A UNIVERSITY LABORATORY COURSE TO IMPROVE SCIENTIFIC COMMUNICATION SKILLS

BY DAVID M. SCHULTZ

A course emphasizing student participation over lectures shows how scientific communication skills can be taught within the regular science curriculum.

I had been bored at conferences before, but never this badly. I was attending an American Meteorological Society (AMS) specialty conference, and I was unimpressed by the presentations from prominent researchers—many of whom were well respected with years of receiving federal research funding and publishing journal articles. For the previous six years, I had been teaching undergraduates how to give better presentations at the National Science Foundation–funded Research Experiences for Undergraduates program in Norman, Oklahoma (Zaras 2005; Gonzales-Espada and LaDue 2006). These lessons needed to be heard by these speakers. The idea for the book *Eloquent Science: A Practical Guide to Becoming a Better Writer, Speaker, and Atmospheric Scientist* (Schultz 2009) was born.

Several years later when the book was nearing completion, I adapted its lessons to a laboratory course "Communication Skills for Scientists" at the University of Helsinki during the winter of 2008/09. This article summarizes how I converted the workshop and book into a 14-week laboratory course focused on scientific communication skills and what I learned while teaching this material.

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DESIGN OF THE LABORATORY COURSE.

I had heard the complaints from my colleagues that undergraduate and graduate students do not know how to write or speak. Often, the weaknesses of the students would be revealed during the writing and defense of their theses, and these skills would be needed if the students pursued a future research career. Even students who write well often require education in how to write a scientific document, which is where a strong advisor can make a positive difference. Often, advisors either do not have the commitment or the skills (or both) to work with students to improve their communication skills. Accordingly, the weaknesses of the advisors are passed down to the students.

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Regardless of what career path students take after graduation, writing and speaking skills are in demand at many jobs. The College Board's National Commission on Writing found that two-thirds of salaried employees in large U.S. companies required writing as part of the job, and writing ability is considered during hiring and promotions at half of those companies ("Writing: A Ticket to Work . . . Or a Ticket Out: A Survey of Business Leaders," available online at www.collegeboard.org/prod_downloads/writingcom/writing-ticket-to-work.pdf).

Also, a survey of private sector companies conducted by the American Meteorological Society in 1995 indicated that colleges and universities could be better preparing individuals for employment in the private sector by "stressing communication skills" (Houghton et al. 1996). Communication skills was also the second-most listed course that should be taught in meteorology programs to prepare students for private sector jobs, beating synoptics, dynamics, and computer skills. As a result of this kind of demand, many college and university science programs are requiring more writing in many of their core curriculum classes. The course at the University of Helsinki was an opportunity not only to teach these skills to students but also to test some of the concepts in *Eloquent Science*.

The course was designed to improve the students' public speaking skills and to bring them closer to completing a submission-quality manuscript. As such, when I advertised the course, I encouraged potential students to be actively working on a journal article, conference extended abstract, or dissertation in order to give the students a writing project to be working on during the course and to invest the students in the success of the course. For students without a project, I recommended writing a review article on something of scientific interest to them.

The class met once a week for a 2.5-h period from late October 2008 through February 2009 (excluding holidays)—my request so that students had enough time to engage in planned group activities, activities that a regular 75-minute class period might limit. Even by breaking up the classroom period with a 10-minute break after 60 minutes and small-group exercises, some students felt that this period was too long, especially because the class was late on Monday afternoon.

I recommended that the students buy two books: *The Elements of Style* (Strunk and White 2000) and *Presentation Zen* (Reynolds 2008). Having read more than 30 books on communication skills while researching the content for *Eloquent Science*, I felt these books were the two most essential purchases. The lectures would be supplemented with Gopen and Swan's (1990) "The Science of Scientific Writing" and draft excerpts from *Eloquent Science*. Although the course material was presented loosely in the order it appears in *Eloquent Science* (Table 1), I made some changes to get the students engaged in writing early in the course and to ensure that I covered the most important topics early in the course, in case I got behind schedule and had to drop topics.

Because of the emphasis on group activities, I did not allow students to audit the laboratory course. Of the 38 students who signed up and attended one of the first two lectures, 29 students (76%) completed the course. Of those 29, 24 (83%) were atmospheric science students and 28 (97%) used English as a second language. Of the 28 students, 24 (86%) were Finnish. All but three or four were working on a Ph.D.; the rest were undergraduates and M.S. students. Forty-three percent of the class had published at least one peer-reviewed scientific article.

