TRESTLE: Atmospheric and Oceanic Sciences (ATOC) Department
Learning Goals
Spring 2016

Group Members:

ATOC Members

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- Alexandra Jahn – ATOC Assistant Professor
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Support Members

- Stephanie Chasteen – TRESTLE PI
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Project Overview:

ATOC is in the process of introducing a new undergraduate major at the University of Colorado Boulder. We recognize that developing effective learning goals and assessments is crucial for the success of our undergraduate major. Therefore, we focused our efforts during Spring 2016 on developing a vision statement and program-level learning goals for our undergraduate major, as well as course-level learning goals, assessments, and instructional techniques for our anticipated gateway course , ATOC 2050.

Background and Context:

To capitalize on the energy surrounding the launch of ATOC's new undergraduate major at the University of Colorado Boulder, our Type 1 TRESTLE proposal targeted two tasks: developing learning goals for the new undergraduate curriculum, and identifying assessment strategies for our courses. During the Spring 2016 TRESTLE Kickoff meeting, we opted to focus our efforts on the program-level vision statement and learning goals, as well as course-level learning goals, assessments, and instructional techniques for our anticipated gateway course, ATOC 2050. Not only did we feel these goals were attainable over a single semester, but by focusing on a course that all ATOC faculty will teach, our TRESTLE efforts would be broadly useful beyond the faculty participating directly in TRESTLE. Additionally, we each individually sought experience with writing learning goals, developing assessments, and expanding our instructional techniques toolkit. We recognized the fact that this type of experience will allow us to continue our efforts beyond the Spring 2016 semester and impact our teaching efforts for years to come.

Describe Your Work so Far:
During the Spring 2016 semester, we completed the undergraduate major vision statements and course-level learning goals for ATOC 2050. In addition, we created working drafts of the program-level learning goals and the ATOC 2050 assessments and instructional techniques.

We presented the ATOC 2050 course-level learning goals at the ATOC Faculty Meeting on March 18, 2016. After this meeting, we received very positive informal feedback. During a subsequent faculty meeting (29 April 2016), we provided the program level learning goals to the faculty, asking for concrete feedback regarding how each of their courses fulfilled the program-level learning goals. This feedback will let us begin the process of enhancing our undergraduate major courses to ensure that all the program-level goals are met.

Concrete Project Outcomes:

- Vision statement: Appendix 1.
    - Complete.
- Program-level learning goals: Appendix 2.
    - Work in progress.
- ATOC 2050 course-level learning goals: Appendix 3.
    - Complete.
- ATOC 2050 instructional techniques and assessment: Appendix 4.
    - Work in progress
  - ATOC 2050 recitation activities: not included in the Appendix
    - Diurnal Cycle Activity - work in progress
    - CO_2-Temperature Assessment Activity - work in progress

Next Steps:

With the new undergraduate major being introduced, the TRESTLE team would like to continue our efforts in the future. We are currently brainstorming the most effective way to accomplish this within our department. Possibilities include a TRESTLE Type 1 proposal, a TRESTLE Type 2 proposal, a Chancellor's Award, or a project of similar scope.

Advice to Others:

As advice to others, we would stress the importance of setting realistic goals. Our original proposal was extremely ambitious and setting more realistic goals for the semester during our first meeting allowed us to be focused and thorough in our work.

We would also recommend taking advantage of the multitude of resources available through the University's Center for STEM Learning program. Both Stephanie and Sarah's knowledge base, insight, and attention to detail were extremely valuable to the success of our project.

Appendix 1.

ATOC Values Statements

"Values" define what it means to be an atmospheric and oceanic scientist. These are the cultural values that students are intended to be brought into, and the value-added that your program wishes to bring to its' students. How do you want your students to be different as a result of your program?

Why are values important?
In the framework of backwards design, the program-level and course-level learning goals, and assessments, need to be aligned with the value statements. They form the guiding mission of your program and courses. Even if what you write isn't perfect, it will help form the guiding principles of your work.

List of values
What does it mean to "think like an atmospheric and oceanic scientist"?

