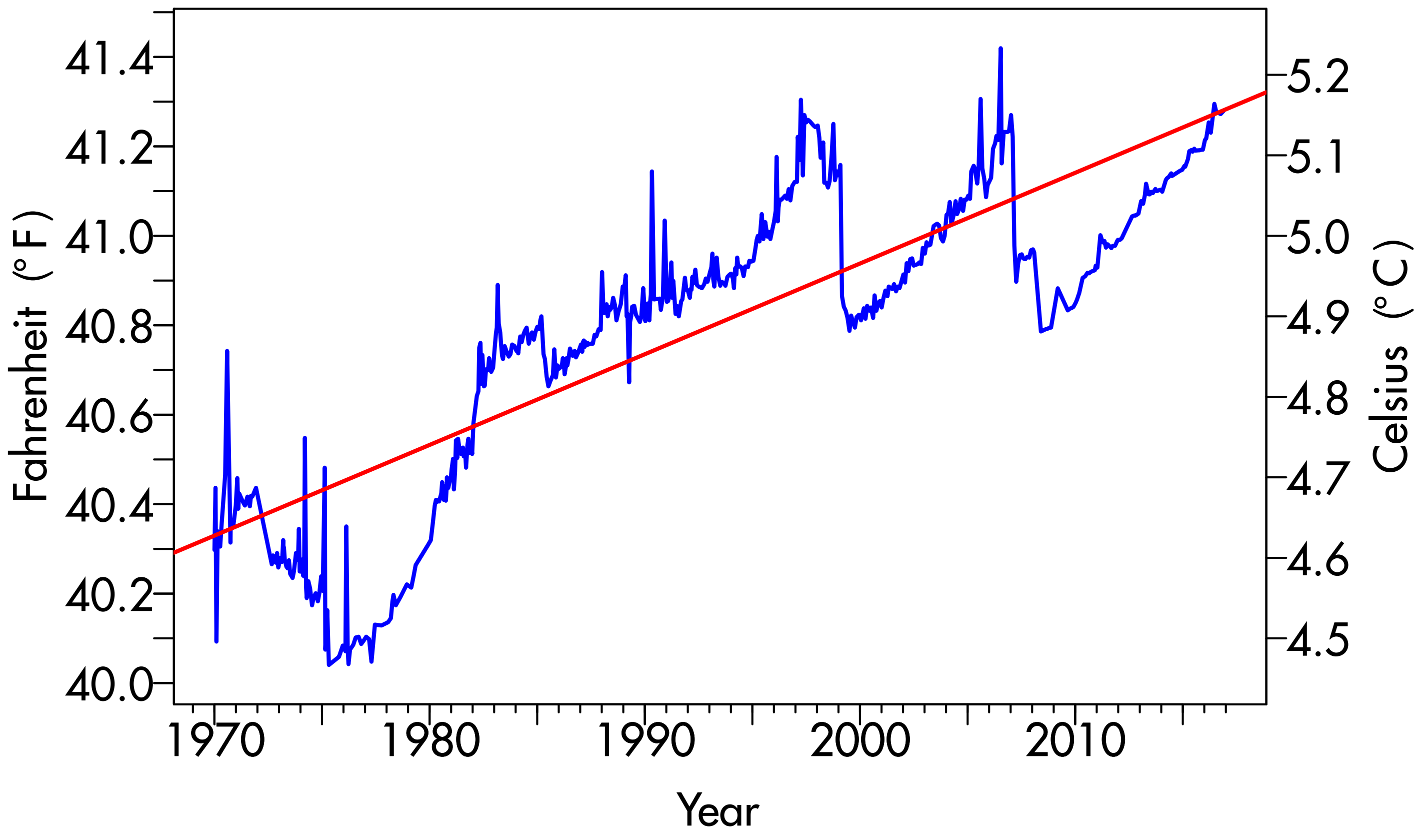


PHYSICAL PROPERTIES

Deep water temperature

Monthly since 1970

The water temperature at a depth of 1,320 feet (400 m) is indicative of conditions in the deeper waters (hypolimnion) of Lake Tahoe. Since 1970 the deep water temperature has increased by 0.95 °F (0.53 °C), at an annual rate of 0.020 °F (0.011 °C), a rate of warming that is half that of the surface water. This increase has not been steady but is punctuated by occasional drops in temperature. These coincide with times when the lake completely mixes to the bottom, an event which allows a huge amount of heat to escape from the lake. The short spikes of temperature increase are temporary effects caused by the motions of internal waves (or seiches).

