7

ACCESSIBLE SCIENTIFIC WRITING

Scientific writing does not need to be turgid, dense text written for a handful of specialists. Indeed, authors should strive to present well-reasoned arguments using clear, accessible language for the audience. This chapter challenges us to write so that others will be able to grasp what we say through the approaches we take to writing the manuscript and the way we organize our writing.

Stereotypical scientists are not known for their communication skills. Perhaps for good reason. Maybe that is why scientists who are talented at explaining to nonscientists the complexities of the universe (Carl Sagan), physics (Stephen Hawking), or evolution (Stephen Jay Gould) are so highly regarded by the public. These people have taken their skills at science and scientific writing and have crossed over into the realm of literary writing.

Many of us are voracious readers, whether it be novels for relaxation, newspapers for current events, or nonfiction for learning. How do we use this experience in our scientific day job? Why do we not translate some of that enjoyable experience to our writing? Is there a fundamental difference between literature writing and scientific writing? Yes, and no.

7.1 THE DIFFERENCES BETWEEN LITERARY AND SCIENTIFIC WRITING

Poetry and prose convey different facts and emotions than scientific writing. Perelman et al. (1998, Section 1.1) define the characteristics of effective technical communication as accuracy, clarity, conciseness, coherence, and appropriateness. In some ways, literary writing violates many of these. Literary writing does not need to be factually accurate if it is fiction. Good literary

writing sometimes relies on ambiguity to develop the story. Literary writing does not need to possess clarity if the author wishes to engage the reader's imagination. And, concision is certainly not a hallmark of literary writing—fans of James Michener testify!

Ideally, our goal as scientific writers is much the same as for literary writers. We want to convey information to our audience, and we want to invoke a response, whether it be informational, emotional, persuasive, or a call to action. Sure, we have more jargon and terms with complicated definitions than literary writing, and our work is found in the nonfiction section of the bookstore (we hope!). Nevertheless, if we visualize our scientific writing being more accessible to the public (imagine writing for your parents or your friends), then we will have gone a long way toward making it more accessible to *scientists*.

I make it a point to read papers or books by authors whose writing style I have a high regard for. This can be anything—classical fiction, scientific papers written during the Victorian period, etc.—to erase the unfortunate memory of the numerous dry, badly written papers one inevitably has to read as background to the research one is presenting. —Kerry Emanuel, Massachusetts Institute of Technology

7.2 MAKING WRITING MORE ACCESSIBLE

Recognizing that we write for our audience, not for ourselves, we need to become considerate of the group for whom we write. Here are some tips for making writing more accessible to the audience.

Demonstrate your points to the audience with clear, specific examples. Every statement should contribute positively toward the paper by presenting evidence, citing a reference, indicating speculation, or offering a hypothesis, for example. Readers are puzzled by statements like, "Nor'easters cause extensive damage to beaches along the East Coast of the United States." Yes, such statements are obvious, but what does the audience do with this information? More specifics on the area of beach lost, the volume of sand washed away, what period of time, and how many houses and buildings have fallen into the ocean give the reader much more context.

Assume your audience is not as knowledgeable about the topic as you are. Explain nuances, jargon, and assumptions. Given the choices of stating or eliminating information that much of your audience may know, err on the side of backtracking a bit and providing your audience with a little more information than you think they may need. The audience wants to feel comfortable reading your article. Starting slowly—but not too slowly—will ease them into the article.

Justify your assumptions. Each study, no matter how carefully designed and executed, makes assumptions. As such, the strongest papers are those that anticipate the rebuttals and address them up front without apology. Even if your assumptions are relatively commonplace for specialists such as yourself, future specialists reading your paper or nonspecialists today might not

know what those assumptions were. Not justifying your assumptions leaves you open to reviewer criticisms, annoying for author and reviewer alike, and lengthening the time to publication. Describe your assumptions from the most plausible to the least plausible or the most general to the least general.

Explain the limitations and alternative explanations of your research. Whether the lack of potentially important measurements, limited grid spacing in your model, issues with the way the data were collected, or instrument calibration problems, being forthright in the paper will enhance, not reduce, your credibility. Do not pretend that you are being smart by not stating the limitations of your work. Astute readers will recognize the limitations anyway and may wonder about your intentions. Reviewers who identify the limitations and alternative explanations for your results will ask you to address them (or reject your manuscript), so you might as well declare them and discuss them on your own terms. Acknowledging and stating limitations also keeps you from overgeneralizing your research results. One way to evaluate your proposed explanations is to take the opposite point of view and try to shoot holes in your arguments. If you were to play devil's advocate (or your arch-enemy) to your paper, what issues would you raise that would be most damaging? Unfortunately, more papers should address the limitations to their work and evaluate alternative explanations for their results. Instead of a sign of weakness, it should be a sign of an honest author.

The right to search for the truth implies also a duty; one must not conceal any part of what one has recognized to be the truth. —Albert Einstein

Consider how your audience will receive your argument. Will they be skeptical or hostile to your conclusion? If so, then develop the text to provide all the evidence first. Do not jump right in with your controversial ideas before they have seen the evidence, and expect them to go along with you. Let them arrive with you to the conclusion that perhaps previously they were not ready to embrace.

Create a document that is accessible to the audience. Everything from the organization of the manuscript to the paragraphs, sentences, words, and figures should be explained to your audience. Be concise without omitting substance. Write so the words sound natural, but professional.

If it's boring to you, it's boring to your reader. —from the poster "The Only 12 ½ Writing Rules You'll Ever Need"

7.3 STRUCTURING LOGICAL ARGUMENTS

Much as the organization of the paper has a certain order that should be followed (e.g., data, methods, results, discussion), arguments also need a certain presentation to maximize reader comprehension. Remember that you are presenting new results to your readers, and you expect them to follow your logic. Therefore, present it in a manner that will make sense to them, as follows:

data → results → interpretation → inference → speculation

The whole chain begins with the *data*. Present the data in the text, and present figures that will support your later argument. After showing the data, the reader is ready to hear the *results*, or what the data are saying. Especially when describing a figure, authors often present results first, to precondition the reader to interpret the figure the way they want.

Next, the reader is open to *interpretation* of that data, a slightly more in-depth analysis of what the data mean. After interpretation, the reader is primed for *inference*, or an extension of the data outside the limited focus of the present argument. Finally, *speculation*, or an educated guess of what the data might imply in an entirely different context, should be presented last. When injecting opinion or speculation, be clear to your audience that it is not fact, but it follows from your data and reasoning.

Rearranging the links in this chain is possible to some extent, and not all steps in this chain will occur in all situations, but too much rearrangement could confuse and frustrate your audience. Consider the following example.

> **DRAFT:** We speculate that buoyant convection caused by the release of conditional instability above a region of low-level frontogenesis was organized into bands by the midtropospheric inertial instability. (*speculation*) Negative absolute vorticity in the Northern Hemisphere implies the presence of inertial instability. (*interpretation*) Calculations are performed on the output from the Rapid Update Cycle from 0000 UTC 20 July. (*data*) The 500-hPa absolute vorticity is negative in the area where the bands form (Fig. 5). (*results*) The occurrence of the bands in the region of negative absolute vorticity indicates inertial instability could have been released. (*inference*) The elimination of the negative absolute vorticity after 0600 UTC shown previously (Fig. 3) suggests that the inertial instability was released, returning the atmosphere to an inertially stable state. (*inference*)

If you felt slightly offended that the author offered the speculation first, and supported the argument later, then you are not alone. Although the author may have felt that the audience was informed of all the necessary information, in fact, the audience was conditioned to be skeptical of this argument by having the speculation presented before the evidence upon which that speculation rested. The author did not allow the structure of the text to carry the reader to the conclusion.

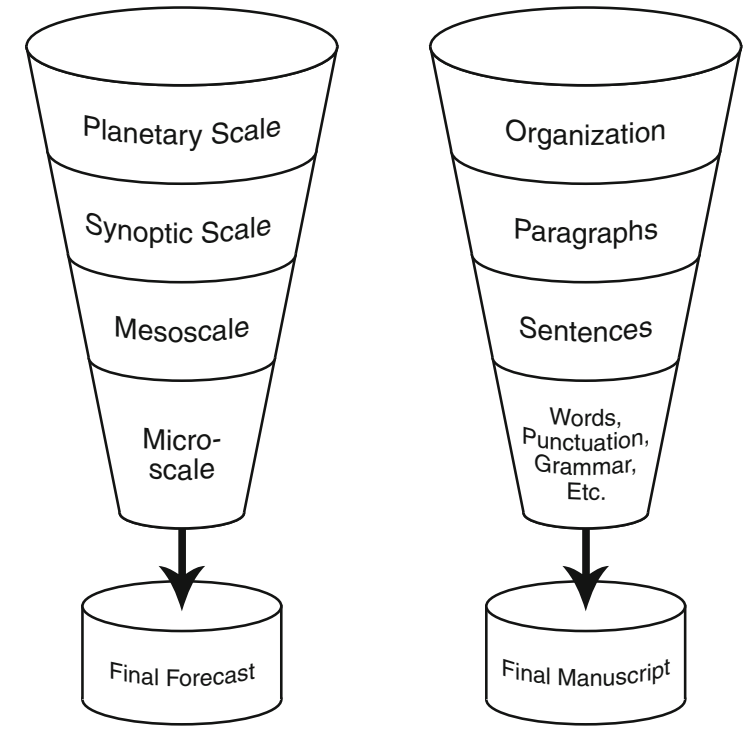
> **IMPROVED:** Calculations are performed on the output from the Rapid Update Cycle from 0000 UTC 20 July. The 500-hPa absolute vorticity is negative in the area where the bands form (Fig. 5). Negative absolute vorticity in the Northern Hemisphere implies the presence of inertial instability. The occurrence of the bands in the region of negative absolute vorticity indicates inertial instability

could have been released. The elimination of the negative absolute vorticity after 0600 UTC shown previously (Fig. 3) suggests that the inertial instability was released, returning the atmosphere to an inertially stable state. We speculate that buoyant convection caused by the release of conditional instability above a region of low-level frontogenesis was organized into bands by the midtropospheric inertial instability.

Similarly, how you organize the text may improve the audience's ability to understand your argument. Organize your text from general to specific, or specific to general, or case study to climatology, or vice versa. Avoid jumping around among topics.

7.4 WRITING IS LIKE FORECASTING

Writing a scientific document is a little like making a weather forecast. Snellman (1982) described the process of making a forecast using the forecast funnel analogy (Fig. 7.1a). The forecast funnel provides a framework for forecasters to visualize the analysis and forecast process sequentially through the different scales of motion in the atmosphere from the planetary scale to the



(a) THE FORECAST FUNNEL (after Snellman 1982)

(b) THE WRITING/EDITING FUNNEL

Fig. 7.1 (a) The forecast funnel (after Snellman 1982) and (b) the writing/editing funnel.

microscale. By focusing on the largest scales first, forecasters understand the environment that may favor or inhibit certain types of smaller-scale weather phenomena. As the forecaster progresses down the funnel, greater attention is paid to how the mesoscale and microscale details evolve within that specific synoptic pattern.

