Climate Dynamics: Why Does Climate Vary?

Preface

As an old saying goes, we are living in an interesting age. For the first time in the Earth's history, the most intelligent dwellers of this planet are perturbing the global energy balance of the climate system to a degree that sustainability of the planet may be threatened. Global warming has become a household phrase and entered the realm of economical and political debate. Consequently, the scientific community is increasingly asked to provide in a timely manner, to the public and policy makers, explanations for changes observed in the state of the climate system, and timely predictions of how it will evolve in the coming decades and centuries. With anthropogenic forcing being traditionally introduced to the public as a perturbation to the radiation balance of the climate system, the tendency to underestimate the complexity of dynamics can be high. Indeed, concepts such as bifurcations, scale interactions, reemergence of ocean temperature anomalies, and oceans' role in integrating stochastic forcing of weather events, have not become as popularly known as the greenhouse effect. But natural variability arising from the complexity of the internal dynamics of the climate system has been, and will remain, in a dominant driver of variability. Dynamics may also make the natural variability and anthropogenic effect more intermingled than the linear fashion that we have often assumed to be.

If anything that has been constant with regard to the state of the climate system, it is that it has always been changing. The change has never been monotonic either. Dynamics underlies or underpins these characteristics of Earth's climate change. With our state of the art models typically underestimating natural climate variability on almost all scales, the chance that our projected global warming may be too monotonic in its pace, is there. Such a chance is probably not even small. Equally likely is the risk for underestimating the potency of warming arising from dynamics. With these considerations, it is not a far-fetched idea that global temperature may cease to rise as fast as it did in the last three decades, or even start to decline over some interval in the coming decades. One thing we have learned from El Nino warming—a natural warming in the climate system-- is that rapid warming is made possible by the positive feedbacks. But in the presence of dynamics, the system also tends to overshoot because of these positive feedbacks. The other point that has often been overlooked is that the behavior of the climate system under anthropogenic forcing may not be a linear supposition of a thermodynamically forced trend on the natural variability. Such an assumption may offer convenience in many situations, but has little scientific basis, and may even be misleading, in light of the recent findings about the diabatic and nonlinear aspects of ENSO. These findings suggest that the very existence ENSO, a natural mode of climate variability, may be linked to the intensity of the radiative heating in the tropics, and that collectively, ENSO events--El Nino and La Nina events---play a fundamental role in the long-term heat balance in the tropical Pacific region. To be sure, the global climate system is not the

same as the ENSO system. The chance for a dramatic reversal in the global temperature trend may be small, particularly with the continuing building up of CO2 in the atmosphere. However small the chance for this scenario to materialize is, we do not want to wait until that has happened to remind us of the importance of climate dynamics. What is at stake is the credibility of climate science. If nature indeed surprises us that way— the rate of increase in global temperature slows down (or even the temperature itself starts to decline) in the coming decades, when the next wave of warming arrives with more severity, our warning of it will not be heeded by the public. The situation may not turn out to be a modern version of "the boy who cried wolf", but the lesson learned in that story may be worth of reminding, given the gravity of the matter. This may sound to be overly alarming for the sake of illustration, but natural variability is likely to dominate the decadal scale predictions, particularly on the regional scales. To advance our understanding of climate change, we need to continue the quest to understand basic climate dynamics across a range of time and space scales.

The volume provides a collection of articles on climate dynamics, aiming to underscore the potency of dynamics in giving rise to climate change and variability. These articles originate from the lectures given in a graduate level class at University of Colorado at Boulder on climate dynamics. Climate experts from NOAA and NCAR participated in teaching this class. The class was designed to expose the students to the major climate phenomena within the climate system, in particular those that owes their existence to the dynamical processes and may showcase why climate varies. The class was also designed to introduce to the students some basic material of climate dynamics as well as to expose them to the forefront research. The lecturers were instructed to make the forefront research material accessible to the minds of graduate students or young researchers. The positive feedback from the students suggests that the lecturers had succeeded in doing so. Lecturers generally balanced the amount of basic material with the amount of cutting edge research. To have a more complete coverage and to replace those lecturers who were not able to convert their lectures in time to an article, additional climate experts around the world were invited to contribute to the book. By covering climate phenomena over a broad spectrum of known climate variability, the book is not only hoped to adequately underscore the complexity of climate dynamics, but also help its readers to have a deeper appreciation of the delicate balance and complex interaction among the various forces that maintain the stability of the climate system. Such an appreciation can only help the development of a sense of urgency in advancing our understanding of the anthropogenic effect on the state of the climate system. Underscoring the importance of climate dynamics is the not the same as downplaying the effect of the anthropogenic forcing. For the same consideration, the debate on the origin of the recent observed warming should not overshadow the fact the delicate balance among the various natural forces within the climate system is being perturbed in a significant way by human activities.

We would like to thank Prof. Brian Toon and Prof. Jeff Weiss of the Department of Atmospheric and Oceanic Sciences at CU who helped to set up this climate dynamics course. We would also like to thank Dr. Randy Dole of NOAA/ESRL who encouraged the lead editor to take on this exercise. We would also like to thank all the NOAA and NCAR researchers and our colleagues in other institutes—University of Hawaii, City University of Hong Kong, and University of Tokyo-- who contributed to the teaching and the writing-up of their lectures. Interacting with our colleagues through such an exercise has proven been a unique opportunity for us to learn more about the dynamics of the climate system and why climate changes. We also own gratitude to all the students who participated in this course. Their feedback has made this exercise a wonderful learning experience for us as well. Teaching at CU is fun and intellectually rewarding. We also like to use this opportunity to thank the National Science Foundation, in particular, the Large-scale and Climate Dynamics program, for its generous support for our research. Finally, our thanks go to the AGU staff—Telicia Collick in particular---who have worked so diligently to keep the progress of the book on track.

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