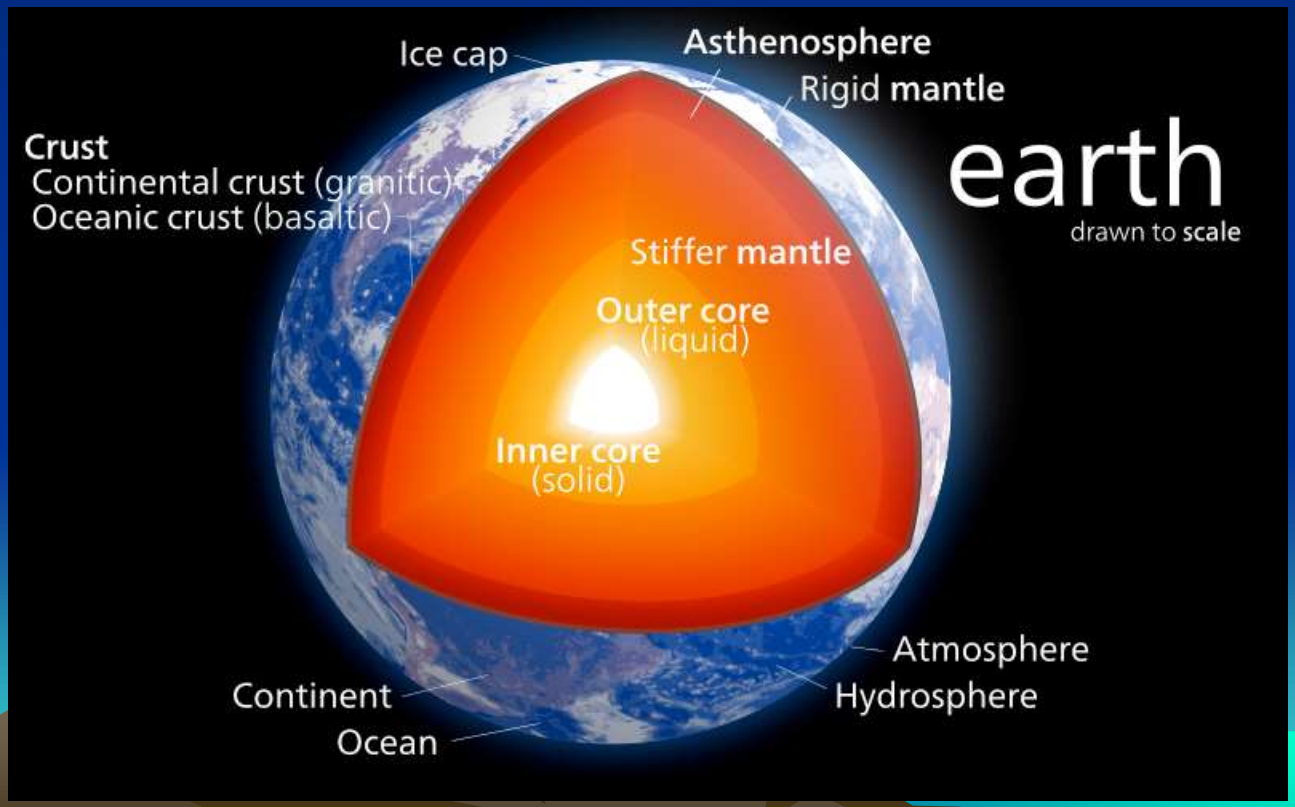
Earth's Magnetic Field

- Why does Earth have a global or world-wide magnetic field, while other similar planets either have no magnetic fields or very different kinds of fields?

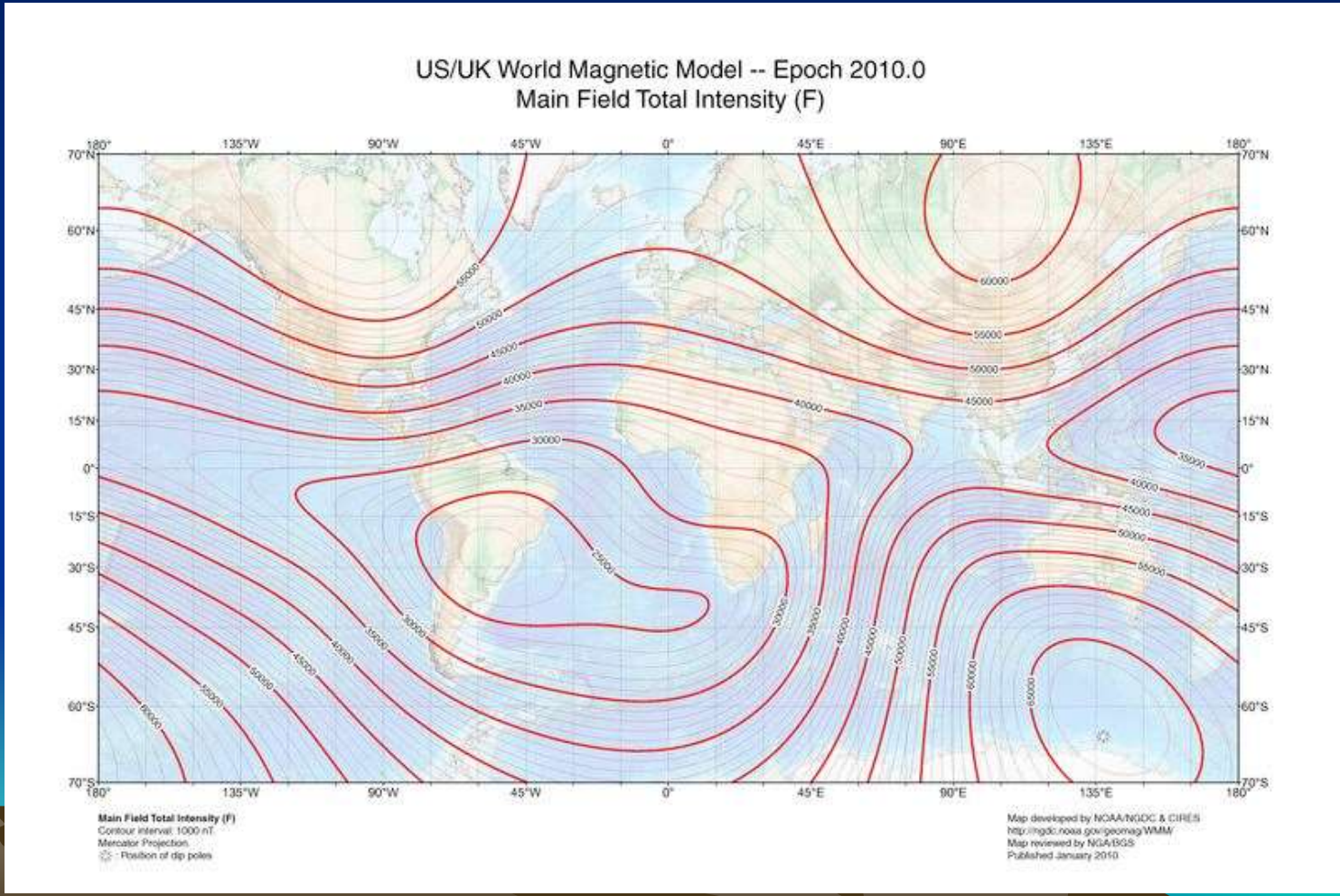
- Why should we care about Earth's magnetic field? What does it do for us?

