

What is the Geomagnetic Field?!



By Hayanon
Translated by Y. Noda
Supervised by Y. Kamide



A Message from C. F. Gauss (1777-1855)

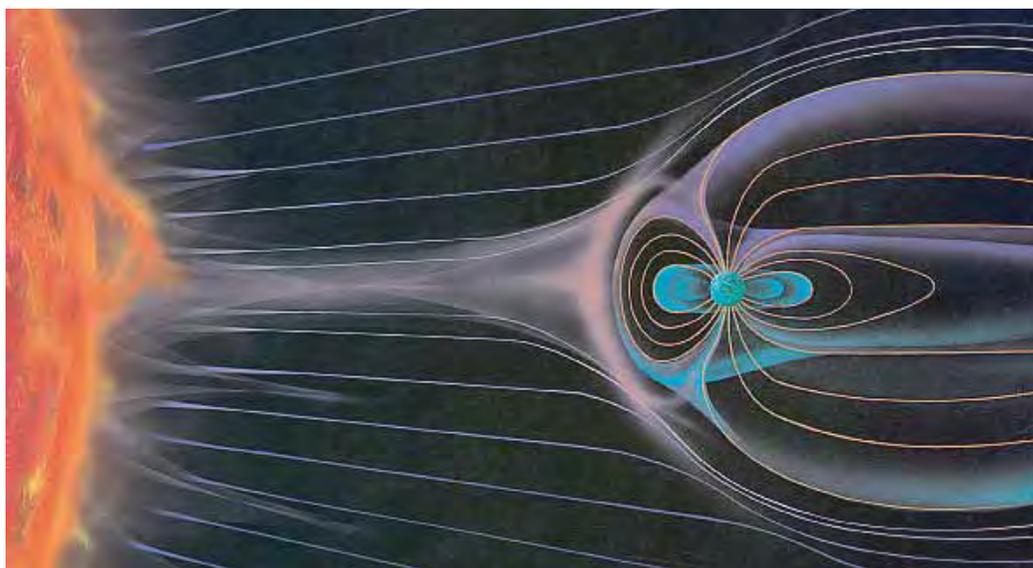


I was born in Germany, the son of a poor gardener. When I was a child, I often found mistakes in my father's calculation in wages for his employees. That gave me more fun than in the playground. Questioned by a teacher in 1st grade about the sum of the first 100 integers, I got the answer in a few seconds. In fact, it's quite simple. Make 100 pairs of numbers, each pair summing up 101, like 1+100, 2+99, ... Then multiply 101 by 100. It is 10100. Divide it by 2, that's 5050, the answer.

$$\begin{array}{r} 1 + 2 + 3 + \dots + 98 + 99 + 100 \\ 100 + 99 + 98 + \dots + 3 + 2 + 1 \\ \hline 101 + 101 + 101 + \dots + 101 + 101 + 101 \\ \\ = 101 \times 100 = 10100 \\ 10100 \div 2 = 5050 \end{array}$$

You may have noticed that some of the theorems in mathematics and physics, units, and formulas were named after me. At the age of 30, I became a professor at Göttingen University, where I enjoyed arithmetic theory, least-squares method, and potential theory. It's nice to meet you, readers, here in this book about my accomplishments estimating the geomagnetic intensity of the Earth using my spherical harmonic analysis. The actual data I used were collected from about 100 observatories over the world, with the support of the Royal Astronomical Society.

By the way, I heard that the geomagnetic field has been decreasing since I measured its intensity. It's really worrisome.



The Earth, a small blue ball in this illustration, is located in the solar atmosphere. The Earth is a huge magnet, whose invisible force protects us from the Sun's harmful radiation. Thanks to the Earth's magnetic field and air, we can live safely and in peace on this planet, Earth.

Today we are visiting a planetarium to see magnificent auroras.

Hi. I'm Mol and this is my robotic dog Mirubo. My favorite subject in elementary school is

Science!

Those auroras were so beautiful. ♥

Yes, they were just like the real ones. ♪

I wish I could see real auroras in Japan.

Huh?

I've heard that auroras will come down to Japan sometime in the future.

What?!

It's not possible!!

Yes, it is. I mean it.

Now, now. Calm down kids.

Pow!

Aargh



What's this all about?

Oh, it's you.
Aurora sensei!



Let's ask him!

Can auroras be seen in Japan in the future?



Definitely.

What a shock!

Whaaam

You see, I'm always right.



But it won't happen for about 1000 years.

1000 years!
Why?! I can't wait that long.

