barriers on the lee shore, even if quite open on the windward shore, for the barrier effect spreads back across the river and pilots the wind along the windward shore, that being the line of least resistance.

Refraction should be evident where there is only virgin water to leeward and the shore is rough, *i.e.* it is covered with vegetation or other protuberances of various kinds.

In the evening along a rough shore, which stoops down to the water's edge and does not allow the wind to slide over a shoreside zone of mud-flats or sand, etc., perhaps refraction may be such as to produce a 20° change of direction, but by day, and especially when the airstream is unstable, the effect must be negligible.

OTHER SHORE EFFECTS That the shore-line is the seat of wind shifts which are permanent is undoubted, but they are more likely to be induced by local thermal effects or by katabatic or anabatic winds over steepish shores than by refraction. The two latter effects both contribute to winds tending to flow more directly offshore or on-shore.

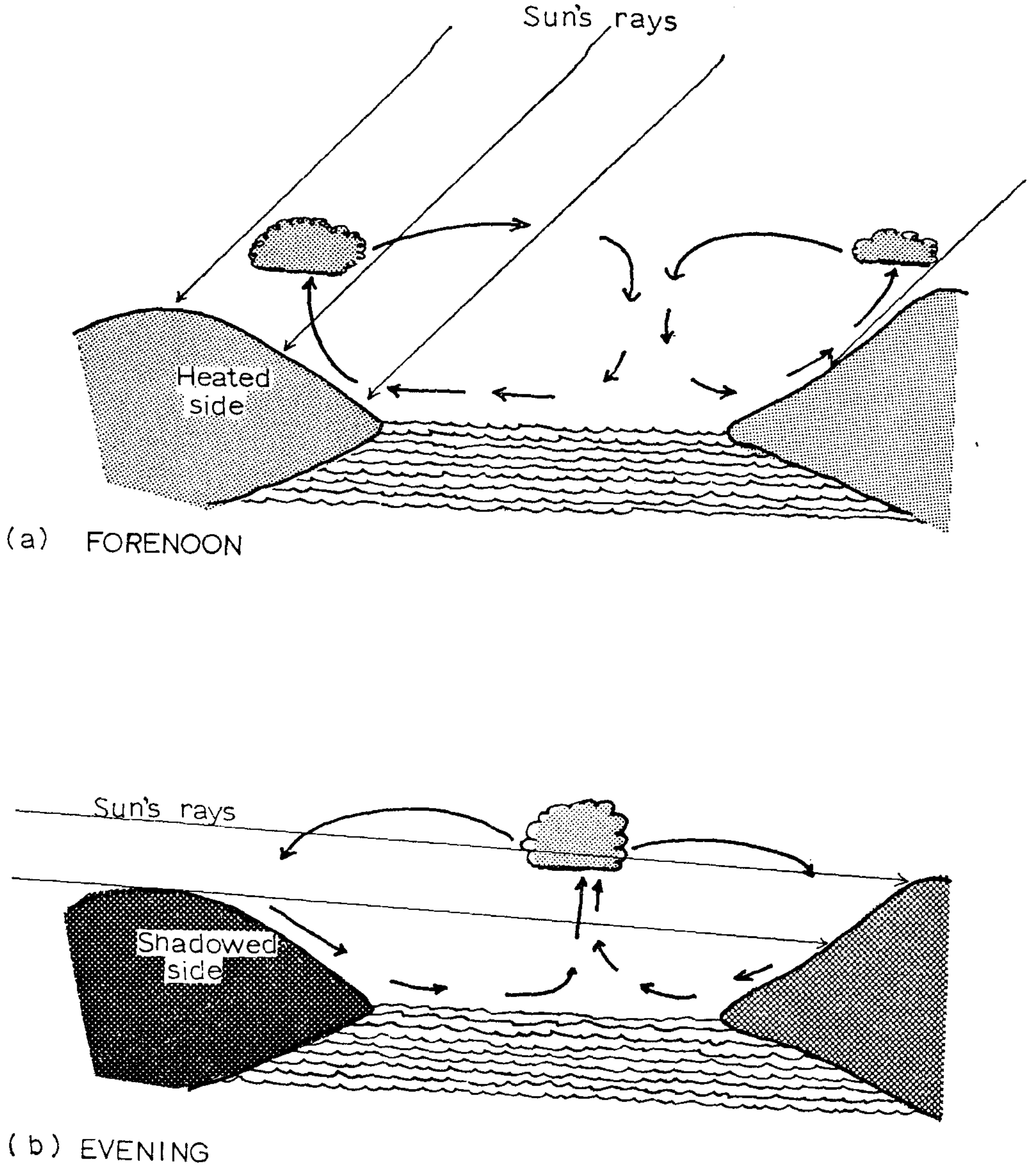
When steep shores stand in the sun thermals occur, and the compensating flow must come off the water. This moist onshore flow can be the strongest form of thermal feed, for it is cool and dense. Thus the thermally induced onshore components may be relatively strong and light or even moderate winds can have the effect impressed on them. The air feeding the thermal "balloons" must slide up very steep-to shores and such upward motions are called anabatic as opposed to katabatics which flow down. In the evening or when the sun has left a steep shore a katabatic will occur, and this downflow will tend to be straight offshore. Lakes and lochs are the places for such katabatic effects to reach their greatest development. See Figs. 5.27 and 5.28.

