NOTES

Acoustic Sounder Observations of the Atmospheric Boundary Layer from the Top of a Steep Mountain

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ABSTRACT

Preliminary results from a series of experiments utilizing an acoustic sounder located at the top of a 1026 m mountain are presented which show some interesting features of the evolution of the atmospheric boundary layer.

1. Introduction and description of the experiment

In recent years atmospheric boundary layers (henceforth ABL) have been the subject of intense study through the use of tall instrumented meteorological towers, balloons, acoustic sounders and FM-CW radar systems. Acoustic sounders in particular because of their relatively low cost, ease of operation and portability, have been deployed in such diverse locations as the North and South Pole, and Alps and on board ships. They are capable of monitoring the stability of the lower atmosphere (Beran *et al.*, 1973; Crease *et al.*, 1977) and, in addition, with proper data acquisition systems, of obtaining quantitative information on turbulence statistics such as the temperature and wind velocity structure parameters C_T^2 and C_v^2 (Neff, 1975; Asimakopoulos *et al.*, 1976; Caughey *et al.*, 1978; Haugen and Kaimal, 1978). When Doppler capability is added, an acoustic sounder can be used to monitor both the mean and turbulent components of air motion (Caughey *et al.*, 1976; Gaynor, 1977; Asimakopoulos *et al.*, 1978).

The height that typical acoustic sounders can sense with reasonably good accuracy is ~1000 m. Yet, especially during periods of large insolation, the height of the ABL during the day far exceeds 1000 m. To overcome the range limitation in studying the evolution of the ABL during such conditions, an acoustic sounder has been installed at the top of Hymettus Mountain in Athens, Greece, at an altitude of 1000 m. The topography of the sounder location and the surrounding area are shown in Fig. 1. The sounder is located on a large porch of the Experimental Station of the Meteorological Institute of the National Observatory of Athens (38°N). No other buildings, free-standing structures or trees exist within a 500 m radius. The mountain itself is approximately two-dimensional with steep slopes on both sides of a N–S ridge.

The acoustic sounder used is an Aerovironment

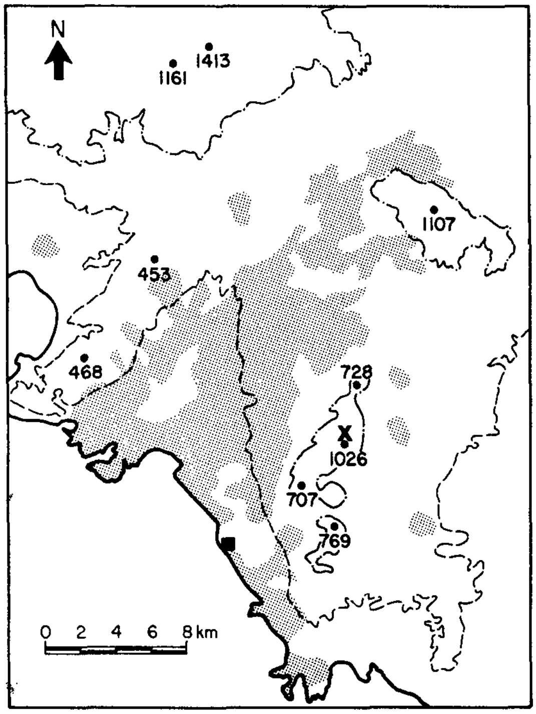

FIG. 1. Map of Greater Athens, Greece, showing the location of the acoustic sounder (x) and the rawinsonde station (■). Populated areas are dotted. The dashed line is the 100 m elevation contour and the dot-dashed line the 500 m contour. Peaks of major mountains and their elevation (m) are also indicated.