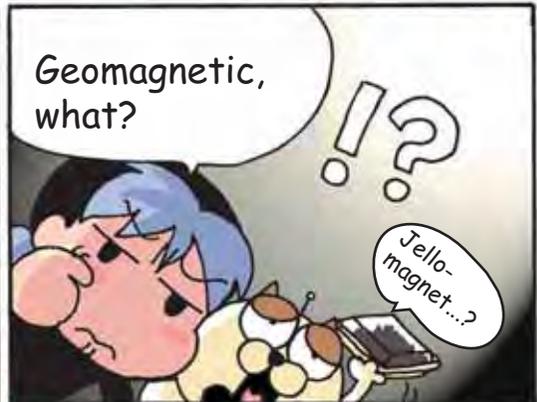
Ha ha ha



I want to see an aurora today!

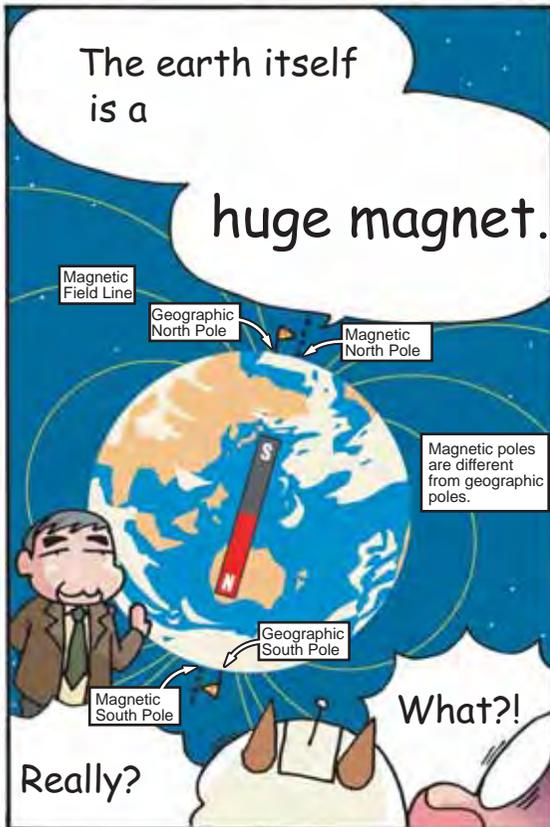
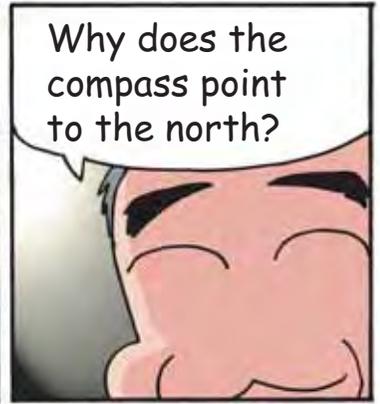
Well, it is not such a simple matter because the aurora relates to the geomagnetic field.

Behave Yourself!



Geomagnetic, what?

Jello-magnet...?

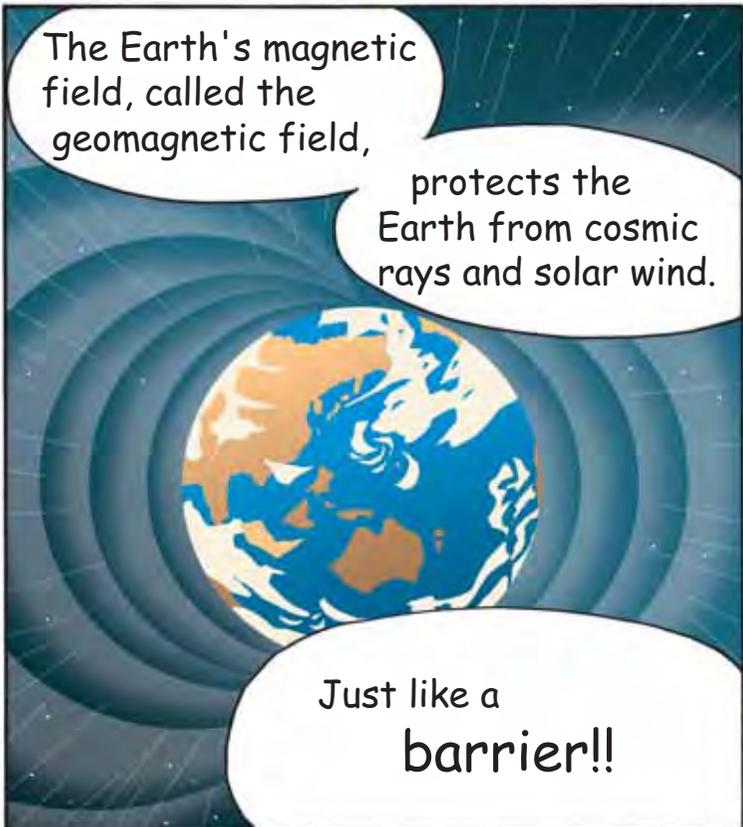




From the galaxy come high-energy particles called cosmic rays, and

solar wind from the sun, to the Earth ...

with terrific speed.



