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INTEGRATING WEB-BASED TECHNOLOGICAL CLASSROOM TOOLS INTO AN UNDERGRADUATE RADAR AND SATELLITE METEOROLOGY COURSE

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1. INTRODUCTION

As part of a graduate level course entitled "Effective Teaching with Technology" administered through the Delta Program at the University of Wisconsin (UW) - Madison, an interactive, self-paced, web-based learning module was developed for an undergraduate Radar and Satellite Meteorology course offered by the Department of Atmospheric and Oceanic Sciences (AOS) at UW-Madison. This paper describes how Teaching-as-Research (TAR) principles were used as guidance to create, administer, and improve the learning module. The project's learning goals and outcomes, technological tools that were utilized (e.g. the Integrated Data Viewer and various Java applets), assessment techniques and results, and possible future pathways to expand web-based educational tools for this course will be discussed. Lastly, a description of how of other forms of technology were integrated into the classroom, and plans for future uses of technology in this particular course, will also be provided.

AOS 441 is a remote sensing class that was first offered during the spring 2006 semester to upper-level undergraduate AOS students. The course, entitled "Radar and Satellite Meteorology", replaces two separate undergraduate classes that were previously dedicated to each respective remote sensing tool. Students are exposed to the basic physical principles that govern remote sensing using ground-based radars and satellite-based passive remote sensing instruments. Applications and the quantitative aspects of remote sensing are stressed in this course to illustrate the myriad uses of radar and satellite data in the geosciences. The course is comprised of two 50 minute lectures and one 110 minute computer "laboratory" per week. A basic meteorology background with little experience in radar meteorology is assumed prior to taking this course.

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The laboratory sessions, which allow the students extended time to hone their newly acquired remote sensing skills using computer-based data analysis and visualization tools, were also overhauled. Since analyzing meteorological data is inherently a visual task, and because previous research in other undergraduate atmospheric science courses has indicated that students preferentially learn via visual methods over verbal (Whittaker and Ackerman, 2002), a major initiative to include self-paced interactive, visual learning activities was undertaken to enhance the student laboratory experience. Since numerous web-based learning activities for the satellite component of the course had already been developed, we focused our efforts on finding or developing web-based learning modules for potential radar topics.

An exhaustive internet search was performed to inventory what types of radar learning tools were currently used. Numerous radar meteorology topics (e.g. radar signatures of severe and/or tornadic thunderstorms, operational radar meteorology training modules for the National Weather Service, etc.) had an abundance of web-based material, but not necessarily interactive learning tools, associated with them. In fact, some of these existing tools were successfully incorporated into the AOS 441 lab section throughout the semester. However, the essentially important topic of how to distinguish precipitating from non-precipitating radar signals (also called "spurious" or "false" signals) was not well-represented by currently available web-based learning tools. Besides the lack of readily available learning activities, this extremely important topic seemed like the perfect candidate to develop an interactive web-based module because it relies heavily on the ability to animate and three-dimensionally visualize radar data.

This paper discusses the development, implementation, and assessment of the AOS 441 web-based learning module related to non-precipitating radar signatures. Section 2 describes the learning goals and outcomes of the project, while section 3 provides an overview of the tools used to develop the module. Results from a formative assessment of the learning module are presented in section 4, and section 5 contains concluding remarks and proposed future work.

2. LEARNING GOALS/OUTCOMES

The field of radar meteorology offers a plethora of potential topics that would be suitably addressed by web-based learning activities. The initial intent of this tutorial was to introduce a wide variety of issues related to radar meteorology (e.g. radar beam propagation, interaction of electromagnetic radiation with precipitation, the structure of precipitating systems from a radar perspective, precipitation estimation using radar data, etc.). However, the scope of such a project was beyond the intentions of the Effective Teaching with Technology (ETT) course and was thought to be too substantive by peer reviews of the initial project plan. Also, the length of such an expansive learning module could be prohibitively long, and it was deemed that student learning could accordingly suffer. Therefore, this tutorial will focus on a radar meteorology topic that many students have not been exposed to through previous experience and/or in other undergraduate courses - specifically, radar signatures that are produced by phenomena not related to actual precipitation. The broad learning goals associated with the tutorial are:

1. Familiarize the student with analyzing radar data; and
2. Expose the students to common examples of non-precipitating radar signatures.