Similarly, writing and editing a manuscript can be considered like the forecast funnel (Fig. 7.1b) in that it requires a focus, first on the largest scales (the organization of the manuscript: chapters in a thesis or sections in an article) before a consideration of the paragraphs, sentences, and words. The chapters (in a thesis) or sections (in an article) are analogous to the planetary-scale flow, organizing and shaping the writing. Paragraphs serve as the synoptic-scale flow, the regular flow of pressure rises and falls that deliver the sensible weather. Sentences are the mesoscale components of the flow, and words, punctuation, grammar, spelling, etc., are the microscale components. High-quality scientific writing requires all scales of the writing/editing funnel to be high quality, in the same way as all meteorological scales need to be properly understood to make a high-quality forecast.

In planning, writing, and especially editing a manuscript, remembering the writing/editing funnel will produce a better organized paper and make the most effective use of your time. For instance, jumping right in at the microscale and spending a lot of time revising word choice and fixing misspellings on a stream-of-consciousness idea when the organization of the paper has not even solidified (planetary scale) may result in an extremely well-written paragraph, but no place for it within the eventual manuscript. Smart authors consider the organization of the paper first before starting on much of the smaller-scale work.

The components of the writing/editing funnel are described in this book: Chapter 4 presented the parts of a scientific paper, the planetary-scale organization to the manuscript. The next three chapters explore the rest, starting with the synoptic scale and working down to the microscale. Chapter 8 focuses on writing effective paragraphs, Chapter 9 focuses on effective sentences, and Chapter 10 focuses on effective words and phrases. Although this book generally does not cover grammar and spelling, some punctuation is discussed in Appendix A.

8

CONSTRUCTING EFFECTIVE PARAGRAPHS

A well-written scientific manuscript demands strong, effective paragraphs for support. An effective paragraph is characterized by unity of theme, and those themes from all paragraphs together provide the constituents of the manuscript. This chapter describes how to construct potent paragraphs, focusing on the coherence internal to a paragraph centering about the unitary theme, as well as the coherence between paragraphs that make the manuscript fluid.

As atoms are to matter, paragraphs are the fundamental organizational unit of a paper. Paragraphs serve this role because each one contains only one theme, which is explored within the bounds of the paragraph. Subsequent paragraphs deliver different themes, and the accumulation of themes with each paragraph builds the content of the manuscript. Thus, effective paragraphs bind the manuscript together.

Effective paragraphs possess two primary characteristics: unity and coherence. Unity means a paragraph consists of one theme only. Everything within that paragraph should be related to that one theme. The focal point of the paragraph, the *topic sentence*, defines the theme of the paragraph. Although typically the first sentence of the paragraph, the topic sentence may sometimes appear at the end of the paragraph for additional emphasis. Should more than one theme be in a paragraph, three options exist—break up the paragraph, one new paragraph for each theme; revise the topic sentence and, hence, the scope of the paragraph to encompass multiple themes; or delete one or more themes. The importance of the topic sentence should not be underestimated. As part of their outlining, some authors write the topic sentences for each paragraph, ensuring a logical flow between topics early in the writing process.

The writer has much control over the paragraph. The main sections of the paper are largely determined by convention, and the structure of sentences is determined by the syntax of the language. The paragraph however has no such formal constraints; the chief constraint is content. —Antoinette M. Wilkinson (1991, p. 437)

Coherence within a paragraph derives from the ordering and relationship between sentences. Sentences within each paragraph should proceed in

a logical order, introducing new concepts sequentially. (An example of how improper ordering can affect coherence is presented in Section 7.3.)

8.1 COHERENCE WITHIN PARAGRAPHS

When I was living in Norman, Oklahoma, colleagues at Iowa State University in Ames, Iowa, invited me to visit. I had never been to Iowa State before and I wanted to see some other places on my way back home, so I drove the 600 miles. From the Web, I determined the following directions to the building that housed the Meteorology Program:

1. From Norman, take Interstate 35 north to Ames.
2. Leave the highway at Exit 111.
3. Drive west on Highway 30.
4. Turn right on University Boulevard.
5. Turn left on Lincoln Way.
6. Turn right on Union Drive.
7. Turn right on Wallace Road.
8. Turn left into the parking lot of Agronomy Hall.

Imagine if I misread the directions, rearranged the order of the instructions, forgot one of the eight steps, or made a wrong turn. With a little concerted effort, I probably could still get to Agronomy Hall. The more the directions were altered, the more effort (and gasoline and time) would be wasted. For travelers familiar with Ames, these directions would probably suffice, even with a few transcription errors. But, for me, making a mistake, being confused, and getting lost were possibilities.

To supplement these directions from the Web, I asked one of my colleagues, Prof. Bill Gallus, to send me directions. Here is what he sent:

1. From Norman, take Interstate 35 north to Ames.
2. Take the first exit for Ames, which is exit 111 (Highway 30), with signs mentioning Iowa State University.
3. Drive west on Highway 30 until the third exit, which is University Boulevard.
4. Take a right on University Boulevard and drive past the big football stadium and the large coliseum.
5. Just beyond the coliseum will be Lincoln Way. Turn left at this light.
6. Be sure to get in the right lane, because you'll be making a right onto Union Drive in only two blocks. This road takes you past the president's mansion.

7. Turn right onto Wallace Road after a block or so. This intersection is at the bottom of the hill.
8. Stay on Wallace for about two blocks until you see the Agronomy Building on your left. It is the large, red-brick building on the southeast corner of the intersection of Wallace and Osborne Drive. Turn left into the parking lot.

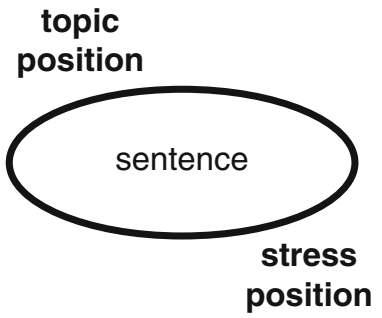
Had I misread Bill's directions, rearranged their order, forgot some steps, or made a wrong turn, the additional detail would have been incredibly helpful in returning me to my desired route. Bill's directions are more informative and longer, but the turns, where I potentially could have made an error, are more descriptive. Sometimes his directions repeat elements from the previous step. For example, the coliseum was mentioned at the end of the fourth step and the beginning of the fifth step. Had I omitted step 4 inadvertently, I might have still found my way knowing that I was to pass the coliseum. As a result of the additional detail and repetition, Bill's directions gave me additional confidence during my drive.

I aim for the happy medium between too much and too little information. I don't know of any formula that directs one toward the optimal amount of information. Inasmuch as the optimal amount depends on the receiver as well as the transmitter—I try to be sensitive to audience response to see what works and what doesn't and adjust accordingly. —Richard Rotunno, National Center for Atmospheric Research

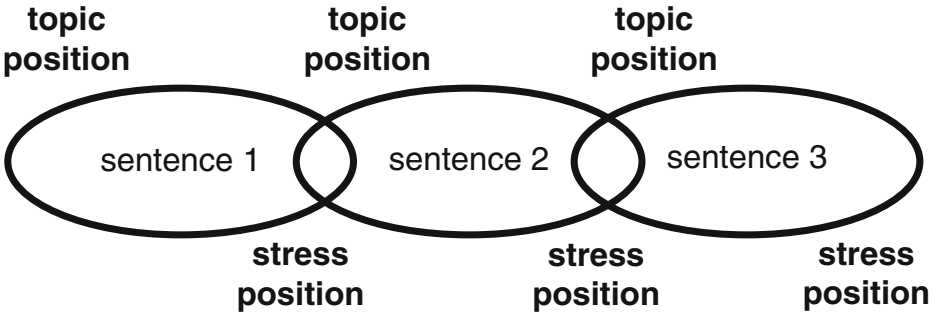
Writing is like providing directions to the reader. You could provide directions such as the terse first set and wish the audience luck on their journey through your manuscript, hoping that they fully understand what you wrote and make no mistakes. Or, you could provide clear, detailed directions, describing how each turn relates to the next, as with Bill's directions. Readers, like travelers, appreciate being led through all the steps. The transitions may be clear in the author's mind, but the author needs to inform the readers of those transitions, especially if the audience is unfamiliar with the topic, just like the traveler unfamiliar with Iowa will want detailed directions. Anticipating how the audience will interpret your writing is one challenge of coherent writing.

The secret to creating a coherent paragraph lies in recognizing the structural expectations that the audience places on the text they read (Gopen and Swan 1990). As the audience reads text, they have "old information," material that they have already been exposed to, and "new information," material that they are just being exposed to. Just as the beginning of a paragraph has a topic sentence, the beginning of the sentence has a *topic position* (Fig. 8.1a). Placing old information in the topic position comforts the reader, providing links backward and context forward. The topic position connects the material previously introduced in the text (e.g., the prior paragraph) and the new material to be introduced in the present paragraph. In this way, writing is linking up information in a logical, flowing manner (Fig. 8.1b), just like steps 4 and 5 in Bill's directions were linked through his repetition of "coliseum."

In the same way that the beginning of a sentence or paragraph is important, the end also has special significance. New information to be emphasized



(a) Structure of a sentence



(b) Maintaining transition in a paragraph by linking the stress position of one sentence to the topic position of the next

Fig. 8.1 (a) A single link in the chain: a sentence with a topic position at the beginning and a stress position at the end. (b) Creating a chain of links: linking the sentences together by connecting the stress position of one sentence to the topic position of the next sentence.

should appear at the end, in the *stress position* (Fig. 8.1a). Readers naturally emphasize the material at the end, whether it be at the end of a sentence, the end of a paragraph, or at the end of a novel. Secondary stress positions within a sentence may also occur before colons or semicolons.

Read this paragraph out loud. Notice how you naturally place the emphasis in your voice at the end of each sentence? Material improperly occupying the stress position might receive undue attention from the reader, and, therefore, the author would fail to communicate the most important point. Furthermore, the material in the stress position typically links forward. Such linkages help the reader infer the relationship between one sentence and the next, thus helping to keep that link in the chain intact.

8.2 EXAMPLES OF COHERENCE

There are many ways to maintain coherence within a paragraph. Here are three examples: repetition, enumeration, and transition.

8.2.1 Repetition

Repeating key words and phrases (what Michael McIntyre of the University of Cambridge calls lucid repetition) is one of the easiest ways to maintain coherence. The words or phrases do not have to be identical, but the linkage should be clear. In the paragraph below, the topic, the life cycle of a cyclone, appears in the first sentence. Each subsequent sentence is linked to the previous one by the italicized words.

> The life cycle of a Bjerknes and Solberg (1922) cyclone, hereafter the Norwegian cyclone model, begins with a small-amplitude *disturbance* on the polar front. This *disturbance* consists of a cyclonic circulation that advects cold air equatorward west of the cyclone center and warm air poleward east of the cyclone center, forming *cold and warm fronts*, respectively. Because the *cold front* is observed to rotate around the system faster than the *warm front*, the cold front eventually *catches up* to the warm front, forming an occluded front. Originally, Bjerknes and Solberg (1922) believed that this *catch up* initially would occur away from the low center.

