

THE ATMOSPHERE

AME Course - 17 February 2025



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Contents



1. Functions of the atmosphere
2. ICAO standard atmosphere
3. Layers of the atmosphere
4. When is/isn't 18 000ft, 18 000ft?
5. Ozone
6. Radiation
7. Atmospheric pressure vs altitude
8. Oxygen partial pressure/concentration vs altitude
9. Jet Streams
10. Ebullism
11. Possible stressors due to flying - at higher altitude

1. Functions of the atmosphere

1. Supplies oxygen
2. Acts as barrier against harmful effects of solar radiation
3. Regulates ambient temperature

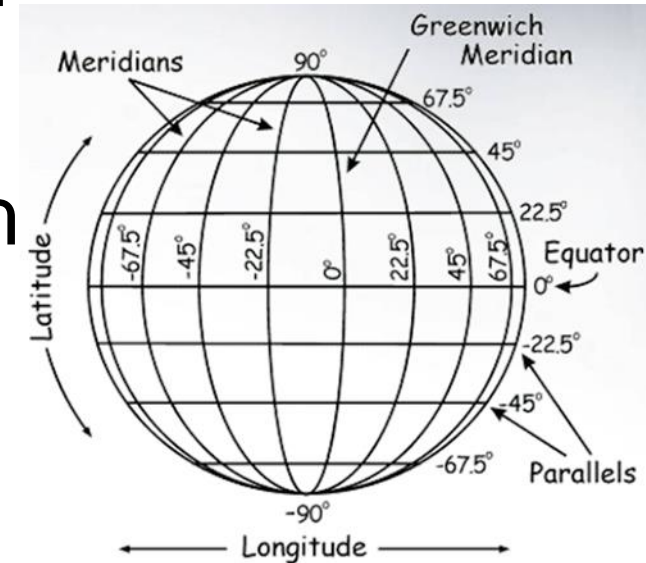


2. International / ICAO standard atmosphere

- Temperate latitude, 45° North
- Dry air
- No dust
- Pressure at sea level:

1 atm = 101 kPa = 1013.25 hectopascals / millibars

= 760mm Hg = 29.92 inches of Hg



2. International / ICAO standard atmosphere ...

- Air density = $1,225 \text{ kg/m}^3$
- Gravitational acceleration = $9,80665 \text{ m/s}^2$
- Temperature at **mean sea level**
 $15^\circ\text{C} = 288^\circ\text{K}$
- Dry adiabatic lapse rate: $1,98^\circ\text{C}/1000 \text{ ft}$
(to tropopause **at 36 089 ft = 11 kms**)

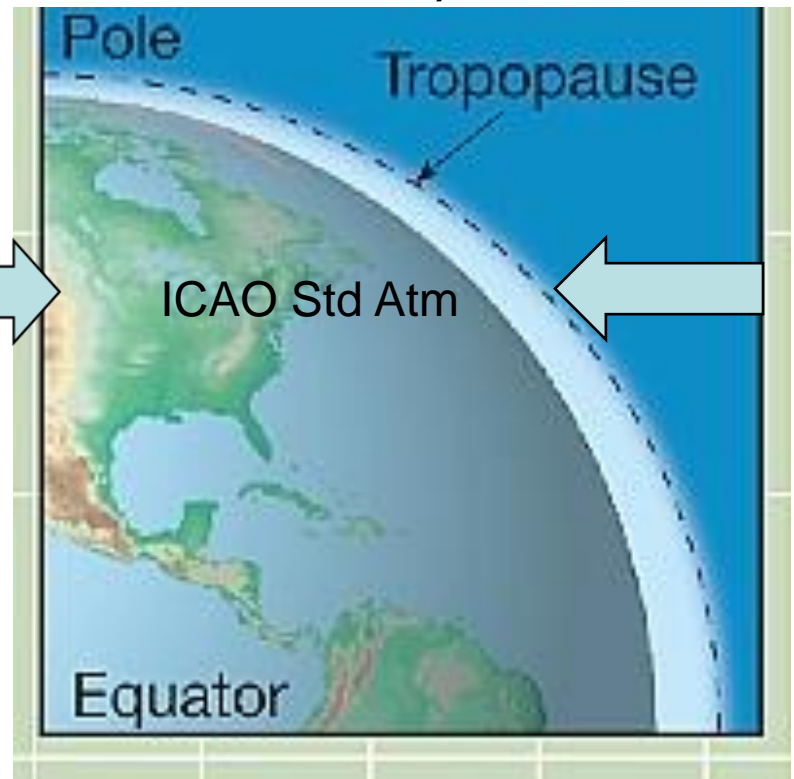


3. Layers of the atmosphere

A balance between two factors:

- Thermal expansion (sun's radiation effect)
- Gravity

ICAO Std Atm at 45°N



N pole vs equator

Twice as thick at the equator

3. Layers of the atmosphere...

Concentric layers around the earth:

Outer Space

5. Exosphere

4. Thermosphere - (the Ionosphere is not the same thing)

3. Mesosphere

2. Stratosphere - (contains the Ozonosphere)

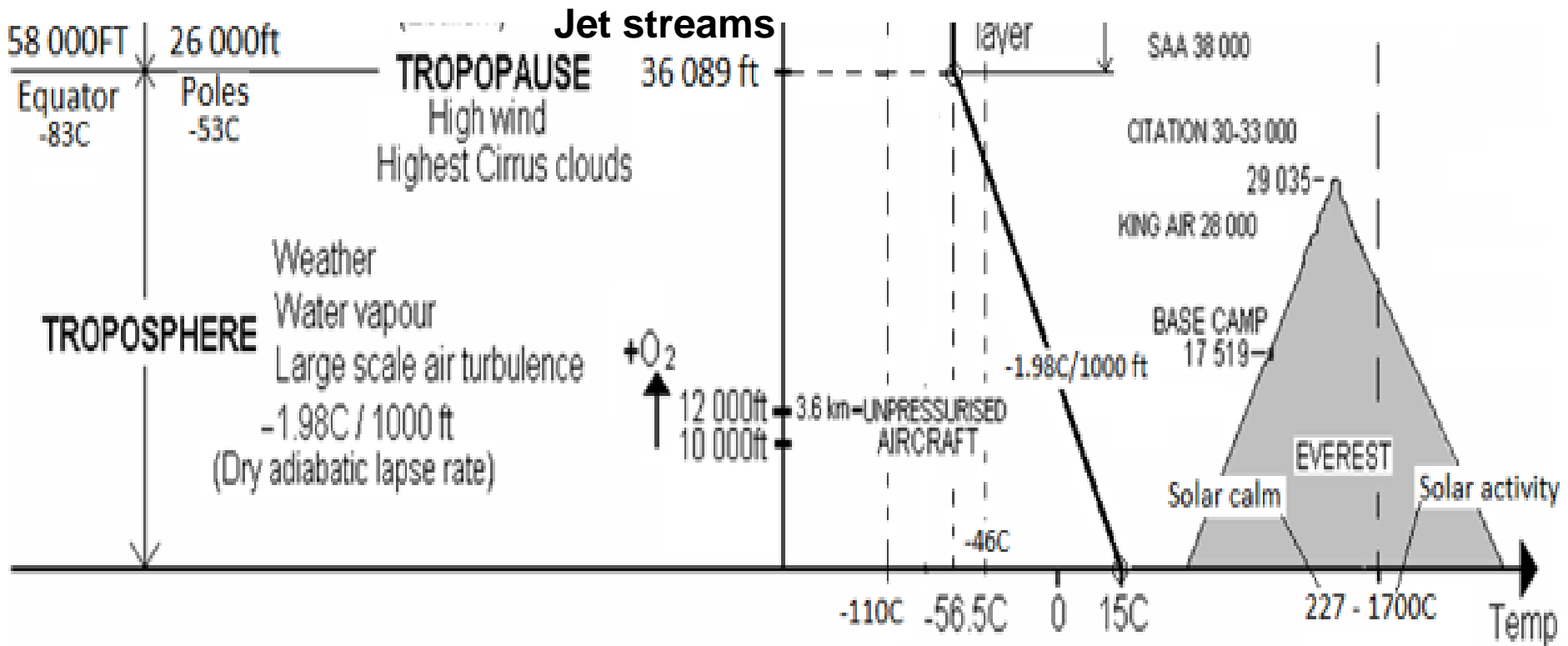
1. Troposphere

Earth's surface



3. Layers of the atmosphere...

Troposphere



3. Layers of the atmosphere...

Twister (Troposphere)



