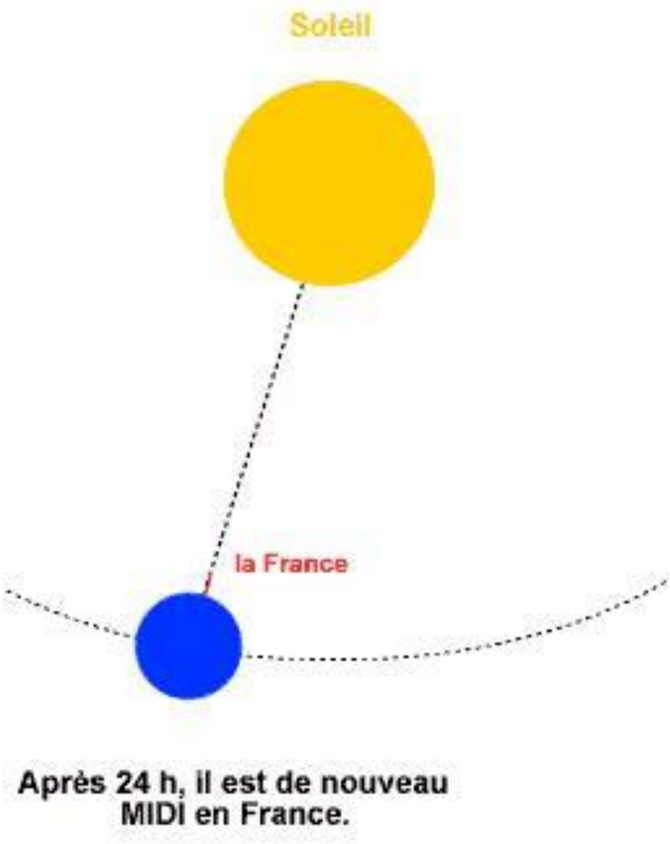
Sequence 2

Technical assistance for sequence n° 2

The second sequence suggests you to undertake a daily observation of the course of the Sun in the sky. Its course above our heads is due to the rotation of Earth around its North/South axis every 24 hours. The variation of this course through one year is caused by the angle this axis makes with the plane of Earth's orbit, and the revolving of Earth around the Sun in approximately 365 days. Let's now have a closer look at these concepts.

Rotation of Earth

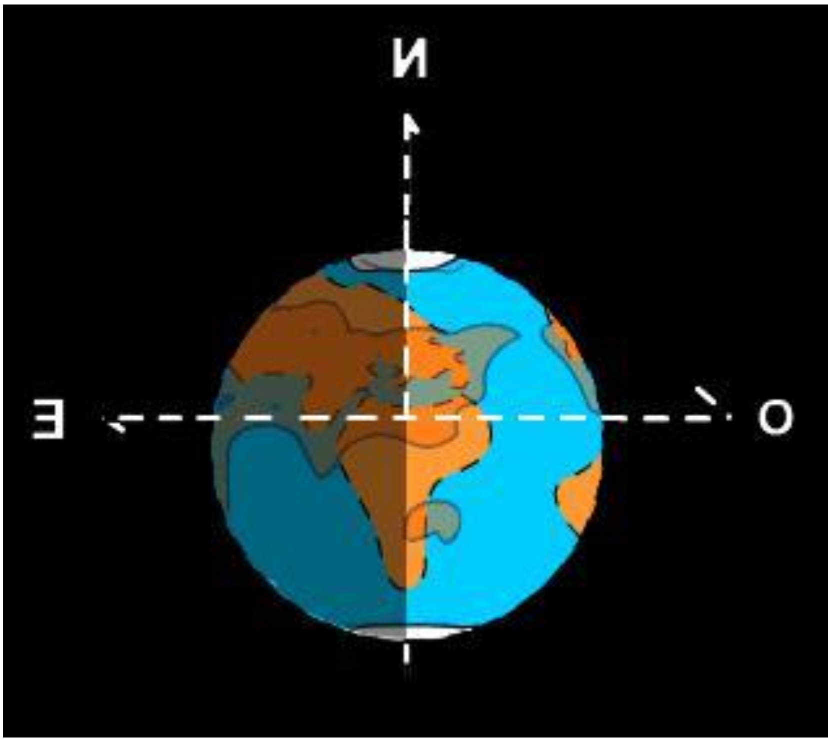
The alternation of day and night is probably the clearest and most striking of all astronomical phenomena for living beings. The Earth rotates upon herself from West to East in 23 hours and 56 minutes in relation to the most distant stars (almost fixed). In one day, it also revolves around the Sun, little less than one degree, which slightly lengthens the duration of the solar day to approximately 24 hours. This is the length of time it takes for the Sun to cross the meridian twice.



