Center for Embedded Networked Sensing

Research Overview October-2008

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The Center for Embedded Networked Sensing is...

5 partner campuses: UCLA, UC Riverside, UC Merced, CalTech, & USC

40 Faculty ~ **84** Grad. Students ~ **42** Undergrads ~ **14** Staff (current yr., approx.)

57 (29 core funded) projects across **9** research and education areas

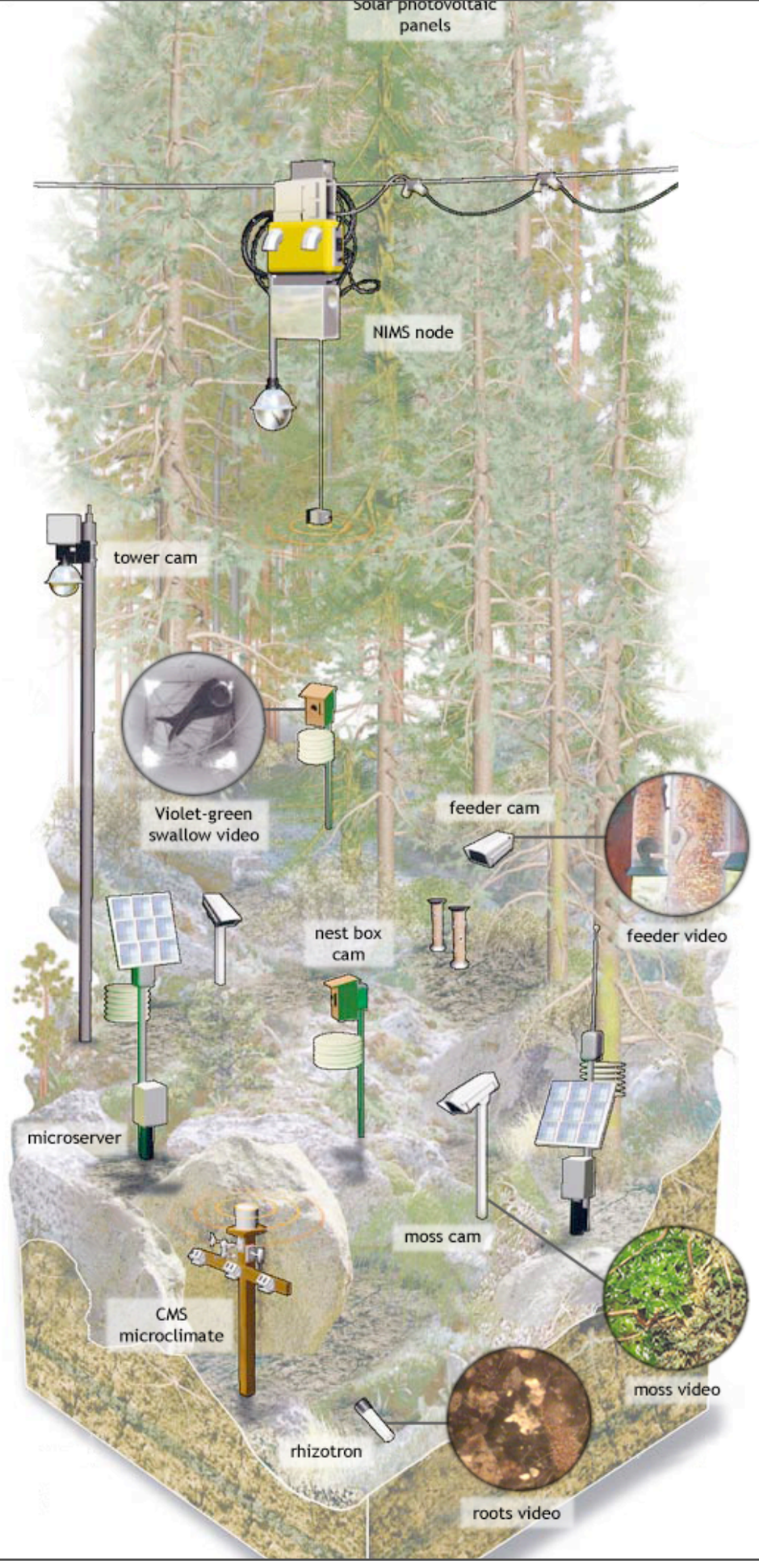
Technology research areas
- multiscale actuated sensing
- platforms and programming
- statistics & data practice
- embedded sensors

Research Applications
- terrestrial ecology
- aquatic ecology
- contaminant transport & management
- seismology & structural health
- participatory urban sensing

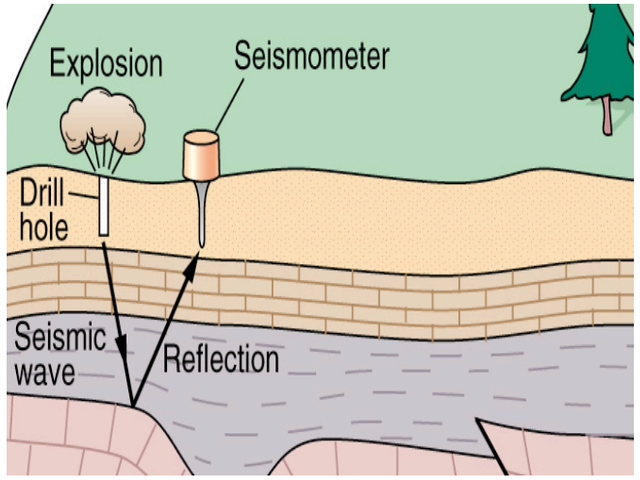
Embedded
in the physical environment
(soil, forest canopy, rivers)

Networked
to share information & adapt function
(data, system status, control)

Sensing
as in measurement instruments
(sensors, transducers)



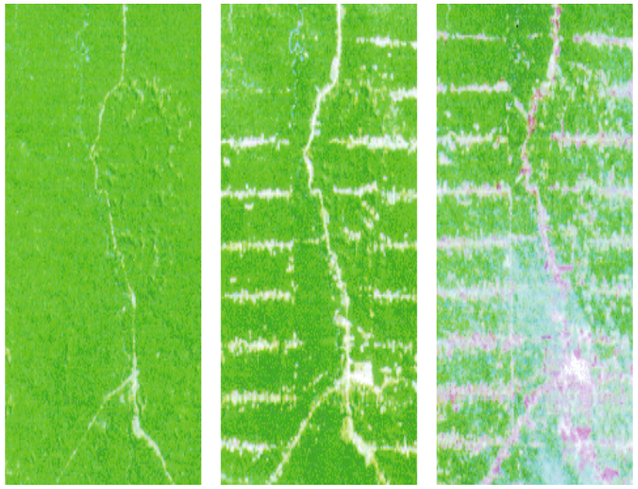
Environmental Monitoring Applications
Spatial variations and heterogeneity



Earth structure inhomogeneities

Exposure to Particulate Matter (PM 2.5)

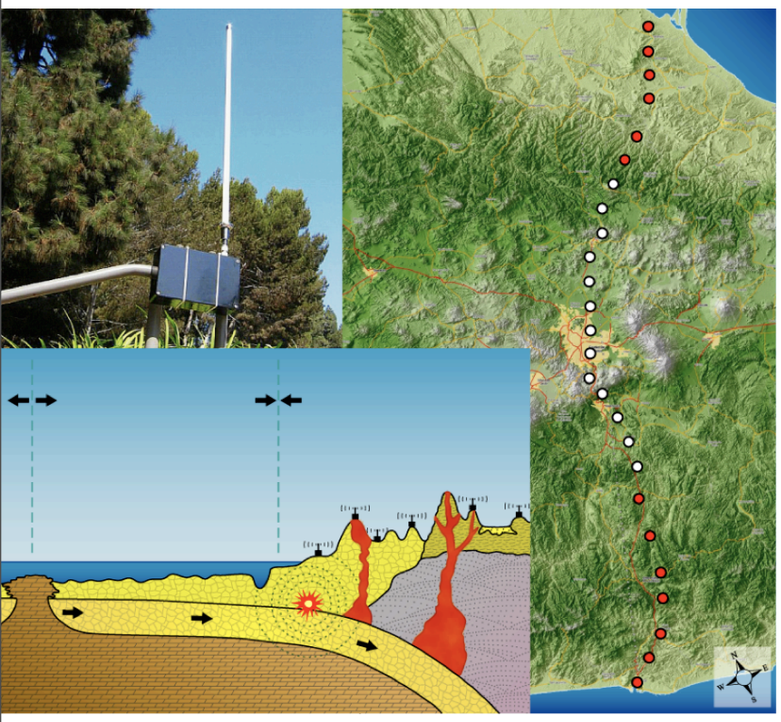
Precision agriculture, water quality management



