Slow-Ascent Stadia Pibals

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1. INTRODUCTION

STADIA or tail pibals (FIG. 1) have been used to correct for the effects of rough terrain and turbulence in the first few minutes of pilot-balloon flights (Middleton [1]). Since previous experiments were designed to improve the accuracy of regular pibal ascents, the tail was made as light as possible in order to obtain normal ascension rate. In the present experiment the detection of wave motion was desired, so a small free lift was used to study the lower layers of the atmosphere in more detail.

2. THEORY

Although the theory of stadia pibal is well known, it is developed here to show a simplified adaptation of the method for micro-meteorological purposes. In FIGURE 1, D is the horizontal distance and d the slant distance to the balloon. θ is the elevation angle, $\Delta\theta$ is the stadia angle subtended by the balloon and tail (l the projection of L on a perpendicular to d). The angle made by L and l will also be θ and

$$\cos\theta = \frac{D}{d} = \frac{l}{L}, \quad \text{or,} \quad \cos^2\theta = \frac{Dl}{dL}.$$

Since $\Delta\theta$ is always small, $l = d\Delta\theta$, where $\Delta\theta$ is in radians. Combining

$$\cos^2\theta = \frac{Dl}{dL} = \frac{Dd\Delta\theta}{dL} = \frac{D\Delta\theta}{L},$$

or,

$$D = \frac{L\cos^2\theta}{\Delta\theta}.$$

Reading $\Delta\theta$ in hundredths of degrees it is found by making $L = 17.45$ feet,

$$D = \frac{100{,}000\cos^2\theta \text{ feet}}{\Delta\theta}.$$

Using tables listing $\cos^2\theta$ to five decimal places, the numerator can be expressed without the decimal point which, divided by the stadia angle in hundredths of degrees, will give horizontal distance in feet. Altitude can then be calculated in the usual way. By coincidence the balloon room in the present experiment measured 17.5 feet high.

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3. RESOLUTION

Errors in horizontal distance will result from inaccurate readings of the intercept angle due to pendulum action of the target or rapidly changing azimuth or elevation angles. Corwin [2] used a balloon tail slightly heavier than neutral to obviate swinging. In the present experiment little swinging was evident due perhaps to the heavier and shorter tail or to the slower ascent rate. Corwin also employed the more accurate method of reading the intercept angle by using a theodolite with a movable cross hair controlled by a vernier reading in minutes of arc.* For expediency in trying out the method, a reticule graduated to read in hundredths of degrees was used. The accuracy in D was variable depending on how steadily the balloon could be maintained in the field. When fairly steady the error was nearly constant (within $\pm$ 50 feet) to a distance of one mile. This resulted from the increasing ability to read the intercept angle to a finer degree due to the steadying effect of distance (limit .0025 degrees). Two methods were employed to refine the readings: first, running three minute averages were made to smooth trajectories, and second, an assistant was used to read the elevation and azimuth angles so that the theodolite operator could concentrate on more accurate readings of the intercept angle.

In order to get more accurate readings close in and at a distance ($<$ 1000 feet and $>$ 5000 feet) further refinement of the method is necessary. Secondary targets at ¼ scale were tried for close in but did not prove satisfactory. This method might prove practical using a theodolite with two

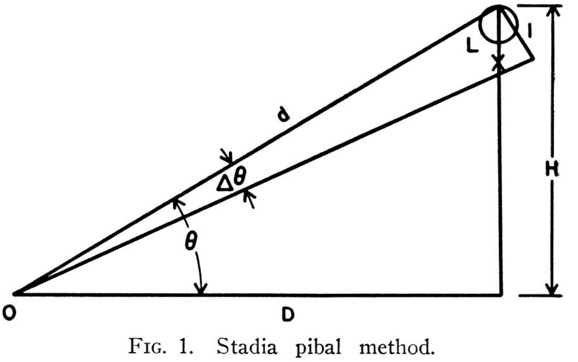

FIG. 1. Stadia pibal method.

* Developed by W. and L. E. Gurley Company, Troy, New York.

settings of magnification. A longer secondary target for the distant readings was not tried but should be practical if precautions against swinging are made as suggested by Corwin above. Due to the difficulty of close-in readings in the present experiment the time was recorded when the intercept angle reached the reticule limit of one degree and previous horizontal distances were interpolated.

