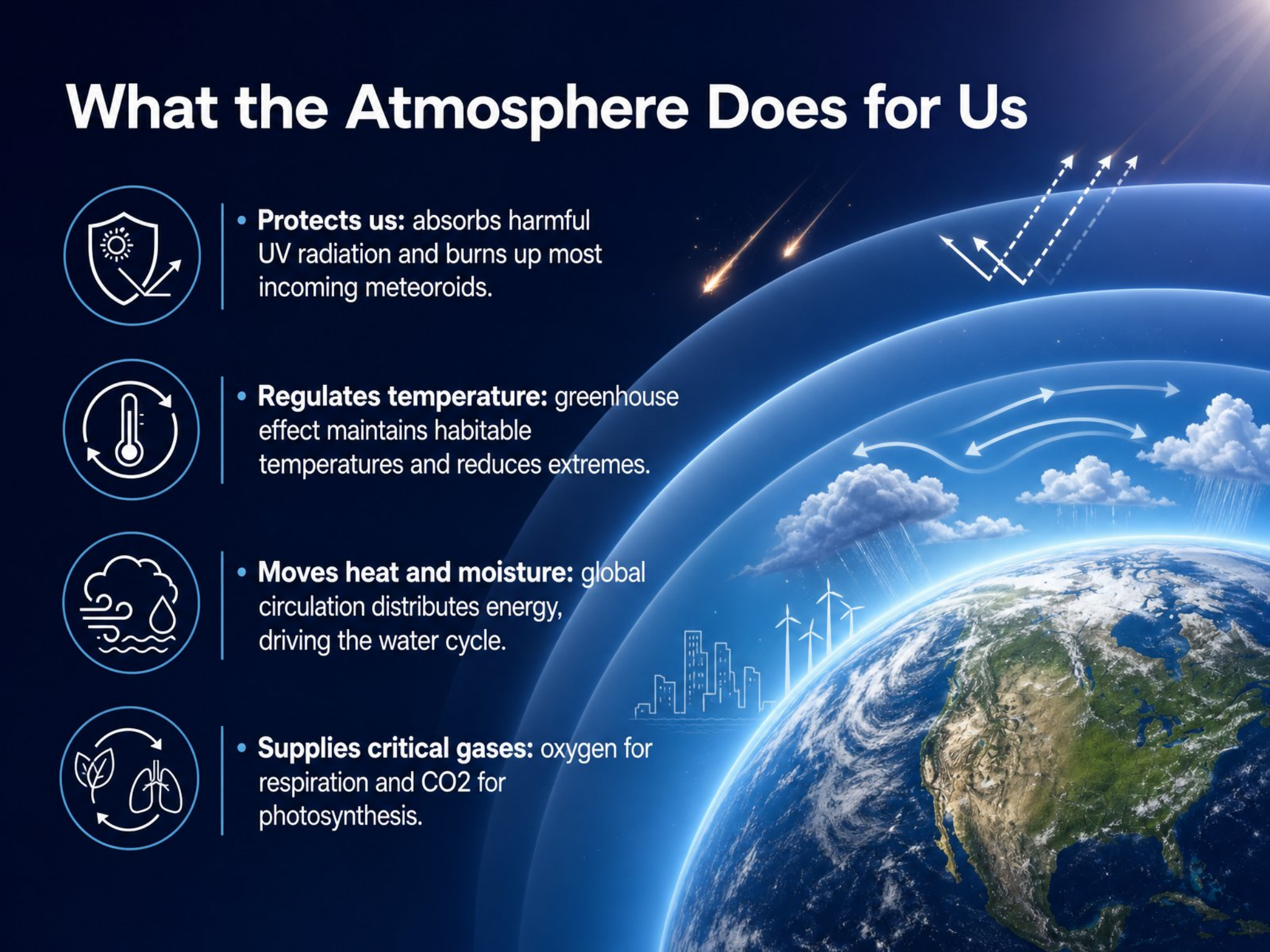
The Atmosphere: Layers, Gases, and Pressure

- Vertical structure, chemical makeup, and pressure dynamics
- Five distinct layers: from troposphere to exosphere
- Permanent gases (N_2, O_2) and variable trace gases (H_2O, CO_2)
- Atmospheric pressure: weight of the air column above us
- Essential for weather, climate, aviation, and daily life

