

Using Real-World Data to Increase Students' Scientific Literacy

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Abstract - The future state of the world's oceans greatly depends on the leaders of tomorrow. That's why increasing today's students' ocean literacy is so important and that's why raising students' overall earth science literacy is a primary goal of the American Meteorological Society (AMS).

Through the creation of high-caliber, scientifically-authentic educational materials, the AMS offers a suite of introductory, undergraduate-level courses that engage students by investigating current topics in Earth science through the use of real-world environmental data.

AMS Ocean Studies, *AMS Weather Studies*, and *AMS Climate Studies* have been developed by the AMS with support from NSF, NOAA, and NASA. Designed to be adaptable to traditional, hybrid, or online instructional settings, these courses have already been adopted by 770 institutions across the United States.

The recently revised 3rd edition *Ocean Studies* textbook features updated topics such as the 2011 Japan earthquake/tsunami event, the 2010 Gulf oil spill, ocean acidification, harmful algal blooms, along with a detailed look at the essential role the ocean plays in Earth's climate system. The textbook also reviews the latest technology for monitoring ocean properties including floats and gliders and cabled ocean observatories.

Updated yearly, the investigations manual contains 30 laboratory activities, two per textbook chapter, and innovatively connects with a third online component, *Current Ocean/Weather/Climate Studies*, via the course website. These online investigations use real-world data from NOAA's National Ocean Service (NOS) and Satellite and Information Service (NESDIS), reports from the IPCC, and from other lead scientific organizations. The course website is an all-inclusive webpage that provides links to numerous external sources that further engage students.

Instructor support materials are available with each course and include a Faculty CD that contains a faculty manual with learning objectives and suggestions for course implementation, as well as investigations manual answer forms compatible with any course management system, test bank questions and answers, textbook images, and PowerPoint® presentations for each chapter. The investigations manual answer forms are files compatible with Respondus®, test-generating software for which many institutions are licensed (answer forms are also provided in Respondus® format). The faculty member has the option of delivering questions through their course management system to allow for automatic scoring and immediate feedback for their students. This feature allows for full integration to a college's e-learning environment.

AMS Ocean Studies, *AMS Weather Studies*, and *AMS Climate Studies* can be taught by experienced science faculty or those new

to teaching the subject matter. Mentoring by AMS-trained course instructors is available to all new instructors.

Keywords – ocean, climate, water, course, online, diversity

I. INTRODUCTION

Developed by the American Meteorological Society (AMS) with support from NSF, NOAA, and NASA, *AMS Ocean Studies*, *AMS Weather Studies*, and *AMS Climate Studies*, are introductory college-level courses available for implementation at undergraduate institutions nationwide. These high-caliber, scientifically-authentic courses place students in a dynamic learning environment where they investigate current topics in Earth science through the use of real-world environmental data. Almost 800 colleges and universities throughout the United States have already offered these unique courses.

Since 2005, *AMS Ocean Studies* has been helping to improve marine science education at approximately 180 colleges and universities. Additionally, the *AMS Ocean Studies* Diversity Project, in cooperation with NOAA and the University of Washington's School of Oceanography, has helped increase access to studies in the marine sciences through implementation at minority-serving institutions (MSIs) and training workshops for MSI course instructors.

II. COURSE BACKGROUND

Development of *AMS Weather Studies* was the first of the three AMS courses and was spurred by recommendations from college faculty attending NSF-funded undergraduate faculty enhancement workshops conducted by the AMS at the NOAA/National Weather Service Training Center in the mid-1990s and the success of *DataStreme Atmosphere*. *AMS Weather Studies* was pilot-tested in the spring semester of 1999 by 14 meteorology workshop participants and *DataStreme* leaders at their colleges, and made available to all institutions the following fall [1]. The course has now been implemented at more than 480 institutions in the U.S.

AMS *DataStreme* course offerings to K-12 in-service teachers for graduate credit began with the national dissemination of *DataStreme Atmosphere* in fall 1996, and was followed by *DataStreme Water in the Earth System* in fall 2001 and *DataStreme Ocean* in fall 2003 [2]. Under the *DataStreme* model, AMS disseminates course materials through Local

Implementation Teams (LITs) across the U.S. during the fall and spring semesters. A LIT typically is led by an experienced precollege teacher, and includes a university faculty member and an Earth scientist employed by NOAA or another agency. LITs recruit up to eight teachers and occasionally an emergency manager, per semester and serve as instructors and mentors to those taking the particular AMS *DataStreme* course. LITs focus on recruiting K-12 teachers who are members of minority groups and/or teach at schools with a 25% or greater minority student population.