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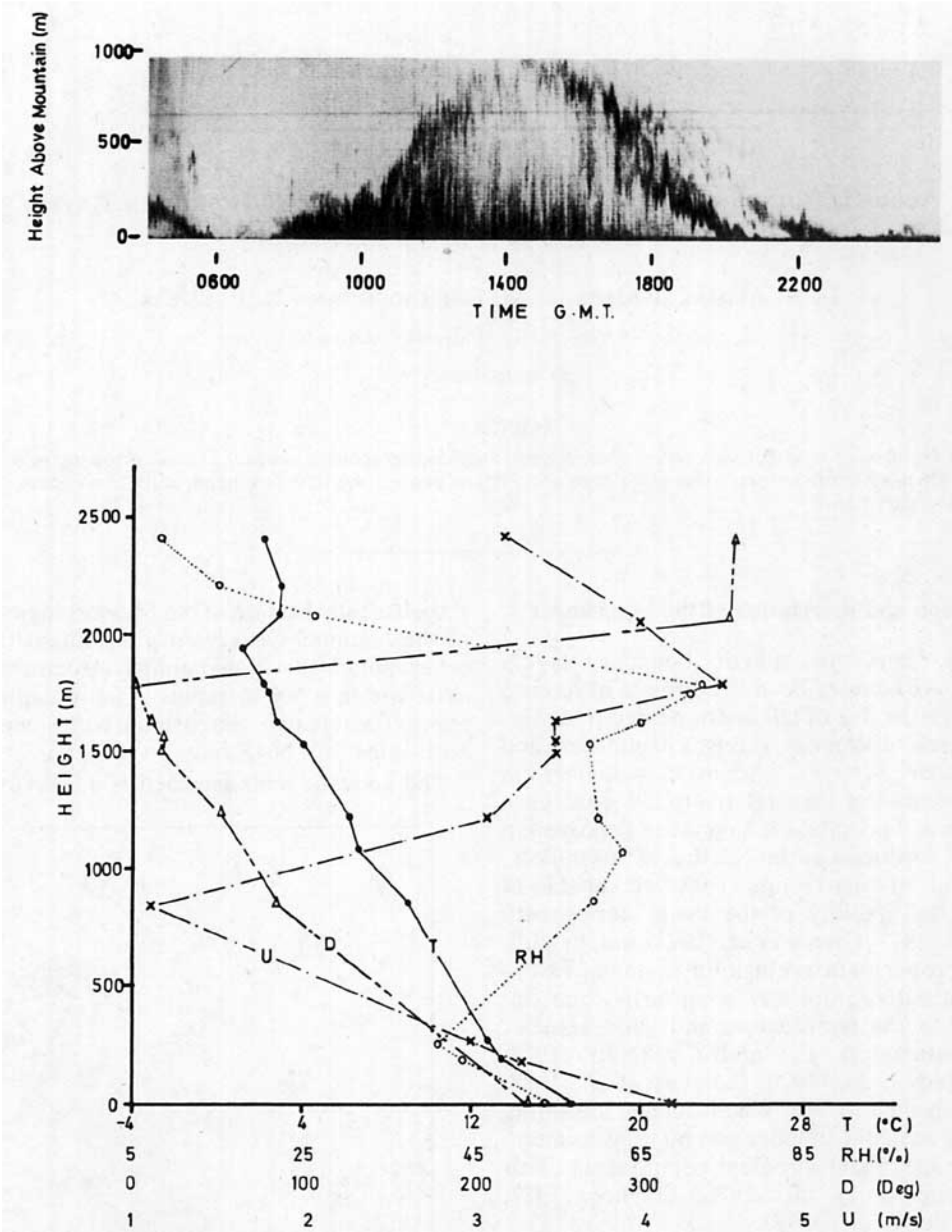

FIG. 2. Facsimile recording of the acoustic sounder echo returns from the top of Hymettus Mountain, Athens, Greece, on 15 April 1979, and the rawinsonde data of the 1200 GMT 15 April 1979 ascent from Athens airport. Wind speed and direction are indicated by dot-dashed and double-dashed lines, respectively, while the temperature is indicated by a continuous line and the relative humidity by a dotted one.

