Letters to the Editor

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ESTIMATION OF CLOUD HEIGHTS AT SUNRISE/SUNSET

Clouds are the visible manifestations of atmospheric processes. As such, cloud observations have been systematically recorded at many places over the world for over a century. Cloud type and amount observations have been fairly accurate. However, visual estimation of heights is very subjective and in the case of medium and high clouds often erroneous. Recent studies based on jet aircraft reports indicate that cirriform clouds and cumulonimbus tops, encountered in flight are actually much higher than the estimates of ground-observers (Deshpande, 1964, 1965). The error is sometimes as high as 15-20,000 ft in the tropics.

2. In the case of the low and medium clouds, the observer is able to judge cloud heights in relation to topographic features such as hill-tops. However, no such reference points are available for estimating heights of clouds in the upper troposphere. Accurate cloud-height observations are essential to aviators for safe navigation. Poor visibility, icing, severe turbulence or even hailstorms sometimes encountered in clouds are great flying hazards. At present the sub-sonic jet aircraft cruise in the upper troposphere while in a few years supersonic transports will have to climb or descent through the tropopause. Clouds near the tropopause may affect the performance of jet aircraft, particularly SSTs. Any aid for the better estimation of cloud heights to ground-observers has, therefore, considerable operational significance.

3. Sun's rays light up mountain tops earlier than valleys in the mornings and fade later from the tops in the evenings. To an observer at a height the sun is visible when it is actually some distance below the horizon of a sea-level observer. From any height, the sea-horizon is below the horizontal by an angle called 'Dip'. The value of the dip of the visible horizon for any height can be easily calculated. It is required to be corrected for refraction and the semi-diameter of sun to find the times of sunrise or sunset. Air Almanac (1965) provides graphs to find correction to the tabulated times of sunrise and sunset at ground level for various declinations and depressions of the sun below the horizon at different latitudes. Using these graphs, values of extension of duration of sunlight with increasing height over Indian latitudes have been calculated for all days in the year. Fig. 1 gives these values for the latitudes 10°N to 30°N at 5-degree intervals and for heights from 10,000 to 60,000 ft. To find the height of any cloud at sunrise/sunset, the observer has simply to note the difference between the times of sun's rays first lighting up the clouds and the ground in the morning and in the evening the time difference between the sunset at the ground and fading of sun's rays from the clouds. In the graph of appropriate latitude (Fig. 1), the height corresponding to the date (abscissa) and the time interval (ordinate) will be the height of the cloud.

4. In the above method, the times of sunrise or sunset at the ground refer to a station directly below the cloud under observation. If the cloud is not overhead, these times have to be calculated. If the clouds are to the east, the sunrise and sunset at a point directly below the clouds will be earlier, while if the clouds are to the west these will be later than those at the observation point. For each degree longitude, (roughly 69 miles), the sunrise/sunset time differs by four minutes.

5. An actual example is given below to illustrate the above method.

A towering *Cb* cell was observed about 20 miles west of Bangalore on 25 July 1965. The times of sunset at Bangalore and of fading of sun-rays from the *Cb* top were 1849 and 1910 IST respectively. The sunset time at a point directly below the *Cb* cloud would be later than at Bangalore by $(4\times20)/69=1\cdot2$ minutes, *i.e.*, it would be $1850\cdot2$ IST. The time interval between the sunsets at the *Cb* top level and at the ground directly below is, therefore, $19\cdot8$ minutes. For the date and time interval, Fig. 1 indicates the height of *Cb* as 50,000 ft.

6. The method suggested above is subject to three limitations. Civil twilight may sometimes illuminate the cloud base or top as distinct from illumination by direct sunlight after the sea-level sunset or before sea-level sunrise. Secondly it may be difficult on some occasions to observe the actual time of sunrise/sunset at the cloud level if intervening cloud layers screen off the sun's rays or if the visibility is poor. It enables the observer to estimate cloud heights only twice a day, namely at