MOUNTAIN AND VALLEY WINDS Wherever there is enough water there will be boats, and so lakes in mountainous districts and at the foot of mountain valleys, as well as lochs and fiords, will have their complement of craft and their own special winds as well.

The simplest case to describe is the wind over a stretch of water between steeply ascending sides as in Fig. 5.27*a*. During the day the slopes and upper portions of the mountains enclosing the lake, etc., will be warmed, and upslope (anabatic) winds will occur with compensating down-currents in the lake centre. In the forenoon east to south-facing slopes will be the major seat of onshore wind due to anabatics while west-facing slopes will remain relatively cool. Air flow will tend to be from the shadowed side to the sunlit side. It has been found that the shading of a portion of a slope up which an anabatic is ascending immediately affects it, weakening it and perhaps diverting the airflow towards the more strongly lit areas nearby.

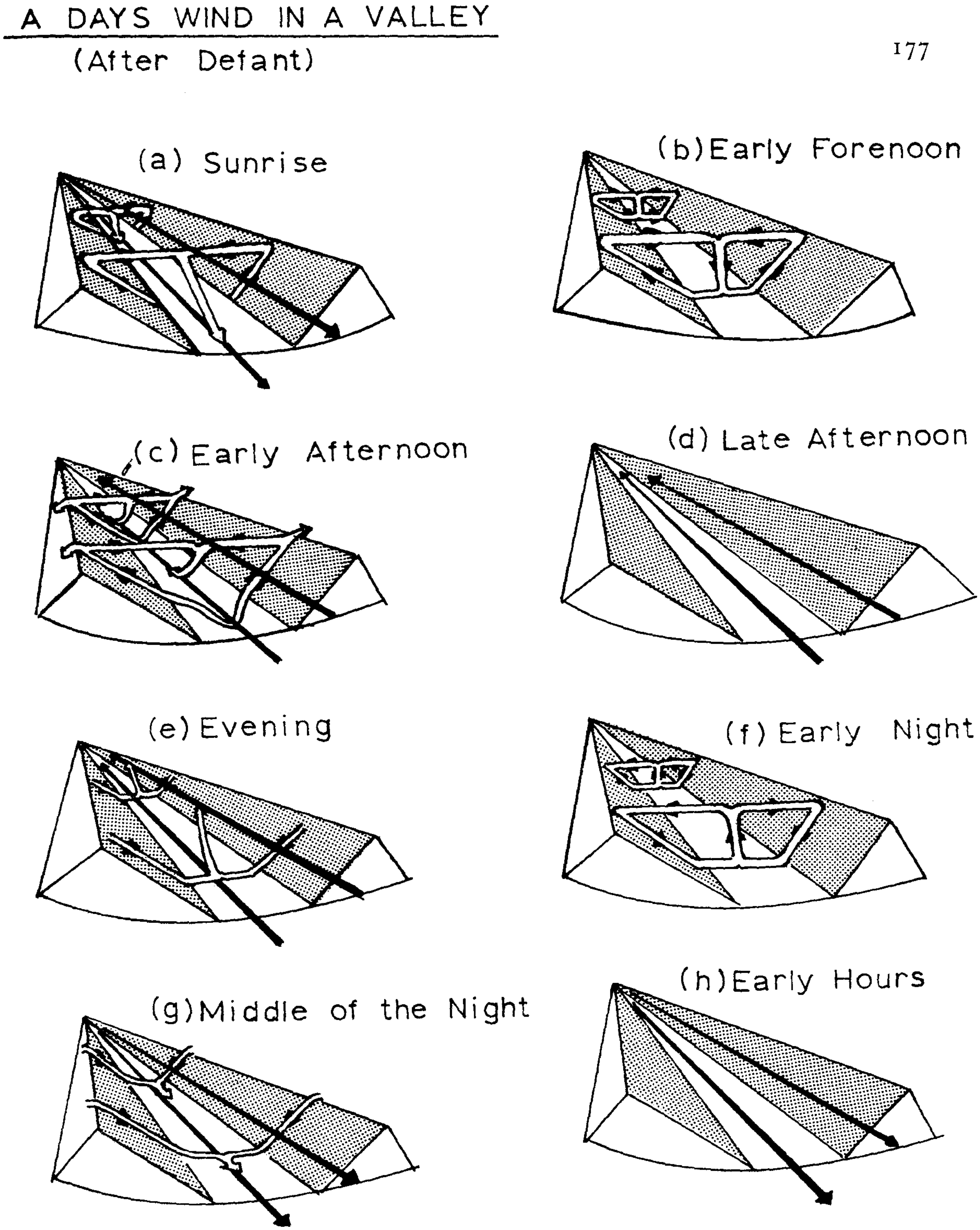
The evening drawing (Fig. 5.27*b*) shows the tendency to stronger offshore flow on the shadowed side. That is off the east-facing slope which is shadowed early in the evening. The visual evidence of such motions is the appearance of cloud over the rising currents, *e.g.* cloud-streets over the ridges by day and cloud backbones along the valley axes by night. Lack of cloud also tells its tale. Wherever the air descends strongly there will be no cloud.