300C monostatic sounder. Its operating frequency is 1.6 KHz with a pulse repetition frequency of 0.17 Hz so that the maximum detection range is about 1000 m. The pulse length is 200 ms which provides a 34 m height resolution. The gain of the receiver is increased linearly with time to compensate for the loss of signal strength caused by the spherical divergence of the wavefront. The echoes are recorded in the usual way by a facsimile recorder which produces a real-time display of the echo strength vs height. Because of the exposed location and the sharp relief of the terrain, wind noise is appreciable so that a substantial screen, consisting of layers of wood, lead and foam, constructed along the manufacturer's instructions, has to be used to improve the signal-to-noise ratio.

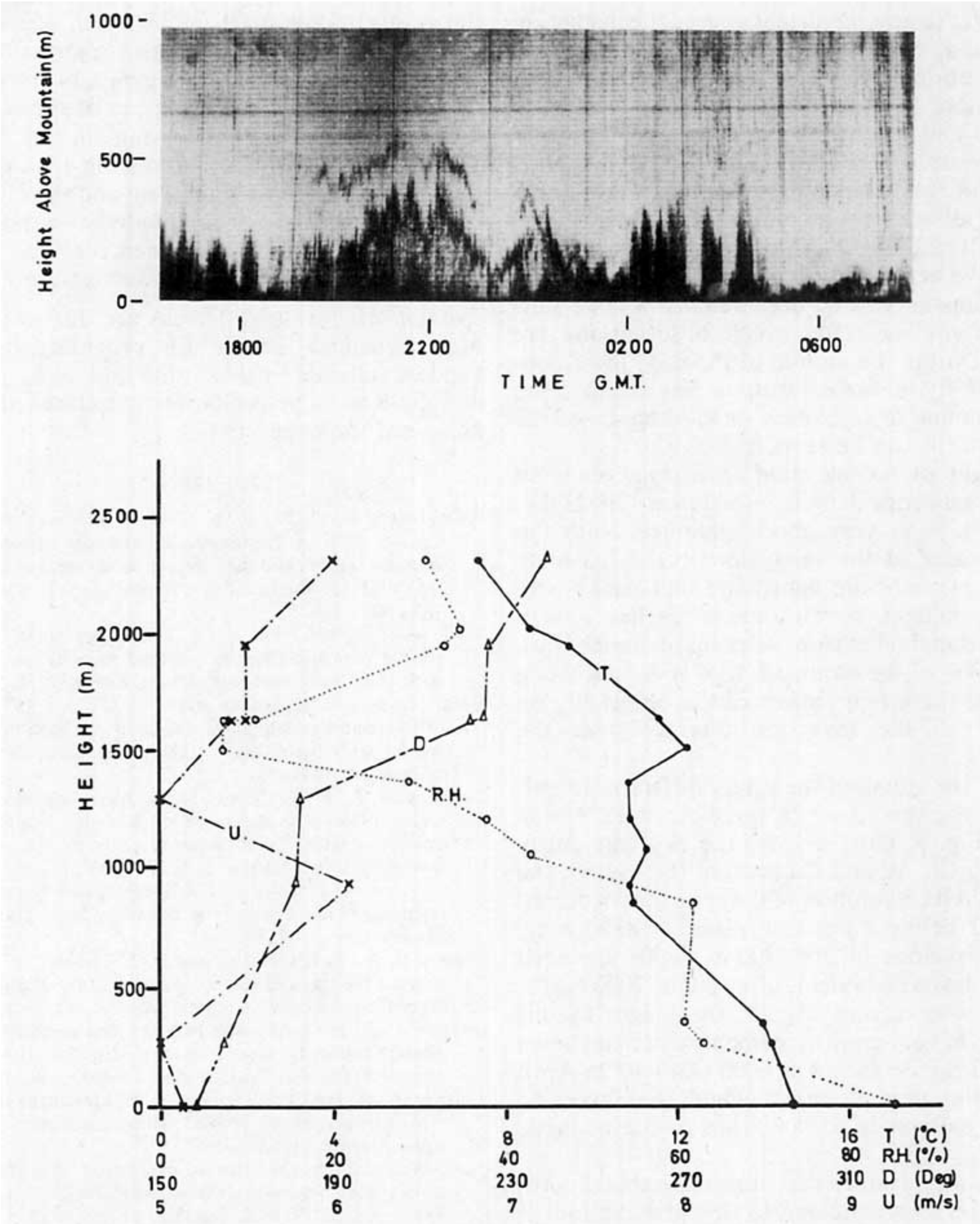

FIG. 3. as in Fig. 2 except that the period displayed is the night of 25–26 April 1979. The rawinsonde data shown are from the 0000 GMT 26 April 1979 ascent.

The acoustic sounder data are complemented by rawinsonde soundings at 0000 and 1200 GMT (0200 and 1400 LST) from the Athens upper air station, located 8 km SW of the mountain top. These upper air soundings, conducted by the Greek Meteorological Service, utilize a Väisälä RS 21-12 CN radiosonde in conjunction with a CORA wind-finding system. In addition, continuous recordings of observations of wind speed and direction, insolation and cloud cover are available from the Meteorological Institute of the National Observatory of Athens, located in the center of the city.

2. Discussion of the observations

The records presented in Figs. 2 and 3 are drawn from a series of observations carried out during April 1979 under mostly fair weather and for both convective and stable conditions.

The first record, shown in Fig. 2, is for the daytime hours of 15 April 1979. During the time period shown, no changes in the synoptic situation took place and the pressure at sea level remained constant at 1022 mb. The sky was clear most of the day with intermittent Ci and Ac clouds around noon, which did not affect to any significant degree the insolation at the ground.