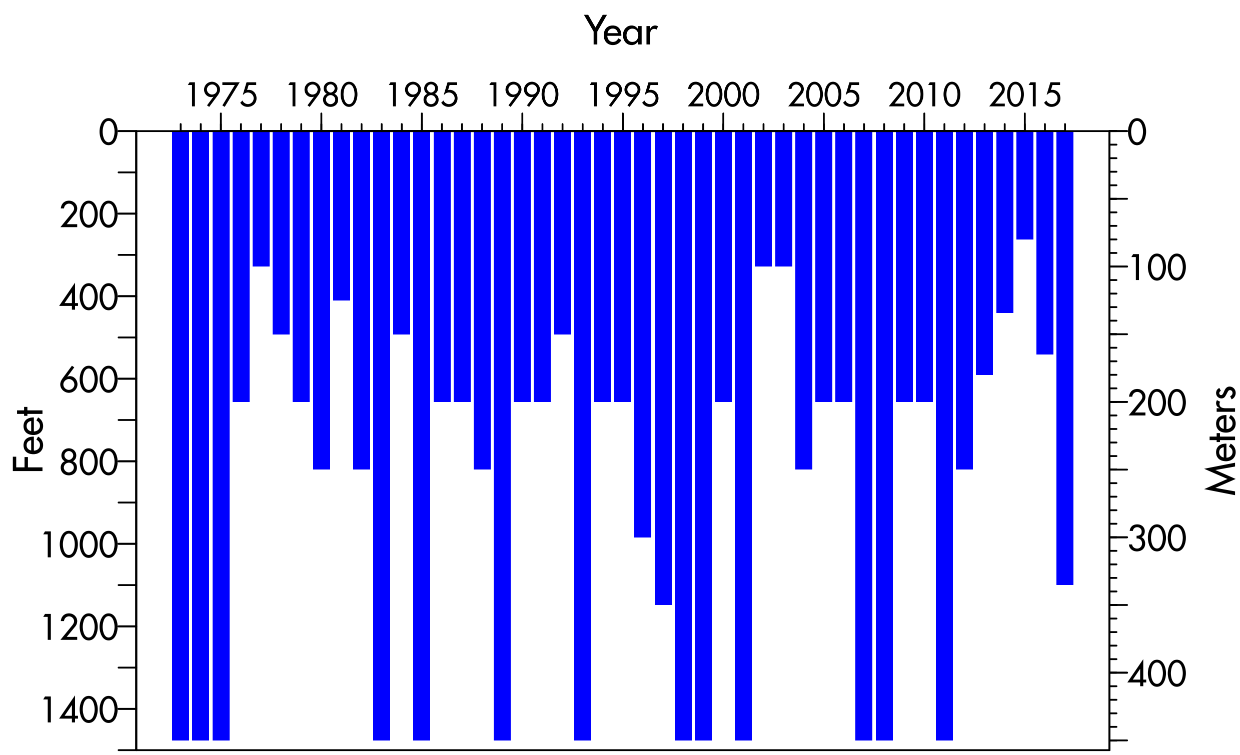


PHYSICAL PROPERTIES

Depth of mixing

Yearly since 1973

Lake Tahoe mixes each winter as surface waters cool and sink downward. In a lake as deep as Tahoe, the wind energy and intense cooling of winter helps to determine how deep the lake mixes. Mixing depth has profound impacts on lake ecology and water quality. Deep mixing brings nutrients to the surface, where they promote algal growth. It also moves oxygen to deep waters, promoting aquatic life throughout the water column. The deepest mixing typically occurs between February and March. In 2016, Lake Tahoe mixed to a depth of only 540 feet (165 m). This lack of deep mixing most likely contributed to the warm surface and bottom temperature, the continuing buildup of nitrate in the lake, and the generally lower clarity. In March 2017 deep mixing occured to a depth of 1100 ft (335 m) Beginning in 2013, the determination of the depth of mixing has been based on high-resolution temperature profiles rather than nitrate concentration sampled at discrete depths.



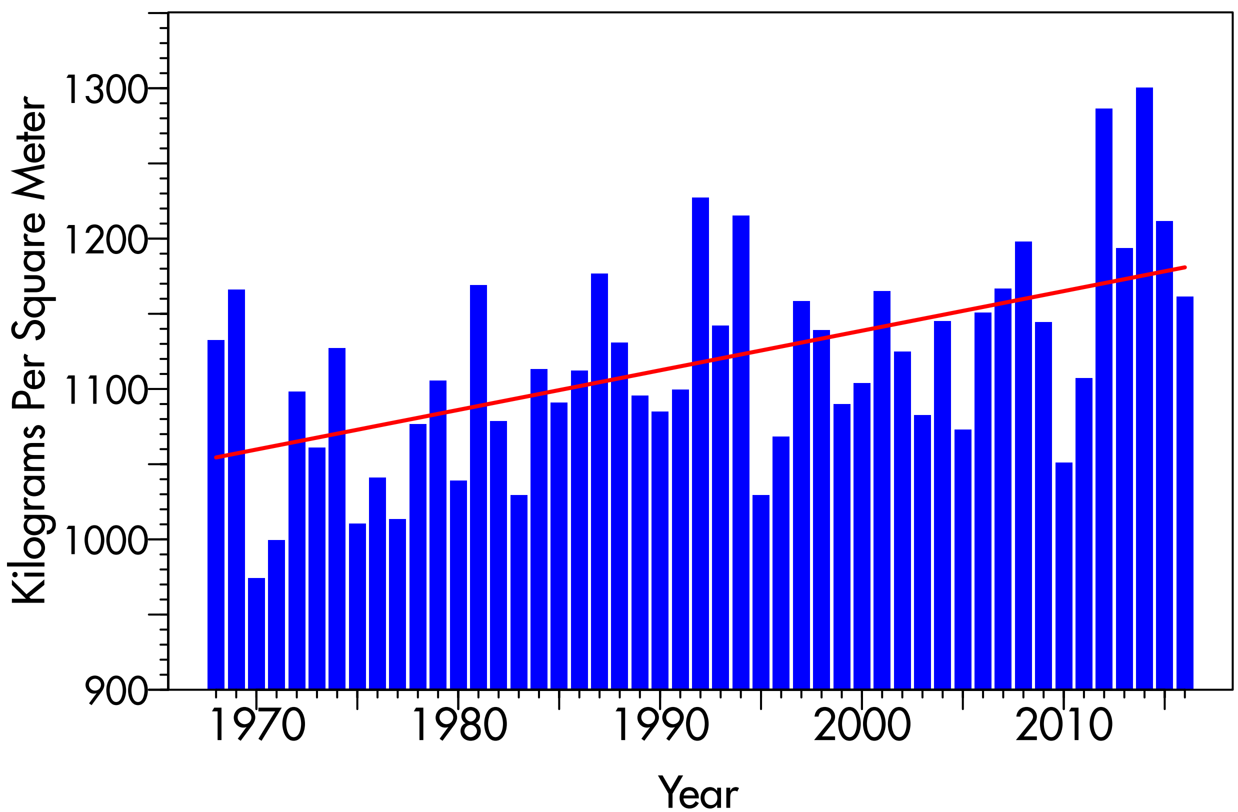
PHYSICAL PROPERTIES

Lake stability

Since 1968

When the lake has a vertical distribution of temperature, it has a corresponding density distribution, with warm and lighter water at the surface, and colder, denser water at depth. The stability index is a measure of the energy required to fully mix the water column when its density is stratified. The average stability index for the upper 330 feet (100 m) of Lake Tahoe is plotted for the period of May through October each year. The values are derived from temperature profiles taken at the Index Station at approximately 10-20 day intervals. There has been an overall increase in lake stability by over 10% in the last 45 years.