3. Layers of the atmosphere...

Temperature changes at altitude

Outer Space

4. Thermosphere: Increases to 2,000°C or higher

3. Mesosphere: Decreases to -110°C

2. Stratosphere

– Temp increases to -3°C at stratopause

– **Isothermal layer** (-56,5°C) up to 65 616 ft

1. Troposphere: Decreases from 15°C at sea level to -56,5°C at tropopause

Earth's surface

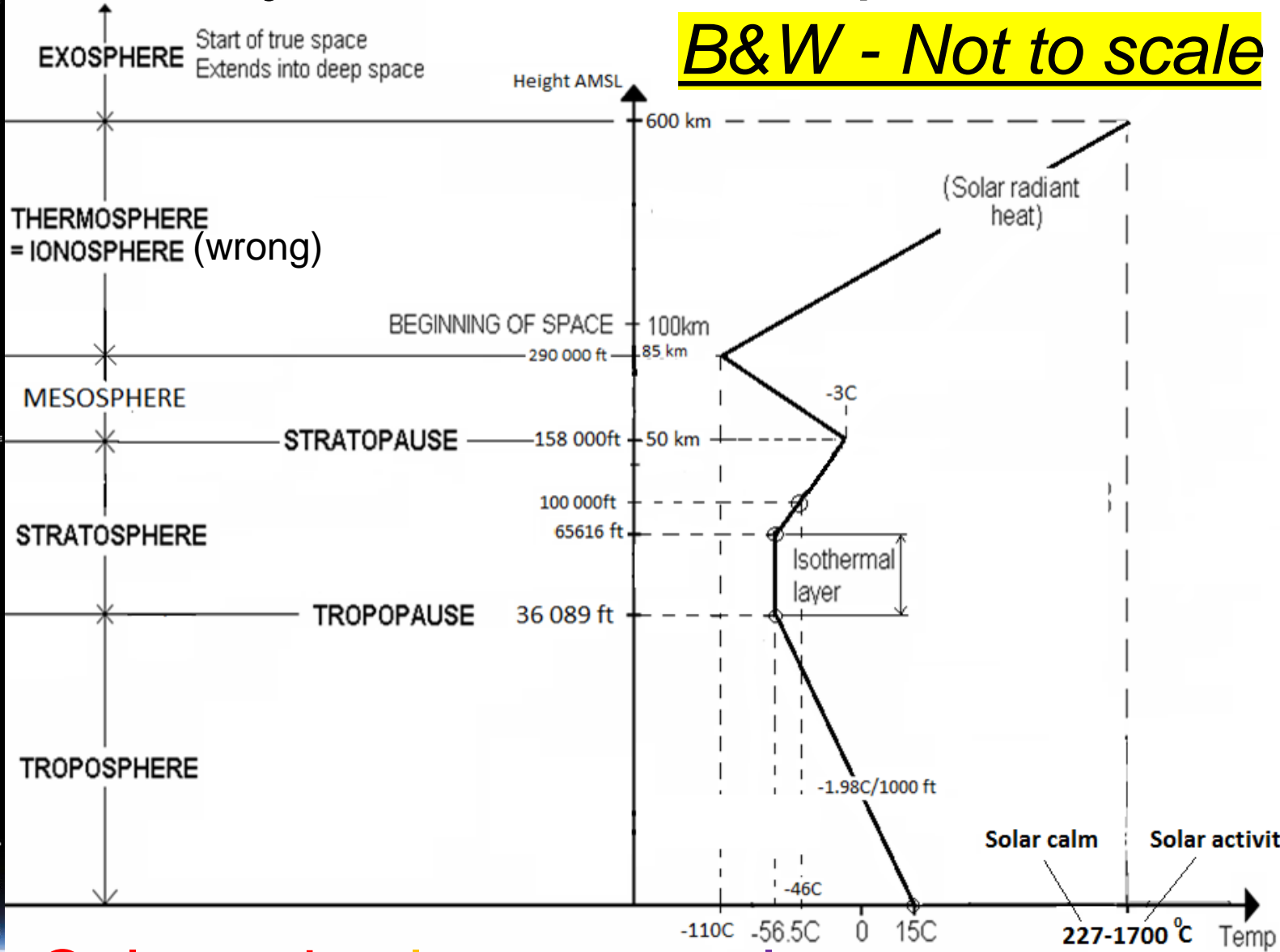
3. Layers of the atmosphere...

B&W - Not to scale

Thermo-

Meso-

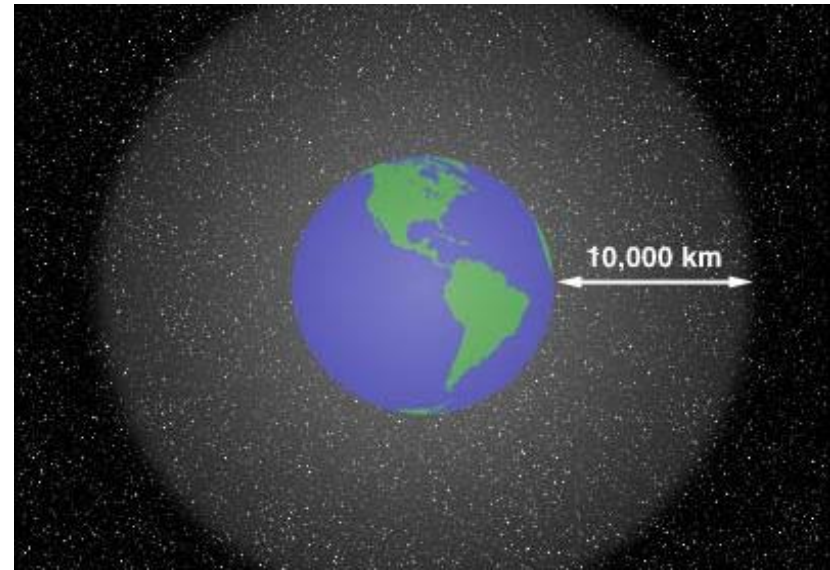
Strato-
Tropo-



Coloured column to scale

3. Layers of the atmosphere...

Outer Space



5. Exosphere:

- Gravitational limit 192 000 km
- Geocorona 10,000 km, (6,200 miles)
- Arbitrary 1 000 km

4. Thermosphere: to 600 km (375 miles)

3. Mesosphere: to 85 km (53 miles) (279 000ft)

Space starts at 100 km = Karman Line

2. Stratosphere: to 50 km (31 miles) (158 000ft)

1. Troposphere: to 11 km (7 miles) (36 000ft)

Earth's surface

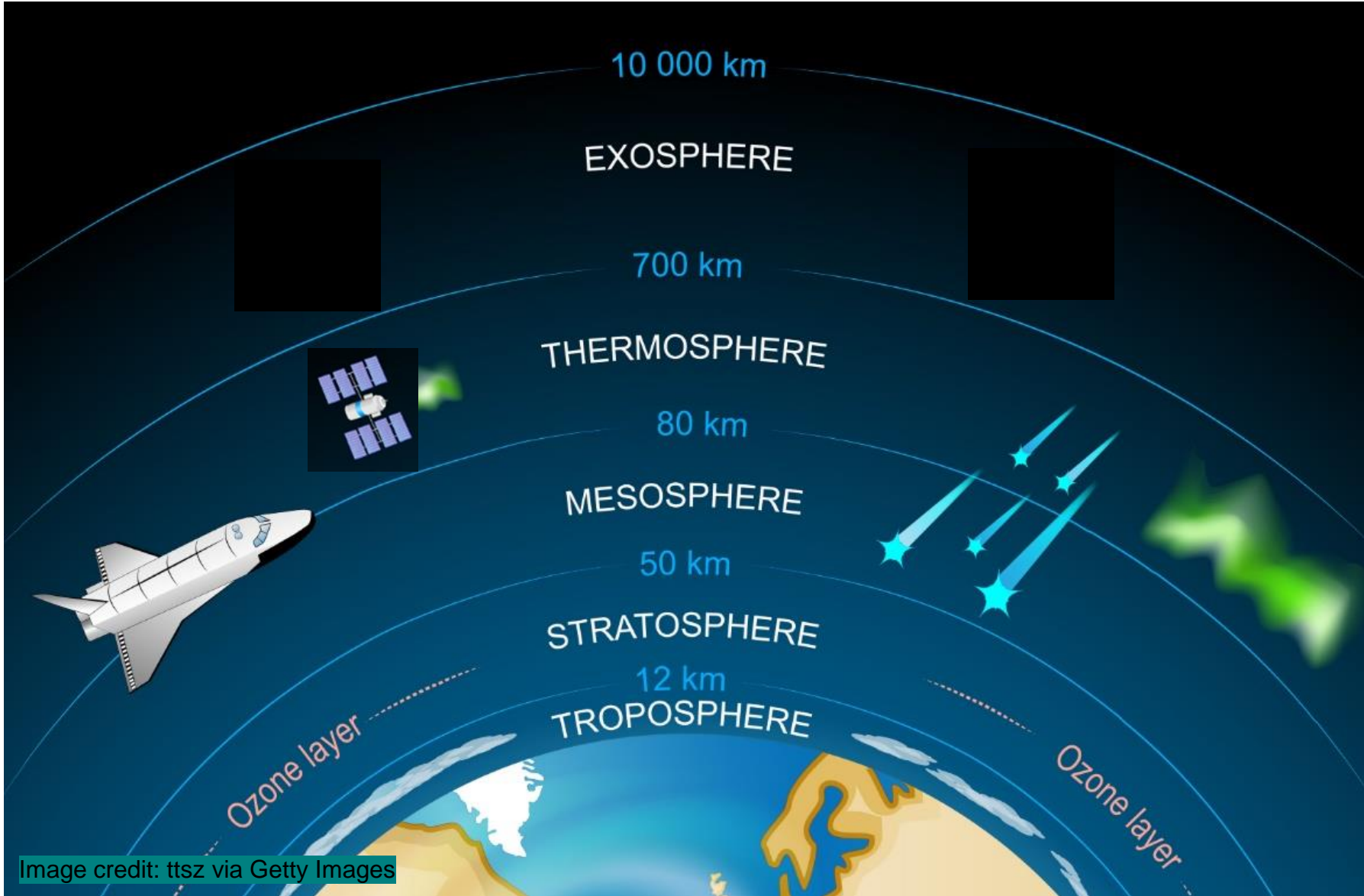


Image credit: ttsy via Getty Images

Diagram not to scale

Ionosphere



Overlaps the meso, thermo & exospheres -
from about 60 km to about 1,000 km amsl

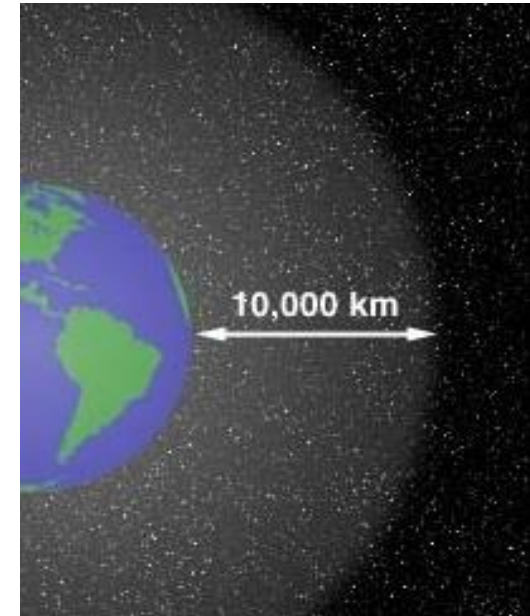
Role in radio propagation to distant places on the
Earth

- Rarely used except by amateur radio hobbyists 'Hams'
- Radio waves can bounce back to Earth beyond the horizon - called "skip" or "skywave" propagation
- Is unreliable, varies according to time of day or night, the seasons, weather, and the 11-year sunspot cycle

Where does **space start**?



