



**TATHASTU**  
Institute Of Civil Services

# DAILY CURRENT AFFAIRS

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S.NO.	TOPIC
1.	CHINA'S WARNING SHOTS WITH MINERALS THAT RUN THE WORLD
2.	TAKING STOCK OF GLOBAL NUCLEAR DISARMAMENT
3.	HOW GLOBAL WARMING AFFECTS FORECASTING

## CHINA'S WARNING SHOTS WITH MINERALS THAT RUN THE WORLD

## China's warning shots with minerals that run the world

**I**n August 15 this year, China announced its decision to restrict the export of antimony, a critical mineral used in strategic sectors such as defence, for military equipment such as missiles, infrared sensors, flares, ammunition, and even nuclear weapons. China's Commerce Ministry justified this move on the basis of "national security", adding that the measure would take effect from September 15. The declaration, however, was part of a series of countermeasures that began in August 2023,

### Moves and countermoves

When it comes to critical minerals, China is not only a stakeholder but also a leader. It dominates every supply chain segment – upstream, midstream, and downstream, covering mining, extraction, refining and processing. It enjoys a near-monopoly status, controlling 60% of rare earth production, 60% of critical minerals production and 80% of the processing worldwide. Therefore, any decision China makes has profound national security implications globally. The European Union and countries such as India, Japan and the United States are strategically vulnerable due to their dependence on critical minerals.

China's intimidating behaviour first gained international attention in the aftermath of the incident in 2010 when a Chinese trawler collided with Japanese Coast Guard boats, after which it halted the exports of rare earth elements to Japan. The event also led to serious global discussions about the world's dependence on China for strategic minerals. The recent antimony episode has only reaffirmed the western belief that China is willing to use critical minerals to coerce. All of this became evident in mid-2023 when China announced a set of restrictions on the exports of critical minerals with U.S. export control measures. In 2023, following the decision by the Netherlands to restrict the supply of semiconductor equipment, under pressure from



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the U.S., China announced curbs on the export of gallium and germanium, two critical minerals used in solar cells and computer chips. Similarly, again in 2023, after the U.S. announced export control on "advanced computing, semiconductors, and semiconductors manufacturing equipment", China reciprocated by curbing the export of "high-purity, high-hardness and high-intensity synthetic graphite material and natural flake graphite and its products", widely used in electric vehicle (EV) batteries, fuel cells, and nuclear reactors. These steps were primarily aimed at responding to U.S. actions and sending a strong signal that if pushed to the wall, China would not hesitate to weaponise the critical mineral supply chain. Apart from these two steps, China has reminded the U.S. of its monopoly and monopsony as a mineral power and buyer, exhibiting the importance of its critical minerals in developing the U.S.'s high technology and green energy sectors. China has also restricted the export of rare earth processing technologies in making rare earth magnets used in EVs, in addition to technologies used to extract and separate critical minerals, hamstringing the U.S.-led attempt to build an alternative supply chain.

### A hardening of foreign policy posture

Restricting access to strategic resources is a classic statecraft strategy, hitting the enemy's weak points, an example being the U.S. oil embargo against Japan in 1940. Therefore, this is expected from an aspiring great power such as China, which seeks to leverage its status as a mineral power. The difference in China's case is that this initially started as an act to intimidate countries. However, with recent countermeasures, critical minerals export controls have now become a part of China's foreign policy objectives. It has moved from the politicisation to the weaponisation stage. For two reasons, China has grown more comfortable using its mineral

resources as a political tool. First, Beijing is reminding the West of its strategic dependency on China by demonstrating its status as a mineral power and exerting control over the supply chain. Second, China is responding in like and believes that it is acceptable to take advantage of the situation to sabotage the West's critical mineral supply chain, which will hinder the development of its high-tech sectors and undermine their efforts to decouple and de-risk.

Those critical minerals utilised in dual-use applications are major targets in particular as they are needed in the building of the Virginia class submarine and the F-35 fighter aircraft, which require several hundred pounds of rare earth elements. This shows that the aggressive, reciprocal and coercive approach has taken over the cooperative and collaborative approach, one of China's two schools of thought. It signals that Chinese curbs via export control will only grow as ties with the West deteriorate. According to China's Natural Resource Minister Wang Guanghua, "China will push forward exploration, increase critical minerals capacity, and enhance mineral resources reserves over the next five years", thus displaying China's ambitions to leave no stone unturned.

