Space Weather and Earth´s Climate

Ulrich von Kusserow, Bremen

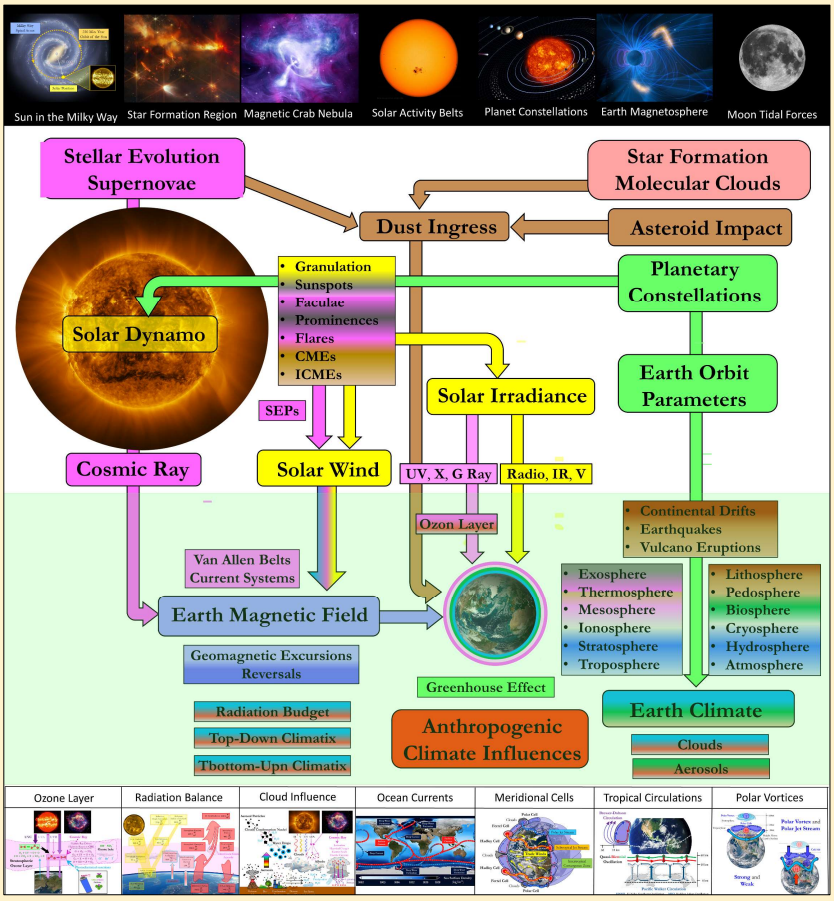
Basics

Firstly, the **Magnetic Sun** is the primary driver of Space Weather, which describes the temporally varying state of the interplanetary medium in the **Heliosphere** of our **Solar System**, and especially in the **Earth's Magnetosphere** and **Ionosphere**. The **Dynamo Processes** occurring in highly electrically conductive, flowing fluids, **Plasma** matter, or liquid metals are what generate the more or less periodically or chaotically changing **Solar** respectively Geo-**Magnetic Fields** in this context. In particular, the Sun emits significantly varying **UV Radiation**, depending on the intensity of **Solar Activity**, which is characterized by the relative **Sunspot Number**. The release of magnetic energy accelerates High-Energy **Solar Particles** in **Flare Processes**, and after **Eruptions** of **Solar Prominences**, massive **Coronal Mass Ejections** can occur into interplanetary space, which, among other things, moderates the **Solar Wind** continuously flowing from the solar corona toward Earth. The varying strength of the **Heliospheric Magnetic Field** during the **Sunspot Cycle** influences the strength of the influx of **Cosmic Ray** from the distant Universe into the Solar System and the Earth's magnetosphere.

