5.0 ENHANCING CAPABILITIES TO MEASURE AND MONITOR EMISSIONS

5.1 HIERARCHICAL MM OBSERVATION SYSTEM

Technology Description

Introduction

- The primary focus of measuring and monitoring (MM) is to develop technologies for the measuring and monitoring of gross and net CO_2 and other GHG emission and sinks. MM must be a component of each mitigation technology option to assure that ***net*** emission reduction is occurring and that the integrity of sinks is verifiable. Measures of performance within each mitigation option, which are quantifiable and support evaluation of progress and possible future financial transactions, must be developed.
- Technology-specific profiles have been developed; but, in addition, there will be new sensor and controls needed to help each mitigation technology improve its performance – those are addressed in those sections.
- An effective MM capability will require a hierarchical structure that can address scales from in situ soil carbon measurements, to emissions from vehicles, to large point sources, and area sources ranging from a landfill to large spatial regions (up to countries).
- Assuring integrity of sinks is another key component of the system. As sequestration (all methods) is implemented, quantitative changes and leakage rates (<<1%?) must be verifiable or else leaks alone could result in emissions exceeding those of today.
- There is significant connection between observations and modeling related to emissions, sinks, and carbon stocks, and climate change mediated biogeochemical feedbacks that will be accomplished with the CCSP and the MM portion of the Climate Change Technology Program (CCTP). CCTP will utilize the Climate Change Science Program (CCSP) advances to the maximum extent.

System Concepts

- Sensors and associated information technology systems that provide an ability to determine carbon stocks, emissions, and sinks in a nested approach that can integrate point source information (e.g., leakage from geologic repository) with regional measurements or indicators of all GHG emissions to allow analysis at the scale-up to countries.
- Systems must be designed to be additive and comparable so that information from one "layer" is verified and used by the next layer. It is probable that some locations will be needed as validation sites to illustrate MM approaches. These sites will have intensive measurement at the ground-based scale and thus verify the ability of remotely sensed systems to accurately estimate carbon stocks and fluxes.
- Integrated MM measures will provide needed data for calculating net CO_2 and other GHG emissions per unit of economic activity.

Representative Technologies

- Inventory reporting methods and emissions factors for activities that provide for full life-cycle accounting of net CO_2 and other GHG inventories, emissions, and sinks.
- Platforms include satellites, buoys, aircraft, ground-based networks, and global arrays, which can house the typically broad spectrum of sensors.
- Innovative chemical or isotopic markers to track sources and sinks at the process level detail that would facilitate regional tracking of GHG emissions.
- Sensors include such items as continuous emission monitors, laser-based technologies (e.g., LIBS), mass spectrometers, lidar, radar, imaging spectroscopy, etc.
- Data technologies include networked transmission (wired and wireless), data archiving technology, and computational platforms for distribution and analysis.

Technology Status/Applications

- Emergence of new sensing technologies – e.g., chemical, laser, infrared, radar, light detecting and ranging (LIDAR), multispectral video, imaging spectrometers, mass spectrometers – and computing power capable of handling large amounts of data has spawned a new generation of instruments, databases, and computer models that can be adapted to MM challenges. However, integrated systems of data collection, management, and processing at the scale needed for MM do not exist.

- NASA's Aura, Aqua, and Terra satellites (part of the Earth Science Enterprise mission) host a suite of scientific instruments that measure atmospheric trace gases, including ozone, aerosols, and greenhouse gases. These instruments are already delivering useful data on aerosols, water clouds, methane, and carbon monoxide. Future missions, e.g., Glory, will continue to enhance the data record of aerosols, clouds, solar irradiance, and other GHGs.
- NASA's Orbiting Carbon Observatory, to be launched in late 2007, is designed to map atmospheric CO_2 on a global basis.
- Simultaneous, high-precision measurements of O_2 and CO_2 and isotopes for estimating the role of various processes within the carbon cycle at regional scales.
- Soil carbon analysis instruments are under development, but not ready for deployment.
- Area-scale CO_2 flux measurement systems are available and under improvement.
- Continuous emission monitors (CEM) are available, but remain too expensive for full deployment and are not linked to data systems to be effective.
- Satellite- and aircraft-based sensors for estimating biomass have been demonstrated and are being improved.