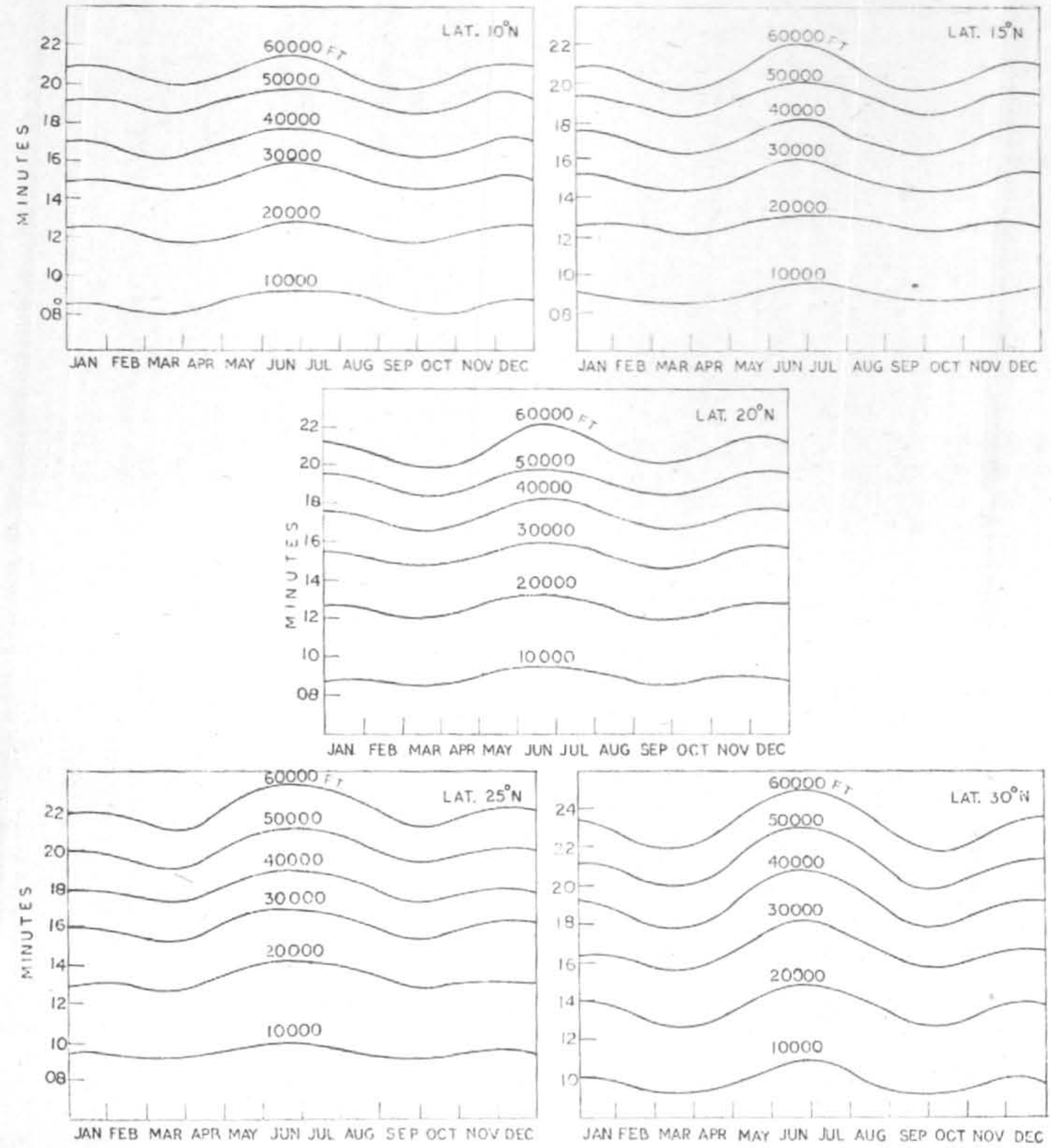

Fig. 1. Extension (in min.) of duration of sunlight by increasing height (ft) at different latitudes

***To find height of cloud*:**

1. Note the time difference (minutes) between sunrise/sunset at the cloud and the ground below.
2. Refer to the graph for the nearest latitude.
3. Read off the height (in feet) corresponding to the date and the time-difference. (10,000 ft = 3048 metres)
4. If the cloud is not over-head, calculate the time of sunrise/sunset at a point directly below the cloud, by applying a correction of 4 minutes for every 69 miles due west/east of observation point.

sunrise and sunset. Nevertheless under favourable atmospheric conditions, cloud height measurements using the method are possible. The method is simple and inexpensive. As only time differences are involved it is fairly accurate. It is felt that regular attempts made by weather observers to use the method will give them valuable training in estimating cloud heights more accurately than at present.

7. My thanks are due to Shri N. C. Lahiri for scrutiny of the data.

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