Earth's Magnetic Field

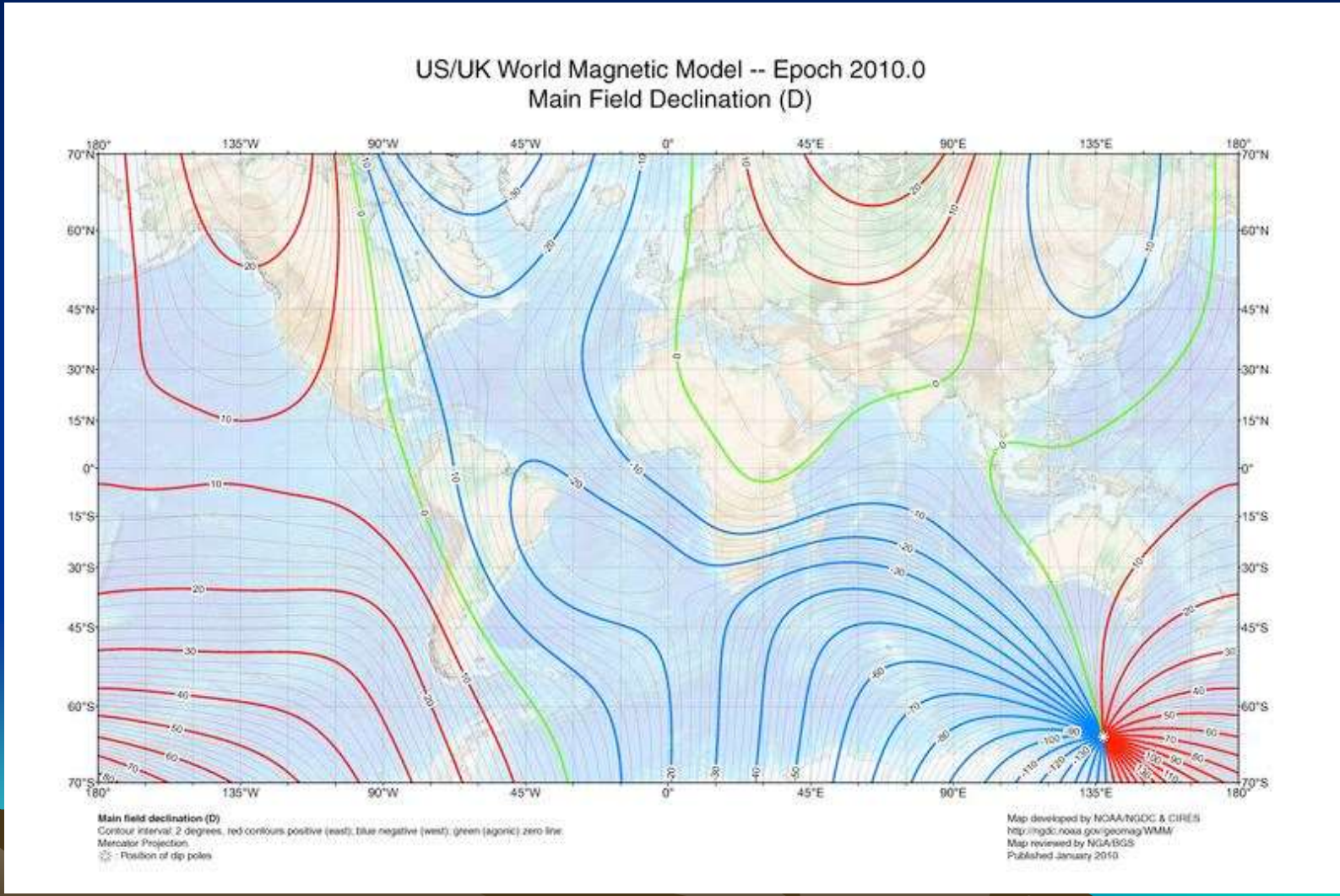
- Heat makes the outer core convect, which makes the Earth's magnetic field



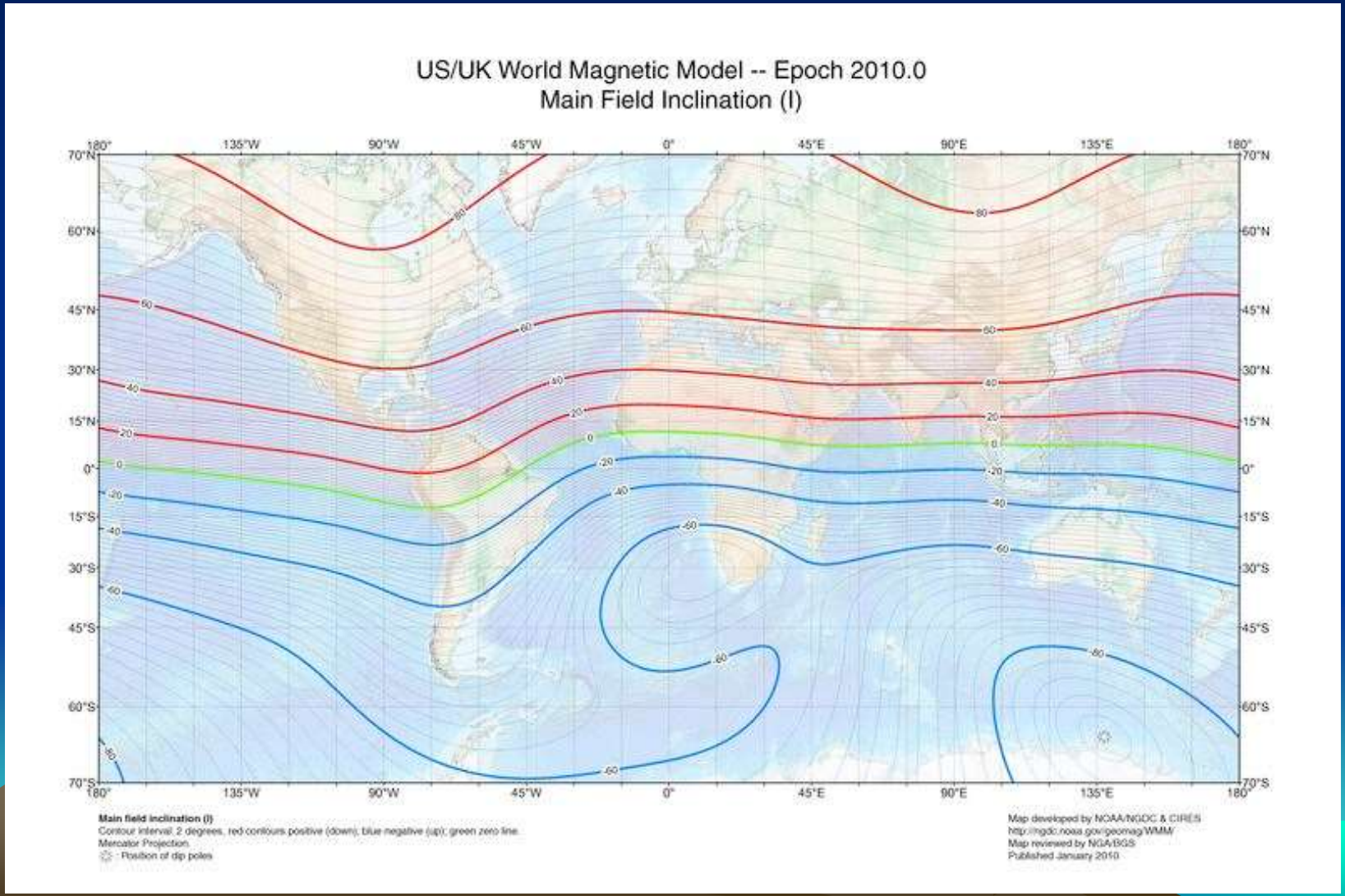
Magnetic field variable Space: Intensity



