

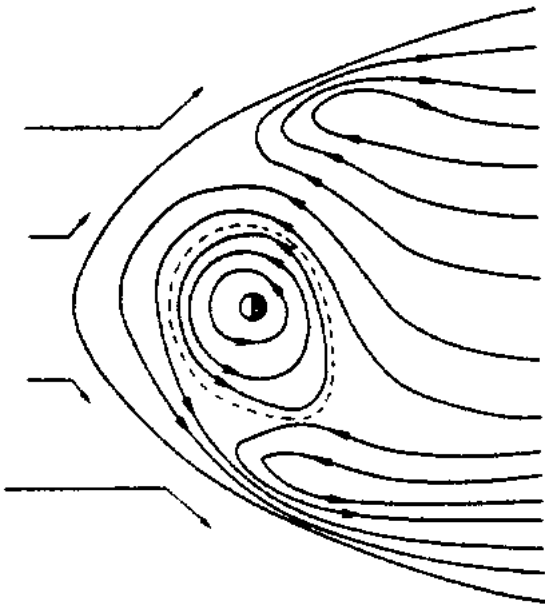
Coupling with the ionosphere

By J. De Keyser

While the motion of the outer regions of the magnetosphere is prescribed by the solar-wind magnetosphere interaction, the motion of the inner regions of the magnetosphere is determined by the ionosphere, which corotates with Earth. Both motions are not mutually independent, since they are connected by the flow of electrically charged particles (that is, electric currents) in the magnetosphere. Although the mechanisms involved in this coupling are still not completely understood, it is clear that the main effect of this giant electric circuit is that solar wind energy is delivered to the Earth's ionosphere in the form of heat.

The flow in the magnetosphere

The flow in the magnetosphere (also called "magnetospheric convection") is closely linked to the magnetospheric electric field, since (low-energy) particles move on electric potential iso-surfaces (surfaces of constant voltage).



The accompanying figure [after Nishida, JGR71, 5669, 1966] sketches a very simple model of the flow in the magnetosphere (in an equatorial cross-section). The Sun is to the left.

The magnetosheath plasma flows from left to right around the C-shaped magnetopause. In the proximity of the Earth the plasma simply rotates around with the Earth's daily rotation.

Plasma is flowing toward the Earth in the central regions of the tail (on the right side of the figure); this motion is forced by the interaction between the solar wind and the magnetotail.

