Course Title: Marine Isotope Biogeochemistry

Coordinator: Prof. Mark Altabet (U Massachusetts)

Instructors:
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Dates: 2-7 July 2017

Course structure:
6-day course in the Interuniversity Institute (IUI) for Marine Sciences, Eilat. The course includes lectures, practical work, research projects and journal clubs.

Main topics:
- Key Problems in Marine Biogeochemistry Studies using Isotopes
- Overview of Isotopes and their applications to marine biogeochemistry
- Isotope Tracer Addition Experiments.
- Natural stable isotope tracing of modern marine biogeochemical processes
- Measuring biological production using isotopes.
- Stable Isotopes in Paleoceanographic Studies
- Natural Isotope applications to sediment biogeochemical processes
- Isotopic studies in Gulf of Eilat.
- Radioisotopes in the sea
- Sediment traps vs 234Th disequilibria measurement of particle fluxes in the ocean.
- Non-traditional isotope applications; mass independent fractionation, isotopomers, trace-metals.

Course Prerequisites:
- Introductory chemistry is required
- Coursework in environmental, earth, or marine sciences preferred
- Assigned readings should be completed before the 1st course day.

Composition of course grade:
- Exam (25%) - Exam takes place during the course
- Practical work (25%)
- Journal club (25%)
- Project report (25%) - The report will be submitted two weeks after the course ends.

Orientation and Level:
The course is limited to 24 graduate (M.Sc/Ph.D) and upper level (3rd-4th year) undergraduate students in the Natural Sciences.

Language of course: English

Syllabus & Schedule

Sunday Morning

Introductory Lecture: Key Problems in Marine Biogeochemistry Studied using Isotopes **(2hrs)**
Readings; Emerson & Hedges *Chemical Oceanography and the Marine Carbon Cycle*; Chapter 6
Topics;
- Primary and new production
- Particle fluxes
- Nutrient cycling
- Ocean circulation and hydrological cycle

Break

Lecture: Overview of Isotopes and their applications to marine biogeochemistry **(2hrs)**
Topics;
- Stable isotope overview; definitions
- How stable isotope ratio measurements are made
- The chemistry of fractionation effects
- Radioisotope overview; definitions
- Compare/contrast stable and radioisotope application

Lunch Break

Sunday Afternoon

Introduction to Student Group Projects (2 to 3/group). **(2hrs)**
Possible topics;
1) Gross vs net community production using ^{18}O labeled water. Quad MS will be used to measure the ^{18}O labeling of dissolved O_2 resulting from photosynthesis as well as O_2/Ar ratio to measure net O_2 changes. Incubations will be made with either whole seawater or photosynthetic organisms (e.g coral, algae). Manipulations of light and nutrients can be made.
2) Denitrification and anammox using ^{15}N labeled nitrogen substrates. Quad MS will be used to measure the ^{15}N labeling of dissolved N_2 resulting from these fixed-N loss process as well as N_2/Ar ratio to measure net changes. Incubations will be made with either sediment slurries or fragments of hard substrate. Manipulations of carbon substrates and nutrients can be made.
3) N_2 fixation using ^{15}N labeled N_2. Quad MS will be used to test procedures for accurate ^{15}N labeling of the dissolved N_2 pool (a current topic of debate in the literature). Incubations will be made with either whole seawater or photosynthetic organisms (e.g coral, algae) but measurement of $^{15}N_2$ incorporation into organic matter (N_2 fixation) can only be made post-course. Manipulations of light and nutrients can be made.
4) Radon and radium isotopes as measures of water exchange across reefs.

Break

Demonstration of relevant sampling and analytical equipment. Guidelines and rules for use **(2hrs)**

Students write brief descriptions of their project choices and hand in by end of day. **(2hrs)**

Dinner

Sunday Evening

Journal Club Discussion of Seminal Papers focusing on historical literature. **(2hrs)**
Choices include;

1. Urey, H. 1933. The separation and properties of the isotopes of hydrogen
2. Urey, H. 1948. Oxygen isotopes in nature and in the laboratory
3. Craig, H. 1957 Isotopic standards for carbon and oxygen and corrections factors for mass spectrometric analysis of carbon dioxide
4. Steeman-Nielsen, E. 1952. On the use of radioactive carbon (C14) for measuring organic production in the sea.
5. Dugdale, R. & G. Goering. 1967. Uptake Of New And Regenerated Forms Of Nitrogen In Primary Productivity