After completing the learning module, students should be able to perform the following learning outcomes addressed by this learning activity:

1. Analyze and interpret radar data through the use of numerous case studies;
2. Identify non-precipitating phenomena using radar data;
3. List criteria to distinguish precipitating versus non-precipitating radar signatures;
4. Discuss the importance of identifying and removing non-precipitating radar signals for estimating precipitation.
5. Design a rudimentary, quantitatively-based quality-control algorithm to remove non-precipitating radar signatures while keeping precipitating signatures intact.

Using the hierarchy of cognitive learning levels proposed by Bloom et al. (1956), the above learning outcomes span the entire learning spectrum, including lower level (e.g. knowledge comprehension, and application) to higher level (analysis and synthesis) processes. It should be noted that the last learning outcome is not currently addressed within the web-based learning module, but is left as a post-module group activity that will hopefully stimulate discussion and build a more robust learning community within the class.

3. TECHNOLOGICAL TOOLS

This section describes the software tools employed in this web-based tutorial, followed by a description of the module in its entirety. Many of the tools are Java applets that allow for seamless portability between computing platforms. All of the tools utilized are available freely for educational and/or non-profit uses.

3.1 Integrated Data Viewer (IDV)

The IDV is a powerful software package developed at the National Center for Atmospheric Research. The IDV was developed solely for visualizing and analyzing geophysical data from different remote sensing platforms and meteorological data streams (e.g. radar, satellite, radiosondes, numerical weather prediction models, etc.). The IDV was used to generate all of the radar images shown in the learning module.

3.2 AnimationS (AniS)

AniS is a Java applet developed at the UW Space Science and Engineering Center (SSEC) that allows a web developer to produce animations of a collection of static images for display on web pages. The AniS package includes an interface with numerous settings to allow the user to control the animation (e.g. stop/start, animation speed, zoom options, looping, etc.). Since temporal continuity and vertical structure are two important factors to consider when identifying radar data not associated with precipitation, this tool was extremely valuable to show animations of three-dimensional radar data throughout the learning module. Fig. 1 shows an example of AniS in the web module.

3.3 QuizImage

QuizImage is another Java applet tool developed at the UW SSEC that allows the instructor to create an interactive learning experience using static images with overlaid text. Educational research has shown that using picture and text combinations assists in building connections between ideas and aids in information retention better than using either method alone (e.g. Mayer et al, 1995 and Haber and Myers, 1982). Two types of image/text learning activities can be developed with QuizImage:

1. “Discover” lessons that allow the user to explore an image with their mouse. As the user moves their mouse around an image, hidden text appears when the mouse is moved over different regions of the image.

2. “Quiz” lessons that allow the instructor to prompt the user to find different features contained in an image. The features are previously identified by the instructor by creating “hotspots” on the image when building the QuizImage activity. The user then clicks on a region of the image that they think contains the feature, and QuizImage prompts them if they are correct (if they click on the “hotspot”) or incorrect (if they click do not click on a “hotspot”).

QuizImage discover lessons were used liberally throughout the learning module (Fig. 2). A QuizImage quiz lesson was used as the final activity of the module to assess student learning of the topics introduced within the module.

3.4 ConceptTutor

ConceptTutor is a Macromedia, flash-based software interface developed at the UW SSEC that allows the web developer and/or instructor to create links in a web page that provide concise and visually appealing details about a specific concept. This tool allows the user to get more information about a topic if needed or desired, but also allows users who already know the concept not to be unnecessarily impeded as they progress through a web-based learning activity. The ConceptTutor creates a separate window linked to a web page that contains a quick summary about the chosen concept, including related images, animations, or audio. ConceptTutor activities are used throughout the radar learning module to introduce concepts that might not be known to all of the potential users of the learning activity (e.g. Fig. 3).