4. EXPERIMENT

A 30-gram pilot balloon weighted to give a free lift of 20 grams was generally employed in this experiment although the free lift was often varied to suit conditions. At times two runs were taken using different rates of ascension. The equipment is shown in FIGURE 2. The tail was a cross-target cut from a corrugated paper carton and weighing 100 grams. The experimental site was located atop Point Loma in San Diego, California, at an elevation of 450 feet above the ocean. See FIGURE 3. The ocean lies to the west, and the area to the east of the channel is flat—not above 25 feet M.S.L. The prevailing sea breeze was westnorthwest, as indicated. Since the prevailing temperature inversion is significant in most of the experiments, radiosonde temperature data is presented from SDV, San Diego, three miles distant directly east.

FIG. 2. Pilot balloon and train. (Official photo, U. S. Navy.)

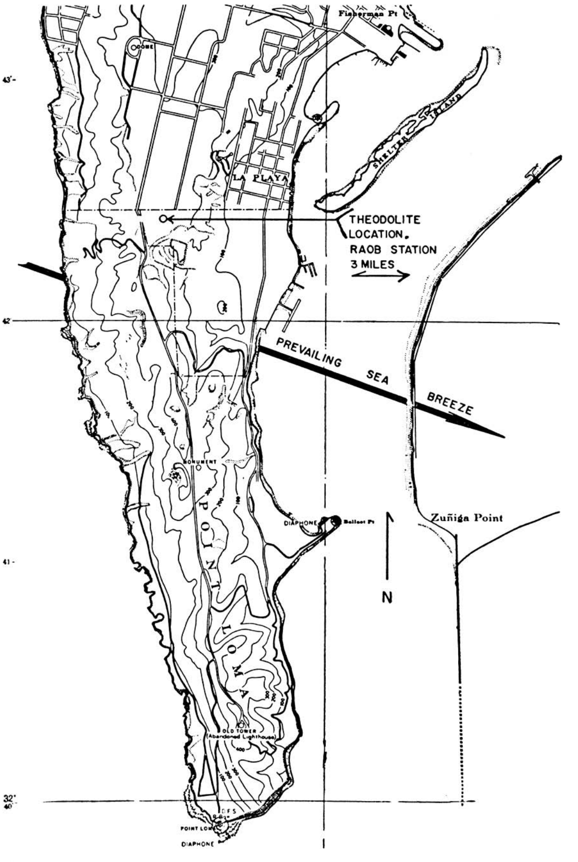

FIG. 3. Experiment location

5. RESULTS

A horizontal balloon projection in FIGURE 4 compares sharp trajectory changes with the inversion height from radiosonde data one hour earlier. Within the limits of error of the radiosonde and the time difference the breaks in the temperature curve correspond well with a sharp

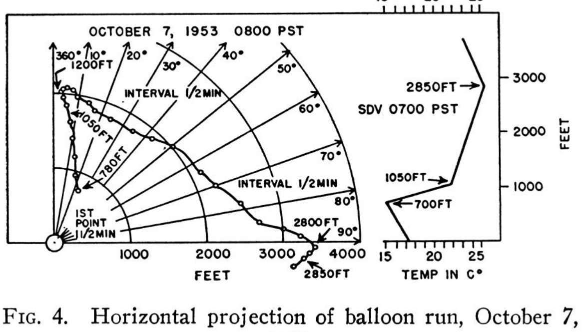

FIG. 4. Horizontal projection of balloon run, October 7, 1953.

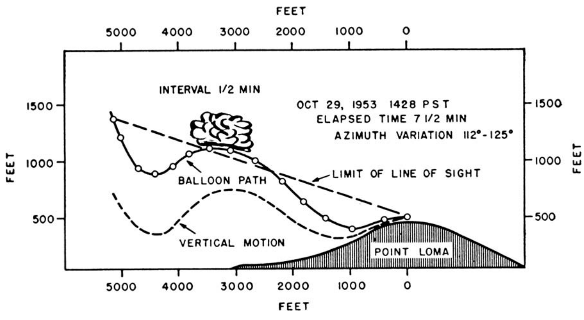

FIG. 5. Height-distance graph in a lee wave, October 29, 1953.

change in airflow. The first point obtained in the sounding was above the base of the inversion but the trajectory has already changed.

A sounding through a standing lee wave is shown in FIGURE 5. A roll cloud was lying at the crest of the first wave. On the second rise the balloon disappeared behind the roll. The wave motion has been deduced by subtracting the average ascent rate from the height-distance curve. Note that the azimuth varied only thirteen degrees.

A series of soundings over a period of 2½ hours is shown in FIGURE 6. Although the base of the inversion was 700 feet at 0700 PST, conditions were changing rapidly and the inversion had risen to 3500 feet by 1900 PST. The series shows that in the lower levels the wind was veering into a normal sea breeze situation whereas the wind above the inversion was backing into the South Southwest.

