"THUNDERSTORMS IN A BOX": USING THE UW-NMS AND VIS5D TO AID STUDENTS IN THE UNDERSTANDING OF SUPERCELL THUNDERSTORMS

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1. Introduction
In the mesoscale meteorology course, at the University of Wisconsin-Madison, students are challenged to apply their classroom knowledge in a lab exercise referred to as "Thunderstorms in a Box". Over the years this lab has grown into a multifaceted, critical thinking exercise, as well as a department tradition. A strength of the lab is the use of the UW-NMS and VIS5D.

2. Design of Lab
This lab is designed for students at the senior undergraduate or graduate level in their meteorological education. The lab relies on students' ability to think critically and apply classroom knowledge. Students work in teams of 2-5 people throughout the course of this lab. The lab exercise consists of three different parts, and is completed over a two-week period of time.

2.1 Part A
The first part of the lab exercise asks students to create what they feel is the "ideal" sounding for creating a supercell thunderstorm. The sounding may not be from an actual event. Students create a vertical profile with the variables of temperature, dew point temperature, wind speed, and wind direction. Students have access to a computer script which calculates items such as CAPE, CIN, HEL, LI, BRN, etc., as well as vertical plots of theta-e, u and v, a hodograph, and a skew-t diagram. Figure 1 shows an example of one group's "ideal" sounding. By allowing students a way to easily check severe weather parameters of their sounding, students then keep adjusting their sounding until it reaches an "ideal" state. Once students are happy with their sounding they hand-plot their values on a skew-t diagram and a hodograph, as well as turning in a written description of what makes their profile conducive to super cell thunderstorm development. It is important that their descriptions of their sounding rely not on the severe weather parameters they attained, but on the physical reasons that their sounding could produce a supercell thunderstorm.

The "ideal" soundings created by the students are used to initialize a University of Wisconsin-Nonhydrostatic Modeling System (UW-NMS) simulation. An "ideal" sounding is used as the initial state at every point in the model. Forcing is applied in the form of a heat source in the center of the grid. Every group's model run receives the same amount of forcing. The heat source shuts off after about 20 minutes, relying on the integrity of the environment created by the sounding to continue vertical motions. The output from the UW-NMS simulations is written out in VIS5D files. Later in the exercise the students view VIS5D animations of their supercell thunderstorm.

2.2 Part B
The second part of the lab exercise focuses on the idea of a supercell index. Students are asked to create an index that can be used to predict the possibility of supercell development. The UW-NMS uses a supercell index in its operational runs. Students are given an explanation of the UW-NMS supercell index, before creating their own. Students determine what factors they feel are important in supercell development, and then must apply a quantitative weight to these factors. The only requirements of the index are that it has a quantitative scale and is easily applicable to the information typically found on an atmospheric sounding. Students are asked to hand in their index including a written description of the physical basis behind it. Each group then presents to the rest of the class their supercell index.

2.3 Part C
In order to tie Part A and Part B together, students test their supercell index. Students share their group's "ideal" sounding with all the other groups. Each group

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then applies their supercell index to all the other soundings. At this point the students still have not seen the VIS5D animations, so they do not know which soundings have produced supercell thunderstorms. Based on their groups supercell index students begin to get a feel for which other group(s) created a successful “ideal” sounding.

The culmination of the lab is when the whole class gets to see the VIS5D animations of each groups UW-NMS simulation. Before we show each animation we look at the groups “ideal” sounding and hodograph. Members of that soundings group explain how features in their sounding are conducive to supercell development. The other groups provide input on how they think the sounding will work based on how the sounding performed with their supercell index. We then look at the VIS5D animation for the group (Figure 2).

3. Why this lab works

The strength of this lab as an educational exercise is that it has components that appeal to every type of learner. Kinesthetic learners, who learn by doing, get very involved in continually adjusting their sounding to make it “ideal”. The creation of a supercell index provides the hands on type of exercise that kinesthetic learners crave. Auditory learners, who learn by hearing, benefit from the group presentations. The class discussions about how to create a supercell index, and what makes a sounding conducive to supercell development reinforce what they are doing in their groups. VIS5D animations, while interesting to all students, help visual learners to be able to conceptualize the three dimensionality of supercell thunderstorms. Classroom chalkboards are limited to two dimensions and thus force educators to draw thunderstorms from various angles. VIS5D allows a storm to be viewed from the south, and then rotated in a continuous motion, so that it may be viewed from the top, bottom, east, west, etc.

This lab exercise also appeals to both creative and structured students. Students, who crave structure in an exercise, benefit from the quantitative nature of the supercell index. Students who thrive in creative environments enjoy the freedom of being able to make their own “thunderstorm”. Students' working in teams is beneficial to competitive and non-competitive students. Within each team students feel part of a group and improve their skills of sharing ideas, listening to each other, and compromise. While the teams work on harmony within, each team is trying to outdo the other teams. Every team is trying to create the most impressive supercell thunderstorm. The “Thunderstorms in a Box” lab allows students to compete for bragging rights of having either the best supercell thunderstorm, and/or the most accurate supercell index.

While this lab challenges students in many different areas, perhaps the most important reason that this lab is a success is that it is fun. On the day we show the VIS5D animations, students from past years have attended class. This lab gives students the pride of having made a “thunderstorm in a box”; while at the same time challenges them to apply classroom knowledge, work in groups, and think critically.

4. Future Goals of Lab

This lab exercise still has room for growth and development. In past years either the instructor or the teaching assistant of the class has run the UW-NMS simulations. Teaching students how to run their own model simulations would be a useful addition to the exercise. The supercell indices created in this exercise are applied only to other groups’ “ideal” soundings. In the future, students may be required to test their index on some historically significant supercell thunderstorm events.

5. References