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Italian RES Investigation in Antarctica: The New Radar System

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THE ITALIAN RADIO ECHO SOUNDING SYSTEM

A Radio Echo Sounding (RES) system is an active remote-sensing instrument that uses electromagnetic wave penetration into the ice to obtain information on the depth of the bedrock and on the ice thickness and its inhomogeneities, *i.e.* internal layering of glaciers and subglacial lake exploration. In 1995 the INGV developed its own airborne radio echo sounding system, which is continuously being upgraded. During the 1995, 1997, 1999, 2001 and 2003 Italian Antarctic Expeditions, the RES system was used to investigate different Antarctic regions. During 2007-2008 campaign, new RES systems will be used. In the following the main characteristics of the systems will be briefly described.

THE OLD SYSTEM

During the 1997 and 1999 Italian Antarctic Expeditions, the RES system developed at the INGV was placed on an aircraft flying 1000 feet above the ice surface; two folded dipole antennas, one for transmitting and the other for receiving echo pulses, were mounted beneath the aircraft wings (Tabacco et al., 1999; Bianchi et al., 2001). This airborne radio sounding system operated at 60 MHz with a pulse length of 0.3 µs -1 µs in 1997 and of 0.25 µs - 1 µs in 1999. The maximum delay of the received signal was 51.2 µs in 1997 and 64 µs in 1999, corresponding to a maximum penetration depth into the ice of about 4.3 km in 1997 and 5.3 km in 1999. The RF pulsed generator used a Phase Lock Loop (PLL) frequency synthesizer which allowed fine frequency corrections, thereby preventing mismatches due to the reflected peak power from the folded dipole antenna. The 4 kW transmitted power allowed us to obtain an adequate amplitude echo signal at the receiver. The receiver consisted of a solid-state low-noise Log envelope detector. The dynamic range of the receiver was 80 dB, and the received echo signal was digitised (8 bit) at a 20 MHz sampling frequency to obtain a temporal precision of about 50 ns. A Trimble 4000 SSE GPS system receiver with antenna mounted on the aircraft fuselage was installed and linked to the radar. Navigation relied on an onboard GPS receiver which recorded the longitude, latitude, altitude and time of acquisition

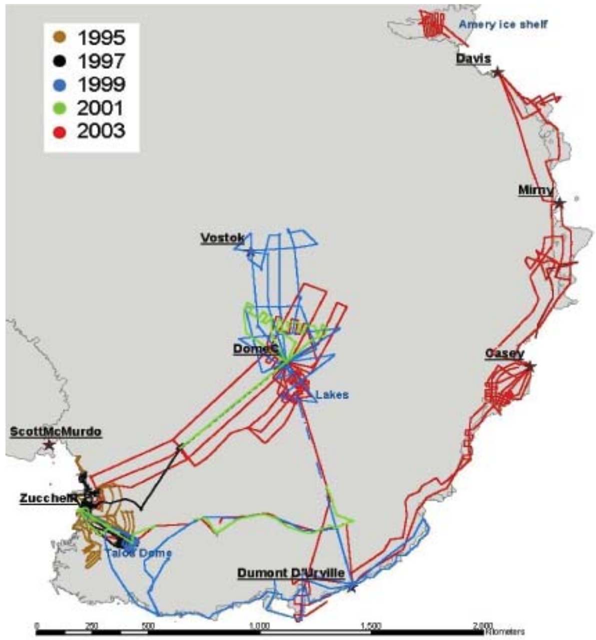

Fig. 1 - RES flight paths of five Italian Antarctic Expeditions.

of each radar trace. The horizontal sampling rate was 10 traces/s, which for a mean aircraft speed of about 70 m/s corresponds to about 143 traces per kilometre (1 trace every 7 m).

The measurements, obtained using the RES system during five Italian Antarctic Expeditions in 1995-2003 (Fig. 1), have been used in different contexts (Tabacco et al., 2002; Cafarella et al., 2006; Urbini et al., 2006). For example, these measurements were used to determine and analyse the bottom morphology and ice thickness of the David Glacier-Drygalski ice tongue in East Antarctica (Bianchi et al., 2001; Tabacco et al., 2000). Satellite-tracking velocity data for the same period were combined with airborne radar surveys of ice thickness to calculate the discharge of the Priestley, Reeves, David, Mawson and Mackay outlet glaciers (Frezzotti et al., 2000). The calculated changes in ice flux of these floating glaciers were subsequently used to determine basal melting and

