Moisture in the Atmosphere

GEOG/ENST 2331 – Lecture 8

Ahrens: Chapter 4

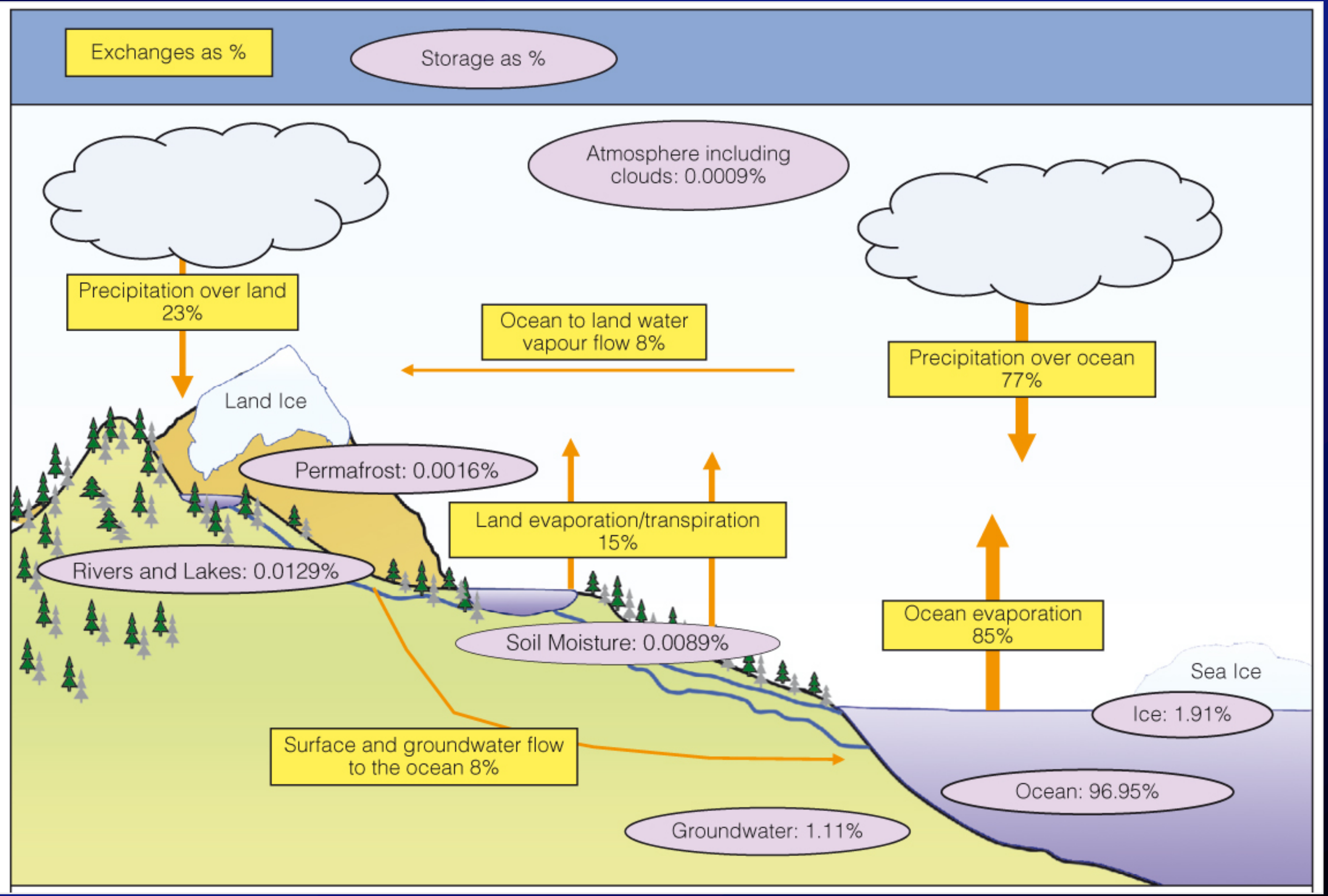
Last lecture

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

