CLIMATE SYSTEM SCIENCE

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Chair of Department:
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Directors of Undergraduate Studies:
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The undergraduate major in Earth and environmental sciences provides an understanding of the natural functioning of our planet and considers the consequences of human interactions with it. Our program for majors aims to convey an understanding of how the complex Earth system works at a level that encourages students to think creatively about the Earth system processes and how to address multidisciplinary environmental problems. The breadth of material covered provides an excellent background for those planning to enter the professions of law, business, diplomacy, public policy, teaching, journalism, etc. At the same time, the program provides sufficient depth so that our graduates are prepared for graduate school in one of the Earth sciences. The program can be adjusted to accommodate students with particular career goals in mind.

The department’s close affiliations with the Lamont-Doherty Earth Observatory, the American Museum of Natural History (AMNH), NASA’s Goddard Institute for Space Studies (GISS), the Earth Institute at Columbia (EI), and several departments within the Fu Foundation School of Engineering and Applied Sciences afford opportunities for student participation in a wide variety of current research programs. Summer employment, research, and additional educational opportunities are available at Lamont and GISS. The department encourages majors to become involved in a research project by their junior year.

All majors and concentrators, when planning their programs of study, should regularly consult the directors of undergraduate studies and make themselves aware of the requirements for their particular program.

Programs of Study

Environmental Science Major

The environmental science major curriculum provides an introduction to a variety of fields of study relevant to the environment. Environmental science majors are required to take three semesters of introductory courses and to develop a grounding in basic physics, chemistry, biology, and mathematics. Here, students may select courses depending on their interest. With this introduction to the Earth's environment and equipped with a knowledge of the basic sciences, students are prepared to choose a set of upper-level courses in consultation with an undergraduate adviser. All environmental science majors are required to complete a research project, providing a practical application of mastered course work. This research culminates in a senior thesis. The research and the thesis are usually done at Lamont-Doherty Earth Observatory with guidance from a faculty member or a research scientist. However, other options are also possible.

Environmental science majors have an option to complete the special concentration in environmental biology for environmental science majors.

Earth Science Major

The major in Earth science follows a similar rationale but is designed to allow students to pursue particular fields of the Earth sciences in greater depth. Compared with the environmental science major, one fewer introductory course is required, while one additional advanced course should be part of the plan of study. The Earth science major also offers the possibility of in-depth field experience through a six- to eight-week geology summer field course, arrangements for which are made through another university. The research and senior thesis capstone requirements are the same as for the environmental science major. The geology summer field course may be used as an alternative means of fulfilling the capstone requirement in the Earth science major.

Climate System Science Major

The climate system science major is designed for students who are interested in how the past, present, and future climate system works and in solution strategies for the rapidly accelerating climate crisis. The overall goal is to establish the fundamental sciences at the core of the climate system, and to inspire solution-oriented analytical thinking and expertise. The flexible course structure combines geology, physics, biology, chemistry, and math with a core in climate system science and climate solution, justice, policy and communication courses. Sample tracks through the major in sea level change, decarbonization and modern climate link to the mission and applied centers of Columbia’s Climate School. We believe that any admitted student has the potential to succeed in climate science.

Climate System Science majors begin with foundational courses in the climate system and introductory courses in global warming, oceanography or other relevant topics. Supporting courses include a grounding in calculus and natural sciences. Five climate core courses include both paleoclimate and modern climate requirements, as well as three other electives. Students pursue topics in climate solutions, policy, justice and communication in courses outside the sciences, in architecture, economics, political science or engineering. All climate system science majors are required to complete a capstone experience, which can include a field course or independent research project, typically at Lamont-Doherty Earth Observatory with guidance from a leading climate scientist.

Concentrations

The program for concentrators serves students who want more exposure to Earth and environmental science than is provided by introductory-level courses. The program aims to provide concentrators with experience in data analysis and a thorough introduction to the Earth’s systems.

The concentrations in environmental science and in Earth science are designed to give students an understanding of how the Earth works and an introduction to the methods used to investigate Earth processes,
including their capabilities and limitations. Concentrators often join the social professions (e.g., business, law, medicine, etc.) and take with them a strong scientific background. They take the same introductory courses as the majors, but fewer basic science and upper-level courses are required.

In addition to the environmental science and Earth science concentrations, the department sponsors a special concentration which must be done in conjunction with the environmental biology major. Students should be aware that they must complete the environmental biology major in order to receive credit for the special concentration. There is also a special concentration in environmental biology for environmental science majors sponsored by the Department of Ecology, Evolution, and Environmental Biology.

**Departmental Honors**

The Department of Earth and Environmental Science awards departmental honors to the major or majors in Earth science or environmental science judged to have the best overall academic record. The award is accorded to no more than 10% of the graduating class, or one student in the case of a class smaller than 10. A grade point average of at least 3.6 in the major and a senior thesis or equivalent research of high quality are required. Students who wish to be considered should contact the director of undergraduate studies early in their senior year.

**Professors**

Ryan Abernathey
Nicholas Christie-Blick
Joel E. Cohen
Hugh Ducklow
Sonya Dyhrman
Peter Eisenberger
Göran Ekström
Pierre Gentine
Steven L. Goldstein
Arnold L. Gordon
Kevin L. Griffin (Chair)
Alex Halliday
Sidney R. Hemming (Director of Graduate Studies)
Bärbel Hönisch
Peter B. Kelemen
Folarin Kolawole
Galen McKinley
Jerry F. McManus (Associate Chair)
Faye McNeill
William H. Menke
John C. Mutter
Meredith Nettles
Paul E. Olsen
Terry A. Plank (Director of Undergraduate Studies)
Lorenzo M. Polvani
G. Michael Purdy
Maureen Raymo
Christopher H. Scholz
Adam H. Sobel
Marc Spiegelman
Martin Stute (Barnard)
Maya Tolstoy
Renata Wentzcohvich

**Associate Professors**

Jacqueline Austrmann
Roisin Commane
Jonathan Kingslake

**Assistant Professors**

Folarin Kolawole
Yves Moussallam

**Adjunct Professors**

Robert F. Anderson
W. Roger Buck IV
Denton Ebel
John J. Flynn
Arthur Lerner-Lam
Alberto Malinverno
Ronald L. Miller
Dorothy M. Peteet
Andrew Robertson
Joerg M. Schaefer
Christopher Small
Andreas Thurnherr
Felix Waldhauser
Spahr C. Webb
Gisela Winckler

**Adjunct Associate Professors**

Anne Bécel

**Emeritus**

Mark Cane
Hugh Ducklow
Arnold Gordon
James Hays
Paul Richards
Lynn Sykes
David Walker

**Guidelines for all Earth Science, Environmental Science, and Climate System Science Majors, Concentrators, and Special Concentrators**

**Advising**

All majors and concentrators, when planning their programs of study, should regularly consult the directors of undergraduate studies, who can be contacted through the department office on the fifth floor of Schermerhorn. The requirements are different for each major and concentration and must be met in conjunction with the general requirements for the bachelor’s degree. Declaration of the major must be approved by the department and filed in the departmental office.

**Substitutions and Exceptions**

1. Higher-level courses may be used to satisfy supporting mathematics and science requirements for students with Advanced Placement preparation with the permission of the major adviser.
2. In addition to the courses listed for the depth, and breadth and related courses requirements, several graduate-level courses offered in the department as well as several advanced courses offered at Barnard may be substituted with the permission of the major adviser.

3. 1000-level courses in the Earth and Environmental Sciences Department cannot be used toward the requirements of any of the majors, concentrations, or special concentrations.

4. The following course is not suitable for undergraduates and can not be used toward meeting any of the requirements for the majors, concentrations, or special concentrations: EESC GU4930 EARTH'S OCEANS # ATMOSPHERE.

**Grading**

A grade of C- or better must be obtained for a course to count toward the majors, concentrations, or special concentrations. The grade of P is not acceptable, but a course taken Pass/D/Fail may be counted if and only if the P is uncovered by the Registrar’s deadline.

**Major in Earth Science**

Please read Guidelines for all Earth Science, Environmental Science, & Climate System Science Majors, Concentrators, and Special Concentrators above.

The major in Earth science requires a minimum of 45.5 points, distributed as follows:

**Foundation Courses**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>EESC UN2100</td>
<td>EARTH’S ENVIRO SYST: CLIM SYST</td>
</tr>
<tr>
<td>EESC UN2200</td>
<td>EARTH’S ENVIRONMENTAL SYSTEMS: THE SOLID EARTH</td>
</tr>
</tbody>
</table>

Students who wish to take both EESC UN2100 EARTH’S ENVIRO SYST: CLIM SYST and EESC UN2300 EARTH’S ENVIRO SYST: LIFE SYST can include one of these under breadth and related fields below.