Impact of fragmentation on species diversity

Algal growth as part of eutrophication

Center-wide focus: Embedded Networked Sensing Observatories

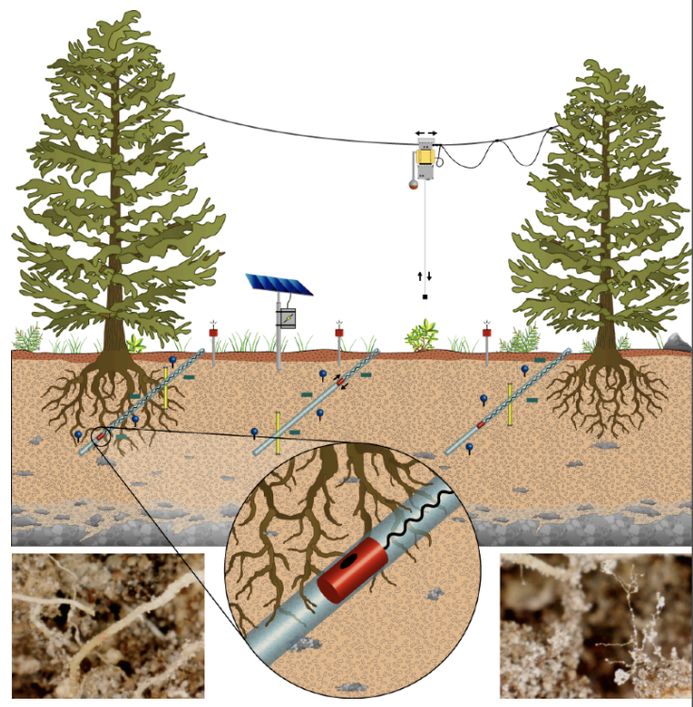


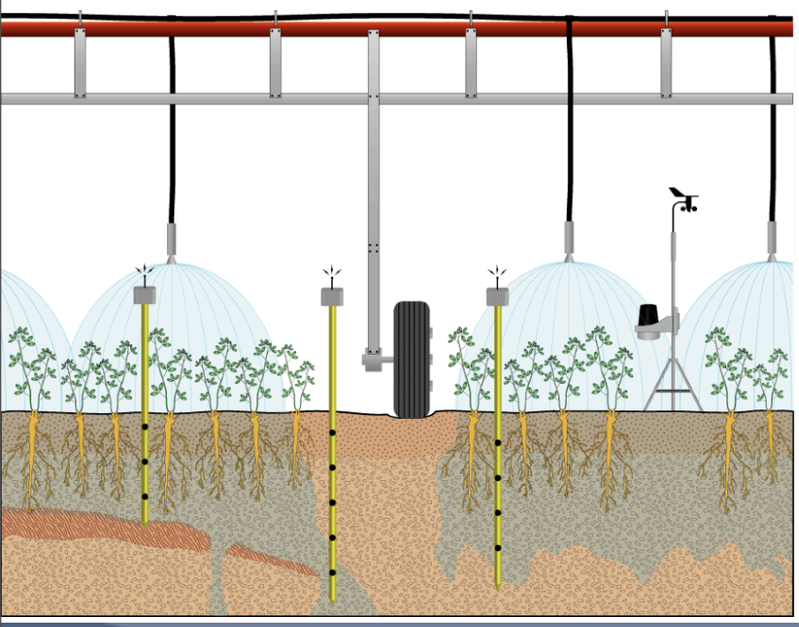
create programmable, distributed, multi-modal, multi-scale, multi-use **observatories** to address compelling science and engineering issues

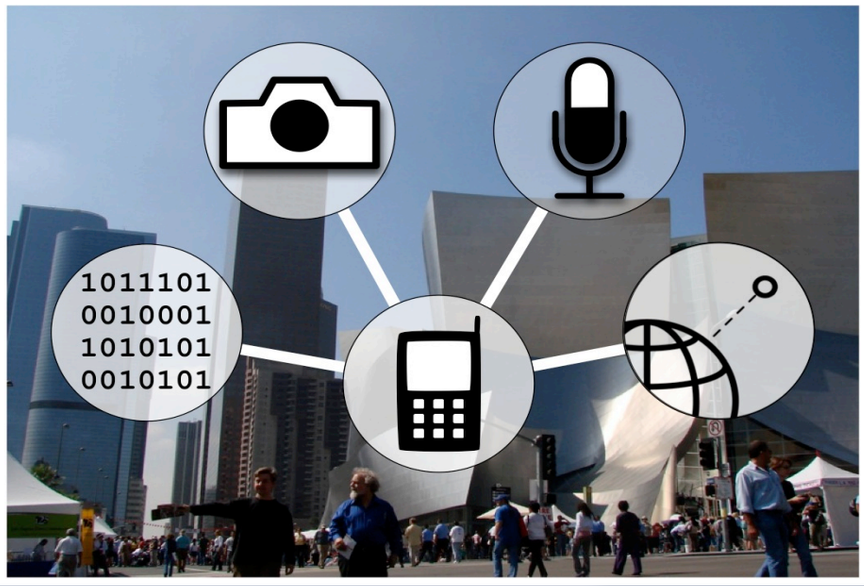
…and reveal the previously unobservable.

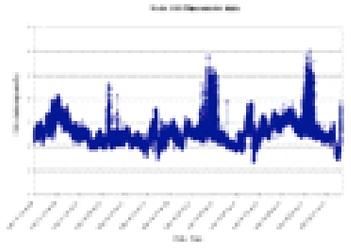
From the natural to the built environment…

