

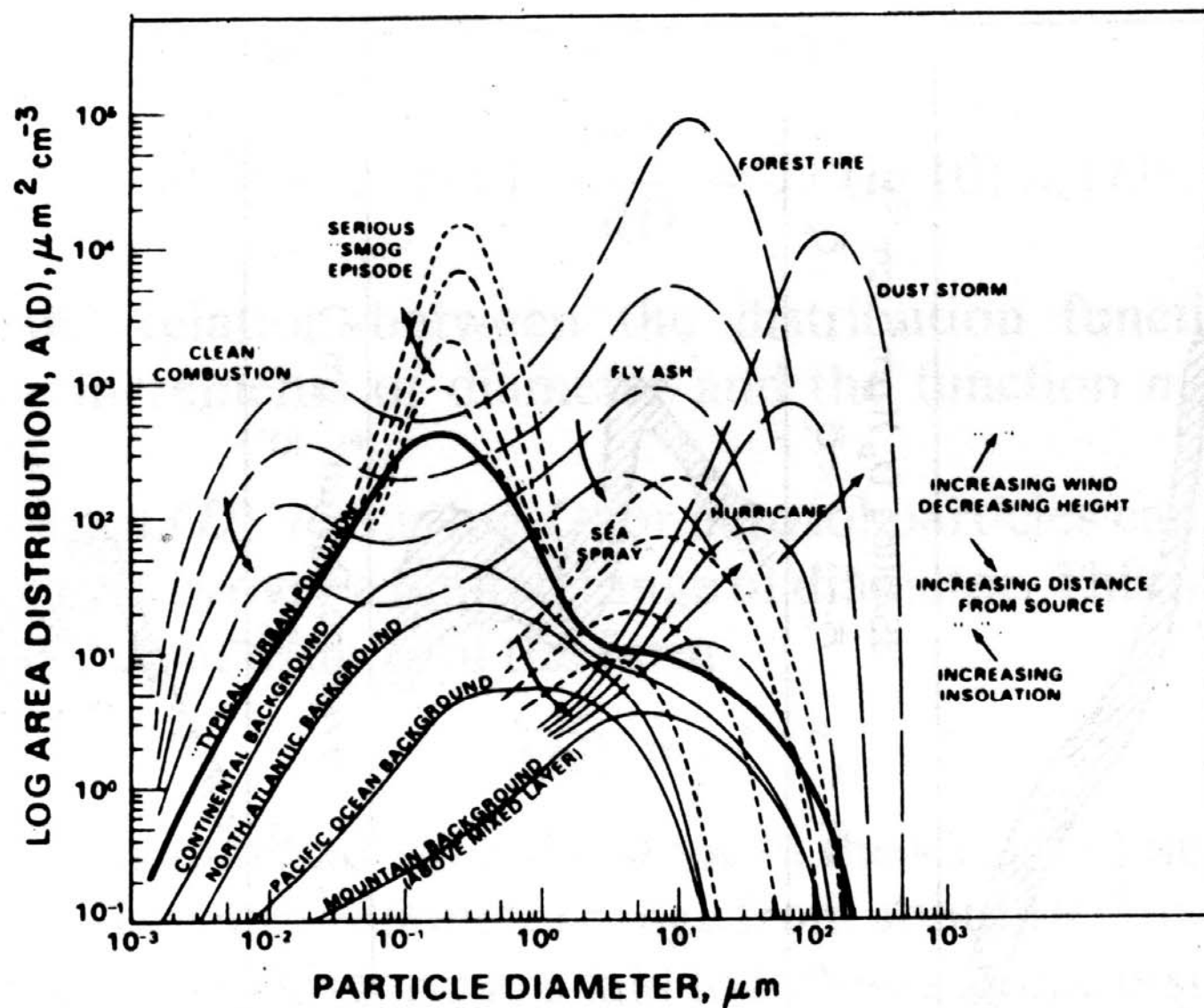


FIG. 6.4. Idealized aerosol spectra, showing typical ground-level background distributions and the general dependence of the spectra on height, wind speed, distance from source, and surface heating. (From Slinn, 1975.)

TABLE 7.1. *Values of Dynamic Viscosity μ and Coefficient of Thermal Conductivity K of Air, and Coefficient of Diffusion D of Water Vapor in Air. (From Houghton, 1985)*

$T(^{\circ}\text{C})$	$\mu (\text{kg m}^{-1} \text{s}^{-1})$	$K (\text{J m}^{-1} \text{s}^{-1} \text{K}^{-1})$	$D (\text{m}^2 \text{s}^{-1})$
-40	1.512×10^{-5}	2.07×10^{-2}	1.62×10^{-5}
-30	1.564×10^{-5}	2.16×10^{-2}	1.76×10^{-5}
-20	1.616×10^{-5}	2.24×10^{-2}	1.91×10^{-5}
-10	1.667×10^{-5}	2.32×10^{-2}	2.06×10^{-5}
0	1.717×10^{-5}	2.40×10^{-2}	2.21×10^{-5}
10	1.766×10^{-5}	2.48×10^{-2}	2.36×10^{-5}
20	1.815×10^{-5}	2.55×10^{-2}	2.52×10^{-5}
30	1.862×10^{-5}	2.63×10^{-2}	2.69×10^{-5}

Note: The tabulated values of D are for a pressure of 100 kPa. Because D is proportional to μ/ρ , it follows that D is inversely proportional to pressure for a given temperature. To obtain D for an arbitrary pressure p (kPa), the tabulated value must therefore be multiplied by $(100/p)$.

TABLE 7.2. Rate of Growth of Droplets by Condensation (initial radius $0.75 \mu\text{m}$). (From Mason, 1971)

Nuclear mass (g)	$r_{\text{dry}} = 0.1$ 10^{-14}	0.22 10^{-13}	0.48 10^{-12}
Radius (μm)	Time (sec) to grow from initial radius $0.75 \mu\text{m}$		
1	2.4	0.15	0.013
2	130	7.0	0.61
4	1,000	320	62
10	2,700	1,800	870
20	8,500	7,400	5,900
30	17,500	16,000	14,500
50	44,500	43,500	41,500

Assumes supersaturation=0.05%, $p=900 \text{ hPa}$, $T=273\text{K}$

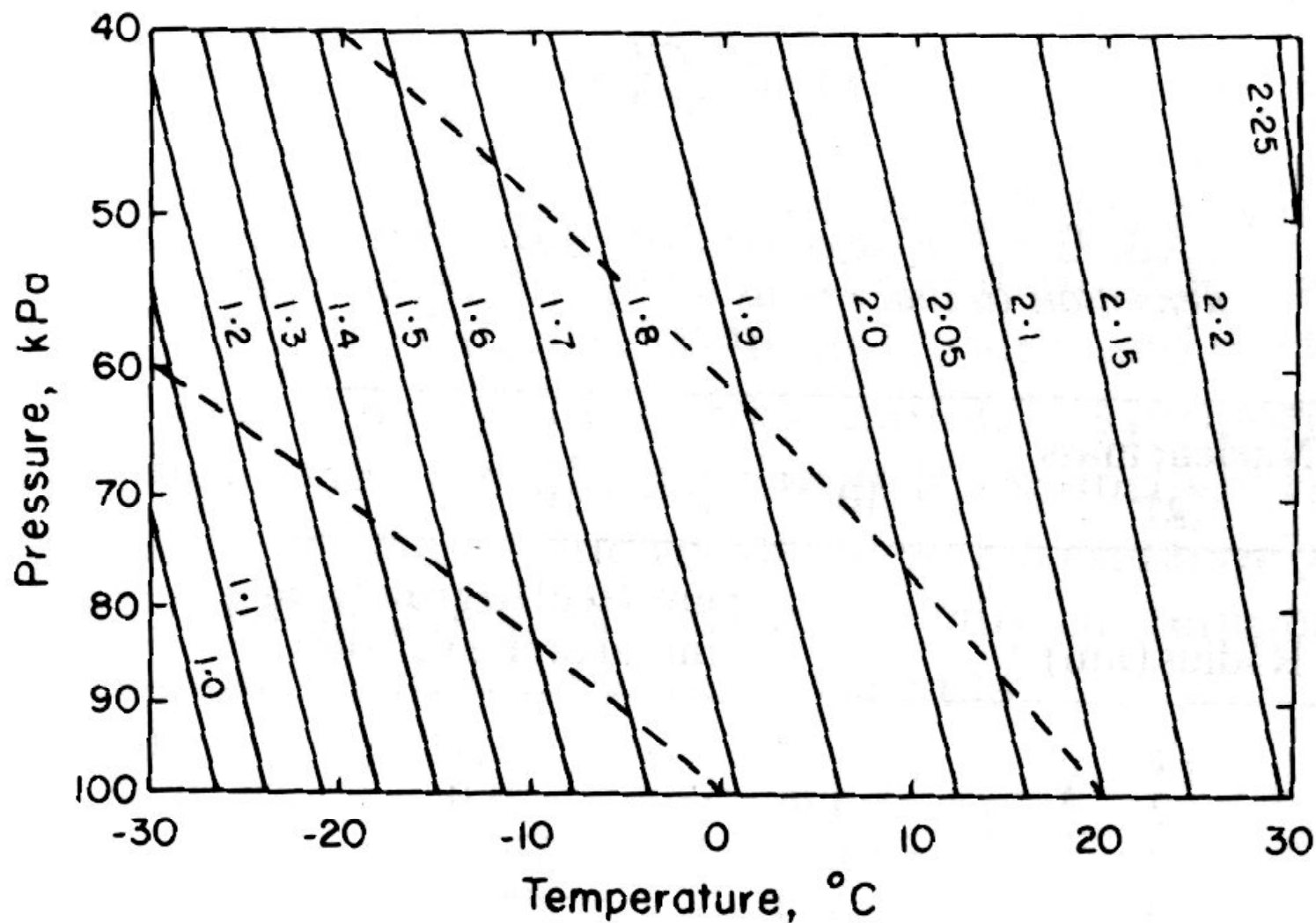


FIG. 7.1. Dependence of the growth parameter $\xi_1 = 1/[F_k + F_d]$ on temperature and pressure. Contours are plotted of the quantity $\log_{10} \xi_1$, with ξ_1 expressed in units of $\mu\text{m}^2/\text{s}$. Dashed lines represent pseudoadiabats corresponding to $\theta_w = 0^\circ\text{C}$ and 20°C .