### India's vulnerability

Like its Qusa partners, Australia, Japan and the U.S., **India remains vulnerable due to its strategic dependence on China.** New Delhi is heavily dependent on the imports of critical minerals such as lithium, nickel, cobalt and copper, which resulted in an import cost of around \$34,000 crore in FY23. It is estimated that India's hunger for minerals will only grow, and so will the import cost, further increasing India's vulnerability. Hence, this episode must act as a wake-up call for India and the policymakers who have been slow in taking precautionary measures such as having partnerships with like-minded countries and investing in developing alternative supply chains.

On August 15, 2024, China announced a restriction on the export of antimony, a critical mineral used in military equipment like missiles, infrared sensors, and nuclear weapons. The decision, taking effect from September 15, was justified by China's Commerce Ministry on grounds of "national security."

# Antimony

88% Production : CHINA.

others: Bolivia, Russia, Tajikistan.

semi metal (silvery, hard & brittle)  
uses: electronics → Semiconductors  
                                → Infrared detectors  
flame retardant materials.  
glass, pottery,



### What are Critical Minerals?

- ❖ A mineral is **critical** when the risk of supply shortage and associated impact on the economy is (relatively) higher than other raw materials.
- ❖ These minerals are **essential for economic development and national security**, and their lack of availability/ the concentration of extraction/ processing in a few geographical locations could potentially lead to **supply chain vulnerabilities**.
- ❖ These (such as lithium, graphite, cobalt, titanium, and rare earth elements) are essential for the advancement of many sectors, including **high-tech electronics, telecommunications, transport, and defence**.
- ❖ It forms part of multiple strategic value chains , including -
  - ☛ **Clean technologies** initiatives such as zero-emission vehicles, wind turbines, solar panels;
  - ☛ **Information and communication technologies**, including semiconductors; and
  - ☛ **Advanced manufacturing inputs and material** such as defence applications, permanent magnets, ceramics.

### Declaration of Critical Minerals:

- ❖ It is a dynamic process, and it can evolve over time as **new technologies, market dynamics, and geopolitical considerations emerge**.
- ❖ Different countries may have their own unique lists of critical minerals based on their specific circumstances and priorities.
- ❖ The **US has declared 50 minerals** critical in light of their role in national security or economic development.
- ❖ Japan has identified a set of **31 minerals as critical for their economy**.
- ❖ The **UK considers 18 minerals critical, EU (34) and Canada (31)**.

### Critical Minerals for India:

- ❖ **Expert Committee** under Ministry of Mines has identified a set of **30 critical minerals for India**.
- ❖ These are Antimony, Beryllium, Bismuth, Cobalt, Copper, Gallium, Germanium, Graphite, Hafnium, Indium, Lithium, Molybdenum, Niobium, Nickel, PGE, Phosphorous, Potash, REE, Rhenium, Silicon, Strontium, Tantalum, Tellurium, Tin, Titanium, Tungsten, Vanadium, Zirconium, Selenium and Cadmium.
- ❖ **Creation of Centre of Excellence for Critical Minerals (CECM)** in the Ministry of Mines is also recommended by the Committee.
- ❖ CECM will **periodically update the list of critical minerals for India** and notify the critical mineral strategy from time to time.

### What is the Significance of Critical Minerals for India?

- ❖ **Economic Development**
  - ☛ **High-Tech Industries:** Critical minerals are essential for sectors like electronics, telecommunications, transport, and defense.
  - ☛ **Green Technologies:** Key for solar panels, wind turbines, batteries, and electric vehicles.
  - ☛ **Job Creation:** Growth in these sectors can lead to increased employment, income generation, and innovation in India.





#### ❖ **National Security**

- ☛ **Defense Applications:** Vital for aerospace, nuclear, and space sectors, requiring reliable materials for extreme conditions.
- ☛ **Self-Reliance:** Securing a steady supply of critical minerals is crucial for India's defense preparedness.

#### ❖ **Environmental Sustainability**

- ☛ **Clean Energy Transition:** Essential for reducing reliance on fossil fuels and lowering greenhouse gas emissions.
- ☛ **Renewable Energy Goals:** Critical minerals support India's aim for 450 GW of renewable energy capacity by 2030.

