CE 374 K – Hydrology

Atmospheric Water

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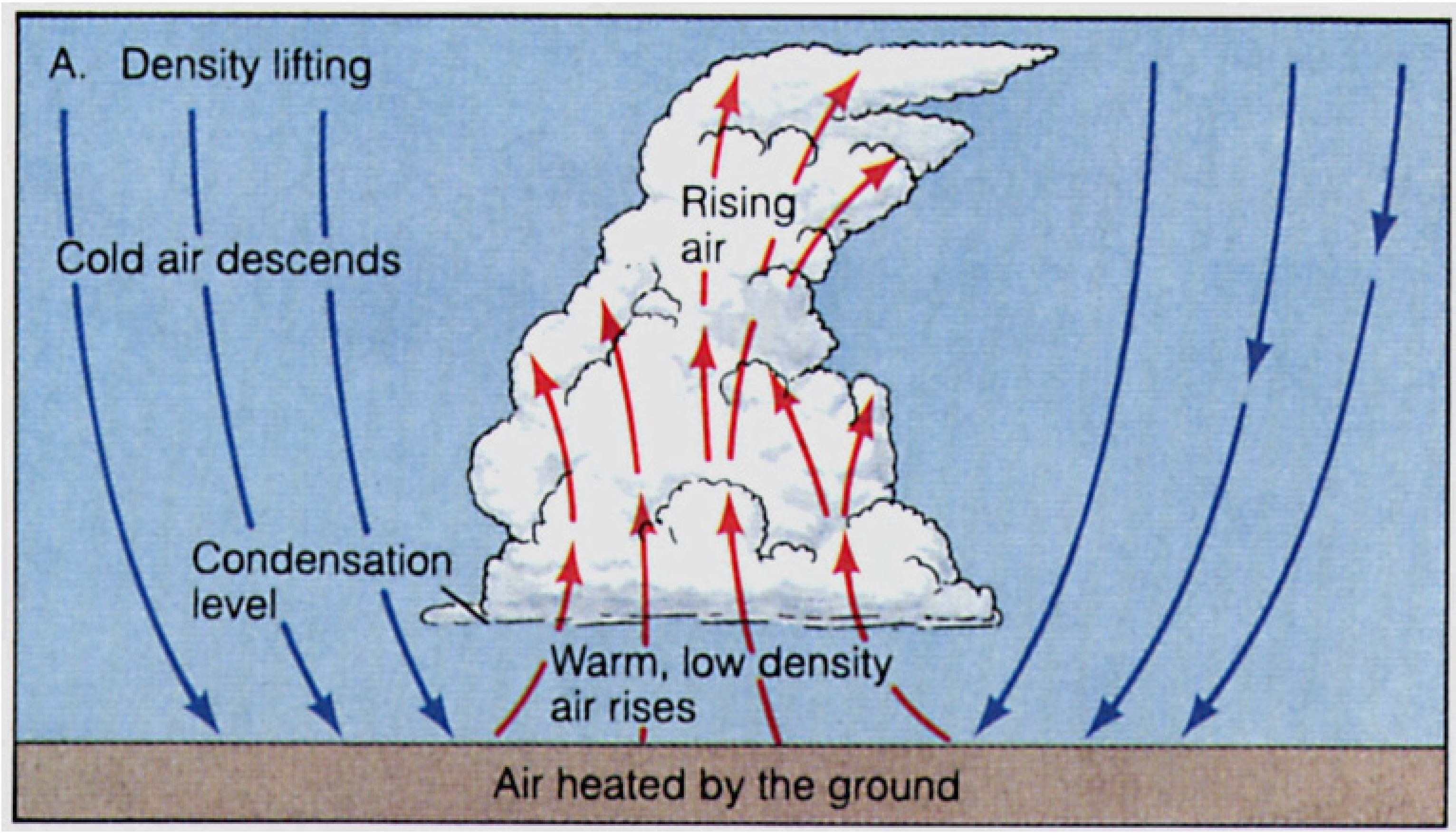
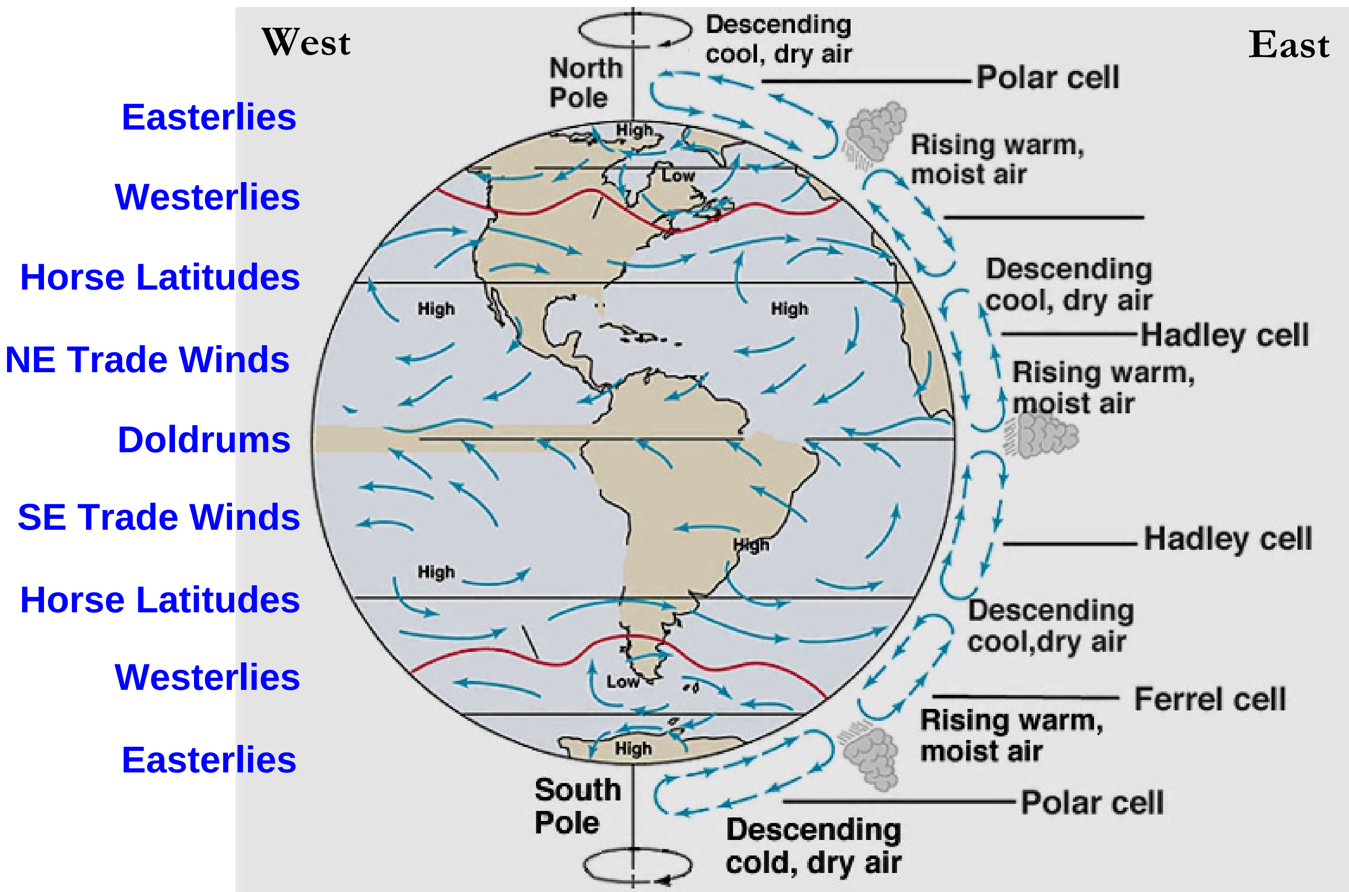
Heat Transport

