P3 TEACHING CLIMATE CHANGE WITH EARTH SYSTEM SCIENCE MODULES: A FISHY STORY

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1. INTRODUCTION

We have developed two Earth System Science Education Alliance (ESSEA) education modules centered on climate change and natural variability and on the impact of natural climate variability on salmon abundance. These modules are intended for use in Cal State Los Angeles undergraduate pre-service teacher course, NATS *183: Earth Science for Elementary Teachers*. In the salmon module students advise a salmon commission on the scientific ties between climate and salmon harvests and on related economic, and cultural impacts. The climate change module is based on a scenario in which students are part of a climate change advisory committee charged with providing the scientific framework for assessing impacts of climate change. In both of these modules, students learn to distinguish between natural variability in the Pacific Ocean and trends in global climate change. These two modules are available on the ESSEA homepage: http://essea.strategies.org/ .

Funding for module development was through a grant to the authors from the Earth System Science Education Alliance (ESSEA). ESSEA is a NASA, NSF and NOAA-supported program implemented by the Institute for Global Environmental Strategies (IGES) to improve the quality of geoscience instruction for pre-service and in-service K-12 teachers using an earth system science approach. Started in 2000, the program currently includes the participation of over forty institutions, with greater than 3,000 teachers having completed an ESSEA course as of fall 2009.

ESSEA supports a series of online courses for teachers that are offered by participating institutions. These institutions and faculty receive the training , and technical support needed to offer courses, Faculty have the ability to create and share their own course modules through the ESSEA website, and to join an active community of Earth system science educators.

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Fig. 1. ESSEA home page

ESSEA supports a series of online courses for teachers that are offered by participating institutions. These institutions and faculty receive the training , and technical support needed to offer courses, Faculty have the ability to create and share their own course modules through the ESSEA website, and to join an active community of Earth system science educators. The inquiry-based courses provide teachers with the content knowledge and tools they need to incorporate Earth system science into their curricula. Each module address federal science standards. ESSEA modules are also available on this site as teacher resources (See http://essea.strategies.org/background.html) .

1.1 .*What is climate change*?

Climate change is a shift in climate relative to a given reference time period which occurs over periods ranging from decades to millions of years (reference). Climate change results from natural factors including solar variability , atmospheric volcanic dust, geological changes, and oceanic/atmospheric changes (Pacific Decadal Oscillation, El Niño/La Niña). More recently, humans have contributed to climate change through the addition of greenhouse gases in the atmosphere, changes in land use (removal of vegetation for farming, city development), ozone depletion, etc.

2. MODULE:THE CASE OF THE DISAPPEARING SALMON

Through this module we establish a connection between salmon abundance and natural climate variation in the Pacific Ocean. Salmon are very sensitive to environmental changes in the oceans and changes in salmon abundance commonly reflect variations in ocean temperature associated with natural oceanic/atmospheric changes.

2.1 The Issue

Researchers have noted that records of salmon abundance in Alaska and the Pacific Northwest (mostly Oregon and Washington) show periods of good harvests alternating with those of poor harvests (Table 1). Interestingly, when salmon catches peaked in Alaska they declined in the Northwest and vice versa. Fisherman were at a loss to explain the pattern of salmon abundance which impacted the economies of coastal fishing communities.

Salmon stock	1947 step	1977 step
Western Alaska sockeye	-37.2%	+242.2%
central Alaska sockeye	-33.3%	+220.4%
central Alaska pink	-38.3%	+251.9%
southeast Alaska pink	-64.4%	+208.7%

Table 1. showing variations in Alaskan salmon stocks. When Alaskan salmon stocks are low, they increase in the Pacific Northwest and vice versa. From Mantua et al 1997

2.2 Task For Students

The assignment for students assumes that a proposal they submitted to work in support of the Northwest Salmon Commission has been accepted. The commision wants to get a better handle on the salmon forecast. They are wondering how the PDO influences the distribution of salmon in the area, how it impacts the local economy and how Native Americans are affected. Commission members are also interested in how to manage the conflicts between salmon advocates, farmers and hydroelectric power companies.

2.3 The *Salmon-Pacific Decadal Oscillation Connection*

The alternating pattern of changing salmon abundance between Alaska and the Pacific Northwest results from a natural climate phenomenon similar to El Niño El Nino's have recurrence interval of once every two to seven years. However the natural climate pattern which is the best at predicting salmon abundance has phases that last 20 to 30 years. This Pacific Decadal Oscillation (PDO), as the researchers call this longer termed climate pattern, has its strongest signature in the North Pacific Ocean, while El Nino's originate near the equatorial Pacific.