Monday Morning

Lecture: Isotope Tracer Addition Experiments. **(2hrs)**
Readings; Lipschultz chapter 2008, Pather et al, 2014
Topics;
- Kinds of processes and their scales
- Design of tracer addition experiment
- Comparison of tracer methods for measuring productivity

Break

Lecture: Natural stable isotope tracing of modern marine biogeochemical processes **(2hrs)**
Readings; Emerson & Hedges *Chemical Oceanography and the Marine Carbon Cycle*; Chapter 5
Topics
- Carbon and nitrogen cycling
- Food web tracing
- Detection of anthropological impacts

Lunch

Monday Afternoon

Split students into groups, part will be working with instructors on final selection and design of projects. Rest will be given demonstration of handling and analysis of experimental data as relevant to their projects. **(2hrs)**

Break

Students complete more detail write-ups' of their experimental project plans and hand in for final review. **(2hrs)**

Dinner

Monday Evening

Journal Club; measuring biological production using isotopes. Primary discussion paper – Bender et al. 1987. A comparison of four methods for measuring community production. **(2hrs)**

Tuesday Morning

Lecture: Stable Isotopes in Paleoceanographic Studies **(2hrs)**
Readings; Emerson & Hedges *Chemical Oceanography and the Marine Carbon Cycle*; Chapter 7
Topics
-Reconstructing past seawater temperature and ice volume
-Reconstructing past productivity
-Reconstructing past nutrient cycling

Break

Lecture: Natural Isotope applications to sediment biogeochemical processes **(2hrs)**
Readings; Adler et al, 2015; Froelich et al. 1979
Topics
-Bacterial respiration processes in the sediments (aerobic and anaerobic)
-Use of stable isotopes of carbon, oxygen sulfur and iron to quantify these processes and the links between them.
-Focus on the processes involving methane in diffusive profiles and seeps

Lunch

Tuesday Afternoon

Begin student projects. **(5hrs)**
Non-light dependent incubations commence. Collection of seawater samples for radiochemical analysis. As needed, small group training of analytical equipment use.

Dinner

Tuesday Evening

Journal Club – Focus on example of isotopic studies in Gulf of Eilat. Specific topic TBA depending on instructor. **(2hrs)**

Analysis of first incubation time point samples. **(2hrs)**

Wednesday Morning

First light collection/incubation for light-dependent student project experiments **(2hrs)**
Analysis of 2nd time point incubations from non-light experiments
Commence 2nd set of non-light dependent incubations as needed.

Break

Lecture; Radioisotopes in the sea **(2hrs)**
Readings *Reviews in Mineralogy and Geochemistry* #**52**: (2003) Uranium Series Geochemistry; Chap. 11. Cochran, K and Masque, P., Short-lived U/Th Series Radionuclides in the Ocean: Tracers for Scavenging Rates, Export Fluxes and Particle Dynamics, pp. 461-492, Chap. 12. Henderson, G. and Anderson R., The U-series Toolbox for Paleoceanography, pp. 493-531
Topics;
- Questions to be addressed by radioisotopes
- Age of deep water
- Fluxes 1: from the sea floor

Lunch

Wednesday Afternoon

Lecture; Radioisotopes continued…. **(2hrs)**
Topics;
- Fluxes 2: down column particle fluxes
- Fluxes 3: land-ocean fluxes

Break

Work on student projects. **(2hrs)**
Analysis of incubation experiments. Analysis of radiochemical samples.

Dinner

Wednesday Evening

Journal Club; Topic – Sediment traps vs 234Th disequilibria measurement of particle fluxes in the ocean. **(2hrs)**

Thursday Morning

Analysis of next time point incubations from experiments **(2hrs)**

Break

Lecture; Non-traditional isotope applications; mass independent fractionation, isotopomers, trace-metals. **(2hrs)**

Lunch

Thursday Afternoon

Completion of student group projects and preparation of presentation **(5hrs)**

Study time for exam.

Dinner

Thursday Evening

Student group presentations of project results (10 to 15 min each) **(2hrs)**

Friday Morning

Course Exam

Break

Student Feedback Session

Lunch and Goodbye