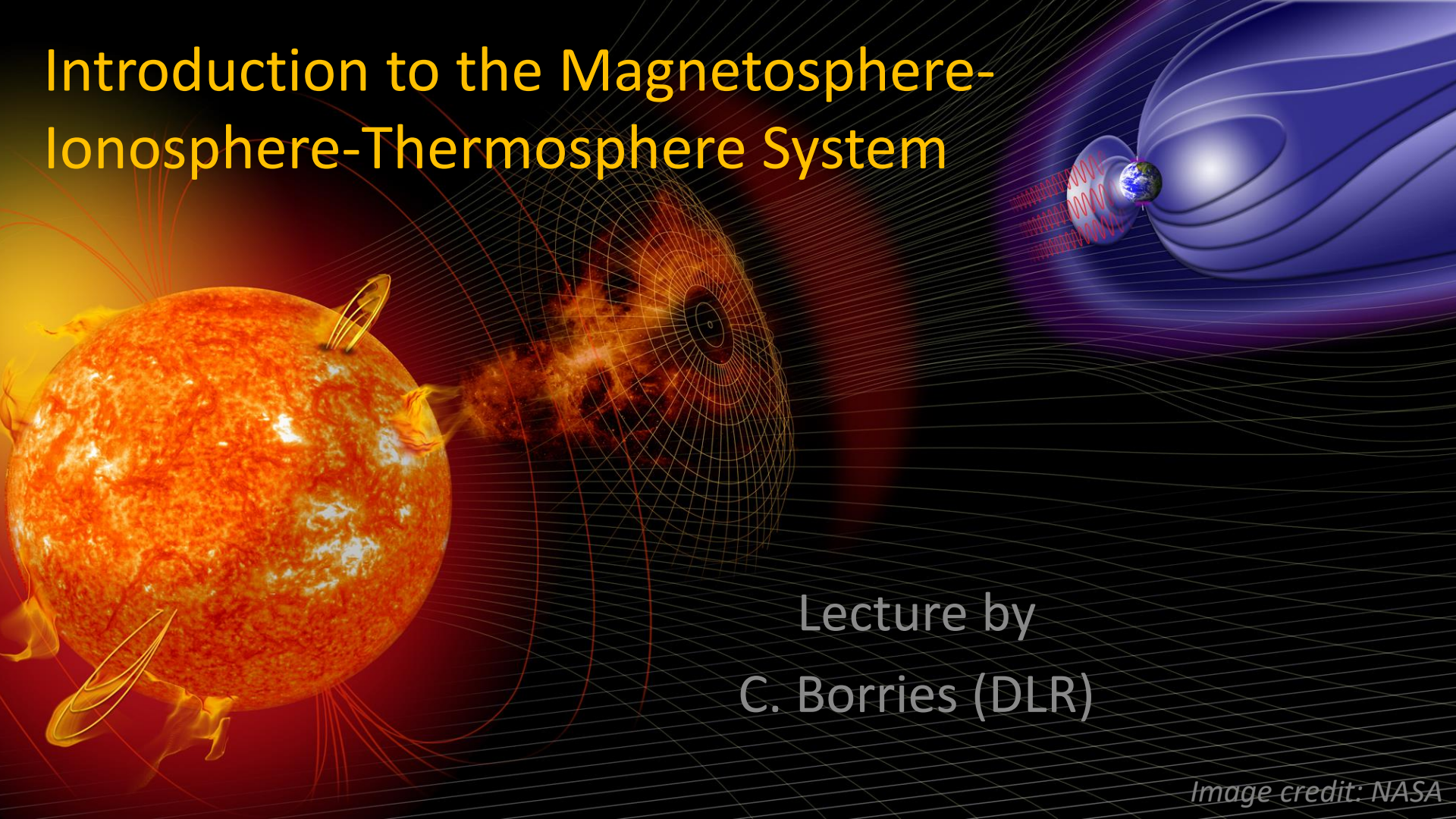
Introduction to the Magnetosphere-Ionosphere-Thermosphere System

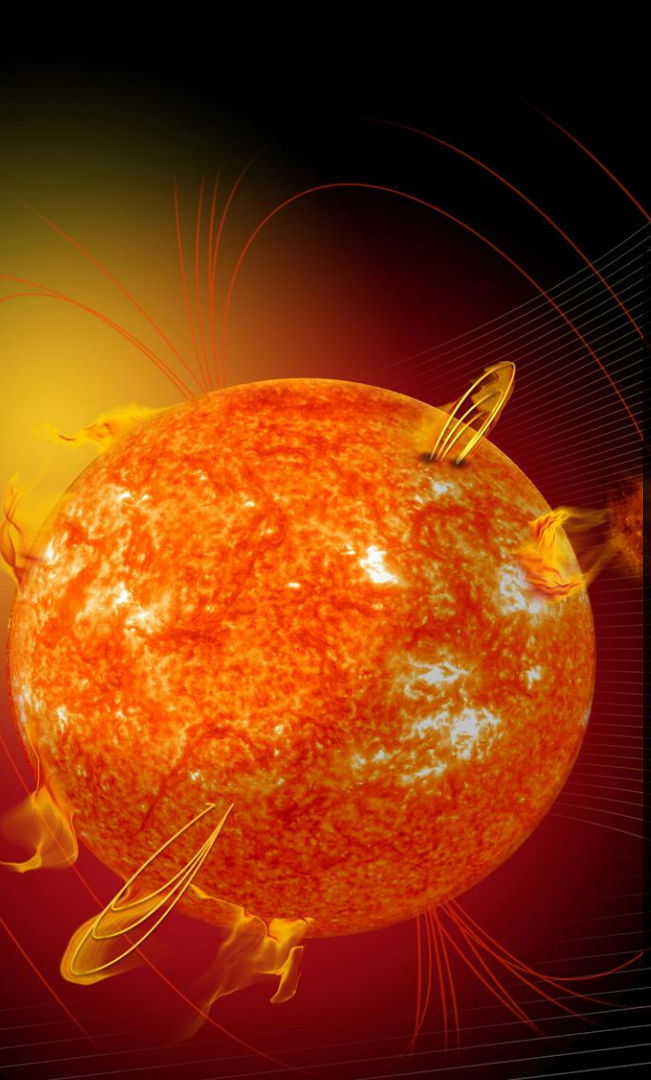


Lecture by
C. Borries (DLR)

