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Tracking Carbon Trail
To Find Why So Much Fills the Atmosphere

December 28, 2007; Page B1

One mystery of global warming underlies all others: Nobody knows precisely where all the world's carbon dioxide ends up every year.

Much of this heat-trapping greenhouse gas stays aloft, promising to make 2007 one of the warmest years on record. Levels of CO2 in the atmosphere have surged 35% in recent centuries, scientists have calculated. Still, that reflects barely half of all the emissions from human activities. Some of it seeps into soil, vegetation and the oceans, where it can't affect climate so immediately.

Recently, however, federal researchers discovered that severe droughts and wildfires have disrupted these natural storehouses of carbon, sometimes venting CO2 equal to annual emissions from millions of cars.

So far, scientists have no reliable way to measure all these fluctuating carbon emissions. Temperature predictions based on future CO2 levels, therefore, could overestimate the risk of greenhouse warming -- or dangerously understate it. "A quarter of all the CO2 that is emitted is going somewhere, and we don't know where," said David Crisp at NASA's Jet Propulsion Laboratory, where he is senior scientist for the $270 million Orbiting Carbon Observatory, set for launch next December. "That raises a lot of red flags."

Moreover, as governments try to prevent climate change through emissions trading -- where buying and selling emissions rights is expected to top $70 billion by the end of next year -- regulators must track CO2 no matter where it comes from or where it goes, to verify transactions.

To pinpoint the places where the planet naturally absorbs CO2 emissions, researchers have turned North America into a test lab. No other region is so thoroughly monitored; nor does any other area emit as much carbon dioxide -- about 27% of the world's annual total.

The U.S., Mexico and Canada together release about 2 billion tons of carbon as CO2 into the air every year -- 85% from the U.S. alone -- but only about a third of it typically is absorbed by so-called carbon sinks, such as new forests, grasslands, crops and soil. The rest is either in the air or unaccounted for. That is according to a new study of 28,000 measurements collected every week from 2000 through 2006 and analyzed by the National Oceanic and Atmospheric Administration's online CarbonTracker system.

The CarbonTracker offers a portrait of the continent in carbon dioxide, locating where greenhouse-gas upwellings are strongest and where new plant growth and soil most readily

remove it from the air. Greenhouse-gas emissions were highest in the Midwest, which released more CO2 than any country except Russia, China, India, and the U.S. as a whole. By the same token, CO2 was absorbed mostly east of the Rocky Mountains and in northern Canada, where vast boreal forests hold twice as much carbon as tropical woodlands.

These detailed calculations reveal a countryside where these natural carbon-storage zones are failing, the NOAA researchers determined. The higher temperatures that result can, through more frequent wildfires and prolonged droughts, further interrupt ancient cycles of carbon storage, spilling even more carbon into the air.

Such comprehensive climate studies have begun persuading many skeptics. The U.S. Climate Change Science Program, which released its first State of the Carbon Cycle Report for North America last month, documented the same troubling trend. NASA and the Japanese Space Agency expect to launch satellites next year to track global CO2 concentrations almost half a million times a day, in a more precise diagnosis of this planetary carbon catch-and-release system.

No one can say with certainty when growing emissions of carbon dioxide, methane and other greenhouse gases will tip the balance of the atmosphere into dangerous climate changes. But recent events have shown how vulnerable the world's ability to recycle carbon can be to even moderate increases in temperatures. "Climate extremes can have a major effect on the amount of carbon dioxide in Earth's atmosphere," said NOAA atmospheric chemist Wouter Peters.

An unusually severe U.S. drought in 2002, the NOAA researchers discovered, left an extra 360 million tons of carbon in the atmosphere -- an amount equal to the annual emissions of 200 million cars -- by stunting plant growth that normally might have absorbed the gas. "We lost half our natural sink," said NOAA geochemist John Miller. In Europe, a severe drought in 2003 left more than 500 million tons of carbon in the air.

In turn, the dry weather from higher temperatures also has made wildfires in the western U.S. more frequent, longer-burning and harder to extinguish. Large-scale fires in western and southeastern states can release as much carbon dioxide in a few weeks as motor-vehicle traffic there does in a year, University of Colorado researchers reported this past October in Carbon Balance and Management.

In a single week this fall, they reported, wildfires in Southern California released 7.9 million metric tons of CO2 -- equal to 25% of the monthly fumes from every car, truck, factory and power plant in the state.

LOOKING FOR CARBON

A prolonged drought in North America during 2002 left millions of tons of extra carbon in Earth's atmosphere, cutting the continent's natural uptake of carbon dioxide in half, researchers at NOAA's Earth System Research Laboratory recently reported. Red areas denote reduced carbon dioxide absorption in the summer of 2002 with blue areas showing enhanced absorption.
Since the beginning of the Industrial Revolution 250 years ago, roughly 315 billion tons of

carbon have been added to the air from the use of fossil fuels, land use changes and cement production, according the U.S. Department of Energy's online calculation of global CO2 trends1. Even so, that's only about half of the total from human activities during that time. The rest was absorbed by the oceans, forests, grasslands, soil, peat and other natural carbon "sinks." The U.S. Environmental Protection Agency's National Greenhouse Gas Inventory2 presents estimates of U.S. greenhouse gas emissions and sinks.

The U.S. Climate Change Science Program recently released its first State of the Carbon Cycle Report3, offering a scientific summary of the carbon cycle in North America, which releases much more CO2 into the air than it naturally absorbs.

A new federal data analysis system called CarbonTracker4 offers the first systematic glimpse into how the continent of North America naturally recycles this critical greenhouse gas. Scientists at the National Oceanic and Atmospheric Administration, who developed the CarbonTracker system, reported their most recent findings in The Proceedings of the National Academy of Sciences5.

These online animations of CarbonTracker data6 illustrate the global ebb and flow of carbon dioxide and the rapid mixing of the atmosphere. CO2 emitted in the US, for example, can reach Asia in a couple weeks.

Almost a quarter of all the world's CO2 ends up in the oceans, but in May scientists reported in Science7 that recent climate change has weakened one of the Earth's natural carbon 'sinks' --- the Southern Ocean around Antarctica.

The largest natural carbon storehouse on land is the Canadian Boreal Forest8, which contains 22 percent of the total carbon stored on the earth's land surface, and almost twice as much carbon per unit area as tropical forests.

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