Key Definitions

- **Weather**: The short-term atmospheric conditions of a place, characterized by elements such as temperature, pressure, wind, humidity, and precipitation.
- **Climate**: The average weather conditions experienced over a longer period (typically 35–40 years) across a larger area, influencing flora, fauna, and human activities.

Significance of Weather Studies

Weather influences daily human activities in several ways:

- **Agriculture**: Determines crop selection, planting, and harvesting schedules.
- **Travel/Transport**: Affects safety and scheduling of air, sea, and land transport.
- **Fishing**: Impacts fishing operations due to wind, waves, and precipitation.
- **Tourism**: Influences tourist destinations and activities based on weather conditions.

Table 1: Significance of Weather Studies

Activity	Impact of Weather
Agriculture	Guides crop selection and farming practices
Travel	Ensures safety and efficiency in transportation
Fishing	Determines viable fishing times and locations
Tourism	Affects tourist preferences and seasonal activities

Indian Meteorological Department (IMD)

- **Role**: The principal agency under the Ministry of Earth Sciences, Government of India, responsible for weather observations and forecasts.
- **Headquarters**: Delhi.
- **Operations**: Manages hundreds of observation stations across India and Antarctica.

Elements of Weather and Climate

The primary elements influencing weather and climate are temperature, pressure, wind, humidity, and precipitation. These are driven by solar energy, with the sun being the sole energy source for Earth.

1. Atmospheric Temperature

Source of Energy

- The sun generates energy through **nuclear fusion**, where atomic nuclei merge to form larger atoms, releasing massive energy.
- Only a small fraction (approximately 1/200 million) of solar energy reaches Earth as **insolation**.

Definition: Nuclear Fusion

- A reaction where two or more atomic nuclei combine to form a larger nucleus, releasing energy.
- Example: In the sun, 600 million tonnes of hydrogen convert to helium every second.

Insolation and Heat Transfer

- **Insolation**: Solar energy reaching Earth's surface in the form of short waves.
- **Short Waves vs. Long Waves**:
  - Short waves (from hotter objects like the sun) traverse the atmosphere with minimal obstruction due to high frequency.
  - Long waves (from cooler objects like Earth's surface) are absorbed or reflected by atmospheric particles due to low frequency.
- **Processes of Heat Transfer**:
  - **Conduction**: Heat transfer to the lower atmosphere in contact with Earth's surface.
  - **Convection**: Heated air expands, rises, and transfers heat to higher atmospheric layers.
  - **Advection**: Horizontal heat transfer via wind.
  - **Radiation**: Emission of long-wave energy from Earth's heated surface, known as **terrestrial radiation**.

Table 2: Processes of Heat Transfer

Process	**Description**	**Example Location**
Conduction	Heat transfer through direct contact	Lower atmosphere
Convection	Heat transfer via rising warm air	Upper atmosphere
Advection	Horizontal heat transfer by wind	Across regions
Radiation	Long-wave energy emission from Earth's surface	Entire atmosphere

Greenhouse Effect

- **Definition**: Absorption of terrestrial radiation by atmospheric gases (e.g., carbon dioxide), heating the atmosphere.
- **Greenhouses**: Structures that trap heat to maintain warm conditions for plants, analogous to the atmospheric greenhouse effect.

Heat Budget

- **Definition**: The balance of incoming insolation and outgoing terrestrial radiation, maintaining Earth's surface temperature.

- **Importance**: Prevents extreme heating or cooling, sustaining life on Earth.

Daily Temperature Variations

- **Maximum Temperature**: Recorded at 2 PM due to delayed atmospheric heating.
- **Minimum Temperature**: Recorded just before sunrise due to energy loss via terrestrial radiation at night.
- **Measurement Instrument**: **Maximum-Minimum Thermometer**, which records both daily extremes using a U-shaped glass tube.

Temperature Units:

- **Celsius**: Water melts at 0°C, boils at 100°C.
- **Fahrenheit**: Water melts at 32°F, boils at 212°F.
- **Conversion Formulas**:
  - °F = (°C × 9/5) + 32
  - °C = (°F - 32) × 5/9

Calculations:

- **Diurnal Range of Temperature**: Maximum temperature - Minimum temperature.
- **Daily Mean Temperature**: (Maximum temperature + Minimum temperature) / 2.
- **Example**: For max 36°C and min 28°C:
  - Diurnal Range = 36°C - 28°C = 8°C
  - Daily Mean = (36°C + 28°C) / 2 = 32°C

Temperature Distribution

- **Isotherms**: Imaginary lines connecting places with equal temperatures.
- **Global Patterns**:
  - Temperature decreases from the equator to the poles.
  - Isotherms bend at land-sea interfaces due to differential heating.
  - Southern Hemisphere isotherms are more parallel to latitudes due to greater ocean coverage.