The PDO flips back and forth between a warm and cool oceanic phase (Figure 2). During a cool phase, the Pacific Northwest is a more favorable environment for salmon than Alaska due to its cooler ocean waters present there and warmer waters off of Alaska (Mantua et al 1997). The opposite occurs during a warm phase of the PDO (see Figure 3). Consequently, the remarkable characteristic of Alaskan and Pacific Northwest salmon over the past half-century has been the large fluctuations at interdecadal time scales of salmon abundance which resemble those of the PDO (Figure 3).

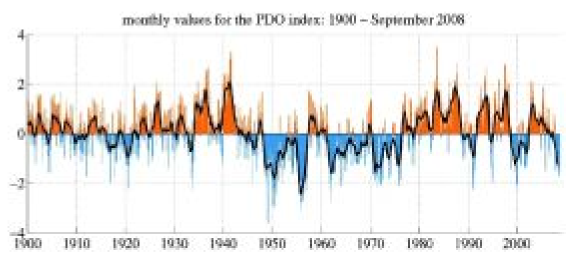

Figure 2. The PDO index showing warm (red) and cool (blue) phases. Superimposed are El Nino events which show up as individual peaks. 20th century PDO "events" persisted for 20-to-30 years, while typical ENSO events persisted for 6 to 18 months. The "cool" PDO regimes prevailed from 1890-1924 and again from 1947-1976, while "warm" PDO regimes (in red) dominated from 1925-1946 and from 1977 through the mid-1990's..

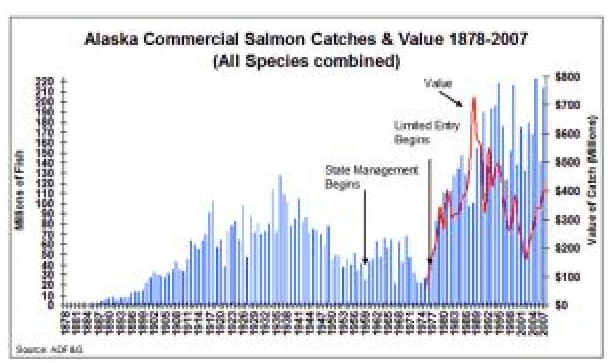

Figure 3. Historical records show salmon abundance resembles the Pacific Decadal Oscillation pattern. When salmon are abundant in Alaska, there is a decline in the Pacific northwest, and visa versa. Note the relationship between the salmon catch and PDO (Figure 2**).** Source:http://www.cf.adfg.state.ak.us/geninfo/finfish/salmon/catchval/history/all_1878.php

Our module allows student to explore the connection between the PDO and salmon numbers through designated online investigations and abundant resources. National Science standards related to Physical Science, Life Science and Earth and Space Science are met.

3. MODULE: CALIFORNIA CLIMATE: PACIFIC OCEAN CONNECTION

The 1999-2009 period was remarkably dry in California and the Southwest with these regions subjected to one of the worst droughts in an approximately 500-year record (Piechota et al. 2004).

Most of California is warming (Figure 4). As California temperatures climb, heat waves have become more frequent. In 2006, over 160 Californians died in a brutal July heat wave. In metropolitan Los Angeles, the frequency and duration of heat spells over the last 100 years have increased dramatically (Tamrazian et al 2008).

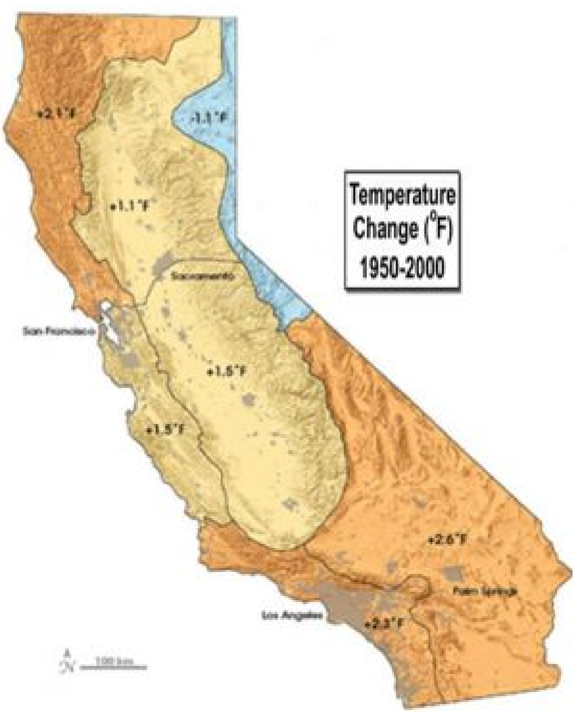

Figure 4. California is warming, but the rates of warming (degrees F per decade) vary by region, with the more urban (shown as grey areas) southern regions warming the fastest and rural regions the slowest. Large urban centers like Los Angeles have shown the greatest increases in temperatures. Source: [LaDochy et al, 2007](#) .

