A Proposed NACP Intensive Field Experiment along the West Coast of the US

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This project will serve as an Intensive Field Experiment for the NACP. The project will provide a regional test of the overall NACP strategy by simultaneously using both bottom-up and top-down approaches to determine the carbon balance of California and Oregon, starting in 2004-2005 to capitalize on existing time-sensitive data.

Overall Objectives

The West Coast Field Experiment will have two overall objectives:

(1) To close the carbon balance of California and Oregon using two complementary approaches: (a) a bottom-up strategy relying on inventories of ecosystem stocks, flux observations, emission inventories, fire histories, remote sensing, and land-surface modeling, and (b) a top-down approach relying on atmospheric observations and transport modeling.

(2) To investigate the controls on regional carbon balance (for example, how Net Ecosystem Production and carbon stocks in vegetation and soil are influenced by forest development, disturbance, fire, chronic drought and climate), and to use this information to predict the future trajectory of regional carbon balance.

High Priority Issues for the NACP

The West Coast Field Experiment will resolve four issues of importance to the NACP.

(1) Understanding and sampling landscape heterogeneity

A key challenge for the NACP is to understand and sample landscape heterogeneity. Research within the NACP is needed to understand how vegetation type, NPP, carbon stocks, and NEP are controlled by climate and disturbance history. This understanding needs to encompass the full span of ecosystems found within North America, including desert, shrubland, grassland, agriculture, savannah, evergreen forest, deciduous forest, alpine/tundra, and coastal/land interface. Other NACP field experiments will likely focus on comparatively homogenous regions, whereas the West Coast Experiment will focus on understanding landscape heterogeneity. *The West Coast Field Experiment will explicitly consider how environmental gradients and landscape heterogeneity influence carbon balance, and use this information in the bottom-up determination of regional carbon balance*. A rapid improvement in understanding how and why carbon cycling differs along gradients in climate, disturbance history, and vegetation is critical for the NACP.

(2) Relating measurements of trace gas concentration made at surface stations to the concentrations aloft

Top-down inversions generally rely on measurements of surface concentration. The accuracy of inversions is contingent on the accuracy of the atmospheric models used to relate concentrations at surface stations to concentrations aloft. Surface stations are typically located in regions where sources and sinks are weak, such as islands, the upwind margins of continents, mountains, and deserts. Careful site selection and sampling are thought to decrease the difference in concentration between the surface and the free atmosphere, though this assumption has been tested only rarely. A key need for the NACP is an improved understanding of the vertical distribution of trace gas concentration above the types of surfaces where stations are typically located. Aircraft campaigns within the West Coast Intensive Experiment will be used to measure the vertical concentrations above NACP surface stations located on islands, at the land-sea interface, in desert, and, possibly, on moorings and tall mountains. A rapid improvement in understanding how trace gas concentration varies with altitude above a range of land/ocean surfaces is critical for the NACP.

(3) Testing the top-down/bottom-up experimental paradigm

There is growing recognition that credible assessments of large-scale carbon balance require a convergence of top-down and bottom-up results. A demonstration of this convergence is at the heart of the overall NACP experimental strategy. The West Coast Field Experiment will explore this strategy by simultaneously quantifying the carbon balance of California and Oregon using both top-down and bottom-up approaches. A rapid demonstration of the convergence of independent bottom-up and top-down assessments of regional carbon balance is critical for the NACP.

(4) Providing measurements of the upwind boundary condition

Much of the NACP's strategy is focused on comparing the composition of air entering North America with that leaving North America. An extensive set of measurements will be required to identify the magnitude, composition, and flow direction of the carbon-enriched (or depleted) plumes of air originating from ecosystems and cities along the West Coast. Additionally, periodic measurements of the vertical composition of air entering North America is needed to understand how surface measurements at the continent's leading edge relate to the composition aloft. The West Coast Field Experiment will begin these measurements. The deployment of instrumentation to further sample the western boundary of North America, and the rapid enhancement of data collection, is critical for the NACP.

Why focus on the West Coast?

Intensive Field Experiments are a key component of the NACP. Regional field experiments will allow researchers to focus initially on smaller, better-constrained, more tractable areas, as they build the understanding and methodology required to determine the Carbon budget for all of North America. The West Coast offers several key advantages as a location for a regional field experiment.

