CPL Theory
Meteorology (CMET)

CAE Oxford
Aviation Academy

CMET 1 – The Atmosphere

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2. Related Documents

Related Documents	Document Identification

Amendments made to this document since the previous version are listed below. All amendments to this document have been made in accordance with CAE OAAM's document management procedure.

Slide	Changes

LAYERS OF THE ATMOSPHERE

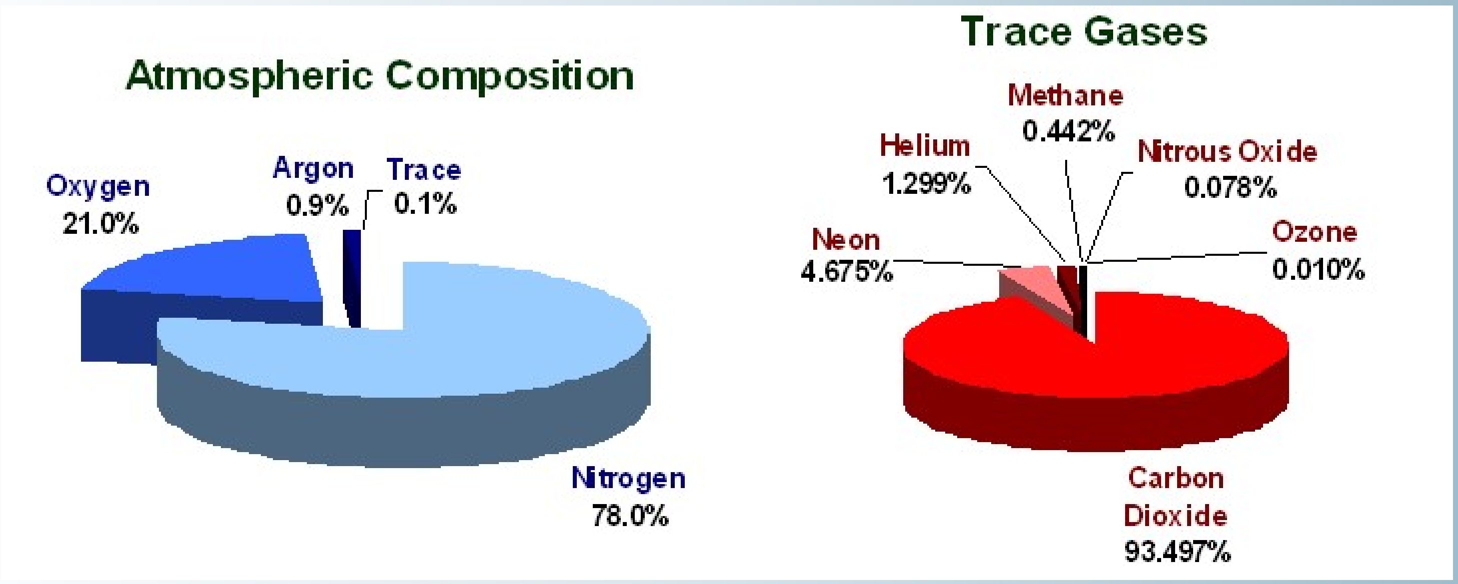
Layers of the Atmosphere

- Before we study specific weather phenomena, we must first understand the area within which weather occurs – **the atmosphere**

COMPOSITION OF THE ATMOSPHERE

Composition of the Atmosphere

- The atmosphere, in it's dry state, contains:
  1. **78% nitrogen**
  2. **21% oxygen**
  3. **1% other trace gases**



- Note: the **composition stays constant** as altitude increases – **oxygen percentage does NOT decrease!**

Composition of the Atmosphere

- However, this assumes a dry atmosphere

- In reality, the atmosphere also contains:

1. A variable amount of water vapour (around 5%)

- The higher the temperature, the more vapour the air can hold

- If the temperature becomes too low, this water vapour may condense to form cloud, fog, rain etc.

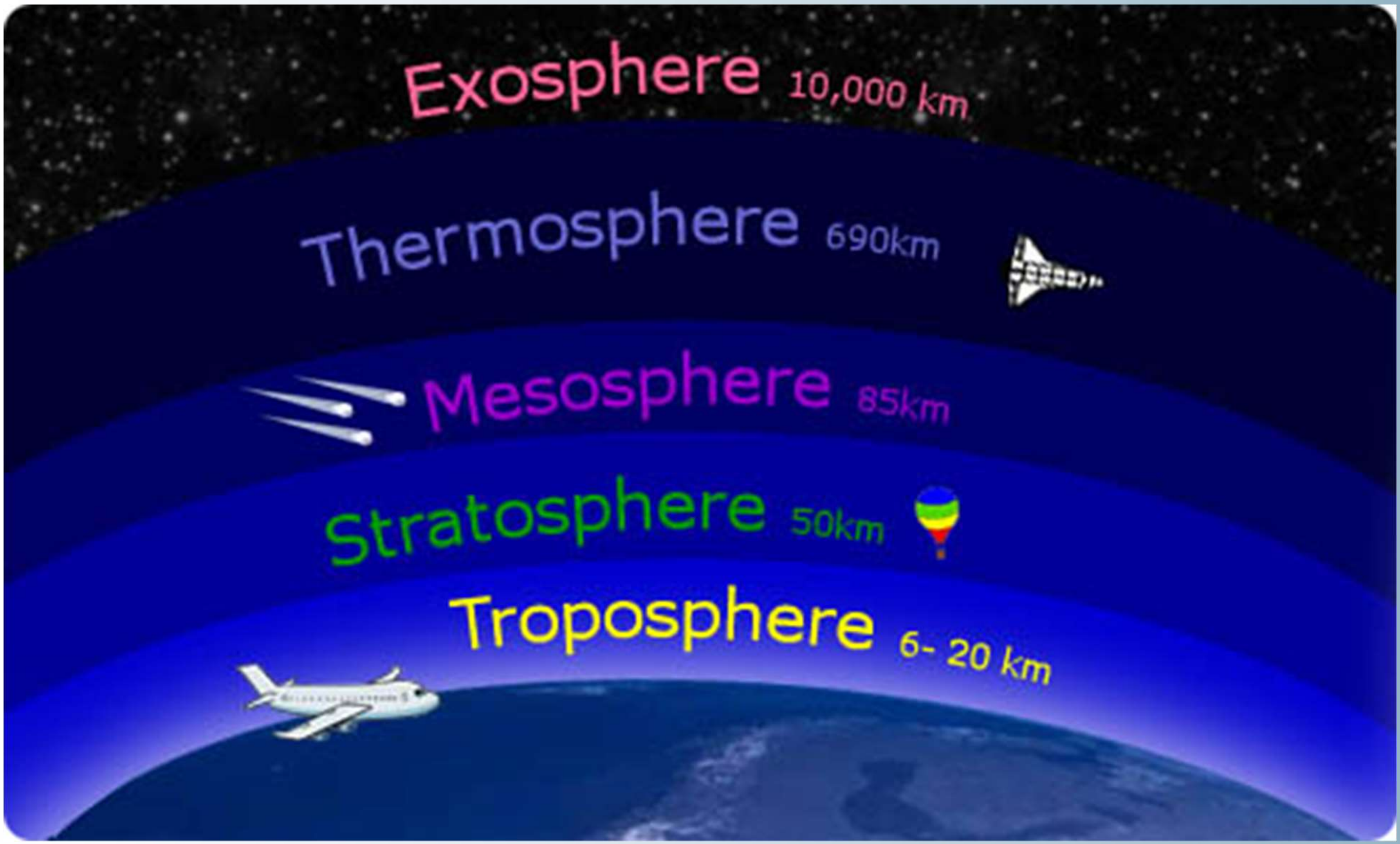
2. Solid particles such as salt, smoke and pollen

- These are known collectively as **hygroscopic nuclei**

- Moisture in the atmosphere will condense onto these to form cloud/rain etc.