- *New: Geocorona - extends up to 630,000 km*
- Particle density of $2.687 \times 10^{25}/\text{m}^3$ is reduced to 5 per cm^3
- Gravity - 192 000 km (exopause)
- Geocorona - 10 000 km
- Exosphere? 600 to 1 000 km (exobase)
- **100 km (FAI)** (Kármán line, 62 miles)
 - Legal definition, international treaties etc
- Where the atmosphere alone no longer supports a flying aircraft at suborbital speeds (aerodynamic lift force) = **80 km (USA)**



Earth's surface

The weightlessness of space



Where do astronauts float freely in space due to 'the weightlessness of space' - **having escaped Earth's gravity?**

- International Space Station??
- Jeff Bezos, William Shatner, Richard Branson??
- All space travellers (when the spacecraft 'engine' is turned off)

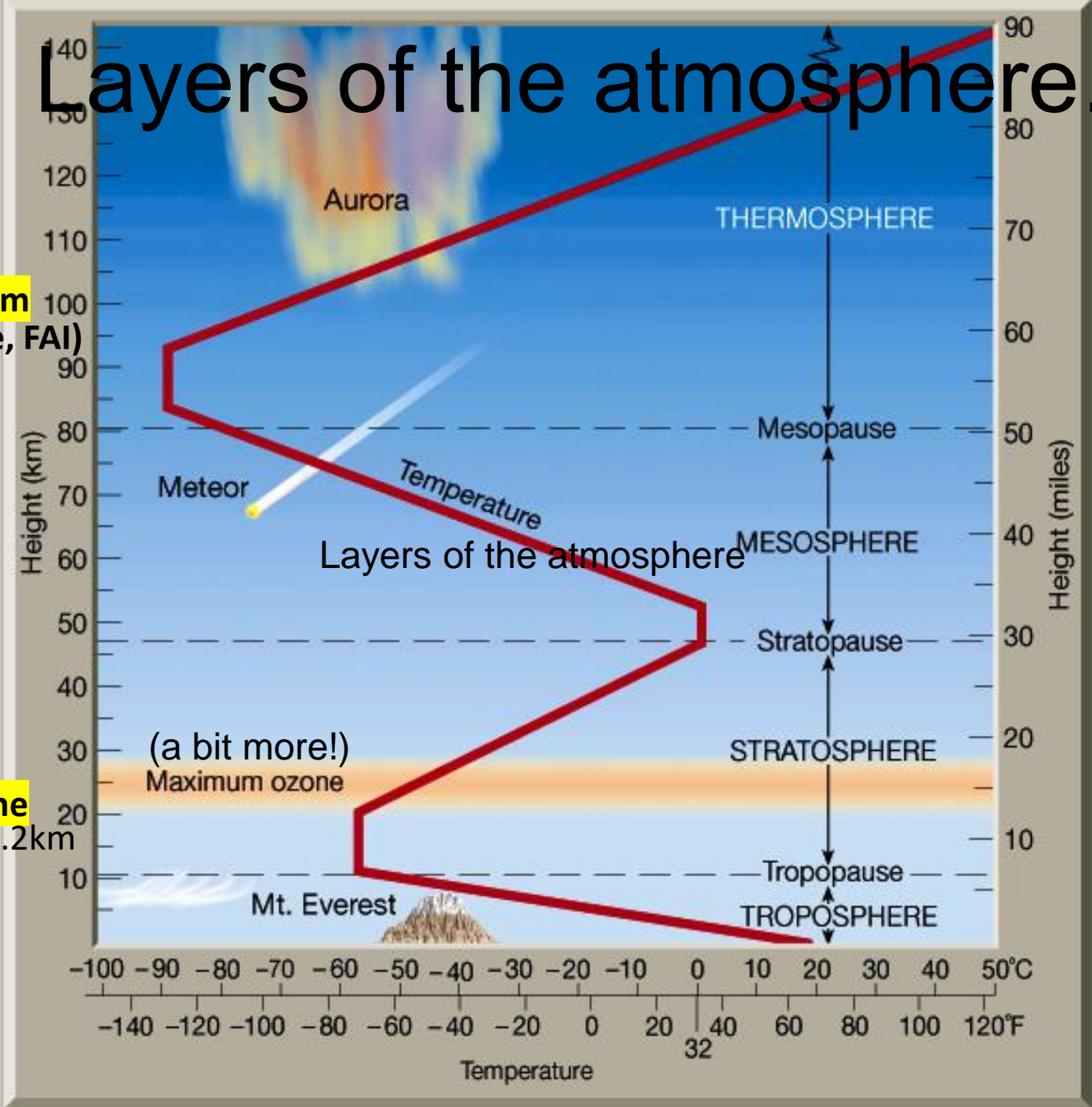
Their apparent weightlessness is **caused by freefall**

Theoretically, astronauts on their way to the Moon, where:
the gravitational pull of the Earth = the gravitational pull of the Moon
(but only if they are stationary at that point – about 33,600 km from the Moon)

The Earth's atmosphere and the moon, seen from the ISS



3. Layers of the atmosphere...



Space: 100 km
(Kármán line, FAI)

Space (USA)

Armstrong line
63 000ft = 19.2km
(Ebulism)

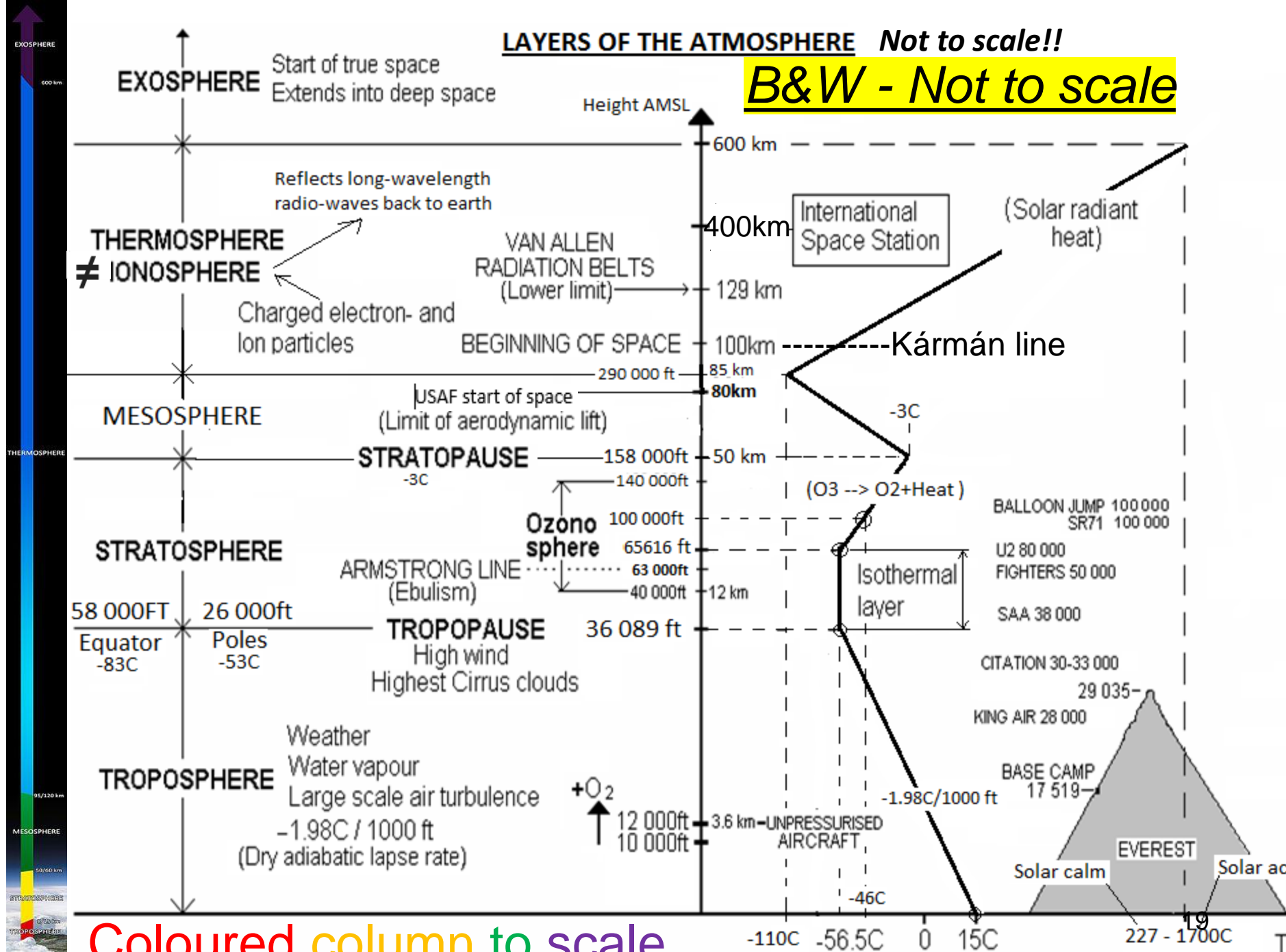
265 000ft

158 000ft

36 089ft

LAYERS OF THE ATMOSPHERE *Not to scale!!*

B&W - Not to scale



Coloured column to scale



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4. When is/isn't 18 000ft, 18 000ft?
5. Ozone
6. Radiation
7. Atmospheric pressure vs altitude
8. Oxygen partial pressure/concentration vs altitude
9. Jet Streams
10. Ebullism
11. Possible stressors due to flying - at higher altitude