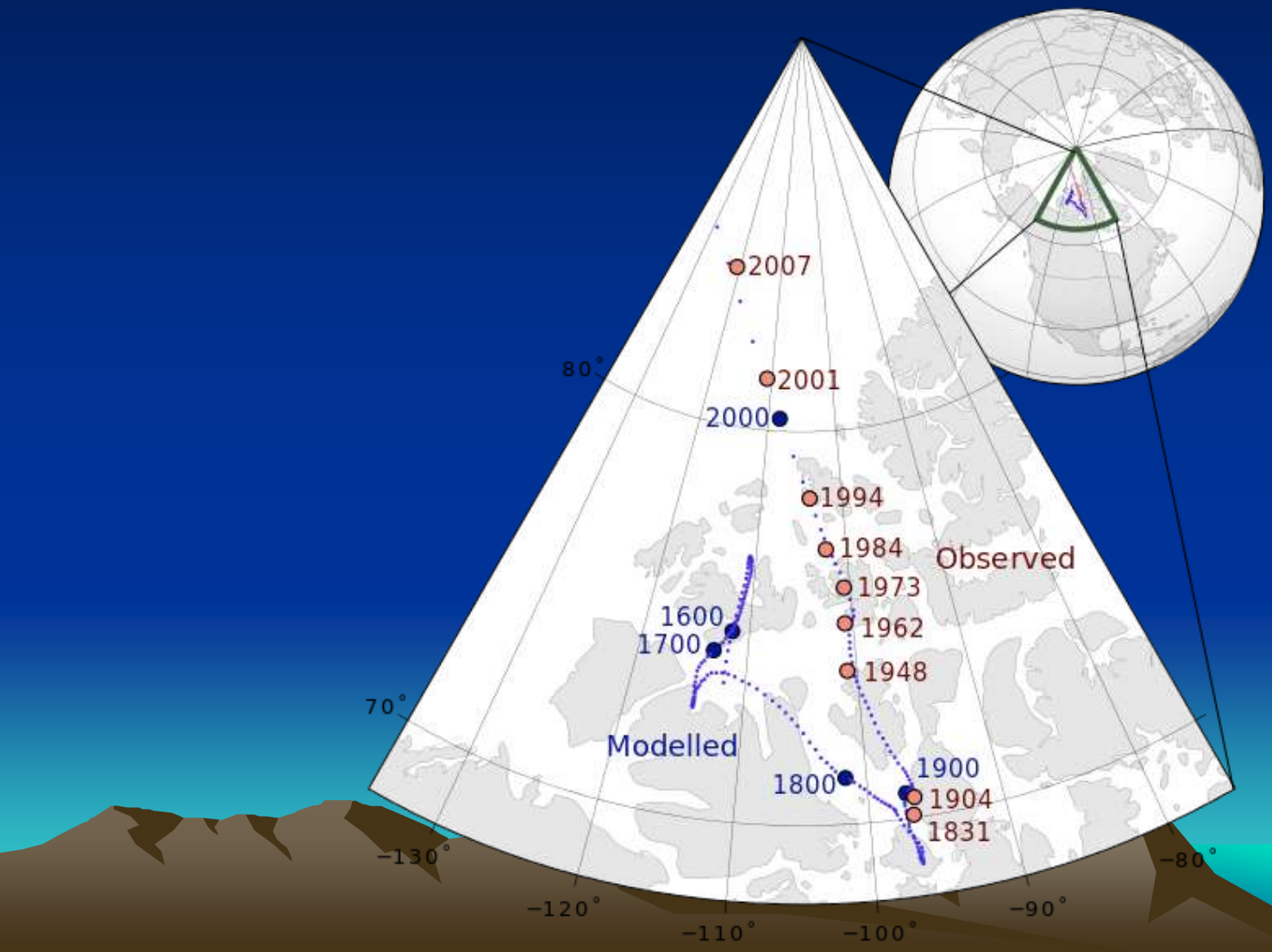
Magnetic field variable
Space: declination



