

# THE USE OF REMOTE SENSING DATA FOR ADVANCING AMERICA'S ENERGY POLICY

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## ABSTRACT

After briefly reviewing America's Energy Policy laid out by the Obama Administration, we outline how a Global Carbon Observing System designed to monitor Carbon from space can provide the necessary data and tools to equip decision makers with the knowledge necessary to formulate effective energy use and practices policy. To stabilize greenhouse gas emissions in the atmosphere in a manner that it does not interfere with the Earth's climate system (which is one of the goals of United Nations Framework for Convention on Climate Change) requires vastly improved prediction of the atmospheric carbon dioxide ( $\text{CO}_2$ ) concentrations. This in turn requires a robust understanding of the carbon exchange mechanisms between atmosphere, land, and oceans and a clear understanding of the sources and sinks (i.e. uptake and storage) of  $\text{CO}_2$ . We discuss how the Carbon Observing System from space aids in better understanding of the connection between the carbon cycle and climate change and provides more accurate predictions of atmospheric  $\text{CO}_2$  concentration. It also enables implementation of greenhouse gas (GHG) mitigation policies such as cap and trade programs, international climate treaties, as well as formulation of effective energy use policies.

**Index Terms**— Energy Policy, Green House Gases, Climate Change, Carbon Sequestration, Global Carbon Cycle, Carbon Observing System

## 1. THE VISION

The guiding principles of America's Energy Policy as articulated by the Obama Administration are [1]: a) Achieve energy independence from foreign oil and secure our energy future by producing more energy at home (both fossil fuels and renewable sources of energy), promoting energy efficiency, and investing in clean and next-generation technologies (such as cars that run independently of fossil fuels), b) Tackle global climate change by reducing GHG emissions and closing the Carbon pollution loophole.

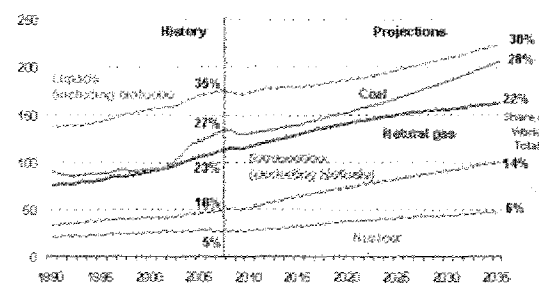
Increasing worldwide energy demand and consumption is one of the root causes of increased energy-related GHG emissions, hence Goals (a) and (b) are coupled tightly together. This paper examines the tight coupling between the two goals and gives an overview of how global remote sensing data obtained from a global Carbon

Observing System can help enable America's Energy Policies.

## 2. WORLD ENERGY USE AND $\text{CO}_2$ EMISSION PROJECTIONS

According to the U.S. Energy Information Administration (EIA) Annual Energy Outlook 2010, the world energy use is projected to grow by 49% between 2007 and 2035 or an annual average increase of 1.4%. Strong growth among non-OECD (Organization for Economic Cooperation and Development) nations drive the demand in increase. While it is expected that there is rapid growth in production and use of renewable sources of energy, fossil fuels are expected to continue to provide most of the world's energy (about three-fourths of total energy needs in 2035) assuming current energy policies around the world are unchanged. Figure 1 illustrates the World energy consumption projection as calculated by the EIA Independent Statistics and Analysis group.

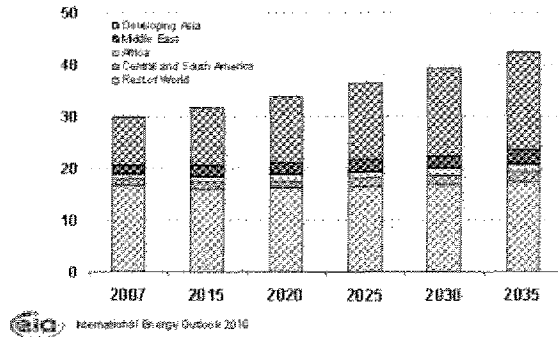
Figure 1. World marketed energy use by fuel type (quadrillion Btu)



EIA International Energy Outlook 2010

From this energy use projection, World's energy-related  $\text{CO}_2$  emissions are projected to rise from 29.7 billion metric tons in 2007 to 42.4 billion metric tons in 2035 (about 43% increase). Much of the increase in this scenario is expected to occur among the developing nations of the world. Figure 2 shows World's energy-related  $\text{CO}_2$  emission projection. (Complete projection scenarios and Figures 1 and 2 herein, can be found in the Annual Energy Outlook 2010 published by EIA[2].)

Figure 2. World energy-related carbon dioxide emissions (billion metric tons)



### 3. THE GLOBAL CARBON CYCLE

Why is the understanding of the global Carbon cycle in the context of energy policy formulation so important? The answer is simple: to be able to provide vastly improved projections of future atmospheric concentration of  $\text{CO}_2$  through better understanding of the mechanisms that promote uptake of anthropogenic  $\text{CO}_2$  into the oceans and land. This understanding will greatly improve our prediction of trends in global climate change and help in developing effective mitigation policies that regulate energy use and practices.