**Supporting Mathematics and Science Courses**

One semester of Calculus at the level of Calculus I or higher (3 credits)

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH UN1101</td>
<td>CALCULUS I</td>
</tr>
</tbody>
</table>

Select one of the following three-course sequences:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
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</thead>
<tbody>
<tr>
<td>CHEM UN1403</td>
<td>GENERAL CHEMISTRY I-LECTURES</td>
</tr>
<tr>
<td>- CHEM UN1404</td>
<td>and GENERAL CHEMISTRY II-LECTURES</td>
</tr>
<tr>
<td>- PHYS UN1201</td>
<td>and GENERAL PHYSICS I</td>
</tr>
<tr>
<td>CHEM UN1403</td>
<td>GENERAL CHEMISTRY I-LECTURES</td>
</tr>
<tr>
<td>- PHYS UN1201</td>
<td>and GENERAL PHYSICS I</td>
</tr>
<tr>
<td>- PHYS UN1202</td>
<td>and GENERAL PHYSICS II</td>
</tr>
</tbody>
</table>

**Capstone Experience**

Select one of the following:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>EESC BC3800</td>
<td>ENVIR SCIENCE SENIOR SEMINAR</td>
</tr>
<tr>
<td>- EESC UN3901</td>
<td>and SENIOR SEMINAR</td>
</tr>
<tr>
<td>EESC BC3801</td>
<td>ENVIR SCIENCE SENIOR SEM II</td>
</tr>
<tr>
<td>- EESC UN3901</td>
<td>and SENIOR SEMINAR</td>
</tr>
</tbody>
</table>

A six to eight week summer geology field course

**Breadth and Related Fields Requirement**

A minimum of 6 points (two courses) chosen with the major adviser are required.

Breadth and related field courses are science courses relevant for an Earth science major that do not require an Earth science background. Several such courses are offered at the 2000-, 3000- and 4000-level in the department and at Barnard. Examples include:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>EESC UN2100</td>
<td>EARTH’S ENVIRO SYST: CLIM SYST</td>
</tr>
<tr>
<td>EESC UN2300</td>
<td>EARTH’S ENVIRO SYST: LIFE SYST</td>
</tr>
<tr>
<td>EESC UN3010</td>
<td>FIELD GEOLOGY</td>
</tr>
<tr>
<td>EESC BC3017</td>
<td>ENVIRONMENTAL DATA ANALYSIS</td>
</tr>
<tr>
<td>EESC GU4050</td>
<td>GLOBAL ASSMT-REMOTE SENSING</td>
</tr>
<tr>
<td>EESC GU4600</td>
<td>EARTH RESOURCES &amp; SUSTAIN DEV</td>
</tr>
<tr>
<td>EESC GU4917</td>
<td>THE EARTH/HUMAN INTERACTIONS</td>
</tr>
<tr>
<td>EAE E2002</td>
<td>ALTERNATIVE ENERGY RESOURCES</td>
</tr>
</tbody>
</table>

Also included among breadth and related fields courses are science, mathematics, statistics, and engineering courses offered by other departments that count toward fulfilling degree requirements in those departments.

**Depth Requirement**

A minimum of 12 points (four courses) chosen with the major adviser to provide depth in the field of Earth science.

These courses build on the foundation and supporting courses listed above and provide a coherent focus in some area of Earth science. Students should include at least one of the following in their course of study:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
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</thead>
<tbody>
<tr>
<td>EESC UN3101</td>
<td>Geochemistry for a Habitable Planet</td>
</tr>
<tr>
<td>or EESC UN3201</td>
<td>SOLID EARTH DYNAMICS</td>
</tr>
</tbody>
</table>

Areas of focus include one of the courses listed above and three or more additional courses. Students are not required to specialize in a focus area, but examples are given below for those who choose to do so.

**Geological Science**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>EESC GU4090</td>
<td>INTRO TO GEOCHRONOLGY</td>
</tr>
<tr>
<td>EESC GU4113</td>
<td>INTRODUCTION TO MINERALOGY I</td>
</tr>
<tr>
<td>EESC GU4223</td>
<td>SEDIMENTARY GEOLOGY</td>
</tr>
<tr>
<td>EESC GU4230</td>
<td>CRUSTAL DEFORMATION</td>
</tr>
<tr>
<td>EESC GU4701</td>
<td>Introduction to Igneous Petrology</td>
</tr>
<tr>
<td>EESC GU4887</td>
<td>ISOTOPE GEOLOGY I</td>
</tr>
<tr>
<td>EESC GU4947</td>
<td>PLATE TECTONICS AND CLIMATE</td>
</tr>
</tbody>
</table>

It is strongly recommended that students focusing in geological science take the summer geology field course as their capstone experience.

**Geochemistry**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>EESC UN3015</td>
<td>The Earth’s Carbon Cycle</td>
</tr>
<tr>
<td>EESC BC3016</td>
<td>ENVIRONMENTAL MEASURMENTS</td>
</tr>
<tr>
<td>EESC BC3200</td>
<td>Ecotoxicology</td>
</tr>
<tr>
<td>EESC GU4090</td>
<td>INTRO TO GEOCHRONOLGY</td>
</tr>
<tr>
<td>EESC GU4113</td>
<td>INTRODUCTION TO MINERALOGY I</td>
</tr>
<tr>
<td>EESC GU4701</td>
<td>Introduction to Igneous Petrology</td>
</tr>
<tr>
<td>EESC GU4885</td>
<td>CHEMISTRY OF CONTINENTAL WATERS</td>
</tr>
<tr>
<td>EESC GU4887</td>
<td>ISOTOPE GEOLOGY I</td>
</tr>
<tr>
<td>EESC GU4926</td>
<td>INTRO TO CHEMICAL OCEANOGRAPHY</td>
</tr>
</tbody>
</table>

It is recommended that students focusing in geochemistry take CHEM UN1403-CHEM UN1404 General Chemistry I and II, and PHYS UN1201 General Physics I as their supporting science sequence.

**Atmosphere and Ocean Science**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>EESC GU4008</td>
<td>Introduction to Atmospheric Science</td>
</tr>
<tr>
<td>EESC GU4920</td>
<td>PALEOCEANOGRAPHY</td>
</tr>
</tbody>
</table>
Major in Environmental Science

Please read Guidelines for all Earth Science, Environmental Science, & Climate System Science Majors, Concentrators, and Special Concentrators above.

The major in environmental science requires a minimum of 47 points, distributed as follows:

Foundation Courses

- EESC UN2100: EARTH'S ENVIRONMENTAL SYSTEMS: THE CLIMATIC SYSTEM
- EESC UN2200: EARTH'S ENVIRONMENTAL SYSTEMS: THE SOLID EARTH
- EESC UN2300: EARTH'S ENVIRONMENTAL SYSTEM: THE LIFE SYSTEM

Supporting Mathematics and Science Courses

One semester of Calculus at the level of Calculus I or higher (3 credits)
- MATH UN1101: CALCULUS I

Select one of the following three-course sequences:
- CHEM UN1403: GENERAL CHEMISTRY I-LECTURES
- PHYS UN1201: and GENERAL CHEMISTRY II-LECTURES
- PHYS UN1202: and GENERAL PHYSICS I

Also included among breadth and related fields courses are science, mathematics, statistics, and engineering courses offered by other departments that count toward fulfilling degree requirements in those departments.

Depth Requirement

A minimum of 9 points (three courses) chosen with the major adviser to provide depth in the field of environmental science.

These courses build on the foundation and supporting courses listed above and provide a coherent focus in some area of environmental science. Students should include at least one of the following in their course of study:

- EESC UN3101: Geochemistry for a Habitable Planet
- EESC UN3201: SOLID EARTH DYNAMICS

Areas of focus include one of the courses listed above and two or more additional courses. Students are not required to specialize in a focus area, but examples are given below for those who choose to do so.

Environmental Geology

- EESC GU4076: Geologic Mapping
- EESC GU4480: Paleobiology and Earth System History
- EAEE E3221

Environmental Geochemistry

- EESC UN3015: The Earth’s Carbon Cycle
- EESC GU4885: CHEMISTRY OF CONTINENTAL WATERS
- EESC GU4887: ISOTOPE GEOLOGY I
- EESC GU4924: INTRO TO ATMOSPHERIC CHEMISTRY
- EESC GU4926: INTRO TO CHEMICAL OCEANOGRAPHY

Hydrology

- CHEM UN1403: GENERAL CHEMISTRY I-LECTURES
- PHYS UN1201: and GENERAL PHYSICS I
- PHYS UN1202: and GENERAL PHYSICS II
- CHEM UN1403: GENERAL CHEMISTRY I-LECTURES
- EEEB UN2001: and ENVIRONMENTAL BIOLOGY I
- PHYS UN1201: and GENERAL PHYSICS I

Capstone Experience

- EESC BC3800: ENVIR SCIENCE SENIOR SEMINAR
- or EESC BC3801: ENVIR SCIENCE SENIOR SEM II
- EESC UN3901: SENIOR SEMINAR
Climate System Science

Please read Guidelines for all Earth Science, Environmental Science, & Climate System Science Majors, Concentrators, and Special Concentrators above.

