

Notes for Teachers on:

Earth's vertical electric field

Introduction:

This document seeks to give practical meaning to the theory describing the electric field between two parallel plates by showing its application in our understanding of the earth's vertical electric field. It is hoped that the fact that the example is set in Antarctica will add to the interest generated by the example.

Required prior knowledge:

The illustration is aimed at students of upper level high-school physics. They will need to have a qualitative knowledge of the physics associated with a pair of charged plates and the electric field that is formed between them. The relationship between resistance and current (Ohms law) is required to understand the reason for siting the experiment on the high Antarctic plateau.

Intended use:

The document is designed to be easily printed and distributed to students as an example of physics being applied to understand aspects of our environment. It is not intended as a first source of instruction on electric fields.

Associated websites:

The following websites can be used to obtain more information about the experiment described in the following document and about the physical principles it describes.

Some Related Websites

Scientific American Article

<http://www.sciam.com/article.cfm?articleID=00000ED3-69CA-1C72-9EB7809EC588F2D7>

Electric Field on the surface of the earth

<http://hypertextbook.com/facts/1998/TreshaEdwards.shtml>

Electric Field in general

<http://hypertextbook.com/physics/electricity/electric-field/>



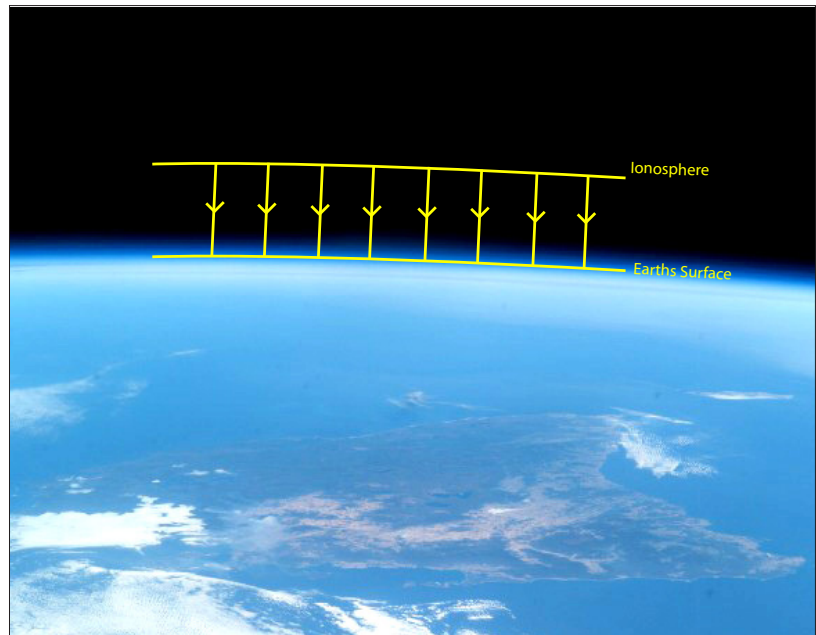
Earth's vertical electric field

Although we don't realise it, we are walking around in a strong electric field. And it turns out that high on the Antarctic plateau is a great place to study it.

Why are the earth and its atmosphere like a pair of charged parallel plates?

In a region of the atmosphere known as the ionosphere, parts of the spectrum of the radiation from the sun is so energetic, that atoms and molecules in the air are separated from some of their electrons. This ionisation is where the ionosphere gets its name. Its lowest levels are about 100 km above the earth's surface. And because the electrons are free to move around, the region can conduct electricity like one of a pair of parallel plates.

The other parallel plate is the earth itself, which is also capable of conducting electricity. And although the earth is spherical, the atmosphere is quite thin. So the atmosphere and the ground form a pair of parallel plates with the same slight curve in them.



A parallel-plate capacitor as seen from space.

Charging the plates

The physics of a pair of parallel plates becomes more interesting when there is a difference in the charge on each of the plates. It is then that the electric field between the plates becomes apparent. The most obvious electrical phenomena in our atmosphere are thunderstorms and it is these that put the charge on our "parallel plates".

Thunderstorms are very violent phenomena. Huge updrafts and downdrafts are moving water and ice up and down inside a thundercloud. They have the effect of giving the top of the cloud a large positive charge and the bottom of the cloud a large negative charge. The transfer of charge from the thundercloud to the ionosphere above and the earth below is what creates the earth's electric field.

On the earth's surface, the electric field can be as strong as 100 to 300 V/m. This means that if you are out in the open, and away from buildings or other things that would affect the field, there can be a few hundred volts between your head and your toes!

Why Antarctica?

The generation and movement of charge through thunderstorms and lightning only occurs over a small part of Earth's surface. Everywhere else, the air acts like the insulating gap between our parallel plates...almost. Air is a poor conductor but it is not an insulator. Even though its resistance is high, the total resistance between the ionosphere and the earth's surface is not high enough to prevent a current of charge from flowing back down to the earth.

