TAHOE: STATE OF THE LAKE REPORT 2015

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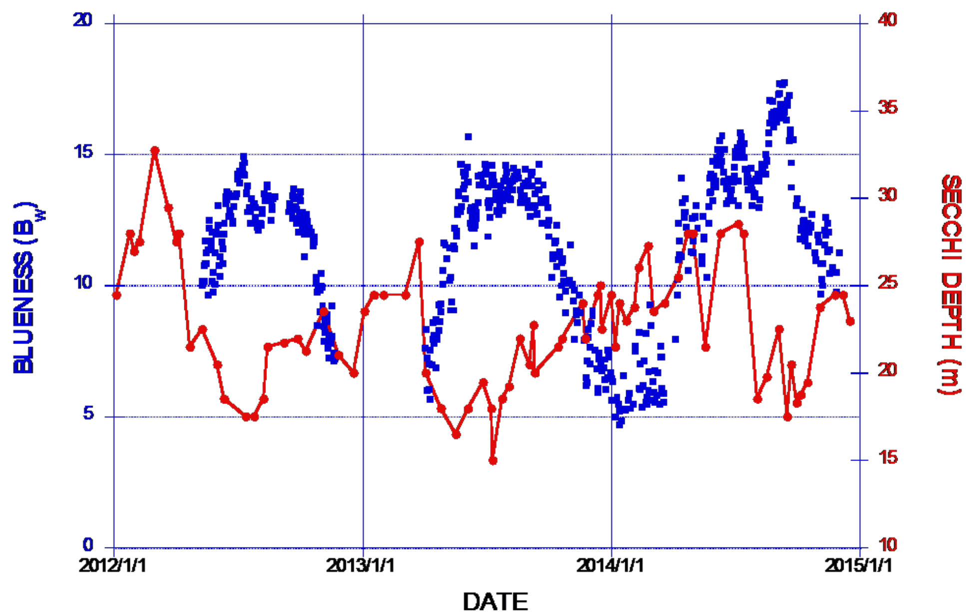
Keep Tahoe Blue or Keep Tahoe Clear?

UC Davis' long-term measurements of decline in Secchi depth readings have been a focal point of advocacy directed at restoring clarity and of restoration efforts themselves. The loss of Tahoe's unique cobalt blue color was at stake among other things. The general assumption was that clarity was synonymous with blueness. But is it?

TERC post-doc Dr. Shohei Watanabe has been leading a collaboration with Laval University, Canada and NASA-JPL to measure the blueness of the lake continuously from one of the research buoys in the center of the lake. Using hyperspectral radiometers that measure the amount of light leaving the lake at each waveband (in other words, the color we observe), he has produced a Blueness Index which provides a unique record of color change in Lake Tahoe.

When the daily average Blueness Index is combined with the measurements of Secchi depth, a surprising result emerges, as evident in the figure below. Blueness and clarity vary opposite to each other. While the clarity is related to the input of very fine particles from the surrounding land, blueness is most strongly related to the algal concentration. The lower the algal concentration, the bluer the lake. The lowest concentration typically occurs in summer when nutrients have been depleted. This is the time of highest particle concentration.

This is good news. We now have an even better understanding of how Lake Tahoe works, and it reinforces the importance of controlling nutrient inputs to the lake, whether from the forest, the surrounding lawns, or even from the air. What is particularly encouraging are the long-term changes. Overall, the blueness has been increasing over the last 3 years and the average annual clarity has stopped declining.



The blueness index plotted against Secchi depth for the last three years. Times of greater blueness occur at times of lower clarity.

