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# Use of Embedded Networked Sensing for the Study of Cyanobacterial Bloom Dynamics

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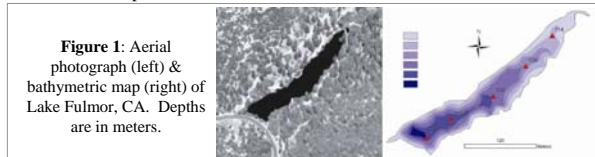
## Development of a sensor network for continuous sensing presence & intelligent sampling

### Networked Aquatic Microbial Observing System (NAMOS)

- **Need low-energy, highly adaptable sensor network**  
 Sensor needs change, and many aquatic & marine processes operate over the course of days, requiring prolonged presence in the environment.
- **Combination of static & mobile components**
  - Allow for high spatial AND temporal resolution in dynamic & heterogeneous aquatic environments\*
  - Mobile component can be informed by static components to direct resources to biologically interesting areas & features.

### Test Site: Lake Fulmor, CA

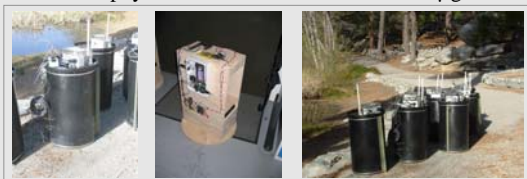
- **Lake Fulmor borders on the James Reserve, near Idyllwild, CA**
  - History of cyanobacterial blooms in late Spring – early Fall
  - Maximum depth of 6 meters



## Network utilizes coordinated static & mobile sensing and sampling components

### Static buoy network

Each buoy is equipped with a computer, sensor suite, and wireless communication. They are networked and communicate with each other and a shore-based station via wireless ethernet. Onboard sensors include a thermistor array for measuring water temperature to 3 m depth and a Turner Designs Cyclops-7 fluorometer capable of detecting chlorophyll *a* concentrations from 0.2-500 µg/L



### Mobile robotic boat

The robotic boat is equipped with similar sensors and processing capabilities in addition to a water sampler capable of taking six 4-ml samples. The robotic boat can be autonomously controlled using information obtained from the network.



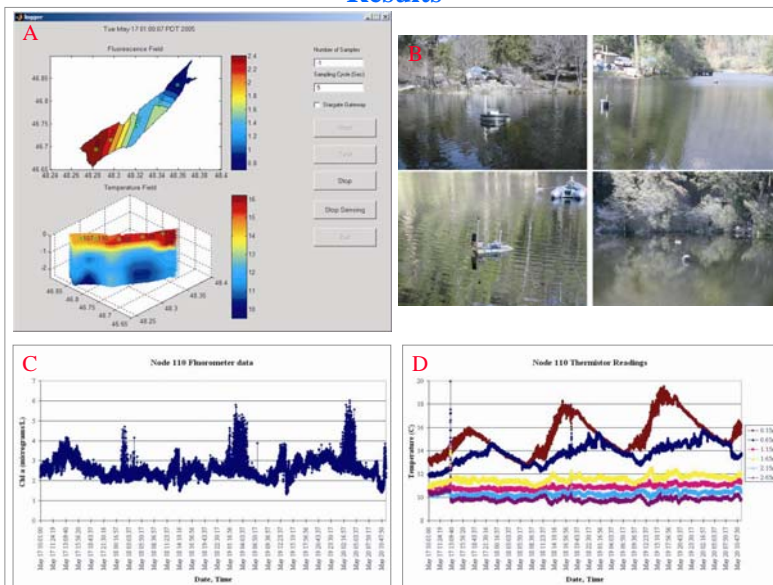
## Use of NAMOS to study cyanobacterial blooms in Lake Fulmor, CA in May, 2005

### Results and Discussion

Over the course of a 4-day NAMOS deployment in May 2005 (Figure 2), the chlorophyll *a* concentration showed high temporal variability. Cyclic daily variations in subsurface chlorophyll *a* fluorescence were observed with a peak between the hours of midnight and 5 am. *Spirulina* sp. and *Anabaena* spp. strongly dominated the phytoplankton community with other filamentous cyanobacteria also present. The sensor network also detailed the spatial distribution of photosynthetic organisms along the length of Lake Fulmor, indicating increased concentrations of chlorophyll *a* towards the southwest end of the lake.

The presence of daily variations in chlorophyll *a* concentration at all static node stations implies a strong vertical migratory behavior of phytoplankton in the lake, most likely *Spirulina* or *Anabaena* spp. Accumulations of chlorophyll *a* in the southwest corner of the lake suggest reduced mixing or increased nutrients in this deeper, more protected area. The ability to resolve these trends at several points along Lake Fulmor and over the course of several days, and the combination of these data with autonomously collected water samples, constitutes a marked improvement over traditional point sampling techniques and allows the construction of testable hypotheses regarding plankton dynamics.

### Results



**Figure 2:** Fluorometer and temperature data from May, 2005 NAMOS deployment. (A) Screen capture of NAMOS visualization, showing chlorophyll *a* fluorescence (top) and temperature (bottom) data for all buoys on May 17, 2005 at 1 pm. (B) Deployed buoys and robotic boat in Lake Fulmor. (C) Chlorophyll *a* variations at node 110 throughout the 4-day May deployment showing a daily peak in fluorescence between the hours of midnight and 5 am. (D) Daily temperature fluctuations at six depths at node 110.

