The Land/Ocean Biogeochemical Observatory data set: what’s it good for?

Ken Johnson & lots of LOBO personnel

MBARI
ESSAY
On the Climate Change Beat, Doubt Gives Way to Certainty

In the decade when I was the lead reporter on climate change for this
To bolster our claim that "There Has Been Little Net Global Warming Over the Past 70 Years," each week we highlight the temperature record of one of the 1221 U.S. Historical Climatology Network (USHCN) stations from 1930-2005.

This issue's temperature record of the week is from Conception, MO. During the period of most significant greenhouse gas buildup over the past century, i.e., 1930 and onward. Conception's mean annual temperature has cooled by 0.12 degrees Fahrenheit. Not much global warming here!

### 1930-2005 Mean Annual Temperature
Conception, MO

![Temperature graph showing annual mean temperature from 1930 to 2005 in Conception, MO.](chart)

- The graph shows the annual mean temperature in °F from 1940 to 2000.
- A horizontal line indicates the mean temperature across the years.
- The temperature values vary significantly from year to year, with fluctuations around the mean.
The Keeling Curve, Atmospheric CO₂ measured at Mauna Loa

"Charles David Keeling's measurements of the global accumulation of carbon dioxide in the atmosphere set the stage for today's profound concerns about climate change. They are the single most important environmental data set taken in the 20th century." C. Kennel
XXXI. On the Influence of Carbonic Acid in the Air upon the Temperature of the Ground. By Prof. Svante Arrhenius.*

I. Introduction: Observations of Langley on Atmospheric Absorption.
underestimated.

One may now ask, How much must the carbonic acid vary according to our figures, in order that the temperature should attain the same values as in the Tertiary and Ice ages respectively? A simple calculation shows that the temperature in the arctic regions would rise about 8° to 9° C., if the carbonic acid increased to 2·5 or 3 times its present value. In order to get the temperature of the ice age between the 40th and 50th parallels, the carbonic acid in the air should sink to 0·62—0·55 of its present value (lowering of temperature 4°—5° C.). The demands of the geologists, that at the genial epochs the climate should be more uniform than now, accords very well with our theory. The geographical, annual and diurnal ranges of temperature would be partly smoothed away, if the quantity of carbonic acid was augmented. The
Environmental chemistry data are often the best record of environmental change.

- Easy to do in the atmosphere, can we do it in the ocean?

That’s what the Land/Ocean Biogeochemical Observatory (LOBO) is all about – sensors, software and platforms to observe change in the coastal ocean.
Goals of the Land/Ocean Biogeochemical Observatory (LOBO) Project

- Design and operate an autonomous network of chemical sensors to study the biogeochemistry of complex coastal environment.

- Demonstrate the potential of an extended chemical sensor networks to significantly improve our observational capabilities and advance our understanding of ecosystem biogeochemistry.
What types of processes can we observe? How can these observations be used to manage the environment?

- Ecosystem Based Management

Can we use this system as an educational tool?

- How do observations relate to California Science Standards?
• http://www.santacruzsentinel.com/archive/2006/December/19/local/stories/04local.htm
Effect of nutrients on plant growth in experimental mesocosms (Fig. 3-1, Clean Coastal Waters, Natl. Acad. Press)

Note – not true in fresh water – P is limiting.
Human production of fixed nitrogen (nitrate, ammonia, urea) now equals natural rate. Original source, Vitousek et al.
Nitrate Concentration (μM)

c. Mississippi River

Cloern 2001
Manure and Fertilizers are key contributors to dissolved ions in natural fresh water. Bacteria in the ground turns Nitrogen fertilizer into Nitrite. The Nitrite then seeps into groundwater.

The groundwater then flows into freshwater. Once in freshwater, the fertilizer begins to accelerate algae growth. When the algae die enough oxygen is consumed to kill off oxygen breathing creatures.
Plants sink from the surface and, in sub-surface waters, bacteria consume oxygen, which can’t be replenished from the atmosphere.

The Dead Zone reached a recorded high of 7,728 square miles in 1999.
Results of hypoxia off Oregon coast – but probably not from eutrophication.
US farmers in the mid 1990's actually use less fertilizer than they did in the early 1980's! Fertilizer use in developing countries surpassed use in developed countries for the first time in 1992. China is now the world leader, with the US in second place. This is a big change -- in 1960, the developing world accounted for only about 12% of world fertilizer use, whereas by 2002, that percentage had increased to ~ 60%.

http://oregonstate.edu/~muirp/fertlim.htm
Global fertilizer use per person

Grain area per person

World Fertilizer Use and Grain Area, Per Capita 1950-88

Source: USDA
Norman Borlaug, father of the “Green Revolution” and 1970 Nobel Peace Prize winner -- “the application of low-cost nitrogen derived from synthetic ammonia, has become an indispensable component of modern agricultural production (nearly 80 million tonnes consumed annually). It is estimated that 40% of today’s 6 billion people are alive, thanks to the Haber-Bosch process of synthesizing ammonia” (Borlaug, 2000).

