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METR 341: Synoptic Meteorology—A Peer Review of Teaching Project Inquiry Project

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Peer Review of Teaching Inquiry Portfolio (2014)

METR 341 (Synoptic Meteorology)

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I. Objectives of this Portfolio

The course discussed in this inquiry portfolio is meant to lead students toward their capstone experience, and as such should bring students nearer an integrated conceptual model of how the atmosphere works. As such, the project presented in this inquiry portfolio was designed to investigate characteristics of course activities which lead students toward this deeper level of conceptual understanding and ability to apply what they have learned through many semesters of courses. Several types of activities are investigated in terms of how much students think they are learning from them, how much students enjoy the activities, and actual resultant student learning gains. Resulting from this analysis, suggestions will be made about which activities optimally engage students to develop an ability to apply their knowledge to real-world weather scenarios.

II. Background of the Problem to Investigate

A. Course History and Development

METR 341 (Synoptic Meteorology) is a course in which students develop an understanding of large-scale atmospheric processes. They learn about the meteorological data necessary for forecasting and diagnosing weather situations, and the codes used to transmit these data internationally. Given this background, students learn how to use these data in conjunction with concepts from much of their prior coursework to explain weather observations in a particular region or location. Students are expected to use their knowledge to produce forecasts of future weather conditions, and to provide high-quality diagnosis of weather events in a case study context; case studies are often based on prior weather systems and scenarios, but can use ongoing weather events. Surrounding this course, students have typically taken or are concurrently taking other atmospheric science coursework in dynamic meteorology, physical meteorology, and atmospheric thermodynamics. A few students come to METR 341 without one or more of these courses. Following this course, students typically take more advanced coursework in dynamic meteorology and specialty topics in atmospheric science.
Advanced Synoptics (METR 442) follows this course, and serves as the capstone course for many meteorology-climatology majors. Thus, though METR 341 must serve to give all students a strong foundation in synoptic meteorology, it must also prepare the subset of students who will take Advanced Synoptics as their capstone course.

Students in METR 341 are all meteorology-climatology majors, mostly at the junior level. Thus, they are mostly very interested in the course material and come to the course with a good idea of how it fits with the larger body of atmospheric science content. Motivating students is therefore generally not problematic. One significant challenge is the differing prior coursework of students in METR 341. Many come having not yet taken atmospheric dynamics. Synoptic meteorology can be taught in a very conceptual way, in a very theoretical and mathematically rigorous way, or preferably (at the undergraduate level) via some combination of these. We necessarily cover some dynamics concepts, including the background mathematics, and some students take to this approach much more readily than others. For students who have not yet taken dynamics, METR 341 also serves to introduce them to many fundamental dynamics concepts which they will learn about more in depth in following coursework.

As an instructor in my third year at UNL, this has been my first semester teaching METR 341. I will be teaching the following capstone course in the next semester. Thereafter, I and another instructor will alternate years teaching this course sequence. Synoptic meteorology is an area I have enjoyed and tend to focus on when teaching other courses, and I received graduate-level training in this area. So developing course content was not challenging—my most significant challenge was designing activities to best engage the students, and getting a sense of the time commitment required by students to participate fully in these activities. I was completely in charge of developing the course, and did so by defining several objectives and outlining the fundamental material that needs to be covered in such a course. The objectives allowed me to develop appropriate activities for the students, and the outline of necessary course content allowed me to develop a series of lectures on which course activities were based. While developing lab exercises, I drew from some activities used in prior sections of this course.
The course design evolved in a distinct series of steps. An initial course outline was developed during early summer 2012 shortly after I first learned I would be teaching this course. As I had several other courses to develop between then and my teaching of this course, not much else was done with METR 341 other than minor changes to the course content. More substantial work was done on the lectures in summer and fall 2013, and they were completed around the time my section of METR 341 first met. Homework assignments and lab exercises were also developed mostly during the fall 2013 semester. As I began teaching the class, my understanding of what skills needed to be developed in the students changed significantly, and I revised the course outline near the beginning of the semester with this in mind. I also slightly modified assignments and lab exercises at this time. During the early spring 2014 semester I also learned about several alternative teaching methods, and decided to incorporate some of those methods. Through the semester as students were surveyed, further modifications were made to address their comments about what was working particularly well or poorly. My experience through this course will also substantially influence how I develop the following capstone course.

B. Identification of a Research Question

No benchmark portfolio was written about this course, so there was no obvious place to start for developing a specific research question to be addressed in this inquiry portfolio. To identify a research question, I went to my field’s expectations for what specific learning gains should occur in this sort of course, on which my course objectives were based. Given these expectations and objectives, I decided to investigate which particular teaching strategies lead to the most significant gains in these directions. The research question was further focused by considering one particular course objective. These were the objectives for METR 341, listed in the syllabus (Appendix A):

1) Develop a good understanding of large-scale atmospheric processes.
2) Be able to apply course concepts, integrated with concepts from prior coursework in atmospheric science, to new situations.
3) Clearly communicate your science in verbal and written form.

In particular, Objective 2 is perhaps the most significant outcome of a synoptic meteorology course—students integrate their knowledge of the atmosphere into a working model, and begin applying that model to weather situations. If students learn to do this the course has been largely successful, so it was a natural question how best to fulfill this objective.

Many types of activities can be incorporated into a synoptic meteorology course, and many types of activities can be useful to help students reach Objective 2. Given the broad array of possibilities, limited course meeting time, and limited time outside of class which students can use for this course, a significant question is which activities best promote development of the skills students need to begin applying their knowledge correctly to new weather situations.

This became the primary question to be addressed in this inquiry portfolio—what activities are especially helpful to students in this regard? To answer this question, learning gains are quantified for various types of course activities. One significant limitation of this study is the very small class size (n=5)—changes to the METR 341 prerequisites in the prior year significantly dropped enrollment below typical values (n=10-20). Nevertheless, the investigation reported here is useful since it identifies optimal instructional methods for this course, which can be further tested in future course offerings with more students.

It is important to investigate this problem, since synoptic meteorology is one of the most fundamental building blocks of a rounded conceptual model of how the atmosphere works. Many students who take this course will eventually use their training as forecasters, in other capacities requiring atmospheric diagnosis, or in graduate school. Thus, it is critical to ensure that this piece of the training received by students in the meteorology-climatology major is especially strong. The investigation reported in this inquiry portfolio was designed to identify optimal instructional practices in and out of the classroom. These practices represent good ways for students and instructors of this course to use their limited time to reinforce knowledge and application skills. In addition, practices identified as useful in this course may be applicable to similar courses in which students are applying knowledge to diagnosis of weather events.
Given that little work of this sort has been published or presented in the field of atmospheric science, future research of this sort may make a particularly large impact on student learning.

From the student perspective, this issue is important to investigate. Building a conceptual model of the atmosphere requires many pieces, and students do not typically have a chance to put this model together until their synoptic meteorology course. By that point, students typically only have one more year in the major, which is little time to build expertise at applying their conceptual model. Thus, students would be interested to receive practice with this higher-order thinking before being required to do similar things in, for instance, a job after graduation. Other than this course and their capstone course, students receive little experience applying their conceptual model of the atmosphere, making it all the more critical that instructors do this well in these courses.

C. History and Significance of Research Question
METR 341 is the course in which students, historically, have first had to publically present their thinking about weather situations via weather discussions. It has often been observed by the author and other synoptic meteorology instructors that students typically come to this task with little understanding of how to do it well. This observation has also served to increase the author’s interest in how such skills can be developed in students. The author has personally not tried to address this issue before, since this is the first time the author has taught this course. Other instructors, however, have given students many opportunities to lead weather discussions, during which the student giving the discussion is questioned by their peers and instructor. During the spring 2014 section of this course, while still including this method, the author did not rely as heavily on it, instead favoring more collaborative context-rich activities which also allowed for immediate instructor feedback.

