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Design and Development of a PC Controlled Acoustic Sounding System for Antarctica

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Abstract

Indian planetary boundary layer programme in Antarctica is being inducted in a phased manner. As part of this programme, a monostatic, PC controlled acoustic sounding system has been designed, developed and installed at the Indian station Maitri (70.7°S: 11.7°E) in Antarctica.

Introduction

Rapid progress in the acoustic sounding technology has made it to be an effective and simple tool for probing the planetary boundary layer (McAllister, 1968,McAllister et al.,1969,Beran et al.,1971,Gurm et al.,1982) and the technique has been utilised in countless applications (Hooke et al.,1972,Somal,1981,Dutta et al.,1989,Rao et al.,1991,Dutta et al.,1990,Venkatachari and Dutta,1990,Prasad et al.,1991). As a result, there has been a rapid progress in the development of technology itself and today, acoustic sounding is an integral part of almost all atmospheric science programmes even under the most hostile Antarctic environment (Neff,1980,Kobayashi and Ishikawa,1983,Fiocco et al., 1990,Dutta et al., 1991) where the success still depends on skill, imagination and efforts particularly in manned operations. The Indian PBL programme in Antarctica is relatively new. By now, an automatic weather station and a 9m operational instrumented tower have been established to record data apart from the surface based meteorological observations, radiation data and radiosonde flights.An acoustic sounder has also been fitted.

General climatic features over Maitri:

The average atmospheric temperature remains between 0 in summer and -30°C during peak winter period. Maitri station experiences winds from ESE and SE directions. During the passage of extra-tropical systems, strong gusty

winds from SE direction are observed. In general, winds are stronger in winter than in summer. In winter, extra-tropical systems around the continent are more prevalent causing strong, gusty winds on most of the days with an average velocity of around 25-30 knots. From the acoustic sounding point of view, the wind speed .beyond 30 knots and snowfall, generally termed as bad weather, are the noise producing sources in which acoustic sounding recording is severely affected.

Design philosophy

The atmospheric studies at the Indian stations Dakshin Gangotri and Maitri have given basic inputs for the design and development of the proposed system. The inputs being the high wind velocities loaded with ice crystals (upto 240 km/hoyr wind velocity is recorded), low temperatures (upto -50°C) and absolutely no noise under normal conditions. The only sources of natural noise are the winds and snowfall, and the man made periodic noise is die to the electricity generators and continuous noise for a short period (5 to 10 minutes only) is during the helicopter operations. Among all these factors, it is advantageous to have lower temperature which reduces the thermal noise of the system in Antarctica. Low noise and normal wind conditions will enhance the system performance in Antarctica. Therefore, if a proper shield is designed, the same system which is functioning in India, will operate in a better way in Antarctica .

Due to limited manpower available to look after the system operation, it was decided to make a PC based system so that the continuous recording, is made automatically for days together on the HDD and the data is transferred onto a CTD/FDD, Also, the colour display gives a better insight into the atmospheric dynamics.

Principle of operation

In this acoustic sounding system., a powerful pulse of sound is transmitted vertically up into the atmosphere by a 6' parabolic fibre glass dish. The weak echo that returns from the atmospheric thermal inhomogeneities are received by the same antenna. These weak signals are amplified and recorded either on a PC or on a conventional facsimile recorder. The trigger for transmission of acoustic energy at regular intervals is available through the PC and it also accepts an external trigger from a facsimile recorder. The advantage of using both the recording media is to see the similarity of patterns and to modify the software to bring the computer pictures close to the analog pictures which are well accepted internationally (McAllister,1968 & McAllister et al., 1969).

