

TAHOE: STATE OF THE LAKE REPORT 2013

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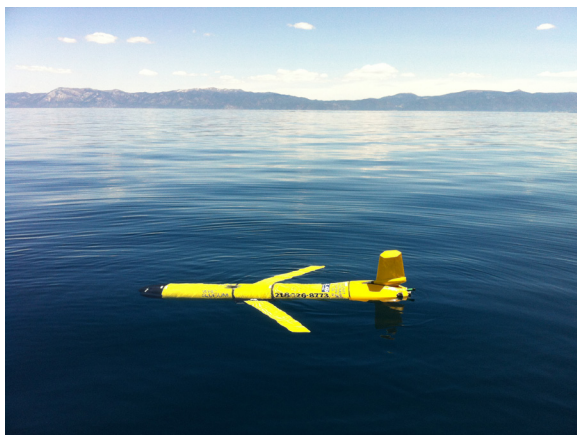
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Overview

While the State of the Lake Report is primarily intended to focus on the trends emerging from long term data collection efforts, this section presents the results of some current and short term projects. In some cases

the projects are complete, but in most cases they are a preview of some new and exciting research directions. This year we focus on five areas: an underwater Glider experiment, the projected 21st century trends in

Tahoe's hydroclimatology, drought adaptation by forests, new efforts on collecting real-time data on Tahoe's water quality and measuring the blueness of Lake Tahoe.



The University of Minnesota, Duluth's Glider just prior to descending into Lake Tahoe for the start of its 11 day mission to traverse Lake Tahoe 17 times.



Research divers Brant Allen and Katie Webb preparing to lay the first section of the underwater cable for Tahoe's first real-time water quality monitoring station.



Cleaning the underwater radiometer at Buoy TB3, a joint project between TERC and NASA/JPL to continuously measure the changing light conditions in the lake.

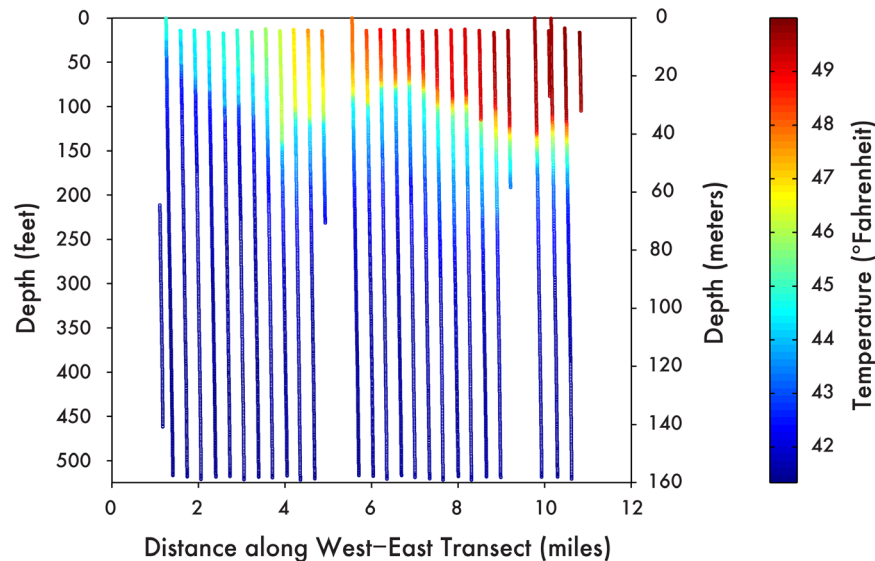
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Underwater Glider experiment