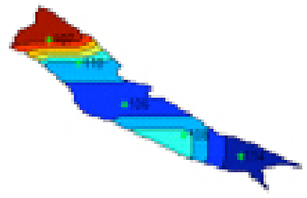
From ecosystems to human systems…



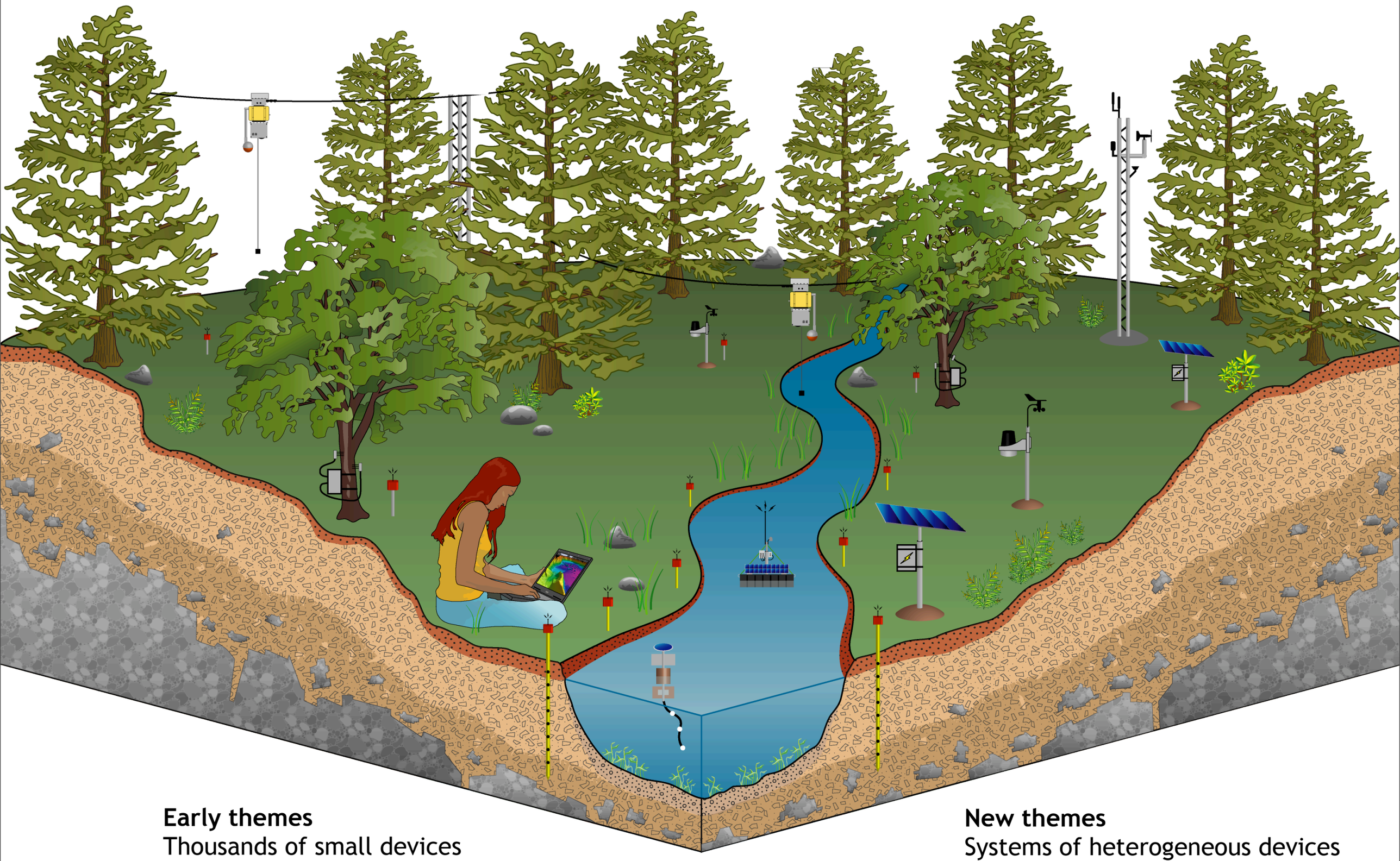








Lessons from the field 2002-2008



Early themes
Thousands of small devices
Fully autonomous systems

New themes
Systems of heterogeneous devices
Humans and models in the loop

So where has this taken us??

To the south: Imaging deep structure in Peru with a wireless seismic network

- Seismic tomography to reveal slab structure and relation to earthquakes.

- Slab dewatering and mechanical interaction between the slab and the overlying plate.

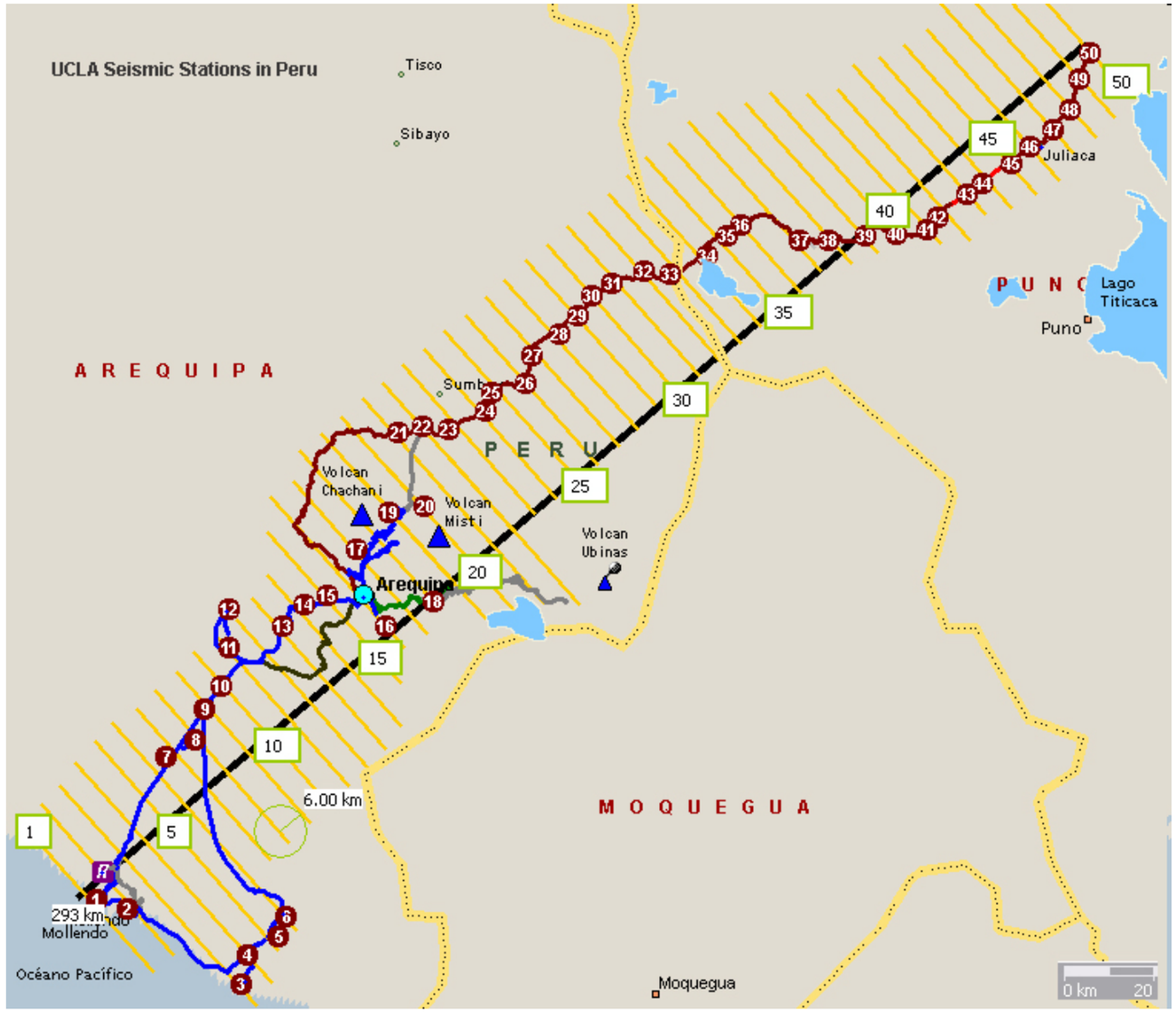
- Obtain receiver functions for crustal and mantle interfaces.

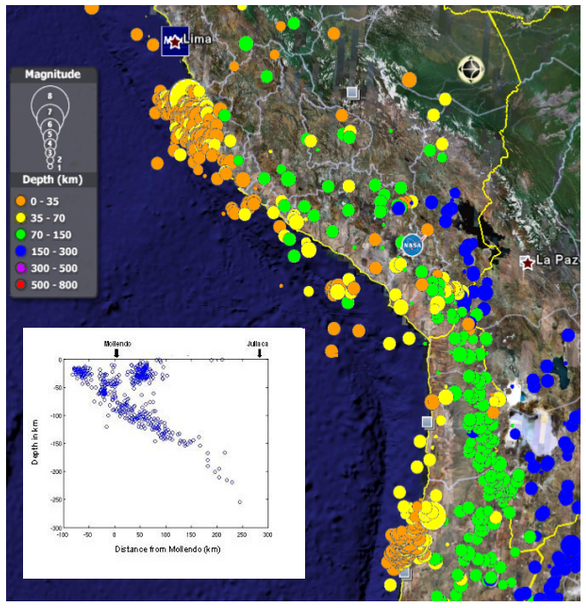
- Locate areas of microseismicity and double Benioff zones, compare them with tectonics.

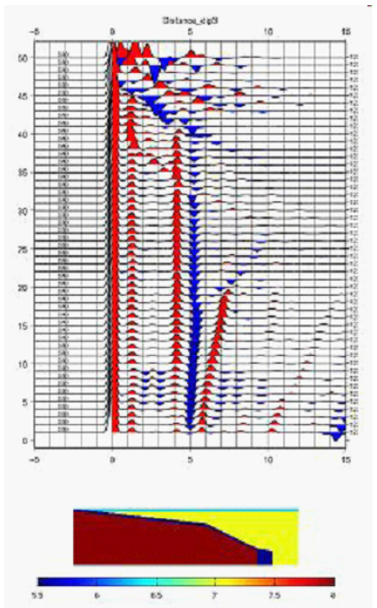
- Look into critical taper wedge modeling and mechanics of mountain building.

- Identify sheer wave splitting areas.