AMS Ocean Studies was the second course to be developed and was based on the development of *DataStreme Ocean* and the course design of *AMS Weather Studies*. *AMS Ocean Studies* was pilot-tested in spring 2005, mostly by faculty already offering the weather course, and was made available for public offering in fall 2005.

AMS Ocean Studies examines the world ocean from an Earth system perspective, emphasizing the flow and transformations of water and energy into and out of the ocean, the physical and chemical properties of seawater, ocean circulation, marine life and its adaptations, interactions between the ocean and the other components of the Earth system, and the human/societal impacts on and response to those Earth system interactions.

AMS Climate Studies evolved similarly to the other courses in that it was developed from the K-12 teacher professional development climate science course, *DataStreme Earth's Climate System (ECS)*. *DataStreme ECS* began in the fall semester of 2010.

AMS Climate Studies focuses on the foundations of Earth's climate system, the basic understandings of climate behavior, contributions of human activities to climate change, societal and ecosystem vulnerability and response to climate variability and change, and the challenge of achieving sustainable development. The course structure is the same as the *AMS Weather Studies* and *AMS Ocean Studies* courses. Since being pilot-tested in spring 2010, *AMS Climate Studies* has been offered by more than 80 institutions across the U.S.

III. COURSE STRUCTURE

A. Introduction

AMS Ocean, *Weather*, and *Climate Studies* are fully-integrated course packages containing both printed and online learning materials. The courses include a comprehensive 15-chapter textbook, Investigations Manual with 30 laboratory-style activities (eInvestigations Manual for *AMS Climate Studies*), course website, faculty website, and a faculty resource CD. Instructors can use these materials in any combination that best suits their needs as a course instructor.

Exclusively for AMS Ocean Studies, is the use of an inflatable globe, which offers a unique way to study marine science. Oceanography comes alive in three-dimensions, helping students understand complex oceanographic principles such as the Coriolis force, plate tectonics, ocean circulation and tidal bulging.

Throughout the remainder of this paper, detailed descriptions of only *AMS Ocean Studies* course materials will be discussed.

B. Textbook

The recently revised *Ocean Studies: Introduction to Oceanography* 3rd edition is a full-color 15 chapter textbook that explores the world ocean from an Earth system perspective. The textbook features updated topics such as the 2011 Japan earthquake/tsunami event, the 2010 Gulf oil spill, ocean acidification, harmful algal blooms, along with a detailed look at the essential role the ocean plays in Earth's climate system. The latest technology for monitoring ocean properties, including floats and gliders, along with cabled ocean observatories are also discussed.

The first text chapter introduces the Earth system and examines the ocean's place in the Earth system. The second chapter focuses on the characteristics of the ocean basin that are largely the products of plate tectonics. Chapter 3 deals with the unique physical and chemical properties of seawater and Chapter 4 covers the origin and distribution of marine sediment. Chapter 5 investigates air-sea interactions and the flow of heat energy in the Earth-atmosphere-ocean system. The next three chapters cover the dynamic ocean: surface and deep-ocean currents (Chapter 6), waves and tides (Chapter 7), and shoreline processes (Chapter 8). Chapters 9 and 10 examine marine ecosystems and life in the ocean. The next two chapters explore the ocean's role in short-term climate variability (Chapter 11) and long-term climate change (Chapter 12). The three remaining chapters consider the future of ocean science (Chapter 13), ocean stewardship (Chapter 14), and public policy and the ocean (Chapter 15).

Each chapter opens with a Case-in-Point, an authentic, relevant, and real-life event or issue that highlights or applies one or more of the main concepts covered in the chapter. In essence, the Case-in-Point previews the chapter and is intended to engage reader interest early on. Rogue waves are discussed in the Case-in-Point of Chapter 7 (Ocean Waves and Tides) and Chapter 12 (The Ocean and Climate Change) opens with a discussion of the shrinking Arctic sea ice cover and its effect on the polar bear habitat. The Case-in-Point is followed by a sample Driving Question, a broad-based query that links chapter concepts and provides a central focus for that week's study. The driving question leads students into the chapter narrative, which is concluded with Basic Understandings along with Review and Critical Thinking Questions.

