Stratus Cloud Drizzle Retrieval During SHEBA from MMCR Doppler Moments

A. S. Frisch
National Oceanic and Atmospheric Administration
Environmental Technology Laboratory
Colorado State University
Boulder, Colorado

M. D. Shupe
Science Technology Corporation
National Oceanic and Atmospheric Administration
Environmental Technology Laboratory
Boulder, Colorado

Introduction

The National Oceanic and Atmospheric Administration/Environmental Technology Laboratory (NOAA/ETL) operated a 35-GHz cloud radar during the year-long Surface Heat Budget of the Arctic Experiment (SHEBA) (1997-1998) at an ice station frozen into the drifting pack of the Arctic Ocean. During this time, there were many times when stratus clouds and drizzle were observed with the radar. We use a cloud radar drizzle technique developed by Frisch et al. (1995), to retrieve drizzle parameters such as the drizzle droplet effective radius, concentration, liquid water and liquid water flux.

Method

The retrieval method we use with the SHEBA data was developed by Frisch et al. (1995). They used a log-normal distribution, and a linear fall speed for the cloud droplets (a reasonable approximation for 45 μ <r< 400 μ). This gives the retrieval for the effective radius

$$r_e = (1.2 \text{x} 10^{-4}\,\overline{W} + 10^{-5}) \exp(-4\sigma_x^2) ,$$

where $\overline{W}$ is the mean vertical droplet velocity, and σ_x is the logarithmic width of the distribution. The logarithmic width is related to the second moment of the Doppler spectrum and the variance of the vertical velocity W. It can be written as

$$\sigma_x = \left(\ln\left[1 + \sigma_v^2 / \left(< V_D >\right)^3 + b / a)^2\right]\right)^{1/2}$$

where a =$1.2 \text{x} 10^{-4}$ sec and b=$1.0 \text{x} 10^{-5}$ m, $<V_D>$ is the mean Doppler velocity, and

$$\sigma_v^2 = \sigma_w^2 + \sigma_s^2 \ .$$

Here, σ_w is the variance of the vertical velocity, and σ_s is the spread of the Doppler spectrum. We assume that if we average for several minutes, $<V_D>$ approaches the mean droplet velocity $\overline{W}$ and that the turbulence is negligible compared to the spread in the droplet velocity.

The liquid water can be expressed as

$$q_l = (a < V_D >)^{-3} 10^{\left(dBZ - 132 + 26\sigma_x^2\right)/10} ,$$

the droplet concentration as

$$N = \frac{3xp3\sigma_x^2}{4\pi\rho_w r_e^3} q_l$$

and the liquid water flux as

$$F_q = -q_l \left[\left(\langle V_D \rangle + b/a\right) \exp\left(-3\sigma_x^2 - b/a\right)\right]$$

Since the reflectivity goes as r^6, if we confine our drizzle retrievals to high reflectivities, then the contribution from the cloud droplets to the reflectivity will be negligible compared to the drizzle droplets.

Drizzle Results

We selected August 4, 1998, to show an example of the drizzle retrieval. Figure 1 shows the time-height cross section for the radar reflectivity. To separate the cloud reflectivity from the drizzle, we only did the retrieval when the reflectivity was greater than –5 dBZ and the Doppler velocity was greater than 0.5 ms^{-1} (Frisch et al. 1995). Each radar data sample is taken every 10 seconds and we averaged the data for 5 minutes. We required that we have at least 20 samples meeting our criteria before doing the retrieval. One of the best times for the retrieval was at 18.4 hours. The following figures show profiles of the drizzle retrievals for this time.

Figure 2 shows the liquid water concentration profile with the highest value of 0.03 gm^{-3} at about 1100 m and the lowest value of about 0.01 gm^{-3} at 175 m. Figure 3 shows the effective radius profile with an effective radius of 75 μ at 1100 m increasing to 275 μ at 175 m. Figure 4 is the profile of the logarithmic spread of the drizzle droplets. It smallest value is 0.28 and then shows some variability to the bottom height of the profile where it has a value of 0.35. Finally, Figure 5 shows the vertical profile of drizzle liquid water flux. The highest values are in the height range of 800 to 1200 m and vary from 1 to 2 mm per day. The lowest value is at 200 m and is 0.07 mm per day.

