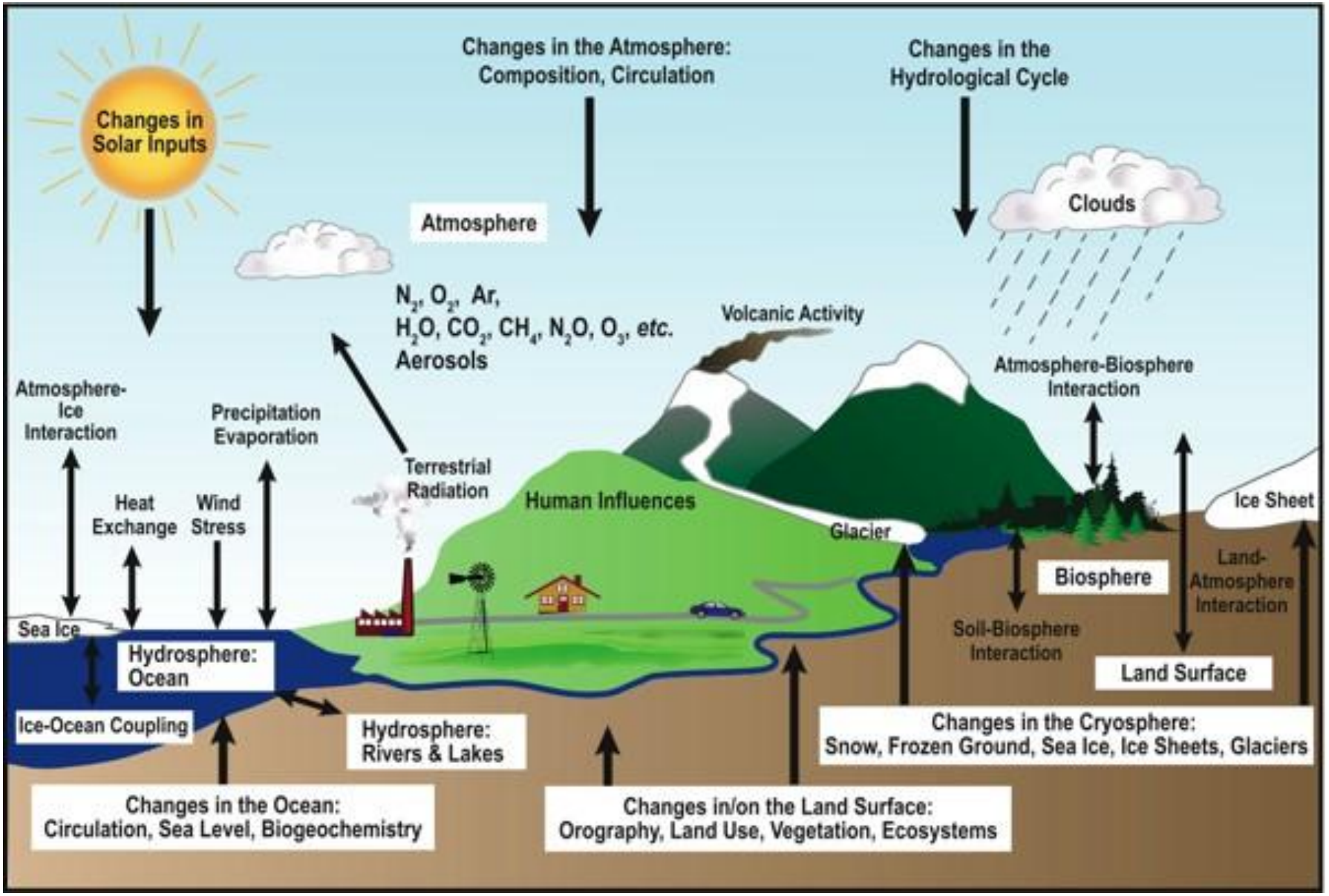
The Earth as an Integrated System


Changes in Solar Inputs
Changes in the Atmosphere: Composition, Circulation
Changes in the Hydrological Cycle
Atmosphere
Clouds
N_2, O_2, Ar,
H_2O, CO_2, CH_4, N_2O, O_3, *etc.*
Aerosols
Volcanic Activity
Atmosphere-Biosphere Interaction
Atmosphere-Ice Interaction
Precipitation Evaporation
Terrestrial Radiation
Heat Exchange
Wind Stress
Human Influences
Glacier
Ice Sheet
Biosphere
Land-Atmosphere Interaction
Sea Ice
Soil-Biosphere Interaction
Hydrosphere: Ocean
Land Surface
Ice-Ocean Coupling
Hydrosphere: Rivers & Lakes
Changes in the Cryosphere: Snow, Frozen Ground, Sea Ice, Ice Sheets, Glaciers
Changes in the Ocean: Circulation, Sea Level, Biogeochemistry
Changes in/on the Land Surface: Orography, Land Use, Vegetation, Ecosystems

