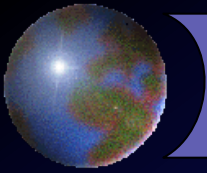


Moisture in the Atmosphere

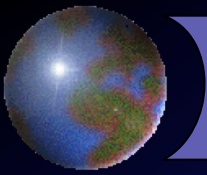
GEOG/ENST 2331 – Lecture 9

Ahrens: Chapter 4



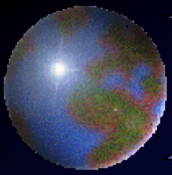
Last lecture

- ⊕ Atmospheric mechanics
 - ▣ PGF, gravity, Coriolis effect, friction
- ⊕ Geostrophic winds
- ⊕ Cyclones and anticyclones

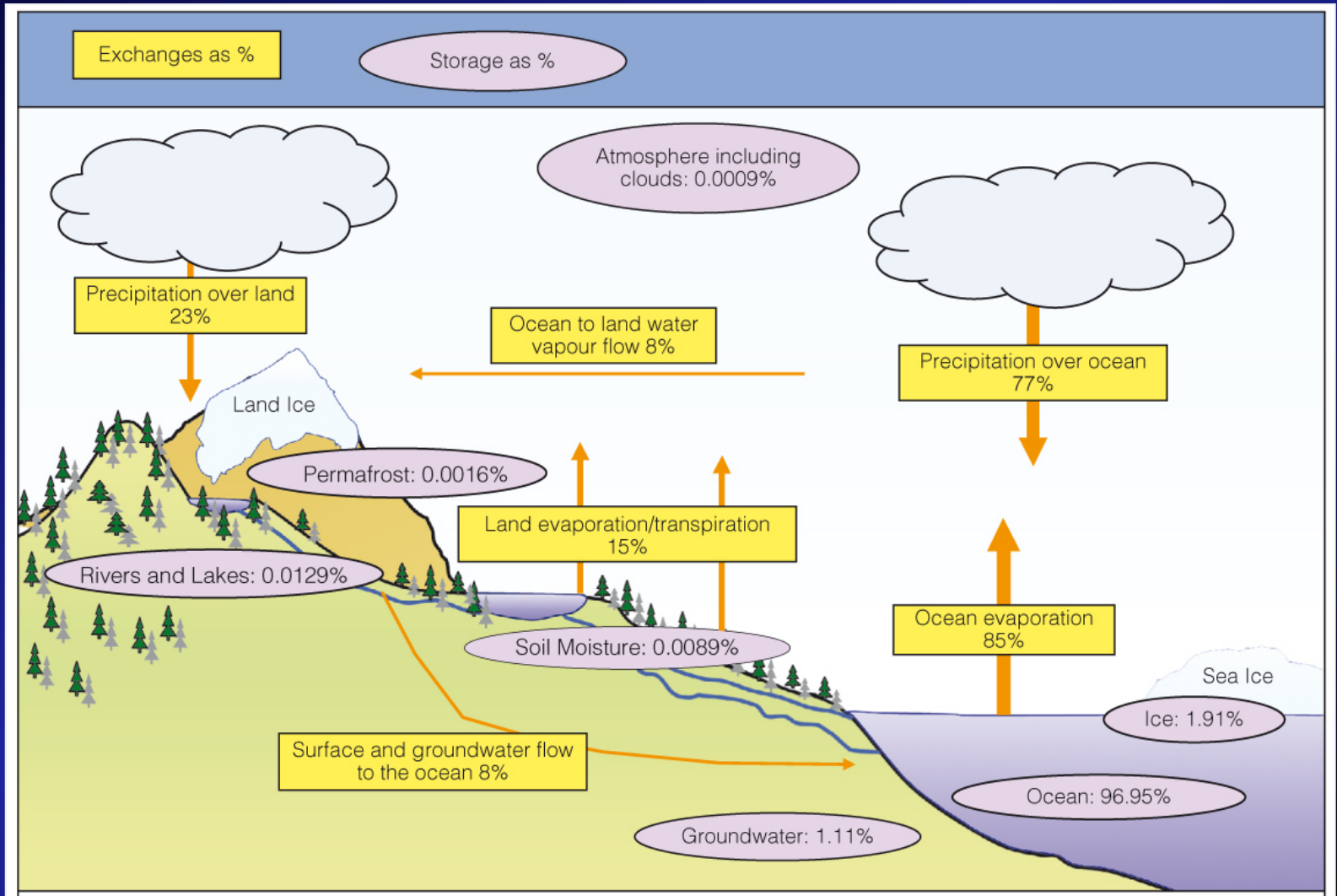


Moisture in the Atmosphere

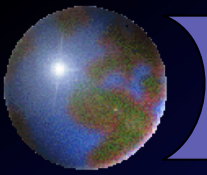
- **Hydrologic cycle**
 - **Changes of phase**
- **Humidity**
- **Adiabatic processes**
- **Humidity and comfort**



