

CUET · GEOGRAPHY · CLASS XI · CODE 313

Composition and Structure of Atmosphere

CUET unit: Natural Hazards and Disasters in India / Climate

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Snapshot

- The atmosphere has a definite composition and a vertical layering.
- It has three components — gases (nitrogen, oxygen, carbon dioxide, ozone), water vapour, and dust particles — each with roles in weather and climate.
- There are five atmospheric layers (troposphere, stratosphere, mesosphere, ionosphere/thermosphere, exosphere), each defined by characteristic density and temperature.
- CUET tests this chapter because atmospheric composition and structure underpin all subsequent topics: insolation, temperature, pressure, precipitation, and climate classification.
- Questions typically focus on gas properties (especially CO₂ and ozone), layer names and altitude ranges, temperature behaviour with altitude, and the tropopause/mesopause boundaries.

Detailed Notes

2.1 Core concepts

- The atmosphere is the colourless, odourless envelope of gases, water vapour, and dust particles that surrounds the earth; air is felt only when it blows as wind, yet it is so essential that humans can survive without food for days but without air for only minutes. (NCERT Ch. 7, p. 64)
- **Vertical concentration of mass:** 99 per cent of the total mass of the atmosphere is confined to the height of 32 km from the earth's surface, even though the gaseous envelope extends much higher. This is the single most important quantitative fact, because it explains why weather, life, and almost all human activity are confined to a very thin shell relative to the earth's radius. (NCERT §Composition of the Atmosphere, p. 64)
- **Variable composition with altitude:** The proportion of gases changes in the higher layers — oxygen becomes negligible at 120 km, while carbon dioxide and water vapour are found only up to 90 km from the earth's surface. Below these heights the bulk composition is uniform (the so-called homosphere); above them it is stratified by molecular weight. (NCERT p. 64)
- **Nitrogen** constitutes the major portion of the atmosphere; oxygen, argon, and carbon dioxide make up most of the rest. Nitrogen is chemically inert under normal

atmospheric conditions and therefore acts as a "diluent" that allows oxygen-based combustion and respiration to occur at sustainable rates. (NCERT p. 64)

- **Carbon dioxide (CO₂):** meteorologically a very important gas because it is **transparent to incoming solar (short-wave) radiation but opaque to outgoing terrestrial (long-wave) radiation**. It absorbs a part of terrestrial radiation and reflects back some part of it towards the earth's surface — this differential transparency is the physical basis of the **greenhouse effect**. The volume of CO₂ has been rising in the past few decades mainly because of the burning of fossil fuels, and this has also increased the temperature of the air. (NCERT p. 64)
- **Ozone:** found between 10 and 50 km above the earth's surface; acts as a filter, absorbing the ultra-violet rays radiating from the sun and preventing them from reaching the surface of the earth. Without ozone, the UV flux at the surface would damage DNA, skin tissue, and the surface layer of the oceans where most marine life originates. (NCERT p. 64)
- **Water vapour:** a variable gas that decreases with altitude; in the warm and wet tropics it may account for up to 4 per cent of the air by volume, while in the dry and cold areas of desert and polar regions it may be less than 1 per cent. Water vapour also decreases from the equator towards the poles. It absorbs parts of the insolation from the sun and preserves the earth's radiated heat, acting "like a blanket" allowing the earth neither to become too cold nor too hot. Water vapour also contributes to atmospheric stability and instability — when it condenses it releases latent heat that powers thunderstorms and cyclones. (NCERT §Water Vapour, p. 64)
- **Dust particles:** solid particles in the air include sea salts, fine soil, smoke-soot, ash, pollen, dust, and disintegrated particles of meteors. Dust particles are generally concentrated in the lower layers, yet convectional air currents may transport them to great heights. The **higher concentration of dust particles is found in subtropical and temperate regions due to dry winds in comparison to equatorial and polar regions** — a counter-intuitive fact frequently asked in MCQs. Dust and salt particles act as **hygroscopic nuclei** around which water vapour condenses to produce clouds. (NCERT §Dust Particles, p. 65)
- **Structure — five layers:** The column of atmosphere is divided into five different layers depending upon temperature condition — troposphere, stratosphere, mesosphere, thermosphere (ionosphere), and exosphere. Density is highest near the surface of the earth and decreases with increasing altitude in all five layers. (NCERT §Structure of the Atmosphere, p. 65)
- **Troposphere:** the lowermost layer; average height 13 km, extending roughly to 8 km near the poles and about 18 km at the equator. Thickness is greatest at the equator because heat is transported to great heights by strong convectional currents. The troposphere contains dust particles and water vapour, and all changes in climate and weather take place here. Temperature decreases at the rate of **1° C per 165 m** of height (the normal lapse rate). It is the most important layer for all biological activity. (NCERT p. 65)