The major in climate system science requires a minimum of 43.5 points, distributed as follows:

**Foundational Courses**
7.5 points minimum (2 courses):

**Required:**
- EESC UN2100 EARTH'S ENVIRO SYST: CLIM SYST

**And any one of:**
- EESC UN1009 GLOBAL WARMING FOR GLOBAL LEADERS
- EESC UN1030 OCEANOGRAPHY
- EESC UN1201 Environmental Risks and Disasters
- EESC UN1600 or EESC GU4600 EARTH RESOURCES # SUSTAIN DEV
- EESC UN2200 EARTH'S ENVIRONMENTAL SYSTEMS: THE SOLID EARTH
- EESC UN2300 EARTH'S ENVIRO SYST: LIFE SYST
- EESC UN2330 SCIENCE FOR SUSTAINABLE DEVPT

**Supporting Courses**
12 points minimum (4 courses):

One semester of Calculus at the level of Calculus I or higher:
- MATH UN1101 CALCULUS I

And any three courses:
- PHYS UN1201 GENERAL PHYSICS I
- PHYS UN1202 GENERAL PHYSICS II
- CHEM UN1403 GENERAL CHEMISTRY I-LECTURES
- CHEM UN1404 GENERAL CHEMISTRY II-LECTURES
- EEEB UN2001 ENVIRONMENTAL BIOLOGY I
- EESC UN2300 EARTH'S ENVIRO SYST: LIFE SYST

**Climate System Core**
15 points minimum (five courses):

**Required: at least one Paleoclimate Course**
- EESC GU4235 SEA LEVEL CHANGE
- EESC GU4330 Introduction to Terrestrial Paleoclimate
- EESC GU4850 Paleobiology and Earth System History
- EESC GU4920 PALEOCEANOGRAPHY
- EESC GU4930 CENOZOIC PALEOCEANOGRAPHY

**Required: at least one Modern Climate Course**
- EESC UN3109 CLIMATE PHYSICS
- EESC GU4008 Introduction to Atmospheric Science
- EESC GU4020 HUMANS # THE CARBON CYCLE
- EESC GU4040 CLIM THERMODYN/ENERGY TRANSFER
- EESC GU4925 Principles of Physical Oceanography
- EESC GU4930 EARTH'S OCEANS # ATMOSPHERE

**Could include: Other Climate System Course**
- EESC BC3109 Hydrology
- EESC GU4040 CHEMISTRY OF CONTINENTL WATERS
- EESC GU4835 WETLANDS AND CLIMATE CHANGE
- EESC GU4885 CHEMISTRY OF CONTINENTL WATERS
- EESC GU4923 Biological Oceanography
- EESC GU4924 INTRO TO ATMOSPHERIC CHEMISTRY
- EESC GU4926 INTRO TO CHEMICAL OCEANOGRAPHY

**Climate Solutions, Justice, Policy, and Communication**
6 points minimum (any two courses below):

**Solutions Courses**
- EESC BC3045 RESPONDING TO CLIMATE CHANGE (Barnard College)
- ARCH UN3120 CITY, LANDSCAPE, & ECOLOGY
- EAB E2002 ALTERNATIVE ENERGY RESOURCES
- EAB E2100 A BETTER PLANET BY DESIGN
- EAB E4001 INDUST ECOLOGY-EARTH RESOURCES
- EAB E4002 ALTERNATIVE ENERGY RESOURCES
- EAB E4006 Field methods for environmental engineering
- EAB E4300 INTRO TO CARBON MANAGEMENT
- EAB E4302 CARBON CAPTURE
- EAB E4301 CARBON STORAGE
- EAB E4305 CO2 UTILIZATION AND CONVERSION
- CEE E3250 HYDROSYSTEMS ENGINEERING
- MECE E4211 ENERGY SOURCES AND CONVERSION
- SDEV GU4250 CLIMATE CHANGE: RESILIENCE # ADAPTATION

**Climate Justice, Policy, Economics**
- ANTH BC3932 CLIMATE CH./GLOB. MIGRATION/HUMAN RIGHTS (Barnard College)
- ANTH V3861
Climate System Science

ARCH UN3400  ENVIRONMENTAL VISUALIZATIONS OF NYC
ECON BC3039 ENVIRONMENTAL & NAT. RES. ECONOMICS (Barnard College)
ECON BC3040 ENVIRONMENTAL LAW (Barnard College)
ECON UN2257  THE GLOBAL ECONOMY
ECON GU4750  GLOBALIZATION # ITS RISKS
POLS UN3648  GOVERNING THE GLOBAL ECONOMY
POLS GU4814  GLOBAL ENERGY SECURITY/GEOPOL
POLS GU4863  INTERNATIONAL POLITICAL ECONOMY OF DEVELOPING COUNTRIES
SDEV UN3355  CLIMATE CHANGE AND LAW
SDEV UN3360  DISASTERS AND DEVELOPMENT

Climate System Capstone
3 points minimum (one course):

EESC 3xxx Undergraduate Research Project (course is under development)
EESC UN3901  SENIOR SEMINAR (taken twice, in fall and spring)

or EESC BC3800 followed by EESC UN3901

Approved Field Course focused on the Climate System ~6 weeks, must be proposed and then approved by DUS

Concentration in Environmental Science

Please read Guidelines for all Earth Science, Environmental Science, & Climate System Science Majors, Concentrators, and Special Concentrators above.

The concentration in environmental science requires a minimum of 25.5 points, distributed as follows:

Foundation Courses
EESC UN2100  EARTH'S ENVIRO SYST: CLIM SYST
or EESC UN2300  EARTH'S ENVIRO SYST: LIFE SYST
EESC UN2200  EARTH'S ENVIRONMENTAL SYSTEMS: THE SOLID EARTH

Supporting Mathematics and Science Courses
Two science or mathematics courses (6-7 points) selected from among those listed for the environmental science major above.

Depth and Breadth and Related Fields Requirements
A minimum of 6 points (two courses) is required as follows:

EESC UN3101  Geochemistry for a Habitable Planet
or EESC UN3201  SOLID EARTH DYNAMICS

One additional course selected from those listed under either Depth Requirement or Breadth and Related Fields Requirement for the environmental science major above.

Special Concentration in Environmental Science for Majors in Environmental Biology

Please read Guidelines for all Earth Science, Environmental Science, & Climate System Science Majors, Concentrators, and Special Concentrators above.

The Department of Earth and Environmental Sciences sponsors a special concentration which must be done in conjunction with the environmental biology major. Students should be aware that they must complete the environmental biology major in order to receive credit for the special concentration.

The special concentration in environmental science requires a minimum of 31.5 points, distributed as follows:

Introductory Environmental Science (13.5 points)
EESC UN2100  EARTH'S ENVIRO SYST: CLIM SYST
EESC UN2200  EARTH'S ENVIRONMENTAL SYSTEMS: THE SOLID EARTH
EESC UN2300  EARTH'S ENVIRO SYST: LIFE SYST

Introductory Science (6 points)
Two courses in chemistry, physics, mathematics, or environmental biology from the supporting mathematics and science list for the environmental science major above.

Advanced Environmental Science (12 points)
Four courses at the 3000-level or above chosen from those recommended for the environmental science major above.
Advanced courses used to fulfill requirements in the environmental biology major cannot count toward requirements for the special concentration.

**Special Concentration in Environmental Biology for Majors in Environmental Science**

Please read Guidelines for all Earth Science, Environmental Science, & Climate System Science Majors, Concentrators, and Special Concentrators above.

The Department of Ecology, Evolution, and Environmental Biology sponsors a special concentration which must be done in conjunction with the environmental science major. Students should be aware that they must complete the environmental science major in order to receive credit for the special concentration.

The special concentration in environmental biology requires a minimum of 39 points, distributed as follows:

**Introductory Environmental Biology and Environmental Science (17 points)**

- EEEB UN2001  ENVIRONMENTAL BIOLOGY I
- EESC UN2100  EARTH'S ENVIRO SYST: CLIM SYST
- EESC UN2200  EARTH'S ENVIRONMENTAL SYSTEMS: THE SOLID EARTH
- EEEB UN2002  ENVIRONMENTAL BIOLOGY II

**Introductory Science (13 points)**

Select one of the following chemistry sequences:

- CHEM UN1403 - CHEM UN1404  GENERAL CHEMISTRY I-LECTURES and GENERAL CHEMISTRY II-LECTURES
- CHEM UN1604 - CHEM UN2507  2ND TERM GEN CHEM (INTENSIVE) and Intensive General Chemistry Laboratory

One term of statistics such as the following:

- STAT UN1101  INTRODUCTION TO STATISTICS
- STAT UN1201  CALC-BASED INTRO TO STATISTICS
- BIOL BC2286  Statistics and Research Design
- EEEB UN3005  INTRO-STAT-ECOLOGY # EVOL BIOL
- EEEB UN3087  CONSERVATION BIOLOGY

**Advanced Environmental Biology (9 points)**

Three additional advanced EEEB courses (3000-level and above), each chosen from a different curricular area (evolution/genetics, ecology/behavior/conervation, anatomy/physiology/diversity, biology laboratory courses).