Many activities have been included in this offering of METR 341, some of which were quite time-consuming for the students to complete and for the instructor to develop and grade. Though these activities help students meet course objectives, it would be best to focus on
activities which most develop the students in desired directions. Focusing on these activities could leave more time for classroom discussion, and more time for students to analyze ongoing weather situations outside of class. If this issue was fully addressed in METR 341, students would leave the class with a strong conceptual model of the atmosphere and the ability to apply that model, and would be prepared for their capstone course. This would ideally be achieved without ‘busy work’, via methods which students enjoy, while leaving students sufficient time to apply what they are learning in additional contexts.

III. Hypothesis and Methodology

A. Literature Background and Hypothesis Statement

The goal of this project is to investigate which methods of teaching are optimal for promoting student learning toward desired outcomes, as specified in the course objectives. To develop a specific hypothesis about which particular instructional methods are optimal, the literature was explored in this area. Though little education research specific to atmospheric science has been published, guidance in the broader geoscience education literature and the literature of several other physical science disciplines was useful for developing a specific hypothesis.

Student learning can be thought of as a progression from novice to expert thinking, and a progression toward expert thinking is facilitated by scaffolded learning experiences which integrate students’ prior learning (NRC 2000). Effective instruction requires some understanding of students’ prior cognitive and affective development, and may include metacognitive elements in which students reflect on the learning process. In addition, a constructivist learning approach has been put forward as beneficial for student growth (e.g. Smith 2002). In this approach and within the context of atmospheric science, students could be given real-time and/or locally-applicable data and asked to form questions, design an investigation, generate explanations for an observed phenomenon, and communicate their results effectively. This process of scientific inquiry requires students to develop more expert-like views as they apply prior and new knowledge to a new weather situation. Such scientific inquiry is more common in advanced atmospheric science courses, after students have learned
much of the fundamental background material. METR 341, the subject of this inquiry portfolio, is a course in which students should begin developing the types of thought leading to scientific inquiry.

Few prior studies have investigated optimal instructional methods in atmospheric science, especially in the context of advanced coursework. The literature notes the necessity of including observational data and instrumentation, to balance the theoretical approach common in many atmospheric science courses (e.g. Etherton et al. 2011). A purely theoretical approach may lead to the loss of many atmospheric science majors (e.g. Roebber 2005), but can be softened by the inclusion of real data in an interactive setting. The approach of using real data in class exercises has been reported in lower-level atmospheric science courses (e.g. Grundstein et al. 2011) and an upper-level undergraduate course (Godfrey et al. 2011). Results of these instructional methods have been mixed; not all have demonstrated increased student learning.

Another potentially-useful element of effective teaching is the inclusion of authentic research experiences in the curriculum, which has been done effectively in a broad range of courses (Quardokus et al. 2012). At the undergraduate level, an effective strategy is to teach background material, have students collect and analyze data toward solving a guided research problem, and then have students design their own research question and execute their own research plan. Ideally these experiences lead to results helpful to the instructor’s research, and have been shown to increase the likelihood that students will go into science careers when they graduate (Hopper et al. 2013). Students are motivated to grow more rapidly when such activities are utilized because they see themselves as part of a larger research initiative, and because of the benefits of peer collaboration and scaffolding (Quardokus et al. 2012).

Additional instructional methods presented in the atmospheric science literature as potentially optimal in certain contexts include hands-on experiments, which students cited as helping to reduce their misconceptions (Mackin et al. 2012), and the use of instrumentation and associated experimental design (Horel et al. 2013). The use of instrumentation or other data
collection activities gives students a chance to become especially close to the development of scientific research, a valuable experience which many students enjoy and appreciate. Success of any such methods should be facilitated by the inclusion of meaningful student-instructor interaction (Cornelius-White 2007).

In addition to the relatively sparse literature on specific teaching methods in the atmospheric sciences, many alternative pedagogies have been proposed and discussed at length in the literature, and many have been applied with success in other physical sciences. Given these successes, and the ease of inclusion of real-time data in atmospheric science coursework including METR 341, several alternative pedagogies were introduced to varying degrees within this course. These pedagogies include the following:

1) Teaching with Case Studies: students are led through an analysis of a weather situation, whether past, current, or theoretical, and they must reach valid conclusions (e.g. Herreid 1994). For example, many METR 341 lectures contained past cases which were analyzed in depth as a class, including class discussion and instructor feedback.

2) Contextual Instruction: students are led through real-world, and often real-time, problems and situations. For example, many METR 341 meetings began with a discussion of current weather, led by one of the students or the instructor.

3) Problem-based Learning: student groups are given a situation and asked to solve some problem using the data given, exercising their ability to apply their knowledge in a new context and their ability to communicate their science with others. For example, several times the METR 341 class was split into groups, and each was given a particular weather situation (such as a historic winter storm event) and asked several questions about the event (such as where would receive the most significant winter weather impacts, and what those impacts would be). Groups then shared their data and conclusions with the larger group, who provided feedback along with the instructor.

4) Just-in-Time Teaching: students are given a problem to complete prior to class, and the instructor uses student answers to modify instruction to address misconceptions and strengthen places where student understanding is weak (e.g. Novak and Patterson...
1998). Students may also be anonymously shown each other’s answers, which serve as a basis for discussion. Many additional alternative instructional methods have been presented in the literature, which could be introduced to atmospheric science coursework. Effects of such coursework additions could be a fruitful basis for future studies.

Given this literature background, the specific hypothesis developed is that students’ analytical thinking and ability to apply concepts in synoptic meteorology, measured by their capacity to respond with correct reasoning given new situations, is most increased by context-rich in-class activities, and especially by activities in which groups of students receive immediate feedback from their peers and instructor on the soundness of their reasoning. Next, methods used and data collected to test this hypothesis will be described.

B. Methods of Inquiry
To test the hypothesis presented above, data needed to be collected for a broad array of course activities, including level of interaction with peers and instructor, and degree and temporal scale of feedback received. Then, learning gains resulting from particular activities needed to be quantified. To assess student reaction to various activities, students were asked how significant of learning gains they felt were associated with different activities, and how much they enjoyed these activities. Then, student perceptions of learning could be compared with actual learning gains.

Students often find it challenging to learn and effectively apply material in synoptic meteorology, though reasons for this difficulty are not well-understood. At this course level, students are typically well-motivated, as they have taken several atmospheric science courses and usually only have one year remaining prior to graduation. Time may be an issue for some students, as many are balancing several other courses alongside METR 341. This was brought up by students as a possible inhibitor of student success in this section of METR 341. Ability is not likely to be a significant issue, though practice thinking in the way required in METR 341
(and the following capstone course) is typically uncommon to this point in the curriculum. Atmospheric science consists of many fundamental building blocks, which must be put together into a coherent mental model before optimal application occurs. A significant purpose of METR 341 is to encourage students to begin thinking in this systems-oriented way.

Data useful to address this issue includes course assessments such as exams and homework assignments, survey responses from students, and qualitative instructor assessments of student engagement in particular activities. Linking observable learning gains with particular course activities provides a means of quantifying instructional effectiveness. Such estimated quantifications are not precise measures, but will be insightful in a relative sense (e.g. one instructional method produces a greater learning gain than another). The value of a quantified study is also limited by the small course enrollment during this section (n=5), as described earlier. The dynamics of such a small course are very different from those in a larger course, as in- and out-of-class interactions are quite different in a class with 5 students than in a class with 15 students (the typical METR 341 enrollment) or more.