In 2016, the stability of the lake fell, but it was still above the long-term rate of increasing stability. This is reflected in the relatively deep mixing in early 2017.

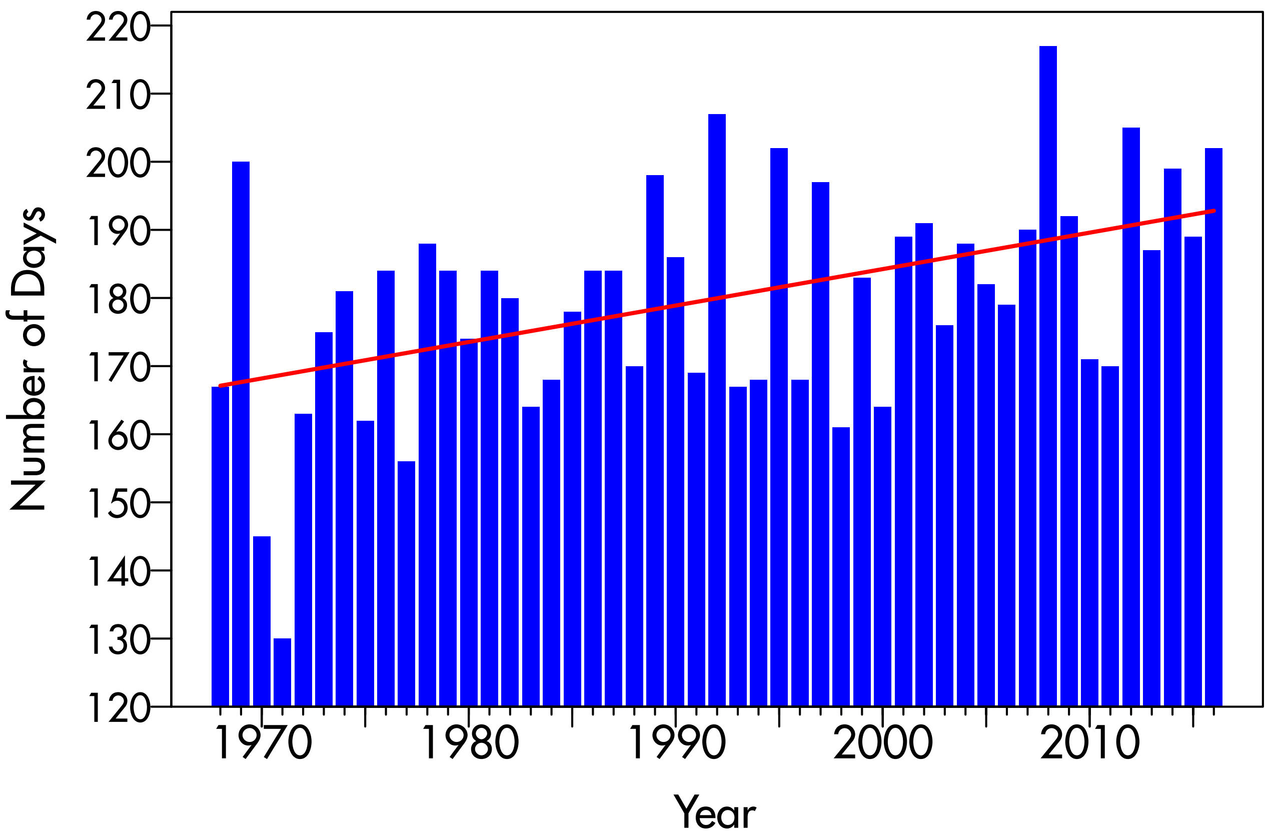


PHYSICAL PROPERTIES

Stratified season length

Since 1968

The stability index, a measure of the energy required to fully mix the lake, can be evaluated for every day of the year. We define the stratification season as the length of time when the stratification index exceeds a value of 600 kilograms per square meter. Since 1968 the length of the stratification season has increased, albeit with considerable year-to-year variation. Overall, the stratification season has lengthened by almost 26 days. In 2016, the length of the stratified season was 202 days.