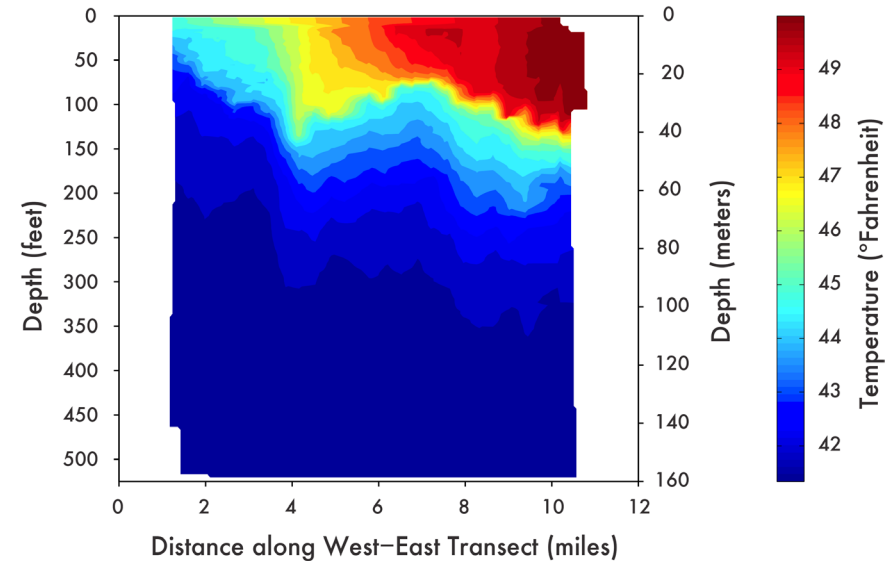
Underwater Gliders are ultra-low powered instrument packages that can measure a range of water quality variables in oceans and lakes. They operate by repeatedly diving and rising along a pre-determined path, and taking measurements while they do so. They have the ability to do this for months at a time under conditions that make conventional sampling dangerous.

In a collaboration with Dr Jay Austin of the Great Lakes Observatory, University of Minnesota, Duluth, TERC conducted a Glider experiment in Lake Tahoe from May 11- May 22, 2013. The Glider conducted 17 measurements transects on the same east-west line, diving repeatedly to a depth of over 500 feet. The panels show the data collected during the transect that commenced at

2:02 PM on May 21, and concluded at 5:30 AM on May 22. The west shore is at 0 miles on the horizontal scale and the east shore is at 12 miles. The first panel shows the raw temperature data, superimposed on the trajectory lines taken by the Glider. The Glider was set to only collect data while descending.



Raw temperature data collected by the Glider along each of its 29 dives along the east-west transect.



Temperature contours along a transect from west (left) to east (right) across Lake Tahoe. The severe tilt is due to a wind-driven "upwelling." This is a common springtime event in Lake Tahoe.

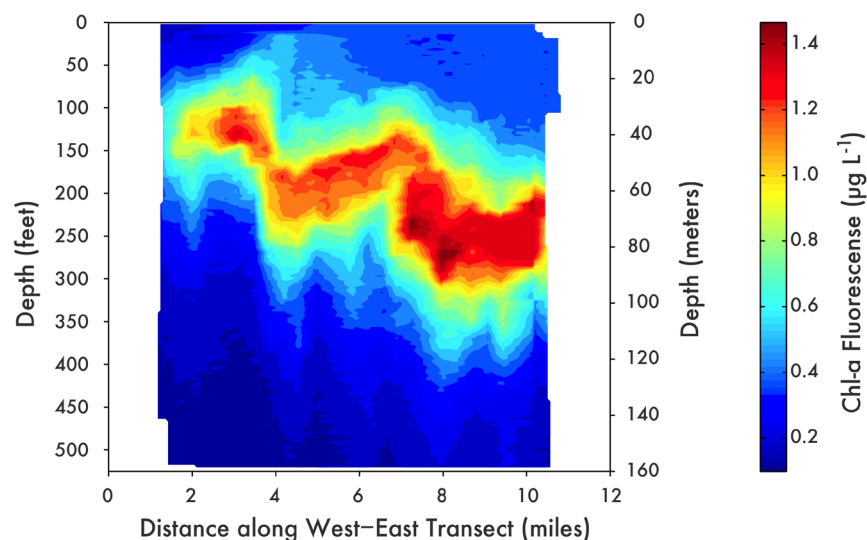
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Underwater Glider experiment, continued