Many people tend to attribute increased temperatures and fires, and a more persistent drought in California to global warming. However, evidence suggests that natural changes in the Pacific Ocean may have an even greater influence on state temperatures and precipitation. The PDO significantly impacts impacts California climate. As mentioned above, the PDO is characterized by cool or warm phase shifts in North Pacific sea surface temperatures which commonly persist for 20-30 years (Mantua et al. 1997). Generally, warm PDO years correspond to warmer California temperatures and above normal southern California rainfall (LaDochy et al. 2007). The opposite generally occurs with the cool PDO years. Other natural events such as El Nino/La Nina also influence California climate.

3.1Task

The scenario calls for students to join a group comprising Arnold Schwarzenegger's Climate Action Team (CAT), consisting of consultants from various state departments. CAT is charged with evaluating the impacts that climate change is having on the state (i.e., economy, resources, human health) now as well as in the near future. Students are tasked with helping present a concise report about how the state's climate is changing and what effects these changes may have on the state's resources (water, energy, forests and agriculture). Their report is crucial to informing state managers and policy makers, including the Governator.

3.2 PDO and ENSO and So. California climate

In the climate change module students :

- Are introduced to the PDO)and the El Niño-Southern Oscillation (ENSO).
- Examine Excel data sets and graphs to see that Pacific oceanic and atmospheric variables influence southern California's temperatures and precipitation.
- Student also examine the urban heat island affect in southern California

Figure 5, shows the PDO cycle in the precipitation record of S. California. In Figure 6, Los Angeles rainfall shows peaks during El Niños and low values during La Nina events. Wetter years and more El

Niños occur during warm PDO phases, while drier years and more La Niñas occur during cool phases.

As with the salmon module, the climate change module allows student to explore the connection between the PDO and California climate through designated online investigations and abundant resources. National Science standards related to Physical Science, Life Science and Earth and Space Science are met.

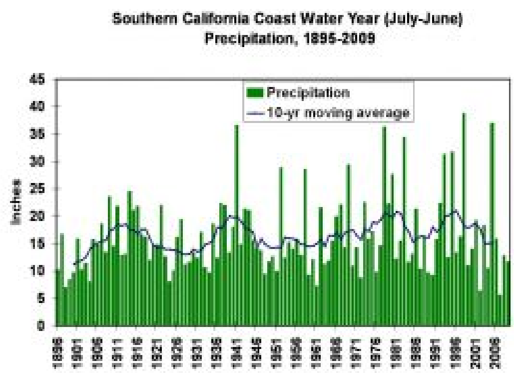

Figure 5. Annual water years (July 1-June 30) rainfall in coastal southern California does not show any marked change over the last 100+ years. However, strong El Nino years show up as peaks, while La Nina years are generally dips. The smoothed running mean shows the PDO influence with lower rainfall during cool phases and higher rainfall during warm phases.
Source: http://www.wrcc.dri.edu/monitor/cal-mon/frames_version.html

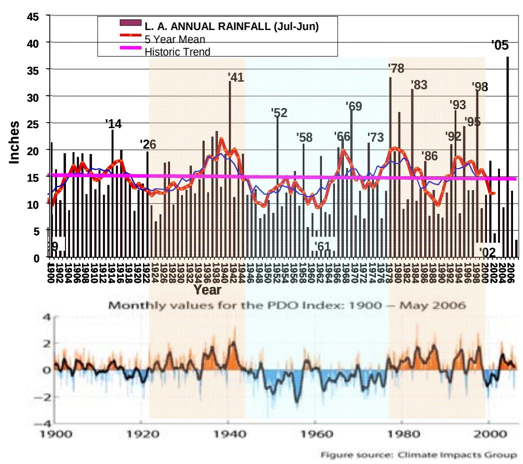

Figure 6. Los Angeles annual precipitation, 1878-2005 and PDO phases. Colored rectangles correlate PDO phases with precipitation.

4. MODULE DISSEMINATION

We plan to disseminate our activity through: 1. Conferences similar to that of AMS. 2. Usage in our general education classrooms. 3. Our internet site which contains links to the activity for downloading. Preliminary assessments of the activity are promising. Attendees (ranging from professionals to mostly K-12 teachers) completing evaluations of the module at the 2008 Satellites in Education conference rated the activity favorably.

5. ACKNOWLEDGEMENTS

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