Image credit: NASA

Outline

- Thermosphere
- Ionosphere
- Magnetosphere
- Space Weather
- MIT coupling
- Lecture overview
- References



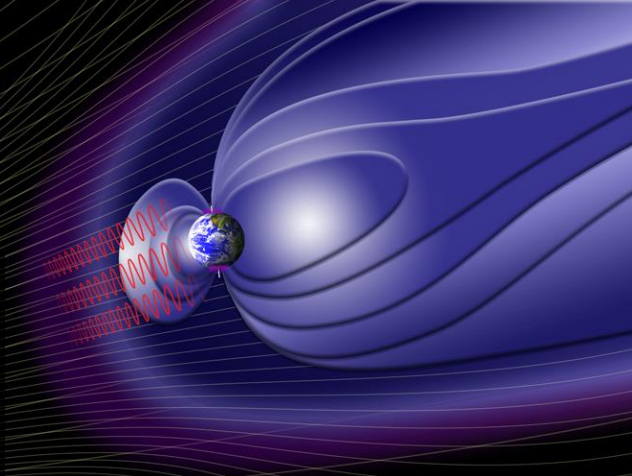
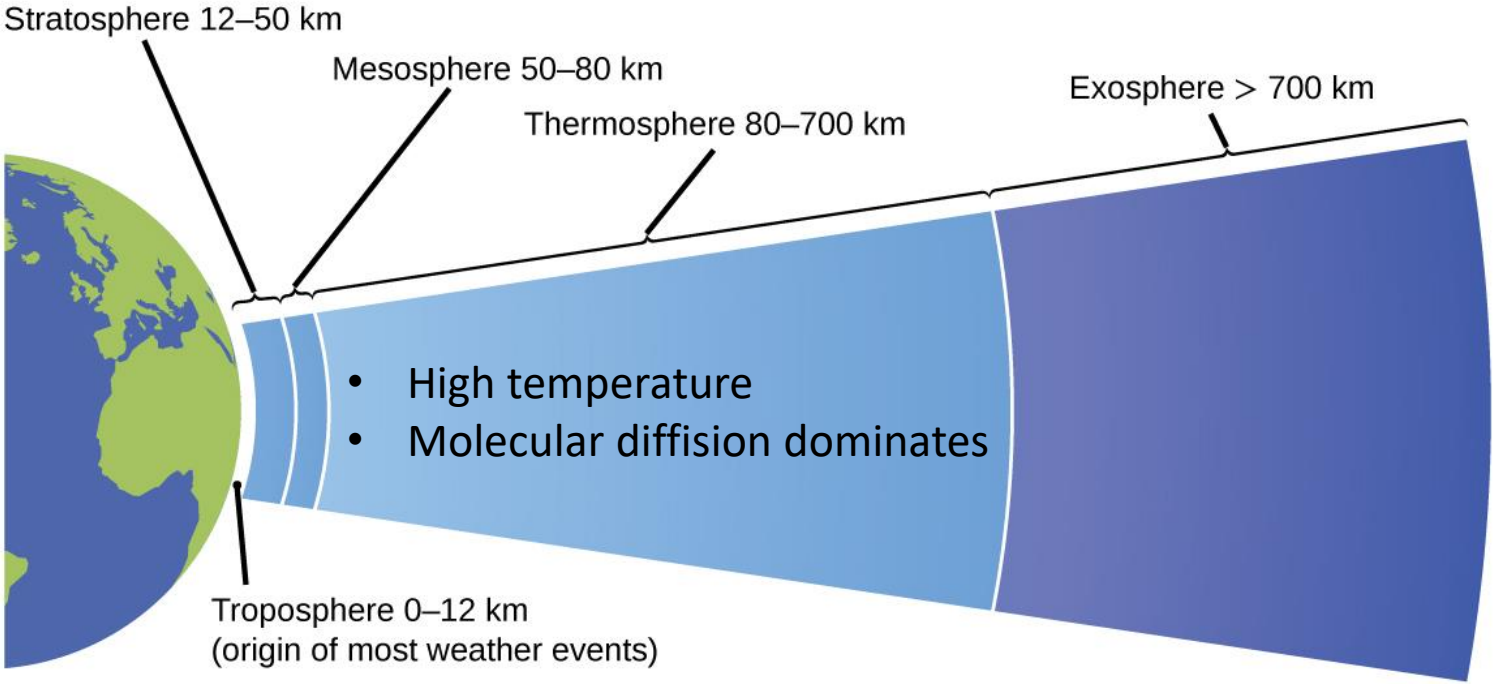
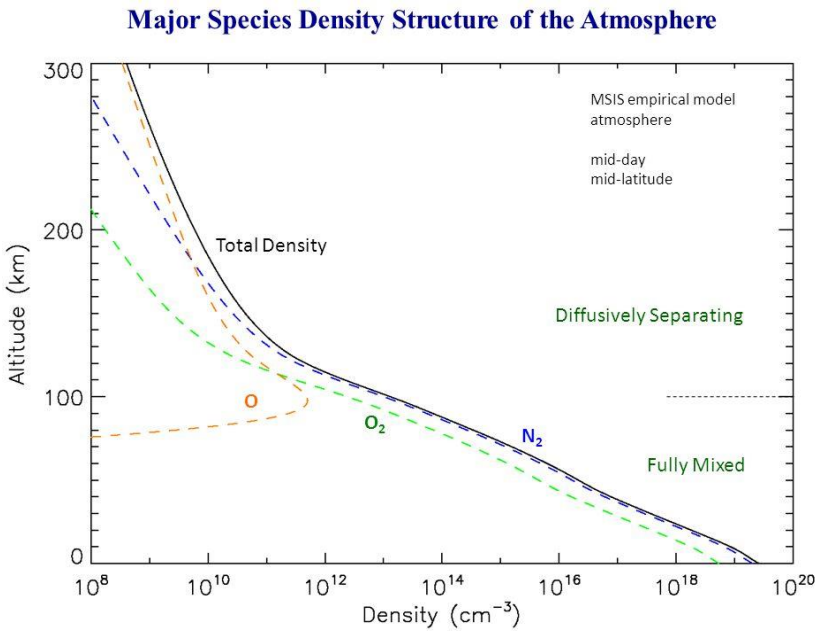