You can’t just stop using fertilizer! Presumably, one has to offer an alternative, which might be more efficient use of fertilizer.
Elkhorn Slough (pronounced "slew") harbors the largest tract of tidal salt marsh in California outside of San Francisco Bay. This ecological treasure at the center of the Monterey Bay coastline provides much-needed habitat for hundreds of species of plants and animals, including more than 340 species of birds.

ESF Field Notes
Field Notes features the hard work that goes on behind the scenes at the Elkhorn Slough Foundation.
Find out how we celebrated Earth Day - Part 2...

Chuck Haugen Conservation Fund Picnic - June 23rd
You, your friends and family are invited! Celebrate a year of conservation successes with free gourmet food, cool kids' activities, live music, a fun silent auction, and guided hikes.
Toro County Park 10:00 am - 3:00 pm
For more information, visit http://www.chuckhaugenconservationfund.org/

Download the Elkhorn Slough Tidal Wetland Project Strategic Plan!
This document describes Elkhorn Slough’s estuarine habitats, characterizes the main...
Data access is available through LOBOViz – an online program for creating user defined graphs of LOBO data.
Past Management Plans

“The most serious problem in Elkhorn Slough is the erosion of wetland habitats from tidal currents”
– Elkhorn Slough Wetland Management Plan (ABA Consultants 1989, prepared for the CA State Coastal Conservancy and Monterey County Planning Department)

“The manipulation of marsh hydrology is one of the most serious threats to Elkhorn Slough resources…strategies include identifying actions and policies that reduce tidal scouring”
– Elkhorn Slough Watershed Conservation Plan, (Scharffenberger 1999, prepared for the ESF and TNC)
TIDAL EROSION
INCREASED TIDAL FLOW DUE TO ARTIFICIAL MOUTH

1854, Coastal Geodetic Survey Map
Note mouth north of main channel

1999, Infrared Aerial Photograph
Note mouth in line with main channel
Generalized focus of principal investigators on EBM grant

HUMAN FRAMEWORK

HUMAN USES / VALUES

KEY SPECIES

ECOSYSTEM ASSETS & SERVICES

HABITAT EXTENT ↔ WATER QUALITY

PHYSICAL DRIVERS

HUMAN IMPACTS

RESTORATION STRATEGIES

POLICY OPTIONS

K. Johnson
HABITAT EXTENT
Extent of salt & brackish marsh, mudflat, & channel habitat

WATER QUALITY
Salinity, dissolved oxygen, turbidity, nutrients, pollutants

PHYSICAL DRIVERS

Geomorphology
Topography, bathymetry, tectonics

Tidal exchange
Tidal range, velocities

Sediments
Supply, size and deposition

Freshwater inputs
Rivers and groundwater

Climate
Freshwater, storms, sea level

HUMAN ALTERATIONS

Tidal restriction
diking/ draining

Artificial mouth
increased tidal prism

Polluted inputs
Nutrients and pesticides in sediments and freshwater

River diversion
Salinas redirected

Groundwater overdraft
for agriculture

Global warming
sea level rise

MANAGEMENT STRATEGIES

Restore formerly diked sites
increase tidal prism in stagnant restricted areas; add sediment to restore elevation of subsided areas

Decrease tidal exchange
to some of the undiked areas

Reduce pollution
improve land use practices

Re-connect rivers
Re-establish riverine sediment sources

Increase freshwater
Inputs or retention patterns

Allow migration
Purchase land upstream to allow estuarine migration
Focus of this talk – hydraulic change, water quality, options.

Data and models.

**HABITAT EXTENT**
Extent of salt & brackish marsh, mudflat, & channel habitat

**WATER QUALITY**
Salinity, dissolved oxygen, turbidity, nutrients, pollutants

**Tidal restriction**
Diking/draining

**Artificial mouth**
Increased tidal prism

**Polluted inputs**
Nutrients and pesticides in sediments and freshwater

**River diversion**
Salinas redirected

**Freshwater inputs**
Rivers and groundwater

**Tidal exchange**
Tidal range, velocities

**Sediments**
Supply, size and deposition

**Physical drivers**
Freshwater inputs: Rivers and groundwater

**Human alterations**
Restore formerly diked sites
Increase tidal prism in stagnant restricted areas; add sediment to restore elevation of subsided areas

Decrease tidal exchange to some of the undiked areas

Reduce pollution improve land use practices

**Management strategies**
Policy Options
Water quality issues:

- External sources of nutrients:
  - historically EXTREMELY high

- Internal sources of nutrients:
  - sediments (~15% organic carbon) are LARGE sources of ammonia.