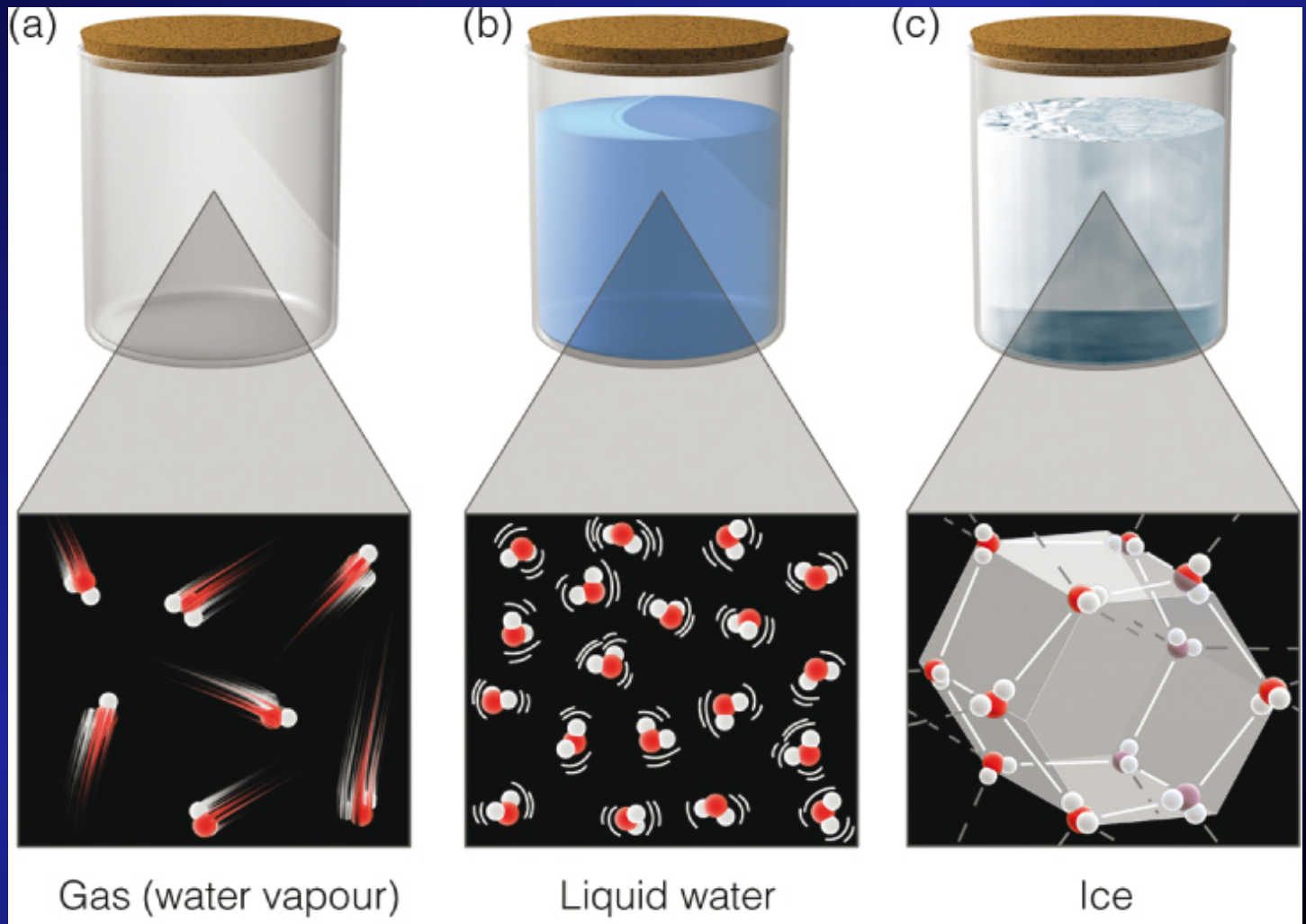
Hydrologic Cycle



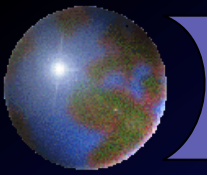
Ahrens:
Figure 5.1



Phases of water



Ahrens: Fig. 4.3



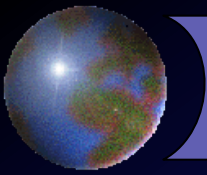
Changes of phase

❁ Evaporation

- ❁ Liquid molecules break free to become gaseous
- ❁ Surrounding material becomes cooler

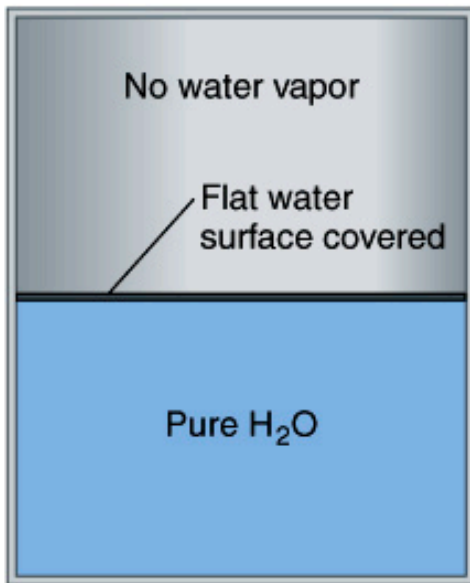
❁ Condensation

- ❁ Gaseous molecules pull together to form a liquid
- ❁ Surrounding material becomes warmer

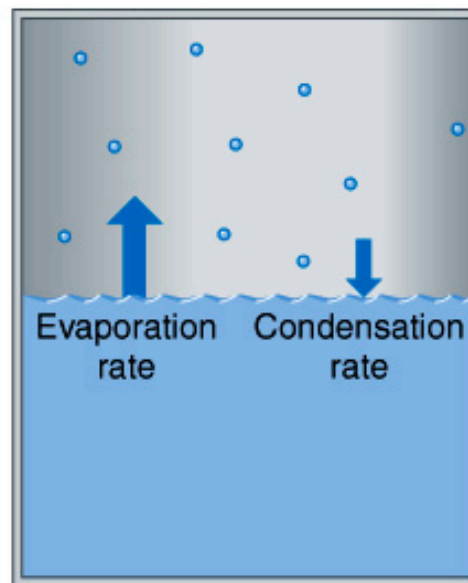


Saturation and equilibrium

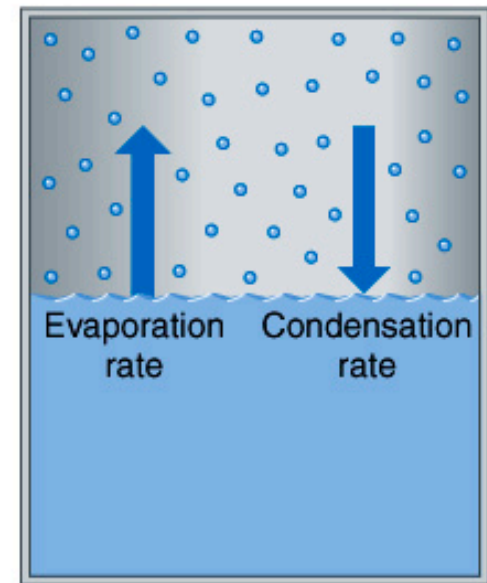
- Water exposed to a gas (or vacuum) will evaporate into it
- Water vapour will bond together and condense
- *Saturation* is the point at which the evaporation and condensation rates are equal



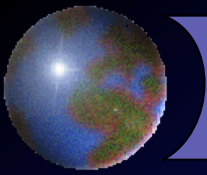
(a)



(b)



(c)