3.5 HyperText Markup Language (HTML)

The basic web design of the tutorial was developed in HTML. The AniS, QuizImage, and ConceptTutor modules were developed separately and embedded into the main web page as a final step. The end result is a web-based tutorial that seamlessly incorporates all of the aforementioned software tools.

3.6 Module Description

The learning module contains the following four main components:

1. Introduction
2. Introductory exercise
3. Case studies
4. Quiz

The module introduction provides a quick overview of the topic to be discussed, learning objectives of the activity, possible pedagogical applications of the module, and any prerequisite knowledge necessary to complete the module. The user then moves to the introductory exercise on the second page. The exercise consists of looping through an animation of radar data associated with a strong, large-scale storm system that was centered over the central United States. The user is asked to watch the animation carefully several times to observe the radar signatures. They can then move on to another page where a QuizImage discover lesson allows them to move the mouse over a snapshot of the previous animation to discover what phenomena produce the radar observed signatures (radar signals are also called “echoes”). This exercise serves as a “teaser” to illustrate the wide variety of both precipitating and non-precipitating features that are readily observed by weather radars.

After another introductory exercise that is very similar to the one just described, the user moves on to the case study section (Fig. 4). The user is presented with the following list of five criteria that can be used to distinguish non-precipitating from precipitating radar signatures:

1. Vertical continuity;
2. Temporal continuity;
3. Radial velocity;

4. Echo pattern;
5. Alternate data sources.

The user then proceeds to any of the following non-precipitating radar signature case studies to explore each individual topic in more detail:

1. Anomalous propagation;
2. Clear air echoes;
3. Surface boundaries;
4. Wildfires.

The user works through each of the non-precipitating case studies, keeping in mind the set of five criteria that can be used to identify non-precipitating radar signatures listed earlier. Each case study provides a short summary of the phenomena of interest, including ConceptTutor windows to describe certain concepts in greater detail. Animated images of the base radar reflectivity (i.e. the lowest elevation angle of radar data), the 1.4 or 2.4 degree elevation angle radar reflectivity (to assess vertical structure), and the base radial velocity for the specific phenomena being presented are shown in each case study. Lastly, a QuizImage discover lesson culminates each case study. As the user moves their mouse over a radar image in the QuizImage lesson, regions of precipitation and non-precipitating radar echoes are labeled accordingly. The module also provides reasons - based on the five criteria listed earlier – why certain signatures are classified as non-precipitating or precipitating. The anomalous propagation example also includes a discussion about the importance of removing spurious radar signatures in a quality control process when estimating precipitation accumulation using radar data. Additionally, the surface boundary case study provides a discussion of why it's important to *not* quality control non-precipitating radar data for forecasting convective storm initiation. Finally, the user can complete a final QuizImage quiz lesson for assessment purposes (see section 4).

4. ASSESSMENT

4.1 Student Assessment

Students are self-assessed throughout the module by using the QuizImage discover lessons. The main assessment component of the module, however, is the final QuizImage quiz lesson where they are prompted to click on an image and identify regions of precipitation and various other forms of spurious echo based on knowledge gained from the learning module. For instance, the final quiz activity prompts the user to first look at animations of radar data for a specific case study that includes precipitation and about four different radar echoes that are not associated with precipitation. After digesting the animations, the user then moves to the quiz session. The user is first prompted to find a region of anomalous propagation. They are given five total attempts to identify the anomalous propagation. After the fifth attempt, the QuizImage lesson automatically provides the answer to the user. This pattern is repeated until all of the categories of spurious echo have been identified. It should be noted that no assessment statistics are currently generated after the user completes the quiz.

4.2 Learning Module Assessment

After completing the radar meteorology learning module, each student was asked to complete an anonymous survey to assess the learning efficacy of the activity. All students complied with the survey request, perhaps motivated by the 2 extra credit points that were allotted to each student if the entire class turned in the surveys. Table 1 summarizes the survey results (numbers provided in the table are average values).