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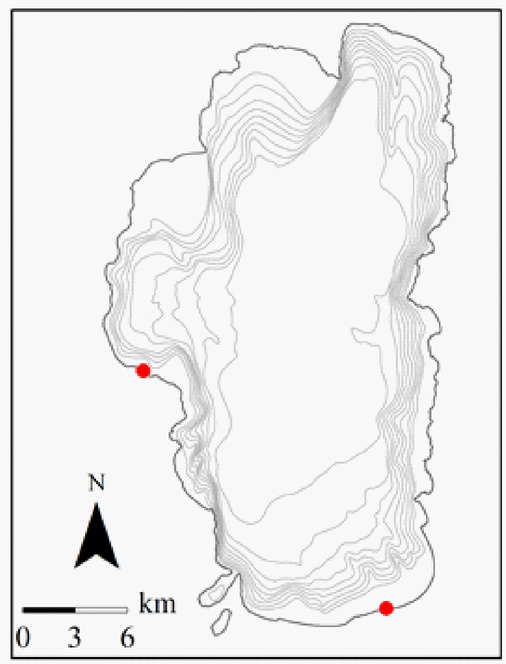
How Low Will it Go?

In 2014, the level of Lake Tahoe dipped below the lake's natural rim, thereby cutting off flow from Lake Tahoe into the Truckee River. When the level next rises above the rim and flow starts again will depend on how wet the next winter is. If it is below average the lake may stay below the rim for another year.

This phenomenon has happened several times in the last 100 years. You can see the record in Section 8.1. The lowest level in the last 100 years occurred on November 30, 1992, when the lake was 2.75 feet below the rim.

One of the consequences of low lake level is that the shoreline moves further out from the land. How far out it will go will depend of the lake level. The figures below show the shoreline location at two sites – Chambers Landing on the west shore and Al Tahoe in South Lake Tahoe. In both figures, the shoreline at end of 2014 and on November 30, 1992 are shown. Where will the shoreline be at the end of 2015?

Chambers Landing pictured with the 2014 shoreline depicted by a yellow line and the 1992 shoreline by a red line.



Chambers Landing is the red dot on the west shore of Lake Tahoe while Al Tahoe can be found at the red dot on the south shore.

Al Tahoe pictured with the 2014 shoreline depicted by a yellow line and the 1992 shoreline by a red line.

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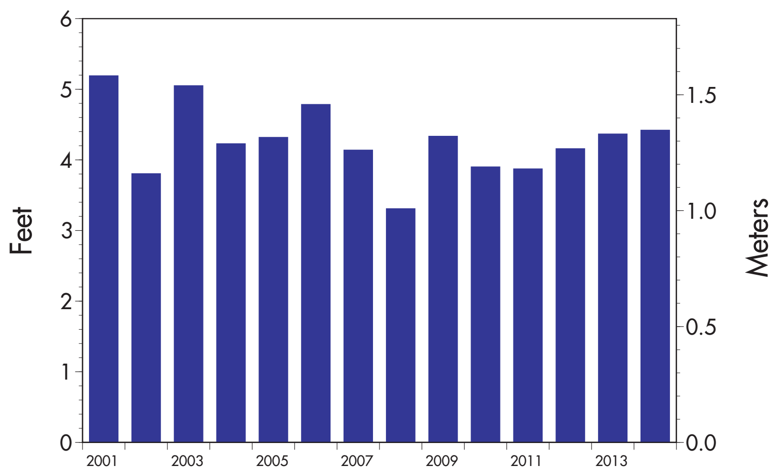
Evaporation from Lake Tahoe

Of the water that leaves Lake Tahoe each year, the largest amount is generally from evaporation from the lake's surface. Because of the size of the lake, the variability of the wind, temperature and humidity across it, and the heat stored in the lake itself, ascertaining how much leaves each day is difficult to quantify.

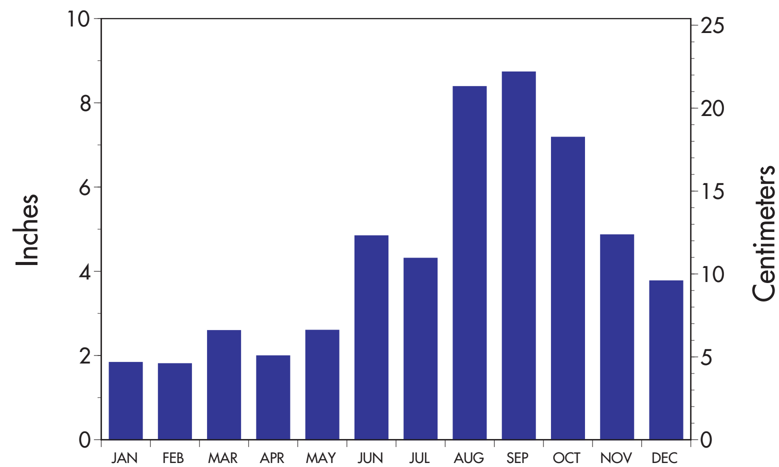
Using the continuous data from all four of the NASA-JPL/TERC research buoys on Lake Tahoe, graduate student Tom Mathis has been able to solve this problem. After creating a sophisticated model that calculates the heat and water loss across the surface based on real-time buoy measurements, Tom is able to calibrate and validate the accuracy of his model using independent water level data.