$A [\mu\text{m}^2 \text{s}^{-1}]$, where $dr/dt = A(S-1)/r$

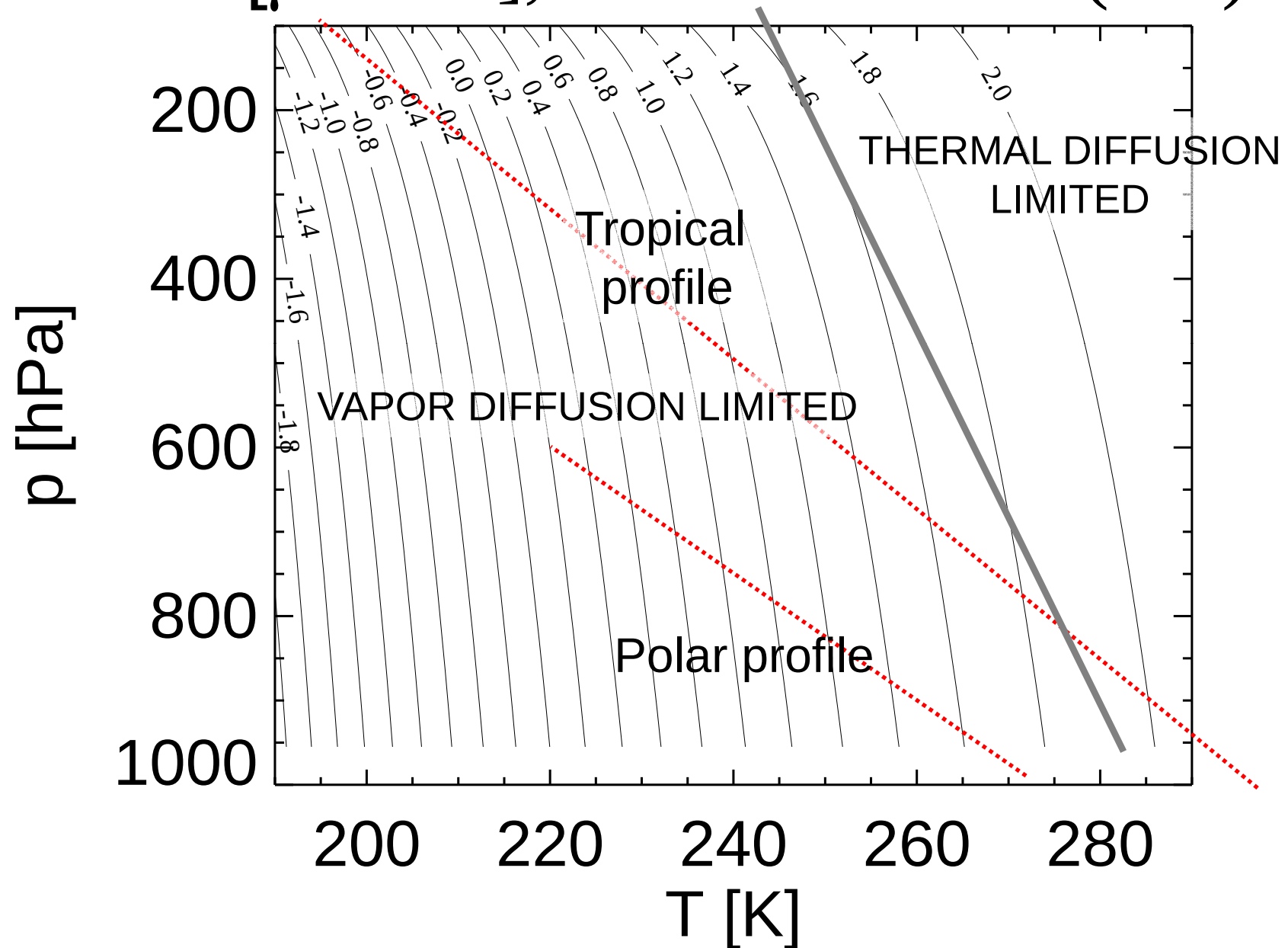


TABLE 7.3. *Distance a Drop Falls before Evaporating, assuming Isothermal Atmosphere with $T = 280\text{ K}$, $S = 0.8$*

Initial radius	Distance fallen
$1\text{ }\mu\text{m}$	$2\text{ }\mu\text{m}$
$3\text{ }\mu\text{m}$	0.17 mm
$10\text{ }\mu\text{m}$	2.1 cm
$30\text{ }\mu\text{m}$	1.69 m
0.1 mm	208 m
0.15 mm	1.05 km

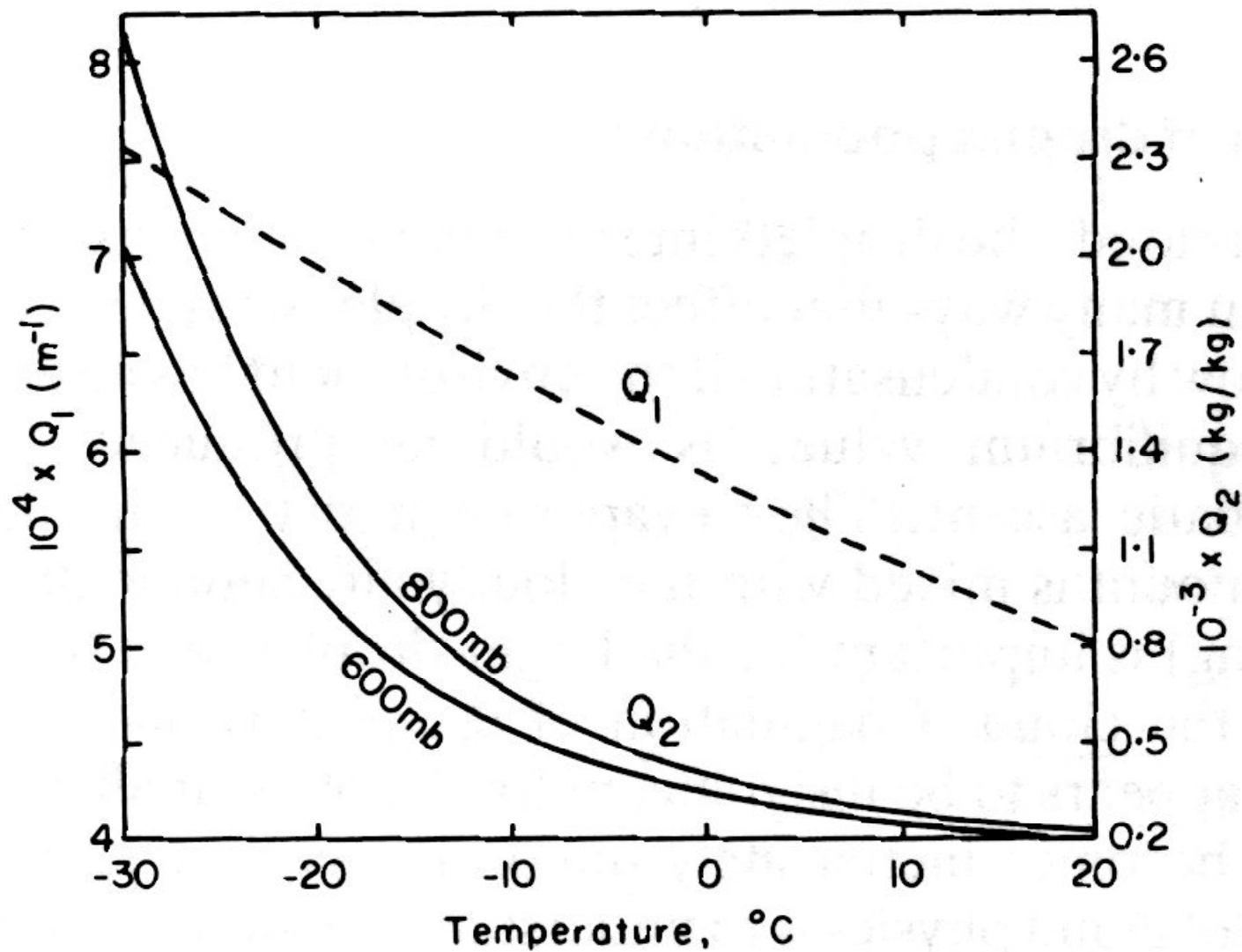


FIG. 7.2. The dependence of Q_1 and Q_2 on temperature. Q_2 depends also on pressure and is shown for 600 mb and 800 mb.