#### ❖ **International Cooperation**

- ☛ **Diversifying Sources:** Collaborations help India reduce dependency on China and enhance mineral security.
- ☛ **Resilience:** Strengthening supply chains through international partnerships.

### Challenges for India Related to Critical Minerals:

- ❖ **Implications of the Russia-Ukraine Conflict:** Ongoing war affects supply chains for minerals like lithium, cobalt, and rare earth elements.
- ❖ **Limited Domestic Reserves:** India has restricted reserves of critical minerals, heavily relying on imports.
- ❖ **Vulnerability:** Dependence on foreign supplies exposes India to price fluctuations and geopolitical risks.
- ❖ **Increasing Demand for Minerals:** The manufacturing of renewable energy technologies and the transition to electric vehicles necessitate larger quantities of minerals such as **copper, manganese, zinc, lithium, cobalt, and rare earth elements**.
- ❖ **India's limited reserves and higher requirements make it reliant on foreign partners to meet domestic needs.**

#### **Background of Critical Mineral Control**

- ★ **China's Dominance in Critical Mineral Supply Chains:** China dominates the global supply chain for critical minerals, controlling 60% of rare earth production, 60% of critical minerals production, and 80% of processing. This gives it a near-monopoly status in the global market, with implications for national security across the world.
- ★ **Strategic Vulnerability of Other Countries:** Major economies like the European Union, India, Japan, and the U.S. are heavily reliant on China for critical minerals, making them strategically vulnerable.

### China's Shift to a Harder Foreign Policy Posture:

- ❖ **Politicization to Weaponization of Critical Minerals:** China's use of mineral export controls has evolved from a political tool to a weapon. Its strategic control over mineral resources is now a central part of its foreign policy. China's restrictions, aimed at weakening the West's critical mineral supply chains, highlight its intent to sabotage the technological advancement of Western nations.







- ❖ **Targeting Dual-Use Minerals:** China's focus on minerals with dual-use applications, such as those used in the Virginia-class submarine and F-35 fighter aircraft, demonstrates its aggressive posture in undermining Western defense capabilities.
- ❖ **China's Expansion Plans:** According to Chinese Natural Resource Minister Wang Guanghua, China plans to increase critical mineral capacity and reserves in the next five years, reinforcing its goal to tighten its grip on global mineral supply chains.

### Historical Moves and Countermoves by China

- ❖ **The 2010 Rare Earth Export Ban to Japan:** China's influence on critical minerals gained international attention after a 2010 incident with Japan, where it halted rare earth exports following a collision between a Chinese trawler and Japanese Coast Guard boats. This highlighted global dependence on China's mineral supplies.
- ❖ **Recent Export Restrictions on Critical Minerals (2023):**
  - ☛ In 2023, China introduced restrictions on gallium and germanium exports, two minerals vital for semiconductors, after the Netherlands limited the supply of semiconductor equipment under U.S. pressure.
  - ☛ China also curtailed the export of synthetic graphite and natural flake graphite, essential for EV batteries and nuclear reactors, in response to U.S. export controls on advanced technologies.

### India's Strategic Vulnerability

- ❖ **India's Dependence on Critical Minerals:** Like other Quad nations (Australia, Japan, U.S.), India relies heavily on China for critical minerals like lithium, nickel, cobalt, and copper. In FY23, India's import bill for these minerals was ₹34,000 crore, reflecting its significant dependency.
- ❖ **Need for Strategic Partnerships and Supply Chain Diversification:** This situation serves as a wake-up call for India to take precautionary measures by fostering partnerships with like-minded countries and investing in alternative supply chains. Failure to act could further exacerbate India's strategic vulnerability in the global minerals market.

### Conclusion

- ❖ China's control over critical minerals gives it significant leverage over global supply chains, affecting national security, technological development, and defense capabilities worldwide. As ties between China and the West deteriorate, the export restrictions on key minerals will likely increase, pushing countries like India to rethink their strategies for securing critical resources.



