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A Stratocumulus Thermodynamic Analysis: July 5 Case Study

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1. Introduction

On July 5 (NCAR Electra flight 4, Mission 186–G) the Electra flew a single aircraft mission which consisted of cross and along-wind legs at 6 different altitudes between 10:43 — 16:00 PDT (17:43 —23:00 GMT). The leg length was kept short (8–10 minutes) to permit maximum vertical resolution, and there were 8 soundings. Observer notes report a thin, solid stratocumulus cloud deck which gradually became more broken in the afternoon. Winds were from the north at 10 - 13 ms^{-1} throughout the flight.

This abstract presents sea surface temperature measurements and conservative variable analyses for several of the July 5 legs. These results are preliminary to a study of the thermodynamic budget on July 5; they indicate that:

1. The sea surface temperature dropped more than 1 K (from 17.3°C to 15.9°C) over the course of the flight (18:01 and at 21:51 GMT).
2. Mixing lines for each of the horizontal sub-cloud legs show the effect of a strong north-south gradient in SST. The source points for the observed mixtures have SSTs colder than those observed in the flight area.
3. There is a clear demarcation over a transition of 5–10 km between air to the south and cooler, (ΔT= —0.3°C) moister (Δr_v = 1 g/kg) air to the north. The FSSP measurements indicate there are small clouds/scud 250 m below cloud base on the cold northern side of this transition. The transition is seen in the saturation point diagrams at 984 mb, 959 mb, and 946 mb. There is no corresponding change in the horizontal wind across the transition regions.

2. Observations

Figure 1 shows the height/latitude cross sections of the flight tracks. Also shown is the time at the mid-point of the track, the pressure level (in mb), and the aircraft direction of travel. The stars indicate the location of the transition between air masses mentioned above in item (3).

Two minute averages of sea surface temperature measurements from two of the surface legs are shown in Figure 2a (18:01 — 18:21) and 2b (21:56 — 22:08 GMT). The technique of Liu and Katsaros (1980) has been used to correct for emission from overlying clouds. The SST measurements show a strong north-south SST gradient late in the flight, and a 1 K cooling (or 1 K radiometer drift) over the 4 hours of the flight.

An independent check of the SST measurement is provided by the mixing diagrams in Figures 3a and 3b. We have used the saturation point notation of Betts (1982), with (θ_*, Q_*) denoting the potential temperature and total water mixing ratio of air taken to its lifting condensation level. These variables mix linearly and are conserved under adiabatic transformations, i.e. air that is a mixture from two sources will have values of (θ_*, Q_*) that fall on a line between the two source points. The saturation points of 3 representative SSTs are also shown; it appears from these mixing diagrams that the surface air was originally cooler than the (θ_* Q_*) of the coldest 15.9°C observed sea surface temperature.

Also striking in both 3a and 3b is the separation of the saturation points into two distinct groups. The separation is observed in each of three sub-cloud legs. Figure 4 shows the temperature, mixing ratio, and droplet concentration measurements for the 984 mb penetration. The lower θ_* branch in Figure 3a is composed of points sampled over the last 2.5 minutes of the time series shown in Figure 4. The radiometric temperature measurement from the PRT6 is included. It indicates that the observed cooling is real, and not an artifact of thermometer wetting by the cloud droplets observed in the sub-cloud region.

References

Betts, A.K., 1983: Thermodynamics of mixed stratocumulus layers: saturation point budgets. *J. Atmos. Sci.*, **40**, 2655–2670.

Liu, W.T., and K.B. Katsaros, 1980. Preliminary analysis of the sea surface temperature variations during JASIN '78, *JASIN News*, **18**, 3–4.