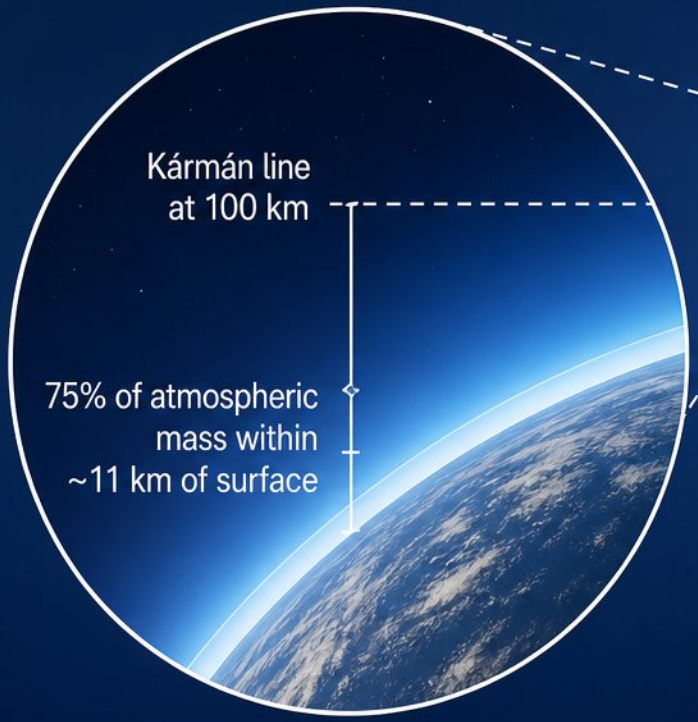
What the Atmosphere Does for Us

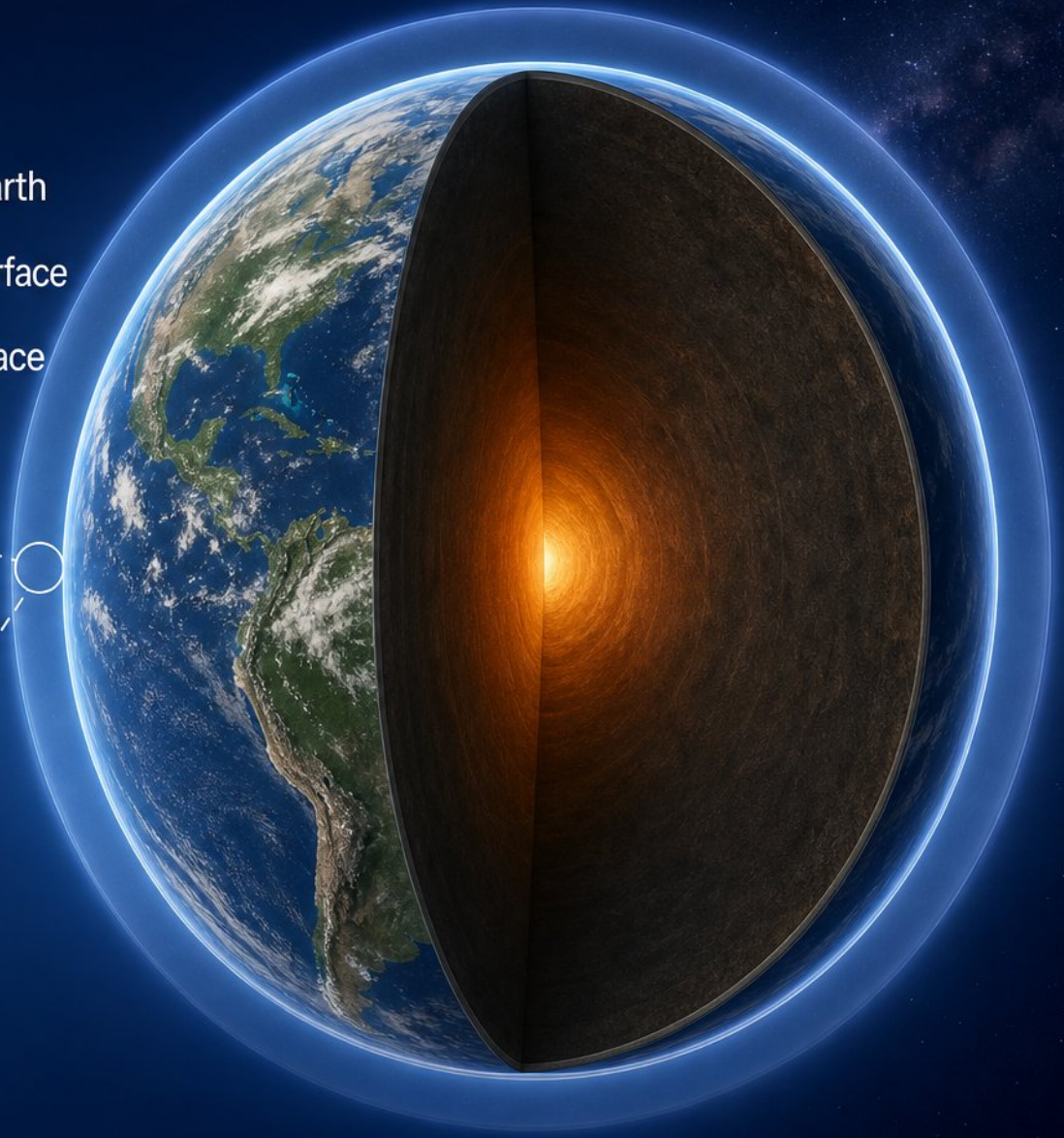
- **Protects us:** absorbs harmful UV radiation and burns up most incoming meteoroids.
- **Regulates temperature:** greenhouse effect maintains habitable temperatures and reduces extremes.
- **Moves heat and moisture:** global circulation distributes energy, driving the water cycle.
- **Supplies critical gases:** oxygen for respiration and CO_2 for photosynthesis.



