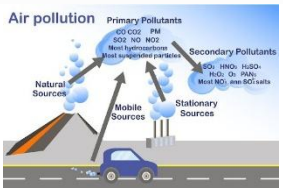
THE WORLD WEATHER ATTRIBUTION ANNUAL REPORT 2025

World Weather Attribution (WWA) is an international scientific collaboration that analyses how human-induced climate change influences extreme weather events such as heatwaves, floods, storms, droughts and wildfires.

Key findings (2025):

- **Heatwaves intensified sharply:** Heatwaves since 2015 have become significantly more intense, with some events **nearly 10 times more likely**, showing that even small increases in global temperature have outsized impacts.
- **Crossing the 1.5°C threshold:** The **three-year global average temperature** is projected to cross the **1.5°C limit for the first time**, despite 2025 being a La Niña year, underlining the strength of long-term warming trends.
- **Limits of adaptation reached:** Several extreme events revealed that **adaptation measures are no longer sufficient** for vulnerable populations, especially in the Global South.
- **Inequality in climate impacts:** Marginalised communities were systematically the worst affected, while **data gaps and weak climate models** limited analysis of many Global South events.
- **Extreme event profile (2025):**
  - 157 humanitarian-impact events identified
  - Heatwaves and floods (49 each) most frequent
  - Storms (38), wildfires (11), droughts (7)
  - Heatwaves emerged as the **deadliest hazard**, with tens of thousands of deaths in single events.

SECONDARY POLLUTANTS



- Secondary pollutants are not emitted directly from a source; instead, they are formed in the atmosphere when primary pollutants (gases) undergo chemical reactions influenced by sunlight, humidity, temperature and stagnation.
- Unlike visible local emissions, they often build up downwind and over time, making control more complex.

Major secondary pollutants:

- **Secondary particulate matter (PM2.5):** Ammonium sulfate, ammonium nitrate.
- **Ozone (O_3):** Formed from nitrogen oxides (NOx) and volatile organic compounds (VOCs) under sunlight.
- **Acids:** Sulfuric acid and nitric acid (contributors to acid rain).
- **Photochemical smog components:** Peroxyacetyl nitrates (PANs), nitrogen dioxide (NO_2).

How are secondary pollutants formed?

- **Emission of precursor gases:** SO_2 (coal-fired power plants, refineries), NOx (vehicles, power plants), ammonia (fertiliser use, livestock, sewage).
- **Atmospheric transformation:**
    1. SO_2 oxidises to sulfate → reacts with ammonia → ammonium sulfate.
    2. NOx oxidises to nitric acid → combines with ammonia → ammonium nitrate.

- **Favourable weather conditions:** High humidity, fog, low temperatures and low wind speeds accelerate these reactions, especially in winter, allowing particles to form within hours and remain airborne for days.

Implications:

- **Regional and transboundary impact:** Secondary aerosols can travel **hundreds of kilometres**, meaning Delhi's air quality is affected by emissions from coal-dominated states beyond NCR.
- **Severe winter smog:** Moist, stagnant winter conditions sharply increase secondary PM2.5, explaining sudden pollution spikes even when local sources are restricted.
- **Policy blind spots:** Focus on visible PM10 or local sources alone is insufficient; control of precursor gases (SO_2, NOx, NH_3) is crucial.
- **Health risks:** Fine secondary particles penetrate deep into lungs, increasing risks of respiratory and cardiovascular diseases.

NATIONAL TECHNOLOGY READINESS ASSESSMENT FRAMEWORK (NTRAF)

- The National Technology Readiness Assessment Framework (NTRAF) is a standardised, objective framework to assess the maturity of technologies from early laboratory research to full commercial deployment using 9 Technology Readiness Levels (TRLs).

Ministry / Department:

- Office of the Principal Scientific Adviser (OPSA) to the Government of India
- Developed in collaboration with the Confederation of Indian Industry (CII)

Aim:

- Establish a common language between researchers, investors and policymakers
- Enable evidence-based funding decisions under national R&D and mission-mode programmes
- Reduce the "Valley of Death" between TRL 4 and TRL 7 by de-risking promising deep-tech innovations

Key features:

- **TRL-based assessment:** Covers the full innovation cycle from Proof of Concept (TRL 1–3) to Prototype Development (TRL 4–6) and Operational Deployment (TRL 7–9).
- **Objectivity over subjectivity:** Uses structured, measurable checklists instead of narrative claims of readiness.
- **Global best practices, Indian context:** Adapted from international models (e.g., NASA TRLs) and customised for India's research and industrial ecosystem.
- **Sector-specific annexures:** Tailored assessment pathways for domains such as **Healthcare & Pharmaceuticals** and **Software**, recognising sectoral differences.
- **Self-assessment tool:** Enables researchers and startups to identify technical gaps before applying for funding.

Significance:

- Improves efficiency of public R&D spending by aligning funding with actual technology maturity.
- Boosts private sector confidence by providing validated, investment-ready readiness benchmarks.