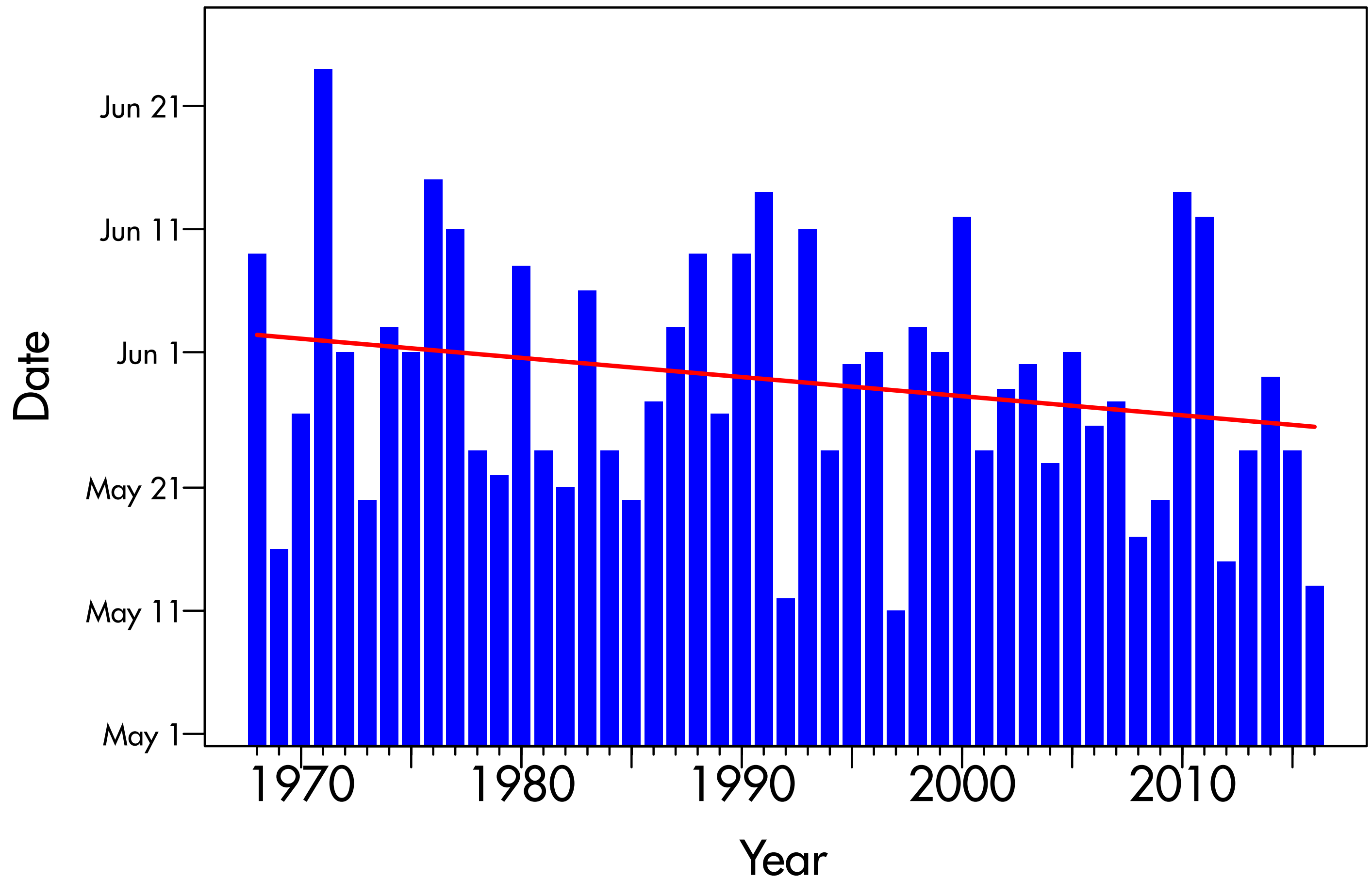


PHYSICAL PROPERTIES

Beginning of the stratification season

Since 1968

The length of time that Lake Tahoe is stratified has been lengthening since 1968. One reason for this is the increasingly early arrival of spring as evidenced by the earlier commencement of stratification. Stratification occurs approximately eight days earlier than it did in 1968. The commencement of the stratification season is typically in late May or early June. In 2016 stratification began on Day 133 (May 12).

