# Alessandro Zanazzi

##  EDDIE Module

## Module name: Paleoclimate and Ocean Biogeochemistry

## Expected dates of Implementation

##  11 and 18 April, 2023

## Course/Course Format:

**Number and length of sessions per week (e.g. Three 50 minute lecture sessions and one 3-hour lab per week)**

 Two 75-minute sessions per week

**Course Description (From course catalog)**

This course studies the six major components of the Earth system (i.e., the atmosphere, the oceans or hydrosphere, the cryosphere, the geosphere, the exosphere, and the biosphere) and investigates the interdependency and connections of these components, with particular emphasis on the effects on the climate system. The Earth’s energy balance, the greenhouse effect, and the biogeochemical cycles of some elements will also be discussed in detail. The course ends with an overview of the most important climatic events that occurred during the Cenozoic and with a discussion of the causes and consequences of ongoing global warming.

**Course Context: Describe student and/or course level, e.g., lower or upper division, major course, etc. (e.g. "An introductory course for non-majors")**

The title of the course is “Climate and the Earth System”. It is a 3000-level, upper-division course taken mostly by Earth Science Education majors (but there are also some Geology and Environmental Science majors as well). All students are juniors or seniors. Typical enrollment is 5-7 students.

**Course Goals and Topics (If available, extended version of learning goals and topics covered)**

##  Goals:

* Explain systems, system components, system interconnections, positive and negative feedbacks
* Compose system diagrams
* Illustrate the components of the Earth and climate systems (i.e., the atmosphere, the hydrosphere, the cryosphere, the geosphere, the exosphere, and the biosphere) and their interactions and interdependencies
* Apply the laws of radiation and the concept of albedo to discuss the Earth’s energy balance and to compute the Earth’s effective radiating temperature
* Explain the greenhouse effect
* Discuss the forces that create winds and ocean currents and the role of winds and ocean currents in the transport of heat from low to high latitudes
* Explain the biogeochemical cycles of carbon, nitrogen, phosphorous, and sulfur
* Discuss the application of stable isotope techniques as paleoclimate proxies
* Explain the most important climatic events that occurred in Earth’s history, including ongoing global warming

Topics:

* Introduction to the Earth and climate systems
* Systems
* Earth’s energy balance
* The atmosphere
* The hydrosphere (oceans)
* The geosphere
* The cryosphere
* The biosphere
* The exosphere
* Biogeochemical cycles
* Climate proxies
* Cenozoic climates
* Pleistocene and Holocene climates
* Modern and future climates

## Learning objectives

**What learning objective(s) (content) are you planning to address in your course using the selected module materials?**

The overarching question the module helps students answer is: How does primary productivity influence global climate at glacial-interglacial timescales? In addition, more specific learning objectives include:

* to illustrate the concentration of both macro and micronutrients in the oceans and to explain the factors that affect it
* to discuss the sources and sinks of nutrients in the oceans
* to explain the Redfield ratio
* to discuss the possible causes of the high nutrient low chlorophyll (HNLC) areas of the oceans
* to illustrate the reservoirs and fluxes of the short-term C cycle
* to explain the use of 232Th as a proxy for windblown continental dust
* to explain the use of BaXS as a proxy for oceanic primary productivity
* to explain the use of alkenones as a proxy for oceanic primary productivity
* to explain the use of ice core bubbles as a proxy for the concentration of atmospheric CO2 in the past
* to discuss the variability of atmospheric CO2 concentration at glacial-interglacial time scales
* to explain the use of benthic foraminifera δ18O as a proxy for deep ocean water temperature and ice volume
* to explain the use of authigenic Uranium as a proxy for sediment oxygenation
* to discuss the different productivity vs. dust relationship in the Southern Ocean vs. Equatorial Pacific
* to formulate hypotheses linking dust, productivity, atmospheric pCO2, global ice volume, deep ocean water temperatures, sediment anoxia

**Quantitative learning objective**

At the end of the module, students will be able to:

* Perform dust flux unit conversions
* Calculate averages and ranges
* Calculate and interpret correlation coefficients (i.e., R)
* Calculate and interpreting p-values

**Working with data learning objective**

* Using the Data Analysis ToolPack of Microsoft Excel
* Creating and interpreting scatterplots and time series plots

## Briefly describe the pedagogical techniques/strategies you plan to use to facilitate the module and reinforce the learning objectives you identified above.

I plan to introduce the module with a short (~20-minute) ppt lecture. After the lecture, I will let students work on the activities. For the entire first activity and for the first part of the second activity, students will work independently. I plan to walk around the classroom to answer questions that students may have and to help them with Excel. During the second part of the second activity, student will work in groups to explore the relationships between one dataset of their choice and the datasets included in the Excel file (i.e., alkenones, δ18O, aU, pCO2).

