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Reflecting Sunlight to Cool Earth
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Ocean Acidification Due to Increasing Atmospheric Carbon Dioxide
Climate Change and Soil Interactions
Climate Change
Elevated Carbon Dioxide
From Kyoto to the Town Hall
Global Carbon Cycle and Climate Change
Long-term Effects of Climate and Nitrogen on Wheat (Triticum Aestivum) Carbon-water Relations in California
The Role of the Ocean Carbon Cycle in Global Change
Ocean Biogeochemistry
Global Warming and the Future of the Earth

Special Report of the Intergovernmental Panel on Climate Change
Effects of Whole-ecosystem Atmospheric Carbon Dioxide Concentration Manipulation on Abundance and Species Diversity of Arthropods in a Post-fire Chaparral Community

REYNA SOLIS

Climate Stabilization Targets National Academies Press
Reducing carbon dioxide (CO2) emissions is imperative to stabilizing our future climate. Our ability to reduce these emissions combined with an understanding of how much fossil-fuel-derived CO2 the oceans and plants can absorb is central to mitigating climate change. In The Carbon Cycle, leading scientists examine how atmospheric carbon dioxide concentrations have changed in the past and how this may affect the concentrations in the future. They look at the carbon budget and the "missing sink" for carbon dioxide. They offer approaches to modeling the carbon cycle, providing mathematical tools for predicting future levels of carbon dioxide. This comprehensive text incorporates findings from the recent IPCC reports. New insights, and a convergence of ideas and views across several disciplines make this book an important contribution to the global change literature.
Climate Change Science GRIN Verlag
The growing problem of changing environmental conditions caused by climate destabilization is well recognized as one of the defining issues of our time. The root problem is greenhouse gas emissions, and the fundamental solution is curbing those emissions. Climate geoengineering has often been considered to be a "last-ditch" response to climate change, to be used only if climate change damage should produce extreme hardship. Although the likelihood of eventually needing to resort to these efforts grows with every year of inaction on emissions control, there is a lack of information on these ways of potentially intervening in the climate system. As one of a two-book report, this volume of Climate Intervention discusses albedo modification - changing the fraction of incoming solar radiation that reaches the surface. This approach would deliberately modify the energy budget of Earth to produce a cooling designed to compensate for some of the effects of warming associated with greenhouse gas increases. The prospect of large-scale albedo modification raises political and governance issues at national and global levels, as well as ethical concerns. Climate Intervention: Reflecting Sunlight to Cool Earth discusses some of the social, political, and legal issues surrounding these proposed techniques. It is far easier to modify Earth's albedo than to determine whether it should be done or what the consequences might be of such an action. One serious concern is that such an action could be unilaterally undertaken by a small nation or smaller entity for its own benefit without international sanction and regardless of international consequences. Transparency in discussing this subject is critical. In the spirit of that transparency, Climate Intervention: Reflecting Sunlight to Cool Earth was based on peer-reviewed literature and the judgments of the authoring committee; no new research was done as part of this study and all data and information used are from entirely open sources. By helping to bring light to this topic area, this book will help leaders to be far more knowledgeable about the consequences of albedo modification approaches before they face a decision whether or not to use them.
A Holistic Approach to International Policy Co-operation and Co-ordination Elsevier
Professor Kondratyev and his team consider the concept of global warming due to the greenhouse effect and put forward a new approach to the problem of assessing the impact of anthropogenic processes. Considering data on both sources and sinks for atmospheric carbon and various conceptual schemes of the global carbon dioxide cycle, they suggest a new approach to studies of the problem of the greenhouse effect. They assess the role of different types of soil and vegetation in the assimilation of carbon dioxide from the atmosphere, and discuss models of the atmosphere ocean gas exchange and its role in the carbon dioxide cycle, paying special attention to the role of the Arctic Basin. The authors also consider models of other global atmospheric cycles for a range of atmospheric constituents, and conclude by drawing together a range of scenarios on modelling the global carbon cycle.
The Carbon Cycle Oxford University Press on Demand
Climate Change: Evidence and Causes is a jointly produced publication of The US National Academy of Sciences and The Royal Society. Written by a UK-US team of leading climate scientists and reviewed by climate scientists and others, the publication is intended as a brief, readable reference document for decision makers, policy makers, educators, and other individuals seeking authoritative information on the some of the questions that continue to be asked. Climate Change makes clear what is well-established and where understanding is still developing. It echoes and builds upon the long history of climate-related work from both national academies, as well as on the newest climate-change assessment from the United Nations' Intergovernmental Panel on Climate Change. It touches on current areas of active debate and ongoing research, such as the link between ocean heat content and the rate of warming.
Global Warming and Economic Development Cambridge University Press
The warming of the Earth has been the subject of intense debate and concern for many scientists, policy-makers, and citizens for at least the past decade. Climate Change Science: An Analysis of Some Key Questions, a new report by a committee of the National Research Council, characterizes the global warming trend over the last 100 years, and examines what may be in store for the 21st century and the extent to which warming may be attributable to human activity.
Carbon Cycle Variability During the Last Millennium and Last Deglaciation Springer
The signals are everywhere that our planet is experiencing significant climate change. It is clear that we need to reduce the emissions of carbon dioxide and other greenhouse gases from our atmosphere if we want to avoid greatly increased risk of damage from climate change. Aggressively pursuing a program of emissions abatement or mitigation will show results over a timescale of many decades. How do we actively remove carbon dioxide from the atmosphere to make a bigger difference more quickly? As one of a two-book report, this volume of Climate Intervention discusses CDR, the carbon dioxide removal of greenhouse gas emissions from the atmosphere and sequestration of it in perpetuity. Climate Intervention: Carbon Dioxide Removal and Reliable Sequestration introduces possible CDR approaches and then discusses them in depth. Land