Layers of the Atmosphere

- Earth's atmosphere is divided into several layers



Layers of the Atmosphere

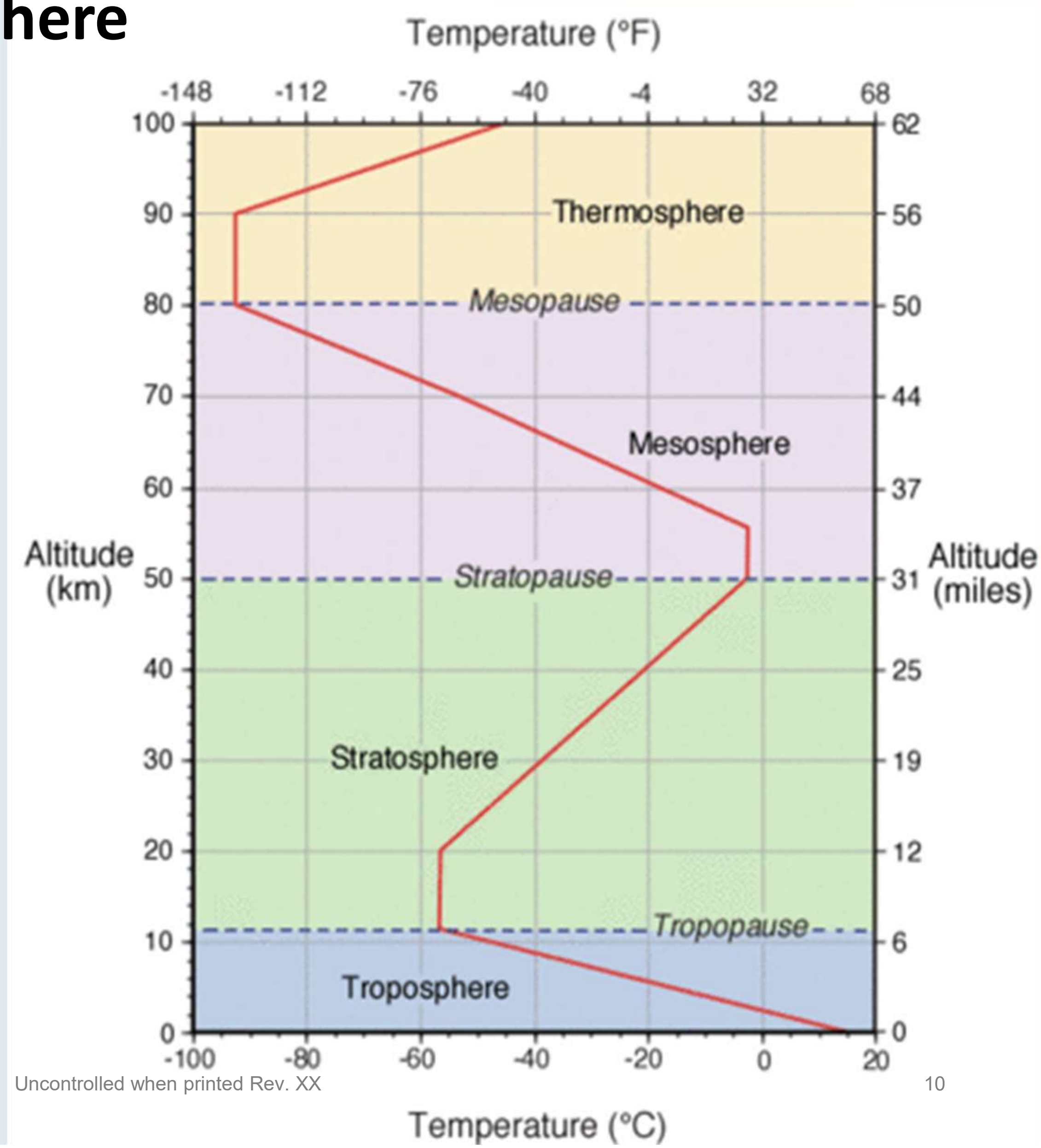
- As you can see, the temperature varies with altitude, sometimes increasing and sometimes decreasing

- In aviation, we are generally only concerned with the lowest 3 components:

1. The Troposphere

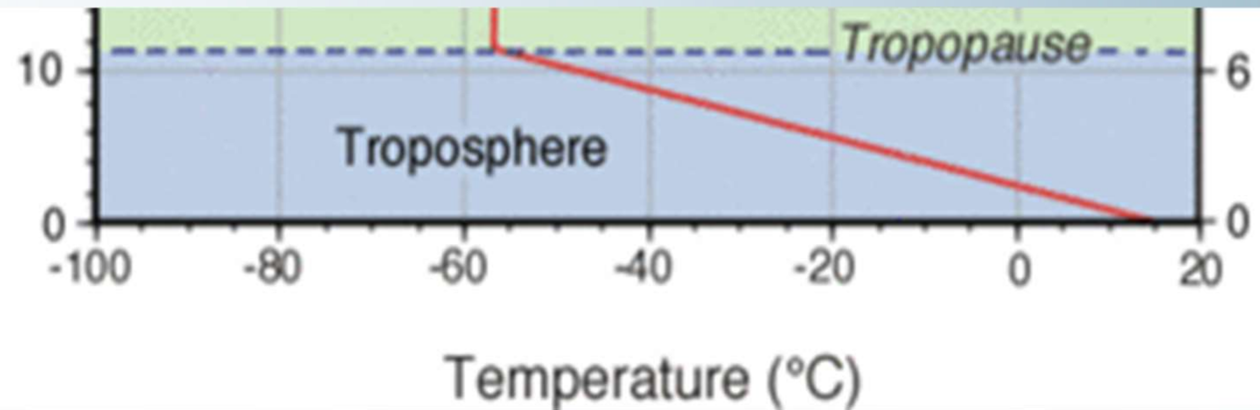
2. The Tropopause

3. The Stratosphere



The Troposphere

- Lowest portion of the atmosphere where **temperature decreases with altitude**
- This is where **most of the water vapour (0-5% by volume), clouds and weather** in our atmosphere are found
- Above the Troposphere, there is almost nil cloud and weather
- This is because there is no longer a **positive lapse rate** (temperature decreasing with altitude) which is **critical in the formation of clouds and precipitation** – more on this later!