Table 3: Temperature Distribution Factors

Factor	Impact on Temperature
Latitude	Higher temperatures near equator due to vertical rays
Altitude	Temperature decreases with height (e.g., Ooty)

Differential Heating	Land heats/cools faster than sea
Distance from Sea	Coastal areas have moderated temperatures
Ocean Currents	Warm currents raise, cold currents lower temperatures
Relief	Windward slopes warmer, leeward slopes cooler

Factors Influencing Temperature

1. **Latitude**: Vertical rays at the equator cause high temperatures; oblique rays at poles cause low temperatures.
2. **Altitude**: Temperature decreases with altitude (e.g., 6 km altitude is colder than sea level).
3. **Differential Heating of Land and Sea**: Land experiences greater temperature extremes than sea.
4. **Distance from Sea**: Coastal areas have lower diurnal ranges due to maritime influence.
5. **Ocean Currents**: Warm currents (e.g., North Atlantic Current) raise coastal temperatures; cold currents (e.g., Labrador Current) lower them.
6. **Relief**: Windward slopes receive more insolation, while leeward slopes are cooler.

Comparison: Coastal vs. Inland Temperature

Aspect	Coastal Areas (e.g., Kerala)	Inland Areas
Diurnal Range	Low due to sea moderation	High due to land extremes
Temperature Extremes	Less extreme	More extreme
Maritime Influence	Strong	Weak

2. Atmospheric Pressure and Winds

Atmospheric Pressure

- **Definition**: The weight of atmospheric air exerted on Earth's surface, measured in millibars (mb).
- **Factors Affecting Pressure**:
  - **Temperature**: Warm air expands, rises, and forms low pressure; cold air contracts, sinks, and forms high pressure.
  - **Altitude**: Pressure decreases with height at ~1 mb per 10 meters.
  - **Humidity**: Humid air is lighter (due to water molecules displacing heavier gases), reducing pressure.
- **Human Adaptation**: The body exerts opposing pressure to balance atmospheric pressure, preventing discomfort except at high altitudes (e.g., ear clogging).

Measurement and Mapping

- **Isobars**: Lines connecting places with equal atmospheric pressure.
- **High and Low Pressure Centres**: Marked as 'H' and 'L' on isobar maps.
- **Pressure Gradient**: Change in pressure over distance; high gradient indicates strong winds.

Global Pressure Belts

- **Equatorial Low Pressure Belt (Doldrums)**: Formed due to high temperatures and rising air; windless zone.
- **Subtropical High Pressure Belts (~30°N/S)**: Formed by subsiding air from equatorial regions.
- **Subpolar Low Pressure Belts (~60°N/S)**: Formed due to air uplift from Earth's rotation.
- **Polar High Pressure Belts**: Formed by cold, sinking air.
- **Seasonal Shifts**: Belts shift 5°–10° north in summer and south in winter due to the sun's apparent movement.

Table 4: Global Pressure Belts

Belt	Latitude	Characteristics
Equatorial Low (Doldrums)	~0°	High temperature, rising air, no winds
Subtropical High	~30°N/S	Subsiding air, high pressure
Subpolar Low	~60°N/S	Uplifted air, low pressure
Polar High	~90°N/S	Cold, sinking air, high pressure

Winds

- **Definition**: Horizontal air movements from high to low pressure areas.
- **Types**:
  - **Air Currents**: Vertical air movements.
  - **Winds**: Horizontal air movements.
- **Naming**: Based on direction of origin (e.g., southwest winds blow from the southwest).
- **Influencing Factors**:
  - **Coriolis Force**: Deflects winds right in the Northern Hemisphere, left in the Southern Hemisphere due to Earth's rotation.
  - **Pressure Gradient Force**: Stronger gradient leads to stronger winds.
  - **Frictional Force**: Obstructions like mountains reduce wind speed; winds are stronger over oceans.

Instruments:

- **Anemometer**: Measures wind speed.
- **Wind Vane**: Indicates wind direction.

Types of Winds

1. **Permanent Winds**:
    - Blow constantly between global pressure belts.
    - Examples:
        - **Trade Winds**: From subtropical high to equatorial low; Northeast in N. Hemisphere, Southeast in S. Hemisphere.
        - **Westerlies**: From subtropical high to subpolar low; stronger in S. Hemisphere.
        - **Polar Winds**: From polar high to subpolar low.
    - **Reason for Direction**: Coriolis effect causes deflection.
2. **Periodic Winds**:
    - Reverse direction periodically.
    - Examples:
        - **Land and Sea Breezes**: Land breezes (night, land to sea); sea breezes (day, sea to land).
        - **Mountain and Valley Breezes**: Mountain breezes (night, downslope); valley breezes (day, upslope).
        - **Monsoon Winds**:
            - **Southwest Monsoon** (summer): Blows from Indian Ocean to Indian subcontinent, causing rain.
            - **Northeast Monsoon** (winter): Dry winds from land to ocean.
3. **Local Winds**:
    - Caused by local temperature and pressure differences.
    - **Examples** (Table 5):

Local Wind	Region	Characteristics
Loo	North Indian Plains	Hot, dry wind
Chinook	Rocky Mountains, N.	Dry, warm wind
Foehn	Alps,	Dry, warm wind
Harmattan	Sahara Desert, Africa	Dry, hot, relieves heat

4. **Variable Winds**:
    - Unpredictable in direction and intensity.
    - Examples:
        - **Cyclones**: Low-pressure systems with inward-spiraling winds.
            - **Tropical Cyclones**: Smaller, devastating, originate over oceans (e.g., Hurricanes, Typhoons).
            - **Temperate Cyclones**: Larger, less destructive, can move over land.
            - **Direction**: Anticlockwise in N. Hemisphere, clockwise in S. Hemisphere.
        - **Anticyclones**: High-pressure systems with outward-spiraling winds; generally calm.
            - **Direction**: Clockwise in N. Hemisphere, anticlockwise in S. Hemisphere.

