7.1 A HYBRID APPROACH TO ONLINE AND TRADITIONAL LEARNING DURING A BOUNDARY LAYER METEOROLOGY COURSE

Morgan B. Yarker*
Yarker Consulting, Cedar Rapids, IA, USA
Eric Kelsey
Plymouth State University, Plymouth, NH, USA
Michel d. S. Mesquita
Uni Research Climate, Bjerknes Centre for Climate Research, Bergen, Norway

1. INTRODUCTION AND THEORETICAL FRAMEWORK

In support of this year's AMS meeting theme "Fulfilling the Vision of Weather, Water, Climate information for Every Need, Time, and Place", this project explores possible avenues to make knowledge about authentic science more accessible in the atmospheric science classroom.

Most classroom time is spent studying theory, which an important component in preparing future atmospheric scientists. However, it has also been shown that teaching theoretical concepts within the context of doing authentic science increase critical thinking and problem solving skills, improves understanding of the scientific process and the nature of science, and still allows for in-depth development of content knowledge (Driver et al. 2000, Duschl & Osborne 2002, Justi & Gilbert 2002, Schwarz & White 2005, Hand 2006, Windschitl & Thompson 2006, Akkus et al. 2007, Hand 2009, Gilbert 2011, NGSS 2013, Yarker 2013).

In order to expose students to authentic atmospheric science processes, they need to be able to collect and work with observed data as well as modeling data. However, working with the data alone is not sufficient because both observed data and modeling data has limitations and may not always align with what is expected based on theory. In order to understand the limitations and strengths of both data sources, it is important that students take part in data collection as well as running computer models. More importantly, it is imperative that students understand that theory, observation data, and models all inform each other.

Warner (2011) discusses the importance of teaching students about the relationship between theory, observations, and models. He points out that they connect to each other in 3 important pathways: 1) atmospheric theory informs data collection methods and data collection methods provide insight that helps us construct theory, 2) atmospheric models are built upon atmospheric theory and theories are created and refined based upon atmospheric models, and 3) atmospheric observations validate, refine, and nudge model simulations and model simulations provide a complete picture whenever observations cannot. This relationship is illustrated in Figure 1.

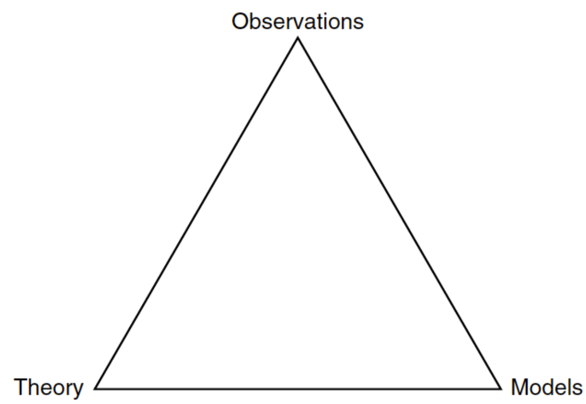

Figure 1 Illustration that depicts the relationship between observations, theory, and models in atmospheric research. Figure from Warner (2011a).

This paper discusses a case study, where eight graduate students in a Boundary Layer Meteorology course at Plymouth State University were given the opportunity to design a research project, collect observation data, run a model simulation, and compare their findings with that of PBL theory learned in the traditional classroom. As a result, the students had a unique opportunity to explore the relationships between model output, observation data, and boundary layer theory by doing authentic science, which can help them better understand the nature of science, PBL content, as well as the limitations and strengths of both observation data and atmospheric models. At the end of the course, the students drafted a paper highlighting their findings, which will be submitted for publication in a scientific journal.

2. COURSE DESCRIPTION

The hybrid approach discussed in this paper was used during an elective, graduate course in Boundary Layer Meteorology course taught at Plymouth State University. There were eight students, four female and four male. Course objectives, as listed in the syllabus, were for the students to:

- Be able to define the atmospheric boundary layer (PBL) and its importance within atmospheric science.
- Be able to describe PBL processes qualitatively and mathematically.
- Learn how to observe, analyze, an model (using WRF) an PBL process.