Even though the sample size (N=9) of the results is admittedly small, the survey results were encouraging. Overall, the students viewed the learning module in a positive fashion, and every student thought it effectively addressed the intended learning outcomes. Also, every student indicated that the data animations were useful to visualize the topics discussed and that they would like to have access to additional learning modules for other radar meteorology topics not covered in this activity. Interestingly, 5 out of 9 students thought audio would make the module more effective. Our initial goal was to keep the length of the module between 15 and 20 minutes. The survey results revealed an average completion time of 13 minutes, and most students thought the activity was slightly shorter than the students' collective perceived optimal length. Lastly, most additional comments centered on minor suggested cosmetic changes to the module. A few students thought that more sample quizzes should be provided, while a few more thought that more examples of non-precipitating radar signatures should be given.

5. CONCLUSION

A web-based learning module was developed for the laboratory component of the AOS 441 undergraduate radar and satellite meteorology course. The learning module utilized numerous Java applets (e.g. AniS, QuizImage, ConceptTutor) to help students animate and visualize ground-based radar data in an effort to learn about radar signatures produced by non-precipitating phenomena. Students were able to immediately assess their ability to analyze and identify spurious radar echoes via a web-based QuizImage quiz lesson. Formative assessment of the learning module was gathered via a post-activity survey given to all of the students. The feedback gained from this assessment was positive, and all of the students felt that the module effectively addressed the learning outcomes presented at the beginning of the activity. Also, the students unanimously felt that the animations in the learning activity effectively helped them visualize the topics presented.

Future plans for the learning module, largely based on the initial feedback gained from this formative assessment, include:

1. Improving numerous cosmetic issues;
2. Including more examples of non-precipitating phenomena;
3. Experimenting with audio components to strengthen the learning efficacy of the module;
4. Incorporating universal design strategies to make the web module more accessible to sight or hearing impaired students;
5. Officially implement the learning module into the AOS 441 syllabus for the Spring 2007 semester, including a pre- and post-test assessment to better gauge the learning activity's effectiveness;
6. Development of web-based learning modules for different radar meteorology topics; and
7. Exploring the possibility of using the existing UW online teaching infrastructure contained in "Learn@UW" to administer pre- and post-module quizzes, as well as building a learning community through the use of the Learn@UW chat forum.

6. ACKNOWLEDGMENTS

The comments from Prof. Barb Ingham and two ETT class member peer reviewers are gratefully acknowledged. Dr. Tom Whittaker from UW SSEC provided invaluable assistance using the IDV software package.

7. REFERENCES

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Question	Results
1. How useful was the learning module 1(useless) to 5 (extremely useful)?	4.1
2. How easy was it to navigate the module: 1(very difficult) to 5 (extremely easy)?	4.3
3. Comment on the length of the module: 1 (too short) to 3 (just right) to 5 (too long)	2.1
4. How long did it take to complete the module?	13 min.
5. Would audio make the learning module more effective?	Yes (5) No (4)
6. Did the module effectively address the learning objectives stated?	Yes (9) No (0)
7. Do the animations help visualize the topics discussed?	Yes (9) No (0)
8. Would you like more of these learning modules in AOS 441?	Yes (9) No (0)
9. Add any additional comments regarding this learning module.	N/A

Table 1: Post-module survey questions administered to the AOS 441 students. Average numerical results or Yes/No tallies are indicated in "Results" column.

Sample Radar Loop

Let's first look at some sample radar data from a large scale perspective. The following radar loop shows a vigorous storm system o 12 and 13 March, 2006 that produced a wide variety of readily identifiable meteorological phenomena. Carefully watch th animation numerous times, though, to see if you can observe any features that may not be related to precipitation. The animation ca be controlled using the buttons above the image.