Image credit: NASA

Thermosphere



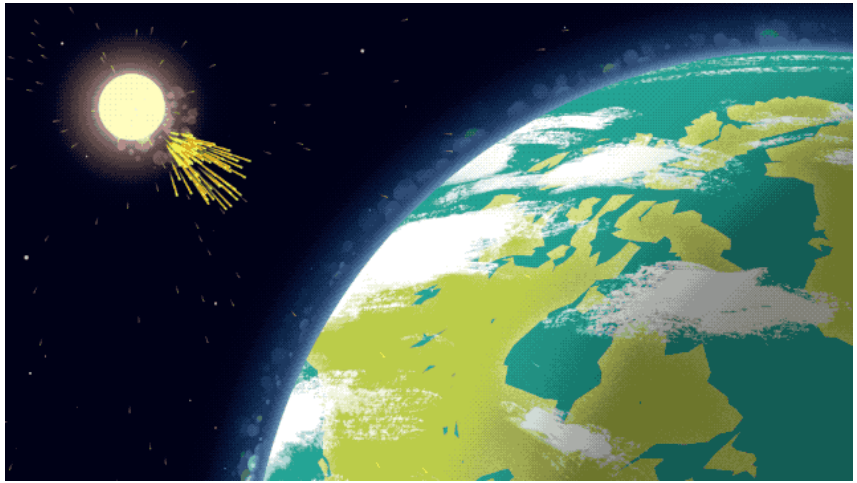
Thermosphere



- Low density (99.9% of air below)
- Turbopause is the intersection with mesosphere
- Diffusive equilibrium
- Chemical composition changes with height (heterosphere)

Ionosphere

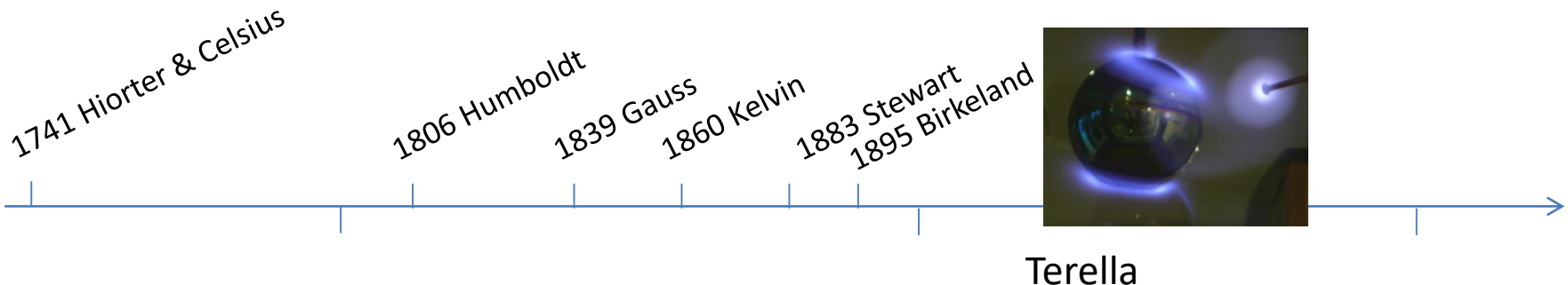
- part of Earth's upper atmosphere, between 80 and about 600 km
- Ionization of atoms and molecules by Extreme UltraViolet (EUV) and x-ray solar radiation
- Other phenomena such as energetic charged particles and cosmic rays also have an ionizing effect and can contribute to the ionosphere.
- Formation of a layer of free electrons.
- Formation of currents
- important because it reflects and modifies radio waves used for communication and navigation.



High altitude currents

- 1741 Hjorter and Celsius observe perturbations in the geomagnetic field coinciding with Aurora
- Idea of upper atmosphere currents by Humboldt (1806)
- Gauss 1839 diurnal variation of the geomagnetic field → charge particles
- Kelvin (1860) and Stewart (1883) contribute to the explanation of geomagnetic fluctuations ,
- Birkeland (1895) simulates polar lights