management practices, such as low-till agriculture, reforestation and afforestation, ocean iron fertilization, and land-and-ocean-based accelerated weathering, could amplify the rates of processes that are already occurring as part of the natural carbon cycle. Other CDR approaches, such as bioenergy with carbon capture and sequestration, direct air capture and sequestration, and traditional carbon capture and sequestration, seek to capture CO2 from the atmosphere and dispose of it by pumping it underground at high pressure. This book looks at the pros and cons of these options and estimates possible rates of removal and total amounts that might be removed via these methods. With whatever portfolio of technologies the transition is achieved, eliminating the carbon dioxide emissions from the global energy and transportation systems will pose an enormous technical, economic, and social challenge that will likely take decades of concerted effort to achieve. Climate Intervention: Carbon Dioxide Removal and Reliable Sequestration will help to better understand the potential cost and performance of CDR strategies to inform debate and decision making as we work to stabilize and reduce atmospheric concentrations of carbon dioxide.

The Phanerozoic Carbon Cycle Springer Science & Business Media

The question of whether the earth's climate is changing in some significant human-induced way remains a matter of much debate. But the fact that climate is variable over time is well known. These two elements of climatic uncertainty affect water resources planning and management in the American West. Managing Water Resources in the West Under Conditions of Climate Uncertainty examines the scientific basis for predictions of climate change, the implications of climate uncertainty for water resources management, and the management options available for responding to climate variability and potential climate change.

A Proceedings Morgan & Claypool Publishers

Global warming/climate change has been a subject of scientific interest since the early 19th century. In particular, increases in the atmospheric concentration of carbon dioxide (CO2) have long been thought to account for Earth's increased warming, although the lack of a dependable set of observational data was apparent as late as the mid 1950s. However, beginning in the late 1950s, being associated with the International Geophysical Year, the opportunity arose to begin accurate continuous monitoring of the Earth's atmospheric concentration of CO2. Consequently, it is now well established that the atmospheric concentration of CO2, while varying seasonally within any particular year, has steadily increased over time. Associated with this rising trend in the atmospheric concentration of CO2 is a rising trend in the surface-air and sea-surface temperatures (SSTs). This Technical Publication (TP) examines the statistical relationships between 10-year moving averages (10-yma) of the Global Land-Ocean Temperature Index (GLOTI), sunspot number (SSN), the Atlantic Multidecadal Oscillation (AMO) index, and the Mauna Loa CO2 (MLCO2) index for the common interval 1964-2006, where the 10-yma values are used to indicate trends in the data. Scatter plots using the 10-yma values between GLOTI and each of the other parameters are determined, both as single-variate and multivariate fits. Scatter plots are also determined for MLCO2 using single-variate and bivariate (BV) fits, based on the GLOTI alone and the GLOTI in combination with the AMO index. On the basis of the inferred preferential fits for MLCO2, estimates for MLCO2 are determined for the interval 1885-1964, thereby yielding an estimate of the preindustrial level of atmospheric concentration of CO2. Lastly, 10-yma values of MLCO2 are compared against 10-yma estimates of the total carbon emissions (TCE) to determine the likelihood that manmade sources of carbon emissions are indeed responsible for the recent warming now being experienced. (Parametric values used in this TP are those available prior to the end of 2012.) Wilson, Robert M. Marshall Space Flight Center OSCILLATIONS; PERIODIC VARIATIONS; SUNSPOT CYCLE; SEA SURFACE TEMPERATURE; LAND SURFACE TEMPERATURE; GLOBAL WARMING; CARBON DIOXIDE CONCENTRATION; ATMOSPHERIC COMPOSITION; CLIMATE CHANGE; FOSSIL FUELS; TEMPERATURE GRADIENTS

