State-of-the-Art Harvard Climate Observatory and Associated Instrumentation

Spring 2025

Prof. Jim Anderson

Lecture Times MW 1:30 PM to 2:45 PM @ Mallinckrodt-Link Room 269

Laboratory Time F 1:30 PM to 2:45 PM Anderson Lab Mallinckrodt

Prof. Andersonâ€™s Contact Info

anderson@huarp.harvard.edu ; 617-998-5550 ; Office: Mallinckrodt-Link 270

Office Hours: Wednesday 11:00-12:00 location TBD and by appointment

Teaching Fellow: Craig Mascarenhas

craigmas@g.harvard.edu ; Office: Mallinckrodt-Link 132B

Office Hours: Wednesday 12:30-1:30 PM @ Mallinckrodt-Link Room 269

Midterm Date: March 3rd during class time @ Mallinckrodt-Link Room 269

Have any questions after reading our syllabus below? Please do not hesitate to reach out directly to Professor Anderson. We are happy to chat and looking forward to working with you all in the Spring!

Course Description:

Events, rather than scientific breakthroughs, have increasingly dominated our collective awareness of the risks associated with rapid, irreversible changes to the Earthâ€™s climate structure. In particular the unprecedented rate of loss of ice volume from the Arctic Ocean that in turn controls critical climate feedbacks; the rate of ice volume loss from the glacial structures of Greenland and the West Antarctic that controls the rate of sea level rise; rapid increases in the frequency, intensity and geographic extent of wild fires, of severe storms with associated losses of life and property, of coastal and inland flooding, of agricultural drought, of deadly heat waves; of glacial loss from Tibet that constitutes the major water source to China and India; the destabilization of the financial and insurance markets; as well as unpredictable and intensifying global refugee flow triggered by a combination of regional food shortages, water shortages and sea level rise. Not only do these events increasingly dominate societyâ€™s collective concern, but these rapidly unfolding changes to the climate structure explicitly engage the responsibility of research universities to society and to emerging generations.

It is a fundamental principal of the physical sciences that a quantitative understanding of the coupled mechanisms that control the response of a given system to external forcing requires high spatial and temporal resolution, three-dimensional determination of the coupled variables, simultaneously observed within the same volume elements of, in this case, the major climate subsystems. This is also the scientific foundation upon which tested and trusted quantitative forecasts of climate risks resulting from the continued use of fossil fuels must be built.

Yet, the critical high-resolution observations quantitatively dissecting the key climate subsystems are not available. They are not available expressly because the current national climate research strategy has not provided the scientific foundation upon which *quantitative forecasts of risk* must be developed. Thus, we present in this EPS/ESE 166 course the new Harvard Climate Observatory to fundamentally herald a new era in the quantitative dissection of the physics controlling critical climate systems. The central objective of the new Harvard Climate Observatory is to explicitly address this problem by introducing the development of a new generation of advanced technology that takes explicit advantage of recent major advances in laser systems, lidars, radars, nanoelectronics, photonics and optical designs in combination with solar powered stratospheric aeronautical design. Together these enable a combination of long duration solar powered observing systems, each targeted at the highest priority risk factors that threaten global societal stability. The resulting observations will, for the first time, provide the irrefutable evidence needed for quantitative forecasts of the dominant risk factors stemming from the global use of fossil fuels.

While satellites have for years dominated the federal climate programs, for the purpose of developing tested and trusted quantitative forecasts of risk, satellites engender significant disadvantages. In sharp contrast to satellite systems, the new Harvard Climate Observatory described in what follows, provides, for the first time, *orders of magnitude* improvement in spatial and temporal, three dimensional resolution, observations that result directly from five factors: (1) reduction in the distance from the observing system to the target from 800 km for the satellite to 20 km for the stratospheric Observatory system; (2) over-the-ground velocity is reduced from 8000 m/sec for the satellite to 30 m/sec for the stratospheric observing system; (3) elimination of interference from ionospheric absorption that blocks large sectors of the electromagnetic spectrum for satellites â€“ sectors of the electromagnetic spectrum that are critical for spatially resolved radar interrogation of, for example, glacial systems, hurricanes, wildfires, etc.; (4) the observatory engages for the first time the unique ability to spend 100% of the time focused on the specific climate target with the optimal ensemble of state-of-art instruments, and (5) the ability to set the trajectory of each of multiple platforms in real time guided by the instantaneous observations obtained by the on-board instruments â€“ a capability that is critical to the high resolution dissection of each of the scientific targets.

Given the central objective of the Harvard Climate Observatory as noted above to rapidly advance the development of laser systems, lidars, radars, optical designs, and imaging systems engaging the disciplines of photonics, analog and digital nanoelectronics, quantum materials, robotics, optical/mechanical design, software systems, and innovative detector technology as an integral design strategy with the new long-duration solar powered stratospheric aircraft technology, EPS/ESE 166 will focus explicitly on this new generation of instrument design. These objectives will markedly advance the accuracy of quantitative forecasts of risk displayed in this graphic:

Course Content and Goals:

This course is designed to establish the strategic structure linking: (a) critical advances in the scientific structure that defines fundamental unknowns limiting our ability to establish quantitative forecasts of risk to societal stability associated with the changing climate, (b) a new Climate Observatory engaging state-of-the-art solar powered stratospheric aircraft in combination with, (c) critical advances in the design of laser systems, lidars, radars and high spatial resolution optical imaging. No prerequisites are assumed for this course in electrical, mechanical and optical engineering as well as in the scientific foundations of climate change. These topics are addressed as part of the course.

Typical enrollees:

Second, third and fourth year students

What can students expect?

Blended Lectures on the science of climate change, strategic approaches to advancing the quantitative understanding of the response of the climate system to continued use of fossil fuels, and laboratory engagement demonstrating new instrumentation.

Details about assignments, course grading structure, and more will be finalized in January when we get closer to the start of Spring Semester 2025.