Advanced courses used to fulfill requirements in the environmental science major cannot count toward requirements for the special concentration.

**Sustainable Development**

Students interested in sustainable development should refer to the Sustainable Development section in this Bulletin.

**Fall 2023**

**EESC UN1001 DINOSAURS AND HISTORY OF LIFE. 4.00 points.**

CC/GS: Partial Fulfillment of Science Requirement

Given in alternate years.

Prerequisites: Recommended preparation: basic high school science and math.

Prerequisites: Recommended preparation: basic high school science and math. Lab is a hands-on introduction to geochronology, paleontology, and historical geology with field trips. (See W1401 for lectures only.) Dinosaurs: a spectacular example of a common, highly successful form of life, dominant for 135 million years. Where did they come from? Why were they so successful? Why did they die out? ... or did they? A basic introduction to the historical sciences and the interface between geology and biology

**EESC 1001**

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<tr>
<th>Course Number</th>
<th>Section/Call Number</th>
<th>Times/Location</th>
<th>Instructor</th>
<th>Points</th>
<th>Enrollment</th>
</tr>
</thead>
<tbody>
<tr>
<td>EESC 1001</td>
<td>001/13223</td>
<td>M W 1:10pm - 2:25pm</td>
<td>Paul Olsen</td>
<td>4.00</td>
<td>20/40</td>
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<td>301 Uris Hall</td>
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</table>

**EESC UN1030 OCEANOGRAPHY. 3.00 points.**

CC/GS: Partial Fulfillment of Science Requirement

Enrollment limited to 160.

Explore the explore the geological foundation of the ocean, understand what drives ocean currents and how ocean ecosystems operate. Case studies and discussions centered on ocean-related issues facing society

**EESC 1030**

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<th>Course Number</th>
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<th>Instructor</th>
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<tr>
<td>EESC 1030</td>
<td>001/13126</td>
<td>T Th 11:40am - 12:55pm</td>
<td>Baerbel</td>
<td>3.00</td>
<td>146/160</td>
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<td>Hoenisch</td>
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</table>

**EESC UN1201 Environmental Risks and Disasters. 3 points.**

CC/GS: Partial Fulfillment of Science Requirement

Priority given to first-years and sophomores.

Prerequisites: high school science and math.

An introduction to risks and hazards in the environment. Different types of hazards are analyzed and compared: natural disasters, such as tornados, earthquakes, and meteorite impacts; acute and chronic health effects caused by exposure to radiation and toxic substances such as radon, asbestos, and arsenic; long-term societal effects due to environmental change, such as sea level rise and global warming. Emphasizes the basic physical principles controlling the hazardous phenomena and develops simple quantitative methods for making scientifically reasoned assessments of the threats (to health and wealth) posed by various events, processes, and exposures. Discusses methods of risk mitigation and sociological, psychological, and economic aspects of risk control and management.

**EESC 1201**

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<th>Course Number</th>
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<th>Times/Location</th>
<th>Instructor</th>
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<tr>
<td>EESC 1201</td>
<td>001/13127</td>
<td>T Th 10:10am - 11:25am</td>
<td>Goran Ekstrom</td>
<td>3</td>
<td>41/60</td>
</tr>
<tr>
<td></td>
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<td>330 Uris Hall</td>
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</table>
### EESC UN1401 Dinosaur History of Life - LEC.
3.00 points.
CC/GS: Partial Fulfillment of Science Requirement
Given in alternate years.

**Prerequisites:** Recommended preparation: basic high school science and math.
Prerequisites: Basic high school science and math. Dinosaurs: a spectacular example of a common, highly successful form of life, dominant for 135 million years. Where did they come from? Why were they so successful? Why did they die out? ... or did they?
A basic introduction to the historical sciences and the interface between geology and biology.

#### Fall 2023: EESC UN1401
<table>
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<tr>
<th>Course Number</th>
<th>Section/Call Number</th>
<th>Times/Location</th>
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</thead>
<tbody>
<tr>
<td>EESC 1401</td>
<td>001/13128</td>
<td>M W 1:10pm - 2:25pm 603 Schermerhorn Hall</td>
<td>Paul Olsen</td>
<td>3.00</td>
<td>58/100</td>
</tr>
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</table>

### EESC UN1600 Earth Resources Sustain Dev.
3.00 points.
CC/GS: Partial Fulfillment of Science Requirement

**Prerequisites:** none; high school chemistry recommended.
Prerequisites: None; high school chemistry recommended. Survey of the origin and extent of mineral resources, fossil fuels, and industrial materials, that are non renewable, finite resources, and the environmental consequences of their extraction and use, using the textbook Earth Resources and the Environment, by James Craig, David Vaughan and Brian Skinner. This course will provide an overview, but will include focus on topics of current societal relevance, including estimated reserves and extraction costs for fossil fuels, geological storage of CO2, sources and disposal methods for nuclear energy fuels, sources and future for luxury goods such as gold and diamonds, and special, rare materials used in consumer electronics (e.g. Coltan; mostly from Congo) and in newly emerging technologies such as superconducting magnets and rechargeable batteries (e.g. heavy rare earth elements, mostly from China). Guest lectures from economists, commodity traders and resource geologists will provide real world input. Discussion Session Required.

#### Fall 2023: EESC UN1600
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<tr>
<th>Course Number</th>
<th>Section/Call Number</th>
<th>Times/Location</th>
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<td>001/13129</td>
<td>T Th 1:10pm - 2:25pm 301 Uris Hall</td>
<td>Peter Kelemen</td>
<td>3.00</td>
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</table>

### EESC UN2100 Earth's Enviro Syst: Clim Syst.
4.50 points.
Prerequisites: high school algebra. Recommended preparation: high school chemistry and physics; and one semester of college science.
Origin and development of the atmosphere and oceans, formation of winds, storms and ocean currents, reasons for changes through geologic time. Recent influence of human activity: the ozone hole, global warming, water pollution. Laboratory exploration of topics through demonstrations, experimentation, computer data analysis, and modeling. Students majoring in Earth and Environmental Sciences should plan to take EESC W2100 before their senior year to avoid conflicts with Senior Seminar.

#### Fall 2023: EESC UN2100
<table>
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<th>Course Number</th>
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<td>EESC 2100</td>
<td>001/13062</td>
<td>T Th 10:10am - 11:25am 603 Schermerhorn Hall</td>
<td>Mingfang Ting, Gisela Winckler</td>
<td>4.50</td>
<td>48/50</td>
</tr>
<tr>
<td>EESC 2100</td>
<td>002/16962</td>
<td>T Th 1:10pm - 2:25pm 603 Schermerhorn Hall</td>
<td>Michela Biasutti, Jennifer Middleton</td>
<td>4.50</td>
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#### Spring 2024: EESC UN2100
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<th>Course Number</th>
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<th>Times/Location</th>
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<th>Enrollment</th>
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<tbody>
<tr>
<td>EESC 2100</td>
<td>002/16962</td>
<td>W 4:10pm - 7:00pm 555 Ext Schermerhorn Hall</td>
<td>Michela Biasutti, Jennifer Middleton</td>
<td>4.50</td>
<td>14/25</td>
</tr>
</tbody>
</table>
EESC UN2200 Earth's Environmental Systems: The Solid Earth. 4.50 points.
CC/GS: Partial Fulfillment of Science Requirement
Priority given to Columbia and Barnard earth science, environmental science, and environmental biology majors should enroll limits be necessary.

Prerequisites: high school algebra and chemistry. Recommended preparation: high school physics.
Recommended preparation: high school chemistry and physics; and one semester of college science. Exploration of how the solid Earth works, today and in the past, focusing on Earth in the Solar system, continents and oceans, the Earth's history, mountain systems on land and sea, minerals and rocks, weathering and erosion, glaciers and ice sheets, the hydrological cycle and rivers, geochronology, plate tectonics, earthquakes, volcanoes, energy resources. Laboratory exploration of topics through examination of rock samples, experimentation, computer data analysis, field exercises, and modeling. Columbia and Barnard majors should plan to take W2200 before their senior year to avoid conflicts with the Senior Seminar.

