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SHORT CONTRIBUTION

Diurnal variation of California coastal stratocumulus from two days of boundary layer soundings

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ABSTRACT

Boundary layer soundings show the diurnal variation of California coastal stratocumulus. During the period of solar heating, cloud base rises and the cloud layer thins, while the subcloud layer becomes more stable, suggesting some daytime uncoupling of the cloud layer from the surface.

1. Experiment

A cross-chain Loran atmospheric sounding system (CLASS) was installed on San Nicolas Island (33.3°N, 119.5°W) off the southern California Coast for the First ISCCP (International Satellite Cloud Climatology Project) Field Experiment (acronym FIRE) to study the stratocumulus boundary layer (Albrecht et al., 1988). 69 high resolution soundings were taken during a 3-week period (Schubert et al., 1987a) and continuous ceilometer data showed the time variation of cloud-base (Schubert et al., 1987b). During a 2-day period (10–12 July 1987) of light winds, (<5 m s^{-1}) associated with a so-called "Catalina eddy" in the low-level flow (Bosart, 1983), a subset of 20 soundings were launched at more frequent intervals. These were the only 2 days of high-frequency soundings. On both days, the ceilometer showed a similar rise of cloud-base during the day and fall at night. These soundings were grouped into 6-h blocks of time (with 5 soundings in each category) to examine the diurnal variation in the boundary layer thermodynamic structure. With solar heating of the cloud layer during the daytime, cloud-base rises, the cloud layer thins and the subcloud layer warms and becomes more stable. This indicates some uncoupling of the cloud layer from the surface as discussed by Nicholls (1984), Nicholls and Leighton (1986), Turton and Nicholls (1987), Bougeault (1985), and Boers and Betts (1988).

The archived thermodynamic data at 5 m vertical resolution were reduced to 25 m by averaging. The four 6-h time blocks for averaging were in local (Pacific Standard) time (2300–0500), (0500–1100), (1100–1700) and (1700–2300 PST), corresponding roughly to night, morning, afternoon and evening averages.

2. Results

Table 1 gives a data summary showing the time blocks for the data, the mean sounding times and other parameters from Figs. 1, 2 and 3. Fig. 1 shows the variation in cloud-base from the ceilometer, cloud-top estimated from the sounding inversion base, the average lifting condensation level (LCL) pressure for air between 300 and 500 m above the surface (all in the subcloud layer) and the LCL of air at 100 m near the surface. The night-time data near 0300 PST is repeated again 24 h later to give a clearer picture of the diurnal curve. There is a rise of cloud-base during the day and a fall at night. Cloud-top does not rise, so the cloud layer thins from about 28 mb in mean thickness at night to only 4 mb in the afternoon. A similar mean diurnal variation in cloud thickness, and the associated cloud liquid water content, was observed during the

Table 1

Data group (PST)	Mean time (h)	Base (ceilometer) (m)	Base (ceilometer) (mb)	Top (sounding) mb	LCL (100 m) mb	LCL (300–500 m) mb	θ_v (100–500 m) K	$\Delta\theta_v$ (500–100 m) K
2300–0500	3.4	557	946	918	937	939	289.8	0.23
0500–1100	8.3	634	937	926	945	932	289.9	0.61
1100–1700	14.4	734	925	921	945	926	291.1	0.82
1700–2300	20.0	607	939	929	946	935	290.7	0.52

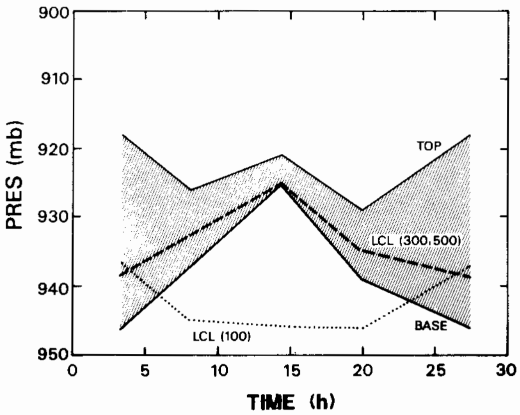

Fig. 1. Diurnal variation of cloud-base and cloud-top pressure (solid; cloud layer is shaded), and lifting condensation level pressure (LCL) of 300–500 m layer mean (dashed), and LCL of air at 100 m (dotted).