Basic system

The basic system consists of four parts:

1. **The system electronics including the pre-amplifier.**
2. **PC based recording system and operating software.**
3. **Antenna assembly and acoustic shield and**
4. **Temperature sensing and control operations.**

Fig 1 shows the block diagram of the acoustic sounding system which shows the entire system operation and the sub system assemblies. In this system, the stable frequency for transmission is generated through a crystal oscillator and is fed to a tone burst generator. The tone burst generator receives a trigger pulse from the recording system (either a PC or a facsimile recorder) enabling it to produce the transmitting tracer packet of sound energy. This is amplified and is transmitted through a 6' parabolic dish of fibre glass enclosed in an acoustic shield. The received signals are amplified by a pre-amplifier having a gain of 90 dB and are then filtered through a band pass filter. These signals are converted into DC through a precision AC/DC converter and are recorded

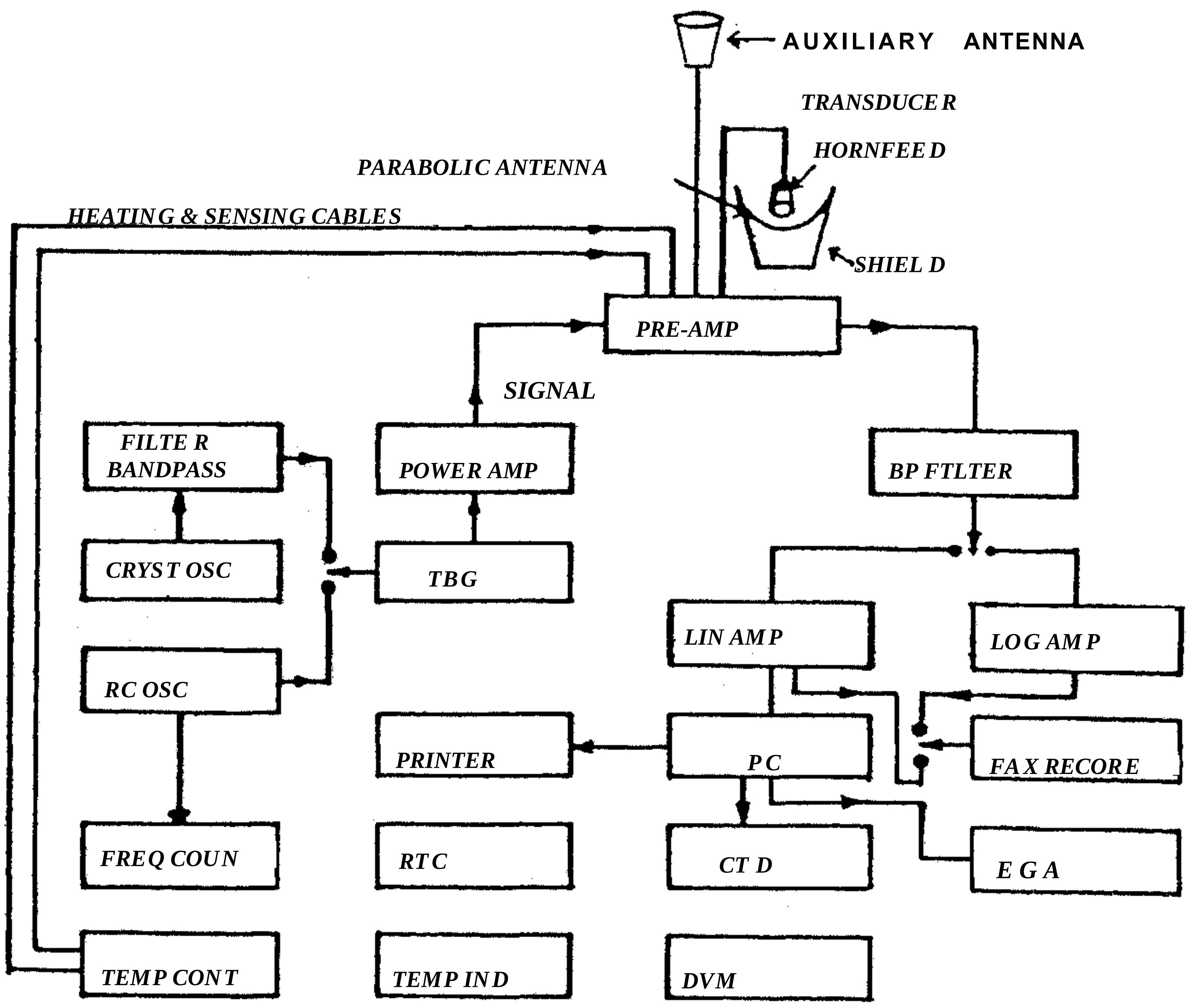

Fig 1: Block diagram of the acoustic sounding system showing the entire system operation and the sub-system assemblies.

Table 1: Acoustic Sounding System Specifications

1.	Transmit frequency	:	2000 Hz Tunable from 500 Hz to 2500 Hz
2.	Transmit power	:	60 W(electrical)
3.	Antenna	:	6' parabolic fibreglass dish
4.	Acoustic shield	:	Conical in 24 parts
5.	Pre-amplifier sensitivity	:	90 dBm
6.	Receiver gain	:	Variable 100 to 140 dB
7.	Recording	:	Digital onCTD/FDD Analog on electrosensitive paper
8.	Digital data range resolution	:	5.82 m
9.	Digital data amplitude resolution	:	8 bit
10.	Software	:	User-friendly
11.	System operations	:	Non-stop

either on a facsimile recorder or onto the PC. The temperature sensing and control is necessary to keep the pre-amplifier at 0°C and the system electronics at +5^{0}C. Table I gives the specifications of the system.

Data acquisition system