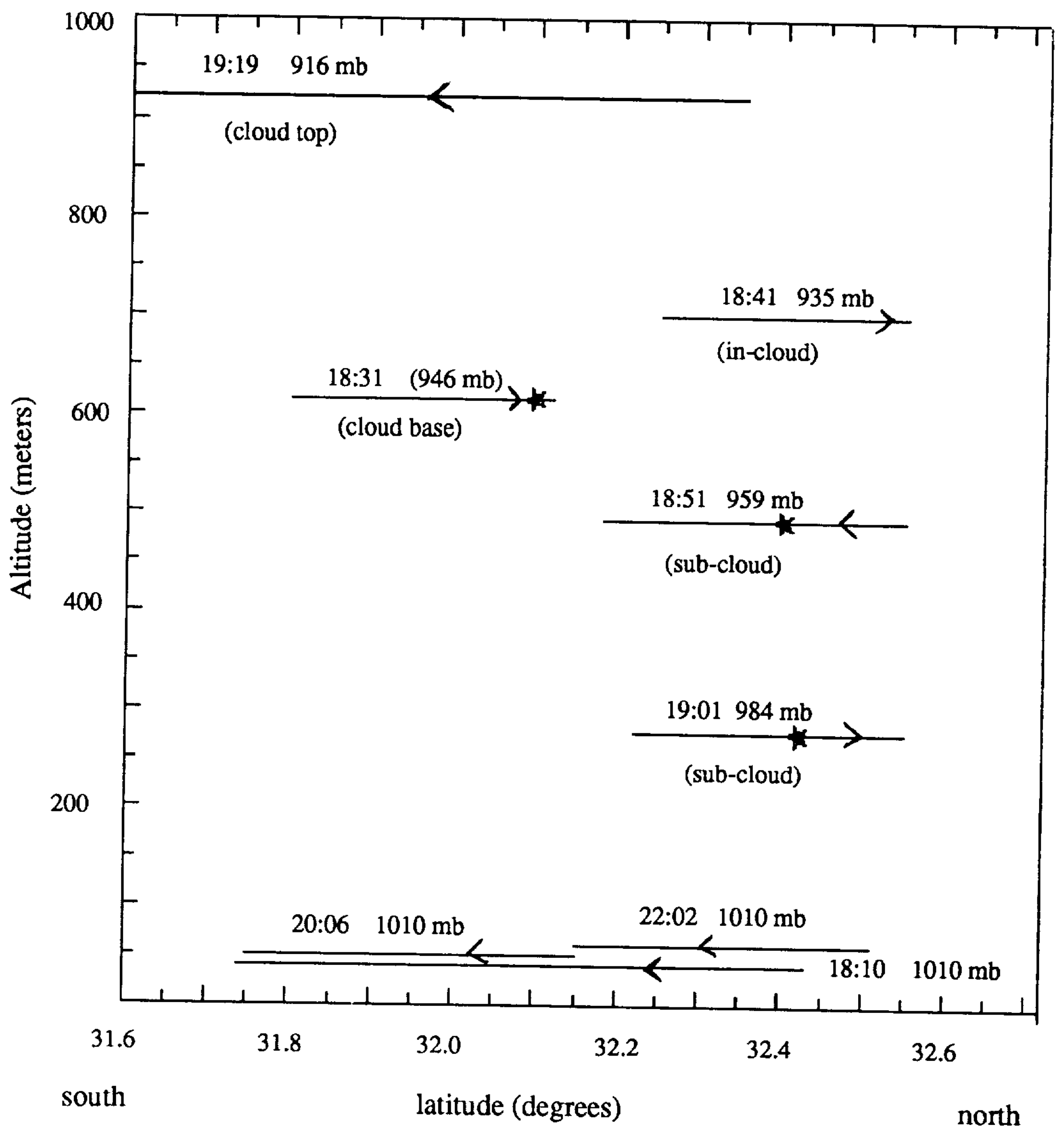

Figure 1 Height/latitude cross section of level Electra legs on July 5. Pressure at flight level, GMT time in the middle of the leg, direction of travel, and approximate location of cloud top and cloud base are noted. Stars indicated location of the transition from warm to cold region.

