Introduction to the Symposium on Observed Climate Change[1]

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In the spring of 2016, the American Philosophical Society's Committee on Meetings asked me to organize and later moderate a symposium on observed climate change. After consulting with several APS Members, I selected three leading scientists to present different and independent methods of measuring observed climate change. The symposium took place a year later in April 2017.

Before introducing the scientists at the April Meeting, I gave a short overview about the underlying scientific issue: whether Earth's climate system would change due to the burning of fossil fuels through an increase in the atmospheric content of carbon dioxide. Scientists have long speculated whether humans cause climate change to occur, and some of the controversy is due to observed carbon dioxide measurements. One scientist, Charles David Keeling of the Scripps Institute of Oceanography, took on the challenge of more accurate measurements (Figure 1). He devised improvements for two factors of his experimental design: he developed an accurate method of measuring carbon dioxide in air samples, and chose two locations where the samples should be taken that did not strongly reflect local sources of carbon dioxide but provided "well mixed" air samples. One location was the Mauna Loa Observatory in Hawaii and the other was the South Pole. These two factors were crucial for detecting a trend in carbon dioxide concentration, which is often referred to as the "Keeling Curve" in the scientific literature.

Figure 2 shows the curve from 1957 to 1967. The up-and-down plot displays a strong seasonal change for the Mauna Loa site; the vegetation effect of taking carbon dioxide out of the atmosphere in spring and summer; and, in the fall and winter, the return of carbon dioxide to the atmosphere due to the decaying vegetation. The average annual approximation to the daily data points shows a nearly straight line with an increasing trend of carbon dioxide concentration. In the early 1960s, this figure caused a great deal of concern in the scientific

1 Read on 28 April 2017 as part of the *Observed Climate Change* symposium.

FIGURE 1. Charles David Keeling receiving the National Medal of Science in 2001. Source: National Science Foundation.

community in regard to future global warming. However, the increase in the concentration was only for a 10-year period. Figure 3 shows a much longer trend sample from 1957 to 2017. Without question, such an increase in carbon dioxide concentration is expected to cause a significant climate forcing and a resultant global warming of the climate system. The bottom line of this symposium is that we are already seeing substantial global and regional warming of Earth's climate. This trend will become even stronger in the future.

Nearly a half century ago, Keeling gave a presentation to the APS; his early work was published the following year in *Proceedings of the American Philosophical Society* (Keeling 1970). Once Keeling's work was published and there was an established trend in carbon dioxide concentration, the global Earth science community needed to confirm the reasons for the trend and predict future impacts on the climate.

The three speakers from the symposium are listed below with a description of their areas of expertise and careers.

CLAIRE L. PARKINSON, *SPEAKER*

Claire L. Parkinson is a climatologist at the National Aeronautics and Space Administration's (NASA) Goddard Space Flight Center and a Senior Fellow at Goddard. She received her Ph.D. from The Ohio State University. Parkinson's research emphasis has been on polar sea ice and its connections to the rest of the climate system and to climate change, with a particular emphasis on satellite remote sensing. This work has involved satellite data set generation and analysis, including the

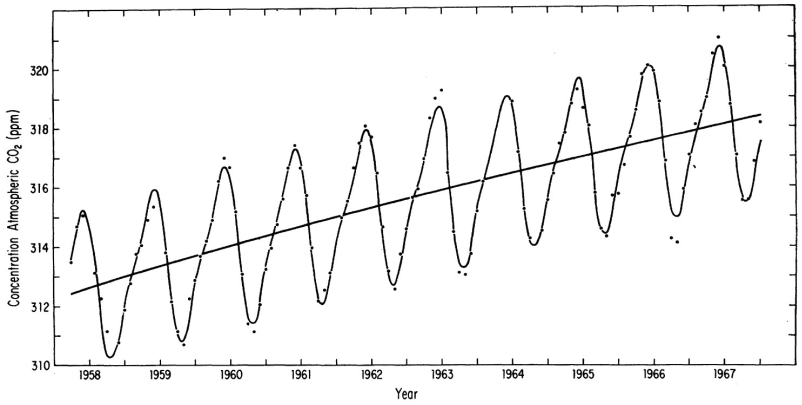

FIGURE 2. This figure from Keeling's 1970 article shows the carbon dioxide concentration taken at Mauna Loa Observatory from 1957 to 1967. The almost-straight line indicates an upward trend in concentration and the up-and-down graph shows the seasonal cycle effect caused by vegetation growth in spring and summer taking carbon dioxide out of the atmosphere and decaying vegetation giving carbon dioxide back to the atmosphere in the fall and winter.
Source: Keeling (1970).

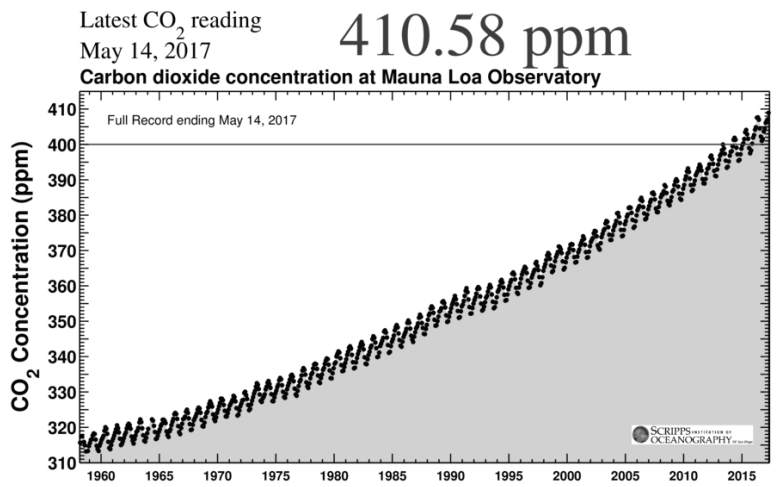

FIGURE 3. Carbon dioxide from 1957 to 2017. The concentration has increased from 315 ppm to over 400 ppm in 2017.
Source: Scripps News. This file is licensed under the Creative Commons Attribution-Share Alike 4.0 International license.