## Are you planning on making any adaptations to the materials? If yes, please describe them here. If no, please indicate why. (*This will be important for the end when you make your final product, you will need to distinguish the modifications you made relative to the original*)

Originally, I planned to make only very small adaptations to the material. After skimming through the module, I liked the way the material was organized and prepared. I simply planned to give some additional instructions to the students in the handout about how to use Excel to make plots and how to use its Data Analysis ToolPack. However, before implementing the module, I went through the material more carefully and read the literature that was associated with the module. Something did not make sense. In the ppt slides that came with the module it was implied that alkanes were used as a proxy for marine primary productivity. In contrast, the articles reported that alkanes are a proxy for terrestrial inputs. I therefore contacted the author of the module (Dr. Allison Jacobel) and she realized that she included in the module the alkane dataset of Martinez-Garcia et al (2011) instead of the alkenone one of Martinez-Garcia et al (2014). Therefore, I corrected the slides and substituted the Martinez-Garcia et al (2011) dataset with that of Martinez-Garcia et al (2014). Allison also contacted the Project Eddie staff and requested the correction of the module in the website. The module has now the right datasets. The conclusions of the module did not change substantially.

## Do you think you will need to incorporate any supplemental materials with this module? If yes, please either describe what you are planning or include any materials you have already found.

I plan to print out the nutrient and chlorophyll maps and to laminate them. Also, in my opinion, the students are not given enough background about the proxies used in the module. Therefore, I added some information in the slides about 232Th, BaXS, alkenones, benthic foraminifera δ18O, aU, ice core pCO2. Future instructors using this module may want to add more. However, I understand that these proxies are complex; the complete understanding of their geochemistry is in most cases beyond the purpose of this activity.

## What assessments are you planning on using to measure student progress? If possible, describe, attach, or provide a link here.

I asked the students to turn in the activities and I graded them out of 10 points.

# **Reflection Questions for after your Implementation**

*(Think about what you would like to read about this activity if you came back to it in 2 years)* Suggestions for this section (not all required, and extras always welcome):

Introductory Statement: The summary should start with one line that captures the context in which the module was used. This should be followed by 2-5 sentences that highlight what was particularly interesting about this particular implementation. This could include the setting, schedule, student group, an exceptional success or unusual adaptation of materials

Example: *A Success Story in Building Student Engagement*

*My course is introductory biology with an environmental emphasis, usually taught with a fairly traditional lecture, textbook, lab, and exam format. In recent years I've been gradually turning over content to allow students to take a more active role in acquiring the material (e.g., through acting out concepts or performing exercises integrated with lectures). This module represents the next phase of that transition—integrating recent data in an engaging, active way. My students were excited about the content and were able to immerse themselves in the data. By the end of the mini-lesson, they were able to examine the topics at a sophisticated level and ask more advanced questions relevant to current research.*

My course is titled “Climate and the Earth System”. It is essentially a course in Earth System science with an emphasis on the climate system. I have been teaching this course for several years using a very structured approach: every class meeting starts with a short (20-25 minute) lecture followed by an in-class activity. For the in-class activities, I have been using active learning techniques such as jigsaws, gallery walks, and think-pair-shares. I have taken quite a lot of material from the Integrate Modules. I have also focused on quantitative skills and reasoning.

This Project Eddie module gave me the opportunity to teach skills and topics that were not taught in previous units. For examples, in this module students learned calculate and interpret coefficient of determinations and p-values. In addition, students became familiar in developing hypotheses about complex connections that are present in the climate system (e.g., dust and productivity).

## How did it go? (What went well and why? What adjustments did you need make in real time and why?)

 At the end of the module, I gave a survey to the students. Students in general really liked the module. I think overall it went well. Students appreciated the opportunity to work with real data, to explore the correlations between different datasets, and to learn data analysis skills. I did not need to make any adjustment in real time. Students, however, did not have enough time to complete the second activity in the 75-minute class time. They had to finish the activity at home. I think the time required for this module that is mentioned on the website is underestimated.

## Student Outcomes (What did students take away? Where did students struggle the most?)

In the survey, the students mentioned that they learned a lot about how we approach analyzing paleoclimate data, about the connections between the various Earth systems. They also mentioned that the module helped develop their critical thinking skills.

They struggled with understanding what each proxy indicates, with data analysis tools and terms, with the geologic time scale, and with naming different areas of the oceans.

## Future Use (Would you do this activity again? What suggestions do you have? What would you change?)

I think this module is an excellent resource for any course in paleoclimatology, oceanography, Earth System science, and geochemistry. It can be adapted to be used at any level from lower-division undergraduate to perhaps even graduate level. I would suggest giving students more background about the proxies and to increase the length of time required to complete the module.