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1. INTRODUCTION

In order to better understand the role of precipitation in cloud dynamics we will discuss a flight with heavy drizzle as observed during the dynamics and chemistry of marine stratocumulus (DYCOMS-II) field study. This field study took place in July 2001 off the coast of California and mainly consisted of flights in nocturnal marine stratocumulus. The flight plan consisted of circles with a perimeter of roughly 180 km. Within the PBL, legs were flown at four different heights; at cloud top, just above cloud base, just below cloud base in the subcloud layer (SC) and near the surface (SF). In addition, three remote sensing legs (RL) were flown above the PBL. In a previous study (vanZanten et al., 2004) we showed that in general during DYCOMS-II higher drizzle rates could be associated with smaller spatial scales, that is the flight averaged precipitation rate was mainly determined by heavily drizzling shafts. Those observations are consistent with the idea that heavy drizzle can induce a transition in cloud structure (Stevens et al., 1998).

Serendipitously a change in cloud structure was probed during the second flight of DYCOMS-II. Visual inspection of the reflectivity data as measured by the Wyoming cloud radar data reveal that the areas of depleted cloud regions are surrounded by 'walls' of heavy precipitation. We named those areas, resembling open cellular convection, pockets of open cells or POCs for short. Here we will describe the mean state of RF02 and discuss preliminary results of characteristics of POCs, after defining them first.

2. MEAN STATE

The mean state of RF02 is summarized by the numbers in Table 1 while thermodynamical profiles can be found in

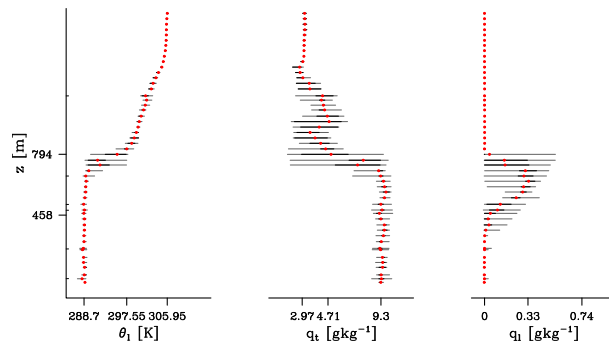


Figure 1: Mean thermodynamical state as observed during RF02. From left to right liquid water potential temperature Θ_l , total water q_t and liquid water q_l . Red dots represent averages over 30 m height intervals based on all flight data, black lines denote inner quartiles and grey lines outer quartiles. Thermodynamical cloud base height and inversion height are specified on the vertical axis, where average leg heights are also marked. For Θ_l and q_t the numbers on the horizontal axis represent mean PBL value, inversion height value and maximum value above the PBL, while for q_l maximum liquid water and adiabatic liquid water content at cloud top are noted.

Figure 1. The profiles show a well mixed PBL with deviations from the well-mixedness being more pronounced for total water than for liquid water potential temperature. The amount of liquid water is roughly half the value of the adiabatic liquid water content.

Surface fluxes of latent heat and sensible heat were estimated in two ways. With help of the TOGA-COARE bulk flux algorithm (Fairall et al. (1996), version 2.5b) the sensible heat flux was computed as $16 \pm 5 \text{ Wm}^{-2}$ and the latent heat flux as $93 \pm 12 \text{ Wm}^{-2}$. For this we assumed the mean state as specified in Table 1 to be valid at a height of 50 m. Eddy correlation estimates were computed for the SF leg, after removing fluctuations on the scale of 15 km and larger. Extrapolation of the flux values down to the sea surface was not feasible due to non linearity of the flux profiles with height. SF fluxes values of $4 \pm 5 \text{ Wm}^{-2}$ for the sensible heat and $84 \pm 12 \text{ Wm}^{-2}$

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h	[m]	800 ± 50
SST	[K]	292.0 ± 0.5
$\overline{\Theta}_t$	[K]	288.7 ± 0.4
\overline{q}_t	[g kg ⁻¹]	9.3 ± 0.3
\overline{u}	[m s ⁻¹]	4.5 ± 1.4
\overline{v}	[m s ⁻¹]	-5.7 ± 1.0

Table 1: Best estimate of mean state, see text for definitions

for the latent heat serve as the next best estimate.

The radiative forcing across cloud top and across the PBL is determined by combining a radiative transfer model and measured longwave radiative (LW) fluxes. Similarly to RF01 (Stevens et al., 2003) offsets of 17 W m^{-2} and 14 W m^{-2} are added to the downward and upward LW flux values. The radiative transfer code is forced by the observed state of the atmosphere. For the PBL and the lowest part of the free troposphere (FT) the mean state as presented in Figure 1 is taken (albeit piecewise linearized) while for the FT above a constant lapse rate was used for the potential temperature and a constant value for the total water (both based on the San Diego sounding). Cloud liquid water was defined as half the adiabatic value. The control run had a similar acceptable agreement between model output and data as is shown for RF01 in Stevens et al. (2003). The LW radiative flux divergence across cloud top is estimated to be $70 \pm 5 \text{ W m}^{-2}$, which is offset by a cloud base warming of 20 W m^{-2} making the total LW radiative flux divergence across the PBL $50 \pm 5 \text{ W m}^{-2}$. Shortwave fluxes were zero because RF02 was a nocturnal flight.