More changes of phase

- Freezing

- Melting

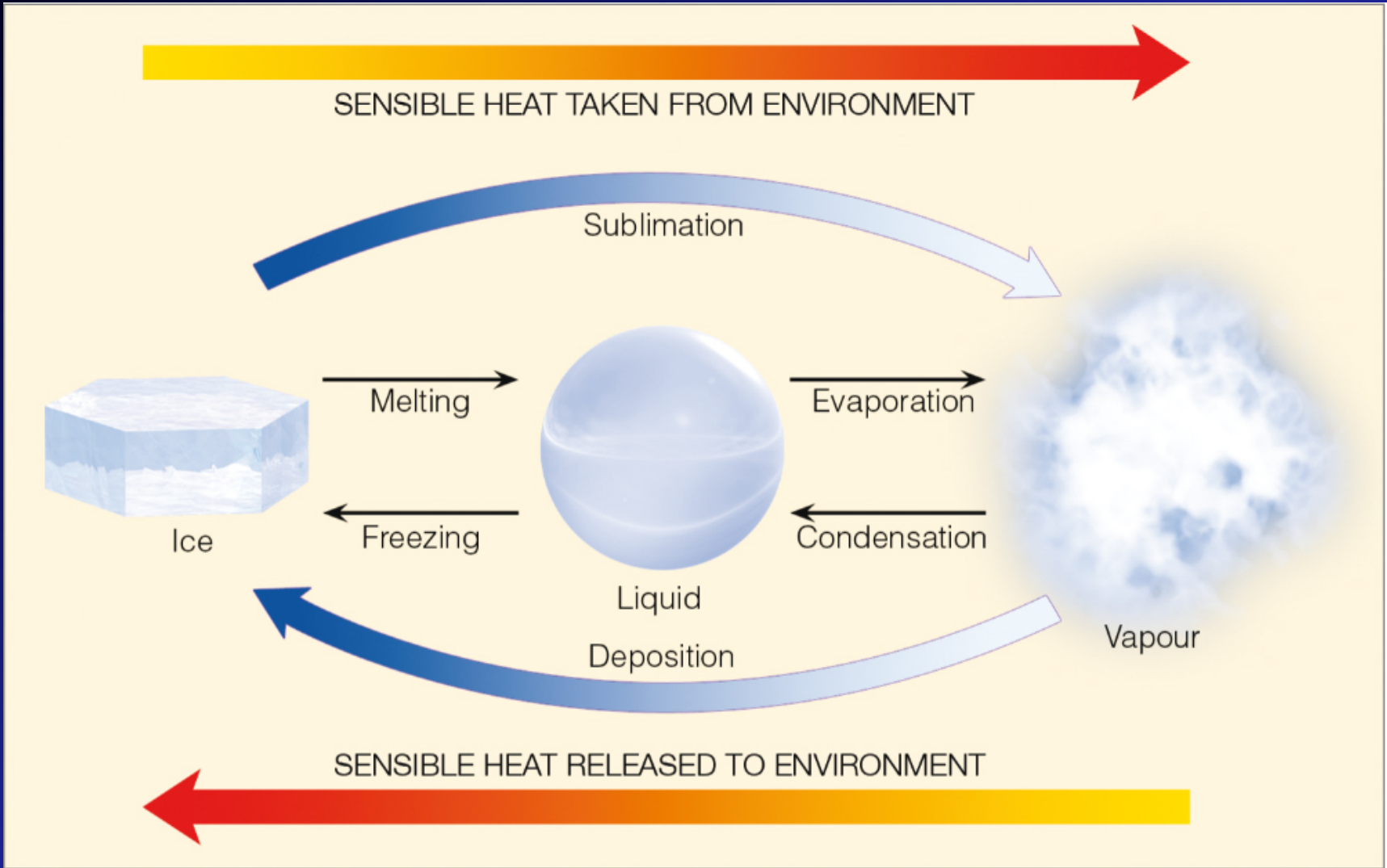
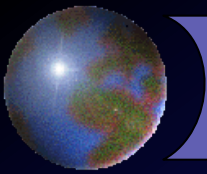
- Sublimation

 - Solid to gas

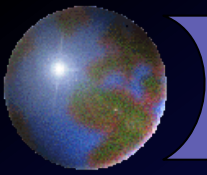
- Deposition

 - Gas to solid

 - Sometimes *also* called sublimation

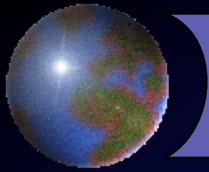


Ahrens: Fig. 2.3



Lecture outline

- ⊗ Hydrologic cycle
- ⊗ **Humidity**
 - ⊗ **Absolute and specific humidities**
 - ⊗ **Vapour pressure**
 - ⊗ **Saturation**
 - ⊗ **Dew point temperature**
- ⊗ Adiabatic processes
- ⊗ Humidity and comfort



Water vapour indices

❁ Absolute Humidity

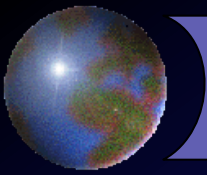
- ❁ Indicates the density of water vapor expressed as a concentration (typically g/m^3)

❁ Specific Humidity

- ❁ Represents a given mass of water vapor per mass of air as a ratio (typically g/kg)

❁ Vapour pressure

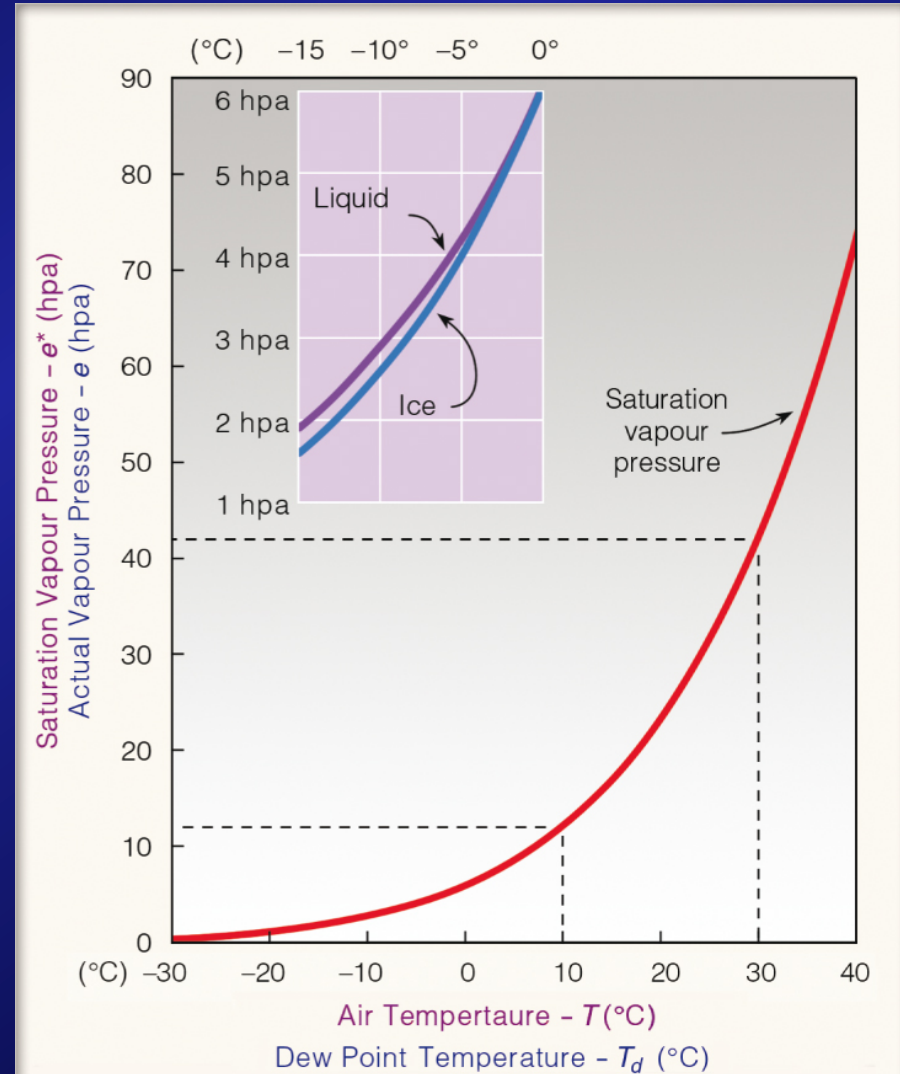
- ❁ The amount of pressure exerted by water molecules in the air (typically mb or hPa)
- ❁ Also called the partial pressure of water vapour