Magnetic field variable Space: Inclination

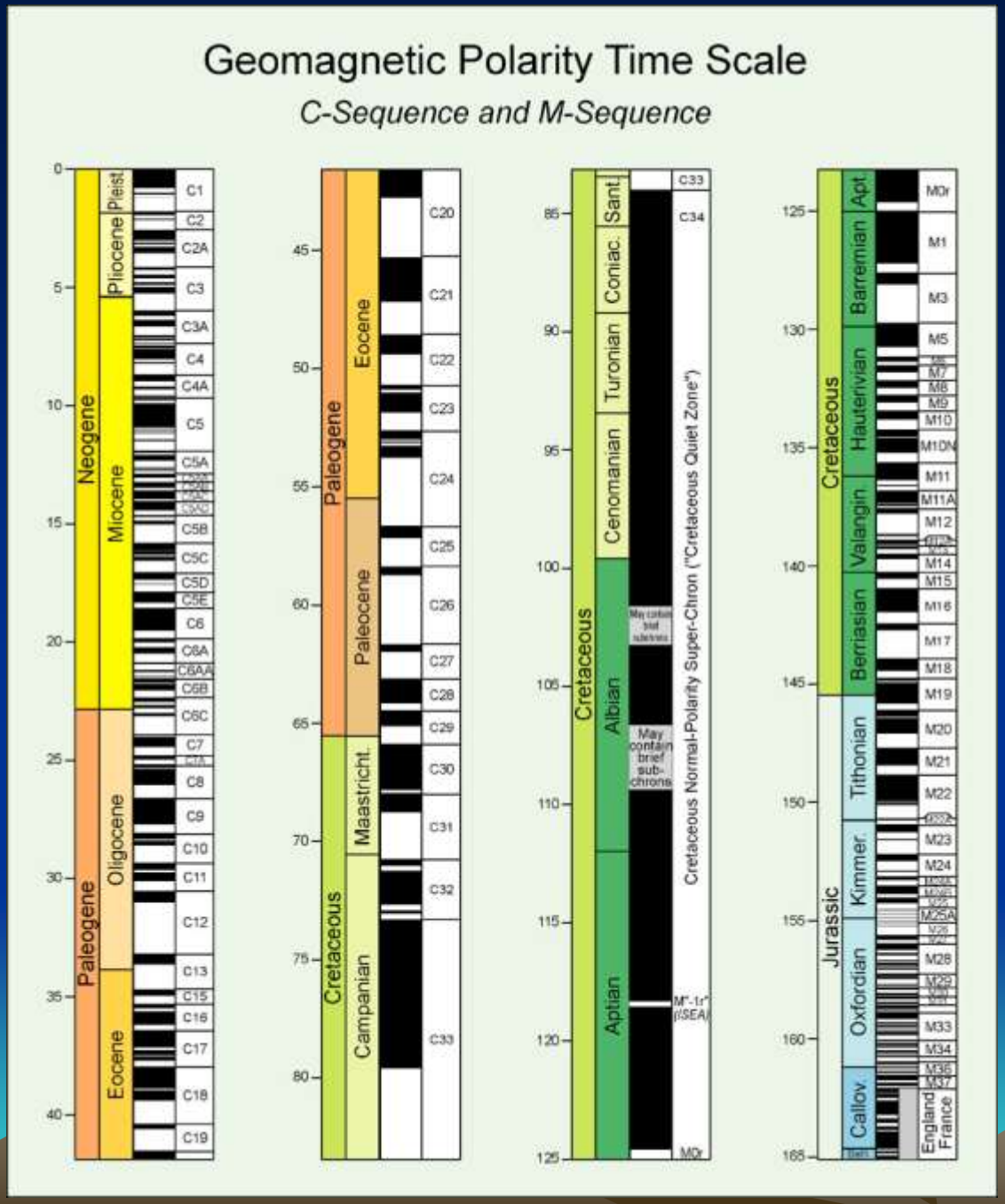


Magnetic field variable Time: Secular Variation



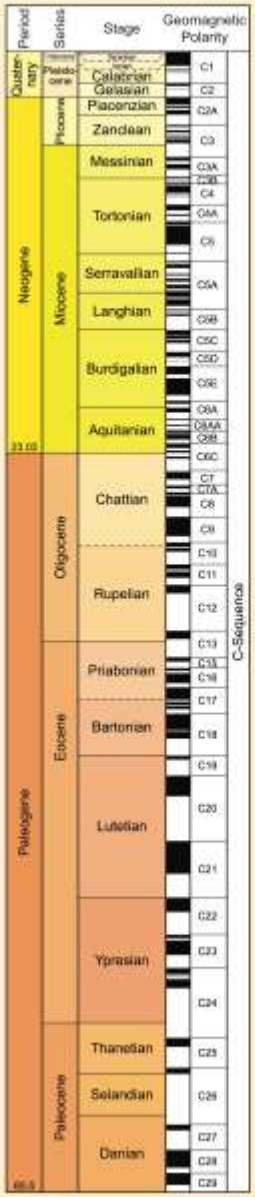
Magnetic field variable Time: Secular Variation

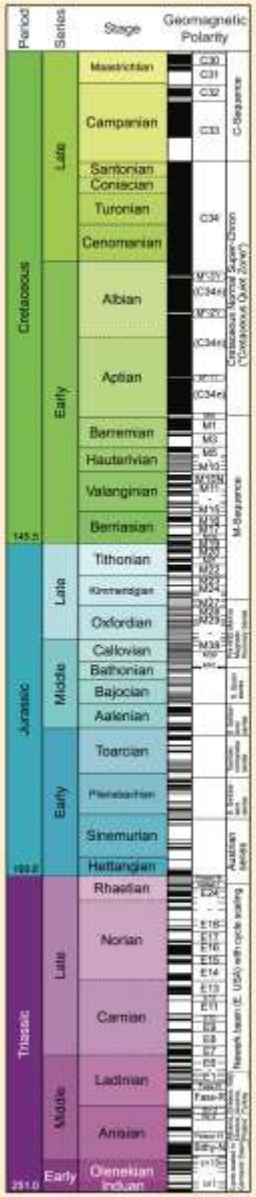
Declination, inclination, and intensity change…

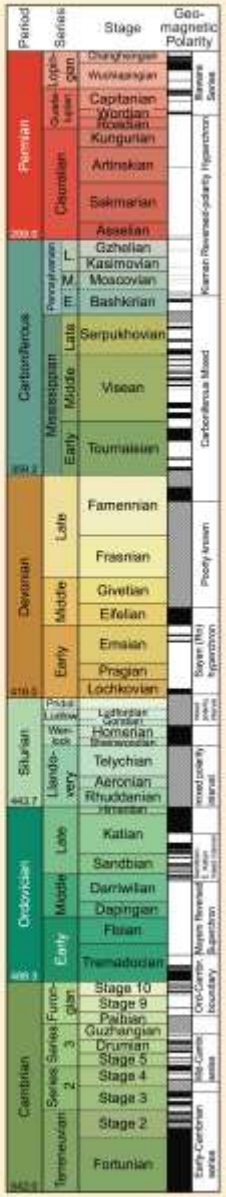

Geomagnetic Polarity Time Scale
C-Sequence and M-Sequence
Neogene
Paleogene
Pleist.
Pliocene
Miocene
Oligocene
Eocene
Paleogene
Cretaceous
Eocene
Paleocene
Maastricht.
Campanian
Cretaceous
Sant.
Coniac.
Turonian
Cenomanian
Albian
Aptian
Cretaceous Normal-Polarity Super-Chron ("Cretaceous Quiet Zone")
May contain brief sub-chrons
Cretaceous
Jurassic
Barremian
Apt.
Hauterivian
Valangin
Berriasian
Tithonian
Kimmer.
Oxfordian
Callov.
England
France

Geomagnetic Polarity Time Scale

modified from Concise Geologic Time Scale (Ogg et al., 2008)