- **Investigative thinking**. Employ the scientific method: ask questions, search existing literature for relevant studies, create and test hypotheses, and draw conclusions based on data.
- **Emphasis on empirical data and modeling.** Examine the physical processes that govern the atmosphere, ocean, and Earth's climate through the use of empirical observations, computer simulations, model output, and visualization.
- **Data-driven conclusions.** Appreciate the power of quantitative observations and modeling to answer questions about the ocean and atmosphere.
- **Process-thinking.** Understand the physical processes that drive the atmosphere, the ocean, and the climate, and be able to apply logic to predict how processes are impacted as different environmental characteristics change.
- **Problem solving.** Able to solve a variety of natural science problems using quantitative methods, such as modeling, theory, and computational data analysis.
- **Professional skills.** Read and comprehend the scientific literature, explain work and results through scientific presentations, collaborate well in groups, exercise leadership skills, and communicate clearly and elegantly both in writing and verbally. Demonstrate awareness of a variety of careers suitable for those with expertise in atmospheric and oceanic sciences.

- **Scientific Ethics**. Students will be knowledgeable of the ethical requirements of conducting scientific research.

Values statement:
ATOC majors apply i**nvestigative thinking** to solve critical **natural science problems** rooted in the **physical processes** of the atmospheric and ocean, employing approaches that emphasize ***scientific theory, empirical data, modeling, and computational data analysis*. ** ATOC majors can **communicate** scientific concepts clearly and elegantly, act with **professional integrity,** and are prepared for a **diverse set of careers.**

Appendix 2.

ATOC Program-Level Learning Outcomes

Program level learning outcomes (or PLLO's) are the end-state for ATOC students once they are done with their undergraduate education. PLLO's should be aligned with program value statements -- if there are values that aren't reflected in the outcomes at all, or vice versa, that indicates a problem. For example, a program level outcome might be that students be able to "work across disciplines" or "use existing tools to interact with data."

Learning Goals for ATOC major students

1. Possess a solid working knowledge of core physical, chemical, and mathematical (STEM) principles
2. Possess a detailed understanding of core atmospheric, oceanic, and climate sciences principles
3. Possess specialized knowledge and skills in one or two areas of atmospheric and oceanic sciences
    - Can include skills in laboratory work, instrumentation, and/or modeling applied to atmospheric and oceanic sciences
4. Possess advanced quantitative problem solving and computational data analysis skills.
    - Ability to derive fundamental relationships; design experiments; acquire, analyze and interpret data.
5. Possess effective verbal and written communication skills and the ability to communicate scientific concepts effectively to a wide audience.
6. Possess experience with modern computer tools, data visualization techniques, and model applications.
7. Possess an awareness of the activities of the ATOC community in Boulder and of the various career opportunities for ATOC majors

Appendix 3.

Course level goals for ATOC 2050 (ATOC gateway course):

1. **Physical processes:** Identify and explain the basic physical processes that drive the coupled atmosphere-ocean system (e.g., energy distribution, phase changes, stability, winds and currents), and be able to apply logic to predict how processes are impacted as different environmental characteristics change.
2. **Graphical literacy:** Draw conclusions from atmospheric and oceanic data through creating and/or interpreting plots and graphs.
3. **Investigative Thinking:** Be able to use logic, data, reasoning, critical thinking, and/or the scientific method to formulate and/or answer a question that is posed about atmospheric and oceanic systems.
4. **Societal and Personal Relevance:** Apply principles from the course to inform everyday choices relating to weather, climate, and/or oceans (e.g., weather safety, weather maps, energy and water conservation.)
5. **Communication**: Demonstrate skill in communicating scientific concepts clearly and elegantly.
6. **Enthusiasm for major.** Develop an identity as an ATOC major, including an enthusiasm for the skills and perspectives of atmospheric and oceanic science, and an appreciation of how content learned in other concurrent courses are related to the major.

Topic level goals for ATOC 2050

PHYSICAL PROCESSES: Identify and explain the basic physical processes that drive the coupled atmosphere-ocean system (e.g., energy distribution, phase changes, winds and currents), and be able to apply logic to predict how processes are impacted as different environmental characteristics change.