Carbon Dioxide Capture and Storage National Academies Press

The exchange of carbon on earth is one of the fundamental processes that sustains life and regulates climate. Since the onset of the Industrial Revolution, the burning of fossil fuels and anthropogenic land conversion have altered the carbon cycle, increasing carbon dioxide in the atmosphere to levels that are unprecedented in the last 800,000 years. This rapid rise in atmospheric carbon dioxide is driving current climate change and further increases are projected to dominate future climate change. However, the fate of the carbon cycle in response to climate change remains uncertain. Insight into how the carbon cycle may change in the future can come from an understanding how it has changed in the past. Key constraints on past carbon cycle variability come from the concentration and stable isotopic composition of atmospheric carbon dioxide recorded in polar ice cores, but reconstructing these histories has been a significant analytical challenge. This thesis presents a new, more precise method for measuring the stable isotopic composition of carbon in carbon dioxide ([delta]13C of CO2) from polar ice. The new method is then used to reconstruct the atmospheric history of [delta]13C of CO2 during the last millennium (~770-1900 C.E.) and last deglaciation (~20,000-10,000 years before present). Previously, methods for measuring the [delta]13C of CO2 had been limited to precision of greater than ±0.05[per mil]. The method presented here combines an ice grater air extraction method and micro-volume equipped dual-inlet mass spectrometer to make high-precision measurements on very small samples of fossil CO2. The precision as determined by replicate analysis is ±0.018[per mil]. The method also provides high-precision measurements of the CO2 (±2 ppm) and N2O (±4 ppb). A new high-resolution (~20 year spacing) record of the [delta]13C of CO2 from 770-1900 C.E is presented that suggests land carbon controlled atmospheric CO2 variability prior to the Industrial Revolution. A deconvolution of the CO2 fluxes to the atmosphere provides a well-constrained estimate of the evolution of land carbon stocks. The relationship between climate and land carbon for this time period constrains future climate-carbon cycle sensitivity, but an additional process affecting land carbon is required to explain the data. This missing process may be related to early anthropogenic land cover change or patterns of drought. A long-standing problem in the field of paleoclimatology is a complete mechanistic understanding of the 80 ppm increase in atmospheric CO2 during the last deglaciation. A horizontal ice core on the Taylor Glacier in Antarctica allowed for the recovery of well-dated, large ice samples spanning the last deglaciation. From this unique archive, a new [delta]13C of CO2 of very high resolution (50-150 year spacing) is reconstructed. A box model of the carbon cycle is used to construct a framework of the evolution of the carbon cycle during deglaciation. During the Last Glacial Maximum, the lower CO2 concentration accompanied by only a

minor shift in [delta]13C of CO2 relative to the early Holocene is consistent with a more efficient biological pump in the Southern ocean, limited air-sea gas exchange around Antarctica, and colder ocean temperatures. The temporal evolution of these factors, as informed by timing of proxy data, reconciles the non-linear relationship between CO2 and [delta]13C of CO2 from the Last Glacial Maximum to the pre-Industrial. However, the data also reveal very fast changes in [delta]13C of CO2 that suggest a rapid emission of depleted carbon to the atmosphere on the centennial timescale that is not captured in current models.