Feedback from the students comes from two evaluations, one at week 5 and one at week 14, at the end of the course. Course evaluations were based on the standard university evaluation form, but I included additional questions to evaluate the success of specific assignments and lectures. One outcome of the week-5 evaluations was that the students felt that the course was too demanding for a mere three op. credits (1 op. credit in the Finnish system is roughly equivalent to about 2.5 hours per week spent on the course inside and outside of class). Therefore, I increased the number of credits to five, satisfying nearly all the students on the week-14 evaluations.

The homework assignments were designed for about 5 hours a week of work outside of the class period. These assignments amounted to 50% of the course grade. The final class presentation and class participation (subjectively determined by me) amounted to 25% each of the course grade. There were no exams.

PRECEPTS OF THE COURSE

These four precepts laid the foundation for the course.

1) You can be taught to be a better communicator.
2) Writing and speaking improves your thinking on your topic.
3) We communicate for our audience, not for ourselves.
4) There is no single way to write or say something. But, there may be better ways.

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Each week had a different homework assignment. This assignment may have involved reading, writing some of their project, or preparing their final presentations. Two other examples included the following assignments.

HOMEWORK ASSIGNMENT: TITLE WRITING. Lipton (1998) defines the five characteristics of a desirable title as informative, accurate, clear, concise, and attention commanding. The first homework assignment was to pick the titles from about 20 articles from a table of contents of a journal and rate them according to Lipton's five characteristics.

> Score each title on each of Lipton's five criteria (1 = excellent, 2 = adequate, 3 = poor). For every article that has at least one score of 3, rewrite the title to improve it. (If attention commanding = 3, imagine you are writing the title of a conference presentation, where you have a bit more latitude in being provocative.)

Table 1. Course content.

Week	Content	Chapters of *Eloquent Science*
1	Introduction and overview of writing skills, how to provide constructive criticism and how to receive it, writing effective titles	3, 20, 21
2	Nonlinear reading, title writing	3, 4
3	How to publish a manuscript, writing effective abstracts, similarities and differences between conference and journal abstracts, parts of a scientific manuscript	1, 4, 6, 23
4	Combating writer's block, brainstorming and outlining, writing effective paragraphs and sentences	5–8
5	Sentences and words	9, 10
6	Effective figures	11
7	Citations, authorship, ethics	12, 14, 15
8	No class (professor at AMS Annual Meeting)	
9	Writing conference abstracts, delivering oral presentations, being asked questions and giving answers, challenges to giving effective presentations	23, 24, 26, 28
10	Constructing the slides	25, 26
11	How to write and respond to reviews	19–21
12	Posters	27
13–14	Final class presentations	

STUDENT PERCEPTIONS ON SCIENTIFIC COMMUNICATION

On the first day of class, I gave the students a 30-question survey on scientific communication. This survey was slightly modified from one previously given to participants at the 14th Cyclone Workshop in Quebec, Quebec, Canada, in late September 2008. The questions arose during the writing of *Eloquent Science*, when I wondered what other authors and students felt about certain issues. The results of the survey were discussed in class during the second class period. Some of the results are presented below.

- Seventy percent have considered or would consider publishing in an online-only journal.
- Forty-seven percent have posted or will post their published articles online.
- Nineteen percent started their writing projects with outlines less than half of the time, 35% used outlines most of the time, and 46% outlined 90% or more of the time.
- Fifty-eight percent would consider a title written as a question appropriate.
- Fifty-eight percent of respondents felt that first-person pronouns are inappropriate in the body of a scientific paper.
- Twenty-seven percent found it acceptable to republish the methods section verbatim in multiple papers to the same journal.
- Six percent knew the difference between an *en dash* and an *em dash* and how to use each one.
- Regarding multipart manuscripts (part I, part II, etc.; Schultz 2010b), 25% thought that they were acceptable in most cases, 59% in some cases, and 16% rarely.
- Sixty-three percent believed that a publication written by a professor based on an M.S. thesis of a student who left the field of atmospheric science should have the author order "Student and Professor."
- Thirty-nine percent believed that submitting a conference abstract on research that has not been started yet is acceptable.