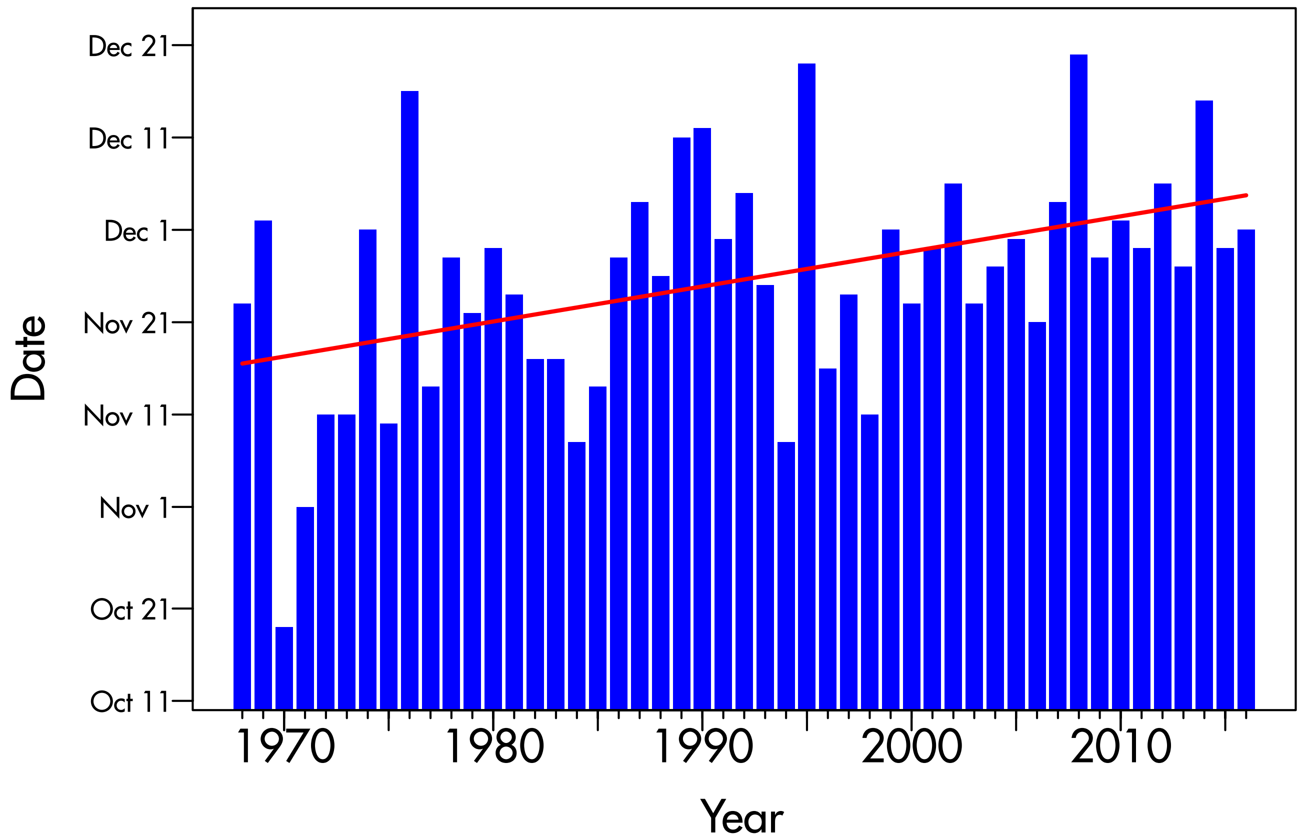


PHYSICAL PROPERTIES

End of stratification season

Since 1968

The length of time that Lake Tahoe is stratified has lengthened since 1968 by almost four weeks. The end of stratification appears to have been extended by approximately 18 days on average. In other words, the fall season for the lake has been considerably extended. In the late 1960's stratification ended in mid-November. Now it often ends in December. In 2016, stratification ended on Day 335 (November 30) This has important implications for lake mixing and water quality, such as the buildup of nitrate at the bottom of the lake.

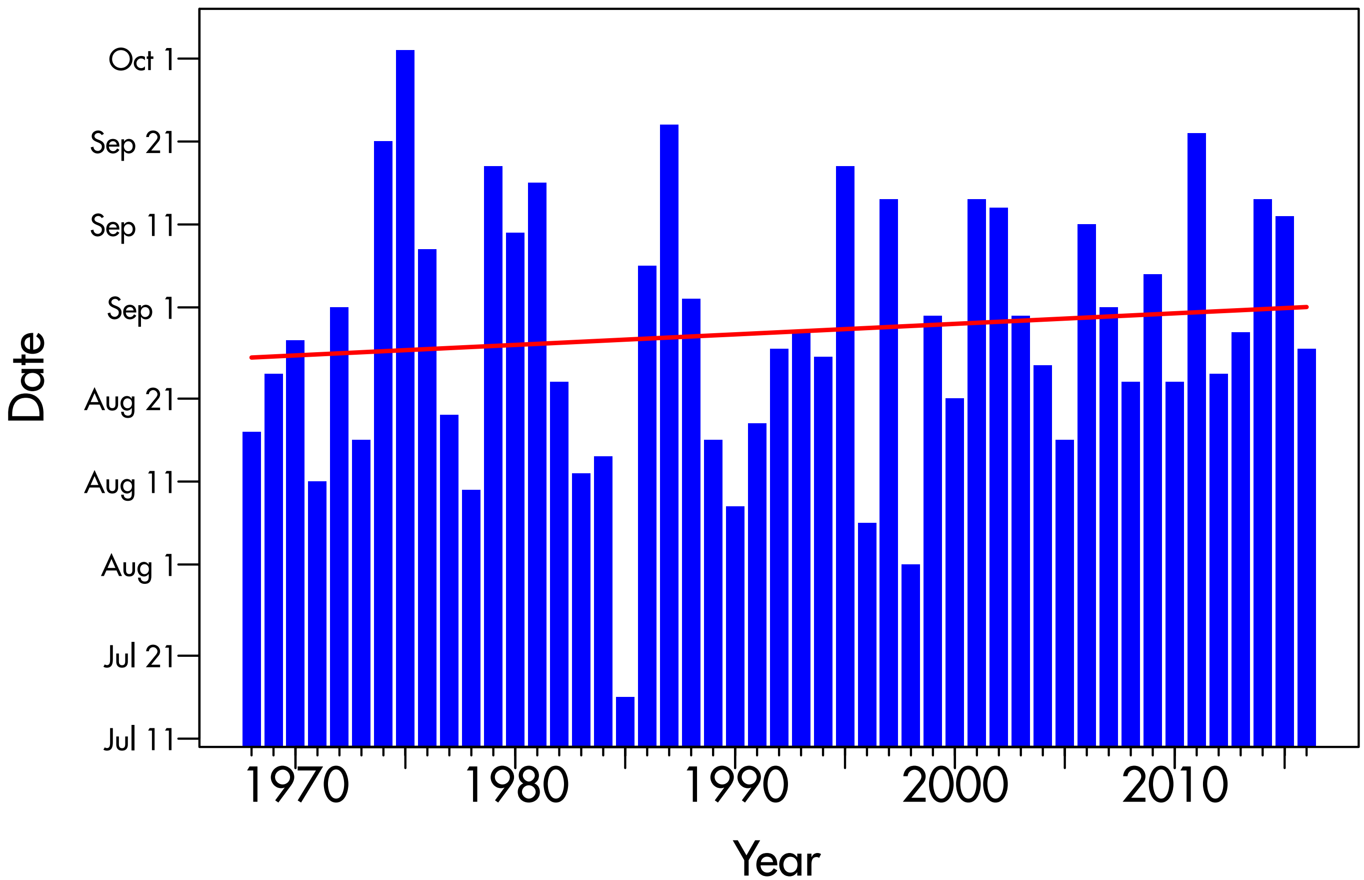


PHYSICAL PROPERTIES

Peak of stratification season

Since 1968

The day of the year when lake stratification reaches its maximum value has been plotted. There is considerable year-to-year variation, but over time there has been only a slight delay in when the peak occurs. In 2016, the peak occurred relatively early on August 31. This was five days earlier than the long-term trend would have indicated.