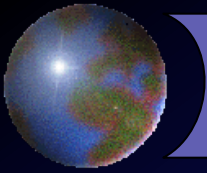


Saturation vapour pressure

- Water vapor pressure at **equilibrium**
- Dependent on temperature and pressure
- Increases non-linearly with temperature
- Similar to *saturation specific humidity*

Ahrens: Active Fig. 4.10



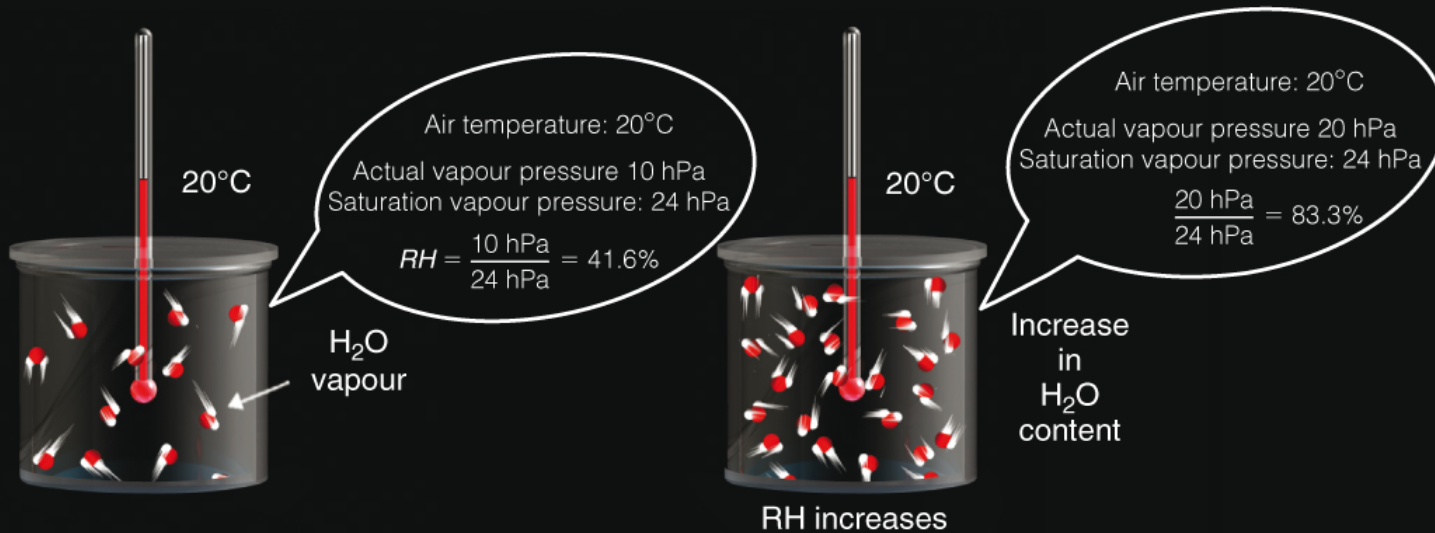


Relative Humidity

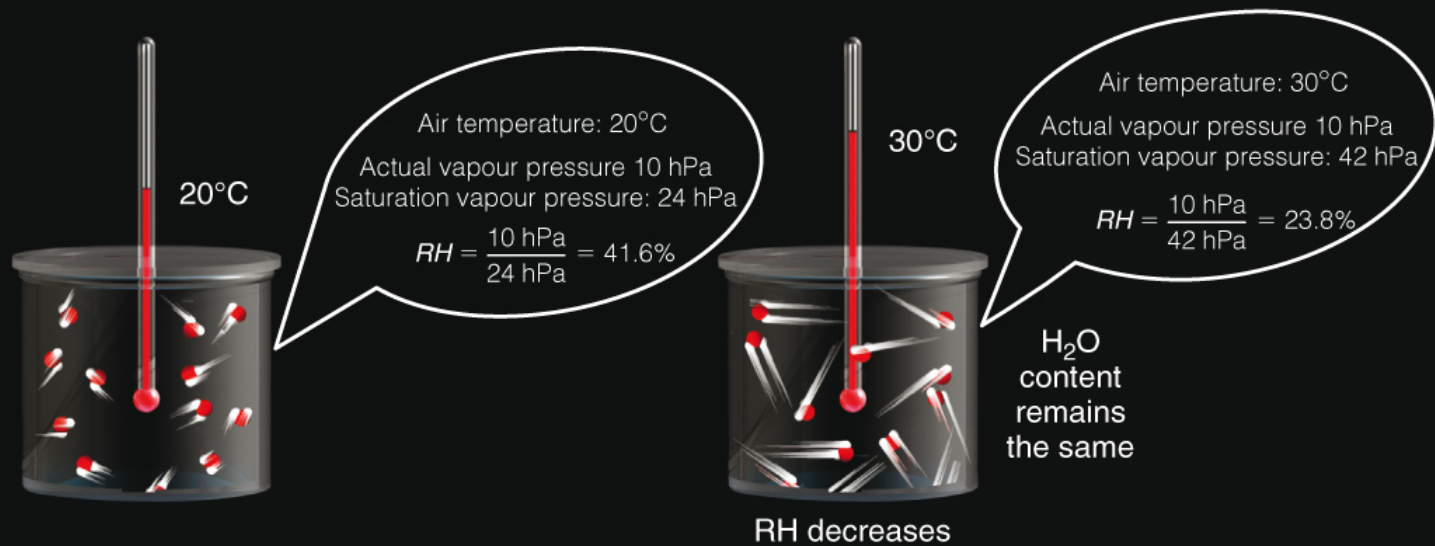
- ❖ Indicates the amount of water vapour in the air relative to the saturation point

$$\begin{aligned} \text{RH} &= \frac{\text{Vapour pressure}}{\text{Saturation vapour pressure}} \\ &= \frac{\text{Specific humidity}}{\text{Saturation specific humidity}} \end{aligned}$$

- ❖ Dependent on specific humidity, temperature, and pressure

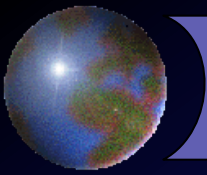


(a) **An increase in water vapour content** with no change in temperature increases the RH. Consequently, RH moves closer to saturation.



