HIGH PRECISION CO_2 SENSOR FOR BALLOONSONDE ATMOSPHERIC MEASUREMENTS

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ABSTRACT
Existing instruments for measuring atmospheric profiles of carbon dioxide can be very sensitive, but are all large and bulky and must be flown using aircraft or large, research gondolas. This work reports on the development of a stand-alone, lightweight CO_2 sensor for use on balloon sondes. This device will have sub part-per-million (ppm) sensitivity and weigh less than 1 kg.

INTRODUCTION
Over the past decade, the importance of understanding the sources and sinks of carbon dioxide and other greenhouse gases has been recognized. A variety of research studies to measure the fluxes and fluctuations of CO_2 from average conditions have been performed, including airborne measurements of CO_2 profiles throughout the troposphere and lower stratosphere. While these experiments have demonstrated precision down to 0.05 ppmv, the instrumentation used has been restricted to airplane or large stratospheric-type balloon gondola platforms due to the size, weight and power requirements of these instruments [*Daube et al., 2002; Goode et al., 2000*]. A more frequent, widespread measurement campaign using smaller, less expensive balloon sondes has been limited by the lack of suitable instrumentation. In this work, we discuss the development of a compact, diode laser-based sensor for measurements of CO_2 with sub-ppmv precision, designed to fly on standard meteorological balloons

EXPERIMENTAL
This sensor uses diode laser wavelength modulation spectroscopy (WMS) to quantify the ambient CO_2 concentration [*Silver et al., 1992*], and comprises two sections: a dual board electronics unit and an optical board containing open-path sample and sealed reference cells (Fig. 1). A vertical cavity surface emitting laser (VCSEL) at 2004 nm is collimated into a beamsplitter, which directs the light through the reference cell onto one photodiode and into a Herriott-style multiple pass, open-air cell onto a second photodiode.

The electronics consists of two circuit boards, one for digital signal processing functions and one for analog functions. The digital board contains a Texas Instruments TMS320C6711 DSP chip and an Actel FPGA, which act as a stand-alone computer. It runs at 160 MHz with 900 MFLOP and 256 kB of on-chip memory; 64 MB of SDRAM are available for program usage and data storage. Upon powering up the board, the program automatically boots and runs. This board also communicates with the data transmitter on the balloon. The analog board controls the laser temperature, output ramp and modulation, reads ambient temperature and pressure and performs all WMS modulation and data collection functions. These boards are contained inside a styrofoam container to keep the boards warm and offer protection from the ambient air. The entire system is powered by a pair of lithium batteries and draws only 3 W of power.

DISCUSSION
In order to achieve sub-ppm precision, the observed signal must be calibrated by an *in situ* reference source. On the larger prior instruments, on-board calibration systems with controlled pressure and temperature cells are used to remove the variations in ambient pressure and temperature; unfortunately these require a great deal of plumbing hardware and system control. By contrast, an open path ambient system can be much simpler and lighter, but determining the gas over a wide range of temperatures and pressures requires a detailed knowledge of the dependencies of the relevant spectroscopic parameters

associated with the measurement, a condition difficult to fulfill. If a reference gas sample could be prepared at the exact same ambient temperature and pressure as the sample using a calibrated standard, the analysis would be significantly simplified and high precision and accuracy could be achieved.

Our sensor incorporates a reference cell which uses a mylar balloon so that the cell internal and ambient pressures are always matched. This cell also has a set of high thermally-conducting copper fins such that ambient in internal temperatures are closely matched as well. With these conditions being met, the observed CO_2 concentration is simply the ratio of the observed reference and sample signals, scaled the their respective paths and by the reference concentration,

$$\chi_i = \chi_{ref} \left(\frac{\alpha_i \ \ell_{ref}}{\alpha_{ref} \ \ell_i} \right) \quad .$$

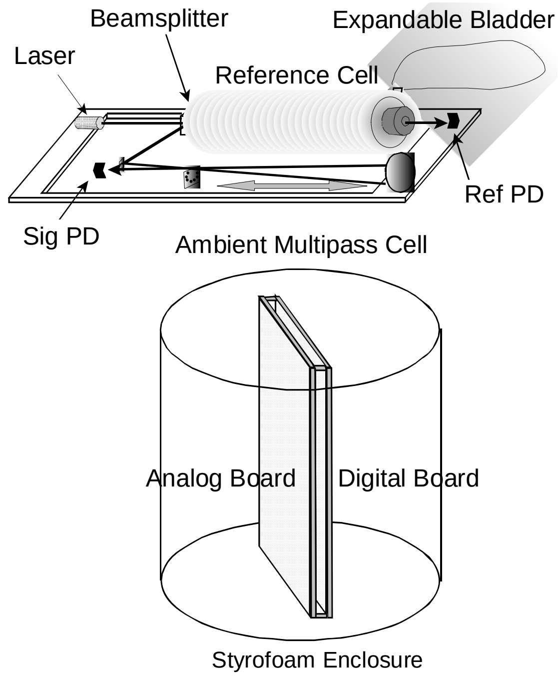

Fig. 1 - Layout of Balloon Sonde CO_2

Operation and results of this sensor will be discussed in the poster presentation. Field tests of the instrument on meteorological balloons are planned for Fall 2005.

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