Planning for Atmospheric Carbon Monitoring in California.

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The Issue

Carbon dioxide (CO_2) is a greenhouse gas (GHG) that is emitted by fossil fuel combustion for electricity production. Globally, roughly half of the CO_2 emitted by fossil fuel combustion has entered the atmosphere, increasing the atmospheric CO_2 concentration, as shown in Figure 1. In-state electricity generation accounts for about 16% of California's CO_2 emissions.[1] Because these emissions contribute to human-induced climate change, the California Energy Commission (Energy Commission) has identified the study of CO_2 and other GHGs as a priority area for research—in particular, the ability to attribute CO_2 sources. Future cost and production strategies for electricity production may be affected by economic and policy responses to global warming, and it will be important to determine the CO_2 contribution of fossil fuel combustion and ecosystem carbon exchange.

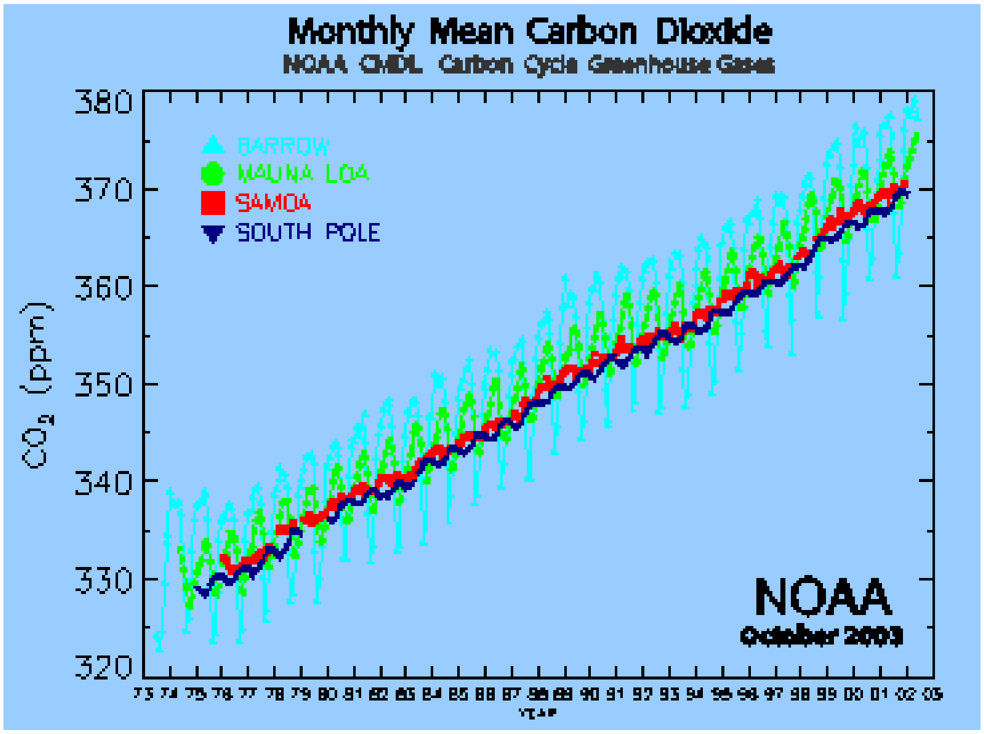

Figure 1. Mean monthly CO_2 concentrations measured at remote marine stations by the NOAA-Carbon Monitoring and Diagnostics Laboratory (shttp://www.cmdl.noaa.gov/ccg/figures/co2obs.jpg)

The natural carbon cycle on Earth causes plants to capture CO_2 from the atmosphere through photosynthesis. Most of this carbon is eventually decomposed by soil microorganisms and transferred back to the atmosphere as CO_2. However, a small part of the carbon may remain stored for significant periods of time in the ecosystem as dead plant material or soil organic matter. Similarly, a small part of the CO_2 that is emitted by fossil fuel combustion can be captured by plants and stored. Such stores of carbon are called “carbon sinks.” Estimation of ecosystem carbon sources and sinks is a key problem for GHG accounting, because the mechanisms are not well understood. Also, it is difficult to estimate statewide carbon sources or sinks from changes in carbon stocks because it is expensive to study a sufficient number of areas to achieve a representative sampling over such a large region.