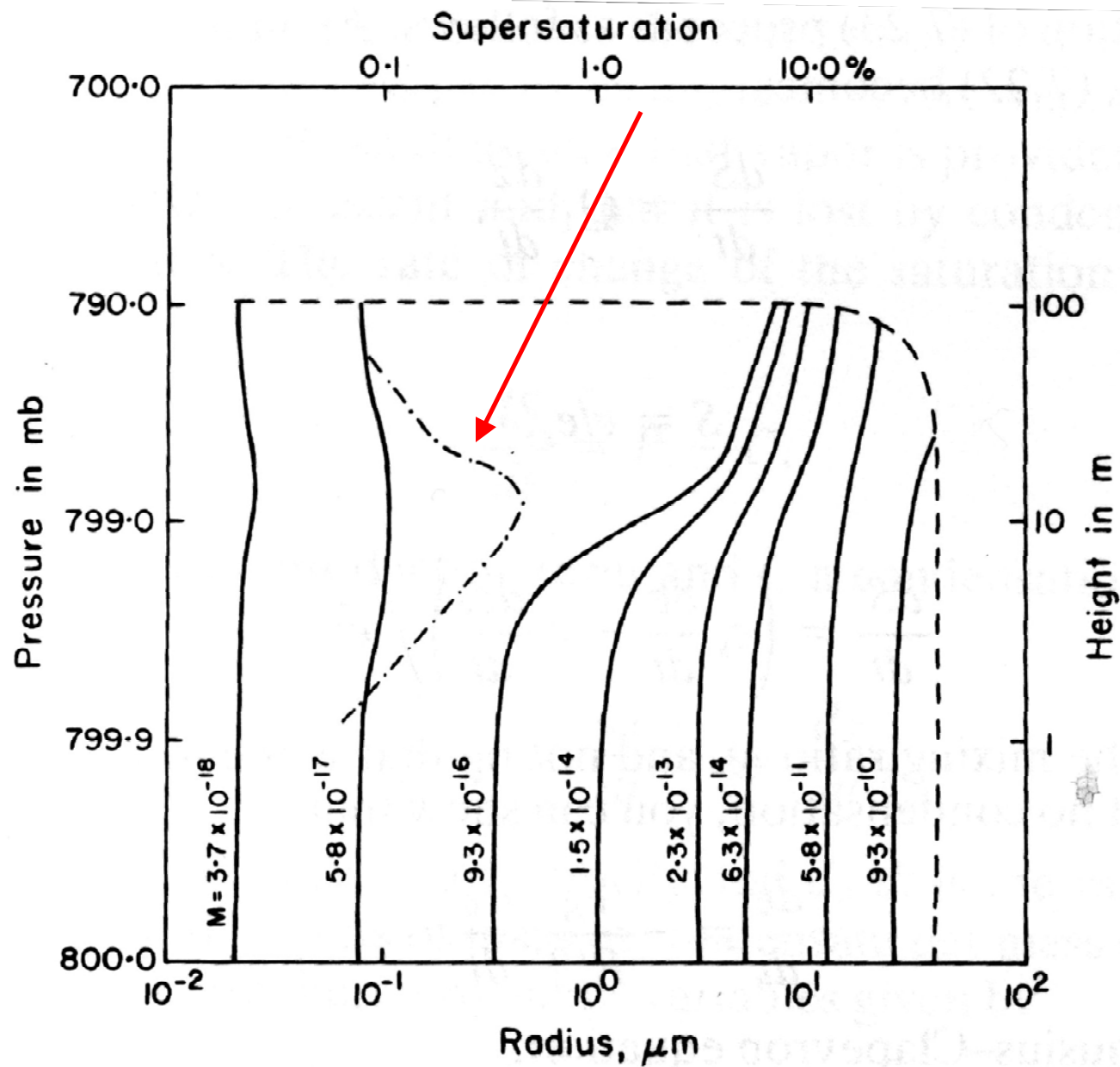


FIG. 7.3. Initial formation of cloud droplets and the variation of supersaturation above cloud base. (Adapted from Mordy, 1959.)

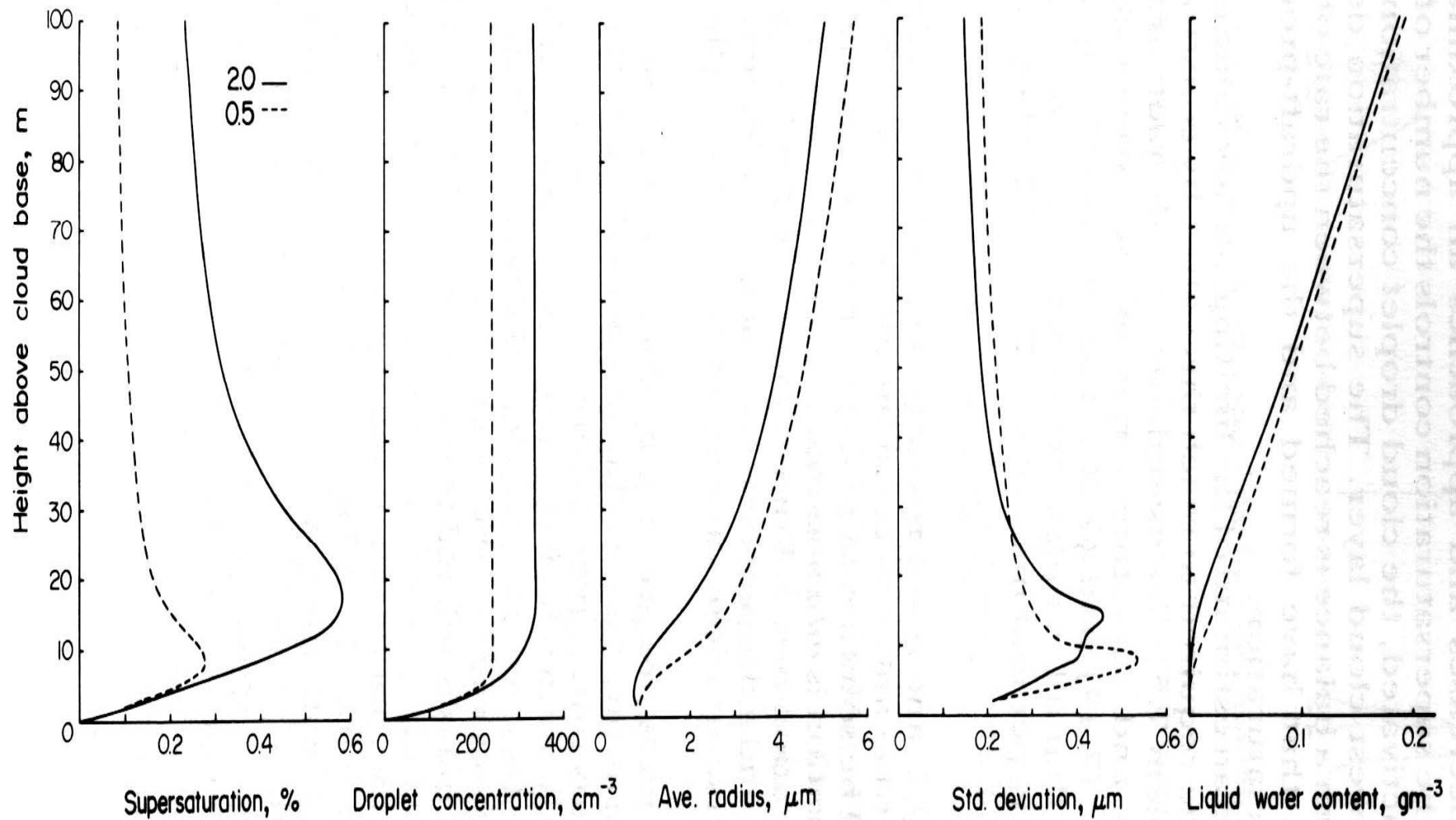


FIG. 7.4. Early development of cloud properties in air ascending at constant velocity of 0.5 m/s or 2 m/s.

