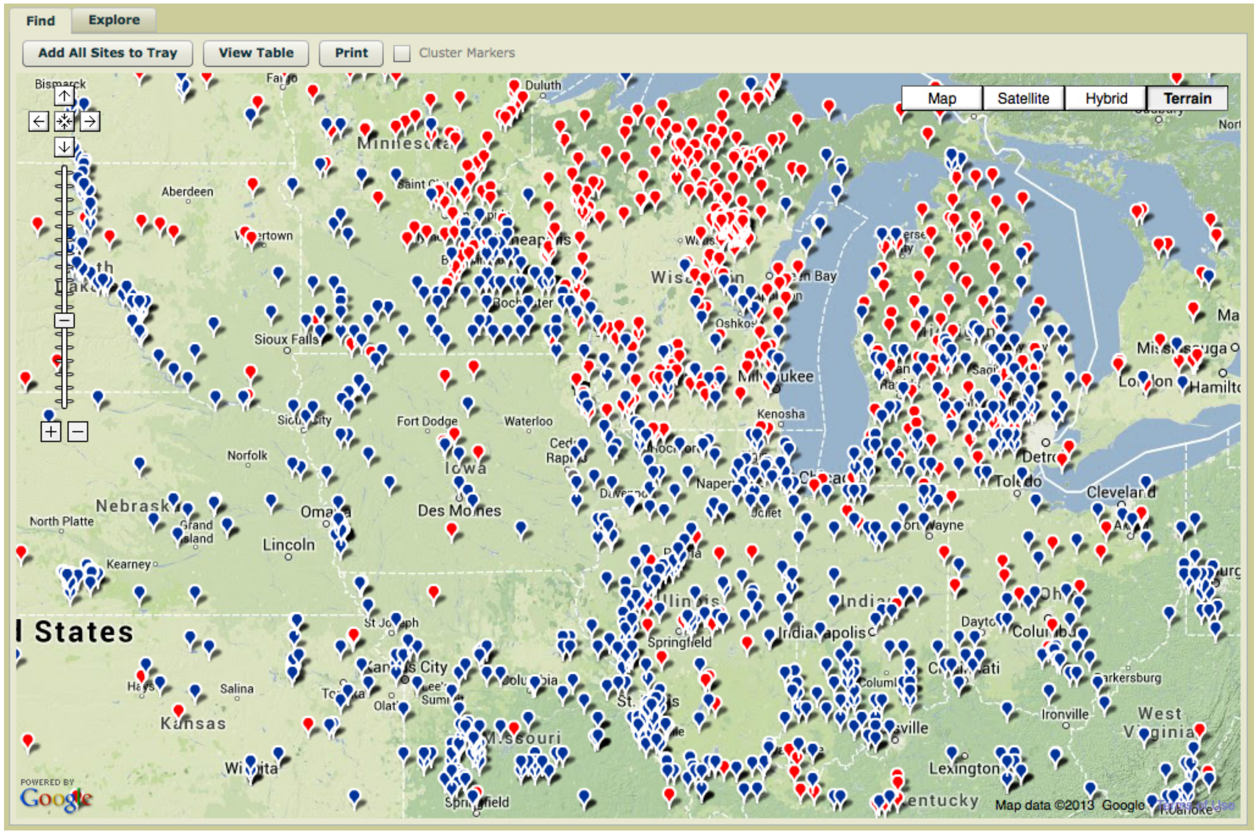
# Best Practices in Teaching with Data: Lessons from Research on Learning

