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Characterizing the Marine Boundary Layer Over East Antarctica

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Abstract

Characterizing atmospheric boundary layer (ABL) is a prerequisite for microwave, mm-wave and infrared communication / radar operations over the marine environment or along the coastal zones. At the same time, ABL acts as a buffer between air and interaction between ice and the ocean. To estimate the various ABL parameters, airborne and remote sensing techniques dominate but these need to be calibrated against the surface based measurements. With this aim, we have develop a shipborne acoustic sounder, which was deployed onboard the ship Magdalena Oldendorff to probe the marine boundary layer along the east Antarctic shelf during January-February, 2002. It has revealed many unique features of ABL, which may lead to a better understanding of various communication problems faced over the marine environment.

Introduction

Characterizing atmospheric boundary layer is a prerequisite for microwave, mm-wave and infrared communication / radar operations over the marine environment or along the coastal zones [1-5]. To estimate the various atmospheric processes, airborne and remote sensing techniques dominate, as there is no stable platform available to deploy the equipment [6-8]. However, for utilizing the remote sensed data, inter-comparison with the shipborne measurements can be made to assess the reliability of remotely sensed data[9-ll]. With this aim, we have develop a shipborne acoustic sounder, which was deployed onboard the ship Magdalena Oldendorff to probe the marine boundary layer along the shelf over east Antarctica.

The Antarctic boundary layer remains predominantly in the stable state throughout the year [12-13]. However, thermal convection has been observed at many stations over the icy continent, primarily during local summer, and under calm/light wind conditions [14-15]. The ocean around the Antarctic continent is one of the most dynamical regions as over the ocean-ice-air interactive space, many strong forces play an interactive role. The katabatic winds flowing from the interior of the continent towards the periphery, result in the flow of inversion air mass, leading to the formation of low-pressure areas and the cyclones. These cyclones, in turn lead to the turbulent ocean, and break pack ice. During the local summer, the solar radiation is available for 24 hours; it melts upper part of the shelf ice and the polar ice around the periphery. This leads to the formation of cold-water drainage from the continent towards the ocean around. At the same time, solar energy also melts pack ice. The cold water so formed by the above two processes, leads to churning in the oceanic water. Thus, the chances of formation of thermal convection remain low, even during summer over the ocean.

Experiment and Observational Site

National Physical Laboratory, New Delhi started the development of a shipborne acoustic sounder in the year 1992[16], and after gaining the experience of various problems associated with the development of a shipborne system, established a monostatic acoustic sounder onboard the ship, Magdalena Oldendorff, which sailed to Antarctica, as part of the 21st Indian Scientific Expedition to Antarctica. The 1.2 m fiberglass-antenna mounted on a vibration damped, gyro-stabilized platform and surrounded by a hexagonal cuff, was deployed in the bow area of the ship. Fig. 1 shows the photograph of the shipborne antenna cuff fitted in the bow and additional ropes had to be utilized to secure its position in heavy rolling and pitching. The PC controlled electronics was housed in a room just below the bow.

The ship after reaching to the Indian Bay in Antarctica, sailed to the South African station, and returned just after a day, to its scheduled position. Fig. 2 shows the ship position on various dates. It is important to note that due to blizzards, and the movement of icebergs, ship can't be anchored at one point; rather, it is maneuvered to safer positions. This makes the ship to change of its position, speed and course etc. frequently and is displayed as a box in Fig. 2. Also, the useful data is limited to only low wind conditions; cyclones and blizzards restrict the usefulness of data.

Fig. 1: Shipborne acoustic sounder antenna Oldendorff

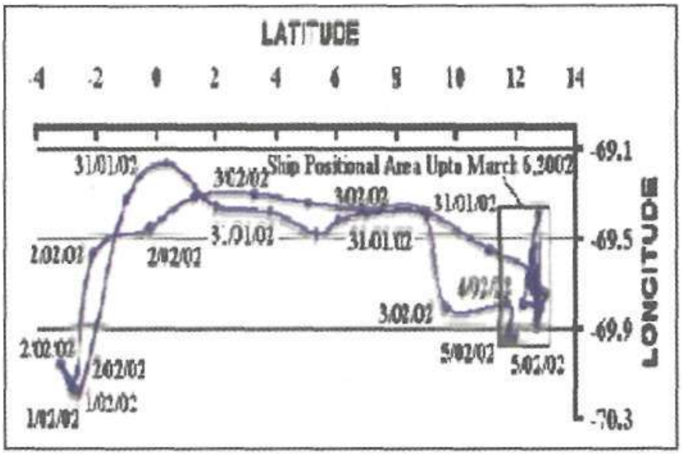

Fig. 2: Position of the ship Magdalena mounted in the bow area along the coast/ shelf in east Antarctica

Observations

The acoustic sounder data has been recorded automatically by a PC controlled system, which had manually selectable parameters for optimizing the data recording in the actual field conditions. After two days of trial run, it was fixed to 4 seconds of sweep rate, thereby probing up to a height of 640 m above the bow area of the ship. The system has recorded many usual and unusual features of the boundary layer, which need considerable attention of the users. The first unusual case was observed on January 23, 2002 when the ship was sailing around the position 69.8°S; 12.15°E (Fig. 3).