determination of decreases in Arctic sea ice coverage since the 1970s and examination of their regional variabilities and impacts, plus the quantification and analysis of the very different time series of sea ice changes in the Antarctic. She has also developed a computer model of sea ice, has done field work in both the Arctic and the Antarctic, and is the lead author of an atlas of Arctic sea ice from satellite data and a coauthor of two other sea ice atlases.

Since 1993, Parkinson has been the Project Scientist for the Aqua satellite mission, which launched in May 2002 and is transmitting data on many atmospheric, ocean, land, and ice variables. She has written an introductory book on examining Earth with satellite imagery, has coauthored with Warren Washington a university textbook on climate modeling, has coedited two books on satellite observations related to global change, and is lead editor of a Data Products Handbook for NASA's Earth Observing System and lead editor of the NASA Earth Science Reference Handbook. In 2010, Parkinson published a book entitled *Coming Climate Crisis? Consider the Past, Beware the Big Fix* about climate change and her concerns regarding the possibility of implementation of potentially dangerous geoengineering projects. In 2011, she led a "Women of Goddard" outreach effort that included production of a book, *Women of Goddard: Careers in Science, Technology, Engineering, and Mathematics*, and a set of six related posters. Outside of her NASA work, she has written a book on the history of western science from 1202 to 1930.

Parkinson is a member of the National Academy of Sciences and the National Academy of Engineering. She is a Fellow of the American Association for the Advancement of Science, the American Meteorological Society, the American Geophysical Union, and Phi Beta Kappa. She was elected a Member of the American Philosophical Society in 2010.

Lonnie G. Thompson, *Speaker*

Lonnie G. Thompson is a Distinguished University Professor in the School of Earth Sciences and a Research Scientist in the Byrd Polar and Climate Research Center at The Ohio State University (OSU), where he received his Ph.D. His research has propelled the field of ice core paleoclimatology out of the Polar Regions to the highest tropical and subtropical ice fields. He and his OSU team have developed lightweight solar-powered drilling equipment for acquisition of histories from ice fields in the tropical South American Andes, the Himalayas, and on Kilimanjaro. These paleoclimate histories have advanced our understanding of the coupled nature of Earth's climate system. Special

emphasis has been placed on the El Niño and monsoon systems that dominate the climate of the tropical Pacific and affect global-scale oceanic and atmospheric circulation patterns. His observations of glacier retreat over the last three decades confirm that glaciers around the world are melting and provide clear evidence that the warming of the last 50 years is now outside the range of climate variability for several millennia, if not longer.

Thompson has published over 185 peer-reviewed publications, including several in the journal *Science*, led over 54 field programs, and has been funded by the National Science Foundation, the National Ocean and Atmospheric Association, and NASA. He has been recognized with many honors and awards, including the National Medal of Science, the Tyler Prize (the World Prize for Environmental Achievement), and the Dan David Prize. In addition, he is an American Geophysical Union Fellow, an American Association for the Advancement of Science Fellow, and a member of the National Academy of Sciences. Thompson was elected a Member of the American Philosophical Society in 2006.

Kevin J. Anchukaitis, *Speaker*

Kevin J. Anchukaitis is an Associate Professor in the College of Social and Behavioral Sciences, School of Geography and Development at the University of Arizona, where he received his Ph.D. He also holds joint appointments in the Department of Geosciences, the Graduate Interdisciplinary Program in Global Change, and the Laboratory of Tree-Ring Research.

Kevin Anchukaitis is a paleoclimatologist, dendrochronologist, and Earth systems geographer specializing in the reconstruction and analysis of climate variability and change over the Common Era and the interaction between past climate and human society. His research uses an array of techniques to develop and interpret evidence for past, present, and future climate dynamics across a range of temporal and spatial scales, from local to global and interannual to millennial. These include dendroclimatology, climate field reconstruction and spatiotemporal data analysis, stable isotopes, proxy systems modeling, and the integration of paleoclimate data with general circulation modeling.

Students in Anchukaitis's lab work on a diverse set of projects related to climate and environmental variability and change across a range of temporal and spatial scales. Possible thesis or dissertation projects include: paleoclimate reconstruction of past drought and temperature variability; integrating climate models and Earth systems data to better understand how the ocean-atmosphere system works

and how it is likely to change in the future; coupled human and natural systems, particularly in Asia and the Americas; improved statistical, proxy system, and climate modeling approaches for understanding climate dynamics and environmental change in the past, present, and future.

Acknowledgments

This research was supported by the Regional and Global Climate Modeling Program (RGCM) of the U.S. Department of Energy, Office of Science (BER), Cooperative Agreement DE-FC02-97ER62402.

Reference

Keeling, C. D. 1970. "Is Carbon Dioxide from Fossil Fuel Changing Man's Environment?" *Proceedings of the American Philosophical Society* 114: 10–17.