Thermodynamic Equation for Absolute Vapor Pressure

$$e_a = \frac{q \cdot P}{\epsilon + (1-\epsilon)q} = \frac{q \cdot P}{0.622 + 0.378q}$$

e_a = Absolute vapor pressure (hPa)

q = Specific humidity (expressed as a dimensionless ratio, kg/kg

P = Total atmospheric pressure (whatever this unit is will be the unit of e_a so we need hPa)

ϵ= The ratio of the gas constants for dry air and water vapor $R_d/R_v = 0.622$

Proof:

Ideal gas laws for dry air and vapor

$$P_d = \rho_d R_d T \qquad\qquad e_a = \rho_v R_v T$$

P_d = partial pressure of dry air (Pascals (Pa))

e_a = partial pressure of water vapor (Pascals (Pa))

ρ_d = density of dry air (kg/m^3) ρ_d = density of water vapor (kg/m^3)

R_d = specific gas constant for dry air (287.05 J/kg *K)

R_v = specific gas constant for water vapor (461.5 J/kg *K)

T = Absolute temperature (Kelvin)

$$q = \frac{\rho_v}{\rho_v + \rho_d} = \frac{\frac{e_a}{R_v T}}{\frac{e_a}{R_v T} + \frac{P_d}{R_d T}} = \frac{\frac{e_a}{R_v}}{\frac{e_a}{R_v} + \frac{P_d}{R_d}} = \frac{e_a}{e_a + (\frac{R_v}{R_d})P_d} = \frac{e_a}{e_a + \frac{P_d}{\epsilon}} = \frac{\epsilon e_a}{\epsilon e_a + P_d}$$

q = specific humidity

ϵ = Gas constant ratio ($\frac{R_d}{R_v} = 0.622$)

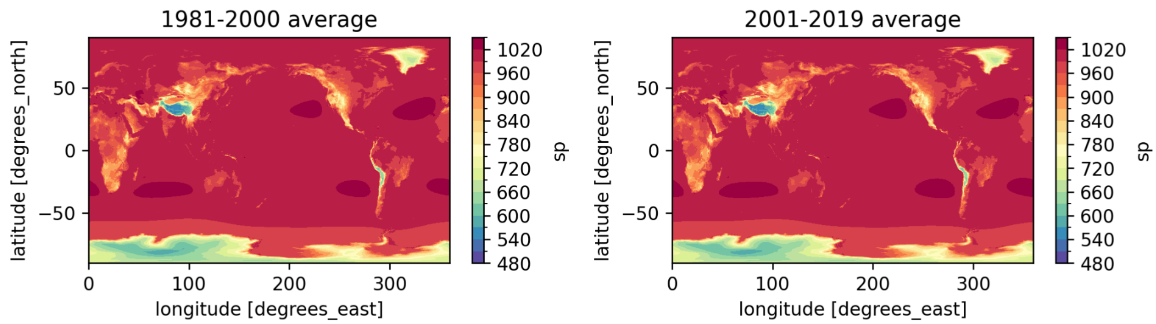
$$q = \frac{\epsilon P_v}{\epsilon P_v + (P - P_v)} = \frac{\epsilon e_a}{P - (1-\epsilon)e_a}$$

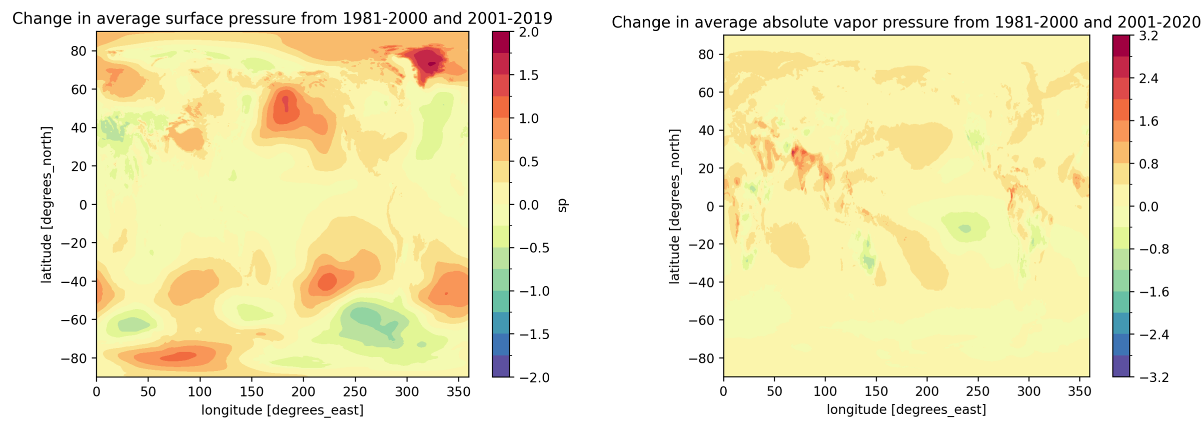
P = surface pressure ($P = P_d + P_v$)