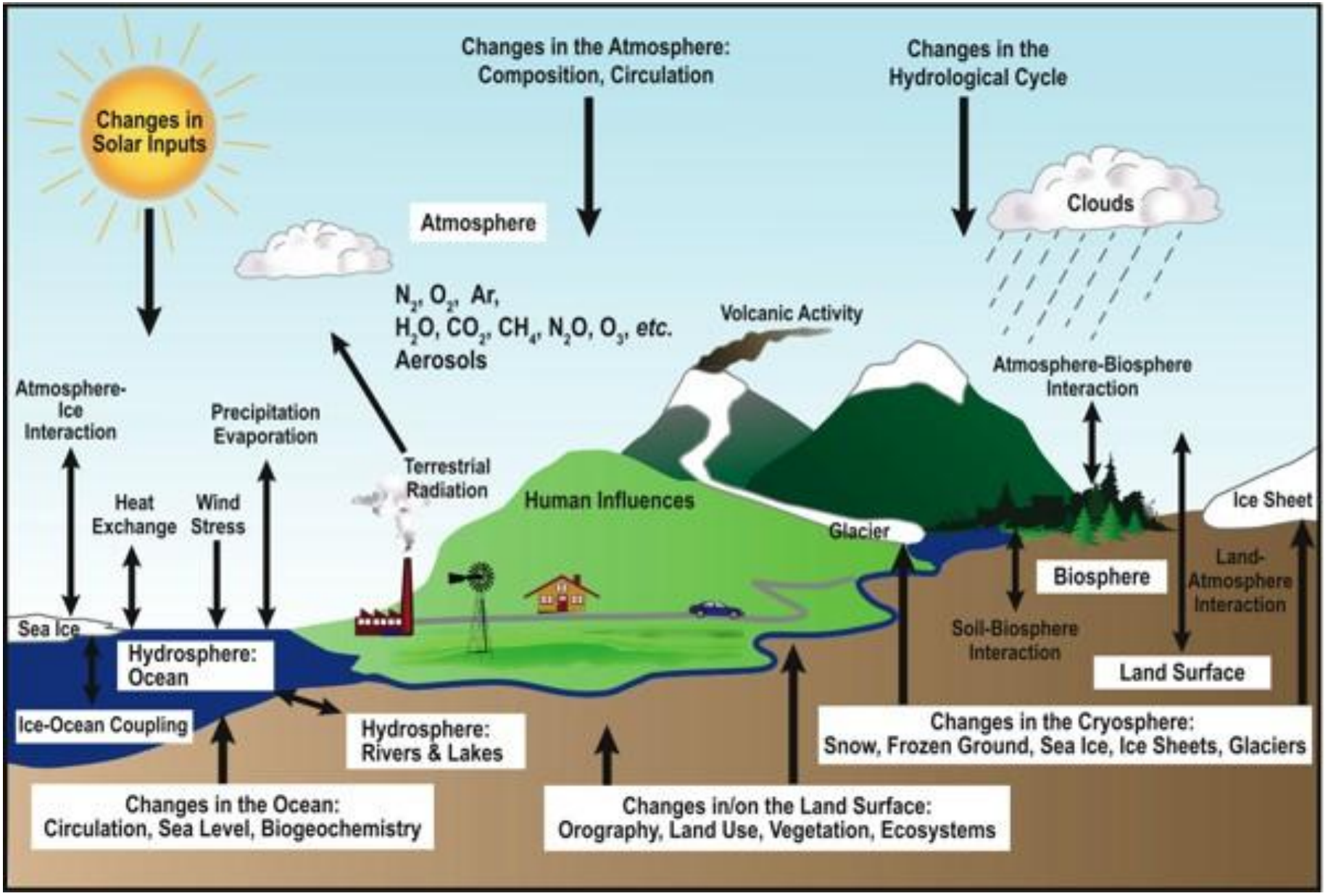
When we think of the earth as an integrated system, there are 5 key words we want to remember.

Components

Word #1

Components

Constituent parts that make up the earth system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Components

Components

In simple language there are 5 parts that make up the earth system

atmosphere

land surface

ocean

ice

Vegetation/living things

Atmosphere

Components

- 78% nitrogen and 21% oxygen
- Other elements make up < 1%
- Air is never completely dry and water can be up to 4% of its volume.
- Residence time of water vapor in the atmosphere is ~10 days.
- It's comprised of many different layers, including stratosphere, troposphere, ionosphere, etc.

Ocean

Components

- Oceans cover about 70% of the Earth's surface.
- The oceans contain roughly 97% of the Earth's water supply.
- They moderate the Earth's temperature by absorbing incoming solar radiation (stored as heat energy).
- The always-moving ocean currents distribute this heat energy around the globe.
- 94% of life on Earth is aquatic.

Land surface

Components

- There is less land than there is water.
- Close to 40% of the Earth's land surface is presently used for cropland and pasture.
- The planetary surface undergoes reshaping over geological time periods because of tectonics and erosion.

Vegetation

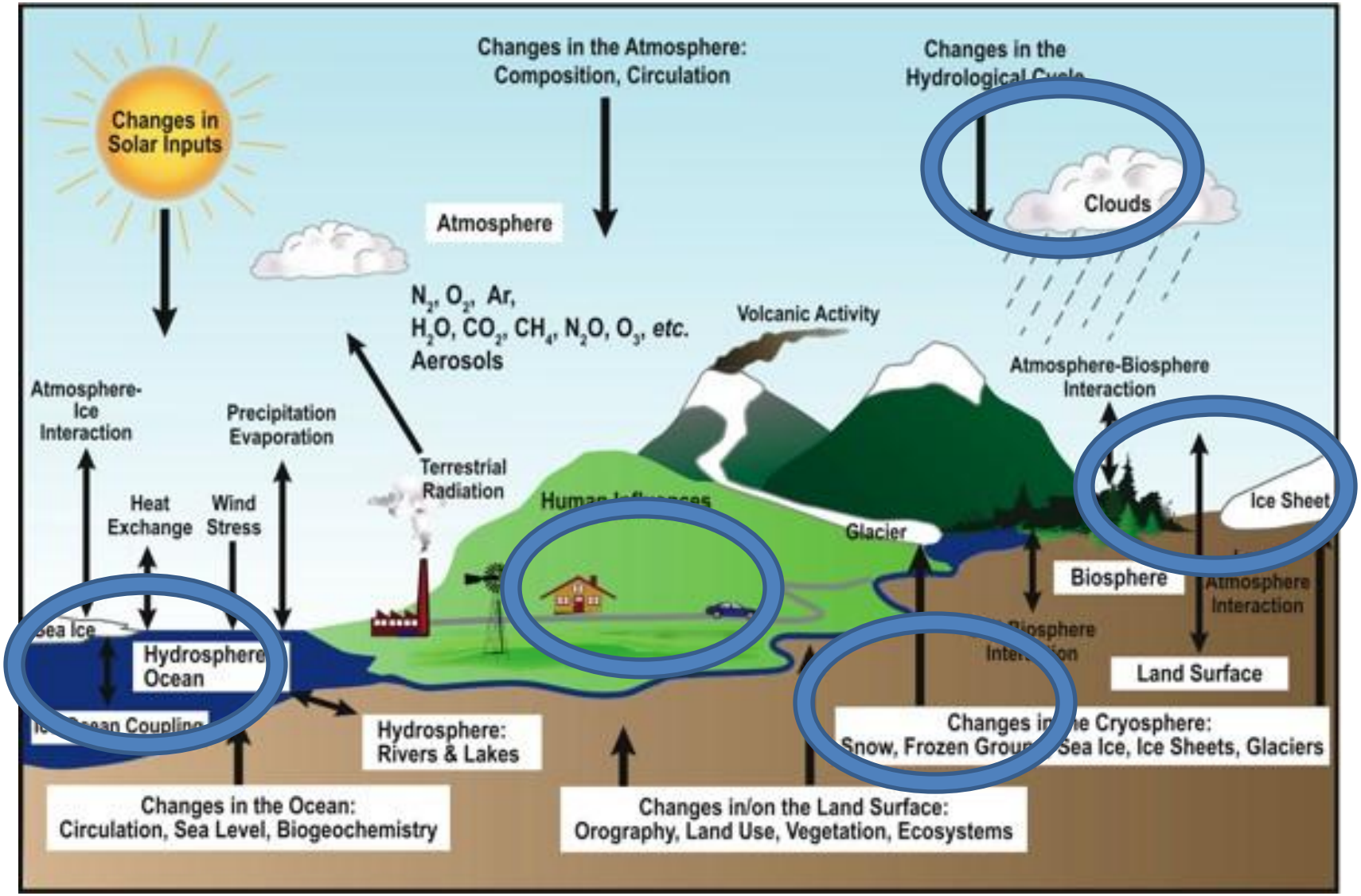
Components

- Is very climate dependent.
- Trees are the longest living organisms on the planet and one of the earth's greatest natural resources.
- Vegetation keep our air supply clean, reduce noise pollution, improve water quality, help prevent erosion, provide food and building materials, create shade, and improve aesthetics