Fall 2023: EESC UN2200

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<tr>
<th>Course Number</th>
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<tr>
<td>EESC 2200</td>
<td>001/13130</td>
<td>T Th 1:10pm - 2:25pm 313 Fayweather</td>
<td>John Mutter, Jonathan Kingslake</td>
<td>4.50</td>
<td>70/80</td>
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<tr>
<td>EESC 2200</td>
<td>001/13130</td>
<td>Th 4:10pm - 7:00pm 603 Schermerhorn Hall</td>
<td>John Mutter, Jonathan Kingslake</td>
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Spring 2024: EESC UN2200

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<th>Course Number</th>
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<th>Enrollment</th>
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<tbody>
<tr>
<td>EESC 2200</td>
<td>001/12441</td>
<td>T 2:40pm - 3:55pm 603 Schermerhorn Hall</td>
<td>Steven Goldstein, Sidney Hemming</td>
<td>4.50</td>
<td>59/55</td>
</tr>
<tr>
<td>EESC 2200</td>
<td>001/12441</td>
<td>T 4:10pm - 7:00pm 603 Schermerhorn Hall</td>
<td>Steven Goldstein, Sidney Hemming</td>
<td>4.50</td>
<td>59/55</td>
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</table>

EESC UN2330 Science for Sustainable Devpt. 3 points.
CC/GS: Partial Fulfillment of Science Requirement

The course provides students with the natural science basis to appreciate co-dependencies of natural and human systems, which are central to understanding sustainable development. After completing the course, students should be able to incorporate scientific approaches into their research or policy decisions and be able to use scientific methods of data analysis. The semester will highlight the climate system and solutions from both physical and ecological perspectives; water resources; food production and the cycling of nutrients; and the role of biodiversity in sustainable development. The course emphasizes key scientific concepts such as uncertainty, experimental versus observational approaches, prediction and predictability, the use of models and other essential methodological aspects.

Fall 2023: EESC UN2330

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<th>Course Number</th>
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<th>Times/Location</th>
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<tr>
<td>EESC 2330</td>
<td>001/13131</td>
<td>T Th 2:40pm - 3:55pm 501 Northwest Corner</td>
<td>John Mutter, Jenna Lawrence</td>
<td>3</td>
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</table>

EESC UN3101 Geoclimatology for a Habitable Planet. 3 points.
Prerequisites: Any 1000-level or 2000-level EESC course; MATH UN1101 Calculus I and CHEM UN1043 General Chemistry I or their equivalents. The origin, evolution, and future of our planet, based on the book How to Build a Habitable Planet by Wallace S. Broecker. This course will focus on the geochemical processes that built Earth from solar material, led to its differentiation into continents and ocean, and have maintained its surface at a comfortable temperature. Students will participate in a hands-on geochemistry project at Lamont-Doherty Earth Observatory.

Fall 2023: EESC UN3101

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<tr>
<td>EESC 3101</td>
<td>001/13133</td>
<td>T Th 11:40am - 12:55pm 603 Schermerhorn Hall</td>
<td>Terry Plank</td>
<td>3</td>
<td>40/45</td>
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</table>

EESC UN3901 Senior Seminar. 3.00 points.
Prerequisites: EESC BC3800 or EESC BC3801 and a good grounding in basic sciences.
Guided, independent, in-depth research culminating in the senior thesis in the spring. Includes discussion about scientific presentations and posters, data analysis, library research methods and scientific writing. Students review work in progress and share results through oral reports. Weekly seminar to review work in progress and share results through oral and written reports.

Fall 2023: EESC UN3901

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<th>Times/Location</th>
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<tr>
<td>EESC 3901</td>
<td>011/14060</td>
<td>Th 4:10pm - 6:00pm 530 Altschul Hall</td>
<td>Jerry McManus, Sidney Hemming</td>
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Spring 2024: EESC UN3901

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<tr>
<td>EESC 3901</td>
<td>001/12520</td>
<td>Th 4:10pm - 6:00pm 202 Altschul Hall</td>
<td>Sidney Hemming, Jacqueline Austermann, Elizabeth Cook</td>
<td>3.00</td>
<td>20/50</td>
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</tbody>
</table>

EESC GU4008 Introduction to Atmospheric Science. 3 points.
CC/GS: Partial Fulfillment of Science Requirement

Prerequisites: advanced calculus and general physics, or the instructor’s permission.
Basic physical processes controlling atmospheric structure: thermodynamics; radiation physics and radiative transfer; principles of atmospheric dynamics; cloud processes; applications to Earth’s atmospheric general circulation, climatic variations, and the atmospheres of the other planets.

Fall 2023: EESC GU4008

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<th>Course Number</th>
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<th>Instructor</th>
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<tr>
<td>EESC 4008</td>
<td>001/13134</td>
<td>T 4:10pm - 6:40pm 417 Schermerhorn Hall</td>
<td>Lorenzo Polvani</td>
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<td>43/47</td>
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</table>
EESC GU4050 GLOBAL ASSMT-REMOTE SENSING. 3.00 points.
CC/GS: Partial Fulfillment of Science Requirement
Enrollment limited to 24. Priority given to graduate students in the natural sciences and engineering.

Prerequisites: Course Cap 20 students. Priority given to graduate students in the natural sciences and engineering. Advanced level undergraduates may be admitted with the instructor's permission. Calculus I and Physics I & II are required for undergraduates who wish to take this course.

Prerequisites: Course Cap 20 students. Priority given to graduate students in the natural sciences and engineering. Advanced level undergraduates may be admitted with the instructors permission. Calculus I and Physics I II are required for undergraduates who wish to take this course. General introduction to fundamentals of remote sensing; electromagnetic radiation, sensors, interpretation, quantitative image analysis and modeling. Example applications in the Earth and environmental sciences are explored through the analysis of remote sensing imagery in a state-of-the-art visualization laboratory.

Fall 2023: EESC GU4050

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<th>Course Number</th>
<th>Section/Call Number</th>
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<th>Instructor</th>
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<tr>
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<td>Th 5:40pm - 6:55pm</td>
<td>Christopher Small</td>
<td>3.00</td>
<td>12/20</td>
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<tr>
<td>EESC 4050</td>
<td>001/13135</td>
<td>F 9:00am - 10:45am</td>
<td>Christopher Small</td>
<td>3.00</td>
<td>12/20</td>
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</table>

EESC GU4085 GEODYNAMICS. 3.00 points.
CC/GS: Partial Fulfillment of Science Requirement
Given in alternate years.

Prerequisites: calculus, differential equations, introductory physics. An introduction to how the Earth and planets work. The focus is on physical processes that control plate tectonics and the evolution of planetary interiors and surfaces; analytical descriptions of these processes; weekly physical model demonstrations.

EESC GU4113 INTRODUCTION TO MINERALOGY I. 4.00 points.
Prerequisites: introductory geology or the equivalent, elementary college physics and chemistry, or the instructor's permission.
Prerequisites: introductory geology or the equivalent, elementary college physics and chemistry, or the instructors permission. Minerals come in dazzling colors, amazing shapes and with interesting optical effects. But mineralogy is also an essential tool for the understanding of Earth evolution. Minerals represent fundamental building blocks of the Earth system and planetary bodies. Minerals form through geological and biological processes such as igneous, metamorphic and sedimentary from high to low temperatures, from the deep interior to the Earth's surface and related to volcanism, tectonics, weathering, climate and life. Minerals are one of our most important sources of information on such processes through Earth's history. Minerals also represent important natural resources and are fundamental to the global economy and modern technology as we know it. The goal of this class is to (1) understand the physical and chemical properties of minerals, (2) learn techniques of mineral identification with an emphasis on optical mineralogy, (3) understand the relationship between minerals and the broader geological context.

Fall 2023: EESC GU4113

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<tr>
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<tr>
<td>EESC 4113</td>
<td>001/13065</td>
<td>T 6:30pm - 8:30pm</td>
<td>Yves Moussallam</td>
<td>4.00</td>
<td>6/15</td>
</tr>
<tr>
<td>EESC 4113</td>
<td>001/13065</td>
<td>T Th 8:40am - 9:55am</td>
<td>Yves Moussallam</td>
<td>4.00</td>
<td>6/15</td>
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</table>

EESC GU4330 Introduction to Terrestrial Paleoclimate. 3 points.
CC/GS: Partial Fulfillment of Science Requirement
Given in alternate years.