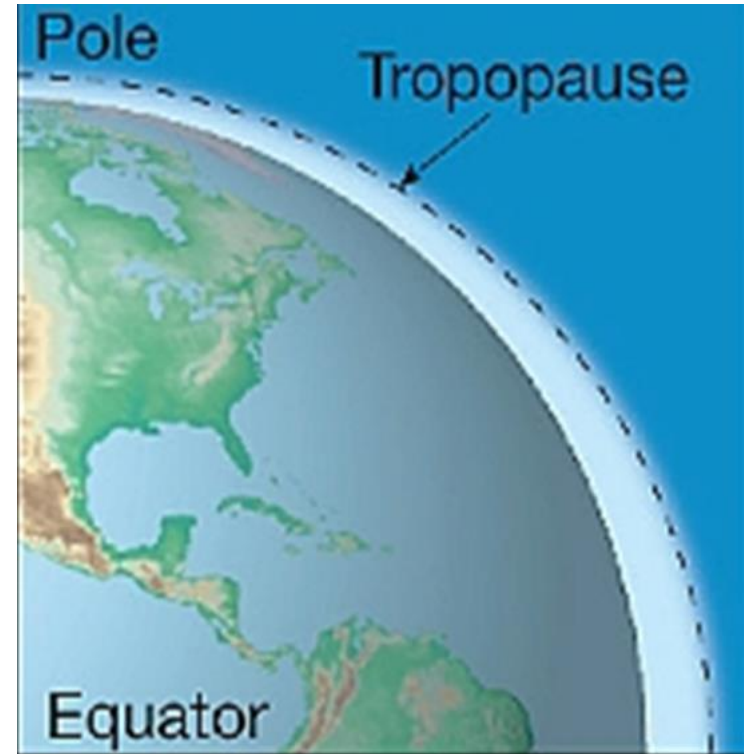
4. When is/isn't 18 000ft, 18 000ft?

Or any other altitude eg 36 000??

Is: ICAO std atm at 45° N

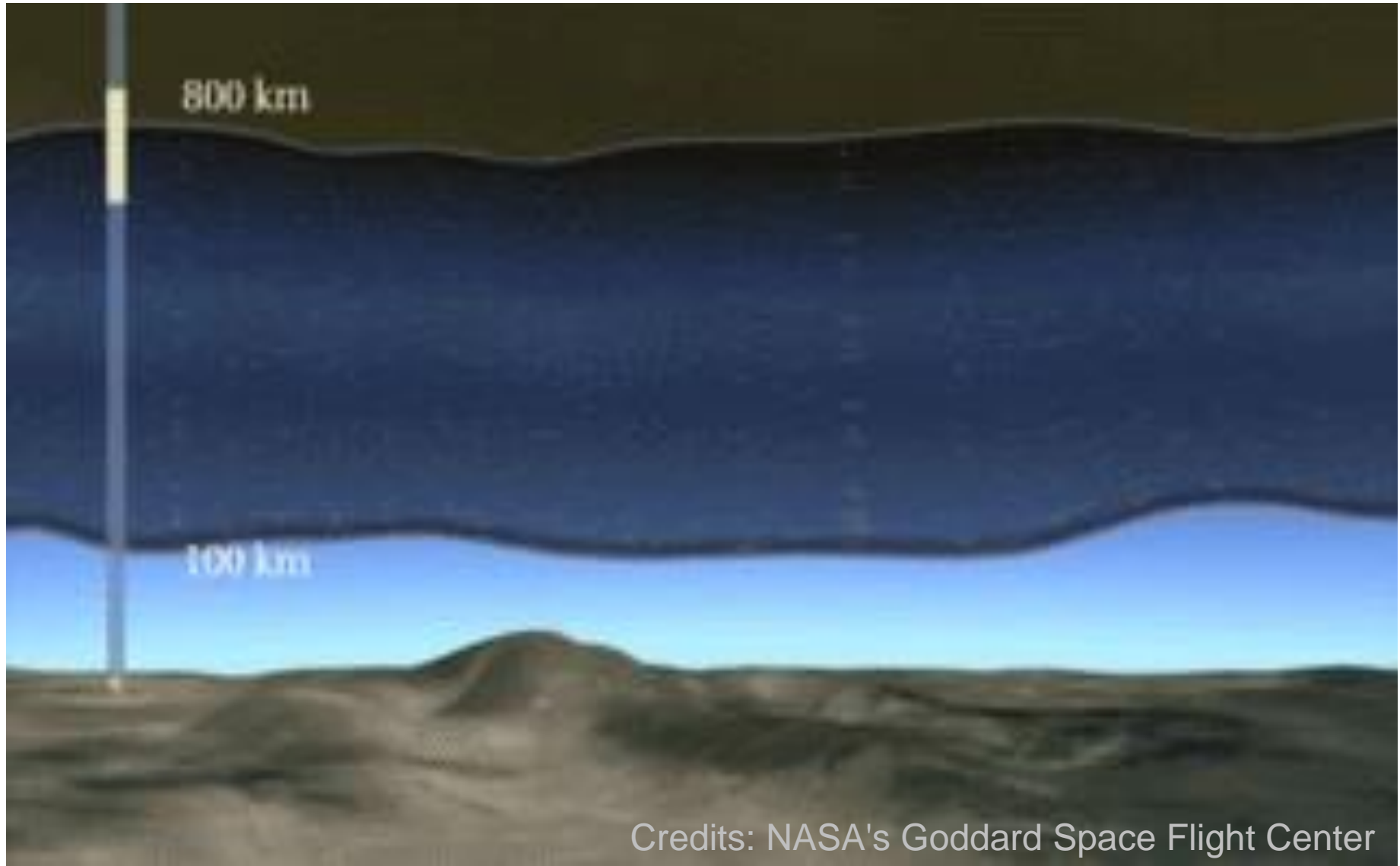
Isn't ?

- Inside a commercial aircraft
- Equator vs north pole
- Measuring AGL vs AMSL
- Sherpa vs Durbanite vs smoker vs COPD
- AGL vs FL 180 vs **aneroid barometer** vs QNH (regional pressure setting) vs transition altitude
- Day vs night, season of the year, solar flux



