Meteorology

Equations and Constants

Wien's Law

Wien's law (or Wien's displacement law) relates an object's maximum emitted wavelength of radiation to the object's temperature. It states that the wavelength of maximum emitted radiation by an object is inversely proportional to the object's absolute temperature. In symbolic form, it is written as:

$$\lambda_{max} = \frac{w}{T}$$

where λ_{max} is the wavelength at which maximum radiation emission occurs, T is the object's temperature, and w is a constant.

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λ_{max} = wavelength (micrometers)
w = 0.2897 μm K
T = temperature (K)

Geostrophic Wind Equation

The geostrophic wind equation gives an approximation of the wind speed above the level of friction, where the wind blows parallel to the isobars or contours. The equation is expressed mathematically as:

$$V_g = \frac{1}{2\Omega \sin\phi\rho}\frac{\Delta p}{d}$$

where V_g is the geostrophic wind, Ω is a constant (twice the earth's angular spin), $\sin\phi$ is a trigonometric function that takes into account the variation of latitude (ϕ), ρ is the air density, Δp is the pressure difference between two places on the map some horizontal distance (d) apart.

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V_g	=	geostrophic wind (m/sec)
Ω	=	7.29×10^{-5} radian*/sec
ϕ	=	latitude
ρ	=	air density (kg/m^3)
d	=	distance (m)
Δp	=	pressure difference (newton/m^2)

*2π radians equal 360°.

Hydrostatic Equation

The hydrostatic equation relates to how quickly the air pressure decreases in a column of air above the surface. The equation tells us that the rate at which the air pressure decreases with height is equal to the air density times the acceleration of gravity. In symbolic form, it is written as:

$$\frac{\Delta p}{\Delta z} = -\rho g$$

where Δp is the decrease in pressure along a small change in height Δz, ρ is the air density, and g is the force of gravity.

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Δp	=	pressure difference (newton/m^2)
Δz	=	change in height (m)
ρ	=	air density (kg/m^3)
g	=	force of gravity (9.8m/sec^2)

Gas Law (Equation of State)

The relationship among air pressure, air density, and air temperature can be expressed by

Pressure = density × temperature × constant.

This relationship, often called the gas law (or equation of state), can be expressed in symbolic form as:

$$p = \rho R T$$

where p is air pressure, ρ is air density, R is a constant, and T is air temperature.

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p = pressure in N/m^2 (SI)
ρ = density (kg/m^3)
T = temperature (K)
$R = 287$ J/kg • K (SI) or
$R = 2.87 \times 10^6$ erg/g • K

Stefan-Boltzmann Law

The Stefan-Boltzmann law is a law of radiation. It states that all objects with temperatures above absolute zero emit radiation at a rate proportional to the fourth power of their absolute temperature. It is expressed mathematically as:

$$E = \sigma T^4$$

where E is the maximum rate of radiation emitted each second per unit surface area, T is the object's surface temperature, and σ is a constant.

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E = radiation emitted in W/m^2 (SI)
$\sigma = 5.67 \times 10^{-8}\ W/m^2 \cdot K^4$ (SI) or
$\sigma = 5.67 \times 10^{-5}\ erg/cm^2 \cdot K^4 \cdot sec$
T = temperature (K)

Relative Humidity

The relative humidity of the air can be expressed as:

$$RH = \frac{e}{e_s} \times 100\%.$$

To determine e and e_s, when the air temperature and dew-point temperature are known, consult Table B.1. Simply read the value adjacent to the air temperature and obtain e_s; read the value adjacent to the dew-point temperature and obtain e.

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e = actual vapor pressure (millibars)
e_s = saturation vapor pressure (millibars)
RH = relative humidity (percent)

TABLE B.1 Saturation Vapor Pressure over Water for Various Air Temperatures

AIR TEMPERATURE (°C)	(°F)	SATURATION VAPOR PRESSURE (MB)	AIR TEMPERATURE (°C)	(°F)	SATURATION VAPOR PRESSURE (MB)
–18	(0)	1.5	18	(65)	21.0
–15	(5)	1.9	21	(70)	25.0
–12	(10)	2.4	24	(75)	29.6
–9	(15)	3.0	27	(80)	35.0
–7	(20)	3.7	29	(85)	41.0
–4	(25)	4.6	32	(90)	48.1
–1	(30)	5.6	35	(95)	56.2
2	(35)	6.9	38	(100)	65.6
4	(40)	8.4	41	(105)	76.2
7	(45)	10.2	43	(110)	87.8
10	(50)	12.3	46	(115)	101.4
13	(55)	14.8	49	(120)	116.8
16	(60)	17.7	52	(125)	134.2