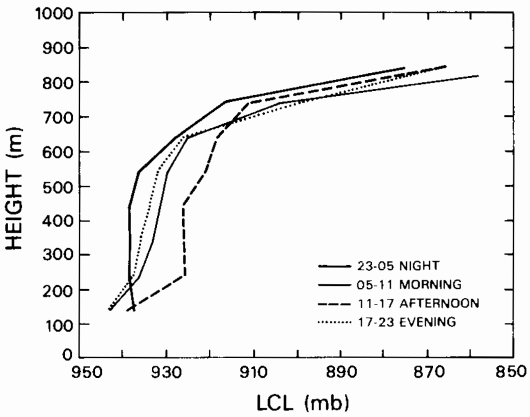

Fig. 2. Variation of LCL pressure with height for 4 averages: night (heavy solid), morning (light solid), afternoon (dashed) and evening (dotted).

whole experiment (Davies and Blaskovic, 1988; Snider, 1988). The mean LCL from 300–500 m agrees quite well with the observed cloud-base, but the 100 m LCL shows a very different variation. This is because the stratocumulus becomes uncoupled from the surface during the daytime. Fig. 2 shows the vertical profile of LCL pressure against height (from which air is lifted) for the 4 averages. The soundings have been further averaged to a 100 m vertical resolution. The night-time profile shows a nearly well-mixed structure in LCL, but during the daytime, a gradient in LCL develops in the subcloud layer, with a clear uncoupling in the afternoon between an upper nearly mixed layer and the surface layer.

Fig. 1 shows that the ceilometer cloud-base is generally lower than the sounding mean LCL of air from 300–500 m. The ceilometer is probably the more accurate estimate of cloud-base, as its vertical resolution is 15 m, and the daytime sounding averages show an appreciable gradient in LCL from 300 to 500 m (Fig. 2). In addition, the sounding data has not been corrected for sensor lags (Schubert et al., 1987a), which typically lead to an underestimate of the humidity,

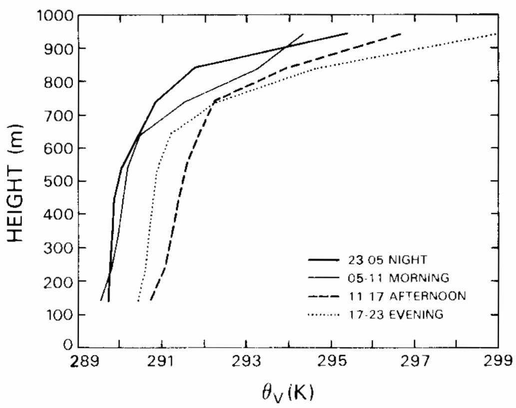

Fig. 3. As Fig. 2, for virtual potential temperature, θ_v, with height.

and a corresponding low bias of the LCL pressure of order 5–10 mb (Betts, 1976).

Fig. 3 shows the corresponding profile of virtual potential temperature, θ_v, with height for the 4 averages. The night-time average shows a neutral, well-mixed structure, but a warming and stabilization during the day is evident.

Table 1 shows the layer mean θ_v (100–500 m) and mean stability $\Delta\theta_v$, the difference in θ_v between 500 m and 100 m. The maximum mean temperature and stability is found in the afternoon after the peak in the solar heating.

3. Conclusion

The CLASS sounding data for 2 days, 10–12 July 1987, at San Nicholas Island show a clear diurnal signal, which confirms the suggestions of Nicholls (1984) and Nicholls and Leighton (1986), that the solar heating of the cloud layer can produce a warming and decoupling of the cloud layer from the surface. The rise of cloud-base of 200 m and stabilization of the subcloud layer during the daytime are consistent with the predictions of the models of Bougeault (1985), and Turton and Nicholls (1987).

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