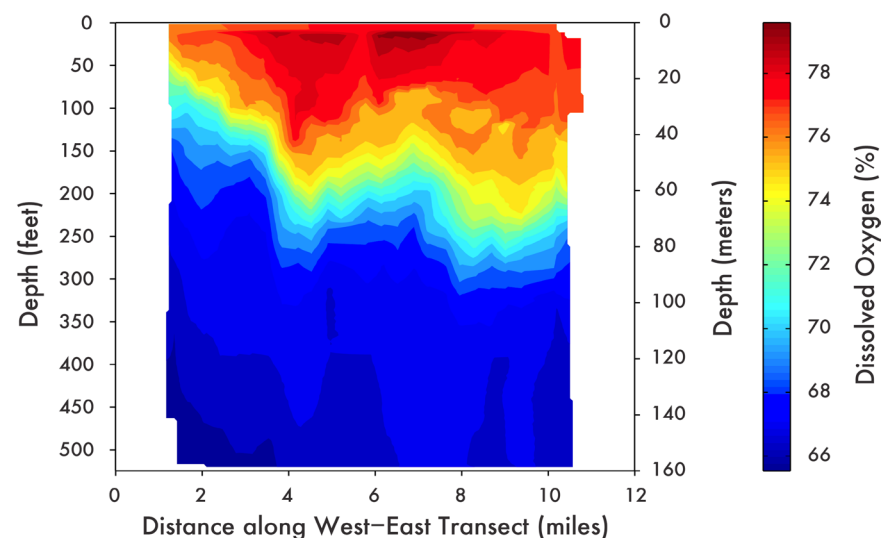
This transect took place under extremely windy conditions, with the wind from the south west. This caused an “upwelling”, where water from as deep as 150 feet on the west shore is raised up to the surface in a giant “internal wave”. Warm surface water is pushed eastward toward Nevada.

This transport impacts all other water quality parameters. Chlorophyll, a measure of algal abundance, that has its highest values in a deep layer centered at about 200 ft, also rises in the west and sinks in the east in response to the induced wave motion. Dissolved oxygen, which tends to have higher concentrations near the surface and lower concentrations at depth, is similarly distorted.

These results highlight the extreme natural variability that is present in Lake Tahoe at short timescales. This variability needs to be understood in order to analyze the long term trends in water quality. Similarly, the lake motions themselves are responsible for transporting pollutants within the lake and need further attention.



Chlorophyll fluorescence contours along a transect from west(left) to east (right) across Lake Tahoe.



Dissolved Oxygen (percent saturation) contours along a transect from west (left) to east (right) across Lake Tahoe.

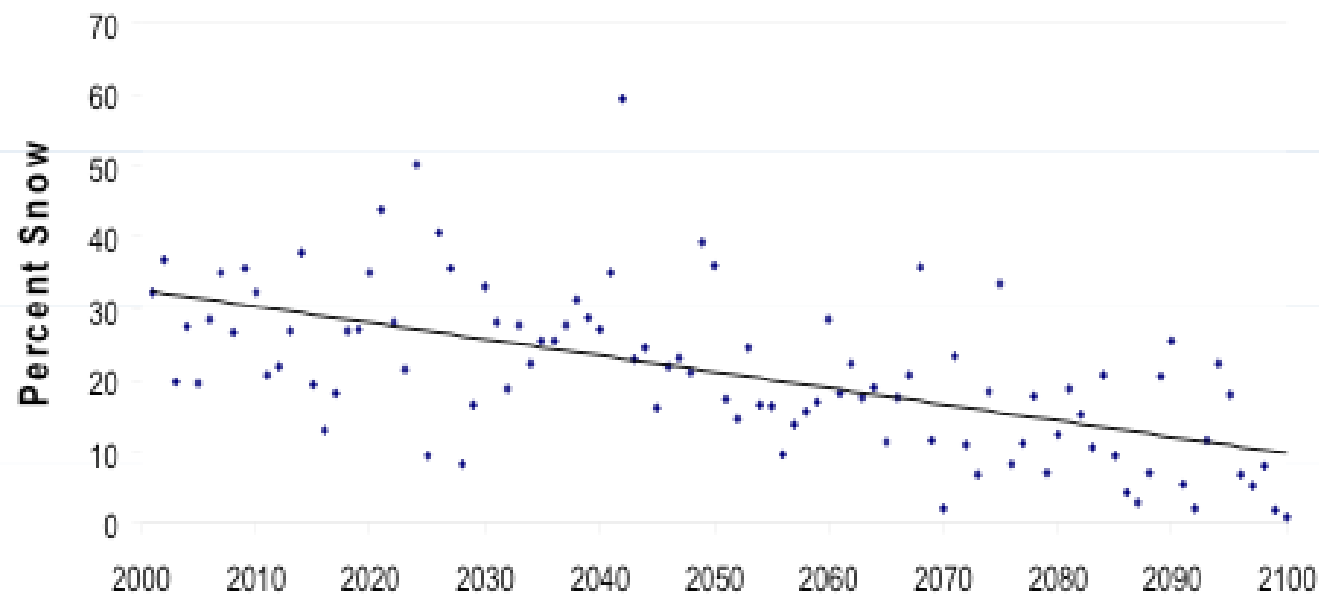
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Projected 21st century trends in Tahoe's hydroclimatology