* *Corresponding author address:* Morgan B. Yarker
Yarker Consulting, 1027 Capri Dr. NE, Cedar Rapids, IA, 52402
morgan@yarkerconsulting.com

- Critically assess the WRF model forecast skill related to observed PBL processes and hypothesize reasons for WRF model deficiencies.

Students were assessed using two written exams and a term project that lasted the entire semester.

The objective of the term project was to have students apply theory learned from the classroom textbook and lectures to the actual atmosphere through data collection and numerical modeling; which, in turn, would also provide them with the opportunity to develop skills to interpret and evaluate data as well as model skill. To make the process as authentic as possible, students developed a research proposal, executed an observational field campaign, set up and ran the Weather Research and Forecasting (WRF) model, analyzed both sets of data, wrote a report, and presented their findings in an oral presentation. Since the term project includes procedures used by practicing scientists, students benefited from the project by having the opportunity to practice the scientific process by doing authentic science research in the classroom. Based on what we know from learning theory, this process provides students to learn content while simultaneously learning and practicing authentic science inquiry.

2.1 Observation Data Collection

As a part of the course, the students were provided with a unique learning opportunity to collect meteorological data for a boundary layer phenomenon of their choice, analyze the data and compare it to theory learned in class as well as a model simulation. Students had access to the Plymouth State University (PSU) vaisala radiosonde system as well as the Mount Washington Observatory Mesonet stations that measure wind, temperature, and relative humidity (Figure 2).

2.2 Model Simulation

Setting up and running a computer forecast model can be a time-consuming task with a very steep learning curve, particularly since no one in the class had prior modeling experience. To guide students through setting up and running the model, the instructor utilized a free online course in Regional Modeling (m2lab.org 2014). The online course instructor, Dr. Michel Mesquita, is an experienced WRF modeler and teacher and took an active role in the course by giving additional presentations and feedback to the students throughout the semester.

The online course utilizes a Moodle platform (Moodle.org 2015), seven tutorials, and an online forum to post questions and facilitate discussion. The tutorials provide participants with background information on the model and its parameters, as well as a step-by-step procedure for choosing and setting up an experiment that can be tested using a model run. Participants are assessed throughout the course, which includes a computer marked content knowledge quiz, a reflective learning essay, and a survey to assess the effectiveness of the course design. Each tutorial aligns with the latest research in learning theory, utilizing a cyclical structure of content introduction, and activity to apply the new content to a modeling situation, and feedback. A summary of the WRF course structure is provided in Table 1.