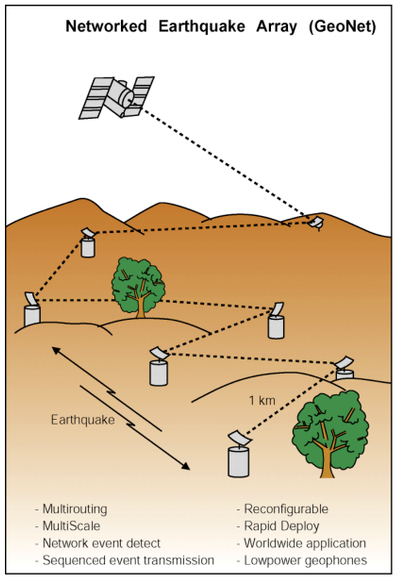
50 wireless seismic sites:
Mollendo-Arequipa-Lake Titicaca

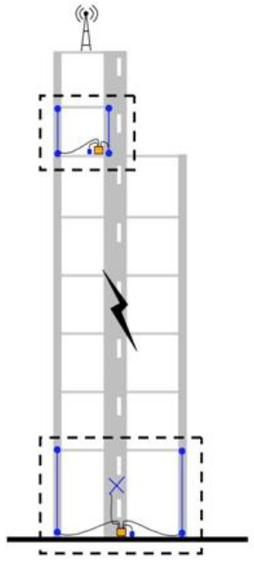


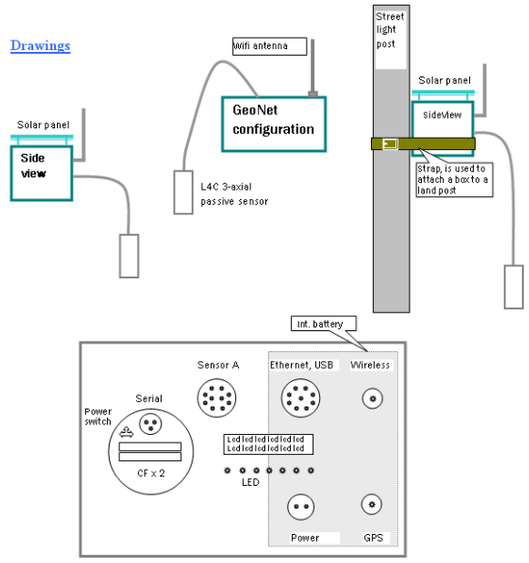




And to the lab: Geo/SHM-net Platform for Rapid Distributed Geophysical and Structural Sensing







Hardware System

- Industry collaboration: Reftek + Leap2 = awesome
- Rapidly deployed
- Lower power from super duty cycling
- GPS and network time redundancy

Software System based on lessons learned in Mexico

- Dynamic duty cycling scheduling *and* data transmission scheduling
- New wireless link quality metric combines ETT and available disk space for routing
- Temporal integrity tracking and repair
- WaveScope integration

New Systems innovations/evaluation

- Systems software evaluation: disruption tolerant network with fine grain logging of status and health
- Temporal integrity research: deployments present opportunity to apply on going research in robust time sync algorithms/services
- Visualization: crucial for detecting problems and enabling better evaluation of system

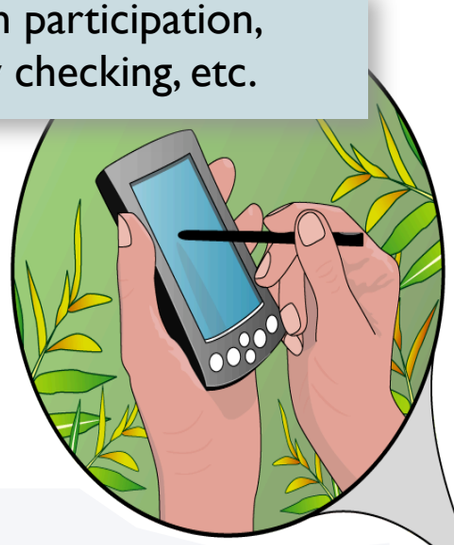
To the bread basket of California: Contaminant Observation & Management WATERS Network Test Bed

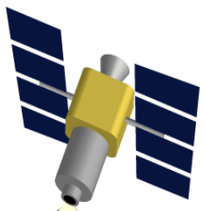
- To date, 4 test sites initiated in and along the rivers of the San Joaquin Valley

To integrating multiple observation scales:
with heterogeneous devices and server side processing, models, GIS

Handheld Sensing

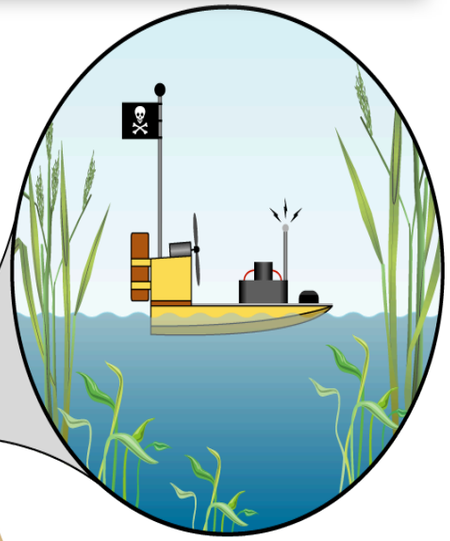
human participation, reality checking, etc.