TERC, in collaboration with Hydroikos Associates; the US Geological Survey/Scripps Institute of Oceanography; Tetra Tech, Inc.; Northwest Hydraulic Consultants; and Hydrology Futures,

LLC., completed a SNPLMA funded study to provide a first assessment of the extent to which climate change needs to be considered in ongoing efforts to protect and manage the unique waters of

Lake Tahoe. The results are published as a series of five papers in the journal Climatic Change (copies available upon request).



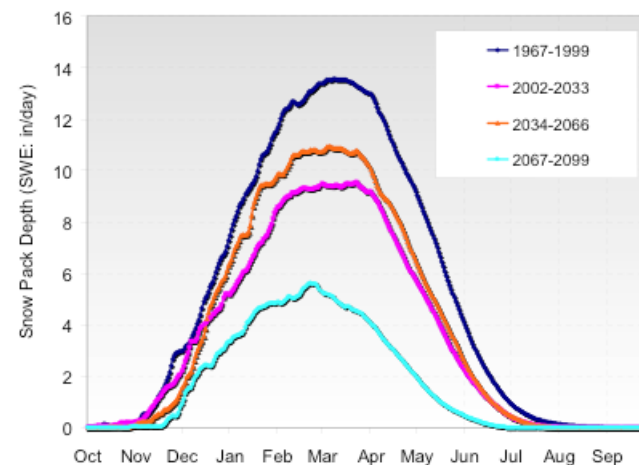
The decline in the percentage of precipitation as snow in the next 100 years under the GFDL-A2 scenario.

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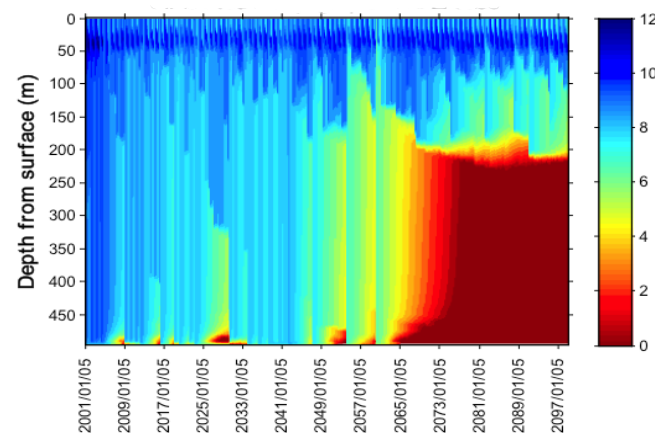
Projected 21st century trends in Tahoe's hydroclimatology, continued

Key findings of the study till the end of the 21st Century included, for the range of scenarios tested:

1. Air temperature increases as high as 10 °F
2. The fraction of snow to rain could fall to 0.1-0.2, leading to reduced water storage in the spring snow pack and increases in drought severity
3. Changes in stream low-flow conditions could render the lower reaches of some streams completely dry more often
4. Dramatic increases in flood magnitude
5. Sediment and nutrient loading to Lake Tahoe from streams should not increase substantially
6. Overall fine sediment load reductions should still be achievable if storm water treatment facilities are properly sized
7. Lake Tahoe could cease to mix to the bottom for extended periods, resulting in complete oxygen depletion in the deep waters with loss of habitat and an increase in sediment nutrient release,
8. Lake surface level is more likely to drop below the natural rim for extended time periods.