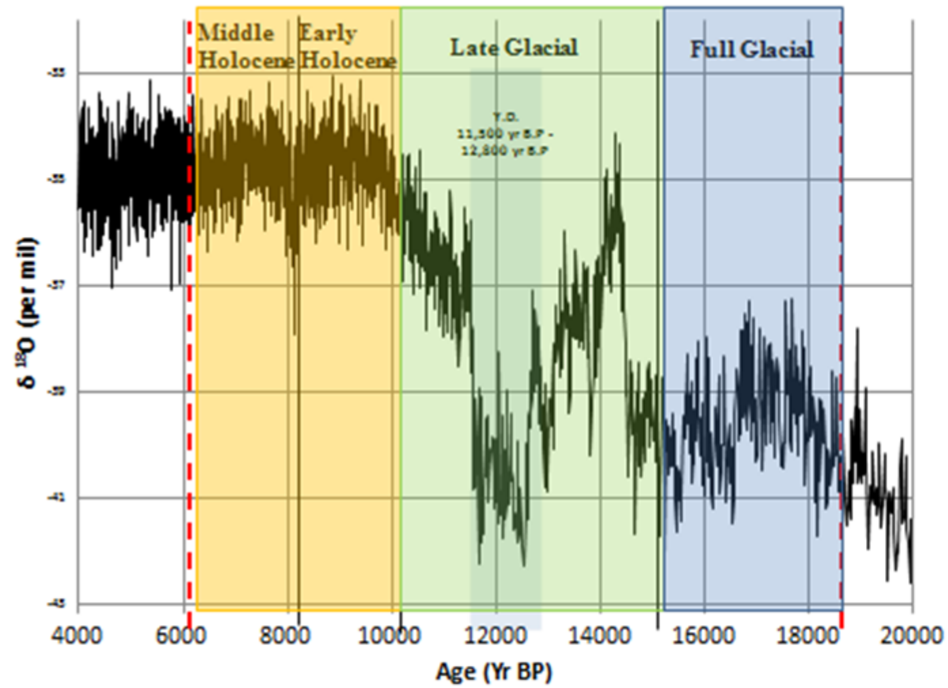



Carol Ormand, SERC, Carleton College


2015 Workshop on Teaching with the Neotoma Database

# What do we mean by 'Teaching with Data?'

Data = Output of scientific research




Modified from GRIP, 2003

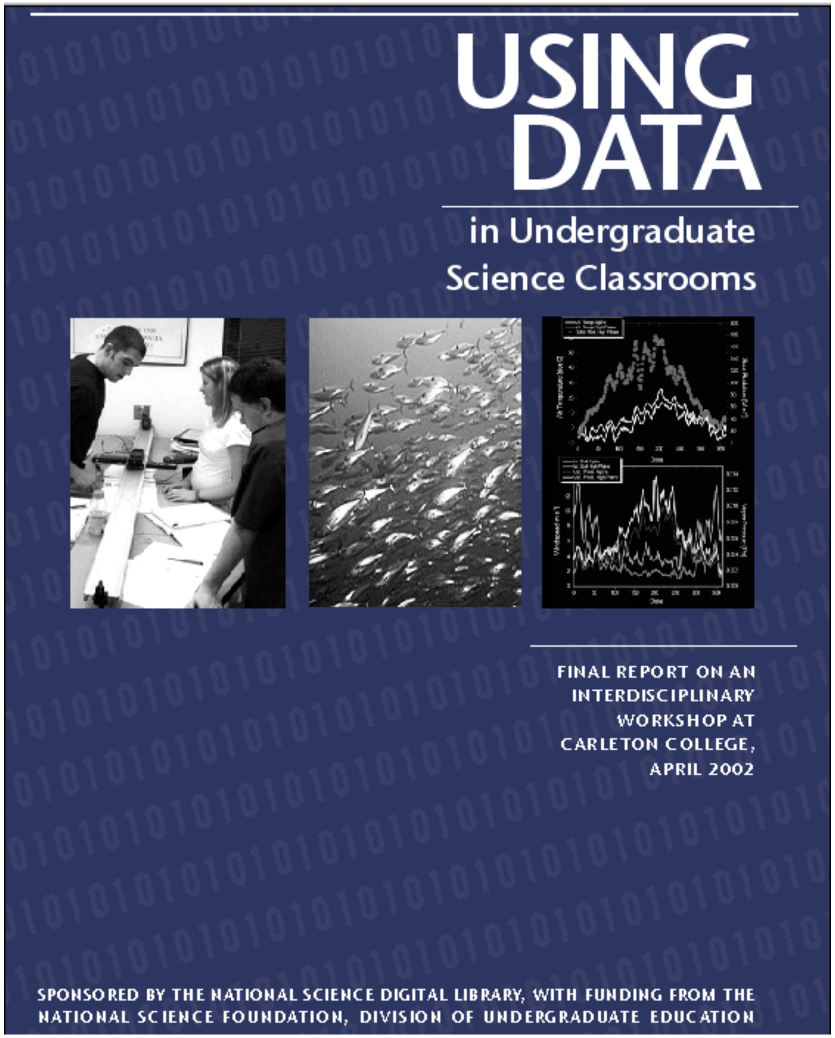
Data Collection | Problem Sets | Labs | Undergraduate Research

Diagrams | Models | Visualizations | Service Learning

# Why Teach with Data?

*Faculty Say*

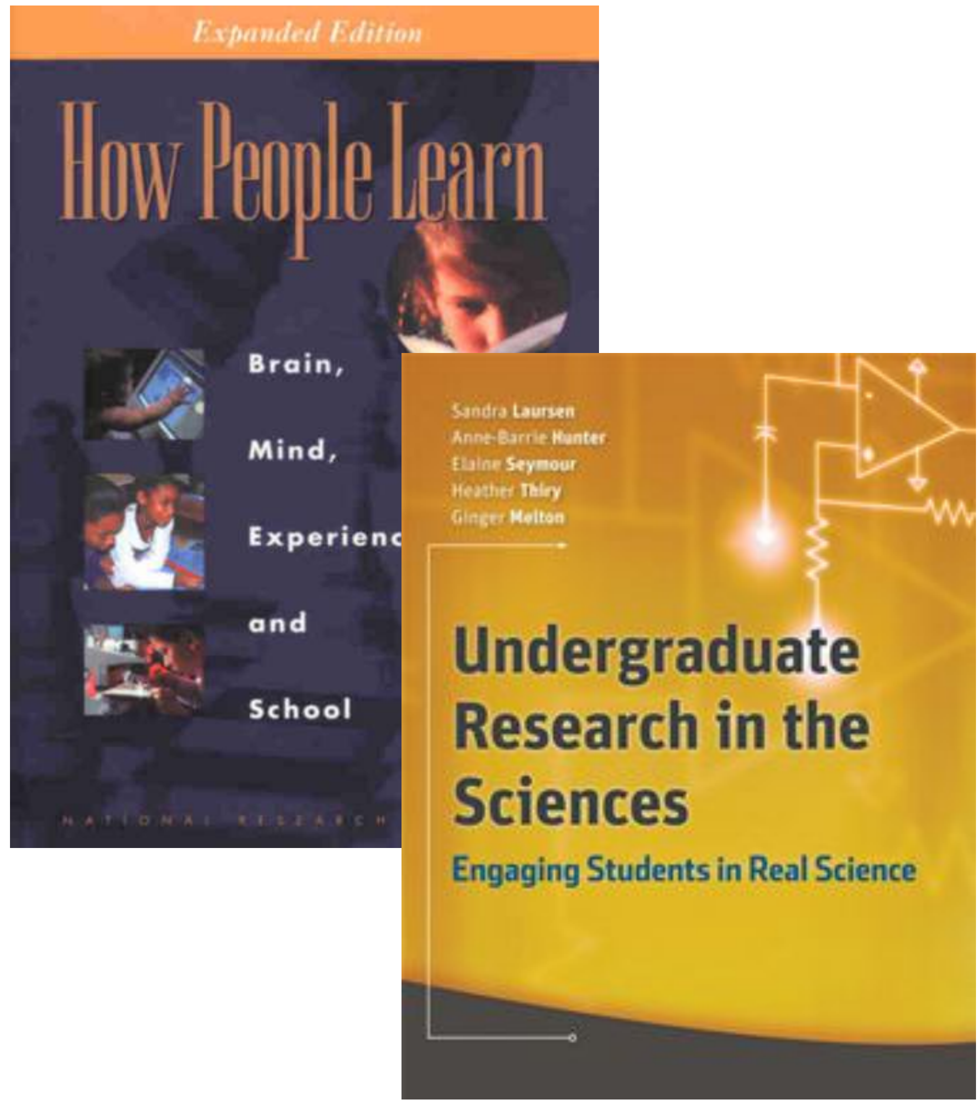
- To prepare students to address real world complex problems
- To develop students' ability to use scientific methods
- To prepare students to critically evaluate the validity of data or evidence and of their consequent interpretations or conclusions
- To teach quantitative skills, technical methods, and scientific concepts
- To improve verbal, written, and graphical communication skills
- To train students in the values and ethics of working with data