4. When is/isn't 18 000ft, 18 000ft?

- Day vs Night vs Seasons



Credits: NASA's Goddard Space Flight Center



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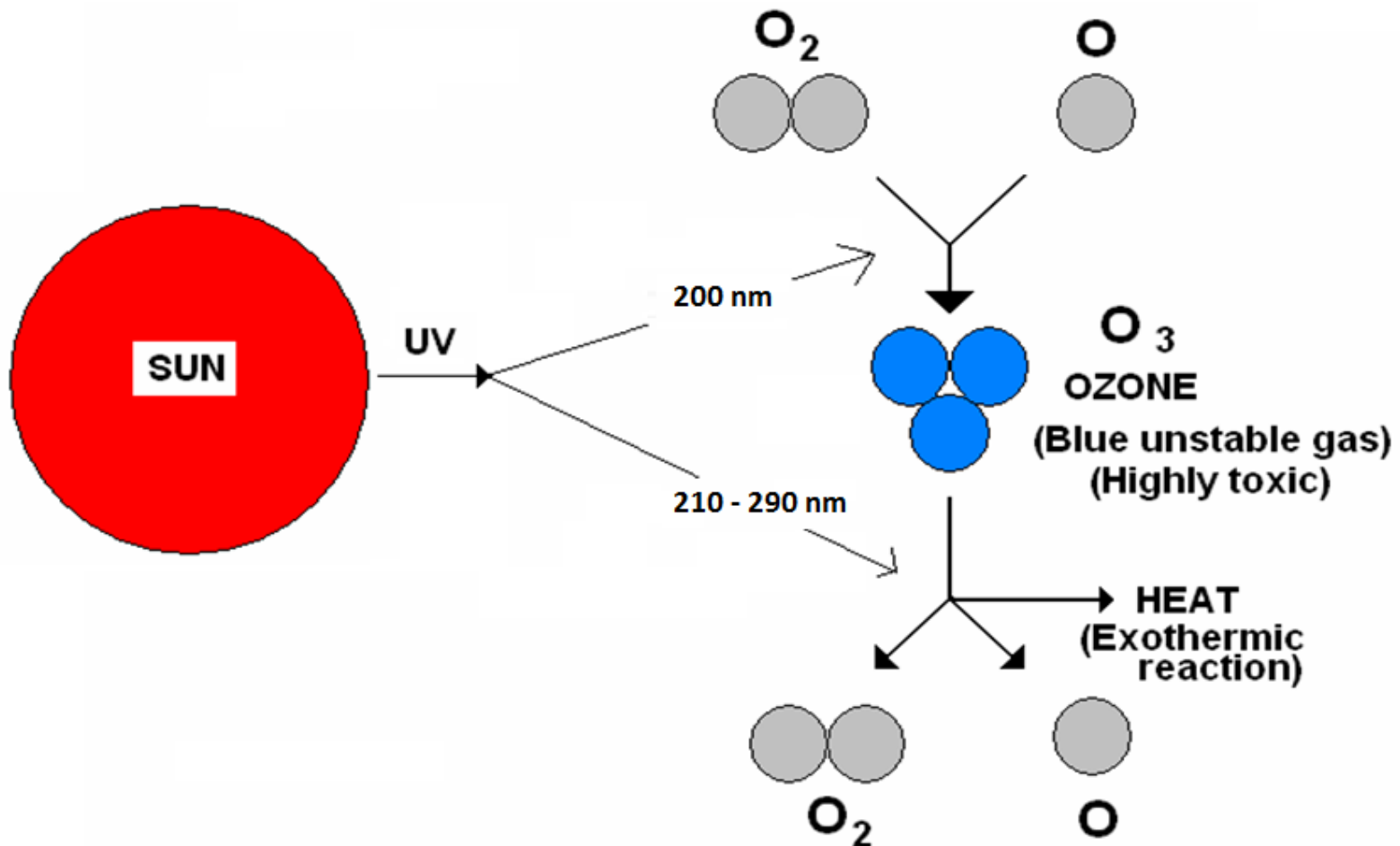


5. Ozone (O₃)

- Ozonosphere – in the Stratosphere
- Ozone is a very strong oxidant
- 40 000 ft (1 ppm -> pulm irritation)
- 120 000 ft (10 ppm-> pulm oedema/death)
- Significant concentrations between 60 000 and 140 000 feet (18 to 43 km)

5. Ozone - formation & destruction

Triatomic form of oxygen



6. Ozone...



- When O_3 is destructed it forms O_2 . This is an exothermic reaction that leads to heating of the ozonosphere
- The ozonosphere acts as a barrier against harmful radiation.
- CFCs cause a 'hole' in ozone layer (chlorofluorocarbons)

5. Ozone...



- An aircraft engine (at normal power) destroys ozone as it heats air before it is fed into the cabin
- At flight idle engine settings (during descent) some ozone can pass through into the cabin while flying in the ozonosphere



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6. Radiation

On Earth, we are constantly exposed to low levels of radiation

- **Ionising (cosmic) radiation**
 - high-energy charged particles, x-rays and gamma rays
 - produced by the stars, including our own sun
- **Non-ionizing, ultraviolet (uv) radiation**
 - also from our sun but lower in energy
 - relatively easy to block

6. Radiation...

Ultraviolet (UV) radiation



- UV radiation from the sun causes skin cancer (melanoma)
- The ozone layer protects us by absorbing most (about 98%) of the UV radiation
- Note: Ozone provides very little protection from cosmic radiation



6. Radiation...

- What is the risk from cosmic radiation?
 - is similar to exposure from a medical X-ray
 - varies with altitude, higher = greater exposure
 - most intense in deep space
 - usually passes right through us (and the earth) without hitting anything
- Danger to pilots & aircrew – cancer & infertility??
 - big **debate** but no definitive proof ???
 - relatively low radiation dose is unlikely to affect human health??
- **NB threat to long-duration interplanetary space travellers & life on Mars and the Moon**

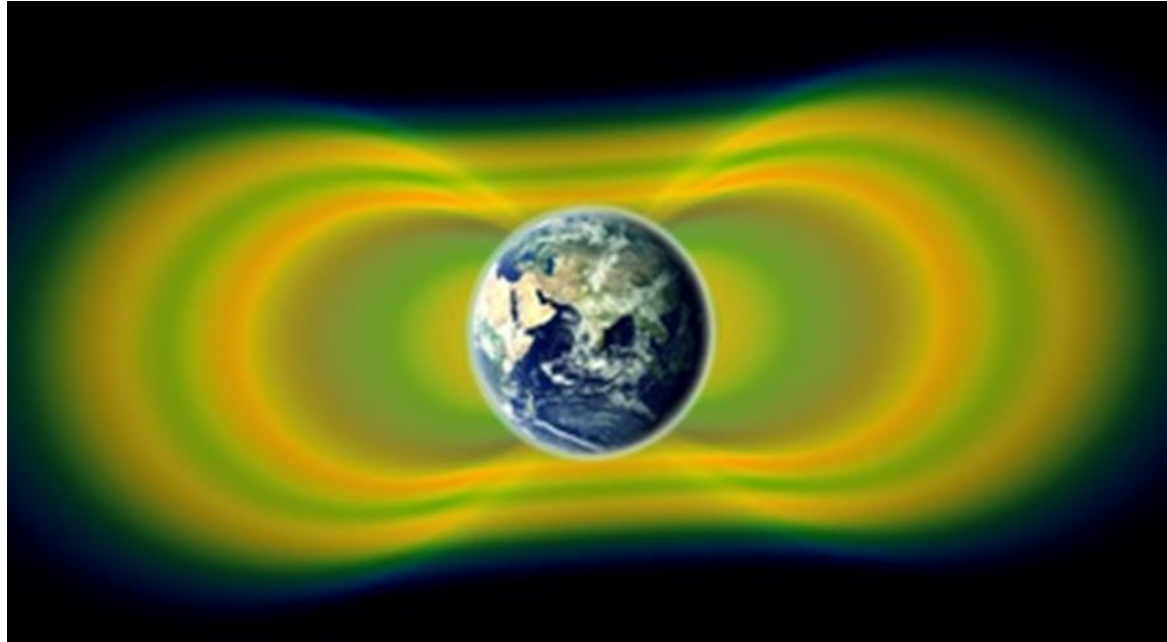
6. Radiation...

Interaction with the atmosphere

- Subatomic particles collide with atoms at 60 000-120 000 ft (18 to 43 km) to form secondary lower energy rays of which some reach the earth's surface
- Ions striking the earth in different areas heat up the atmosphere,
 - causing pressure differentials,
 - **resulting in wind**