Ice

Components

- The cryosphere includes all forms of frozen water on the Earth's land or sea surfaces
- Seasonal snow cover is the largest component of the cryosphere.
- Glaciers and ice sheets cover about 10 percent of the Earth's land area.
- All continents except Australia bear ice in the form of mountain glaciers, ice sheets, or ice caps.
- Glaciers and ice sheets store about 75 percent of the world's freshwater.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Components

Cycles

Word #2

Cycles

The differing components are connected are through Cycles.

Hydrological Cycle

Components

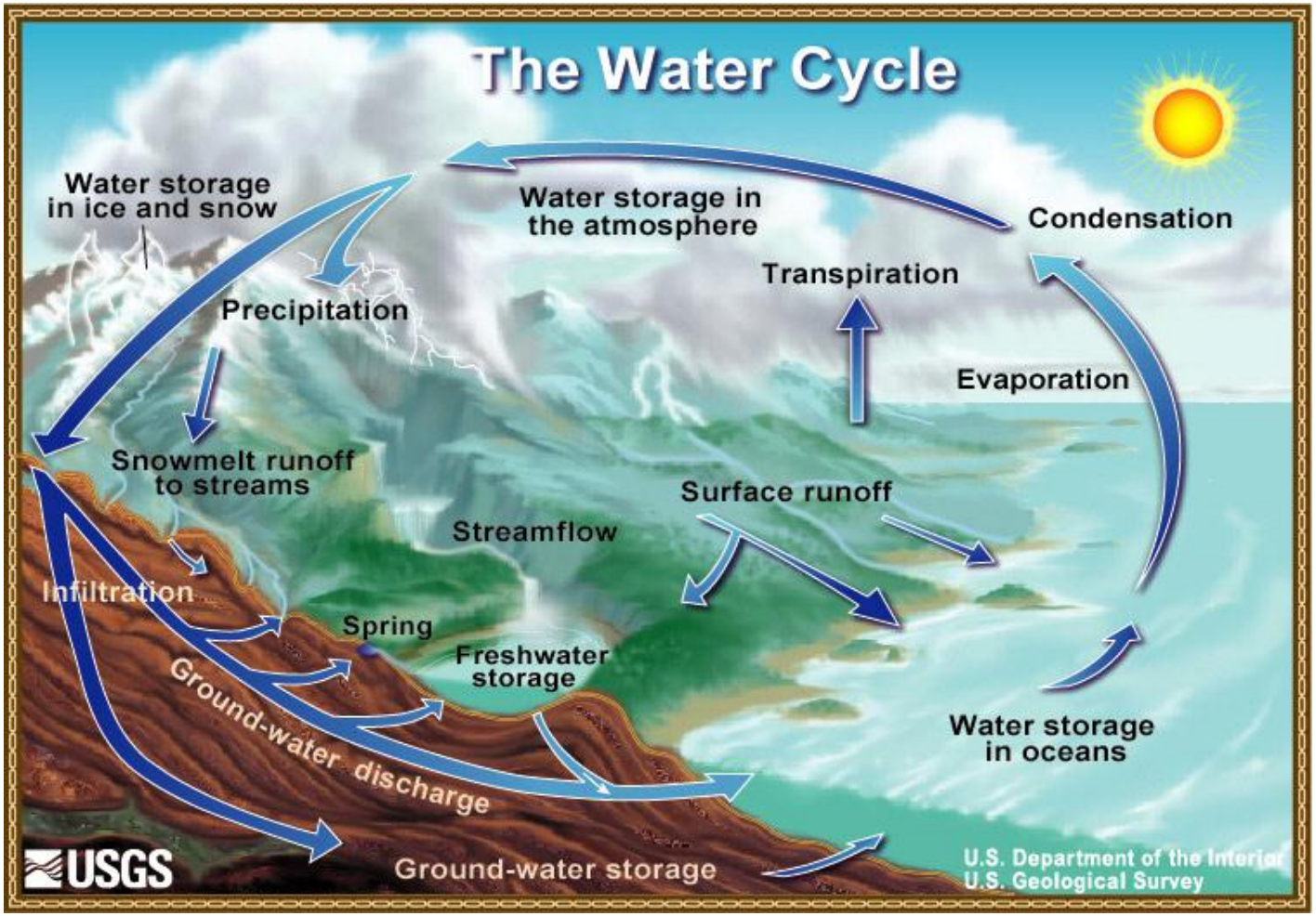
Cycles

Water never leaves the Earth. It is constantly being cycled through the atmosphere, ocean, and land. This process, known as the **water cycle**, is driven by energy from the sun. The water cycle is crucial to the existence of life on our planet.

Hydrological Cycle

Components

Cycles



Hydrological Cycle

Components

Cycles

The sun heats up liquid water and changes it to a gas by the process of evaporation. Water that evaporates from Earth's oceans, lakes, rivers, and moist soil rises up into the atmosphere.

The process of evaporation from plants is called transpiration.

Hydrological Cycle

Components

Cycles

As water (in the form of gas) rises higher in the atmosphere, it starts to cool and become a liquid again. This process is called condensation. When a large amount of water vapor condenses, it results in the formation of clouds.

Hydrological Cycle

Components

Cycles

When the water in the clouds gets too heavy, the water falls back to the earth. This is called precipitation.

When rain falls on the land, some of the water is absorbed into the ground forming pockets of water called groundwater. Most groundwater eventually returns to the ocean. Other precipitation runs directly into streams or rivers. Water that collects in rivers, streams, and oceans is called runoff.

Carbon Cycle

Components

Cycles

There are four primary reservoirs for carbon. It can be in the atmosphere. It can be in land-living animals and plants or the by-products of these. It can be in the oceans, including in animals and plants living there. Finally, it can be in the sediments, including in fossil fuels.

The different places carbon can be are connected by pathways of exchange. This is all referred to as the carbon cycle.