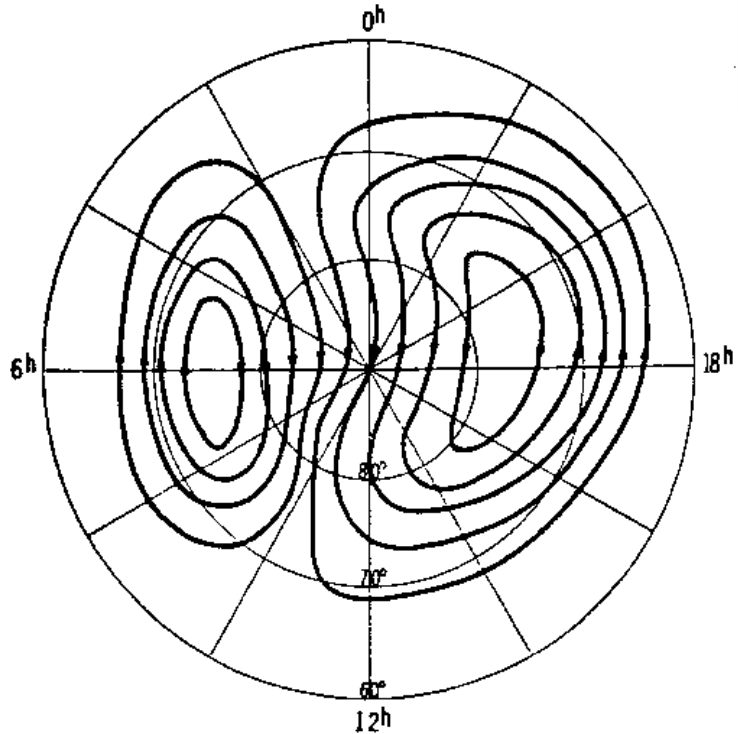


The flow in the ionosphere

It turns out that in regions where the plasma is tenuous the magnetic field lines can be considered to be very good conductors; they behave like electrical wires connecting the denser regions of the magnetosphere (in particular the tail) and the ionosphere. The magnetospheric electric field - and therefore also the flow pattern - is therefore "projected" onto the ionosphere. At the same time, however, the ionosphere behaves like a resistor (like in an electrical boiler) whose resistance depends on many factors. For instance, the ionospheric resistance is much lower when it bathes in sunlight. Therefore, these dynamic changes in the ionosphere in turn will affect the flow in the magnetosphere. That's why the picture of magnetospheric convection given above is oversimplified.

Het beeld van de "magnetosferische convectie" dat hierboven gegeven werd, is daarom te sterk vereenvoudigd.

The figure [after Nagata and Kokubun, Rept. Ionosphere Space Res. Japan 16, 256, 1962] shows the typical ionospheric flow pattern above the northern polar cap (the Sunward direction corresponds to 12h, while 0h points to the tailward direction). The magnetic field lines connect the two ionospheric convection cells to the respective pre- and post-midnight magnetospheric convection patterns in the magnetotail.



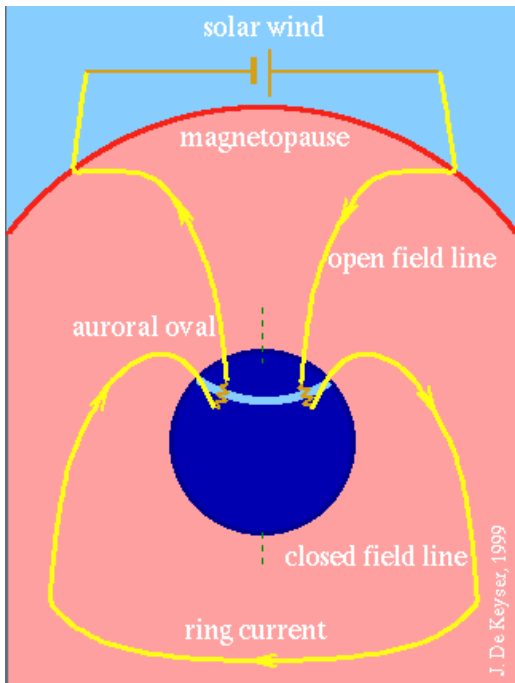
The electric potential difference between the centers of the two convection cells is typically a few times 10000 Volt; its value is determined to a large extent by the ambient solar wind conditions.



Electric currents coupling the magnetosphere and the ionosphere

Since the ionospheric conductivity is not infinite, the ionosphere does not short-circuit the magnetospheric electric potential differences. Sustained currents therefore flow in the coupled ionosphere-magnetosphere system.

The energy source is the solar wind, which forces the flow in the outer magnetosphere. Indeed, motion of a conducting medium in the Earth's magnetic field generates an electric potential, just like in your bicycle's dynamo where the rotating motion of the wheel is used to drive the motion of an electric conductor in a small permanent magnet, thus generating electricity. The electric current flows along the magnetic field lines (since the charged particles move along the field lines), which behave like copper wires. These currents are therefore called <field-aligned currents> (or <Birkeland currents>). They transport electromagnetic energy down to the ionosphere. The ionosphere itself acts like a resistor in which the electromagnetic energy is dissipated in the form of heat, thus warming up the upper atmosphere.



A more detailed view of this current circuit is shown in the diagram. The diagram shows a view as seen from the tail toward the Sun. The electromotive source is the motion of the solar wind.

The current penetrates through the dawnside magnetopause along open magnetic field lines. It flows through the ionospheric resistance, and then outward again as a field-aligned current on a closed field line. This current then continues through the plasma sheet, contributing to the cross-tail ring current (sometimes it is called the "partial ring current"). The current then flows back again along closed field lines toward the ionosphere, through it, and outward again along open field lines.

The net result of this current circuit is that solar wind energy is transported to the ionosphere and converted there into heat. This conversion takes place in the light-blue strip in the figure. This is the region separating the open and closed terrestrial magnetic field lines, that is, the <auroral oval>. It is the region where aurorae occur.