Start < >

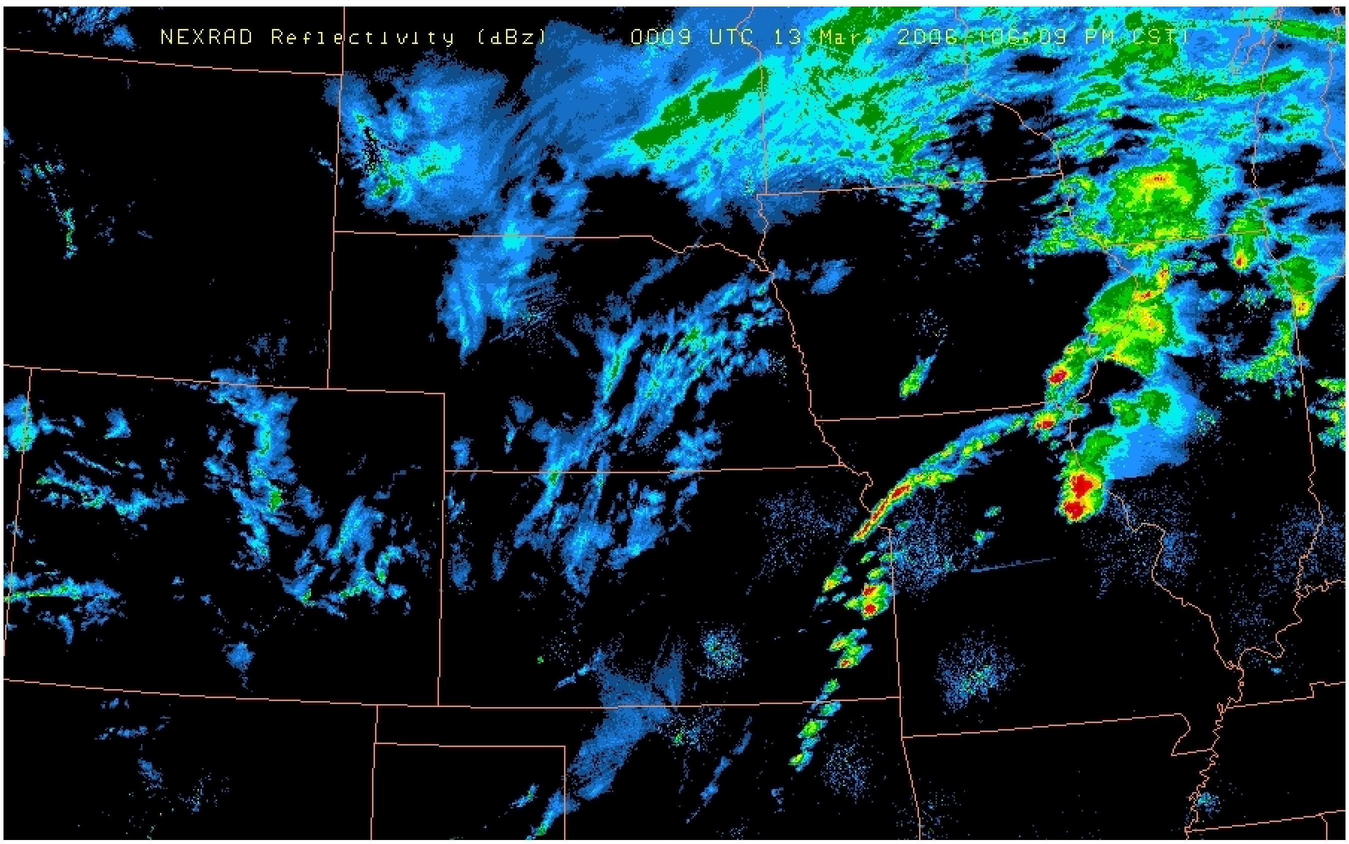


Figure 1: Snapshot of a sample radar reflectivity (dBZ) animation produced with the AniS Java applet.

Radar Snapshot

The image below is a snapshot at 2351Z, 12 March 2006 taken from the animated radar imagery on the previous page. As you move your mouse over the
image below, various radar features (both precipitating and non-precipitating) will be highlighted.

Move mouse pointer to discover things.