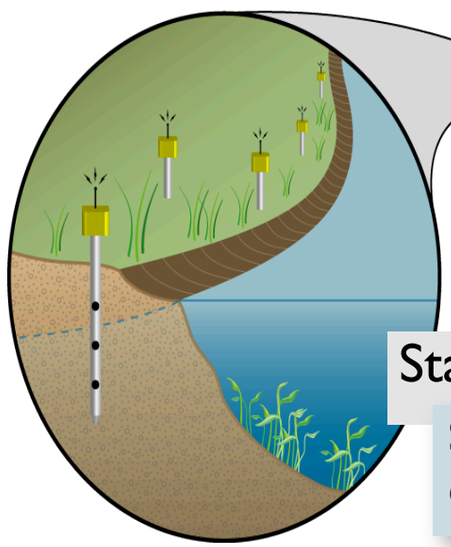


Remote Sensing

Overlaying the "big picture" on local events

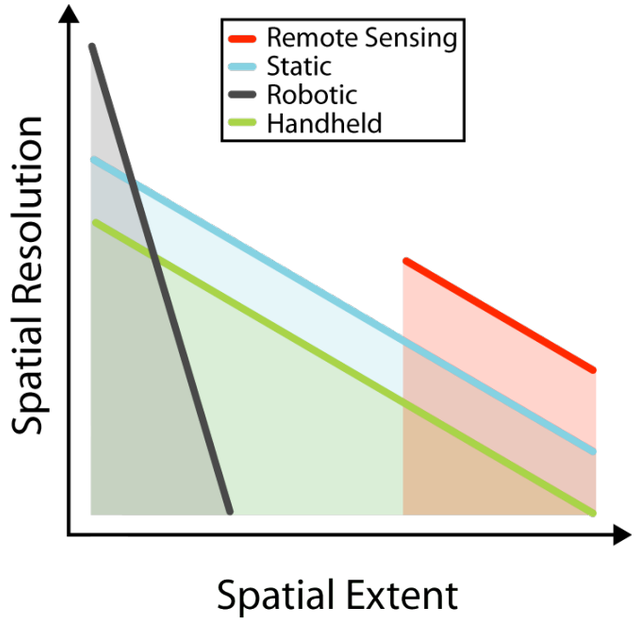


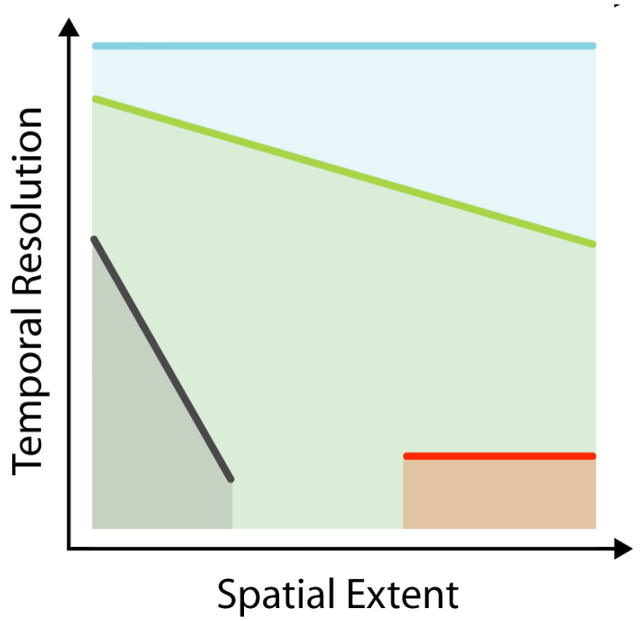
Robotic Mobility



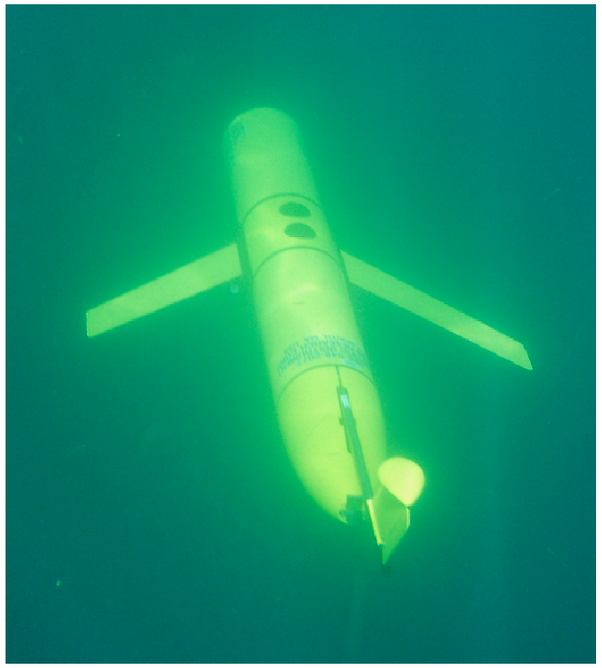
Static Sensing

Stationary sentinels, continuous in time

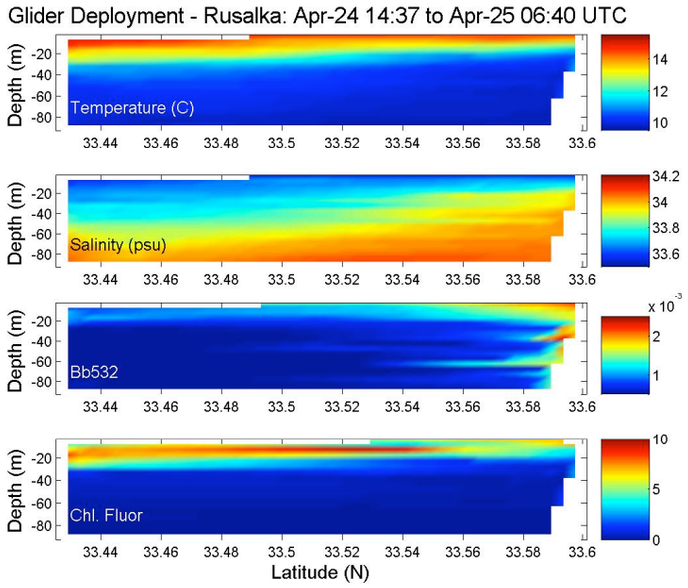




Under water: Networked Aquatic Microbial Observing and Sensing Systems for Monitoring Coastal Harmful Algal Blooms



Environmental sensing to assist human effort for characterizing and studying coastal water quality.



- Partnerships with coastal municipalities.
- Partnerships with water management agencies.
- Partnerships with marine mammal and seabird rescue and animal care centers.

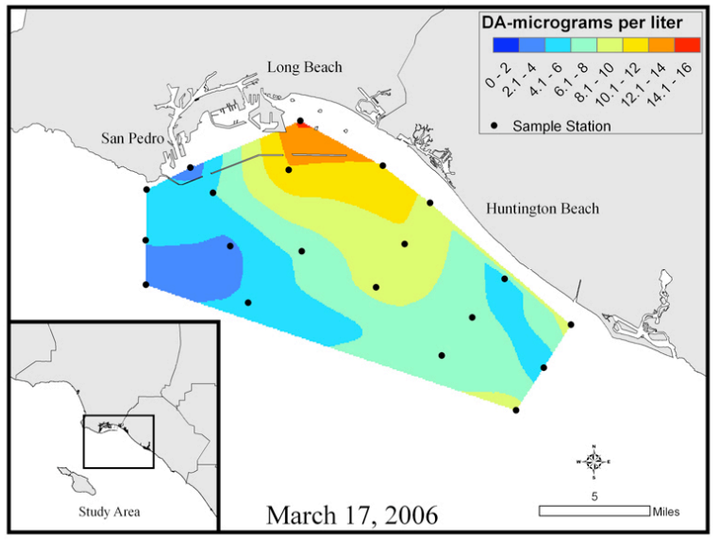
Hardware Developments:

Autonomous stationary & mobile sensing platforms

- Sensor buoys and pier monitoring stations
- Robotic boat and autonomous glider

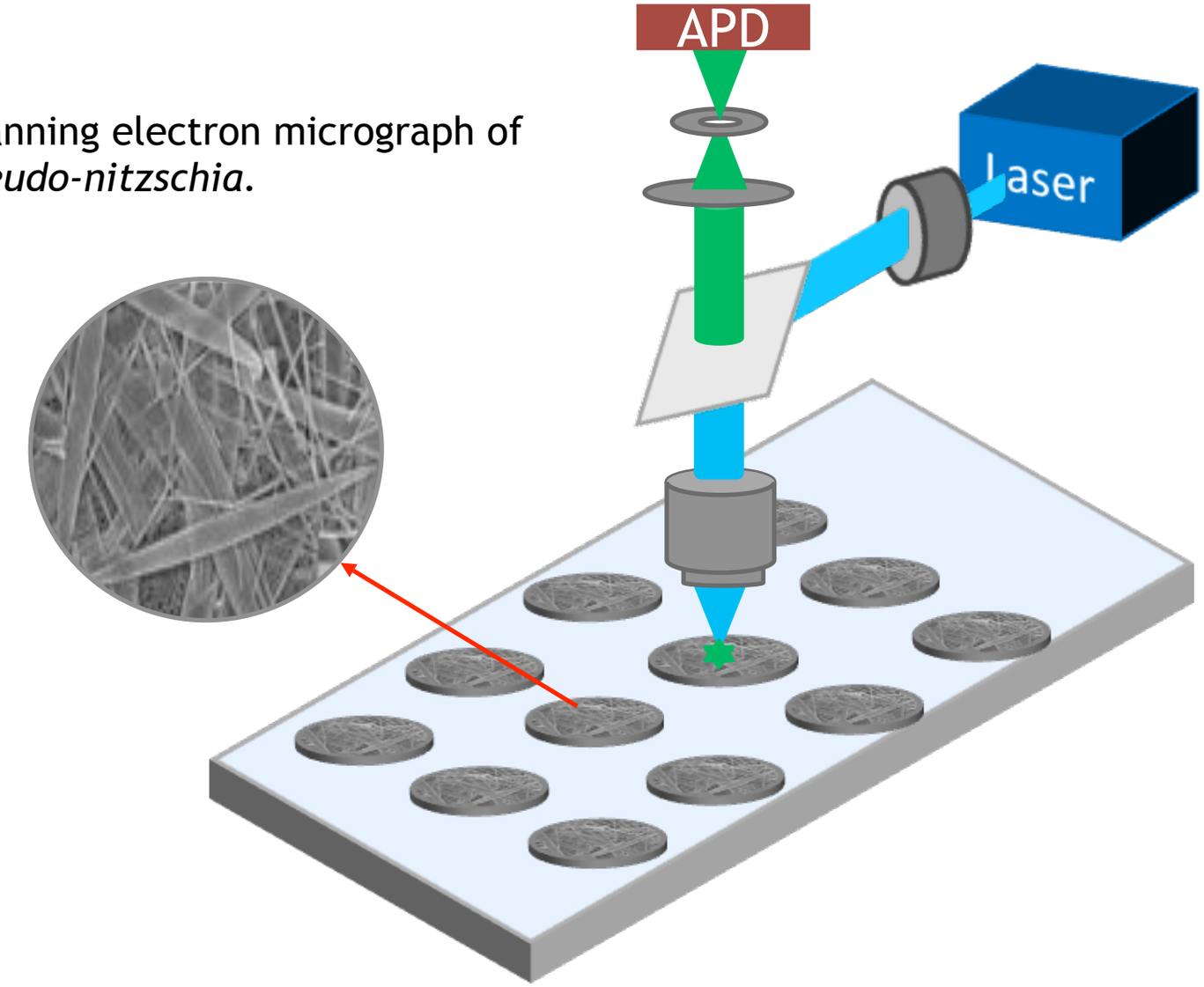
Software Developments:

- Wireless networking of stationary and mobile sensor nodes
- Station-keeping algorithms
- Algorithms for cost-efficient, adaptive sampling



And back to the lab: Field-operational marine monitoring sensor system

Scanning electron micrograph of *pseudo-nitzschia*.