Other avenues exist which might provide helpful information for assessing the effectiveness of teaching in METR 341. For instance, the instructor undertook reading of the pedagogical literature to understand several alternative instructional methods, and further work along these lines might lead to the incorporation of additional useful strategies. A longitudinal study, though beyond the scope of this project, would be highly insightful—students could be assessed prior to entering METR 341, followed through the course via detailed measures of learning, and surveyed throughout their final undergraduate year (following METR 341) to see the extent to which concepts learned in the course were applied in later coursework. Such longitudinal studies are rare anywhere in the natural sciences, but hold significant promise for obtaining a more holistic view of student development through their undergraduate years.
C. Data Collection

Several data sources were collected, representing student performance on and perceptions of activities on several distinct temporal scales. Feedback on the products of these activities was also received by students on several temporal scales. The following sources of data were gathered:

- Measures of reasoning and conceptual model application when presented with a new situation, and how these skills have changed over the semester (learning gains):
  - Exam questions focus on application of specific course concepts, and can be linked to specific activities in which these concepts were reinforced. The focus here will be the final exam, in which all students (n=5) participated.
  - All students also completed an initial survey on the first day of class (Appendix B), and 2 students completed a final survey which was due at the final exam (Appendix C). These surveys contained the same question asking students to describe the process they would use to produce a forecast for an unfamiliar location. The same question appeared in a slightly altered form on the final exam. These items will be used to get a sense of student longitudinal growth in their understanding of this key concept from synoptic meteorology.

- Measures of student perceptions about various course activities:
  - Two mid-semester surveys were given with full participation (n=5) on which students were asked how much they learned as a result of various activities, and how much they enjoyed those activities (Appendix D). Activities about which students were specifically questioned included:
    - Lectures: material was presented in a traditional lecture setting as a series of PowerPoint presentations. Given the small class size, lectures were more interactive than in a usual course, and frequently included discussions of ongoing weather and diversions to investigate questions posed by the students. Interaction and feedback were relatively low in lectures compared to other instructional methods.
In-class activities: this broad category included a variety of activities during class time, most commonly problem-based learning and contextual instruction activities (see Table 1, below). These activities ranged from low to high in terms of interaction and feedback.

In-class weather discussions: many classes were started with an interactive discussion of ongoing weather, during which the focus was on concepts being taught currently or recently. The instructor led these weather discussions. They are considered a subset of in-class activities (included below in Table 1), but were specifically asked about on surveys.

Homework assignments: several take-home assignments were given through the semester, which gave students opportunities to apply course material or investigate topics of personal interest. Relative to other course activities, homework was considered low in terms of interaction with others and feedback received. This was the course activity on the longest temporal scale.

Lab exercises: in their weekly lab meetings, students completed a series of exercises designed to have them use meteorological data to describe and/or explain certain atmospheric phenomena. These exercises also took place on a relatively long temporal scale, since students often had more than a week to complete them, and were considered low on the spectrum of interaction with others and feedback received.

In-lab weather discussions: these were similar to the in-class weather discussions, but were occasionally led by the students. Interaction and feedback were often observed to be lower than during in-class weather discussions. Using the data available, it would not be possible to separate gains resulting from the two types of weather discussions.
Table 1: In-class activities through the spring 2014 section of METR 341. Duration of activity is included, along with relative assessment of the degree of interaction with peers and feedback from instructor in each activity (1=low, 3=high).

<table>
<thead>
<tr>
<th>Date</th>
<th>Activity Type</th>
<th>Brief Activity Description</th>
<th>Duration (min)</th>
<th>Peer Interaction</th>
<th>Instructor Feedback</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-23-14</td>
<td>Wx Discussion</td>
<td>Discussion of current wx</td>
<td>25</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>1-28-14</td>
<td>Wx Discussion</td>
<td>Ongoing winter storm discussion</td>
<td>35</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>1-30-14</td>
<td>Group Case Study</td>
<td>Students asked to discuss maps in groups &amp; develop forecasts</td>
<td>20</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>2-11-14</td>
<td>Wx Discussion</td>
<td>Likely winter storm discussion</td>
<td>40</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>2-13-14</td>
<td>Journal Article Discussion</td>
<td>Each students takes section of article and leads discussion</td>
<td>25</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>2-25-14</td>
<td>Problem-based Learning</td>
<td>Groups given case study to discuss &amp; present to full group; verification</td>
<td>20</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>3-6-14</td>
<td>Problem-based Learning</td>
<td>Groups given case study to discuss &amp; present to full group; verification</td>
<td>40</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>4-3-14</td>
<td>Group Theoretical Situation</td>
<td>One group develops solution to theoretical situation; verification</td>
<td>20</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>4-8-14</td>
<td>Contextual Forecast</td>
<td>Lecture about forecasting: chose site &amp; produced forecast as group</td>
<td>50</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>4-10-14</td>
<td>Just-in-Time Teaching</td>
<td>Students answer questions prior to class, which informed discussion</td>
<td>10</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>4-17-14</td>
<td>Contextual Forecast</td>
<td>Applied temperature forecasting concepts to new site as group</td>
<td>20</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>4-22-14</td>
<td>Problem-based Learning</td>
<td>Groups given case study to discuss &amp; present to full group; verification</td>
<td>35</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>4-24-14</td>
<td>Case Study</td>
<td>Went through case as full group</td>
<td>10</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>4-24-14</td>
<td>Problem-based Learning</td>
<td>Groups given different aspects of upcoming weather to discuss/share</td>
<td>15</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

The primary dependent variable to be measured is learning gain on particular concepts. Secondary dependent variables include student perceptions of their learning resulting from particular course elements, and their enjoyment of each of those elements. Independent variables which might predict outcomes in these areas include types of activities included in the course and their temporal duration, degree of peer and instructor interaction, and degree of peer and instructor feedback.
Since the author has not offered this course in the past, usual assumptions about consistent presentation through time are invalid. The primary (and admittedly quite large) assumption of this project is that the small number of students enrolled forms a representative sample of the larger population from which students in this course are typically drawn. With such a small population, the ability for any one student to skew final results is large. In addition, interpersonal dynamics are different from what would be expected in a larger course. The increased frequency and degree of interaction and feedback in this section of METR 341 may mean that a certain set of instructional methods were particularly effective, but the same set may not be identified in a larger class. This is potentially a negative outcome of the small class size, but also provides further opportunity for testing the results of this inquiry portfolio project.

IV. Data Analysis and Assessment of Findings

A. Interpretation of Data: Learning Gains

In this section, observed level of and changes to student understanding will be presented. Understanding in several areas will be assessed: a) specific understanding of the forecast process, a key concept in synoptic meteorology; b) level of understanding demonstrated on final exam questions, along with an assessment of how these concepts were reinforced for students; and c) understanding of the place of synoptic meteorology within the field of atmospheric science, and the importance of knowing something about synoptic meteorology. In area (b), learning gains will be related to levels of interaction, feedback, and temporal scale of associated activities.

In an initial survey, given the first day of class, students were asked to “please outline the process (procedural steps) you would follow to make your forecast,” where a specific forecast location had been identified earlier in the question (Appendix B). The same question was asked on the exit survey (Appendix C), and on the final exam. Since only 3 students provided responses to the exit survey, final exam responses will be compared with entrance survey responses to this question. Entrance survey and final exam responses to this question are
included in Appendix E. Though there is no correct response to this question, a list of approximately ten major considerations is expected, and many minor considerations could be listed. The number of reasonable considerations provided by each student in the entrance survey and final exam is presented below (see Table 2):

Table 2: Number of valid forecast considerations mentioned by students at the beginning of the semester and on the final exam.

<table>
<thead>
<tr>
<th>Student</th>
<th>Entrance Survey</th>
<th>Final Exam</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>8</td>
<td>11</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>14</td>
</tr>
<tr>
<td>3</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>4</td>
<td>6</td>
<td>17</td>
</tr>
<tr>
<td>5</td>
<td>3</td>
<td>13</td>
</tr>
<tr>
<td>Average</td>
<td>5.2</td>
<td>12.6</td>
</tr>
</tbody>
</table>

All students were able to discuss more considerations at the end of the semester (average n=12.6) than at the beginning (average n=5.2), with an average increase of 142%. Several students made significant gains in this area, and most were able to produce a clear, well-formulated list of considerations by the final exam. In addition, student responses indicated better understanding of forecasting as a process rather than a disconnected set of steps, as was the case at the beginning of the semester (Appendix E). The perceived role of model guidance also changed through the semester. Many students come to synoptic meteorology courses with an overreliance on model guidance, and one goal is that they will begin to think about weather observations first and consult model guidance secondarily. At the same time, though, students need to understand that model guidance can be very useful, and should not neglect it during the forecast process—it requires its proper place. Only one student mentioned the use of model guidance on the entrance survey, a surprising result. This student appeared to have the typical overreliance on model guidance seen in students at this level. By the end of the semester, all 5 students mentioned model guidance in their discussions, and no students appeared over-reliant on model guidance. This qualitative improvement is seen as an important learning gain. This section of material was taught via an in-class example through
which the students and instructor produced a forecast for an unknown site while learning about the procedure to do so. Among course activities through the semester, this activity was near the top in terms of instructor-student interaction and immediate feedback.