(b) **An increase in temperature** with no change in water vapour content decreases the RH. Consequently, RH moves further from saturation.

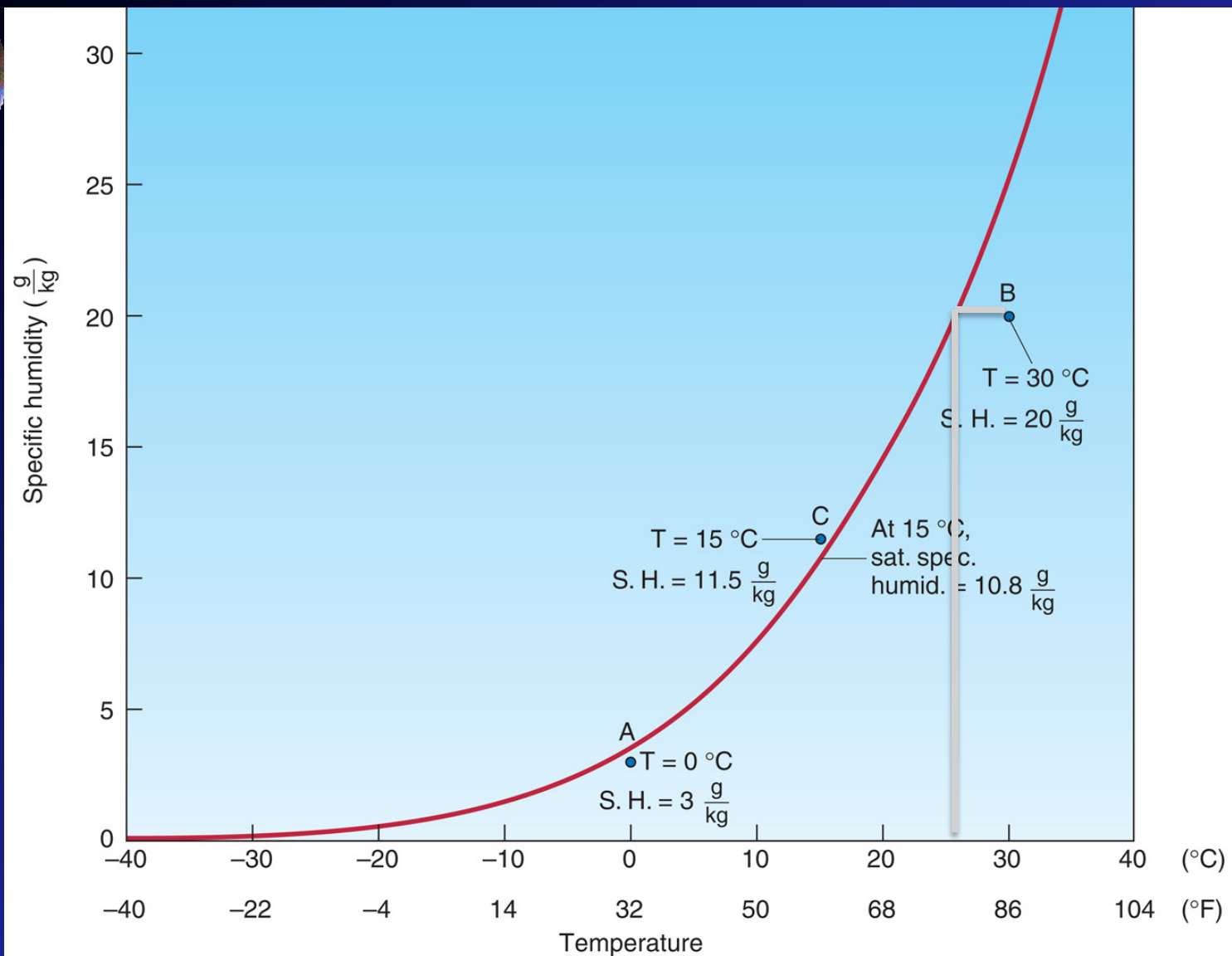
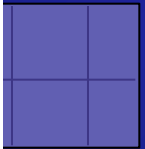
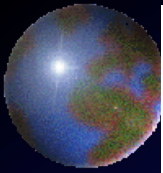




Dew point temperature

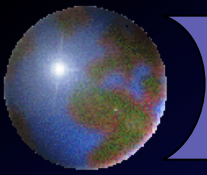
- ❁ Another index of moisture (not temperature)
 - ❁ Temperature at which the vapour pressure **would** equal the saturation vapour pressure
 - ❁ High vapour pressure means high dew point

- ❁ If the air cools to this temperature, it will become saturated
 - ❁ If $T = T_d$ then $RH = 100\%$



