Auroral Studies Shed Light On the Physics of Space

Because it is affected by the topography of the polar magnetic field, the solar wind, the interplanetary magnetic field, and cold mesopheric temperatures, the behavior of the upper atmosphere in the arctic region is relevant to global change and space weather issues, and may have implications for arctic system science. In this and following issues of Witness the Arctic*, we will present overviews of current research efforts on arctic upper atmosphere topics, including studies of the aurora, occurence and physics of noctilucent clouds, and the polar ionosphere.*

In 1859, British astronomer Richard Carrington, observing the sun as part of a long-term study of sunspot behavior, noted an enormous brightening in one sunspot group. Seventeen hours later, an intense disruption occurred in the terrestrial magnetic field, accompanied by an aurora that could be seen as far south as Cuba. In noting a possible connection between these events, Carrington marked the birth of space physics—the study of the portion of the space environment that falls within the Sun's sphere of influence and, consequently, is of direct relevance to life on Earth.

The aurora continues to be a central topic in space physics because it provides a unique window into the Earth's near-space environment. The aurora is produced mainly by electrons precipitating from space. Because the air density in the upper atmosphere is so low, auroral electrons are constrained to move in tight helical orbits along the Earth's magnetic field lines. This means that auroral arcs can be interpreted as magnetic field structures illuminated by incoming electrons in the same way that images are produced on a television screen. Similarly, auroral motions are a projection of time-dependent dynamics in the remote magnetosphere.

Early theories proposed that the aurora resulted from the direct entry of solar wind electrons into the polar atmosphere. Although still prevalent in the popular literature, this explanation was refuted by observational evidence. Auroral particles come from a population of electrons and ions which has built up over time in the stretched anti-sunward tail of Earth's magnetic cavity. The magnetic field of an approaching solar wind triggers the explosive release of the particles into the atmosphere. This triggering process—referred to as "reconnection"—is fundamental to all plasmas. Reconnection is being studied through programs funded by NSF, the National Atmospheric and Space Administration (NASA), and the Departments of Defense and Energy (DoD and DOE).

To produce the observed optical effect, auroral electrons must be accelerated to a velocity of ~50,000 km/s during their journey from the magnetosphere to the atmosphere. The mechanism by which this acceleration occurs is another outstanding issue in plasma physics, and is the focus of current satellite missions (e.g., NASA's POLAR and IMAGE spacecraft). (photo courtesy of Craig Heinselman, SRI International).

Research programs supported by several agencies address the aurora's effects on space weather, global change, and the energy balance of the Earth's atmosphere. The Coupling, Energetics and Dynamics of Atmospheric Regions (CEDAR; see page 5) and Geospace Environment Modeling (GEM) programs of the NSF Division of Atmospheric Sciences examine solar influences on global change, including climate changes linked to long-term variations of the Sun. The Sun Earth Connections Program, a major NASA effort dedicated to understanding the flow of energy from the Sun to the Earth, includes the Living With a Star program, which supports research and space missions to describe the Sun's effects on space weather and global change. With contributions from NSF, NASA, DoD, DOE, and the National Oceanic and Atmospheric Administration, the interagency National Space Weather Program supports research leading to better predictive capabilities for space weather operational forecasting. This substantial investment in space science reflects the growing numbers of space- and ground-based technical systems that are vulnerable to adverse conditions in the space environment.

Another current research focus concerns the feedback between the arctic upper atmosphere and the distant magnetosphere. Although it is the incoming particles that produce auroral light, electrons are in fact moving into and out of the polar ionosphere in equal numbers. This coupling can affect the efficacy with which the aurora forms. For instance, the fact that the aurora is more likely to occur in nighttime than in daytime is related to the elevated electrical conductance of the sunlit ionosphere. Several new instruments designed to improve daylight observations of the aurora are under development with support from the NSF Division of Atmospheric Sciences and should contribute significantly to elucidating the mechanism by which the increased electrical conductance is transferred to the magnetosphere. In addition, the NSF GEM program recently initiated a multi-million-dollar effort to study the coupling between the magnetosphere and ionosphere.

Permanent ground-based facilities in the Arctic provide essential observations to complement space-based investigations of the aurora. NSF supports the Søndrestrøm Facility in Greenland and the Polar Cap Observatory in Resolute Bay, Canada, and contributes to the deployment and operation of radiowave and optical instruments throughout the Arctic. While these instruments and facilities are designed to observe the aurora and other manifestations of the interaction between the atmosphere and the magnetosphere, they are also important logistics hubs for other arctic research.

For more information, see the National Space Weather Program web site (www.spacescience.org/SWOP/NSWP), the NSF Atmospheric Sciences web site (www.geo.nsf.gov/atm) or the Søndrestrøm web site (www.isr.sri.com), or contact Jeff Thayer (650/859-3557; thayer@sri.com) or John Kelly (650/859-3749; kelly@sri.com) in Menlo Park, CA (fax for both: 650/322-2318).