For a long time, we thought that Earth was motionless, at the centre of the universe, and that all the stars were turning around it. Aristarque de Samos (310-230 before Christ) was the one who laid the foundations for our actual cosmology, saying that Earth was revolving around the Sun in one year and rotating upon herself in one day "like a spinning top". His system got to us thanks to the works of his contemporaries (such as Archimedes) and of Greek historians. The Polish Nicolas Copernic (1473-1543), used his theories and was the first to dare a theory where Earth was a planet just like any other, revolutionizing not only astronomy but also the whole human thought.

The daily course of the Sun in the sky

It is the rotation around the North/South axis that gives us the delusion that the Sun (and the stars) are turning above our heads, in the opposite direction : rising in the east, at its highest at midday to the South (for the northern hemisphere) and finally setting in the west.



We should draw your attention about the notion of "solar midday". It is the exact time when the Sun is at its highest in the sky, and therefore the time when the shadows it casts are at their shortest. Its course in the sky is exactly symmetrical with regard to its position at solar midday : etymologically, "midday" means the half of the day, of the sunny period. Be careful : this midday is not a clock midday! Furthermore, this moment changes during the year, but we'll see this notion in future sequences.

Preconceptions !

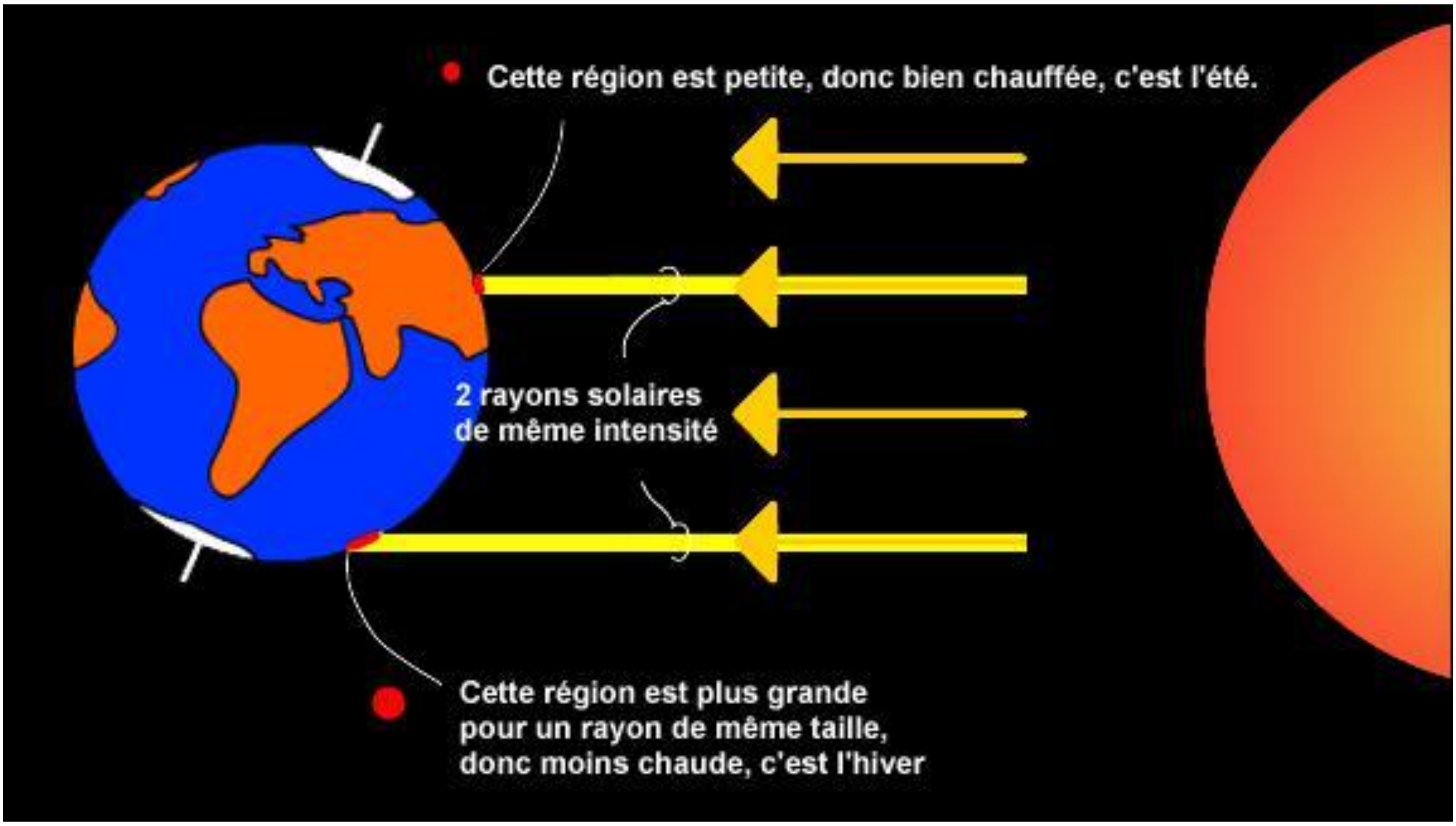
People often believe, wrongly, the Sun rises exactly in the eat and sets in the west. It is absolutely true only two days in the year : the days of the equinox (when the day lasts exactly as long as the night). In winter, it rises in the south-east and sets in the south-west, shortening its course in the sky (for the northern hemisphere). In summer, it goes to the north, lengthening the sunny period (of course, the opposite case happens in the southern hemisphere). Where do these variations come from???