Dew Point Temperature

A&B: Figure 5-9

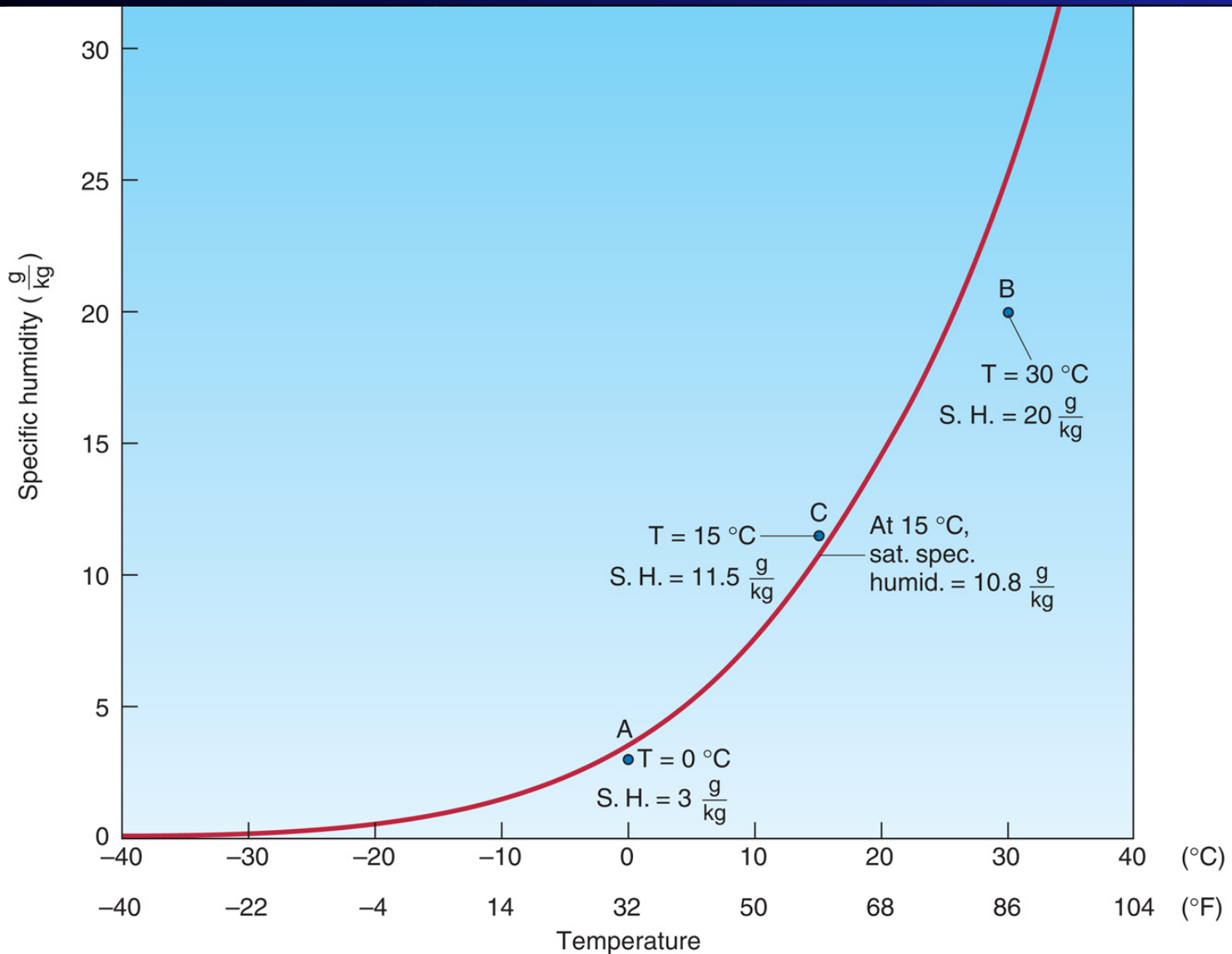
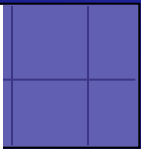
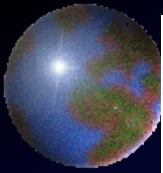


Methods of Achieving Saturation

- ⊕ Cool the air to the dew point

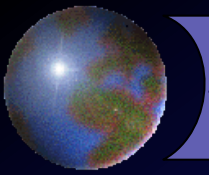
- ⊕ Add water vapour to the air

- ⊕ Mix cold air with warm air
 - ▣ *If the warm air has higher specific humidity*



Achieving saturation

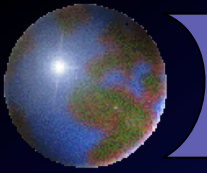
A&B: Figure 5-9



Dew

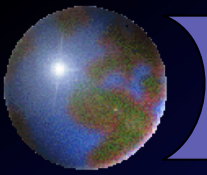
- ⊕ At night the ground cools quickly
 - ▣ Emission of IR

- ⊕ Air above the ground cools due to conduction
 - ▣ Reaches dew point temperature
 - ▣ Condensation begins



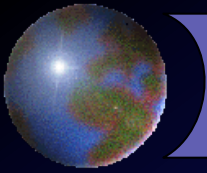
Frost

- Like dew, but with a dew point temperature below 0°C (*frost point temperature*)
 - *Deposition* into ice crystals rather than *condensation*
- *Frozen dew*: dew point is above 0°C , but temperature drops below after condensation



Lecture outline

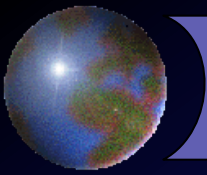
- ⊗ Hydrologic cycle
- ⊗ Humidity
- ⊗ **Adiabatic processes**
 - ⊗ **Dry adiabatic cooling**
- ⊗ Humidity and comfort



Temperature change

- ⊕ *Diabatic* process: adds or removes energy from a system
 - ▣ Heat transfers

- ⊕ *Adiabatic* process: changes temperature without adding or removing heat



Diabatic processes

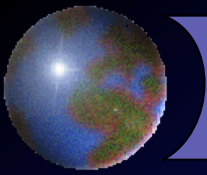
- ⊗ Mixing

- ⊗ Advection

 - ▣ Warm, moist air moves over a cool surface

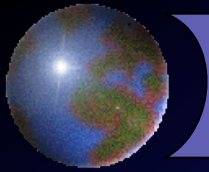
- ⊗ Radiation

 - ▣ Night-time cooling



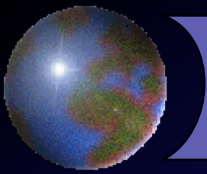
Adiabatic processes

- ❁ Changes in pressure cause changes in temperature
 - ❁ If the pressure drops, a parcel of air will expand and cool down
 - ❁ If the pressure rises, a parcel of air will be compressed and warm up