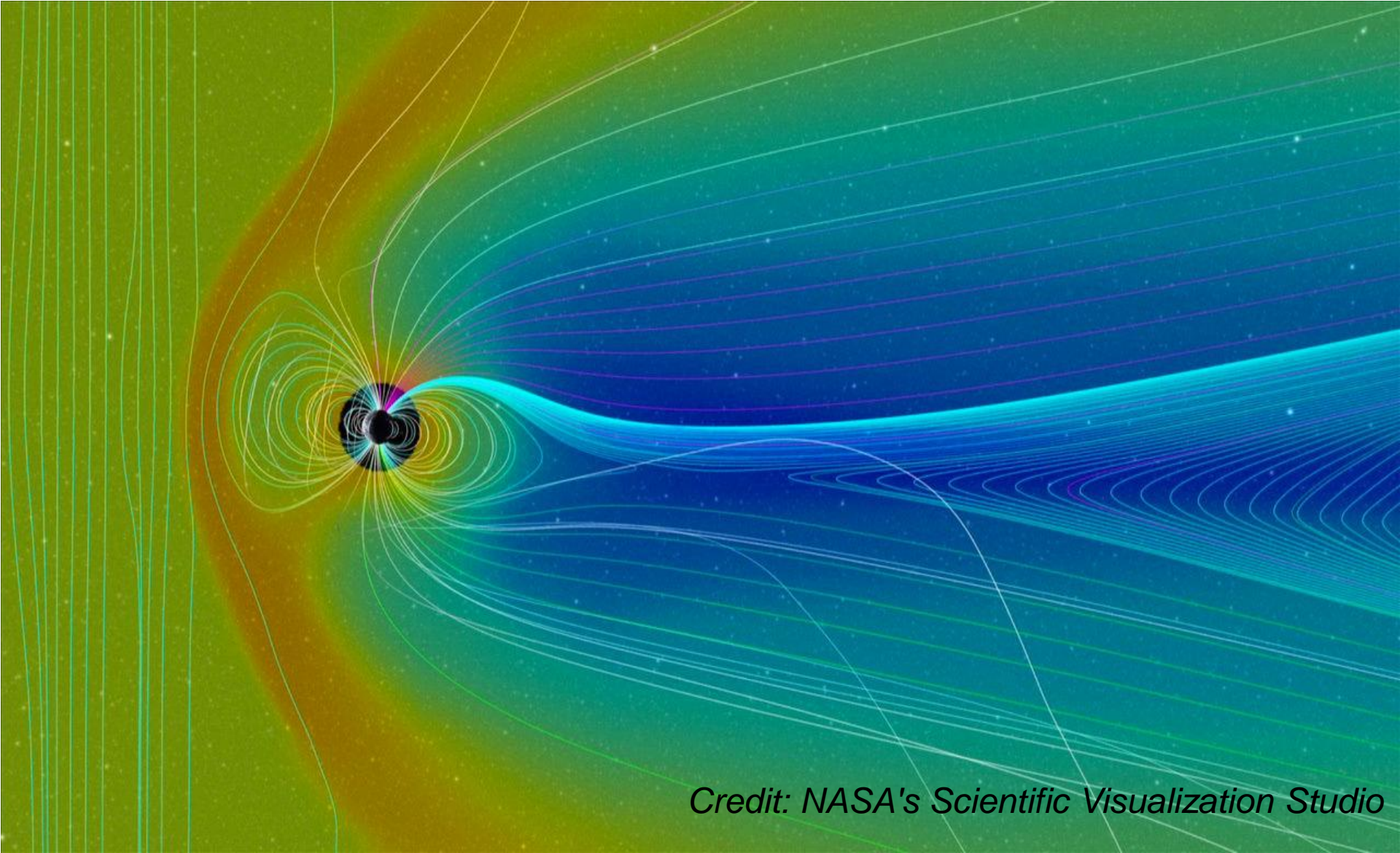
6. Radiation... van Allen Belts



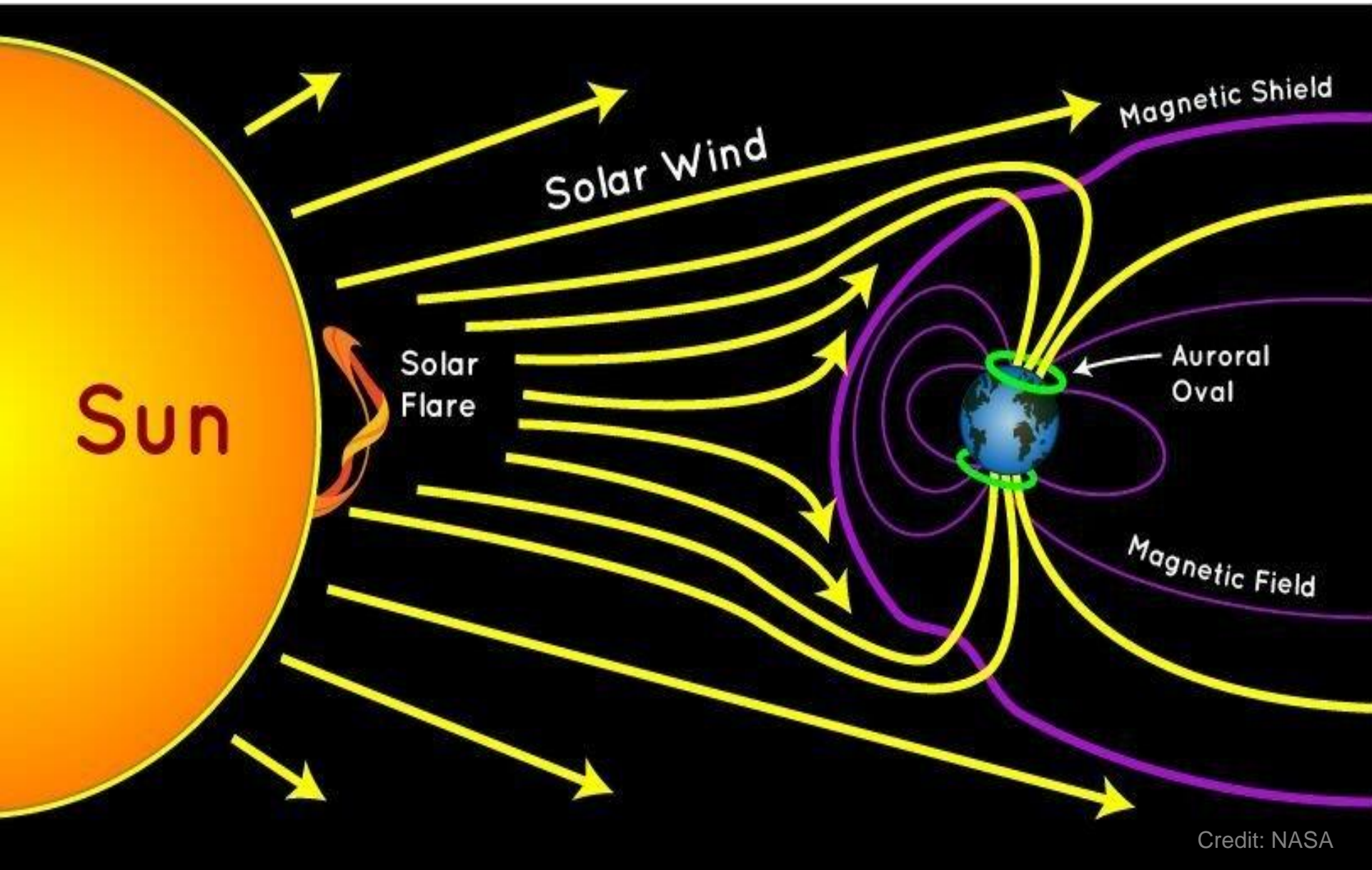
- Magnetosphere: the region around a planet dominated by the planet's magnetic field.

6. Radiation...

Solar Wind & Van Allen belts



Credit: NASA's Scientific Visualization Studio



Credit: NASA

Aurora borealis / australis

- polar lights, northern lights, southern lights

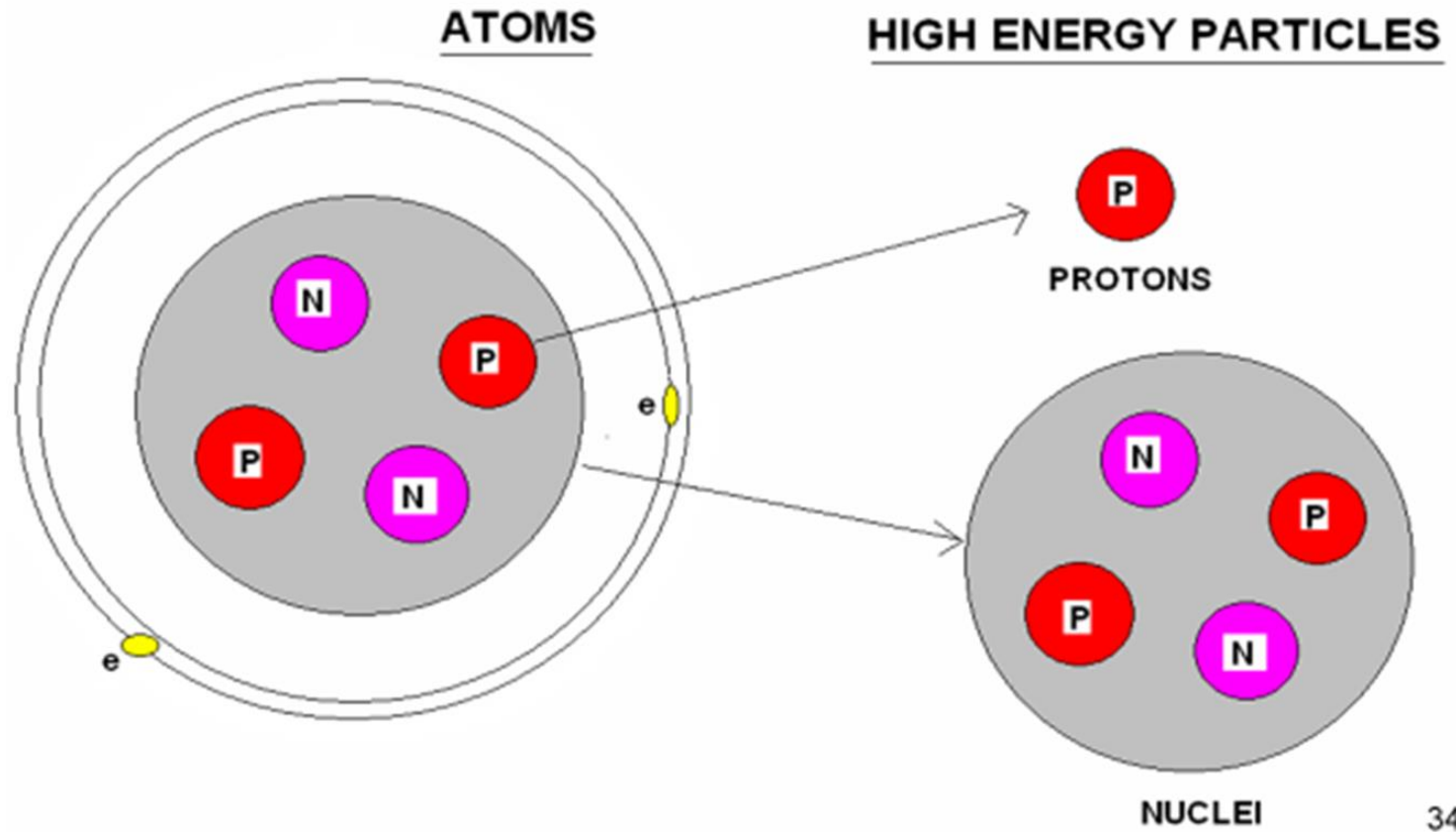
- a natural light display in the Earth's sky
- predominantly seen in the high/low-latitude regions
- result of disturbances in the magnetosphere caused by solar wind