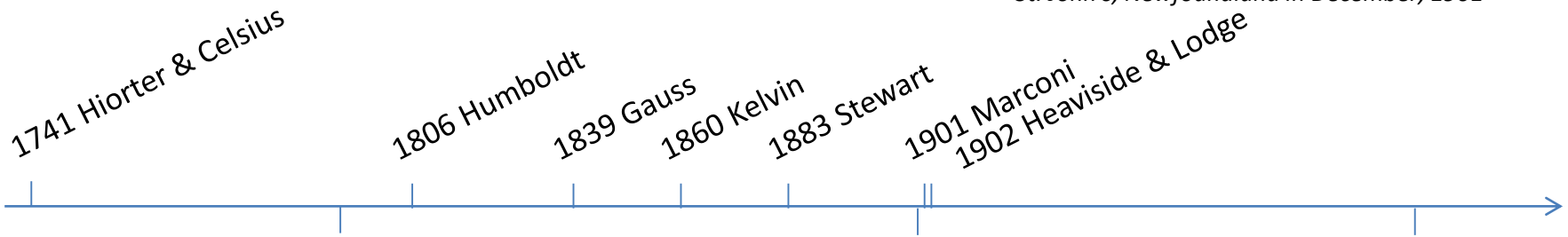
Anders Celsius



Radiowave reflexion

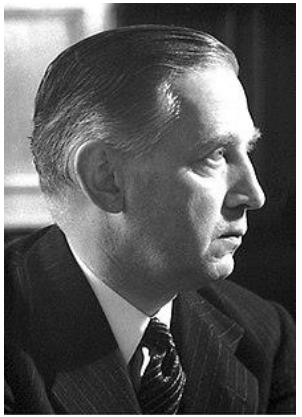
- 1901 the topic of electric currents became interesting when Marconi suceeded to transmit radio waves over the Atlantic.
- 1902 Heaviside and Lodge explained reflexion of EM-wave on free charge carriers in the upper atmosphere, which are generated by solar UV-radiation
- 1902 prediction of Kenelly-Heaviside layer (E-layer)

Marconi with his receiving apparatus on Signal Hill, St. John's, Newfoundland in December, 1901

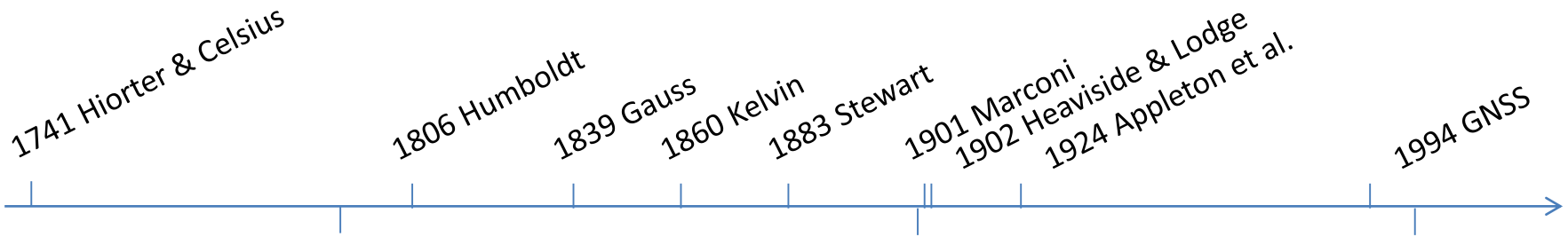


Electron density layers

- 1924 prove of Kennelly-Heaviside layer (E-Schicht) through radiowave experiments (Appleton (Nobel price 1947), Barnett in England, Breit, Tuve in USA)
- Today more than 100 ionosonde stations worldwide, technique radio echo sounding; radar systems; GNSS; in-situ onboard satellites.



Sir E.V. Appleton



Earth as a magnet

- William Gilbert (1544-1603)
- *De Magnete, Magnetisque Corporibus, et de Magno Magnete Tellure* (About magnets, magnetic bodies and the giant magnet Earth) published 1600
- Earth is a giant magnet
- Experiments with a spherical magnet „Terrella“

Earth‘ Magnetic Field

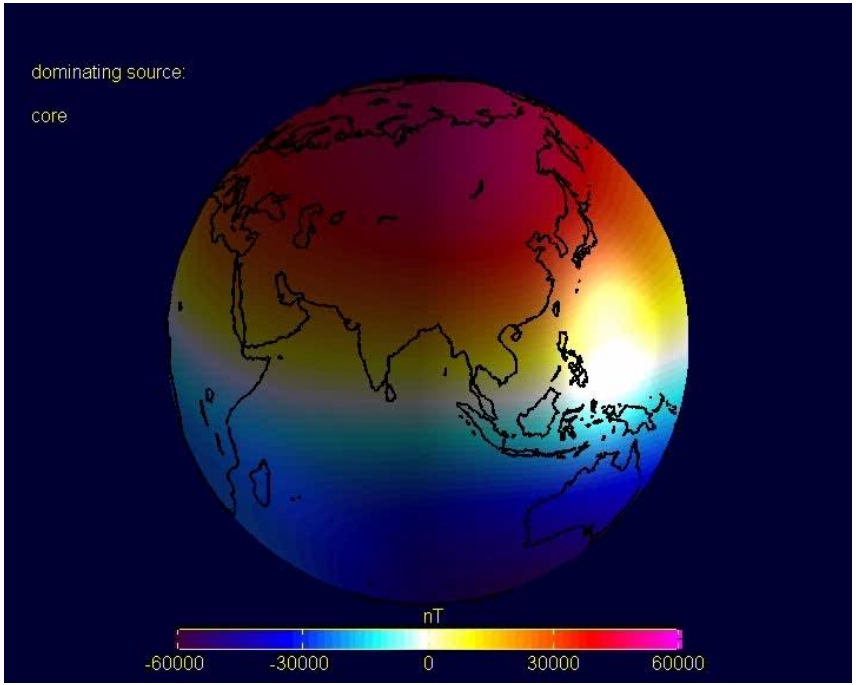
- In the 1830s a world-wide network of magnetic observatories was set up
- realized that disturbances of the compass needle, which were occasionally noticed, occurred on a world wide pattern.
- They seemed to come from outside the Earth, and Alexander von Humboldt named them magnetic storms
- 1838, Carl Friedrich Gauss proved 95% of Earth's magnetic field is internal, 5% external

