NRL TETHERED BALLOON MEASUREMENTS AT SAN NICOLAS ISLAND DURING FIRE IFO 1987

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1. Introduction

This presentation gives an overview of the tethered balloon measurements made during the FIRE marine stratocumulus IFO at San Nicolas Island in 1987. The instrumentation utilized on the balloon flights, the 17 flights over a 10 day period, the state of the data analysis, and some preliminary results are described.

A goal of the measurements with the NRL balloon was to give a unique and greatly improved look at the microphysics of the clear and cloud-topped boundary layer. For this goal, collocated measurements were made of turbulence, aerosol, cloud particles, and meteorology. Two new instruments which were expected to make significant contributions to this effort were the saturation hygrometer (Gerber, 1980), capable of measuring 95% < RH < 105% (with an accuracy of 0.05% near 100%), and used for the first time in clouds; and the forward scatter meter (Gerber, 1987) which gives in situ LWC measurements at more than 10 Hz.

Due to technical problems the tethered balloon was not functional until 15 July, near the end of the IFO period. This permits only several days of intercomparisons with the measurements collected by other FIRE investigators at SNI (Davidson, Pt. Sur; Hanson, Electra; Fairall, wind profiler and photometers; Snider, microwave radiometer). Balloon measurements were made for an additional week after the other FIRE investigators had left. Several flights were made upwind of SNI by the NOSC aircraft during that week.

The meteorology during the additional week following 19 July was characterized by several episodes of fractional Sc cloud cover, which were mostly missing earlier in the IFO period. Two such episodes occurred on the morning flight of 23 July when the cloud cover was rapidly decreasing, and on the morning flight of 24 July when the opposite trend occurred. A study of the relationship between turbulence and microphysics for these two fractional-cloudy cases would address a goal of FIRE: to understand the factors which cause the formation and evolution of fractional Sc cloud cover.

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2. Experimental Aspects

The instrumentation which was flown on the tethered balloon is listed in Fig. 1, and the method by which it was attached to the balloon is shown. Most instrumentation was mounted on a pallet hung 35m below the balloon. The motion of the pallet was not constrained, except for being pointed into the wind with a large wind vane. Two flux gate magnetometers, two inclinometers, and altimeter form a positioning system with which an orthogonal transformation of the velocity vector measured by the bivane can be made to correct for the motion of the pallet. The motion of the pallet during flight was well behaved. With a high degree of persistence, the intermittent motion of the pallet was perpendicular to the direction of the wind with a period of oscillation of 11.8 s.

