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CALGEM: Measuring California's Greenhouse Gas Emissions

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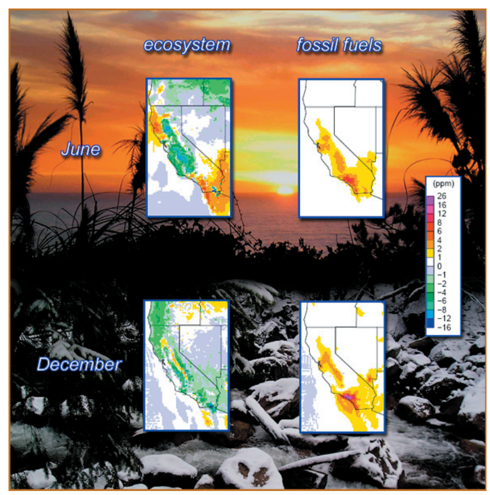
The state of California has embarked on a trailblazing effort to fight global warming by reducing emissions of greenhouse gases (GHGs). Assembly Bill 32, recently passed by the California legislature and signed into law by Governor Arnold Schwarzenegger, requires the state to substantially reduce GHG emissions by the year 2030—and, by the summer of 2008, to develop a plan for accomplishing this.

The bill requires California to reduce its carbon emissions to 1990 levels by 2020, a reduction of 25 percent. By 2050, carbon emissions must be reduced to 80 percent below 1990 levels. Given that California has the fifth largest economy in the world—with total greenhouse gas emissions estimated at around 400 million metric tons per year, the most of any state—both these targets require substantial reductions.

Several years ago scientists at Lawrence Berkeley National Laboratory recognized the need to monitor emissions regionally and began studying the problem. They are now taking the first steps toward a monitoring network with a pilot project called CALGEM: the California Greenhouse Gas Emissions Project.

Measuring net exchange of greenhouse gases

In 2003, a group led by Marc Fischer in Berkeley Lab's Environmental Energy Technologies Division (EETD) began an exploratory project with the California Energy Commission to develop a method of quantifying GHG emissions on regional scales. Fischer, William Riley of the Earth Sciences Division, and Shaheen Tonse of EETD designed a statewide network of atmospheric measurements to monitor carbon dioxide (CO_2) emissions, described in a report titled "Development of an Implementation Plan for Carbon Monitoring in California."



Computer-simulated maps show predicted CO^2 concentrations in the lower atmosphere from net ecosystem carbon exchange and fossil fuel combustion. Summer and winter show different patterns of CO^2 absorption by photosynthesis and release by respiration. Fossil fuel CO^2 emissions are concentrated in urban areas and more constant from season to season.

Using data from existing sources, plus computer models for atmospheric gas transport, Fischer's group predicted variations in CO_2 concentrations across California. Atmospheric CO_2 is affected by anthropogenic (human-caused) emissions, mostly the combustion of fossil fuels, and by ecosystem carbon exchange.

The lower atmosphere responds to additions and removals of CO_2 on daily to seasonal time scales. The team predicted variations of midday CO_2 from ecosystem exchange and fossil fuel emissions in the lower 100 meters of the atmosphere for two seasons. They showed that the two signals are large enough to measure and also vary enough, spatially and temporally, that by measuring CO_2 at many sites, human contributions could be identified. With this exploratory study as proof of concept, the Berkeley Lab group launched CALGEM.

"We will design an atmospheric measurement network to quantify greenhouse emissions, and estimate whether the atmospheric measurements are likely to provide sufficient accuracy and precision to tell whether GHG control strategies are working or not," says Fischer.

Many other greenhouse gases besides carbon dioxide contribute to climate warming, including methane (CH_4), nitrogen oxides, and halocarbons. Non-CO_2 greenhouse gases are estimated at 15 percent of total California emissions. CH_4 is the most significant. Most methane is biological in origin, whether from livestock or the breakdown of organic waste in landfills; lesser amounts are emitted by the delivery and use of natural gas and by decomposition of organic material in flooded fields and natural wetlands.

“Emissions of CH_4 and other non-CO_2 GHG gases are poorly quantified,” says Fischer. “Uncertainties range from 25 percent to a full order of magnitude.” Taken together, these gases have an effect on climate change comparable to total atmospheric CO_2. Accurately estimating their emissions is crucial to measuring the effectiveness of GHG reduction programs.

A network of measurements

Fischer, Riley, and Pieter Tans, of the National Oceanic and Atmospheric Administration’s (NOAA’s) Environmental Science Research Laboratory, are designing an instrumentation network to measure non-CO_2 GHGs in California. Atmospheric measuring techniques will be demonstrated at two of the sites in the eventual CALGEM network.

Ground-based measurements will include continuous monitoring and flask sampling at tall towers. Dedicated instruments at one site will continuously measure CH_4 and CO_2, plus carbon monoxide (CO) as a tracer of combustion. Flasks will be collected twice a day, which NOAA will analyze for a host of GHG species. Aircraft and satellite remote sensing will provide estimates of the total amount of GHGs in the atmosphere.

One tower will also take measurements of radon (^{222}Rn) to monitor the rate at which GHGs are diluted in the atmosphere. Radon, a naturally occurring radioactive gas with a half life of 3.8 days, is excellent for tracing atmospheric mixing and the origin of atmospheric air masses. For example, air originating near the land surface has more radon, while air masses coming from the ocean have less radon.

Says Fischer, “Together, these measurements will provide an unparalleled tool for monitoring trends in atmospheric GHG concentrations in California.”

Possible locations for the complete regional greenhouse gas measurement network include the San Francisco and Sacramento towers equipped by Berkeley Lab, existing measurement sites operated by other institutions on the North Coast and near San Diego, and several tower locations in the Central Valley and near Los Angeles. Aircraft and satellites will supplement the ground stations.

Computer modeling to design a better network

Based on initial measurements, the research team is also devising data analysis and modeling techniques to quantify surface emissions and figure out which expansions to the network will best minimize uncertainty.

“As in the initial exploratory project on CO_2,” says Fischer, “we’ll combine current ‘bottom-up’ models of surface greenhouse-gas emissions with regional-scale models of atmospheric transport, to predict atmospheric GHG concentrations for different sources in California.”

The mathematical procedure adds noise to the model’s predictions to produce “pseudodata” of GHG concentrations, mimicking statistical and systematic uncertainties. The researchers estimate surface emissions using “inverse-model” methods, matching the measured data as closely as possible to the noisy pseudodata. To find the network that best reduces uncertainty in emissions measurement, pseudodata calculations will be run on many different network designs.

“The measurements will represent the beginning of a long-term record of GHG concentrations, representing California’s contribution to global climate change,” Fischer says. “The modeling and analysis will provide an initial estimate of the current level of GHG emissions at the regional level and provide recommendations for a more complete monitoring network.”

As California implements reduction programs to achieve the goals of Assembly Bill 32, CALGEM will enable California to estimate how well the programs are working to reduce greenhouse gas emissions.

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