The figure on the left shows annual evaporation for the last 14 years. Despite some year-to-year variability, the annual evaporation is 4.27 feet (51.2 inches). The figure on the right shows how evaporation varied monthly in 2014. August and September were the months with the greatest evaporation with a monthly loss in excess of 8 inches. During the winter, evaporation fell to just 2 inches per month.

Daily lake evaporation rates will soon be part of TERC's real-time lake data displays around the basin.



The annual evaporation from 2001 to 2014.



Distribution of monthly evaporation during 2014.

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Let's Go Launch a Boat

One of the consequences of the drought and the falling lake level is that launching a boat at Lake Tahoe has become far more difficult. The table below shows the status of Lake Tahoe's public boat launches, as of July 1, 2015. Only three of seven have enough water to remain open. If water level continues to drop, the remaining boat ramps will be threatened.

PUBLIC BOAT LAUNCH	OPERATOR	CURRENT STATUS	PREVIOUS FULL-SEASON CLOSURE	NOTES
Cave Rock Boat Ramp	NV State Parks	OPEN	None	Only one of two boat launch lanes open.
Sand Harbor State Park Boat Ramp	NV State Parks	CLOSED	2000	Frequently has closed for the second half of the season
El Dorado Beach Boat Ramp	City of South Lake Tahoe	CLOSED	2014	Last season fully open was 2010
Coon Street Boat Launch	CA State Parks	CLOSED	Unknown	---
Lake Forest Boat Ramp	Tahoe City PUD	OPEN	Not in past 5 years	Dredged in Spring 2015
Tahoe Vista Recreation Area Boat Launch	North Tahoe PUD	CLOSED	Never closed before	Built in 2009
Ski Beach	Incline Village GID	OPEN	Not in past 20 years	---

Coons Street boat launch in Kings Beach. Photo: E. Blackmer

Tahoe Vista boat launch. Photo: E. Blackmer

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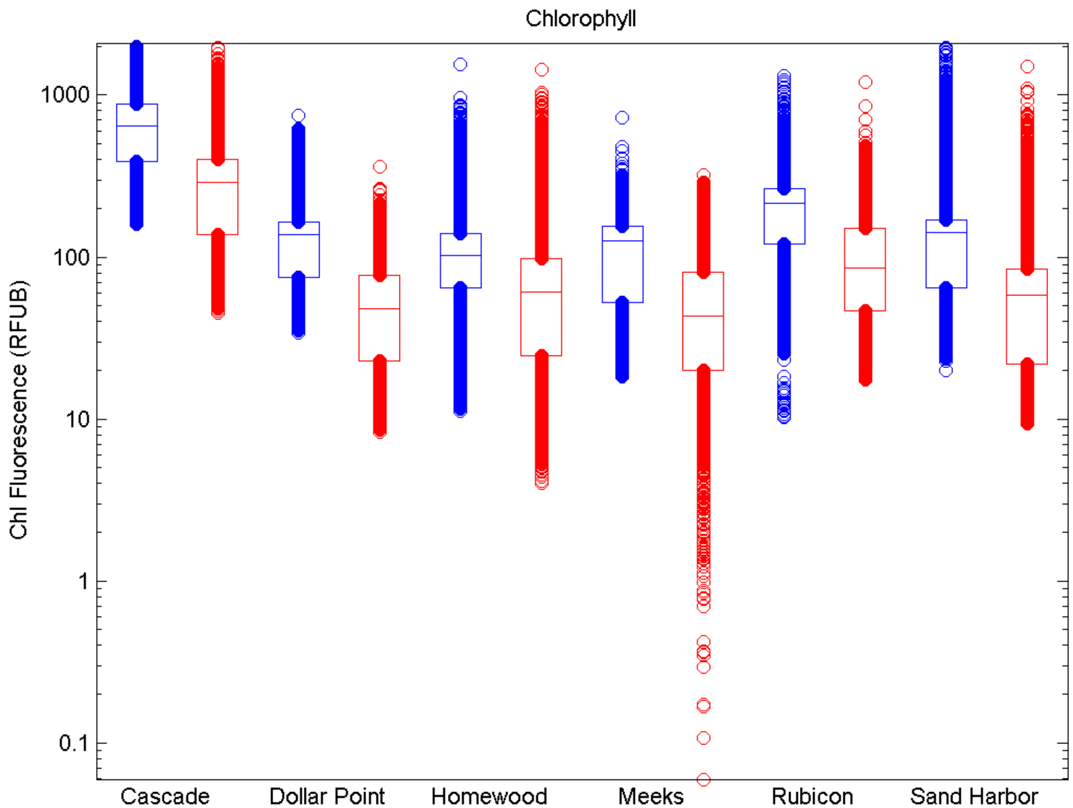
Tahoe's Nearshore Network