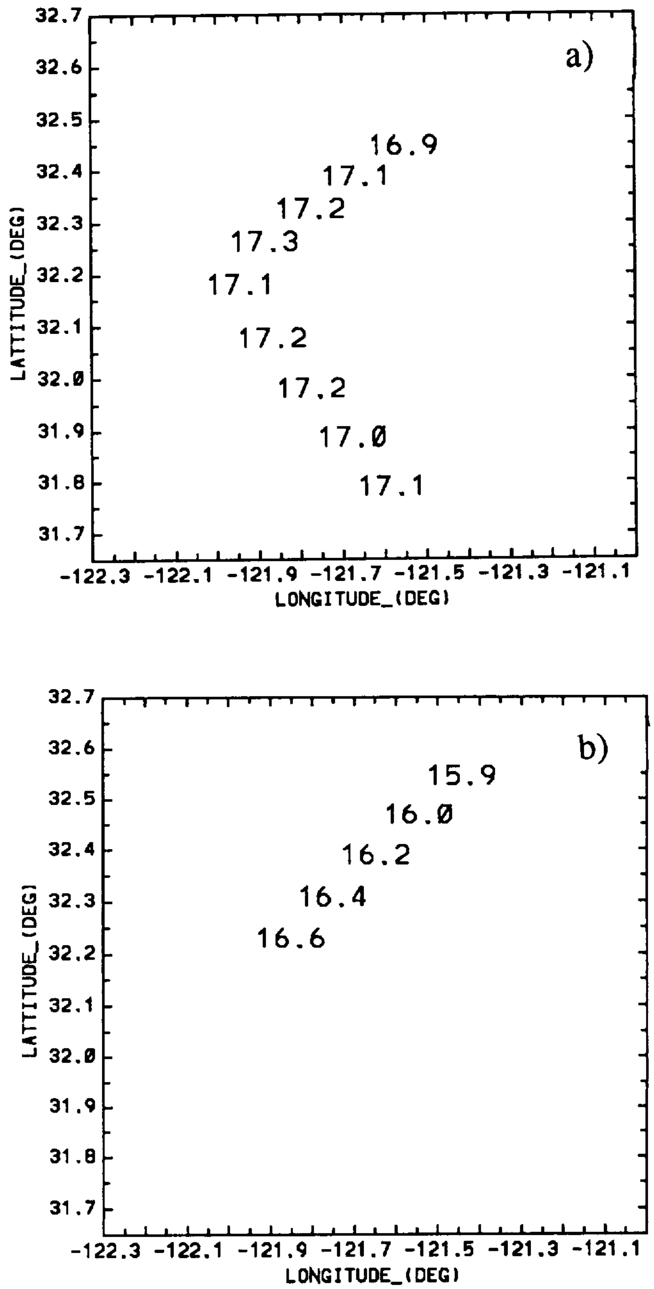

Figure 2 a). Two minute averages of SST (°C) from the 1010 mb leg 18:01 — 18:21 GMT. b) As in a), for 21:56 — 22:08 GMT

