

Introduction to Tropical Meteorology

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Key concepts, processes, and phenomena that define the weather and climate of the tropical belt (23.5°N–23.5°S).

1. Geographic & Seasonal Setting

Feature	Description
Tropics	Region between the Tropic of Cancer (23.5°N) and Tropic of Capricorn (23.5°S).
Sun Angle	Near-vertical solar rays year-round → high insolation, small seasonal temperature range.
Solar Declination	Determines the position of the intertropical convergence zone (ITCZ) and the timing of wet/dry seasons.
Land-Sea Contrast	Strongly influences monsoon circulations and the distribution of rainfall.

2. Fundamental Thermodynamics

1. Energy Balance

- Incoming solar radiation** ~340 W/m² (global average) → ~400 W/m² in the tropics.
- Outgoing longwave radiation** balanced by latent heat release (~80% of the tropical energy budget).

2. Moist Static Energy (MSE)

$$[\text{MSE}] = c_p T + gz + L_v q$$

- Governs vertical motions: parcels with higher MSE rise, releasing latent heat.

3. Clausius-Clapeyron Relationship

- Saturation vapor pressure increases ~7% per °C warming → stronger potential for extreme precipitation.

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3. Core Atmospheric Features

Feature	Mechanism	Typical Location	Seasonal Behavior
Intertropical Convergence Zone (ITCZ)	Convergence of trade winds, strong convection, deep moist clouds	Near equator, shifts $\pm 10^\circ$ with seasons	Follows the sun: northward in boreal summer, southward in austral summer
Hadley Circulation	Thermally driven overturning cell: warm air rises at ITCZ, sinks near 30° latitude, returns at the surface as trade winds	Ascending branch at ITCZ, descending branch at subtropical highs	Weak seasonal shift; intensity modulated by land?sea heating contrast
Trade Winds	Surface return flow of Hadley cell; Coriolis deflection ? easterlies	0° – 30° latitude (both hemispheres)	Strengthens during the respective hemisphere's winter (greater temperature gradient)
Tropical Waves (e.g., Kelvin, Rossby ?gravity, Madden-Julian Oscillation)	Large?scale equatorial wave dynamics; modulate convection	Propagate eastward/westward along the equator	MJO: 30?60?day cycle, alternating active/inactive phases of rainfall
Monsoons	Seasonal reversal of surface pressure gradients between land and ocean	South Asia, West Africa, Australia, North America	Summer: onshore flow ? wet season; Winter: offshore flow ? dry season

4. Convection & Cloud Systems

System	Vertical Extent	Typical Rainfall	Key Drivers
Cumulus	1–5?km	Isolated showers	Local surface heating, low? level moisture
Cumulonimbus (Deep Convective)	Up to 15–20?km (tropopause)	Intense, short? duration storms	Strong MSE, ITCZ or monsoon convergence

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System

Vertical Extent

Typical Rainfall

Key Drivers

**Mesoscale Convective

Systems (