Large environmental gradients provide an ideal system for sorting out the relationships between climate, disturbance history, vegetation type, NPP, carbon stocks and NEP

The West Coast is particularly appropriate for studies to understand the interactions between climate, disturbance, fire, vegetation type, NPP, carbon stocks, and NEP. California and Oregon have strong climatic gradients from the Pacific coast to the mountains to the Great Basin/southeastern deserts. The associated gradients in productivity and soil and plant carbon stocks are very large; the range of carbon stocks and productivities in California and Oregon is comparable to that in the entire US. Oregon and California ecosystems are subject to natural (fire, insects, severe drought) and human (logging, land conversion, water diversion) disturbances that control carbon balance. Oregon and California include regions that are thought to currently act as carbon sinks, due to fire suppression and woody encroachment, and other areas that are thought to currently act as carbon sources, due to recent disturbance.

The West Coast provides an excellent laboratory for determining the relationships between climate, disturbance history, vegetation type, NPP, carbon stocks, and NEP. It is possible to identify nearby study sites along climate and disturbance gradients that span the range encountered throughout much of North America. Intensive studies along these gradients can be used to determine how vegetation type, NPP, carbon stocks, and NEP are controlled by climate and disturbance history.

The West Coast's geography lends itself to the top-down approach

Past research to quantify the transport of atmospheric pollutants (e.g. by the California Air Resources Board) and to explore the potential for wind energy (e.g. by the California Energy Commission) has contributed to a strong understanding of the wind climatology for the western US. The mean circulations vary seasonally, but are generally predictable, especially in comparison to many continental regions in the US. In general, air enters the western US from the Pacific, where it is well mixed. This homogenous source will allow the characterization of CO_2, CO, CH_4, and O_2 composition with just a few coastal, island or moored stations. The air then passes over areas of high source or sink activity in western California and Oregon (urbanized areas near the coasts; intensive agriculture, especially in the Central and Willamette valleys; forests, especially in Oregon and northern California), and exits to the Great Basin and southeastern deserts. These deserts lack strong carbon sources or sinks, and atmospheric mixing during daytime is extreme, which will allow the characterization of a large fraction of the exiting air with just a few desert or mountain stations.

California and Oregon have a strong south to north gradient in the relative importance of anthropogenic and natural carbon sources and sinks. Air passing over southern California is impacted most strongly by combustion; air passing over central California is impacted by a mix of anthropogenic sources and agriculture; air passing over northern California and southern Oregon is impacted most strongly by ecosystem gas exchange. The Pacific Coast provides an excellent laboratory for investigating the feasibility of the top-down approach for determining regional carbon balance. A series of stations deployed to sample air entering California and Oregon from the Pacific, and exiting to the desert, will allow calculation of the regional carbon balance. These calculations will be evaluated by comparison with the results from the bottom-up approach. The south-to-north gradient will allow a test of the ability of top-down approaches to partition the sources and sinks between anthropogenic and biological processes. These stations will also provide a critical upwind boundary for the NACP's broader focus on the North American continent.

Strong synergy with ongoing research, and data available from other sources, will jumpstart the project and allow rapid progress

A large amount of carbon cycle research is already underway in California and Oregon. Extensive records of atmospheric composition are available for stations at Cape Meares, Oregon, Trinidad Head, California, and Scripps Pier, California. Aircraft campaigns tied to the Trinidad Head site have been conducted, or are planned, as part of COBRA-NA 2003 and the CMDL network. NIGEC and DOE TCP fund terrestrial carbon research in California and Oregon. NASA funds investigators in California and Oregon who are using remote-sensing and/or modeling to study large-scale carbon balance (e.g. NASA EOS core validation sites are in Oregon). California and Oregon are well suited to remote sensing; many archived scenes and products from previous studies are available. A demonstration project has been completed in western Oregon using key elements of NACP - a bottom-up approach that is a nested hierarchy of observations (inventories, extensive sites, chronosequences and intensive flux sites) combined with remote sensing and process modeling to map NEP and carbon stocks.

Likewise, a large amount of relevant data is available from various state agencies. Work relevant to the top-down approach has been done within the context of air quality research, including monitoring air quality, developing high-resolution transport and chemistry models, and compiling emission inventories and databases (e.g., California Energy Commission, California Air Resources Board). The hydrological budget for California is well characterized, providing opportunities to validate land-surface models at large scale. The West Coast Experiment will be coordinated with, and will complement, research that is already underway. The availability of expertise, infrastructure, and existing data will jump start the project and allow rapid progress.