In 2014, we established a network of water quality instrument stations at various points on the shoreline around the lake. The program aims to understand the causes of degradation of Lake Tahoe's nearshore and provide the essential data needed to guide restoration and future stewardship.

By June 2015, 7 stations were installed and fundraising for the remaining 13 stations was well underway with individuals, businesses and homeowners' associations around the basin working with TERC on completing the network. Data that is being collected include algal concentrations, turbidity, temperature, wave height and dissolved oxygen concentration. Graduate student, Derek Roberts, is using the results are as the basis for his PhD research project.

What has been learned so far? To start, we now have baseline data for the instrumented sites to know what "normal" and "extreme" conditions are. The figure left shows the distribution of algal concentration (as relative fluorescence units) from six sites for a winter period (1/9/14 – 2/8/14) shown in blue and a spring period (3/21/14 – 4/23/14) shown in red. The line across each box is the median value recorded (from the approximately 84,000 measurements). The upper and lower bounds of the boxes represent the 75th and 25th percentiles respectively, and the symbols represent all values outside this range (the extremes).

At all sites, algal concentration is higher in winter, often by a factor of 2 or 3. Cascade Lake (next to Emerald Bay) has the highest algal concentration, while the lowest median concentrations in Spring were in Meeks Bay and Dollar Point. The most extreme low values were on the west shore, due in large part to cold water upwellings.



Variation of chlorophyll concentration at six sites in winter (blue) and spring (red). The lines across each box show the median value.

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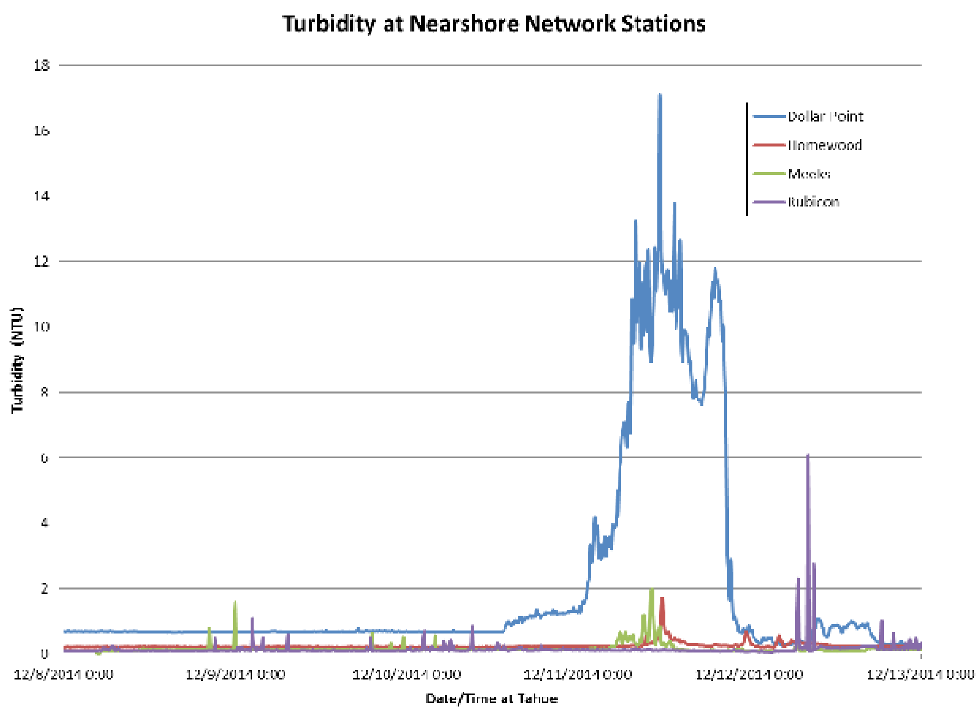
What Happens to the Nearshore During a Storm

