HOW TO WRITE AN EFFECTIVE SCIENTIFIC PAPER

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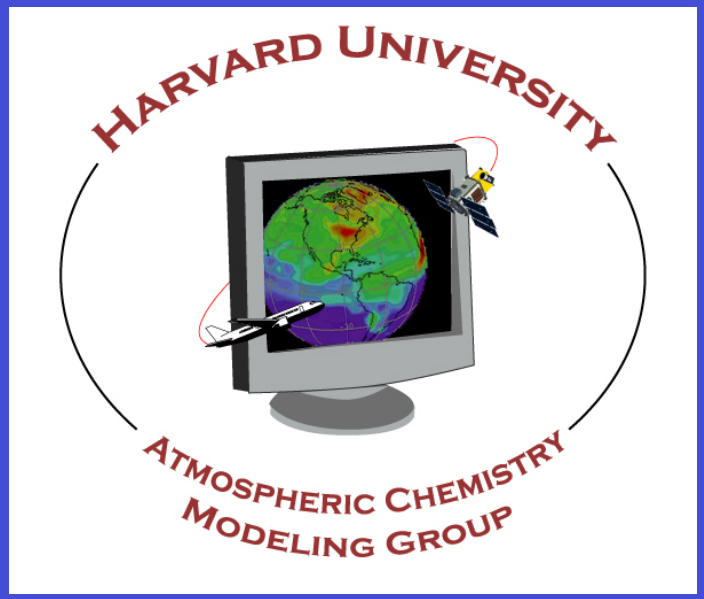
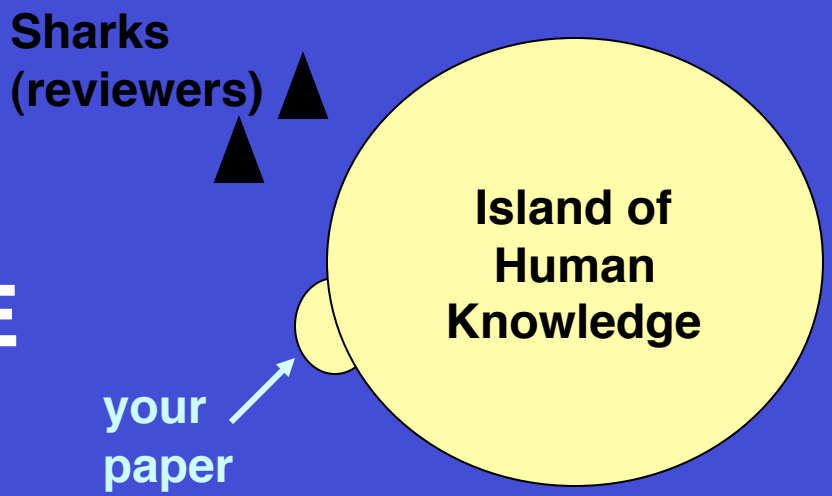


Disclaimers:

- General rules suffer plenty of exceptions; each paper is a unique situation
- Don't let me tell you how to write, let me try to improve YOUR writing

WHAT IS A SCIENTIFIC PAPER?

• It is an addition to human knowledge; this is a reversible statement (addition of knowledge takes place through scientific papers)



• A scientific paper is <u>not:</u>

- a technical report or term paper
  - a paper is worth writing only if it has general implications for knowledge
- a gospel
  - paper should be scholarly but you're not writing for the ages – others will come after you with newer data and better models. Think of your role as guiding their future efforts
  - being occasionally wrong is forgiven, being boring is not.

WHY WRITE SCIENTIFIC PAPERS?

"Scientists are motivated by two things: (1) to understand the world, (2) to get credit for it"

- A scientific career is all about expansion of human knowledge
- In the academic and public sectors, scientific papers ARE the means for this expansion.
- "Publish or Perish" should indeed be the rule for scientists working as individuals - scientific papers ARE your professional contribution. You don't publish, you're out.
- Quantity doesn't matter beyond an expected number – quality is what matters
- What determines the perceived quality of a scientific paper? (now routinely- perhaps unfortunately – measured by the citation index)
  - Originality and importance of ideas
  - Effectiveness of communication, particularly when it comes to planting the flag for new ideas
  - Advertising: presentations, communications at meetings and with visitors, email exchanges, citations…

VIEW PAPER WRITING AS PART OF YOUR RESEARCH, NOT A POST-RESEARCH ACCOUNT

"The paper is not a description ot the work, it IS the work" – Richard Feynman said something like this

- Start writing the paper as soon as possible – view it as a tool of your research. Iterate and agonize over the paper as part of your research
- Write the intro as you engage into your research – what are you trying to do? Why is it important? What has been done before?
- Write the Methods once you think they're mature – can you defend them in writing? If you have difficulty in the writing that often means there's a problem with the methods
- Write results and discussions as the ideas come to you – spend an hour here and there writing them down in paper form. That will help crystallize them in your mind and may lead to new ideas
- Spend a bit of time each day with your evolving paper. Try to go through it with the eyes of a critical reader (be your own worst critic!)

PREPARING YOUR PAPER FOR CONSUMPTION

- Play to your customer base! Think of HOW scientists (e.g., you!) read papers. Very few will read your paper in a thorough and deliberate way, from beginning to end. You have to market your paper for the casual readers!
  - Title and abstract are for the search engines…most readers will not go beyond that.
  - Figures + captions and Tables + footnotes must be self-contained…a lot of readers go through those w/out reading the text. Some may look for quick explanation in text, so discussion of figures/tables in text should jump at reader (I like paragraphs starting with "Figure X shows…"
  - Make your figures attractive for use in presentations, both by you and others. If you wouldn't use a figure in a presentation, then fix or delete the figure!
  - Many readers are interested in your paper mainly because they want some specific numbers, or a synthesis or references to previous work; oblige them by being scholarly.
  - The take-home messages of the paper should be "in your face", I.e., in abstract, in intro, in conclusions, to make sure the "diagonal reader" gets the message. Don't be shy about planting the flag.

