Two courses missing from meteorology programs at US universities

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Abstract

This presentation describes the need for, and potential content of, two meteorological courses usually lacking in meteorology programs at US universities. These subjects are somewhat related and potentially could be combined into one course. The first subject is that of "Design and execution of field programs in the atmospheric sciences". While it might be argued that there is such diversity in meteorological field activities that "hands-on" learning is best, there are many aspects common to most field studies that students could benefit from via formal lectures. Such a course might best be taught at the advanced graduate level, where students are closer to participating in, and perhaps helping design, such activities. The second, somewhat complementary course, might be titled "International Meteorological Activities and the functions of National Meteorological Services". Rarely are US students (unlike foreign students) exposed to the enormous variety of meteorological activities that occur globally. An equally small number of students have a good conceptual understanding of the different components of any National Meteorological Service (including that of the US). Material common to both courses would include covering the existing (and research) observing systems across the globe – this material is often left out of courses on meteorological instrumentation.

Motivation for developing this material has come from the development of courses for international audiences with widely varying backgrounds. A sample syllabus is provided.

Introduction

Given the large number of undergraduate and graduate meteorology programs at US universities it would seem that the curriculum should be well established by now. Generally speaking it is standardized- in substantial part to satisfy requirements of the US NWS. At the graduate level there is more flexibility for specialized courses. Though the authors have little formal experience teaching as part of university programs we have noticed the lack of two subjects that appear to be taught in few locations. These are described separately, though if time were short the material could be compressed into a one-semester course.

Our motivation for writing this material is our experience in organizing 3-week full-time courses in Latin America for a broad audience. Our students included undergraduate and graduate students in multiple subjects (since there are few meteorology programs in Latin America), meteorology faculty, weather forecasters and "others". Many of the personnel of weather services in Latin America do not have easy access to formal education in meteorology – other than forecaster training courses offered by the WMO training centers, and even these opportunities can be limited.

Our courses had multiple objectives, but included training everyone in making and analyzing pilot balloon observations, understanding how meteorological services should function, and how to carry out applied research activities to strengthen local forecasting capabilities. Based on personal experience (MD) teaching an Instruments and Observations course in 1988 at Texas A&M University, where a multi-site sounding experiment around a local lake was carried out with the students of the class, we considered a short field experiment to be a unifying part of our courses. The class helped plan the field observation campaign, carry out the observations, and finally process the data and write the summary report. To do this was a major challenge to the students in a three-week course. The almost uniformly positive comments about the experience from the class members led us to believe that this should be a more widely available opportunity for students early in their careers.

Taken together, our course material can be compressed into two general subjects: 1) international activities and meteorological service function and 2) field programs and experimental meteorology.

Field experiments

There is no shortage of faculty to teach a course about field experiments. There are faculty members who participate in field experiments in the atmospheric sciences in nearly every meteorology program – probably worldwide. A field techniques course might be a required course, such as in most geology programs. Other degree programs, for example botany and zoology, commonly require or at least offer courses in field techniques. Why then are virtually no courses offered in meteorology that explain field techniques?

Perhaps it is that there is such variety of instrumentation and focus of field programs. Perhaps it is that they are technology-dependent, and may become dated with time, unlike more theoretical courses. Perhaps there is little written guidance available, and so the material would have to be developed from scratch. Perhaps it is too specialized to justify a full semester course and too few students would choose the course. Perhaps it requires a background in both theoretical meteorology and engineering to cover the material. Whatever the reasons, we think that the material needs to be taught at an early stage of a researchers career. Realistically, it would be challenging to incorporate the material into an undergraduate instruments course though by no means impossible. A full course would be more suitable for a graduate student who has passed the basic requirements for a MS degree and wishes to build background, or is working with field experiment data sets.

Of course, it is becomingly increasingly common in “big science” to contract an organization to handle details of a field program. Researchers shouldn’t have to concern themselves with how to fuel an aircraft or how to obtain a land lease for a radar. However, there is a large “gray area” where science returns are a function of logistical details, and the more one knows of the details of field activities the more science is likely to come out of the project.