In December 2014, the lake was blasted by two severe windstorms. On December 11, 2014, winds came from the southwest at 40 mph. The first panel shows the impact of the storm on turbidity at four west shore stations. Dollar Point recorded huge increases in turbidity up to 16 NTU (100 times larger than the desired value) in response to the storm, due to the breaking of 4 feet waves on the shore. The other west shore sites were sheltered, and had smaller, short term impacts. Most notable is the abrupt decline in turbidity immediately after the storm, indicating no lasting degradation.



Turbidity at four nearshore stations with strong southwest winds.

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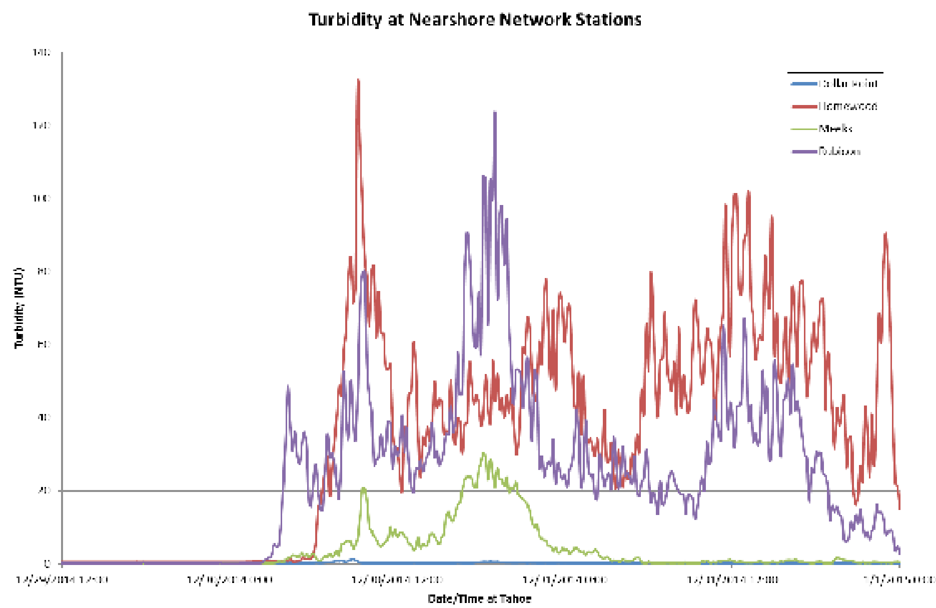
What Happens to the Nearshore During a Storm, continued

The second storm struck on December 30, 2014. The winds from this storm were lower (25 mph) and blew in from the northeast. For this storm Dollar Point was sheltered and saw almost no change in turbidity. However, Homewood and Rubicon saw turbidity rise to 50-100 NTU, a level that persisted for over 48 hours.

Neither of these events represent degradation of Lake Tahoe. Rather, they inform us of the impacts and duration of natural, albeit extreme, events. Knowing this, we can better recognize and understand the increases in turbidity that arise through poor land use practices.

Locations of the four nearshore stations relative to the wind direction.



Turbidity at four nearshore stations with strong northeast winds.