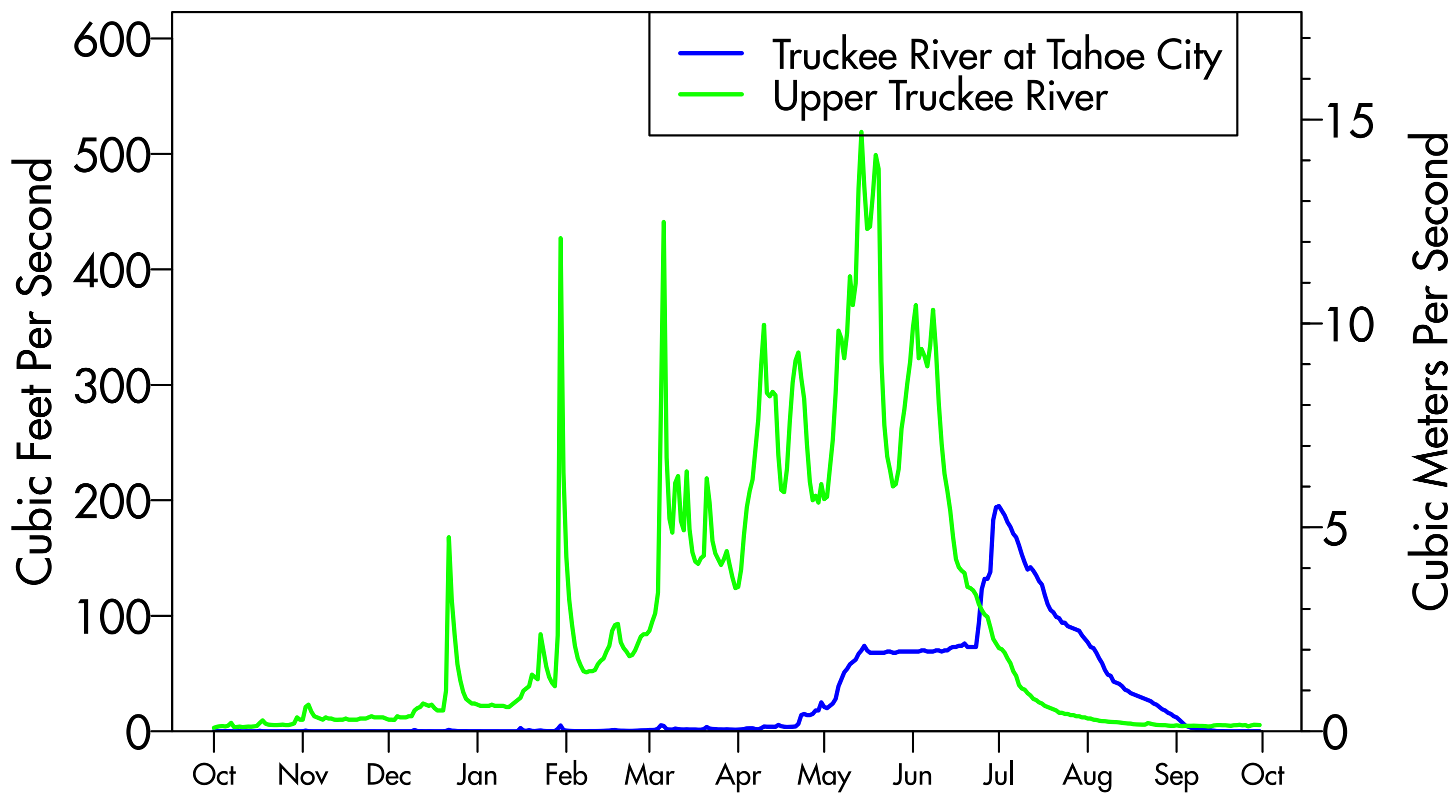
PHYSICAL PROPERTIES

Mean daily streamflow of Upper Truckee River vs. Truckee River

Water Year 2016

The largest stream flowing into Lake Tahoe is the Upper Truckee River. The small peaks in the hydrograph generally represent rain events or short warm periods in winter or spring. The extended seasonal increase (March-June) represents the snowmelt. The peak snowmelt flow was approximately 499 cfs, compared to the long-term average of 300 cfs.

The Truckee River is the only outflow from Lake Tahoe. It is a regulated flow, with release quantity controlled by the Federal Water Master. Typical maximum summer discharge is approximately 300 cfs in mid-June. In 2016, the lake level was below the lake's rim for much of the year, so outflow was essentially zero until April. Streamflow data are collected by the U.S. Geological Survey under the Lake Tahoe Interagency Monitoring Program (LTIMP).