Pronouns can also be used to link sentences, if the pronoun has a clear noun to which it refers.

> *Galway (1975)* developed an outbreak definition that included three classifications of family outbreaks: small (6–9 tornadoes), moderate (10–19 tornadoes), and large (20 tornadoes). *He* found that 73% of the tornado deaths from 1952 to 1973 were attributed to outbreaks with 10 or more tornadoes.

In the two examples above, despite being excerpted from journal articles and devoid of the surrounding text, the text makes sense because the grouping of sentences exhibits coherence.

8.2.2 Enumeration

Organizing a list of items through enumeration helps readers follow your argument. If more than a few sentences for each item are needed, start a new paragraph for each item. Make this enumerated list within the text painfully clear to the audience. Use "first," "second," etc., as the extra "-ly" in the adverbs "firstly," "secondly," etc., is not needed. Alternatively, for longer enumerations, the topics could be listed as a numbered list, as a bulleted list, or as a table.

> These jet-streak winds could play *three* roles in the resulting convection. *First*, the jet streak provides upper-level synoptic-scale ascent leading to development of cirrus, reducing insolation and slowing the removal of the low-level

capping inversion. *Second*, the low-level synoptic-scale ascent associated with the jet streak favors the removal of the cap through adiabatic cooling, which would counter the cloud-radiative effects and promote the development of deep, moist convection. *Third*, the strength of the incoming winds affects the magnitude of the deep-layer shear and storm organization, favoring long-lived, isolated, rotating storms.

8.2.3 Transition

Read the following paragraph.

> **DRAFT:** Whether or not the center of a mammatus lobe is warmer or colder than ambient depends on the individual lobes and the height at which the temperature is examined. Lobes simulated in experiment M2 have both warmer and colder cores than ambient (Fig. 4a). Lobe 1 has a warmer-than-ambient core near the bottom of the lobe. Lobes 2 and 3 have colder-than-ambient and near-ambient cores (Fig. 4a). Lobe 1 is warmer than ambient at lower heights near the base of the lobe; at higher heights, the perturbation is colder than ambient. Lobes simulated in experiment M3 have core temperatures near ambient for most of the depth of the mammatus lobe (Fig. 4b).

The paragraph seems to read as a list of observations about lobes 1, 2, and 3 and two experiments, M2 and M3. Why are these observations important and how do they relate to one another? Although repetition of "lobe" and "experiment" provides some comfort, meaning may still elude the reader.

Transitional devices are words or phrases that are used to maintain coherency by indicating relationships between sentences and sentence fragments. Transitional devices can indicate similarity, contrast, sequence, emphasis, causality, or summary (see the sidebar). By inserting just a few transitional devices into the paragraph (seven italicized words in a 119-word paragraph), the relationship between these observations becomes much clearer.

> **IMPROVED:** Whether or not the center of a mammatus lobe is warmer or colder than ambient depends on the individual lobes and the height at which the temperature is examined. *For example*, lobes simulated in experiment M2 have both warmer and colder cores than ambient (Fig. 4a). *Specifically*, lobe 1 has a warmer-than-ambient core near the bottom of the lobe, *whereas* lobes 2 and 3 have colder-than-ambient and near-ambient cores (Fig. 4a). *Furthermore*, lobe 1 is warmer than ambient at lower heights near the base of the lobe; at higher heights, the perturbation is colder than ambient. *In contrast*, lobes simulated in experiment M3 have core temperatures near ambient for most of the depth of the mammatus lobe (Fig. 4b).

COMMON TRANSITIONAL DEVICES FOR SCIENTIFIC WRITING

Sequence
again, and, besides, then, further, furthermore, next, moreover, in addition, first, second, third, etc.; (a), (b), (c), etc.; 1), 2), 3), etc.; following this, subsequently, to enumerate, also, another, last, plus

Comparison and contrast
at the same time, on the contrary, in contrast, nevertheless, notwithstanding, nonetheless, conversely, like, unlike, even so, in the same way, as, unless, whether, though, even though, regardless, irrespective, otherwise, in comparison to, even when, to the contrary, but, or, nor, yet, inasmuch, contrary to, comparing, alternatively, rather, despite, ironically

Examples
for example, for instance, in the case of, in general, especially, if, specifically, in particular, generally, on this occasion, in this situation, to illustrate, to demonstrate, as an illustration, as a demonstration, unless, such as, provided that, once again, another example, a further example, a further complication, in such cases, in this way, in some of these cases, for these reasons, one way, another way, as discussed, using, particularly, that is, more specifically, except

Time
while, since, simultaneously, presently, meanwhile, thereafter, thereupon, afterward, at the same time, next, sometimes, in the meantime, eventually, following this, later, usually, occasionally, concurrently, preceding this, as, presently, at the time of this writing, often, rarely, throughout, by, at, during, continuing

Cause and effect
therefore, thus, consequently, as a consequence, for this reason, hence, accordingly, because, due to, in spite of, despite

Emphasis
surprisingly, indeed, interestingly, curiously, in fact, of course, naturally, evidently, certainly, clearly, obviously, apparently, fortunately, especially, significantly, perhaps, from my perspective, if possible, if so, basically, in reality, essentially

Concluding
finally, therefore, in summary, to conclude, in conclusion, to summarize, as I have shown, hence, thus, in other words, as said earlier, in any case, as a result, at least, as mentioned above, as said previously, thereby, in the present article, simply put

8.3 COHERENCE BETWEEN PARAGRAPHS

Coherence exists within a paragraph through the orderly succession of sentences. Yet, to create fluidity through the document and a lucid story for the reader, coherence must also exist through the orderly succession of paragraphs. Coherence between paragraphs is created through the same mechanisms discussed in Section 8.1, except on the paragraph scale using sentences, and occasionally words, as the transitioning elements. To demonstrate this coherence for a specific example, the first one or two sentences and the last sentence in the first six paragraphs of an article have been reprinted below, omitting the citations.

Introduction

[1] Single- and multiple-banded (hereafter, banded) clouds and precipitation are commonly observed in association with frontal zones in extratropical cyclones. . . . Indeed, some observational studies over extended periods of time show the presence of MSI [moist symmetric instability] in association with banded precipitating baroclinic systems to be rather common.

[2] Although we do not deny the likely existence of slantwise convection or the possible involvement of MSI in some precipitating systems in the atmosphere, it is our contention that CSI [conditional symmetric instability, a form of MSI] is frequently misused and overused as a diagnostic tool. We believe the following four reasons are responsible, in part, for the present situation. . . . Thus, for these four reasons, CSI is commonly observed yet often misinterpreted and misunderstood.

[3] The purpose of this article is twofold: to attempt to limit further misuse of the CSI paradigm by researchers and forecasters alike by highlighting common pitfalls, and to encourage future research explorations that are directed at the deficiencies in our understanding of MSI and slantwise convection. The remainder of this article is as follows. . . . Finally, Section 8 consists of a summary of main points, directions for future research, and a concluding discussion.

An ingredients-based methodology for slantwise convection

[4] Throughout this article, we wish to differentiate between *free convection* and *forced convection* as motions in the atmosphere that are associated with the presence and absence of instability, respectively. Unless otherwise specified, we use the generic term *convection* to imply free convection (gravitational or symmetric). [This paragraph is only two sentences long.]

[5] To clarify some of the confusion surrounding the concepts of CSI and slantwise convection, we find it useful to demonstrate parallels with the more familiar concepts of moist gravitational instability and convection. An exploration of these parallels begins with an ingredients-based methodology for forecasting deep, moist convection. . . . "Remove any one of these [ingredients] and there well may be some important weather phenomena, but the process is no longer deep, moist convection."

[6] For the purposes of this article, we adopt the same triad of ingredients from moist gravitational convection (instability, moisture, and lift) for the production of moist slantwise convection, where the requisite instability becomes MSI, rather than moist gravitational instability. . . . The ingredients-based methodology firmly labels CSI as the instability, clearly separate from the lifting mechanism.

Even with most of the central text within each paragraph omitted, the remaining text remains mostly readable. The reason is the effective coher-

ence between the paragraphs. For example, enumeration was used within paragraphs 2 and 3. Repetition of "MSI" and "precipitating systems" was used between paragraphs 1 and 2, and repetition of "ingredients" was used between paragraphs 5 and 6.

Some improvement in coherence between paragraphs 2 and 3 could have been gained by repeating "misinterpreted and misunderstood" at the beginning of paragraph 3 with a slight revision: "The purpose of this article is twofold: to attempt to limit further *misinterpretation* of the CSI paradigm by researchers and forecasters alike by highlighting common pitfalls, and to encourage future research explorations that are directed at *correcting our misunderstandings* of MSI and slantwise convection." This revision shows more

SECTIONS AND SUBSECTIONS

Sections and subsections can be important to your paper for helping the reader see the organization of the paper more clearly. Sections and subsections allow readers to identify quickly the topics of interest to them and to skip the others. Section headings also provide some relief from whole pages of uninterrupted text, which can be imposing to a reader. However, creating subsections does not substitute for good transitional writing between the paragraphs (Section 8.3). Here are a few basic rules for creating sections and subsections:

- In general, at least two sectional headings are needed (e.g., Section 3.1 or 3a must be followed by a Section 3.2 or 3b). However, a minority of authors have argued that a single subsection within a section is legitimate. Creating a second subsection, they argue, would be forced, not natural.
- In general, some introductory text should exist between a major heading and a subheading (e.g., between the heading for Section 4 and the heading for Section 4.1). This material can be introductory material or a discussion of what will be covered within the section.
- Balance the number of headings, the number of topics to be discussed, and the length of the text under each heading. Too few headings and the corresponding text may be too long; too many headings and the corresponding text may be too short.
- Heading titles should have the same properties of a manuscript title, albeit much shorter: informative, accurate, clear, concise, and attention commanding (Table 3.1).
- Use descriptive titles, avoiding one-word titles (except for "introduction," "conclusions," etc.).
- Keep titles at each level parallel, if possible. If the titles are verb phrases (e.g., "Constructing the climatology," "Evaluating model performance"), do not intersperse noun phrases (e.g., "Comparison of control and no-flux simulations").
- Repeating the title in the body of the text shortly after starting the new section can give the readers comfort that you are going to address the topic that is described by the title.

Before submitting a manuscript, separate from the text and list all the section and subsection headings (e.g., table of contents, outline). Are the titles parallel (Section 9.4)? Does the organization of the paper as told through the outline make sense? See Section 4.15 for examples of effective paper organization.

clearly that the misinterpretations and misunderstandings of CSI will be addressed within the article.