ICE FORMATION AND CONDENSATIONAL GROWTH

TABLE 9.1. *Temperatures at which different substances nucleate ice. (From Houghton, 1985)*

Substance	Crystal lattice dimension		Temperature to nucleate ice (°C)	Comments
	a axis (Å)	c axis (Å)		
Pure substances				
Ice	4.52	7.36	0	—
AgI	4.58	7.49	−4	Insoluble
PbI ₂	4.54	6.86	−6	Slightly soluble
CuS	3.80	16.43	−7	Insoluble
CuO	4.65	5.11	−7	Insoluble
HgI ₂	4.36	12.34	−8	Insoluble
Ag ₂ S	4.20	9.50	−8	Insoluble
CdI ₂	4.24	6.84	−12	Soluble
I ₂	4.78	9.77	−12	Soluble
Minerals				
Vaterite	4.12	8.56	−7	(Silicate)
Kaolinite	5.16	7.38	−9	
Volcanic ash	—	—	−13	
Halloysite	5.16	10.1	−13	
Vermiculite	5.34	28.9	−15	
Cinnabar	4.14	9.49	−16	
Organic materials				
Testosterone	14.73	11.01	−2	(Bacteria in leaf mold)
Chloesterol	14.0	37.8	−2	
Metaldehyde	—	—	−5	
β-Naphthol	8.09	17.8	−8.5	
Phloroglucinol	—	—	−9.4	
Bacterium	—	—	−2.6	
<i>Pseudomonas Syringae</i>				

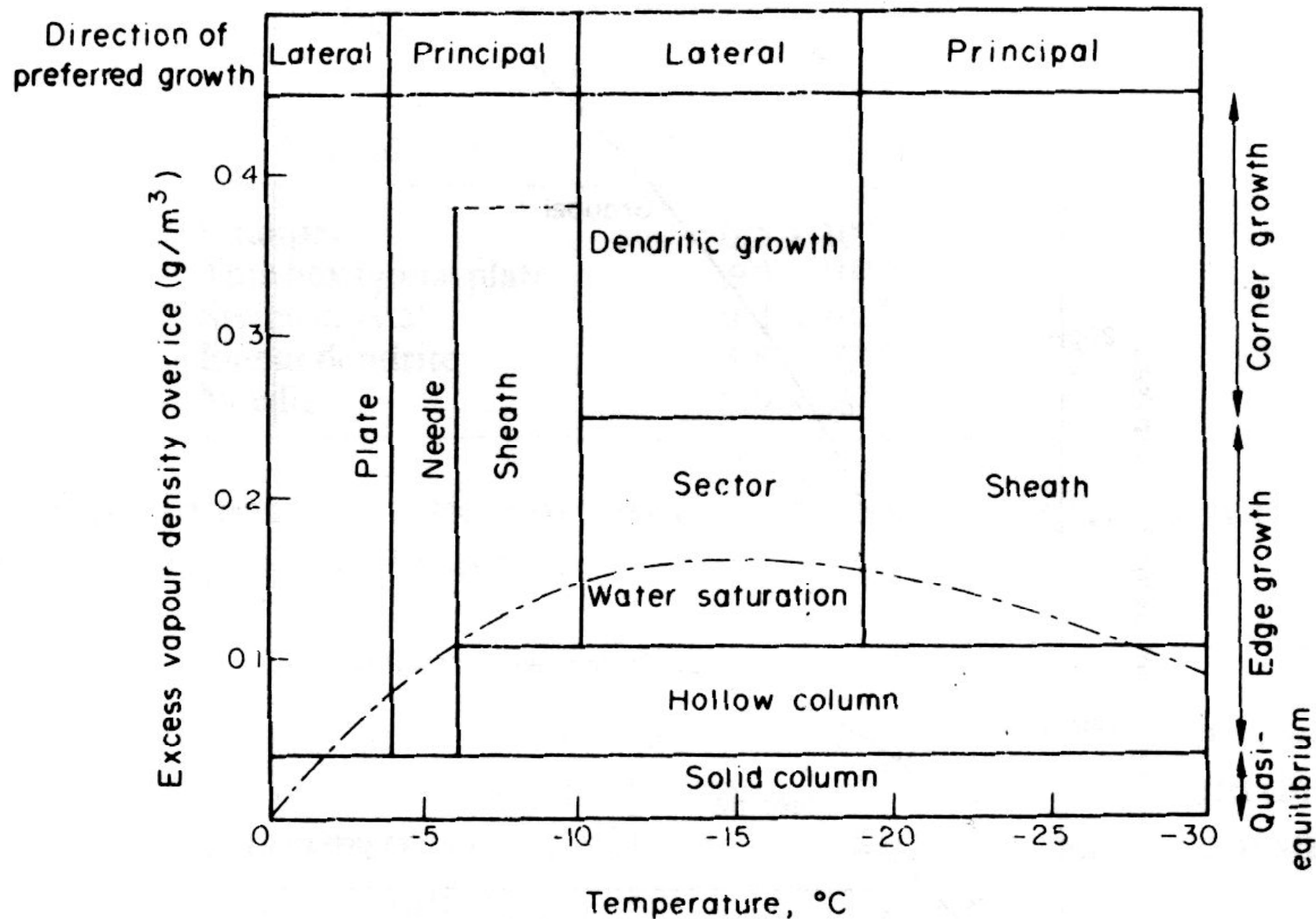


FIG. 9.6. Kobayashi's diagram of crystal habit as function of temperature and excess vapor density over ice saturation. (From Fletcher, 1962.)

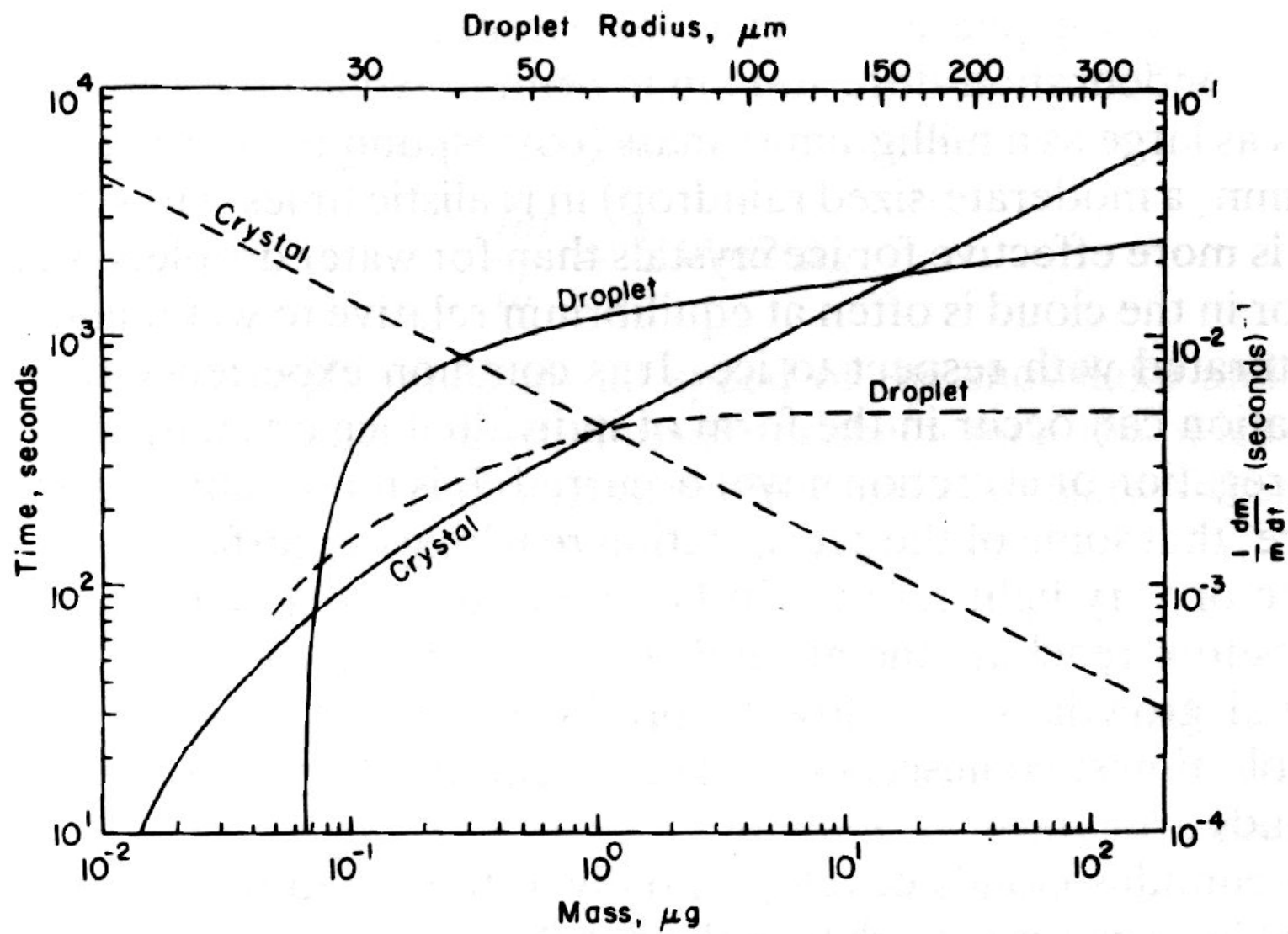


FIG. 9.8. Times required for an ice crystal and a water droplet (solid curves) to grow to the indicated mass. Top scale gives the corresponding drop radius. Dashed curves are for the rates of fractional increase of mass, referred to the scale on the right.