## TAKING STOCK OF GLOBAL NUCLEAR DISARMAMENT

# Taking stock of global nuclear disarmament

In the United Nations calendar, September 26 is the International Day for the Total Elimination of Nuclear Weapons. This year's General Assembly agenda includes a session on the Treaty on the Prohibition of Nuclear Weapons (TPNW), or the Ban Treaty, as distinguished from the Treaty on the Non-Proliferation of Nuclear Weapons, NPT. It will be a chance to take stock at a time when the UN is bitterly divided – over the war in Ukraine; over the Israel-Palestine conflict; and in responding to accelerating climate change and other related inequalities. Nuclear possession – threats or their use – threads through all these divisions. How the countries, including India, that have stayed out of the TPNW respond to the discussions will therefore matter greatly. If they allow the treaty's supporters to continue their efforts in expanding the Ban Treaty's footprint, the goal of the treaty – total nuclear disarmament – will be boosted. But if the treaty is undermined, nuclear weapons will become more entrenched, and the shadow of nuclear use will lengthen.

### What the Ban Treaty says

The TPNW, which came into force in 2021, has once again divided the nuclear haves and their allies, and the nuclear abstainers. It is extensive in its prohibitions: signatories are barred from developing, testing, producing, stockpiling, transferring, using, deploying, keeping, or threatening to use any nuclear explosive devices. Thus, it goes beyond the NPT, which bans proliferation, but only promises to consider disarmament, and is silent on nuclear use, including deterrence.

The TPNW arose from a collection of UN agencies and NGOs coming together under the Humanitarian Initiative to highlight the lasting and pernicious consequences of nuclear weapons, covering development, deployment, and use on people, their health, and



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the environment. Discussions moved to the UN, with the General Assembly mandated to convene a conference in 2017 to negotiate a legally binding instrument to prohibit nuclear weapons, leading towards their total elimination.

Thus the only treaty that legally bans all nuclear weapons and their use was adopted, but without the participation of nuclear weapons states and their allies, despite these states reiterating their commitment to nuclear disarmament. All of them registered their opposition to the treaty during its negotiation and when it came into force, thereby establishing themselves as 'persistent objectors' who could not be bound by the treaty's provisions and who do not consider it as contributing to customary international law.

Yet, resistance to the treaty amongst the allies of the nuclear haves may not be unyielding. Recent nuclear developments, such as Russia's nuclear sabre-rattling, China's rising weapons count, Iran's continuing uranium enrichment, and North Korea's tests and threats have renewed discussions on nuclear risks. A group of former leaders and officials of NATO states published an open letter urging their countries to join the treaty and thereby "place nuclear weapons on the same legal footing as chemical and biological weapons". Among the former Prime Ministers and other officials are two former NATO Secretaries-General and a former UN Secretary General. These are significant voices.

As of July 2024, the TPNW had 70 states parties. Another 27 had signed but not yet ratified it. This support from 97 states represents almost 50% of states and parties bound to the legal framework on weapons of mass destruction. Their efforts could precipitate a process of questioning several beliefs about nuclear deterrence.

Assumptions about deterrence have already been tested since Russia invaded Ukraine in 2022.

Despite China and Russia's 'friendship without limits', Chinese President Xi Jinping made public his opposition to Russian President Vladimir Putin's nuclear sabre-rattling. The U.S. signalled that nuclear adventurism would be met with a commensurate response; it did not specify that such a response would necessarily be nuclear. Washington also did not change its nuclear preparation level as a result. In other words, nuclear threats were countered without an overtly nuclear response, thereby contradicting one of the justifications for continued nuclear possession.

### Treading a fine line

Sitting out a treaty is not the same as undermining it. India has not signed the NPT. New Delhi perceives the NPT to be discriminatory, believes that it does not promote disarmament, and is contrary to India's interests. However, India has arguably benefited from the NPT's curbing of the spread of nuclear weapons. It has never actively undermined the treaty – rhetoric and abstention notwithstanding.

Other nuclear possessors could similarly tread a fine line of staying away from the TPNW while not challenging it. The TPNW has weaknesses, chiefly, the lack of a robust enforcement mechanism, but its normative potential in delegitimising nuclear possession and deterrence should not be underestimated. If the treaty eventually succeeds in relegating nuclear weapons to the same pariah status as chemical and biological weapons, that will make us all much safer. This will certainly not happen during the General Assembly session or any time soon. The norm against nuclear use has solidified over decades; nuclear testing is gradually being delegitimised by the Comprehensive Test Ban Treaty, even if it has not come into force. The Ban Treaty could similarly start an honest discussion about the utility and effectiveness of nuclear weapons.