Climate Change and Developing Countries Elsevier

Climate Change and Soil Interactions examines soil system interactions and conservation strategies regarding the effects of climate change. It presents cutting-edge research in soil carbonization, soil biodiversity, and vegetation. As a resource for strategies in maintaining various interactions for eco-sustainability, topical chapters address microbial response and soil health in relation to climate change, as well as soil improvement practices. Understanding soil systems, including their various physical, chemical, and biological interactions, is imperative for regaining the vitality of soil system under changing climatic conditions. This book will address the impact of changing climatic conditions on various beneficial interactions operational in soil systems and recommend suitable strategies for maintaining such interactions. Climate Change and Soil Interactions enables agricultural, ecological, and environmental researchers to obtain up-to-date, state-of-the-art, and authoritative information regarding the impact of changing climatic conditions on various soil interactions and presents information vital to understanding the growing fields of biodiversity, sustainability, and climate change. Addresses several sustainable development goals proposed by the UN as part of the 2030 agenda for sustainable development Presents a wide variety of relevant information in a unique style corroborated with factual cases, colour images, and case studies from across the globe Recommends suitable strategies for maintaining soil system interactions under changing climatic conditions

Quantification and Reduction of Uncertainties Associated with Carbon Cycle-climate System Feedbacks Springer Science & Business Media

The globally averaged surface temperature of the Earth has increased during the past century by about 0.7°C. Most of the increase can be attributed to the greenhouse effect, the increase in the atmospheric concentration of carbon dioxide that is emitted when fossil fuels are burned to produce energy.The book begins with the important distinction between weather and climate, followed by data showing how carbon dioxide has increased and the incontrovertible evidence that it is caused by burning fossil fuels (i.e., coal, oil, and natural gas). I also address the inevitable skepticism that global warming arouses and offer a number of responses to the global warming skeptics. After dealing with the skeptics, I analyze both the current and future effects of global warming. These future effects are based on scenarios or “storylines” put forth by the International Institute for Applied Systems Analysis. In closing, I address the controversial (and grim) suggestion that we have already passed the “tipping point,” which is the time after which, regardless of our future actions, global warming will cause considerable hardship on human society. I intend this book to be approachable for all concerned citizens, but especially students of the sciences and engineering who will soon be in a position to make a difference in the areas of energy and the environment. I have tried to frame the debate in terms of what the engineering community must do to help combat global warming. We have no choice but to think in terms of global environmental constraints as we design new power plants, factories, automobiles, buildings, and homes. The best thing for scientists to do is to present what we know, clearly separating what is known from what is suspected, in a non-apocalyptic manner. If matters are clearly and passionately presented to the public, we must be prepared to accept the will of the people. This presents the scientific community with an enormous responsibility, perhaps unlike any we have had in the past. Contents: Weather and Climate (and a Little History) / Are the Concentrations of Greenhouse Gases in the Atmosphere Increasing? / The Greenhouse Effect and the Evidence of Global Warming / The Skeptics: Are Their Doubts Scientifically Valid / Impacts: The "So What" Question / The Bottom Line

Carbon Dioxide and Global Change National Academies

Master's Thesis from the year 2017 in the subject Psychology - Miscellaneous, grade: 1,5, University of Kassel (Center for Environmenal Systems Research), language: English, abstract: In stock-flow relationships inflows and outflows of a stock accumulate over time. Previous studies have shown people’s poor understanding of accumulation. This study examines the relationship between performance in a stock-flow experiment and depth of information processing. Half of the participants read a text about the dangers of climate change to prompt deeper processing (and understanding) of the following stock-flow task. Then they were given one of two scenarios in which the atmospheric carbon dioxide level rose/fell from year 2000 and stabilized at a higher/lower level until the year 2100. They had to choose the correct carbon dioxide emissions and uptake trajectory in order to realize the development of the carbon dioxide level in their scenario. Performance was low. More than half of the participants chose emission trajecto-ries similar to the shape of the atmospheric carbon dioxide curve which is an indication for pattern matching. Giving participants information about the dangers of climate change did not increase their performance.