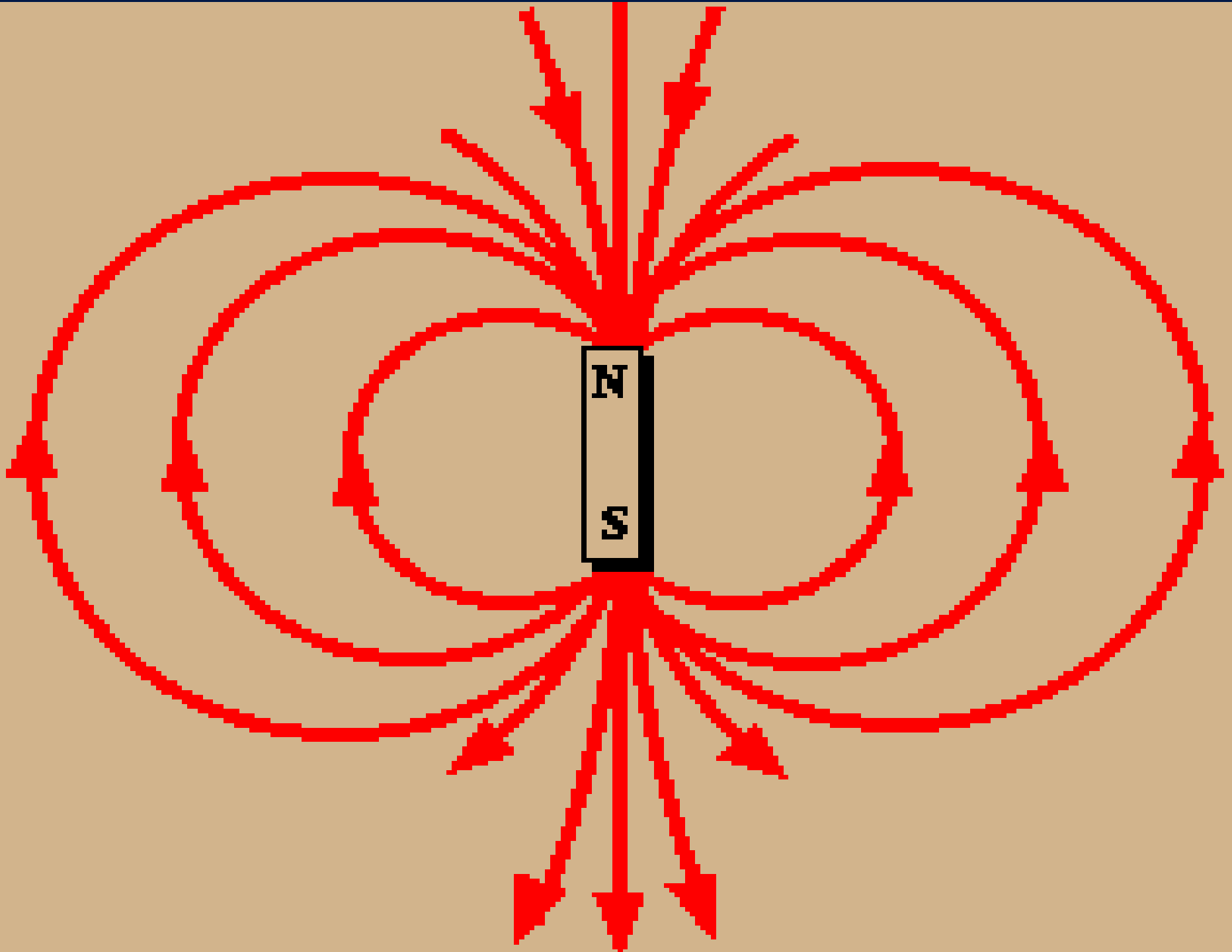




Earth's Magnetic Field

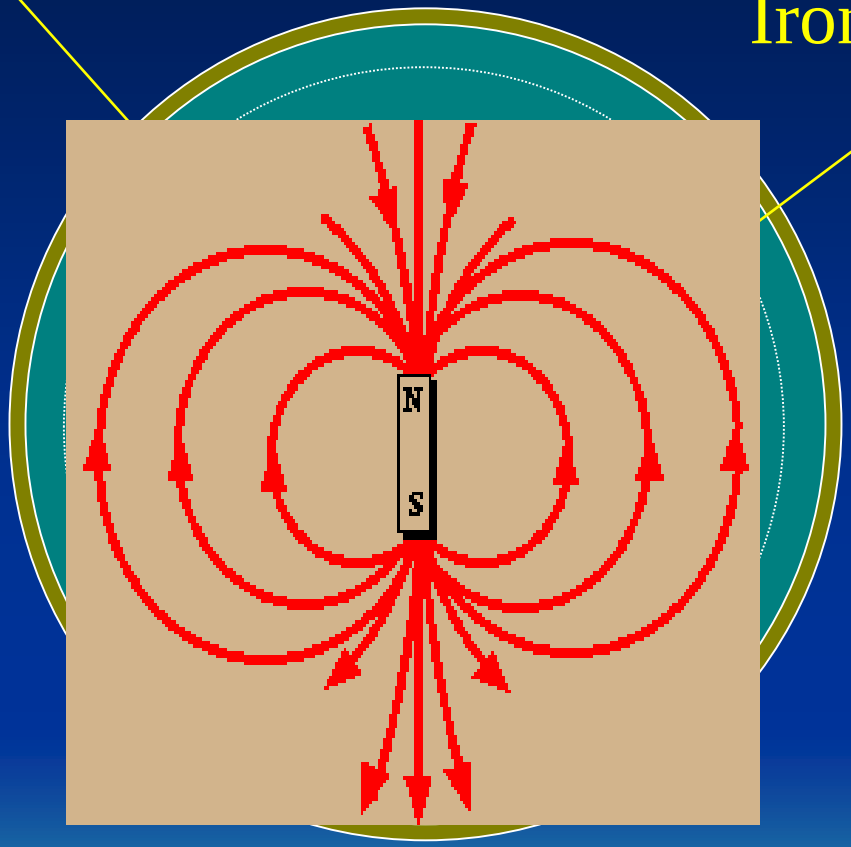
- Magnetic fields are made wherever there is an electric current, that is the movement of electrons.

- In a regular bar magnet, the magnetic field comes from the electrons orbiting around the nuclei of the iron atoms. All the electrons orbit in the same direction.


N
S

Solid Inner Core
2400 km diameter
Iron & Nickel

Liquid Outer Core
2270 km thick
Iron & Nickel



Earth's Magnetic Field

- In the earth, electrical currents run through the molten iron core. Friction within the molten, flowing iron knocks electrons off iron atoms.

- The molten iron flows at about 0.8 inches per second, but the electrical currents can flow faster.