Provisions of the Treaty

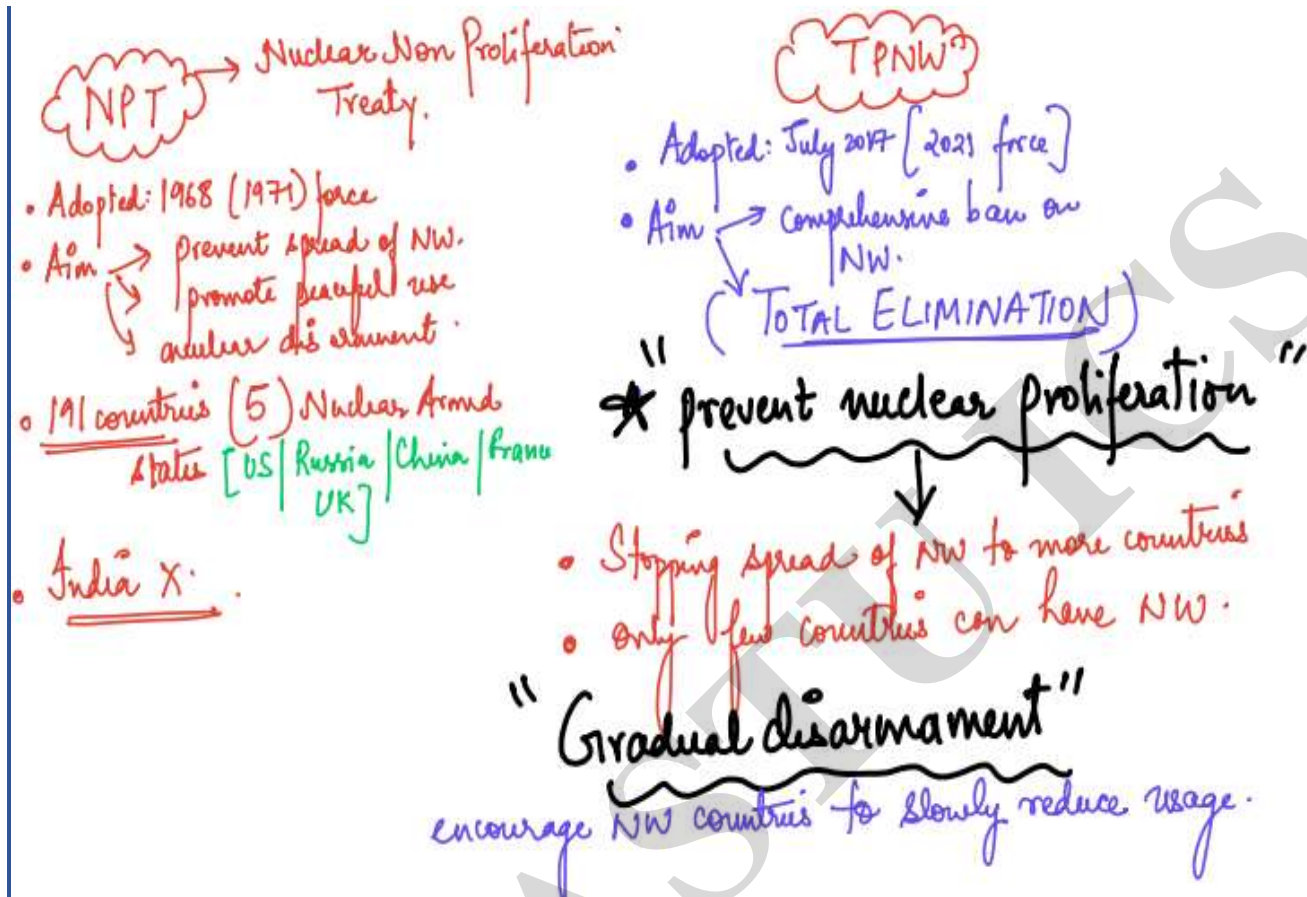
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The Ban Treaty could start an honest discussion about the utility and effectiveness of nuclear weapons

### Context:

- ❖ September 26 marks the International Day for the Total Elimination of Nuclear Weapons, highlighting the ongoing global discussions around nuclear disarmament.





#### Treaty on the Prohibition of Nuclear Weapons:

- ❖ The TPNW is a legally binding international treaty that prohibits all activities related to nuclear weapons.
- ❖ **Objective:** To achieve the complete elimination of nuclear weapons and establish a global norm against their use.