- **Tropopause:** the zone separating the troposphere from the stratosphere; air temperature at the tropopause is about -80°C over the equator and about -45°C over the poles. The temperature here is nearly constant, hence the name "pause." (NCERT p. 65)
- **Stratosphere:** found above the tropopause and extends up to a height of **50 km**. One important feature is that it contains the **ozone layer**, which absorbs ultra-violet radiation and shields life on earth from this intense, harmful form of energy. Because temperature rises with altitude here (due to ozone absorbing UV), the layer is highly stable and is the cruising height of jet aircraft. (NCERT p. 65)
- **Mesosphere:** lies above the stratosphere, extending up to a height of **80 km**. In this layer, once again, temperature starts decreasing with the increase in altitude and reaches up to **minus 100°C at 80 km**. The upper limit of the mesosphere is known as the **mesopause** — the coldest natural location in the atmosphere. (NCERT p. 65)
- **Ionosphere (Thermosphere):** located between **80 and 400 km** above the mesopause. It contains electrically charged particles known as **ions**, and hence the name. **Radio waves transmitted from the earth are reflected back to the earth by this layer** — the basis of long-distance short-wave broadcasting. Temperature here starts increasing with height. (NCERT p. 65)
- **Exosphere:** the uppermost layer of the atmosphere above the thermosphere. It is the highest layer but very little is known about it. Its contents are extremely rarefied and it gradually merges with outer space. (NCERT p. 66)
- **Elements of weather and climate:** the main elements of the atmosphere subject to change and influencing human life on earth are **temperature, pressure, winds, humidity, clouds, and precipitation** — six elements that are taken up in detail in Chapters 8, 9 and 10. Geographers are concerned mainly with the first two layers (troposphere and stratosphere) because all human and biological activity, as well as all weather phenomena, are contained within them. (NCERT p. 66)

2.2 Definitions to memorise

Term	Definition	Page
Atmosphere	Mixture of gases, water vapour and dust particles that envelopes the earth all round	64
32 km rule	The height within which 99% of the total mass of the atmosphere is confined	64
Greenhouse effect	Warming caused by CO_2 being transparent to incoming solar radiation but opaque to outgoing terrestrial radiation, trapping heat near the surface	64
Ozone layer	Layer between 10–50 km altitude that absorbs UV rays from the sun and prevents them from reaching the earth	64