Final exam questions were related to activities in which students had the appropriate concept(s) reinforced, and average scores on final exam questions were calculated (see Table 3). Groups of questions with especially high or low performance relative to the average for each difficulty category were investigated in terms of which activities had most strongly reinforced those concepts.

Table 3: Average score on each final exam question, and activities most strongly reinforcing the topic tested in each question. Average scores are color-coded from highest to lowest average scores, in the order blue (highest), green, yellow, orange, red (lowest). Difficulty level ranges from 1 (easy) to 3 (difficult), based on instructor assessment of how challenging a particular problem should be. Question number and primary reinforcing activity are shaded green if average score was >10% higher than the difficulty category average, and red if average score was >10% lower than the difficulty category average.

<table>
<thead>
<tr>
<th>Question</th>
<th>Avg. Score</th>
<th>Diff. Level</th>
<th>Primary Reinforcing Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>75</td>
<td>2</td>
<td>Lecture</td>
</tr>
<tr>
<td>2</td>
<td>51</td>
<td>3</td>
<td>Homework</td>
</tr>
<tr>
<td>3</td>
<td>68</td>
<td>3</td>
<td>Homework</td>
</tr>
<tr>
<td>4</td>
<td>80</td>
<td>2</td>
<td>Wx Discussions</td>
</tr>
<tr>
<td>5</td>
<td>65</td>
<td>1</td>
<td>Lecture</td>
</tr>
<tr>
<td>6</td>
<td>100</td>
<td>1</td>
<td>Wx Discussions</td>
</tr>
<tr>
<td>7</td>
<td>100</td>
<td>1</td>
<td>Wx Discussions</td>
</tr>
<tr>
<td>8</td>
<td>60</td>
<td>2</td>
<td>Homework</td>
</tr>
<tr>
<td>9</td>
<td>60</td>
<td>2</td>
<td>Lecture</td>
</tr>
<tr>
<td>10</td>
<td>66</td>
<td>3</td>
<td>Homework</td>
</tr>
<tr>
<td>11</td>
<td>79</td>
<td>3</td>
<td>Group Theoretical Situation</td>
</tr>
<tr>
<td>12</td>
<td>57</td>
<td>2</td>
<td>Lecture</td>
</tr>
<tr>
<td>13</td>
<td>57</td>
<td>2</td>
<td>Wx Discussions</td>
</tr>
<tr>
<td>14</td>
<td>96</td>
<td>2</td>
<td>Contextual Forecast</td>
</tr>
<tr>
<td>15</td>
<td>65</td>
<td>2</td>
<td>Lecture</td>
</tr>
<tr>
<td>16</td>
<td>67</td>
<td>1</td>
<td>Lab Exercise</td>
</tr>
</tbody>
</table>
Difficulty level of final exam questions was coded as easy, moderate, or difficult based on the instructor’s assessment; students may not agree with these values (Table 3). Average score was 80.5% on easy questions, 65.7% on moderate questions, and 56.8% on difficult questions. Questions on which the average student score was >10% higher or lower than this average value were thought to test topical areas of which students had an especially strong or weak understanding. Thus, these questions were thought to represent those best-suited to assess which reinforcing activities provided the most or least optimal means for students to practice applying their knowledge in a way that would stay with them for some time.

Eight questions were answered with an above-average level of understanding among questions in their difficulty category (question numbers shaded in green in Table 3). Of these questions, 4 had been reinforced primarily through weather discussions, and 1 each had been primarily reinforced through homework, a group theoretical situation exercise, a contextual forecasting exercise, and a problem-based learning exercise. Except the question reinforced primarily by homework, the primary activities supporting these questions were conducted within class time, and were characterized by a high degree of peer interaction and instructor feedback. These activities were generally of short temporal scale, but learning gains were also significant with homework in one case, which had the longest temporal scale of any course activity. Thus, temporal scale of activities does not preliminarily appear to be as significant as ensuring that students receive timely feedback and are able to discuss their reasoning with others.

Five questions were answered with below-average understanding for their difficulty category (question numbers shaded in red in Table 3). Four of these questions had been reinforced
primarily by the lecture, with little discussion of these concepts outside of lecture. The other question had been reinforced primarily through a lab exercise. Primary activities supporting these questions were mostly conducted outside of the regular class or lab meeting time (e.g. reviewing lecture material, working on a lab exercise), and were characterized by a low degree of peer interaction and instructor feedback.

Students demonstrated a near-average understanding for their difficulty level on the remaining ten questions. These questions were primarily supported by lectures (n=5), homework (n=3), and weather discussions (n=2). Some concepts covered primarily in lecture were well-understood, while others were not. The difference may be that students considered some topics particularly important so studied them more. Two questions on which student understanding was especially poor (numbers 21 and 22; see Table 3) had been covered in a lecture during the week preceding the final exam, when students were working on long-term homework assignments and studying. Students generally learned material from lecture at an average level, as long as they had sufficient time to process that information. Reinforcement by homework also seemed to provide students with an average to slightly above average understanding of concepts.

Results on the final exam clearly show that certain activities are better than others for developing deep conceptual understanding and application ability in students. Course activities characterized by strong peer interaction followed by immediate instructor feedback lead to optimal learning gains, while those characterized by little peer interaction and delayed or no instructor feedback lead to relatively poor learning gains. Notably, all questions reinforced by a collaborative in-class activity were answered with higher-than-average understanding for questions in their difficulty category. Reinforcement primarily by homework assignments generally led to average learning gains, and concept exposure only in lecture generally led to below-average learning gains. The general value of activities in which peers interact, reach a conclusion, and then receive immediate instructor feedback has been documented in prior literature (e.g. Prince 2004). Worth stressing is the small sample size in the study reported
here, which limits the broad application of these results without further research. In synoptic meteorology, where a wide variety of archived and real-time data are available, it is reasonable to assume that active learning exercises should motivate students and promote their deeper learning, so these activities are recommended in future courses.

Finally, it is hoped that students will gain an appreciation for the value of synoptic meteorology, and will see how it fits with a broader understanding of atmospheric science. On the entrance and exit surveys, students were asked the following questions:

a) What do you perceive as the value(s) of knowing something about synoptic meteorology?

b) From your perspective, where/how does synoptic meteorology fit into a rounded picture of the atmospheric system?

Student responses to these questions are presented in Appendix F. What can be said about student responses to these questions is severely limited by the small number of students who turned in a final survey (n=2).

On the first question, students were asked what the value is of knowing something about synoptic meteorology. Initially, one student indicated that knowledge of large-scale processes was critical to understanding smaller-scale weather features (Appendix F); on the exit survey this student replied with similar reasoning but stronger verbiage, noting the foundational aspect of synoptic meteorology. The second student initially indicated synoptic meteorology is valuable because of being able to forecast severe weather, which is a topic shared between synoptic and mesoscale meteorology. By the exit survey, this student indicated application of synoptic meteorology to broader forecasting problems, and also recognized synoptic meteorology as a basis for this area. Though student reasoning on this question was not markedly changed through the semester, students exited the course with a clearer view of the foundational aspect of the science they had learned.

