An Instrument to Enable Identification of Anthropogenic CO₂ Emissions Using Concurrent CO Measurements

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The ASCENDS measurement concept

In order to separate physiological fluxes from biomass burning and fossil fuel use, the NRC report Earth Science and Applications from Space: National Priorities for the Next Decade and Beyond requires ASCENDS to simultaneously measure boundary layer CO₂ and another tracer, likely carbon monoxide (CO). While this technology could ultimately benefit three of the decadal survey missions (ASCENDS, GEOCAPE, and GATSCAPE), the incisions can be described as having a twin tail in one sense. ASCENDS is designed to enable the ASCENDS mission concept. An active (laser-based) system will be used to detect CO₂ concentrations within a field of view of approximately 110 meters in diameter at the ground. To be used for ASCENDS, the CO₂ concentrations must be measured at the same place, and the same time, with approximately the same field of view. Currently we are assuming 230 meters for the field of view for the CO₂ measurement in our sensitivity calculations. Both the 4.7 and 2.3 micron channels will be required for the CO₂ derivation, the 2.3 micron measurement is the more challenging and has not been demonstrated at (or even near) sufficient spatial and temporal resolution by any existing or developing instrument.

The relationship between CO and CO₂ concentrations is complex.

The figure below highlights the importance of CO measurements to the global carbon cycle and the assessment of CO₂ sources and sinks. The data shown are in-situ CO and CO₂ data measured onboard the NASA DC-8 over the southeastern US during the summer of 2004. This flight segment shows both strong correlations and anticorrelations between CO and CO₂ ranging from the surface and upper troposphere (~12 km). This complexity arises from the seasonal uptake of CO₂ by vegetation during summer in the presence of CO and CO₂ from combustion sources. In the first boundary layer flight segment, CO and CO₂ are strongly correlated, while the opposite condition exists in the following boundary layer segment. Under these conditions, the CO data is invaluable for assessing the importance of combustion sources relative to vegetative uptake on CO variability. Despite the large-scale anticorrelation in the third boundary layer segment, the importance of combustion sources can be seen in small-scale correlations between CO and CO₂ within the larger segment. Similar anticorrelations in the upper troposphere such as in the third high altitude segment provide a valuable indicator of deep convection.

The expected total column CO sensitivity required to identify man-made sources of CO₂ is ~5ppbv.

We have conducted a preliminary analysis of in situ measurements of CO from five commercial aircraft as part of the MAZOS (Measurements of Ozone and water vapor by in-service Airbus aircraft) program. This program added CO to its suite of measurements in 2002. Data analysis are from profiles sampled on take-offs and landings. The figure below shows short-term variability (one day or less) in CO column amount over all MAZOS locations. This variability is represented by taking the difference between consecutive profiles separated by a day or less. The cumulative probability distribution of these daily changes in CO column provides a measure against which to assess a given sensitivity (shown by dashed lines) and the likelihood that the CO column change will exceed that sensitivity. Additional work examining seasonal behavior and relative variance in boundary layer and free tropospheric CO have also been conducted. These details can be found at www-air.larc.nasa.gov/missions/ascends/COCOA.

Introduction

We have developed an instrument concept that will enable the measurement of CO from the top of the atmosphere to the Earth’s surface with high sensitivity and at both the spatial and temporal resolutions required for ASCENDS (Fig. 1). Our concept is based on the development of a novel instrument that has been designed to enable an ASCENDS mission. We are developing an innovative CO sensor that will enable the ASCENDS mission to identify CO contributions from anthropogenic and natural sources and sinks of global carbon.

The atmospheric CO spectrum and effects of surface emission and solar reflectance

The two CO spectral regimes offer different altitude sensitivity for remote measurements. In the 4.7 micron thermal emission band CO sensitivity peaks in the mid to upper troposphere where thermal contrast is greatest; but there is little PBL sensitivity due to low thermal contrast between the surface and the lower atmosphere. In the 2.3 micron reflected solar regime, thermal emission is negligible, resulting in sensitivity that is nearly constant with altitude. A simultaneous measurement using both bands provides CO profile information including an estimate of PBL CO.

High variability in scene reflectance makes measurement of CO in the 2.3 micron band extremely challenging.

Changes in scene reflectance during measurement leads to a significant reduction in SNR in typical (sequential) 2.3 micron GFCR implementations since the background (evacuated) cell and CO cell measurements see different input intensities.

The COCOA GFCR’s simultaneous CO and background measurement, collected by the same focal plane array, eliminates most of the error associated with reflectance variation.

Heredity of the GFCR

The MAPS and UARS/HALOE programs – examples of the heritage of NASA LaRC and GATS, Inc. in GFCR technology, space-based sensing and analysis – have made profound contributions to atmospheric science. MAPS, the first science payload on the Space Shuttle, provided man’s first view of global tropospheric CO distributions and the global impact of pollution from space. HALOE was the first to observe trends in stratospheric chlorine and show conclusively that the main cause for ozone destruction was man-made chlorine.

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