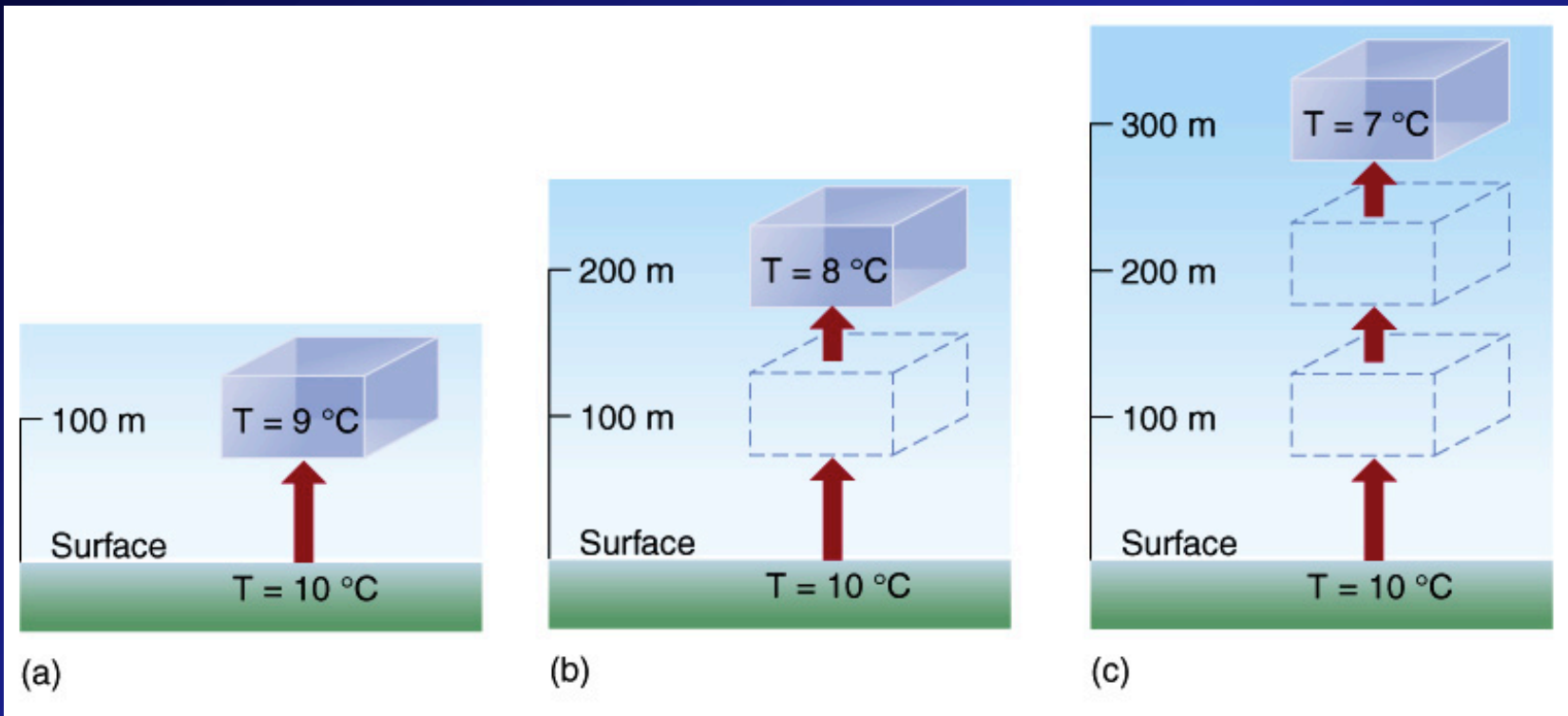


What is a 'parcel' of air?

- ⊗ A volume of air with distinct properties
- ⊗ No fixed dimensions or shape
- ⊗ Creates a mental picture for visualizing atmospheric conditions
- ⊗ I talk about a cubic metre of air on occasion – a blob of air

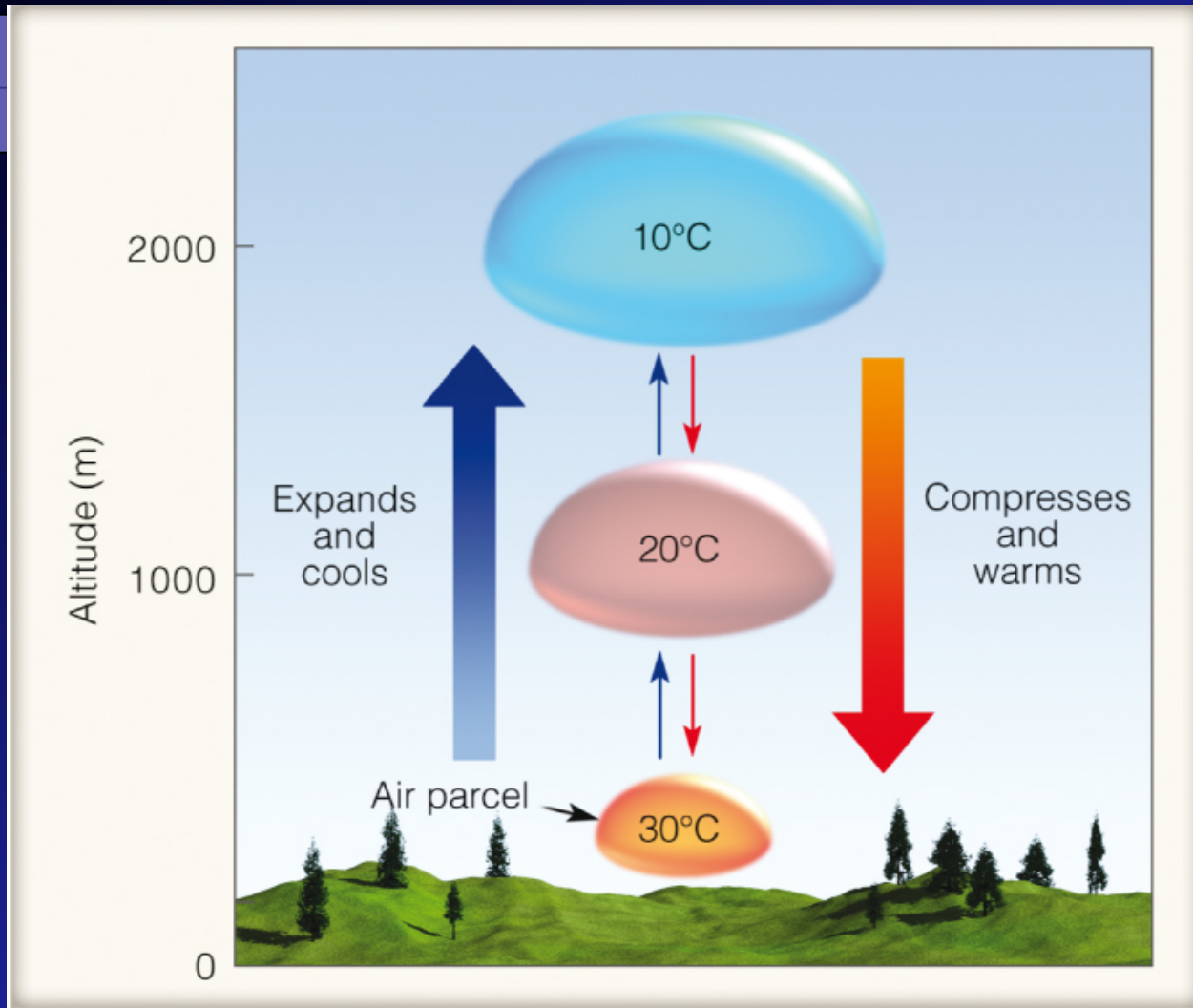
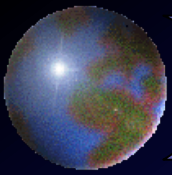