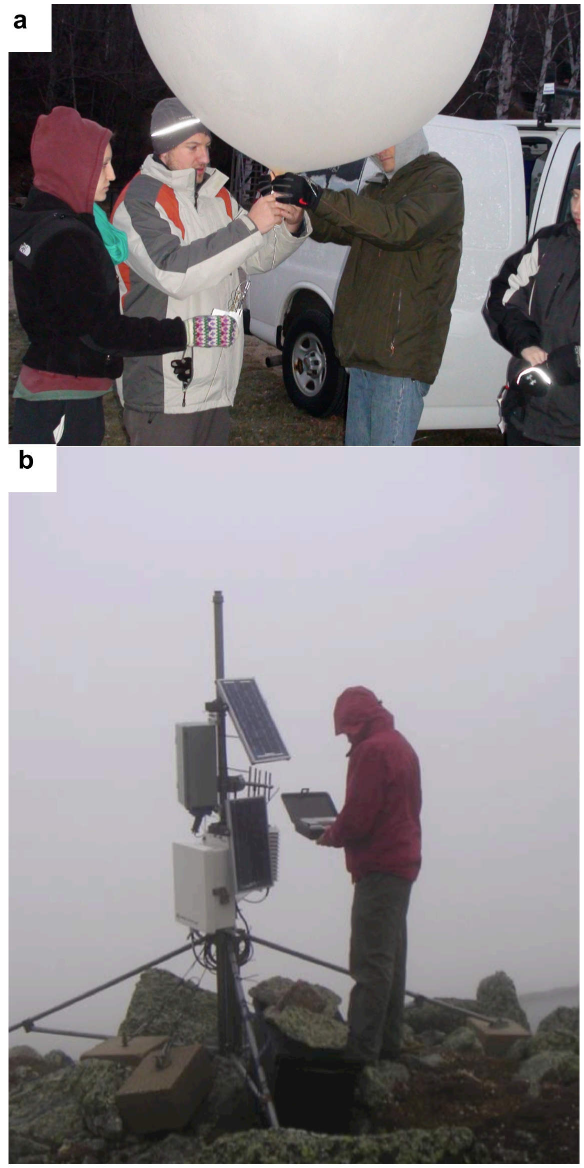

Figure 2 Students in the Hybrid PBL class (a) prepare a balloon to collect upper air data with a Vaisala radiosonde and (b) collect surface data from one of 18 Mount Washington Observatory mesonet stations.

As a part of the online WRF modeling course, students had access to a version of WRF for educational purposes that provides a more compact version of WRF that can be run on a desktop computer (Mesquita 2013). However, the students in this group had access to WRF that was already installed on a server at Plymouth State University. Additionally, since they ran the model for educational purposes, the NCAR Yellowstone supercomputer was provided free of charge.

Although setting up and running WRF as a part of the class is a difficult and time-consuming task, it is also very important because computer models play a key role in scientific research and in developing our understanding of the atmosphere (de la Rubia & Yip 2008). Current research in the field of science education indicates that the best way for students to understand complex models is to have them work with, experiment with, modify, and apply models in a way that is significant and informative to the learner (Harrison & Treagust 1998, Justi & Gilbert 2002, Schwarz & White 2005, Schwarz et al. 2009, Gilbert 2011, NGSS 2013).

WRF Online Course Structure	
Part 1	Course preparation
Part 2	WRF Installation
Part 2A	Copied WRF files on your directory
Part 2B	Setting up e-WRF (optional)
Part 3	Experiment design
Part 4	Designing experiments with WPS
Part 5	ungrib.exe and metgrid.exe
Part 6	real.exe and wrf.exe
Part 7	tlist, schemes, and more

Table 1 Structure of the online WRF modeling course

2.3 Student Project Results

The students wrote a research proposal before collecting data, therefore had a specific question in mind when they decided what data they were going to collect and how they would do it. In particular, they compared the data they collected to expected values as described by theoretical constructs as discussed in PBL textbooks commonly learned in class. Specific topics include radiation cooling and radiation balance, Diel boundary layer evolution in mountain environments, and the topographic flow effects as a result of surface roughness. Students plotted data and interpreted their results, which have been written for scientific publication later this year. An example of one of the student plots is provided in Figure 3.

3. DATA COLLECTION AND ANALYSIS

In order to evaluate the success and challenges of the course, student data was collected from anonymous surveys, course evaluations, class assignments and the computer marked content quiz from the online modelling course.

Since there were only eight students in the class, it is not useful to generalize results using statistical analysis. However, it is possible to qualitatively analyze the results using coding procedures (Merriam, 1998). All student responses were given a descriptive code and then all codes were categorized into similar clusters, called categories. Once categories were determined, trends could be identified between the students, which highlights their general successes and struggles with the course.