Estimated snow pack depths at different time intervals under the GFDL-A2 model scenario.



Estimated dissolved oxygen concentration in Lake Tahoe over the next 100 years under the GFDL-A2 model scenario. Note the complete loss of oxygen below 200 m after 2065.

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Drought adaptation by forests

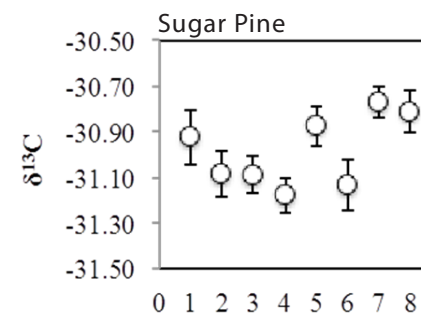
Experiments have been established by researchers from UC Davis and the USDA Forest Service Pacific Southwest Research Station to evaluate ecologically important plant traits in sugar pine, western white pine, and

white bark pine, three co-dominant and dominant tree species in the Lake Tahoe Basin. Determining water-use efficiency by measuring the carbon stable isotope ratio, $\delta^{13}\text{C}$, may improve our understanding of drought adaptation

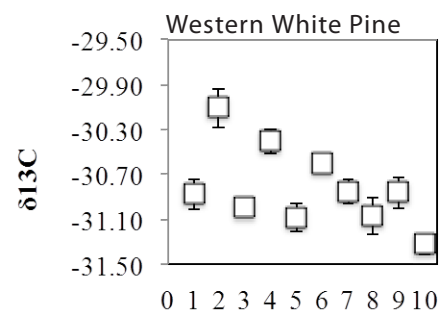
and provide information about how populations of forest tree species will respond to global climatic change (e.g. adaptation from standing variation). The less negative value of $\delta^{13}\text{C}$ corresponds with higher water use efficiency.



Sugar pine seedlings at the Institute of Forest Genetics.



Population	Number
Bliss SP	1
Carnelian Bay	2
Glenbrook	3
Granlibakken	4
Heavenly	5
Sand Pit	6
Sugar Pine Point	7
Tunnel Creek	8



Population	Number
Armstrong Pass	1
Blackwood Cyn	2
Echo Lake	3
Flume	4
Heavenly	5
Incline Lake	6
Jakes Peak	7
Meiss Mdw	8
Montreal Cyn	9
Mt Watson	10

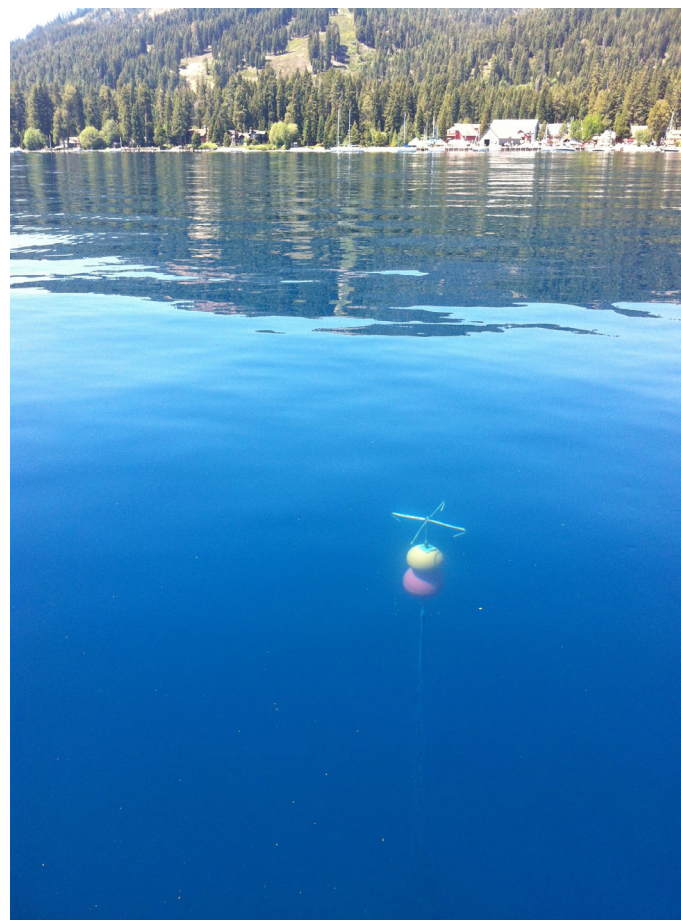
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Real-time monitoring of water quality in Lake Tahoe