Moisture in the Atmosphere

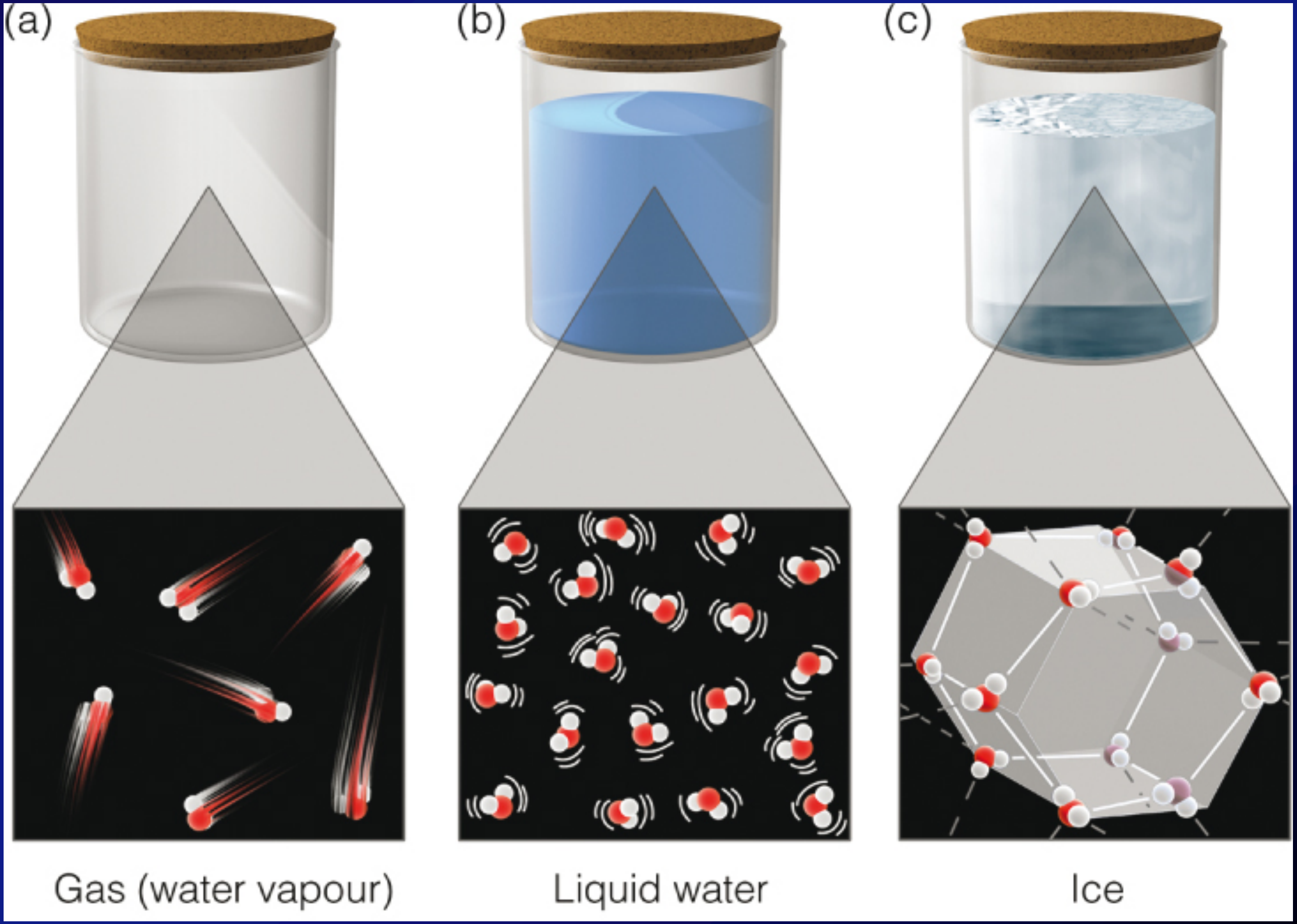
- **Hydrologic cycle**
  - **Changes of phase**
- Humidity
- Adiabatic processes
- Humidity and comfort