Source: Hurtigruten

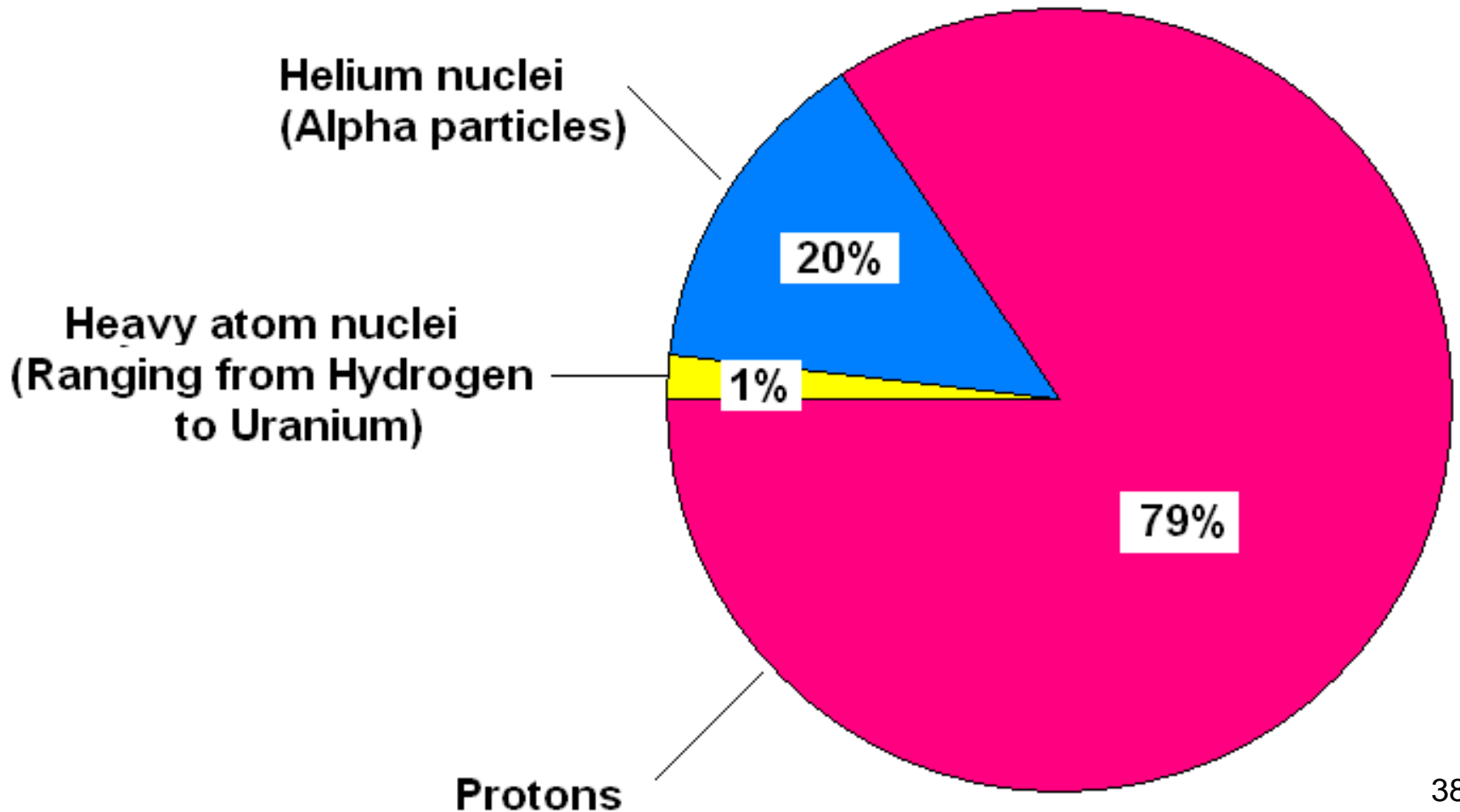
6. Radiation (cont)

Ionising Radiation



6. Radiation...

HIGH ENERGY PARTICLES





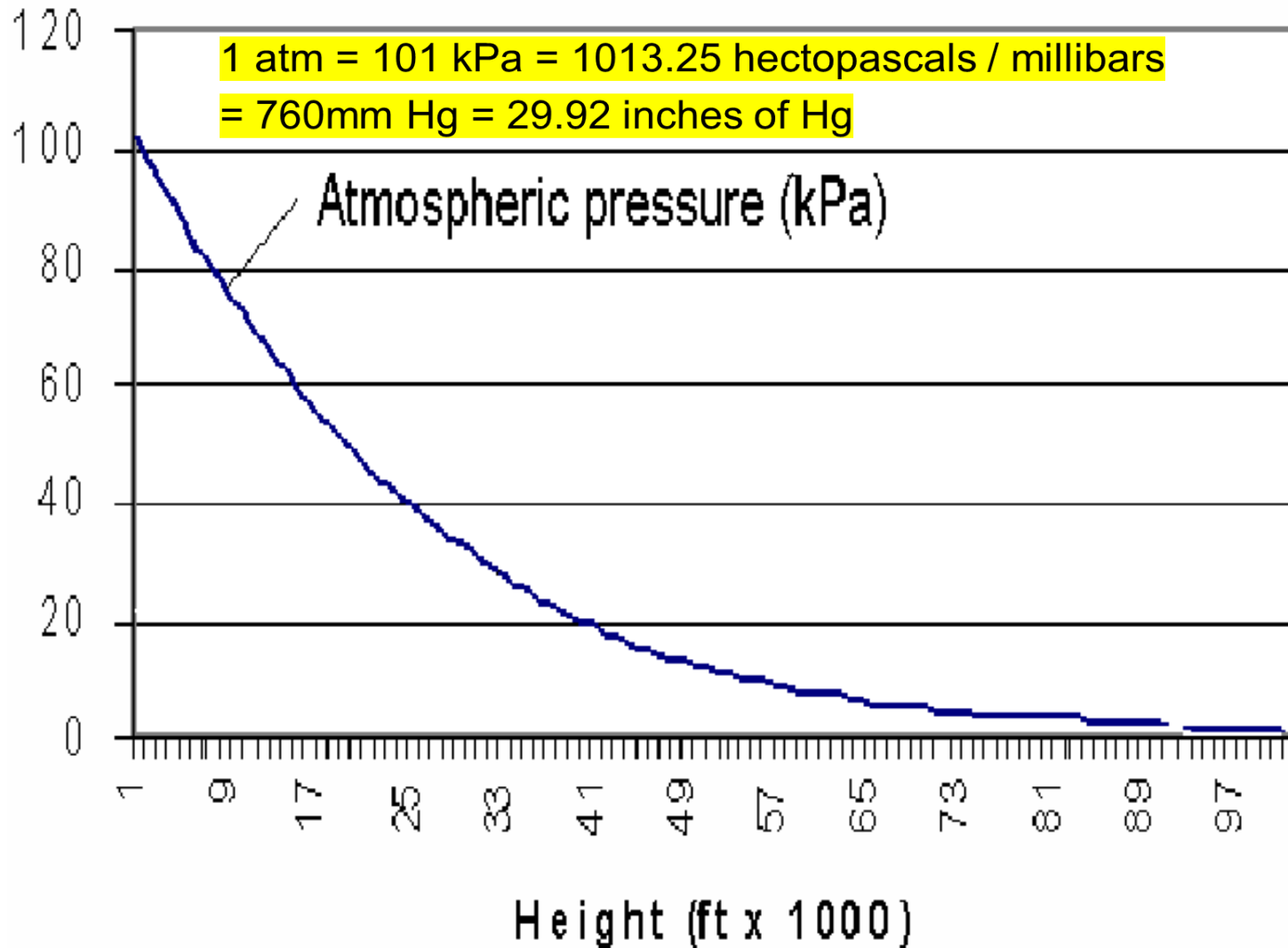
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7. Atmospheric pressure vs altitude

- Pressure decreases exponentially with height above sea level
- 1 atmosphere at msl
- 1/2 atmosphere at 18 000 ft
- 1/4 atmosphere at 36 000 ft
- 1/8 atmosphere at 72 000 ft
- etc



7. Atmospheric pressure vs altitude...





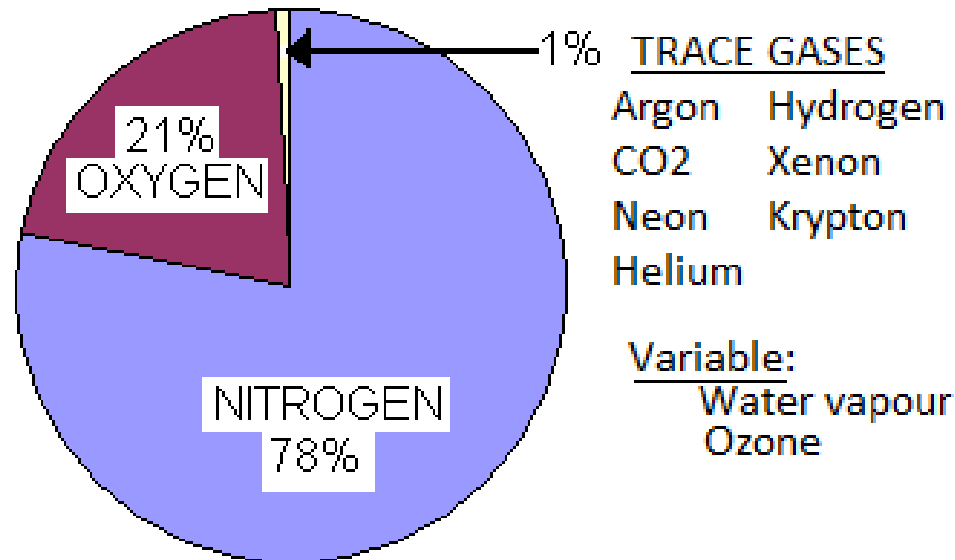
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8. O₂ partial pressure/concentration vs altitude...