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How Cold is Lake Tahoe?

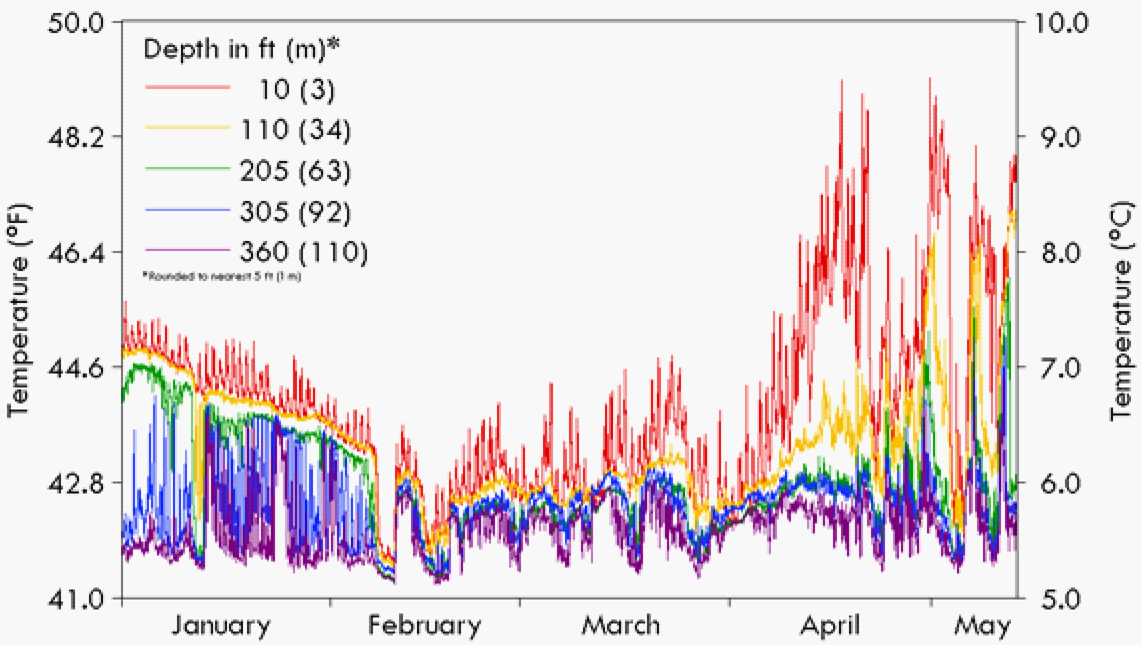
Temperature in the lake is constantly changing in response to the weather, the seasons, and especially the internal motions of the lake itself. A string of 16 high-resolution thermometers (a "thermistor chain") located off Homewood, CA, is providing graduate student Heather Sprague with unique data on Tahoe water temperatures.

Connected to the shore at Obexer's Marina by an underwater cable, data are gathered at 30 second intervals. The figure shows temperatures from just 5 of the instruments for the first 5 months of 2014. The uppermost (red) line shows the temperatures 10 feet below the surface. Here water temperature changes daily in tune with the rising and setting of the sun. Even in winter the water temperature can change 1 °F during the day. In summer, it can be 4 or 5 °F.

At a depth of 110 feet these daily changes are more muted, and we see the seasonal changes more clearly. Temperatures are lowest near the end of March.

Deeper down in the lake (305 and 360 ft.), the temperature fluctuations are again large, with temperature changes in the range of 2-3 °F. While they look like they are occurring daily, these fluctuations are in fact occurring every 19 hours, the result of a curious interaction with the earth's speed of rotation and the size and latitude of Tahoe. Even longer periods and larger amplitude fluctuations take place in the spring. These fluctuations are due to oscillations that travel around the edge of the lake once every 5 days.

The oscillations revealed by measuring temperature are similar to the oscillations that produce musical sounds. Read the next section to see (and hear) how this connection is being made and allowing us to hear the music produced by Lake Tahoe.



Temperature traces at five depths near Homewood, CA.