Earth's Magnetic Field

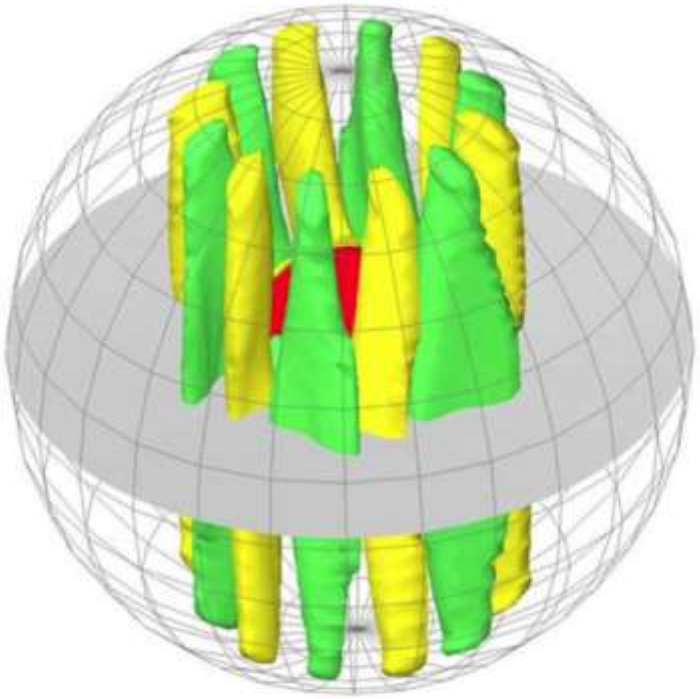


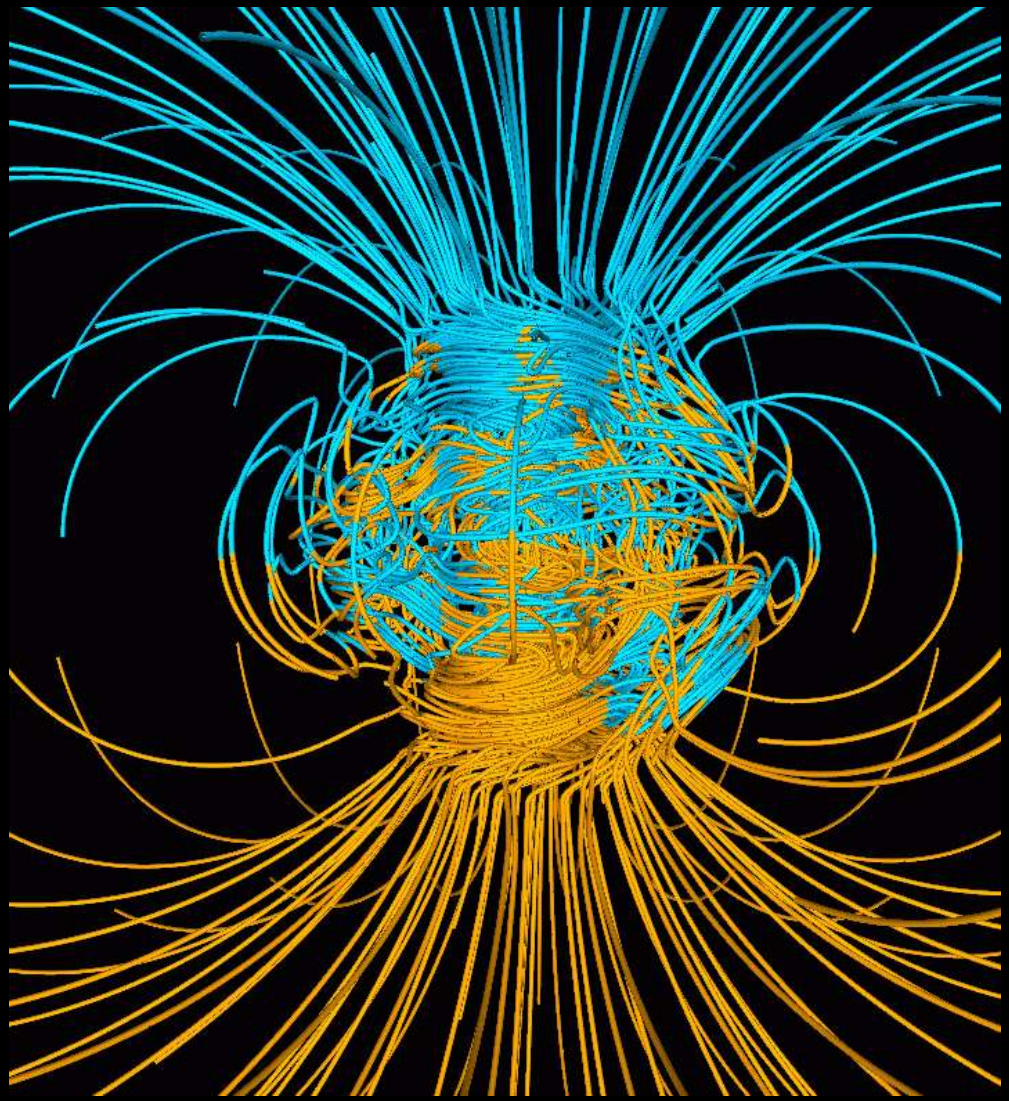
Figure 2. Snapshot of convection cells aligned nearly parallel to the rotational axis, visualized by the isosurfaces of the z component of vorticity **W**. The yellow ($W_z > 0$) and green ($W_z < 0$) surfaces indicate cyclonic and anticyclonic convection cells. Reproduced from *Kageyama and Sato* [1997c], with the permission of the authors and the publisher (American Physical Society).

Earth's Magnetic Field

- The electrical currents within the earth cause earth to act like a gigantic electromagnetic generator.

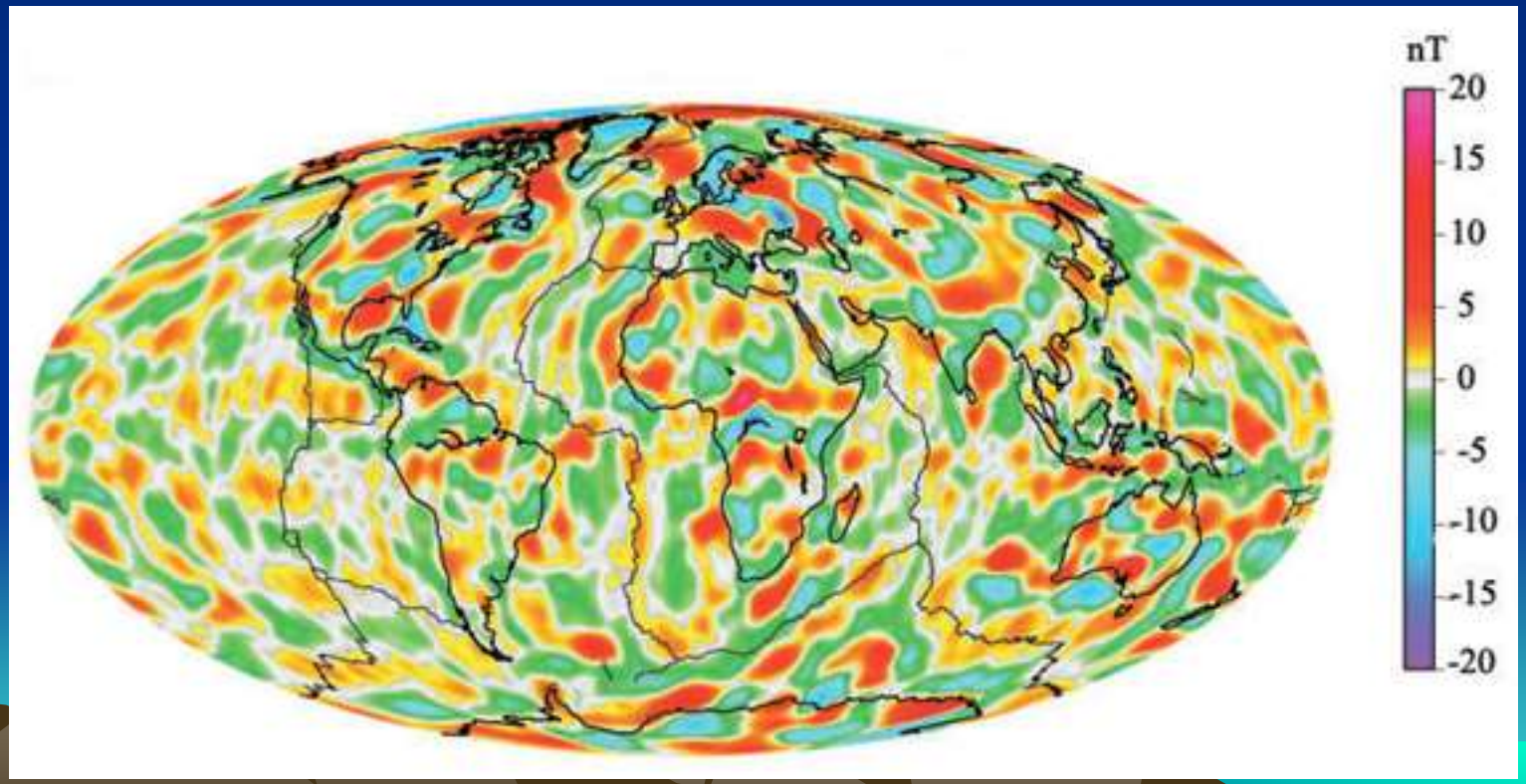
- This is called the **Dynamo Theory** of magnetic field generation.