On the second question, students were asked how synoptic meteorology is related to the rest of atmospheric science. The first student replied with similar reasoning on both the entrance and exit survey (Appendix F), noting that synoptic meteorology is a foundation or starting point
from which one can learn more about the rest of the atmosphere. The use of the term “atmospheric system” by this student in the exit survey may indicate a more holistic understanding of how the various atmospheric components are interrelated. On this question, the second student did not provide a meaningful response on the entrance survey, but on the exit survey provided a short response indicating the importance of synoptic meteorology as a “starting point” in atmospheric science.

B. Interpretation of Data: Student Perceptions of Course Activities

It is also useful to assess what students think about course activities. Key questions include:

- Which course activities do students report enjoying, and do they overlap those activities shown to promote the most significant learning gains?
- Which activities do students report not enjoying, and are those activities associated with significant learning gains?
- Which course activities do students perceive as contributing most significantly to their learning, and are these in fact the activities for which learning gains were greatest?
- Similarly, what activities are cited most commonly as contributing to the best learning?

On two mid-semester surveys (Appendix D), students were asked how much they enjoyed several course activities. The ten responses for each activity were then averaged at the end of the semester to calculate an average value for that activity. Results are presented below in Figure 1.
Students generally most enjoyed those activities characterized by significant peer interaction and instructor feedback. In-class activities and weather discussions were rated most highly by students. Encouragingly, these activities were also associated with the strongest learning gains. Lectures were also rated highly in this area, which is unusual but is likely because this offering of the course was so small that lectures were often just as much discussion between the instructor and students as they were the instructor traditionally lecturing. Homework and lab exercises were not enjoyed much by most students. Homework assignments were associated with strong learning gains, however, and some students reported they were extremely helpful for learning concepts, so a case is not supported for eliminating homework assignments. Lab exercises were fairly neutral in terms of learning gains. It is the instructor’s sense that lab exercises could be an excellent hands-on learning experience. Thus, these results indicate a need to rework lab assignments so they are more immersive and hands-on, and so they are more targeted toward specific desired learning outcomes. Given the significant time investment required to complete the labs, a case could also be made for reducing the length and/or number of lab exercises. When specifically asked what their least favorite course activity was, a strong majority of students replied lab exercises (not shown). Conversely, students reported most enjoying the in-class activities (e.g. problem-based learning exercises,
As these were the activities which appeared to most contribute to increased student understanding, it is recommended that more such activities be incorporated into future sections of the class, especially if further research indicates similar results with a larger population.

Students were also asked how much the same activities were contributing to their learning, on a scale from 0 (not at all) to 10 (very much). This ‘student-perceived learning’ gives an idea of which activities students will tend to value, if they think these activities are helping them learn. **Figure 2** below shows the results of this question.

![Student-Perceived Learning](image)

**Figure 2**: Average student-perceived learning for several primary course activities, ranging from 0 (students perceived they learned nothing) to 10 (students perceived they learned a lot).

Students perceived they were learning the most from in-class activities, lecture, and weather discussions, which was generally a correct assessment. The value of lecture may have been overestimated in terms of association with measured learning gains. Homework and lab exercises were perceived to contribute moderately to learning, which was generally the case in reality, though the value of lab exercises may have also been overestimated. Weather discussions during lab time were perceived as less useful, possibly because they were often led by a lab assistant with minimal instructor feedback. Overall, responses to this question indicate...
that students had a fairly accurate sense of which activities strongly contributed to their learning. Students were also asked which course activity most contributed to their learning, and mentions of each activity were counted; results are shown in Figure 3.

![Figure 3: Number of times each activity was mentioned as being the most significant contributor to learning in METR 341.](image)

In-class activities and weather discussions were infrequently cited as most contributing to learning in the course, though students rated these events highly in terms of resultant perceived learning gains. A reason for this discrepancy is not apparent, and these results are also at odds with measured learning gains. These observations highlight the potential value in showing students data which indicate how they may learn best. Students thought homework and lab exercises were contributing substantially to their learning, although those activities were not rated highly in terms of how much students enjoyed them. It is valuable to encourage metacognitive thought in students, who may often not consider their learning process (e.g. NRC 2000). These results provide a possible baseline for metacognition discussions in future sections of METR 341.

Student quotes shed substantial light on what students thought about certain course activities. While mostly positive, a few students honestly discussed things they thought were not working well in the course. A sample of student quotes follows:
“I find the labs to be too intensive and time consuming. At a certain point, they become overwhelming which isn’t beneficial to learning.”

“The lab is massively overwhelming. Several of the labs were just too intense and time consuming.”

“I really enjoyed doing the map activity…and looking at another set of maps over Europe…They really helped explain why something happened and made us justify any assumption or explanation we made.”

“I learn best when I can bounce ideas off of other people, and I retain the information better when I talk about it.”

“My favorite instructional method is by far the group activities. This is where we get to test our knowledge…in a semi-real world scenario. Aside from the fact that it breaks up the routine of a normal lecture, it also provides a secondary avenue for learning. Some people have different learning styles and these activities have something for everyone: auditory, visual, and kinesthetic.”

“My favorite instructional method has been the in-class activities. They allow hands on learning with IMMEDIATE FEEDBACK. This is the most helpful tool, since we know right away if we made a mistake or have a flaw in our understanding. This immediate feedback does not happen in any other part of the class.”

“I think it is great to see how other students are making their forecasts and what they are taking into account as well as what the professor looks at while he is making his forecasts.”

“General class discussion during class has been the best…Just the engagement of everyone together really helps to get a general understanding.”

“I like lectures because it gives most of the needed information and the format is very open so I can ask questions at nearly any time. Lectures are the best way I learn.”

“Working through those difficult homework problems was what provided the impetus for me to cement those equations, and how they’re applied, in my head.”
C. Future Inquiry Directions

The inquiry project presented here has been useful and should improve student learning in future offerings of this and similar courses. Prior to this project, it was only anecdotal which course activities most contributed to learning in METR 341, or any similar course. Given the results of this project, it is now clear which methods are optimal, and these methods, characterized by significant peer interactions and rapid instructor feedback, will be integrated more thoroughly into future offerings of similar courses. Such changes should be carefully assessed to ensure they are having a continued positive impact on student learning.

Many potential future directions for inquiry have become apparent during the completion of this project. Given the small enrollment, a similar study could be completed on a larger student population to either reinforce the results obtained, or to show a different set of results. The study could be started earlier in the semester so more data could be gathered on learning gains through the semester. Since a key focus of METR 341 is to get students started at meaningfully applying their conceptual model of the atmosphere, assessment activities could be designed to more carefully test this particular skill, and these new assessment items could be more closely aligned to particular in-class activities to allow a more robust assessment of learning goals related to specific activities. Finally, it would be useful to more thoroughly assess how student views of atmospheric science and the role of synoptic-scale processes change through the semester.

V. Assessment of the Portfolio Process

Synoptic meteorology is foundational to atmospheric science, and it is critical that students strengthen their ability to think critically and independently in this course. Anecdotal evidence from teaching similar courses, and from education literature in the physical sciences, has pointed to the value of problem solving using data from real events. This inquiry project allowed further investigation of optimal instructional methods for this particular course, and led to the qualitative and partially quantified conclusion that hands-on in-class activities seem
to support the best learning gains. In addition, this project led to the conclusion that a high degree of peer interaction and detailed, immediate instructor feedback are critical aspects of optimal instructional strategies in this course. These findings have given added confidence in using such instructional methods in future offerings of this and similar courses, and represent a piece of evidence that can be used to make the case that the introduction of some alternative instructional methods may lead to learning gains. Interaction with other faculty in the Peer Review of Teaching Advanced program at the University of Nebraska-Lincoln has been valuable in developing my personal view of teaching and the process by which teaching effectiveness should be investigated. I plan to incorporate changes to my future courses based on the findings of this research, and to continue investigating and seeking to improve my teaching effectiveness in future coursework.
References


Appendix A: Course Syllabus

METR 341/841 – Synoptic Meteorology

Syllabus: Spring 2014

Lecture: TR 2:00 – 3:15 PM, 104 Bessey Hall        Lab: M 2 – 3:20 PM, 105 Bessey Hall
Instructor: Matthew Van Den Broeke (mvandenbroeke2@UNL.edu)  Office: Bessey Hall 306 Office
Hours: T 3:15 – 4:15 PM, R 3:15 – 4:30 PM; others by appt. (email me)
Course Assistant: Curtis Riganti (CRiganti@Huskers.UNL.edu)

Course Content:
This course is designed to give students an understanding of large-scale atmospheric processes, and introduce concepts used in forecasting. We will learn and apply map analysis techniques through the semester. Other topics will include codes used for meteorological data, isentropic analysis, theory of cyclones and anticyclones, motion and effects of upper-air systems, fronts and frontogenesis and lower levels and midlevels, forecasting techniques for a wide variety of situations, and an introduction to IPV thinking and quasigeostrophic theory. Students will have many hands-on opportunities to practice and reinforce concepts learned in class.