Term	Definition	Page
Variable gas	A gas whose proportion changes with location/altitude (e.g., water vapour)	64
Hygroscopic nuclei	Dust and salt particles around which water vapour condenses to form clouds	65
Convictional currents	Vertical air currents that transport dust and heat to great heights, especially over the equator	65
Troposphere	Lowermost layer of the atmosphere (avg. 13 km), where all weather occurs	65
Normal lapse rate	Rate of temperature decrease in the troposphere: 1°C per 165 m of height	65
Tropopause	Zone separating the troposphere from the stratosphere; temperature is nearly constant ($\approx -80^{\circ}\text{C}$ over equator, $\approx -45^{\circ}\text{C}$ over poles)	65
Stratosphere	Layer above the tropopause up to 50 km, containing the ozone layer	65
Mesosphere	Layer above the stratosphere extending to 80 km; temperature again decreases with altitude	65
Mesopause	Upper limit of the mesosphere at ≈ 80 km; temperature falls to $\approx -100^{\circ}\text{C}$	65
Ionosphere	Layer 80–400 km above the mesopause that contains ions and reflects radio waves	65
Thermosphere	Alternative name for the ionosphere — temperature increases with height here	65
Exosphere	Uppermost layer above the thermosphere; extremely rarefied; merges with outer space	66
Insolation	Incoming solar radiation absorbed and modified by water vapour and gases	64
Terrestrial radiation	Long-wave radiation emitted by the earth, partially absorbed by CO ₂ and water vapour	64
Stability/Instability	Tendency of an air parcel to resist or favour vertical movement, modulated by water vapour content	64
Elements of weather	Temperature, pressure, winds, humidity, clouds, precipitation	66
Negligible-oxygen altitude	120 km — height at which oxygen becomes almost absent	64
CO ₂ /water-vapour ceiling	90 km — upper limit of significant CO ₂ and water vapour	64
Tropics water vapour max	Up to 4% by volume in warm-wet tropics	64

Term	Definition	Page
Polar water vapour min	Less than 1% in cold deserts and polar regions	64
Subtropical-temperate dust max	Highest dust concentration zone due to dry winds	65

2.3 Diagrams / processes to remember

- Figure 7.1 — Structure of the Atmosphere (p. 65):** A vertical profile plotting altitude (km) on the Y-axis against temperature (°C) on the X-axis. It shows the five layers stacked top to bottom — troposphere, stratosphere, mesosphere, thermosphere (ionosphere), exosphere — separated by the tropopause (≈ 10 km average), stratopause (≈ 50 km), and mesopause (≈ 80 km). The temperature curve is a "zig-zag": it falls in the troposphere, rises in the stratosphere (because ozone absorbs UV), falls again in the mesosphere (reaching -100°C at the mesopause), and rises sharply in the thermosphere. CUET examiners frequently print a blank version of this profile and ask students to identify either a layer or a "pause," so the rule to memorise is **odd-layered decline, even-layered rise** (troposphere–decline, stratosphere–rise, mesosphere–decline, thermosphere–rise).
- Composition pyramid:** The bottom 32 km is where 99% of atmospheric mass sits, with the troposphere alone containing virtually all weather-producing water vapour and dust. Above this, the proportion of light gases (hydrogen, helium) rises and heavy gases (oxygen, CO₂) fall away — the reason oxygen becomes negligible by 120 km.
- Greenhouse mechanism:** Short-wave solar radiation enters → strikes the earth's surface → is re-emitted as long-wave terrestrial radiation → absorbed by CO₂ and water vapour → re-radiated downward → raises the temperature of the lower troposphere. Students must remember that CO₂'s role is **selective transparency** (transparent to short-wave, opaque to long-wave), not generic "trapping."
- Hygroscopic-nuclei process:** Dry dust and sea-salt particles enter the lower atmosphere → are lifted by convection → water vapour condenses around them when the air cools to dew point → microscopic water droplets coalesce into visible clouds. This explains why polluted, dust-laden urban skies often produce thicker, persistent cloud cover.
- Troposphere thickness gradient:** 18 km at the equator (strong convection lifts the tropopause) → 13 km on average → 8 km at the poles (cold, sinking air keeps the tropopause low). The rule is the reverse of intuition: hot equator pushes the layer up; cold poles compress it down.
- Layer-by-layer functions:** Troposphere = weather. Stratosphere = UV shield. Mesosphere = burns up meteors (the visible "shooting stars" occur here). Ionosphere = reflects radio waves. Exosphere = transition to space.