The carbon cycle is the biogeochemical cycle by which carbon is exchanged among the Earth's atmosphere, land, and oceans. It is considered as one of the most important cycles of the Earth, allowing for carbon (the building blocks of life) to be recycled and reused throughout the Earth's components. The flow of carbon exchange between reservoirs on Earth occurs because of various chemical, physical, geological, and biological processes. The oceans contain the largest active pool of carbon. Most of the carbon resides in the deep ocean, however, and does not rapidly exchange with the atmosphere.

The *global carbon budget* is the balance of the exchange of carbon between the carbon reservoirs. Examining the exchange rate between reservoirs can provide information about whether each reservoir is functioning as a source or sink for  $\text{CO}_2$ . Today, the global carbon budget is dominated by redistribution of carbon emitted from burning of fossil fuels between atmosphere, oceans, and land. Carbon released into the atmosphere as a result of anthropogenic activities and exchanged between atmosphere, land, and ocean plays a major role in the regulation of the climate of Earth. About half of the  $\text{CO}_2$  released in the atmosphere as a result of human activities resides in the atmosphere, while the rest are absorbed in

land and oceans. Understanding the sources as well as uptake and storage of  $\text{CO}_2$ , commonly referred to as "sources" and "sinks" and its change as a function of time is crucial to understanding Earth's climate change [3].

The physical climate system and the biogeochemical processes are tightly coupled together. Changes in Earth's climate affect the exchange of atmospheric  $\text{CO}_2$  between land surface and ocean, and changes in  $\text{CO}_2$  fluxes affect Earth's radiative forcing and thus the physical climate system. Some recently developed atmosphere-ocean general circulation models have explored the feedback between carbon cycle and climate change, and have confirmed the potential for strong feedback between them [4,5,6].

Figure 3. The Global Carbon Flux

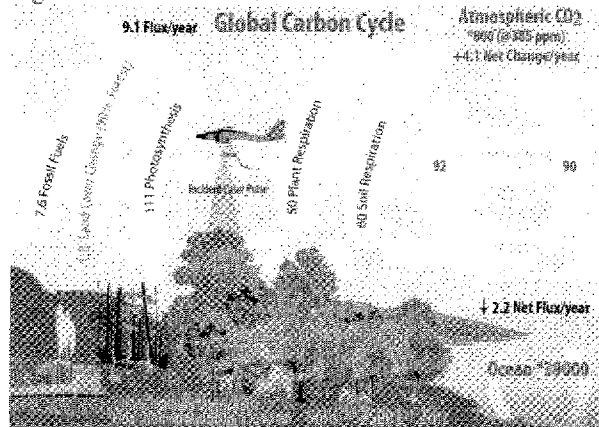


Figure Credit: Compton J. Tucker (NASA Goddard Space Flight Center)

Simulation of the global carbon cycle must account for the processes shown in Figure 3. As this Figure shows, the present day global carbon cycle is not in equilibrium because of anthropogenic carbon emissions that are released into the atmosphere. These carbon sources must be included in climate models, but such calculations are not easy because human-induced changes to the carbon cycle are small compared to large natural fluxes, as indicated in the Figure. Recent studies [7] demonstrate the large sensitivity of climate model output to assumptions about carbon cycle processes. Future carbon cycle models, coupled to new remote sensing datasets and in situ measurements, may permit more definitive assessment of  $\text{CO}_2$  concentrations in the atmosphere for given emission scenarios [8].

### 4. CARBON MONITORING FROM SPACE

As discussed in the previous section, understanding the global carbon cycle is crucial to understanding Earth's climate change and the mechanisms that drive this change.

This understanding is necessary for accurate projections of future CO<sub>2</sub> atmospheric concentrations based on current anthropogenic emissions. A global observational infrastructure capable of measuring sources and sinks of CO<sub>2</sub> is vital for enabling an integrated understanding of issues that are relevant to formulating energy use and practices policies. The carbon exchange occurs between three primary reservoirs: atmosphere, land, and oceans. It is imperative for the observing infrastructure to measure global concentration and exchange rate of carbon in each reservoir. We describe current and future technologies needed for such measurements.

#### 4.1. Atmosphere

Global atmospheric CO<sub>2</sub> can be measured via remote sensing observation systems. NASA's Orbiting Carbon Observatory (OCO) is designed to measure line of sight atmospheric column CO<sub>2</sub> using grating spectrometers. Advanced active optical remote sensing technologies (i.e. lidars) currently being developed at NASA Goddard Space Flight Center and elsewhere will soon be able to provide vertical profiles of the atmospheric CO<sub>2</sub> concentrations. NASA's ASCENDS (Active Sensing of CO<sub>2</sub> Emissions over Night, Days, and Seasons) mission slated for launch toward the end of the decade provides CO<sub>2</sub> concentration measurements at all latitudes and enables the development of an inventory of global CO<sub>2</sub> sources and sinks. It can also elucidate the connection between climate change and the carbon cycle. Additionally, this mission helps identify anthropogenic CO<sub>2</sub> sources and sinks to enable effective mitigation policies such as carbon cap and trade programs.

