4.7 THE TOTAL WATER BUDGET OF NOCTURNAL STRATOCUMULUS

Margreet vanZanten*, Bjorn Stevens
University of California Los Angeles, Los Angeles, CA

Gabor Vali
University of Wyoming, Laramie, WY

Don Lenschow
National Center for Atmospheric Research, Boulder, CO

1. INTRODUCTION

In this abstract preliminary data will be presented on the role of drizzle in the total water budget of nocturnal stratocumulus during DYCOMS-II (Dynamics and Chemistry of Marine Stratocumulus). The DYCOMS-II campaign took place in July 2001 off the coast of California in uniform stratocumulus fields (Stevens et al., 2002). During nine flights an extensive data set of, among others, microphysical variables was collected with the C-130 of NCAR. Besides in-situ instruments such as the SPP-100, A260X and the 2DC, which measured the droplet spectrum from 2 μm up to 1500 μm, the Wyoming Cloud Radar (WCR) was also mounted on the aircraft (Vali et al., 1998). The reflectivity Z, as obtained by the WCR, can be translated into a rainrate R with a suitable Z-R relationship. Such a Z-R relationship is usually constructed with the aid of in-situ probes. In this way the combined use of both in-situ probes and radar extends the range in time and space over which an estimate of R can be given beyond the limited range of the in-situ probes only.

The six flights discussed here are all the night-time entrainment flights of DYCOMS-II: starting just before local midnight and ending with a so-called lidar leg flown above the top of the boundary layer shortly after sunrise. The flight pattern consisted of 30 minute long circles with a diameter of roughly 60 km, flown both in a clockwise and counter-clockwise direction at several heights in and just above the boundary layer. This flight pattern was chosen to facilitate estimation of the divergence of the windfield, see paper P1.20 for information. The cloud cover was solid on all flights except one; for rf02 the lidar derived cloud cover was slightly lower *i.e.*, 97%. Surprisingly, despite a homogeneous looking cloud deck quite a range of drizzle rates was encountered amongst the flights. Thus the role of drizzle in the total water budget of these nocturnal clouds also varies considerably. This makes the DYCOMS-II data set an interesting one for a study on this topic, because it might shed light on important questions regarding the role of precipitation in the climatology of stratocumulus and its relation to ambient aerosol and liquid water path.

2. DRIZZLE DATA

Most stratocumulus during the DYCOMS-II flights can be characterized as being situated in a marine airmass. Only flight rf03 shows influences of continental air as can be seen from the average drop concentration N which is considerably higher than for the other flights (Table 1). The values for R in the table show that there is quite a span of drizzle values, ranging from no drizzle to heavy drizzle. In four of the six cases drizzle reached the surface. Also within each flight large variability exists, which is illustrated with the values in the last two columns. Half of the total amount of R is falling in 20% or even less of the area and the difference between the mean R and the maximum found over a 500 m segment are a factor ten or higher.

The importance of drizzle in the total water budget is illustrated in Fig. 1. Depletion times are plotted as function of the liquid water path (LWP) and R with the values for LWP and R included for the six flights. The figure shows that for rf02, rf04 and rf07 (based on the radar data) the drizzle flux is an important factor in the total water budget. The val-

* *Corresponding author address:* Margreet vanZanten, Dept. of Atm. Sciences, 405 Hilgard Ave., Box 951565, Los Angeles CA 90095-1565; e-mail: zanten@atmos.ucla.edu

flight	N	R	A	R_{max}
	cm^{-3}	mm day^{-1}	%	mm day^{-1}
rf01	125	0.06	81.5	0.4
rf02	46	0.60	95.0	10.4
rf03	206	0.30	89.1	3.7
rf04	81	0.62	86.3	8.1
rf05	151	0.01	98.0	0.1
rf07	90	1.67	86.1	18.1

Table 1: Overview of some drizzle characteristics of the six flights calculated from the in-situ probes. The droplet number concentration N is an average for the total cloud depth, the average rainrate R (and the numbers in the related columns) is given for the cloud base leg. A is the percentage of the area in which half of the total amount of R is falling and R_{max} is the maximum value of R calculated for 500 m segments. The SPP-100 malfunctioned during rf05 so N is obtained from the FFSSP and R is based on the A260X only.

ues of R_{max} in the last column of Table 1 and the upper 10% values of the rainrate based on the radar data show that locally the role of drizzle maybe even more pronounced.

