PROGRESS TOWARDS DEVELOPMENT OF THE GLIDERSONDE: A RECOVERABLE RADIOSONDE SYSTEM

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Abstract

The motivation and history of development of a recoverable radiosonde system using a glider lifted aloft by a radiosonde balloon – the "glidersonde", is summarized in this poster. The current status of development efforts currently involve at least three separate groups; in the USA, in South Africa, and a version, developed in New Zealand, is now being marketed commercially. These efforts are briefly summarized, as are some limitations that still need to be overcome for widespread adoption of such technology.

1. Motivation for recoverable radiosonde systems

The glidersonde project, initially began at NSSL in 1997 with funding from the US National Weather Service (NWS). The initial funding by the US NWS was motivated by the shift from OMEGA to GPS sounding systems in the Caribbean Sea region (as well as everywhere else) initiated by the shutdown of the Omega navigation system on October 1, 1997. The change to GPS-based windfinding effectively doubled the cost of supporting the Caribbean radiosonde network, which was partially supported by the US NWS for hurricane forecasting. This coupled with the Pan American Climate Studies Sounding Network (PACS-SONET) project (whose PI was at NSSL) that had just started and was attempting to increase wind soundings throughout the tropical Americas through the use of pilot balloons, provided motivation to develop an all-weather sounding system that could be inexpensively operated on a routine basis.

The primary motivation for the glidersonde development was to allow for sustainable soundings from a denser array of sounding stations in the developing countries of the tropics, where the sounding network continues to be insufficient for accurate routine weather forecasting.

2. History of the glidersonde development

The idea of returning a radiosonde package for reuse has existed for as long as radiosondes have, and most radiosondes today carry a message about returning a radiosonde for refurbishing. However, returning a radiosonde directly to a specific location has only been feasible since the advent of radio navigation systems like LORAN and OMEGA, and such a possibility has improved with the availability of GPS. The development of the first glidersonde prototype, carried out primarily in Norman, Oklahoma, was similar to that described in US patent #6,144,899). This activity started in 1997 and has continued intermittently to the present. Collaborative testing and development of the glidersonde and its powered variant was carried out with the South African Weather Service, which was faced with increased radiosonde costs and reduced operating budgets. Very recently, several of the individuals involved in the original development received financial support from the state of Oklahoma in July 2007 to commercialize this concept.

One of the primary objectives of seeking a patent on the glidersonde was to ensure that a radiosonde vendor would not develop the same idea, patent it, and then not develop the concept. It is apparent that if glidersondes can be produced economically, they will substantially reduce the need for expendable radiosondes – which while of great benefit to the meteorological community, may not be in the interest of many radiosonde manufacturers.

A prototype glidersonde has been developed in New Zealand along the lines of the original effort organized at NSSL. This system, called the “DataBird” appears to be close to a commercially viable system. It remains undescribed in either formal literature and the test data has not been made available, so the actual status is somewhat uncertain.

Two general variants of the glidersonde concept currently exist. The original glider version, carried aloft by a freely ascending balloon, can provide ascent soundings that are, in principle, limited in height only by the size of the balloon. During the glidersonde development, a powered model aircraft was used to test navigation software. This led to the concept of a “powersonde”, or small model aircraft designed to make multiple soundings to approximately the middle-troposphere. Both of these concepts are described below.

3. Types of recoverable radiosonde sounding systems

The *glidersonde* system uses a radiosonde balloon to carry a glider, together with a radiosonde or similar sensor package, to high altitudes where it is released. The glider then returns to the launch point (or other designated point) with the aid of an onboard GPS and flight navigation computer. The meteorological measurements are made during the ascent by balloon and these data are recorded on the computer’s memory. This is downloaded after recovery of the glider. If the glider carries an independent radiosonde the data is transmitted as the glider ascends and is processed by the radiosonde ground station. The glidersonde computer can be programmed to release the glider from the balloon at a specific GPS altitude, and the GPS can also activate the parachute at a certain distance above the surface for a soft landing of the glider. Alternatively, the glider can ascend until the balloon bursts, and the glider can also glide directly to the surface without a parachute.

The principle advantages of the glidersonde are that it does not carry a heavy motor and can thus be used in most airspace (if the glider is small enough) and that it can ascend to almost unlimited altitudes – dependent on the balloon used.