Hydrologic Cycle



Ahrens: Figure 4.1

Phases of water



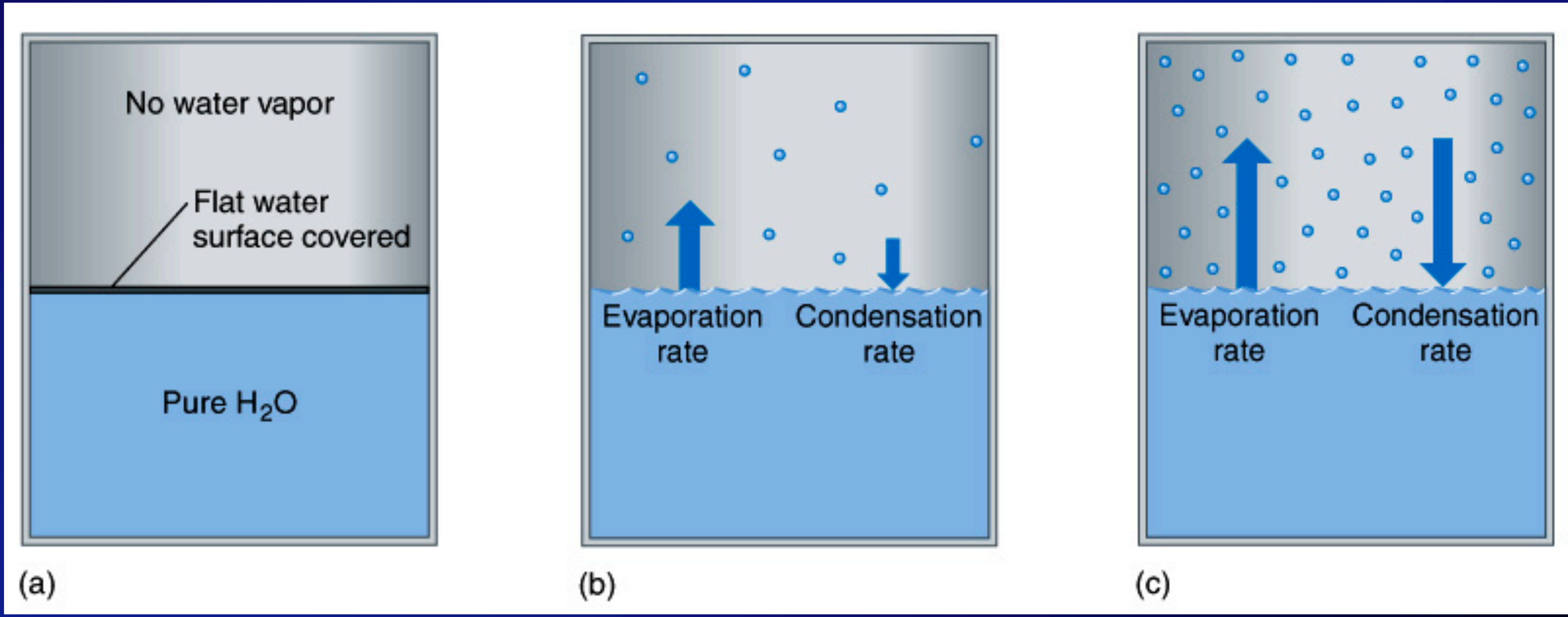
Ahrens: Fig. 4.3

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

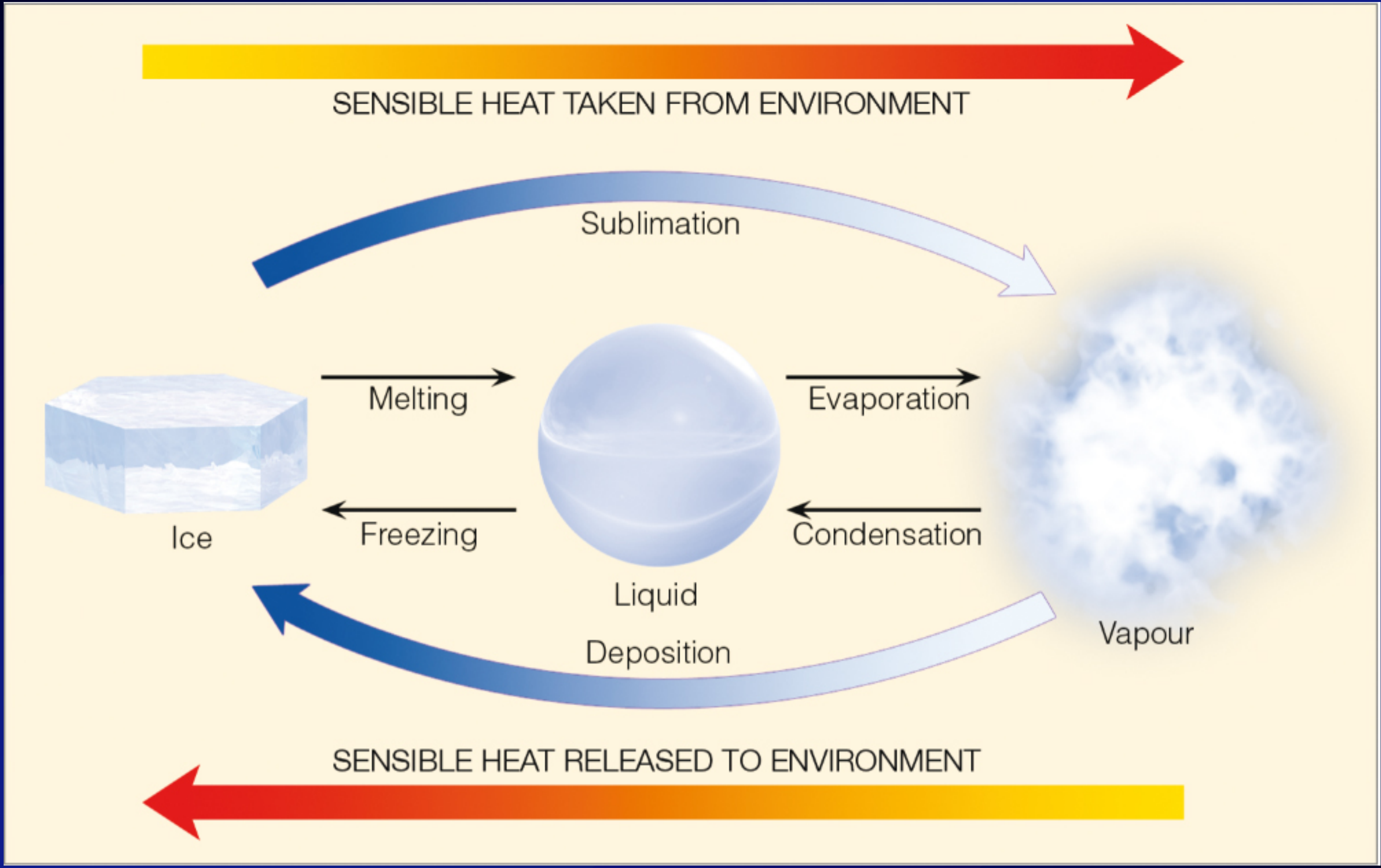


A&B: Figure 5-2

More changes of phase

- Freezing
- Melting

- Sublimation
  - Solid to gas
- Deposition
  - Gas to solid
  - Sometimes *also* called sublimation



