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CUET · GEOGRAPHY · CLASS XI · CODE 313

Atmospheric Circulation and Weather Systems

CUET unit: Atmospheric Circulation and Weather Systems

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

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📌 Snapshot

- Differential atmospheric pressure drives wind, which redistributes heat and moisture across the planet.
- Three forces govern wind (pressure gradient, Coriolis, friction), shaping the global pattern of pressure belts and the three-cell model of general circulation.
- Air masses, fronts, and the contrast between extra-tropical and tropical cyclones are all high-frequency CUET topics.
- Violent local storms (thunderstorms, tornadoes) and local winds (land/sea breeze, valley/mountain wind) complete the coverage.
- CUET tests this chapter heavily because it bridges physical geography concepts (pressure, temperature) with real-world weather phenomena and map-based questions.

📖 Detailed Notes

2.1 Core concepts

- **Atmospheric pressure** is defined as the weight of a column of air per unit area from mean sea level to the top of the atmosphere, expressed in **millibars (mb)**. Average sea-level pressure is **1,013.2 mb**. Pressure is measured with a mercury barometer or aneroid barometer. (NCERT §Atmospheric Pressure, p. 76)
- **Vertical variation of pressure:** Pressure decreases rapidly with height — approximately **1 mb per 10 m** rise in the lower atmosphere. At sea level: 1,013.25 mb / 15.2°C; at 10 km: 265.00 mb / –49.7°C (Table 9.1). The vertical pressure gradient force is balanced by an opposing gravitational force, so strong upward winds are not felt. (NCERT §Vertical Variation of Pressure, p. 76)
- **Horizontal distribution of pressure:** Measured at sea level to eliminate altitude effects. **Isobars** are lines joining places of equal pressure. Close isobars = strong pressure gradient; distant isobars = weak gradient. (NCERT §Horizontal Distribution of Pressure, p. 77)
- **World pressure belts:** Equatorial low (near equator); subtropical highs (30°N and 30°S); sub-polar lows (60°N and 60°S); polar highs (poles). These belts shift with the apparent movement of the sun — southward in northern hemisphere winter, northward in summer. (NCERT §World Distribution of Sea Level Pressure, p. 77)

- **Forces controlling wind direction and velocity:** Three forces act on horizontal winds near the surface: (i) Pressure Gradient Force — drives air from high to low pressure; stronger gradient = faster wind; (ii) Frictional Force — reduces wind speed; greatest at surface, effective up to 1–3 km altitude, minimal over sea; (iii) Coriolis Force — caused by Earth's rotation; deflects wind to the right in the Northern Hemisphere and to the left in the Southern Hemisphere; maximum at poles, zero at equator; proportional to latitude and wind velocity. (NCERT §Forces Affecting the Velocity and Direction of Wind, pp. 78–79)
- **Geostrophic wind:** In the upper atmosphere (2–3 km above surface), friction is absent. When isobars are straight, pressure gradient force and Coriolis force balance each other, resulting in a wind blowing **parallel to the isobar**. This is the geostrophic wind. (NCERT §Pressure and Wind, p. 79)
- **Cyclonic and anticyclonic circulation:** Wind around a **low** (cyclone) is anticlockwise in the Northern Hemisphere and clockwise in the Southern Hemisphere. Wind around a **high** (anticyclone) is clockwise in the Northern Hemisphere and anticlockwise in the Southern Hemisphere (Table 9.2). Over low pressure: air converges and rises; over high pressure: air subsides and diverges. (NCERT §Pressure and Wind, p. 79)
- **General circulation of the atmosphere — three-cell model:** (i) **Hadley Cell** (tropics): Air rises at ITCZ due to convection, moves poleward, sinks at ~30°N/S (subtropical high), returns to equator as trade winds (easterlies). (ii) **Ferrel Cell** (middle latitudes): Sinking cold polar air and rising warm subtropical air; surface winds are westerlies. (iii) **Polar Cell**: Cold dense air subsides at poles and blows toward middle latitudes as polar easterlies. Heat transfer from lower to higher latitudes maintains the general circulation. (NCERT §General circulation of the atmosphere, pp. 80)
- **ENSO:** Warm Pacific water drifts toward South American coast (El Nino), replacing the cool Peruvian current. Pressure changes over the Pacific constitute the **Southern Oscillation**. The combined El Nino + Southern Oscillation = **ENSO**. Strong ENSO years bring: heavy rain on arid west coast of South America, droughts in Australia and sometimes India, floods in China. (NCERT §General Atmospheric Circulation and its Effects on Oceans, p. 80)
- **Local winds — Land and sea breezes:** Day: land heats faster → low pressure over land, high over sea → sea breeze (sea to land). Night: land cools faster → high pressure over land, low over sea → land breeze (land to sea). (NCERT §Land and Sea Breezes, p. 81)
- **Mountain and valley winds:** Day: slopes heat up → air rises upslope → valley breeze. Night: slopes cool → dense cold air descends into valley → mountain wind. Cool air draining from high plateaus/ice fields into valleys = **katabatic wind**. Warm wind on leeward side of mountains: moisture condenses on windward side; descending dry air warms adiabatically — can melt snow rapidly. (NCERT §Mountain and Valley Winds, p. 81)