8.4 LENGTH AND STRUCTURE OF PARAGRAPHS

In scientific writing, four to eight sentences per paragraph seems to be optimal in most cases. Although shorter paragraphs of two or three sentences can be used for emphasis from time to time, avoid single-sentence paragraphs as a general rule. Such paragraphs should be eliminated, merged in with another paragraph, or developed into a longer paragraph. On the other hand, coherent paragraphs much longer than eight sentences may be functional, but you may wish to break them up. Because the white space around paragraphs on the printed page serves partially as a visual break for the reader, long tracts of text can be imposing to the reader and are candidates for splitting into multiple paragraphs.

Paragraphing calls for a good eye as well as a logical mind. —William Strunk and E. B. White (2000, p. 17)

Within the paragraph, the sentences should vary in length and in rhythm, specifically in their construction or the location of the subject and verb within the sentence. Too many short sentences sound too sing-songy or elementary, whereas too many long sentences tire the reader. In the same way, the assemblage of paragraphs in the manuscript should also have variety in length and structure.

9

CONSTRUCTING EFFECTIVE SENTENCES

Well-written sentences convey information succinctly and precisely. Examples presented in this chapter guide authors toward improving their sentences. These improvements include such topics as subject–verb placement, overuse of passive voice, improper or inconsistent verb tense, and misplaced modifiers.

In the previous chapter, I said that paragraphs are the fundamental organizational unit of a paper. If this is the case, then sentences are the vehicle that delivers the message. Sentences composed of a series of disorganized words go nowhere. Whereas the construction of paragraphs focuses on coherence and unity of message, the construction of sentences focuses on concision and precision. In other words, sentences should say exactly what is meant in as few words as possible.

> A dog goes into a telegraph office, takes a blank form, and writes: "Woof woof woof. Woof, woof. Woof. Woof woof, woof."
>
> The clerk examines the paper and politely tells the dog: "There are only nine words here. You could send another 'Woof' for the same price."
>
> The dog looks confused and replies, "But that would make no sense at all."

Just like the dog's message, sometimes too many words can turn an otherwise clear sentence into nonsense. In this chapter, I present ways to improve the concision and precision of sentences. For some authors, applying the examples in this chapter will reduce the length of their drafts up to 20%, and, in the process, enhance clarity and precision. Although many of the examples to follow in this chapter will be grammatical, the present book is not intended to teach basic grammar skills. Nevertheless, some reminders about proper grammar usage will likely be useful.

9.1 ACTIVE VOICE VERSUS PASSIVE VOICE

One of the challenges facing scientific and technical writers is minimizing the use of passive voice and incorporating more active voice. Overuse of passive voice makes the manuscript dense to read and longer than necessary, so including more active voice generally strengthens manuscripts.

In active voice, the grammatical subject of the sentence acts upon the verb, whereas in passive voice, the subject is acted upon by the verb, which is a combination of a form of the verb "to be" (e.g., is, was, were) and the past participle (a verb with an "-ed" ending, commonly).

ACTIVE: I performed a simulation using a nonhydrostatic mesoscale model to understand the evolution of the squall line.
PASSIVE: A simulation was performed using a nonhydrostatic mesoscale model to understand the evolution of the squall line.

ARE FIRST-PERSON PRONOUNS ACCEPTABLE IN SCIENTIFIC WRITING?

Some teacher or professor in your past might have taught you to avoid the use of the first person (*I* or *we*), leading to a forced marriage with the passive voice. To appear disconnected from the research, common practice among authors of scientific and technical documents is to favor the passive voice, with the person who performed the simulation unstated and irrelevant. Such obtuse writing style has not always been the preferred style. Prior to the 1920s in the United States, active voice and first-person pronouns were quite common in scientific writing. Because science is done by individuals who make conscious decisions in designing, implementing, and communicating their research, such an air of impersonality, frankly, is disingenuous. We are intimately tied to our research and bias creeps in. The least we can do is acknowledge it.

Avoid first-person pronouns in the abstract—many journals do not allow it. However, most journals accept limited use of the first person in the body of the paper. I believe the first person can be quite effective when used sparingly and with purpose. Beware, however, that others may feel differently.

Avoid describing the rote methods of the research or the manuscript format almost entirely in first person or talking about yourself in the third person as "the author." Generally, you can use "this work" or "the present article" with the active voice to avoid first or third person.

DRAFT: I examined the events from Tables 1 and 2 for evidence of cloud-to-ground lightning. [sounds too conversational]
IMPROVED: The events from Tables 1 and 2 were examined for evidence of cloud-to-ground lightning.

DRAFT: We discuss the spatial distribution of the precipitation in northern Utah.
IMPROVED: The spatial distribution of the precipitation in northern Utah is discussed in the present article.

The subject of the sentence in active voice is "I," whereas the subject of the sentence in passive voice is "simulation." Because the first person "I" in this context is not generally used in a scientific document (see the below sidebar), passive voice dominates most scientific writing, even in situations where active voice would be preferred. Nevertheless, both active and passive voice are acceptable in scientific literature, although some authors would benefit from incorporating more active voice.

Here are three ways to change a passive sentence into an active one. First, put the object doing the action as the subject of the sentence (e.g., before the verb).

PASSIVE: Gamma or lognormal distributions commonly have been used to model *drop size distributions*.
ACTIVE: *Drop size distributions* commonly are modeled with gamma or lognormal distributions.

IMPROVED: The present article discusses the spatial distribution of the precipitation in northern Utah.

I use the first person very consciously to emphasize an action or decision that affects the outcome of the science being described.

DRAFT: Given option A and option B, the authors chose option B to more accurately depict the location of the front.
IMPROVED: Given option A and option B, we chose option B to more accurately depict the location of the front.

In the above example, because the results of the research may depend strongly on that choice, I want to make it clear to the audience that *we* made a decision to do something that impacts the outcome of the paper; two options were available, but *we* chose option B.

Similarly, the first person helps make sentences discussing speculation less awkward and more clear by indicating exactly who is speculating.

DRAFT: It is speculated that . . .
[Who is "it"? Who is speculating?]
DRAFT: The author speculates that . . .
[awkward]
IMPROVED: I speculate that . . .

If you feel that a sentence starting with "I" may sound too bold for many readers of a scientific paper, then move the first-person pronoun away from the start of the sentence with an introductory phrase: "Because the aerosol concentration increased dramatically, I speculate that. . . ."

Finally, I should comment about the use of "we" in a single-authored manuscript, or what is termed a *nosism*. Referred to by some authors derogatorily and incorrectly as *the royal we*, "we" in this context actually refers to "the author and the reader." Although some authors are comfortable with the nosism, others see "we" as condescending or patronizing. As with all language debates, exercise caution when employing contested language in your own writing.

Second, eliminate part of the verb.

PASSIVE: Improved warnings *are perceived to be* an important safety benefit of weather radars.
ACTIVE: Improved warnings *are* an important safety benefit of weather radars.

Third, pick a different verb.

PASSIVE: A stationary snowband *was initiated* over southeastern Wyoming.
ACTIVE: A stationary snowband *formed* over southeastern Wyoming.

Consider the following pair of sentences.

PASSIVE: Light snow lasting four and a half hours was officially reported at Raleigh.
ACTIVE: Raleigh officially reported light snow lasting four and a half hours.

Call for Papers from the Journal of the Passive Voice*: A new publication has been started. It has been reported to be a sub-publication of* Annals of Improbable Research *(AIR). The new journal has been named* Journal of the Passive Voice*. Articles written entirely in the passive will be seen to have been published in this new journal.* —Annals of Improbable Research*, 4 (3), p. 15.*

Both sentences are acceptable and would be welcome in a scientific document. How do you decide which to use? The answer depends on the desired emphasis, location within the document, and context within the paragraph (Table 9.1). Should you want to emphasize "snow," the sentence in the passive voice would be favored because its subject is "snow." On the other hand, if the sentence appears in a paragraph about the weather in Raleigh, the sentence written in active voice would probably be better.

Table 9.1 When to use active versus passive voice

Active voice is best used:
- to emphasize the subject of the sentence
- to emphasize the person or people doing the science ("I speculate that . . .")
- when describing figures or other work
- in declarative sentences, such as topic sentences
- to avoid sentences that begin with "there are" or "it has been shown that"

Passive voice is best used:
- when the subject of the sentence is unstated, unknown, or irrelevant
- to emphasize the object of the sentence
- within the data and methods section (to avoid first person)
- within abstracts (to avoid first person)
- for variety
- for coherence in the paragraph

To maintain the coherency of the paragraph through repetition (Section 8.2.1), you may need to choose one voice over the other to reverse the order of the sentence. In the first example below, choosing active voice in the first sentence means a similar structure to both sentences, which may sound elementary to some readers. In the second example, reversing the order of the first sentence by employing the passive voice results in coherency through repetition of "reduced dataset" in the stress position of the first sentence and in the topic position of the second sentence. Alternatively, both sentences could be combined, as in the third example, keeping active voice throughout.

FIRST SENTENCE ACTIVE: The reduced dataset consisted of stations that reported at least 80% of the possible surface observations. This reduced dataset consisted of 692,790 observations of nonfreezing drizzle from 584 stations.

FIRST SENTENCE PASSIVE: Stations that reported at least 80% of the possible surface observations were separated into a reduced dataset. This reduced dataset consisted of 692,790 observations of nonfreezing drizzle from 584 stations.

COMBINED: The reduced dataset consisted of stations that reported at least 80% of the possible surface observations, resulting in 692,790 observations of nonfreezing drizzle from 584 stations.

Articulate the action of every clause or sentence in its verb. —George Gopen and Judith Swan (1990)

In addition to writing in active voice, another way to make your sentences more potent is to choose verbs that emphasize action. Avoid weak verbs such as "occur," "see," "exist," and "observed"; favor stronger words that describe the relationship in the sentence rather than just saying the relationship exists. Too many sentences with "is," "are," "has," and "have" bore the reader (and the writer). As previously described, the reader looks to the verb in the sentence to see what the subject is doing, and passive sentences that lack action limit their ability to tell the story. Furthermore, selecting active verbs creates a more concise and precise sentence: "Brevity is a by-product of vigor" (Strunk and White 2000, p. 19).

DRAFT: An environment favorable for an airstream boundary *is* the result of the strong convergence and deformation associated with the surface cyclone.

IMPROVED: The strong convergence and deformation associated with the surface cyclone *creates* an environment favorable for an airstream boundary.

Do not be afraid to use the thesaurus. You do not have to write "Smith et al. (1995) ostended" when you mean "Smith et al. (1995) showed," but a little variety will improve your writing. Table 9.2 can help.