Ahrens: Figure 2.1

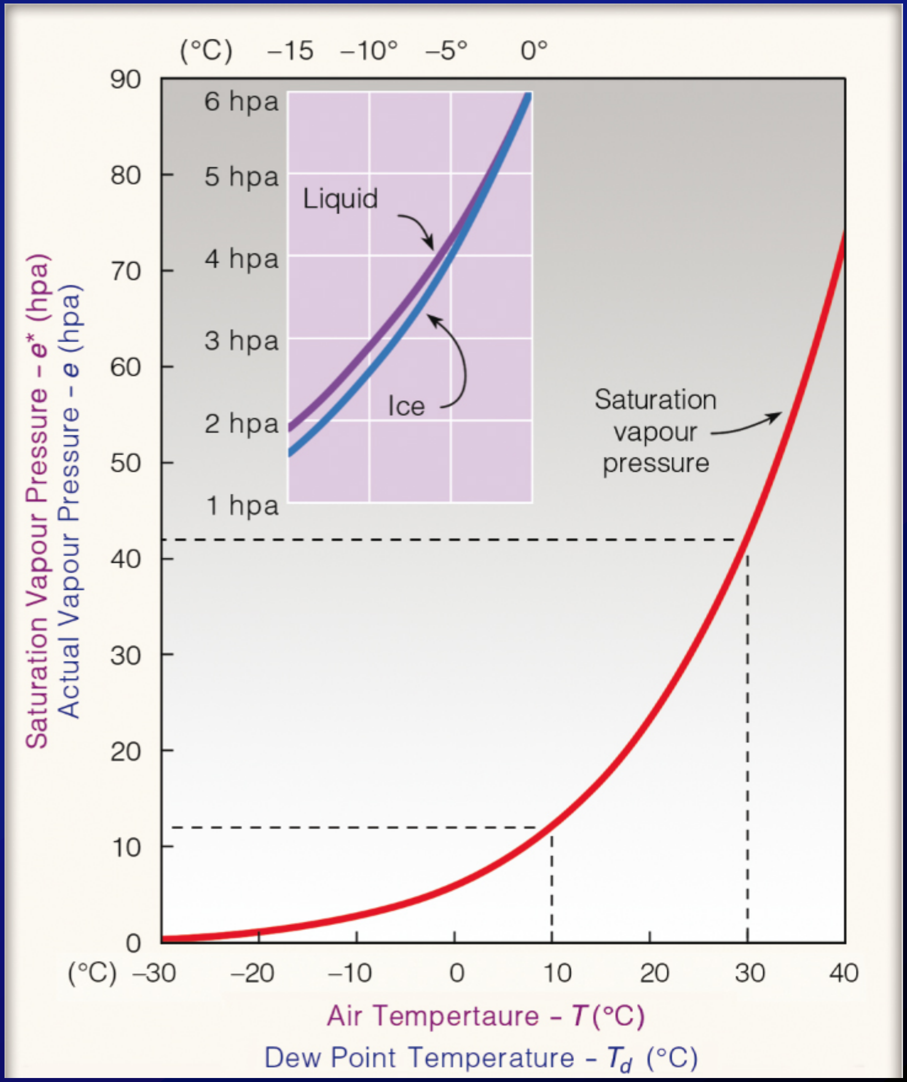
Water vapour indices

- 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

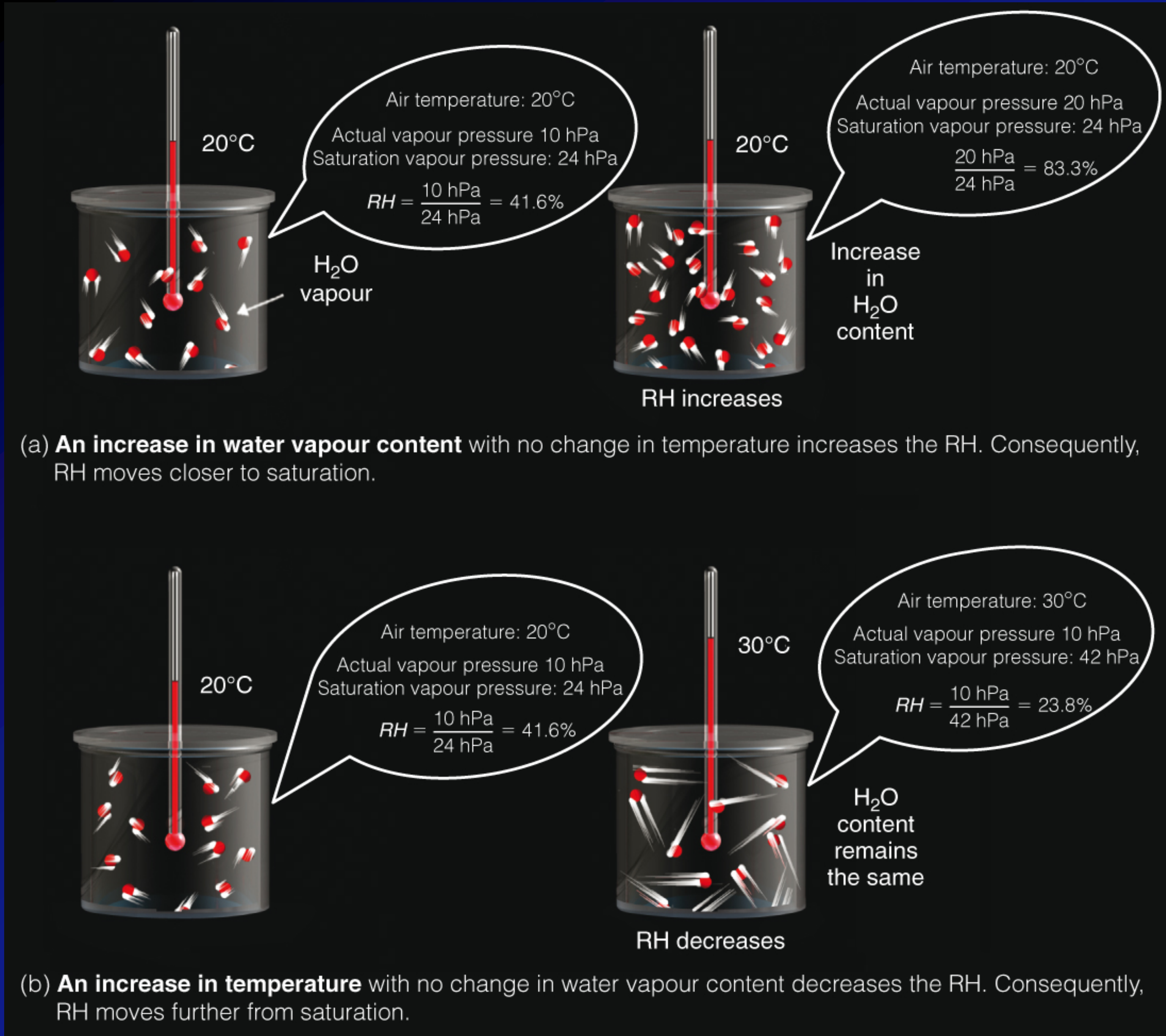
Relative Humidity

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

$$\mathrm{RH} = \frac{\text{Vapour pressure}}{\text{Saturation vapour pressure}}$$