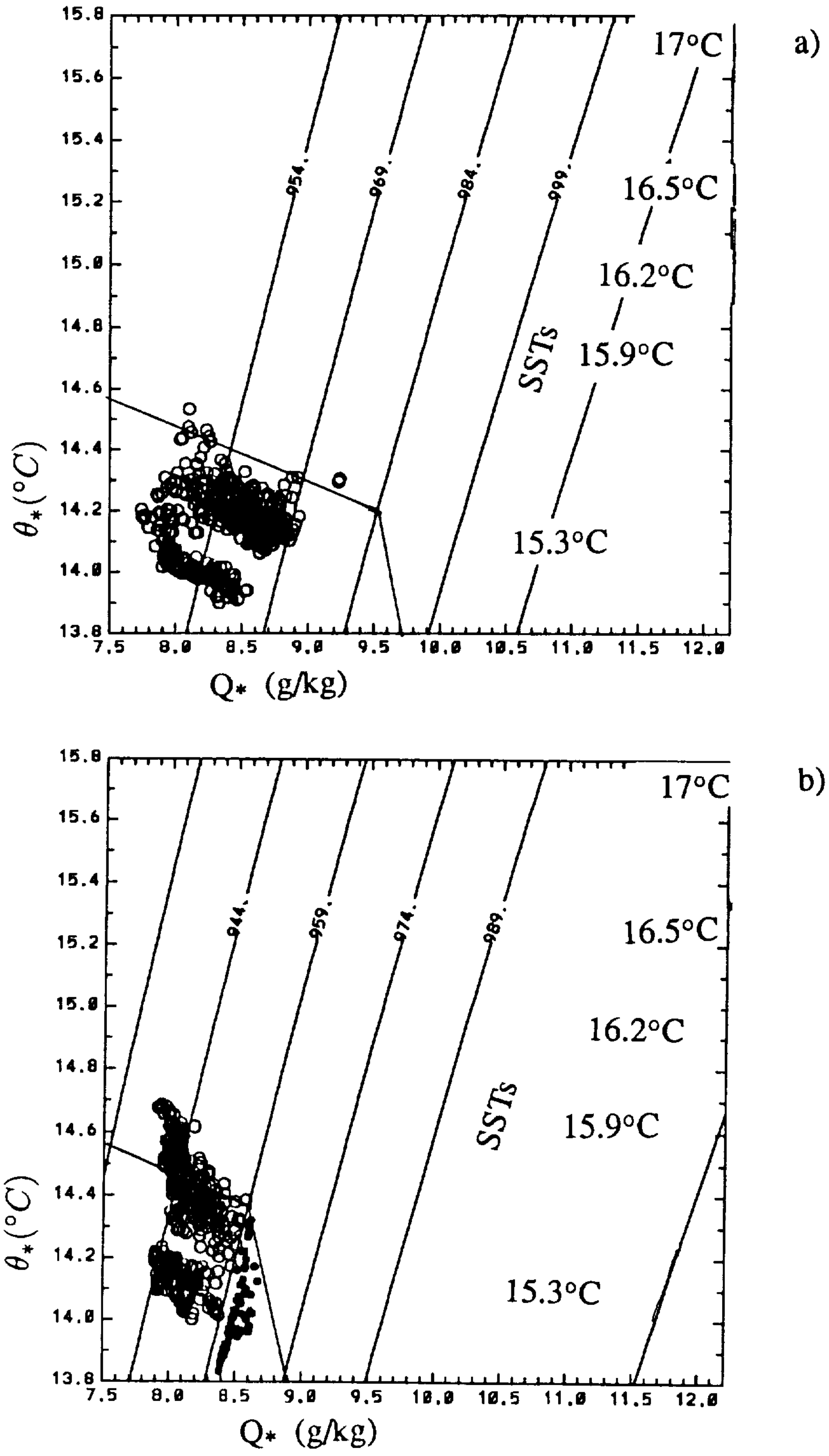

Figure 3 a) $\theta_* - Q_*$ diagram for the 984 mb leg (18:57–19:05 GMT). Saturation points for SSTs from Fig. 2 are also shown. The 289 K θ_v density isopleth is given for reference. b) As in a), but for the 959 mb (18:47 — 18:55 GMT) leg. Unsaturated points are denoted by open circles, saturated points by dots. θ_v isopleth is 289 K