Distinguish between **weather and climate processes**. This could include concepts such as:

- Identify examples of weather and climate
- Appreciate regional differences in weather and climate and their respective causes

- Distinguish the temporal and spatial scales associated with weather and climate processes

Describe the global distribution of **incoming/outgoing/net energy** and appreciate how it impacts global temperatures and heat transport in the atmosphere and ocean. This could include concepts such as:
- Solar radiation distribution and the seasons
- Milankovitch cycles
- Net radiation budgets
- The greenhouse effect
- Global wind belts and ocean currents
- Oceanic and atmospheric sensible and latent heat fluxes
- Transient weather phenomena
- The daily cycle of the atmospheric boundary layer

Explain how **phase changes** of water occur, and how they impact weather, climate, and/or ocean circulation. This could include concepts such as:
- Methods of achieving saturation
- Relative versus absolute measures of humidity
- Latent and sensible heat, Bowen ratios
- Cloud formation
- Precipitation processes
- Cloud seeding
- Sea ice formation/melt

Analyze how the atmosphere and ocean are a **coupled system.** This could include concepts such as:
- The carbon cycle
- Heat and gas fluxes
- Wind stress and its influence on upwelling, sea ice processes, thermohaline circulation
- Tropical cyclone genesis
- El Nino - Southern Oscillation
- Land-sea breezes and monsoon circulations

Name and describe the **dynamics** that drive atmospheric winds and ocean currents across all scales, and use logic to predict how processes will evolve over time. This could include concepts such as:

- Pressure gradient, Coriolis, centrifugal, and frictional forces
- Geostrophic and gradient wind balances
- The three-cell atmospheric model
- Divergence and convergence in the atmosphere
- Surface currents
- Ekman transport, downwelling, and upwelling
- Western intensification
- Thermohaline circulation
- Air masses and fronts
- Thunderstorms and tornados
- Midlatitude cyclones
- Tropical cyclones
- Oceanic eddies

Describe static **stability** in the atmosphere and oceans and apply these concepts to assess how situations will evolve. This could include concepts such as:

- Positive, negative, & neutral buoyancy
- Factors influencing the environmental lapse rate
- Assessing atmospheric stability
- Inversions
- The influence of salinity and temperature on oceanic stability
- Sea ice impacts on oceanic stability

GRAPHICAL LITERACY: Draw conclusions from atmospheric and oceanic data through creating and/or interpreting graphs

- **Select appropriate datasets or data subsets** for carrying out an investigation.
- **Select a plot type** to best represent the relationships in a given data set, and **justify** this choice of plot type.
- **Generate, interpret, and annotate** basic atmospheric and oceanic plots, maps, and figures.

This could include items such as:

- Basic weather maps at the surface and common pressure levels: identify high and low pressure systems, and regions of divergence and convergence

- Meteograms: Use temporal changes in humidity, temperature, and winds to identify weather events, such as fronts
- Atmospheric soundings from radiosondes (e.g., Skew-T and Stuve diagrams): identify cloud layers, inversions, and vertical wind shear. Examine profiles and common indices for severe weather potential.
- Isotope plots: identify how shifts in isotopic composition reflect a changing climate (i.e., ice sheets growing versus melting; detection of anthropogenic carbon dioxide in measurements). Understand the isotopic fractionation processes that have led to these observed shifts.
- Carbon dioxide and global temperature plots: Identify and explain seasonal versus interannual and decadal changes in carbon dioxide and global temperature; detect trends

INVESTIGATIVE THINKING: Be able to use logic, data, reasoning, critical thinking, and/or the scientific method to formulate and/or answer a question that is posed about atmospheric and oceanic systems.

- Select and summarize literature relevant to an investigation.
- Formulate and justify a hypothesis (e.g., predict how a given weather situation will evolve)
- Use data to verify the hypothesis or prediction.
- Draw a conclusion based on data and use scientific argumentation to justify that conclusion (i.e., state the claim, the evidence, and the reasoning that links evidence to the claim).
- Critique the original hypothesis

COMMUNICATION: Demonstrate skill in communicating scientific concepts clearly and elegantly.

- Effectively present the relevance of oceanic and atmospheric science to diverse audiences.
- Present results from class projects to peers
- Prepare short reports on class projects
- Participate in group projects
- Participate actively in discussions
- Provide objective feedback of your peers' work

SOCIETAL and PERSONAL RELEVANCE: Apply principles from the course to inform everyday choices relating to weather, climate, and/or oceans (e.g., lightning safety, energy conservation.)