- The oxygen concentration at different heights in the atmosphere remains remarkably **constant** at 20,9% (up to the mesopause)

ATMOSPHERIC COMPOSITION

Remarkably constant between
sea level and 300 000ft



Federal Aviation Administration ZONES	ALTITUDES	PRESSURE
Physiological Efficient Zone	Sea Level - 12,500 feet	760 - 523 mm/Hg
<p>General body adaptation. Minor trapped gas problems (ears, sinus, and GI tract) with shortness of breath, dizziness, headaches and fatigue in the upper region if exposure too long</p>		
Physiological Deficient Zone	12,500 - 50,000 feet Mount Everest!!	523 - 87 mm/Hg
<p>Most flying done here. Major physiological problems...hypoxia and decompression sickness if not in a pressurised cabin</p>		
Space Equivalent Zone	50,000 ft - 1000 miles	87 - 0 mm /Hg
<p>Very hostile to humans. "Armstrong's line" at 63,000 feet, unprotected exposure above this level causes ebullism. Need a sealed suit or cabin</p>		

Everest 29 035ft

(Base camp altitude 5 340m = 17 519ft)

- **Physiological Deficient Zone**



8. O₂ partial pressure/concentration vs altitude

- maintaining sufficient pO₂ at higher altitudes

Ambient pressure decreases as altitude increases

To maintain pO₂ at 21 kPa & SaO₂ at 98% in an unpressurised cockpit	
Altitude in ft	Inhaled O₂ %
Sea level	21% (ambient air)
18 000	42%
36 000	100%
36 000 – 48 000	Positive Pressure Breathing

Higher than 50 000ft – Pressure suit

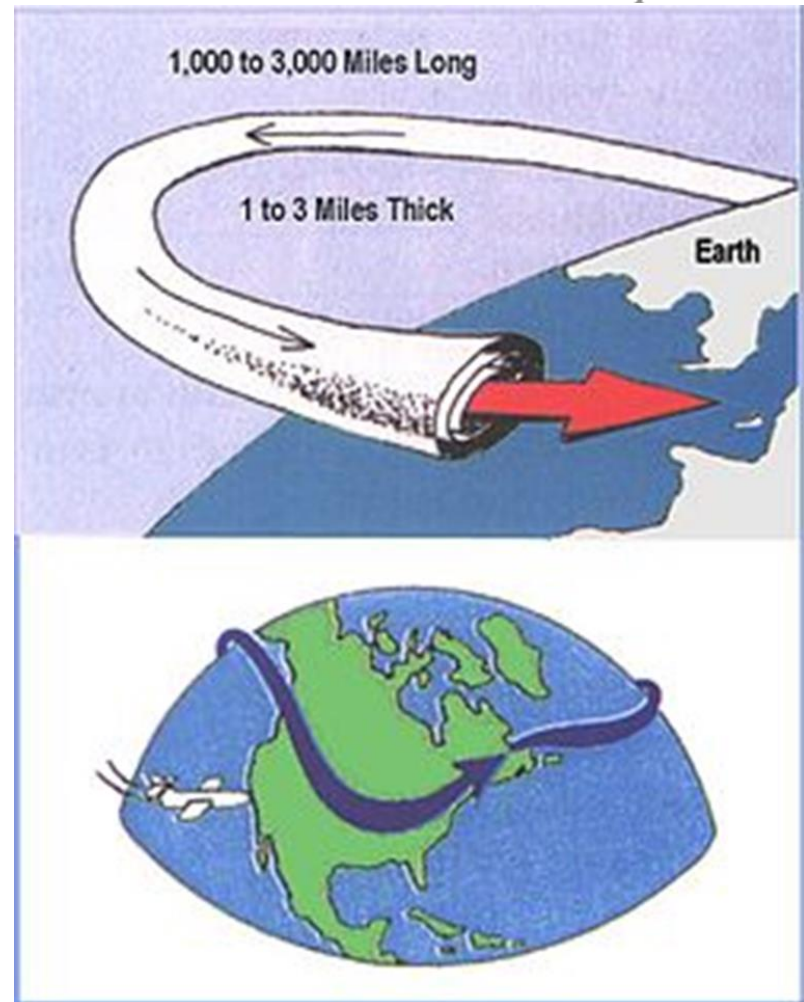


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9. **Jet Streams**
10. **Ebulism**
11. **Possible stressors due to flying - at higher altitude**

9. Jet Streams



- Fast flowing, narrow air currents
- Located in/near the tropopause
- Most are westerly winds
- Typically have a meandering shape
- May start, stop, split, combine again, reverse direction



9. Jet Streams...



- **Polar jets**
 - Strongest, can travel faster than 100 m/h (160 km/h)
 - 7 to 12 km (23,000 to 39,000 ft) amsl
- **Subtropical jets**
 - Somewhat weaker & higher
 - 10 to 16 km (33,000 to 52,000 ft) amsl
- **So what?**
 - Can cause long flights to be much faster/slower than expected

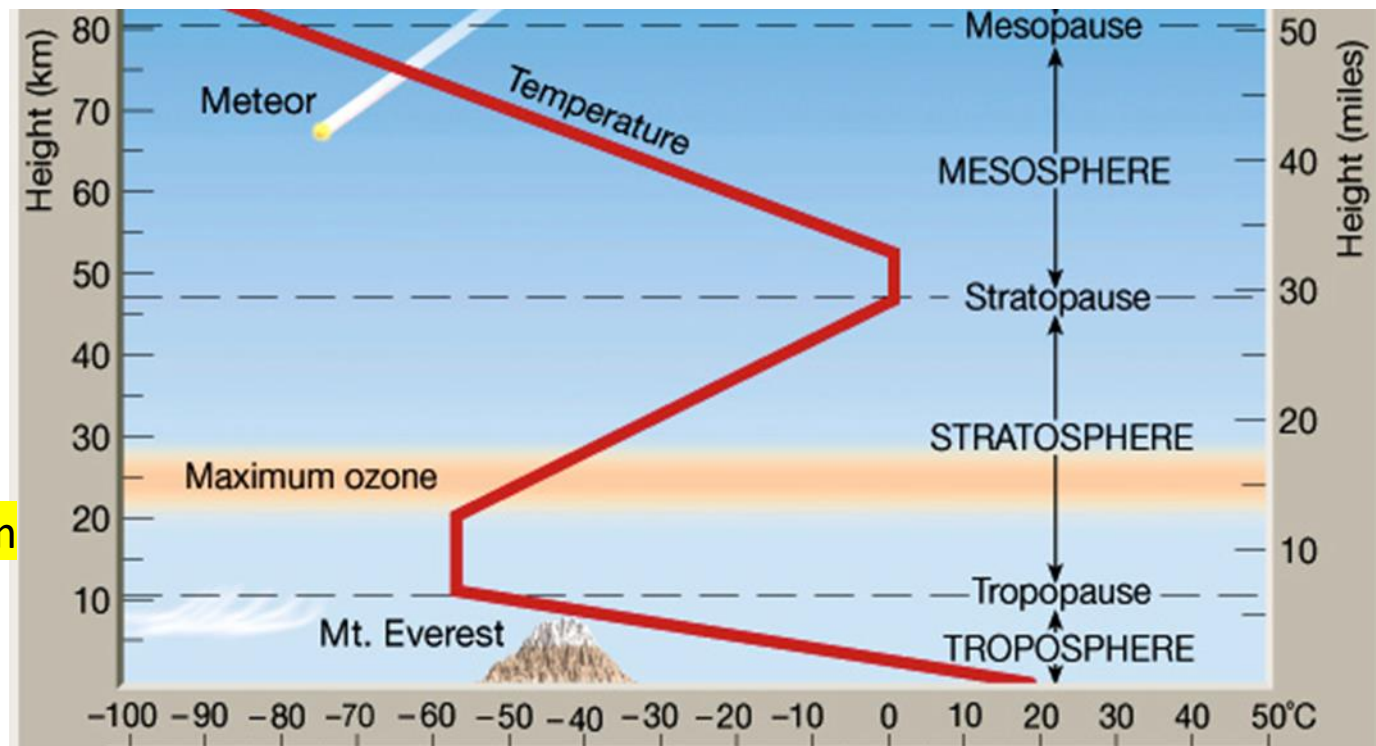




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- 10. Ebulism**
- 11. Possible stressors due to flying - at higher altitude**

10. Ebullism ('boiling' of body fluids)

- At the Armstrong line (63 000 ft; 19,2 km) barometric pressure is 47 mm Hg = vapour pressure of water.



Armstrong line:

63 000ft = 19.2km

10. Ebullism ('boiling' of body fluids) ...

- At higher altitudes water vapour and other gases escape from the body fluids (ebullism) forming bubbles in blood and mucous membranes of mouth and conjunctivae (but no change in temperature – so no real boiling)
- Bubbles in the veins and atria of the heart can block the circulation.
- Exposure to near vacuum for 1,5 - 2 min is survivable.





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11. Possible stresses due to flying - at higher altitude

- Ozone toxicity
- Ionising radiation
- Hypobarism
- Hypoxia
- Hypothermia



11. Possible stresses due to flying - at lower altitude

- Noise
- Vibration
- Spatial disorientation
- Acceleration / G-LOC (G-force induced loss of consciousness)
- CAT (Clear air turbulence)





One millisecond from the end

?

A 30-23-12

A 30-23-05

ENTERING VEHICLE CONTROL ZONE

CF 18 Fighter Jet, Lethbridge, Canada. 2010