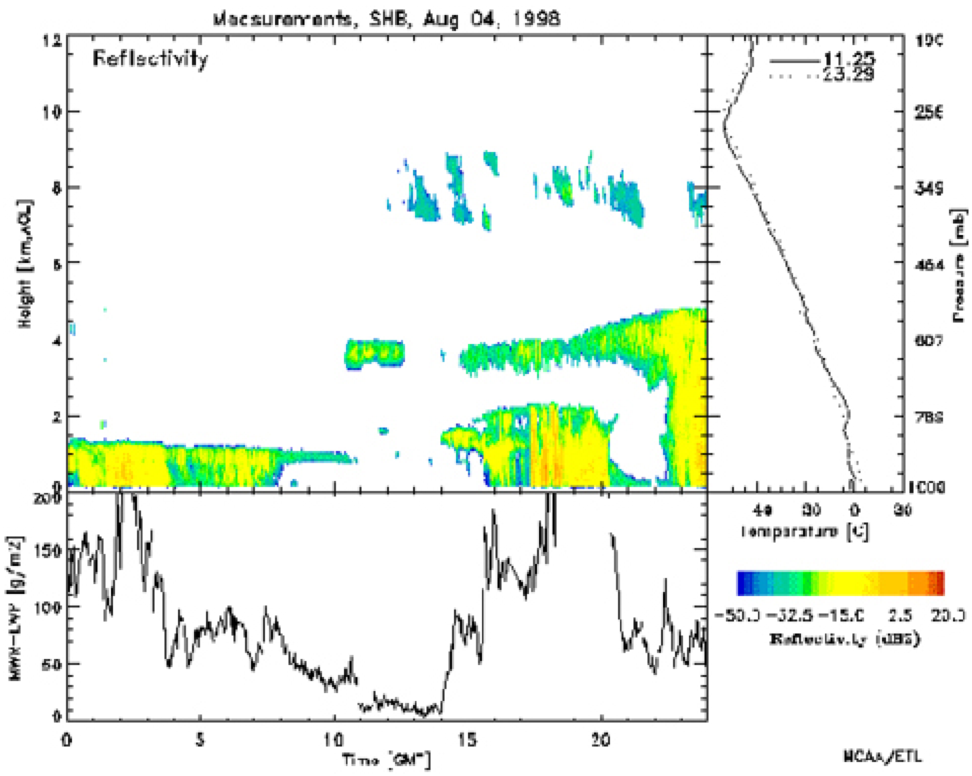

Figure 1. Time-height plot of radar reflectivity (top), right temperature sounding, bottom, microwave radiometer measurement of liquid water path.

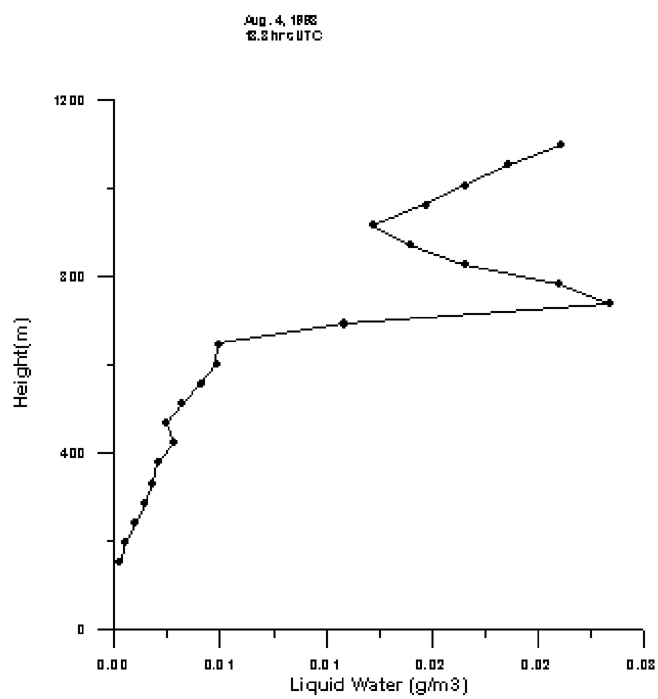

Figure 2. Liquid water profile.

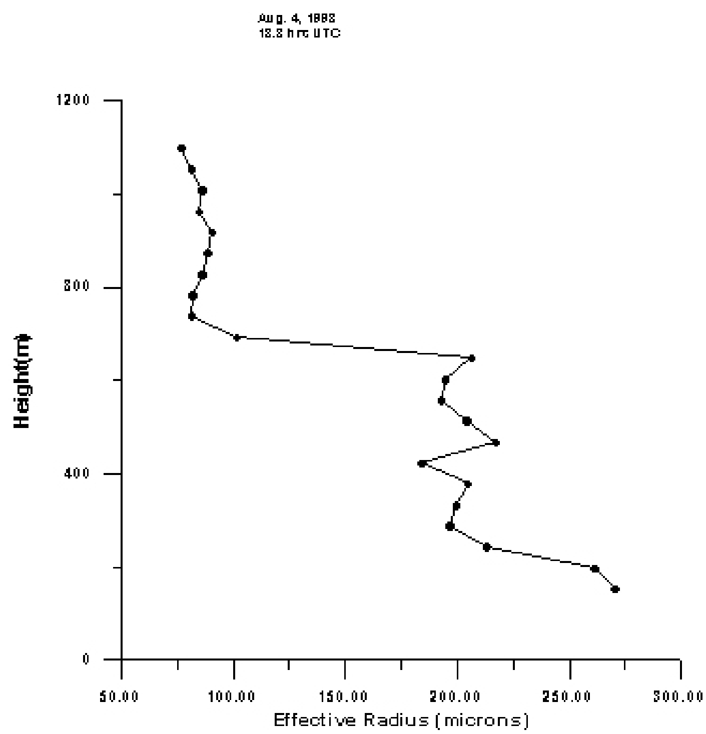

Figure 3. Effective radius profile.