Earth's Magnetic Field
Global Field



Earth's Magnetic Field

- "local" field: Lithospheric Magnetic Anomalies.



A little more info…

- The earth's magnetic field isn't strong enough for us to feel, but many animals can sense it and even use it to navigate. It's only about 0.4 Gauss, much weaker than a small magnet you can hold in your hand.

The poles “flip”

- Every so often, what was the North magnetic pole suddenly becomes the South magnetic pole.

The poles “flip”

- how long does the process take? thousands of years?

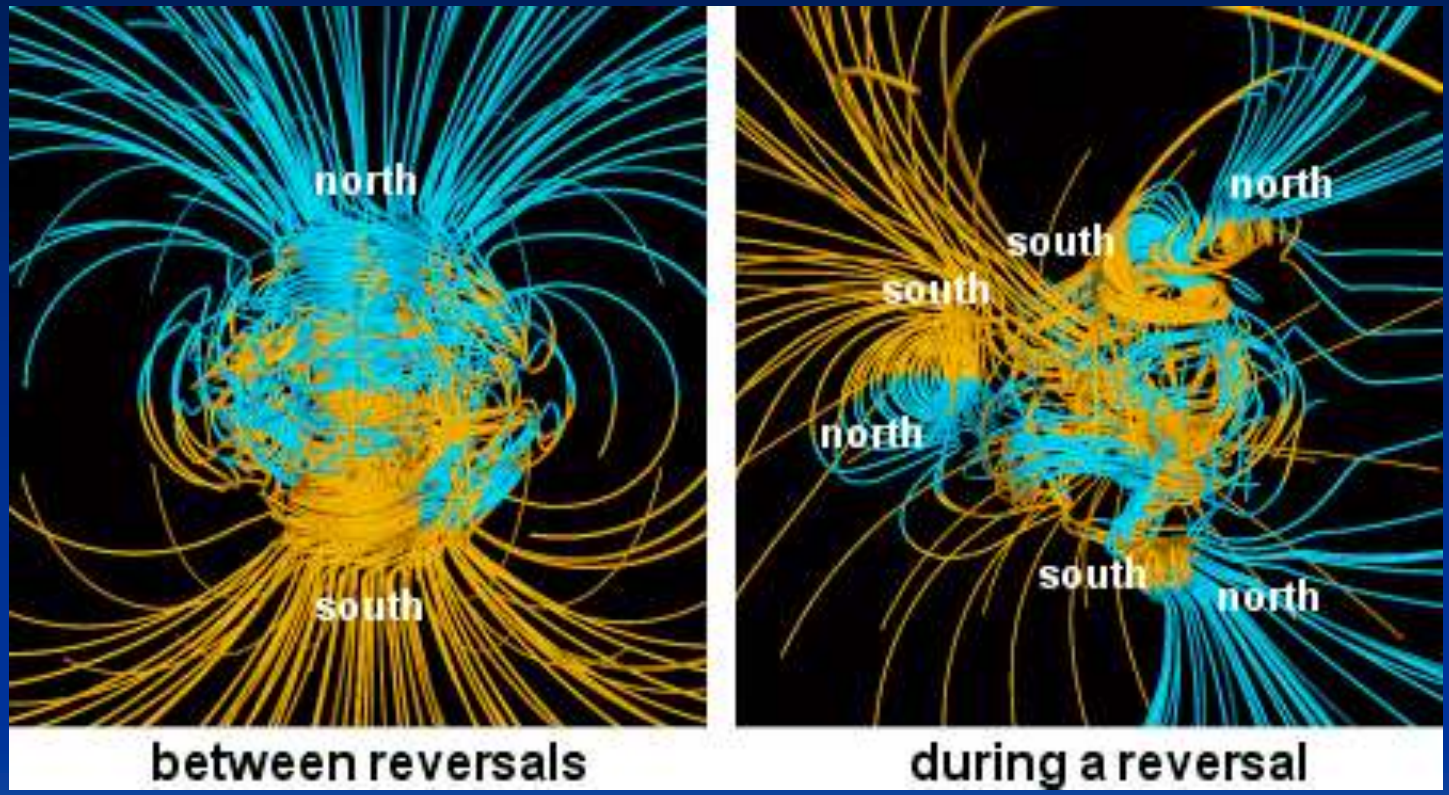
Hypothesized triggers

We used to think that these flips are triggered by external events that directly disrupt the flow in the Earth's core.

- impact events
- internal events such as the arrival of continental slabs carried down into the mantle
- or the initiation of new mantle plumes from the core-mantle boundary.

What about the Chicxulub impact, at the Cretaceous–Paleogene boundary? Is there a reversal?
What about the 20+ reversals in the past 5 my? Do we have evidence of impact events?

The poles “flip”