# Why Teach with Data?

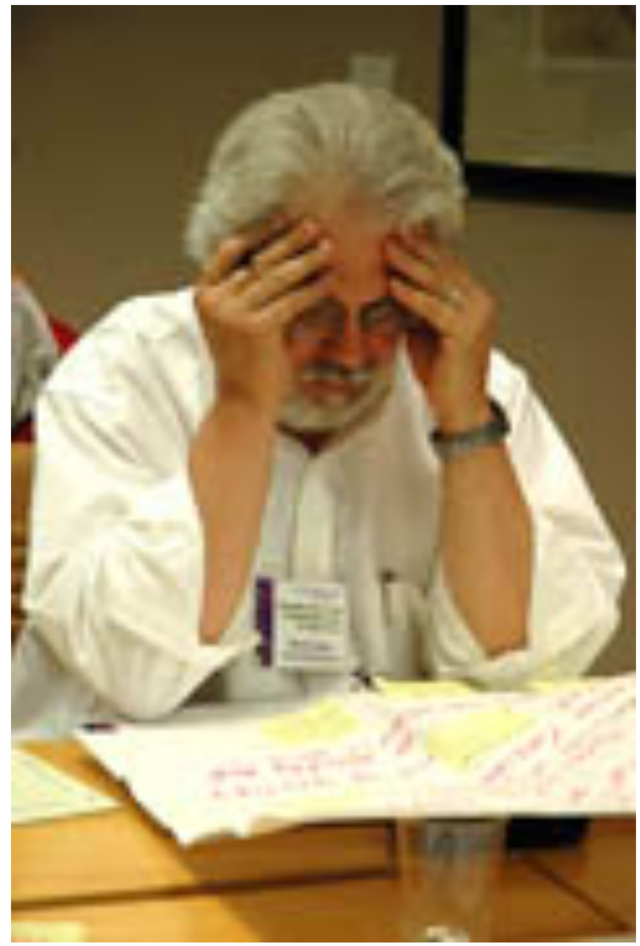
*Researchers say*

- Rich cases tie to prior knowledge
- Gaining sensitivity in preparation for future learning
- Authentic experience of science
- Adaptive scientific problem solving
- Confidence

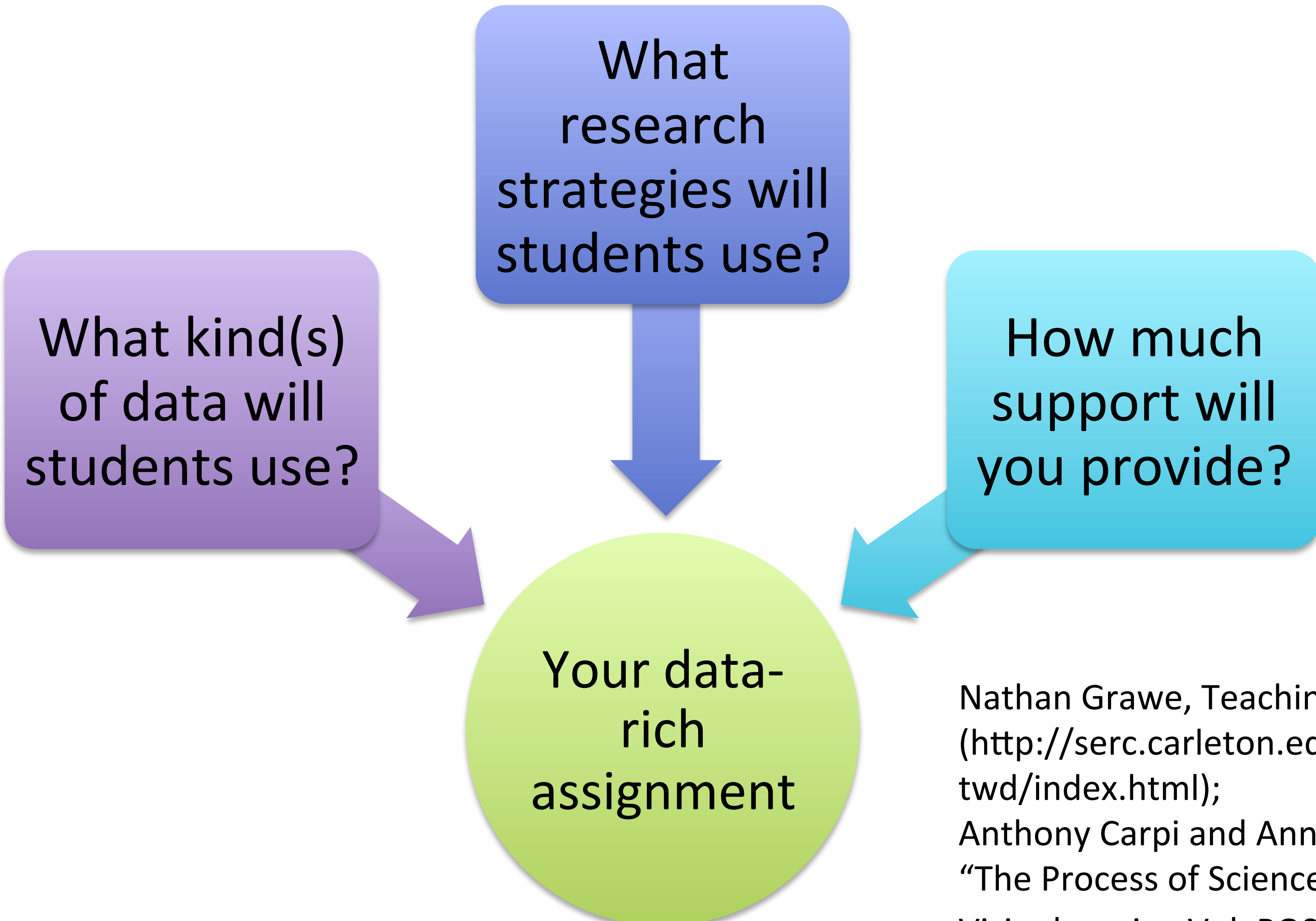


# Why is Teaching with Data Hard?

- Matching level of student expertise to the data-rich problem
- Finding/developing data analysis tools that can be mastered
- Preparing data and designing the activity
- Assessment/grading
- Course content vs. data exploration time tradeoff



# Best Practices for Teaching with Data




Nathan Grawe, Teaching with Data (http://serc.carleton.edu/sp/library/twd/index.html);
Anthony Carpi and Anne E. Egger, "The Process of Science" Visionlearning Vol. POS-2 (8), 2009.