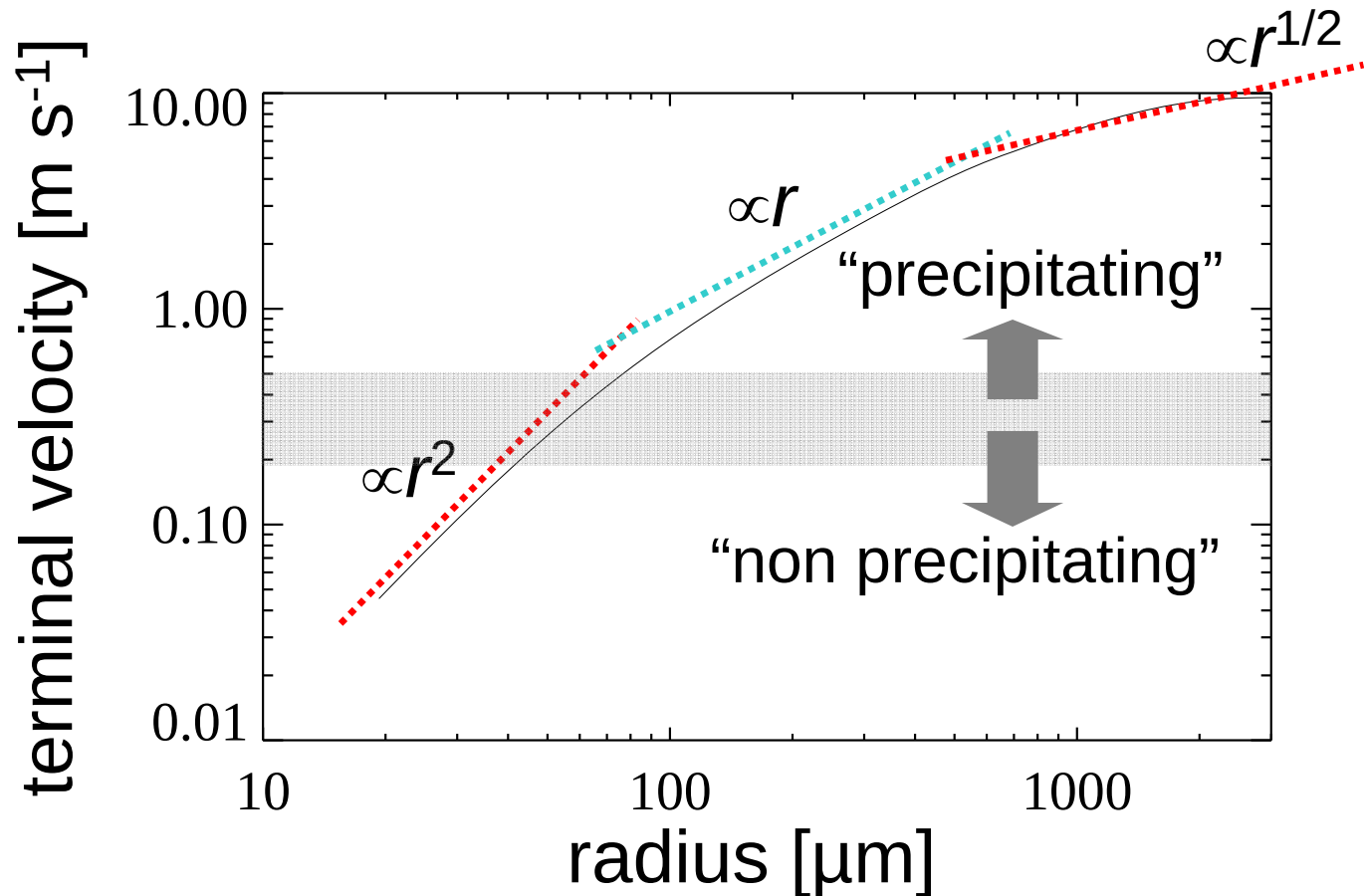


FIG. 1. The general view of the dry-ice-seeded racetrack pattern in supercooled cloud layer 37 min after the start of the seeding and 24 min after the end of the seeding. The cloud layer extended between 4500 and 6800 ft over Utica, NY, with a top temperature of -5.6°C . The picture was taken at 1521 UTC 24 Nov 1948 from an altitude of 17 630 ft. (From Langmuir 1961b.)

PRECIPITATION

Terminal velocity of drops

- Balance between **gravitational** force ($= mg$) and **drag** force ($\propto$ size)
- Time taken for drop to reach terminal velocity is very short



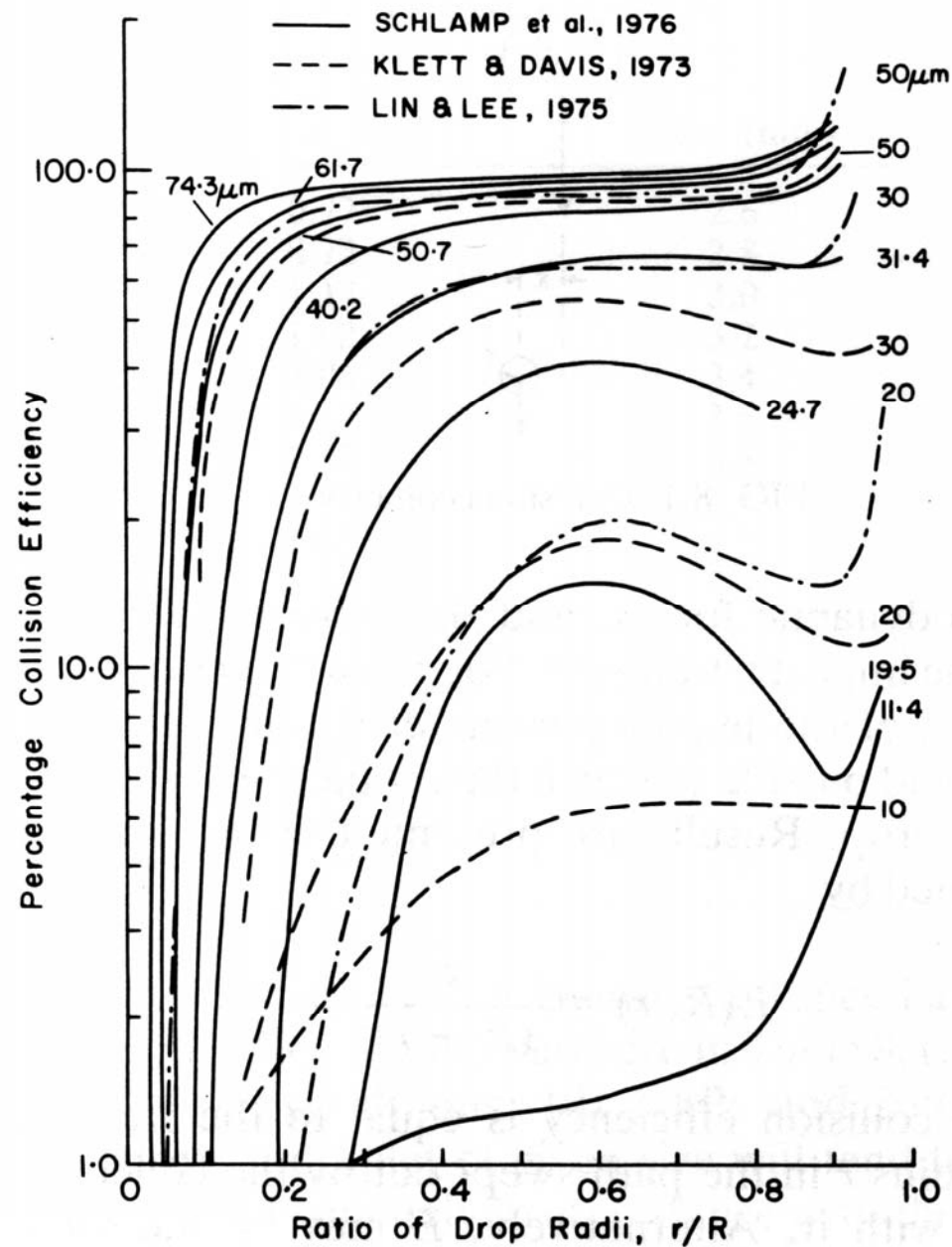


FIG. 8.2. Computed collision efficiencies for pairs of drops as a function of the ratio of their radii. Curves are labeled according to the radius R of the larger drop.