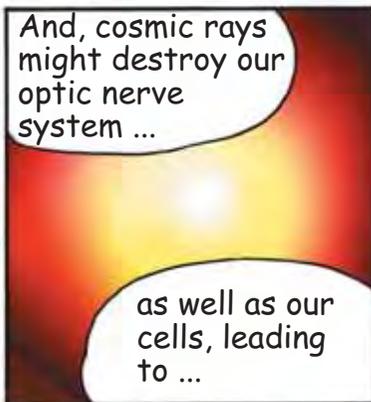
The Earth's magnetic field, called the geomagnetic field,

protects the Earth from cosmic rays and solar wind.

Just like a barrier!!



Without the barrier, solar wind would blow away the atmosphere.



And, cosmic rays might destroy our optic nerve system ...

as well as our cells, leading to ...



mutation or extinction of

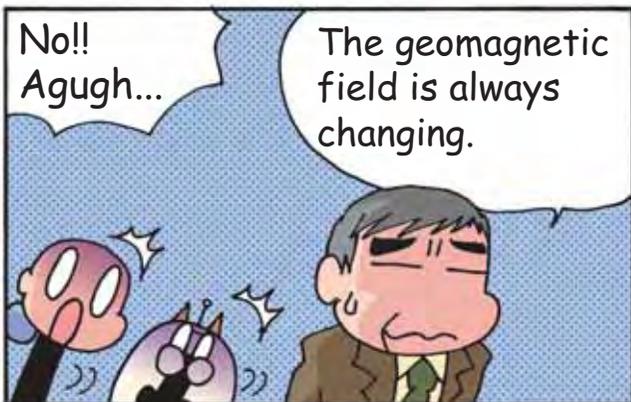
life on the Earth.



The geomagnetic field is great!!

Wahoo!!

But that friendly barrier does not exist forever.



No!! Agugh...

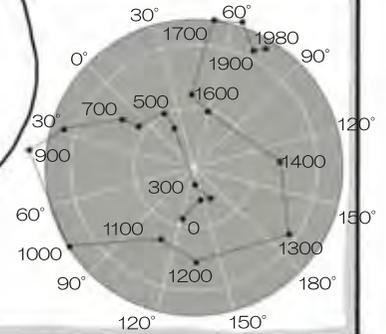
The geomagnetic field is always changing.

The geomagnetic north pole at present is here, 11.5° off the north pole, at the northwest corner of Greenland.

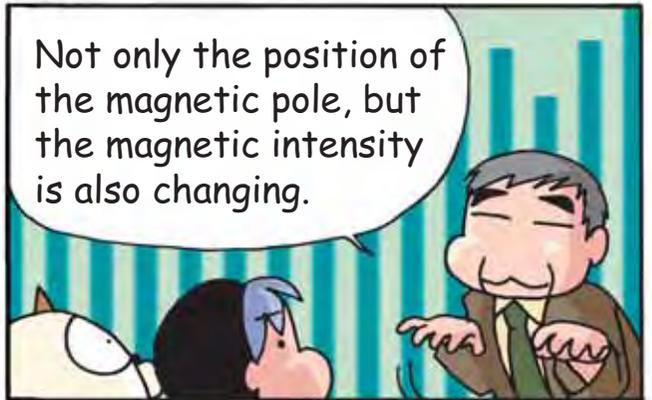


The geomagnetic north pole has been moving all through the long history of the Earth.

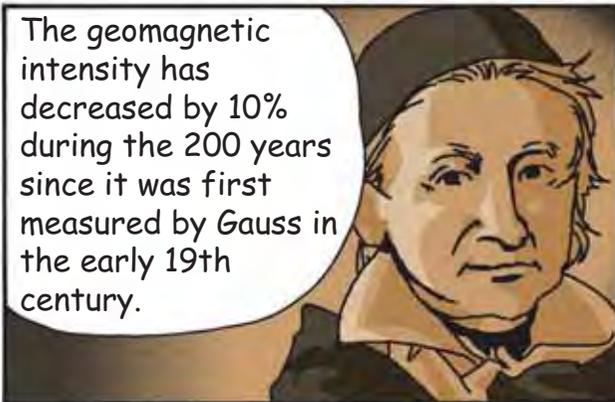
Movement of the geomagnetic north pole for the past 2000 years.



Not only the position of the magnetic pole, but the magnetic intensity is also changing.



The geomagnetic intensity has decreased by 10% during the 200 years since it was first measured by Gauss in the early 19th century.