Portrait of the mathematician and philosopher Carl Friedrich Gauss

Earth‘ Magnetic Field

- Earth's field is combination of several magnetic field:
  - Main magnetic field
  - External magnetic field
  - Anomalous, induced magnetic field
- superimposed on and interact with each other

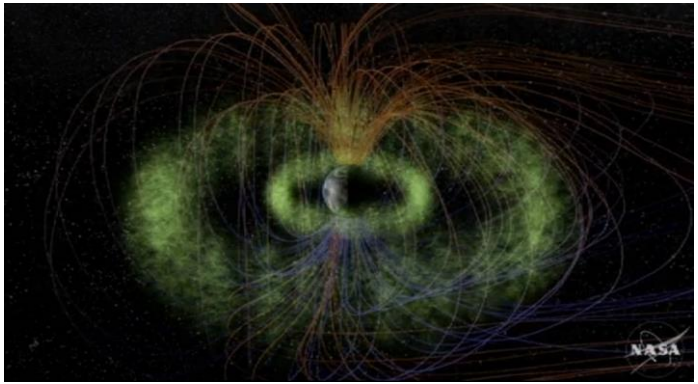
- Movie: Earth's magnetic field at 430 km above sea level simulated from the Comprehensive Magnetic Model (CM4).



Movie courtesy Nils Olsen, DTU

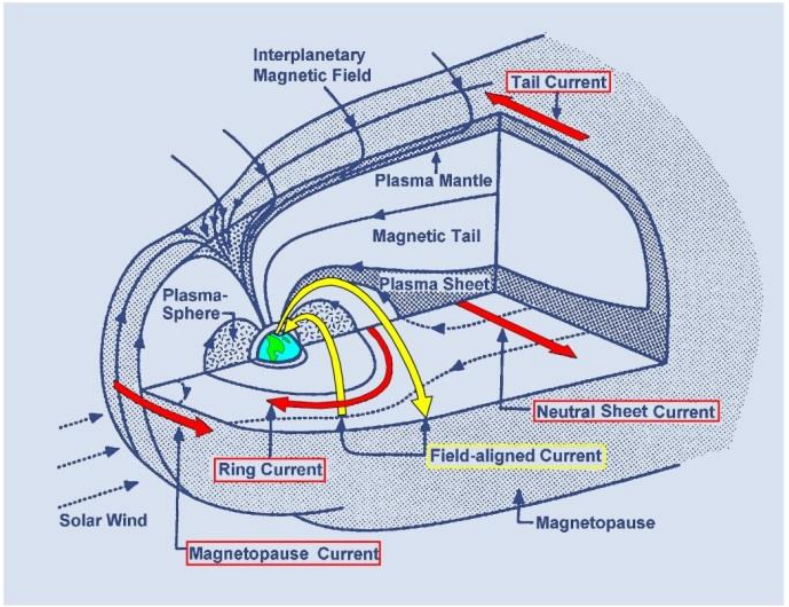
Magnetosphere

- 1958 the first scientific spacecrafts were launched
- Explorers 1 and 3 discovered the radiation belt (van Allen)
- scientists did fully appreciate the complexity of electric and magnetic phenomena that occur in the Earth's magnetic environment.
- In 1959 Thomas Gold of Cornell University proposed to name that environment **"magnetosphere"**



Magnetosphere

- A magnetosphere is that area of space, around a planet, that is controlled by the planet's magnetic field.
- It protects Earth atmosphere from solar wind
- The shape of the Earth's magnetosphere is the direct result of being blasted by solar wind.



