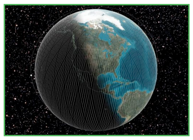
ACTIVE SENSING OF CO_2 EMISSIONS OVER NIGHTS, DAYS, AND SEASONS (ASCENDS)

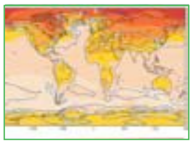
Launch: 2013-2016 **Mission Size: Medium**



CO_2 measurements: day and night, all seasons, all latitudes

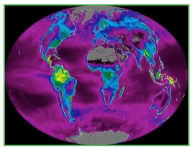
Inventory of global CO_2 sources and sinks

Connection between climate and CO_2 exchange



Improved climate models and predictions of atmospheric CO_2

Identification of human-generated CO_2 sources and sinks to enable effective carbon trading



Closing of the carbon budget for improved policy and prediction

ACTIVE SENSING OF CO_2 EMISSIONS OVER NIGHTS, DAYS, AND SEASONS (ASCENDS) MISSION

The primary human activities contributing to the nearly 40 percent rise in atmospheric CO_2 since the middle of the 20th century are fossil-fuel combustion and land-use change, primarily the clearing of forests for agricultural land. More than 50 percent of the CO_2 from fossil-fuel combustion and land-use change has remained in the atmosphere; land and oceans have sequestered the nonairborne fraction in roughly equal proportions. However, the balance between land and oceans varies in time and space. The current state of the science cannot account with confidence for the growth rate and interannual variations of atmospheric CO_2. The variability in the rate of increase in the concentration of CO_2 in the atmosphere cannot be explained by the variability in fossil-fuel use; rather, it appears to reflect primarily changes in terrestrial ecosystems that are connected with large-scale weather and climate modes. The overall pattern is important and is not understood. The geographic distribution of the land and ocean sources and sinks of CO_2 has likewise remained elusive, an uncertainty that is also important. As nations seek to develop strategies to manage their carbon emissions and sequestration, the capacity to quantify current *regional* carbon sources and sinks and to understand the underlying mechanisms is central to prediction of future levels of CO_2 and therefore to informed policy decisions, sequestration monitoring, and carbon trading (Dilling et al., 2003; IGBP, 2003; CCSP, 2003, 2004).

Background: Direct oceanic and terrestrial measurements of carbon and of the flux of CO_2 are important but are resource-intensive and hence sparse and are difficult to extrapolate in space and time. Space-based measurements of primary production and biomass are valuable and needed, and the problem of source-sink determination of CO_2 will be aided greatly by such measurements and studies, but it will not be resolved by this approach. There is, however, a different complementary approach. The atmosphere is a fast but incomplete mixer and integrator of spatially and temporally varying surface fluxes, and so the geographic distribution (such as spatial gradient) and temporal evolution of CO_2 in the atmosphere can be used to quantify surface fluxes (Tans et al., 1990; Plummer et al., 2005). The current set of direct in situ atmospheric observations is far too sparse for this determination; however, long-term accurate measurements of atmospheric CO_2 columns with global coverage would allow the determination and localization of CO_2 fluxes in time and space (Baker et al., 2006; Crisp et al., 2004). What is needed for space-based measurements is a highly precise global data set for atmospheric CO_2-column measurements without seasonal, latitudinal, or diurnal bias, and it is possible with current technology to acquire such a data set with a sensor that uses multiwavelength laser-absorption spectroscopy.

The first step in inferring ecosystem processes from atmospheric data is to separate photosynthesis and respiration; this requires diurnal sampling to observe nighttime concentrations resulting from respiration. Analyses of flux data show that there is a vast difference in the process information obtained from one measurement per day versus two (i.e., one measurement per day plus one per night), with a much smaller gain attributable to many observations per day (Sacks et al., 2007). It is also essential to separate physiological fluxes from biomass burning and fossil-fuel use, a distinction that requires simultaneous measurement of an additional tracer, ideally carbon monoxide (CO).