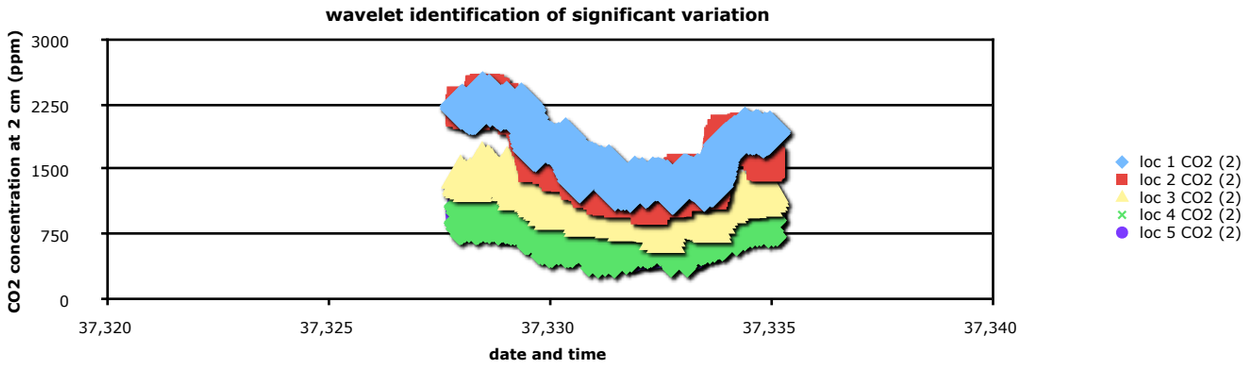
The sensor system is:

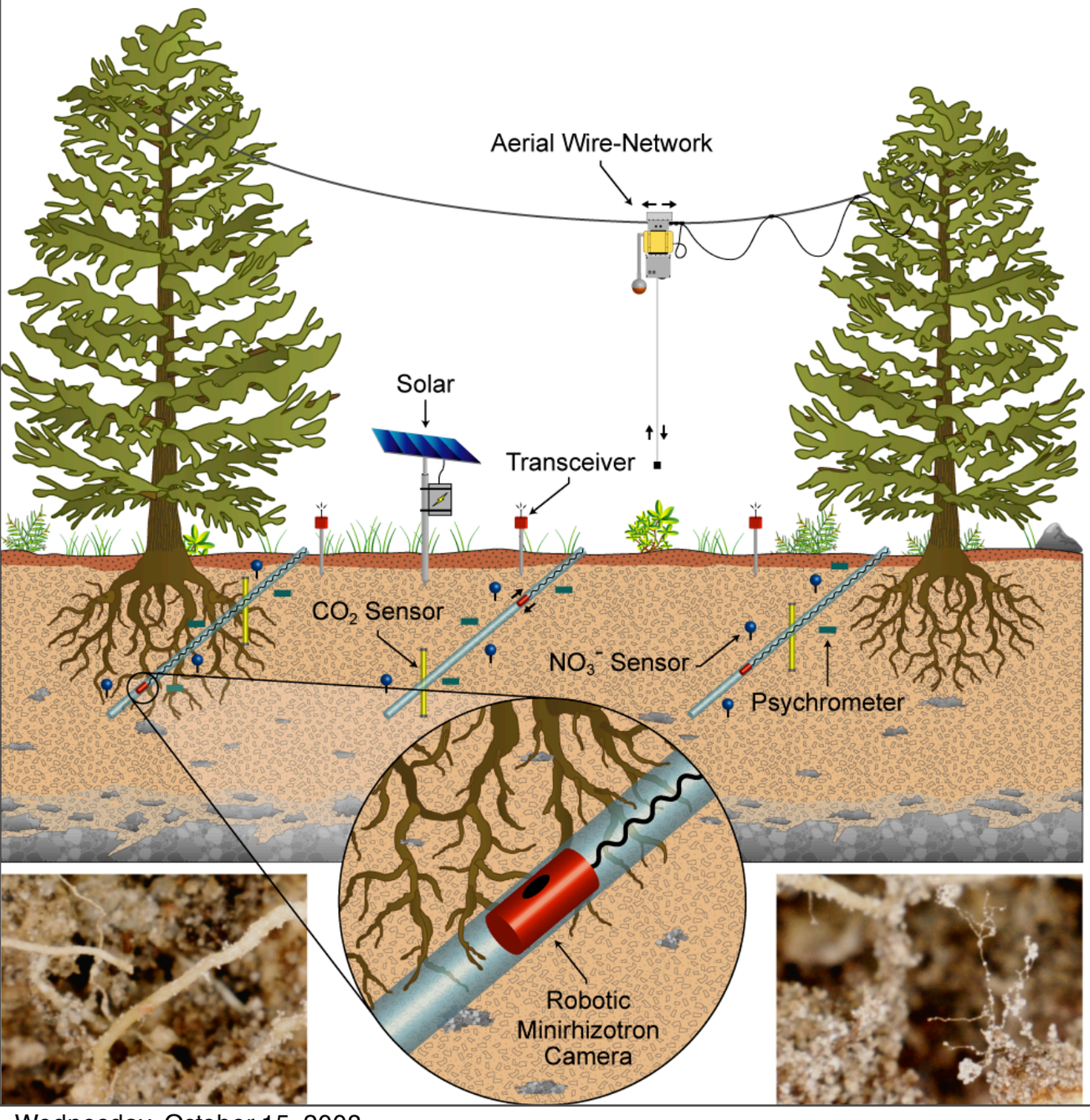
- Portable
- Measurements are in real time
- Ultra Sensitive
- High chance of measurements from a single cell.

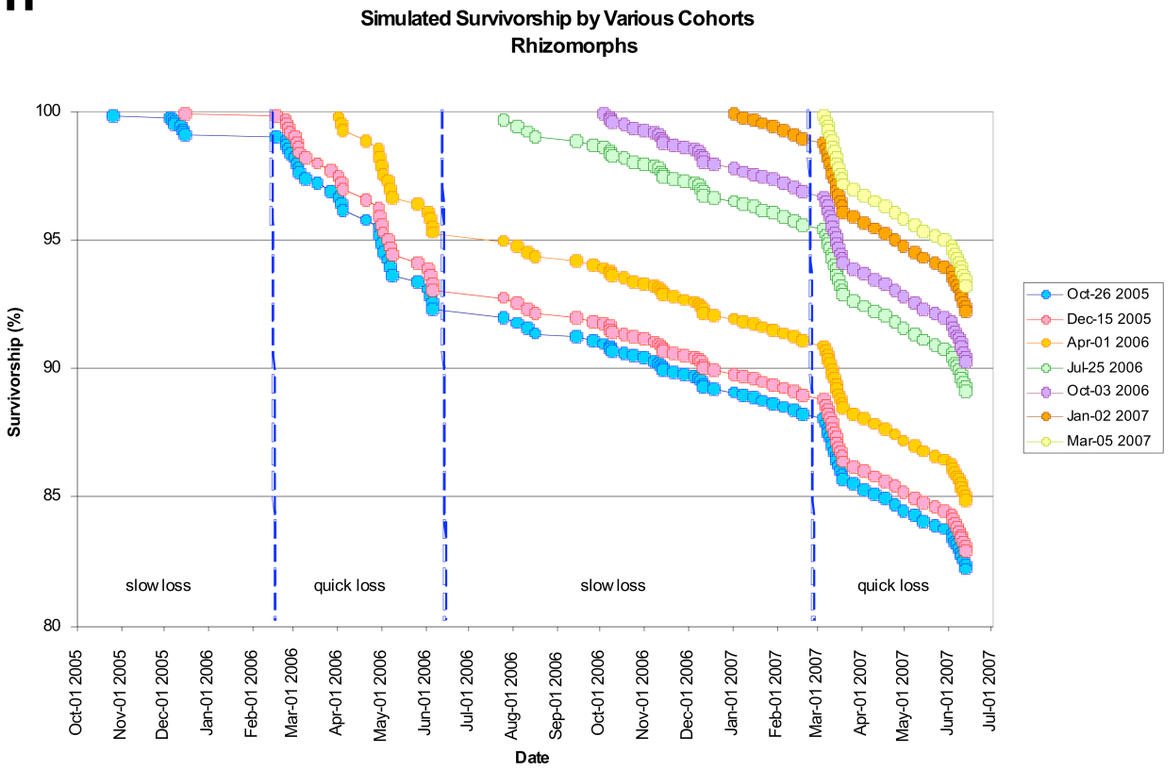
- Domoic Acid (DA) is produced by bloom of the diatom Pseudo-nitzschia australis.
  DA, once entered the marine food chain through accumulation in shellfish tissue, has caused sickness or mortality in people and animals such as brown pelicans and sea lions (USC)
- Cell array to immobilize and pattern the cells on surface (Caltech)
- Conforcal LIF Optical detection of low concentrations of DA in small sample volume (UCLA)

