Radiometric Sounding System

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Introduction

Vertical profiles of solar and terrestrial radiative fluxes are key research needs for global climate change research. These fluxes are expected to change as radiatively active trace gases are emitted to the earth's atmosphere as a consequence of energy production and industrial and other human activities (DOE 1990). Models suggest that changes in the concentration of such gases will lead to radiative flux divergences that will produce global warming of the earth's atmosphere.

Direct measurements of the vertical variation of solar and terrestrial radiative fluxes that lead to these flux divergences have been largely unavailable because of the expense of making such measurements from airplanes. These measurements are needed to improve existing atmospheric radiative transfer models, especially under the cloudy conditions where the models have not been adequately tested.

A tethered-balloon-borne Radiometric Sounding System has been developed at Pacific Northwest Laboratory to provide an inexpensive means of making routine vertical soundings of radiative fluxes in the earth's atmospheric boundary layer to altitudes up to 1500 m above ground level (Alzheimer et al. 1993). Such vertical soundings would supplement measurements being made from aircraft and towers.

The key technical challenge in the design of the Radiometric Sounding System is to develop a means of keeping the radiometers horizontal while the balloon ascends and descends in a turbulent atmospheric environment. This problem has been addressed by stabilizing a triangular radiometer-carrying platform that is carried on the tetherline of a balloon sounding system (Figure 1). The platform, carried 30 m or more below the balloon to reduce the balloon's effect on the radiometric measurements, is leveled by two automatic control loops that activate motors, gears and pulleys when the platform is off-level. The sensitivity of the automatic control loops to oscillatory motions of various frequencies and amplitudes can be adjusted using filters.

The prototype Radiometric Sounding System was tested in 1993 in a series of ascents on the Hanford Reservation in eastern Washington during a moderately turbulent winter day. During a flight to a height of about 200 m, the platform was kept level to within about 0.8° of horizontal with a standard deviation of less than 2°. A theoretical model of an oscillating radiometer (Shaw and Whiteman 1993) shows that this performance will produce useful radiometric measurements.

Progress

Given the successful initial performance of the stabilization system, recent emphasis has focused on making various engineering improvements to the prototype Radiometric Sounding System. Key progress includes the following:

- Two single-axis rate sensors are being installed to improve the level sensing performance. These rate sensors use vibrating micro machined quartz tuning forks to sense angular rate. Rate sensor drift, while small, will be corrected at intervals by a long-term-average measurement of the earth's gravity vector; this measurement is taken using a pair of single-axis linear accelerometers.
- The "breadboarded" signal conditioning and control loop electronics are being miniaturized and made into printed circuit boards.
- An enclosure for the electronics and flux gate magnetometer has been designed to protect them from the elements.
- A new double pyranometer has been installed on the stabilized platform. The radiometers now include an

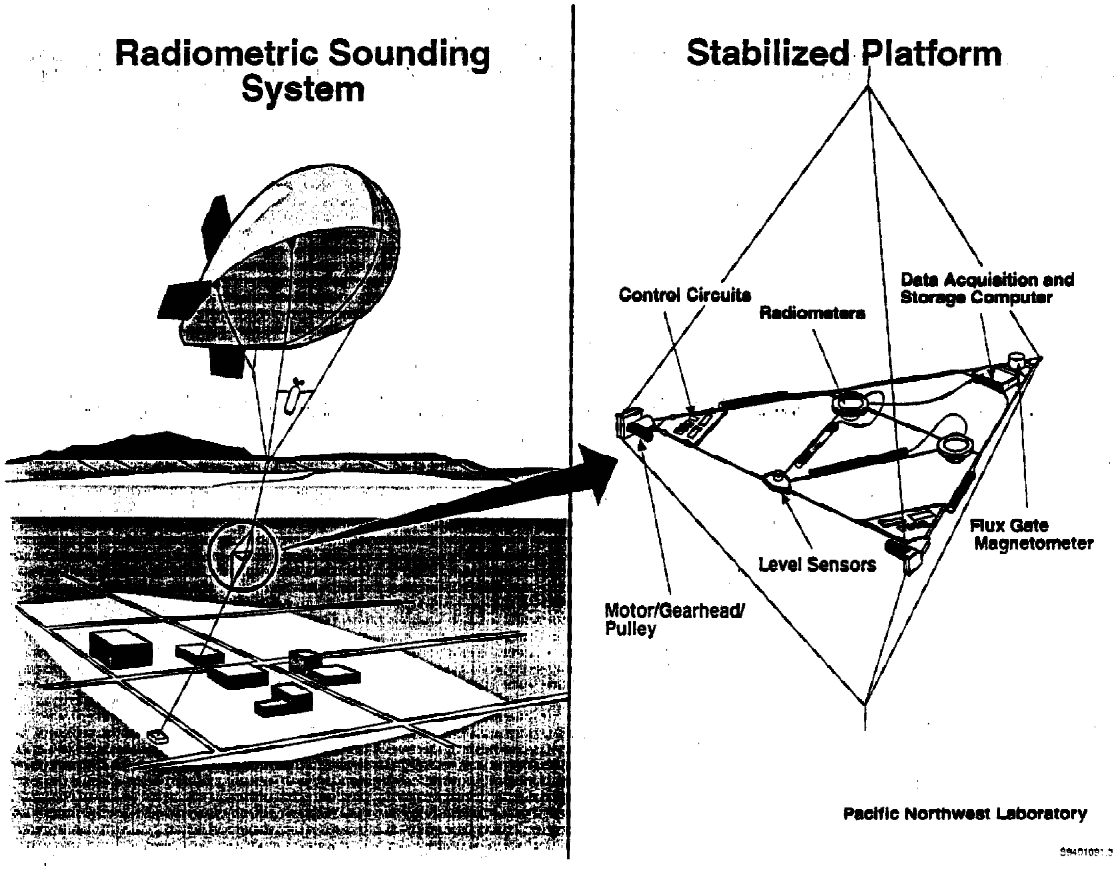

Figure 1. Prototype Radiometric Sounding System.

upward- and downward-looking pyranometer and an upward- and downward-looking total hemispherical radiometer. From these measurements, upward- and downward fluxes of long- and short-wave radiation can be determined.

- Electrical and mechanical components on the stabilized platform have been miniaturized and/or relocated to reduce or eliminate their radiometric signatures on the on-board radiometers.
- A new 5-m^3 balloon that can fly safely in winds up to 18 m/s has been purchased.
- A backup or spare stabilized platform is being constructed.
- The design of a special motion-sensing platform, used to measure the frequency and amplitudes of tetherline motion, has been improved to match the weight and geometric characteristics of the stabilized platform more closely. The motion-sensing platform will be used in special flights to obtain the engineering information necessary to optimize the control loop closure on the stabilized platform.
- Waivers and flight clearances have been obtained from the Federal Aviation Administration for a series of flight tests to be conducted to elevations of 6000 ft MSL at Hanford, Washington, during March and early April of 1994. A set of calibrated Eppley Precision Spectral

Pyranometers (PSPs), Eppley Precision Infrared Radiometers (PIRS), and duplicates of the on-board radiometers will be operated on the ground during the planned balloon flights.

Future Work

The performance of the modified stabilization system will be tested in a variety of different meteorological situations in 1994, and the radiometers will be tested and calibrated. Further modifications to the Radiometric Sounding System will be made with the goal of developing a routine sounding capability for Cloud and Radiation Testbed sites. In future work, the Radiometric Sounding System will be used to study the evolution of radiative flux profiles through the life cycles of different cloud systems, to compute associated radiative flux divergences, and to obtain *in situ* data for comparison with radiative transfer models.

Acknowledgments

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