Choose active verbs rather than their noun forms. Avoid phrases such as perform a comparison, make a generalization, provide information, or reveal

Table 9.2 Some action verbs for scientific writing (augmented from Schall 2006, pp. 54 and 113)

acknowledge	compare	disagree	guide	list	recommend
admit	conclude	display	highlight	maintain	reiterate
analyze	consider	dispute	hypothesize	mean	report
argue	construct	distinguish	illuminate	measure	represent
articulate	construe	effect	illustrate	narrate	restrict
ascertain	contrast	elucidate	imply	neglect	reveal
assert	deduce	elude	improve	note	simplify
assert	define	employ	indicate	obtain	specify
assess	delineate	establish	infer	offer	speculate
attribute	demonstrate	estimate	inform	organize	state
believe	depict	evaluate	insist	postulate	suggest
calculate	derive	evince	interpret	predict	summarize
challenge	designate	exhibit	introduce	present	support
characterize	detail	explain	investigate	propose	surmise
clarify	determine	extrapolate	invoke	prove	synthesize
classify	devise	generalize	issue	provide	yield

a possible indication, when you can use more simple words such as compare, generalize, inform, or indicate. Similarly, often we add superfluous words when a more direct approach would suffice: acts to dry out → dries out; creates a moister environment → moistens; is used to denote → denotes; found to be → is; serves to introduce → introduces; and makes a measurement → measures.

9.2 SUBJECT–VERB DISTANCE

Consider the following sentence:

> **DRAFT:** Extratropical cyclones with two or more warm-front-like baroclinic zones over the central United States and southern Canada during 1982–1989 were examined.

Twenty words separate the subject "cyclones" from the verb "were examined." This distance keeps the readers in suspense, waiting to know what happens to the cyclone. Readers need understanding of what the subject is doing, and delays in receiving the second piece of information (the doing) inhibits comprehension. Words in between the subject and its verb are viewed as less important.

IMPROVED: Extratropical cyclones over the central United States and southern Canada during 1982–1989 were examined for the presence of two or more warm-front-like baroclinic zones.

9.3 VERB TENSE

Choosing verb tenses in scientific writing can also be confusing and not without controversy. The following guidelines appear to be generally held by most authors:

- Scientific fact is reported in the present tense: "The wavelength of maximum emission of solar radiation is 0.5 μm," "Ice pellets are frozen raindrops."
- Past events are described using the past tense: "On 12 December, 23 cm of snow fell," "An unusual climate shift occurred over the North Pacific Ocean around 1977."
- Present tense is used when referring to a figure, table, or calculation: "Table 3 shows," "the values are statistically significant."
- When the action started in the past and continues in the present, the present perfect tense (verb form of "have" and the past participle) is used: "the model has been developed."
- When the action started in the past continues in the present and will continue in the future, the present perfect progressive tense (verb form of "have" plus "been" and the present participle) is used: "the model has been developing."
- Future tense can be employed when referring to what will happen later in the paper, although concision argues for dropping the "will" and using the present tense: "Section 3 will discuss . . ." versus "Section 3 discusses. . . ."

Disagreements begin when considering the following situation. Should your own research (particularly the methods and results sections), as well as that of others, be reported in the past tense or in the present tense?

EXAMPLE 1: The simulation is/was run for 24 h, initialized from 1200 UTC 31 January.

EXAMPLE 2: Hansen (2005) derives/derived . . .

Most authors choose to write in the past tense because the work was done in the past. Furthermore, the use of past tense ensures that such a statement will remain true in the future, even if subsequent research comes to a different conclusion. These generalizations, however, are not supported by everyone.

Some authors argue that because published articles are in the past, their conclusions represent fact and should therefore be discussed in the present tense. (When past actions are discussed in the present tense, you can see why people get confused over verb tenses!) Nevertheless, others disagree, arguing reporting in the present tense "confers authority without substantiation." Ultimately, you must make up your own mind as to the verb tense you prefer in these situations. Whatever verb tense you choose, be consistent throughout the manuscript.

9.4 PARALLEL STRUCTURE

School teachers may have told you to mix up your writing by not repeating the same words and sentence structures. Although our teacher's advice may be appropriate for literary writing, repeating sentence structures, words, and phrases can be quite beneficial to readers of scientific documents (Section 8.2.1), especially in lists or when making comparisons. In performing experiments, scientists try to control as many variables as possible, changing only one variable at a time. Precise writing works the same way. Keeping structures parallel will help the reader follow your train of thought.

DRAFT: The cyclonic path of the cold conveyor belt is represented by trajectories 21–23, whereas trajectories 24 and 25 resemble the anticyclonic path.
IMPROVED: Trajectories 21–23 resemble the cyclonic path of the cold conveyor belt, whereas trajectories 24 and 25 resemble the anticyclonic path of the cold conveyor belt.

Similarly, words and expressions joined by a conjunction require the same form.

DRAFT: Many of the standard statistical tests of differences assume independence of data points and that the underlying distribution of the sample is known.
IMPROVED: Many of the standard statistical tests of differences assume that data points are independent of each other and that the underlying distribution of the sample is known.

DRAFT: Given the gaps in our knowledge of the structure, evolution, and the dynamics of surface cold fronts . . .
IMPROVED: Given the gaps in our knowledge of the structure, evolution, and dynamics of surface cold fronts . . .

9.5 COMPARISONS

Another form of nonparallel structure is incomplete comparisons.

DRAFT: Surface confluence in west Texas with this surface pressure pattern was much smaller. [The reader is probably asking, "Smaller than what?"]
IMPROVED: Surface confluence in west Texas with this surface pressure pattern was much smaller during the weak-dryline days than the strong-dryline days.

In the next example, the sentence suffers from both a partial comparison (what is being rigorously compared with theory?) and passive voice ("was incapable of being performed"). The revision solves both problems.

DRAFT: A more rigorous comparison with theory was incapable of being performed because of the lack of theoretical studies on this complex situation with these three instabilities forced by frontogenesis.
IMPROVED: Comparing these observational and numerical-modeling results with theory was not possible because theoretical and idealized-modeling studies are lacking for this complex situation with these three instabilities forced by frontogenesis.

Sometimes in our haste, we leave out words, shortening the sentence. Unfortunately, such omissions can convey sloppiness, ambiguity, or worse, inaccuracy. This is an example of how care should be taken with wording.

DRAFT: Mammatus form in the four simulations initialized with soundings taken when mammatus were observed, whereas no mammatus form for the one no-mammatus sounding.

The second half of the sentence suggests that the mammatus form from soundings rather than in simulations. The revised sentence clarifies this inaccuracy.

IMPROVED: Mammatus form in the four simulations initialized with soundings taken when mammatus were observed, whereas no mammatus form in the simulation initialized with the one no-mammatus sounding.

If the word "than" is present, check to see that the comparison is complete and that the structure is parallel. In the draft example below, the sentence reads as if the static energy of the subcloud air is being compared to the height

of the cloudy air ("higher than the cloudy air"). The two proposed revisions make it clear that the *static energies* of the subcloud and cloudy layers are being compared. Thus, make sure that apples are being compared to apples and not to broccoli.

DRAFT: The static energy of potentially warm, dry subcloud air is higher than the cloudy air above.
IMPROVED: The static energy of potentially warm, dry subcloud air is higher than that of the cloudy air above.
IMPROVED: The static energy of potentially warm, dry subcloud air is higher than the static energy of the cloudy air above.

The word "both" can be problematic, especially in comparisons. In the draft example below, whether the author meant the diabatic heating term was larger than the differential vorticity advection term and the Laplacian of the thermal advection term individually or the sum of the two terms is ambiguous, as shown by the two improved examples. Only the author knows which interpretation represents the correct meaning.

DRAFT: The diabatic heating term dominated both the differential vorticity advection term and the Laplacian of the thermal advection term.
IMPROVED: The diabatic heating term dominated *the two terms*, differential vorticity advection *and* the Laplacian of the thermal advection, *individually*.
IMPROVED: The diabatic heating term dominated *the sum of* the differential vorticity advection term *and* the Laplacian of the thermal advection term.

Sometimes to describe a comparison, authors choose a sentence structure with parenthetical words or phrases. Such sentences, however, may be difficult to read and interpret. Often, such sentences are better written explicitly, even if they become longer. Revisions may also be possible by completely rewording the sentence.

DRAFT: When temperature increases (decreases), relative humidity decreases (increases).
IMPROVED: When temperature increases, relative humidity decreases, and when temperature decreases, relative humidity increases.
IMPROVED: Temperature and relative humidity are inversely related.

A word pair that can slow down readers is "former/latter." Such words make sentences more concise, but often at the expense of requiring the reader to look backward in the text to remember the order.

DRAFT: . . . , where equation (1) is the continuity equation and equation (2) is the thermal wind equation. The implication of the former equation is . . .
IMPROVED: . . . , where equation (1) is the continuity equation and equation (2) is the thermal wind equation. The implication of the continuity equation is . . .

9.6 NEGATIVES

Negative information is more difficult for people to comprehend, often resulting in reduced understanding and reading rate because readers must first comprehend the statement, then negate it. Wording sentences positively improves their readability and tends to make them shorter. Eliminating the word "not" often makes a stronger sentence, as the examples below indicate.

DRAFT: This modeling study did not prove conclusive.
IMPROVED: This modeling study was inconclusive.

DRAFT: There did not appear to be any preferred geographical regions in which bow echoes developed from particular modes.
IMPROVED: Bow echoes showed no geographical preference to develop from particular modes.

Furthermore, increasing the number of negatives, especially words with a negative connotation (e.g., avoid, never, fail, unless, however), in a sentence further confounds comprehension.

DRAFT: At 1900 UTC, areas of drizzle across Pennsylvania were not associated with regions of higher visibility, unless fog was not present additionally.
IMPROVED: Areas of simultaneous fog and drizzle across Pennsylvania at 1900 UTC had lower visibility than areas of drizzle only.

9.7 MISPLACED MODIFIERS

Misplaced modifiers are also called dangling modifiers or dangling participles. As in the discussion of phrases starting with "using" on page 23, modifying words or phrases should be close to the words or phrases they modify. Not doing so often results in confusion or amusement for the reader. Phrases at the beginning of a sentence are especially problematic.

DRAFT: Inside the tornado, the model results show a rapid decline in wind speed. [The model is inside the tornado?]
IMPROVED: The model results show a rapid decline in wind speed inside the tornado.

DRAFT: Over the central United States, forecasters have found that castellanus clouds may mark the initial stages of elevated nocturnal thunderstorm development. [Forecasters are over the central United States? In hot-air balloons?]
IMPROVED: Forecasters have found that castellanus clouds over the central United States may mark the initial stages of elevated nocturnal thunderstorm development.

9.8 RHYTHM AND AESTHETICS

All the advice in this chapter means nothing if the sentence does not make any sense. After writing, read the sentences out loud. How do they sound? If you have to read the sentences twice to understand them, then your readers will have to read them three or more times. Look for a natural rhythm in your writing that helps the audience get comfortable when they read your work.

If something does not sound right, reword it. Reverse a word or two. Does that improve it? If not, try larger changes to the sentence. Perhaps, reverse the order of the sentence.

Where possible, avoid visually complex sentences, the visual equivalent of quicksand for readers. Too many of these will be tiresome for the reader. Things that add to visual clutter include equations, numbers, parenthethical phrases, too many phrases set off by commas, and symbols. Abbreviations with periods cause the reader to stop, as if at the end of the sentence, disrupting the flow in reading. Acronyms force readers to read all capital letters, which takes longer because they have less practice reading in all capitals. Text with many equations and not enough explanation in between is visually imposing. Follow the examples of authors who have written such articles well by interspersing text and equations to create a visual balance.