The Tropopause

- The boundary between the Troposphere and the Stratosphere
- Temperature no longer decreases with height – a marked change in temperature lapse rate
- The height of the tropopause varies:

1. Over the poles

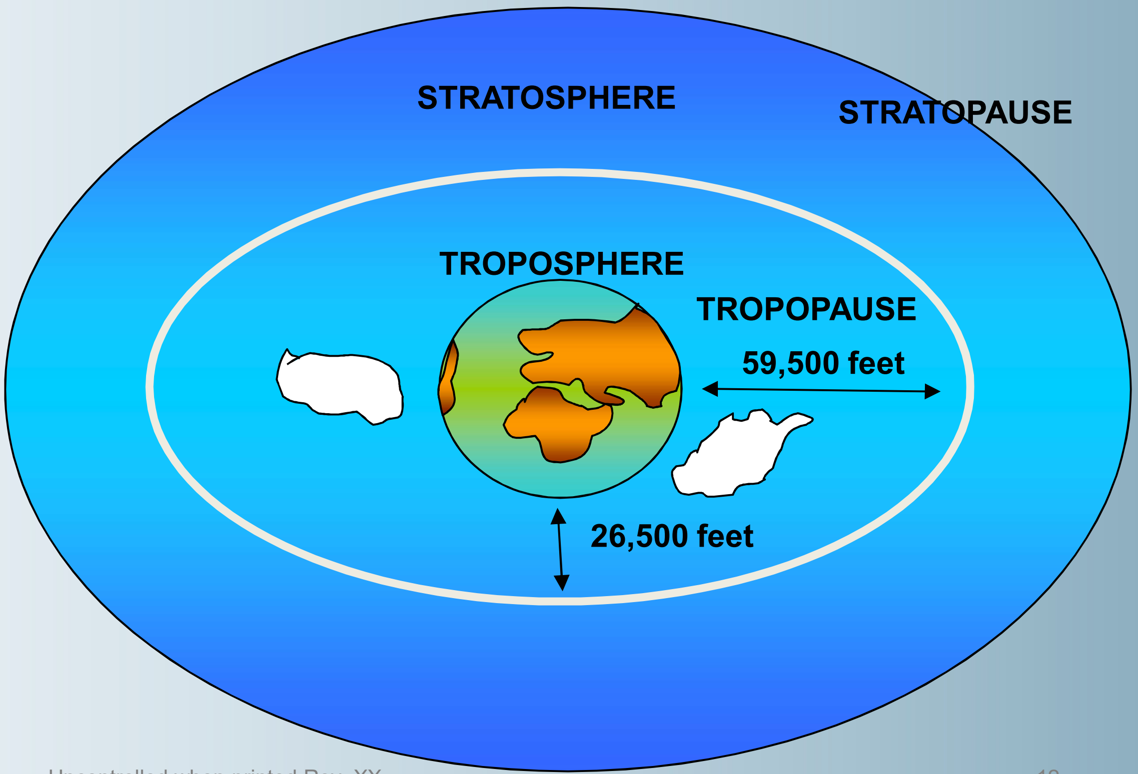
- 26,500ft / 8km / 5miles

- Temperature is -40°C

2. Over the equator

- 59,500ft/18km/10miles

- Temperature is -70°C



The Tropopause

- Variation in Tropopause height is due to:
- Earth's rotation
- Tropical heating

- Surface temperature variations due to latitude, season, land and sea will all cause varying heights of the tropopause.

- During the summer season, the tropopause is higher in each region than in the winter.

- The significance of the tropopause height is that it usually marks:

- The maximum height of cloud

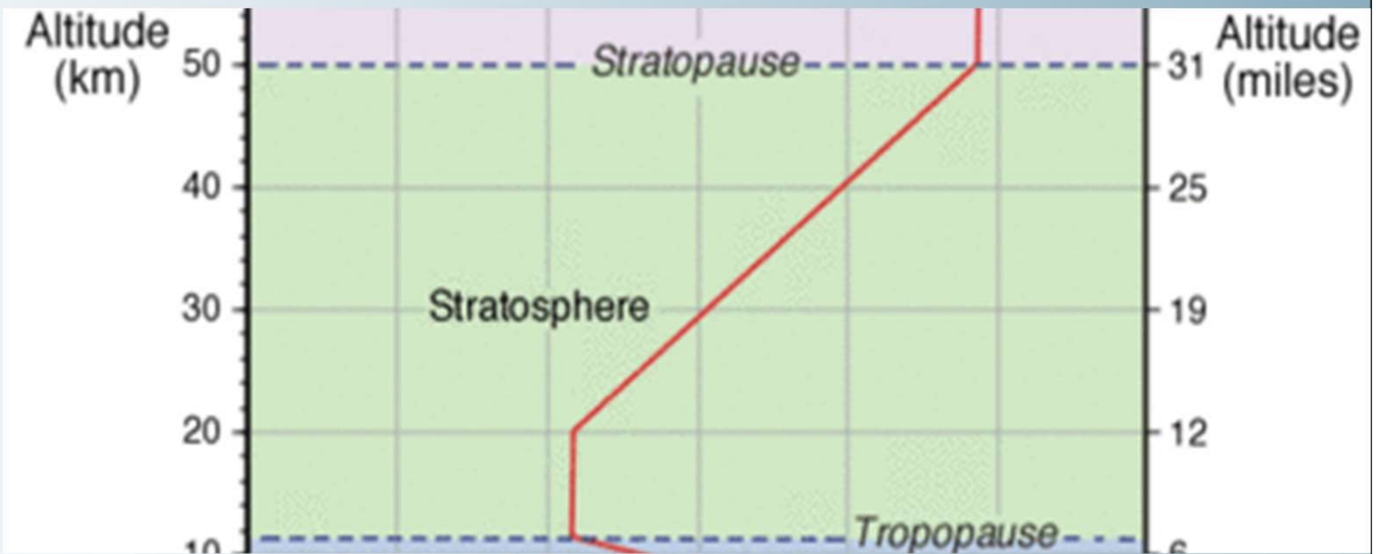
- The presence of Jet Streams

- The Presence of Clear Air Turbulence (CAT)

- The maximum wind speed

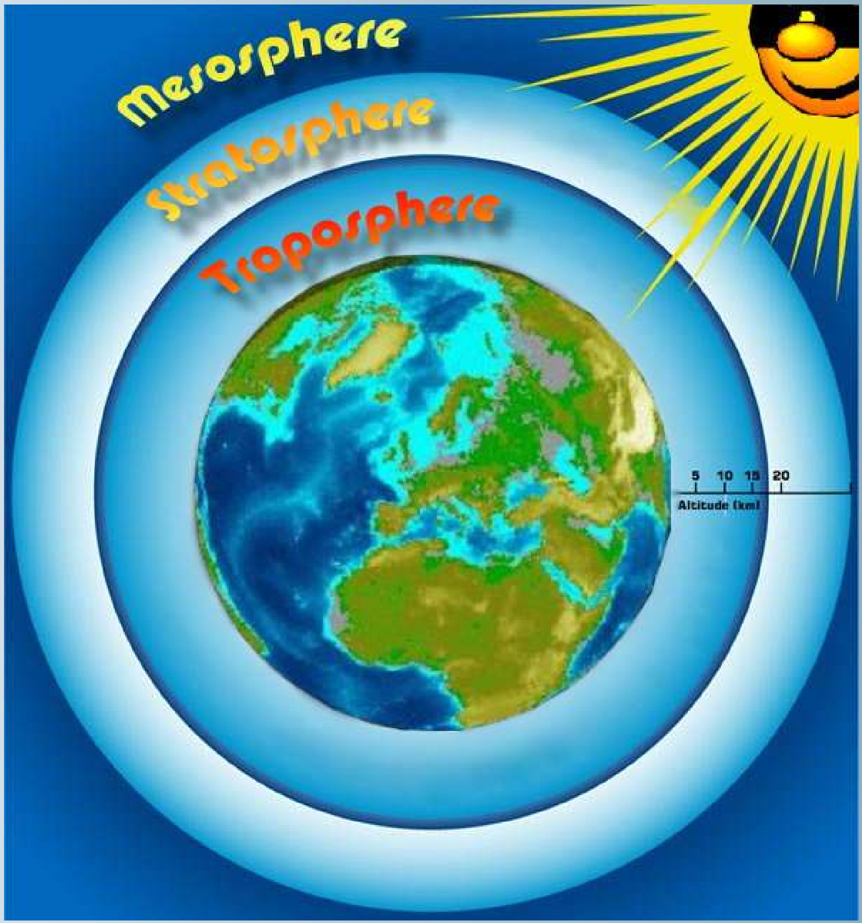
The Stratosphere

- In the lower portion of the stratosphere, temperature is constant – known as an **isothermal layer**
- In the upper stratosphere, **temperature begins to increase with height**
- This is due to the presence of the **ozone layer** – a layer of ozone molecules that absorb heat (incoming UV rays) from the sun
- High UV doses are harmful to humans so the ozone layer protects us
- As the ozone absorbs UV it heats up, resulting in higher temperatures