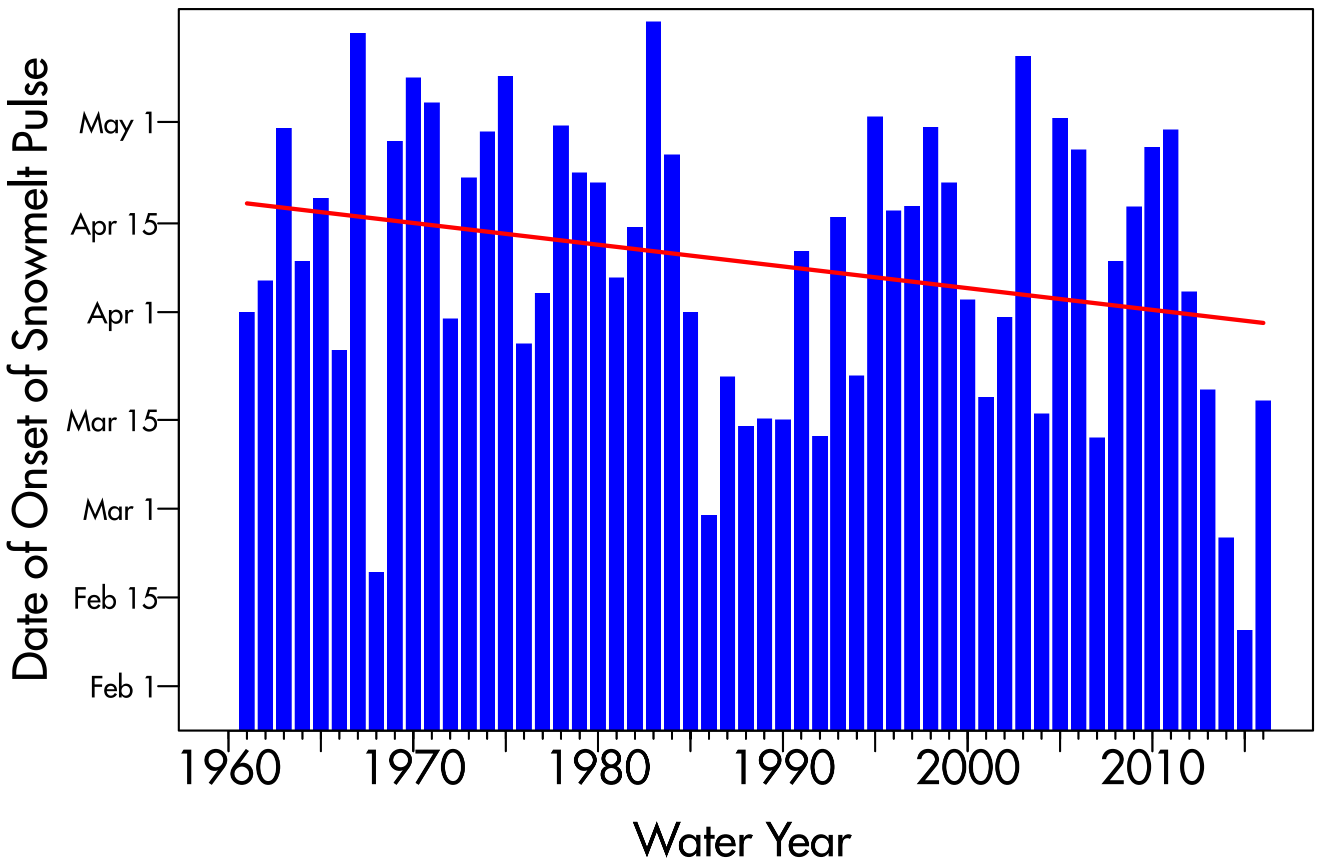


PHYSICAL PROPERTIES

Onset of snowmelt pulse

Yearly since 1961

Although the date on which snowmelt commences varies from year to year, since 1961 it has shifted earlier an average of almost 3 weeks (19 days). This shift is statistically significant and is one effect of climate change at Lake Tahoe. In 2016, peak snowmelt occured on March 29. The onset of the pulse is calculated as the day when flow exceeds the mean flow for the period Jan. 1 to Jul 15. The value for 5 gauged streams are averaged. In the past, we used the peak of the stream hydrograph to estimate this property.