A Planet-Sized Ocean of Air: Scale and Mass

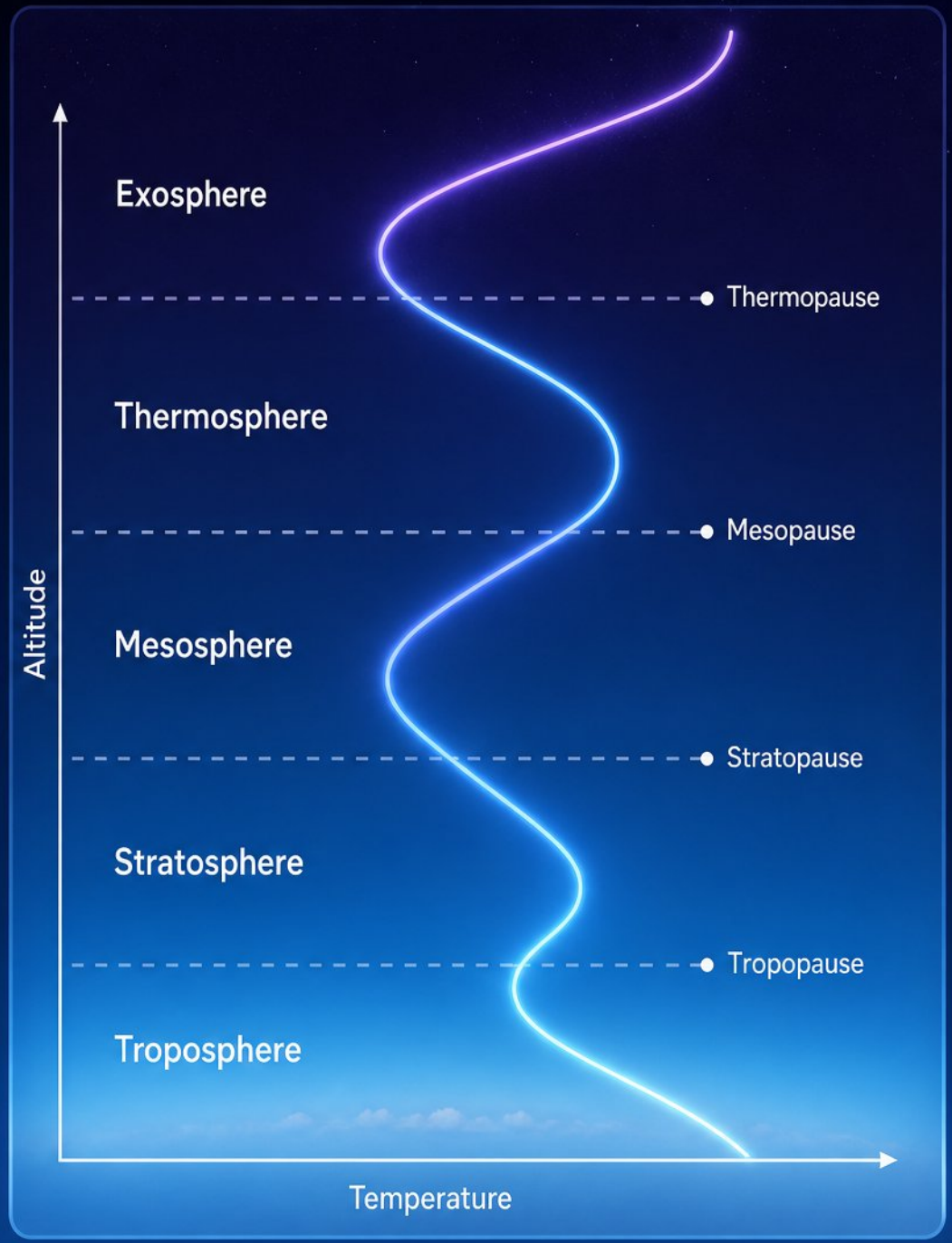
- We live at the bottom of a deep ocean of air
- Total mass: ~5.15×10^{18} kg, one-millionth of Earth
- 75% of atmospheric mass lies within ~11 km of surface
- Kármán line at 100 km marks the boundary of space





How We Divide the Vertical Structure

- Distinguished by temperature trend, composition, movement, and density
- Five main layers: troposphere, stratosphere, mesosphere, thermosphere, exosphere
- Boundaries named "pauses" (tropopause, stratopause, mesopause, thermopause)
- Temperature-altitude profile is the primary defining metric



Layer 1: Troposphere — Where Weather Lives

- Surface to ~12 km (poles 9 km, equator 17 km)
- Contains 75-80% of atmospheric mass & nearly all water vapor
- Temp drops with height (~+17°C surface to −51°C tropopause)
- Convection-driven: almost all clouds, storms, rain form here
- Our living layer; commercial aviation operates within it

Layer 2: Stratosphere — Home of the Ozone Layer

- Extends from ~12 km to 50–55 km above the surface
- Temperature increases with height due to ozone absorbing UV
- Ozone layer shields life from harmful high-energy radiation
- Extremely stable air; pollutants can linger for years
- Ideal cruising altitude for long-haul jet flights

