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CUET · GEOGRAPHY · CLASS XI · CODE 313

Water in the Atmosphere

CUET unit: Water in the Atmosphere (Climate)

By **UniDrill** · NCERT-grounded study material

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📌 Snapshot

- Water exists in the atmosphere in three states — gaseous, liquid and solid — cycling through evaporation, transpiration, condensation and precipitation.
- Key humidity terms (absolute, relative, specific humidity; saturation; dew point) form the conceptual backbone of all atmospheric-moisture questions.
- There are four forms of condensation (dew, frost, fog/mist, clouds), and clouds are classified by height and appearance into four basic types — cirrus, cumulus, stratus, nimbus.
- Precipitation takes four forms (rain, snowfall, sleet, hailstones), with three genetic types of rainfall (convectional, orographic/relief, cyclonic/frontal).
- World rainfall distribution varies by latitude and continental position, relevant to both physical geography and India-specific climate questions in CUET.

📖 Detailed Notes

2.1 Core concepts

- Water vapour varies from **0 to 4 per cent by volume** of the atmosphere and plays an important role in weather phenomena. Water exists in the atmosphere in three forms — gaseous, liquid and solid — and there is a continuous exchange between the atmosphere, oceans and continents through evaporation, transpiration, condensation and precipitation. (NCERT Ch. 10, §Intro, p. 86)
- **Humidity** is the water vapour present in the air, expressed quantitatively in three ways:
- **Absolute humidity** is the actual amount of water vapour present in the atmosphere — the weight of water vapour per unit volume of air, expressed in **grams per cubic metre**. Absolute humidity differs from place to place. (NCERT p. 86)
- **Relative humidity** is the percentage of moisture present in the atmosphere compared to its full capacity at a given temperature. As temperature changes, the moisture-retaining capacity changes and therefore RH changes. RH is **greater over oceans and least over continents**. (NCERT p. 86)
- **Saturated air** is air that contains moisture to its full capacity at a given temperature — it can hold no additional moisture at that stage. The **dew point** is the temperature at which saturation occurs in a given sample of air. (NCERT p. 86)

- **Evaporation** is the process by which water is transformed from liquid to gaseous state. Heat is the main cause. **Latent heat of vaporisation** is the amount of heat energy required to convert a unit mass of liquid into vapour without a change in temperature. (NCERT §Evaporation and Condensation, p. 86)
- **Factors that increase evaporation:**
- Higher temperature → greater absorption and retention capacity of air;
- Low moisture content of air → higher potential to absorb;
- Greater movement of air → replaces saturated layer with unsaturated layer, sustaining evaporation. (NCERT p. 86)
- **Condensation** is the transformation of water vapour into water; caused by loss of heat. In free air, condensation results from cooling around very small particles termed **hygroscopic condensation nuclei**. **Particles of dust, smoke and salt from the ocean are particularly good nuclei** because they absorb water. Condensation also takes place when moist air contacts a colder object or when the temperature is close to the dew point. (NCERT p. 86)
- **Conditions for condensation:** (i) temperature reduced to dew point with volume constant; (ii) both volume and temperature reduced; (iii) moisture added through evaporation. **The most favourable condition is the decrease in air temperature.** (NCERT p. 87)
- **Forms of condensation** (classified by temperature and location):
- **Dew** — moisture deposited as water droplets on cooler surfaces of solid objects (stones, grass blades, plant leaves). Ideal conditions: clear sky, calm air, high relative humidity, cold and long nights. Dew requires **dew point above freezing**. (NCERT §Dew, p. 87)
- **Frost** — forms on cold surfaces when condensation takes place at or below freezing (0°C); excess moisture is deposited as **minute ice crystals**, not water droplets. Ideal conditions are the same as dew, but air temperature must be at or below freezing. (NCERT §Frost, p. 87)
- **Fog** — when an air mass containing large water-vapour content cools suddenly, condensation takes place within itself on fine dust particles; fog is a **cloud with its base at or very near the ground** and reduces horizontal visibility to **less than 1 km**. In urban-industrial centres, smoke provides plenty of nuclei. (NCERT §Fog and Mist, p. 87)
- **Mist** — limits visibility to **between 1 km and 2 km**. The only difference between mist and fog is that **mist contains more moisture than fog** — each nucleus in mist carries a thicker layer of moisture. **Mists are frequent over mountains** because rising warm air up the slopes meets a cold surface. **Fogs are drier than mists** and occur where warm air currents meet cold currents. Fogs are essentially mini-clouds whose condensation nuclei are dust, smoke and salt particles. (NCERT p. 87)