The data acquisition system (DAS) is based on INTEL 80286 microprocessor with 1 MB RAM. It has been provided with a HDD of 40 MB, a CTD of 60 MB and a FDD of 1.2 MB. The data enters through an 8 bit A/D card with a conversion time of 35 micro seconds. The data file is in sequence of 170 levels (Range gates) of 8 bit resolution for each scan of 6 seconds and each level is designated a number in sequence starting from 1 to 170. The A/D card also provides a sync pulse or accepts an external trigger. The software is interactive and is TURBO-BASIC. It has an EGA/VGA monitor to display colour facsimile pictures which can be captured with a camera or can be copied on a colour printer. The data is printed on an IBM compatible dot matrix printer to form a usual B & W facsimile hard copy.

Software

The software has been developed using TURBO basic. The vertical range of 1 km (6 seconds) has teen divided into 170 range gates. In each gate data is taken for 2.944 m secs and an equal amount of gap is given. Thus we have 170 voltage levels with 8 bit resolution each corresponding to a fixed height. Depending upon the magnitude of the voltage, a 3 x 3 matrix of dots is given a colour. The software can give 16 colours but such a picture is confusing and therefore, we have only five colours with the black background.

Design of acoustic shield

The 6' parabolic dish has been developed using Ciba company resin LY 556 and hardner HY 951 with compatible fibre glass cloth. It takes about 20 hours to dry at 70°C. The material has been tested to maintain its shape and strength upto -60°C. The other dish was made of usual fibre glass material which has been tested to work well upto -30°C. Both of these antennas are working very well in Antarctica for the past two years and no physical deformity like cracks etc. has been noticed due to the cold Antarctic environment. The acoustic transducer along with an exponential horn is a commercially available 50 W transducer and has been tested to work well upto -40°C. In fact, the transmission is never switched off even under the adverse atmospheric conditions so that movement of the coil remains free and the heat dissipated in the transducer coil is enough to keep it warm in winter. Also, it is sealed at the top with an insulating material to protect it from severe cold.

The height of the shield is 2.45 m with the outer lower base diameter of 2.25 m and outer upper diameter of 2.4 m. Inside the shield, 10 cm thick foam is pasted all around to enhance S/N ratio by 22 dB. Fig 2 shows the shield erected at Maitri.

