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Deployment of Autonomous GPS Stations in Marie Byrd Land, Antarctica

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Abstract

During the 1998–1999 Antarctic field season, we installed three autonomous GPS stations in Marie Byrd Land, West Antarctica to measure glacio-isostatic rebound and rates of spreading across the West Antarctic Rift System. The systems collect data throughout the entire year and therefore must function during the warm, relatively mild summer, and cold, harsh winters. They are powered by gel cell batteries that are charged by wind and solar power. The system includes dual data logging capability. We log data at 5 minute intervals within the receiver and at 30 second intervals to a serial data logger. We do not require 365 days of continuous data for well determined crustal velocities, but rather long periods (> 24 hours) of continuous data distributed throughout the year. Therefore, for simplicity, we designed the system to accept occasional data interruptions. The batteries, in addition to supplying power, act as a thermal capacitive heat storage device to help regulate the temperatures within the system. This storage system absorbs the majority of the 10–15 watts of power from the receiver and 5 watts from the data logger, which helps to maintain temperature for long periods of time. Power is switched off when the temperature within the system enclosure reaches 50°C and is reconnected at 20°C . If battery voltage drops too low the batteries will freeze. Therefore, we cut the power off when the batteries drop to a low voltage of 12.45V. Power is restored at 13.2V. The temperature and power hysteresis allows for a minimum of several days of data to be collected before system shutdowns. A check of all three stations in late January 1999 indicated that the thermal and power control systems are performing as expected.

Introduction

In December of 1998 we installed three autonomous Global Positioning System (GPS) stations in Marie Byrd Land, West Antarctica to measure glacio-isostatic rebound and tectonic deformation (Figure 1). An important, but poorly understood piece in the global tectonics puzzle is found in Antarctica. It is widely accepted that active deformation is ongoing in western Marie Byrd Land (wMBL) and the Ross Embayment, which are both part of the West Antarctic Rift System [Behrendt *et al.*, 1991; Behrendt and Cooper, 1991], but rates and causes of the deformation are unknown. Two possible causes of the deformation observed in this region include tectonic extension in the Ross Embayment as West and East Antarctica separate [Richard and Luyendyk, 1991; Luyendyk *et al.*, 1994], and crustal uplift caused by isostatic rebound following the last glacial maximum [Ivins and James, 1996; Wahr *et al.*, 1995].

The type and magnitude of deformation in this region has serious implications both for global tectonic interpretations and ice sheet models. If active extension is occurring in the Embayment, it could affect interpretations of the global plate tectonic model, depending on the magnitude, which may be as high as 10 mm/yr [Behrendt and Cooper, 1991], or as low as 1 mm/yr [Lawver and Gahagan, 1994] (Table 1). Knowing the rate could also aid in improving our understanding of the extension occurring in the Embayment as well as the uplift history of the Transantarctic Mountains. Determining the uplift rates due to post glacial rebound will help to determine the timing and configuration of the ice sheet during the Last Glacial Maximum, and may help to determine whether the ice sheet collapsed during the mid-Holocene, about 6000 years ago.

In order to measure the ongoing deformation in wMBL, we installed three continuously recording, autonomous GPS stations on outcrops in wMBL with baselines of about 100–200 km. The stations will gather data for at least four years, and have been installed in concert with a series of autonomous stations in the Transantarctic Mountains, resulting in an unprecedented long baseline array across the Ross Embayment. The remote GPS stations are powered by a combination of batteries, solar panels, and a wind generator. The data collected will allow us to determine the crustal motions to an accuracy of 1 mm/yr horizontal and 3 mm/yr vertical [Argus and Heflin, 1995]. The array will also detect horizontal strain gra-

dients in wMBL, and combined with strain data from the Transantarctic Mountains, will allow us to construct models for tectonic extension and postglacial rebound.

GPS Control System

The autonomous GPS system features regulators that control the voltage and thermal environment within the box. We do not require 365 days of continuous data for well determined crustal velocities, but rather long periods (> 24 hours) of continuous data distributed throughout the year. Therefore, to minimize points of failure, we designed the system to accept occasional data interruptions. The batteries, in addition to supplying power, act as a thermal capacitive heat storage device to help regulate the temperatures within the system which are expected to vary by as much as 100°C. This storage system absorbs the majority of the 10–15 watts of power from the receiver and 5 watts from the data logger, which helps to maintain temperature for long periods of time. Power is switched off when the temperature within the system enclosure reaches 50°C and is reconnected at 20°C. If battery voltage drops too low the batteries will freeze. Therefore, we cut the power off when the batteries drop to a low voltage of 12.45V. Power is restored at 13.2V. The temperature and power hysteresis allow for a minimum of several days of data to be collected before system shutdowns.