Dry adiabatic cooling



Parcels expand and cool at the *dry adiabatic lapse rate* of $1^{\circ}\text{C}/100$ m ($10^{\circ}\text{C}/\text{km}$)

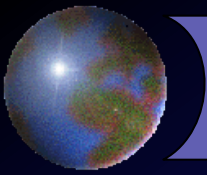
A&B: Figure 5-15



Adiabatic warming

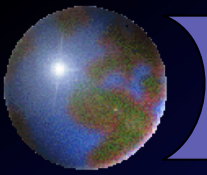
Descending air warms at exactly the same rate

Ahrens: Figure 6.2



Lecture outline

- ⊗ Hydrologic cycle
- ⊗ Humidity
- ⊗ Adiabatic processes
- ⊗ **Humidity and comfort**
 - ▣ **Humidex**



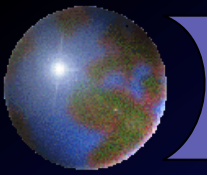
It is not the heat, it is... the Humidity

☉ 'Dry heat'

- ☐ Sweat evaporates readily
- ☐ Body cools down easily

☉ High humidity

- ☐ Sweat does not evaporate
- ☐ Body cannot shed heat



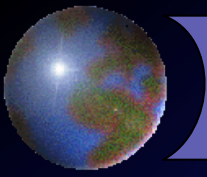
Even when it is cold?

☉ 'Dry cold'

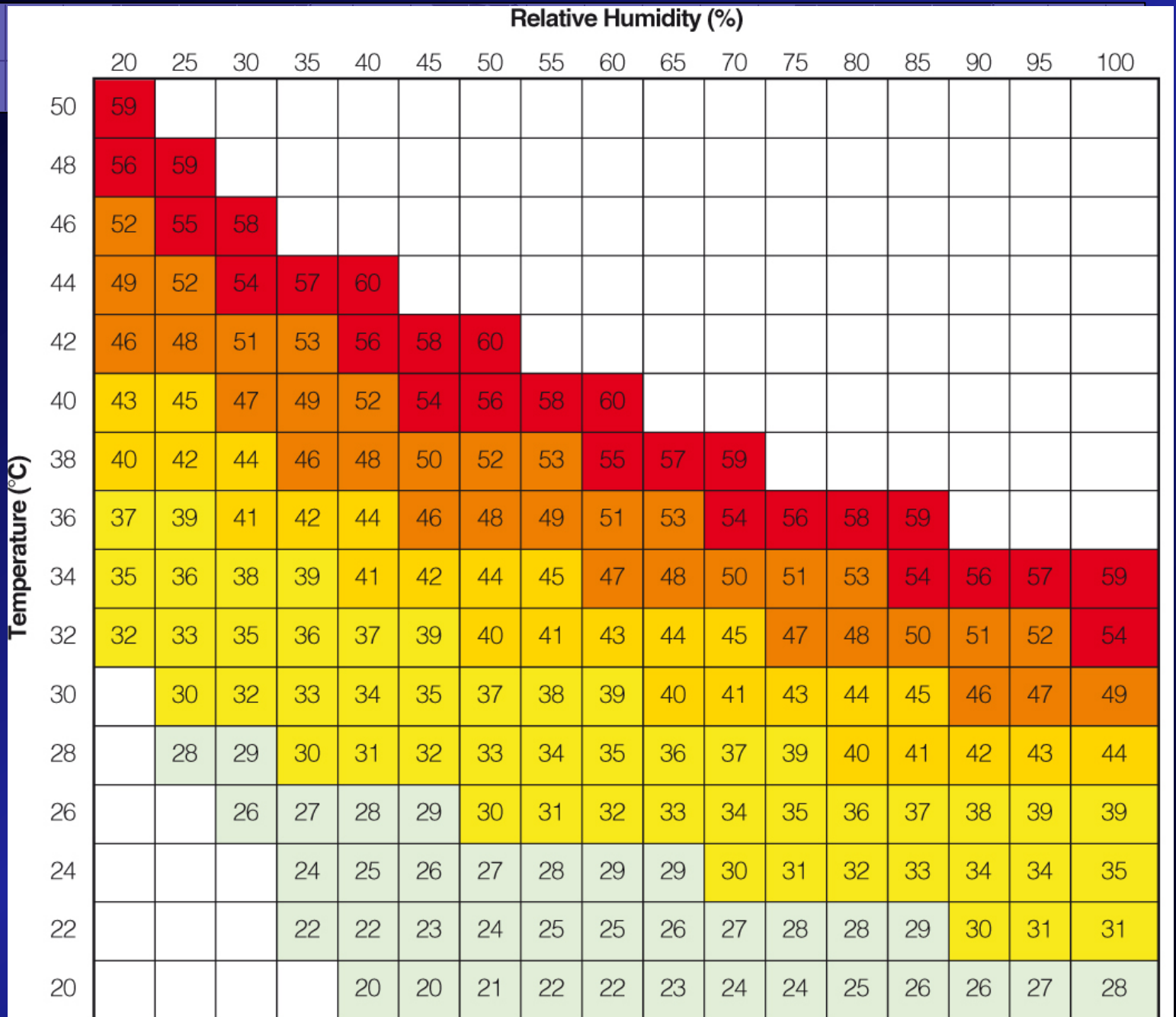
- ☐ Sweat evaporates readily
- ☐ But the body does not sweat much

☉ High humidity

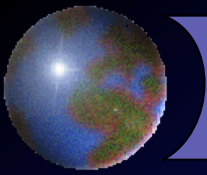
- ☐ Sweat condenses in clothing
- ☐ Damp clothing provides much less insulation



Humidex

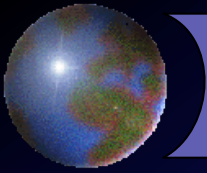


Ahrens:
Fig. 4.19



Summary

- Three important humidity indices:
 - Vapour pressure, relative humidity, dew point temperature
- Adiabatic processes
 - Rising air expands and cools
 - Sinking air is compressed and warms
- Humidex
 - Interesting but not so important



Coming up

- ⊕ Atmospheric stability
- ⊕ Saturated lapse rates
- ⊕ Ahrens: Chapter 6