- **Air masses:** A large body of air with little horizontal variation in temperature and moisture. Forms over homogeneous **source regions**. Five types: Maritime tropical (mT), Continental tropical (cT), Maritime polar (mP), Continental polar (cP), Continental arctic (cA). Tropical air masses are warm; polar air masses are cold. (NCERT §Air Masses, p. 81)
- **Fronts:** Boundary zone between two different air masses; formation = **frontogenesis**. Four types: (a) Cold front — cold air advances into warm air; (b) Warm front — warm air advances into cold air; (c) Stationary front; (d) Occluded front — warm air completely lifted above land. Fronts occur in middle latitudes, cause steep temperature/pressure gradients, bring abrupt weather changes, cloud formation, and precipitation. (NCERT §Fronts, pp. 81–82)
- **Extra-tropical cyclones:** Form in mid and high latitudes along the polar front. Anticlockwise circulation (Northern Hemisphere). Has a clear frontal system (warm + cold fronts). Can originate over land and sea. Warm sector wedged between cold sectors; cumulus clouds along cold front. Cold front overtakes warm front → occluded front → cyclone dissipates. Move from **west to east**. Affect larger areas than tropical cyclones but are less destructive. (NCERT §Extra Tropical Cyclones, pp. 82–83)
- **Tropical cyclones:** Violent storms over warm tropical oceans (sea surface temperature > 27°C). Called Cyclones (Indian Ocean), Hurricanes (Atlantic), Typhoons (Western Pacific/South China Sea), Willy-willies (Western Australia). Conditions for formation: SST > 27°C, Coriolis force, small vertical wind speed variation, pre-existing low-pressure system, upper divergence. Energy source = condensation in cumulonimbus clouds. Eye = calm region of subsiding air; Eye wall = maximum wind velocity (up to 250 km/hr), torrential rain. Diameter of circulating system: 150–250 km; storm diameter in Bay of Bengal/Arabian Sea/Indian Ocean: 600–1,200 km. Move at ~300–500 km/day. Move from **east to west**. Dissipate on reaching land (moisture cut off). Landfall = where cyclone crosses the coast. Cyclones crossing 20°N recurve and are more destructive. (NCERT §Tropical Cyclones, pp. 83)
- **Thunderstorms and tornadoes:** Caused by intense convection on moist hot days; cumulonimbus clouds produce thunder, lightning, hail. Intense updraft of warm air grows clouds; downdraft brings cool air and rain. A **tornado** = spiralling wind descending like a trunk, very low pressure at centre, highly destructive; occurs in middle latitudes. Tornado over sea = **water spout**. (NCERT §Thunderstorms and Tornadoes, p. 84)
- **Pressure-wind diagrammatic elements (Figure 9.1):** A trough is an elongated extension of low pressure into a region of higher pressure; a ridge is an elongated extension of high pressure into low; a COL is the saddle-shaped neck between two highs and two lows arranged alternately. These diagrammatic features are commonly tested in NTA's map-based questions because they were illustrated in Figure 9.1 (NCERT p. 77).