Differences between the Tropopause and Stratosphere:

- **Temperature** – Temperature in the stratosphere is approximately constant at lower levels, increasing at higher levels
- **Vertical movement of air** – Due to the very low lapse rate, air in the stratosphere is stable, with little or no vertical movement
- **Water Vapour** – Most of the water vapour is in the troposphere, so cloud seldom appears in above the tropopause



THE INTERNATIONAL STANDARD ATMOSPHERE (ISA)

The International Standard Atmosphere (ISA)

A hypothetical average atmosphere set by ICAO for use as a standard against which actual atmospheric conditions can be compared:

- Mean Sea Level Pressure = **1013.25 hPa**
- Pressure Lapse Rate = **1 hPa/30 ft (reducing with altitude)**
- Mean Sea Level Temperature = **+15°C**
- Temperature Lapse Rate (or ISA ELR) up to 36,090ft = **1.98°C/1000ft (reducing with altitude)**
- Temperature of the Tropopause = **-56.5°C**
- Height of the Tropopause = **36,090 ft**

Note: this is usually rounded to 2°C/1000ft

The International Standard Atmosphere (ISA)

- Temperature from 36,090ft to 65,617ft = **Constant at -56.5°C**
- From 65,617ft to 104,987ft = **0.3°C/1000ft (*increasing* with altitude)**
- Mean Sea Level Density = **1.225kg/m³**

METHODS OF HEAT TRANSFER

Methods of Heat Transfer

- Heat is a form of energy
- Temperature is simply a measure of how much heat energy a body possesses
- Heat may be transferred in 3 ways:

1. Radiation

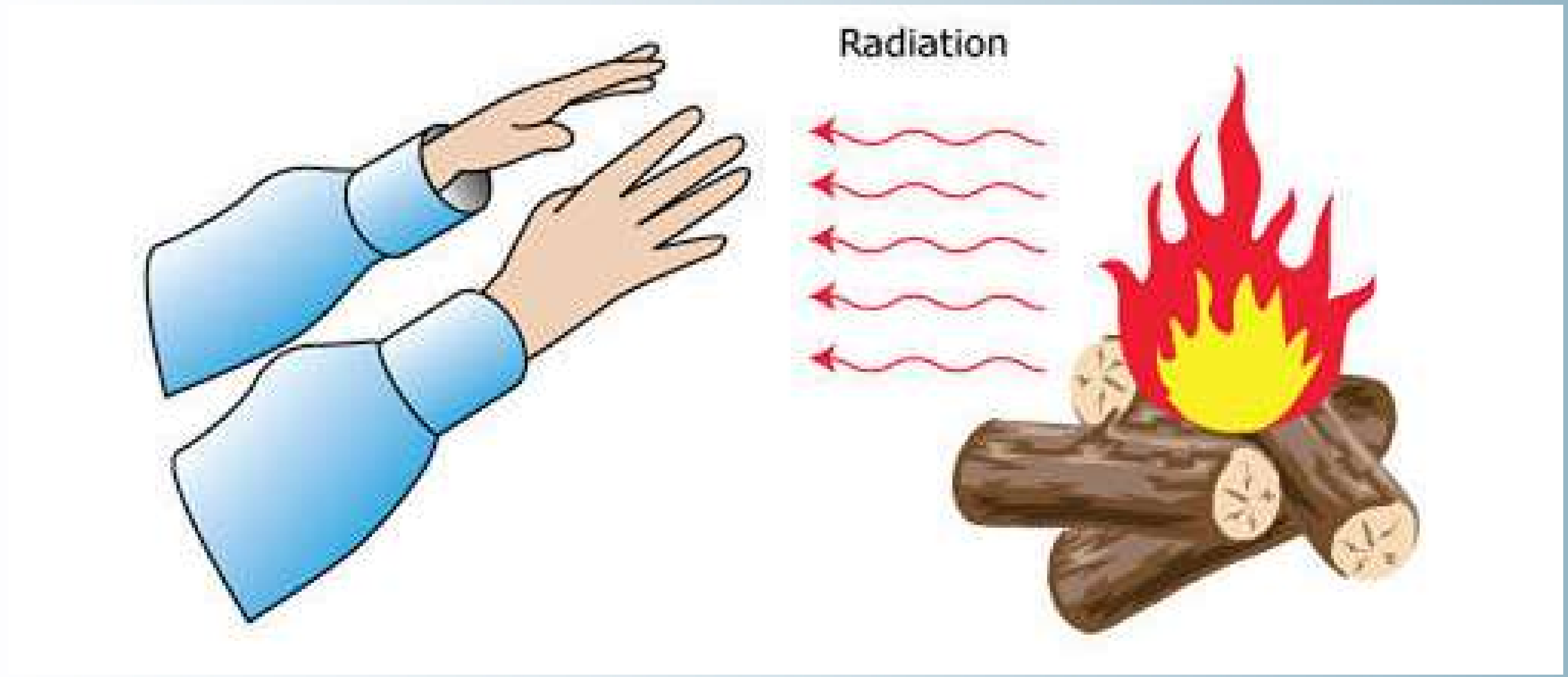
2. Conduction

3. Convection

Radiation

The transfer of heat by electromagnetic waves

- Any object with a temperature above absolute zero (-273°C) radiates heat energy in the form of electromagnetic waves