Because of this the aurora will venture ever farther south. It's expected that the auroral belt will reach Japan in 1000 years.

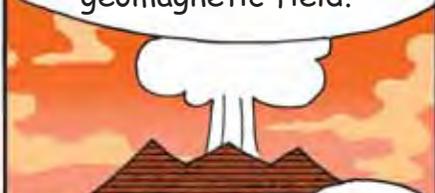


If the geomagnetic intensity keeps decreasing at the current pace, it will be zero in 1200 years.

Bang!



When lava flows cooled down, forming volcanic rocks after erupting from a volcano, they acquired records of the geomagnetic field.



Amazing!

It's like a magnetic disk!



Researchers found that some of the volcanic rocks collected from different volcanoes in the world are reversely magnetized.

I see, volcanic rocks are remaining as they were.



The layer in Chiba Prefecture, Japan, has a high-quality geomagnetic record, ...



which shows that 700,000 years ago the geomagnetic field disappeared and the magnetic poles were reversed.

Great!!



Fossils of foraminifers there suggest that

40% of them living in the shallows of the sea ...

died out due to the massive ultraviolet light which fell down to the Earth at the geomagnetic reversal.



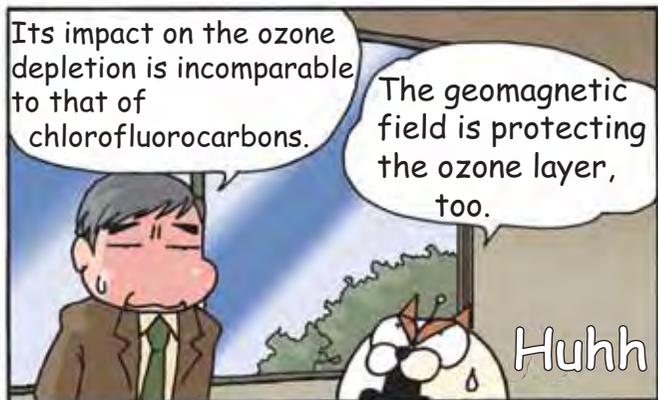
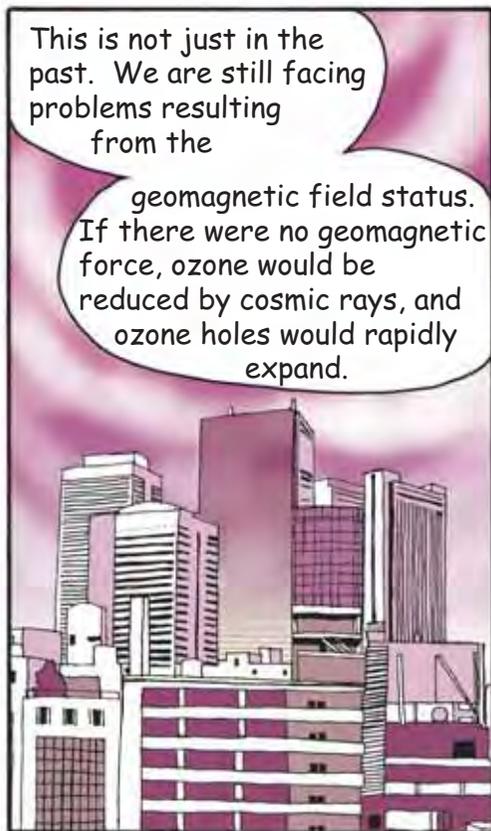
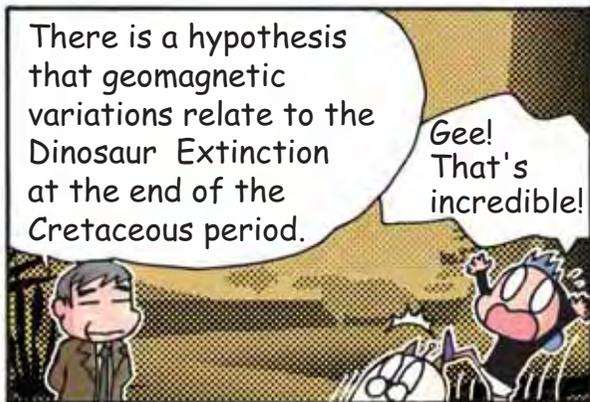
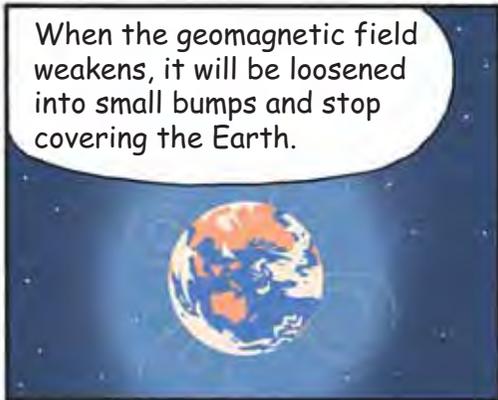
40%?! Besides, organic-carbon produced from foraminifers' corpses contributed to **global warming**.