Layer 3: Mesosphere — The Coldest Region

- From stratopause (~50 km) to mesopause at ~80–85 km
- Temperature drops with height, reaching −85°C to −90°C
- Incoming meteors burn up through friction with denser air
- Noctilucent clouds occasionally form near the mesopause
- Air pressure far too low to breathe, even at its base

Layer 4: Thermosphere — Intense Energy, Thin Air

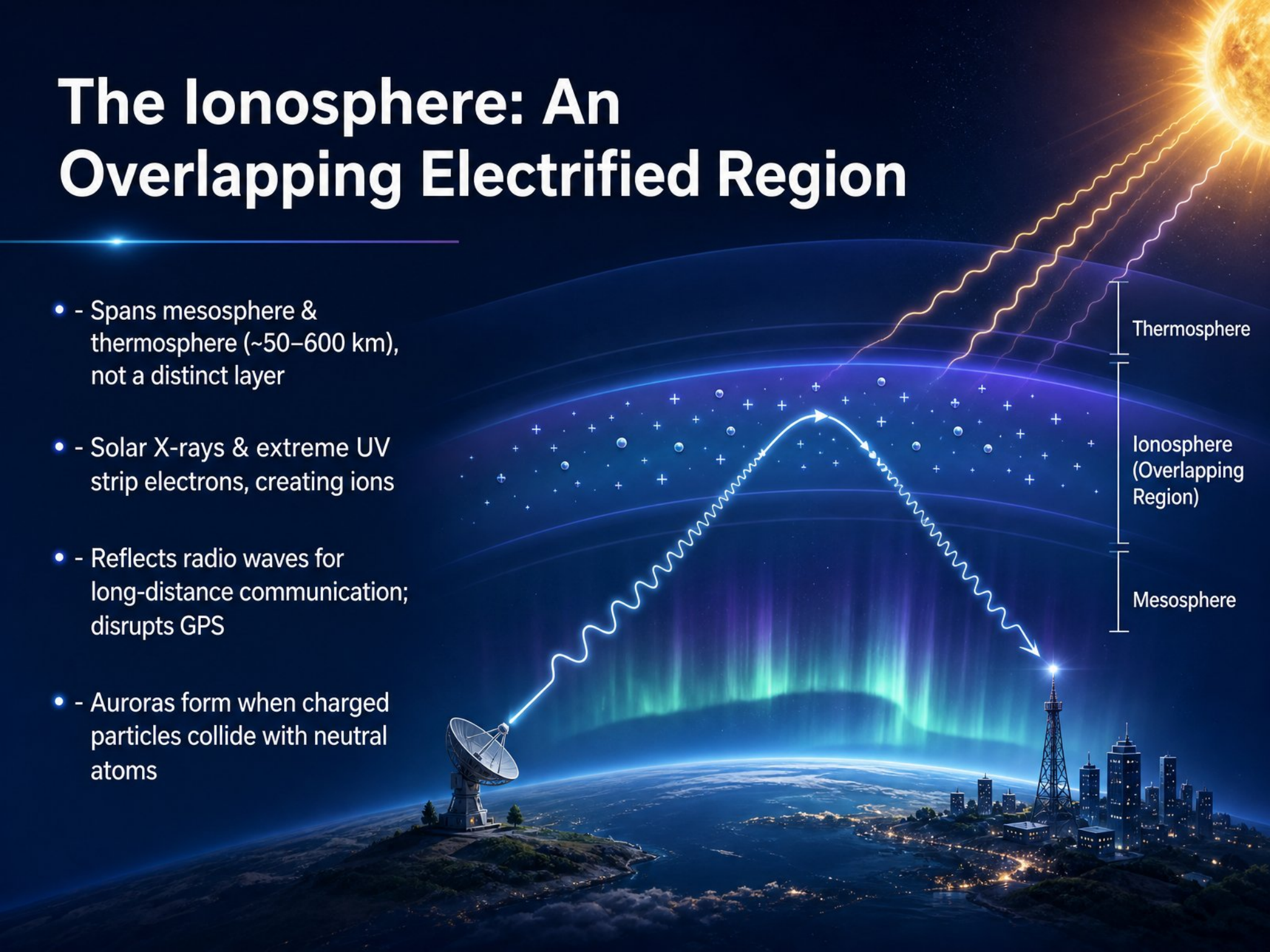
- Extends from ~85 km up to ~1,000 km; height varies with solar activity
- Temperatures soar to 1,500–2,000°C from absorbed extreme UV and X-rays
- Feels freezing cold despite high temps due to extremely low gas density
- ISS and many satellites orbit here; auroras and the ionosphere occur here