# Designing your Data-Rich Assignment: Why Active Learning?

PNAS PNAS

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## Active learning increases student performance in science, engineering, and mathematics

**Scott Freeman[a,1], Sarah L. Eddy[a], Miles McDonough[a], Michelle K. Smith[b], Nnadozie Okoroafor[a], Hannah Jordt[a], and Mary Pat Wenderoth[a]**

[a]Department of Biology, University of Washington, Seattle, WA 98195; and [b]School of Biology and Ecology, University of Maine, Orono, ME 04469

Edited* by Bruce Alberts, University of California, San Francisco, CA, and approved April 15, 2014 (received for review October 8, 2013)

**To test the hypothesis that lecturing maximizes learning and course performance, we metaanalyzed 225 studies that reported data on examination scores or failure rates when comparing student performance in undergraduate science, technology, engineering, and mathematics (STEM) courses under traditional lecturing versus active learning. The effect sizes indicate that on average, student performance on examinations and concept inventories increased by 0.47 SDs under active learning (*n* = 158 studies), and that the odds ratio for failing was 1.95 under traditional lecturing (*n* = 67 studies). These results indicate that average examination scores improved by about 6% in active learning sections, and that students in classes with traditional lecturing were 1.5 times more likely to fail than were students in classes with active learning. Heterogeneity analyses indicated that both results hold across**

225 studies in the published and unpublished literature. The active learning interventions varied widely in intensity and implementation, and included approaches as diverse as occasional group problem-solving, worksheets or tutorials completed during class, use of personal response systems with or without peer instruction, and studio or workshop course designs. We followed guidelines for best practice in quantitative reviews (*SI Materials and Methods*), and evaluated student performance using two outcome variables: (*i*) scores on identical or formally equivalent examinations, concept inventories, or other assessments; or (*ii*) failure rates, usually measured as the percentage of students receiving a D or F grade or withdrawing from the course in question (DFW rate).

The analysis, then, focused on two related questions. Does active learning boost examination scores? Does it lower failure rates?

Freeman, Scott, Eddy, Sarah L., McDonough, Miles, Smith, Michelle K., Okoroafor, Nnadozie, Jordt, Hannah, and Wenderoth, Mary Pat (2014). Active learning increases student performance in science, engineering, and mathematics. Proceedings of the National Academy of Sciences. (Meta-analysis of 225 studies of STEM learning.)

# What Kind(s) of Data will Students Use?

- Processed data
  - Ex: Datasets uploaded to the Neotoma database with calibrated $^{14}C$ ages
- Published research data
  - Ex: You might give students some of your own published data to work with (probably processed, to some extent)
- Simulated data
  - Ex: Ages based on an age-depth model could be considered simulated data
- Student-generated data
  - Ex: If you take students with you to collect data at your field site and upload it to the Neotoma database, it would be student-generated data
- Data provided by civic partners

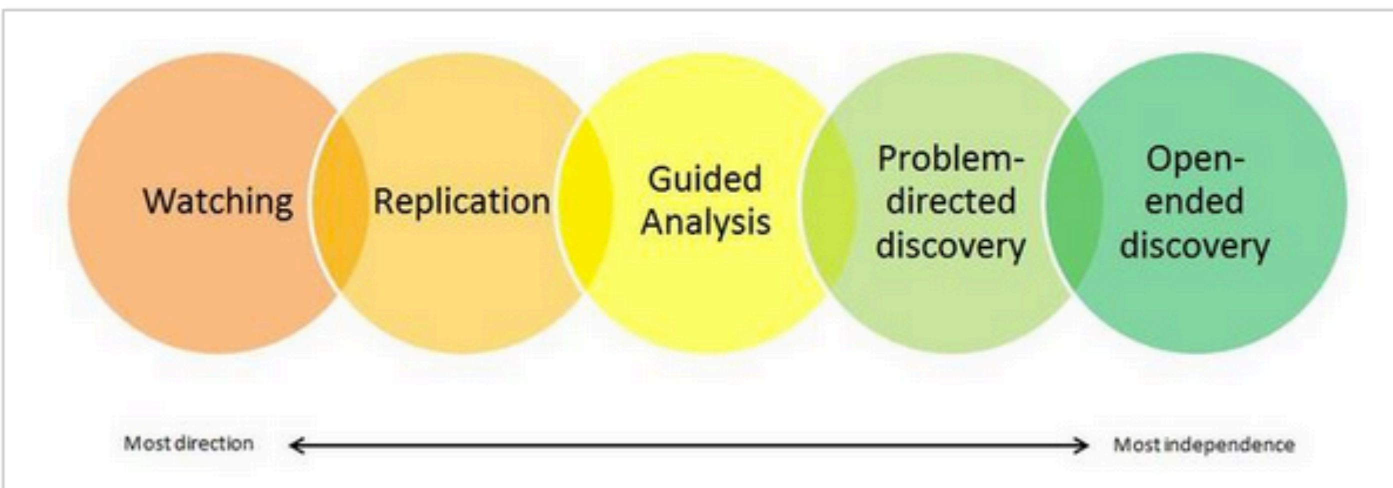
# What Research Strategies Will Students Use?

- Experimentation
  - Ex: explore the effect of changing one variable
  - It's hard for me to think of how to do this in teaching with historical data (such as that in the Neotoma database)
- Description
  - Ex: Describe the distribution of spruce forests in North America 10,000 years ago
- Comparison
  - Ex: Compare the distribution of spruce forests in North America 10,000 years ago to now
- Modeling
  - Ex: compare the temperature distributions predicted by a climate model for a particular time period to the distribution of temperature-sensitive species for that same time

# How Much Support Will You Provide?

The amount of scaffolding students will need can depend on:

- Students' prior experience working with data
- The complexity of the data and/or interface
- Time available for the activity
- Learning goals for the activity (what do you want students to be able to do after they complete the activity?)