The textbook is typically used in conjunction with the rest of the course package materials, but can also be used alone in a traditional lecture-style course (Figure 1).

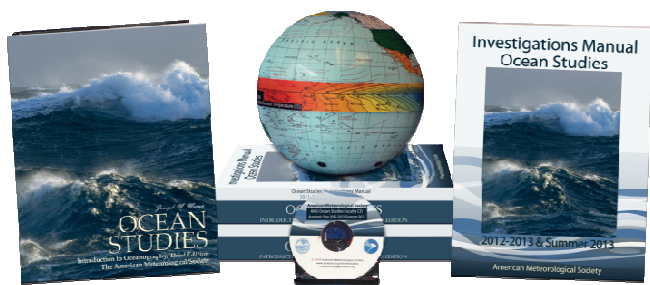


Figure 1. AMS Ocean Studies course package materials.

C. Investigations Manual

The *AMS Ocean Studies* Investigations Manual (IM) includes 30 lab-type investigations; two per textbook chapter (Table 1). Packaged with the manual is an inflatable globe (to represent the ocean in true three-dimensional spatial relationships), which guides visualization of ocean phenomena, including tides, El Niño/La Niña, ocean currents, and tsunami wave propagation. In the tides investigation, for example, students create model lunar-induced tidal bulges on the globe and deduce tides at equatorial and mid-latitude locations. In another investigation, students cut and tape scaled strips of recent Pacific Ocean SSTs and SST anomalies on the globe and compare this data to segments showing major past El Niño and La Niña events.

TABLE 1
AMS OCEAN STUDIES INVESTIGATIONS MANUAL ACTIVITIES

1A	Earth's Ocean
1B	Ocean in the Global Water Cycle
2A	"Seeing" the Bottom of the Ocean
2B	Ocean Bottom Bathymetry
3A	Seawater Temperature, Salinity and Density
3B	Fresh Water, Ocean Water and Sea Ice
4A	What Goes Down
4B	Sediment from Land to Sea
5A	Ocean-Atmosphere Connections
5B	Incoming Solar Radiation and Sea Surface Temperature
6A	Wind-driven Ocean Circulation and Ocean Gyres
6B	Density-driven Circulation and Water Masses
7A	Deep- and Shallow-Water Waves
7B	Tides
8A	Coastal Processes
8B	Open Ocean and Coastal Impacts of Tropical Cyclones
9A	Upwelling and Ocean Productivity
9B	Chesapeake Bay Estuary
10A	Marine Food Webs
10B	Ocean Life
11A	Seawater Temperature, Pressure and Surface Ocean Currents
11B	El Nino/La Nina: The Ocean-Atmosphere Connection
12A	Change in Earth's Climate System
12B	The Ocean and Climate Change
13A	The Sea and the Shore
13B	Sensing the Top 2km of the Ocean in Near Real-time
14A	Fisheries and Overfishing
14B	Fisheries and Bycatch
15A	Oil Spills and the Marine Environment
15B	Ocean Policy – Determining the Boundaries

D. Course Website

The secure course website includes *Current Ocean Studies* (COS) investigations, Weekly Ocean News, and supplemental information including links to real-time oceanographic data, informational websites, chapter self-test questions, and geoscience career information (Figure 2). The weekly *Current Ocean Studies*, posted on Mondays during the fall and spring semesters, enhances the Investigations Manual activities with an analysis of current ocean data. This provides the instructor the option of introducing students to the dynamic ocean in near real-time by assigning the COS activities, the real-world case studies in the IM, or both.