#### Key Provisions:

- ❖ **Comprehensive Ban:**
  - Prohibits the development, testing, production, acquisition, possession, stockpiling, transfer, use, and threat of use of nuclear weapons.
- ❖ **Obligations for States Parties:**
  - States must take measures towards the total elimination of nuclear weapons.
  - Engage in international cooperation and assistance regarding nuclear disarmament.
- ❖ **Non-Discrimination:**
  - All states, regardless of their nuclear status, are bound by the treaty's provisions.
- ❖ **Monitoring and Reporting:**
  - States parties are encouraged to report on their implementation of the treaty.
- ❖ **Origin :**
  - The TPNW originated from a movement emphasizing the humanitarian consequences of nuclear weapons, led by a coalition of non-nuclear states and civil society organizations.





- ☛ In December 2016, the UN General Assembly adopted a resolution to negotiate a legally binding instrument to prohibit nuclear weapons.
- ☛ The treaty was adopted on July 7, 2017, at the United Nations Headquarters.
- ❖ **Current Membership:**
  - ☛ As of July 2024, there are 70 states parties that have ratified the treaty, and an additional 27 states have signed but not yet ratified it.
- ❖ **Notable Supporters:**
  - ☛ Many non-nuclear weapon states, including countries from Africa, Latin America, and the Pacific Islands, actively support the TPNW.
- ❖ **Nuclear-Armed States:**
  - ☛ Nuclear-armed states (e.g., the U.S., Russia, China, France, the UK) and their allies have not signed the TPNW, viewing it as ineffective in addressing security concerns.
- ❖ **Entry into Force:**
  - ☛ The TPNW entered into force on January 22, 2021, following the deposit of the 50th instrument of ratification

### Current Global Landscape

- ❖ **Division Among States:**
  - Creates a divide between nuclear-armed nations and abstainers.
  - Many nuclear states oppose the TPNW.
  - Rising nuclear threats have led some NATO officials to advocate for joining the treaty.
- ❖ **Support for the TPNW:**
  - As of July 2024, 70 states are parties to the TPNW; 27 have signed but not ratified.
  - Nearly 50% of states engaged in weapons of mass destruction treaties support the TPNW.
  - Challenges traditional beliefs around nuclear deterrence.

### Geopolitical Tensions and Deterrence

- ❖ **Recent Developments:**
  - Events like Russia's nuclear threats and North Korea's activities rekindle discussions on nuclear risks.
  - Prominent figures advocate treating nuclear weapons like chemical and biological weapons.
- ❖ **Testing Deterrence Assumptions:**
  - The Ukraine conflict tests the effectiveness of nuclear deterrence.
  - Non-nuclear responses to threats contradict justifications for nuclear arsenals.

### India's Position

- ❖ **Nuclear Stance:**
  - India has not signed the NPT, viewing it as discriminatory and against national interests.
  - Benefits from the NPT in limiting nuclear proliferation but remains neutral towards the TPNW.
- ❖ **Treading the Line:**
  - Other nuclear states may navigate their positions on the TPNW without undermining it.
  - The TPNW, despite lacking enforcement mechanisms, has the potential to challenge the legitimacy of nuclear weapons.







## Conclusion

### ❖ Future Implications:

- The TPNW could redefine the status of nuclear weapons, similar to chemical and biological weapons, enhancing global safety.
- Current UN discussions may not lead to immediate changes but can foster meaningful dialogue on nuclear weapons' role and utility.

## Attempt it!

**Q.1 With reference to Treaty on the Prohibition of Nuclear Weapons (TPNW) consider the following statements:**

1. It is a UN sponsored treaty which prohibit states from participating in any nuclear weapons-related activities.
2. India is not a signatory of this treaty.
3. It is the first legally binding international agreement that prohibits the use of nuclear weapons.

**Which of the statements given above are correct?**

- [A] 1 and 2 only  
[B] 2 and 3 only  
[C] 1 and 3 only  
[D] 1, 2 and 3

**Answer: (D)**

### ❖ Notes:

1. Statement 1: It is a UN sponsored treaty that contains provisions which prohibit states from participating in any nuclear weapons-related activities.
2. Statement 2: India is not a signatory of this treaty.
3. Statement 3: It is the first legally binding international agreement that prohibits the use of nuclear weapons.