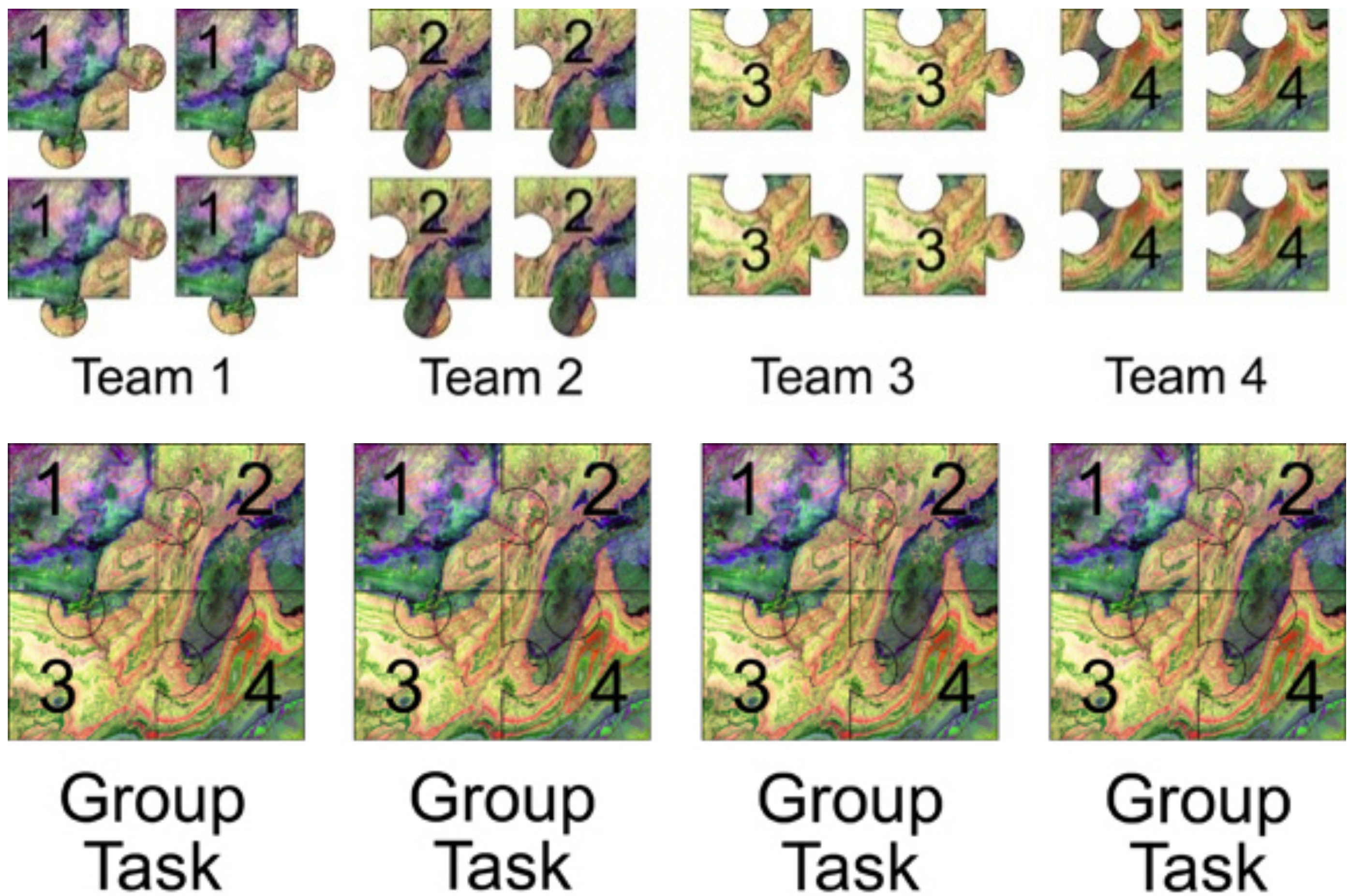
# Designing your Data-Rich Assignment: Best Practices for Maximizing Learning

- Begin by articulating learning outcomes
  - If you don't know what you want them to learn, they won't learn it
- Structure the assignment to meet those goals
  - Give students the opportunity to practice whatever you want them to be able to do!
- When is team work beneficial?
  - When it replicates scientific inquiry
  - When you expect some students to struggle with some of the required skills
  - When you want students to be exposed to multiple data sets, but to explore just one in depth (consider using the jigsaw technique)

# Designing a Data-Rich Assignment: the Jigsaw Method

Part I:

Part II:




Read all about it: http://serc.carleton.edu/sp/library/jigsaws/index.html

# Designing your Data-Rich Assignment: Best Practices for Maximizing Learning

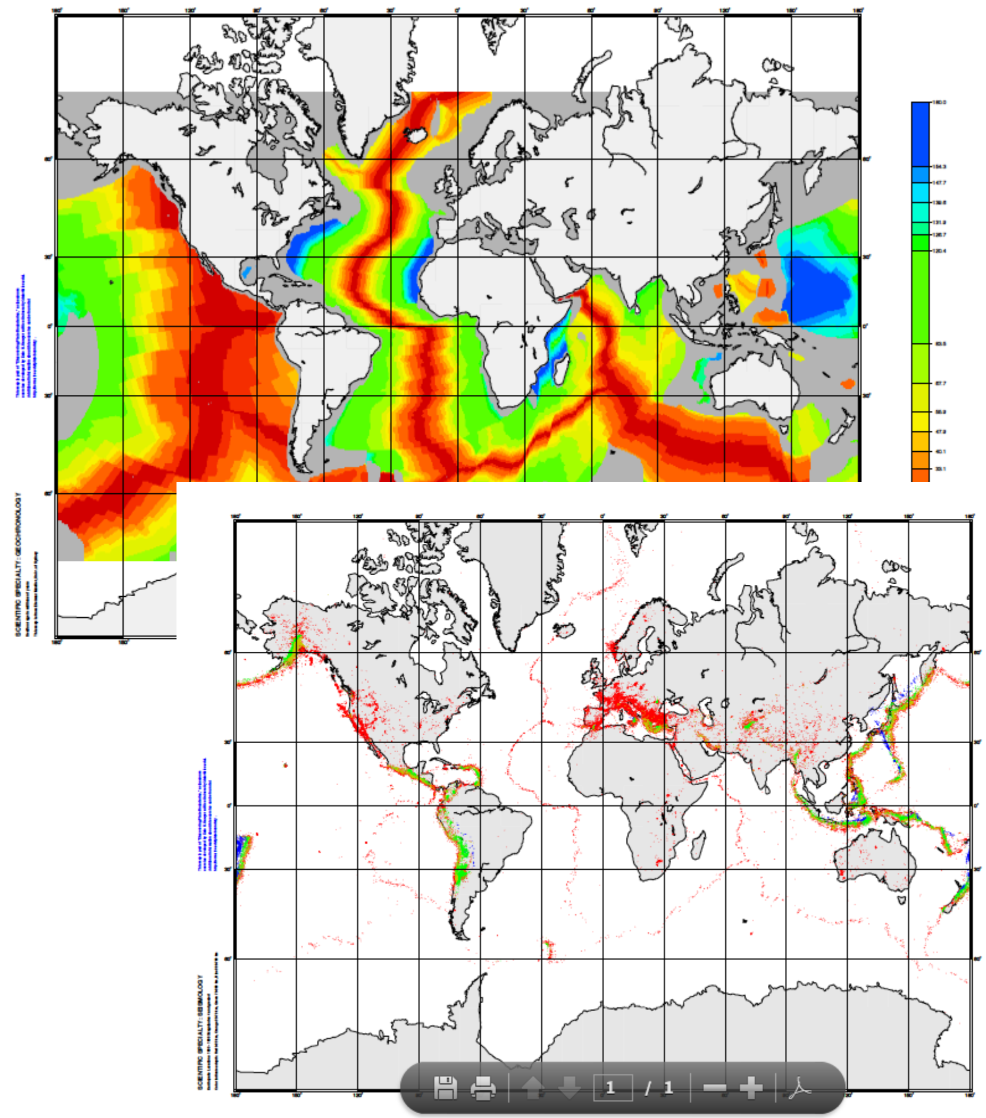
- Scaffold your assignment
  - Break it into sub-tasks
  - Require that students check in at the end of each part
- Provide instruction on methods/tools
  - How to access the Neotoma database
  - How to “get” the data (if that’s part of the assignment)
  - How to use Excel?
  - How to use R?