THE INTRODUCTION

write it first – do it early, revisit often; use it to think about what your paper is about, to test your command of the literature

- Time-honored approach: begin with a mini-review and finish the intro by saying what your paper is about
- Better (I think), more direct approach:
  - First paragraph: state succinctly the problem – don't encumber with too many refs
  - At end of first paragraph or beginning of second: tell us in one sentence what your paper is about
  - Second and following paragraphs: now that you told us what your paper is about, give us the background information, what people have done before, the limitations, etc. (copious referencing)
  - Last paragraph: elaborate on what you'll be doing in your paper.

A few words about references…

- Showing command of the literature is extremely important. You need to describe the foundation on which your contribution to human knowledge is based. Extensive referencing is the scholarly and ethical thing to do, it's also useful to readers and it makes your paper more accessible by search engines!
- So be serious about literature search and reading papers – devote a bit of time to this each day. Use search engines (like SCI) to search forward in time.
- Never cite a paper for which you haven't read at least the relevant part.
- Cite papers in a context that makes it clear what the paper did – otherwise the reference is useless. If you're not clear on what the paper you're citing actualy did, go back and (re-)read the paper – it's the intellectually honest thing to do and you may learn something.
- Don't cite textbooks – they may be difficult for reader to access, information may be buried.
- There's nothing wrong with citing yourself or your group extensively – in fact that's normal since that's the work you typically build on, and that's part of advertising. But don't ignore what others have done!
- References should be helpful to the reader, not of historical interest (unless you're writing a review)

Methods section following the Intro

- Write this as soon as you think that your methods are mature – the writing process will make you check whether they really are
- Often you'll be working with a complicated model or using a messy data set. Focus your methods section solely on what is important for your paper. Reference other papers for peripheral information.
- Provide useful numbers for future modelers to use
- Make sure all math is clean (next slide)

A few words about math…

- Equations are often necessary to describe methods, but can also be an excellent way to set the stage – sometimes your arguments can be encapsulated neatly in an equation. Peripheral equations should be avoided or moved to an Appendix – don't force the reader to understand something that's not crucial to the paper
- There is no excuse for math errors, yet they happen to the best of us – check and double-check.
- Define all terms in your equations.
- Your notation should be textbook-quality. Don't use words or multi-letter variables in equations. Always try to make your equations more compact and reduce their number (but don't skip steps in derivation).
- Use standard notation and terminology as much as possible – it makes it easier for the reader to follow.

Results sections

- Use section headers descriptive of the science: “Model comparison to observations”, “Results and discussion” are generally not good.
- Progress from general to specific
- If not clear from the header, start the section with a brief statement of what it’s about
- Start by presenting your results (Figure X shows…) and then discuss what they mean
- Logical, linear flow of thought is essential – you’ve thought a lot about your results and what they mean, share this progression with reader
- One theme per paragraph – first sentence lays out the theme, last sentence provides link to next paragraph. Few paragraphs need to be longer than ½ page – longer than 1 page is sure sign of confused thinking.
- Quantitative uncertainty estimates are invaluable, but don’t wring your hands about lack of confidence in your results! The reader expects you to focus on what you can say with confidence.

A few words about comparing model with observations

"Nobody believes a modeling paper except the author, everybody believes an observational paper – except the author"

- Comparisons with observations should have a clear purpose in terms of learning about the atmosphere. You should tell us what features you're looking for
- No one cares that the model "does a good job", "is in reasonable agreement", etc. What are you actually testing in the model? What increased confidence in terms of processes are you getting from the comparison? Can you usefully make the comparison quantitative?

Abstract and Conclusions

…can wait to be written until rest of paper is mature

- Abstract is of course the most important part of the paper – many readers will read just that. Focus on what is new - essential ideas, essential numbers. One fact/idea per sentence. Everything that you would like the casual reader to remember should be there.
- Most (but not all!) papers need a conclusions section. A default approach is to treat it as an extended abstract. But this is also an opportunity to be reflective about what you learned, the uncertainties remaining, the links to other problems, etc.
  - First paragraph: focus on what you did. Begin with "We have used…", "We have investigated…"
  - Following paragraphs: one major finding per paragraph. First sentence states the finding, following sentences elaborate.
  - Final paragraph should have some forward-looking perspective. Don't let paper finish on a whimper!

Some general editorial remarks…

- "Dr. So-and-so, your presentation was just superfluous! When will it be published?"
- "It will be published posthumously"
- "Wondeful! I can't wait!"

- Strive for logical, linear flow. Put yourself in the perspective of the reader.
- Be as short as possible. "Every word must hurt"
  - Be on the lookout for unnecessary words and sentences.
  - Use short words (e.g., "use" vs. "utiilize")
  - Remove value judgments: "Surprising", "interesting", "unfortunately" have no place in a scientific paper.

  …but not all words must be short. Use strong, effective words with precise meaning. Build your vocabulary . Love the English language. Crosswords, manuals of style, language columns…
- Use scientific words as much as possible but with their precise meaning. Beware of words with different scientific vs. lay meanings, such as "significant", "ideal". Use them in their scientific meaning.
- A scientific paper is above all about being clear, objective, to the point. This means forgetting some rules learned in expo writing. For example, there's nothing wrong with starting a sentence with a symbol. Nothing wrong with starting a sentence with "But" (it beats the tired "However"). Nothing wrong with repetitions if they enhance clarity, and often they do.