Other questions on the survey gauged students' opinions about the order they write and read the sections in journal articles, open access versus page charges for publishing, what they thought the mean rejection rate is among journals that publish atmospheric science (the correct answer is 37%; Schultz 2010a), their biggest weaknesses in writing using the English language, their biggest challenges in writing a scientific manuscript, and what resources they use when needing help writing a scientific article. More results from the survey and a comparison to survey results from respondents at the 14th Cyclone Workshop are discussed in the electronic supplement to this article (http://dx.doi.org/10.1175/2010BAMS3037.2).

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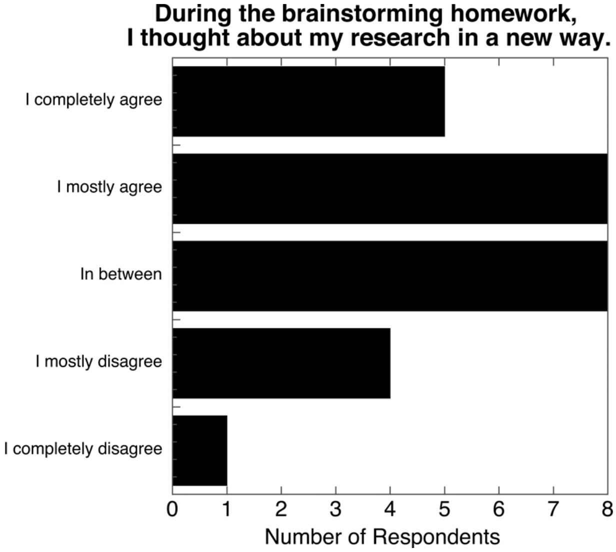

Fig. 1. Number of respondents on the week-5 evaluation to the statement "During the brainstorming homework, I thought about my research in a new way."

This exercise was a good start to the class for several reasons. First, the assignment gave the students an assignment with concrete criteria. Having concrete, goal-oriented tasks first builds the students' confidence and satisfies their needs as goal-seeking learners (Roebber 2005). Second, the assignment showed the students that the peer-reviewed literature was fallible. Specifically, given the importance of the title to attracting an audience to an article and how easy it is to improve most titles, the exercise showed how little thought some authors put into their titles. Third, the students could easily improve upon many of the titles, without having read much more than the abstract. Fourth, I thought the assignment would be fun for the students and provide the opportunity for some humor in seeing how bad some of the titles were. Finally, the exercise provided a natural opportunity to follow up during the next class period with the first in-class exercise (described later in this article).

HOMEWORK ASSIGNMENT: BRAINSTORMING. One of the most interesting assignments I gave (and also the most polarizing) was the brainstorming exercise. The assignment was motivated by the chapter on brainstorming in *Eloquent Science*. Although I felt obliged to say something about brainstorming in the book, I wondered whether any readers would find it useful. After all, how many of us follow the advice that we were taught in school to brainstorm before writing? How often do we take the time to sit undisturbed and think about our research? Thus, I wanted to test if the students found a brainstorming session useful.

> Consider the paper (or review article) that you want to write and spend a solid 90 minutes brainstorming. Afterward, revise your notes, looking for connections. Identify connections, and revise your notes to make a coherent outline of the paper.

To ensure that they took the session seriously, I emphasized that a minimum of 90 minutes with no distractions was required. I figured that they would probably write down everything they could think of in 30–45 minutes, but they needed to push their mind beyond that, looking for other connections and ideas.

Curious about their impressions of this exercise, I asked during the next class period. Some students felt that this was a waste of time, whereas others gained new insight into their research because they were forced to keep thinking beyond the point where the thinking came easy. On the evaluation form, I asked students whether they thought about their research topic in a new way during this exercise. Figure 1 shows one of the biggest spreads on any question from either evaluation, with 13 respondents who agreed, 5 who disagreed, and 8 who were neutral. Despite this result, only two respondents (8%) to a different question disagreed with the statement that "The brainstorming homework was a good use of time." My view is that this exercise was a worthy one, helping take half the class to places that they had not been before in thinking about their research.

IN-CLASS ASSIGNMENTS. Nobel Prize–winning author Doris Lessing said, "You only learn to be a better writer by actually writing." Thus, I wanted to minimize the amount of lecturing I did in the laboratory course, even if it made more work for myself in planning exercises and then grading them. Here is a selection of some of the in-class assignments.