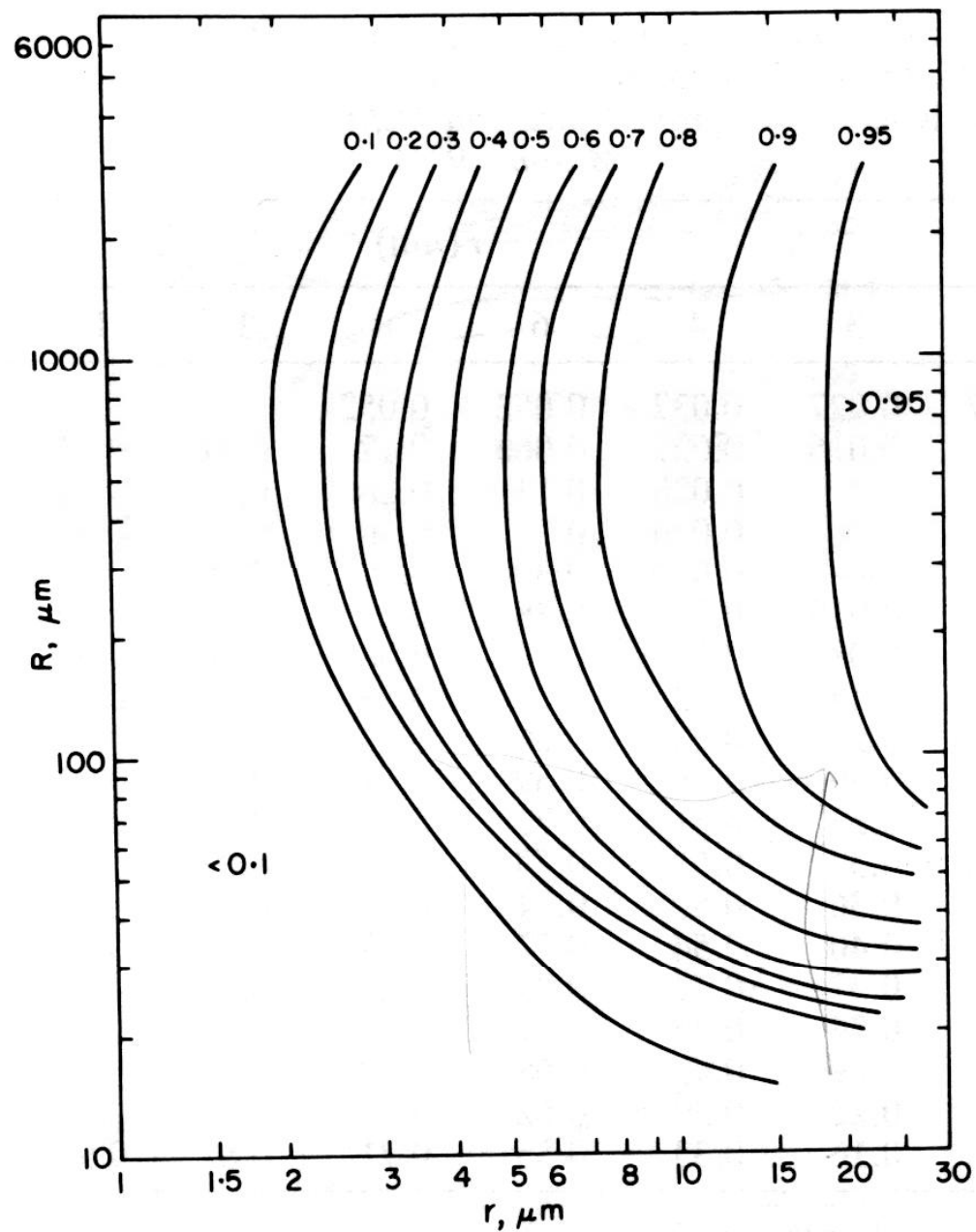


FIG. 8.3. Field of $E(R, r)$ based on data in Table 8.2.

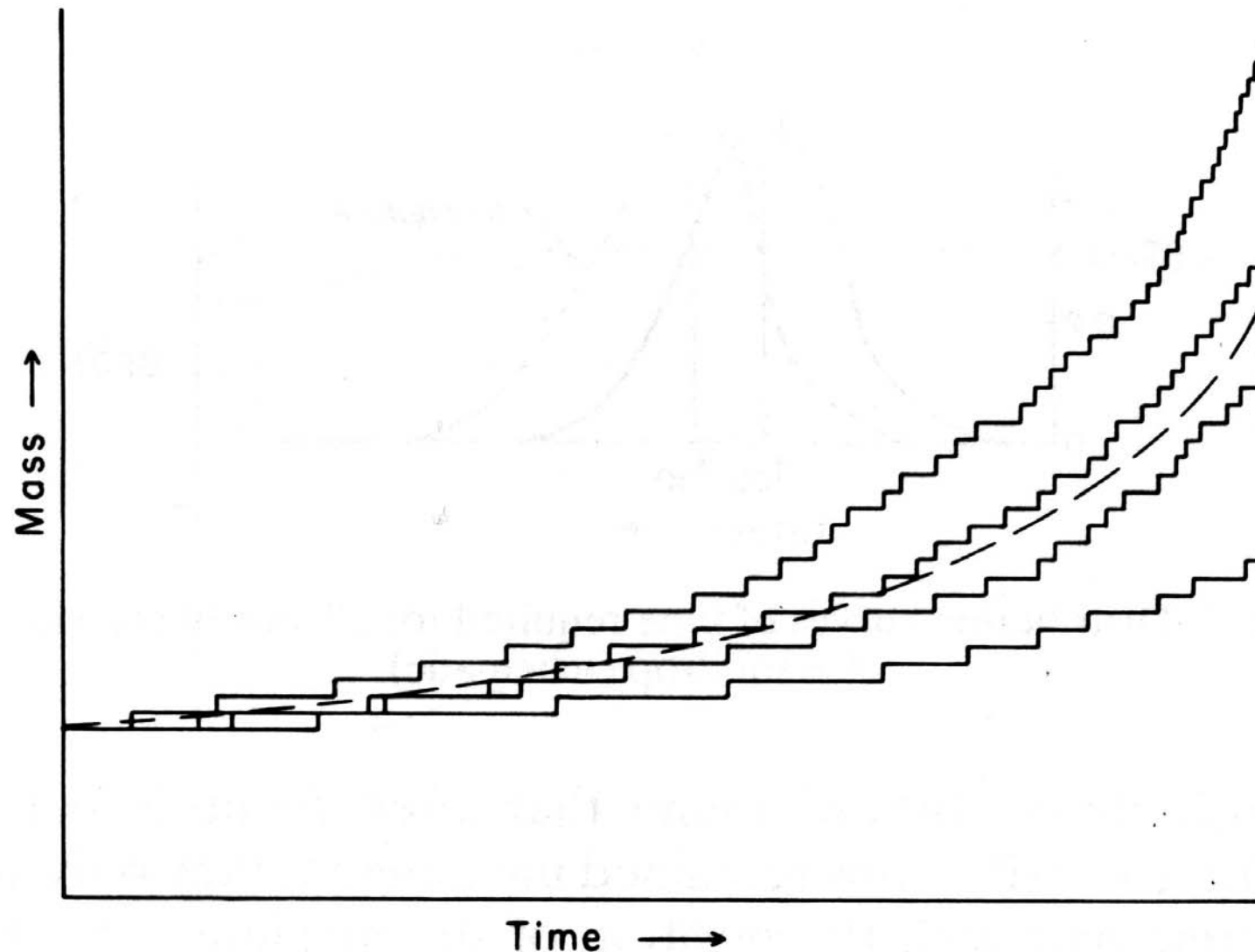


FIG. 8.7. Schematic illustration of droplet growth by discrete captures, including statistical variability. Shown are four realizations of the growth of a drop by collection of smaller, equal-sized droplets. The average growth for many such realizations is indicated by the dashed line.