Layer 5: Exosphere — The Final Frontier

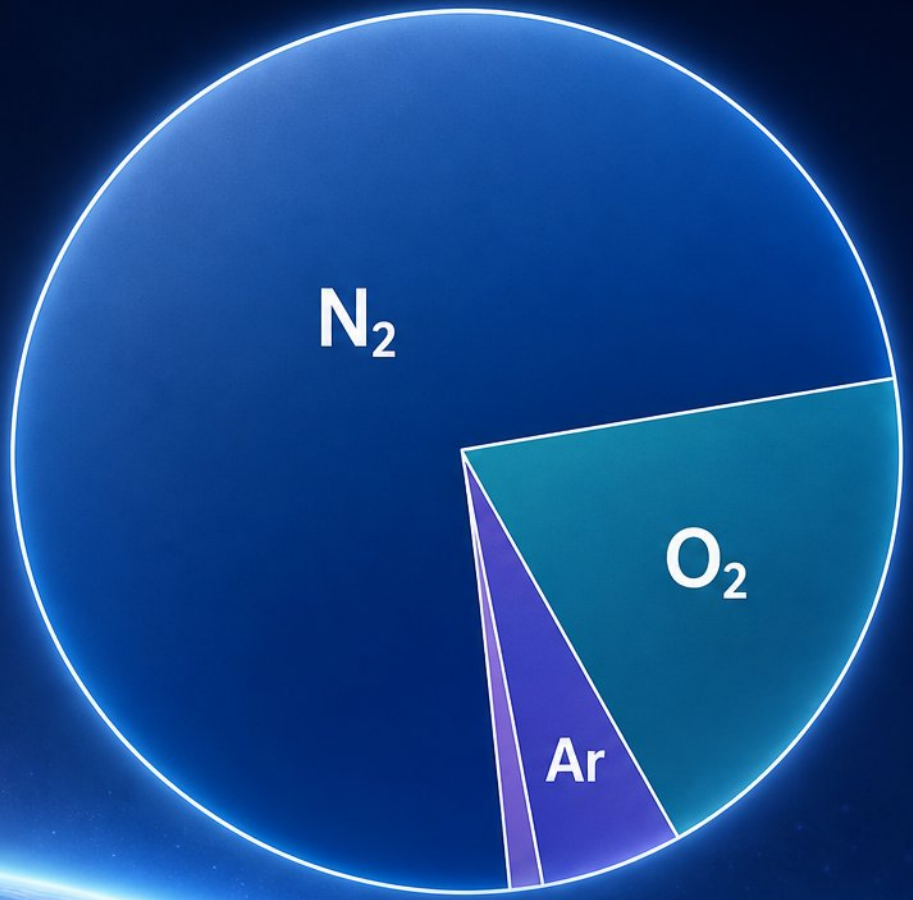
- Extends from ~500 km out to 10,000+ km, fading into space
- Particles are so sparse they rarely collide with each other
- Light gases like hydrogen and helium can escape Earth's gravity
- Many high-altitude satellites orbit within this layer
- The geocorona may stretch far beyond the Moon's orbit

The Ionosphere: An Overlapping Electrified Region

- - Spans mesosphere & thermosphere (~50–600 km), not a distinct layer
- - Solar X-rays & extreme UV strip electrons, creating ions
- - Reflects radio waves for long-distance communication; disrupts GPS
- - Auroras form when charged particles collide with neutral atoms