- **Smog** — fog mixed with smoke; a condition typical of urban-industrial centres. (NCERT p. 87)
- **Clouds** are masses of minute water droplets or tiny crystals of ice formed by condensation of water vapour in free air at considerable elevations. According to **height, expanse, density and transparency/opaqueness**, clouds are grouped into four basic types: **cirrus, cumulus, stratus, nimbus**. (NCERT §Clouds, p. 87)
- **Cirrus** — formed at high altitudes (**8,000–12,000 m**); thin and detached; feathery appearance; always white. (NCERT p. 87)
- **Cumulus** — formed at **4,000–7,000 m**; look like cotton wool; exist in patches; have a **flat base**. (NCERT p. 87)
- **Stratus** — layered clouds covering large portions of the sky; generally formed by loss of heat or mixing of air masses with different temperatures. (NCERT p. 87)
- **Nimbus** — **black or dark gray**; form at middle levels or very near the surface; extremely dense and opaque to the sun's rays; sometimes seem to touch the ground; shapeless masses of thick vapour. These are the rain-bearing clouds. (NCERT p. 88)
- **Combined cloud categories:** high clouds — cirrus, cirrostratus, cirrocumulus; middle clouds — altostratus, altocumulus; low clouds — stratocumulus, nimbostratus; clouds with extensive vertical development — cumulus, cumulonimbus. (NCERT p. 88)
- **Precipitation** is the release of moisture from the atmosphere after condensation of water vapour, when air resistance can no longer hold the droplets against gravity. Four forms:
- **Rainfall** — liquid precipitation.
- **Snowfall** — when the temperature is lower than 0°C, moisture is released in the form of **hexagonal crystals** that form flakes of snow.
- **Sleet** — frozen raindrops and refrozen melted snow-water; occurs when a warm-above-freezing air layer overlies a sub-freezing layer near the ground; raindrops from the warm layer solidify into small pellets of ice not bigger than the raindrops from which they form.
- **Hailstones** — small, rounded, solid pieces of ice formed by raindrops being solidified as they pass through colder layers; **hailstones have several concentric layers of ice one over the other**. (NCERT §Precipitation, p. 88)
- **Types of rainfall** (by origin): three main types — convectional, orographic (relief), and cyclonic (frontal).
- **Convectional rain** — heated air becomes light, rises in convection currents, expands, loses heat, condenses; **cumulus clouds form**; rain falls with thunder and lightning but is **short-lived**. Common in equatorial regions and interior parts of continents, particularly in the northern hemisphere summer. (NCERT p. 88)

- **Orographic (relief) rain** — saturated air mass encounters a mountain, is forced to ascend, expands and cools, moisture condenses. **Windward slopes receive greater rainfall**; after giving rain on the windward side, descending winds on the leeward slope warm up and their capacity to take in moisture increases, leaving the leeward slope dry — called the **rain-shadow area**. Also known as relief rain. (NCERT p. 89)
- **Cyclonic (frontal) rain** — associated with extra-tropical cyclones described in Chapter 9. (NCERT p. 89)
- **World distribution of rainfall:** Rainfall decreases steadily from the equator to the poles. Coastal areas receive more than the interior. Rainfall is **more over oceans than over landmasses**. Between **35° –40° N and S**, rain is **heavier on the eastern coasts** and decreases westward (trade-wind belt). Between **45° –65° N and S**, due to the **westerlies**, rainfall is first received on the **western margins** of continents and decreases eastward. Wherever mountains run parallel to the coast, rain is greater on the windward side and decreases on the leeward side. (NCERT §World Distribution, p. 89)
- **Annual precipitation regimes:**
- **Over 200 cm/year** — equatorial belt, windward western-coast slopes of cool-temperate mountains, and coastal monsoon land.
- **100–200 cm/year** — interior continental moderate-rainfall zones; coastal areas of continents.
- **50–100 cm/year** — central tropical land and eastern/interior temperate land.
- **Less than 50 cm/year** — rain-shadow zones in the interior of continents and high latitudes. (NCERT p. 89)
- **Seasonal distribution** matters for effectiveness; the equatorial belt and the western parts of cool temperate regions receive rainfall **evenly distributed throughout the year**, whereas monsoon lands have strongly seasonal regimes. (NCERT p. 89)