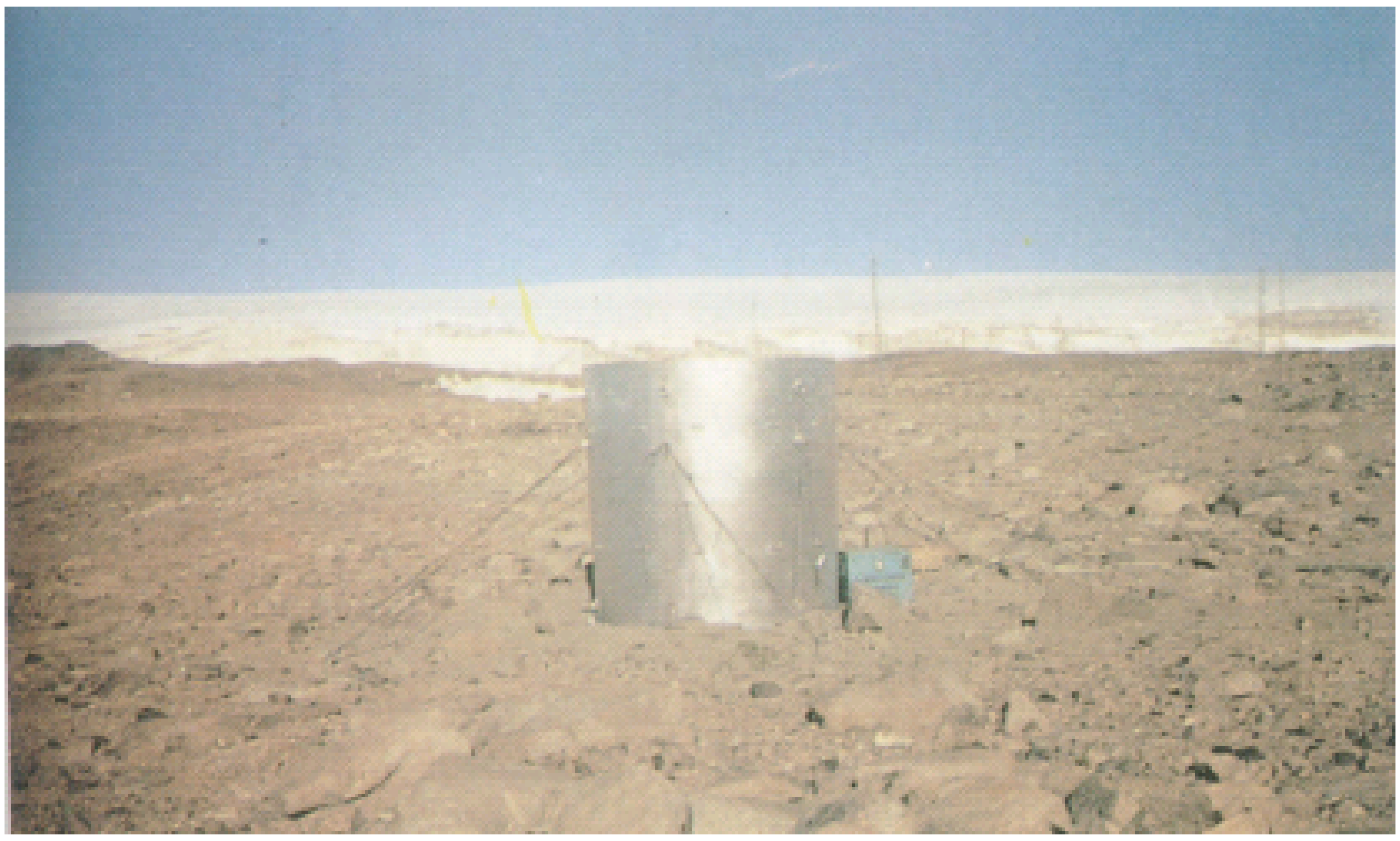

Fig 2 : The shield installed at the Indian station Maitri.