Differential heating causes circulation

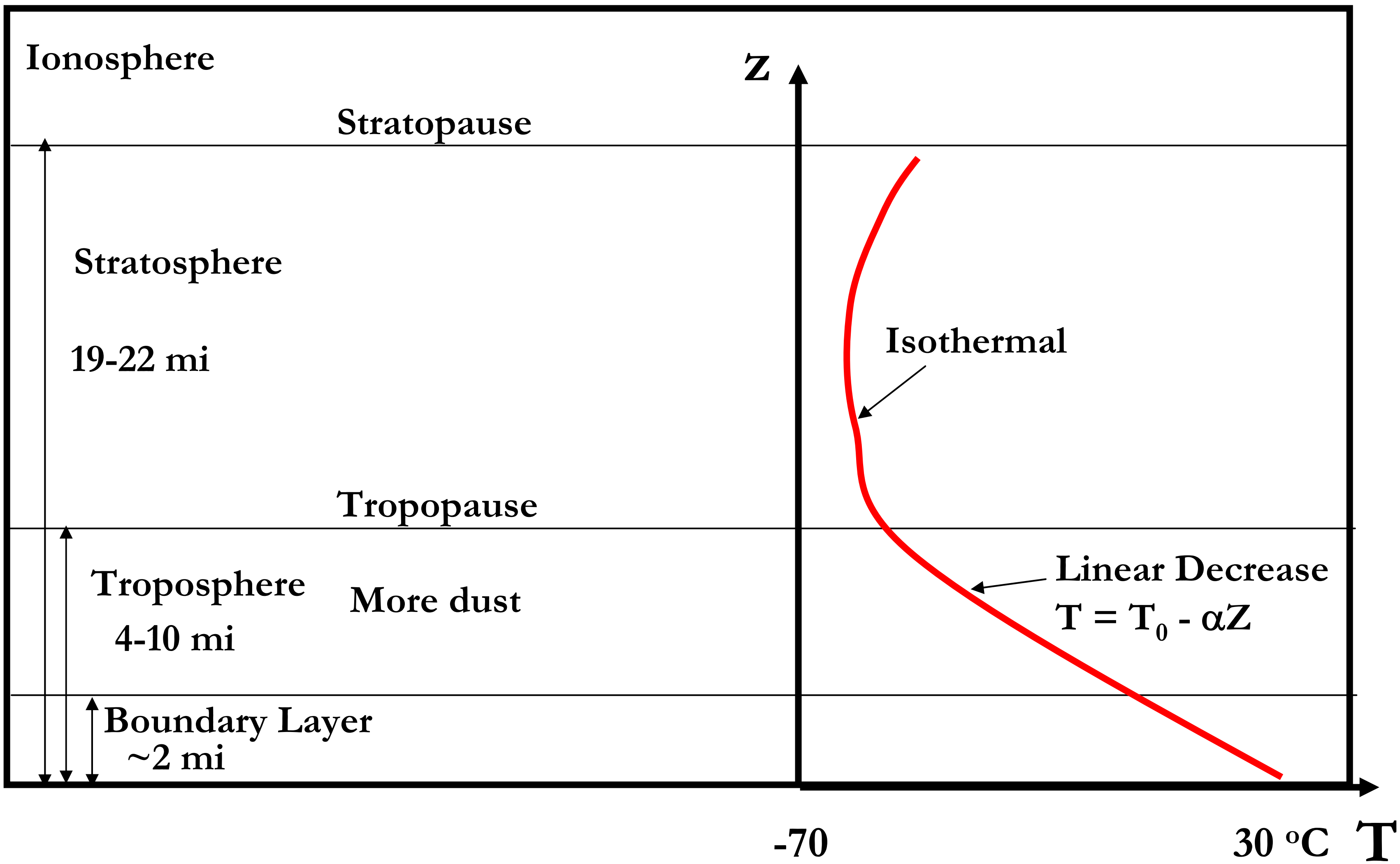


Rotating Earth

- Three circulation cells



Structure of the Atmosphere



Temperature and Pressure in the Atmosphere

- Troposphere
  - Temperature decrease $T(Z) = T_0 - \alpha Z$
    - α = lapse rate = 6.5 ^{o}C/km in standard atmosphere
  - Pressure distribution $$p(Z) = p_0 \left(\frac{T}{T_0} \right)^{g/R\alpha}$$
- Stratosphere
  - Pressure distribution $$p(Z) = p_0 \exp\left(-\frac{gZ}{RT} \right)$$