Space Weather

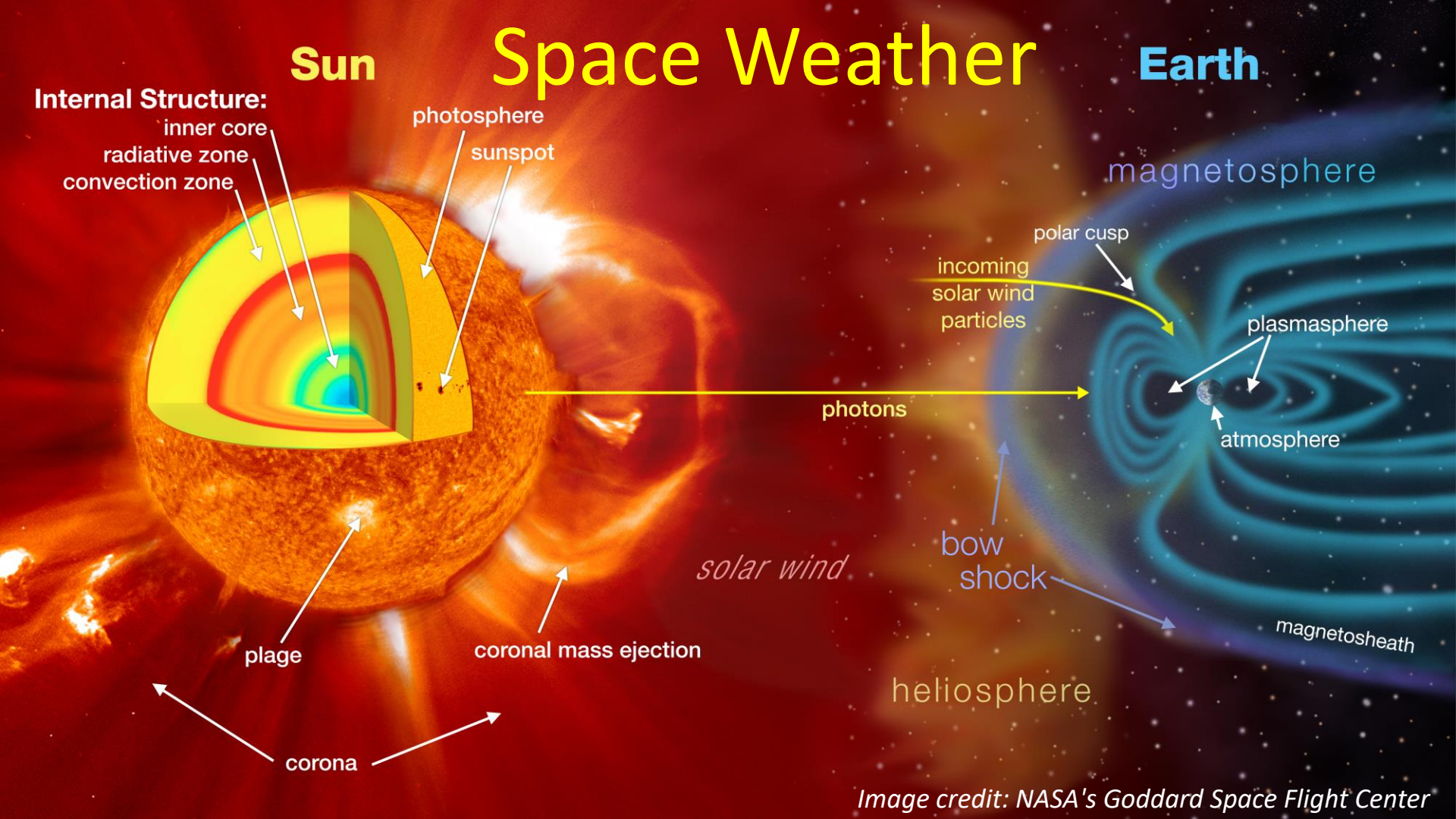
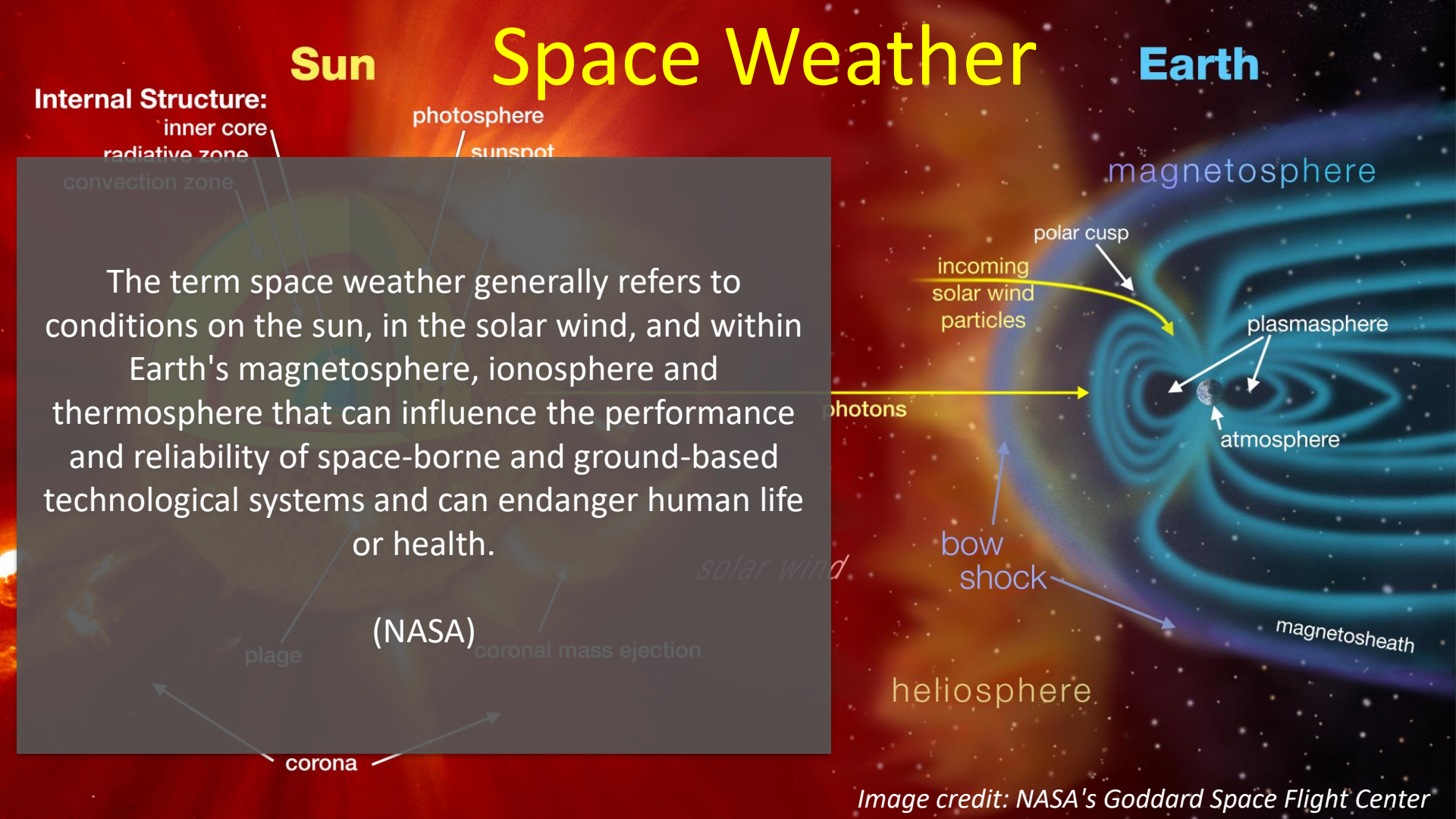