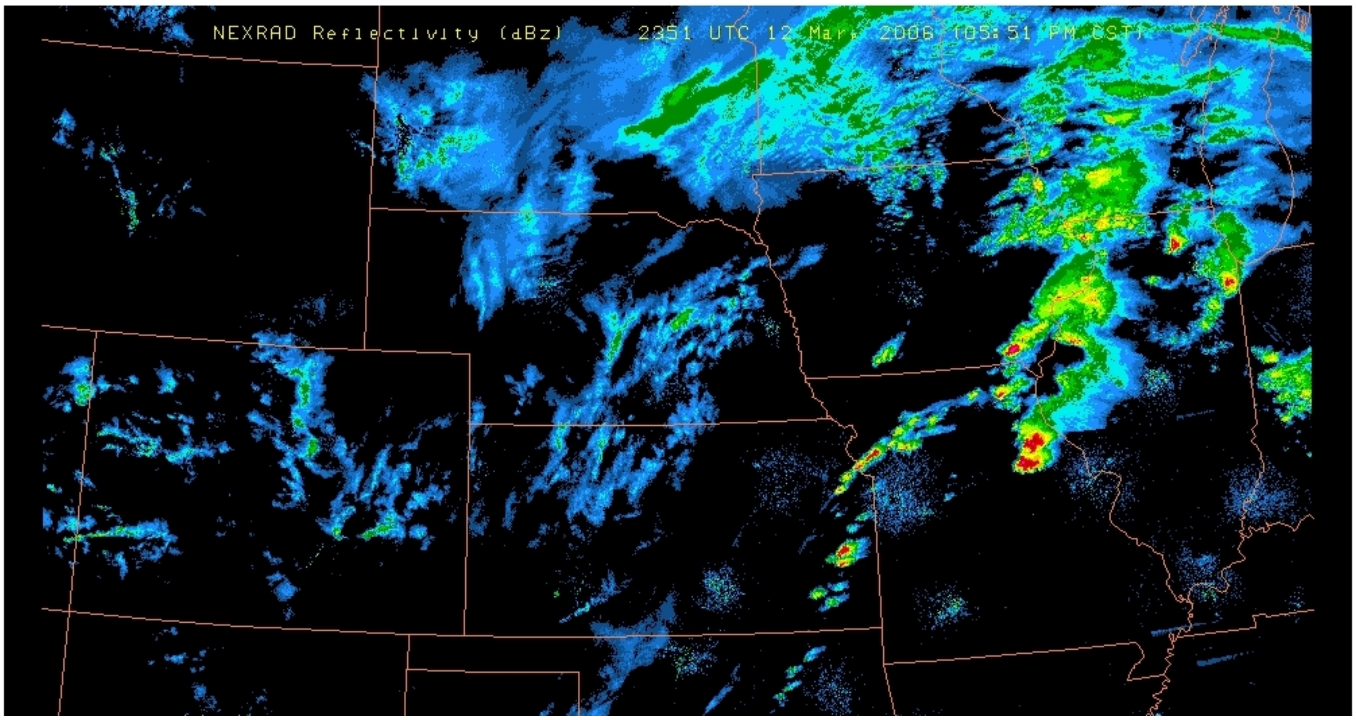


Figure 2: A snapshot of a sample QuizImage discover lesson.