A vertical array of temperature, pressure and dissolved oxygen measuring instruments are installed at a depth of 120 m off the west shore of Lake Tahoe, adjacent to TERC's long-term Index station. A 600 m long underwater cable from the shore connects to the array and provides power and transmits data to the internet every 30 seconds.

The temperature acts as a tracer for mixing processes in the lake, allowing us to understand the mechanisms by which dissolved oxygen is transferred to the deep water. This is a critical question that needs to be addressed in order to better understand climate change impacts on Lake Tahoe. The pressure data are being used to study the long period waves at the surface of the lake (seiches) and to also relate their impact on internal processes in the lake.

This project is made possible through a collaboration with Obexer's Marina, who are providing the terminus land site for the underwater cable. Funding to launch the project was provided by the UC CITRIS program and private donors.



The sub-surface buoy atop the instrument array at Homewood.

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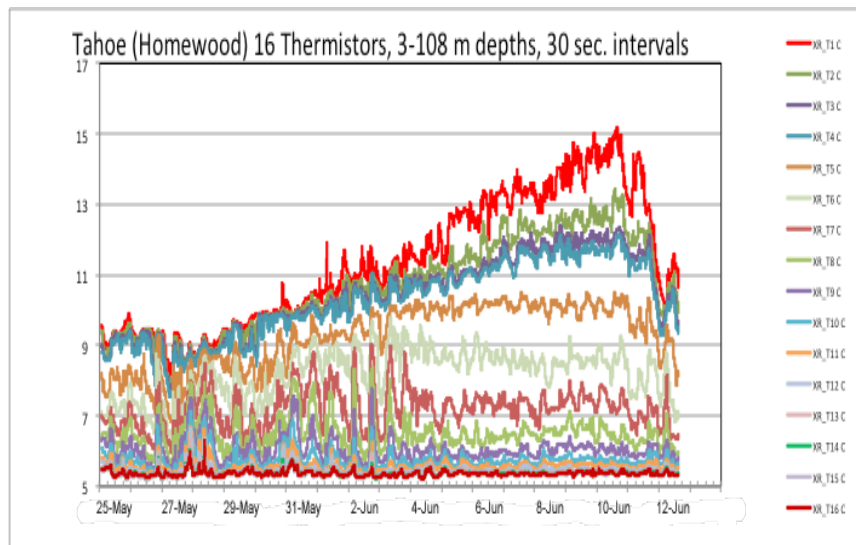
Real-time monitoring of water quality in Lake Tahoe, continued

The left panel represents nineteen days of temperature traces that show the gradual warming of the surface water through June 12. The peak temperature was 15 °C (59 °F). Intense winds for the next three days cooled the surface layer of the lake by 4 °C