Composition of the Atmosphere

Components in Dry Air	Volume Ratio compared to Dry Air	Molecular Mass - *M* (kg/kmol)	Molecular Mass in Air
Oxygen	0.2095	32.00	6.704
Nitrogen	0.7809	28.02	21.88
Carbon Dioxide	0.0003	44.01	0.013
Hydrogen	0.0000005	2.02	0
Argon	0.00933	39.94	0.373
Neon	0.000018	20.18	0
Helium	0.000005	4.00	0
Krypton	0.000001	83.8	0
Xenon	$0.09\ 10^{-6}$	131.29	0
Total Molecular Mass of dry Air			**28.97**

Water Vapor

- Water vapor - H2O - one Oxygen atom and two Hydrogen atoms
- Hydrogen 1 atomic unit
- Oxygen 16 atomic units
- Water vapor 18 atomic units
- Ratio of wet air to dry air
- **Dry air is more dense than humid air!**

$$\frac{M_v}{M_d} = \frac{18}{28.97} = 0.622$$

Atmospheric Moisture

- Vapor pressure
  - e = vapor pressure of water vapor
  - Water vapor normally behaves as an ideal gas
  - ρ_v = vapor density (mass per unit volume)
  - T = Temperature (degK)
  - R_v = vapor gas constant = R_o/M_v
  - R_o = Universal gas constant
  - M_v = molecular weight of water vapor

$$e = \rho_v R_v T$$

- Partial pressure of water (vapor pressure) adds to partial pressures of the other gaseous constituents
  - Water vapor is about 1-2% of total pressure
- Humidity - quantity of water vapor present in air (absolute, specific or a relative value)
- Specific humidity - ratio of mass of water vapor in moist air - to mass of air

Specific Humidity, q_v

- q_v = mass of water vapor per mass of moist air
- M_v = mass of water vapor
- M_d = mass of dry air
- m_v = molecular wt of water vapor
- m_d = molecular wt of dry air
- e = partial pressure of water vapor
- P_d = partial pressure of the dry air
- P = Total pressure of the air

$$q_v = \frac{M_v}{M_v + M_d} = \frac{\frac{m_v e}{RT}}{\frac{m_v e}{RT} + \frac{m_d P_d}{RT}} = \frac{m_v e}{m_v e + m_d P_d}$$

$$= \frac{\frac{m_v}{m_d} e}{\frac{m_v}{m_d} e + (P - e)} = \frac{0.622e}{0.622e + (P - e)} = \frac{0.622e}{P - 0.378e}$$