Secondly, the constantly changing **Magnetic Sun** is the **Energetic Driver** of the Earth's Climate, which varies over time and space. Under the influence of the changing **Planetary Constellations** within the solar system over the course of its evolution, the **Earth's Parameters** also change periodically, causing significant changes in the latitude-dependent **Solar Irradiation** on Earth and thus also in its climate over large timescales. The natural **Greenhouse Effect** is of central importance for the Earth system's **Radiative Energy Budget**, but humans have increasingly influenced it in recent decades. In addition to radiation processes and various "**Top-Down**" and "**Bottom-up**" **Climatic Factors** in the Earth's system, **Heat Transport** in the **Oceans** and in the stratospheric and tropospheric **Atmospheric Layers** from the equator to the polar regions as well as the **Human Influence** also plays a significant role in **Changes** in the **Earth's Climate**.

Finally, the question arises as to the extent to which **Space Weather**, mediated as well by **Magnetic Fields**, can also exert a significant **Influence on** the **Earth's Climate**.

Variety of Complex Interaction Processes



Aspects of Space Weather

Space Climate Changes in the **Solar System** related to the …

- Faint Young Sun Problem
- Passage through Spiral Arms of the Milky Way
- Encounter with dusty Molecular Clouds
- Eruption of a Supernova located not far away
- Changing Solar Dynamo Processes caused by Planetary Constellation changes

Space Climate Changes in the Earth´s Magnetosphere related to …

- Changes of the Earth´s Dynamo processes, magnetosphere, Van Allen Belt
- Excursions or Reversals of the Earth´s Magnetic Field

Space Weather Changes related to …

- Moderation of the Solar Activity and Solar Wind
- Moderations of the influx of Cosmic Ray by changes in the Heliospheric Magnetic Field

Aspects of Earth´s Climate

- **Changes of Earth Orbit Parameters** Milankovitch Cyles, lunar tides
- **Lithospheric and Pedospheric Changes** Continental drifts, earthquakes, vulcano eruptions
- **Radiative Energy Budget** under sunlight absorption, reflection, scattering, refraction, reemission, greenhouse gas, aerosol and cloud influence
- **„Top-Down" Climatic Influencing Factors** stratospheric ozone dynamics due to solar UV radiation, cloud formation and albedo effect, Aerosol influence and greenhouse effects, Earth surface processes, ice albedo effect
- **Bottom-Up" Climatic Influencing Factors** driving atmospheric circulations, generation of natural and anthropogenic aerosols, propagation of atmospheric waves
- **Heat Transport** in the **Atmosphere** and **Oceans** under solar influence, convection cells, circulations and oscillations, ENSO, QBO, polar vortex
- **Anthropogenic Influences** growth of world population, energy demand, waste, environmental pollution, exhaust and greenhouse gases, aerosols out of industry, commerce, transport, and settlement, rainforest deforestation, ozone hole formation by chlorofluorocarbons, …

Summary

Together with other influencing factors, the Magnetic Sun determines the Heliospheric Space Weather and, more or less directly, the development of the Earth's Climate. A multitude of **Complex**, non-linear, often more or less periodic positive and negative **Feedback Processes** interact in the solar atmosphere and solar wind, in the magnetosphere, ionosphere, and the various atmospheric layers of the Earth, as well as on the Earth's surface, in the biosphere, and in the oceans. Their **Effects** on the Earth's climate can **Overlap** in an unmanageable way. Even if **Correlations** between **Climate Parameters** previously considered insignificant are much better understood and integrated into the theoretical framework in the future due to better **Data** and the results of **Model Calculations**, scientists should always bear in mind the general **Limits** of **Gaining Knowledge** in such **Complex Systems** with so many system parameters.

Literature

C. J. Schrijver, G. L. Siscoe (Eds., 2010) Heliophysics – Evolving Solar Activity and the Climates of Space and Earth. Cambridge University Press
U. v. Kusserow, E. Marsch (2023) Magnetisches Sonnensystem – Solare Eruptionen, Sonnenwinde und das Weltraumwetter. Springer Sachbuch
J. Vinós (2023) Solving the Climate Puzzle: The Sun's Surprising Role. Critical Science Press
V. Bothmer, J. A. Daglis (2024) Space Weather: Physics and Effects. Springer Praxis Books
U. v. Kusserow (2025) Sonnenflecken und das Erdklima. Artikelserie in ASTRONOMIE+RAUMFAHRT im Unterricht (uvkusserow@t-online.de)

Image Rights