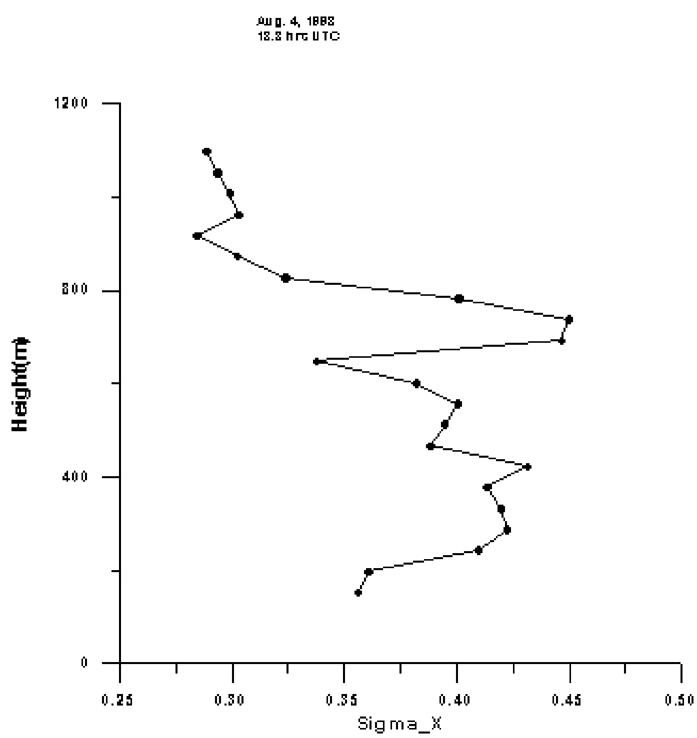

Figure 4. Logarithmic spread of the drizzle droplet distribution.

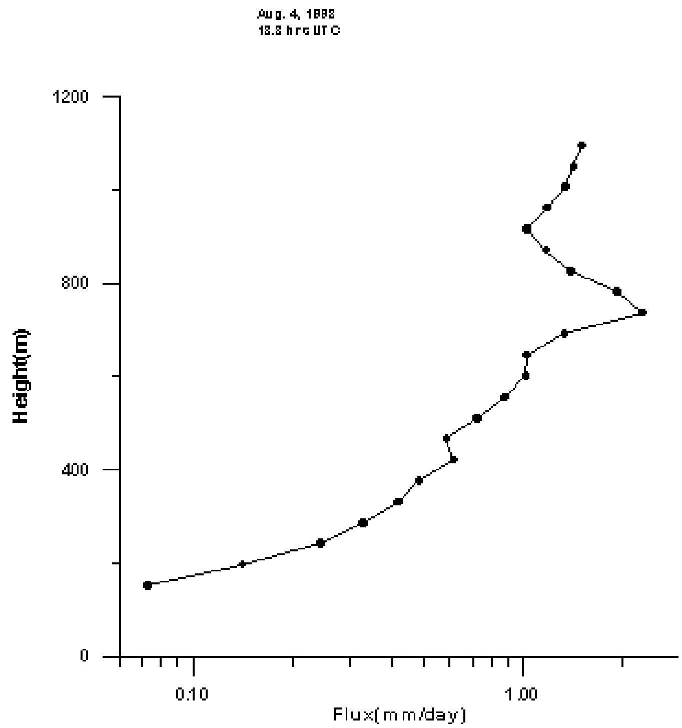

Figure 5. Vertical drizzle flux.

Discussion

There are several possibilities for errors. First of all, we assume that the Doppler velocity is approximately equal to the fall velocity of the drizzle droplets. This assumes that the air motion contribution is small. This becomes a reasonable approximation for longer averages when the updrafts and downdrafts are averaged out. The second contribution is the effect of turbulence on the spread of the Doppler spectrum. Both of these contributions are probably negligible in the Artic, however, instrumented aircraft which flew during SHEBA may help in indirectly evaluating these errors.

Acknowledgments

Contributions by Shelby Frisch were supported by interagency agreement #DE-A103-97ER623342/ A002 with the U.S. Department of Energy (DOE). Contributions from M. Shupe were supported by the NSF SHEBA Program under Agreement #OPP-9701730.

Corresponding Author

Shelby Frisch, Shelby.Frisch@noaa.gov, (303) 497-6209

References

Frisch, A. S., C. W. Fairall, and J. B. Snider, 1995. Measurement of stratus cloud and drizzle parameters in ASTEX with Ka-band Doppler radar and a microwave radiometer. *J. Atmos. Sci*., **52**, 2788–2799.