Earth's Energy Budget and Climate Forcing

Earth's Energy Budget

The **Earth's energy budget** refers to the balance between incoming solar radiation and outgoing terrestrial radiation. It governs global temperatures and climate systems.

1. **Incoming Solar Radiation (Shortwave):**
   - ~340 W/m² reaches Earth's atmosphere.
   - **30% reflected** (albedo) by clouds, ice, and surfaces.
   - **70% absorbed** (19% by atmosphere, 51% by land/oceans).
2. **Outgoing Terrestrial Radiation (Longwave):**
   - Earth emits infrared radiation (heat).
   - **Greenhouse gases (GHGs)** trap some heat, maintaining ~15°C avg. temperature.
   - Imbalance (more absorbed than emitted) → **global warming**.

Climate Forcing (Radiative Forcing)

Climate forcing measures perturbations to Earth's energy balance, expressed in **Watts/m²**.

1. **Natural Forcings:**
   - **Solar variability** (minor impact, ~0.1 W/m²).
   - **Volcanic aerosols** (cooling effect by reflecting sunlight).
2. **Anthropogenic Forcings:**
   - **CO_2, CH_4, N_2O** (major warming: +2.3 W/m² since 1750).
   - **Aerosols** (cooling: -0.5 W/m²).
   - **Land-use changes** (albedo modification).

Schematic Diagram: Earth's Energy Budget & Climate Forcing

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|          SUN                |
|   (340 W/m² Solar Radiation) |
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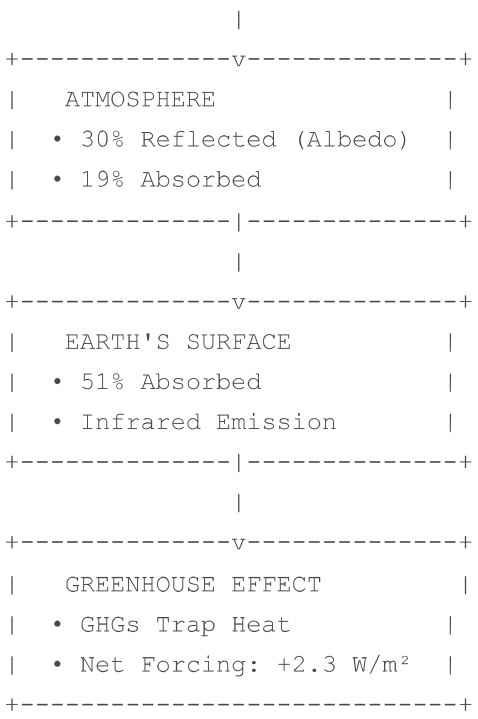

Key Implications:

- **Positive Forcing** (e.g., CO_2) → **Warming**.
- **Negative Forcing** (e.g., aerosols) → **Cooling**.
- Current **net anthropogenic forcing**: ~**+1.6 W/m²** (IPCC 2021), driving climate change.

Applications in Climate Science

1. **Predicting Global Warming:** Energy budget models project temperature rise.
2. **Policy Making:** Guides IPCC reports and emission reduction targets.
3. **Extreme Weather Analysis:** Links forcing to hurricanes, droughts.