3. REGIONS OF POCKETS OF OPEN CELLS

In order to be able to compare POCs with more stratiform cloud areas we have to specify the POC region for each leg. We have based our definition on ΔT_B , the difference in brightness temperature of 11 and $4 \mu\text{m}$ as measured by the GOES-10 satellite. ΔT_B acts as a proxy for the effective radius while the effective radius is an indication whether it drizzles or not. vanZanten et al. (2004) have shown ΔT_B values less than 2 K to be positively associated with areas with heavy drizzle, while Stevens et al. (2004) show that ΔT_B can be used to label POC regions. A satellite based criterion can be applied to both PBL and above PBL legs, contrary to an airborne data based criterion which doesn't work for either the SF leg (radar data) or the RL legs (drizzle drop data). Another advantage is its suitability for tagging POCs from space. A disadvantage is the necessary advection of the flight track in order to match with the nearest satellite overpass. This advection is done by determining the mean vector wind and its time variation based on all PBL leg data of RF02. Next,

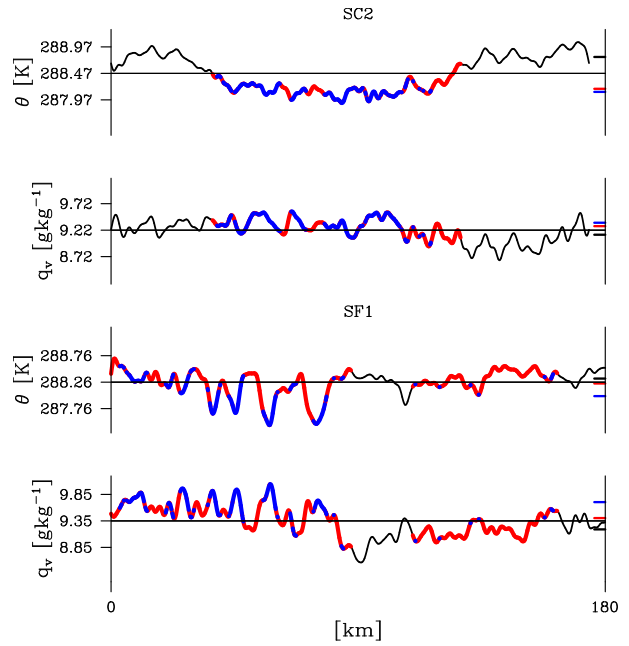


Figure 2: Potential temperature Θ and water vapor q_v for the second SC leg and the SF leg. POC areas are denoted by a thick red line while stratiform regions are given by a thin black line, the presence of drizzle drops is shown in blue. The horizontal line is the leg averaged value while the short colored lines on the right denoted the averages over the POC area (red), the stratiform area (black) and the drizzle region within the POC area (blue).

areas with low-pass filtered ΔT_B values less than 1.5 K are determined to be POCs while higher values denote the more stratiform region. While the choices in the filtering and the choice of the 1.5 K limit are somewhat arbitrary the sensitivity to the exact choice is small.

The sequence of satellite images clearly reveals that the POCs advected into the measurement area (although temporal development also took place) during the flight; this explains why the POCs were less pronounced in the beginning of the flight. When the amount of precipitation encountered was significant the correlation between the defined POC regions and drizzle was high. Heavy drizzle rates of 1 mm d^{-1} and higher were estimated (based on radar data, valid at a height of 70 m , vanZanten et al. (2004)) in the POCs while the amount of drizzle was insignificant or even zero in the stratiform region at the same time; this is illustrated in Figure 2 for the second SC and only SF leg. However, the main point shown in Figure 2 is the fact that the subcloud layer in the POCs are colder and moister than the stratiform areas due to the evaporation of drizzle. Note that the SF1 leg (flown three hours later) as a whole is colder and moister than the SC2 leg. Secondly, besides being colder and moister at the size of the POC area (most visible in the SC2 leg) the Θ and q_v data are also anticorrelated on a scale of the

order of ten kilometers (most clearly seen in the SF1 leg), similar to what has been found by Paluch and Lenschow (1991).

Assuming leg averaged vertical velocity to be zero, the POCs are associated with updraft motion while the stratiform regions are linked to downward motion; averaging over drizzling areas only the ascending motion becomes even more pronounced. This points in the direction of a more cumulus like type of convection. Vertical velocity variance shows a decrease in the POCs compared to the stratiform region which is most pronounced for the SC legs. Horizontal velocity variances show a similar decrease so the turbulent kinetic energy is less as a consequence as well. Both findings are consistent with Large Eddy Simulations reported in Stevens et al. (1998).

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