In the first homework assignment (described earlier), each student rated the quality of 20 titles of published journal articles. During the next class period, I asked the students to bring their lists to class, and, within a group of three students, select the absolute worst title among them all and propose a new title. The group was then responsible for presenting the results in front of the class, often to the snickers at the poorly written titles coming from the audience. This exercise further demonstrated to the students that the peer-reviewed literature is not necessarily

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well written and that the students can do better with just a little bit of effort.

Peer reviewing of other students' work was a common activity during the in-class assignments. The class was broken up into groups of three students rotating each others' writing samples among themselves, making comments directly on the paper and having open face-to-face discussions between authors and reviewers. For their homework, the students would revise their own writing based on the written feedback. Most students (81%) found this helpful to their learning.

Précis (pronounced *pray-see*) is an exercise to condense text that retains much of the original author's words, unlike paraphrasing that condenses text using the words of the person doing the paraphrasing. I find that précis easily shows me the redundancies and superfluous words and phrases in blocks of text (whether my own or others'). For the in-class exercise, the students were to write a précis from the first paragraph of an article on sequencing woolly mammoth DNA (Poinar et al. 2006). Then, students read their précis to the rest of the class and discussed it. Many students found that they could condense the 244-word paragraph to between 30% and 60% of its original length. Just over half of the students (54%) found this exercise useful for learning how to make their writing more concise, suggesting that I might have spent more time working with the students on applying précis to their own writing.

FINAL IN-CLASS PRESENTATION. The sidebar "Final class presentation assignment" lists the assignment for the final presentation. The final projects were held over two days. Despite the explicit instructions to make their presentation accessible to nonspecialists, 6 of the 29 presentations (21%) were not what I would consider appropriate for the panel, indicating the difficulty that students (if not scientists in general) have in presenting the value of their research to nonspecialists. A positive outcome was that 13 (45%) of the presentations fought the urge to prepare a wordy scientific presentation and used aspects of the *Presentation Zen* (Reynolds 2008) minimalist approach to presentations (almost the same number that found the book useful from the week-14 evaluations). A few students even had fun with their presentations, envisioning a field program (complete with scientific-sounding acronym) or mobile field research instrumentation. In the week-14 evaluations, 77% of the respondents found these presentations worthwhile.

OTHER RESULTS FROM THE CLASS EVALUATIONS. Because the majority of the laboratory was focused on writing and there was just

FINAL CLASS PRESENTATION ASSIGNMENT

You are seeking funding for your research project about which you have been writing. You have identified a private foundation, The Eloquent Science Foundation, that funds basic and applied science. Assume that you have already submitted a detailed written proposal with budget and this presentation is your final opportunity to convince them to fund your research. Give it your best shot!

Although the panel that will approve your proposal is scientifically literate (i.e., they have college degrees in science), they are not specialists in your field. You are to prepare an 8-minute presentation to this panel describing your proposed research and why it is important that it be funded. Your presentation to the panel will be different from a typical scientific presentation at a conference where you present results of your study. Although you may present some results in your presentation to illustrate that your proposed research yields feasible results, the focus of your presentation should be on persuading the panel to fund your research. You do not need to discuss your budget or resources with the panel. Focus on explaining the importance of the work to science and society. Place your work in the context of the rest of your discipline. Why is it important? What new advances may result from your work and its applications? Are opportunities available to patent your results or grow a business? How will your results benefit society?

After your presentation, there will be two minutes for the panel to ask questions. The panel turns out to be the rest of the class. Everyone in class will be providing comments, as well as numerical scores, on your presentation that will be added together to contribute to your grade for this project. The people with the best scores will win prizes. (Unfortunately, my resources are not sufficient to fully fund your proposed research!)

You will be graded on your presentation skills, how well you use the English language, the quality of your slides, and how convincing your argument is. Your grade will be a combination of my scores and those of the panel (the rest of the class).

To the panel: Your written evaluations on each presentation will be graded for the quality of your comments and the insight you have into the others' presentations. I will remove the panelists' names from the evaluations and give them to the speakers at the end. Your comments will help your classmates improve in the future. Do not hold back on your constructive criticism.