Sometimes you may be left with material that you feel compelled to include in the text, but you face difficulties in fitting the material into the structure of the paragraph while maintaining coherence. "A footnote!" you think. Footnotes serve a purpose, of course, but they should not take the place of an effectively written transition.[1] Avoid a large number of footnotes for ancillary, tangential, or unimportant material. If possible, either eliminate the footnoted material or include it in the text.

1. Readers expend time and effort searching out footnoted material. A large number of footnotes can be exhausting for the reader's eyes and can limit your ability to communicate your argument coherently.

10

USING EFFECTIVE WORDS AND PHRASES

How you choose your words can make the difference between text that is confused or clear, long-winded or lean, and ordinary or extraordinary. Eliminating redundant and complex words, trimming verbose and unnecessary phrases, and choosing precise and meaningful words engage the reader most effectively. Applying the lessons in this chapter to your writing will help convey your meaning to the reader concisely and precisely.

In the song "Open the Door, Richard," Louis Jordan calls out (followed by the crowd response in parentheses):

I met old Zeke standin' on the corner the other day.
That cat sure was booted with the liquor. (He was what?)
He was abnoxicated. (He was what?)
He was inebriated. (He was what?)
Well, he was just plain drunk. (Well, alright then!)

Jordan tries a colloquialism (booted with the liquor), a nonexistent word (abnoxicated), and a more tasteful word (inebriated), until he finally gives the crowd a word they understand.

As with sentences, words convey meaning, ideally with both concision and precision for audience understanding. If paragraphs are the fundamental organizational unit of a paper and sentences are the vehicle by which the message is delivered, then words are the sparkling new coat of paint on the vehicle that makes the sentences shine. Or, for poorly chosen words, the crud on the windshield that obscures a clear view down the road.

10.1 CONCISION

One of my teachers said, "do not use a $10 word in place of a 10-cent word." For example, authors often use the word "utilize" because it sounds more scientific, but "use" has the same meaning and is shorter. The same thing holds for the following pairs of complex–simple words: perform–do, initiate–start, facilitate–cause, and propagation–move. (The difficulties with "propagation" often go beyond it being a pretentious word. Page 361 has further discussion.) Authors might choose more complex words because they want to make their arguments more complex (and more impenetrable) or because they want to impress others with their large vocabularies. Whatever the reason, using complex words when simple ones would suffice generally makes the writing less clear.

Making writing concise is as much about reducing unnecessary words as it is reducing the complexity of the words. Minimize your use of phrases that have become intimately linked to one another so as to be cliché (e.g., meaningful dialog, time and time again, first and foremost).

Like gratuitous variation, superfluous material can act as verbal camouflage. It can activate irrelevant connections in the reader's brain, and impede perceptual processing by making word patterns needlessly complicated. —Michael McIntyre (1997, p. 201)

Other phrases are simply redundant such as "smaller in size" ("small" already implies size) or "model simulation" ("model" and "simulate" are both similar terms). Use "smaller" or "simulation" (or "model results") instead. More examples are given in Table 10.1. Save some words, and be more creative.

Similarly, Table 10.2 lists words and expressions to avoid. One thing to notice about this table is the large number of phrases that begin with "it": "it has been noted that," "it is known that," and "it is clear that." These phrases are bad for two reasons. First, they add unnecessary length. Try removing these phrases from your sentences—the meaning of the sentence often will be unaffected. Second, the "it" is undetermined. "It has been hypothesized that enhanced deposition leads to more latent heat release." What does the "it" refer to? Who hypothesized this? If "it" is known, reword the sentence to incorporate the references or the first-person pronoun.

Table 10.1 Redundant word combinations; words that could be eliminated are in parentheses

(absolutely) essential	(definitely) proved	(long) been forgotten	simply (speaking)
(already) existing	empty (void)	mix (together)	smaller (in size)
(alternative) choices	(end) result	(model) simulation	(solar) insolation
at (the) present (time)	(fellow) colleague	never (before)	(temporal) evolution
(basic) fundamentals	fewer (in number)	none (at all)	the (color) white
(completely) eliminate	first (began)	off (of)	the white(-colored) *noun*
(completely) false	(general) overview	(overall) summary	(time) evolution
(continue to) remain	(generally) tend to	past (experience)	variety of (different)
(currently) underway	introduced (a new)	period (of time)	(very) unique

On the other hand, the little word "about" deserves more respect than it gets (Table 10.2). Authors commonly step around this word with such verbosity as "approximately," "regarding," "with respect to," "more or less," or "in the vicinity of."

A different perspective on the phrases in Table 10.2 comes from Montgomery (2003, p. 9), who argues that such phrases may serve an important function such as pacing, flow, or transition. I agree that an occasional and purposeful use of such phrases can benefit the text, but I also caution that overuse of these phrases, which unfortunately occurs too often in scientific writing, runs the risk of wearing out the reader's patience.

Describe the science, not the figures. If the figure does not need an introduction, do not introduce it. This change not only reduces the number of

Table 10.2 Words and expressions to avoid and their shorter alternatives (partially adapted from Day and Gastel 2006, Appendix 2, and U.S. Air Force 2004, pp. 81–87)

Avoid	Alternative	Avoid	Alternative
a 15-min temporal basis	every 15 min	it should be noted that	(omit)
a greater number of	more	it was found that	(omit)
despite the fact that	although	it was/is noted that	(omit)
due to the fact that	because	more or less	about
for the purpose of	(reword)	note that	(omit)
in a number of cases	some	of particular interest	(reword)
in order to	to	on the order of	about
in reference to	about	over the Mongolia region	over Mongolia
in spite of the fact that	even though	summertime	summer
in terms of	by, in	temperature of −30°C	−30°C
in terms of stability	(omit or reword)	the period 1977–1999	1977–1999
in the context of	(omit)	the result indicates that	(omit)
in the event that	if	the results show	(omit)
in the matter of	about	the smallest values of lapse rate	the least stable
in the spring of 2008	in spring 2008	the southeastern part of Finland	southeastern Finland
in the vicinity of	near, about	the state of California	California
is equal to	is	through the use of	by, with
is shown to be	is	thunderstorm activity	thunderstorms
it appears that	(omit)	upward vertical velocity	ascent
it is apparent that	apparently	was acting to	was
it is contended that	(omit)	was found to be	was
it is important to note that	(omit)	was noted to	was
it may be expected that	(omit)	was observed to	was
it may be that	I think	with regard to	about
it must first be established that	(omit)	with respect to	about

words, but also shifts the focus from the figure to the science, which is where it should be. Further discussion of this point is found in Section 11.13.

DRAFT: Figure 5 shows plots of surface temperature in the no-ice and control simulations, showing that the elimination of sea ice produced warmer arctic temperatures.

IMPROVED: The elimination of sea ice in the no-ice simulation resulted in warmer arctic temperatures compared to that of the control simulation (Fig. 5).

10.2 PRECISION

The words we choose convey our thoughts. A carelessly chosen word can cause the reader to slow down, be confused, or even misinterpret the author's intended meaning. In addition, using excessive jargon and figurative language or anthropomorphizing inanimate objects fails to adequately describe the relevant science, and, to more careful readers, inadequately hides our lack of knowledge of the science. In this section, we look at how we can choose our words to achieve more precise meaning.

Don't be afraid of elegant prose. Just as clothing can be utilitarian (keeping you warm and dry) and attractive at the same time, the best writing clearly communicates its message while providing a bit of aesthetic delight. Your prose doesn't have to be overly fancy to be pleasing. Like a classic tuxedo or black dress, a straightforward scientific paper can still sparkle with clarity and precision. —Bob Henson, writer/editor/media relations associate, University Corporation for Atmospheric Research

10.2.1 Denotation versus connotation

Words have two meanings—their *denotation*, the dictionary definition or literal meaning, and their *connotation*, the associated or implied meaning. Be aware of both meanings when writing. Use the dictionary to determine if the word you are considering has the exact meaning you intend. Sometimes similar words may have slightly different denotations. If a word is not precisely what you mean, use a thesaurus (along with a dictionary) to find a more precise word.

As an example of denotation versus connotation, authors commonly overuse "state" to mean "say," as in "Smith et al. (1996) stated the sky is blue." The primary definition of "state" in many dictionaries is "to declare definitively" as in legal proceedings (state your name) or in a scientific context (state a hypothesis or state the problem). This denotation is a much stronger and precise meaning than its connotation. Perhaps returning to this stronger meaning for "state" is something that we in science should strive for. Similarly, "claim" has the denotation of "say," but the connotation is that a person is not being truthful. Inappropriate use of "claim" can lead to implied bias against that person.

Sometimes words in common usage can be troublesome in scientific contexts. Consider "significance" (see also page 362), as in "a significant temperature anomaly." The scientific context implies that statistical tests have shown the results to be statistically significant, although the connotation is just "an impressive temperature anomaly." A selection of words that have scientific meanings different from their connotations are listed in Table 10.3.

Table 10.3 Words with troublesome connotations in a scientific context; see further discussion in Appendix B

accuracy/skill	correlate/correlation	severe storms
causing	observed/seen	severe weather
chaos/random	propagate	significance/significant
collaboration/coordination	resolution	theory

10.2.2 Jargon

Scientific writing cannot avoid *jargon*, the language that has been developed and has evolved to describe our science. Some jargon is specialized vocabulary, defined in scientific reference material, such as the *Glossary of Meteorology* (Glickman 2000), and essential for concisely conveying concepts between experts. Other jargon is scientifically incorrect, inappropriate, vague, or colloquial, as some examples in Appendix B demonstrate. In preparing your paper or presentation, jargon that is not likely to be understood by your audience should be defined or changed to a simpler language the audience will understand.

Sometimes multiple terms have arisen to describe the same thing. As an example, all the following terms refer to the same phenomenon: retrograde occlusion, back-bent, loop, broken-back, or bent-back occlusion, bent-back warm front, bent-back front, and secondary cold front. Part of good scholarship is not to create any more unnecessary terms, but to identify and clarify any discrepancies or confusion with existing terms. If multiple terms exist, consistency is key to communicating with your audience. For example, "gravity current" and "density current" describe the same phenomenon. Upon first mention of the phenomenon in your paper, introduce both terms, saying that both terms have been used interchangeably, but pick one term and stick with it throughout the manuscript. Even terms we think we may be familiar with, we may misuse. For example, "mammatus clouds" is incorrect, because mammatus are not clouds, but cloud forms.

Weather weenies, people who are passionate about the weather (see how I defined my jargon?), are a unique species. Online discussion groups about storm chasing have arisen, daily meetings in the weather-map room take place, and national forecasting contests challenge the best. Part of being a weather weenie is understanding the jargon, to be part of the in-crowd. Jargon can also intimidate others who are unfamiliar with that specialized jargon. But, more importantly, such jargon fosters sloppiness and a poor understanding of meteorological knowledge and atmospheric processes. In your writing, eliminate map-room jargon that is colloquial or obscures scientific meaning.