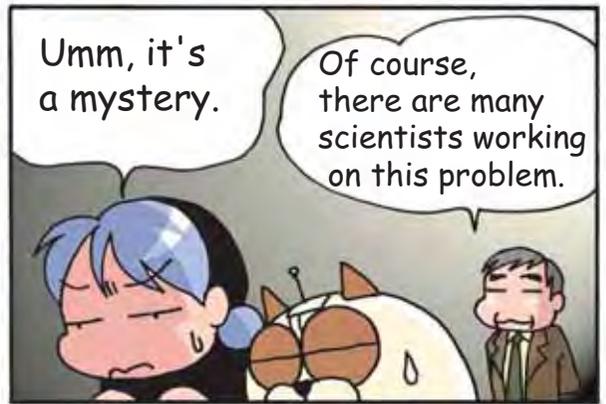
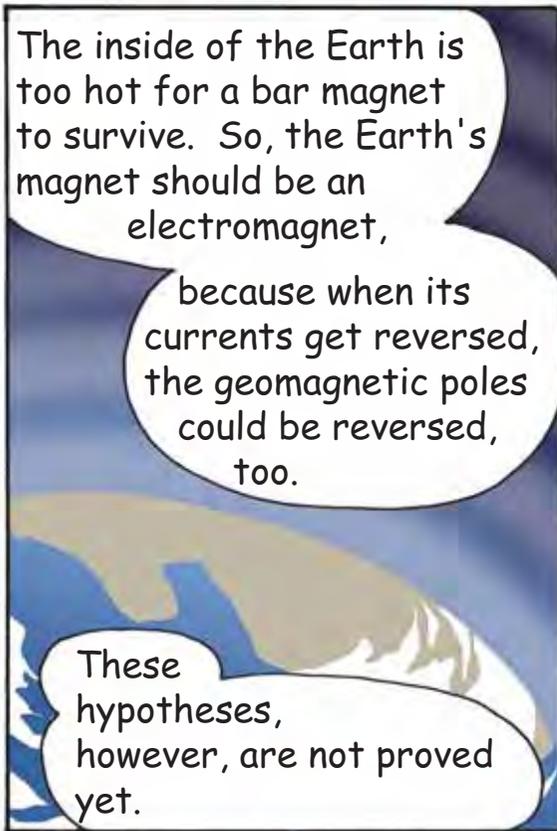
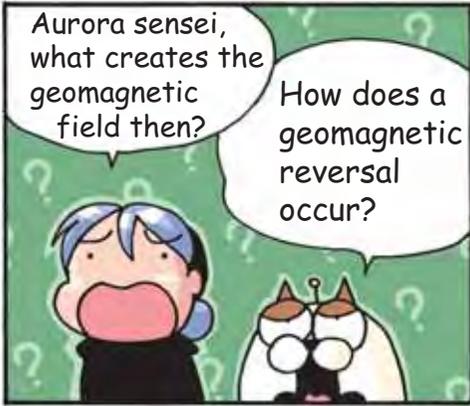


Geomagnetic changes have great impact on the Earth's environment in this way.

