World’s Largest Iceberg A23a Disappears, Highlighting Rapid Changes in Antarctic Cryosphere and Global Climate Dynamics

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Recent Developments:

- The **world's largest iceberg, A23a**, has completely disintegrated after nearly **40 years**, with its remaining fragments becoming too small to be detected by satellites.
- **A23a** calved from the **Filchner–Ronne Ice Shelf** in **1986**, remained grounded on the seabed for more than three decades, started drifting in **2020**, and eventually fragmented in the warmer waters of the **Southern Ocean**.
- Although the disappearance of a single iceberg is a natural event, scientists consider **A23a** an important case study for understanding the evolving **Antarctic Cryosphere**, its interaction with the **Southern Ocean**, and its implications for the global climate system.

About Iceberg A23a:

Origin, Characteristics:

- **A23a** originated from the **Filchner–Ronne Ice Shelf** in **West Antarctica** after calving in **1986**.
- At its peak, the iceberg covered approximately **4,000 sq km**, nearly twice the size of **London**, and weighed about **one trillion tonnes**.
- The iceberg remained grounded on the continental shelf for decades before drifting northward under the influence of **ocean currents**, **winds**, and **warmer waters**.
- Progressive **wave action**, **basal melting**, and **fragmentation** eventually caused the iceberg to disappear from satellite monitoring.

Cryosphere:

Meaning, Components:

- The **Cryosphere** refers to all regions of the Earth where water exists in **solid form** throughout the year or seasonally.
- Major components include:
- **Ice Sheets**, **Glaciers**, **Ice Shelves**.
- **Sea Ice**, **Icebergs**, **Snow Cover**.
- **Permafrost**, **Seasonally Frozen Ground**.

Importance of the Antarctic Cryosphere:

- **Antarctica** contains the **largest ice sheet** on Earth, covering nearly **14 million sq km**.
- The Antarctic Ice Sheet stores around **90% of the world's ice** and nearly **70% of global freshwater**.

- Complete melting of the Antarctic Ice Sheet could raise the **global mean sea level** by approximately **58 metres**.
- The Antarctic Cryosphere plays a crucial role in regulating the **Earth's energy balance**, **global ocean circulation**, and **climate system**.

Major Factors Driving Changes in the Antarctic Cryosphere:

Rising Ocean Temperatures:

- Relatively warmer ocean water reaches the underside of floating **ice shelves**, causing **basal melting**.
- Basal melting weakens ice shelves even where atmospheric temperatures remain below freezing.
- Weakening of ice shelves reduces their ability to restrain inland glaciers.

Atmospheric Warming:

- Increasing air temperatures accelerate:
- **Surface melting**, **Meltwater pond formation**, **Hydrofracturing**.
- Meltwater entering surface cracks expands fractures and accelerates ice-shelf disintegration.

Changing Ocean Currents, Wind Systems:

- Variations in **Southern Ocean circulation** transport warmer water towards Antarctic ice shelves.
- Changing wind patterns modify the movement of floating sea ice and influence glacier stability.
- Shifts in the **Antarctic Circumpolar Current** affect iceberg drift and melting.

Iceberg Calving, Wave Action:

- **Iceberg calving** is a natural process within the Antarctic ice cycle.
- Warmer waters, weakened ice structures, and persistent wave action can accelerate iceberg fragmentation.
- **A23a** demonstrates how long-stable icebergs may rapidly disintegrate after entering warmer oceanic environments.

Changes in Snowfall, Mass Balance:

- The Antarctic Ice Sheet gains mass primarily through **snowfall**.
- Ice loss occurs through **iceberg calving**, **surface melting**, and **ice discharge into the ocean**.
- Overall ice-sheet stability depends upon the balance between **accumulation** and **mass loss**.

Importance of the Antarctic Cryosphere:

Climate Regulation:

- Extensive snow and ice surfaces reflect a significant proportion of incoming **solar radiation**.
- High reflectivity helps maintain Earth's global energy balance and moderates planetary temperatures.

Freshwater Reservoir:

- Antarctica stores the largest reserve of frozen freshwater on Earth.
- The Antarctic Ice Sheet represents one of the most significant long-term freshwater resources globally.

Global Ocean Circulation:

- Formation of **Antarctic Bottom Water** drives the global **Thermohaline Circulation**.
- This circulation regulates long-term heat, oxygen, and nutrient transport across the world's oceans.