# Designing your Data-Rich Assignment: Best Practices for Maximizing Learning

- Provide instruction on analysis and presentation
  - Be specific about how you expect them to analyze the data
  - Be specific about how you expect them to report their findings
    - You may have to show them "basic" things like how to format graphs and diagrams
- Model the behaviors you want students to adopt
  - And be explicit, as you do ("Here's an example of what I expect you to do for this week's lab assignment… ")
- Develop a robust rubric for assessment
  - And consider handing it out with the assignment – so that students know from the start what you are expecting from them

# Rediscovering Plate Tectonics: Dale Sawyer Plate Tectonics Jigsaw

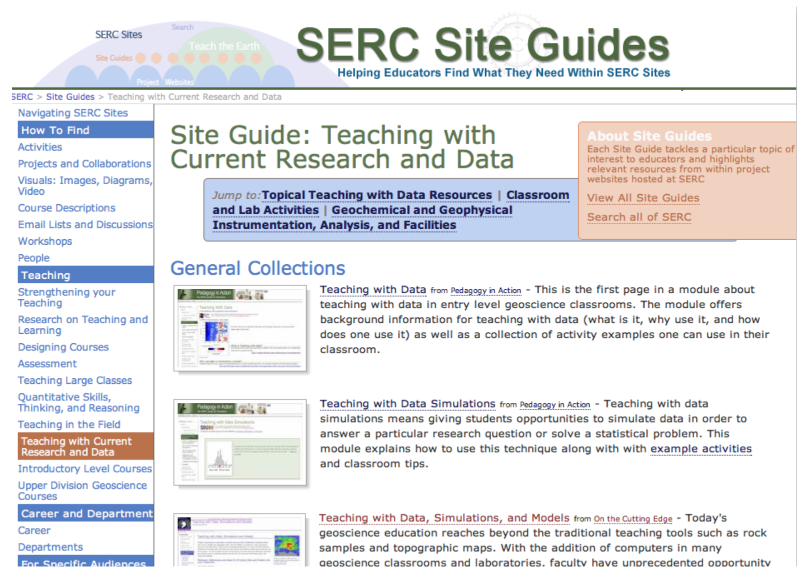
- Constructing the argument for plate tectonics from key historical evidence
- What data would you use?
- How would you have students access the data?
- What support would you offer?
- How would you evaluate student learning?



# Data-Rich Classroom Activities: Promoting Adoption

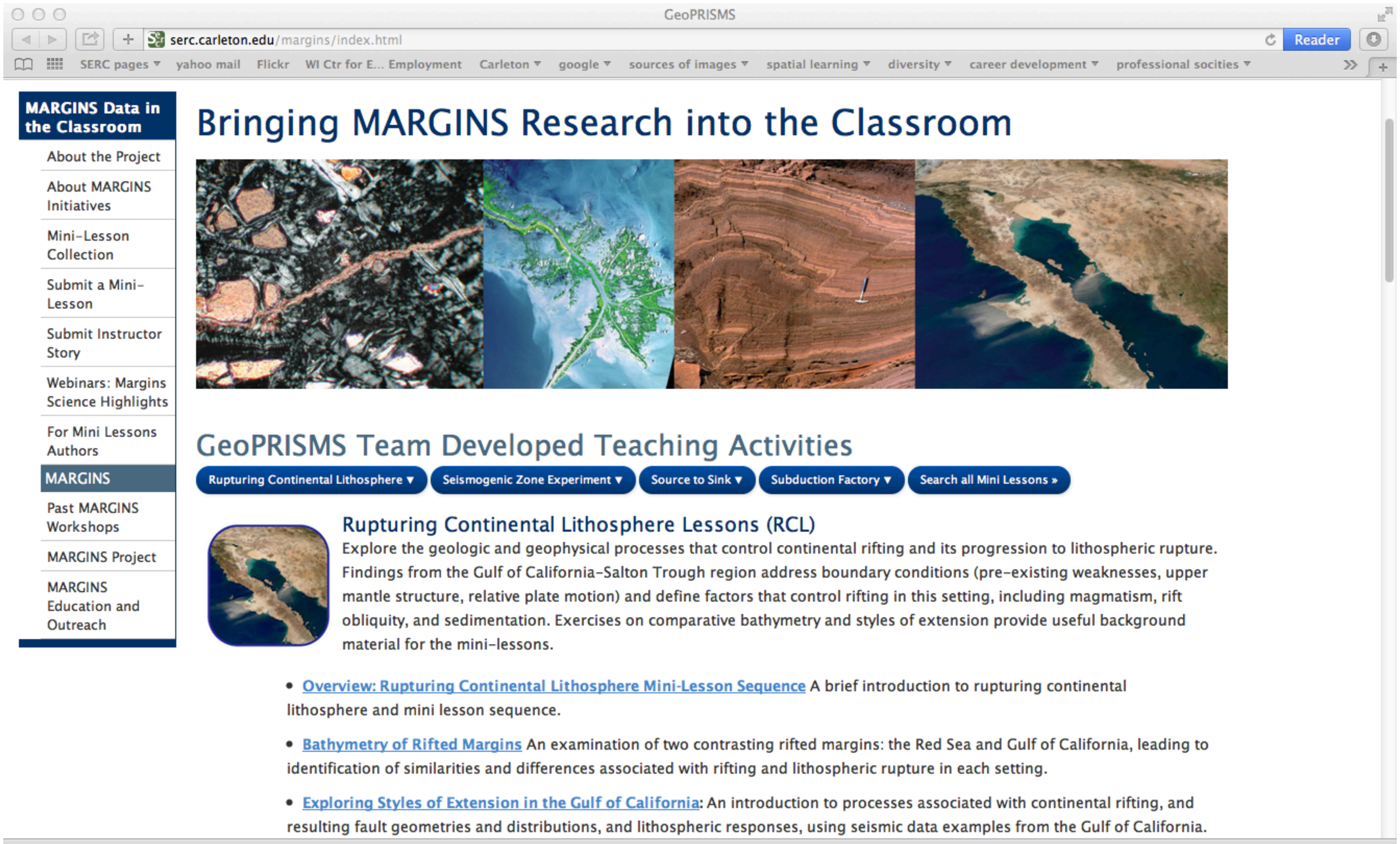
- Data set or tools can be transformative
- Organizing the data/materials is important, particularly if this work is burdensome
- Dissemination/adoption can be very fast if the activities are aligned with needs/wants
- Ready access to activities can support dissemination and use  of strong ideas
- Ready-made activities can support teaching of new ideas (scientific or otherwise)