Carbon Cycle

Components

Cycles

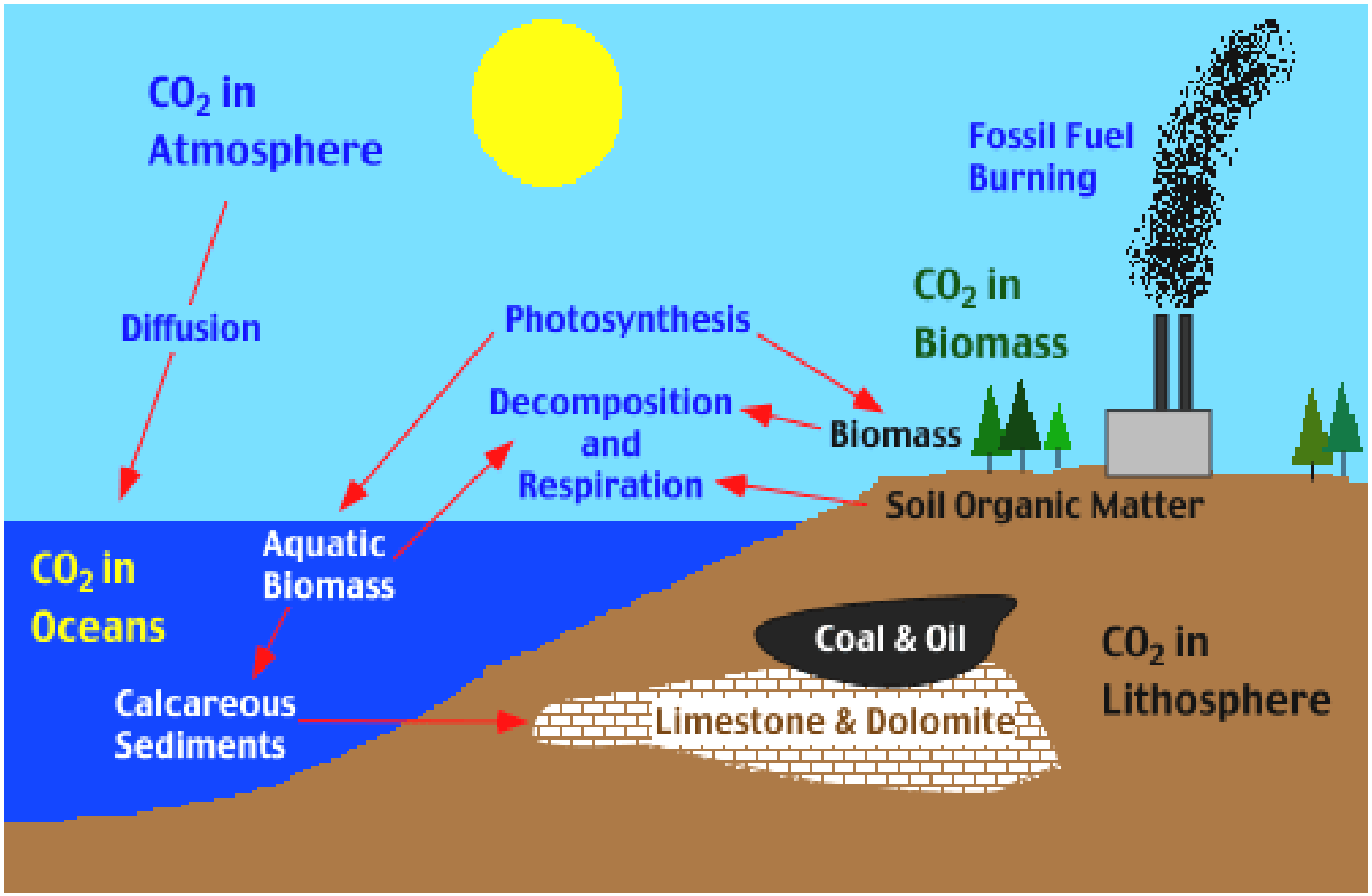
Estimated size of C reservoirs (Billions of metric tons)

• Atmosphere	• 578 (as of 1700) to 766 (in 1999)
• Soil organic matter	• 1500 to 1600
• Ocean	• 38,000 to 40,000
• Marine sediments & sedimentary rocks	• 66,000,000 to 100,000,000
• Terrestrial plants	• 540 to 610
• Fossil fuel deposits	• 4000

Carbon Cycle

Components

Cycles



Carbon Cycle

Components

Cycles

•Plants remove carbon from the atmosphere and from sea water by photosynthesis.

•Animals eat the plants and release the carbon back into the environment again through respiration.

•Burning and decay are two other processes that move carbon from living organisms to the non-living environment and the atmosphere.

Carbon Cycle

Components

Cycles

•Carbon from living and dead biological organisms are moved into the atmosphere in two forms. As CO_2 and as methane. Both are greenhouse gases.

•Burning fossil fuels release carbon into the atmosphere.