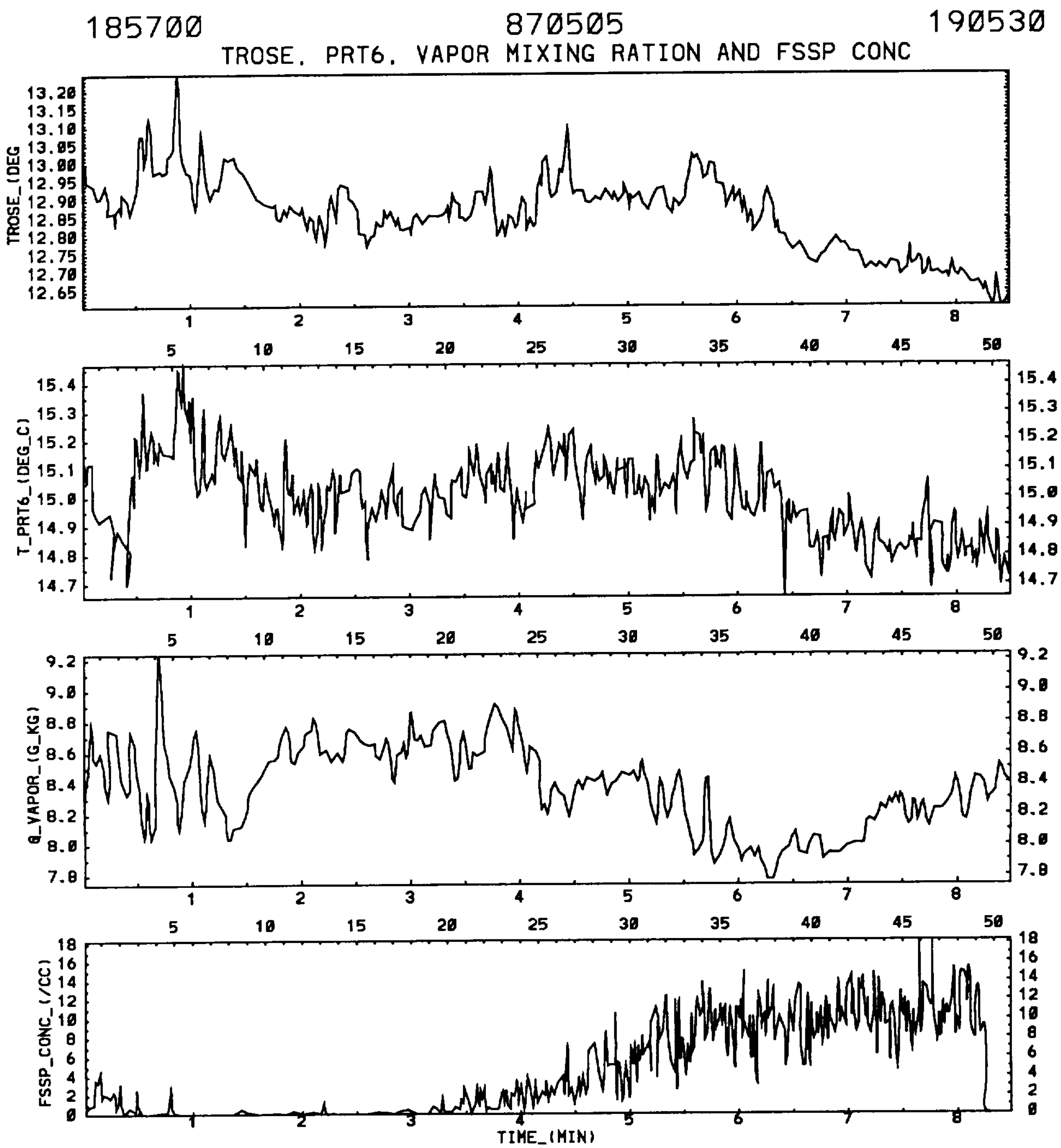

Figure 3 Time series of a) Rosemont temperature, b) PRT6 radiometric temperature, c) Vapor mixing ratio (from top Cambridge dewpoint thermometer) and d) FSSP droplet concentration for the 984 mb leg shown in 3a. Top abscissa label is distance (km).