- Be prepared to respond to communication of weather events, such as:
    - Severe weather watches and warnings
    - Avalanche forecasts
    - Lightning safety
    - Wildfires
    - Air quality issues
    - Drought and flood monitor warnings
    - Tsunami warnings
- Be aware of how climate variability and change may interact with human activities, such as :
    - sea-level rise
    - geo-engineering
    - renewable energy production
    - permafrost and sea ice melting
    - agricultural production
    - coastal erosion
    - disease vectors
- Understand how individual everyday choices about transportation, food, and housing impact carbon and water footprints

ENTHUSIASM FOR MAJOR: Develop an identity as an ATOC major, including an enthusiasm for the skills and perspectives of atmospheric and oceanic science, and an appreciation of how content learned in other concurrent courses are related to the major.

- Appreciate how course content from physics, mathematics, and chemistry form the foundation for upper-level courses in atmospheric and oceanic sciences
- Appreciate the unsolved mysteries of atmospheric and oceanic sciences (e.g., rogue waves, surface winds in tornadoes)
- Identify personally relevant areas of study within ATOC
- Recognize and identify personally relevant career options in ATOC
- Make personal connections with ATOC students and faculty to share information and skills
- Participate in ATOC, college, local or regional scientific communities and/or events such as seminars, poster sessions, and scientific meetings.

Appendix 4.
Assessment Plan and Data Activity for ATOC 2050

Course Goal	Final assessment	Instruction
1- Physical processes: Identify and explain the basic physical processes that drive the atmosphere-ocean system (e.g., energy distribution, phase changes, stability, coupled systems, winds and currents) and their couplings, and be able to apply logic to predict how processes are impacted as different environmental characteristics change.	At the final exam, have the students build a concept map for a particular topic (e.g. wind-driven circulation of the ocean), in which they explain the connections between various concepts presented during class. (This would require introducing concept maps during instruction.)	http://serc.carleton.edu/NAGTWorkshops/visualization/examples/gulfstream.html http://serc.carleton.edu/sp/library/teachingwdata/examples/ModernCO2.html Wind lidar example below
2- Graphical literacy: Draw conclusions from atmospheric and oceanic data through creating and/or interpreting plots and graphs.	Ask students to plot a dataset. Check for things such as axis labels, titles, units, etc. Ask students to interpret the figure. What conclusions can be made from the figure? Ask students to choose a dataset and plot it to answer a question	http://serc.carleton.edu/sp/library/teachingwdata/examples/ModernCO2.html Wind lidar example below
3- Investigative Thinking: Be able to use the scientific method and critical thinking to answer a question that is posed about atmospheric and	Ask students to summarize their reading of current literature pertaining to the question.What does the literature suggest the	http://serc.carleton.edu/NAGTWorkshops/visualization/examples/gulfstream.html http://serc.carleton.edu/NAGTWorkshops/visualization/examples/localclimate

oceanic systems (e.g., carry out a literature search, make a hypothesis, test the hypothesis with data, and draw conclusions.)	answer to the question is? Ask students to test their hypothesis using scientific data. Ask students to make conclusions from their results compare to their original hypothesis was correct. The assessment be based on a rubric including each of these steps listed in "investigative thinking" at left	.html Give the students a question about an atmospheric or oceanic system. Ask the students to hypothesize the answer to the question.
4- Societal and Personal Relevance: Apply principles from the course to inform everyday choices relating to weather, climate, and/or oceans (e.g., weather safety, weather maps, energy and water conservation.)		Have students read and write a reflection on the avalanche forecasts for a given location for a given time period. http://avalanche.state.co.us/ Have students assess whether or not they would do an outdoor activity (e.g. hiking, baseball, golfing) given a certain forecast
5- Communication: Demonstrate skill in communicating scientific concepts clearly and elegantly.	Have students evaluate other students based on the rubric	Have students write a lab report pertaining to an exercise given for #3. Have students orally present their results from #3 to the class.
6- Enthusiasm for major. Develop an enthusiasm for the skills and perspectives of atmospheric and oceanic sciences, which is embodied in the above course goals.	Participate in departmental or regional atmospheric/oceanic activities, such as attend a seminar and write a reflection on how the seminar relates to what they have learned in class	

Develop an appreciation of how content learned in other concurrent courses are related to the major.	thus far Research potential employers who require atmospheric or oceanic science expertise and write a reflection on how a student could prepare themselves for a position with that employer	

Wind Lidar Example:
Wind profiling lidar (or meteorological tower data) for a few diurnal cycles: hypothesize at what time of day (due to stability impacts) high or low turbulence and high or low wind speeds would be expected. Then read in the wind speed and turbulence data, plot a time series at a given height, explain if that time series reflects what they had hypothesized.