Course Goals:
This course is designed to give you the introductory theory of how the atmosphere operates on a large scale, and to give you practice applying these concepts on a daily basis. In the course, we also hope you are beginning to integrate what you have learned about atmospheric science in many courses, and will give you practice with this through case studies. Our goals for the course are:
   1) Develop a good understanding of large-scale atmospheric processes.
   2) Be able to apply course concepts, integrated with concepts from prior coursework in atmospheric science, to new situations.
   3) Clearly communicate your science in verbal and written form.

Textbooks which we will follow for portions of the semester will be: a) Midlatitude Synoptic Meteorology (Lackmann) and b) Weather Analysis and Forecasting Handbook (Vasquez).

Course Policies:
Environment: Our classes should be interactive, professional, and challenging. Ask questions during class—discussion is often especially valuable when learning synoptic meteorology. Please arrive on time, use laptops only for class work, and have cell phones off or silenced.

Class meetings will generally consist of a lecture, possibly a weather discussion, and some time to go over homework questions. Many class meetings will also contain interactive activities designed to reinforce concepts. Exam reviews will occur during class meetings.

Late Policy: Your work should be turned in by the due date; if it is not, there will be a 15%/day deduction in your final percentage. I will be understanding of emergencies that may arise—in all cases, please communicate with me. If possible, please let me know via email or in person if you are unable to turn in an assignment on time—we may be able to make other arrangements.
**Help with the Course:** As your instructor, I want to see you do well in this course. If you have questions about the material, homework, etc., see me before or after class, send me email anytime (which is the best way to communicate with me), or come to office hours. If more time is needed we can make arrangements to meet. *I expect you to take an active role in making sure you understand course material!*

Grades, homework assignments, handouts, and review sheets will be posted on [Blackboard](#).

**Course Assessment:**

<table>
<thead>
<tr>
<th>Component</th>
<th>%</th>
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<tbody>
<tr>
<td>Exam 1</td>
<td>15</td>
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<tr>
<td>Exam 2</td>
<td>15</td>
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<tr>
<td>Final Exam</td>
<td>20</td>
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<tr>
<td>Homework</td>
<td>25</td>
</tr>
<tr>
<td>Lab Exercises</td>
<td>20</td>
</tr>
<tr>
<td>Weather Discussions/Class Activities</td>
<td>5</td>
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</tbody>
</table>

*Exams* are designed to test your knowledge of course material and ability to meaningfully apply it. The final exam is cumulative, but a majority of material will be from after Exam 2. Exams must be taken on the scheduled date—please talk to me *before* the exam if this is not possible.

*Homework assignments* will be varied in length and form. 6 assignments will be given for each section of material (2 prior to each exam). In addition, 3 long-term assignments will be given (over the duration of the semester). Details are listed below. *It is expected that all work and writing you turn in represents your own thought (there will be grade penalties if not), though working with other students is encouraged.*

<table>
<thead>
<tr>
<th>Homework 1 – 6</th>
<th>Problem sets</th>
<th>10% each</th>
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</thead>
<tbody>
<tr>
<td>Homework 7</td>
<td>Case study &amp; wx discussions</td>
<td>15%</td>
</tr>
<tr>
<td>Homework 8</td>
<td>Short paper/presentation</td>
<td>20%</td>
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<tr>
<td>Homework 9</td>
<td>Forecasting notebook</td>
<td>10%</td>
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Note that, in total, homework adds up to 105% (there is some extra credit built in).

*Lab Exercises* will also be varied in length and form. Some will be computer-based, while some will be paper-based. For a few of the labs, you will be required to write up a formal report on your work (extra time will be given for these write-ups).

Each student will give 2 *weather discussions* in class during the semester. These discussions will be graded on clarity and completeness, and should include an overview of current conditions and reasoning for a prediction (observational and numerical).

The *grading scheme* for this course will approximately follow this scale (grades are guaranteed if your percentage is within these ranges):

<table>
<thead>
<tr>
<th>Grade</th>
<th>Percentage</th>
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<tbody>
<tr>
<td>A+</td>
<td>97+</td>
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<tr>
<td>A</td>
<td>92.5 – 96.99</td>
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<tr>
<td>A-</td>
<td>90 - 92.49</td>
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<tr>
<td>B+</td>
<td>87.5 - 89.99</td>
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<tr>
<td>B</td>
<td>82.5 - 87.49</td>
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<tr>
<td>B-</td>
<td>80 - 82.49</td>
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<tr>
<td>C+</td>
<td>77.5 - 79.99</td>
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<tr>
<td>C</td>
<td>71.5 - 77.49</td>
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<tr>
<td>C-</td>
<td>70 - 71.49</td>
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<tr>
<td>D+</td>
<td>67.5 - 69.99</td>
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<tr>
<td>D</td>
<td>62.5 - 67.49</td>
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<tr>
<td>D-</td>
<td>60 - 62.49</td>
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</table>
**Academic Honesty:** Any instance of academic dishonesty will be taken seriously, and substantial penalties will be levied. For UNL’s student conduct code, see: (http://stuafs.unl.edu/ja/code/).

**Reasonable Accommodation:** Students with disabilities are encouraged to contact the instructor for a confidential discussion of their individual needs for academic accommodation. It is the policy of the University of Nebraska-Lincoln to provide flexible and individualized accommodation to students with documented disabilities that may affect their ability to fully participate in course activities or to meet course requirements. To receive accommodation services, students must be registered with the Services for Students with Disabilities (SSD) office, 132 Canfield Administration, 472-3787 voice or TTY.

In this course it’s my hope that we can have some fun learning about cloud-scale and precipitation processes. I also hope this course will build your critical thinking skills in a way applicable to other coursework, and to life in general. And always, if you have questions about anything in meteorology, please ask!