Current Research, Development, and Demonstration

RD&D Goals

- Develop an integrated system that meshes observations (and estimations) from point sources (e.g., power plant or geologic storage site), diffuse sources (e.g., from commercial and agricultural systems), regional sources (e.g., city/county), and national scales so that checks and balances up and down these scales can be accomplished. The system should be able to attribute emissions/sinks to both national level activities and individual/corporate activities and provide verification for reporting activities.
- Inexpensive and easily deployed sensors for a variety of applications (stack emissions, N_2O emissions across agricultural systems, CO_2 fluxes across forested regions, CO_2 and other GHG emissions from transportation vehicles.
- Accurate "rules-of-thumb" (reporting/accounting rules) for practices that reduce emissions or increase sinks where comprehensive and accurate measurement is not feasible. Such rules must be based on sound scientific principles.
- A high-resolution system that captures process-level details of sources and sinks (e.g. O_2 or CO_2, isotopes) and a methodology to scale it up reliably.
- Data archiving and analysis system-to-integration observations and reporting information.

RD&D Challenges

- Alter current remotely based sensors (satellite and aircraft) from a focus on measuring atmospheric constituents to a focus of measuring CO_2 and other GHG stocks and net fluxes.
- Ground-based biomass and soil carbon measurement methods that are rapid, inexpensive, and accurate – and can address heterogeneity issues.
- Methods to detect leakage rates from geological storage systems that may be small and may be highly variable over space and time.
- Methods to measure ocean CO_2 sinks and leakage rates.
- Sensors that could be placed on individual emission sources (e.g., stack or vehicle exhaust) to provide data for new or modified MM technologies to aid emissions reduction by energy production systems.
- Development of specific sensors, and their application to vertical integration of net emissions across all scales.
- Formalized data and information systems that capture and distribute data, and that provide protocols for reporting results.
- Framework under which measuring and monitoring are linked in a functional manner – and also work within a regulatory system for carbon credits or incentives.
- Simultaneous measurements of many chemical/isotopic variables to capture process details.
- Explore the use of current remotely based sensors (satellite and aircraft) for measuring CO_2 and other GHG stocks and net fluxes.

RD&D Activities

- Scientific research on climate and the carbon cycle are resulting in new sensors and methods to estimate stocks and fluxes.
- Newly funded R&D on sequestration options is resulting in new measurements systems for net ecosystem exchange of carbon, soil carbon and biomass changes, leakage indicators from geological systems, and ocean CO_2 exchange methods.
- Geophysical methods to determine integrity of geologic storage systems are under development and can be tested as large-scale demonstrations come on-line.
- By 2010-2012, current plans will deploy satellites capable of measuring greenhouse gases in columnar samples of the atmosphere. With focused development and data-handling systems, such a sampling regime could be used to estimate a region's or nation's emissions. The Integrated Earth Observation System (IEOS) will facilitate these developments.

Recent Progress

- Ongoing demonstrations of geologic storage systems are helping to define the needs for characterizing particular geological structures and constant monitoring.
- Global networks of greenhouse gas monitoring stations, in conjunction with advanced modeling techniques, have continually improved the understanding of greenhouse gas concentrations.
- Laser-induced breakdown spectroscopy instrument to measure soil carbon in situ for less than 10% of the lab costs of other methods with comparable reliability.
- Mid-range infrared spectroscopy to measure soil carbon and chemical composition.
- Ocean buoys that can measure and transmit data from multiple depths are being used in scientific studies, but are not ready for cost-effective deployment.
- Recent research shows coupling of interannual variability of trace gases (CO_2, CO, and CH_4) and biomass burning. (Van der Werf et al. *Science* Vol 303, Issue 5654, 73-76, 2 January 2004).

Commercialization and Deployment Activities

- Limited application within various technology areas is occurring, but no vertically integrated system is being tested at this time.