A laser-based CO_2 mission—the logical next step after the launch of NASA's Orbiting Carbon Observatory (OCO),[1] which uses reflected sunlight—will benefit directly from the data-assimilation procedures and calibration and validation infrastructure that will handle OCO data. In addition, because it will be important to overlap the new measurements with those made by OCO, the ASCENDS mission should be launched in the 2013-2016 time frame at the latest.

Science Objectives: The goal of the ASCENDS mission is to enhance understanding of the role of CO_2 in the global carbon cycle. The three science objectives are to (1) quantify global spatial distribution of atmospheric CO_2 on scales of weather models in the 2010-2020 era, (2) quantify current global spatial distribution of terrestrial and oceanic sources and sinks of CO_2 on 1-degree grids at weekly resolution; and (3) provide a scientific basis for future projections of CO_2 sources and sinks through data-driven enhancements of Earth-system process modeling.

Mission and Payload: The ASCENDS mission consists of simultaneous laser remote sensing of CO_2 and O_2, which is needed to convert CO_2 concentrations to mixing ratios. The mixing ratio needs to be measured to a precision of 0.5 percent of background (slightly less than 2 ppm) at 100-km horizontal length scale over land and at 200-km scale over open oceans. Such a mission can provide full seasonal sampling to

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[1] The Orbiting Carbon Observatory (OCO) is a NASA Earth System Science Pathfinder (ESSP) project mission designed to make precise, time-dependent global measurements of atmospheric CO_2 from an Earth-orbiting satellite. OCO should begin operations in 2009. See description at http://oco.jpl.nasa.gov/.

high latitudes, day-night sampling, and some ability to resolve (or weight) the altitude distribution of the CO_2-column measurement, particularly across the middle to lower troposphere. CO_2 lines are available in the 1.57- and 2.06-μm bands, which minimize the effects of temperature errors. Lines near 1.57 μm are identified as potential candidates because of their relative insensitivity to temperature errors, relative freedom from interfering water-vapor bands, good weighting functions for column measurements across the lower troposphere, and the high technology readiness of lasers. To further reduce residual temperature errors in the CO_2 measurement, a concurrent passive measurement of temperature along the satellite ground track with an accuracy of better than 2 K is required. Atmospheric pressure and density effects on deriving the mixing ratio of CO_2 columns can be addressed with a combination of simultaneous CO_2 and O_2 column density measurements at the surface or cloud tops, or possibly with surface-cloud-top altimetry measurements from a lidar in conjunction with advanced meteorological analysis for determining the atmospheric-pressure profile across the measured CO_2 density column. The concurrent on-board O_2 measurements are preferred and can be based on measurements that use an O_2 absorption line in the 0.76- or 1.27-μm band. The mission requires a Sun-synchronous polar orbit at an altitude of about 450 km and with a lifetime of at least 3 years. The mission does not have strict requirements for specific temporal revisit or map revisit times, because the data will be assimilated on each pass and the large-scale nature of the surface sources and sinks will emerge from the geographic gradients of the column integrals. The important coverage is day and night measurements at nearly all latitudes and surfaces to separate the effects of photosynthesis and respiration. The maximal power required would be about 500 W, with a 100 percent duty cycle. Swath size would be about 200 m.

Ideally, a CO sensor should complement the lidar CO_2 measurement. The two measurements are highly synergistic and should be coordinated for time and space sampling, with the minimal requirement that the two experiments be launched close together in time to sample the same area.

Cost: About $400 million.

Schedule: ASCENDS should be launched to overlap with OCO and hence in the 2013-2016 (the middle) time frame. Technology development must include extensive aircraft flights demonstrating not only the CO_2 measurement in a variety of surface and atmospheric conditions but also the O_2-based pressure measurement.

Further Discussion: See in Chapter 7 the section "Carbon Budget Mission (CO_2 and CO)."

Related Responses to Committee's RFI: 4 and 20.

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