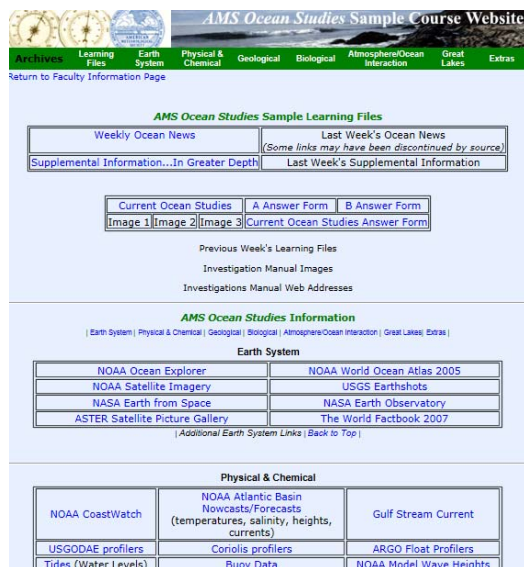
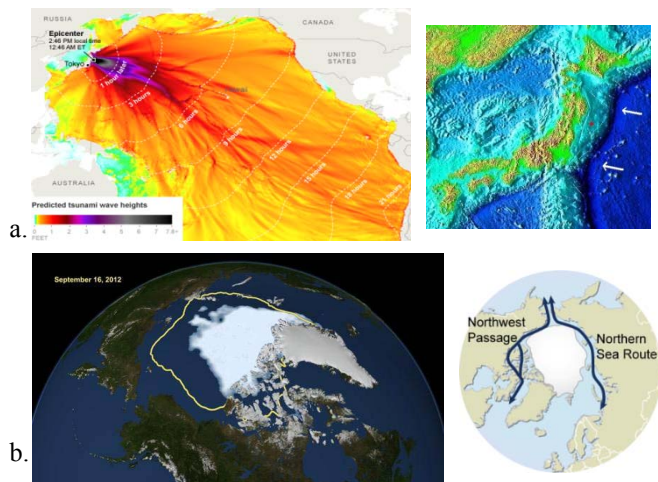


Figure 2. Screenshot of *AMS Ocean Studies* course website.

Emphasis is placed on using current, real-world data when possible because it allows students to learn about the fundamental science as notable events occur. A few examples include the 2011 Japan tsunami, the 2012 record-low Arctic sea ice, and Superstorm Sandy. In all of these instances, online activities were created as these events were occurring; students learned the science as it was happening (Figure 3).



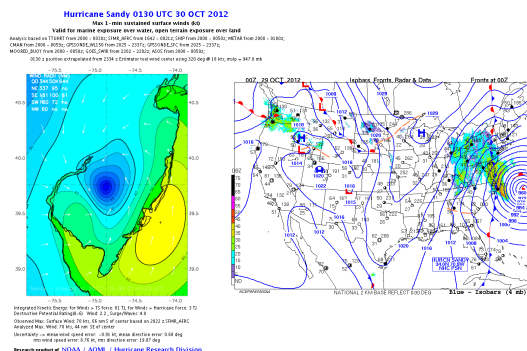


Figure 3. Excerpts from actual coursework associated with (a) Japan tsunami/earthquake (NOAA NGDC, PMEL), (b) record low Arctic sea ice in 2012 (NASA), and (c) Superstorm Sandy (NOAA).

The Weekly Ocean News, which consists of links to timely ocean news items and a chronology of ocean-related historical events, is freshly prepared on Monday and updated as the week progresses. Weekly “In Greater Depth ...” supplemental information files provide a detailed examination of various ocean topics.

E. Faculty Resource Materials

Course instructors receive a Faculty CD containing a faculty manual, Investigations Manual answer forms compatible with course management systems, test bank questions, textbook images, and PowerPoint® presentations for each chapter. The faculty manual describes the course and its components and contains suggestions for course implementation in a variety of classroom settings. Included for each text chapter is an outline, summary, and learning objectives. The CD Investigations Manual answer forms are files compatible with Respondus®, test-generating software for which many institutions are licensed. This program opens formatted files and converts them to various course management system files.

A secure faculty website delivers answers to chapter Review and Critical Thinking, Investigations Manual, and *Current Ocean Studies* questions. The website includes Respondus®-formatted answer forms for *Current Ocean Studies*.

F. Course Implementation

AMS Ocean, *Climate* and *Weather Studies* can be implemented as a new institutional course offering, a revision of an existing course, the expansion of an existing course to include a lab component, or may be used to create an online course, particularly as an online lab science course. The courses can be offered in instructional settings including online, blended/hybrid, face-to-face lecture or lecture/laboratory by experienced science faculty or those new to teaching the subject matter. Mentoring by course instructors already offering the course and AMS staff is available to all new instructors.

G. Course License Procedure

A license is required for institutions using the course package (Figure 1), which includes the textbook, Investigations Manual (eInvestigations Manual for *AMS Climate Studies*), and course (referred to as RealTime Climate Portal in *AMS Climate Studies*) and faculty websites. A license is not required for institutions that use only the textbook. Students enrolled in the course receive local institutional credit and purchase course materials through their college bookstore.