2.4 Common confusions / NTA trap points

- Students confuse the **ozone layer altitude (10–50 km, within the stratosphere)** with the height at which oxygen becomes negligible (120 km). NTA frequently swaps the two numbers as distractors.
- **CO₂ vs. O₂ ceiling heights:** CO₂ and water vapour exist only up to **90 km**; oxygen becomes negligible at **120 km**. A common distractor reverses 90 km and 120 km between the two gases.
- The **troposphere is thickest at the equator (18 km)** and thinnest at the poles (8 km). Many students invert this, wrongly assuming the colder pole must have the thicker atmosphere.
- **Ionosphere reflects radio waves** — it is sometimes called the thermosphere. NTA may ask which layer is used for radio communication; the answer is ionosphere, not stratosphere.
- Temperature **decreases** in the troposphere and mesosphere with increasing altitude, but **increases** in the stratosphere and thermosphere. Confusing the temperature profile of the mesosphere (decreasing) with the stratosphere (increasing) is a classic trap.
- The **normal lapse rate is 1° C per 165 m**, not per 100 m or per 1000 m. Examiners insert "1°C per 100 m" as a tempting wrong option.
- **Tropopause temperatures** — about –80°C over equator and –45°C over poles. Counter-intuitively, the tropopause is **colder over the equator** (because it is much higher and the air has cooled more), even though the surface is hottest there.
- **Water vapour is up to 4% in warm-wet tropics and less than 1% in cold deserts/polar regions** — distractors often use 6% or 10% as fake maxima.
- **Hygroscopic nuclei** are dust and salt particles, not water droplets themselves. Students mistakenly tick "water droplets" because of the close association with clouds.
- **CO₂ is transparent to short-wave, opaque to long-wave** — never the reverse. Statement-based questions test exactly this asymmetry.
- The **mesopause is at 80 km with –100° C**, the coldest point in the atmosphere — not the thermosphere, which heats up rapidly above 80 km.
- Carbon dioxide is the chief greenhouse gas mentioned in this chapter, but **water vapour also acts like a blanket** preserving the earth's radiated heat — distractors that say "only CO₂ contributes to greenhouse effect" are wrong.

2.5 Key data table (NCERT figures only)

Parameter	Figure / fact	Source (NCERT p.)
Mass of atmosphere within 32 km	99% of total	64
Height at which oxygen becomes negligible	120 km	64

Parameter	Figure / fact	Source (NCERT p.)
Upper limit of CO ₂ and water vapour	90 km	64
Ozone layer altitude range	10–50 km	64
Water vapour maximum (warm-wet tropics)	Up to 4% by volume	64
Water vapour minimum (cold desert/polar)	Less than 1% by volume	64
Average troposphere height	13 km	65
Troposphere height at poles	≈ 8 km	65
Troposphere height at equator	≈ 18 km	65
Normal lapse rate (troposphere)	1°C per 165 m	65
Tropopause temperature over equator	≈ –80°C	65
Tropopause temperature over poles	≈ –45°C	65
Upper limit of stratosphere	50 km	65
Upper limit of mesosphere (mesopause)	80 km, ≈ –100°C	65
Ionosphere altitude range	80–400 km	65

Practice MCQs

PYQ Alignment

Chapter 7 on atmospheric composition and structure is a foundational chapter that CUET tests with moderate frequency — typically 1–2 direct factual MCQs per year and several derivative questions in adjacent climate chapters. Common stand-alone question types include identifying the gas responsible for the greenhouse effect, matching atmospheric layers with altitude ranges or temperature behaviour, the role of ozone, the height of the troposphere at the equator vs. poles, and the specific rate of the normal lapse rate (1°C/165 m). It also forms the conceptual backdrop for questions on insolation, temperature inversion, and climate change that appear in Chapters 8–12; expect at least one statement-based or assertion-reason item per shift that draws on this chapter's facts. Map/diagram-based items frequently use Figure 7.1, so memorising the zig-zag temperature profile and the four "pauses" is high-yield.