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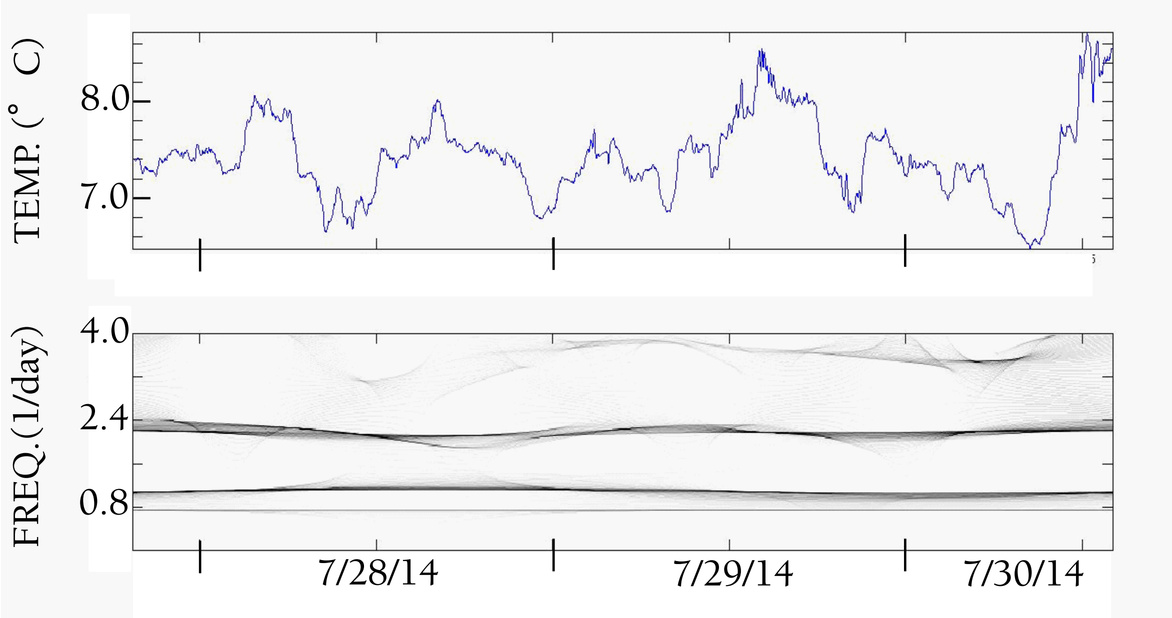
Lake Music

Lake Tahoe is in a constant state of motion. Many of these motions take the form of vertical oscillations. These oscillations vary in size and frequency, and depend on interactions between the temperature difference from top to bottom in the lake, the strength and direction of the wind, and the daily rotation of the earth about its axis. At each depth and on each day, oscillations are changing accordingly.

The temperature record from three days at a depth of 120 feet off Homewood, CA (upper panel), show the oscillations clearly. They are not unlike the vibrations that a plucked guitar string might exhibit. This idea has inspired a collaboration between the UC Davis Department of Mathematics and TERC. With guidance from Dr. Naoki Saito, undergraduate student Jordan Leung and graduate student Alex Berrian have converted Tahoe's inherent music into an audio file. The data used were temperature measurements TERC student Heather Sprague recorded every 30 seconds at 16 depths ranging from 10 feet to 360 feet below the lake surface.

For each temperature recorded, the trend was removed and a sophisticated mathematical procedure called 'synchrosqueezing' was used to generate time-frequency curves (lower panel). Here you can see the major frequencies in the time series and how these change over time. These curves are then mapped to pitches in a music scale in the human-audible range. Each time series is assigned a different musical instrument, with lower pitch instruments such as a double bass used for the deeper parts of the lake and higher pitch instruments such as a violin used for the shallower parts. Each instrument played different notes according to the calculated frequency with volume altered according to the observed trend.

To listen to a sample of lake music based on 14 days of data from 10 ft. below the surface, scan the QR code or simply go to http://terc.ucdavis.edu/local_resources/music/soundsoftahoe_.mp3



The oscillating temperatures recorded over a three-day period off Homewood is pictured above. Converting these oscillations using 'synchnosqueezing' is shown in the lower panel.

Scan QR code (left) to listen to Lake Tahoe's inherent music.