From time-to-time NCAR does organize courses that cover aspects of field observations, but these are not routinely offered.

Our courses were necessarily simplified because we needed to reach a wide audience, but a course for US graduate students could assume a stronger background in meteorology. In the following section we describe the course content, subject by subject (not lecture-by-lecture).

Possible course #1: Designing and carrying out meteorological field programs

Why go to the field? Viewing field observations as part of a total research program. *How much of your research funds should go to observations? Big versus small science.*

Identifying specific/testable hypotheses… Defining the scope of the study- all observations at once or a little at a time? Iterating among the scientific community; developing an implementation plan.   Individual versus group research.

Tools of the trade: What hardware is out there to use?

-The spectrum of atmospheric sounding systems – what is out there and the characteristics of each. *Students are exposed to little of this.*

-Specialty systems – ships, aircraft, radars and other remote sensors of various kinds - and where to get them. Advantages and limitations. Real cost of operation.

-Overview of strategies for measuring the atmosphere. Fixed networks in space and time versus mobile/adaptable networks. Advantages of each. (e.g. budget studies versus morphological /structure studies)

-Surface observations and networks. Benefits and limitations of surface data. Simple/low cost versus complex /expensive.

Strategies for using sounding systems and networks

-long duration, low sampling rate or fast and furious?

-Many sites with limited data or extensive obs's from few sites

-mobile or fixed?

Using research aircraft effectively

- types of aircraft available and advantages of each

- few long flights or many short flights?

- multiple aircraft operation?

- in-situ or remote sampling?

- complications: diurnal cycle and evolution of systems, sensor calibration, coordination of multiple users…complications in analyzing data.

- what about UAV's?

Where to conduct your experiment? How to seek help.

-conduct your experiment in a data rich or data poor area?

-should you get help from logistics specialists (for example EOL/JOSS)?

International field programs – advantages and complications

Educational issues – Do you want to involve students? Get help from the host country? Merging educational activities into a field program.

Logistics and the "ops-center" – how to anticipate problems in running the field experiment. How much help do you need? Benefits of real-time analysis and forecasting.

Data processing drudgery… or is it? Who should do "quality" control? Long-term archival of the data.

Actually doing research with the observations…the usual complications.

Getting the reports written and collaboration issues. Evaluating the success of your field program. How do you measure success - by the number of publications or success in answering original questions? Do you need a follow-on experiment? Dealing (politely) with program managers.

Key course activities

Besides formal lectures on the above topics, a course on this subject should also include a short field program to investigate a meteorological subject of local interest. This might not always be feasible, especially if the instructor does not have access to meteorological equipment, but this is likely to be the exception. It would be ideal if a UCAR-wide equipment pool were available for such courses, to avoid the necessity of every department having its own materials.

Another possibility is to collaborate with one or more other meteorology programs at other universities in the design and execution of a short field program. If a similar course were being offered during the same semester, it would be possible to design the experiment for late in the semester, leaving enough time to process the data and analyze the results. The advantage of multi-university collaboration, asides from more possible equipment to bring to the field and more students to help with measurements at multiple sites, is that a flavor of multi-institutional collaboration can be found in such activity. And the students, if formed into mixed-university groups, could begin to develop personal links that could last beyond graduate school.

The "ideal" educational field program would sample a feature that can be expected to be present on many days during the semester. Such a features might be sea- (or lake-) breezes and slope circulations. For some universities in the eastern US this may be a challenge. Propagating or transient phenomena are harder to measure in a short field program – unless they can be predicted well in advance and a sampling network deployed on short notice.

***Some problems common to a short field program would be*:**

-limited time to collect data set (cannot sample diurnal cycle well)

-Synoptic variability could mask feature of interest

-Set-up problems limit effective data gathering period

-relatively little time to analyze data set and interpret results - before course ends.

the main advantages of such a field program include:

-Large number of people available to set-up and operate multiple stations.

-Good cross-fertilization of perspectives, diverse student body…

Although the field experiment would be primarily for exposing students to field work, it would be desirable to actually study a feature that would lead to genuinely new understanding.