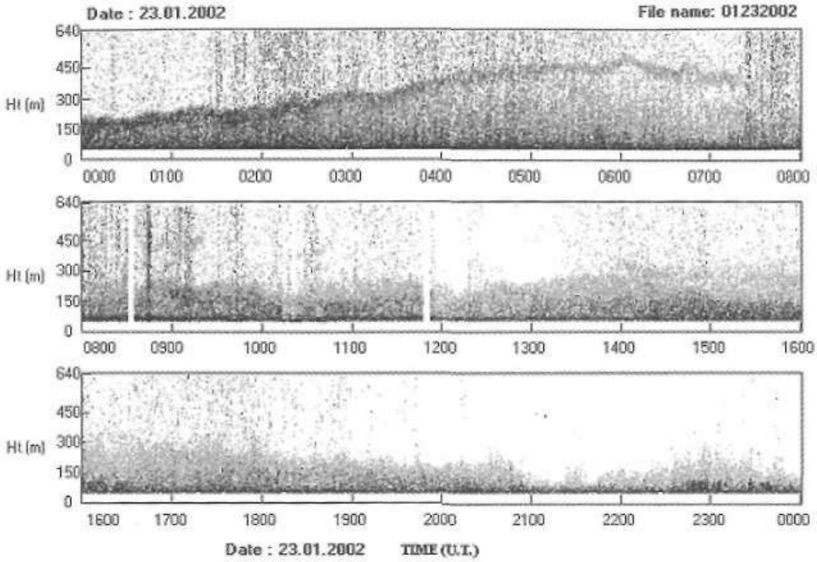

Fig. 3: Marine atmospheric boundary layer dynamics probed by the shipborne acoustic sounderreveals signatures of rising layer, a unique situation over the ocean-ice-air interface

On this day, surface layer rise has been observed over the pack ice floating over the ocean. The rising layer started at about 0015 hrs (U.T.) and continued up to 0615 hrs. This indicates solar heating of the icy surface over the ocean, without any significant mixing with the underneath water. In the Antarctic water, normally mixing takes place rapidly as the water below 4° C or above tends to be lighter. But, if the ice field is strong, under such a situation, water vapor remains mixed below the rising layer, resulting in a low refractivity gradient close to the oceanic surfaces. On the other hand, due to the formation of surface based layer at night (Fig. 3) the steep humidity lapse rate close to the oceanic surface, may result in steep humidity gradients across lowest few meters.

The second strange incidence has been recorded on February 2, 2002, when ship was around the position 70.17°S, 2.87°W (Fig. 4). On this day, thermal convection has been recorded for almost 24 hours, which is the only case in the entire period of recording. Of course, there was some period (0800-1030 hrs), when convection has been perturbed either by the surface cooling or by the horizontal winds. But to support this type of formation of thermal convection, only solar radiation heating the icy / oceanic surfaces alone can't be advocated. There must be some mechanism by which either oceanic surface becomes relatively much warmer than the overlying air or there is absolutely no mixing between the upper layer of the pack-ice and the underneath water. In the absence of supporting oceanic and atmospheric temperature profiles, interpretation of this record is difficult at the moment, but such cases may account for diurnal and seasonal variations in the availability of moisture in the coastal atmosphere, which may lead to the formation of various types of phenomena dominated by evaporation of water from ice/oceanic surfaces and ultimately lead to several radio/optical phenomena over the ocean[17].

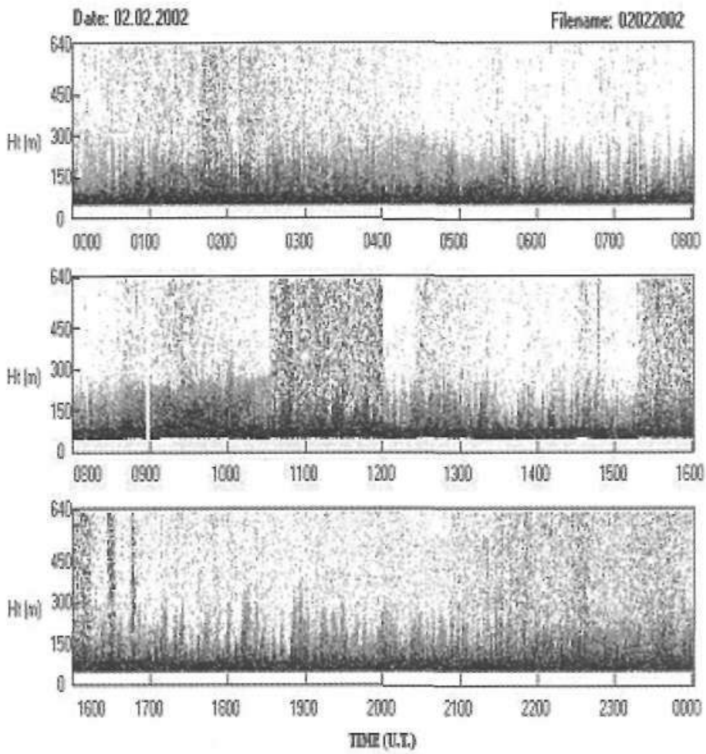

Fig. 4: Thermal convection over cold oceanic water reveals strong ocean-ice-air interaction.

Conclusion

The ships sailing to Antarctica are practically stationary in one region for a long time and thus provide unique opportunity to carryout such developmental projects. The successful development and deployment of the shipborne acoustic sounder shows its utility to provide round-the-clock dynamics of the marine atmospheric boundary layer, which is required for various applications in communication [18-20].

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