Algebra to solve for e_a

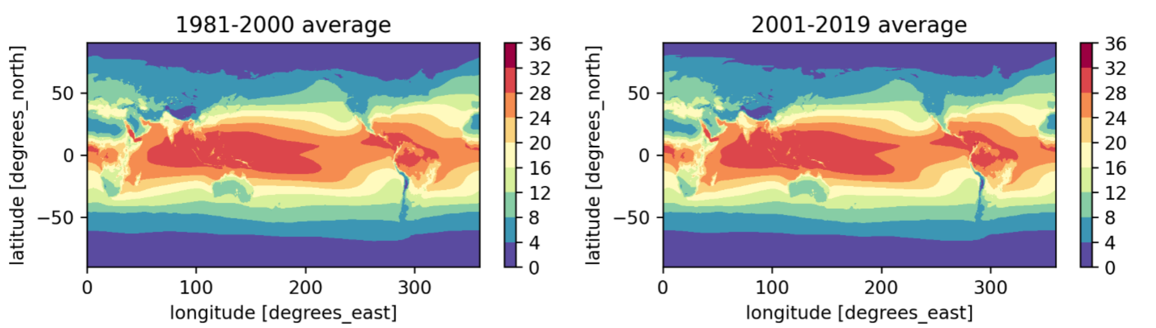
$$(p - (1-\epsilon)e_a)q = \epsilon e_a$$
$$Pq - (1-\epsilon)q \cdot e_a = \epsilon e_a$$
$$Pq = \epsilon e_a + (1-\epsilon)q \cdot e_a$$
$$Pq = e_a(\epsilon + (1-\epsilon)q)$$
$$e_q = \frac{Pq}{\epsilon + (1-\epsilon)q}$$

Multi-Year Annual Mean Surface Pressure for 1981-2000 and 2001-2019





Multi-Year Annual Mean Absolute Vapor Pressure for 1981-2000 and 2001-2019



Tetens formula for Temperatures above 0 Celsius for Saturation Vapor Pressure

$$e_s = 6.109 \cdot e^{\frac{17.625 \cdot T}{T + 243.04}}$$

Tetens formula for Temperatures below 0 Celsius for Saturation Vapor Pressure

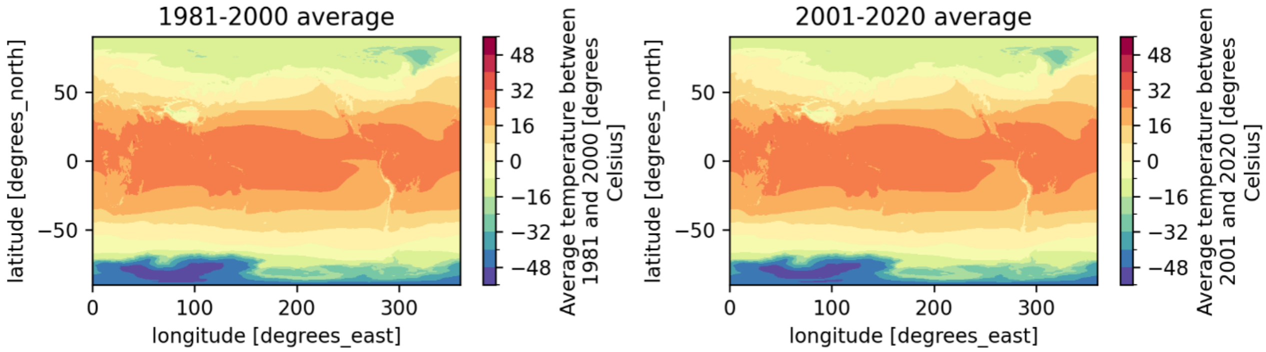
$$e_s = 6.109 \cdot e^{\frac{21.875 \cdot T}{T + 265.5}}$$