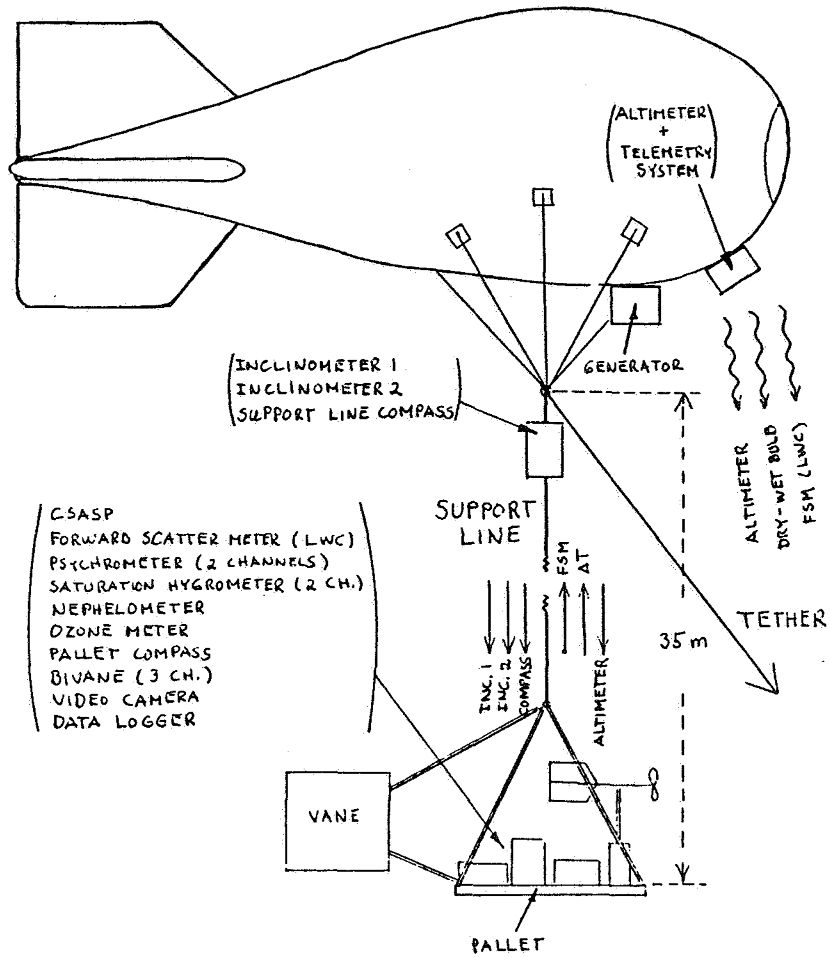

Fig. 1 - List and mounting locations of instrumentation carried on the tethered balloon. Arrows indicate data flow.

Data was collected at either 5 Hz or 1 Hz. Several data channels were in addition telemetered to the surface where they were logged at 0.3 Hz.

The typical flight of the balloon lasted 3 hrs., with an initial ascent of 0.5 m/s to the free atmosphere above the boundary layer, and with a stepwise descent consisting of about 25 min. holds at several levels to obtain turbulence statistics. The 17 flights are summarized in Table 1.

Table 1. Balloon Flight Date, Time, Duration, and Local Meteorology.

No.	Date (July)	Duration of Flight	Cloud Cover	Wind Dir.	Sfc. Wind (m/s)	Inversion Ht. (m)
1	15	1511-1707	10/10	NW	7	640
2	16	0900-1140	10/10	W	2	760
3	16	1737-1930	10/10	W	2	-
4	17	1100-1415	10/10-5/10 (d)	NW	9	1070
5	18	0735-1115	1/10	WNW	2	670
6	18	1407-1552	0/10	NW	5-7	400
7	19	0522-0706	<1/10	NW	5-7	335
8	19	1332-15559	<<1/10	NW	2-4	460
9	20	0817-1013	6/10-1/10 (d)	WNW	5-7	640
10	20	1803-1945	0/10	WNW	5	-
11	21	1305-1535	0/10	WNW	<2	-
12	22	1744-1946	0/10	NW	7	380
13	23	0952-1225	8/10-1/10 (d)	NW	9	640
14	23	1518-1648	0/10	NW	9-13	-
15	24	0756-1101	6/10-10/10 (i)	NW	7-9 (d)	550
16	24	1723-1945	1/10-4/10	NW	9	360
17	25	0815-1026	1/10-5/10	NW	7	400

(d = decreasing, i = increasing)

3. Data Reduction and Quality

This large raw data set has been reduced to a stage where analysis of any variables for any of the flights is practical. Algorithms have been developed for use during analysis, and the variables have been stored in separate data files for easy access. The data files are stored in compressed form on 1.2 Meg floppy disks which can be ready by IBM PCs of compatibles; copies of the disks are available to FIRE investigators.

Use of the data requires careful attention to its quality, because not all instruments operated properly all the time: No useful data resulted from the ozone meter. For condensing conditions RF interference caused the data channels which are both telemetered and logged on the pallet to be noisy on the pallet logger. The forward scatter meter was over ranging on the first several flights. During flight 4 where a great deal of drizzle occurred the saturation hygrometer failed, and on some other flights drift in the sensor was noticed; however, useful data was collected. Only a limited record was obtained with the video camera, the best was for flight 13. The CSASP particle spectrometer and other sensors functioned properly throughout. On flight 2 all data except that telemetered was inadvertently lost.

4. Results

The data analysis is just commencing so that very few results are presently available. Examples of the measurements are shown in Figs. 2 and 3 which give respectively the 5 Hz data for LWC from the forward scatter meter, and the RH from the saturation hygrometer. Both profiles are for the ascent of flight 13 when a fractional cloud cover of Sc was in the process of dissipating. Figure 2 shows the cloud layer extended from 500m to 650m, and that the LWC profile was very different from the adiabatic LWC profile. Figure 3, as well as the other data, shows that RH within the cloudy air ranges from about 99.5% to 100.2%, and that deep layers of subsiding air exist in the clouds where RH < 100%. The large sub- and supersaturated conditions suggested by Curry (1986) for Arctic stratus were not seen in the marine Sc. In Figure 3 the supersaturation peak at the top of the main cloud at 625m is consistent with radiation-forcing calculations of Davies (1985); although, the cause of the peak due to a strong updraft cannot be ruled out until the w field is analyzed.