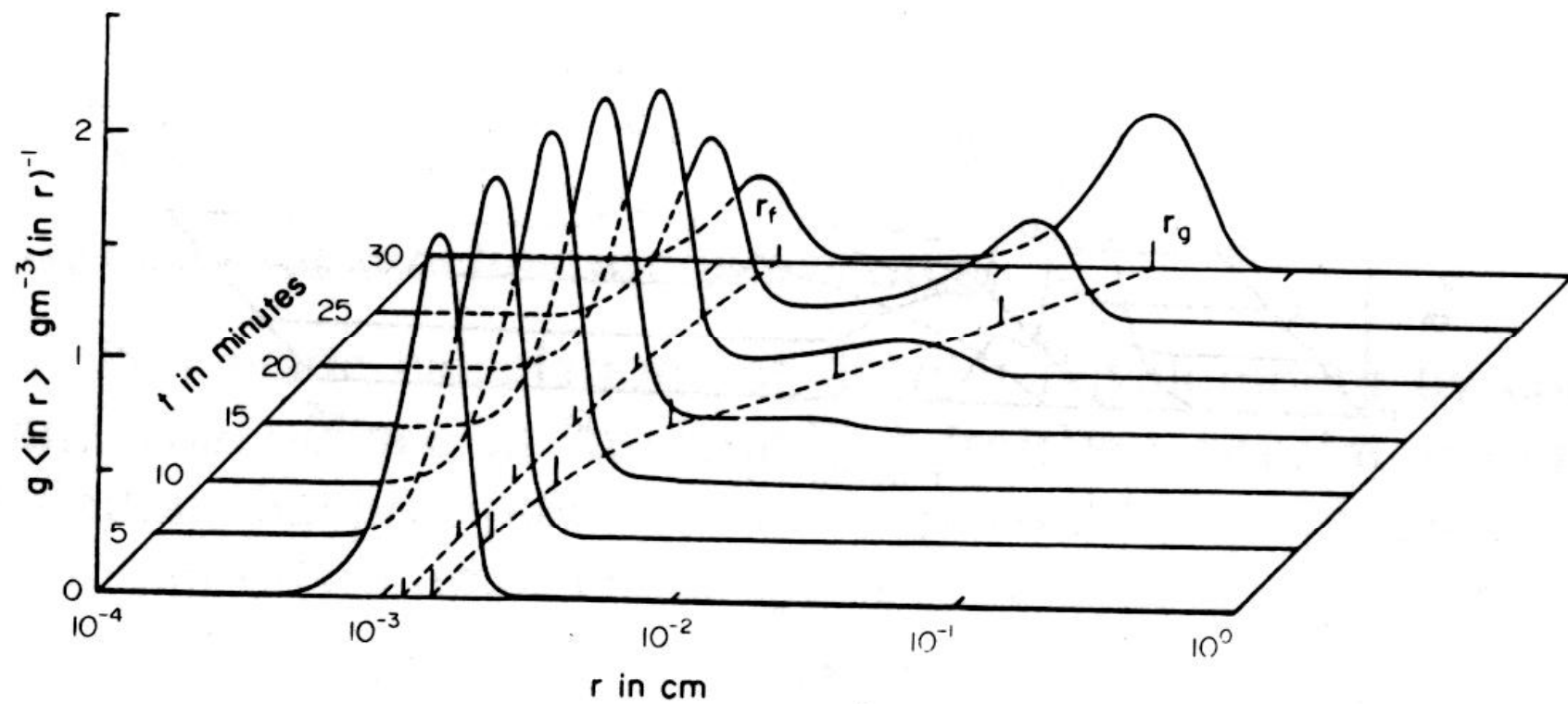
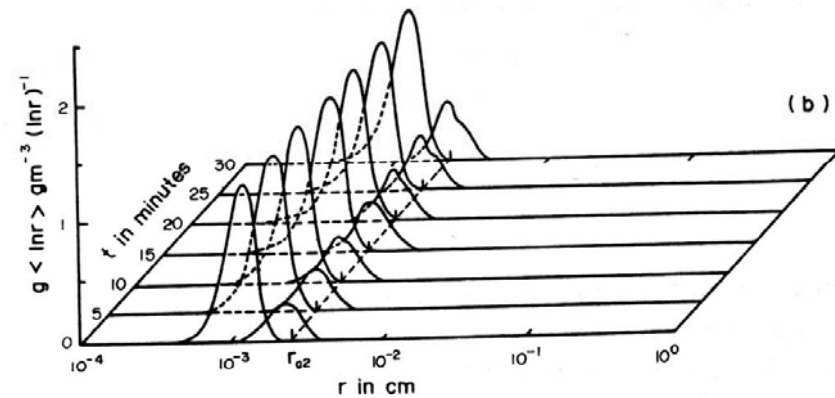
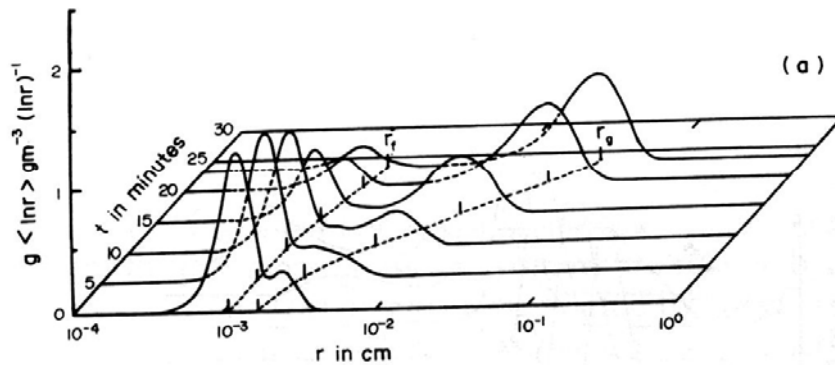


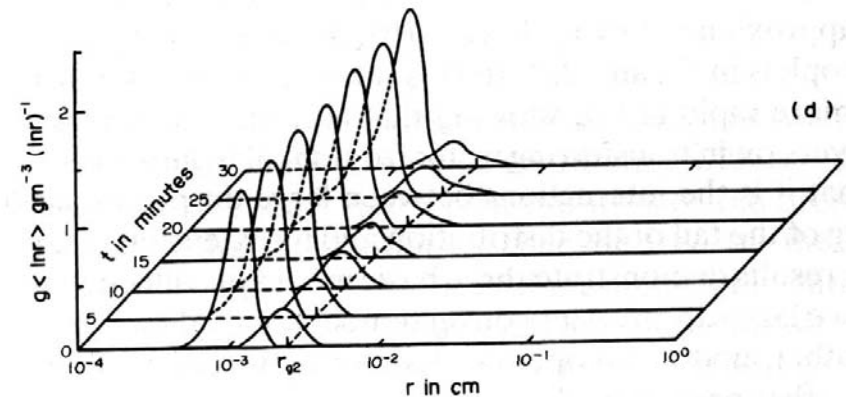
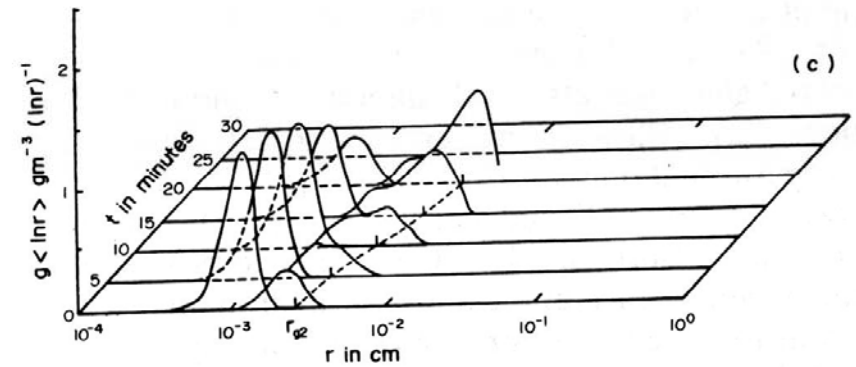
FIG. 8.10. Example of the development of a droplet spectrum by stochastic coalescence. (From Berry and Reinhardt, 1974b.)

All collisions



Collisions only for S_1 drops:
“autoconversion”

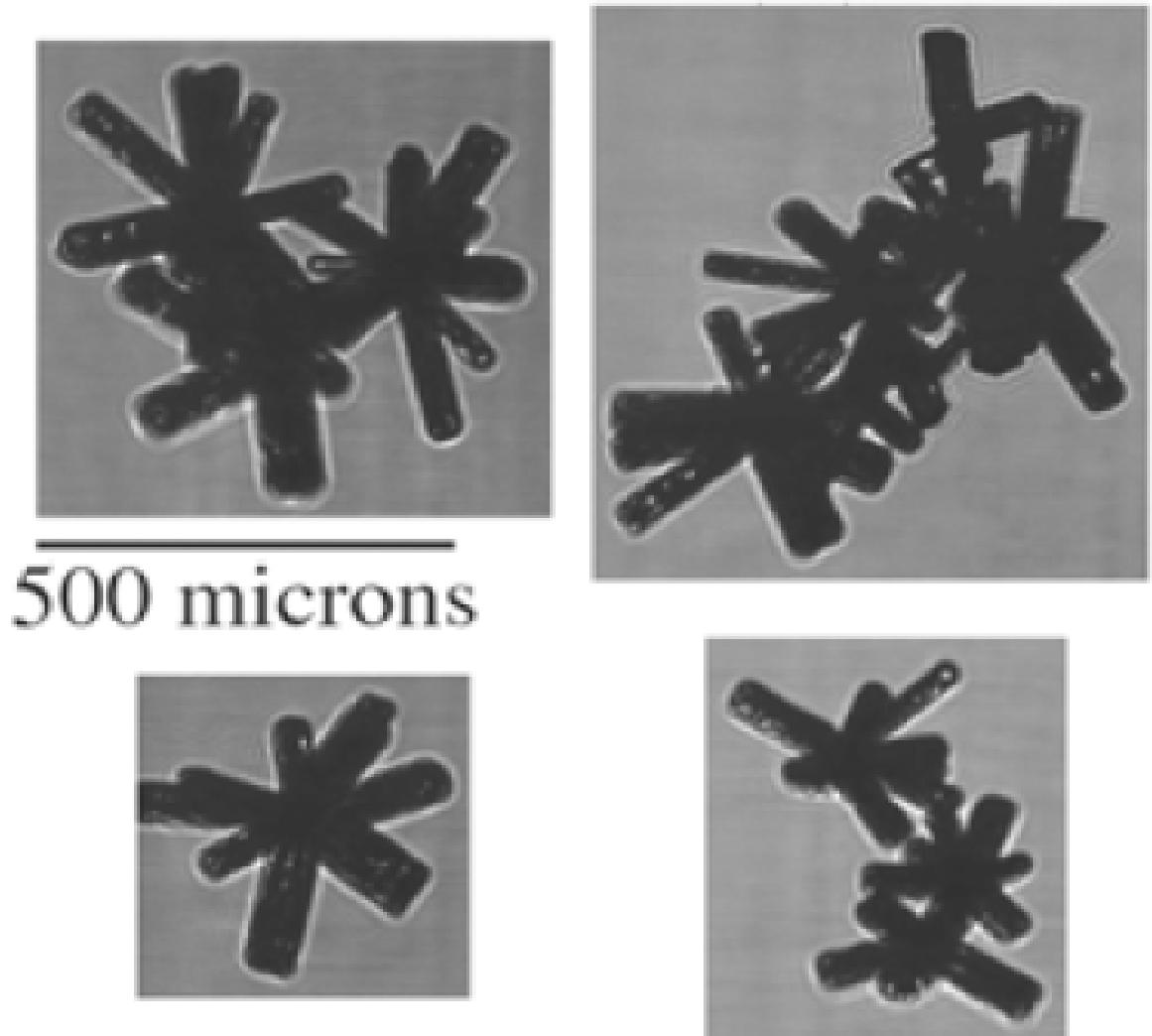
Collisions between S_1 and
 S_2 drops only: “accretion”