$$\approx \frac{0.622e}{P}$$

$$q_v = \frac{\rho_v}{\rho_a} \approx \frac{0.622e}{P}$$

Relative Humidity, R_h

- e_s = Saturation Vapor Pressure
  - Max moisture air can hold @ given temp

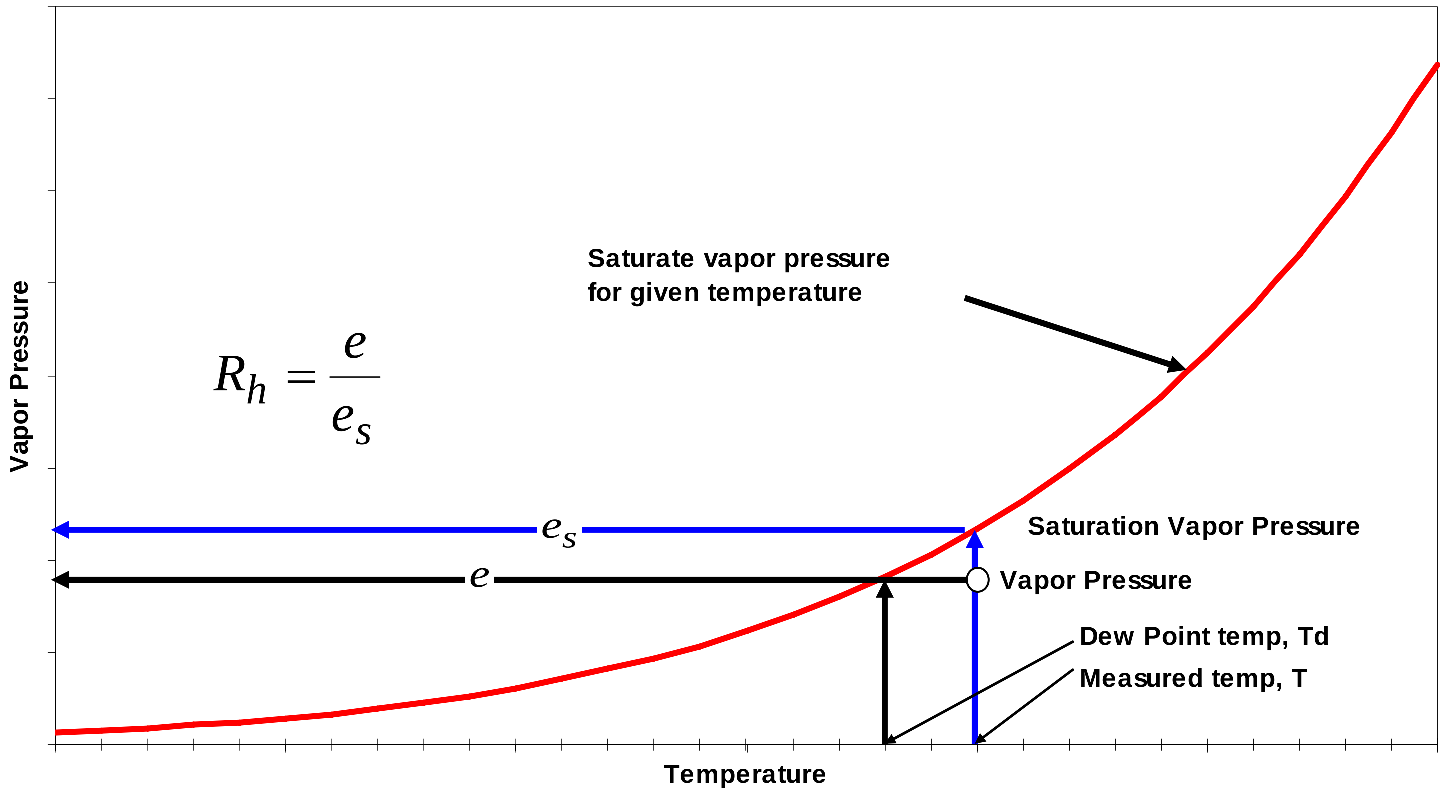
$$e_s = 611e^{17.27T/237.3T}$$

- R_h = vapor press/sat. vapor press

$$R_h = \frac{e}{e_s}$$

