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A New Formula for the Rain Dew Point III

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Abstract

In paper I in this series, the author derived the following equation for rain dew point [1].

$$To–T=(3kTo^2/\sigma_o a_o)(P^*_{H2O}/Pair)$$

This equation has its origin in the author's research in 2012 [2]. The author applied it to rain drops in another paper [3]. Then it was simplified by using Lord Kelvin's equation for rising vapor pressure through curvature of the surface [4, 5]. In this paper new tables, more complete than the one in paper II, [6] will be presented for To=0°C, -10°C and -22.5°C as the starting temperature of the rain cloud. Values for σ_o and P^*_{H2O} (surface tension of the water droplet, vapor pressure of the water droplet) for those temperatures have been obtained from the literature [7, 8]. The values for T, the undercooling temperature for the rain cloud, will be in the new tables. Water can only be supercooled to about -40°C, so we are only taking this down to -22.5°C for the starting To. The calculations will be presented in RESULTS.

Keywords: Rain Droplets, Curvature, Surface Tension, Equilibrium Water Vapor Pressure, Lord Kelvin

Introduction

We have to review the table for ΔT presented in paper I. There To was taken to be 0°C with varying altitudes h of the cloud. That table is the following, for To=0°C. There will be two other tables for To=-10°C and -22.5°C.

T(calculated)	Pair	h (storm cloud)	ΔT=To-T
272.6 Kelvin	1 atm	0 m	0.5308 Kelvin
272.5 Kelvin	0.8 atm	2000 m	0.6636 Kelvin
271.8 Kelvin	0.4 atm	7000 m	1.327 Kelvin
270.5 Kelvin	0.2 atm	12,000 m	2.654 Kelvin

It was noted that temperature decreases at a rate of 6.5°C per 1000 m altitude rise. In this table in INTRODUCTION ΔT due to water vapor change is far less than that caused by the pressure drop.

Results

For the vapor pressure over liquid water below 0°C, there is formula (1) due to Bolton (1980) [8]. The pressure P^*_{H2O} is in [hPa] and temperature t in [°C].

$$P^*_{H2O} = 6.112 \exp((17.67 * t) / (t+243.5)) \qquad (1)$$

Now 1 hPa=0.000986923 atm. The surface tension σ_o of the supercooled water is from data by Hacker (1951) [7]. Here is the table of these values from To= 0°C, -10°C and -22.5°C. Hacker's data goes from 27.5°C down to -22.5°C.

To	P^*_{H2O}(hPa)	P^*_{H2O}(atm)	σ_o(ergs/cm^2)
0°C	6.112	0.006032	75.705
-10°C	2.868	0.002830	77.36
-22.5°C	1.01134	0.0009981	79.67

These numbers will be used in (2), which was derived in paper I [1]. a_o is assumed to be constant ($46.6\text{x}10^{-16}$ cm^2) as the density is near 1 gram/cm^3. k, Boltzmann constant, is 1.381×10^{-16} erg/K.

$$To-T=(3kTo^2/\sigma_o a_o)(P^*_{H2O}/Pair) \qquad (2)$$

Now, the object is to arrive at T, the undercooling effect of the water vapor, from the various To starting temperatures. Here is the table for To=-10°C=263.15 Kelvin. We assume σ_o and a_o are independent of pressure and also P^*_{H2O}.

T(calculated)	Pair	h (storm cloud)	ΔT=To-T
262.93 Kelvin	1 atm	0 m	0.22°C
262.87 Kelvin	0.8 atm	2000 m	0.28°C
262.59 Kelvin	0.4 atm	7000 m	0.56°C
262.02 Kelvin	0.2 atm	12,000 m	1.13°C

Here is the table for To=-22.5°C=250.65 Kelvin.

T(calculated)	Pair	h (storm cloud)	ΔT=To-T
250.58 Kelvin	1 atm	0 m	0.070°C
250.56 Kelvin	0.8 atm	2000 m	0.087°C
250.48 Kelvin	0.4 atm	7000 m	0.175°C
250.3 Kelvin	0.2 atm	12,000 m	0.35°C

Discussion

It is seen that the temperature drop due to the water vapor effect falls off as the starting To decreases. P^*_{H2O} becomes vanishingly small as To goes to -22.5°C. We notice that the pressure has a greater effect than the water vapor.

Acknowledgements

Here the author wishes to mention Saint Albert the Great, patron of scientists. Also, we note that Saint Dominic wrote the Rosary, the prayer to the Virgin Mary.

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