For example, do not refer to vorticity maxima in the jet stream as "energy." In fact, start in the map room, the area forecast discussions, the chat rooms, the weather blogs, and the mailing lists. Elevating the level of discourse will benefit your writing as well your scientific understanding.

DRAFT: Upper-level support overran the surface low center resulting in bombogenesis.
IMPROVED: Cyclonic vorticity advection increasing with height was associated with the rapid-deepening phase of the surface cyclone.

Accurately describe the process, making sure to not eliminate words or levels that may seem obvious to you but may make the wording unclear for the reader.

DRAFT: Cold advection moved over eastern Texas.
IMPROVED: A region of cold advection at 850 hPa moved over eastern Texas after 1200 UTC.

10.2.3 Unclear pronouns

The antecedent of the pronoun (the noun that the pronoun represents) should always be clear. Pronouns standing by themselves, not adjacent to a noun, are immediately suspect. To avoid problems, put a noun after each isolated example. "This" and "it" are especially abused. During revisions, search through the manuscript for "this" and "it," fixing instances in which the antecedent is vague.

DRAFT: Frederick (1966) provided further support for *this* by showing the eastward progression of the warm spell across the United States, suggesting that *it* may be related to eastward-moving offshoots of the Aleutian low.

It is surprising how often repeating a noun works better than substituting a pronoun such as "it," "this," "them," "ones," etc., and it is surprising how seldom a repeated noun jars upon the reader. —Michael McIntyre (1997, p. 200)

Although the antecedent to "this" is in the previous sentence, which is not shown here, repetition (Section 8.2.1) would maintain the coherence from one sentence to the next and also define the unclear pronoun. Second, what does "it" refer to: "support," "evolution," "progression," "warm spell," or "United States"? The sentence can be reworded to define the antecedents for "this" (evolution) and "it" (progression). (The jargon "offshoots" is also dealt with as well.)

IMPROVED: Frederick (1966) provided further support for this evolution by showing the eastward progression of the warm spell across the United States may be related to eastward-moving secondary low centers developing from the Aleutian low.

Here is another example where an unclear pronoun starts the sentence. Examples like this one happen when the author tries to refer to large parts of the previous sentence as the antecedent. Unfortunately, the audience may not recognize which parts of the previous sentence the author intended to be the antecedent.

DRAFT: Such conditions lead to super-refraction of part of the radar beam, leading to the systematic underestimation being less than normal with increasing range. *This* means that the derived adjustment factors would be too large. [What is "this" referring to?]
IMPROVED: Such conditions lead to super-refraction of part of the radar beam, leading to the systematic underestimation being less than normal with increasing range and derived adjustment factors being too large.
IMPROVED: Such conditions lead to super-refraction of part of the radar beam, leading to the systematic underestimation being less than normal with increasing range. This range-dependent underestimation means that the derived adjustment factors would be too large.

An additional problem with pronouns is the *implicit "that,"* modifying phrases where the "that" may be omitted. Although omitting "that" may be common in writing, comprehension is sometimes limited by doing so. In addition, the implicit "that" is problematic for readers for whom English is a second language because the sentence structure is such that the words after the noun may not be recognized as modifiers. For clarity, include the "that," making it explicit.

DRAFT: Cloud microphysical properties must be parameterized from the larger-scale fields the model can resolve.
IMPROVED: Cloud microphysical properties must be parameterized from the larger-scale fields that the model can resolve.

This problem is not limited to "that"; read the sentence below with and without the "where."

By knowing the ingredients needed to produce thundersnow, we can better explain the locations (where) thundersnow occurs.

For most readers, including the "where" is more explicit and clear.

10.2.4 Choosing the best words

Some words have been used many times or have definitions that are so vague that these words fit many circumstances. Unfortunately, such words are nearly

worthless when precision is required. Consider the words in Table 10.4. These abstract words have lost their meaning in many scientific contexts. They are easy words to settle for when faced with a need to be explicit and precise. Rewrite sentences to eliminate these words when they are used ambiguously and choose more precise words. Consider the following examples:

DRAFT: Sounding analyses indicate the less stable nature of the lower troposphere over the surface occluded front.
IMPROVED: Soundings indicate the lower troposphere is less stable over the surface occluded front.

DRAFT: Situations that favor convective activity commonly occur in the spring and summer seasons.
IMPROVED: Convective precipitation commonly occurs in the spring and summer.

DRAFT: The coldest air is upstream of the trough axis, a favorable factor for further cyclogenesis.
IMPROVED: The coldest air is upstream of the trough axis, favoring further cyclogenesis.

DRAFT: A variety of factors appear to play a role in why the precipitation was so widespread in this storm.
IMPROVED: The precipitation in this storm was widespread for the following three reasons . . .

The vagaries of word choices sometimes lead to other interpretation problems as well. Consider the word "role" (P. A. Lawrence 2001). If a powerful tropical cyclone devastated Japan, how many different processes could be listed as playing a "role" in the cyclone's development? If something plays a role, what about other unmentioned items? How long would such a list be? Given all the ingredients required to produce a tropical cyclone, is it appropriate to say that any ingredient can play "the primary role"?

One way around the vagaries of these unfortunate words is to define the word precisely upon its first use. For example, "The high albedo of stratus strongly regulates the amount of incoming solar radiation. This role of stratus. . . ." Once defined this way, "role" can be used throughout the manuscript, referring specifically to the high reflectivity of stratus.

Nouns and pronouns are not the only parts of speech that can be less than meaningful. Adjectives and adverbs can also be empty and vague (Table 10.5). Obviously, what may be "obvious" to you might not be "obvious" to

Table 10.4 Potentially weak nouns when used in some circumstances. Not every use of these words is weak, but precision can be lost when using such words.

ability	degree	forcing	process
activity	development	influence	relationship
analysis	dynamics	interaction	role
approach	effect	issue	sense
case	element	level	situation
character	environment	manner	system
concept	event	nature	thing
context	factor	perspective	use

Table 10.5 More words to avoid

actually	feel	obvious(ly)	soon
basically	important	of course	still
certain(ly)	interesting	practically	type of
clear(ly)	kind of	quite	various
current(ly)	naturally	recent(ly)	very
extreme(ly)	now	regarding	wish

others. Different people may have different opinions about what constitutes "clear" evidence, so avoid irritating those people who have higher standards than you do. Rather than *stating* something is "interesting," explain *why* it is interesting.

Be careful about words that have meanings related to time. Words such as "recently" should be avoided. Is one year ago recently? Is ten years ago recently? "Now" can be also problematic as its casual use may confuse the literal reader. Is the author referring to "now" as in the time the paper was written? The time the case study occurred? The time when the paper is being read? Instead of "now" or "at this time," say "as of June 2006" or "at the time of this writing (March 2008)."

"Very" and "quite" are overused; eliminating most occurrences strengthens most sentences. Watch out for other verbal tics that add length not meaning, such as "basically," "practically," "various," "still," "really," and "kind of." Exclude any form of "feel" from your writing (e.g., "we feel the data show"); science is done with facts, not with feelings.

Quotes around colloquial or slang words can be distracting to readers and are usually unnecessary. Either find a more appropriate word, avoid

colloquialisms or slang that ESL authors may not be able to interpret, or italicize a definition word.

10.2.5 Braggadocio and superlatives

Muhammad Ali said, "It's not bragging if you can back it up." Although boxers display braggadocio as part of their job, scientists who do so are generally viewed with skepticism, disdain, or worse. Be careful what you boast about in your papers, even if it is true. For example, some authors like to claim to be the first to do something. Before writing such flourish, think about whether it is really necessary and what others might think. Avoid phrasings such as "first," "novel," or "pioneering." Making such claims may be appropriate when

ASK THE EXPERTS

CREATING NEW SCIENTIFIC TERMINOLOGY

Mark Stoelinga, Senior Scientist, 3TIER, Inc.

From 1989 to 2003, I was part of a group at the University of Washington headed by Prof. Peter Hobbs that documented a characteristic set of frontal structures and associated precipitation systems in the central United States. Collectively, these structures became part of a new conceptual model for cyclones east of the Rocky Mountains, originally introduced as the Cold Front Aloft (CFA) conceptual model by Hobbs et al. (1990), and later expanded to the Structurally Transformed by Orography Model (STORM) by Hobbs et al. (1996).

Early in this research endeavor, it was clear to Hobbs's group that they were documenting frontal structures that did not conform to existing conceptual models and terminology for synoptic-scale structures, and so part of the research process involved the challenge of either conforming the new structures to existing terms, applying older terms that had fallen into disuse, or developing completely new terms for some of the features observed. As a member of this group, I share the following hindsight wisdom of what was done right and what was not, in the form of four guidelines for developing terminology for new or modified concepts in science:

1. Use existing terminology whenever possible. Sometimes in science, we believe we have discovered a new process or described a new phenomenon that has not been documented previously. A careful search of the literature may indicate that essentially the same phenomenon has been described before, and existing terminology is sufficient. Even if the same phenomenon does not appear in the literature previously, many phenomena can be described using existing terminology. For example, in choosing the term "cold front aloft," Hobbs et al. (1990) properly acknowledged that the term was not new and that it was in fairly wide use among the U.S. operational forecasting community during the 1930s through 1950s to describe the same types of structures that our group was seeing fifty years later. Thus, Hobbs et al. (1990) were re-introducing the term, long after it had fallen out of favor.

2. Follow existing customs and conventions. Choose terms similar to existing terminology if the concept has some similarities to, or is a counterpart to, an existing concept. For example, to describe thunderstorm-induced straight-line winds, Hinrichs (1888) coined the term "derecho," a Spanish word meaning "direct" or "straight ahead." Hinrichs (1888) chose the

writing review articles about time-tested research or referring to people being honored at named symposia but are generally viewed negatively when describing your own articles.

In science, we expect evidence in support of claims. Superlative-laced writing demands similar supportive evidence. If you say that a particular cyclone was intense, provide evidence to indicate how intense it was. Do you have quantitative information that ranks this event relative to others?

Specific word choices may fuel trouble. Using "always," "never," "best," and other absolutes encourages readers to think of exceptions. Similarly, studies are rarely "comprehensive," and the level of detail in your "detailed" research is in the eye of the reader. (Shouldn't all our research be detailed?) You may say

word to be the straight-line counterpart to "tornado," derived from the Spanish word "*tornar*" meaning "to turn" (Hinrichs 1888; Johns and Hirt 1987).

3. Terms must be scientifically accurate, precise, and descriptive. If a new term is to be created, the principal task of the creator is to define a term that is scientifically accurate and precise, and sufficiently describes, albeit extremely briefly, the concept at hand. One example of a poorly defined term is "bent-back warm front," because such fronts rarely possess warm advection, the defining characteristic of a warm front. Also, part of the skill in creating a new term is to develop an appealing name. Creating a verbose name, even if accurate, can harm the chances of adoption. Many times a balance must be considered between conciseness, precision, and appeal.