IV. NATIONAL DISSEMINATION/DIVERSITY PROJECT

A. Background

The U.S. faces a serious challenge in attracting members of racial and ethnic minority groups to scientific careers, especially those in the geosciences [1]. According to 2006 data, almost 12% of the overall U.S. science and engineering workforce is composed of minorities, including African Americans, Hispanic Americans, American Indians, Alaskan Natives, Native Hawaiians, and Pacific Islanders [3], even though these groups represent about 32% of the U.S. population [4]. Within the geosciences, minorities earn only 6.3% of all science and engineering bachelor's degrees, 4.4% of master's degrees, and 2.4% of Ph.D. degrees, according to 2007 data [5]. In order to maintain a robust and competitive scientific workforce, it is essential to increase minority participation in the sciences [2, 6].

A challenge in attracting minority students to the geosciences is that many colleges and universities with high minority enrollments focus on the traditional sciences and often do not offer an introductory course or degree program in the geosciences [6]. To help alleviate this problem, the AMS makes available *AMS Ocean Studies*, *AMS Climate Studies*, and *AMS Weather Studies*, which can be added to an institution's general education course offerings. Since 2002, AMS has initiated course implementation through NSF-supported Geoscience Diversity/National Dissemination Projects. Participating U.S. institutions include Historically Black College and Universities, Hispanic Serving Institutions, Tribal Colleges and Universities, Alaska Native and Native Hawaiian Serving Institutions. These institutions have at least 25% minority student enrollment.

B. AMS Ocean, Weather, and Climate Studies Diversity Projects

College faculty participants have attended expenses-paid, week-long workshops that cover fundamental course understandings and implementation procedures. Key to these workshops has been presentations by NOAA and university scientists as well as field trips to science laboratories.

The *AMS Weather Studies* Diversity Project workshops were offered at the NOAA/National Weather Service Training Center in Kansas City, MO from 2002-2007 (Figure 4). The 145 minority serving institutions participating in the program

have offered the weather course to more than 16,000 students. This project served as a model for *AMS Ocean Studies* and *Climate Studies* Diversity Projects [6].



Figure 4. *AMS Weather Studies* Diversity Project faculty members at the National Weather Service Training Center in Kansas City, MO.

The *AMS Ocean Studies* Diversity Project offered course implementation workshops at the University in Washington and NOAA facilities in Seattle, WA from 2006-2008 (Figure 5). Participants then attended a diversity workshop and presented posters at the subsequent AMS Annual Meeting. The 75 institutions participating in the Ocean Diversity Project have already offered the course to more than 8000 students.



Figure 5. *AMS Ocean Studies* Diversity Project faculty at the University of Washington's School of Oceanography.

AMS partnered with Second Nature, the organizing entity behind the American College and University Presidents' Climate Commitment (ACUPCC), in recruitment efforts for the *AMS Climate Studies Diversity Project*. Faculty are brought to Washington, D.C. for the week-long workshop where they receive presentations from climate scientists and high-level speakers from organizations such as NASA, NOAA, and Howard University (Figure 6). In its second year, the Project has already trained 50 MSI faculty members. Subsequent workshops will be held throughout the next 2 years, targeting a total of 100 MSIs.

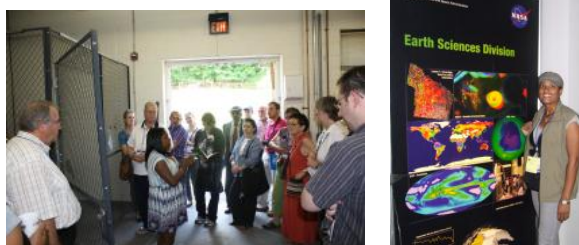


Figure 6. *AMS Climate Studies* Diversity Project faculty at Howard University Beltsville research site (left) and NASA (right).

Although AMS does not track individual students for privacy reasons, there is anecdotal evidence of students choosing additional science courses and several have indicated intent to pursue geoscience major programs upon course completion.

V. CONCLUSIONS

AMS Ocean Studies, *AMS Climate Studies*, and *AMS Weather Studies* have together introduced real-world geoscience education to 770 institutions, 350 of which are MSIs. The courses deliver highly motivational learning experiences that encourage additional student exploration of the geosciences, possibly leading to careers in science or science education.

The AMS will continue to encourage even more institutions to offer these courses in order to raise scientific literacy and will continually update the courses to fit the changing needs of colleges and incorporate the very latest in research and applications.

AMS is also in the process of seeking developmental funding for *AMS Water Studies*, to build upon its suite of courses.

ACKNOWLEDGEMENTS

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