COPPER

- Copper (Cu) is a naturally occurring metallic element (Atomic number: 29) known for its excellent electrical and thermal conductivity.
- It is among the oldest metals used by humans and is central to modern industrial, digital and green economies.

Characteristics of Copper:

- **Chemical characteristics:**
  - **Symbol:** Cu and **Atomic weight:** 63.546 amu
  - High resistance to corrosion and oxidation
  - Forms important alloys such as **brass (Cu+Zn)** and **bronze (Cu+Sn)**
- **Physical characteristics:**
  - Excellent **electrical and thermal conductivity** (second only to silver)
  - Ductile and malleable, enabling easy wiring and shaping
  - Naturally reddish-brown; one of the few coloured metals
- **Unique properties:**
  - **100% recyclable** without loss of quality
  - **Antimicrobial** in nature, useful in healthcare settings
  - Enhances **energy efficiency**, reducing CO_2 emissions over product life cycles

Applications of Copper:

- **Energy and power sector:** Used extensively in power grids, transformers, renewable energy systems, and battery storage.
- **Electric vehicles (EVs):** EVs use over twice the copper of conventional vehicles due to motors, batteries and wiring.
- **Digital and AI infrastructure:** Data centres, especially hyperscale AI facilities, require massive copper volumes for cooling and power transmission.
- **Construction and manufacturing:** Plumbing, roofing, industrial machinery and electronics rely heavily on copper.
- **Defence and healthcare:** Used in defence electronics, ammunition and antimicrobial medical surfaces.

India and Copper: Current Status

- India is recognised copper as a **critical mineral** under its resource strategy.
- Over **90% dependence on imported copper concentrate**

Major producers across globe: Chile, Peru, DR Congo, China, USA

KAIMUR WILDLIFE SANCTUARY

- Kaimur Wildlife Sanctuary is the **largest wildlife sanctuary in Bihar**, known for its rich biodiversity, forested plateaus and historical–archaeological heritage.

Located in: Kaimur and Rohtas districts of Bihar

- Situated in the **Kaimur Range**, covering parts of the **Kaimur Plateau and Rohtas Plateau.**

History:

- Established in 1979 as a wildlife sanctuary.
- Historically significant region with prehistoric cave paintings, megaliths, fossil sites, and forts such as Rohtasgarh Fort and Shergarh Fort.
- Long recognised for its ecological potential, with recent evidence of tiger movement prompting the tiger reserve proposal.

Key geological and physical features:

- **Plateaued landscape** of the Kaimur hills with steep escarpments and forested valleys
- **Numerous waterfalls:** Karkat, Telhar, Dhua Kund, Tutla Bhawani, Manjhar Kund, Kashish
- **Lakes and water bodies:** Anupam Lake, Karamchat Dam, Kohira Dam.
- **Forest types:** Tropical Dry Mixed Deciduous forests, Dry Sal forests, Boswellia forests, Dry Bamboo brakes

Significance:

- **Biodiversity hotspot**: Home to Bengal tiger, leopard, sloth bear, pangolin, sambar, chital, four-horned antelope, nilgai and over 70 resident bird species, with migratory birds from Central Asia in winter
- **Tiger conservation potential**: Large, contiguous forest landscape suitable for a viable tiger population and ecological corridors in eastern India
- **Ecological balance**: Helps maintain forest–river–plateau ecosystems of southwestern Bihar

GLACIER DISAPPEARANCE

- Glacier disappearance refers to the complete extinction of individual glaciers when their area falls below 0.01 sq km or their remaining ice volume drops below 1% of original levels, due to sustained warming and mass loss.

Key trends:

- **Mid-century peak:** Global glacier extinction is projected to peak between **2041–2055**, depending on warming levels.
- **Scale of loss:**
  - ~2,000 glaciers/year under **+1.5°C** warming
  - ~4,000 glaciers/year under **+4.0°C** warming
- **Regional variation:**
  - Small-glacier regions (European Alps, Caucasus) see early peaks before 2040.
  - Large-glacier regions (Greenland periphery, Arctic Canada) face delayed but prolonged loss.
- **High-Mountain Asia:** Hosts over one-third of global glaciers and strongly shapes the global mid-century extinction peak.

Key reasons:

- Rising global temperatures increasing melt rates beyond accumulation.
- Prevalence of small glaciers, which respond rapidly to warming.
- Delayed response of large glaciers, leading to sustained long-term loss.

- Insufficient climate mitigation, locking in future ice loss even if emissions stabilise later.

Relevance for UPSC Examination

- **GS Paper I – Physical Geography**
  - Glaciers, cryosphere dynamics, climate–landform interaction
  - Impact of glacier retreat on rivers and geomorphology
- **GS Paper III – Environment & Climate Change**
  - Climate change impacts, global warming thresholds (1.5°C vs 2°C+)
  - Water security, disaster risk (GLOFs), and ecosystem services
  - International climate negotiations and mitigation urgency