The EU Emissions Trading Scheme Springer Science & Business Media

The last 30 years has seen the development of increasingly sophisticated models that quantify canopy carbon exchange. These models are now essential parts of larger models for prediction and simulation of crop production, climate change, and regional and global carbon dynamics. There is thus an urgent need for increasing expertise in developing, use and understanding of these models. This in turn calls for an advanced, yet easily accessible textbook that summarizes the “canopy science” and introduces the present and the future scientists to the theoretical background of the current canopy models. This book presents current knowledge of functioning of plant canopies, models and strategies employed to simulate canopy function, and the significance of canopy architecture, physiology and dynamics in ecosystems, landscape and biosphere.

Evidence and Causes CRC Press

International agreements such as the Kyoto Protocol, EU regulation and country-specific national climate policies offer some hope of addressing climate change. But all too often implementation of these high level objectives is derailed at the sub-national, local and - perhaps most important - individual level, by a variety of structural, policy and perceived barriers that result

in a failure of effective action. Drawing on original research from Sweden, a world leader in effective environmental solutions, this volume examines the difficulties of aligning climate policy from international to national and sub-national levels. The authors address the full range of barriers and complexities, including governance structures, the relationship between 'experts' and the public, political feasibility, tax measures, perceptions of 'fairness' and self-interest, and the importance of environmental values. Also covered are the roles and perceptions of organizations and professions, the place of carbon-free technologies (such as wind power), the relationship between national and EU regulations, and the monumental challenge of governing the climate in a bordered and divided world. This volume is a vital source of information for all those seeking to create effective, coordinated responses to the challenge of climate change.

Mechanisms, Applications and Laboratory Techniques GRIN Verlag

This study examined the in situ effects of elevated CO2 on arthropod abundance in a chaparral community using a series of controlled CO2, ambient Light, controlled Temperature (CO2 LT) null-balance chambers and a Free Atmosphere Carbon dioxide Enrichment (FACE) ring. Abundance of most arthropod groups, including parasitic wasps (Hymenoptera), decreased with elevated CO2, resulting in reduced total arthropod abundance. However, abundance of moths (Lepidoptera, primarily Geometridae and Microlepidoptera) appeared to increase. The relationship of springtail (Collembola) and predatory arachnid abundance vs. CO2 concentration was curvilinear, with abundance peaking near 450-550 ppmv, and lowest at 750 ppmv. While other studies have shown that plant biomass typically increases with elevated CO2 concentrations, our results suggest that arthropod biomass may decrease. Arthropod species diversity was also measured, using the modified Coleman's rarefaction function to estimate species richness. In contrast to decreasing abundance, diversity of arthropods appeared to increase with elevated CO2, although the relationship was not significant. A separate study examined the effect of elevated CO2 and host plant density on psyllids collected from lilac shrubs. Psyllid densities increased on lilac shrubs under elevated atmospheric CO2, and there was evidence of an interaction between shrub density and CO2 effects. Results of this study suggests that ecosystem function is likely to be affected by CO2-mediated alteration of arthropod services, such as nutrient cycling and energy flow to higher trophic levels.

Urban CO2 Emissions Inst for Biospheric Research

The importance of carbon dioxide extends from cellular to global levels of organization and potential ecological deterioration may be the result of increased CO2 in our atmosphere. Recently, the research emphasis shifted from studies of photosynthesis pathways and plant growth to ground-breaking studies of carbon dioxide balances in ecosystems, regions, and even the entire globe. Carbon Dioxide and Terrestrial Ecosystems addresses these new areas of research. Economically important woody ecosystems are emphasized because they have substantial influence on global carbon dioxide balances. Herbaceous ecosystems (e.g., grasslands, prairies, wetlands) and crop ecosystems are also covered. The interactions among organisms, communities, and ecosystems are modeled, and the book closes with an important synthesis of this growing nexus of research. Carbon Dioxide and Terrestrial Ecosystems is a compilation of detailed scientific studies that reveal how ecosystems generally, and particular plants specifically, respond to changed levels of carbon dioxide. Contributions from an international team of experts Empirical examination of the actual effects of carbon dioxide Variety of terrestrial habitats investigated Specific plants and whole ecosystems offered as studies

