Title

Planning an atmospheric observing strategy to constrain California's green house gas emissions: Initial results

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Planning an Atmospheric Observing Strategy to Constrain California's Green House Gas Emissions: Initial Results

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ABSTRACT

We describe work to develop an atmospheric measurement strategy to estimate and attribute CO_2 exchange to terrestrial ecosystems in California. Using models of the natural carbon cycle, fossil fuel emissions, and regional meteorology, we predict CO_2 concentration "signals" that would be measured with different observing platforms. Simulations in April 2002 show woody savanna and forest ecosystems are growing actively and storing carbon, while crop lands are not yet growing actively and act a net source of CO_2. Fossil emission from metropolitan areas is the largest of all sources and also important for the spatially extensive Central Valley. Maps of predicted CO_2 signals for surface stations (100 m layer) largely mirror the emissions maps near strong sources while column integrated concentrations (as would be observed with sounding instruments) reflect averaged fluxes. Of major significance, we predict that large plumes of CO_2 enriched or depleted air are advected to produce significant signals at marine stations as much as 300 km West of the coast. Hence, such stations can not be considered as a pristine boundary condition for air entering California. Ongoing work will quantify these results for other seasons, examine the influence of specific land surface elements to signals using footprint analysis, and estimate atmospheric signals obtained from different management strategies for carbon sequestration.

INTRODUCTION

Carbon dioxide is emitted by fossil fuel combustion for human needs including electricity production, and is exchanged with the biosphere as part of the natural carbon cycle. The California Energy Commission (CEC) has identified attribution of sources and sinks of CO_2, and other green house gases (GHGs), as a priority area for research. Currently, the CEC 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), the net flow of ecosystem carbon into and out of the atmosphere [1].

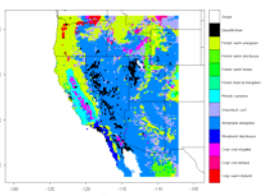
In addition to inventory methods, several types of measurements can be used to quantify or constrain ecosystem exchange. Eddy covariance flux measurements provide direct measurements but observe relatively small (less than or about 1km) patches of land. Inverse methods estimate land surface fluxes covering large scales (continent to hemisphere) using measured variations in gas concentrations but must estimate atmospheric transport from a combination of measurements and models.

Here we describe initial work to design a measurement strategy for applying inverse methods to the regional scale in the California region. Here we predict atmospheric CO_2 concentration signals in the California region to identify spatial distributions and temporal variations. The work is performed in a three step process.

1) Simulate maps of NEE and meteorology using a coupled land-surface and atmosphere regional-scale model.
2) Simulate CO_2 concentrations signals due to biosphere exchange and fossil fuel CO_2 using a tracer transport model driven by the meteorology calculated in 1).
3) Examine the spatial patterns of the CO_2 signals to identify locations that provide opportunity to separate the biospheric and fossil fuel contributions.

Vegetation Map of Western US

- This figure shows the distribution of land cover in the Western region.
- In the April, 2002, period used for the following simulations only woody savanna and forests were parameterized to have sufficient leaf area to support active photosynthesis. Crop lands in the central valley were parameterized as bare soil.



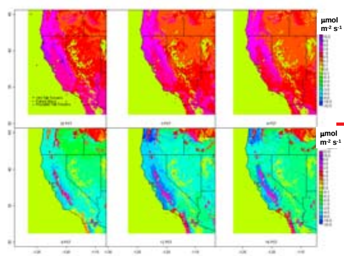
CO_2 Flux Maps

- Net CO_2 ecosystem exchange (NEE) depends upon the balance of uptake through photosynthesis and release from ecosystem respiration
  - Photosynthesis depends the amount and type of vegetation present, the water and nutrient status of the ecosystem, available sunlight
  - Respiration depends on the amount of organic matter present to decompose, the presence of microorganisms and soil moisture and temperature
- Maps of NEE (and meteorology) are simulated using a coupled version of the NCAR land-surface and mesoscale climate models (LSM and MM5) [2].
- The figure below shows one diurnal cycle of NEE for a day in April, 2002
  - Most of California and Oregon (excepting dry land) region show nighttime respiration
  - Forests and woody savanna show active daytime uptake
  - Crop lands are assumed to have little vegetation and act as a source of CO_2

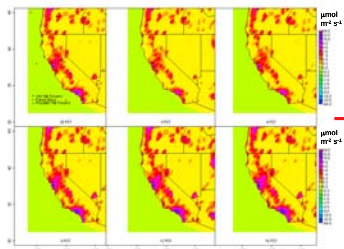
CO_2 Flux from Net Ecosystem Exchange (NEE)