Components

Cycles

Balance

Word #3

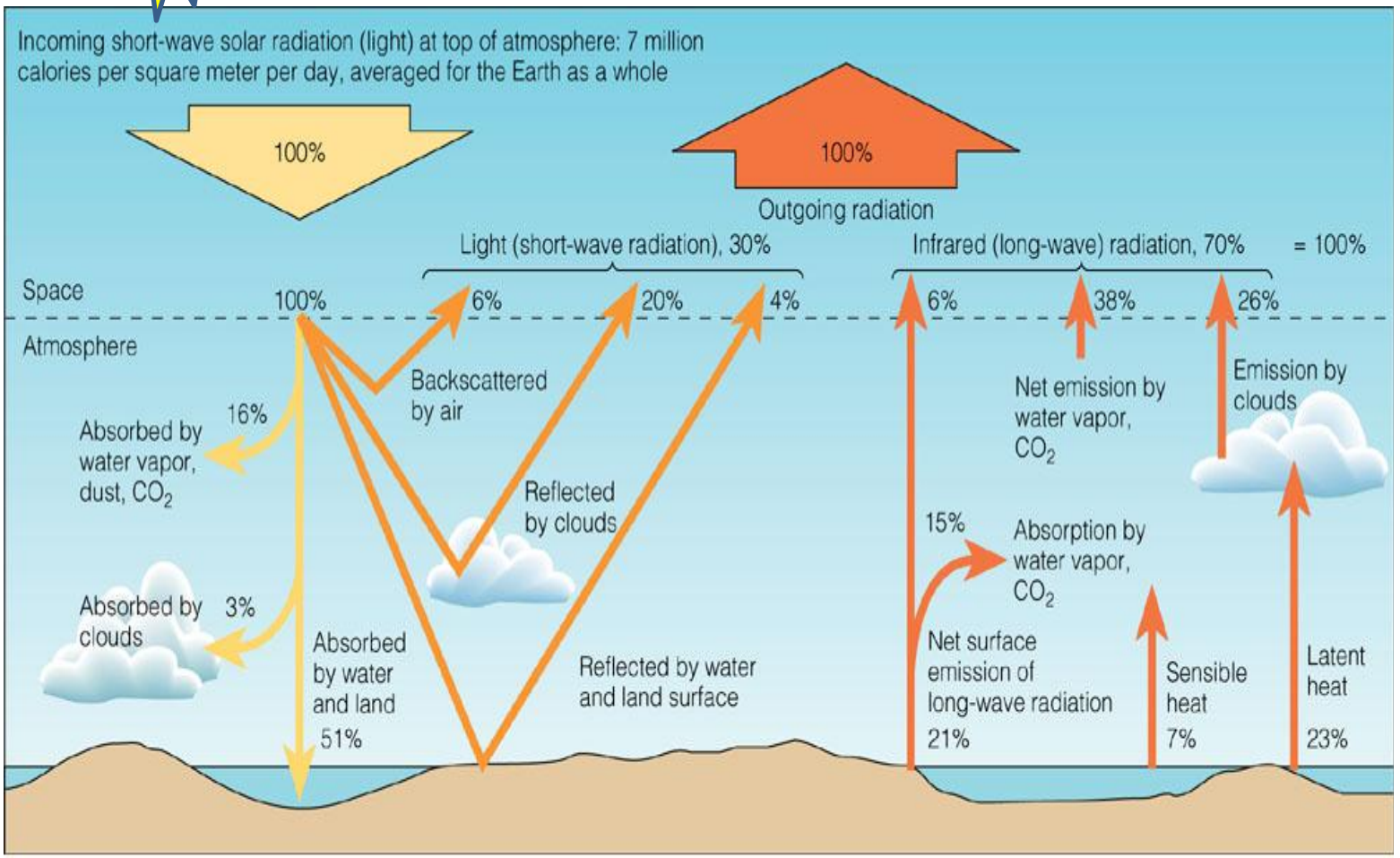
Balance

We can talk about balance with respect to a number of earth's characteristics e.g. Energy.

Balance occurs when incoming is matched by outgoing. Cycles are an important part if achieving balance through exchange.

Energy Balance

- Components
- Cycles
- Balance



Energy Balance

Components

Cycles

Balance

- Input and outflow of heat comprise the earth's heat budget
- We assume thermal equilibrium (Earth is not getting warmer or cooler) or the overall heat budget of the earth is balanced

Components

Cycles

Balance

Forcing

Word #4

Forcing and Response

Changes in the components of the atmosphere can occur over time (short timescales and long timescales) due to external factors. The external factors are called *forcings*. The change is called a *response*.

Forcing and Response

Components

Cycles

Balance

Forcing

A forcing need only change one component but because components are linked through cycles all other components may have a response i.e. not just the one being directly forced.

Forcing and Response

Components

Cycles

Balance

Forcing

Three climate forcings in the natural world.

Tectonic Processes

These are generated by the earth's internal heat and affect its surface by means of processes that alter the basic geography of the earth's surface. Examples include the movements of continents across the globe, the uplift of mountain ranges, and the opening and closing of ocean basins. These processes change very slowly over millions of years or much longer.

Forcing and Response

Components

Cycles

Balance

Forcing

Three climate forcings in the natural world.

Earth-orbital changes

These result from variations in the earth's orbit around the sun. The changes alter the amount of solar radiation received on earth by season and latitude. Orbital changes occur over tens to hundreds of thousands of years.

Forcing and Response

Components

Cycles

Balance

Forcing

Three climate forcings in the natural world.

Changes in the strength of the sun

These affect the amount of solar radiation arriving at the earth. For example the strength of the sun has slowly increased over the time the earth has existed. Shorter term changes occur over decades, centuries, and millenia and are partially responsible for climatic changes at the shorter timescale.

Forcing and Response

Components

Cycles

Balance

Forcing

A fourth forcing exists...

Anthropogenic forcing

The unintended by product of agricultural, industrial and other human activities by way of additions to the atmosphere of materials such as carbon dioxide and other gases, sulfate particles and soot.

Forcing and Response

Components

Cycles

Balance

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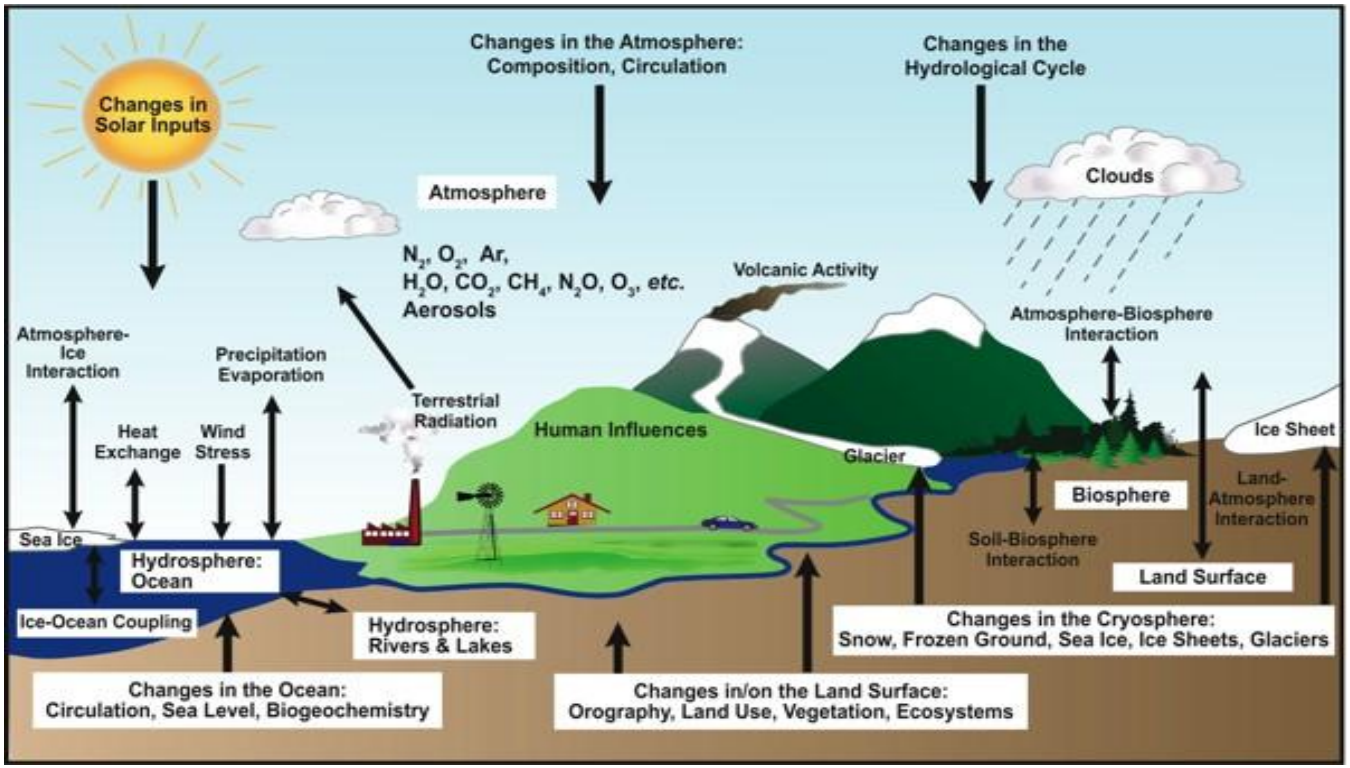