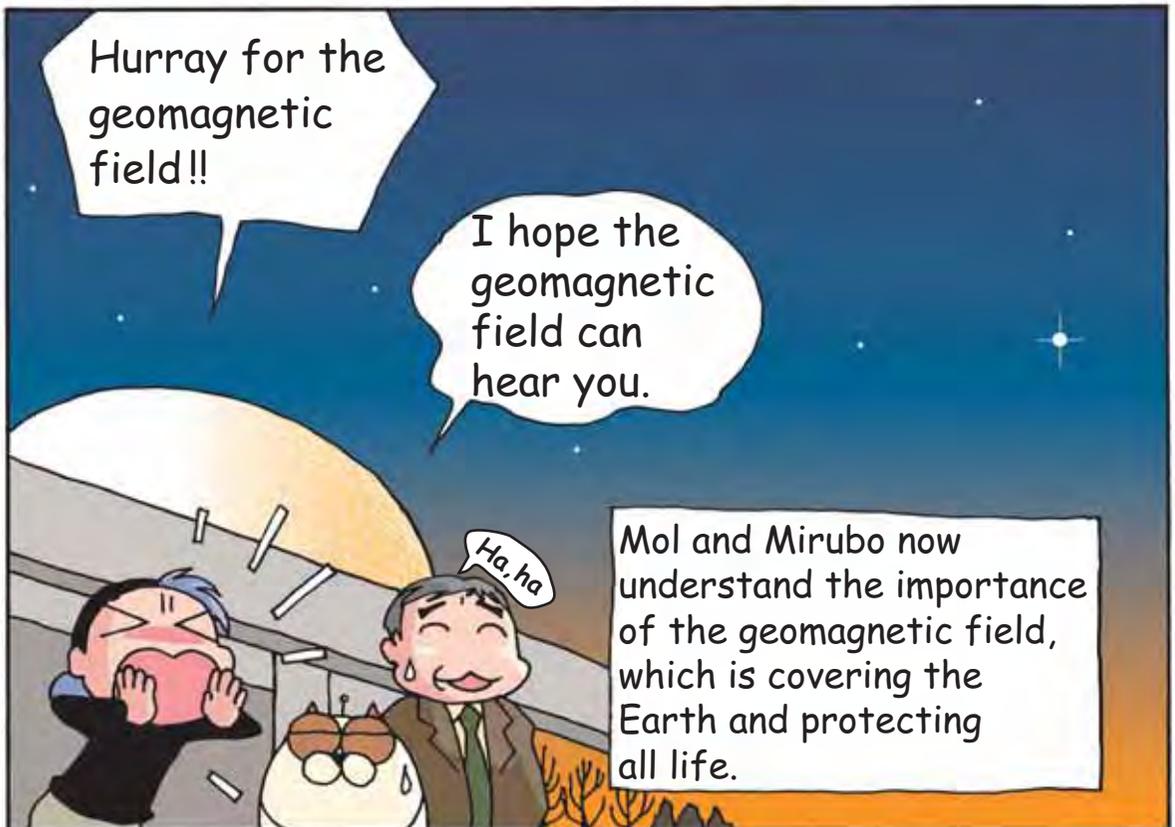
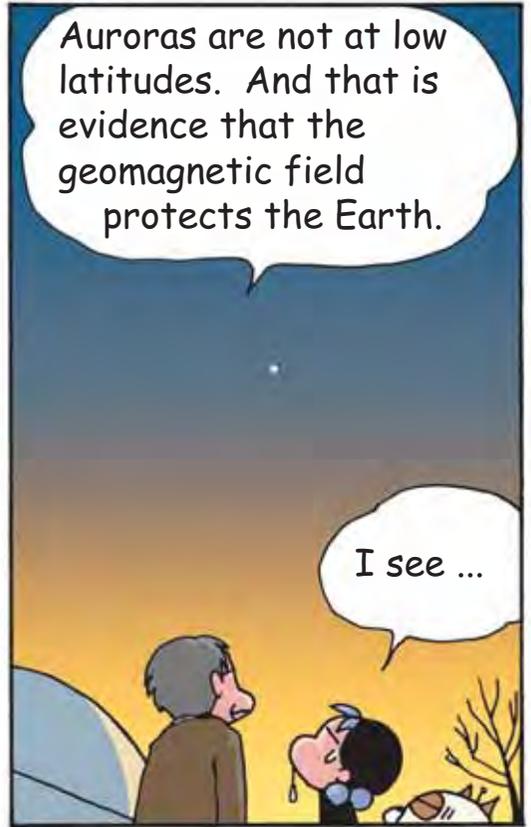
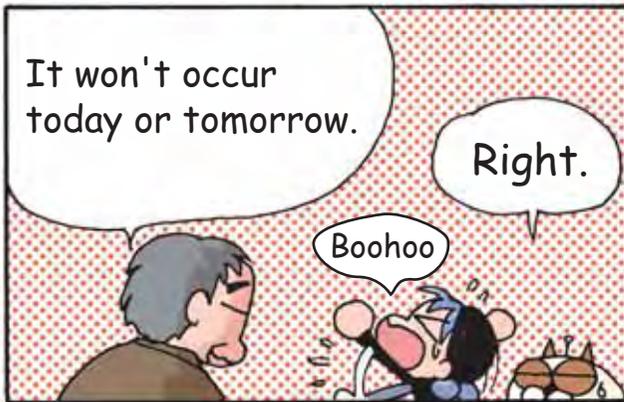
Scary ... I hate it.











What is the Geomagnetic Field?!



Hello, Mol and Mirubo. Let's talk about the Earth's magnetic power.



I understand that the Earth itself is a gigantic magnet.



Wow, I want to buy a magnet that big! How much does it cost?



Seriously, even though the Earth possesses the magnetic field, there is no magnet buried in the Earth interior.



What does that mean? Did someone dig deep into the ground? Where does the Earth's magnet come from?