Rotation axis inclination

Earth completes a course around the Sun in one year (365.25 j), following a trajectory (called orbit) inscribed in a plane called ecliptic. Just as a spinning top, it glides on a circle (accurately an ellipse) about 150 million kms radius. Its characteristic is that its rotation axis in inclined with regard to the plane of the ecliptic : the axis between the two poles has a 23.5 degrees inclination and always points in the same direction to the stars (the famous "pole star").

The seasons are linked to this inclination, and not to the distance Earth-Sun. So, when the northern hemisphere gets warmer under summer sun, the southern hemisphere gets through the harshness of winter. That's why the

North pole is lit during the whole of summer, and the South pole is in darkness, Earth showing mostly its northern hemisphere to sunrays. The north-south rotation axis always pointing the same way, the reverse situation happens six months later.



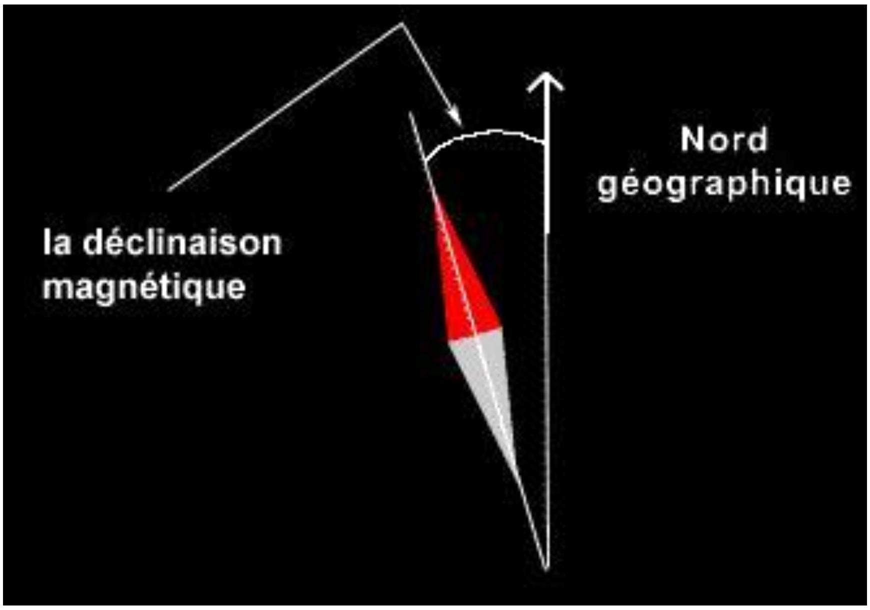
North and South : thake care!