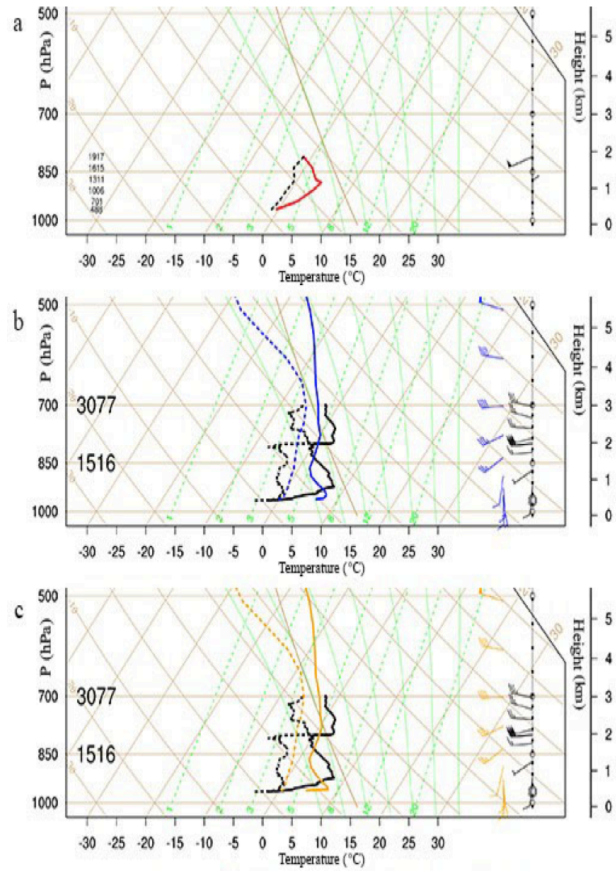

Figure 3 Example of a student-generated plot from the data collected.

4. RESULTS AND DISCUSSION

As a result of the term project, students experienced the full research cycle, from proposal development, to field campaign and atmospheric modelling, to data analysis and reporting results via paper write up and oral presentation. It is extremely important for students to have practice with the scientific process, because it helps them develop an understanding of the scientific process, which can make them more rounded scientists. In addition, students also learned important content knowledge that is not often covered in traditional classes, like how to evaluate computer models and what theoretical parameters need to be incorporated into the models in order to improve their ability to capture PBL behaviour for mountain regions. Student's ability to critically evaluate model output, recognize limitations, and conceptually apply atmospheric theory that could improve model simulations are all indicators that students have a deep understanding of the content as well as the scientific process (Warner 2011a, Warner 2011b, NGSS 2013).

Survey results indicate that students had a positive experience with the course, but it was not without challenges. Some success were that all students reported that it was helpful to run WRF as a part of understanding the atmosphere and enjoyed the real-world, hands on approach of the data collection. While all students reported recognizing the relevance of this course to their professional lives, only one student stated that they recognized that having experience running a model could help them in their future employment. Regardless, six of the seven students reported that it was useful to compare model data to observed data in order to evaluate the model and compare their findings to what the "expected" outcome would be based on theory. As stated earlier, students' recognizing the importance of evaluating data in light of our theoretical understanding of the atmosphere indicates a deep understanding of the scientific process (Windschitl & Thompson 2006, NGSS 2013).

As expected, utilizing a semester-long course that includes data collection, a model simulation, and a term project cannot be executed without some challenges. Although the group was able to successfully setup and run WRF, all students reported struggling with the model, which included their lack of an in-depth conceptual understanding of WRF itself. It is not surprising that the students aren't completely confident with the model, because research shows that it takes time and practice to achieve this confidence and one semester is generally not sufficient (Warner 2011a, Warner 2011b). One of the biggest hurdles is the technical issue with running WRF, particularly if the learner is unfamiliar with Unix and working with computer clusters.

Perhaps the least surprising challenge that students reported was that the entire term project as a whole was daunting. Although students reported learning a lot and feeling like the skills they gained during the class will benefit them in the future, completing the term project was a challenge. There is no shortage of research that discusses the effort required to utilize authentic science practices in the classroom, however it has also been shown to increase critical thinking and problem solving skills, improve the understanding of the scientific process and the nature of science, and still allows for in-depth development of content knowledge (Driver et al. 2000, Duschl & Osborne 2002, Justi & Gilbert 2002, Schwarz & White 2005, Hand 2006, Windschitl & Thompson 2006, Akkus et al. 2007, Hand 2009, Gilbert 2011, NGSS 2013). Additional benefits are that the students had practice doing authentic science, which better prepares them for a career as a scientist, hence making them more marketable.

5. FINAL THOUGHTS

Although the approach utilized in this classroom can be daunting and is not without its challenges, the instructor achieved successful outcomes and the students left the course more experienced, practiced scientists who are better prepared for a career in the atmospheric science field. In addition, this approach aligns with learning theory research and achieved similar findings.

Some lessons learned from the first attempt at using the hybrid approach is that more time needs to be spent helping students conceptually understand WRF before having them start the process of running the model, including practice with Unix. Research indicates that this will help lesson some of the technical issues with setting up the model run (Warner 2011b).