#### 4.2 Biomass

Lidar instruments can also be used effectively to measure the forest canopy heights and the total amount of biomass, and hence estimate the carbon stored in them. Currently this technology is being used on airborne platforms via various NASA airborne campaigns to estimate biomass on local scales. NASA's currently planned DESDyni (Deformation, Ecosystem Structure, and Dynamics of Ice) mission, using a multi-beam lidar instrument, will enable global measurement of height and forest canopy structure as well as understanding of changes in carbon storage in Earth's vegetation layer. The mission will enable understanding of the effects of changing climate and land use on atmospheric CO<sub>2</sub> concentrations.

#### 4.3 Oceans

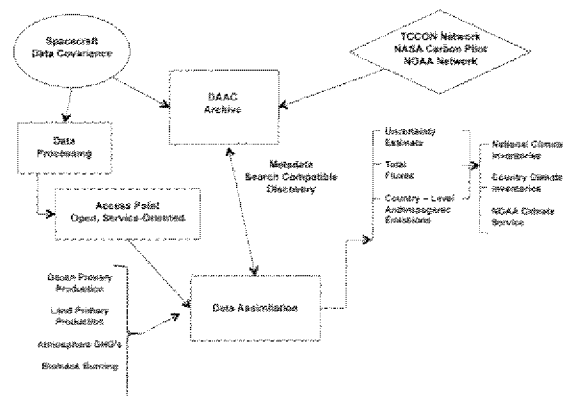
Oceans, sometimes referred to as the climate engines of the Earth, are the largest reservoirs of carbon. Dissolved organic matter or carbon (DOM/DOC) in the ocean surface water can be measured via its color. The ocean color data can be used to measure the quantities of the organic matter types

such as marine phytoplankton. NASA's SeaWiFS satellite data has been used to calculate the amount of CDOM in the water column. The currently planned NASA's ACE (Aerosol, Clouds, Ecosystems) mission, slated for launch toward the end of the decade, will provide ocean color measurement continuity on global scales and aids in improving estimates of the ocean CO<sub>2</sub> uptake.

### 5. DATA TO INFORMATION

Any greenhouse gas accounting system, such as the International Group on Earth Observations' (GEO) Global Carbon Observing and Analysis System (GCOAS) or the Greenhouse Gas Information System (GHGIS) described by Duren et al. [9], will attempt to provide situational awareness needed to proactively reduce emissions, influence land use change, and sequester carbon. It will likely require a combination of space and aircraft-based remote sensing along with in situ measurements and computer modeling. Remotely sensed climate data acquisition systems need to be appropriately tailored for the specific policy support; for example, cap-and-trade, offsets, and international treaties. The United Nations Framework Convention on Climate Change (UNFCCC) is calling for "measurable, reportable, and verifiable" data, which has implications like the need to increase the frequency of national inventory reporting by developing countries. This drives the need for remote sensing, as pointed out recently by the International Panel on Climate Change (IPCC). Examples of priorities include the need for sustained continuity of ocean color (such as to be provided by NASA's future mission ACE), land-use change measurements and improved biomass measurements (such as to be provided by NASA's future mission DESDyni), and atmospheric CO<sub>2</sub> measurements (such as that to be provided by NASA's OCO-2 and the ASCENDS mission).

Figure 4. Schematic of data to information system



## 6. POLICY IMPLICATIONS

One of the objectives of the United Nations Framework for Convention on Climate Change (UNFCCC) is “stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.” Understanding the global carbon cycle and the extent that the anthropogenic CO<sub>2</sub> emission can be deposited into land and oceans as carbon sinks is necessary to establish the “dangerous” level of CO<sub>2</sub> concentration.

Future world CO<sub>2</sub> emissions will depend on several factors. First, they will depend on global population growth trends, because emissions are generated by energy use practices by industries, and agricultural trends, as well as other activities that usually increase with the size of the population. Second, emissions will depend on world economic growth, because as people grow more affluent they generally demand more energy-consuming goods and services. Third, emissions will depend on technological trends that determine the efficiency of energy use and the mix of carbon-emitting and non-carbon-emitting energy sources in the economy. Missions like those referenced in section 4 will go a long way to resolving some of the fundamental scientific processes at work, and together with enhancements to already existing data records, these mission data sets and their subsequent assimilation into models will permit scientists to develop more accurate and longer-term predictions of atmospheric CO<sub>2</sub> concentration, climate change, and energy trends at the more useful regional and local levels.

While investing in clean energy and renewable technologies are extremely important to advancing America’s energy policy, it is equally important to develop a carbon observing system from space that aids in understanding the connection between the global carbon cycle and climate change and allows more accurate predictions of future CO<sub>2</sub> concentrations in atmosphere. This accurate prediction is vital to the formulation of future effective energy-related policies. At the same time, this investment will also enable implementation of GHG mitigation policies such as cap and trade programs or international treaties.

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