<table>
<thead>
<tr>
<th>Date</th>
<th>Topic</th>
<th>Work Due</th>
</tr>
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<tbody>
<tr>
<td>14 Jan</td>
<td>Lecture 1: Introduction/review; Scales of motion</td>
<td></td>
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<tr>
<td>16 Jan</td>
<td>Lecture 2: Contouring and map analysis</td>
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<tr>
<td>21 Jan</td>
<td>Lecture 3: METAR and upper-air codes</td>
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<td>23 Jan</td>
<td>Lecture 4: Thermodynamic diagrams; Stability</td>
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<td>28 Jan</td>
<td>Lecture 5: Isentropic analysis</td>
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<td>30 Jan</td>
<td>Lecture 6: Cross-sectional analysis (104 Bessey)</td>
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<td>30 Jan</td>
<td>Lecture 7: Polar Front Theory; Norwegian Cyclone Model (219 Bessey)</td>
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<tr>
<td>11 Feb</td>
<td>Lecture 8: Hobbs Model of Plains lee cyclones</td>
<td>Homework 1 (lectures 1 – 6)</td>
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<tr>
<td>13 Feb</td>
<td>Lecture 9: Cyclone/anticyclone climatology &amp; types; cyclone structure/features (104 Bessey)</td>
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<tr>
<td>13 Feb</td>
<td>Lecture 10: Coastal cyclogenesis; Coastal fronts; Cold air damming (219 Bessey)</td>
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<tr>
<td>18 Feb</td>
<td>Lecture 11: Wind balances (geostrophic, ageostrophic, gradient); Vorticity</td>
<td>Homework 2 (lectures 7 – 10)</td>
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<td>20 Feb</td>
<td>EXAM 1 (covers lectures 1 – 10)</td>
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<tr>
<td>25 Feb</td>
<td>Lecture 12: Troughs/ridges; vertical tilt/connection to surface weather systems</td>
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<td>27 Feb</td>
<td>Lecture 13: Blocking; Henry’s Rule; Wavenumber</td>
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<td>4 Mar</td>
<td>Lecture 14: Baroclinic instability; Jetstreams; Jetstream circulations</td>
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<tr>
<td>6 Mar</td>
<td>Lecture 15: Observations of fronts and drylines; Front-Jet connections</td>
<td>Homework 3 (lectures 11 – 14)</td>
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<tr>
<td>11 Mar</td>
<td>Lecture 16: Frontogenesis</td>
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<tr>
<td>13 Mar</td>
<td>Lecture 17: Mid- and upper-tropospheric fronts</td>
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<tr>
<td>18 Mar</td>
<td>Lecture 18: Introduction to IPV Thinking</td>
<td>Homework 4 (lectures 15 – 17)</td>
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<tr>
<td>20 Mar</td>
<td>EXAM 2 (covers lectures 11 – 17)</td>
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<tr>
<td>25 Mar</td>
<td>NO CLASS: SPRING BREAK</td>
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<td>27 Mar</td>
<td>NO CLASS: SPRING BREAK</td>
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<tr>
<td>1 Apr</td>
<td>Lecture 19: Introduction to Quasigeostrophic Theory</td>
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<td>3 Apr</td>
<td>Lecture 20: The forecast process/funnel; forecasting precipitation type</td>
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<td>8 Apr</td>
<td>Lecture 21: Fog, drizzle, cloud, and wind forecasting</td>
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<td>10 Apr</td>
<td>Lecture 22: Temperature forecasting</td>
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<tr>
<td>15 Apr</td>
<td>Lecture 23: Snow forecasting; Winter storms</td>
<td>Homework 5 (lectures 18 – 22)</td>
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<td>17 Apr</td>
<td>Lecture 24: Use of deformation, trough tilt, and other upper-air features in forecasting</td>
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<td>22 Apr</td>
<td>Lecture 25: Forecasting convective events</td>
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<td>24 Apr</td>
<td>Lecture 26: Numerical Modeling 1: Gridpoint vs. spectral; sigma coordinates; data assimilation</td>
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<td>29 Apr</td>
<td>Lecture 27: Numerical Modeling 2: Current operational models and their biases</td>
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<tr>
<td>1 May</td>
<td>Student presentations</td>
<td>Homework 6 (lectures 23 – 27)</td>
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**Final Exam:** 7 May (Wednesday), 1 – 3 PM, 104 Bessey Hall (HW 7 – 9 are due at the Final Exam, but you can turn them in earlier)
Lab Schedule

<table>
<thead>
<tr>
<th>Date</th>
<th>Topic</th>
<th>Work Assigned</th>
<th>Date work due</th>
</tr>
</thead>
<tbody>
<tr>
<td>13 January</td>
<td>Lab 1: Map analysis in IDV</td>
<td>Maps</td>
<td>16 January</td>
</tr>
<tr>
<td>20 January</td>
<td>NONE (MLK Day)</td>
<td>none</td>
<td>X</td>
</tr>
<tr>
<td>27 January</td>
<td>Lab 2: Thermodynamic diagrams</td>
<td>Diagrams and writing</td>
<td>30 January</td>
</tr>
<tr>
<td>AMS Week</td>
<td>Lab 3: Isentropic analysis</td>
<td>Diagrams and writing</td>
<td>10 February</td>
</tr>
<tr>
<td>10 February</td>
<td>Lab 4: Cyclone structure</td>
<td>Formal write-up</td>
<td>17 February</td>
</tr>
<tr>
<td>17 February</td>
<td>Lab 5: Coastal cyclone case study</td>
<td>Maps and wx discussion</td>
<td>24 February</td>
</tr>
<tr>
<td>24 February</td>
<td>Lab 6: Upper-level wind and vorticity</td>
<td>Maps and writing</td>
<td>3 March</td>
</tr>
<tr>
<td>3 March</td>
<td>Lab 7: Upper-air features</td>
<td>Formal write-up</td>
<td>10 March</td>
</tr>
<tr>
<td>10 March</td>
<td>Lab 8: Jetstreams</td>
<td>Maps and wx discussion</td>
<td>13 March</td>
</tr>
<tr>
<td>17 March</td>
<td>Lab 9: Fronts and frontogenesis</td>
<td>Maps and writing</td>
<td>20 March</td>
</tr>
<tr>
<td>24 March</td>
<td>NONE (Spring Break)</td>
<td>none</td>
<td>X</td>
</tr>
<tr>
<td>31 March</td>
<td>NONE</td>
<td>none</td>
<td>X</td>
</tr>
<tr>
<td>7 April</td>
<td>Lab 10: Forecasting I</td>
<td>Maps and wx discussion</td>
<td>10 April</td>
</tr>
<tr>
<td>14 April</td>
<td>Lab 11: Winter weather forecasting</td>
<td>Maps and wx discussion</td>
<td>17 April</td>
</tr>
<tr>
<td>21 April</td>
<td>Lab 12: Forecasting case study</td>
<td>Formal write-up</td>
<td>28 April</td>
</tr>
<tr>
<td>28 April</td>
<td>Lab 13: Numerical weather models</td>
<td>Maps and wx discussion</td>
<td>1 May</td>
</tr>
</tbody>
</table>

There are 14 labs. The lab grade will be distributed as follows:

- Shorter labs (10): 7% each
- Formal reports (3): 10% each
Appendix B: Initial Survey from First Day of Class

Entrance Survey: METR 341-841 (Synoptic Meteorology), Spring 2014

Name: ______________________________________
Best email address for this course: ______________________________________
Hometown: ______________________ Interests/hobbies: ______________________
How do you learn best?

What would you most like to learn while in this class?

Please indicate some times which would work well for you to come to office hours.

What do you perceive as the value(s) of knowing something about synoptic meteorology?

From your perspective, where/how does synoptic meteorology fit into a rounded picture of the atmospheric system?

Please rate the following from 0 – 5, where 0 = very easy and 5 = very difficult.
1) How challenging have your METR courses been so far?    0 1 2 3 4 5
2) How challenging have your required MATH courses been so far?   0 1 2 3 4 5
3) How challenging have your required PHYS courses been so far?   0 1 2 3 4 5
4) How difficult do you expect METR 341-841 to be?     0 1 2 3 4 5
5) How much do you think you’ll enjoy learning the material in this class? (0=not at all; 5=a lot)  0 1 2 3 4 5

You’re expected to make a forecast of temperature and precipitation for Tonopah, Nevada (if you’re familiar with this location, please think of a location you are NOT familiar with).
   a) Please list 6 pieces of data you would consider while making your forecast, and briefly note how each would be useful.

   b) Please outline the process (procedural steps) you would follow to make your forecast.
Appendix C: Final Survey at End of Semester

Exit Survey: METR 341-841 (Synoptic Meteorology), Spring 2014

Name: ________________________________________

What was the most effective instructional method for you in this class? Can you briefly describe why?

What was the most beneficial thing you learned in this class?

How could this class be improved?

What do you perceive as the value(s) of knowing something about synoptic meteorology?

From your perspective, where/how does synoptic meteorology fit into a rounded picture of the atmospheric system?

