Stratus Cloud Measurements with a K_α-Band Doppler Radar and a Microwave Radiometer

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The goal of the Atlantic Stratocumulus Transition Experiment (ASTEX) held in the North Atlantic during June 1992 was to determine the physical reasons for the transition from stratocumulus to broken clouds. Some possible reasons for this transition were such things as cloud top entrainment instability (Randall 1980; Betts and Ridgway 1989) and the decoupling effects of drizzle (Albrecht 1989). As part of this experiment, the Environmental Technology Laboratory's cloud sensing Doppler radar and three-channel microwave radiometer were deployed on the island of Porto Santo in the Madeira Islands of Portugal along with a CO_2 Doppler lider. A more detailed description of the experiment, methodology and results can be found in Frisch et al. (accepted).

Drizzle properties in stratus were examined using a log-normal droplet distribution model that related the model's three parameters to the first three Doppler spectral moments of the cloud radar. With these moments, we are then able to compute the drizzle droplet concentration, modal radius, liquid water, and liquid water flux as a function of height.

In the case we have examined, we find that near cloud top, the number of drizzle droplets varies from 10 to almost 10,000 droplets per cubic meter. In the lower part of the cloud, the droplet number decreases linearly from about 1000 per cubic meter at 1200 meters to about 1 per cubic meter near the ground. Similarly, the liquid water shows a large variation in the upper part of the cloud, varying from 0.1 to 0.25 grams per cubic meter; in the lower part of the cloud, the liquid water concentration deceases from 0.25 grams per cubic meter at 1200 meters height to about 0.01 grams per cubic meter near the ground. The liquid water flux is about 0.6 mm per hour at 1200 meters, and about 0.1 mm per hour near the ground, which indicates a considerable evaporative loss of liquid water.

As another aspect of the radar measurements, we used a log-normal cloud droplet model, along with other information about stratus clouds, to relate the cloud radar reflectivity and radiometer integrated liquid water to determine the liquid water profiles along with the droplet modal radius and number. These observations are consistent with other in-situ measurements of cloud liquid water and droplet number.

Finally, turbulence measurements were made in cloud using the cloud droplets as air motion tracers. Our daytime results showed two vertical velocity variance maxima, one near cloud top and the other in near cloud base.

We noted a diurnal difference in the cloud turbulence. The upper maximum is greater at night than during the day, which is consistent with radiative cooling being somewhat compensated for by solar warming during the day. The lower maximum is larger in the daytime than at night. The vertical velocity skewness is negative in the upper part of the cloud, indicating that this part of the cloud is acting like an upside down boundary layer with the cloudtop cooling causing the cooler air parcels to accelerate. In the lower part of the cloud, we find that the skewness is positive, more like the usual convective boundary layer behavior. Between the two turbulence maxima, a minimum value in the variance was noted, indicating that the transport of water and water vapor would be inhibited at that level and must be supplied by other scales of motion or the upper part of the cloud would eventually dissipate.

Acknowledgments

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References

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