The higher the temperature where a magnet is located, the more it loses its intensity. Deep inside the Earth is a few thousand degrees, too hot for a magnet to survive.



Sounds interesting! I'll do an experiment with my magnets.



That's a good idea. One picture is worth a thousand words.

I'll give you a clue. The inside of the Earth has molten metals which carry an electric current.



It's an electromagnet!!



That's right. The Earth has an electromagnet inside. It generates magnetic fields like a bar magnet does. When the intensity and direction of the electric currents change, magnetic poles can even be reversed.



Oh, my. My compass can't be used anymore after the

geomagnetic poles are reversed.



Don't worry. It will be in the far distant future, over 1000 years.



Ah, there is a long long time left.



In the Earth's history, however, 1000 years is rather short.

Anyhow, the geomagnetic field is always changing. In auroras a large amount of electricity is flowing. The phenomena called "magnetic storms" cause huge electric currents, inducing magnetic fields all over the world.



Is their intensity very strong? Strong enough to harm me?



The maximum is approximately 1-10 million amperes.



Really? My house has only 30 amperes!



Do you know what animals can sense the Earth's magnetic field?



I don't know. Maybe it's you.



No way, I don't have such power. It's pigeons, dolphins, migrating birds, etc.

Various experiments are being conducted on their perceptions of magnetic field.



Mirubo, I think you need to install a magnetic sensor in your brain. You don't have a sense of direction at all.



No kidding, Mol!!



Geomagnetic Field Hotline



Aurora

Lights seen in the polar sky caused by the **solar wind**, the flow of charged particles called **plasmas**. The solar wind enters the Earth's magnetosphere and travels into the nightside of the Earth, being accelerated along magnetic field lines, then colliding with the atmosphere over the polar regions. This collision creates the lights. The aurora is 100 - 500 km above the Earth's surface.

Carl Friedrich Gauss (1777-1855)

Gauss was a German mathematician and physicist. In 1839, he proved that the Earth's magnetic field originates from inside the Earth and not from outside. The unit gauss is used for measuring the magnetic intensity.

Compass

A device for deciding directions with a magnetic needle. When two magnets are brought together, the N-pole of one magnet attracts the S-pole of the other, or the N-poles of two magnets repel. The N-pole of a compass heads toward Earth's S-pole in the north pole region, and thus informs us which direction is north.

Cosmic Rays

Various types of high energy particles fluttering in space, including galactic cosmic rays coming from outside the solar system and solar energetic particles originating from solar flares. Most cosmic rays are absorbed or weakened in the Earth's atmosphere at around 100-500 km above the Earth.

Cretaceous Period

The period about 140-65 million years ago, and the last section of the Mesozoic Era. The climate then was mild, plants were exuberant, and dinosaurs thrived. At the end of the Cretaceous, dinosaurs and ammonites extinguished. Various causes are thought to be responsible for the extinction, such as a meteorite event, drastic climate change, geomagnetic reversal, etc. The Mesozoic is followed by the Cenozoic Era, the age of mammals.

Foraminifer

Foraminifers are tiny unicellular

organisms mainly found in the sea. They have calcareous shells formed from carbon dioxide in the air.

Geomagnetic Field

The Earth has the magnetic property of a big bar magnet. There exists the N-pole in the south polar region and the S-pole in the north polar region, generating a world of magnetic fields surrounding the Earth.

Organic Carbon

Living matter is made up of organic compounds associated with organic carbon. When plants or animals die, stored organic carbon forms carbon dioxide.

Ozone Hole

The ozone layer exists at an altitude of about 30 km, surrounding the Earth. In 1980, it was found to be mostly depleted in the stratosphere above the Antarctic, like a hole circling around the south pole. The ozone hole is known to be largest in September.

Plasma

Every substance is made up of atoms. When atoms are stripped of negatively charged electrons, they become positively charged ions. A gas made up of positively and negatively charged particles is called a plasma. Over 99% of the Universe is made up of plasmas, different from solid, liquid, and gas. This is the reason why plasmas are called the fourth state of matters.

Solar Wind

Flows of charged particles, **plasmas**, coming out of the sun. The Earth's magnetic field is swept into a tail-like shape away from the sun. A comet's tail forms in the same way.

Ultraviolet Light

The Sun emits various wavelengths of light. Among them is high-energy ultraviolet light with a wavelength of 400 nanometers. Ultraviolet light is harmful to our lives, causing risks of cancer or gene damage. It is mostly absorbed, however, near the **ozone layer** 30 km above the ground.