An overview of the archives in which evidence of terrestrial paleoclimate is preserved, the approaches to developing and applying proxies of climate from these archives, approaches for constraining the time represented by the information, and interpretations that have been developed from such archives. Important archives to be included are ice cores, caves, wetlands, lakes, trees, and moraines. The time interval covered will be mostly the last few tens of thousand years, and chronometers based on radiocarbon, U-series and surface exposure dating will be presented. The course will consist of a formal lecture on one day and a recitation on the second day which will emphasize examples and problem solving.
EESC GU4600 EARTH RESOURCES # SUSTAIN DEV. 3.00 points.
CC/GS: Partial Fulfillment of Science Requirement

Prerequisites: none; high school chemistry recommended.
Prerequisites: none; high school chemistry recommended. This course is open to graduate students, and juniors and seniors within DEES, Sus Dev, Engineering, Chemistry, Physics, and APAM - or with the instructors permission. Survey of the origin and extent of mineral resources, fossil fuels, and industrial materials, that are non renewable, finite resources, and the environmental consequences of their extraction and use, using the textbook Earth Resources and the Environment, by James Craig, David Vaughan and Brian Skinner. This course will provide an overview, but will include focus on topics of current societal relevance, including estimated reserves and extraction costs for fossil fuels, geological storage of CO2, sources and disposal methods for nuclear energy fuels, sources and future for luxury goods such as gold and diamonds, and special, rare materials used in consumer electronics (e.g. ,Coltan; mostly from Congo) and in newly emerging technologies such as superconducting magnets and rechargeable batteries (e.g. heavy rare earth elements, mostly from China). Guest lectures from economists, commodity traders and resource geologists will provide ;real world; input.

Spring 2024
EESC UN1009 GLOBAL WARMING FOR GLOBAL LEADERS. 3.00 points.
Global Warming will dominate civic discourse and inform economic, social, and governmental policies throughout the 21st century, in all walks of life. This course will cover the basics of climate science, anthropogenic global warming, proposed solutions and policy challenges facing society in response to our changing planet. This course will increase your confidence and ability to engage in public discourse on the subject of climate change, climate change solutions, and public policy concerning our collective future.

EESC UN1010 GEOLO EXCUR TO DEATH VALLEY,CA. 2.00 points.
Enrollment limited to 20.

The trip is restricted to first-years and sophomores from Columbia College/General Studies, Barnard College, and the School of Engineering and Applied Science. Early application is advised, and no later than November 12. A spring-break excursion focused on the geology of Death Valley and adjacent areas of the eastern California desert. Discussion and Applied Science. Early application is advised, and no later than November 12. A spring-break excursion focused on the geology of Death Valley and adjacent areas of the eastern California desert. Discussion sessions ahead of the trip provide necessary background. Details at: https://eesc.columbia.edu/content/eesc-un1010

Fall 2023: EESC GU4600
Course Number Section/Call Number Times/Location Instructor Points Enrollment
EESC 4600 001/13232 T Th 1:10pm - 2:25pm 301 Uris Hall Peter Kelemen 3.00 20/30

EESC GU4925 Biological Oceanography. 3 points.
CC/GS: Partial Fulfillment of Science Requirement
Given in alternate years. Enrollment limited to 24. Priority given to graduate students and then graduating seniors.

Prerequisites: introductory college-level biology and chemistry.
An overview of the biology and ecology of the oceans with a focus on the interaction between marine organisms and the physics and chemistry of the oceans.

EESC GU4925 Principles of Physical Oceanography. 3 points.
CC/GS: Partial Fulfillment of Science Requirement
Prerequisites: Recommended preparation: a solid background in mathematics, physics, and chemistry.
Physical properties of seawater, water masses and their distribution, sea-air interaction influence on the ocean structure, basic ocean circulation pattern, relation of diffusion and advection with respect to distribution of ocean properties, ocean tides and waves, turbulence, and introduction to ocean dynamics.

Fall 2023: EESC GU4925
Course Number Section/Call Number Times/Location Instructor Points Enrollment
EESC 4925 001/13138 T Th 8:40am - 9:55am 417 Schermerhorn Hall Andreas Thurnherr 3 18/25

EESC GU4949 Introduction to Seismology. 3 points.
CC/GS: Partial Fulfillment of Science Requirement
Prerequisites: advanced calculus and general physics, or the instructor's permission.
Methods and underpinnings of seismology including seismogram analysis, elastic wave propagation theory, earthquake source characterization, instrumentation, inversion of seismic data to infer Earth structure.
### EESC UN2100 Earth’s Environment System: The Solid Earth. 4.50 points.

**Prerequisites:** high school algebra. Recommended preparation: high school chemistry and physics; and one semester of college science.

Origin and development of the atmosphere and oceans, formation of storms, winds and ocean currents, reasons for changes through geologic time. Recent influence of human activity: the ozone hole, global warming, water pollution. Laboratory exploration of topics through demonstrations, experimentation, computer data analysis, and modeling. Students majoring in Earth and Environmental Sciences should plan to take EESC W2100 before their senior year to avoid conflicts with Senior Seminar.

**Fall 2023: EESC UN2100**

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<tr>
<td>EESC 2100</td>
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<td>T Th 10:10am - 11:25am 603 Schermerhorn Hall</td>
<td>Jerry McManus, Suzana De Camargo</td>
<td>4.50</td>
<td>48/50</td>
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<tr>
<td>EESC 2100</td>
<td>001/13062</td>
<td>T 4:10pm - 7:00pm 603 Schermerhorn Hall</td>
<td>Jerry McManus, Suzana De Camargo</td>
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**Spring 2024: EESC UN2100**

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<tr>
<td>EESC 2100</td>
<td>001/12424</td>
<td>T Th 10:10am - 11:25am 603 Schermerhorn Hall</td>
<td>Mingfang Ting, Gisela Winckler</td>
<td>4.50</td>
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<tr>
<td>EESC 2100</td>
<td>001/12424</td>
<td>T 4:10pm - 7:00pm 555 Ext Schermerhorn Hall</td>
<td>Mingfang Ting, Gisela Winckler</td>
<td>4.50</td>
<td>44/50</td>
</tr>
<tr>
<td>EESC 2100</td>
<td>002/16962</td>
<td>T Th 1:10pm - 2:25pm 603 Schermerhorn Hall</td>
<td>Michela Biasutti, Jennifer Middleton</td>
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<tr>
<td>EESC 2100</td>
<td>002/16962</td>
<td>W 4:10pm - 7:00pm 555 Ext Schermerhorn Hall</td>
<td>Michela Biasutti, Jennifer Middleton</td>
<td>4.50</td>
<td>14/25</td>
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### EESC UN2200 Earth’s Environment System: Life System. 4.50 points.

**Prerequisites:** high school algebra and chemistry. Recommended preparation: high school physics. Recommended preparation: high school chemistry and physics; and one semester of college science. Exploration of how the solid Earth works, today and in the past, focusing on Earth in the Solar system, continents and oceans, the Earth's history, mountain systems on land and sea, minerals and rocks, weathering and erosion, glaciers and ice sheets, the hydrological cycle and rivers, geochronology, plate tectonics, earthquakes, volcanoes, energy resources. Laboratory exploration of topics through examination of rock samples, experimentation, computer data analysis, field exercises, and modeling. Columbia and Barnard majors should plan to take W2200 before their senior year to avoid conflicts with the Senior Seminar.

**Fall 2023: EESC UN2200**

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<tr>
<td>EESC 2200</td>
<td>001/13130</td>
<td>T Th 1:10pm - 2:25pm 313 Fayerweather</td>
<td>John Mutter, Jonathan Kingslake</td>
<td>4.50</td>
<td>70/80</td>
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<tr>
<td>EESC 2200</td>
<td>001/13130</td>
<td>Th 4:10pm - 7:00pm 603 Schermerhorn Hall</td>
<td>John Mutter, Jonathan Kingslake</td>
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**Spring 2024: EESC UN2200**

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<th>Course Number</th>
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<tr>
<td>EESC 2200</td>
<td>001/12441</td>
<td>T Th 2:40pm - 3:55pm 603 Schermerhorn Hall</td>
<td>Steven Goldstein, Sidney Hemming</td>
<td>4.50</td>
<td>59/55</td>
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<tr>
<td>EESC 2200</td>
<td>001/12441</td>
<td>T 4:10pm - 7:00pm 603 Schermerhorn Hall</td>
<td>Steven Goldstein, Sidney Hemming</td>
<td>4.50</td>
<td>59/55</td>
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### EESC UN2300 Earth’s Environment System: Climate System Science. 4.50 points.

**Prerequisites:** high school algebra. Recommended preparation: high school chemistry and physics. Role of life in biogeochemical cycles, relationship of biodiversity and evolution to the physical Earth, vulnerability of ecosystems to environmental change; causes and effects of extinctions through geologic time (dinosaurs and mammoths) and today. Exploration of topics through laboratories, data analysis, and modeling. REQUIRED LAB: EESC UN2310. Students will be expected to choose a lab section during the first week of class from the options listed in the Directory of Classes. Co-meets with EEEB 2002.