2.2 Definitions to memorise

Term	Definition	Page
Humidity	Water vapour present in the air	86
Absolute humidity	Weight of water vapour per unit volume of air (g/m³)	86
Relative humidity	Percentage of moisture present compared to full capacity at a given temperature	86
Saturated air	Air containing moisture to its full capacity at a given temperature	86
Dew point	Temperature at which saturation occurs in a given air sample	86

Term	Definition	Page
Evaporation	Transformation of water from liquid to gaseous state	86
Transpiration	Loss of water vapour to the atmosphere from plants	86
Latent heat of vaporisation	Heat energy required to convert a unit mass of liquid into vapour without temperature change	86
Condensation	Transformation of water vapour into water, caused by loss of heat	86
Hygroscopic condensation nuclei	Small particles (dust, smoke, salt) around which water vapour condenses in free air	86
Dew	Moisture deposited as water droplets on cool surfaces when dew point is above freezing	87
Frost	Moisture deposited as minute ice crystals when dew point is at or below freezing	87
Fog	Cloud with base at or near the ground; visibility < 1 km	87
Mist	Near-ground condensation with visibility 1–2 km; more moisture per nucleus than fog	87
Smog	Fog mixed with smoke (urban condition)	87
Cloud	Mass of minute water droplets or ice crystals formed at elevation by condensation	87
Cirrus	High cloud, 8,000–12,000 m, thin, feathery, white	87
Cumulus	Cloud at 4,000–7,000 m, cotton-wool appearance, flat base	87
Stratus	Layered cloud covering large portions of sky	87
Nimbus	Black/dark gray rain-bearing cloud, middle level or near surface	88
Precipitation	Release of moisture from the atmosphere after condensation	88
Snowfall	Solid precipitation as hexagonal flakes when temperature < 0°C	88
Sleet	Frozen raindrops/refrozen melt-water, small ice pellets	88
Hailstones	Small rounded solid ice pieces with concentric layers, formed by raindrops freezing in cold layers	88
Convectional rain	Rain from rising heated air forming cumulus clouds; short-lived, with thunder	88
Orographic / relief rain	Rain produced when air ascends a mountain barrier; windward heavy, leeward dry	89
Rain-shadow area	Leeward side of a mountain that receives little rain	89
Cyclonic / frontal rain	Rain associated with extra-tropical cyclones and fronts	89

Term	Definition	Page
Westerlies belt rain	Rainfall received first on western margins of continents (45°–65° N/S)	89

2.3 Diagrams / processes to remember

- **Figures 10.1 and 10.2 (p. 88):** Photographs of two cloud types — students are asked to identify them. These typically show cirrus (thin feathery streaks) and cumulus (cotton-ball patches), the two most identifiable categories. CUET often uses similar images in map/diagram items.
- **Condensation process flow:** Warm moist air rises → cools as it expands → reaches dew point → saturated → excess water vapour condenses around hygroscopic nuclei (dust, smoke, salt) → forms dew/frost/fog/cloud depending on temperature and location.
- **Orographic rainfall diagram (conceptual, p. 89):** Moist air strikes mountain barrier → forced to ascend (windward slope) → expansion → cooling → condensation → rain on windward side → descending air on leeward slope warms up → moisture-holding capacity increases → leeward side dry → this dry zone is the **rain-shadow area**. The Western Ghats vs Deccan Plateau is the classic Indian example (linked via Chapter 12).
- **Convectional rainfall process (p. 88-89):** Strong surface heating (especially in equatorial belt) → air rises in convection currents → expansion and adiabatic cooling → cumulus cloud formation → rapid condensation → thunder and lightning → heavy but short-lived rainfall. Diurnal pattern: such rains usually fall in the afternoon when surface heating is maximum.
- **Precipitation pathway:** Continuous condensation in free air → droplets grow → air resistance fails → gravity prevails → droplets fall as rain (above 0°C), snow (hexagonal crystals below 0°C), sleet (warm-over-cold layer → frozen pellets), or hailstones (raindrops cycle through cold layers, gather concentric layers of ice).
- **World rainfall belts (conceptual map, p. 89):** Equatorial belt (>200 cm) → trade-wind dry belt (around 25°–30° N/S, deserts) → westerly belt (45°–65°, western margins wet) → polar (<50 cm). Memorising this latitude-coast pairing answers most distribution MCQs.
- **Four-cloud classification matrix:** Height (high/middle/low/vertical) × form (wispy/heap/sheet/dark mass) → cirrus, cumulus, stratus, nimbus. Compound types (cirrostratus, altocumulus, nimbostratus, cumulonimbus) combine these in fixed ways.