Until now, we have used the geographic north : the direction of the north pole from the point of observation. This north pole is nothing more than the place where the rotation axis passes through Earth. To discover the exact North, we generally use a compass.

How does a compass work?

The use of a compass can raise questions about magnetism, but you will have to be careful in your explanations and only explain a few facts in that difficult field.
The needle of a compass is a magnet with a north and a south pole (the use of the word "pole" is an analogy with Earth). Two magnets can attract or repulse themselves according to their place with regard to the poles, that is why you have to use a compass far from any piece of magnetic material. Non-magnetized iron magnetize when they get close to a magnet (try with nails or needles). A few coins, still in use in 2001, are attracted by a magnet because they are made with nickel. Finally, a coil of electric wire act just like a magnet when power runs in it. (see file n°15 of the ministère de l'éducation nationale, on http://www.eduscol.education.fr/)

However, the two magnetic poles (North and South) do not exactly match with the geographic ones. Furthermore, they slowly drift from year to year. You have to compensate with a correction called magnetic variation to the direction shown by the compass in order to find geographic north, correction depending on our place on Earth, as well as the date (this question in the magnetism will not be explained to the pupils).



You should know that the North-South direction given by your compass slightly drifts (a few degrees) from the geographic poles, and that you will get a more accurate estimation of their direction with the shadow at solar midday. Enjoy and measure this angle with your pupils!

Sequence 2

Technical assistance for sequence n° 2

Sequence 2 tackles with the notions of the vertical and horizontal. At a small scale, these notions are very intuitive, but at the scale of our planet, more thorough explanations would be needed.

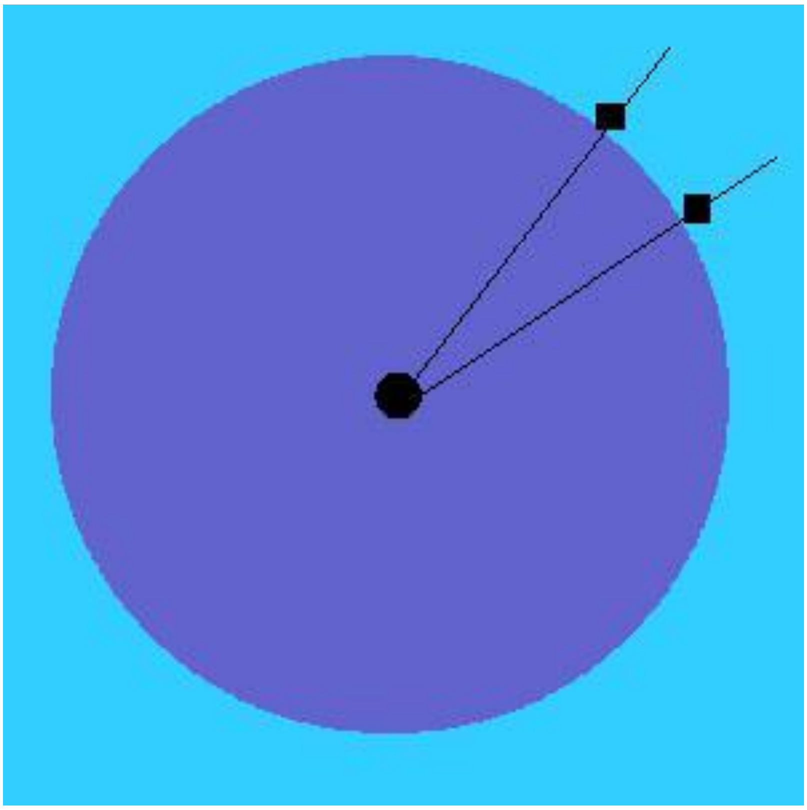
To imagine the vertical and horizontal

The vertical in one point is the direction given by a plumb line. A weight hung at the end of a line tightens it in the vertical direction with regard to the place.
The horizontal is the line on a plane equal to the surface of a liquid at rest : a plane that can be determined with an air level. It is a long bar containing a short glass tube of liquid with a bubble. When the level is horizontal, the bubble is centred in the middle of the glass tube. If it is not, the bubble drifts to one of the extremities.