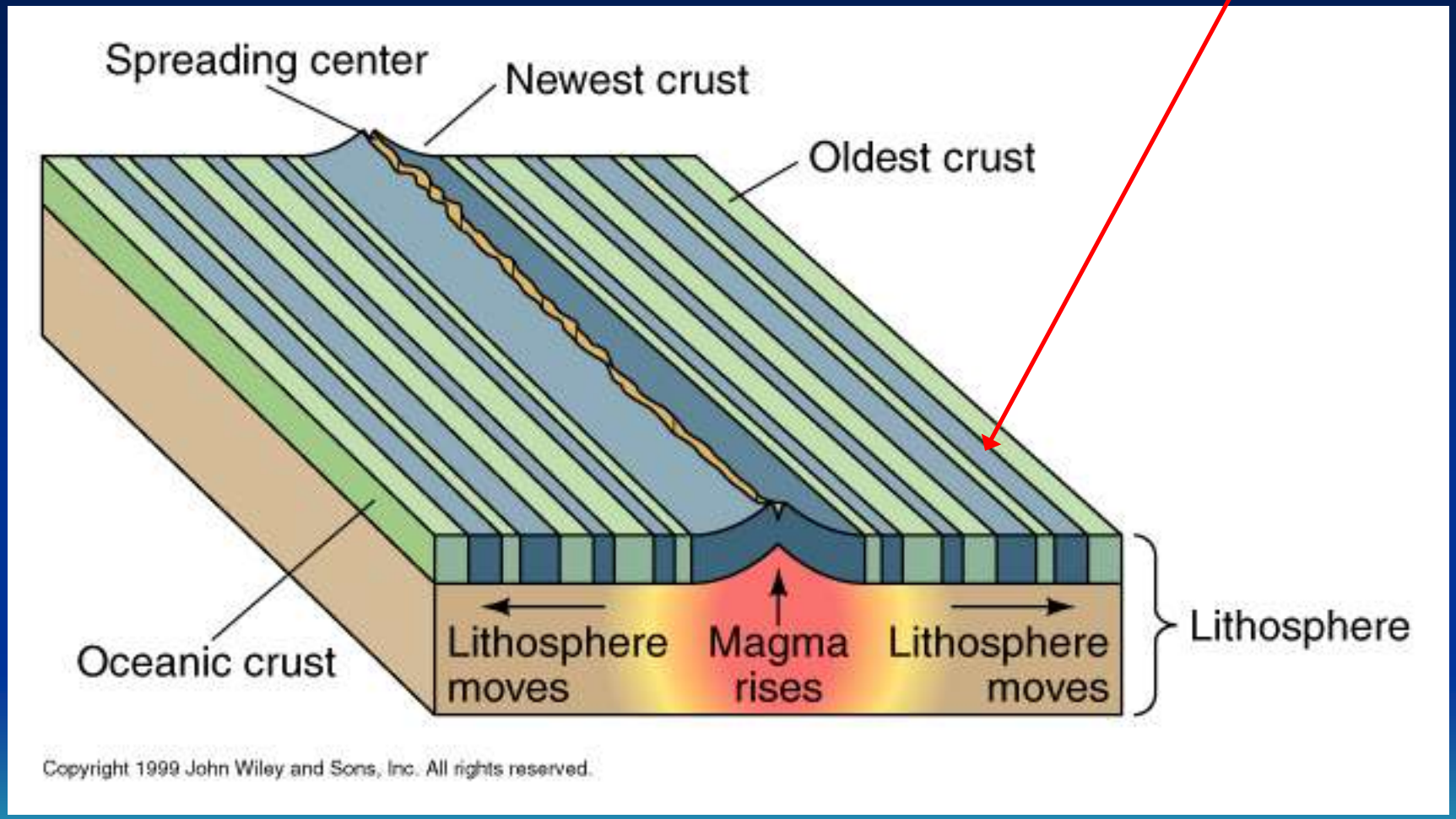


NASA computer simulation using the model of Glatzmaier and Roberts.[28] The tubes represent magnetic field lines, blue when the field points towards the center and yellow when away. The rotation axis of the Earth is centered and vertical. The dense clusters of lines are within the Earth's core.

The poles “flip”

- Lava that cools quickly on the sea floor records these flips and lets us date them.

Stripes of different magnetic polarity form in the rocks as the lava from the mid-ocean ridge cools.



Strange Things Going On

- Earth's magnetic field is **NOT** aligned with its rotational axis.
- The magnetic field is tilted 12^{o} to the rotational axis, and doesn't even pass directly through the center of the earth.
- Does this mean that the electrical currents don't flow evenly and uniformly inside the earth? Is there turbulence inside?

Magnetic Fields in Space

- Earth's magnetic field extends 7-10 times the earth's diameter outward from the earth.
- The earth's magnetic field would be spherical, but the solar wind compresses it on the side closest to the sun, and stretches it out into a long tail on the side opposite the sun.
- Overall, it's kind of tadpole shaped.

Why do we care?

- Earth's magnetic field isn't just "there" with no purpose. Without it, you and I and every living thing on this planet would be dead (including the cockroaches!)

- The magnetic field channels away the solar wind.
- It also prevents erosion of the atmosphere.

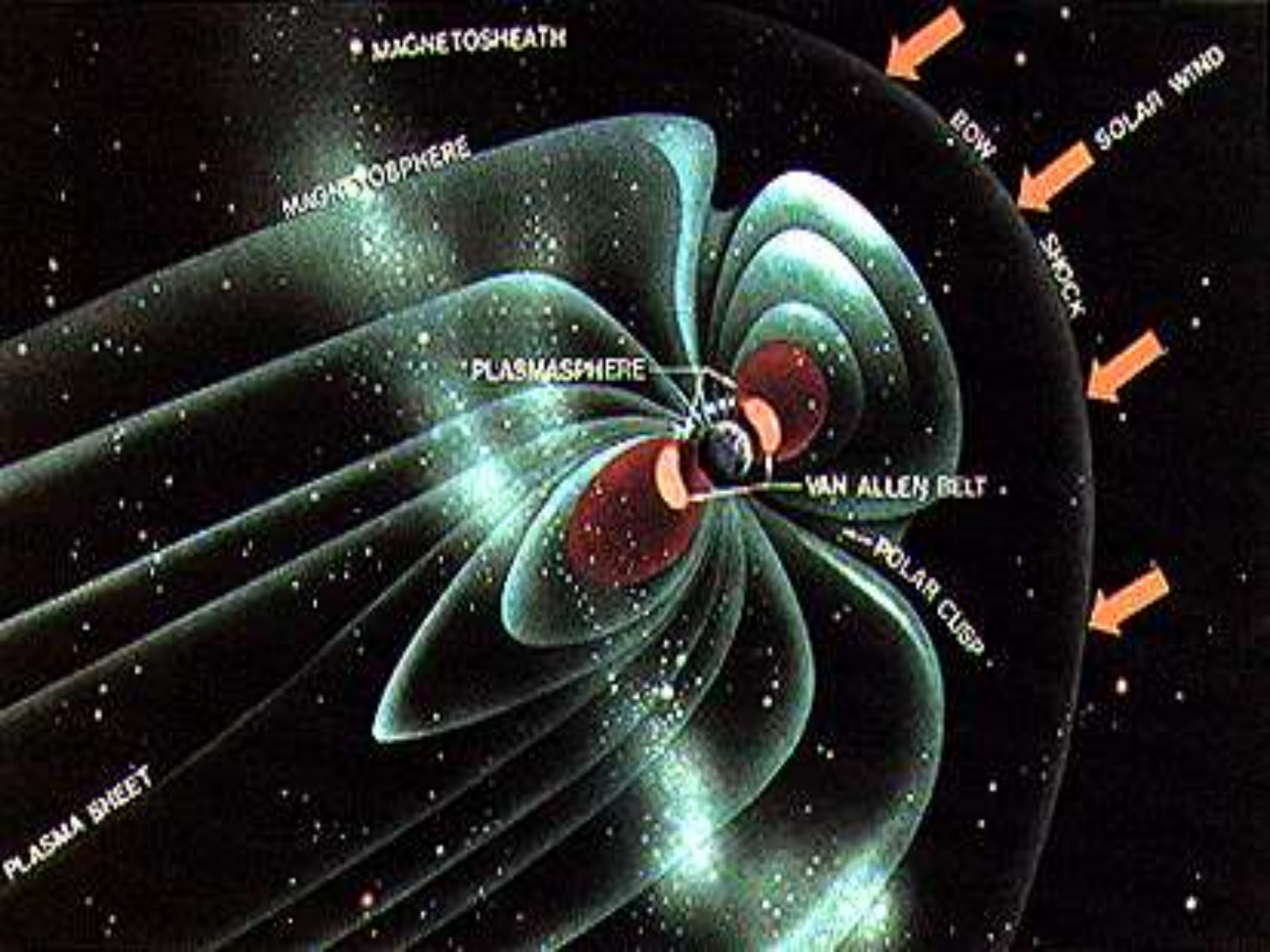
Solar Wind

- So what is the solar wind anyway?
  - It's radiation: extremely hot, high-energy, fast-moving charged particles (ions) given off by the sun. Most of these particles are protons.
  - If you were exposed to it for just a few hours without protection, your skin and every organ in your body would be burned, and you'd have a fatal dose of radiation poisoning.

How does the magnetic field protect us?

- The magnetic field captures the solar wind and channels much of it into a donut of radiation around the earth.

- This donut (actually 2 layers – one inside the other) is called the Van Allen Radiation Belt (V.A.R.B.)


MAGNETOSHEATH
BOW SHOCK
SOLAR WIND
MAGNETOSPHERE
PLASMASPHERE
VAN ALLEN BELT
POLAR CUSP
PLASMA SHEET