

Water Vapour, Atmospheric Role, Greenhouse Effect, Significance

April 6, 2026 • vajiramandravi.com



Water Vapour is the gaseous form of water present in the atmosphere and is a highly variable component influencing weather and climate. It is produced through evaporation, boiling and sublimation processes and forms a key link in the hydrological cycle. Despite forming a small fraction of atmospheric volume, it plays a dominant role in regulating Earth's temperature and atmospheric processes.

Water Vapour

Water Vapour is a dynamic atmospheric component controlling heat balance, moisture distribution and weather formation processes across different climatic regions globally.

- **Abundance and Composition:** Water vapour is the most abundant greenhouse gas, accounting for nearly 95% of greenhouse gases. It contributes around 4% of air volume in warm tropics and less than 1% in cold polar and desert regions.
- **Distribution:** Its concentration decreases with altitude due to reduced temperature and pressure and also declines from equator towards poles due to lower evaporation and insolation levels.

- **Formation Processes:** Water vapour forms through evaporation of liquid water, boiling and sublimation of ice directly into vapour. Continuous exchange occurs between oceans, land and atmosphere through the **hydrological cycle**.
- **Physical Properties:** It is less dense than dry air, enabling convection currents that help in cloud formation. It is transparent but absorbs longwave radiation effectively, making it thermally significant.
- **Atmospheric Role:** It contributes to both stability and instability of air masses. Rising moist air leads to cloud formation, while its uneven distribution influences weather systems and precipitation patterns.
- **Variability:** Water vapour is a variable gas with rapid changes in concentration compared to other greenhouse gases. It continuously cycles through evaporation and condensation processes in the atmosphere.
- **Heating Impact:** Water vapour heats the atmosphere much more than aerosols. Aerosols, especially over the **Indo-Gangetic Plain**, are significant, but their heating effect is lower compared to water vapour.

Water Vapour Related Terms

Water Vapour is associated with several atmospheric processes and terms that define moisture content, phase changes and weather phenomena in the atmosphere.

- **Humidity:** **Humidity** refers to the amount of water vapour present in the air. It includes absolute humidity measured in grams per cubic metre and relative humidity, which indicates the percentage of moisture relative to maximum capacity at a given temperature.
- **Condensation:** Condensation is the process where water vapour changes into liquid water due to cooling. It leads to formation of clouds, fog and precipitation and releases latent heat, slightly reducing atmospheric temperature.
- **Precipitation:** Precipitation is the release of condensed moisture in forms like rain, snow, sleet, or drizzle. It occurs after condensation when water droplets or ice crystals grow large enough to fall under gravity.
- **Sublimation:** Sublimation is the direct conversion of ice into water vapour without passing through liquid phase. It is responsible for gradual disappearance of snow in cold regions even when temperatures remain below freezing.
- **Clouds:** Clouds are masses of tiny water droplets or ice crystals formed by condensation of water vapour. They vary in types such as cirrus, cumulus, stratus and nimbus based on altitude and structure.
- **Dew Point:** Dew point is the temperature at which air becomes fully saturated with water vapour, leading to condensation. At this point, relative humidity reaches 100% and further cooling results in dew or frost formation.
- **Evaporation:** Evaporation is the transformation of liquid water into vapour due to heat absorption. It increases with temperature, air movement and lower humidity and plays a crucial role in adding moisture to the atmosphere.

Water Vapour and Greenhouse Effect

Water Vapour plays a dominant role in Earth's greenhouse effect by absorbing radiation and amplifying warming through feedback mechanisms in the climate system.

- Water vapour is the most abundant greenhouse gas and is responsible for around half of Earth's greenhouse effect, making it the primary contributor to atmospheric heat retention.
- It absorbs longwave radiation emitted by Earth and re-radiates it back to the surface, acting like a blanket that prevents extreme temperature variations between day and night.
- Increase in gases like carbon dioxide and methane raises temperature, enhancing evaporation. This increases water vapour concentration, which further intensifies warming through a positive feedback mechanism loop.
- Without greenhouse gases, Earth's average temperature would be about -18°C instead of the current 15°C, highlighting the essential warming role of water vapour and related gases.
- Unlike CO₂, water vapour has a short atmospheric residence time due to continuous evaporation and condensation, but its concentration strongly depends on temperature changes.
- Research shows precipitable water vapour produces heating rates of about 0.94 and 0.96 K per day in **Himalayan regions** like Nainital and Hanle, significantly higher than aerosol effects.
- According to IPCC findings, atmospheric water vapour is increasing by 1-2% per decade and can rise by about 7% for every 1°C increase in temperature, amplifying climate warming.

Water Vapour Significance

Water Vapour is essential for maintaining Earth's climate system, driving weather processes and regulating energy balance through complex atmospheric interactions.

- **Hydrological Cycle Role:** It is a key component of the water cycle, linking evaporation, condensation and precipitation processes, ensuring continuous circulation of water between atmosphere, land and oceans.
- **Energy Transfer:** Water vapour transfers latent heat during phase changes, playing a crucial role in atmospheric thermodynamics and influencing weather systems such as cyclones and monsoons.
- **Climate Regulation:** It maintains Earth's energy balance by absorbing and emitting radiation, thereby stabilizing surface temperatures and preventing extreme climatic conditions.
- **Cloud Formation:** Condensation of water vapour leads to cloud formation, which reflects incoming solar radiation and absorbs terrestrial radiation, directly affecting Earth's radiation budget.
- **Extreme Weather Influence:** Increased water vapour enhances energy in the atmosphere, leading to intense storms, heavy rainfall and variability in weather patterns, including droughts and floods.
- **Regional Climate Impact:** Studies highlight its strong radiative effect in sensitive regions like the Himalayas, where it significantly influences local climate and atmospheric heating processes.
- **Environmental Balance:** Water vapour contributes to both wet and dry extremes by intensifying the global water cycle, making wet areas wetter and dry areas drier, thereby shaping global climatic patterns.

Source: <https://vajiramandravi.com/current-affairs/water-vapour/>

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