Currently, the Energy Commission estimates CO_2 emissions using accounting data for fossil fuel emissions and a combination of inventory surveys and simple models for net ecosystem exchange (NEE), which is the net balance of ecosystem carbon fluxes into and out of the atmosphere). The net ecosystem fluxes occur continuously, but because they vary with interannual and seasonal climatic variability and land use and management, the uncertainties in these estimates are not well quantified. A focused effort for monitoring atmospheric CO_2 concentrations has the potential to reduce the uncertainties by providing additional observations on regional NEE.

Anticipated Benefits for California

Providing environmentally sound electricity. This work will provide the foundation for a network of atmospheric monitoring sites and trace-gas sampling protocols that will enable researchers to more precisely identify the CO_2 contributions from ecosystem processes and fossil fuel combustion to global warming. The resulting tool will enable the quantification and verification of net CO_2 emissions, strategies for within-state carbon sequestration, and emissions trading. This project addresses state and national needs for quantification of terrestrial sources and sinks of carbon cycle gases.

Project Description

To address the need for source attribution of CO_2 emissions, PIER-EA funded work by Lawrence Berkeley National Laboratory to develop an atmospheric measurement strategy for monitoring of CO_2 in California. The objectives of this work were to: 1) Estimate temporal and spatial distributions of NEE and meteorology in the Western US for representative time periods covering the seasonal cycle of NEE, 2) Estimate temporal and spatial distributions of fossil fuel CO_2 emissions in the Western US, 3) Predict temporal and spatial distributions of CO_2 concentration signals from NEE and fossil fuel CO_2 emissions inside and outside California, and 4) Use the atmospheric CO_2 concentration signals predicted for existing and potential future monitoring stations to judge the suitability of these stations for quantifying NEE within CA.

Results

First, predicted maps NEE showed large spatial and diurnal and annual variations due to the seasonal nature of different ecosystems CO_2 exchange. In contrast, fossil fuel CO_2 emissions were much more constant in time but strongly geographically concentrated near urban centers. Second, the resulting atmospheric CO_2 concentration signals from NEE and fossil fuel emissions were easily measurable with existing methods at many locations within CA. For example, Figure 2 shows the mean midday near surface (0-100 m) concentration signals (relative to a background concentrations) from NEE inside and outside CA and fossil fuel CO_2 emitted inside and outside CA. The signals from sources within CA were significantly larger than measurement limits of current instrumentation (~ 0.2 ppm). Third, based on the predicted spatial distribution and temporal correlations from signals at existing and potential future stations, a combination of existing terrestrial sites including flux measurement sites and tall communication towers would be effective as observation stations for identifying and separating CO_2 concentration signals from NEE within CA from signals due to fossil fuel emissions and NEE outside CA. Project recommendations included: 1) a set of CO_2 observing stations, sampling frequencies, measurement protocols; 2) a summary of additional trace gas species that could be measured to aid in separating the sources of CO_2; 3) additional predictive modeling and data analysis that should be performed to prepare for implementation of atmospheric CO_2 monitoring.