Finally, despite the challenges, students had the opportunity to compare observations and model data while simultaneously learning atmospheric science theory. It is important to note that every classroom can utilize data collection and atmospheric models, even if a classroom doesn't have access to the technology that this classroom had. Students achieve similar learning outcomes by manually collecting observations using low-tech surface data instruments. Additionally, if a computer cluster or supercomputer are not available, m2lab.org provides a free version of WRF for educational purposes (e-WRF), which is easier to install and can be run on a desktop computer (Mesquita 2013). In sharing our classroom experience, we hope to inspire other instructors to try utilizing both observation and modeling techniques in the classroom.

6. REFERENCES

Akkus, R., M. Gunel, and B. Hand, 2007: Comparing an inquiry-based approach known as the Science Writing Heuristic to traditional science teaching practices: Are there differences? *Int. J. Sci. Educ.,* **29**(14), 1745-1765.

de la Rubia, T. D. and S. Yip, 2008: Advocacy of computational science (Editors' preface). *Sci. Model. Simul.,* **15,** 1-2.

Driver, R., P. Newton, and J. Osborne, 2000: Establishing the norms of scientific argumentation in classrooms. *Sci. Educ.,* **84**(3), 287-312.

Duschl, R. A., and J. Osborne, 2002: Supporting and promoting argumentation discourse. *Stud. Sci. Educ.,* **38,** 39-72.

Gilbert, S., 2011: *Models-Based Science Teaching.* Arlington, VA: NSTA Press, 204 pp.

Hand, B., 2006: Using the Science Writing Heuristic to promote understanding of science conceptual knowledge in middle school. *Linking science & literacy in the K-8 classroom,* C. Reinburg, J. Cusick, A. Cocke, and B. Smith, Eds., National Science Teachers Association, 117-126.

Hand, B., L. Norton-Meier, J. Staker, and J. Bintz, 2009: *Negotiating Science: The Critical Role of Argument in Student Inquiry.* Portsmouth, NH: Heinemann, 240 pp.

Harrison, A. G., and D. F. Treagust, 1998: Teaching science effectively with analogies: An approach for pre-service and in-service teacher education. *J. Sci. Teach. Educ.,* **9,** 85-101.

Justi, R., and J. Gilbert, 2002: Science teachers' knowledge about and attitude towards the use of models and modeling in learning science. *Int. J. Sci. Educ.,* **24**(12), 1273-1292.

Merriam, S., 1998: *Qualitative Research and Case Study Applications in Education.* San Francisco, CA: Jossey-Bass 275 pp.

Mesquita, M. d. S., cited 2013a: *Regional Climate Modeling Using WRF*. [Retrieved from m2lab.org.]

Mesquita, M. d. S., cited 2013b: e-WRF: WRF for Educational Purposes. Computer program. [Available at m2lab.org.]

Moodle.org, cited 2011: About Moodle. [moodle.org.]

NGSS, 2013: Next Generation Science Standards: For States, By States. Achieve, Inc.

Schwarz, C. V., and Coauthors, 2009: Developing a learning progression for scientific modeling: Making scientific modeling accessible and meaningful for learners. *J. Res. Sci. Teach.*, **46,** 632-654.

Schwarz, C., and B. White, 2005: Metamodeling knowledge: Developing students' understanding of scientific modeling. *Cognit. Instr.,* **23**(2), 165-205.

Warner, T., 2011: *Numerical Weather and Climate Prediction.* Cambridge: University Press. 550 pp.

Warner, T. T., 2011: Quality assurance in atmospheric modeling*. Bull. Am. Meteorol. Soc.,* **92,** 1601-1610.

Windschitl, M., and J. Thompson, 2006: Transcending simple forms of school science investigations: Can pre-service instruction foster teachers' understanding of model-based inquiry? *Am. Educ. Res. J.,* **43**(4), 783-835.

Yarker, M. B., 2013: Teacher challenges, perceptions, and use of science models in middle school classrooms about climate, weather, and energy concepts. Dissertation, University of Iowa, 120 pp.