Release to atmosphere occurs during night

Uptake from atmosphere occurs during day



CO_2 Flux from Fossil Fuel Emissions

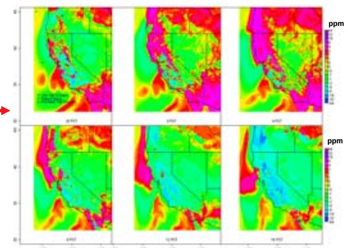


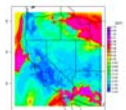
- Maps of CO_2 emitted by fossil fuel combustion are estimated from a gridded version of the EPA National Emission Inventory [3] for Carbon Monoxide (CO) assuming an average CO_2:CO emissions ratio of 30:1.
- CO_2 emissions are concentrated in the urban areas of San Francisco and Los Angeles and dominate all other fluxes
- The spatially extensive areas in the surrounding sub-urban areas and in the Central Valley are comparable to nighttime ecosystem respiration
- The diurnal pattern of CO2 emissions are less pronounced than the diurnal pattern of NEE

CO_2 Concentration Maps

- Maps of CO_2 concentration signals are simulated using the US EPA Community Multiscale Air Quality (CMAQ) [4] driven by the flux maps and meteorology from previous page
- Concentration signals for lowest model layer (0-100m) typically reflect effect of surface fluxes smeared by atmospheric transport
  - Typical NEE signals in the range of –4 to 4 ppm (-20 to 20 in some areas)
  - Fossil CO_2 signals 16 in suburban to > 32 ppm in urban areas
  - Plumes from land produce 4 to 8 ppm signals are present during day over coastal waters to > 300 km off shore
  - Column integrated signals are calculated to reflect signals that would be observed by the NASA Orbiting Carbon Observatory (to be launched in 2007)
    - Signals reflect approximate diurnal average of emission
    - Spatial patterns reflect regional averages
    - Signal strengths are reduced relative to near surface signals (note different scale on image)

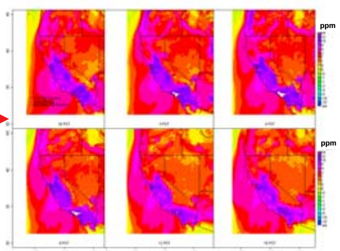
CO_2 Concentration from NEE

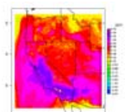




Midday column integrated CO_2 relevant for NASA Orbiting Carbon Observatory (OCO)

CO_2 Concentrations from Fossil Emissions



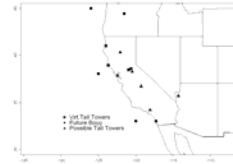


References

1) Franco, G. (2002). Inventory of California Greenhouse Gas Emissions and Sinks: 1990-1999, California Energy Commission.
2) Riley, W.J., H.S. Cooley, Y. He, and M.S. Torn, Coupling MM5 with ISOLSM: Development, Testing, and Applications, *NCAR MM5 Symposium*, Boulder, CO2003
3) Data provided by LADCO. http://www.ladco.org/
4) http://www.epa.gov/asmdnerl/models3/cmaq.html

Station Map

- We also identify a set of present and future measurement stations in the Western Region
- Three sets of initial station locations were considered:
  1) offshore bouys planned by NOAA for future deployment
  2) Ameriflux sites where CO_2 is or could be measured using "virtual tall towers"
  3) Tall (>250m) transmission towers in the Central Valley that might be used as platforms in the future



Conclusions

- We simulated CO_2 fluxes and the resulting concentration "signals" from NEE and fossil emissions for the Western region during April 2002
- CO_2 Flux maps show:
  - Woody savanna and forest ecosystems are growing strongly (and storing carbon)
  - Crop lands are not yet growing actively and act a net source of CO_2.
  - Fossil CO_2 emission from metropolitan areas are largest of all sources
  - Fossil emission is weaker but still important in spatially extensive Central Valley
- CO_2 concentration maps show:
  - Near surface (100 m layer) concentration maps largely reflect surface fluxes
  - Column integrated signals reflect both spatial and temporal averaging
  - Plumes of CO2 enriched or depleted air significantly affect concentrations to 300 km off shore

Ongoing/future Work

- Expand analysis to cover annual variations in carbon cycle and meteorology
  - Include specific analysis of dominant air flow patterns of California
- Conduct footprint analysis to quantify the influence of specific land surface elements to concentration signals
  - Estimate the reduction in uncertainty for inversion of land surface flux derived with different choices of observing stations
- Estimate atmospheric signals obtained from different management strategies for carbon sequestration
- Expand analysis to include non-CO_2 green house gases (e.g., CH_4 and N_2O)

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