The Discovery of Global Warming National Academies Press

Among global environmental issues, climate change has received the largest attention of national and global policy makers, researchers, industry, multilateral banks and NGOs. Climate change is one of the most important global environmental problems with unique characteristics. It is global, long-term (up to several centuries) and involves complex interactions between climatic, environmental, economic, political, institutional and technological pressures. It is of great significance to developing countries as all the available knowledge suggests that they, and particularly their poorer inhabitants, are highly vulnerable to climate impacts. The projected warming of 1. 4 to 5. 8° C by 2100 and the related changes in rainfall pattern, rise in sea-level and increased frequency of extreme events (such as drought, hurricanes and storms) are likely to threaten food security, increase fresh water scarcity, lead to decline in biodiversity, increase occurrence of vector-borne diseases, cause flooding of coastal settlements, etc. Recognizing the potential threat of severe disruptions, the United Nations Conference on Environment and Development was organized in 1992 in Rio de Janeiro, Brazil to begin to address ways to reduce these impacts, which led to the formulation of the UN Framework Convention on Climate Change. This Convention and the subsequent Kyoto Protocol recognize “the common but differentiated responsibility” of developing and industrialized countries in addressing climate change. Developing countries thus have a unique role to play in formulating a sound, reasoned, and well informed response to the threat of climate change.

Climate Intervention National Academies Press

This study examined the in situ effects of elevated CO2 on arthropod abundance in a chaparral community using a series of controlled CO2, ambient Light, controlled Temperature (CO2 LT) null-balance chambers and a Free Atmosphere Carbon dioxide Enrichment (FACE) ring. Abundance of most arthropod groups, including parasitic wasps (Hymenoptera), decreased with elevated CO2, resulting in reduced total arthropod abundance. However, abundance of moths (Lepidoptera, primarily Geometridae and Microlepidoptera) appeared to increase. The relationship of springtail (Collembola) and predatory arachnid abundance vs. CO2 concentration was curvilinear, with abundance peaking near 450-550 ppmv, and lowest at 750 ppmv. While other studies have shown that plant biomass typically increases with elevated CO2 concentrations, our results suggest that arthropod biomass may decrease. Arthropod species diversity was also measured, using the modified Coleman's rarefaction function to estimate species richness. In contrast to decreasing abundance, diversity of arthropods appeared to increase with elevated CO2, although the relationship was not significant. A separate study examined the effect of elevated CO2 and host plant density on psyllids collected from lilac shrubs. Psyllid densities increased on lilac shrubs under elevated atmospheric CO2, and there was evidence of an interaction between shrub density and CO2 effects. Results of this study suggests that ecosystem function is likely to be affected by CO2-mediated alteration of arthropod services, such as nutrient cycling and energy flow to higher trophic levels.