2.4 Common confusions / NTA trap points

- Students confuse **absolute humidity** (g/m³, an absolute measure) with **relative humidity** (a percentage of full capacity). NTA frequently tests the definitional difference.

- **Fog vs mist**: both are near-ground condensation, but **fog reduces visibility to < 1 km** while **mist limits it to 1–2 km**; counter-intuitively, **mist contains more moisture per nucleus than fog** (so mist nuclei carry thicker moisture layers).
- **Dew vs frost**: both form on surfaces, but dew requires **dew point above freezing**; frost requires **dew point at or below freezing**. NTA may swap the temperature condition as a distractor.
- **Most favourable condition for condensation** is **decrease in air temperature** — not increase, not addition of pressure. A common distractor uses "increase in air temperature."
- **Orographic vs cyclonic rain**: orographic rain is caused by a mountain barrier; cyclonic rain by frontal/cyclonic activity. Both involve rising air, hence the confusion.
- **Cloud altitudes**: cirrus is highest at **8,000–12,000 m**, cumulus is middle at **4,000–7,000 m**, nimbus is near surface or middle level. NCERT Exercise Q1(iv) directly tests "which is the highest cloud" — answer is cirrus.
- **Hailstones have concentric layers** of ice — distractors describe them as solid uniform ice; remember the onion-like layered structure.
- **Westerlies belt rule (45° –65°)**: rain first hits the **western** margins of continents (not eastern). At 35°–40°, the reverse holds — rain is heavier on **eastern** coasts because of trade winds and warm currents.
- **Rainfall is more over oceans than landmasses** — a counter-intuitive fact (we only measure rain that falls on land).
- **Latent heat of vaporisation** is heat used to convert liquid to vapour without temperature change — distractors say "raises the temperature."
- **Stratus clouds form by loss of heat or mixing of air masses** — not by convection (that produces cumulus). Mixing the formation mechanism is a classic trap.
- **Nimbus clouds are rain-bearing**; pure stratus and cumulus are not heavy rain producers by themselves — only their compound forms (nimbostratus, cumulonimbus) bring heavy rain.

2.5 Key data table (NCERT figures only)

Parameter	Figure / fact	Source (NCERT p.)
Range of water vapour in atmosphere	0–4% by volume	86
Absolute humidity unit	grams per cubic metre	86
Where RH is greatest / least	Greatest over oceans, least over continents	86
	Decrease in air temperature	87

Parameter	Figure / fact	Source (NCERT p.)
Most favourable condition for condensation		
Fog visibility	< 1 km	87
Mist visibility	1–2 km	87
Cirrus altitude	8,000–12,000 m	87
Cumulus altitude	4,000–7,000 m	87
Snowfall threshold temperature	< 0°C	88
Hailstone structure	Concentric layers of ice	88
Rainfall belt at western margins (45°–65° N/S)	Due to westerlies	89
Rainfall belt on eastern coasts (35°–40° N/S)	Trade winds dominant	89
Heavy-rainfall zone threshold	> 200 cm/year (equatorial, windward W coasts, monsoon coasts)	89
Moderate-rainfall zone	100–200 cm/year (interior continents, coastal areas)	89
Low-rainfall threshold	< 50 cm/year (rain-shadow, high latitudes)	89

🎯 Practice MCQs

📊 PYQ Alignment

This chapter appears consistently in CUET Geography papers with about 5–6 MCQs per year. Questions focus on the definitions of humidity types (absolute vs relative vs saturated), cloud classification by altitude (cirrus highest, nimbus rain-bearing), forms of condensation (especially distinguishing dew/frost via the freezing condition and fog/mist via visibility), and types of rainfall — particularly orographic rain and the rain-shadow concept (which dovetails with the Western Ghats / Deccan dryness in Chapter 12). Map/data items often quote the four annual rainfall regimes (>200, 100–200, 50–100, <50 cm) and ask students to associate them with latitude or continental position. Statement-based and match-the-following questions on cloud types and precipitation forms are nearly guaranteed.