Fig. 1. The "DataBird" glidersonde produced in New Zealand by GPS Boomerang. Launch configuration (left), the glider as it approaches to land (right). Red box is counterweight used when a radiosonde is not carried. Both images from GPS Boomerang web site at: http://www.gpsboomerang.com/

The *powersonde* system is a modified model airplane, usually with a gasoline engine (Fig. 2). This aircraft uses similar navigation and flight software as the glidersonde, except that the powersonde must ascend and descend under power. Advantages of the powersonde include: 1) multiple soundings can be carried out during one flight (ascent rates can easily be 300m/min with a powersonde so that 3 ascents and 3 descents can be made from sea level to 3 km in about one hour, 2) soundings can be made away from the launch site – the powersonde can be programmed to fly to a different location, make soundings, and return, 3) No balloon gas or balloon is needed – only widely available gasoline – and in small quantities 4) apart from the flight control software only widely available model airplane technology is required. Unfortunately, limitations of the powersonde are significant. These include: 1) relatively heavy motor (~ 1 kg or more) requiring FAA cleared airspace or transponder or both, 2) noise and flight hazard in populated areas, 3) limited altitude – about 6 km above sea level may be a practical limit to soundings, 4) some skill in flying model aircraft is needed for landings and takeoffs.

Because of the current limitations to powersondes and their likely restriction to special field experiments where very frequent soundings might be required, we only discuss the glidersonde in the text below.

Fig. 2. Prototype powersonde in South Africa with gasoline engine and fiberglass body. Otherwise very similar to a number of model airplanes.

4. Problems that have prevented full development of recoverable sounding systems

A number of complications have prevented development of a fully-functioning glidersonde prototype in the USA development effort. Most significant has been the lack of a suitable testing area where airspace was available for trial flights. This was especially important for the powersonde, with its metal gasoline-powered engine, but was also an issue for the glidersonde version being tested (~2 kg). In addition, lack of funding was a problem, and while considerable support was initially available, this ended before a viable prototype was available. Although the glidersonde's systems were tested in a prototype version, a commercial version, with a lighter and more aerodynamic fuselage and a flight computer reduced in size is still needed to make the overall unit lighter and more durable.

It appears that the New Zealand Databird version of the glidersonde has moved the concept forward to a near-commercial stage, though an independent evaluation of its reliability has yet to be carried out. The system is light enough (less than 600 gm total mass including radiosonde) to be tested without special waivers by the US Federal Aviation Administration. The South African and Norman, Oklahoma activities are in an active stage of development, but the information is somewhat proprietary. However, flight results and some engineering details from these developments will be presented at the TECO-2008. Hence this report focuses on more conceptual aspects of the glidersonde concept.

5. Suggestions to move the activity forward and to apply the technology to sounding networks in developing countries

a) need to develop sensors suited for the glidersonde

A key issue in developing a cost-effective glidersonde is the development of a package of fully recoverable sensors. Carrying aloft current commercial radiosondes in the DataBird would succeed in bringing back a radiosonde with sensors likely in need of some re-calibration. This is often not feasible in the field, and it would be expensive to send radiosondes back to the factory after each flight. Current radiosonde sensors for humidity and temperature are fragile and likely to be damaged/contaminated on landing or in flying through rainfall at glider speeds. Sensors will be needed that are robust enough to take repeated flights to above 100mb and land without damage or the need for laboratory recalibration. Such sensors are likely to come from those used in automated surface weather stations, but will need to be light, relatively inexpensive and have low power requirements. At worst, temperature and humidity sensors capable of being replaced or removed and recalibrated at the launch station after each flight need to be developed; this may possibly be the most economical option.

Although the primary focus of recoverable radiosonde technology has been on weather and climate monitoring in data sparse areas, a reliable glidersonde system would allow for more complex sensors to be carried aloft, such as for measuring ozone, methane, or any number of trace gases or aerosols. This is prohibitively expensive to do routinely at the present time but would become feasible with a large glidersonde. This possibility needs further exploration.

b) produce the glidersonde in some quantity, with several variants for varying payloads and glide speeds

The current DataBird is of extremely limited production, hence it is not clear what a realistic per unit cost might eventually be. However, there is a clear need to produce the glider in quantity to reduce the per unit cost and to develop several airframe versions for different sensor package sizes. Sensors might range from none (windfinding can be accurately obtained via the glider's GPS position information during ascent), to radiosonde-equivalent sensors, to specialized trace gas and aerosol measuring systems. The Glidersonde should be scalable to any size payload, however, the balloon size and gas required would likely become quite expensive much beyond standard-sized radiosonde balloons (which range from 300 to ~1200gm).

The current DataBird is only a prototype, without documented testing by third parties. Some communication with the developer indicates a willingness to carry out testing and development of the currently advertised version. The cost should invariably come down as the actual glider (from cursory examination of a DataBird at the 2007 American Meteorological Society annual convention in San Antonio) appears quite inexpensive to construct. Of course, if the DataBird were truly indestructible and was never lost then it would have to be sold at a very high price, otherwise the manufacturer would never recover the development costs. However, it is realistic to expect losses from icing, winds that are too strong for the glider to return to the launch site, damage on landing (most recovery sites will not be perfectly flat and soft) and hardware failures of one component or another.