The evolution of the ABL height is clearly seen. The inversion, located below the mountain top at night, rises and reaches the mountain top approximately 3 h after sunrise (at 0351 GMT) and dips below about 3 h after sunset (at 1701 GMT). No returns at all are present between 0500 and 0700 GMT or after 2230 GMT for at least 3 or 4 h. After sunset, wave activity and multiple layering are evident, circumstances that are found in a large percentage of the days for which observations are available. During the middle of the day, local convective activity that reaches up to 500 m above the ridge and is due to insolation of the surface of the mountain itself, can be seen.

The height of the elevated inversion, obtained from the rawinsonde data, is ~1900 m at 1200 GMT, a value that is in very good agreement with the return indicated at the same time in the facsimile record. Because of the light wind that backs with height, the balloon, by the time it reaches 2000 m MSL, is within 0.5 km from its point of launch, i.e., ~7–8 km SW of the mountain top. It is interesting to note that there is no effect of the orography on the height of the inversion directly over the mountain.

At night, the situation is entirely different, as evidenced by the record of 25 to 26 April 1979, displayed in Fig. 3. On the 25th, the sky was partly cloudy with Ci, Ac and Cu present throughout the day so that ABL evolution of the type that occurred on 15 April 1979 did not take place. Instead, only convective plumes of 200–300 m depth are seen during the day which yield, after about 2000 GMT, to a shallow inversion. Again, the height of this inversion is in very good agreement with that shown by the rawinsonde ascent at 0000 GMT of 26 April 1979. By the time it has reached the inversion height the balloon is within 5 km of the acoustic radar site.

An interesting feature that appears in this record, though by no means unique to this observation, is the returns after 0200 GMT which are similar to those caused by convective plumes over flat terrain in daytime. These returns may possibly be attributed to updrafts caused by deflection of the mean wind by the steep slopes at the mountain top.

The details of these interesting features of the ABL evolution in rough terrain and the climatology of various observed or anticipated phenomena (such as lee waves which have been reported by glider pilots) are presently under investigation.

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