Result

Fig 3 shows the facsimile picture of surface based inversion and elevated layers recorded at Maitri. The radiative cooling produces surface based inversion and the cold dense air mass so produced flows down the slopes of Antarctica under gravity and develops into the katabatic wind. At Maitri, the wind flow is always from SE or ESE which is responsible for cold air mass close to surface forming stable ground based inversions.

in Antarctica other thermal convective cells going upto an altitude of several hundred metres are rare and arc recorded on a really calm, sunny day as seen in Fig 4.

Discussion

The noise free data recorded at Maitri indicates that the design parameters have been selected carefully. The results indicate that the PBL over this region is remarkably different than the PBL observations in India (Somal,1981,Dutta et al., 1987 & 1989). Also, it has recorded highly complex and highly variable

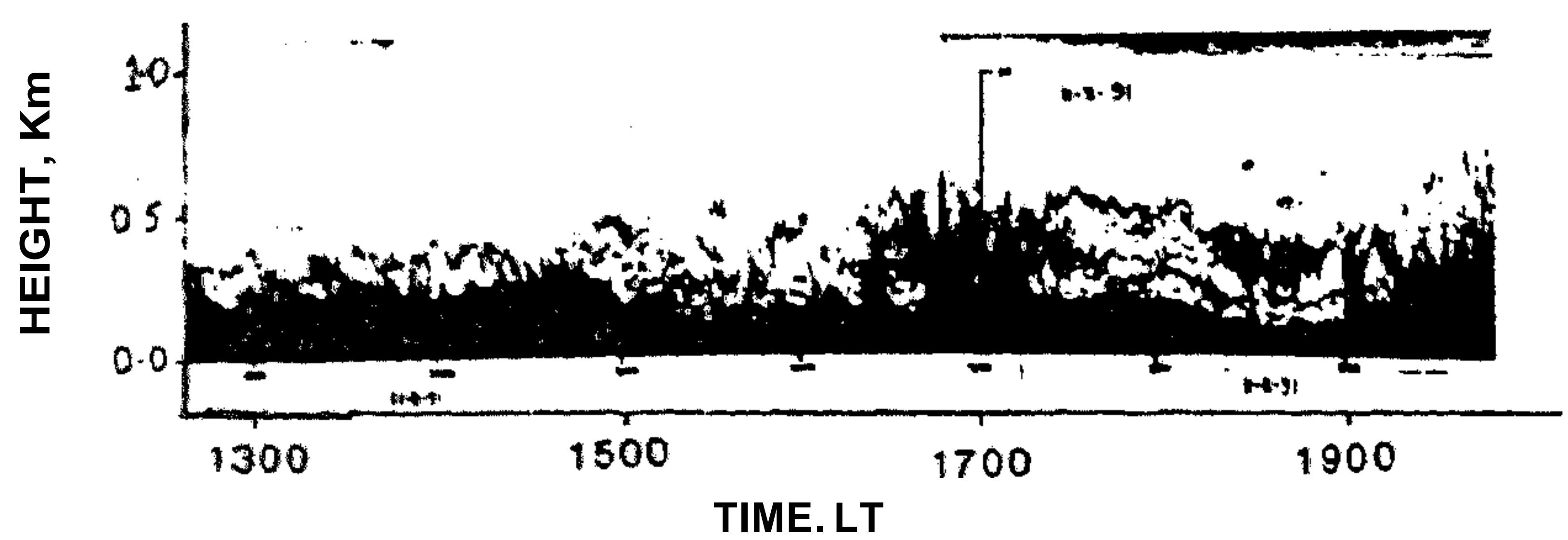

Fig 3 : Facsimile pictures recorded at Maitri showing the surface based inversions and elevated inversions.