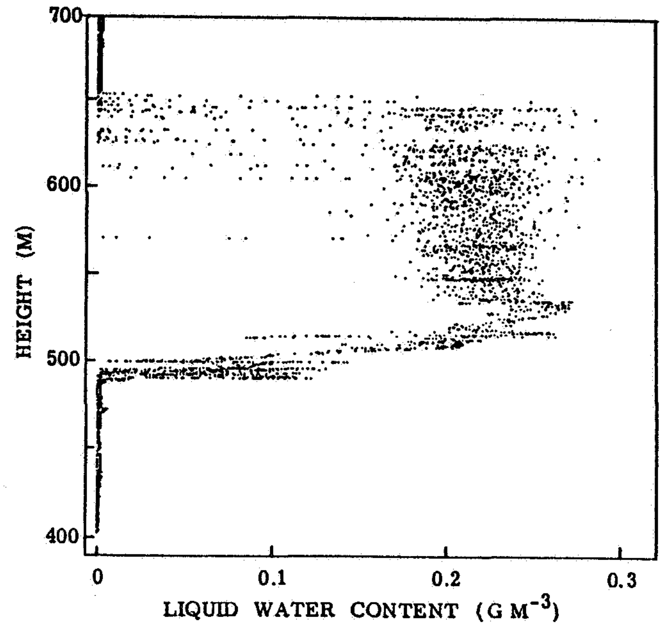

Fig. 2 - Liquid water content on the ascent of flight 13 during Sc dissipation.

5. Conclusions

This data set, while unfortunately only partially simultaneous with the bulk of the FIRE stratocumulus observations, is unique and worthwhile in its own right. For the first time accurate RH measurements near 100% have been made in-cloud; although, the use of the saturation hygrometer reflected a learning experience which will result in substantially better performance the next time. These measurements were made in conjunction with other microphysical measurements such as aerosol and cloud droplet spectra, and perhaps most important of all, they were all collocated with bivane turbulence measurements thus permitting flux calculations. Thus the analysis of this data set which consisted of about 50% stratocumulus cases including increasing and decreasing partial cloud cover, should lead to new insights on the physical mechanisms which drive the boundary-layer/cloud/turbulence system.

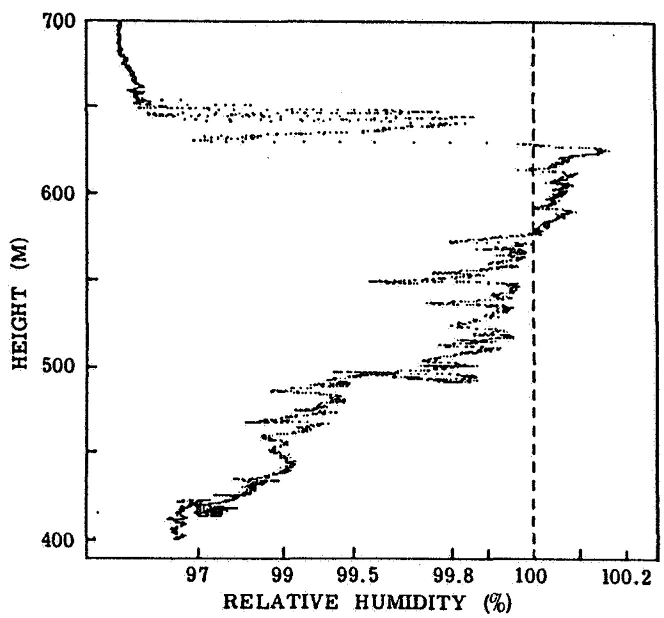

Fig. 3 - Relative humidity profile measured with the saturation hygrometer on the ascent of flight 13.

Addressing the entrainment mechanism at the top of the clouds should be especially amenable with this data set. In addition to the listed authors, investigators associated with Fire and located at the following institutions are looking at portions of this data: McGill University, NASA Goddard, U. of Washington, Colorado State University, and CIRES.

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