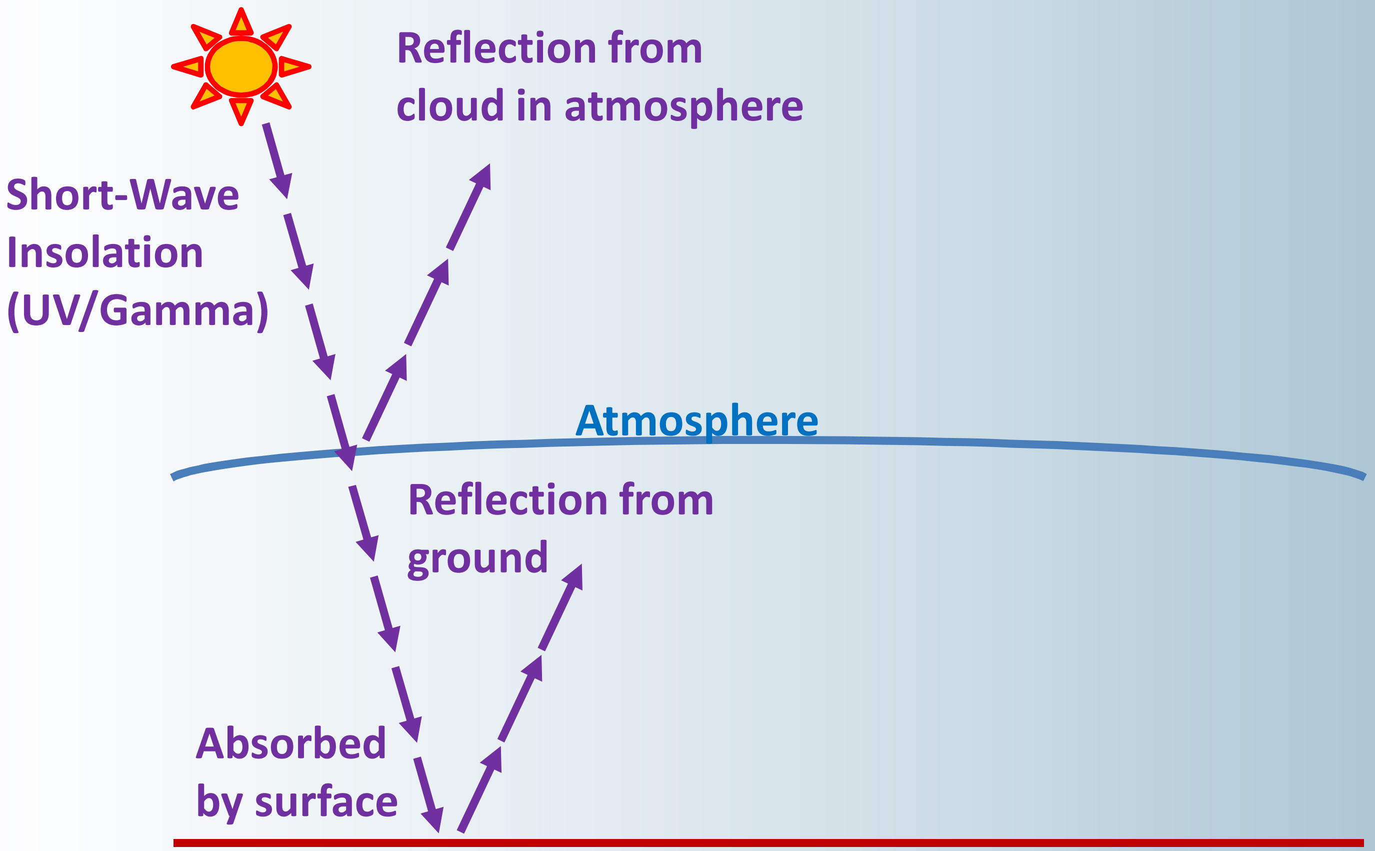


- The hotter the body, the shorter the wavelength. The sun (extremely hot) emits radiation with very short waves
- These waves from the sun are known as **insolation**

Radiation

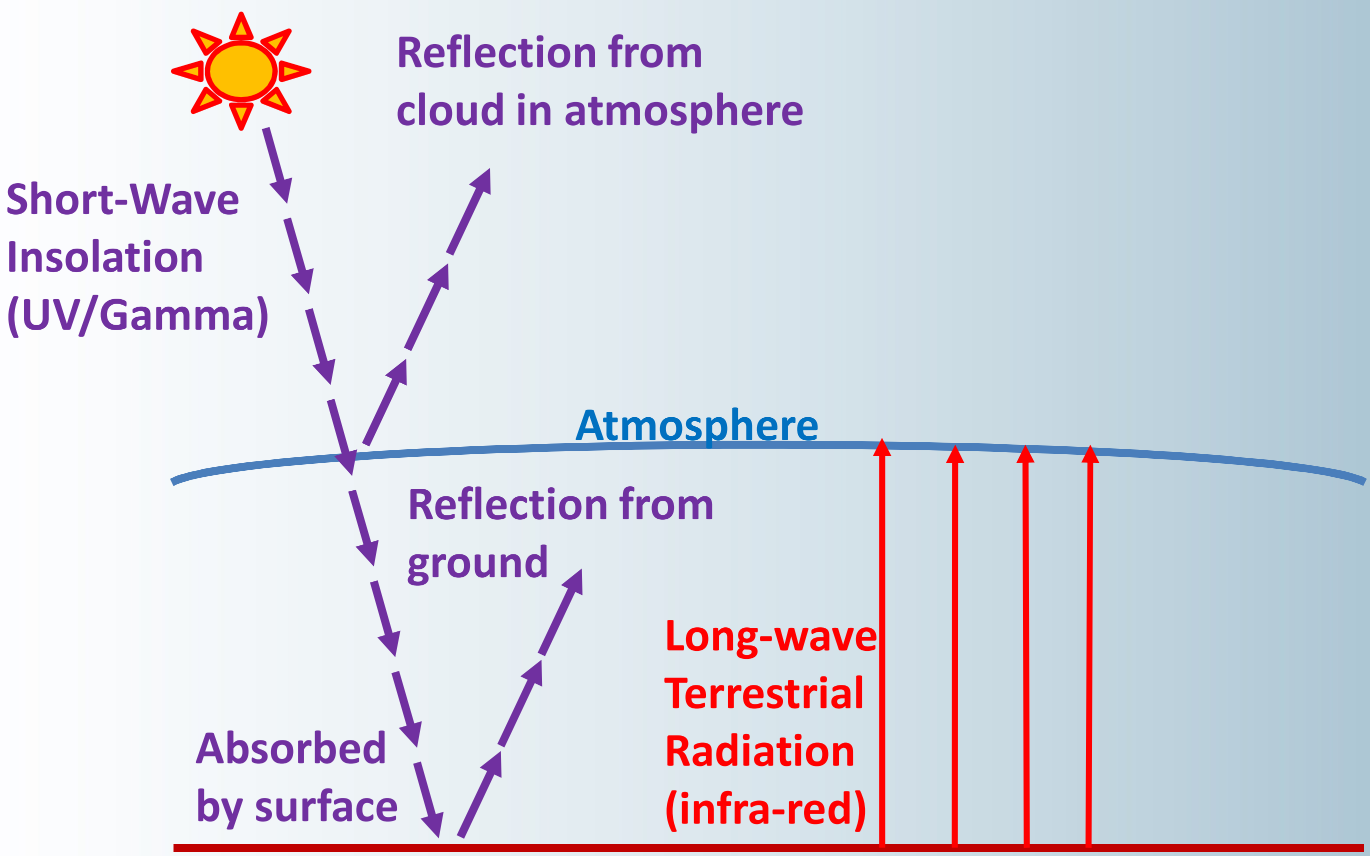
Insolation can travel through space and once it reaches our atmosphere:

- Over half is lost through reflection from ground and cloud tops, as well as scattering by dust, water vapour, smoke etc
- Less than half is absorbed by the earth's surface