Composition: The Permanent Gases



- **Nitrogen (N_2):** ~78% — dilutes oxygen, vital for protein formation

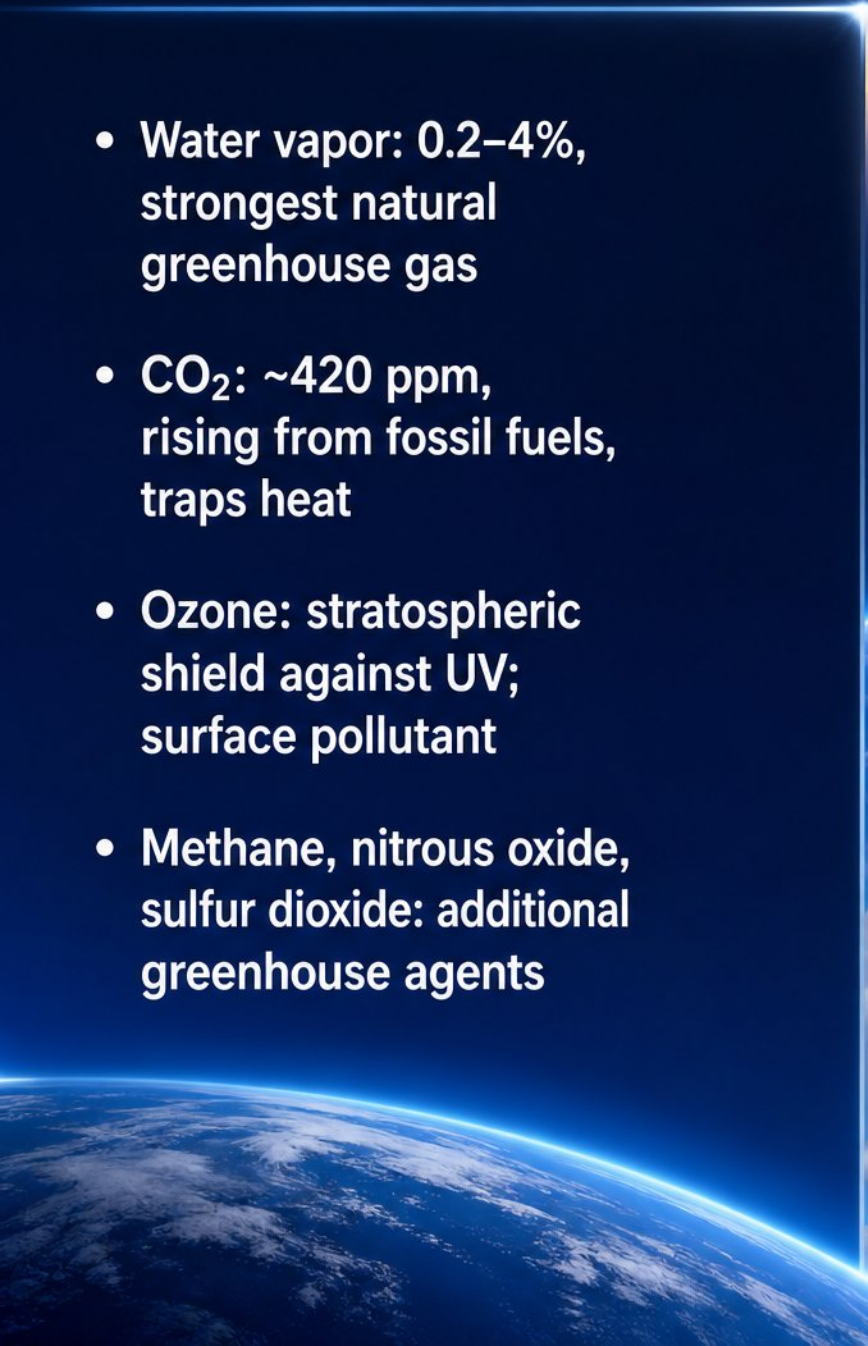
- **Oxygen (O_2):** ~21% — supports respiration and combustion