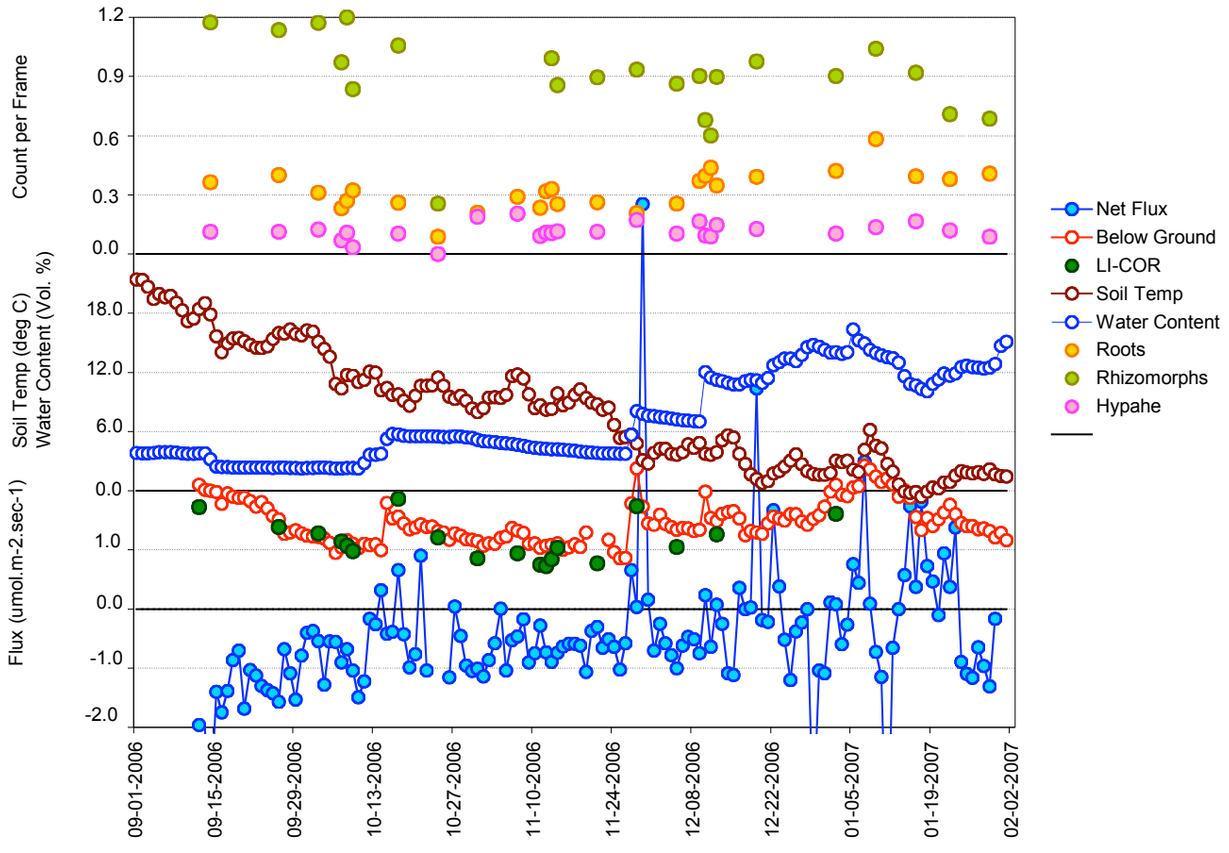
To Soil Systems at James Reserve and La Selva, Costa Rica:

Terrestrial Ecological Observing System



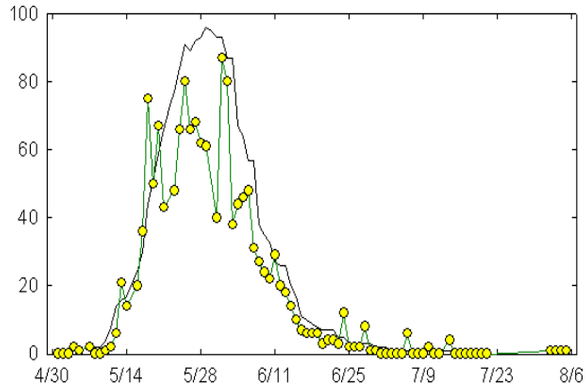






And to one surprisingly versatile sensor while we wait for all that stuff to come back from the lab:

(aka, If you cant go to the field with the sensor you want...go with the sensor you have!



1. Sensing plant phenology at multiple scales

Detecting flowers, leaves & changing landscapes

James Reserve & La Selva CR

2. Cameras as reconfigurable robotic sensors

Linking image processing to real-time camera control

James Reserve

3. Coupling carbon flux and imaging

Relating eddy flux carbon values and forest greenup

James Reserve; Berkeley

4. Modeling soil surface energy balance

Mapping light and energy balance on the forest floor

James Reserve AMARSS

5. Detecting objects in complex fields

Animal visit classification for behavior and plant ecology

James Reserve; La Selva CR

6. Modeling plant architecture with imagers

3D models of plants and trees for forest productivity

University of Southern California

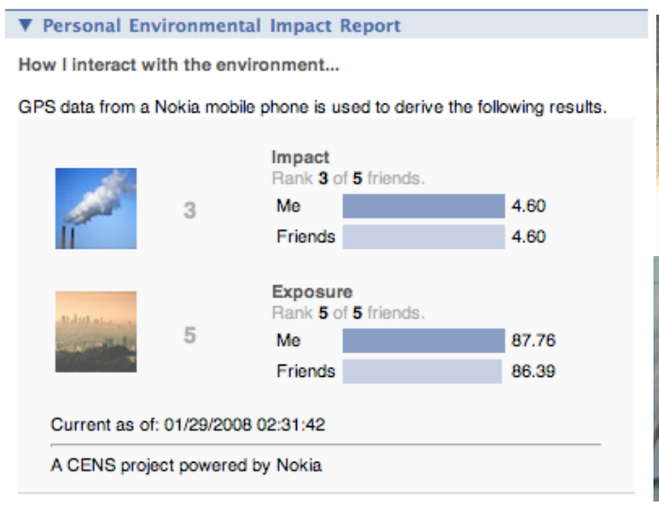
And finally to the public: Participatory Urban Sensing

Enabled by 2 x 10^9 mobile phone users, increasingly with:

- Digital imagers, location (GPS, cell tower), bluetooth connected sensors
- Automatic-geocoding of data
- Programmed, user-initiated, or server-initiated capture
- Server-side processing and presentation of personal data

Motivated by 6 x 10^9 people on planet earth and their concerns...