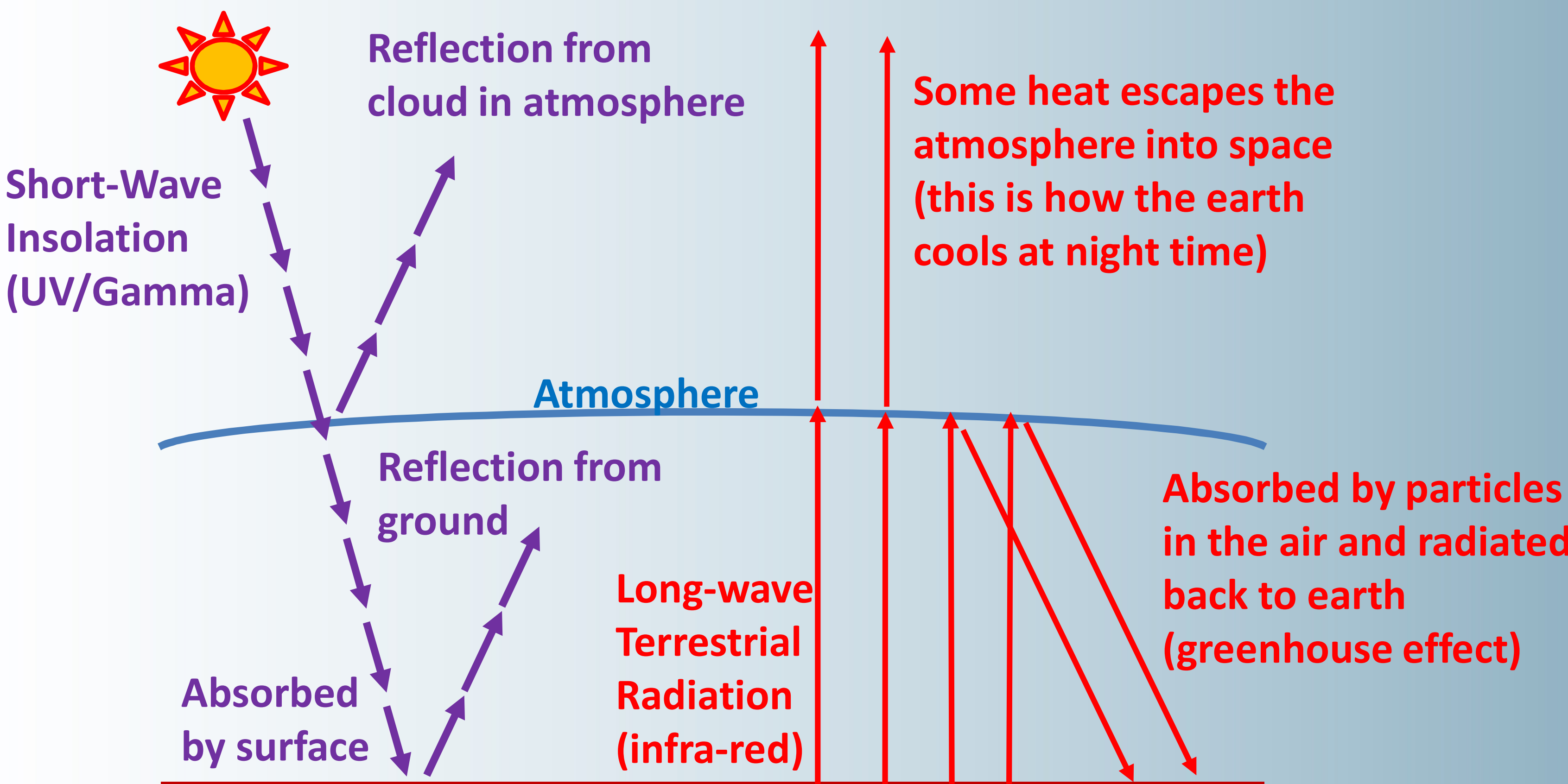
Radiation

- As the earth absorbs this radiation, it warms
- However, it is not nearly as hot as the sun so the earth emits long wave radiation – known as **terrestrial radiation**



Radiation

- Less than half terrestrial radiation escapes the atmosphere – its longer wavelength means that it is largely absorbed by water vapour and CO_2
- These molecules then radiate the heat back to earth – the **greenhouse effect**



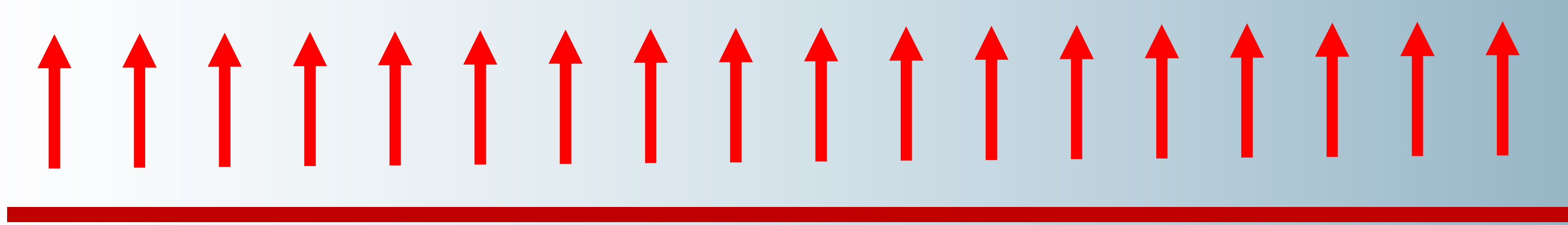
Conduction

The transfer of heat through contact

- As the surface of the earth is heated by insolation, **the air in contact with the surface is heated by conduction**
- Air is a poor conductor of heat so **only the air close to the surface is heated**
- This is why temperature decreases with altitude in the Troposphere

COOL Air further away from the surface is not in direct contact and will remain cooler during the day

WARM Air close to the surface is heated just like a frying pan



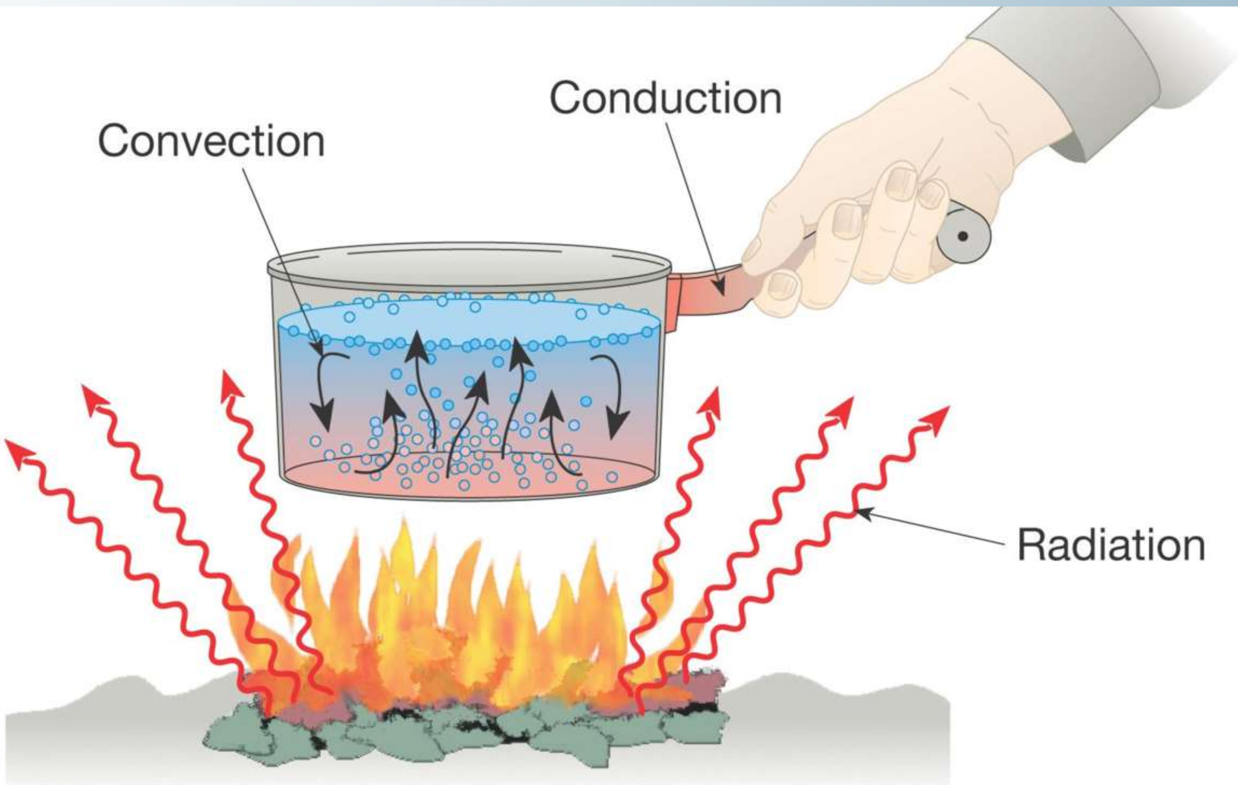
Convection

The transfer of heat through movement of a body (vertically)