Report of the Carbon Dioxide Assessment Committee Cambridge

University Press
Anthropogenic perturbation of global biogeochemical cycles, particularly through emissions of radiatively active greenhouse gases into the atmosphere-chiefly carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O)--is altering the Earth's climate and inducing feedbacks from the terrestrial biosphere and oceans on future CO2 levels and the climate system. Identifying and quantifying these feedbacks and quantifying and reducing uncertainties associated with them in process-rich Earth system models (ESMs) are important for advancing our understanding of the Earth system, predicting future atmospheric CO2 levels, informing carbon management and energy policies, and fostering the future of life on Earth. This dissertation presents three studies designed to advance our understanding of biogeochemical processes and their interactions with climate under conditions of increasing atmospheric CO2 and to offer an approach for understanding observational representativeness and for scaling up measurements. In the first investigation, I analyzed emission-driven simulations of ESMs from the fifth phase of the Coupled Model Intercomparison Project (CMIP5) in which atmospheric CO2 levels were computed prognostically. Comparison of ESM prognostic atmospheric CO2 over the historical period with observations indicated that ESMs, on average, had a small positive bias in predictions of contemporary atmospheric CO2, due in part to weak ocean carbon uptake. I found a significant linear relationship between contemporary atmospheric CO2 biases and future CO2 levels for the multimodel ensemble, and used this emergent constraint to create a contemporary CO2 tuned model (CCTM) to estimate an atmospheric CO2 trajectory for the 21st century for the Representative Concentration Pathway (RCP) 8.5. The CCTM yielded CO2 estimates of 600 $\pm$ 14 ppm at 2060 and 947 $\pm$ 35 ppm at 2100, which were 21 ppm and 32 ppm below the multi-model mean during these two time periods, respectively. This analysis indicated that much of the model-to-model variation in projected CO2 during the 21st century was tied to biases that existed during the observational era and that model differences in the representation of concentrationó3carbon feedbacks and other slowly varying carbon cycle processes appear to be the primary driver of this variability. In the second study, I extended a quantitative methodology for stratifying sampling domains and understanding the representativeness of measurements, measurement sites, and observational networks. Multivariate spatiotemporal clustering was applied to down-scaled general circulation model results and data for the State of Alaska at 4 km2 resolution to define multiple sets of ecoregions across two decadal time periods and to identify optimal sampling locations for those ecoregions. I developed a representativeness metric and used it to characterize environmental dissimilarity between potential sampling sites. This analysis provided insights into optimal sampling strategies and offered a framework for up-scaling measurements that can be applied at different spatial and temporal scales to meet the needs of individual measurement campaigns. In the third investigation, I applied a feedback analysis framework to three sets of long-term climate change simulations from the Community Earth System Model version 1.0 (CESM1(BGC)) to quantify drivers of nonlinear terrestrial and ocean responses of carbon uptake. In the biogeochemically coupled simulation (BGC), the effects of CO2 fertilization and nitrogen deposition were expressed in the biosphere. In the radiatively coupled simulation (RAD), the effects of rising temperature and circulation changes due to radiative forcing from CO2, other greenhouse gases, and aerosols were expressed in the atmosphere. In the third, fully coupled simulation (FC), both the bigoeochemical and radiative coupling effects acted simultaneously. I found that climateó3carbon sensitivities derived from RAD simulations produced a net ocean carbon storage climate sensitivity that is weaker and a net land carbon storage climate sensitivity that is stronger than those diagnosed from the FC and BGC simulations. For the ocean, this nonlinearity was associated with warming-induced weakening of ocean circulation and mixing that limited exchange of dissolved inorganic carbon between surface and deeper water masses. For the land, this nonlinearity was associated with strong gains in vegetation productivity in the FC simulation that were driven by enhancements in the hydrological cycle and increased nutrient availability. I developed and applied a nonlinearity metric for individual model variables to rank nonlinear responses and drivers. For these simulations, the overall climateó3carbon cycle feedback gain at 2300 was 28% lower when estimated from climateó3carbon sensitivities derived from the RAD simulation than when derived from the difference between the FC and BGC simulations. The gain estimated from compatible emissions calculations corresponded well with the gain estimated from FC ? BGC climate--carbon sensitivity parameters, confirming the validity of the larger gain. This difference has direct implications for carbon management and energy policies because underestimating the climate--carbon cycle feedback gain would result in allowable emissions estimates that would be too low to meet climate change targets. In these studies, I have shown that 1) we can reduce uncertainties in future climate projections by improving models to more closely match the long-term time series of observed atmospheric CO2; 2) we can reduce sampling biases and partition important environmental gradients to design an optimized network of sampling sites at desired scales; and 3) we can reduce uncertainties in the assessment of climate--carbon cycle feedbacks due to nonlinear terrestrial and marine responses by deriving climate--carbon sensitivities from fully coupled and biogeochemically coupled simulations.
CO2 and O2 Climate Stabilization TargetsEmissions, Concentrations, and Impacts over Decades to Millennia
This paper estimates an urban carbon dioxide emissions model using satellite-measured carbon dioxide concentrations from 2014 to 2020, for 1,236 cities in 138 countries. The model incorporates the global trend in carbon dioxide concentration, seasonal fluctuations by hemisphere, and a large set of georeferenced variables that incorporate carbon dioxide-intensive industry structure, emissions from agricultural and forest fires in neighboring areas, demography, the component of income that is uncorrelated with industry structure, and relevant geographic conditions. The income results provide the first test of an Environmental Kuznets Curve relationship for carbon dioxide based on actual observations. They suggest an environmental Kuznets curve that reaches a peak near or above $40,000 per capita, which is at the 90th percentile internationally. The research also finds that economic development has a significant effect on the direction of the relationship between population density and carbon dioxide emissions. The relationship is positive at very low incomes but becomes negative at higher incomes. The paper also uses cities' mean regression residuals to index their carbon dioxide emissions performance within and across regions, decomposes model carbon dioxide predictions into broad source categories for each city, and uses the regression residuals to

explore the impact of subway systems. The findings show significantly lower carbon dioxide emissions for subway cities.