- Nutrients lead to high organic carbon production
  - potential for oxygen loss
    - worsens as tidal exchange rates diminish.

Conclusions:

- Hydraulic solutions to the erosion problems may well exacerbate water quality.
LOBO chemical sensor network:  www.mbari.org/lobo
One year of nitrate in Elkhorn Slough and “nutrient-rich” Monterey Bay.

Green line is Chesapeake Bay target level for inorganic nitrogen.
Nitrate source external: appears on rising tide.

Graph showing nitrate concentration over time with peaks at 1 ppm and 0.15 ppm.
LOBOVIZ Plot Page Station(s) M1SURF.TXT; Y Var(s). NITRATE[μM]

Station(s) L01SURF.TXT; Y Var(s). NITRATE[μM]

Station(s) L03SURF.TXT; Y Var(s). NITRATE[μM]
Annual nitrate transport past L03 exceeds combined annual transport of San Lorenzo, Pajaro, Salinas and Carmel Rivers.
NH₄⁺ source internal. Largest values on falling tide.
Internal $\text{NH}_4^+$ source is flux from sediment.

Benthic flux chamber near Kirby Park.

Note rapid increase in ammonia and drop in oxygen.
High water velocity is good:
- nutrient export
- less eutrophication

and bad:
- erosion and wetlands loss

Water quality constrains erosion control options.

- Reduced tidal exchange = lower oxygen.
- External nutrient inputs must be limited.
  - Natural variability provides test.
- Sediment sources of ammonia will confound solutions.
Ecology
Stability in an ecosystem is a balance between competing effects. As a basis for understanding this concept:

*Students know* biodiversity is the sum total of different kinds of organisms and is affected by alterations of habitats.

*Students know* how to analyze changes in an ecosystem resulting from changes in climate, human activity, introduction of nonnative species, or changes in population size.

*Students know* how fluctuations in population size in an ecosystem are determined by the relative rates of birth, immigration, emigration, and death.

*Students know* how water, carbon, and nitrogen cycle between abiotic resources and organic matter in the ecosystem and how oxygen cycles through photosynthesis and respiration.

*Students know* a vital part of an ecosystem is the stability of its producers and decomposers.

*Students know* at each link in a food web some energy is stored in newly made structures but much energy is dissipated into the environment as heat. This dissipation may be represented in an energy pyramid.

* Students know* how to distinguish between the accommodation of an individual organism to its environment and the gradual adaptation of a lineage of organisms through genetic change.
California Science Standards

Biogeochemical Cycles

Each element on Earth moves among reservoirs, which exist in the solid earth, in oceans, in the atmosphere, and within and among organisms as part of biogeochemical cycles. As a basis for understanding this concept

Students know the carbon cycle of photosynthesis and respiration and the nitrogen cycle.

Students know the global carbon cycle: the different physical and chemical forms of carbon in the atmosphere, oceans, biomass, fossil fuels, and the movement of carbon among these reservoirs.

Students know the movement of matter among reservoirs is driven by Earth's internal and external sources of energy.

* Students know the relative residence times and flow characteristics of carbon in and out of its different reservoirs.
The Light Bottle/Dark Bottle or Oxygen method of determining primary production:

\[ 6 \text{ CO}_2 + 12 \text{ H}_2\text{O} (+ \text{sunlight}) \rightarrow C_6\text{H}_{12}\text{O}_6 + 6 \text{ O}_2 + 6 \text{ H}_2\text{O} \]

About 1 mole of oxygen produced for each mole of carbon incorporated into organic compounds. Oxygen traces primary production and respiration.

The scientific tools: what can you do with biogeochemical sensor data? Oxygen as an example.
L02  Jan 2006 to present
California Science Standards

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LOBOVIZ Plot Page

Station(s) L01SURF.TXT; L02SURF.TXT; L04SURF.TXT; M1SURF.TXT; Y Var(s), NITRATE[μM]

Station(s) L01SURF.TXT; Y Var(s), WATERDEPTH[M]
LOBO-0010 Northwest Arm, Halifax, Canada

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<th>Value</th>
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IDEA: Instrumentation Development for Environmental Activities

www.mbari.org/lobo

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