Components

Cycles

Balance

Forcing

Feedback

Word #5

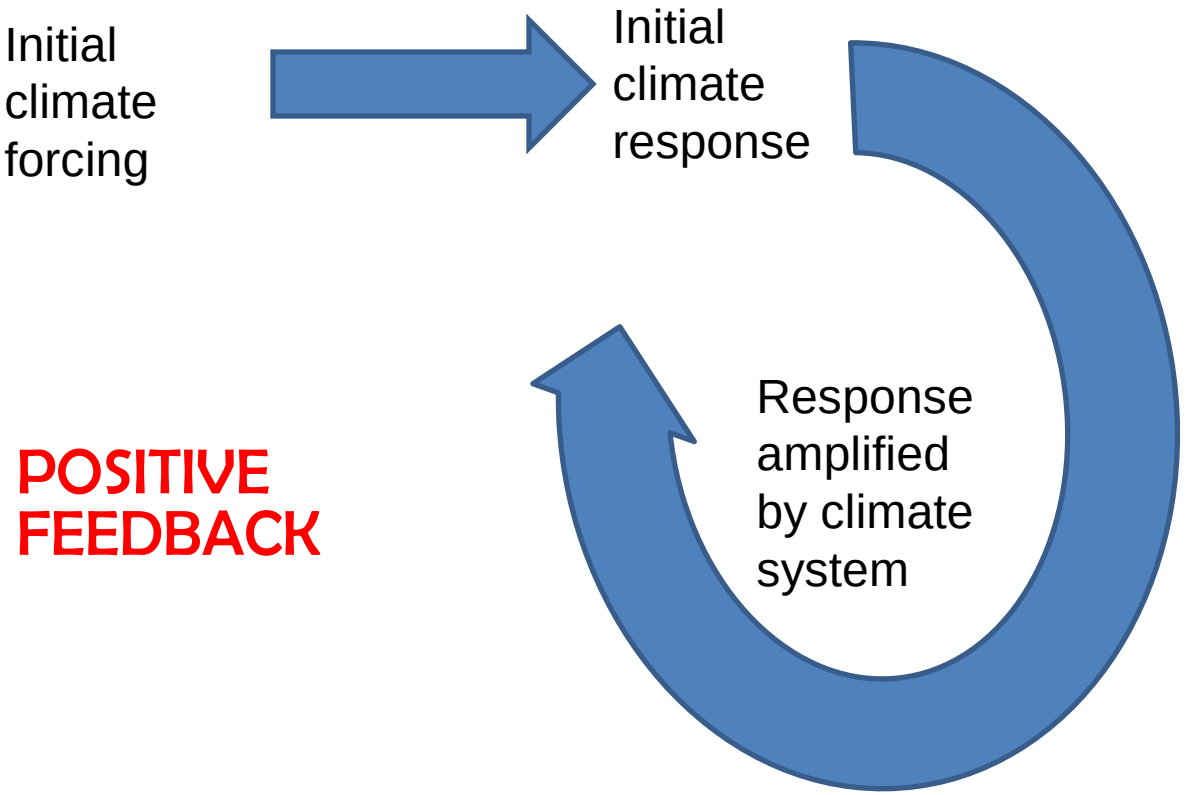
Feedback

A process that amplifies a change already underway due to a forcing.

Feedback

Can have two types of feedback.

- Components
- Cycles
- Balance
- Forcing
- Feedback



POSITIVE FEEDBACK

Feedback

Can have two types of feedback.

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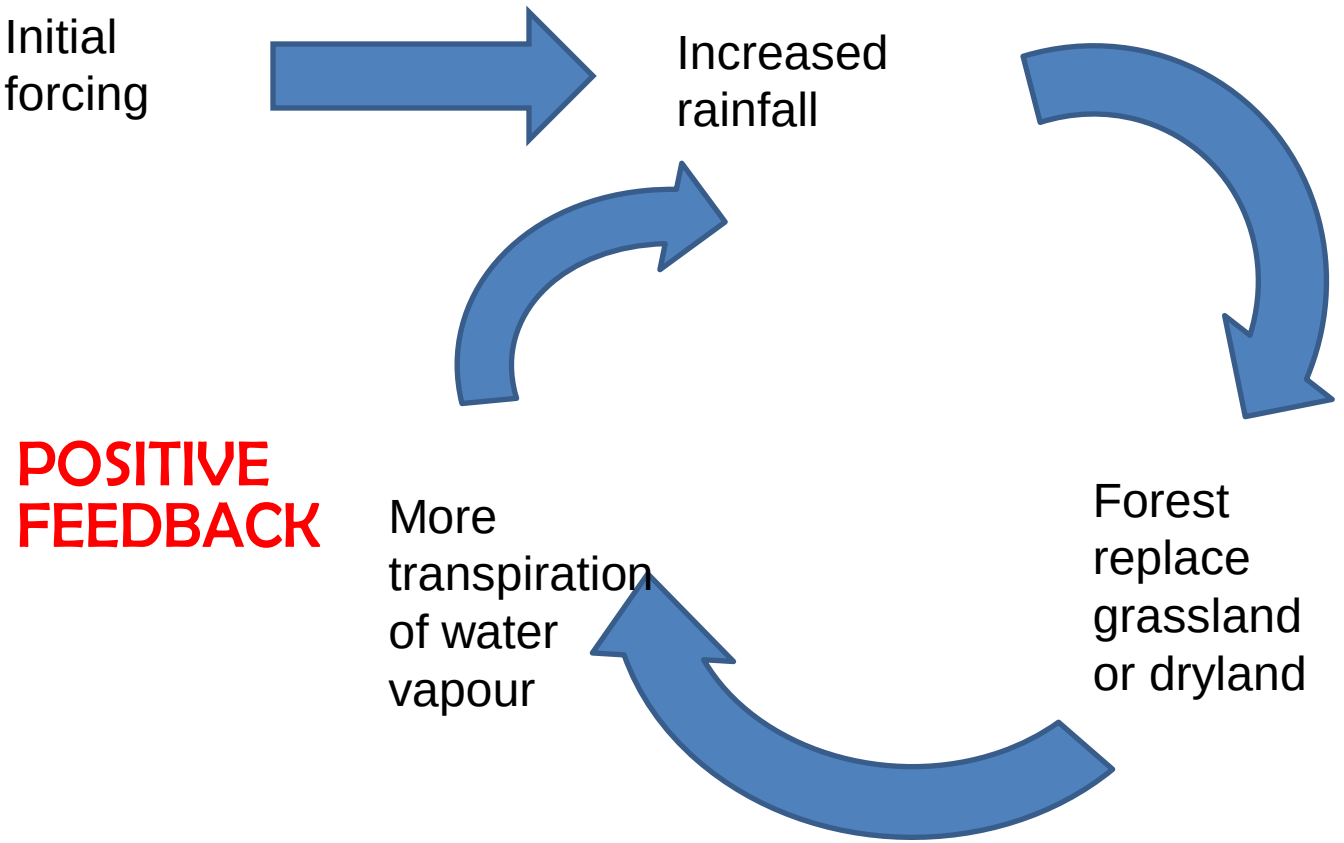
- Cycles
- Balance
- Forcing
- Feedback