Impacts of Changes in the Antarctic Cryosphere:

Changes in Ocean Circulation:

- Freshwater released from melting ice reduces ocean **salinity** and **water density**.
- Altered density affects **deep-water formation** and may weaken global ocean circulation patterns.
- Changes in **Antarctic Bottom Water** formation can influence climate far beyond the polar regions.

Sea-Level Rise, Coastal Vulnerability:

- Accelerated ice-sheet mass loss contributes to rising global sea levels.
- Sea-level rise increases:
- **Coastal flooding**, **Shoreline erosion**, **Saltwater intrusion**, **Damage to coastal infrastructure**.
- In India, vulnerable regions include **Mumbai**, **Kolkata**, **Sundarbans**, and several low-lying coastal ecosystems.

Marine Ecosystems:

- Reduction in sea ice alters habitats for:
- **Krill**, **Penguins**, **Seals**, **Whales**, and other marine organisms.
- Changes in prey availability influence breeding success, migration patterns, and food-web stability.

Ice–Albedo Feedback:

- Ice and snow possess high **albedo**, reflecting most incoming sunlight.
- Declining ice cover reduces surface reflectivity, increasing heat absorption and accelerating further warming.
- This creates a **positive climate feedback loop**, amplifying global warming.

Global Significance of Ice Shelves:

Role of Ice Shelves:

- Floating ice shelves act as **buttresses**, slowing the movement of land-based glaciers towards the ocean.
- Collapse of ice shelves does **not directly raise sea level**, but it accelerates glacier discharge, contributing indirectly to long-term sea-level rise.
- Continuous monitoring of ice shelves is therefore essential for climate forecasting.

India's Antarctic and Polar Research Initiatives:

Indian Antarctic Programme:

- India launched the **Indian Antarctic Programme** in **1981**.
- The programme has established three research stations:
- **Dakshin Gangotri (1983)**.
- **Maitri (1988)**.
- **Bharati (2012)**.
- At present, **Maitri** and **Bharati** remain operational research stations.

National Centre for Polar and Ocean Research:

- The **National Centre for Polar and Ocean Research (NCPOR)** functions under the **Ministry of Earth Sciences**.
- It serves as the nodal institution for implementing India's Antarctic, Arctic, and Southern Ocean research programmes.

- The institution is headquartered at **Goa** and coordinates annual scientific expeditions to Antarctica.

India and the Antarctic Treaty System:

- India became a signatory to the **Antarctic Treaty** in **1983**.
- India is also a Consultative Party with decision-making rights under the **Antarctic Treaty System**.
- The Treaty promotes:
- **Peaceful use of Antarctica**, **Scientific cooperation**, **Environmental protection**, **Prohibition of military activities**.

Related International Frameworks:

Antarctic Treaty System:

- Signed in **1959** and entered into force in **1961**.
- Antarctica shall be used exclusively for **peaceful purposes** and **scientific research**.
- Territorial claims remain frozen while the Treaty remains in force.

Protocol on Environmental Protection to the Antarctic Treaty (Madrid Protocol):

- Adopted in **1991** and enforced from **1998**.
- Declares Antarctica a **"Natural Reserve, devoted to Peace and Science."**
- Prohibits **mineral resource activities** except for scientific research.

Significance for India:

Climate Security, Coastal Management:

- Antarctic ice loss directly influences long-term sea-level rise affecting India's extensive coastline.
- Understanding Antarctic processes improves coastal adaptation and disaster preparedness strategies.

Monsoon Research, Oceanography:

- Southern Ocean processes influence global ocean circulation and climate variability.
- Improved Antarctic observations contribute to better understanding of long-term climate variability affecting the **Indian Monsoon**.

UPSC Value Addition:

Important Terms:

- **Cryosphere**.
- **Ice Shelf**.
- **Iceberg Calving**.
- **Basal Melting**.
- **Hydrofracturing**.
- **Ice–Albedo Feedback**.
- **Antarctic Bottom Water**.
- **Thermohaline Circulation**.

Important Organisations:

- **National Centre for Polar and Ocean Research**.
- **Ministry of Earth Sciences**.

- **Scientific Committee on Antarctic Research (SCAR)**.
- **Council of Managers of National Antarctic Programs (COMNAP)**.

Related International Agreements:

- **Antarctic Treaty (1959)**.
- **Madrid Protocol (1991)**