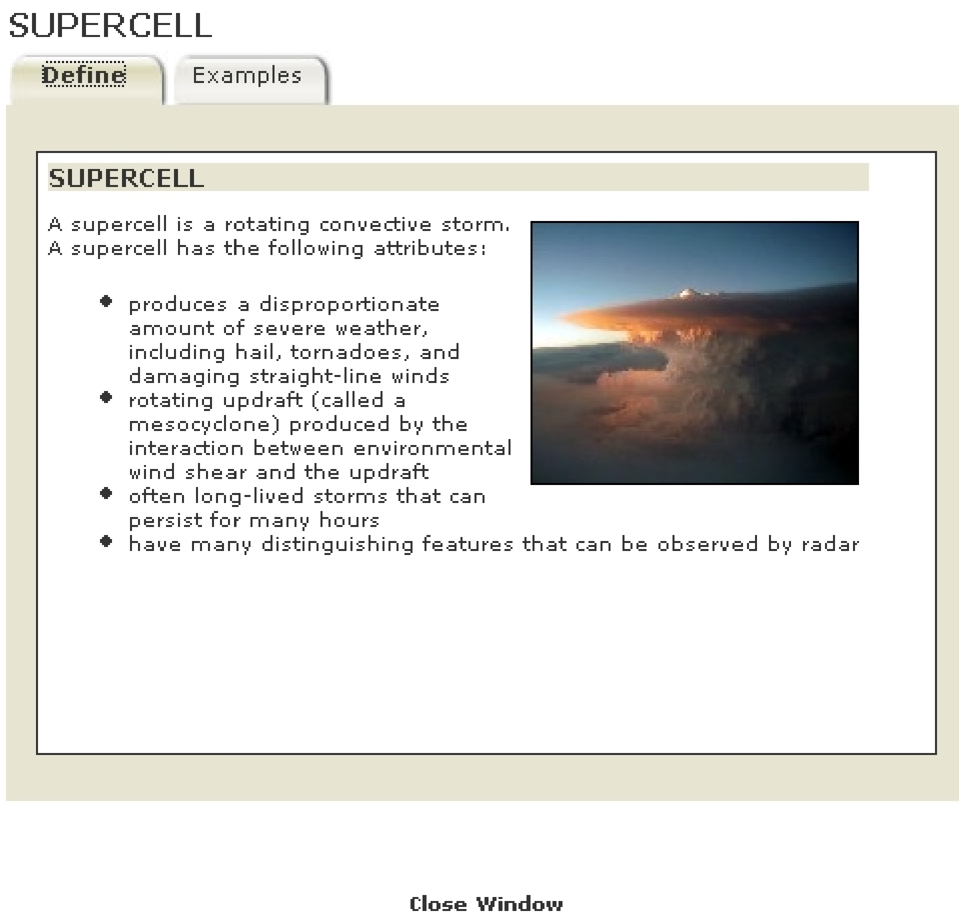


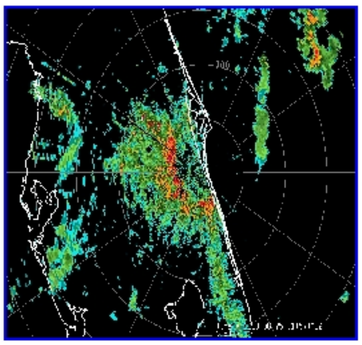
Figure 3: A sample ConceptTutor example used in the learning module.

Examples of Non-Precipitating Radar Echoes

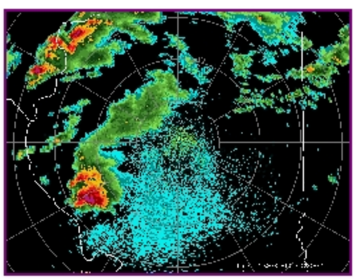
The previous animations highlight numerous examples of radar reflectivities associated with non-precipitating features. These non-precipitating radar echoes (often called "false" or "spurious" echoes) are often difficult to discern, especially when looking only at a static, individual base reflectivity image. As you progress through this learning module, combinations of the following criteria will be used to identify spurious radar echoes:

1. **Vertical continuity.** Is there vertical structure in the 3-D radar data? Most precipitation has vertical continuity, especially near the radar.
2. **Temporal continuity.** Does the radar echo have temporal continuity? Most precipitation has temporal continuity (bee careful...some non-precipitating echoes do to!)
3. **Radial velocity.** Most precipitating echoes have a non-zero radial velocity. Again, use this criterion wisely as many non-precipitating echoes have non-zero radial velocities.
4. **Echo pattern.** Use your meteorological instincts. Does the radar echo *look* like precipitation? This criterion can identify some spurious echoes, but is not entirely foolproof.
5. **Alternate data sources.** Surface observations and satellite imagery can help identify whether the radar echo is associated with precipitation.

Click on any of the below links to further investigate examples of the various non-precipitating echoes that were observed in the previous animations.



Anomalous Propagation Module



Clear Air Echo Module

Figure 4: Snapshot of the case study web page.