## HOW GLOBAL WARMING AFFECTS FORECASTING

# How global warming affects forecasting

Existing models cannot reproduce monsoon trends in the past half century and are considered unreliable for the future. Meteorologists will need to figure out if the predictability of natural modes such as hurricanes, El Niño, La Niña, and the Indian Ocean Dipole will decrease as the warming is relentless, if not accelerating

### FULL CONTEXT

Raghu Murtugudde

**W**ith the record warming of 2023-2024, we are getting a clearer picture of what global warming does. The medley of extremes strewn across the planet has covered the gamut from deadly heatwaves to devastating cyclones and floods, from droughts to wildfires.

According to some estimates, the world has already crossed the 1.5°C warming threshold (that is, the earth's average surface temperature has increased by more than 1.5°C over the pre-industrial average). The caveat is that global temperatures are an estimate produced from a combination of data and climate models. As the 1.5°C limit is part of a demand by the Alliance of Small Island Developing States, scientists have built models to predict what environmental disturbances crossing this threshold could invite. However, and more importantly, it is not yet clear how long the warming has to remain above the threshold for the projected impacts to materialise.

The spectacular show that nature has put up during 2023-2024 is also a stark reminder that we are far from able to predict the weather and the climate with the requisite skills and spatial-temporal scales to manage disasters effectively. The loss of lives, property, and infrastructure continue to traumatise humanity, especially the poor, who remain very vulnerable to extreme events.

### 2024 versus our predictions

Meteorologists predicted the 2023 El Niño as early as in the spring of that year, which is remarkable. But the level of warming during 2023-2024 has caught them, and the public, by surprise because it was much higher than expected from the addition of the so-called mini-global warming by the El Niño to the ongoing background warming. We speculate that water vapour thrown up by the underwater volcano Hunga Tonga-Hunga Ha'apai during 2022 and CO<sub>2</sub> emitted by the wildfires exacerbated the warming.

The 2023 monsoon was deficit but it did not qualify as an El Niño drought, the reasons for which researchers are yet to diagnose. Predictions from nearly all major weather centres earlier promised a strong La Niña in late 2024. Now this seems less likely. Perhaps nature has another googly in waiting. Similarly, weather forecasts have called for the most intense hurricane season in decades but this has yet to step beyond the normal.

The monsoon season has evolved erratically and has once again left many parts of India dry while producing devastating floods and landslides in many others. Now 2024 is set to emerge as a monsoon-surplus year; yet it can hardly be called a typical La Niña monsoon.

The cyclone season in the North Indian Ocean has also been weaker than what one would expect from a La Niña year. While some weather centres were very gung-ho about an Indian Ocean Dipole (IOD) emerging in the Indian Ocean, it has played trout so far.

To be clear: this is not a litany of grievances against predictions. It is an expression of caution: that we will be remiss if we don't learn all the lessons from this extraordinary period of warming vis-à-vis their implications for the future of predictions and for the climate projections we keep producing.

### Predictions may pose challenges

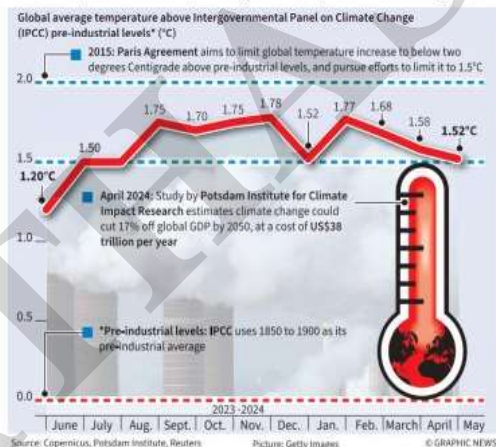
A quote often attributed to physicist Niels Bohr is apt here: prediction is difficult,



**Blazing heat:** Residents collect drinking water from a tanker amid a water crisis in Delhi, on a hot summer day in New Delhi on June 6. SHIV KUMAR PUSHPAKAR

## Global warming

The global average temperature for the last year was the highest ever documented, at 1.63°C above pre-industrial levels, according to the EU's Copernicus Climate Change Service



especially if it's about the future. Weather and climate predictions frequently remind us of this. We do learn our lessons and continue to improve the models and the observational networks we need to produce better predictions.

But what if predictions continue to become more difficult with global warming? Put another way, are all the misfires we have had this year just a coincidence or are they a portent of what is to come?