Two soundings were taken on April 6, 1954, with different ascent rates. FIGURE 7 shows a horizontal run of about three miles showing the effects of ascending and descending air currents without the formation of a wave, due to the instability of this lower layer. FIGURE 8 with a greater ascent rate compares a regular pibal taken by SAN, Lindbergh Field, San Diego, about five miles eastnortheast, with the stadia pibal 43 minutes later. The variability in ascent rate of the

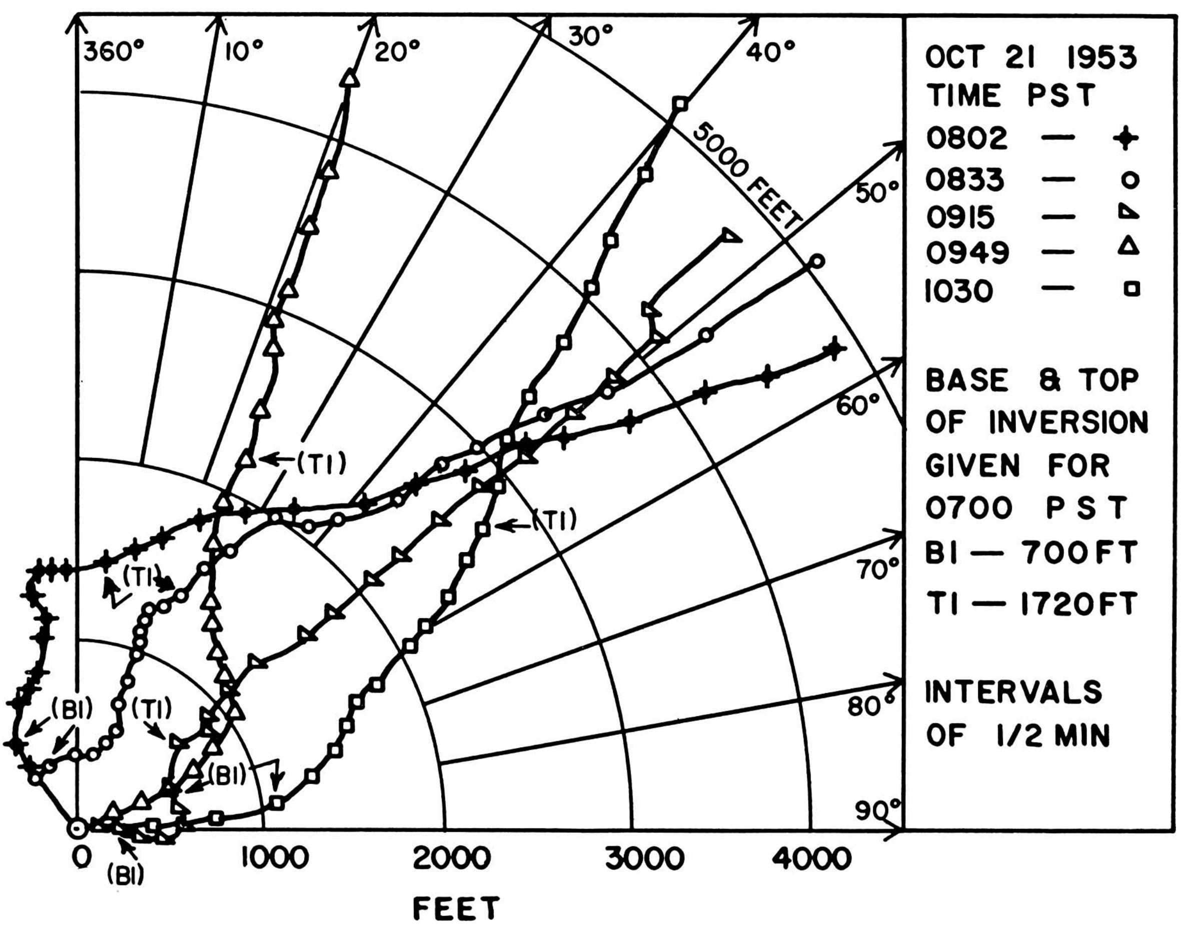

FIG. 6. Horizontal projection of balloon runs, October 21, 1953.

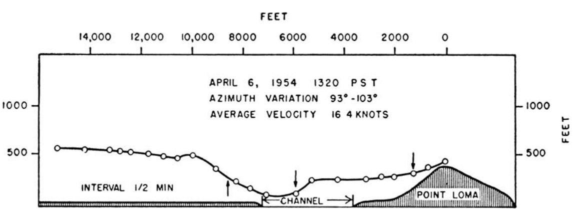

Fig. 7. Height-distance graph in an unstable layer, April 6, 1954.

stadia pibal is noticeable by the change in vertical spacing between points. The radiosonde plots for 0700 and 1900 PST are included to compare with regions of highest variability of wind structure and associated turbulence.