POSITIVE FEEDBACK

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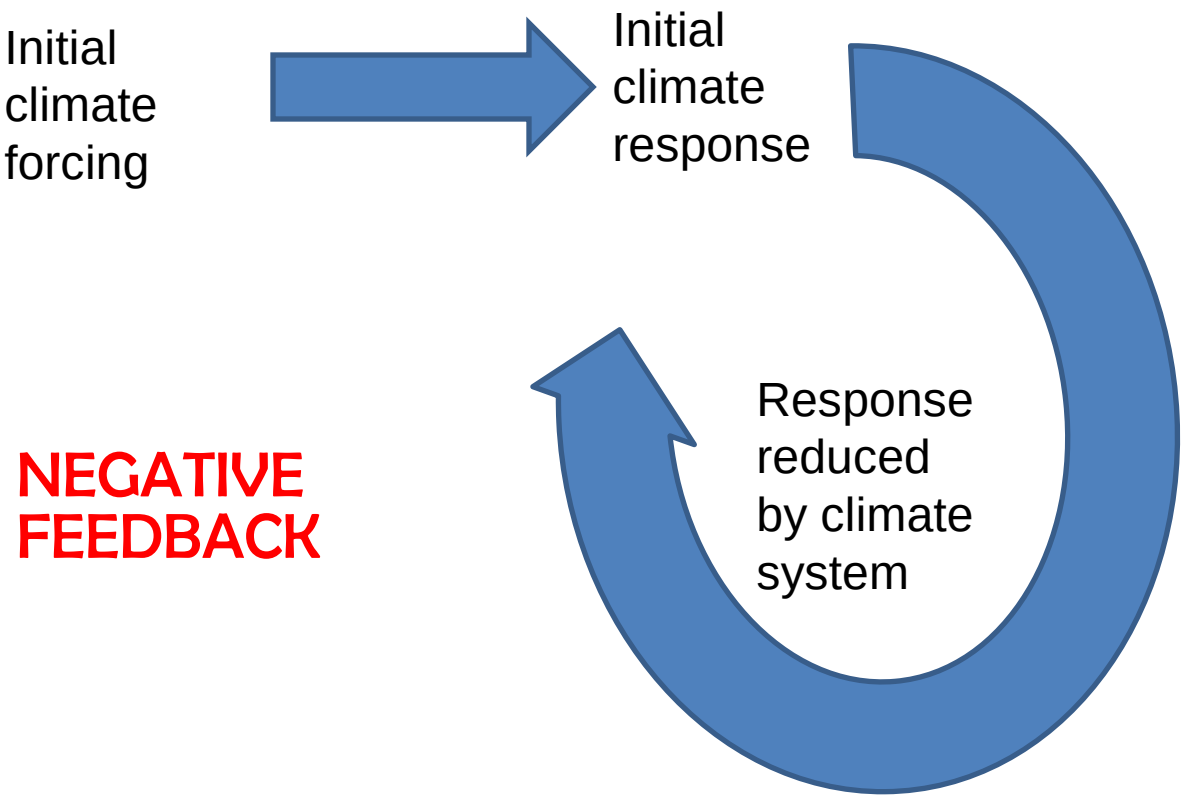
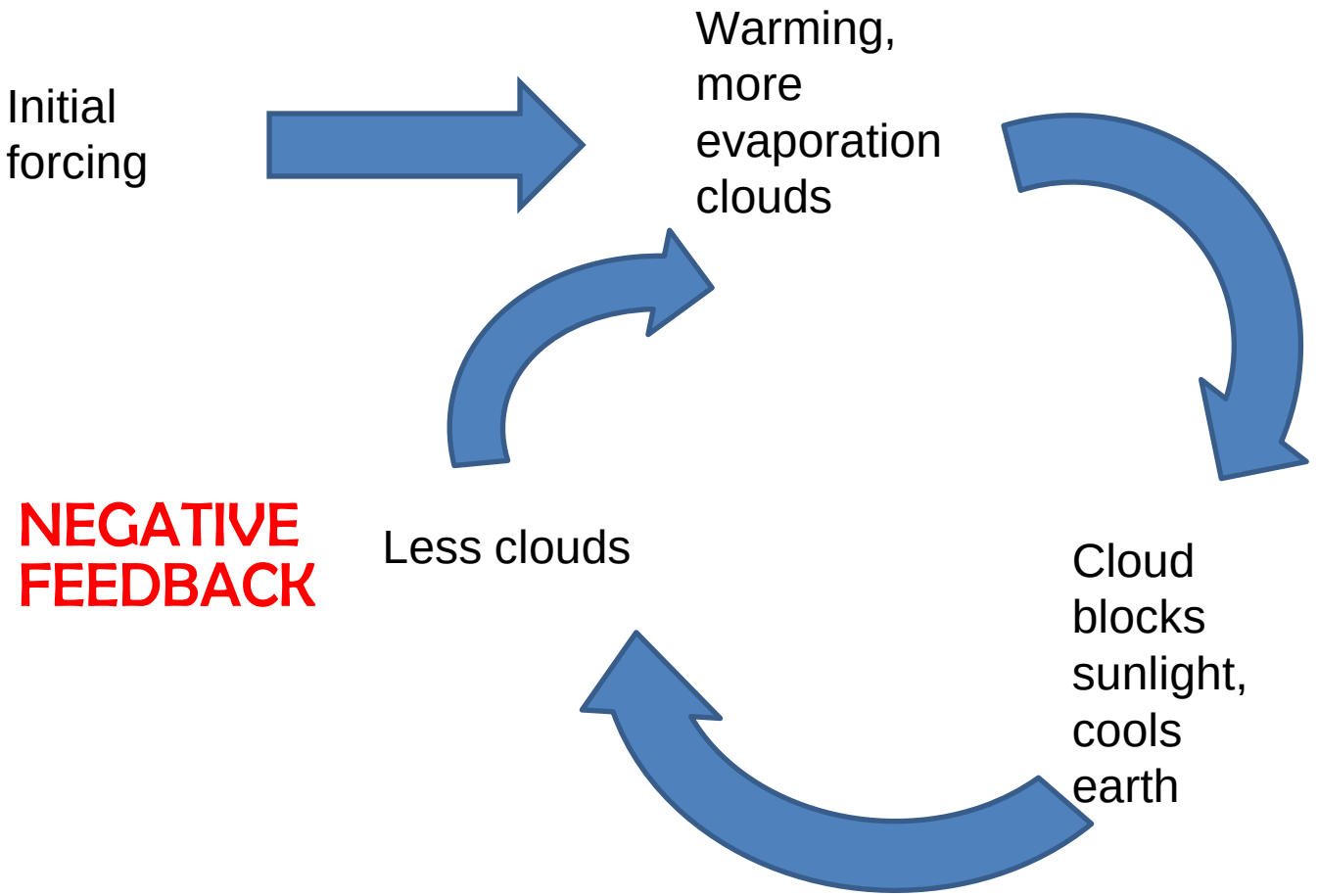