The upslope winds commence as soon as the sun is up and reach their maximum in the middle of the day. Their downslope counterparts get under way immediately after sunset.



5·27: *Tendency for wind over lakes in light weather.*

This sideways flow is predominant on lakes closed by the mountains, but when the sailing area lies at the open end of a valley which rises in ridges to a mountainous interior axial flow along the valley floor is the more prevalent wind. In the Alps, for example, a



5.28: *In big valleys the winds will be a mixture of upslope-downslope and mountain or valley wind.*[23]

valley wind flows up the valleys from about 0900–1000 until sunset. By night the mountain wind reverses the direction and flows from the head of the valley.

There are thus two superimposed winds of thermal origin to be allowed for. As must be evident these will rarely be in phase. A morning wind in a valley with a north–south axil will have (if there is no strong opposing wind due to large-scale pressure patterns) a valley wind along its axis, and superimposed on this will be an upslope wind orientated towards the sunlit western slopes. The resultant wind will be skewed into having westerly components, but these will obviously vary with the nature of the terrain. This is such a difficult problem that the only thing to do is to reproduce more or less faithfully some drawings by a German oceanographer F. Defant which originally illustrated a study he made of these winds.

In Fig. 5.28*a* the mountain wind still blows down the valley while katabatic winds sink off the slopes. It is sunrise. By 0900 or thereabouts the mountain wind has fallen calm, while the upslope winds have commenced. The lake wind will be predominantly an onshore flow and weak at that (Fig. 5.28*b*). In the early afternoon (Fig. 5.28*c*) the valley wind has developed and the upslope wind has built to its maximum with compensating backbone downcurrents. In Fig. 5.28*d* it is late afternoon and the upslope winds have ceased, but the valley wind is still blowing at reduced strength. In the evening the downslope winds set in while the valley wind falls to nothing. The lake wind is now predominantly offshore and a cloud backbone may begin to appear over the rising currents in the middle (Fig. 5.28*e*).

Moonlit sailing in such enchanted surroundings will be aided by winds such as in Fig. 5.28*f* during the early night and reinforced in the middle of the night by the mountain wind which by the early hours (Fig. 5.28*h*) is left alone to sink coolly towards the plains.

FLOW IN THE LEE OF RIDGES Mountain and valley winds are a phenomenon of settled weather, and they sink to nothing if the sky is overcast. What happens, however, when the moderate or strong winds blow obliquely over an upwind ridge and the sailing site is in the lee?

What *can* happen is illustrated in Fig. 5.29. With relatively light winds, whose speed does not change very much with height, laminar streaming may be the rule. This requires fairly gentle hills and a stable airstream. So an airstream of tropical origin flowing over downs, for instance, could produce this sort of flow. The whole airstream might well be cloudy.

Standing-eddy streaming is a big brother of the dense barrier flow discussed in Chapter Four. It likewise has a stationary roller in the lee, and under it surface winds can be towards the hills even when the forecast is for winds in the diametrically opposite direction. The situation, which is more easily recognised than either of the above, is when standing waves develop down-stream of the ridge. Such ridges do not need to be very high. A sharp set of craggy peaks are not as effective as more modest hills with relatively gentle upslopes stretched athwart the wind.

Roll clouds form some 2 to 20 miles downwind of the ridge, and the first of these is closer to the ridge than the second roller is to the first. Under these roll clouds the winds can be very variable and quite unpredictable. They can often be seen being shredded and torn by the rotating winds. Over them, at as much as 20,000 ft, lie the truly characteristic clouds of lee waves—altocumulus lenticularis to give them their full and explanatory