Beauty and Strangeness (or why I love atmospheric science)

Joy M. Monteiro

The more you think about the living world around you, the more it hits you like a ton of bricks. The atmosphere, in most part the reason why the living world exists, is also guaranteed to have the same effect on those that approach it with sufficient curiosity. The beauty, strangeness, magnitude and fury of the atmosphere has fascinated both poets and philosophers for a long time. Compared to its more ponderous cousins, the ocean and the mantle, the atmosphere is moody and mercurial, changing at timescales that are directly relevant to us. The various moods of the atmosphere directly impact our own, and we organise our lives and work around its changes. This dynamic nature of the atmosphere makes it vital to the survival of life, and makes it such an interesting object of study.

The scientific study of the atmosphere is a fairly young discipline, though people have systematically observed and wondered about the atmosphere since time immemorial. The reason for this is also the reason why environmental science is quite different from the other branches of science. In biology, for example, one can come up with a hypothesis, design an experiment to verify it, carry the experiment out and restart the whole process if unsuccessful. Such a process leads to incremental (or sometimes dramatic) increase in the understanding of the system under study, be it a bird or a plane. Over time, this leads to a fuller understanding and enhances the ability of the scientist to make generalisations and predictions.

In the environmental sciences, however, the luxury of experimentation is simply not there. Scientists have had to resign themselves to merely observing the environment and drawing conclusions[1]. More fundamentally, this difference can be thought of as the environmental sciences having to invoke a sort of "ergodic hypothesis": that is, we have to assume that observing one atmosphere for a sufficiently long amount of time will give us enough information to draw conclusions about all possible atmospheres. In the end, it was the emergence of a mathematically sophisticated physics that enabled the *art* of observing the weather to become atmospheric *science*. It has been ton after ton of bricks all the way since.

All general theories of weather and climate have been made possible by consistent and ever more accurate measurements of atmospheric and oceanic phenomena over the decades. The understanding of weather and climate is undoubtedly the modern Helen of Troy: a quest that has launched a thousand ships (and planes and satellites). This progress in observation and theory, combined with the advent of computers, have finally given the environmental sciences their own iterative process: Measure, theorise, simulate and repeat. Computer simulations are playing an increasingly prominent role in the environmental sciences, both as tools in validating theories and as oracles, describing a future climate in the presence of ever-growing quantities of CO_2 in the atmosphere and the oceans.

Over the past hundred years, atmospheric scientists have dealt with various phenomena: Jet streams, clouds, convection, the greenhouse effect, waves, the Hadley circulation, the polar vortex and monsoons, among others. They have discovered atmospheres where clouds are not made of water, but

[1] This situation, of course, has changed with the advent of computers. But more about that later.

methane and ammonia and carbon dioxide. They have showed the possibility of exotic behaviour like the runaway greenhouse and clouds that grow downwards rather than upwards. They have speculated upon what kinds of atmospheres would allow for life to exist. However, few phenomena have been understood to an extent that that the atmospheric science community can heave a collective sigh of satisfaction and say “It is done!”. Thus, atmospheric science is as interesting today as it was a hundred years ago, with advances in theory, observation and simulation occuring with increasing frequency. On the other hand, atmospheric science has also proved to be of immense societal value. Atmospheric scientists tell us when to carry our umbrellas or to stay at home. They have saved lives by predicting tornadoes and hurricanes. They have helped renewable energy companies make informed decisions about siting their facilities and farmers insure themselves against an uncertain weather. Whether you are in it for the excitement of discovering something new or to help society make more informed decisions, atmospheric science has something for everyone.

Atmospheric Science is not limited to studying the Earth’s atmosphere. Indeed, many interesting problems arise while trying to study the atmospheric circulations of celestial bodies such as the Sun, Jupiter, Titan or Mars. This is also a way to go beyond our ergodic hypothesis and study climates very different from our own, testing the limits of our understanding. The main challenge in studying atmospheres arises not from the staggering number of degrees of freedom they possess. It mainly arises from the fact that atmospheric circulations are a subtle interplay between fluid mechanics, radiative processes, condensable substances such as water vapour and the rotation of a planet. Some of these make the circulation more unpredictable, while others serve to constrain the available range of motions. Building a mathematical theory that we can comprehend depends crucially on what processes we consider important. This choice depends on the spatial scale (clouds don’t care about planetary rotation, while the jet streams can hardly be bothered by individual clouds) or temporal scale (weather is created by atmospheric dynamics, while the climate is mostly a radiative problem) of interest.

As mentioned before, the exponential increase in computing power has completely changed the way atmospheric/climate science is done. Numerical models of the climate have helped us gain new insights since their dynamics can be systematically explored, much like a poor cockroach in the clutches of a curious biologist. The development of these models has outpaced the growth in theory and observations. This deficiency is slowly being rectified, and models of the atmosphere have made remarkable progress in reproducing atmospheric dynamics, especially in the finer spatial scales so important to understanding changes in climate. This progress is primarily due to the fruitful interaction between modellers, theorists and observational scientists rather than the inexorable increase in computing power. The possibility of working with people from such varied backgrounds is one of the reasons why it is now an exciting time to be a climate scientist.

With the prospect of climate and ecological change due to human activities becoming more of a reality day by day, the importance of the earth and environmental sciences cannot be underestimated. Their increasing relevance is underlined by the fact that organisations like NASA have shifted their focus to doing earth science from space rather than space science from earth. The Indian government recently established a Ministry of Earth Sciences, indicating that this shift is global. In this context, atmospheric science plays a vital role since the major uncertainty in climate change projections is due to clouds. The least understood aspect of a changing climate is how atomspheric circulations will change, and this knowledge is vital in ensuring the food and water security of an ever-increasing human population.

Atmospheric science has come a long way from something that was mainly of interest to ship captains: It now plays a vital role in the daily lives of people everywhere, and its intellectual challenges continue to attract scientists itching for a fight. Study of the atmosphere and climate has transcended political boundaries, and has lead to the emergence of a truly global science. This change has been helped in part by the realisation that localised phenomena like the monsoons can only be understood as part of global circulation patterns. On the other hand, understanding weather and climate has lead scientists to relate to their own environment better, and many of them actively address local environmental issues. These are the reasons why I continue to be fascinated by the study of atmospheres, like many before me and I'm sure, many will be after me.