Collisions only for S_2 drops only:
“self-collection”

Ice crystal aggregates in Cirrus clouds

- Taken using an imaging probe on an aircraft
- Most crystals show irregular aggregated shape
- Snow in midlatitudes mostly grows by aggregation



Westbrook et al. 2004

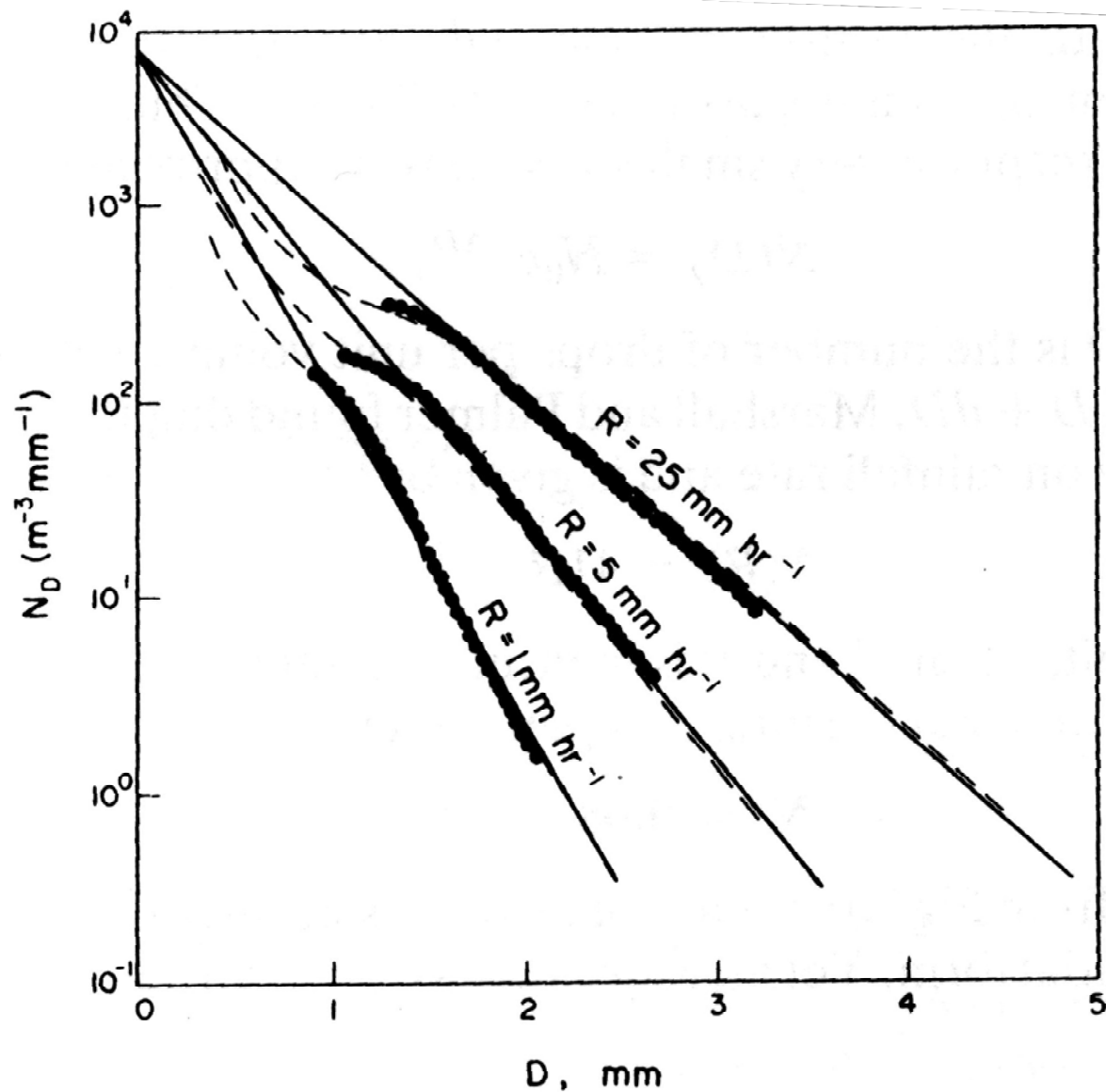


FIG. 10.2. Measured drop-size distributions (dotted lines) compared with best-fit exponential curves (straight lines) and distributions reported by others (dashed lines). (From Marshall and Palmer, 1948.)

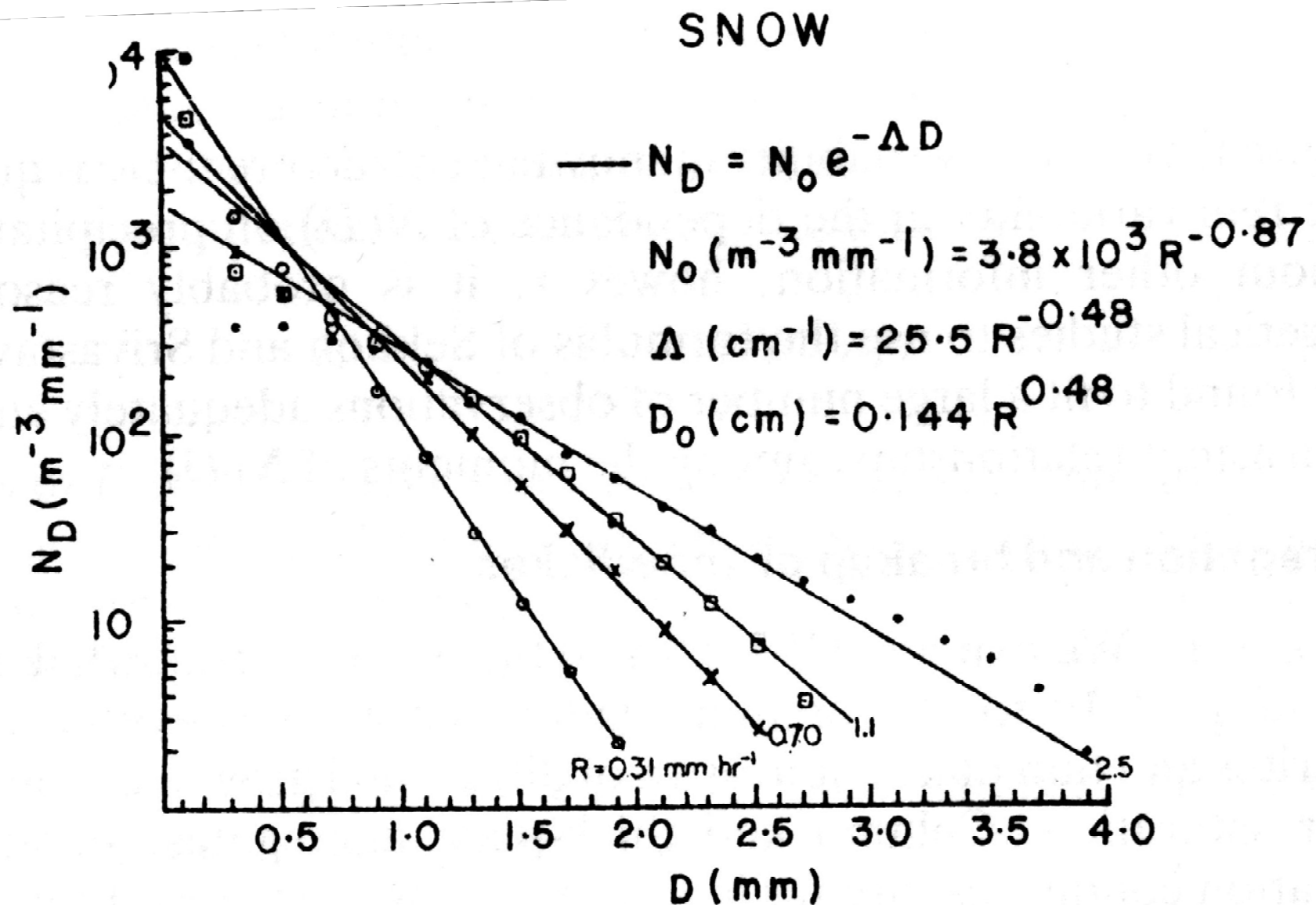


FIG. 10.9. Size distributions of snowflakes in terms of diameters of drops produced by melting the snowflakes. (From Gunn and Marshall, 1958.)