Comparison: Tropical vs. Temperate Cyclones

Aspect	Tropical Cyclones	Temperate Cyclones
Origin	Tropical oceans	Temperate regions (fronts)
Size	Smaller diameter	Larger diameter
Impact	Highly destructive	Less destructive
Movement	Dissipate over land	Can move over land
Wind Direction	Anticlockwise (N.H.), clockwise (S.H.)	Same

3. Atmospheric Humidity

Definitions

- **Humidity**: Invisible water vapor in the atmosphere.
- **Absolute Humidity**: Actual amount of water vapor per unit volume.
- **Relative Humidity**: Ratio of absolute humidity to the atmosphere's water-holding capacity at a given temperature, expressed as a percentage.
    - Formula: Relative Humidity = (Absolute Humidity / Total Water-Holding Capacity) × 100
- **Saturation Level**: When the atmosphere is fully saturated with water vapor (relative humidity = 100%).
- **Saturation Point**: Temperature at which saturation occurs, leading to condensation.

Measurement

- **Hygrometer**: Measures atmospheric humidity using wet and dry bulb thermometers.
- **Condensation**: Process where water vapor turns into visible water droplets (e.g., dew, fog).

Sources of Water Vapor

- Evaporation from oceans, rivers, lakes, and soil.
- Transpiration from plants.

Forms of Condensation

- **Dew**: Water droplets on surfaces due to cooling at night.
- **Fog**: Suspended water droplets reducing visibility.
- **Frost**: Ice crystals formed when dew freezes.
- **Mist**: Light fog with moderate visibility.

4. Clouds

Types of Clouds

- **Cirrus**: Thin, feathery clouds at high altitudes.
- **Stratus**: Thick, low-layered clouds.
- **Cumulus**: Cotton-like clouds with vertical development due to convection.
- **Nimbus**: Dark, rain-bearing clouds with dense water droplets.
- **Combinations**: Cirrostratus, stratocumulus, cumulonimbus, nimbostratus.

Table 6: Cloud Types

Cloud Type	Altitude	Appearance	Characteristics
Cirrus	High	Thin, feathery	No precipitation
Stratus	Low	Thick, layered	Light drizzle possible
Cumulus	Variable	Cotton-like, puffy	Fair weather, vertical growth
Nimbus	Low	Dark, dense	Rain-bearing

5. Precipitation

Definition

Precipitation occurs when water droplets in clouds grow too heavy to resist gravity, falling as rain, snow, or hailstones.

Types of Precipitation

1. **Rainfall**: Water droplets falling from clouds.
2. **Snowfall**: Ice crystals in cold climates (below 0°C).
3. **Hailstones**: Layered ice pellets formed by repeated condensation in the atmosphere.

Types of Rainfall

1. **Orographic (Relief) Rainfall**:
   - Moisture-laden winds rise over mountains, cool, condense, and cause rain on windward slopes.
   - Leeward slopes receive little rain, forming **rain shadow regions** (e.g., Tamil Nadu during southwest monsoon).
2. **Convectional Rainfall**:
   - Caused by intense surface heating, leading to rising air, condensation, and afternoon showers (4 O'Clock rains).
3. **Cyclonic (Frontal) Rainfall**:
   - Occurs at fronts where warm and cold air masses meet, causing warm air to rise, cool, and condense.

Table 7: Types of Rainfall

Type	Cause	Characteristics
Orographic	Mountain barriers	Windward: heavy rain, Leeward: dry
Convection	Surface heating, rising air	Afternoon showers (4 O'Clock rains)
Cyclonic	Meeting of warm and cold air masses	Frontal rainfall, widespread

Extreme Rainfall Events

- **Torrential Rain**: Intense, short-duration rainfall causing flash floods and landslides.
- **Cloud Burst**: Rainfall exceeding 10 cm/hour, common in mountainous regions (e.g., Kavalappara, Mundakkai landslides in Kerala).

Extended Activities

1. **Temperature Monitoring**:
    - Use a maximum-minimum thermometer to record daily max/min temperatures.
    - Calculate diurnal range and daily mean temperature for display.
2. **Rainfall Measurement**:
    - Use a rain gauge to measure daily rainfall and create a bar diagram.
3. **Cloud Observation**:
    - Collect images of different cloud types using ICT and prepare a digital album.