- **Argon (Ar):** ~0.93% — chemically inert noble gas

- **Trace noble gases:** neon, helium, krypton, and xenon

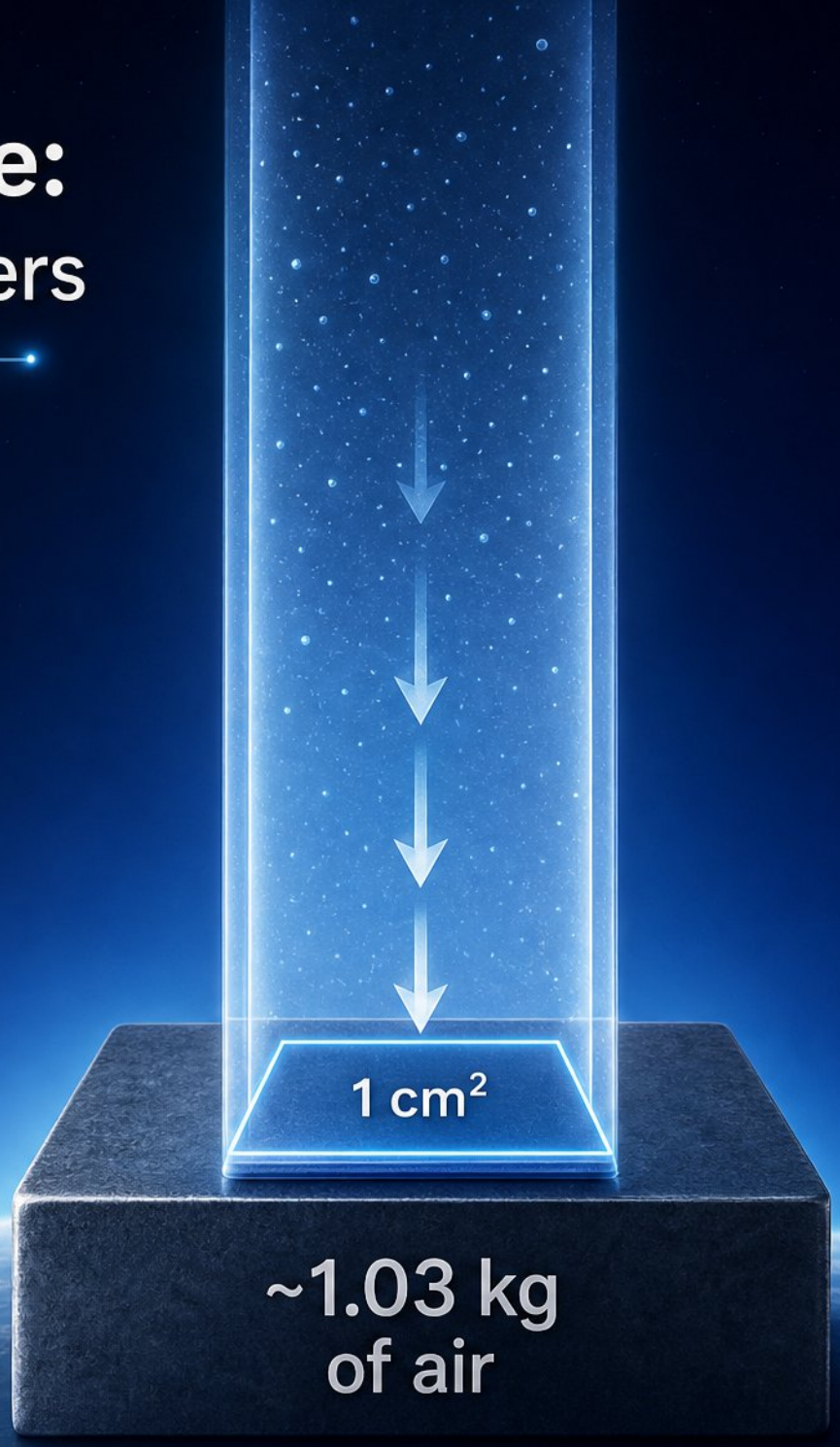
Composition: Variable and Trace Gases

- Water vapor: 0.2–4%, strongest natural greenhouse gas
- CO_2: ~420 ppm, rising from fossil fuels, traps heat
- Ozone: stratospheric shield against UV; surface pollutant
- Methane, nitrous oxide, sulfur dioxide: additional greenhouse agents



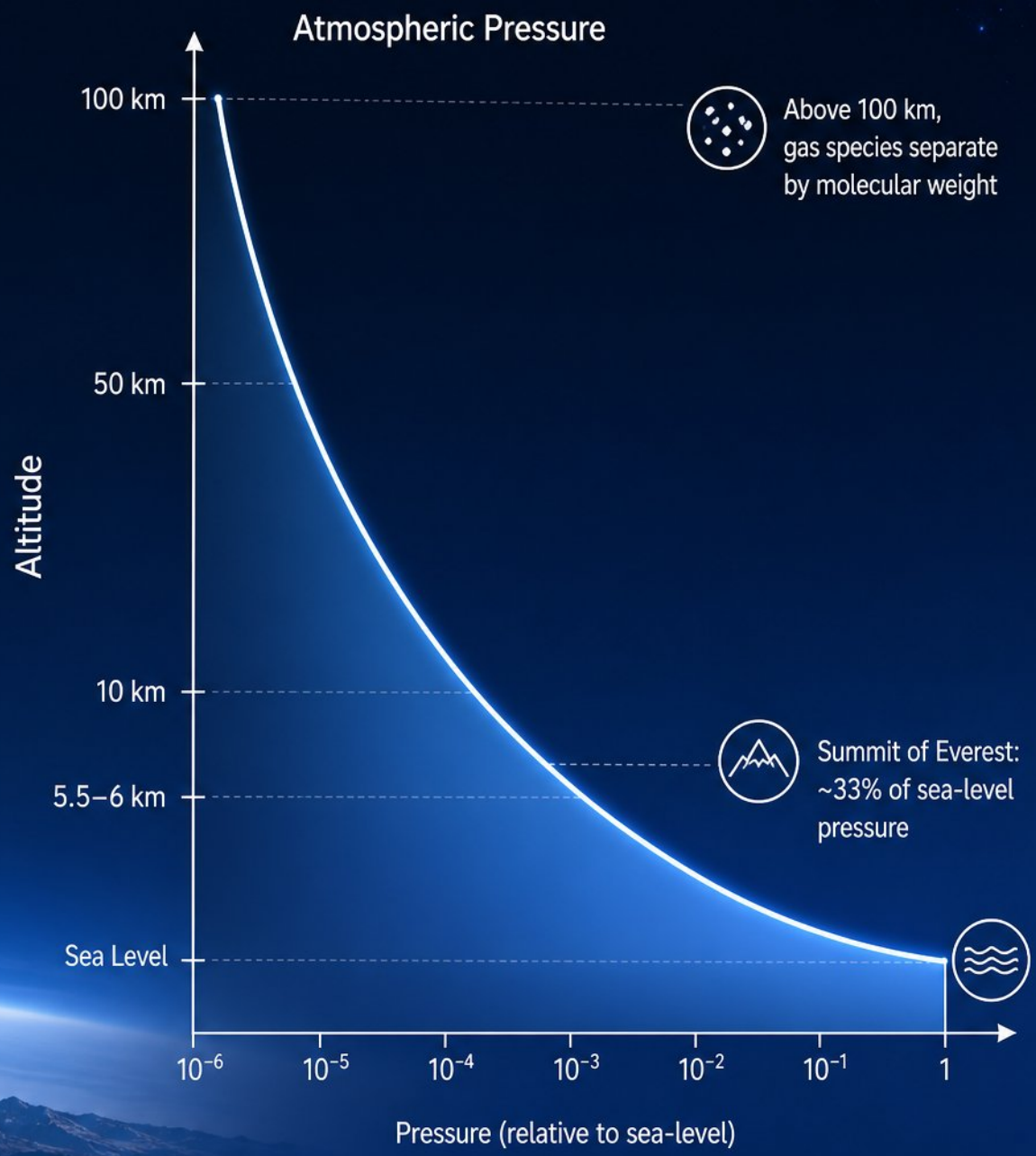
Atmospheric Pressure:
What It Is and Why It Matters

