Curriculum Units by Fellows of the Yale-New Haven Teachers Institute
2015 Volume III: Physics and Chemistry of the Earth's Atmosphere and Climate

Introduction

I was invited to lead this seminar apparently due to my teaching of “Introduction to Earth and Environmental Physics” (Physics 342), which is offered, every other year,by the Department of Physics at Yale. In the off-years for Physics, it is sometimes offered by the Geology and Geophysics Department. Indeed, many similar courses exist at Yale, and although there are parallels and similarities among these courses, each reflects the specific interests and proclivities of the instructor. My own professional interest lies in fundamental physics – in particular experimental tests of the so-called standard model of particle physics by use of precision techniques. In 2008, I was recruited by Professor Meg Urry, then chair of the Physics Department, to teach Physics 342, the motivation being a departmental colloquium I gave on a prehistoric natural nuclear reactor, a geological phenomenon that occurred approximately two billion years ago (the Oklo phenomenon) which has a deep connection to fundamental physics. Because a discussion of this phenomenon consists of just one class lecture, I was faced with developing a curriculum on a broad subject for which I had no obvious professional experience. Also, at the time, no satisfactory elementary books on the principal subject of concern (global warming) existed. Fortunately, my unusual background (undergraduate study in chemical engineering, a ten-year stint at the Los Alamos National Laboratory where I ended up being a weapons physics team leader) is such that I was able, after some panicked efforts, to develop an elementary model of the atmosphere that jibes well with the standard treatments.

The goal of my seminar was to motivate and present this model to the Fellows, along with discussions of human impacts on the climate and environment, in broad terms, due to the principal industrial and military activities that occur worldwide.

It is increasingly assumed that climate change, due to carbon dioxide release associated with human activity, is occurring, and that this is a fact to be taught. Teachers need the background and some basic understanding of the scientific evidence behind global warming and climate change, in order to form their own informed opinion on the subject if they are to be truly effective teachers. I will perhaps be labeled as a pariah in that my stance, in leading this seminar, is that we don’t know if the climate is changing due to human activities. My goal was to lead the Fellows to make their own informed decisions. Certainly the predicted “hockey stick” runaway global warming did not come to pass, and the term global warming has been replaced, in the popular press, with the term “climate change.” In any case, amid the ever-increasing rate of release of carbon dioxide into the atmosphere, we are conducting a global experiment that has potential to end badly. Or have no effect at all. Or perhaps stave off an ice age, or possibly start one. The problem is that we would like the Earth to remain exactly as it is now. That isn’t going to happen, irrespective of human activity; the evidence in the Earth’s geological record proves with 100% reliability that things will change. We don’t, however, want to make things worse.

A main theme of this seminar was to point out that the scientific community is not anywhere near 100% agreement on issues of global warming and climate change; it is unfortunate that the issues have become polemical and politically polarizing. On the other hand, when solid scientific evidence of environmental harm from human activity has been presented in the past, for example in the case of ozone-depleting CFCs, the world has worked together to come up with a workable solution – in that case the Montreal Protocol of 1987 and the phase-out of CFCs. This Protocol proved feasible; in particular it made allowances for developing countries to delay the phase-out of CFCs, essential for refrigeration. However, even today after that delay, we can still wonder about how many deaths occur due to lack of, for example, access to refrigeration for medical supplies like antibiotics because of the increased cost and energy use that comes with the replacements for CFCs. There is a balancing act: Does the excess suffering due to lack of technological resources outweigh the worldwide risk associated with ozone depletion, and who decides? I am not offering an answer or an opinion; these are questions that we, as members of a modern society, should, and perhaps must, ask ourselves.

The foundation of this seminar was built on two books, *The Alchemy of Air* , by Thomas Hager, and *The Two Mile Time Machine* , by Richard B. Alley. These books are both historical, but in different ways. The first describes the scientific and engineering history of the rise of artificially produced fertilizer that relies on the "fixation" of atmospheric nitrogen by the Haber-Bosch process. Indeed, this process is what allows the current level of world population without mass starvation; the flip side is that many current global problems can be traced to overpopulation, and we should also be concerned that artificial fixation of nitrogen is equal to all natural processes, leading to over-fertilization of aquatic systems in particular. The second book describes the history of the Earth's climate and atmosphere as determined through the study of the Greenland and Antarctic ice sheet cores. This book paints a picture of a historically widely variable climate, with huge changes in temperature and weather patterns that occur frequently (10,000 year time scale, therefore short on a geological time scale) and progress quickly when they happen. One point in the book is that the Earth, at present, is too cold to have an ice age in that there is not enough moisture transported to the northern latitudes where snow and ice can accumulate – so perhaps global warming's climate change will be a new ice age. The overall message from this book is that the Earth's climate has varied widely in the past, and will likely do so in the future. Human-induced climate change has to be identified in this context. These two books were supplemented by newspaper articles, *National Geographic* and *Scientific American* articles, and various online resources including *Wikipedia* , which tends to be accurate and useful as an entry point to a subject.

The seminar also included four field trips. The first was to Kroon Hall, which is the Yale School of Forestry's LEED-certified building located next door to Sloane Physics Laboratory, where the seminar was held. The Fellows were able to see first-hand how an energy-efficient large building is constructed and operated. The second field trip was to my two laboratories, one where we are operating a detector to search for dark matter, the mysterious material that makes up much of the mass of the Universe, and one where we are studying quantum zero-point forces that are responsible for many natural biological phenomena. The third field trip was to the Yale Central Power Plant,where the Fellows were able to see what's behind the light switch that many people take for granted, and witness the tremendous technology and infrastructure behind modern society, as well as the dedicated effort and commitment to keep it all running. The fourth field trip was to the Peabody Museum Mineral Hall, where the effects of the climate and the development of life are evident in the mineralogical history of the Earth presented there.

A number of demonstrations were performed for the seminar, including ones addressing black body radiation, carbon dioxide and its properties, oxygen and its properties, fixation of nitrogen and catalysis, adiabatic processes, and the nature of light and artificial illumination.

The Fellows' units represent thoughtful analyses of the subjects and issues that were discussed in the seminar; Fellows have tied their particular units into the Connecticut curricular expectations and academic standards. Terry Bella addresses the carbon cycle, and presents calculations on carbon storage in different environmental and geological reservoirs, and the transport of carbon between those reservoirs. Jon Cap's unit presents a study of robotics as relating to manufacturing efficiency and uses in environmental studies. In particular, artificial satellites, including Earth-observing satellites for weather and environmental studies, can be considered as special types of robots. Alva Hanson, Jr. and Patricia Sorrentino worked together on complementary units that address their unique and challenging teaching needs at an alternative high school for students at risk of dropping out. The goal of their team-taught units is to give their students the background to have a debate on the reality of human-induced climate change. Mr. Hanson will provide the scientific background for this debate, while Ms. Sorrentino will provide the framework under which an effective debate can take place. An important point that is addressed by her unit is that the "winner" of a debate isn't necessarily correct. Deborah Johnson's unit addresses the effects of human activity on Long Island Sound, which receives much excess, for example, soluble nitrogen due to runoff water from Connecticut and from Long Island. Alexandra Novak's unit presents a study of solar energy culminating in a project where students build their own solar oven. Finally, Larissa Spreng's unit provides a detailed study of the structure of the Earth's atmosphere and solar energy, and similarly culminates in having the students build their own solar oven.

Steve K. Lamoreaux