Cloud Physics Lab
LAB 3: Properties of Clouds

Introduction:

Parameters like drop size distribution, liquid water content, and distance between drops vary greatly between clouds, as well as within individual clouds. These parameters also vary with time as a cloud evolves and develops. In this lab you will be required to plot the cloud droplet size distribution for different types of clouds.

Objective:

a) Plot the size distribution of cloud droplets for different types of clouds
b) Calculate the surface area density of the cloud droplets (in $cm^2\ m^{-3}$) and the mean distance between droplets (in mm) for different types of clouds.

Theory:

The drop size distributions of actual clouds can be quite complex, and vary from cloud to cloud. Some distributions have more than one peak, while others have a single peak. In general, maritime cumulus clouds have larger drops and broader distributions than do continental clouds. In many instances a form of the *gamma distribution*, having the form, represents the drop-size distribution very closely

$$n_d(D) = aD^2 \exp(-bD) \tag{1}$$

where *a* and *b* are constants

One can obtain the following formulas for the properties of cloud droplets:

a) The number density of the droplets

$$N(D_1 : D_2) = \frac{a2!}{b^3} \tag{2}$$

b) The liquid water content of the cloud

$$M\,(D_1 : D_2) = \frac{\pi a \rho_l\, 5!}{6b^6} \tag{3}$$

where $\rho_l = 10^3$ kg/m^3.

c) The surface area density of the drops

$$A(D_1 : D_2) = \frac{\pi a 4!}{b^5} \tag{4}$$

d) The mean drop diameter

$$\overline{D} = N^{-1} a \frac{3!}{b^4} \quad (5)$$

e) The mean distance between drops

$$\bar{r} = 0.620 N^{(-1/3)} \quad (6)$$

If two of cloud properties are known one can determine the constants *a* and *b* by using two of the above equations. For example, if *N* and *M* are known then from equations (2) and (3)

$$a = b^3 N / 2 \quad (7)$$

and

$$b^6 = \frac{\pi a \rho_l 5!}{6M} \quad (8)$$

Equations (7) and (8) can be solved to determine *a* and *b*.

Table (1) gives observed typical values for the properties of clouds. For all clouds, the level of observation is just below the freezing level, except for fog and cirrus. Cirrus consists entirely of ice crystals, and the values shown in this table are liquid equivalents [1][2]. The values of *a* and *b* in the last two columns were calculated from the observations of *N* and *M*.

Table 1. Observed typical values for the properties of clouds [1][2].

Environment	cloud-type	r (µm)	N (cm^{-3})	M (g/m^3)	a (m^3)	b (m^{-1})
continental	stratus	4.7	250	0.28	3.50×10^{24}	3.04×10^{5}
	cumulus	4.8	400	0.26	9.66×10^{24}	3.64×10^{5}
	fog	8.1	15	0.06	0.06×10^{24}	1.99×10^{5}
maritime	stratus	6.7	80	0.30	0.33×10^{24}	2.03×10^{5}
	(strato)cumulus	10.4	65	0.44	0.15×10^{24}	1.67×10^{5}
continental or maritime	cirrus (-25 °C)	-	0.11	0.03	6.33×10^{18}	0.49×10^{5}
	cirrus (-50 °C)	-	0.02	0.002	3.14×10^{18}	0.68×10^{5}

Materials and Procedures:

1. Run the Matlab script **Lab3a.m** to plot three graphs of the size distribution of cloud droplets for different types of clouds.
2. Run Matlab script **Lab3b.m** to calculate surface area density of the cloud droplets (in $cm^2\ m^{-3}$) and the mean distance between droplets (in mm) for different types of clouds. Results are written in a file named *results.txt*

Analysis and Conclusions:

1. Discuss the behavior of the cloud droplet number density with the droplet radius for each type of clouds.
2. Discuss the results of the surface area density of the cloud droplets and the mean distance between droplets for different types of clouds (Results in file *results.txt*)

Questions:

1. What did you learn about cloud properties by completing the activity?
2. What is the major difference between clouds and fog?
3. Explain the differences between the number density of the stratus, cumulus, and fog continental clouds.
4. Explain the differences between the number density of the stratus and cumulus maritime clouds.
5. Why maritime clouds have fewer number density than continental clouds.

References

1. Hess, M., P. Koepke and I. Schult 1998. Optical properties of aerosols and clouds. *Bull. Amer. Meteor. Soc.*,**79**, 831-44.
2. Rosenfeld, D. and I. M. Lensky 1998. Satellite-based insights into precipitation formation processes in continental and maritime convective clouds. *Bull. Amer. Meteor. Soc.*, **79**, 2457-76.