# Data-Rich Classroom Activities: Examples on the SERC website

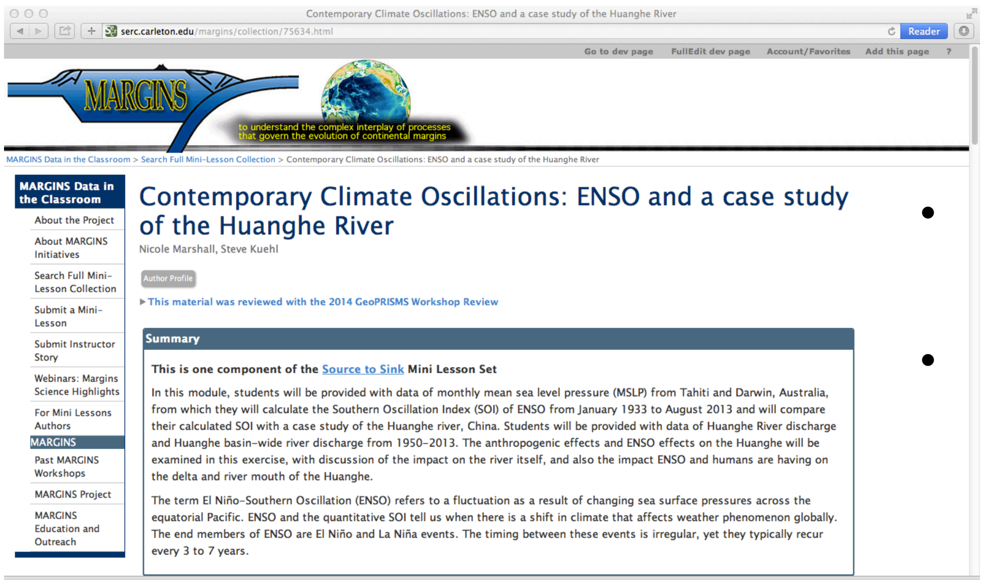



- GeoPRISMs
- Exploring Genomics Data
- InTeGrate
- GETSI
- (and far too many more to show today)
- … and soon Neotoma…

# Data-Rich Classroom Activities: GeoPRISMs



# Data-Rich Classroom Activities: Example from GeoPRISMs




- **Part 1:** A lecture introducing ENSO and SOI. Brief discussion of the take-home assignment and groups are assembled.
- **Part 2:** The take-home group assignment where the students will take sea surface pressure measurements and convert them into SOI values. They will then make the SOI plot.
- **Part 3:** The Huanghe river is introduced in class. Students are sitting in the groups that worked on the SOI plot together. They can discuss answers to the in-class worksheet questions in this module.
- **Part 4:** Completion of module consists of a class discussion of their answers and any additional discussion of the Huanghe (other figures or conclusions from the Wang et al. (2006) study).

# Data-Rich Classroom Activities: Exploring Genomics Data






## Overview of Chamaecrista Genomics Research

**Genomics research requires:**

1. **A biological question**
2. **Sequences**
3. **Computational methods** to analyze the sequence data
4. **A critical researcher** to evaluate the results and connect the results to larger picture

The *Chamaecrista Explorer* is designed to help you develop genomics research questions and get you started analyzing genomics data by guiding you through different strategies. The web interface guides you through strategies for exploring genomics data and using it to understand biological questions about *Chamaecrista fasciculata*.

The Chamaecrista Explorer has been developed and evaluated with support from the National Science Foundation (DUE-0837375 and DEB-0746571.)

**Using the *Chamaecrista* Genomics Explorer**

Making sense of genomics data can be a bit daunting. The Explorer is designed to get you started analyzing genomics data by guiding you through five different strategies. You can start with any one of the strategies to ask and answer thoughtful questions. As you get more comfortable with the data, you'll find yourself combining several strategies to ask and answer more sophisticated questions. Approach the Explorer like you would a pick your own adventure type of book.

Research Problems in Lab

- 20 to 1 ratio – differentiated learning
- Complexity of tools can be limiting
- Supporting work out of class
- Evaluating progress

*Places where sharing helped:*

- *Faculty knowledge of subject*
- *Classroom management*

# Data-Rich Classroom Activities: Exploring Genomics Data

**“Using the *Chamaecrista* Genomics Explorer**

“Making sense of genomics data can be a bit daunting. The Explorer is designed to get you started analyzing genomics data by guiding you through five different strategies. You can start with any one of the strategies to ask and answer thoughtful questions. As you get more comfortable with the data, you'll find yourself combining several strategies to ask and answer more sophisticated questions. Approach the Explorer like you would a pick your own adventure type of book.

“The strategies:

- *Chamaecrista* biology
- Candidate genes
- Gene expression
- Variation among genotypes
- Functional genomics”

# Data-Rich Classroom Activities: InTeGrate


- Climate of Change
- Natural Hazards: Hurricanes
- Mineral Resources
- Soil Sustainability
- Living on Plate Boundaries
- Map your Hazards
- Environmental Justice and Freshwater Resources
- Geoscience Teaching Methods
- Water and Human Activity


# Data-Rich Classroom Activities: InTeGrate

Climate of Change module:

- Forecasting climate variability and change
- Deciphering short-term climate variability
- Anomalous behavior
- Slow and steady?
- Systems@play
- Adapting to a changing world

## Unit 2 Deciphering Short-Term Climate Variability

Cindy Shellito, University of Northern Colorado (lucinda.shellito@unco.edu) Author Profile

▸ **This material was developed and reviewed through the InTeGrate curricular materials development process.**

**Summary**

**Making Sense of Ocean and Atmospheric Data Depicting Climate Variability**

In this lesson, students will be provided with data depicting the cyclic changes in tropical Pacific climate associated with the El Niño-Southern Oscillation. Students will try to identify patterns in the data and discuss their findings with the class. An auxiliary lab or homework exercise provides students with data from the North Atlantic and guides them in identifying cyclic changes associated with the North Atlantic Oscillation.

### Learning Goals

*Unit 2 Teaching Objectives*

- Cognitive: Provide students with an understanding of how ocean-atmosphere interactions lead to short-term climate variability, such as the El Niño-Southern Oscillation or the North Atlantic Oscillation.
- Behavioral: Provide students with experience examining climate data from observations and formulating hypotheses regarding the cause of change.