**Fall 2023: EESC UN2300**

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<th>Course Number</th>
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<tr>
<td>EESC 2300</td>
<td>001/12449</td>
<td>M W 11:40am - 12:55pm 313 Fayerweather</td>
<td>Paul Olsen, Matthew Palmer, Sonya Dyhrman</td>
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**Spring 2024: EESC UN2300**
EESC UN3010 FIELD GEOLOGY. 3.00 points.
Fee: to be determined.

The centerpiece of this course is a geological field trip during Spring Break in Barbados. The class will meet weekly before the trip to prepare for it and after the trip to synthesize what was learned and to create a field guide. Subjects to be covered: plate tectonics, convergent plate margins and accretionary prisms, local Barbados geology; ice ages, Milankovitch cycles, sea level; introduction to coral reefs and fossil coral reef geology; Barbados terrestrial ecology; limestone caves, hydrology; dating methods; overview of Barbados history, economy, culture. In order to observe the modern-day coral reef (the modern day live analog to the fossil coral reefs we will see) the class will go snorkeling. In order to observe the effects of cave formation and water flow in limestone terrains the class will participate in an extensive visit to a cave. The class will also participate in an exercise in geological mapping of a series of coral reef terraces. Priority: Priority is given to junior and senior majors and concentrators in Earth Science or Environmental Science at Columbia College and the School of General Studies, and Barnard College Environmental Science majors and minors. Others (non-DEES majors and non-Barnard Environmental Science students) may also be allowed to enroll if space permits. All students need permission of the instructor. Students who sign up will be put on a waitlist and will be considered after contacting the instructor

Spring 2024: EESC UN3010

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<th>Course Number</th>
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<th>Instructor</th>
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</table>
| EESC 3010     | 001/12475           | T 7:30pm - 9:20pm
603 Schermerhorn Hall | Steven Goldstein, Sidney Hemming | 3.00   | 19/20      |

EESC UN3109 CLIMATE PHYSICS. 3.00 points.
This is a calculus-based treatment of climate system physics and the mechanisms of anthropogenic climate change. By the end of this course, students will understand: how solar radiation and rotating fluid dynamics determine the basic climate state, mechanisms of natural variability and change in climate, why anthropogenic climate change is occurring, and which scientific uncertainties are most important to estimates of 21st century change. This course is designed for undergraduate students seeking a quantitative introduction to climate and climate change science. EESC V2100 (Climate Systems) is not a prerequisite, but can also be taken for credit if it is taken before this course

Spring 2024: EESC UN3109

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<th>Enrollment</th>
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</thead>
</table>
| EESC 3109     | 001/12499           | T 10:10am - 11:25am
555 Ext Schermerhorn Hall | Adam Sobel     | 3.00   | 15/25     |

EESC UN3201 SOLID EARTH DYNAMICS. 3.00 points.
Prerequisites: any 1000-level or 2000-level EESC course; MATH UN1101 Calculus I and PHYS UN1201 General Physics I or their equivalents. Concurrent enrollment in PHYS UN1201 is acceptable with the instructor's permission.
Prerequisites: any 1000-level or 2000-level EESC course; MATH UN1101 Calculus I and PHYS UN1201 General Physics I or their equivalents. Concurrent enrollment in PHYS UN1201 is acceptable with the instructors permission. Properties and processes affecting the evolution and behavior of the solid Earth. This course will focus on the geophysical processes that build mountains and ocean basins, drive plate tectonics, and otherwise lead to a dynamic planet. Topics include heat flow and mantle circulation, earthquakes and seismic waves, gravity, Earth's magnetic field, and flow of glaciers and ice sheets

Spring 2024: EESC UN3201

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</table>
| EESC 3201     | 001/12507           | T 11:45am - 12:55pm
417 Schermerhorn Hall | Meredith Nettes         | 3.00   | 19/30     |

EESC UN3901 SENIOR SEMINAR. 3.00 points.
Prerequisites: EESC BC3800 or EESC BC3801 and a good grounding in basic sciences.

Guided, independent, in-depth research culminating in the senior thesis in the spring. Includes discussion about scientific presentations and posters, data analysis, library research methods and scientific writing. Students review work in progress and share results through oral reports. Weekly seminar to review work in progress and share results through oral and written reports

Fall 2023: EESC UN3901

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</table>
| EESC 3901     | 011/14060           | Th 4:10pm - 6:00pm
530 Altshul Hall | Jerry McManus, Sidney Hemming | 3.00   | 9/50       |

Spring 2024: EESC UN3901

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<th>Enrollment</th>
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</table>
| EESC 3901     | 001/12520           | Th 4:10pm - 6:00pm
202 Altshul Hall | Sidney Hemming, Jacqueline Austermann, Elizabeth Cook | 3.00   | 20/50      |

EESC GU4090 INTRO TO GECHRONOLOGY. 3.00 points.
CC/GS: Partial Fulfillment of Science Requirement Given in alternate years.

Prerequisites: one term of college-level calculus, and solid Earth system science or its equivalent.

An overview of approaches to estimating ages of sedimentary sequences and events in Earth history to be co-listed at Stony Brook and Rutgers. Intended for students with good backgrounds in the physical sciences, who want to use geochronological techniques in their studies. Because of the hands-on nature of geochronology and thermochronology, we are going to run the course as a series of 5 workshops held on Saturdays (possibly a Sunday depending on scheduling)

Spring 2024: EESC GU4090

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</table>
| EESC 4090     | 001/12529           | Sa 10:00am - 4:00pm
603 Schermerhorn Hall | Sidney Hemming  | 3.00   | 18/20     |
EESC GU4210 GEOPHYSICAL FLUID DYNAMICS. 3.00 points.
Required course for M.A./Ph.D. candidates focusing in physical oceanography and atmospheric sciences. Elective for undergraduate majors in the Department of Earth and Environmental Sciences.
Prerequisites: APMA E3101, APMA E3201 or equivalents and APPH E4200 or equivalent or the instructor’s permission.
Prerequisites: APMA E3101, APMA E3201 or equivalents and APPH E4200 or equivalent or the instructors permission. Fundamental concepts in the dynamics of rotating stratified flows. Geostrophic and hydrostatic balances, potential vorticity, f and beta plane approximations, gravity and Rossby waves, geostrophic adjustment and quasigeostrophy, baroclinic and barotropic instabilities

Spring 2024: EESC GU4210

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<tr>
<td>EESC 4210</td>
<td>001/12539</td>
<td>T Th 8:40am - 9:55am</td>
<td>Dhruv Balwada</td>
<td>3.00</td>
<td>17/35</td>
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EESC GU4300 THE EARTH’S DEEP INTERIOR. 3.00 points.
Prerequisites: Vector calculus, differential equations, one year of college physics (mechanics, electromagnetism, waves)
An overview of the geophysical study of the Earth, drawing upon geodesy, gravity, seismology, thermal studies, geomagnetism, materials science, and some geochemistry. Covers the principal techniques by which discoveries have been made, and are made, in deep Earth structure. Describes fundamental properties and features of the crust, mantle, and core

Spring 2024: EESC GU4300

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<tr>
<td>EESC 4300</td>
<td>001/12544</td>
<td>T Th 10:10am - 11:25am</td>
<td>Goran Ekstrom</td>
<td>3.00</td>
<td>9/30</td>
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EESC GU4560 THE ECOLOGY OF TREELINE IN A CHANGING CLIMATE. 3.00 points.
Prerequisites: Introductory Biology. Earth Science and one course in ecology recommended. Treelines are the boundaries between forests and low stature alpine and tundra vegetation, thought to be controlled by climate and therefore likely to respond to climate change. In 1807 Alexander von Humboldt and Aimé Bonpland described treeline as a global phenomenon and a bioclimatological reference that all other vegetation could be referenced against. Despite being clearly linked to climate, the mechanisms that control treeline formation and persistence remain an active area of scientific research and debate. The lack of a complete mechanistic understanding of how climate controls the location of treeline opens the important question of how treeline will respond to climate change. Furthermore, while physical site characteristics determine the potential location of treeline, trees may be absent for a variety of factors, complicating the predicted ecosystem response to a changing climate. These factors include local peculiarities of the environment, a regional lack of capable species, or a multitude of disturbances, including those caused by humans. This course is focused on the ecology treeline in light of global climate change and will provide students with a foundational understanding of fundamental ecological concepts as they pertain to this important ecological boundary between ecosystems and biomes. In addition, students will learn to (1) find, read, and discuss the primary scientific literature, and (2) communicate their findings via written, oral, and audio-visual formats. Topics include ecophysiology, population ecology, community ecology, biogeochemistry and ecosystem ecology

Spring 2024: EESC GU4560

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<tr>
<td>EESC 4560</td>
<td>001/12547</td>
<td>T Th 11:40am - 12:55pm</td>
<td>Kevin Griffin</td>
<td>3.00</td>
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EESC GU4885 CHEMISTRY OF CONTINENTAL WATERS. 3.00 points.
Given in alternate years.