$$= \frac{\text{Specific humidity}}{\text{Saturation specific humidity}}$$

- Dependent on specific humidity, temperature, and pressure



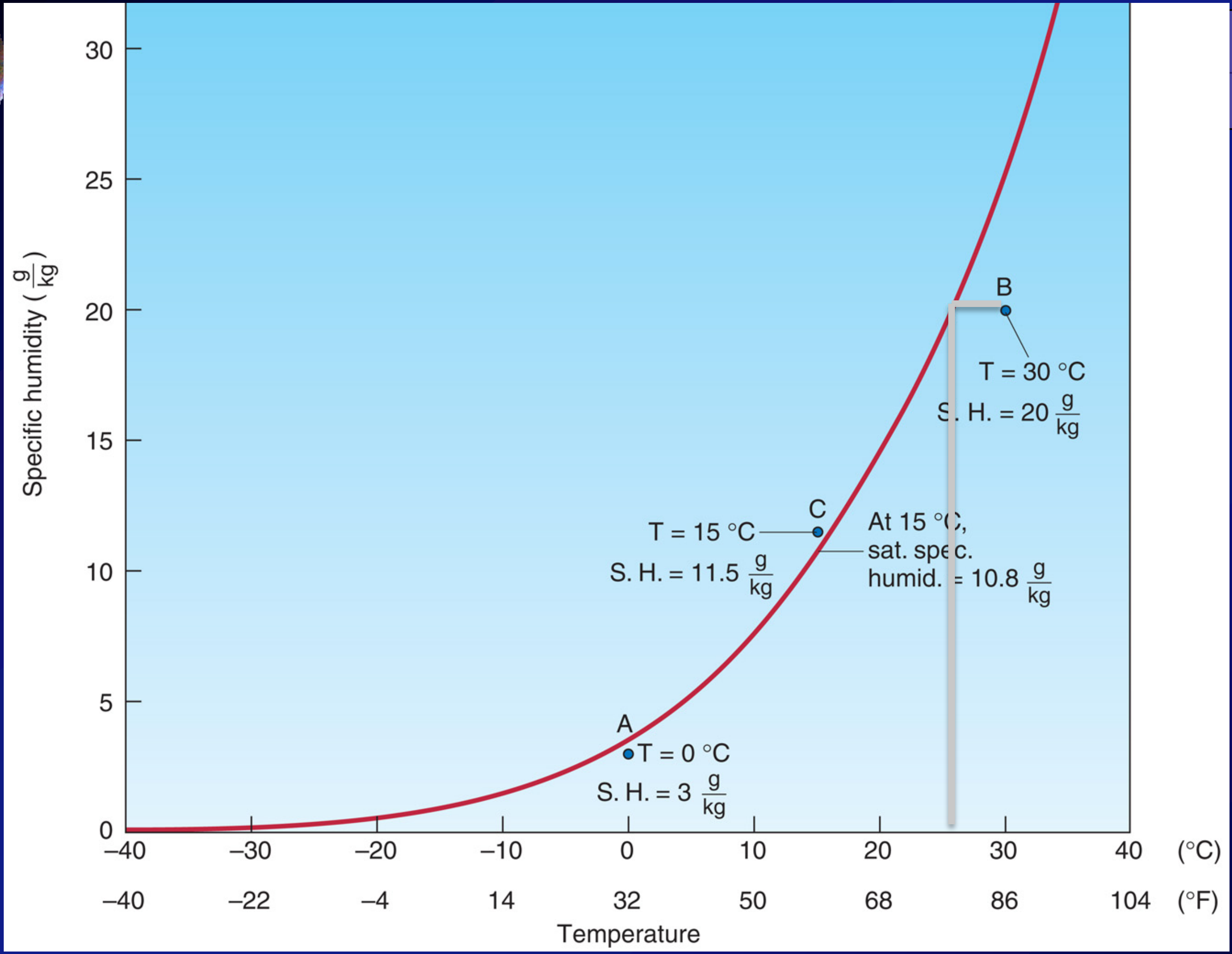
(a) **An increase in water vapour content** with no change in temperature increases the RH. Consequently, RH moves closer to saturation.