Many studies have reported the impacts of warming on hurricanes, monsoons, El Niños, La Niñas, the IOD, etc. But the bigger question is: if the world is already warmer than 1.5°C, are there any conclusions we can draw about how all these natural variabilities have responded thus far?

Unfortunately, the period of warming we have experienced of late hasn't been long enough for us to confidently say what changes we can already detect in the dominant climate modes. The models are

amazing in their ability to reproduce all natural modes given just the energy coming from the Sun at the top of the atmosphere. But they are not perfect: model answers often disagree; even the same model can produce different answers depending on its configuration.

For example, existing models cannot reproduce monsoon trends in the past half century and are considered unreliable for the future – they can only make skillful forecasts for the present. We have also not sorted out yet whether monsoon patterns are variable from decade to decade – patterns that we may currently be calling trends. We also don't know whether climate change can extend the timescale of natural decadal variability and make it a real trend. We need to address these critical questions to advance our understanding of processes and to make better predictions.

### Predicting the future of predictions

There is plenty of hope for the future of

predictions, but as the adage goes, hope is not a strategy. We have our work cut out for us. We obviously need to continue to improve our models and build on the fact that models are already capable of amazing feats, with some deficiencies. We need to figure out if the predictability of natural modes such as hurricanes, El Niño, La Niña, IOD, etc. will decrease as the warming is relentless, if not accelerating. Well-trained and enthusiastic scientists toil to improve models and data networks and bring the latest technologies, including artificial intelligence, machine learning, and sensor-fit drones, to bear on this pressing challenge.

We have plenty of reasons for optimism vis-à-vis reliable and actionable early warnings at the hyperlocal scale.

### Lessons from 2023

We currently make climate projections using the same or similar models that project future climate based on how the concentrations of specific emissions increase, how populations grow, and what mitigation policies we implement, among other factors. For the coming decade or two, projection uncertainties depend on the model uncertainties themselves plus natural variabilities in a warming world.

The uncertainties in projections beyond a couple of decades are related entirely to the imagined scenarios that drive model simulations.

The inability to capture the response of natural modes to warming will continue to haunt all projections. It will be necessary to translate improved weather and climate predictions to improve the models.

The best strategy to ensure projections are reliable may be to restrict ourselves to just a decade or two into the future. The ongoing geopolitical perturbations and their cascades into markets, economies, and societies underscore the difficulty of imagining the future beyond a decade or so as well.

Overall, it is critical that we assess the costs and benefits of the considerable human, financial, and computational resources for climate projections out to 2100.

Raghu Murtugudde is professor, IIT Bombay, and emeritus professor, University of Maryland.

### THE GIST

Meteorologists predicted the 2023 El Niño as early as in the spring of that year, which is remarkable. But the level of warming during 2023-2024 has caught them, and the public, by surprise because it was much higher than expected from the addition of the so-called mini-global warming by the El Niño to the ongoing background warming.

According to some estimates, the world has already crossed the 1.5°C warming threshold (that is, the earth's average surface temperature has increased by more than 1.5°C over the pre-industrial average).

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#### Existing models and monsoon trends:

- ❖ Current models struggle to reproduce monsoon trends over the past 50 years.
- ❖ As a result, predictions for future monsoon behavior are considered unreliable.
- ❖ Meteorologists need to assess how natural phenomena like hurricanes, El Niño, La Niña, and the Indian Ocean Dipole (IOD) will behave as global warming intensifies.

#### Global warming in 2023-2024:

- ❖ The record warming of 2023-2024 provides a clearer picture of the impacts of global warming.
- ❖ A variety of extreme weather events have been observed, including heatwaves, cyclones, floods, droughts, and wildfires.

#### Crossing the 1.5°C threshold:

- ❖ It is estimated that global temperatures have surpassed the 1.5°C warming threshold (above preindustrial levels).
- ❖ The duration of this warming above the threshold is unclear, and the full extent of environmental impacts remains uncertain.

#### Future predictions and challenges:

- ❖ Predicting the future behavior of climate modes (hurricanes, El Niño, etc.) will be a challenge as global warming continues.
- ❖ Improved models and observational networks, including technologies like AI and machine learning, are needed to improve predictions.

#### Uncertainties in long-term projections:

- ❖ Climate projections for the next decade or two are uncertain due to model limitations and natural variabilities.
- ❖ Projections beyond 20 years become even more speculative, based on imagined future scenarios.