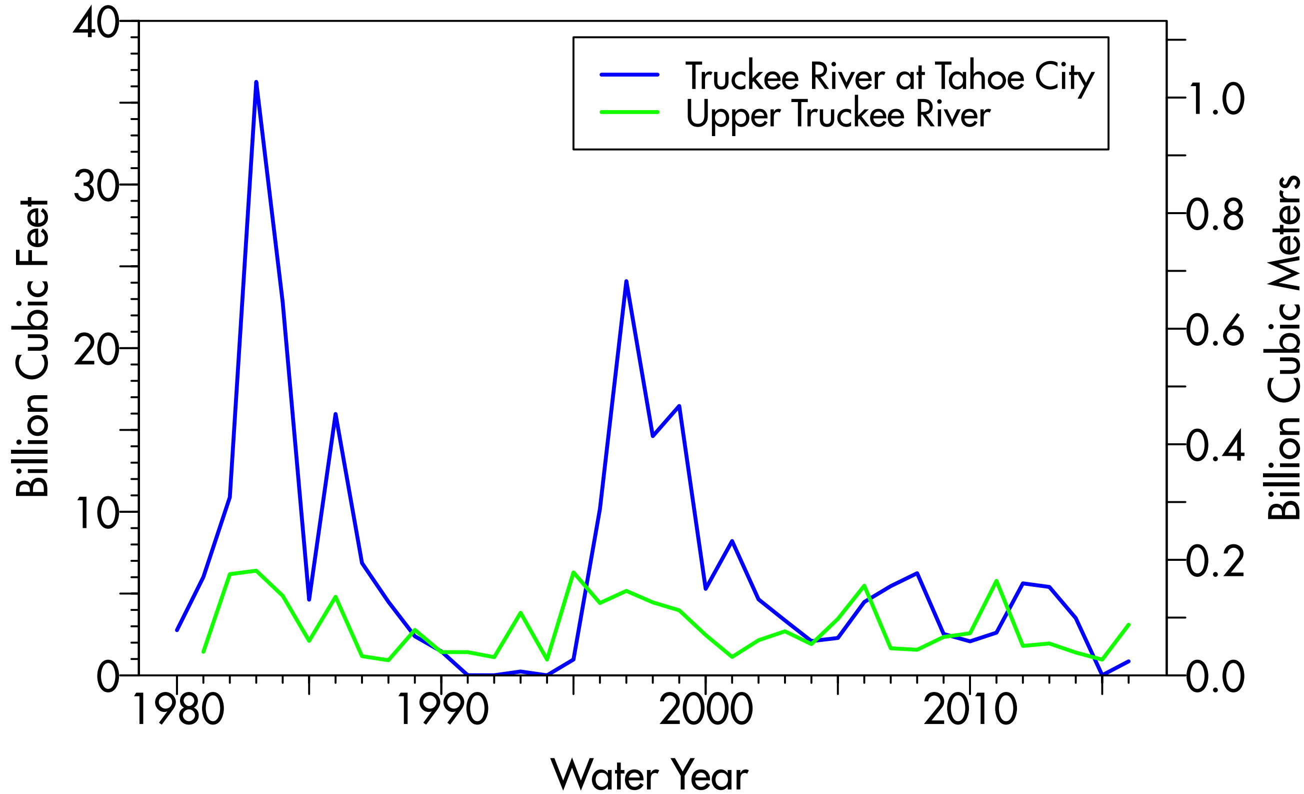


PHYSICAL PROPERTIES

Annual discharge volume for upper Truckee River and Truckee River

Since 1980

Flow into Lake Tahoe (e.g. Upper Truckee River) and discharge out of Lake Tahoe (Truckee River at Tahoe City) have shown considerable variation. The large peaks in discharge from the lake correspond to years when precipitation (and therefore total inflow) was the greatest, e.g. 1982-1983, 1986, 1995-1999. Similarly, the drought-like conditions in the early 1990s and the low precipitation years in the beginning of the 2000s culminating in the recent drought year also stand out. Since many of the pollutants of concern for Lake Tahoe's clarity enter along with surface flow, year-to-year changes in clarity are influenced by precipitation and runoff. The average annual Upper Truckee inflow since 1981 is 2.95 billion cubic feet, while the average annual outflow through the Truckee River is 6.75 billion cubic feet. In 2016, discharges into and out of the lake were well below the long-term averages. The Upper Truckee River inflow volume was 3.10 billion cubic feet. The Truckee River discharge was 0.86 billion cubic feet.

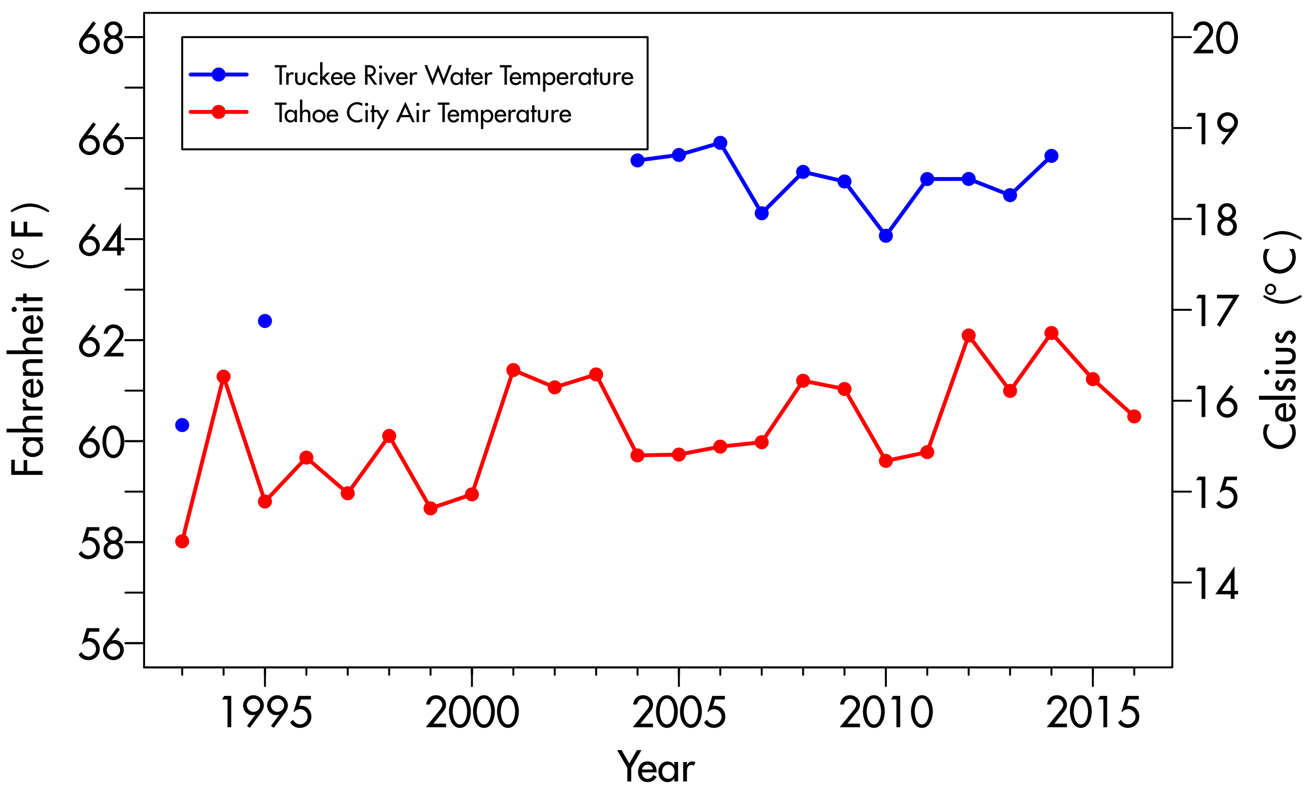


PHYSICAL PROPERTIES

Truckee River July-September water temperatures

Since 1993

Water temperature of the Truckee River as it departs Lake Tahoe in the summer months (July-September) is measured by the U.S. Geological Survey. Data gaps prevent a complete pattern, but the measurements suggest that a 4-5 °F (2.2-2.8 °C) rise in the average temperature may have occurred since 1993. Average air temperatures from Tahoe City for the same period also suggest a temperature rise but at a lower rate. Elevated river temperatures can also negatively impact fish spawning and fish rearing. In 2016, there was flow from the Truckee River from Lake Tahoe for only part of the year, so an average water temperature could not be calculated.



PHYSICAL PROPERTIES

Truckee River summer discharge and lake elevation

Since 1993

Flow rate of the Truckee River as it departs Lake Tahoe in the summer months (July-September) and lake level for the same period is measured by the U.S. Geological Survey. Here the relationship between these two variables is evident, with mean daily river discharge typically showing a one- to two-year lag from the lake elevation. Gage height is measured relative to a datum of 6,220 feet. Release of water from Lake Tahoe is controlled by the Federal Water Master.