NEGATIVE FEEDBACK

Feedback

Can have two types of feedback.

- Components
- Cycles
- Balance
- Forcing
- Feedback



Components

Cycles

Balance

Forcing

Feedback

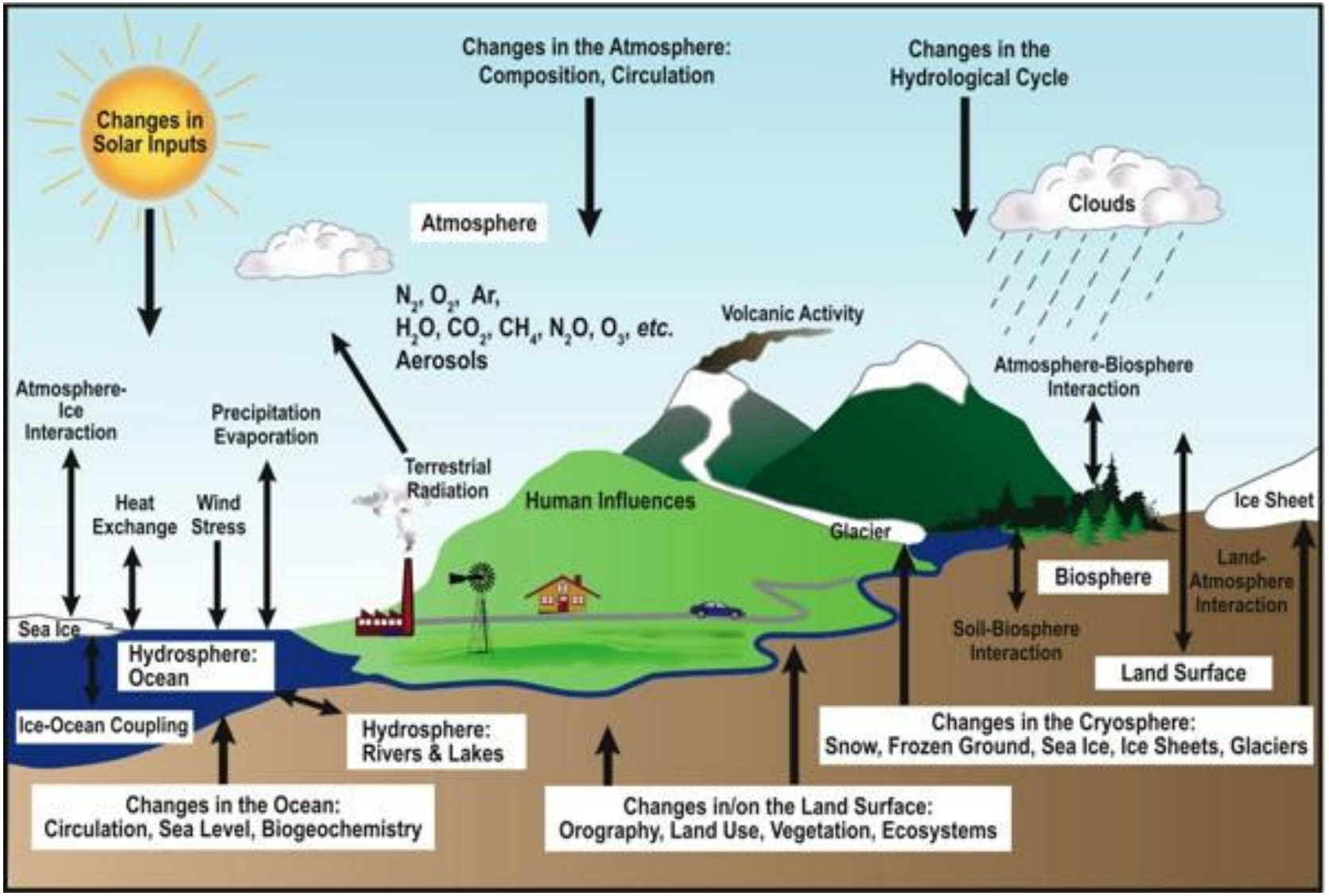
Word #5

Feedback

A process that amplifies a change already underway due to a forcing.

Feedbacks can be immediate or delayed.

The Earth as an Integrated System



5 Words

Components

Cycles

Balance

Forcing

Feedback

Thank You

The Earth as an Integrated System

Discussion Question?

Does human behaviour suggest a recognition of the earth as an integrated system?