- T_d = Dew Point Temperature
  - temp at which air becomes saturated

Even More Humidity



Example

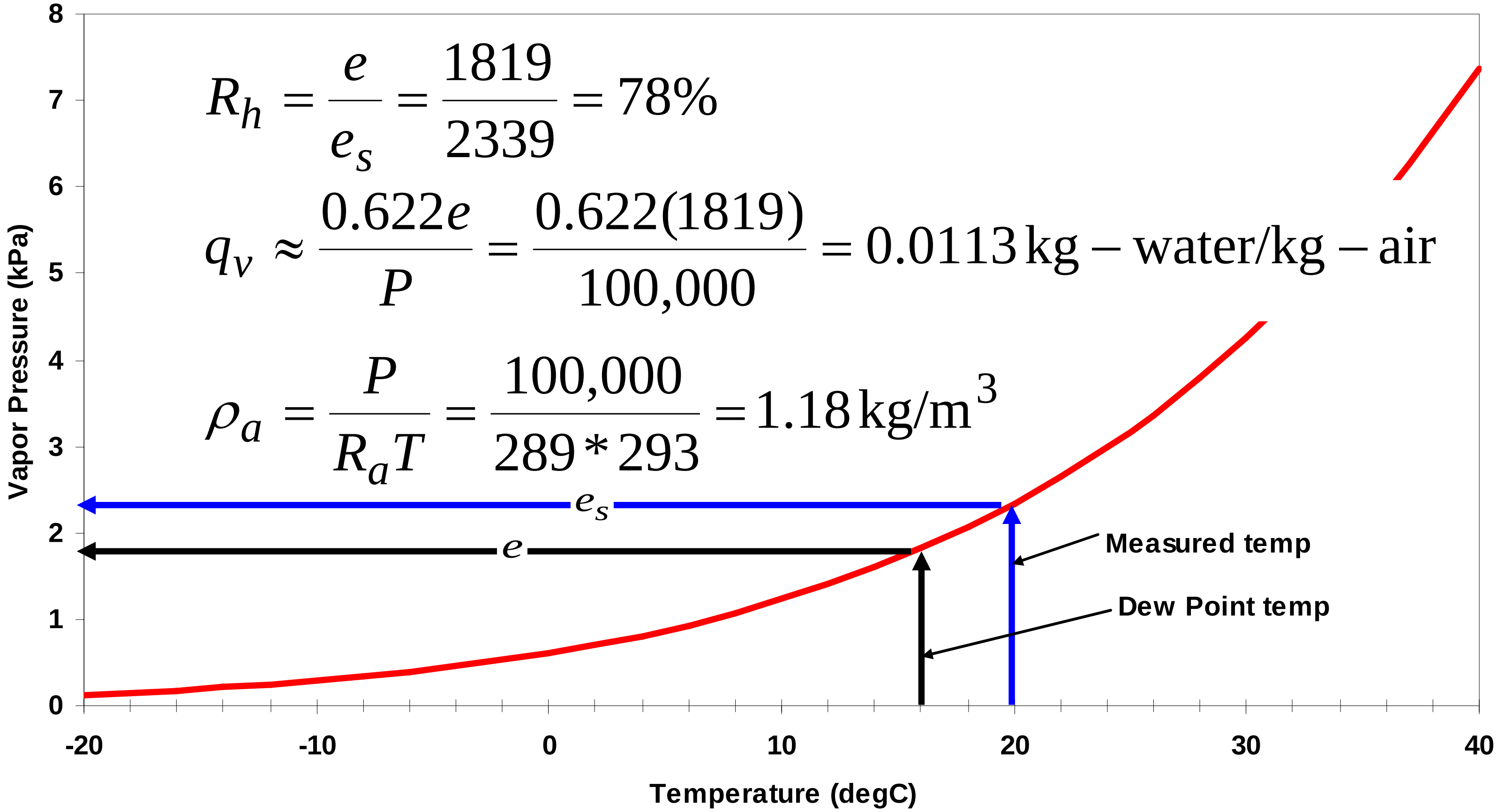
- Air pressure = 100 kPa
- Air temperature = 20 degC
- Wet-bulb (Dew Point) temperature = 16 degC
- Find:
  - Vapor pressure
  - Relative humidity,
  - Specific humidity,
  - Air density