- **Jet streams:** Narrow belts of high-altitude (above 12,000 m) westerly winds in the troposphere, with velocities of 110–184 km/hr in winter and roughly half in summer. The most constant are the mid-latitude (sub-polar) jet stream and the sub-tropical jet stream. Their meridional shifts steer extra-tropical cyclones and influence the timing of the Indian monsoon by guiding tropical easterly and sub-tropical westerly jets across the subcontinent.
- **Names of tropical cyclones by basin (memory hook):** Cyclones (North Indian Ocean), Hurricanes (North Atlantic and East Pacific), Typhoons (Western North Pacific including South China Sea), Willy-willies (north-western Australia), and Tornado-like Baguios in the Philippines. This naming convention is a direct CUET test point (NCERT p. 83).
- **Hot, dry local winds (regional examples):** Loo (north India), Foehn (Alps), Chinook (eastern slopes of the Rockies), Sirocco (North Africa to southern Europe) all develop when descending dry air heats adiabatically — closely related to the "warm wind on the leeward side of mountains" passage in NCERT. Mistral (Rhone valley, France) and Bora (Adriatic) are by contrast cold descending winds.
- **Vertical structure of a tropical cyclone:** A mature tropical cyclone has three vertical zones — (i) an inflow layer (0–1 km) of warm, moist convergent air at the surface; (ii) a deep middle layer (1–10 km) of ascending air and condensation in the eye wall; (iii) an upper outflow layer (10–15 km) where divergence at the tropopause exhausts the rising air. The 'eye' is a column of subsiding warm air, calm and cloud-free, surrounded by the eye wall with the strongest winds.

2.2 Definitions to memorise

Term	Definition	Page
Atmospheric pressure	Weight of a column of air per unit area from mean sea level to the top of the atmosphere	76
Millibar (mb)	Unit of atmospheric pressure; sea-level average = 1,013.2 mb	76
Isobar	Line connecting places of equal atmospheric pressure	77
Pressure gradient	Rate of change of pressure with respect to distance	78
Coriolis force	Deflecting force due to Earth's rotation; right in NH, left in SH; zero at equator	78–79
Geostrophic wind	Wind blowing parallel to isobars in upper atmosphere where pressure gradient force balances Coriolis force	79
ITCZ	Inter Tropical Convergence Zone — equatorial low pressure zone where trade winds converge	80
Hadley Cell	Convective circulation cell in the tropics between equator and ~30°N/S	80
Ferrel Cell	Mid-latitude circulation cell; surface westerlies	80

Term	Definition	Page
Polar Cell	High-latitude cell; polar easterlies at surface	80
El Nino	Appearance of warm water off coast of Peru, replacing the cool Peruvian current	80
ENSO	Combined phenomenon of Southern Oscillation and El Nino	80
Air mass	Large body of air with little horizontal variation in temperature and moisture	81
Source region	Homogeneous surface over which an air mass forms	81
Frontogenesis	Process of formation of a front	81
Occluded front	Front where warm air is completely lifted above land surface	82
Katabatic wind	Cool air draining from high plateaus and ice fields into valleys	81
Eye (cyclone)	Calm region with subsiding air at the centre of a tropical cyclone	83
Eye wall	Region around the eye with maximum wind velocity and torrential rain	83
Landfall	Place where a tropical cyclone crosses the coast	83
Tornado	Violently spiralling wind with very low central pressure; descends like an elephant trunk	84
Water spout	Tornado occurring over the sea	84
Trough	Elongated extension of a low-pressure area into surrounding high pressure	77
Ridge	Elongated extension of a high-pressure area into surrounding low pressure	77
COL	Saddle-shaped neck between two highs and two lows arranged alternately	77
Anticyclone	A high-pressure system with diverging surface winds; rotates clockwise in NH, anticlockwise in SH	79
Jet stream	Narrow band of high-velocity westerly winds in the upper troposphere; 110–184 km/hr in winter	80

2.3 Diagrams / processes to remember

- **Figure 9.1 (p. 77):** Isobars, pressure and wind systems in Northern Hemisphere — shows trough, ridge, COL, high and low pressure centres with isobar values.
- **Figure 9.4 (p. 79):** Geostrophic wind diagram — shows how Coriolis force (C) and pressure gradient (P_H) combine to produce wind V parallel to isobars in both hemispheres.

- **Figure 9.5 (p. 79):** Convergence and divergence of winds — over low: surface convergence + upper divergence; over high: surface divergence + upper convergence.
- **Figure 9.6 (p. 80):** Simplified general circulation — shows Hadley, Ferrel and Polar cells, position of ITCZ, subtropical high (STH), sub-polar low (SPL), polar high; jet streams shown at STH and SPL levels.
- **Figure 9.7 (p. 81):** Land and sea breezes — day vs night reversal of pressure gradient between land and sea.
- **Figure 9.8 (p. 82):** Vertical sections of warm front, cold front, and occluded front — useful for understanding cloud types and precipitation patterns associated with each.
- **Figure 9.9 (p. 82):** Extra-tropical cyclone — plan view showing warm sector, cold front, warm front, and cold air wrapping around; cross-section showing vertical extent (~9 km).
- **Figure 9.10 (p. 83):** Vertical section of tropical cyclone — eye, eye wall, rain bands, tropopause, steering wind flow, outflow at top; height scale (~15 km).