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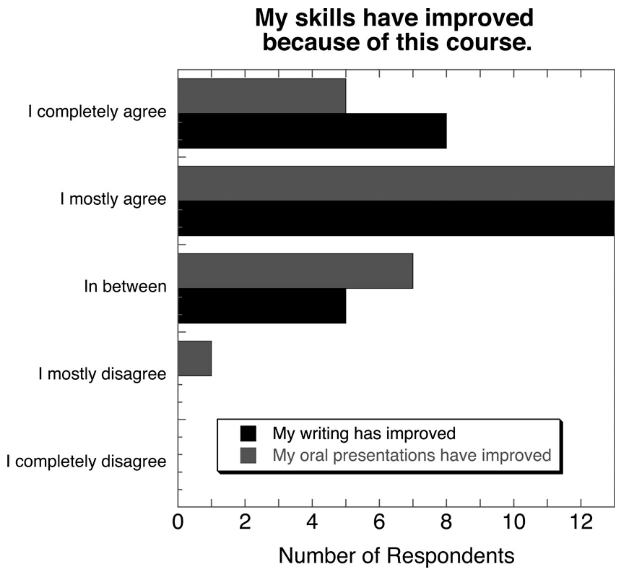

Fig. 2. Number of respondents on the week-14 evaluation to the statements "My writing has improved because of this course" and "My skills at preparing and giving oral presentations have improved because of this course."

one opportunity for delivering an oral presentation, it is not surprising that most students felt that their writing improved more than their oral presentation skills (Fig. 2). Several commented that some of the best things about the course were that the writing assignments were "demanding," "made me think," and "made me think about writing and how to improve."

Despite this emphasis on writing, students wanted *even more time* spent on writing: how to write introductions, conclusions, and the other sections of the manuscript, and more on the structure of manuscripts. They also wanted more time spent on writing paragraphs and sentences and more time spent revising their own writing during the in-class peer reviews.

The most serious weaknesses of the course were that the pace was a bit too slow for some people (although 78% thought that the pace was OK), that it was difficult for undergrads who did not have a writing assignment (despite my recommendation that having one would make the class easier), and that the course needed a tutorial section for one-on-one interaction (few students, however, ever took advantage of my open-office policy to stop by and talk about the course). Because most students (as well as the professor) were atmospheric scientists and my examples drew heavily from atmospheric science, 22% of the respondents wanted more examples from outside atmospheric science. Indeed, these others came from electronics, geophysics, geodesy, physics, and economics.

At the end of the course, 92% of respondents were satisfied with the course, and 89% said that they would recommend it to other students. Even the subjective grading was not a problem, with most students (76%) finding the grades fair.

CHALLENGES. Despite having written a book on communication, I found it difficult to get the students to open up and discuss during the laboratory setting. Finnish students in particular are quite independent and introspective, shying away from offering their opinions and even answering factual questions in class. [Ventola (1992) provides a frank perspective on the challenges that Finns face communicating using scientific English.] According to some sage advice I received from a Finnish colleague after the frustration of teaching my first course in Helsinki in 2007, one key to opening up the discussion is to start within small groups. In selecting the three-member groups, another colleague told me to avoid creating a three-member group with one woman, who would usually be reluctant to speak up in the presence of two usually less-inhibited males. Because of the small size of the classroom relative to the large number of students, mixing up the groups beyond the nearest-neighbor approach was usually difficult, but I did think that the small-group discussions, followed by the whole-class discussions, was a successful approach, in general.

This type of course demanded lots of grading, which was difficult to find the time to do thoroughly, especially for assignments written by nonnative English speakers. A native English-speaking teaching assistant (rare in Finland) would have helped ease this burden. Consequently, peer review was a necessary part of the course to help provide more thoroughness than I alone could have provided. [After the class was over, I discovered holistic grading (Dyrud 1994), where the students are given a grade of *excellent*, *acceptable*, or *unacceptable* and are given a chance to make revisions. Holistic grading is a process that is more similar to the real world, reduces the subjectivity of grading, allows for students to revise their work, and can save the instructor an incredible amount of time from making numerous minor comments. Next time I teach, I will incorporate this technique.]

However, peer review has the added benefit to the students of receiving feedback from their peers rather than an authority figure (the professor). Also, students tend to focus on the small-scale issues because writing (or editing) for novices (scientific and English language) is relatively new, so they focus

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on the mechanics. With more experience, writing becomes a reflective process (e.g., Scardamalia et al. 1984). Thus, when I graded the students' writing assignments, I usually stuck to the larger-scale issues with the writing (organization, coherence, precision), leaving language and grammar errors alone.