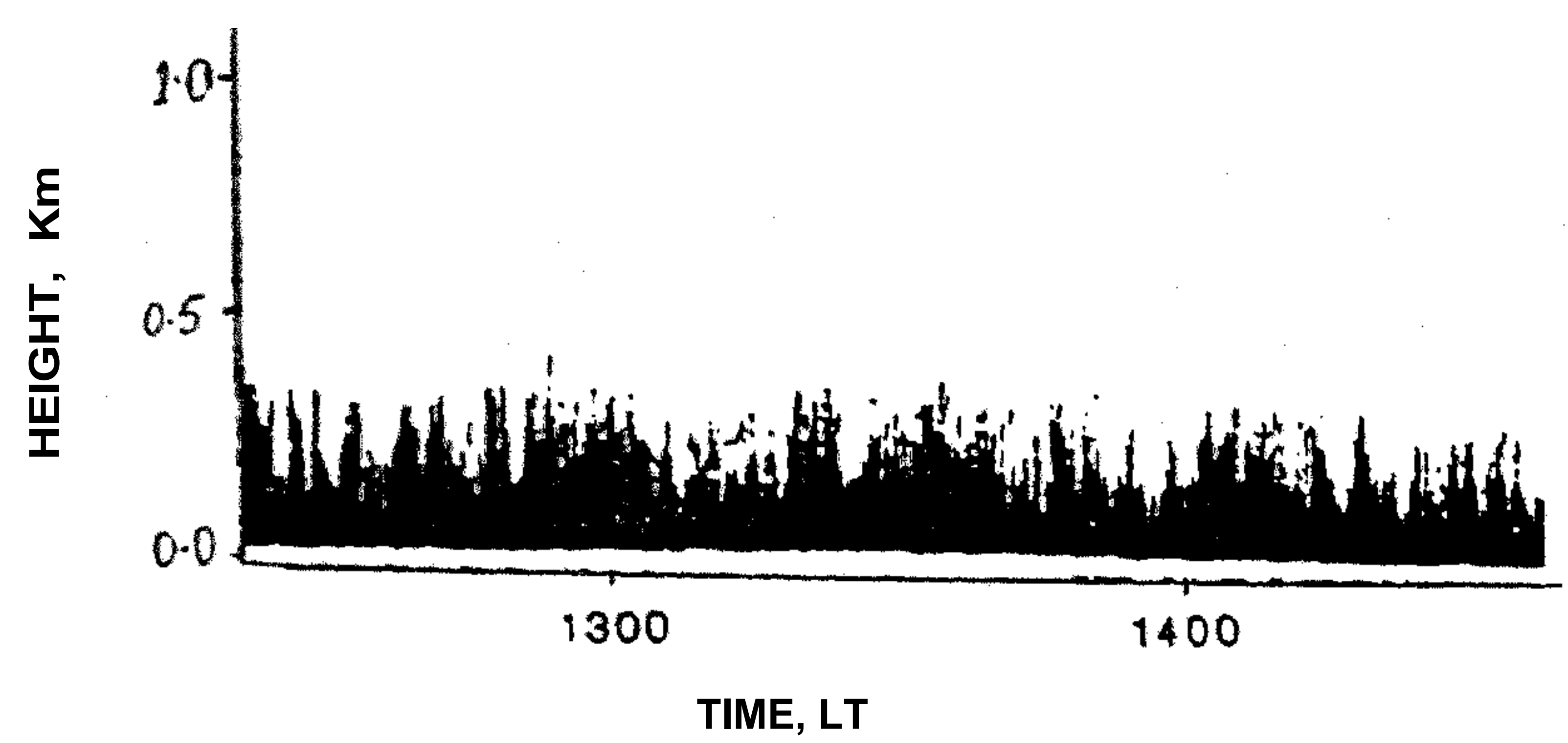

Fig 4: Echogram showing thermal convective cells going upto 350m.

PBL conditions varying in terms of time and space. This variability is seen even in the tower measurements and the automatic weather recording data as recorded at Maitri.

Lidar measurements of the Antarctic troposphere have also been carried out (Smiley et al.,1980,Smiley,1980) for which acoustic sounding is a complementary technique.

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