2.5 Key data table (NCERT figures to memorise)

#	Quantity	Value	NCERT page
1	Average sea-level pressure	1,013.2 mb	76
2	Vertical pressure decrease in lower atmosphere	1 mb per 10 m	76
3	Standard pressure at 5 km	540.48 mb	76
4	Standard pressure at 10 km	265.00 mb	76
5	Frictional force effective up to	1–3 km altitude	78
6	Minimum SST required for tropical cyclone formation	>27°C	83
7	Peak wind velocity in tropical-cyclone eye wall	up to 250 km/hr	83
8	Diameter of circulating low (tropical cyclone)	150–250 km	83
9	Diameter of full storm system in Bay of Bengal/ Arabian Sea	600–1,200 km	83
10	Forward speed of a typical tropical cyclone	300–500 km/day	83
11	Latitude beyond which Indian cyclones recurve	20°N	83
12	Vertical extent of an extra-tropical cyclone	~9 km	82
13	Vertical extent of a tropical cyclone	~15 km	83
14	Jet-stream velocity in winter	110–184 km/hr	80
15	Standard pressure at sea level (SI)		76

#	Quantity	Value	NCERT page
		1,013.25 mb / 15.2°C	

2.4 Common confusions / NTA trap points

- **Coriolis deflection direction:** Students often reverse the hemispheres. Remember: Northern Hemisphere = deflect RIGHT (anticlockwise cyclone around low); Southern Hemisphere = deflect LEFT (clockwise cyclone around low). NTA presents Table 9.2 as a direct MCQ source.
- **Tropical cyclones are NOT formed near the equator** — because Coriolis force is zero at the equator, the low pressure simply gets filled rather than intensifying into a cyclone. NTA loves this as a "which of the following is correct" option.
- **Extra-tropical vs tropical cyclone movement direction:** Extra-tropical cyclones move west to east; tropical cyclones move east to west. NTA frequently uses this contrast.
- **Eye vs Eye wall confusion:** The eye is calm (subsiding air); the eye wall has the most violent weather (maximum wind, torrential rain). Students mix these up.
- **El Nino effects:** The arid west coast of South America gets rain (not drought); Australia gets drought (not rain). NTA uses reversed cause-effect distractors.
- **Geostrophic wind is in the upper atmosphere** (2–3 km above surface, friction-free) — NOT at the surface. Surface winds are affected by all three forces.
- **Hadley vs Ferrel vs Polar cell — direction of surface wind:** Trade winds (Hadley) are easterlies; westerlies (Ferrel) are westerlies; polar winds (Polar cell) are easterlies. NTA often flips the Ferrel cell direction since "Ferrel" sounds unfamiliar.
- **Cyclone names by basin — keep the basin-name pairing intact:** Hurricane = North Atlantic; Typhoon = Western Pacific/South China Sea; Willy-willy = NW Australia; Cyclone = Indian Ocean. Reversing Atlantic and Pacific names is the commonest trap.
- **Front types — cold, warm, stationary, occluded:** An occluded front forms when a faster-moving cold front overtakes a warm front and lifts the warm air completely above the surface. NTA frames this as "warm air lifted above land" — pick occluded (NCERT p. 82).
- **Land breeze vs sea breeze direction:** Sea breeze blows from sea to land during the day (sea = high pressure relative to heated land); land breeze blows from land to sea at night (land cools faster). NTA flips the directions or the time of day.
- **Tornado vs water spout:** Both are intense low-pressure spiralling columns. A tornado is over land; the same vortex over water is a water spout. NTA equates them entirely as a trap (NCERT p. 84).

🎯 Practice MCQs

📊 PYQ Alignment

This chapter is one of the most frequently examined in CUET Geography (313), typically contributing 4–6 MCQs per year. Questions most often focus on the Coriolis force and wind direction in cyclones/anticyclones, the pressure belt sequence (equatorial low to polar high), conditions for tropical cyclone formation, differences between tropical and extra-tropical cyclones, and the three-cell model of general atmospheric circulation. The full solved archive of CUET PYQs on this unit is at `/pyq/geography`.