4. Try to get terminology right the first time, and avoid subsequent changes. Perhaps the aspect of the evolution of the CFA conceptual model that caused the greatest consternation in the research community was the change, and subsequent repeal of that change, to the words that CFA stands for—a rather eggregious violation of this guideline. Our group received criticism for using a term implying a front can develop above the surface when classical frontogenesis theory dictates that fronts are strongest in the presence of a rigid or semi-rigid boundary such as the ground or the tropopause (e.g., Hoskins and Bretherton 1972). In response to this criticism, our group changed the unabbreviated term to "cold frontogenesis aloft" in three papers published in 1995. However, reviewers and readers of these three papers were both confused by and critical of the new definition. In response, our group quickly reverted to "cold front aloft" again in 1996. In hindsight, the initial criticism could probably have been addressed without changing the term, particularly in light of subsequent research that identified the stable layer east of the lee trough as the missing lower boundary over which the front could advance aloft.

One of the principal challenges in creating new terminology is predicting how it will be received and used by the community, and how its definition might need to be adjusted in the future. Often while the initial study is underway, a research group may informally develop terms for convenience, to facilitate communication among the members of the group. Such terms can easily be revised and refined prior to their formal introduction via publication in the scientific literature. However, these terms must be carefully vetted (with consideration of the guidelines presented here) before submission. Once a term is introduced in the literature, modification or retraction may be impossible.

that "numerous" or "a limited number" of papers appear in the literature about a particular topic, but do you have a count? If so, provide a list of citations.

10.3 PROPER FORM

Avoid contractions, clichés, colloquialisms, and anthropomorphism. One reason is to assist readers who are not native English speakers. The other reason is that strong scientific writing generally does not contain these styles. This section addresses other types of proper form: abbreviations and acronyms, numbers and units, and adjective–noun agreement.

10.3.1 Abbreviations and acronyms

If a phrase is long and cumbersome to keep spelling out every time, then it is a candidate for a good acronym. Always define abbreviations and acronyms on first use. Spell out the word, then place the acronym in parentheses after.

> **CORRECT:** Model Output Statistics (MOS) surface temperatures from the Nested Grid Model (NGM) had a 1.4°C bias during near-surface temperature inversions.

Then, use the acronym throughout the rest of the manuscript—do not revert back. If you must introduce a lot of acronyms, consider a separate table defining all acronyms and variables. Often you do not need to introduce a relatively common acronym. Some abbreviations that are better known than their expanded forms (e.g., DNA, CAPE, NASA) should be defined upon first usage, but can be more commonly used in abstracts and titles without definition. Some journals may provide a list of acronyms and abbreviations that can be used without definition.

Often people will introduce acronyms as a shorthand for their own sake. "Jones and Stewart (2006)" becomes "JS06." Although convenient for you to avoid writing out "Jones and Stewart (2006)" all the time, readers may be frustrated, especially if you introduce more than a few acronyms. Does the acronym help the audience? Most are not necessary. If the acronym is only used a few times throughout the paper, consider whether it needs to be introduced at all.

You can also avoid creating new acronyms. If you introduce a long term or phrase that might require an acronym, you can minimize the number of times you need to use this term (and hence the acronym) in two ways. The first way is to structure a sentence (and surrounding sentences) so that you use a pronoun rather than the word or substitute a shorter more generic word in place of the longer word (e.g., "the cloud," "the dependent variable," "the

model"). Alternatively, refer to the phrase by a shorter phrase. For example, after introducing a new type of two-moment cloud microphysical parameterization scheme, use the phrase "this new scheme" instead of an acronym.

10.3.2 Numbers and units

Although journals employ different styles, the following guidelines about numbers and units are consistent across many journals:

1. Numbers that are measurements, money, or decimals, should be written in numeric form.
2. Numbers less than or equal to ten should generally be spelled out, unless they are part of a list of numbers or quantities.
3. If a sentence begins with a number, spell out the number. Thus, avoid putting large numbers at the start of sentences.
4. Do not mix numbers in numeric and written form when used in a similar way, as in the example below.

> **CORRECT:** . . . whether using a 2-layer, 10-layer, or 100-layer model . . . [The "2" would normally be spelled out when describing a "two-layer model."]

Use the International System of Units (SI), wherever possible. Where measurements are taken in non-SI units and the measurement value is important, place the SI units in parentheses after the measurement.

> The 12-h accumulation of new snow at Albany, New York, measured 2 in. (51 mm) with a liquid equivalent of 0.11 in. (2.8 mm).

If you have used a statistical test to assess significance, include the following information: the name of the test, the statistic (e.g., t or F value), the degrees of freedom, and the probability of the statistic. If p is very small (e.g., 0.000056), writing $p < 0.001$ is sufficient. Furthermore, most common statistical tests assume the data are independent and identically distributed, and meteorological data are often neither, in time or space. Thus, has the time series been examined to ensure that samples have uncorrelated errors? If there is a correlation, has this been factored into the test (Wilks 2006, p. 144)?

10.3.3 Adjective–noun agreement

As Lipton (1998, p. 21) says, "Puppies are warm, not temperatures." Temperature is the quantitative measurement of the heat content of the air, whereas "hot," "warm," "cool," and "cold" refer to qualitative perceptions. Thus "warm temperature" is incorrect.

10.4 ELIMINATING BIAS

Sometimes you know who will read your articles; other times you do not. Knowing who your audience will be and catering to them can help the readability of your papers. For example, if you were working on South American cold surges, then many authors from South America are likely to read your paper. People who study cold surges in the Northern Hemisphere (North America, eastern Asia) may also read your paper. Therefore, avoid terms and phrases that are unlikely to be known by this audience. Choose simpler words rather than more complicated words that mean the same thing. An alternate view comes from some readers who say that the author's writing style should not be compromised to make it easier on those for whom English is a second language. Using the full range of English, they argue, helps such readers learn the styles and cultures of the authors. Despite that argument, I would prefer to reduce the burden on my audience by more carefully choosing my words.

10.4.1 Gender bias

The English language—like the Romance languages, which descended from Latin—has words to distinguish males from females: he versus she, him versus her. English does not have specific words for when the gender of a person is unknown or irrelevant, unlike Spanish and German that have a neuter gender. In contrast, the Finnish language has no gender at all—*hän* serves as "he" or "she." Unfortunately, in English, we have to be more clever to avoid language that favors one gender over another. So, how do we deal with something such as the following?

> **GENDER BIASED:** A master of the art of living draws no sharp distinction between work and play. His labor and leisure, his mind and body, his education and recreation, he hardly knows which is which. He simply pursues his vision of excellence through whatever he is doing and leaves others to determine whether he is working or playing. To him, he always seems to be doing both.
> —Wilfred Petersen

These are the best approaches to make your writing gender neutral:

- If possible, choose gender-neutral nouns: "chair" rather than "chairperson," "humanity" rather than "mankind/womankind," etc.
- Use both masculine and feminine: "he or she," "his and hers" (although this is awkward, especially when used many times in the text).
- Make the pronoun plural ("they"), and make other changes accordingly. Keep the sentence grammatically correct by ensuring subject–verb agreement.
- Rewrite the sentence to eliminate the pronoun.

Thus, the paragraph can be rewritten to incorporate these approaches.

> **GENDER NEUTRAL:** Masters of the art of living draw no sharp distinction between work and play. Labor and leisure, mind and body, education and recreation—which is which is hardly known. These masters simply pursue their vision of excellence through whatever they are doing and leave others to determine whether they are working or playing. To themselves, they always seem to be doing both.

On the other hand, other approaches have been suggested that are less satisfactory:

1. The following constructions, albeit convenient, are awkward: "he/she," "s/he," or "(s)he."
2. You could use "one," but the result usually reads stilted, like when using "the author" to avoid the first person.
3. In some contexts, you could rewrite the sentence to say "you," but that would rarely work in a scientific context.
4. Some authors alternate "he" and "she" in examples, especially in longer texts like books. I argue for precision. If the gender is not known, do not force one upon the unsuspecting person.

Another mistake that can be made is to refer to a cited author as "he," when, in fact, the author may be a "she," or vice versa (e.g., Pat and Kelly could be either he or she; authors may only use their first initials; Kimberly Elmore is a he; the gender of authors from other countries may not be clear from their names). In such cases where you cannot be certain, it would be best to word the text in a gender-neutral manner.

10.4.2 Geographical bias

Despite globalization, the world is a big place. Although Americans may know where China is on a map, how many could name the rivers and mountain ranges there? What if the boot were on the other foot: Is it fair to expect a Chinese meteorologist to know the locations of the Ohio River Valley or Olympic Mountains? To aid in making manuscripts accessible to those not from your geographical area, define locations on a map. Some authors have a map of geographical place names as one of their first figures. Alternatively, annotating the figures or providing more description in the text of locations would assist others. Even if you are writing for a domestic audience, avoid general descriptions without meaning to outsiders (e.g., Golden Triangle, Capital District), unless you define them. Make your writing precise. Do not just say "the East Coast" without including "of the United States," at least for the first time.

Have you ever tried to read a paper about weather in the Southern Hemisphere? Reading "northerly flow" makes me think of cold air. In fact, northerly flow in the Southern Hemisphere is generally warm, having come from the equatorward, not poleward, direction. Thus, for our Southern Hemisphere colleagues, I recommend replacing "northward" and "southward" with their hemispheric-neutral words: "poleward" and "equatorward," respectively. Another example is to replace "positive vorticity" with "cyclonic vorticity." Such small efforts are worthwhile to those readers.

10.4.3 Cultural bias

Americans (of which I am one) tend to think the rest of the world understands us, or at least we like to think so. Sometimes our choice of words might be unfamiliar to people from other countries. Rewording those sentences or providing clarification can always help. I am not suggesting they be eliminated—I am suggesting that we choose words carefully and with purpose. Avoid metaphors and other colloquial expressions, especially those that may not translate well for the audience for whom English is a second language, such as "throwing out the baby with the bathwater."

10.5 MINIMIZING MISINTERPRETATIONS

The goal in scientific writing is to convey scientific content both accurately and precisely. Poorly structured text diverts readers' focus away from learning about your research toward trying to understand what the text means. By applying the guidance in this and the previous chapters, you can improve the readability of your manuscripts.

Do not write so that you can be understood, write so that you cannot be misunderstood. —Epictetus

Nevertheless, despite all your best efforts to be as precise and clear as possible, others may still misinterpret your writing. Once or twice a year I see my work miscited or misunderstood by others. Sometimes they have missed my point entirely, even contradicting sentences from my abstract. Although some of these instances may come from people not reading carefully and not citing my work properly, other situations may arise because of diversity in the scientific community. Specifically, the same piece of text can be interpreted a number of ways by different readers. In fact, Gopen and Swan (1990) argue that you can never completely eliminate alternative interpretations—the best you can hope to do is minimize interpretations other than your intended one by carefully structuring the text and considering all possible interpretations (and misinterpretations). Such approaches simply require practice, experience, and an open mind.