*Unit 2 Learning Outcomes*

- Case Study 2.1
  - Students will be able to interpret lat-lon contour plots and Hovmöller diagrams.
  - Students will be able to explain how temperature and pressure anomalies affect the location of precipitation in the tropical Pacific.
- Case Study 2.2
  - Practice reading lat-lon contour plots of pressure and precipitation.
  - Depict changes in pressure and precipitation over time on a map of the North Atlantic.
  - Explain how pressure changes and precipitation patterns may be connected.
  - Be able to explain the importance of examining an anomaly.

# Data-Rich Classroom Activities: GETSI

GEODETIC education RESOURCES

**Infinitesimal strain analysis using GPS data:**
**Module for structural geology or geophysics course**

Recommend 1

## Index

- Goal
- Summary
- Context
  - Audience
  - Skills
  - Design
- Download Materials
  - Basic Module
  - **2014 Napa Quake** *NEW*
  - One Day Option
  - Extension Options
  - Background Documentation
- Module Development

## Goal

Students are able to access and analyze GPS data in order to calculate and interpret ongoing strain in the region between three neighboring GPS stations.

Play Slideshow ‹ Previous Photo Next Photo ›

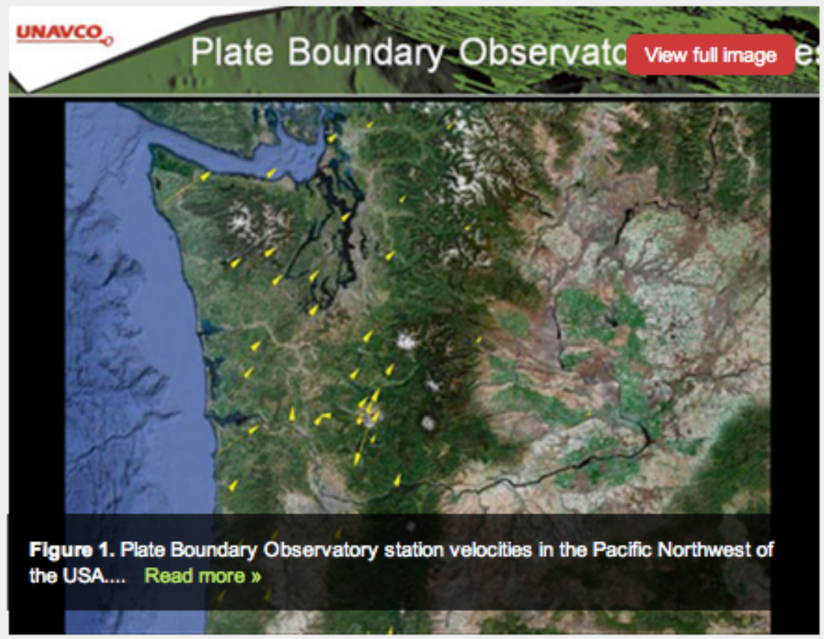
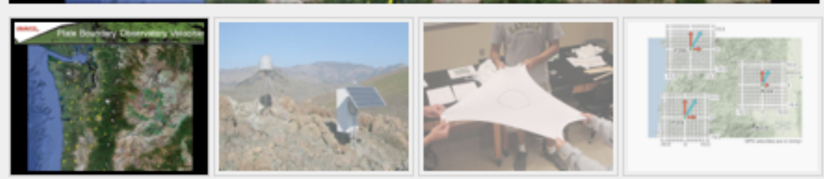



**Figure 1.** Plate Boundary Observatory station velocities in the Pacific Northwest of the USA.... Read more »



# SERC Site Guides

**Helping Educators Find What They Need Within SERC Sites**





# Site Guide: Teaching with Current Research and Data

*Jump to:* **Topical Teaching with Data Resources** | **Classroom and Lab Activities** | **Geochemical and Geophysical Instrumentation, Analysis, and Facilities**

**About Site Guides**

Each Site Guide tackles a particular topic of interest to educators and highlights relevant resources from within project websites hosted at SERC

View All Site Guides

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## General Collections

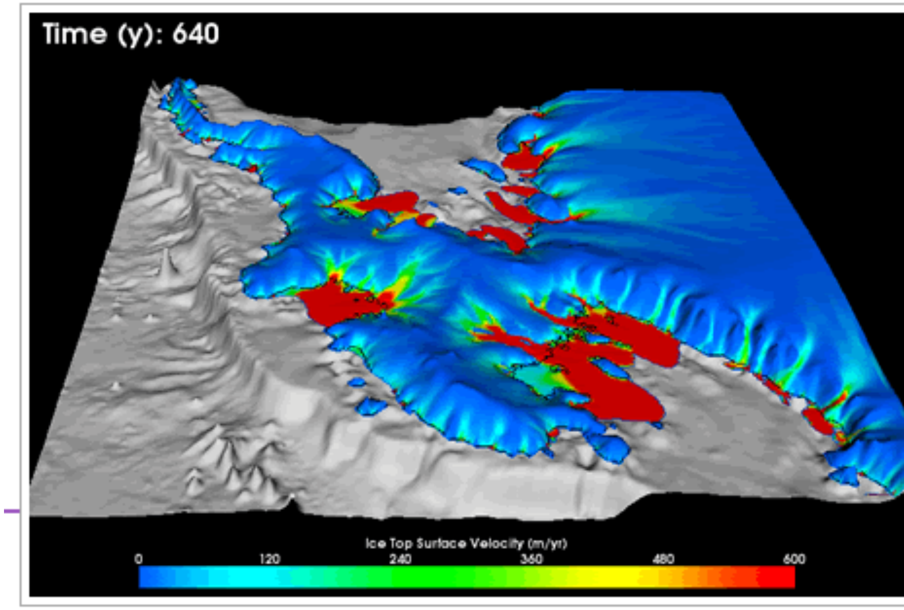
Teaching with Data from Pedagogy in Action - This is the first page in a module about teaching with data in entry level geoscience classrooms. The module offers background information for teaching with data (what is it, why use it, and how does one use it) as well as a collection of activity examples one can use in their classroom.

Teaching with Data Simulations from Pedagogy in Action - Teaching with data simulations means giving students opportunities to simulate data in order to answer a particular research question or solve a statistical problem. This module explains how to use this technique along with with example activities and classroom tips.

Teaching with Data, Simulations, and Models from On the Cutting Edge - Today's geoscience education reaches beyond the traditional teaching tools such as rock samples and topographic maps. With the addition of computers in many geoscience classrooms and laboratories, faculty have unprecedented opportunity

# Teaching with Data

- It can be done
- Time consuming – but worth it in the eyes of faculty
- Success grounded in learning theory
- Following other projects' examples can make it easier




An image created with the Visualization Toolkit showing a model of Antarctic ice growth. Image by Chuck Anderson, Penn State University.

## Questions or comments?