Solar-Terrestrial Environment Laboratory (STEL), Nagoya University

STEL is operated under an inter-university cooperative system in Japan. Its purpose is to promote "research on the structure and dynamics of the solar-terrestrial system," in collaboration with a number of universities and institutions both in Japan and abroad. The Laboratory consists of four research Divisions: Atmospheric Environment, Ionospheric and Magnetospheric Environment, Heliospheric Environment, and Integrated Studies. The Center for Joint Observations and Data Processing is also affiliated to the Laboratory to coordinate joint research projects and construct data bases. At its seven Observatories/Stations, ground-based observations of various physical and chemical entities are conducted nationwide.

<http://www.stelab.nagoya-u.ac.jp/>



National Geophysical Data Center (NGDC) Space Environment Center (SEC)

National Oceanic and Atmospheric Administration (NOAA)

NGDC and SEC of NOAA, located in Boulder, Colorado, are part of the US Department of Commerce. NGDC provides scientific stewardship, products and services for geophysical data describing the solid earth, marine, and solar-terrestrial environment, as well as earth observations from space. Continually monitoring Earth's space environment, SEC provides reliable and useful solar-terrestrial information, conducts research and development programs to understand the environment, and plays a leadership role in the space weather community.

<http://www.ngdc.noaa.gov/>

<http://www.sec.noaa.gov/>

はやのん Hayanon

Graduated from the Department of Physics of Ryukyu University, Hayanon, a writer and cartoonist, has contributed a number of serials in popular magazines on the basis of her strong background in science and computer games. Her consistent writing style, expressing a love for science, is well accepted.

<http://www.hayanon.jp/>

子供の科学 Kodomo no Kagaku (Science for Children)

Kodomo no Kagaku, published by the Seibundo Shinkosha Publishing Co., Ltd. is a monthly magazine for juniors. Since the inaugural issue in 1924, the magazine has continuously promoted science education by providing various facets of science, from scientific phenomena in everyday life to cutting edge research topics.

<http://www.seibundo-net.co.jp/>

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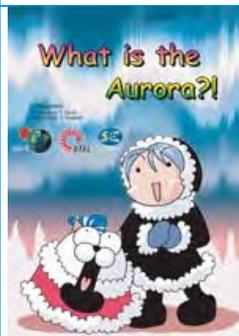
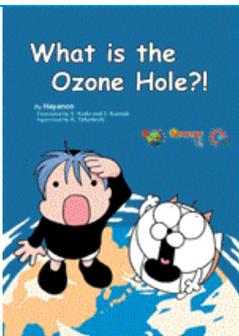
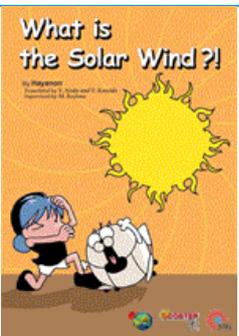
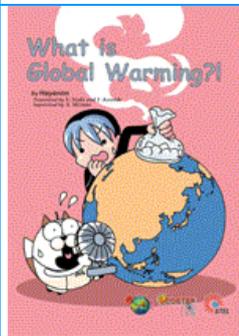
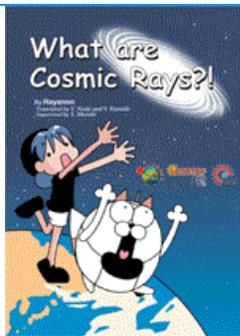
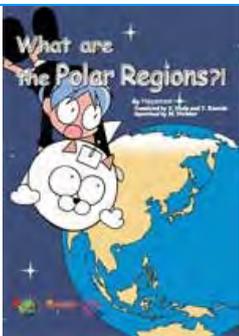
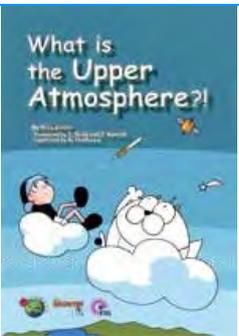
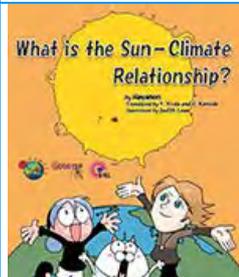


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Public Outreach

■ Booklets

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What is the Aurora?!	What is the Geomagnetic Field?!	What is the Ozone Hole?!	What is the Solar Wind?!
			
What is Global Warming?!	What are Cosmic Rays?!	What are the Polar Regions?!	What is the Upper Atmosphere?!
			
What is the Sun-Climate Relationship?!			
			

All of these can be downloaded as pdf from the website given below.

<http://www.stelab.nagoya-u.ac.jp/ste-www1/doce/outreach.html>

■ Open House

STEL opens its research facilities to tours by groups of school children, students and local companies. The Laboratory also conducts an Open House once a year, typically in June. Many visitors of all ages observe firsthand the work of the four research Divisions and Geospace Research Center, and enjoy the excitement of scientific