Striking in the figure are the differences, sometimes as high as a factor ten, in the R based on the radar and the in-situ probes. Besides being due to an inherent time (and space) disparity between the two ways of obtaining R, this can be also partly explained by the fact that the R from the in-situ probes is calculated from the SPP-100 and A260X only, thus neglecting the contribution of the very large drops with a diameter > 650 μm. Further the rainrate based on the radar is not yet calculated with Z-R relationships constructed specifically for DYCOMS-II. Both topics are currently being investigated.

Finally, note that the times in Fig. 1 are only valid for the theoretical case that no replenishment of total water takes places through turbulent fluxes or large scale advection. As such it also shows indirectly how much in-flow of total water is needed when a cloud is known to exist beyond the time period given in the plot.

3. FUTURE RESEARCH

In this abstract we have tried to show that the DYCOMS-II dataset is suitable for a study of the role of drizzle in the total water budget of nocturnal stratocumulus due to the availability of both radar and in-situ data and the variability in the drizzle rates of the various flights. We are planning to calculate the drizzle rates based on the 2DC as well, taking into account the tail of the droplet spectrum as far as it is statistically significant. Z-R relationships will be constructed for each flight in order to derive rainrates from the radar which are more tailor-made than the ones used here. Finally, fluxes will be calculated for liquid water and water vapor in order to compute the total water budget of each flight. During this analysis special attention will be paid to how to take into account the variability in the drizzle data.

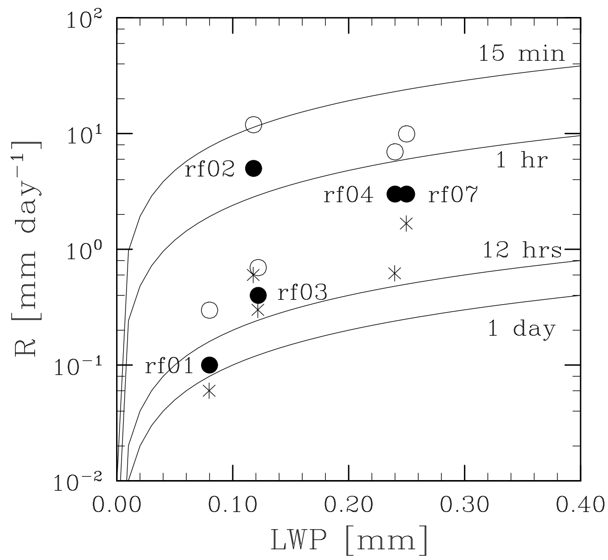

Figure 1: Depletion times of cloud as a function of the liquid water path (LWP) and the rainrate R. LWP and R values, based both on the radar (mean values given by filled circles and upper 10% values for 1 km segments by open circles) and the in-situ probes (mean value given by asterisks), are added for each flight. The rainrate of the radar is calculated at cloud base height from the lidar leg with $Z = 4R^{1.37}$. Note that rf05 is not included in the figure due to the negligible amount of drizzle.

Acknowledgments M.C. van Zanten and B. Stevens acknowledge support from NSF grant ATM-0097053. G. Vali acknowledges support from NSF grant ATM-0094956.

References

Stevens B. and 31 co-authors., 2002: Dynamics and chemistry of marine stratocumulus - DYCOMS-II. *Bull. Amer. Meteorol. Soc.*, submitted.

Vali G., R. D. Kelly, J. French, S. Haimov, D. Leon, R. E. McIntosh, A. Pazmany, 1998 Finescale structure and microphysics of coastal stratus. *J. Atmos. Sci.*, **55** 3540–3564.