Two projections of a sounding are shown in Figures 9 and 10. This balloon run was taken about midway between the 0700 and 1900 PST radiosondes from SDV. The base and top of the inversion at 0700 and 1900 PST are indicated together with an estimated height of the base at 1300 PST (Johnson [3]). It is to be noted that if this estimate is nearly correct, a reverse flow

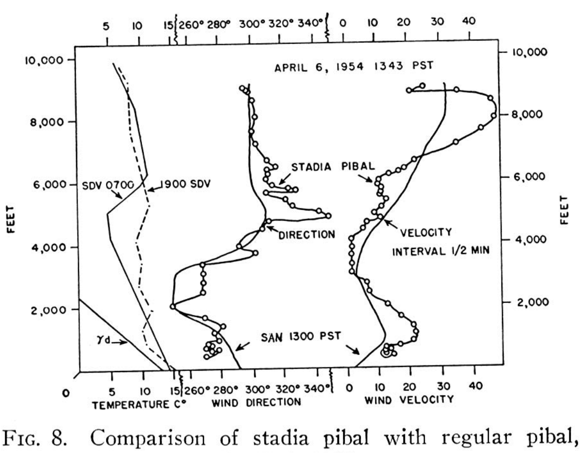

Fig. 8. Comparison of stadia pibal with regular pibal, April 6, 1954.

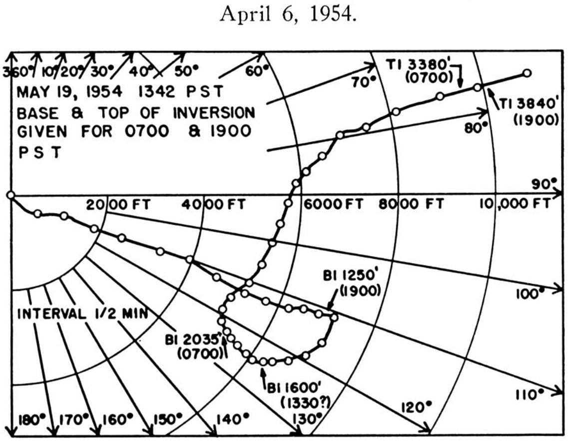

Fig. 9. Horizontal projection of balloon run, May 19, 1954.

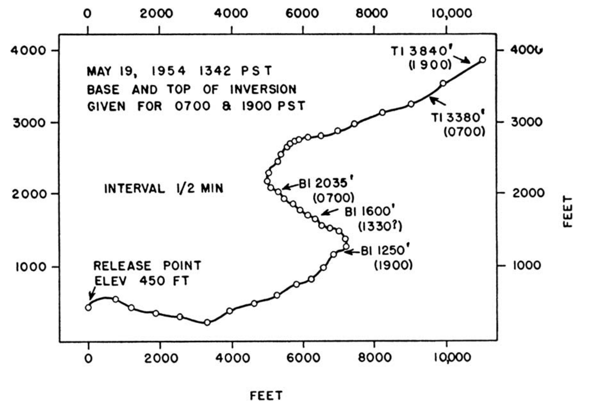

Fig. 10. Height-distance graph of balloon run, May 19, 1954.

exists just below the inversion base and in the lower part of the inversion layer as a counter current to the sea breeze. The 1300 pibal from SAN shows a gradual shift into southsouthwest in this layer (SAN surface 290/07; 1000 ft 320/05; 2000 ft 240/04; 3000 ft 270/03; 4000 ft 210/06).

6. Conclusions

The foregoing examples demonstrate the detail of air flow obtainable from the stadia pibal method. It is believed that this method should prove to be a useful tool for experimenters in the micrometeorological field.

7. Acknowledgment

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[3] Johnson, W. R., 1953: "Diurnal Height Variation of The Temperature Inversion in Southern California," *Technical Bulletin, 3rd Weather Group,* Air Defense Command, Vol. 1, No. 2, pp. 1–6.

[4] *The Measurement of Upper Winds by Means of Pilot Balloons,* M. O. 396, Meteorological Office, Air Ministry, London, 1936.

[5] "Tail Method, Principle and Preparation," in: *Weather Station Handbook for The Observer,* TM 1-235, War Department Technical Manual, May 1945, Chapter III, pp. 29–31.