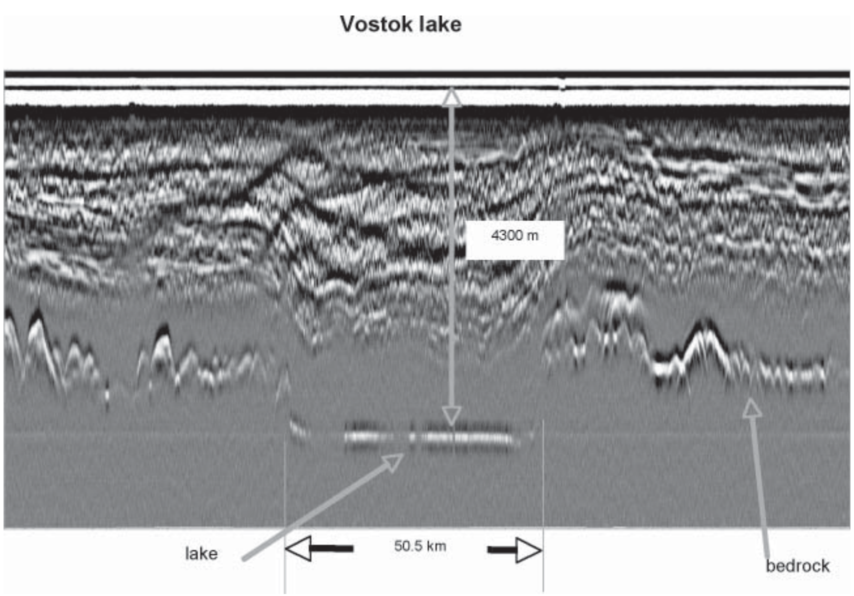

Fig. 2 – RADAR signal of Lake Vostok.

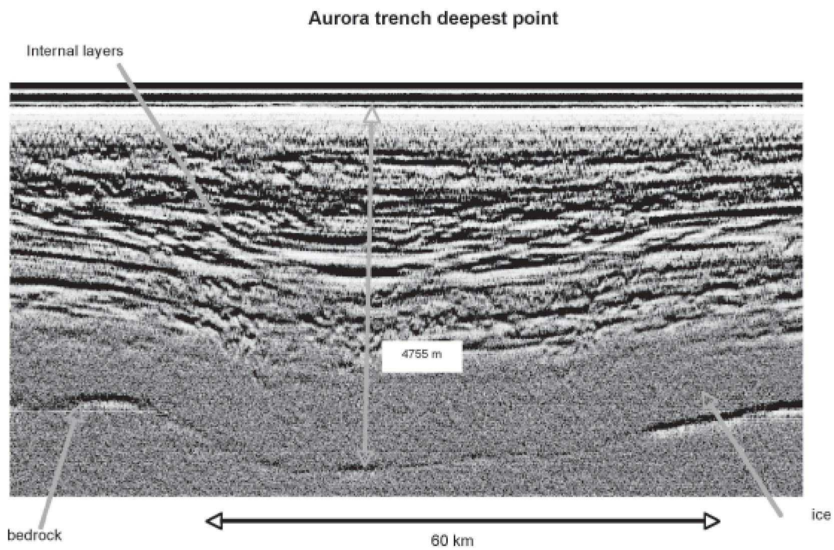

Fig. 3 – Aurora trench deepest point

freezing rates. This RES system was also used to make many measurements in the Antarctic region in support of different projects such as the European Project for Ice Coring in Antarctica (EPICA). Data were used to reconstruct the precise bedrock topography at Dome C in Antarctica (Remy and Tabacco, 2000). Knowledge of the topography of this region was used to select the optimal location for drilling a deep ice core at Dome C (Capra et al., 2000).

During the 1999 and 2001 Italian Antarctic Expeditions, extensive airborne radar surveys were carried out over the Vostok-Dome C region and the Aurora trench (about 6000 km of radar traces were acquired). The aim was to define the morphological characteristics of the Aurora Trench and to improve subglacial lake exploration (in Fig. 2 the RADAR signal of Lake Vostok is shown). The radar data was used to determine the ice thickness and bedrock topography in the entire area; in addition, analysis of the shape and amplitude of bottom reflections allowed the detection of sub-glacial "lake" mirror features in 30 radar tracks (Tabacco et al., 2003). The deepest point in the Aurora trench (Fig. 3), located at 118.328° E; 76.054°S, has a bed elevation of -1549 m and an ice thickness of 4755 m.

The most extensive Radar measurements (more then 30000 km in 35 flights) were completed during the 2003 Italian campaign in order to estimate the bedrock topography and the mass balance of the eastern Antarctic ice-cap.

NEW SYSTEMS

Two enhanced RES systems, with a new antenna system (8 folded dipoles) and the implementation of powerful signal processing techniques (time domain and frequency domain correlations), are being developed by the INGV (Bianchi et al., 2003).

The new 150 MHz RADAR is an envelope and phased-coded RADAR with a better signal-to-noise ratio than the old 60 MHz RADAR.

The 300 MHZ Snow RADAR, with a shorter transmitted pulse (subpulse in the phase coded RADAR), will have a better vertical resolution (less than 3 m) in the ice and the capacity to distinguish internal layers, so that ice accumulation rates can be determined based on the depth of known isochronal horizons. These improvements will be achieved by a new analog-to-digital (AD) converter card used to digitalize the acquired RADAR traces and by mounting the new antenna system beneath the wings of the Twin Otter. The AD converter is a PCI 64 bit PC card with 2 channels, 14 bit resolution and 100 MHz sampling rate on each channel. The antenna system is made up of two arrays of 8 broadband folded dipoles: 4 antennas for transmitting the signal and 4 for receiving the echo. The antennas are fed in phase, and the harness is a single feed point with the splitters in line. The array will improve the beam convergence and directionality, while increasing the amplitude of the signal.

The new systems are under construction at the INGV, and the new antennas will be mounted on the Twin Otter airplane in spring 2006 for a flight test in Calgary, Canada. The first on field test of the two RADAR systems are scheduled for the 2006 – 2007 Antarctic campaign.

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