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

Ahrens: Active Fig. 4.11

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%

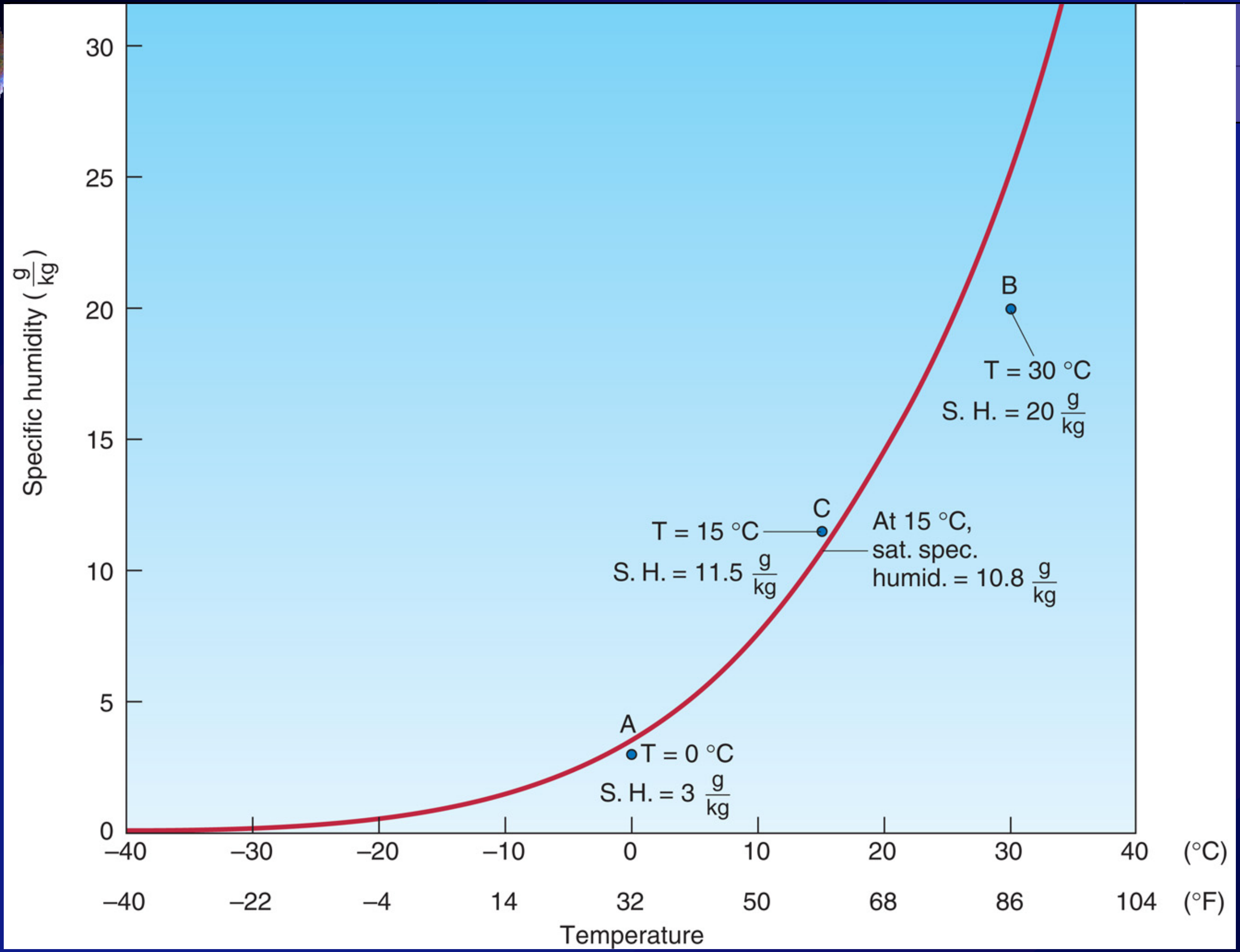


Dew Point Temperature