The complaints by the students without preplanned writing projects could have been resolved by offering two versions of the course: one tied to those writing a paper and another tied to those not writing their own paper. That said, I have a hard time imagining a writing laboratory absent a writing assignment tailored to the individual student's needs. If this laboratory were to be taught to students lacking their own writing assignment, it would be preferable to assign a topic for them to work on (e.g., a literature review, position paper, research proposal, graduate school application essay). Thus, I probably needed to exert more control over their writing assignments early in the class.

WHERE WE'VE BEEN, WHERE WE'RE GOING. The origin of this laboratory course was a communications workshop for undergraduate students that I started teaching in 2000. By 2005, the workshop consisted of two 4-h periods, with the first four hours being nearly all lecture material and the second four hours being peer-review evaluation of writing samples written by the students. Over the years, the course has been reorganized, distilled, and presented in different contexts (e.g., invited talks to university students, lectures at the AMS Student Conference since 2008). This laboratory course at the University of Helsinki was the first time that the content was expanded to 14 weeks.

I have also considered an intermediate-length laboratory course one week long of intensive lectures and in-class exercises in the morning and individual time for writing or presentation preparation in the afternoon. Such a course might be given during a summer school or retreat. Such seclusion from the daily grind has obvious benefits to keeping the students focused on writing, as this lack of focus is one of the common excuses for not starting or completing writing assignments.

Although the book was developed from a workshop for undergraduates, it was designed for all levels of students, as well as practicing scientists. Thus, exercises and other aspects from this course could be incorporated into existing curricula at colleges and universities (see sidebar on "Incorporating writing and speaking into a core curriculum course"). More writing, more speaking opportunities, and more opportunities for peer review within existing classes will help contribute to a greater emphasis on communication skills for students without compromising the traditional lecture-based material. In fact, evidence suggests that the more opportunities for students to express themselves in situations that mimic the real world, the better the learning experience.

ACKNOWLEDGMENTS. I thank all the students over the years that attended and provided comments to improve

INCORPORATING WRITING AND SPEAKING INTO A CORE CURRICULUM COURSE

Many of the exercises from this course on communication skills can be employed outside of this course. For example, even core curriculum courses can include writing assignments and lessons to help improve student writing incrementally. For example, remove the abstract from an article and have the students write a new abstract. In the University of Helsinki course, I used Weinstein and Sanders's (1989) "Wind increases in rapid marine cyclogenesis," a 2.5-page article with no abstract. Most students (84%) found this to be a useful exercise. Another exercise is to give them a paper (perhaps already published), an article where the research approach can be questioned, or an article that has an unexpected result, and ask the students to write a review. Most students (77%) found this exercise useful, although a few missed the point of choosing something they disagreed with or they did not follow the proper format of a review, despite having had a lecture on the structure of a review. Other resources to give instructors ideas about how to include writing and speaking exercises in the classroom include the following:

- Gross Davis (1993) provides some guidance to instructors wanting to incorporate more writing and speaking exercises in their classroom.
- Market (2006) found that students are more likely to make better forecasts on days with precipitation if they write an area forecast discussion.
- "Incorporating writing skills in a measurements laboratory" by Professor Petra Klein of the University of Oklahoma appears in Schultz (2009, p. 338).

An outtake chapter from *Eloquent Science*, "Incorporating Communication Skills into Teaching" can be found on the Resources section of eloquentscience.com.

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the workshops and courses I taught. I also thank John Knox, Daphne LaDue, Paul Croft, and two anonymous reviewers for their comments on earlier versions of this article. Partial funding for Schultz comes from Vaisala Oyj.

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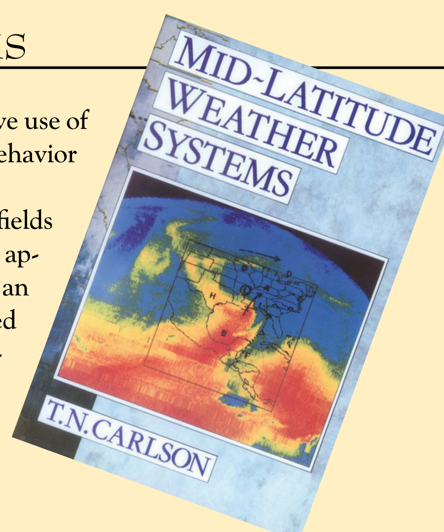

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