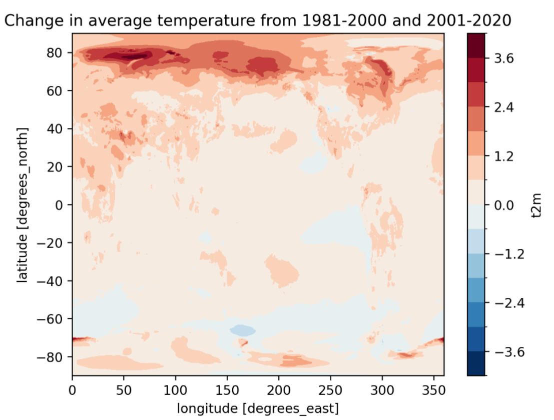
e_s = Saturation vapor pressure (hPa)

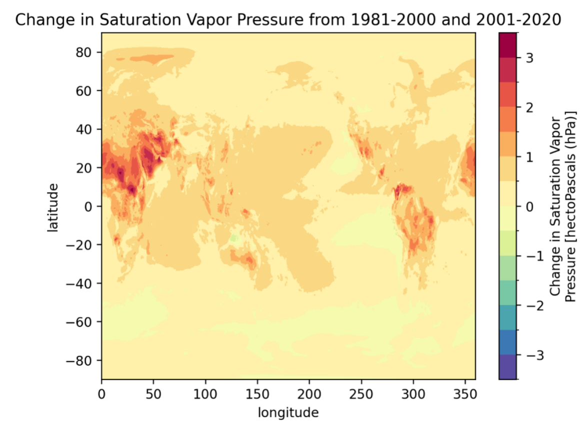
T = temperature in degrees celcius

e_o = The standard saturation vapor pressure at 0 degrees celsius = 6.1078

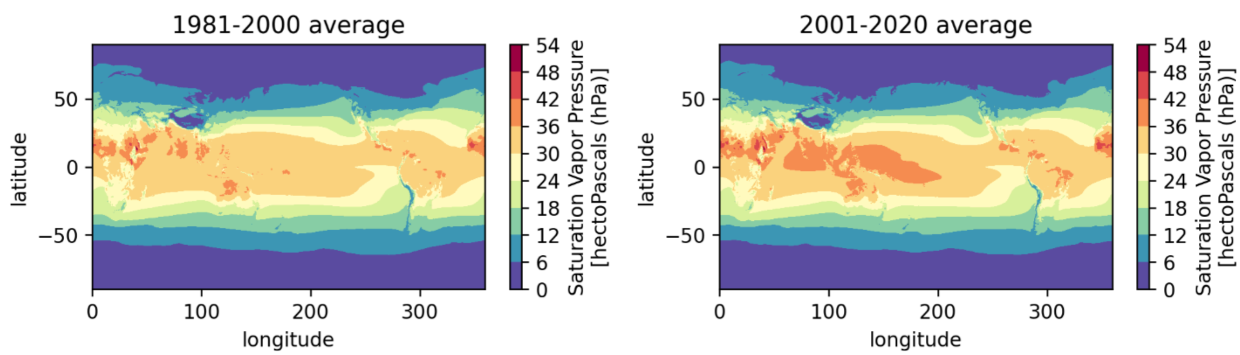
Multi-Year Annual Mean Temperature for 1981-2000 and 2001-2020







Multi-Year Annual Saturation Vapor Pressure for 1981-2000 and 2001-2020



Calculating VPD

$$VPD = e_s - e_a$$