Please rate the following from 0 – 5.
1) How difficult was METR 341-841 for you? (0=easy; 5=difficult) 0 1 2 3 4 5
2) How much did you enjoy learning the material in this class? (0=not at all; 5=a lot) 0 1 2 3 4 5

You’re expected to make a forecast of temperature and precipitation for Tonopah, Nevada (if you’re familiar with this location, please think of a location you are NOT familiar with).
   a) Please list 6 pieces of data you would consider while making your forecast, and briefly note how each would be useful.

   b) Please outline the process (procedural steps) you would follow to make your forecast.
Appendix D: Mid-Semester Survey Given Twice

Mid-Semester Survey: METR 341-841 (Synoptic Meteorology), Spring 2014

Name: ________________________________

Please answer the following questions to the best of your ability. Your responses will help improve the instruction in this course. Thank you for your participation.

Please rate the following aspects of instructional methodologies you’ve experienced in this course. A rating of 0 = very little; 5 = neutral; 10 = very much. You may also answer NA (not applicable).

<table>
<thead>
<tr>
<th>Instructional method</th>
<th>How much have you enjoyed this activity?</th>
<th>How much have you learned from this activity?</th>
<th>How would you rate the overall value?</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Lectures</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2) Class group activities</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3) Class weather discussions</td>
<td></td>
<td></td>
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<tr>
<td>4) Homework assignments</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>5) Lab exercises</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>6) Lab weather discussions</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

What has been your favorite instructional method used in this class in recent weeks? Briefly explain why.

What has been your least favorite instructional method used in this class in recent weeks? Briefly explain why.

What is one thing you feel you have learned well in the past two weeks? What contributed to your learning this item or topic well?

Are there any other comments you would like to share about the course at this point?
Appendix E: Forecast Process Student Responses

Students were asked the following question on a course entrance survey:

“You’re expected to make a forecast of temperature and precipitation for Tonopah, Nevada (if you’re familiar with this location, please think of a location you are NOT familiar with).

b) Please outline the process (procedural steps) you would follow to make your forecast.”

In addition, students were asked the following question on their final exam:

“You’re given an unfamiliar location for which you are to forecast. Outline the steps in your method.”

Responses to the final exam and entrance survey questions are here presented for the 5 students enrolled in METR 341:

STUDENT 1

Entrance Survey:

b) Please outline the process (procedural steps) you would follow to make your forecast.

1. Start at a large scale, looking at upper air maps to determine the jet.
2. Move down in the atmosphere, see clouds, fronts, LLS, and temp advection.
3. Take a look at the current sat images for cloud/ fronts.
4. Surface obs for a better indication of fronts.
5. Some sounding to determine temps.

Final Exam:

14) You’re given an unfamiliar location for which you are to forecast. Outline the steps in your method.
(10 pts.)

1. If an unfamiliar location, look outside.
2. Look at past climatological data for the site.
3. Know the recent weather.
4. Keep in mind geographical features plays a big role.
5. Any large bodies of water are also influential.
6. Employ the forecast funnel, start large scale then grow smaller.
7. Look at models, examine current surface do to make sure it’s similar.
8. Use Storm Intensity figure site for model comparisons.
9. Read a local AFD, find out if there are any ongoing factors you need to be aware of.
10. Talk to a local met, find out if there was any known breeze at the site.
STUDENT 2

Entrance Survey:

I would start with looking at upper air maps and current surface data. I would then start to look at motions in the atmosphere to see how things might change.

Final Exam:

14) You’re given an unfamiliar location for which you are to forecast. Outline the steps in your method.

(10 pts.)

The first thing I would do is look up the location on Google Maps to get a sense of the topography, vegetation, and proximity to bodies of water. Next, I would look to see what the general climatology is like for the area. I would then look at what the weather has been like for the past few days. All of this should help me at least get a general sense of what conditions can and will be like in this area.

Once all of the preliminary research is complete, I would go through the forecast funnel, starting with the synoptic scale features and working my way down and applying all of that to what I now know about the more specific local features.

Then, I would go back and verify my forecast to see what mistakes were made and learn about the general feel for the site over time.

- Hourly, 30cm, dew to surface, satellite, water vapor, radar, sounding, live for verticity advection, look at model guidance, and not over the local AFD for preliminary guidance.
STUDENT 3

Entrance Survey:

I would analyze those maps to see what conditions seem to be taking place, such as fronts or current characteristic. In order to make a forecast.

Final Exam:

1. Global/hemispheric obs. I would look at upper level hemispheric maps to know what kind of pattern I am in—be it active or zonal.

2. Synoptic obs. What is going on in my area? I would look at maps centered on my continent to determine what synoptic scale features may be affecting me.

3. Take a closer look! What is going on in my region? Is there a convection anywhere nearby? What is the topography like? Etc.

4. Local obs. What is going on in my state/province/territory? Any fog, rain, storms, clouds that may affect me?

5. After taking this top-down approach, I would have a good understanding of what Atmospheric features may be affecting me. I would be able to then make a well-educated forecast based on any factors I saw. (A sneak peek at guidance?)
STUDENT 4

Entrance Survey:

Know the current conditions.
See the pattern of weather over the last few hours.
Use the data above to try and see whether the same weather will continue or change.

Final Exam:

14) You’re given an unfamiliar location for which you are to forecast. Outline the steps in your method.
   (10 pts.)

1. Look at the topography. Grade it. Mountains, Lakes, Rivers, Oceans?
2. Look outside. See what the current weather is. Use a webcam or satellite.
3. Know the local climatology. For the region, does current weather fit with climate average?
4. Know recent weather. Has it precipitated recently? Is there snowcover?
5. Start looking at large scale weather patterns. Continental scale waves today.
6. Look for any embedded short waves. These can cause unexpected weather.
7. Look for any advection. Is there going to be colder or warmer air moving in?
8. What is the moisture like, and how does that affect stability?
9. Examine Surface Data. Look at surrounding surface data and see all.
   Does anything stand out?
10. Compare your data with other sources and assess if correct. (Weather hark sign)
11. Make an Initial Prediction.
12. Consider any other factors (fires, floods, wind/low pressure) that matters with your forecast.
STUDENT 5

Entrance Survey:

1) View current observations
2) Pull up models
3) Make basic forecast
4) Look at models more
5) Fine-tune forecast
6) Check against other forecasting groups.

Final Exam:

10) 1) Learn the topography at the location
     2) Look outside
     3) Look at climate data
     4) Look at current weather
     5) Start w/ large scale
     6) Look for short waves
     7) Look for advection
     8) Assess the moisture/stability situation
     9) Examine surface data
7) Compare w/ climate and other data
8) Make initial values
9) Account for any other factors
10) Read the AFD
11) Consult models w/ verification.
12) Make final forecast.
Appendix F: Student Responses about their Understanding of Synoptic Meteorology

Students were asked the following questions on their entrance and exit surveys:

a) What do you perceive as the value(s) of knowing something about synoptic meteorology?

b) From your perspective, where/how does synoptic meteorology fit into a rounded picture of the atmospheric system?

Responses to these questions are here presented for the 2 students who completed both surveys:

STUDENT 1, Question (a)

Entrance Survey:

I feel like in order to understand the small scale features such as thunderstorms it is important to know the broader reasons as to how they occur.

Exit Survey:

I feel that it is extremely valuable to know synoptic meteorology. It is the foundation for diving deeper into the other small-scale features. If you don't understand the main upper level forcing mechanisms it would be nearly impossible to understand the rest.

STUDENT 2, Question (a)

Entrance Survey:

Being able to forecast severe weather locations for safety of individuals and or major sporting events.

Exit Survey:

The forecasting funnel. Synoptrics is the basis for forecasting, which is where I see myself later in life.
STUDENT 1, Question (b)

Entrance Survey:

I feel like it provides the solid foundation to further, more specific research into the other areas of meteorology.

Exit Survey:

Like I said in the previous question, synoptic meteorology is the foundation and starting point for delving into the rest of the atmospheric system. The large scale patterns play a significant role in how the Earth's weather is

STUDENT 2, Question (b)

Entrance Survey:

Synoptic is where we see the atmospheric system heading to.

Exit Survey:

smack dab in the middle. It is the starting point for everything