While it will be a challenge to make a major cost savings by using a glidersonde over a routine non-recoverable radiosonde, it may be much easier to justify carrying expensive sensors aloft in a recoverable glider. For example, ozone soundings are infrequently made because of their relatively high cost, while measurements of gases like methane, or aerosols that might be valuable to measure for climate monitoring purposes, are not routinely done because of the high cost of the sensors to make the measurements. If recoverability can be introduced into the equation the main problem becomes one of miniaturization, which is becoming possible for many sensors. The weight limit for a glidersonde, following FAA regulations, is about 2 kg, but if airspace can be obtained or otherwise restricted for glidersonde use then larger payloads are obviously possible. Balloon size eventually becomes a constraint for large packages, but a 6 m^3 balloon inflated with hydrogen can lift ~ 6 kg.

6. Technical issues likely to affect the glidersonde deployment as an operational system

Meteorological conditions favorable for glidersonde deployment are those typically found in the tropics and subtropics during the warm season: relatively weak winds (often alternating in direction) throughout much of the troposphere. This will favor small displacements and greater probability of the glider being able to return to the original launch point. Middle-latitude sites, with strong westerly winds aloft, would more often require returns to an alternative recovery point that would then necessitate transportation of the glider to the launch site for reuse. Icing is an unknown factor on glidersonde operation; this is likely to be significant only in middle-latitude operation.

Glidersonde-type technology is likely to have a significant positive impact in meteorological services that presently have limited funds for radiosonde operations or where the budget for radiosonde operations is a large fraction of the overall budget of the meteorological service. This is often the case in countries with small meteorological services or where weather service staff salaries are low. In developed countries where labor costs are high the additional labor cost involved in possibly refurbishing a damaged glider or replacing a sensor package may reduce the over cost reduction of a glidersonde activity. Likewise, in a large and modern meteorological service, with expensive resources (radars, supercomputers etc) the cost savings using glidersondes may be a small fraction of the overall meteorological service budget.

Although perhaps a minor detail, the simplest glidersonde version records the data onboard the glider and this data is recovered after the glider lands. Thus, data distribution will take up to several hours longer than with current radiosondes, where the data is obtained in real-time at the ground station and transmitted shortly after balloon burst. Glidersondes could be developed to transmit this data as it is being taken, or carry a fully reusable radiosonde system, but this adds some complexity.

Small gliders should not require substantially more inflation gas than radiosondes. A glider of the dimensions of the DataBird, with a combined balloon, glider, and radiosonde/sensor package, is ~ 1 kg, and can be lifted with ~1 m^3 of gas. Hydrogen gas costs in developed countries is ~ $5-10 per m^3, so a glidersonde can be lifted (at a moderate ascent rate) with probably 2 m^3 (~$10-$20 gas cost). A glider for windfinding only (without a radiosonde package) can probably be engineered for a mass well under 500 gm (the DataBird without a 300gm counterweight or radiosonde package weighs ~270 gm). Such a glider is desirable because it permits replacing pilot balloon observations with a glider for obtaining wind profiles to high altitudes independent of cloud cover. To do this economically requires that gas requirements be kept to a minimum, especially in remote locations where transportation of gas cylinders or gas generation supplies may be difficult.

While the launching of a glidersonde should take no more space than a conventional radiosonde the landing of the glider, whether by parachute deployment just above the surface (as with the NSSL prototype glider) or a direct glide into the ground (as with the DataBird) will take a larger area, and one where there are no conflicts with aircraft or obstacles on the ground. An advantage of the glider is that it can return to a different location from the launch point, but that implies recovery personnel and transport back the launch site. If the launch and return points are far apart then this transport cost in time and personnel may be significant, and would reduce somewhat the value of recoverability.

7. Need to address the "other" factors limiting the possible benefits of glidersonde deployment as part of a national or regional sounding network.

Even the most affordable sounding technology will fail in its objectives if there is poor infrastructure to make the observations, transmit the data, assimilate the observations into forecast models, and then to use and validate these forecasts at the regional and local levels. Supplying gas to inflate balloons is a non-trivial detail at many sites worldwide, as is the reliability of communications. Many weather services in Africa or Latin America do not directly use their own radiosonde or pilot balloon observations for quantitative weather forecasting (they transmit the observations – for other forecast centers to use), resulting in less than highly motivated observers and forecasters. These, and many other practical issues need to be dealt with to ensure that the full potential of and recoverable radiosonde technology that may become operation in the future.

8. Internet Resources related to Glidersondes

Web pages with glidersonde material:

http://www.nssl.noaa.gov/projects/**glidersonde**/

http://www.nssl.noaa.gov/projects/pacs/web/RECOVERABLE/index.shtml

http://patft.uspto.gov/netacgi/nph-Parser?Sect1=PTO1&Sect2=HITOFF&d=PALL&p=1&u=%2Fnetahtml%2FPTO%2Fsrchnum.htm&r=1&f=G&l=50&s1=6,144,899.PN.&OS=PN/6,144,899&RS=PN/6,144,899

http://www.gpsboomerang.com/

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