- Pressure: weight of the air column above a unit area; 101,325 Pa at sea level
- At sea level, every cm^2 supports ~1.03 kg of air—we are adapted to this
- Horizontal pressure differences drive wind and global circulation
- Lower pressure at altitude means less oxygen per breath; formulas predict the drop



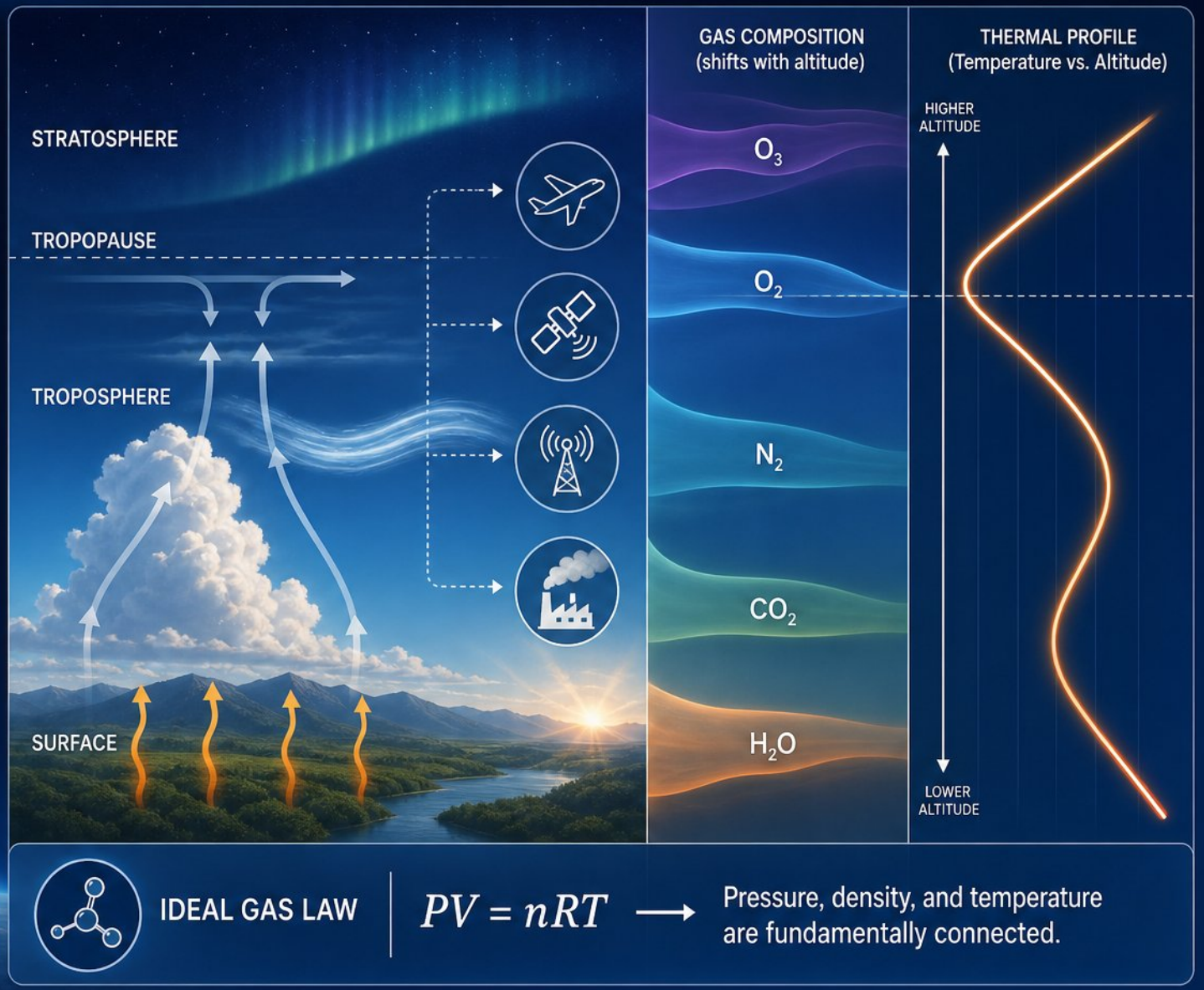
How Pressure Changes with Altitude

- - ~Half the atmosphere's mass lies below 5.5–6 km
- - Pressure drops by factor e (~2.718) per ~8.5 km rise
- - Above 100 km, gas species separate by molecular weight
- - Summit of Everest: ~33% of sea-level pressure
- - At 100 km: less than one-millionth of surface pressure



Putting the Model Together: Layers, Gases, and Pressure as One System

- Surface heating drives tropospheric convection; tropopause caps vertical mixing
- Pressure, density, and temperature linked by the ideal gas law
- Allows aircraft, satellite, radio, and pollution prediction
- Explains cloud heights, jet stream location, and high-altitude UV risk



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