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

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

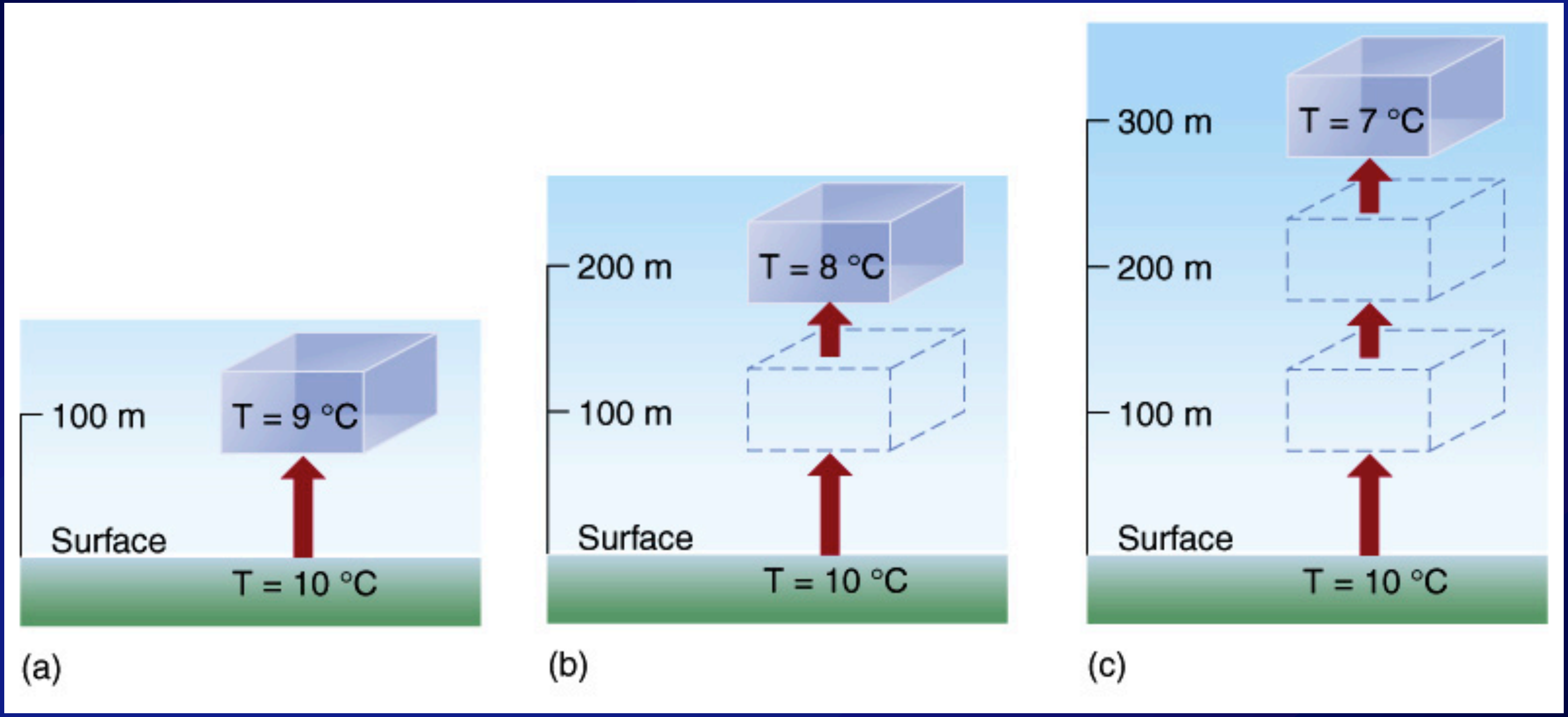
Adiabatic processes

- 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?