Image credit: NASA's Goddard Space Flight Center

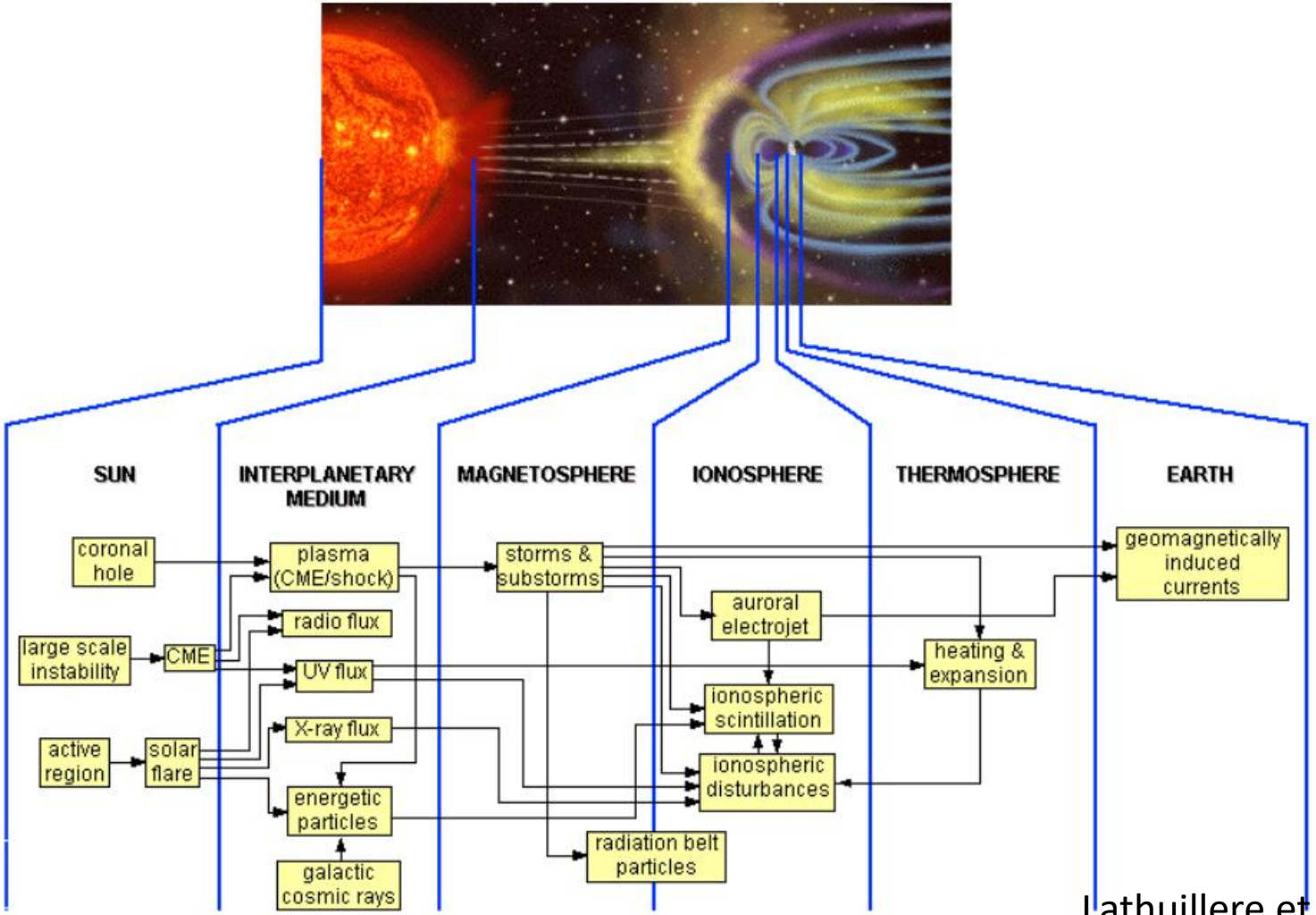
Space Weather



The term space weather generally refers to conditions on the sun, in the solar wind, and within Earth's magnetosphere, ionosphere and thermosphere that can influence the performance and reliability of space-borne and ground-based technological systems and can endanger human life or health.

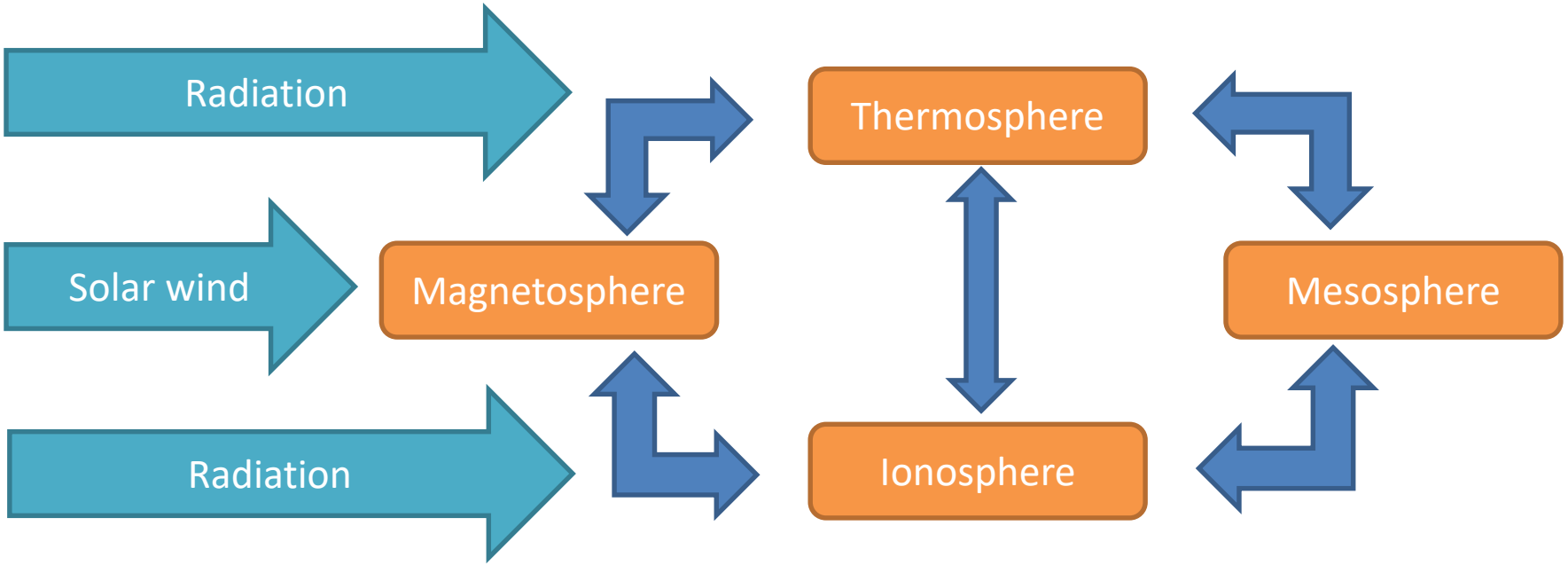
(NASA)