Example

$$R_h = \frac{e}{e_s} = \frac{1819}{2339} = 78\%$$

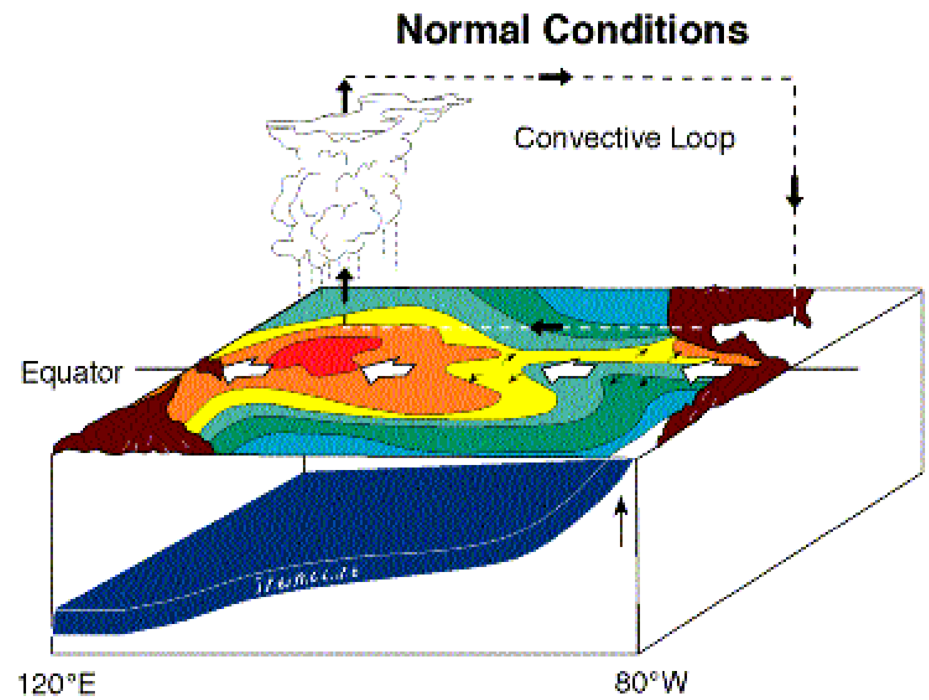
$$q_v \approx \frac{0.622e}{P} = \frac{0.622(1819)}{100{,}000} = 0.0113\,\text{kg} - \text{water/kg} - \text{air}$$

$$\rho_a = \frac{P}{R_a T} = \frac{100{,}000}{289 * 293} = 1.18\,\text{kg/m}^3$$



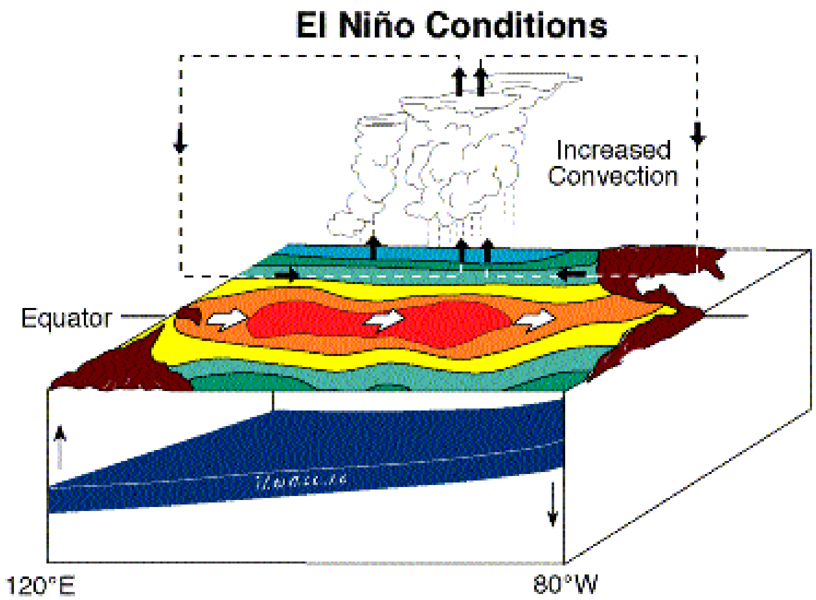
Non - El Nino Conditions

- Trade winds blow west across the Pacific,
- Piling up warm water in the west Pacific.
- Surface temperature is warmer in the west, and cooler off South America, due to upwelling of cold water from deeper levels.
- This cold water is nutrient-rich, supporting high levels of primary productivity, diverse marine ecosystems, and major fisheries.
- Rainfall is over the warmest water, and the east Pacific is relatively dry.



El Nino Conditions

- Trade winds relax in the central and western Pacific
- Rise in sea surface temperature
- Decline in primary productivity, adversely affecting higher levels of the food chain, including commercial fisheries.
- Rainfall follows the warm water eastward, with associated flooding in Peru and drought in Indonesia and Australia.



Risk from El Nino