- As the air above the surface is heated by conduction, it expands and becomes less dense

- This generates rising currents of warm air – known as **thermals**

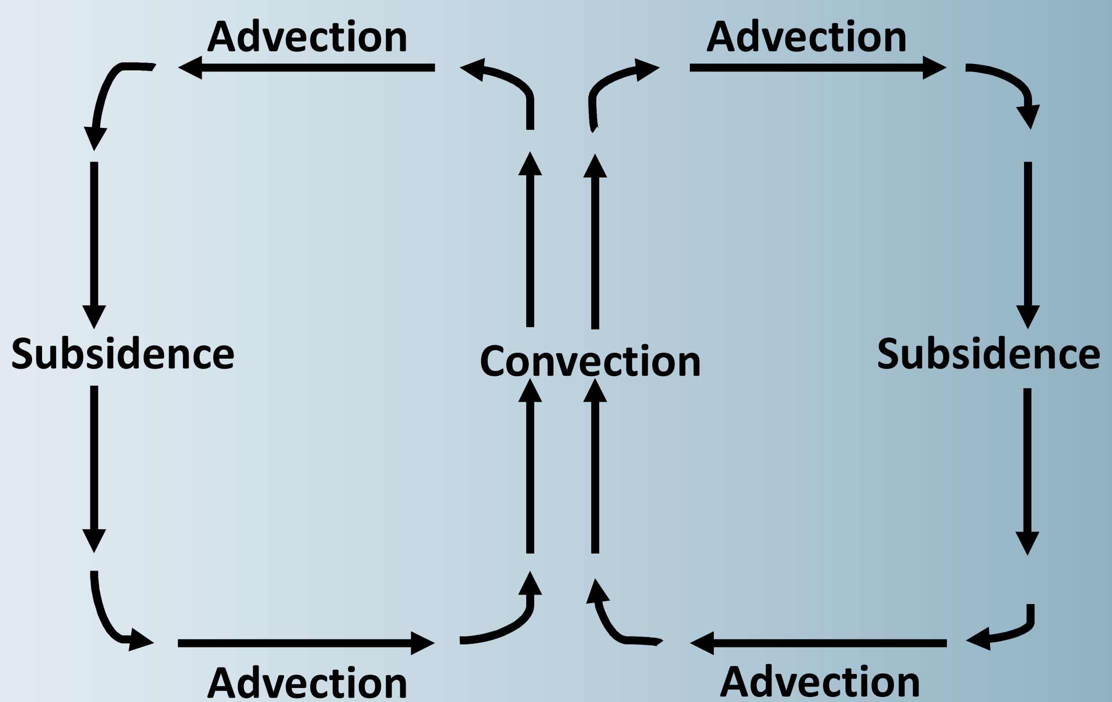
- The process of warm air expanding and rising is known as **convection**



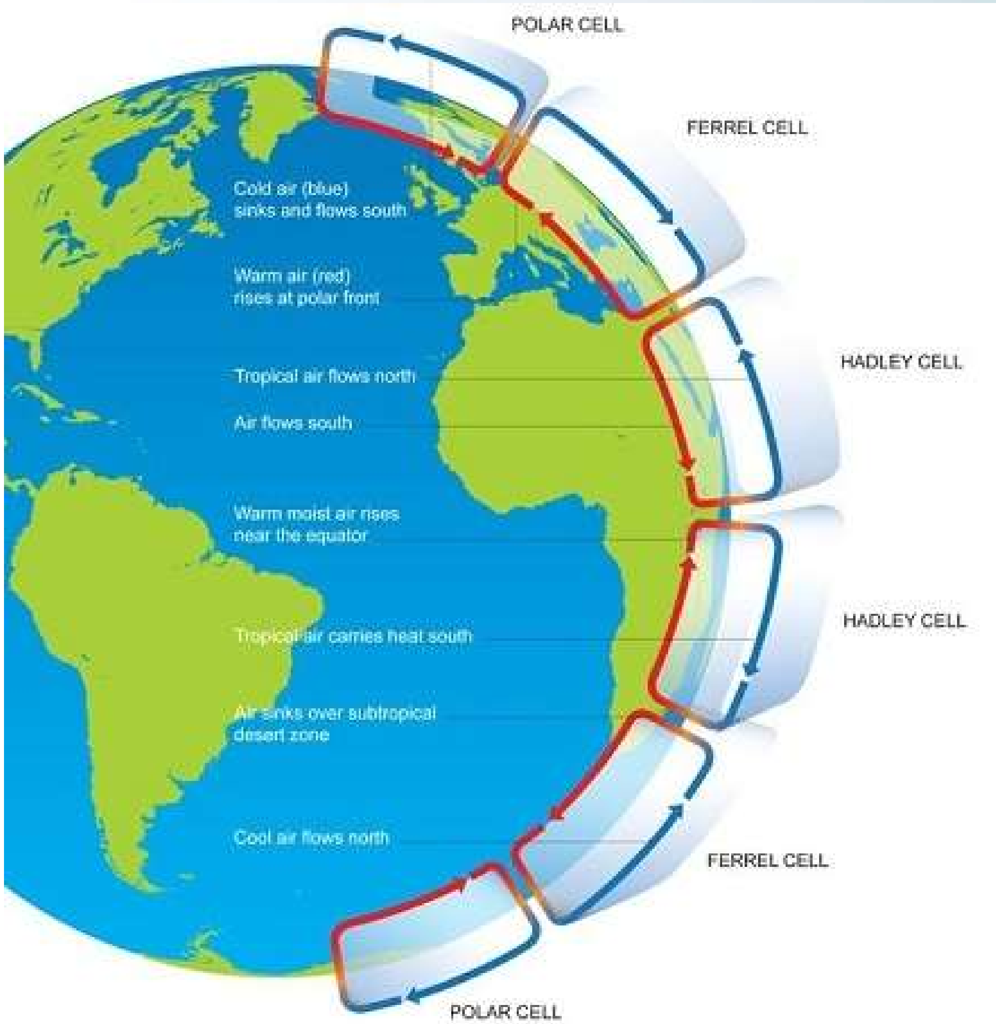
ROLE OF HEAT TRANSFER IN THE ATMOSPHERE

Role of Heat Transfer in the Atmosphere

- Warm air rising via convection will cool as it gets further away from the surface
- As the air cools, it will move horizontally before descending again
- The horizontal movement of air is called **advection**
- Once the air has cooled enough, it will condense and sink again
- Air sinking is known as **subsidence**
- These movements of air all combine to form a simple **Circulation Cell**



Role of Heat Transfer in the Atmosphere



- The process of uneven heating of the earth from the sun causes large scale convection, advection and subsidence, this sets up global weather patterns and winds.
- Several large scale parcels of circulating air develop known as cells
- **Equatorial trough**: Heating at the equator causes widespread convective activity creating a low near the equator
- **Sub-Tropical ridge**: Air moves away from equator, cools and subsides, creating a resident high in the sub-tropical region
- **Sub-polar low**: Resident low near the poles due to large scale convection
- **Polar high**: Resident high over the poles due to subsidence of cold polar air