Time Frame and Measurements

The specific experimental plan will depend on the review process and the ultimate composition of the Science Team. The review process should focus on selecting proposals that directly address one or more of the two Overall Objectives and four High Priority Issues outlined above. It is neither appropriate nor possible at this point to specify projects that should be funded, or to outline a detailed set of tasks. Nonetheless, it is likely that successful proposals will share one or more of the following elements.

Intensive year-round measurements

The fluxes of carbon between the land and the atmosphere, and the transport of carbon in the atmosphere, vary seasonally. The goal of the NACP is to quantify these fluxes on annual and longer time periods, and, consequently, a short, intensive field campaign alone would not provide the information needed to address the overall objectives. It is likely that many of the measurements will continue for one or more years.

Measurements of carbon fluxes and stocks along ecological gradients

Measurements along gradients can be used to understand how vegetation type, NPP, carbon stocks, and NEP are controlled by climate and disturbance history. A strong hierarchical design is needed for spatial representativeness and hypothesis testing (e.g. sink-source transitions following disturbance). The use of multiple independent measurement approaches (e.g. biometry and tower fluxes) increases both the science return and the confidence in the measurements. For example, a series of eddy covariance towers and associated biometry plots deployed along chronosequences (series of matched sites that differ in time since disturbance) provides a measure of how the carbon cycle recovers from disturbance. Likewise, a series of towers and plots along a climate gradient can provide information on how climate influences vegetation and carbon cycling. Inventory plots and extensive sites that cover the variation in climate and vegetation can provide spatial information for regionally representative stocks and fluxes.

Measurements of atmospheric composition along spatial gradients

The top-down approach relies on characterizing the horizontal and vertical gradients in atmospheric composition. The horizontal gradients at the surface can be measured with high-precision, in-situ instruments at permanent monitoring stations. These stations can be automated, allowing year-round observation. The vertical gradients are more difficult to measure, requiring intensive aircraft campaigns. The best overall approach will likely combine long-term ground-based measurements of the east-west and north-south gradients in CO_2, CO, CH_4, and O_2, with at least two aircraft campaigns to characterize the air aloft. All of these measurements should be tied to the standards used at other NACP sites, and coordinated with other research already underway (at, for example, Trinidad Head).

Regional synthesis

The goal of both the NACP and the West Coast Field Experiment is to quantify the carbon balance at large spatial scales. Achieving this goal will require that researchers understand the contemporary and past history of disturbance regimes along the West Coast. Key questions include whether changes in the fire regime can shift the region from a sink to a source from year to year (e.g., the Southern California fires of October 2003), and what the impacts are of fire suppression, wildfire, logging, water diversion, insect outbreaks, and agriculture over the last century on contemporary regional-scale carbon fluxes. These analyses will require active participation by researchers with expertise in forest demography, remote sensing, ecological process modeling and land-surface modeling, atmospheric transport modeling and inversion, and the assembly of land-use, fire, and emissions databases.

Rapid exchange of information between all members of the Science Team

The various researchers should work together as a team. Site selection must be an interdisciplinary effort combining the needs of remote sensing, ecosystem process modeling, atmospheric transport modeling, and ecological analysis. For example, researchers with expertise in atmospheric transport should be involved in the selection of sites for monitoring the spatial patterns of atmospheric composition. Researchers with expertise in remote sensing and land-atmosphere modeling should be involved in the selection of ecological gradients. Researchers with expertise in field data analysis need statistical power in making inferences on carbon stocks and fluxes (e.g. replicated plots and spatial representativeness). Researchers making long-term measurements should make their data available in near real time using radio, phone or satellite links.

Deliverables:

The West Coast Intensive Field will address four High Priority Issues. The Science Team will be selected and organized to focus tightly on these Priority Issues, as well as the two Overall Objectives. The West Coast of North America has several attributes that will facilitate progress. The West Coast Intensive Experiment will take advantage of the geographic and climatic diversity in Oregon and California to improve understanding of the spatial patterns of ecosystem carbon stocks and exchange, and also of the strategies required to assess large-scale carbon exchange using surface concentration measurements. The West Coast Intensive Experiment will increase the observations of trace gases being made at the upwind boundary of North America. Finally, the West Coast Intensive Experiment will provide a regional test of the overall NACP strategy by attempting to close the carbon balance of California and Oregon using independent top-down and bottom-up approaches.