The wind and solar regulators are temperature compensated. The batteries charge at a higher voltage when they are cold and at a lower voltage when they are hot, thus preventing outgassing and prolonging the life of the batteries. Power to the receiver and data logger is shut off when the battery voltage drops to 12.45 volts. This maintains a high electrolyte solution so that the batteries won't freeze, even at -40°C. The system is not turned back on until the battery voltage reaches 13.2 volts, which allows for a minimum of one day of data to be collected when the batteries are cold and over five days of data when the batteries are warm. Baking soda is used to absorb excess hydrogen in the event that the batteries do outgas.

Three thermostats control the temperature within the box. The system is shut down at 50°C to protect the electronic components within the box and also prevent the batteries from overheating and outgassing. The system does not restart until the temperature in the box drops to 20°C. The hysteresis

allows for a minimum of one day of data to be collected between power outages. A thermal strip heater is turned on when the system is colder than 0°C. The data logger is turned off in cases below 0°C to protect the disk drive. The GPS receiver continues to collect data during cold states.

Data

The system includes dual data logging capability. We log data at 5 minute intervals within the receiver and at 30 second intervals to a serial data logger. At present downloads occur by visits to the sites. The Marie Byrd Land network is over 1000 km from McMurdo making real-time downloads infeasible at this time. Data can be retrieved from the data logger via its SCSI port making downloads virtually instantaneous. These high speed downloads are critical. Downloading a year's worth of data over a serial port would take over one day, which is logistically not possible given our current flight resources and other difficulties of operating within Antarctica's harsh environment.

We have retrieved three weeks of data from MBL3 located in the Clark Mountains (Figure 2). Indications are that the system is performing as expected. During this time period the system reached its peak temperature once and shut down for about 1.5 days. The battery voltages indicate that the temperature compensation is working — higher voltages are observed for lower temperatures. Voltages have remained above 13 volts and have not reached yet dropped to the low-voltage disconnect. Repeatabilities for the solutions from the three stations are 5 mm in north, 4 mm in east, and 11 mm in vertical, which is comparable to repeatabilities within the global GPS network [Zumberge *et al.*, 1997]. Ambiguities were resolved.

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Figure 1. Ross Sea region map (left panel) showing the location of our GPS stations (stars) in MBL and those in the Transantarctic Mountains (Raymond et al.) and outcrop onshore (shaded). Dashed oval is approximate outline of the Marie Byrd Land Dome [LeMasurier and Landis, 1996]. VLB = Victoria Land Basin, CT = Central Trough, EB = Eastern Basin. Vector indicates possible extension magnitude and direction across the Ross Sea rift. Detail (right panel) shows locations of GPS stations, mountain ranges and glaciers in western Marie Byrd Land. Outlines show grounding lines at the coast and for islands in the Sulzberger Ice Shelf. Bathymetric contours are shown for the edge of the continental margin but no detail is shown for the continental shelf.

Figure 2. a) GPS Time series data for station MBL3. b) Internal and external station temperatures. c) Battery voltage of the system.

Table 1. Estimated motions in western Marie Byrd Land

signal source	V_h : horizontal velocity (mm/yr)	direction of V_h	horizontal gradient of V_h	V_v : vertical velocity (mm/yr)	horizontal gradient of V_v
Ross extension ¹	< 10	NE	none?	< 0.2	NE-SW
MBL Dome ²	> 0.02	W or E	E-W	> 0.1	E-W
PGR ³	< 2	N or S	N-S	< 10	N-S
mass balance ⁴	< 0.2?	N or S	N-S	< 1?	N-S

¹Extension rate is about 50 km/5 m.y. maximum; rift shoulder uplift 1 km/5 m.y. maximum.

²Maximum vertical rate at Dome center 3 km/30 m.y. or greater if later; horizontal rate estimate at 20% vertical.

³Maximum rates from ICE-3G model in wMBL.

⁴Massbalance strain rates unknown but assumed 10% of PGR [Conrad and Hager, 1995; James and Ivins, 1997].