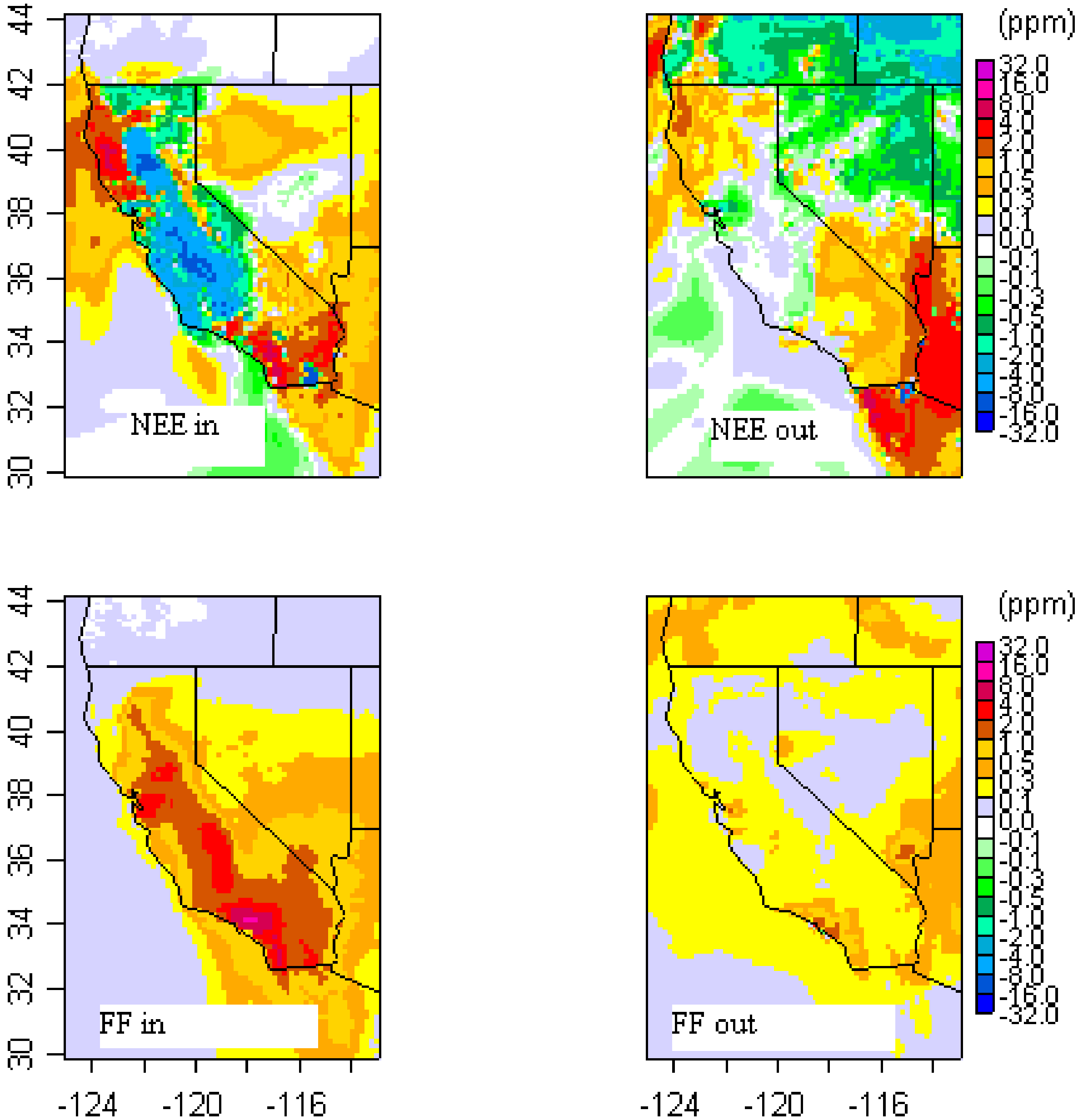

Figure 2. Maps of June midday mean surface layer CO_2 concentrations resulting from NEE inside (upper left) and outside (upper right) California, and fossil CO_2 emissions inside (lower left) and outside (lower right) California. The horizontal and vertical axes are longitude and latitude respectively. Note that CO_2 concentration contours are logarithmically scaled.

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[1] California Energy Commission. November 2001. *Inventory of California Greenhouse Gas Emissions and Sinks: 1990–1999.* P600-02-001F. Figure ES-8.