Prerequisites: Recommended preparation: a solid background in basic chemistry.
Prerequisites: Recommended preparation: a solid background in basic chemistry. Introduction to geochemical cycles involving the atmosphere, land, and biosphere; chemistry of precipitation, weathering reactions, rivers, lakes, estuaries, and groundwaters; students are introduced to the use of major and minor ions as tracers of chemical reactions and biological processes that regulate the chemical composition of continental waters

Spring 2024: EESC GU4885

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<tr>
<td>EESC 4885</td>
<td>001/12552</td>
<td>T Th 11:40am - 12:55pm</td>
<td>Robert Anderson</td>
<td>3.00</td>
<td>26/30</td>
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</table>
EESC GU4924 PALEOCEANOGRAPHY. 3.00 points.
CC/GS: Partial Fulfillment of Science Requirement
Given in alternate years.

Prerequisites: Complements GU4937 Cenozoic Paleoceanography, intended as part of a sequence with GU4330 Terrestrial Paleoclimate. For undergrads, UN2100 Earth System: Climate or equivalent, or permission of instructor

Prerequisites: Complements GU4937 Cenozoic Paleoceanography, intended as part of a sequence with GU4330 Terrestrial Paleoclimate. For undergrads, UN2100 Earth System: Climate or equivalent, or permission of instructor. The course examines the ocean's response to external climatic forcing such as solar luminosity and changes in the Earth's orbit, and to internal influences such as atmospheric composition, using deep-sea sediments, corals, ice cores and other paleoceanographic archives. A rigorous analysis of the assumptions underlying the use of climate proxies and their interpretations will be presented. Particular emphasis will be placed on amplifiers of climate change during the alternating ice ages and interglacial intervals of the last few million years, such as natural variations in atmospheric greenhouse gases and changes in deep water formation rates, as well as mechanisms of rapid climate change during the late Pleistocene. The influence of changes in the Earth's radiation distribution and boundary conditions on the global ocean circulation, Asian monsoon system and El Nino/Southern Oscillation frequency and intensity, as well as interactions among these systems will be examined using proxy data and models. This course complements W4937 Cenozoic Paleoceanography and is intended as part of a sequence with GU4330 Terrestrial Paleoclimate for students with interests in Paleoclimate.

Spring 2024: EESC GU4924
Course Number  Section/Call Number  Times/Location  Instructor  Points  Enrollment
EESC 4924  001/12556  T Th 11:40am - 12:55pm  Roisin Commane  3.00  13/30

EESC GU4924 INTRO TO ATMOSPHERIC CHEMISTRY. 3.00 points.
CC/GS: Partial Fulfillment of Science Requirement

Prerequisites: Physics UN1201, Chem UN1403, & Math UN1201 (Calc III), or their equivalents. Recommended: EESC UN2100 or EESC GU4008. Prerequisites: Physics W1201, Chemistry W1403, Calculus III, or equivalent or the instructors permission. EESC W2100 preferred. Physical and chemical processes determining atmospheric composition and the implications for climate and regional air pollution. Atmospheric evolution and human influence; basics of greenhouse effect, photolysis, reaction kinetics; atmospheric transport of trace species; stratospheric ozone chemistry; tropospheric hydrocarbon chemistry; oxidizing power, nitrogen, oxygen, sulfur, carbon, mercury cycles; chemistry-climate-biosphere interactions; aerosols, smog, acid rain

Spring 2024: EESC GU4924
Course Number  Section/Call Number  Times/Location  Instructor  Points  Enrollment
EESC 4924  001/12560  T Th 11:40am - 12:55pm  Roisin Commane  3.00  13/30

EESC GU4947 PLATE TECTONICS AND CLIMATE. 3.00 points.
CC/GS: Partial Fulfillment of Science Requirement
Given in alternate years.

Prerequisites: course in solid earth geology or geophysics; solid background in math and physics

What produced the change from the hothouse to the ice house Earth in the last ~60 million years? What caused earlier ice ages and huge swings in sea level that covered so much of the continents with marine sediments? The possible answers, from weathering of rocks during periods of enhanced mountain building to changes in the rate of CO2 release at mid-ocean ridges, all involve plate tectonics. We review the development of the plate tectonic theory, including role Columbia researchers played in making the break-throughs that first confirmed the theory. We will discuss ideas about what might control plate motions on Earth as well as what we know about different kinds of tectonics on other planets. Researchers working on cutting-edge observations and models relating tectonics and climate will be invited to air their views to the class.

Spring 2024: EESC GU4947
Course Number  Section/Call Number  Times/Location  Instructor  Points  Enrollment
EESC 4947  001/12564  T Th 2:40pm - 3:55pm  W Buck  3.00  15/40

EESC GR9910 SEM IN ATMOSPHERIC SCIENCE. 1.00-3.00 points.
May be repeated for up to 10 points of credit.

Prerequisites: the instructor’s permission. Prerequisites: the instructors permission. Current research developments in atmospheric sciences including tropical climate variability, stratospheric dynamics, atmospheric chemistry, remote sensing of the Earth’s atmosphere, and global climate modeling.

Of Related Interest

Environmental Science (Barnard)

EESC BC1001  Environmental Science I
EESC BC1011  Environmental Science I Lab
EESC BC3014  Field Methods in Environmental Science
EESC BC3016  ENVIRONMENTAL MEASUREMENTS
EESC BC3017  ENVIRONMENTAL DATA ANALYSIS
EESC BC3025  HYDROLOGY
EESC BC3033  Waste Management
EESC BC3050  BIG DATA WITH PYTHON
EESC BC3200  Ecotoxicology
EESC BC3300  WORKSHOP SUSTAINABLE DEVELOPMENT

Physics

PHYS UN1018  WEAPONS OF MASS DESTRUCTION

Generally Alternate Year Courses

EESC UN1001  DINOSAURS AND HISTORY OF LIFE
EESC UN1201  Environmental Risks and Disasters
EESC UN1401  DINOSAURS # HISTORY OF LIFE-LEC
EESC UN3015  The Earth’s Carbon Cycle
EESC GU4009  CHEMICAL GEOLOGY
EESC GU4040  CLIM THERMODYN/ENERGY TRANSFER
EESC GU4085  GEODYNAMICS
EESC GU4113  INTRODUCTION TO MINERALOGY I
EESC GU4330  Introduction to Terrestrial Paleoclimate
EESC GU4223  SEDIMENTARY GEOLOGY
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<tr>
<td>EESC GU4300</td>
<td>THE EARTH'S DEEP INTERIOR</td>
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<tr>
<td>EESC GU4630</td>
<td>AIR-SEA INTERACTION</td>
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<tr>
<td>EESC GU4701</td>
<td>Introduction to Igneous Petrology</td>
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<tr>
<td>EESC GU4835</td>
<td>Wetlands and Climate Change</td>
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<tr>
<td>EESC GU4885</td>
<td>CHEMISTRY OF CONTINENTAL WATERS</td>
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<tr>
<td>EESC GU4887</td>
<td>ISOTOPE GEOLOGY I</td>
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<tr>
<td>EESC GU4888</td>
<td>Stable Isotope Geochemistry</td>
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<td>EESC GU4920</td>
<td>PALEOCEANOGRAPHY</td>
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<tr>
<td>EESC GU4926</td>
<td>INTRO TO CHEMICAL OCEANOGRAPHY</td>
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<tr>
<td>EESC GU4937</td>
<td>CENOZOCIC PALEOCEANOGRAPHY</td>
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<tr>
<td>EESC GU4929</td>
<td>Mixing and Dispersion in the Ocean</td>
</tr>
<tr>
<td>EESC GU4949</td>
<td>Introduction to Seismology</td>
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<tr>
<td>EESC GR6111</td>
<td>Modern analytical methods in geochemistry</td>
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<tr>
<td>EESC GR6701</td>
<td>Igneous and metamorphic processes during the creation and evolution of the tectonic plates</td>
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<tr>
<td>EESC GR6810</td>
<td>The Carbon Cycle</td>
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<tr>
<td>EESC GR6901</td>
<td>Research Computing for the Earth Sciences</td>
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<tr>
<td>EESC GR6909</td>
<td>Advanced Time Series Analysis</td>
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<tr>
<td>EESC GR6920</td>
<td>DYNAMICS OF CLIMATE</td>
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<td>EESC GR6921</td>
<td>ATMOSPHERIC DYNAMICS</td>
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<td>EESC GR6922</td>
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<td>EESC GR6928</td>
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<td>EESC GR6930</td>
<td>Ocean Dynamics</td>
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<tr>
<td>EESC GR9500</td>
<td>SEM-PLANT PHYSIOLOGY &amp; EC</td>
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