TEMPERATURE VARIATION

Temperature Variation

- The temperature of the Earth's surface depends on its:

1. **Reflectivity** (ability to reflect light)
2. **Conductivity** (ability to conduct heat)
3. **Cloud Cover**

   - During the day this will produce lower surface temperatures as the insolation cannot reach the ground

   - By night, this will insulate against heat loss, keeping the surface warmer by absorbing terrestrial radiation

4. **Specific Heat** (energy required to raise the temperature of an object by 1°C)

Temperature Variation

- **Specific Heat** (energy required to raise the temperature of 1 unit of mass by 1°C)
- **Latent Heat** (energy required to change state without a change in temperature)

+20°C → +21°C

1 calorie required

-0.5°C → +0.5°C

81 calories required

- 1 calorie for change in temp.
- 80 calories for change in state (latent heat)

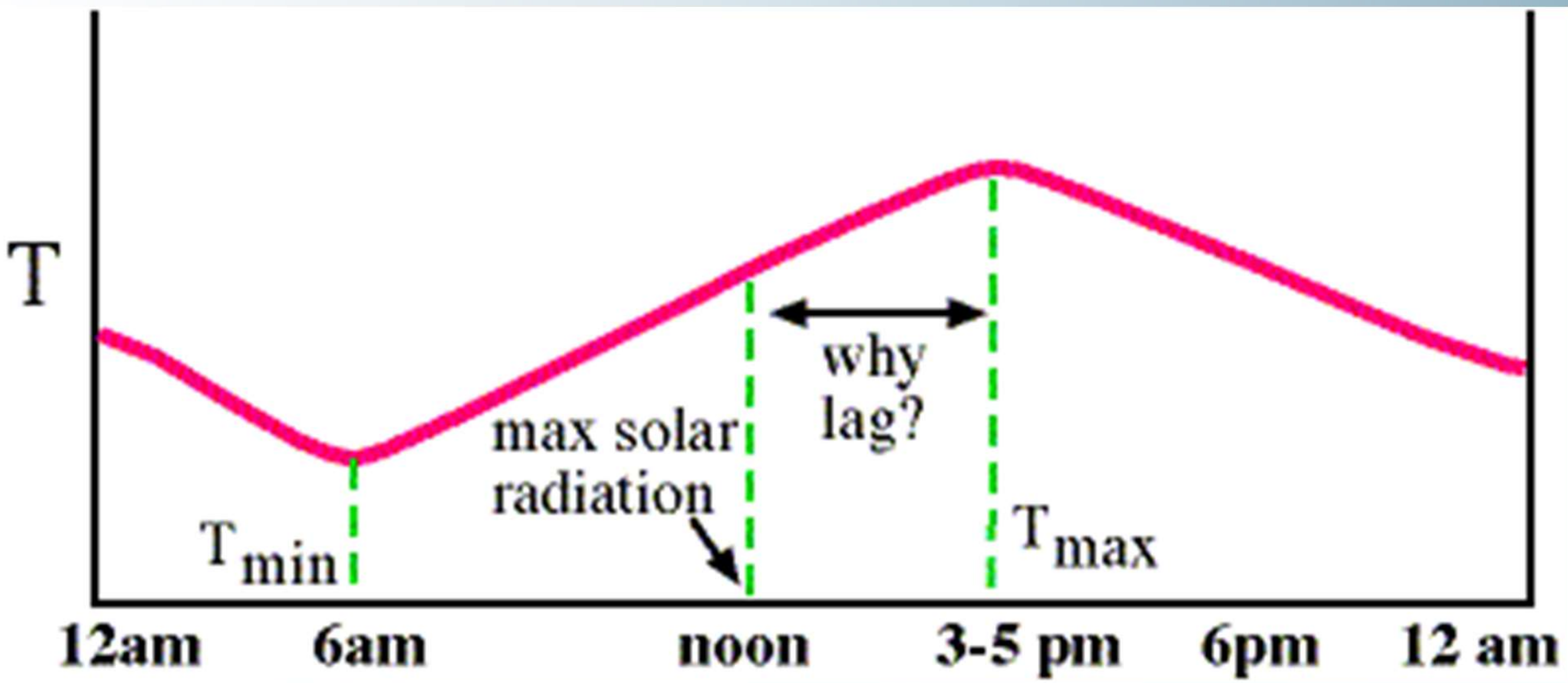
+99.5°C → +100.5°C

561 calories required

- 1 calorie for change in temp.
- 560 calories for change in state (latent heat)

Diurnal Variation of Temperature

- Diurnal refers to the **24 hour or daily variation**
- **Peak temperature is around 2-3pm** as the surface air continues to warm by conduction
- **Minimum temperature is around dawn** as the surface has been losing heat all night by terrestrial radiation

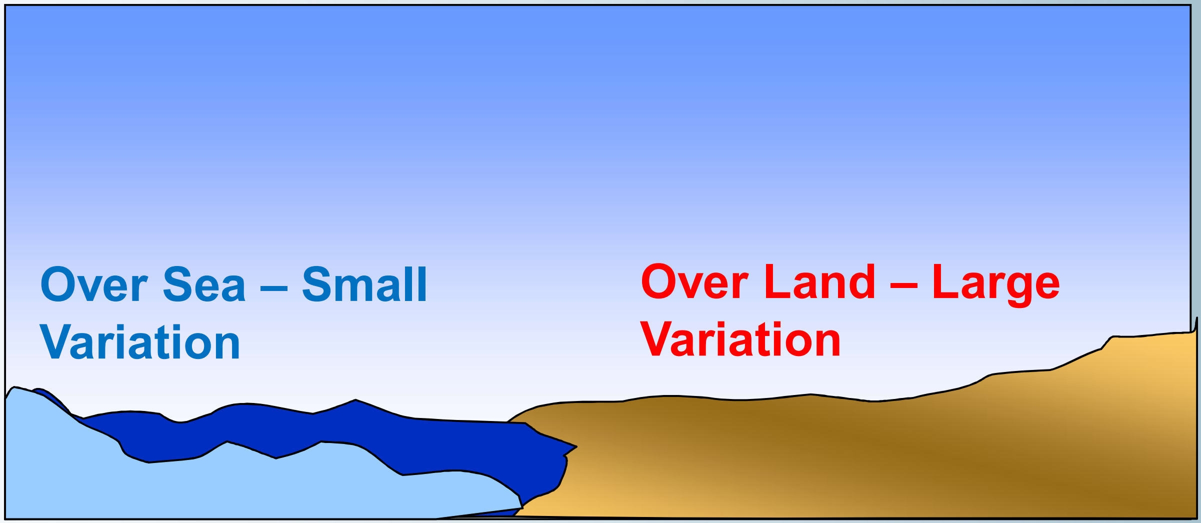


Diurnal Variation of Temperature

- Location will also affect the temperature variation

- Over 24 hours, the **temperature variation over the sea is gradual** and often **less than 1°C**. This is because the high specific heat of the ocean keeps coastal temperatures cooler during the day and warmer at night.

- Inland locations have a much greater range, for example, **desert areas may vary by as much as 20°C** in a 24 hour period. Inland, the atmosphere heats up more during the day and cools off more during the night.



Diurnal Variation of Temperature

- Atmospheric conditions will also affect diurnal variation of temperature
- **Wind** will mix up the air and **reduce the diurnal variation**
- **Calm conditions increase diurnal variation**
- **Cloud cover will reduce the diurnal variation** at a particular place

Note: An **Isotherm** is a line on a chart joining areas of equal temperature

"But to be fair, there's a fifty percent chance of just about anything."