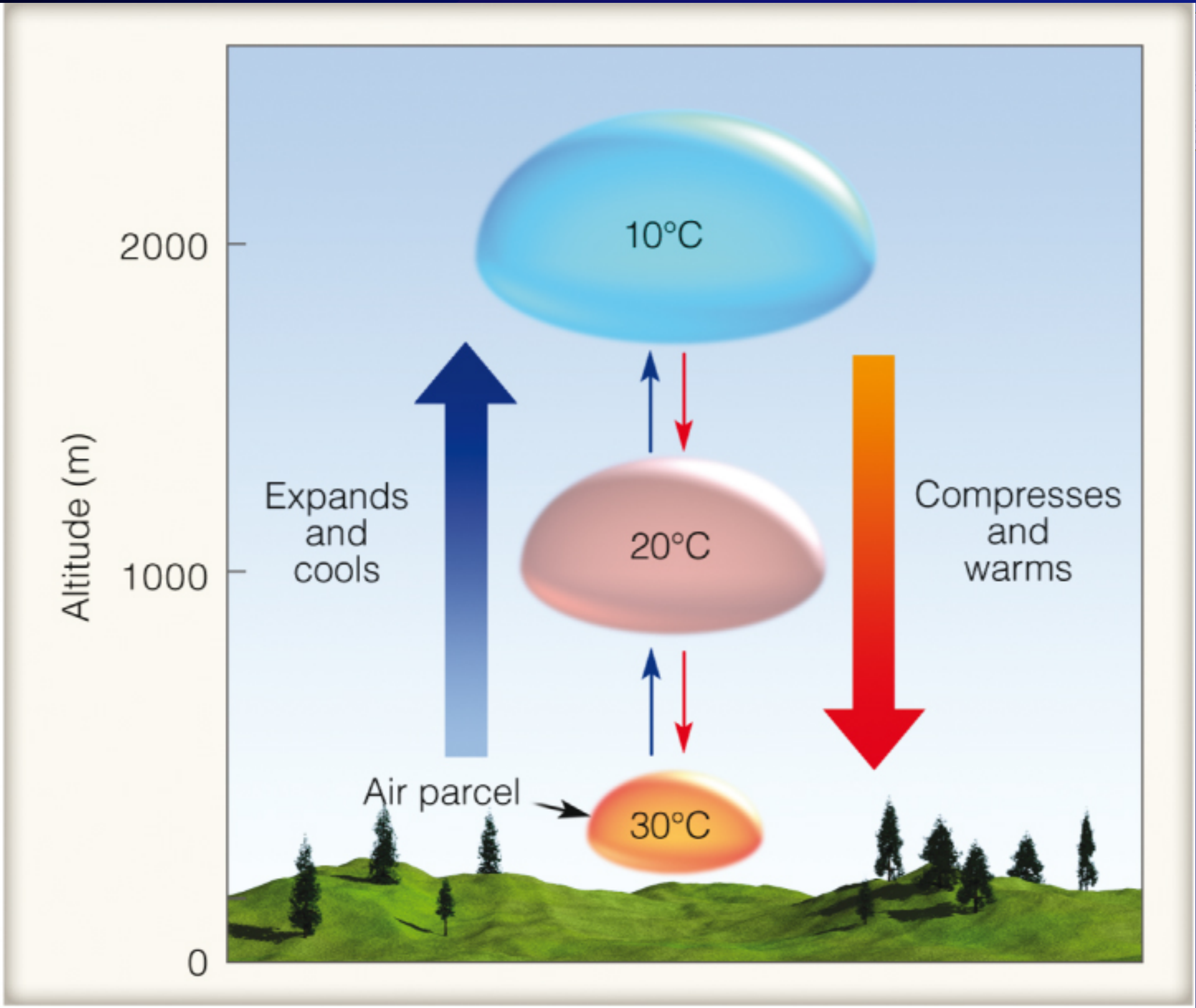
- A volume of air with distinct properties
- No fixed dimensions or shape
- Creates a mental picture for visualizing atmospheric conditions
- Visualize a cubic metre of air – a blob of air

Dry adiabatic cooling



Parcels expand and cool at the ***dry adiabatic lapse rate*** of 1^{o}C/100 m (10°C/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

Temperature (°C) \ Relative Humidity (%)	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
50	59																
48	56	59															
46	52	55	58														
44	49	52	54	57	60												
42	46	48	51	53	56	58	60										
40	43	45	47	49	52	54	56	58	60								
38	40	42	44	46	48	50	52	53	55	57	59						
36	37	39	41	42	44	46	48	49	51	53	54	56	58	59			
34	35	36	38	39	41	42	44	45	47	48	50	51	53	54	56	57	59
32	32	33	35	36	37	39	40	41	43	44	45	47	48	50	51	52	54
30		30	32	33	34	35	37	38	39	40	41	43	44	45	46	47	49
28		28	29	30	31	32	33	34	35	36	37	39	40	41	42	43	44
26			26	27	28	29	30	31	32	33	34	35	36	37	38	39	39
24				24	25	26	27	28	29	29	30	31	32	33	34	34	35
22				22	22	23	24	25	25	26	27	28	28	29	30	31	31
20					20	20	21	22	22	23	24	24	25	26	26	27	28

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