For each given point, only one vertical and an infinity of horizontals exist. In the schoolyard, every vertical are parallel to each other, and perpendicular to the horizontals. But on the surface of the Earth, the verticals, (as well as the horizontals) are not all parallel one to the other. All of them are related to the centre of the Earth.

To prove it, you could measure the variations of the plumb line :
2 plumb lines 111 km distant from one another (1° latitude) would make an angle of 1°.
2 plumb lines 1 km distant, there would be 1/100 th degree, or 36 seconds. On the 10 meters of a classroom, it would become 0.36 seconds, a difference much smaller than our protractor could show.
The angle between the verticals can be measured only between very distant points (hundreds of kms).

Everyone know that the Earth is round, but it seems plane to us. How can we reconcile these two views?
Our close environment (the streets, the wall of the schoolyard...) are on such a small part of our spherical Earth that it can be deemed as plane.
At the scale of the planet, the vertical to our place is no more than the extension of the line that joins our position on the surface to the centre of the world. So, when we go from one place to another (from Lille to Marseille), the lines change, changing the vertical.
Of course, if the trip is a small one (from one end of the schoolyard to the other), the lines are nearly the same.



At the scale of our planet, the horizontal is locally contained in the plane tangent to the surface of the Earth (spherical). For short distances, these tangential planes merge and two horizontal planks placed at the two ends of your classroom will not seem inclined one to the other. Not because the angle between these two planks is nil, but because it is too small for you to measure! remember that the Earth's radius is approximately 6370 km, and as such you'd need great horizontal dimensions (at least a few dozens of kms) in order to see the curve (the horizon at sea, for example).

What are the vertical and horizontal?

What is the common "denominator" we could use to understand the physical nature of these two notions? Gravitation, of course! The gravitation attracts the weight used to tighten the plumb line. It also attracts the water and makes its surface horizontal.

What gravitation is precisely?

We could describe it as a characteristic of matter : "matter attracts matter". Two bodies attract each other, all the more they are massive and the distance between them is small. For example, if you drop a lump of chalk, it falls on the ground. Why? Because the Earth and the chalk attract themselves mutually.

Where?

In fact, each particle of which the Earth is made attract the chalk, but because of its spherical shape (also for reasons of homogeneity as well as distribution of the mass in the successive layers that make the inner structure of the Earth), and you can deem that the Earth's mass is concentrated on its mass centre (that can be taken in first estimate as the centre of the Earth). The attraction of the Earth on the chalk will then be directed towards the centre of the Earth. That is why the plumb line is directed towards the centre of the Earth and materialize the vertical in one point : it stretches towards the "centre of the Earth's masses".

Consequently, if you drop the chalk without casting it, the lump will also follow the vertical!

What about the horizontal?

The same happens with all the particles of a body of water : they are all attracted to the centre of the Earth. At rest, all the parts of the surface of a vessel full of water will be at the same distance from the centre of the Earth. That is why the surface of a liquid in a vessel is parallel to the surface of the Earth : at our scale, it draws a horizontal plane, and at the scale of the planet, it matches the curve of the Earth. Locally, the surface of the ocean (without the waves!) is plane, but at the global scale, it is a sphere.

Further...

Does the vertical really go through the centre of the Earth? The answer would be yes if the Earth was really a perfect sphere and if the masses of which it is made were absolutely symmetrical with regard to the centre of this sphere. More accurately, it is slightly plane to the poles. It is just as if the Earth was surrounded with a "roll" around the equator. This morphological asymmetry creates a small deviation in the resulting forces of gravitation acting on the plumb line. Consequently, the plumb line is slightly attracted towards the equator and does not precisely point towards the centre of the Earth, but towards the "centre of masses" that make up our planet.