



# Impact of Climate Change on Earth's Rotational Dynamics

**For Prelims:** [Shift in Earth's Axis](#), [Climate change](#), [Leap second](#), [Precession](#), [Summer solstice](#), [Winter solstice](#), [vernal equinox](#)

**For Mains:** Earth's Rotation and Climate Change, Important Geophysical Phenomena

[Source: TH](#)

## Why in News?

Recent research highlights that [melting polar ice caps](#) due to [climate change](#) are causing the **Earth to spin more slowly**, leading to minute changes in the duration of a day.

- This phenomenon, while not immediately noticeable in daily lives, could have significant implications for technology reliant on precise timekeeping.

## How is Climate Change Affecting Earth's Rotation?

- **Melting Ice Caps:** The melting of polar ice sheets causes **water to flow towards the equator**, increasing the **Earth's oblateness and moment of inertia**.
  - Studies show that over the last two decades, the Earth's rotation has slowed by **approximately 1.3 milliseconds per century**.
    - The principle of **angular momentum** explains this effect, as polar ice melts and moves towards the equator, the **Earth's moment of inertia (mass distribution near the equator)** increases, causing its **rotational speed (velocity)** to decrease to conserve **angular momentum, resulting in a slower spin**.
    - Projections indicate that **if high emission scenarios persist**, this rate may **increase to 2.6 milliseconds per century**, making climate change a dominant factor in the Earth's rotational slowdown.
- **Axis Shifts:** The melting ice also [influences the Earth's axis of rotation](#), causing a slight but **measurable shift**. This movement, while small, is another indicator of how climate change impacts fundamental Earth processes.
  - The Earth's rotational axis is tilted relative to its geographic axis. This tilt causes a phenomenon known as the **Chandler wobble, which can affect rotational timing and stability**.

## Other Factors Affecting the Earth's Rotation Speed

- [Groundwater Depletion](#): The loss of groundwater can also alter mass distribution, contributing to changes in rotational dynamics.
- **Torsional Waves:** Convection currents in the Earth's outer core **generate torsional waves that impact the planet's rotation**. These waves oscillate through the Earth and can correlate with changes in the length of a day.
  - **Torsional waves are oscillating movements within the Earth's outer core** that twist

or rotate around the Earth's axis, influencing the planet's rotational speed.

- **Influence of Celestial Bodies:** Earth's rotation is influenced by the Moon and also other celestial bodies. About 1.4 billion years ago, the **Moon was much closer to Earth, resulting in significantly shorter days of just 18 hours and 41 minutes.** Today, a day is 24 hours, and it continues to **increase due to the Moon's gradual distancing.**
  - The gravitational pull of the **moon creates tidal forces that can affect the rotation of the Earth.** These tidal effects typically contribute to a gradual slowing of the planet's rotation over time.
- **Earth's Interior Dynamics:** Movements within the **Earth's mantle and core** can influence rotational speed. These include changes in the **tilt of the inner core or fluctuations in core density.**

## What are the Implications of Slowdown of Earth's Rotation?

- **Leap Seconds:** The rotation of the Earth affects the need for **leap seconds** to synchronize **atomic clocks with solar time.**
  - A slowdown in rotation may necessitate the addition of leap seconds, impacting systems reliant on precise timekeeping.
  - This adjustment can cause issues in technology, such as **network outages or discrepancies in data timestamps.**
- **Global Positioning Systems (GPS):** GPS satellites rely on precise time measurements. Variations in Earth's rotation can affect the **accuracy of GPS systems, potentially leading to minor errors in navigation** and location services.
- **Sea Level Rise:** The redistribution of mass from melting polar ice contributes to **changes in sea levels.** A slowdown in Earth's rotation can affect ocean currents, including the **Global Mean Ocean Circulation (GMOC),** potentially influencing regional climate patterns and exacerbating issues related to sea level rise.
  - GMOC is a large-scale system that moves water, heat, and nutrients across the world's oceans. It plays a vital role in regulating global climate by redistributing heat between regions.
- The redistribution of mass from melting polar ice contributes to **changes in sea levels.** A slowdown in Earth's rotation **can affect ocean currents and potentially influence regional climate patterns,** exacerbating issues related to sea level rise.
- **Earthquakes and Volcanic Activity:** Although less direct, changes in Earth's rotation and **mass distribution can influence tectonic processes.**
  - Variations in rotation might impact the **stress distribution in Earth's crust, potentially influencing seismic and volcanic activity.**
- **Climate Change Evidence:** This phenomenon is a stark reminder of climate change's extensive impact, **affecting not only weather patterns and sea levels** but also the very mechanics of our planet's rotation.

## What are the Motions of the Earth and Their Effects?

- **Earth's Rotation:** The Earth rotates around its axis, which is an imaginary line running from the North Pole to the South Pole. This **rotation occurs from west to east.**
  - It takes **approximately 24 hours to complete one full rotation,** resulting in the cycle of day and night.
  - **Effects:**
    - **Precession:** It involves the **wobble in Earth's rotational axis,** altering the direction it points relative to fixed stars.
      - **Precession** affects the timing and intensity of seasons. Currently, the Northern Hemisphere experiences winter during perihelion and summer during aphelion. In about 13,000 years, **these conditions will reverse, making Northern Hemisphere winters colder and summers hotter.**
    - **Coriolis Effect:** Rotation affects wind and ocean currents, causing them to turn right in the Northern Hemisphere and left in the Southern Hemisphere due to

the **Coriolis force**.

- **Time Zones:** Different regions experience **sunrise and sunset at different times**, necessitating the establishment of time zones.
- **Circle of Illumination:** The boundary **line dividing the day and night sides** of the Earth is known as the circle of illumination.
- **Revolution of the Earth:** Earth revolves around the **Sun in 365 days, 6 hours, 9 minutes at a speed of 29.29 to 30.29 km/s**. The extra 6 hours, 9 minutes results in an additional day every four years, designated as a [leap year](#) with 29th February.
  - **Effects:**
    - **Seasons:** The tilt of the Earth's axis relative to its orbit around the Sun results in varying angles of sunlight throughout the year, causing the four seasons: spring, summer, autumn, and winter.
    - **Solstices:** The [summer solstice](#) (around 21st June) and [winter solstice](#) (around 21st December) mark the longest and shortest days of the year, respectively.
    - **Equinoxes:** The [vernal equinox](#) (around 21st March) and [autumnal equinox](#) (around 23rd September) are characterised by nearly equal lengths of day and night.
    - **Axial Tilt:** Earth's axis is tilted at  $23.5^\circ$  from the vertical, perpendicular to its orbit around the sun. This axial tilt, also known as obliquity, creates an angle of  $66.5^\circ$  with the orbital plane. **This tilt, combined with Earth's revolution around the sun, affects the length of days and nights and is crucial for the changing seasons.**

**Drishti Mains Question:**

Q. Discuss the implications of climate change on Earth's rotational dynamics

**UPSC Civil Services Examination Previous Year Question (PYQ)**

**Prelims**

Q. Variations in the length of daytime and nighttime from season to season are due to (2013)

- (a) the earth's rotation on its axis
- (b) the earth's revolution around the sun in an elliptical manner
- (c) the latitudinal position of the place
- (d) revolution of the earth on a tilted axis

**Ans: (d)**