- Individual health and wellness
- Public health, urban planning, epidemiology
- Civic concerns (transportation, safety, culture…)
- Resource management

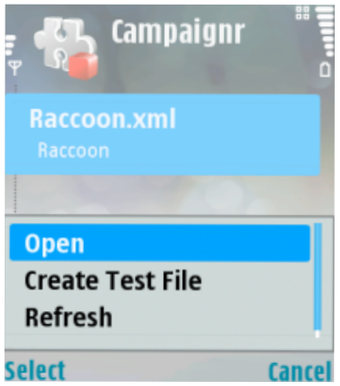


To more merging and leveraging: Merging models and sensing

Cell Phones + Wearables

\+

Campaignr



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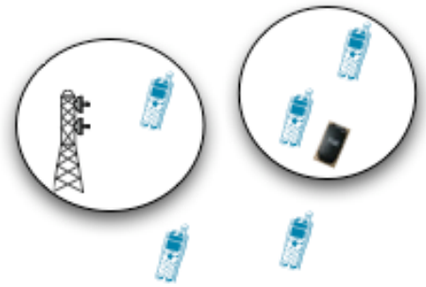
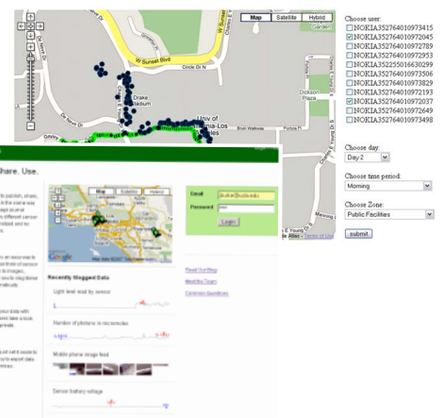
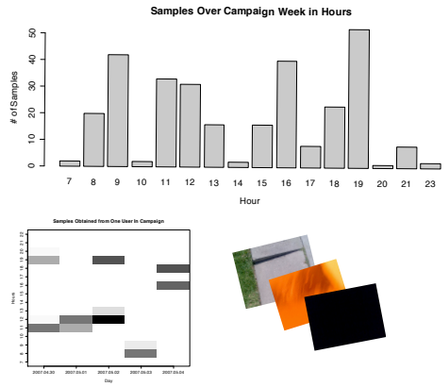
Image,
Audio, Location

Attestation
Service





Data posted to SensorBase and Geoserver & managed by Campaign Framework.

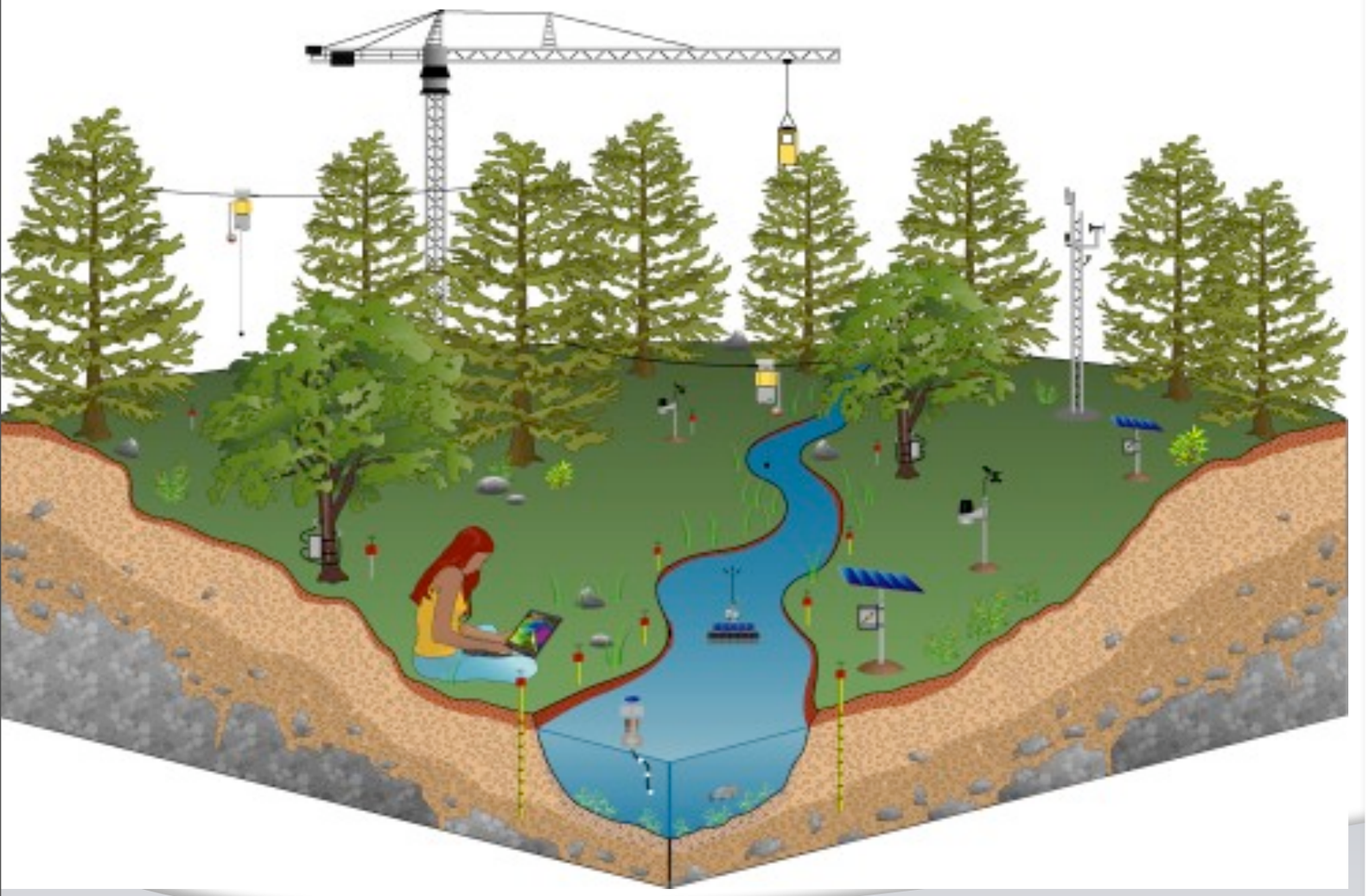


Reputation
Framework

Mobility and
Context Analysis

Feedback and
Control

And Overall to an Ever-increasing focus on Coupled Human-Observational Systems



Hamilton, Hansen, Kohler, et al.

Support human in the loop systems

- Interactive systems take advantage of human observation, actuation, and inference
- ***Analogous to MRI technology***
- Expands the types of sensors that can be used
- Leverages multi-scale data source and models: remote sensing, geographic information system, ..
- ***A new focus on user-facing aspects of these systems***

Ruth West, Director, Interactive Technologies

Three Center Accomplishments

1. As thought-leaders in wireless sensing, we changed the research focus from “sensor networks” to innovative and effective “distributed sensing systems”:
   - Mobile systems: adaptive sampling, system architecture, platforms, and tools, from NIMS robotic, to rapidly deployed systems, to participatory urban sensing using mobile phones
   - Data and deployment integrity: theory, algorithms, online tools
   - Imagers as sensors in the field: algorithms, platforms, deployment data
   - Usable, deployable systems: LEAP, Sensorkit, Acoustic ENSbox, Campaignr, Sensorbase
2. Real science with distributed sensing growing out of authentic, intimate, sustained collaborations among domain scientists and technologists
   - AMARSS soil respiration
   - Palmdale Closed-loop irrigation system
   - San Joaquin/Merced river digitization
   - Mexico slab subduction
   - Harmful algal bloom dynamics
   - ARB study of PM 2.5 exposure near ports
3. Tiered approach to undergraduate research mentoring and integration
   - Undergraduate research teams with graduate, staff and faculty leadership
   - Embraced by faculty and graduate students as an opportunity for exploration
   - Successfully engaged women and under-represented minorities

It takes an Ecosystem...

The center has allowed us to create a vital, innovative, multi-disciplinary research environment at UCLA that nourishes:

Undergrads and Graduate students...

Professors and Post-docs...

Civil Engineers and Ecologists...

Hardware designers and Information theorists..

to come together and innovate...

in matters of great importance...

and in a manner that has real impact.