Possible course #2: International Meteorological Activities and the functions of National Meteorological Services

The second subject deserving of a course, or part of a course, and one that is rarely covered in US universities, is related to how meteorological services operate. There are many more than 200 meteorological services in the world; in many countries there are meteorological services for the general public, for the aviation community, for the Navy or Air Force, and for specific industrial sectors that are strongly dependent on the weather. The links between all these meteorological services is rarely understood by US students, who are poorly exposed to global geography, let alone the details of international organizations like the WMO and the global flow of data.

The lack of emphasis for data at the global level is often expressed in undergraduate synoptic meteorology classes, where students are invariably shown analysis examples from the US, and most often of high amplitude synoptic weather events. Such events are relatively easy for beginning students to analyze. However, more typical analysis exercise, from a global perspective, might be to produce a synoptic analysis over Africa or Indonesia – such exercises are rarely given to US students. If such examples were chosen for an exercise in synoptic analysis we suspect that the students would rapidly express an interest in global observations.

In tropical meteorology classes, whether at undergraduate or graduate levels, the emphasis on analysis is now greatly reduced from several decades ago. This is a consequence of global analyses being widely available on the Internet and the manipulation of such analyses does not require knowledge of the observations that were ingested. Thus, awareness of the observational base for the analyses has diminished.

Additional motivation for this course comes from US students lack of awareness of how meteorological services function. The US NWS, the largest single "consumer" of meteorology graduate students, is a large institution with ~ 4000 employees. In an organization this size there is a high degree of specialization, and any given employee may be aware of only a portion of the overall activities of the organization. But with specialization comes a difficulty to assess the overall operation, objectives and direction of such an organization.

The proposed course would provide an oversight of how the international meteorological community is organized, how weather services function, how they improve, and how they justify their existence.

Topics covered might include:

Why this course is needed. The global nature of meteorology. *180+ countries, multiple weather services within many of the countries.*

The global organization of meteorological observations: the WMO and other international frameworks.

The WWW, GTS, GDPS, GCOS, GAW, etc. and their subcomponents.

National Meteorological Services - and the many "other" weather services…

The private sector that is associated with Weather Services and global meteorological activities.

Basic functions of a meteorological service: *what must a weather service do*?

Problems facing any meteorological service – an overview.

Designing a meteorological service from scratch. What has to be considered? *Should the met service of Chile look the same as that of Cameroon?*

The spectrum of meteorological forecast challenges and needed observations: basic aspects you must know.

How to equip your met service – where is a meteorological Wal-Mart when you need it? *Fixed budget and infinite possibilities…how do you prioritize?*

More problems; how to distinguish between lack of information, mis-information, and corrupt practices. ("business as usual" depends on where you are doing business…)

The issue of sustainability – how long do you want your Weather *Service* to last? What components fail first…

Data exchange *issues*. Does anyone really believe in free exchange of data? Arguments for and against it…

Commercial considerations – government versus private responsibility for forecasting and observing.

Funding your meteorological service – how do you justify your existence?

Validating your success – how do you measure success of a met service? Forecast skill validation and what is a good forecast *really* worth to society?

Staffing your meteorological service. How to ensure your met service has the trained/educated personnel you think it needs. How much education is "enough"?

A class project that has been popular with students in our short courses has been to build a weather service "from scratch" with a given budget and annual operating expense. The class can be broken into groups with each group designing a weather service for the same country. Or, each group can design a met service for a different country. Either exercise is valuable. The main benefit of such a project is reinforce student awareness of the constraints involved in establishing and maintaining any weather service.

Such a project involves:

1. Determining users, needs, and critical forecasting priorities
2. Evaluating observing systems relevant to the country…does a dry country need
3. radars? Soundings - what kind and number? how often? where?
4. Describing forecast staffing needs and infrastructure
5. Designing the forecast procedure from observation through validation
6. Specifying staff training and education - what courses do your staff need?
7. Ensuring that the weather service is sustainable within the allowed budget