The limited ability the air has to conduct stems from the presence of small ions. As we get higher up in the atmosphere, the air becomes less dense and the mean free path increases. The ability of the air to conduct improves because the mean free path is greater and the small ions are more mobile.

Closer to the ground, the resistance of air is much higher and if the ground is at a high altitude, a lot of resistance is shorted out. This means the resistance between the ionosphere and a site high on the Antarctic plateau is less than that to sea level. The result is a larger current flow at a high altitude site and an electric that field is easier to measure.

The Space and Atmospheric Physics group at the Australian Antarctic Division operate equipment that measures the earth's electric field so that we can learn more about aspects of its cause. This experiment is run in conjunction with Russian scientists and is situated at Vostok station in Antarctica.



The electric field mill at Vostok.

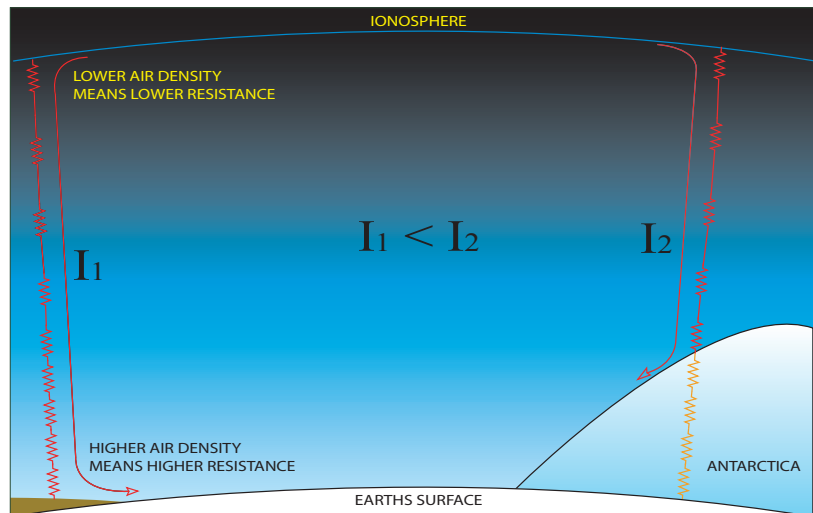
Vostok has the record for the coldest surface temperature ever recorded. This is because it is not only in Antarctica, it is near one of the highest points on the Antarctic continent. They have measured temperatures as low as -89°C there and in the summer, it rarely gets above -20°C .

Vostok cement

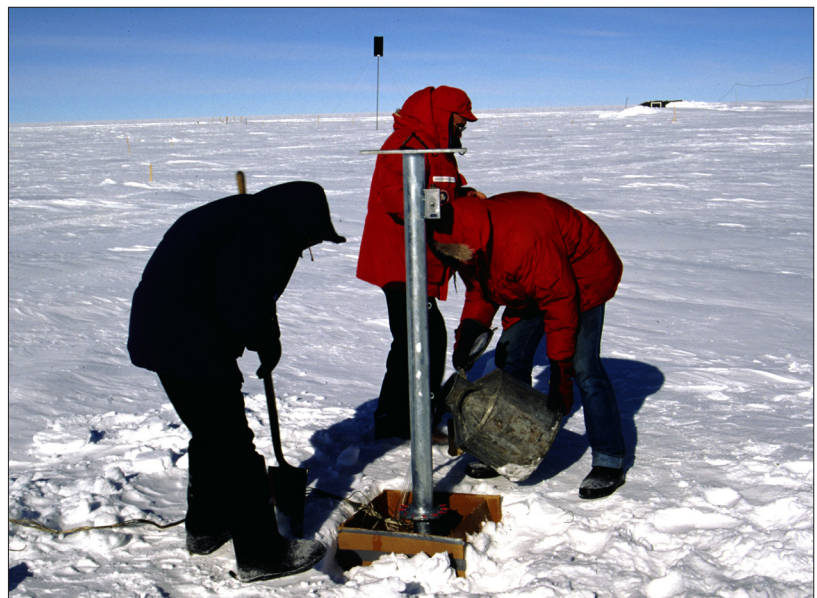
When engineers from the Australian Antarctic Division installed the experiment that measures the electric field

at Vostok, they used a substance called Vostok cement to hold it in place. After digging a hole in the snow and setting the pole that would hold the experimental apparatus in place, the hole was filled with Vostok cement. This magical compound is sourced from the kitchen, transported to the site in a well insulated bottle, and poured into the hole while it is still liquid. And it is just....water. Vostok remains so cold all year round that, after the water has frozen into a solid block of ice it will never thaw out!

Compiled by Damian Murphy (Australian Antarctic Division) and Jak Denny (Rosny College).



Currents from the ionosphere to the ground.



Pouring Vostok cement.