The Curriculum Foundations Workshop on Meteorology

By Bill Marion and Craig Clark

Unless your university has an undergraduate major in meteorology, you might not know that meteorology students complete at least as many mathematics courses as the engineering students do — Calculus I, II and III and differential equations. In order to get a better sense of the mathematical needs of these students, faculty from around the country who teach in meteorology programs were invited to participate in a two-day Curriculum Foundations II workshop which was held at Valparaiso University in Northwest Indiana in late February 2008. The meeting was hosted jointly by the Department of Mathematics and Computer Science and the Department of Geography and Meteorology. It took place in the new wing of a building dedicated to the meteorology program.

Fourteen meteorology faculty, representing 11 colleges and universities, attended the workshop. (Three other meteorologists who had originally planned to come were unable to because of bad weather conditions in various parts of the country.) Four mathematics faculty were present. Their roles were to help facilitate the conversation, to address questions about curricular issues and mathematics content, and to hear what the meteorologists had to say.

Prior to their arrival on campus, the participants took part in an electronic discussion about their expectations for the workshop. It quickly became clear that one of the major concerns of the meteorologists was the mathematical preparedness of their first-year majors. It appears that meteorology has become a very attractive program. Perhaps as a result, students come to the major with very disparate quantitative abilities. A substantial number of students struggle in the first two calculus courses and, as a result, many don't make it to the second year of their meteorology program. Thus, one of the main questions the meteorology faculty wanted to address when they arrived was what, if anything, can be done to remedy the situation.

A little bit of background might help. While incoming students *should* know that meteorology is a math-intensive major, many are not prepared for college-level calculus courses. Their mathematical preparation varies substantially. Most programs estimate that between 25% and 50% of their majors take Calculus I their first semester, with a much smaller number starting in Calculus II. The remaining students begin their math program in pre-calculus. As

Two of the participants at the Curriculum Foundations Workshop: Bill Marion, Mathematics, Valparaiso University and Clint Rowe, Meteorology, University of Nebraska-Lincoln.

for meteorology courses, at least one largely qualitative survey course is typical. The meteorologists agreed that it would be beneficial for their students if they saw more calculus-based applications in this course or in some other meteorology course that might be offered early in the program, but it would be logistically challenging, given the varying mathematics placement of incoming students. Math-intensive courses such as the atmospheric dynamic meteorology sequence and atmospheric thermodynamics, are not typically taken by the students until their junior year. Thus, a sound mathematical preparation is what would benefit students most.

To tease out some specifics, the meteorologists were asked a couple of questions. "Are practical applications of mathematics more important than conceptual understanding?" Second, "What calculus topics should receive more emphasis?"

Though responses to the first question varied, the consensus was that both mattered. A majority felt that the conceptual aspects may be more important overall, since many of the meteorological applications can be taught in their upper-level courses. However, practical problem-solving skills are critical. Toward this end, it was suggested that more applied problems be included in the calculus sequence. While there are not many textbook examples

related to the study of weather, there are many problems from related fields, such as physics, which could be assigned to hone students' skills. Another idea that gained some currency in the group was for mathematics and meteorology faculty to work together to develop some elementary calculus-based meteorological problems.

To address the second question, a list of topics covered in the calculus sequence was provided and the meteorologists were asked to rank their importance and to suggest the semester in which they should be covered. The primary change they recommended was that the standard vector content should be covered early, if not multiple times.

Other important calculus topics for the study of meteorology include derivatives, limits, integrals, Fourier transforms, and Taylor's Theorem. The group wasn't concerned that much about the remaining ordering, especially in the third semester. However, they did emphasize that it was essential for their students to be able to interpret mathematical concepts, such as function, limit, derivative, and definite integral, when the function to be analyzed is represented as discrete data points and via a graph rather than by a formula. On the whole, the consensus was that mathematicians should use whatever sequencing was most effective pedagogically. The crucial thing was that students be well prepared to handle the more quantitative meteorology courses that are offered in their junior and senior years.

Mainly anecdotal, yet fairly pervasive, evidence pointed to another issue: students have the greatest difficulty in the second semester calculus course. The poorest math students do not make it to Calculus II, but a significant number of students get adequate grades in Calculus I and subsequently struggle to pass Calculus II. The causes are not well-known. One of the mathematicians commented, however, that it is not unusual for the second-semester course to begin with applications of the integral and end with infinite series. In between, topics such as integration techniques, improper integrals, conic sections, parametric equations, and polar coordinates are covered. Such a hodgepodge of topics can make it challenging, even for the better prepared students, to assimilate and master the material. One of the meteorologists added that during the same semester meteorology students are taking calculus-based physics, making for a high workload.

So, where does this leave us in terms of the original question: What should we educators be doing in the first two years of college to prepare students interested in studying the weather? First, we should acknowledge that there are many students entering the field who are well-prepared. The real concern is with those whose mathematics background is weak. Some felt that there is not much that can be done, while others believed that we must do better. All agreed that these students' problem-solving skills need to be strengthened considerably, probably through a revised pre-calculus course or sequence. (The mathematicians responded that, indeed, there is a national effort to do just that.)

Other issues discussed were the use of technology, underrepresented groups entering the discipline, and preparedness for graduate study. The meteorology faculty stressed that their students should become familiar with a number of different software packages, one being Excel, and should develop some skill in programming, especially in FORTRAN. For the most part the meteorologists were satisfied with what their students were getting, although they were concerned that a typical first computer science course in object-oriented programming did not fit the bill — too much overhead for what their students really needed.

As for the underrepresentation of women and students of color, the good news is that the enrollment and graduation of women has increased substantially — in some programs it is approaching 50%. Unfortunately, the same cannot be said of minority students.

After graduation most students go on to careers in operational meteorology and broadcasting, while some go directly to graduate school. For the latter some exposure to linear algebra, numerical methods, Fourier

Curriculum Foundations is a project of CRAFTY, the MAA subcommittee dedicated to "Curriculum Renewal Across the First Two Years." Currently in Phase II, the project organizes workshops to consult faculty in other disciplines about the mathematics they would like their students to learn during their first two years in college. See the February/March 2009 issue of FOCUS for more information. In this issue, we publish reports on the workshops for the Arts (pages 8-9) and Meteorology (pages 10-12).

analysis, statistics, and partial differential equations is helpful.

In the end, the meteorology faculty emphasized that what is most important for their students to get out of the first two years of college-level mathematics is the ability to make sense of quantitative data and to apply confidently a variety of mathematical tools and concepts in a variety of settings. The mathematics faculty came away from the workshop with a clearer idea of how their courses affect other disciplines; in addition, offering the right set of upper-level math courses might lead to more students double-majoring.

The feedback from the meteorologists after the workshop ended was encouraging. It suggests that these types of conversations at the local level need to happen on a regular basis. At Valparaiso University, discussions with a number of departments are under way to restructure second semester calculus and to revise the first computer science course. The hope is to meet more broadly the needs of science, mathematics, engineering, and meteorology majors.

Bill Marion is Professor of Mathematics and Computer Science at Valparaiso University. He teaches both mathematics and computer science and is a member of the Curriculum Foundations II Steering Committee. Craig Clark is Assistant Professor of Geography and Meteorology at Valparaiso University and teaches courses in global climate change, data analysis and atmospheric thermodynamics.

Found Math

If there is a parallel universe in which smells are theorems, *100% Love* would be something like a proof of Riemann's conjecture.

Luca Turin, in *Perfumes: The Guide*