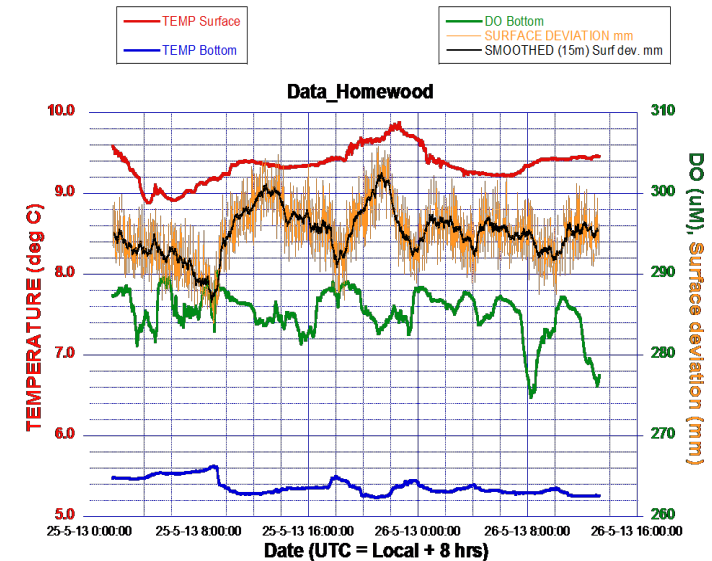
(8 °F) in two days. Note that the bottom temperatures are virtually unchanged.

The right panel shows thirty six hours of data from the real time station. The green trace shows the variations in the dissolved oxygen

concentration at the lake bottom. The black trace is the fluctuation of the lake surface. The red and blue lines are the surface and bottom temperatures, respectively.



All 16 temperature traces for 19 days. Note the rapid cooling at the end of the record. High winds forced the mixing of the lake surface.



Oxygen fluctuations at the bottom of the lake were not expected. They appear to vary in the opposite direction to the lake level.

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Measuring the blueness of Lake Tahoe

Most people are familiar with the slogan “Keep Tahoe Blue”, yet the goal for Lake Tahoe has always been phrased in terms of clarity rather than color. Using hyperspectral radiometric measurements that measure the light upwelling from the lake, it is possible to quantify the actual color of the lake water. This is being done using instruments deployed

upon a buoy in the center of Lake Tahoe (TB3) in collaboration with NASA/JPL. Measurements are being taken every 30 minutes during daylight hours. It is planned to start transmitting data in real time in 2013.

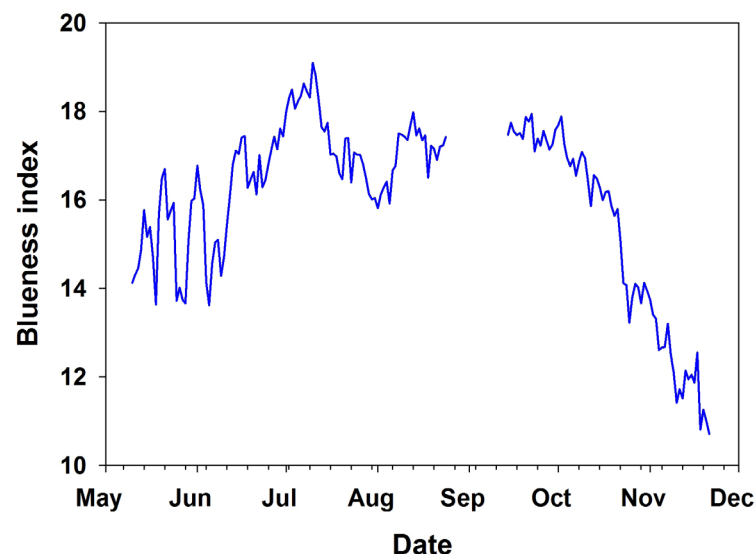
The importance of this data is that it can help understand what drives changes in

lake color at a range of time scales, from hours to years. These measurements are unique and are part of what is being done to better understand the linkages between water quality contaminants and the spectral response of lakes. A long term goal of the project is to use remotely sensed imagery from satellites to provide similar data for lakes world-wide.



Radiometric profiles are taken regularly to calibrate the buoy sensors.