Image credit: NASA's Goddard Space Flight Center



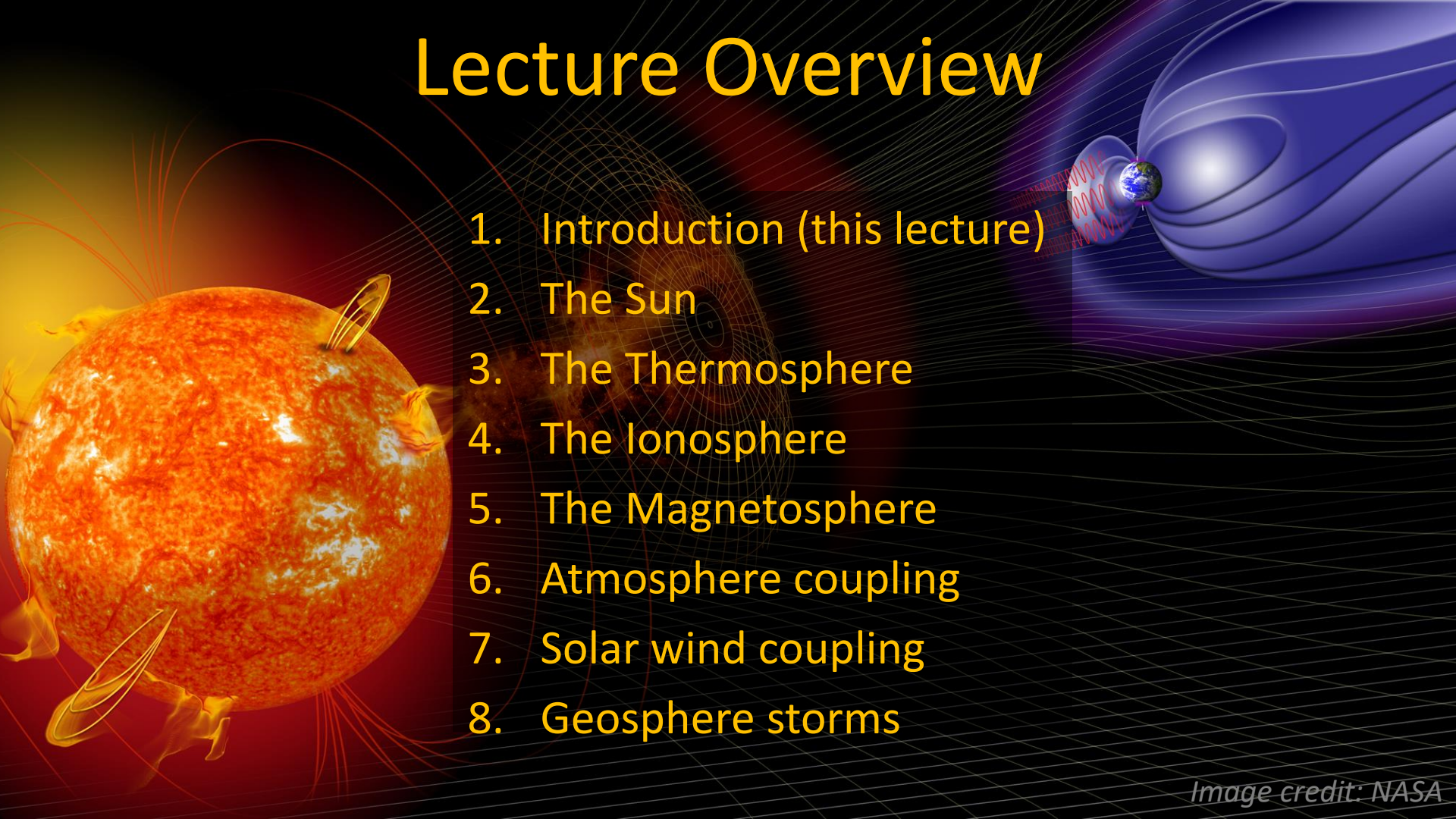
Lathuillere et al. (2002)

MIT-coupling



Everything is coupled

Lecture Overview



1. Introduction (this lecture)
2. The Sun
3. The Thermosphere
4. The Ionosphere
5. The Magnetosphere
6. Atmosphere coupling
7. Solar wind coupling
8. Geosphere storms

Image credit: NASA

References

- Prölss, G. W.: Physik des erdnahen Weltraums - eine Einführung; *Springer,* **2004**, XV, 529
- Kelley, M. C.: The Earth's Ionosphere: Plasma Physics & Electrodynamics; *Academic Press,* **2009***, 96*

Ionosphere seen from ISS

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https://www.youtube.com/watch?v=o4FSg-90XIA