Topic 2: Earth Systems Science

1. Definition and Overview

Earth System Science (ESS) is the study of the Earth as an integrated system composed of interacting physical, chemical, biological, and human processes.
It emphasizes the **interconnectivity** among the atmosphere, hydrosphere, biosphere, geosphere, and anthroposphere (human systems).

Aspect	Description
Core Idea	Earth operates as a single, self-regulating system.
Components	Geosphere, Hydrosphere, Atmosphere, Biosphere, Anthroposphere
Purpose	Understanding global changes and predicting environmental impacts.
Approach	Interdisciplinary, combining geology, climatology, oceanography, ecology, and human sciences.

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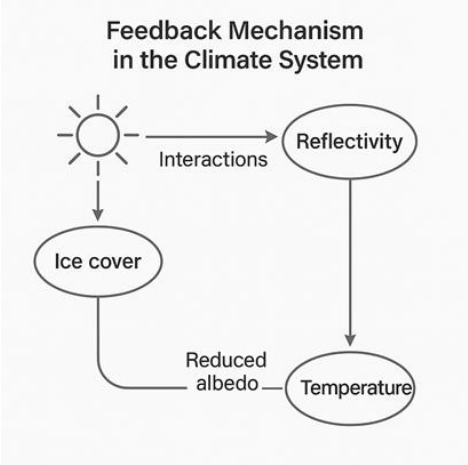
2. Evolution of Earth System Science

Period	Development
Pre-1970s	Individual study of Earth's components (e.g., geology, meteorology, oceanography).
1970s–1990s	NASA's Earth observation programs (e.g., Landsat) revealed global interconnections.
2000s–Present	Focus on **climate change**, **human impacts**, and **sustainability modeling**.

3. Major Subsystems of the Earth System

Subsystem	Key Processes	Examples
Atmosphere	Weather, climate regulation, gas exchange	Greenhouse effect, monsoon
Hydrosphere	Water circulation, ocean currents	Water cycle, Gulf Stream
Geosphere	Tectonics, volcanism, rock formation	Earthquakes, mountain building
Biosphere	Photosynthesis, respiration, nutrient cycling	Carbon sequestration
Anthroposphere	Human activities, technology, urbanization	Deforestation, fossil fuel use

Diagram 1: The Earth System and Its Interactions



4. System Interactions and Feedbacks

Earth's systems interact through the exchange of energy and matter, creating **feedback mechanisms**.

Type of Feedback	Definition	Example
Positive Feedback	Amplifies change	Melting ice reduces albedo → increases warming
Negative Feedback	Counteracts change	Increased CO_2 → more plant growth → CO_2 absorption
Dynamic Equilibrium	System maintains balance over time	Global temperature stabilization

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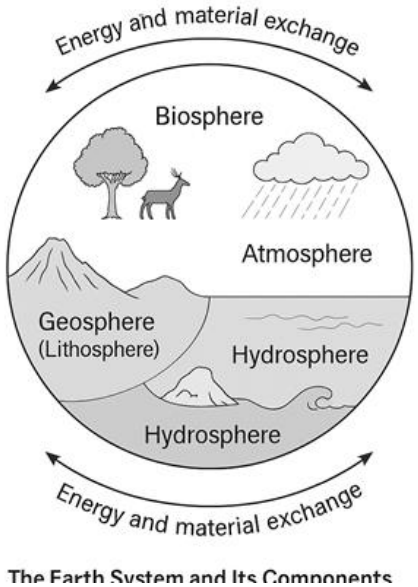
Diagram 2: Feedback Mechanism in the Climate System



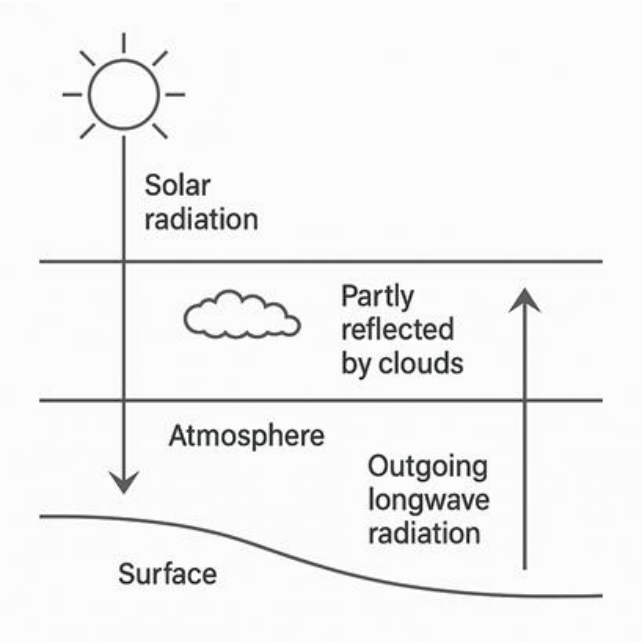
The Earth System and Its Components

5. The Earth's Energy Balance

The Earth system is powered mainly by **solar energy**, balanced by energy emitted back into space.

Input / Output	Source / Pathway
Incoming Energy	Solar radiation (shortwave)
Absorbed Energy	By land, water, and atmosphere
Outgoing Energy	Longwave infrared radiation
Imbalance Effect	Causes climate change

Diagram 3: Simplified Global Energy Budget



6. Earth as a Closed System

- **Closed with respect to matter** (minimal exchange with space)
- **Open with respect to energy** (continuous solar input and radiation output)

System Type	Exchange Type	Example
Open System	Energy & matter	River
Closed System	Energy only	Earth
Isolated System	None	Theoretical concept (universe as a whole)

7. Example Case Studies

Case Study	System Focus	Outcome
Amazon Rainforest	Biosphere–Atmosphere	Deforestation reduces evapotranspiration and rainfall
Arctic Ice Melt	Cryosphere–Atmosphere	Positive feedback leading to warming
Coral Reefs Decline	Ocean–Biosphere	Ocean acidification affects biodiversity

8. Summary

- Earth System Science integrates multiple disciplines to understand **Earth as a whole**.
- Interactions among subsystems lead to **complex feedbacks** controlling climate and life.
- Human activity has become a **dominant driver** — marking the **Anthropocene** epoch.