**Blueness of Lake Tahoe
from May 11 to Nov 21, 2012**



Quantification of water color for a 7 month period in 2012. The values shown are the b^* coordinate values of the $CIE L^*a^*b^*$ color space. Higher values indicate increased “blueness.” The decrease in blueness is evident in fall and winter. Short term fluctuations in blueness are seen in May and June. Data gap around September was due to instrument maintenance.

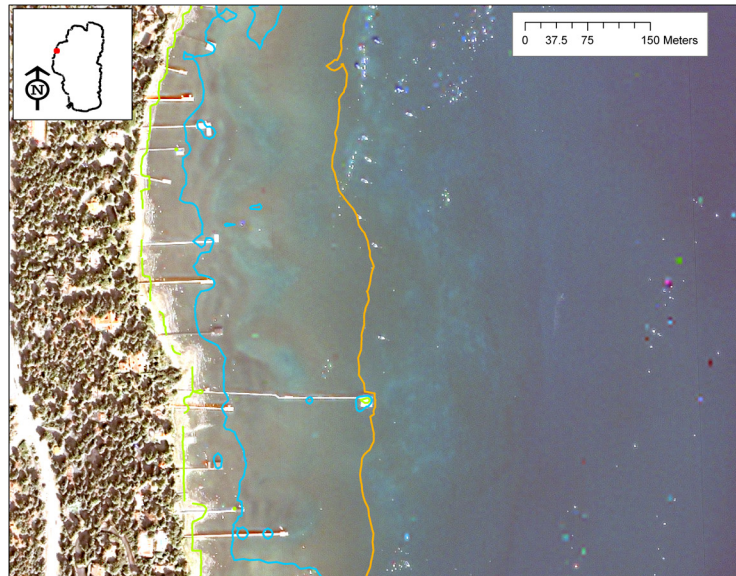
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Shoreline change due to prolonged drought

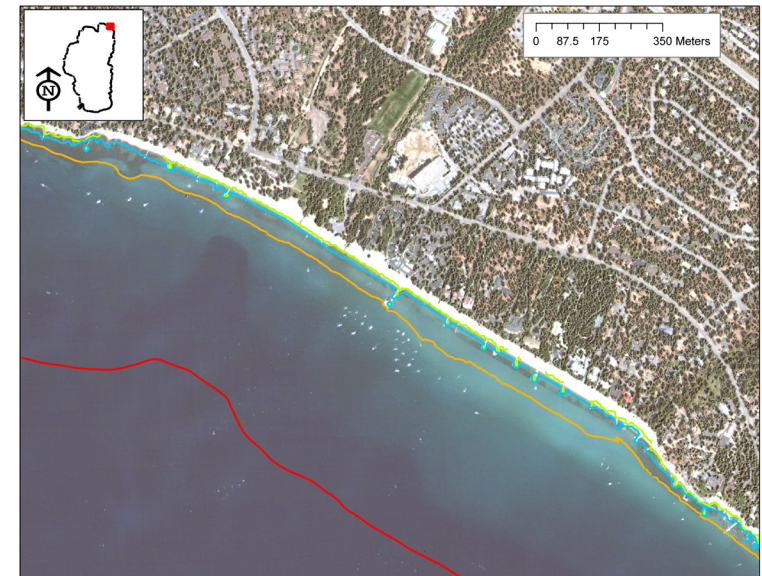
In a dry year lake Tahoe typically loses 1.5 feet of water level. Predictions of future climate conditions in the basin point to more extreme events in the future. A 5-year drought could conceivably reduce the lake level to

6215.5 feet, or 5 feet below the record 1992 levels. How would the shoreline look under those conditions. The images below show the shoreline positions corresponding to the natural rim of the lake (without the dam), the 1992 drought

shoreline, the 5 year drought shoreline, and the shoreline corresponding to the ancient drought 5000 years ago when lake level was lower by 40 feet for hundreds of years.



Three shorelines positions for McKinney Bay, CA. Green – the natural rim, blue- the 1992 drought, and orange – a possible 5 year drought. Note the dock positions.



Four shorelines positions for Incline Village, NV. Green – the natural rim, blue- the 1992 drought, orange – a possible 5 year drought, and red – the ancient drought. Note the dock positions.