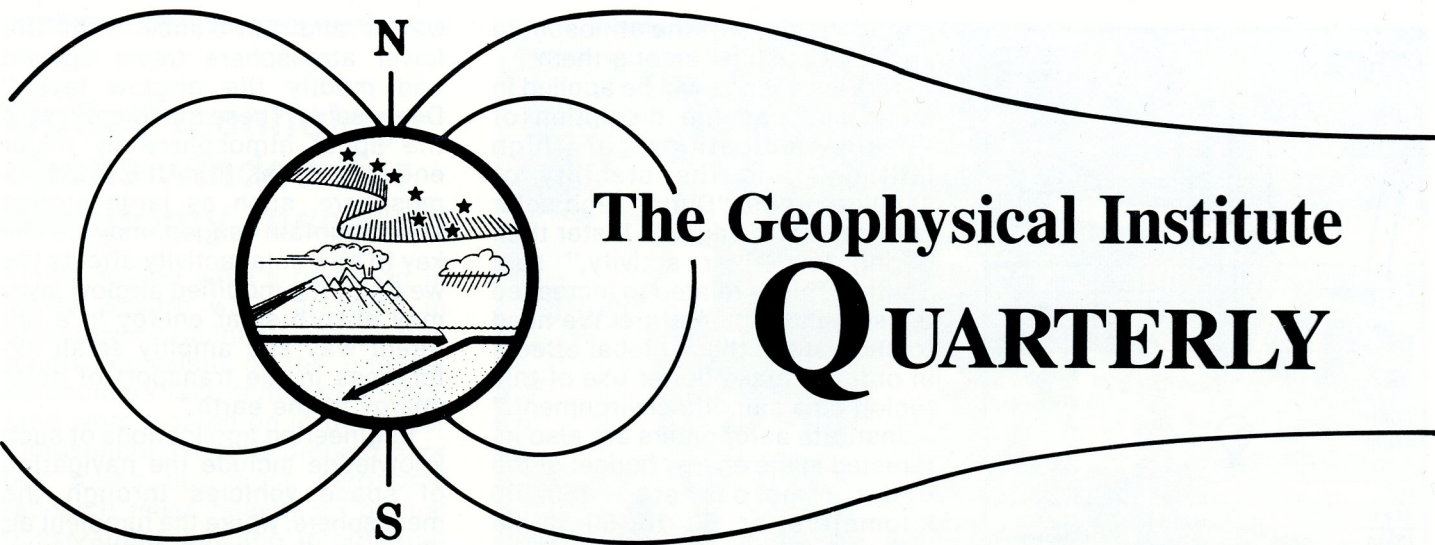




Cruising the shoreline of space

Recent headlines on global warming and the ozone layer reflect new concern about Earth's primary resource, the protective atmosphere that provides the most basic conditions for life.

Traditionally, atmospheric scientists study the lower atmosphere (troposphere and stratosphere) to answer questions about its dynamics and the consequences of human activity. Another group of scientists, aeronomers, explores the physics and chemistry of the shoreline of space—the upper and middle atmosphere. For the planet earth, this region is a physical buffer zone between the life-sustaining environment near the surface and the lethal radiation fluxes in interplanetary space.

"While we understand much of the atmosphere, we know very little about what major changes man's activity in space may cause," said Roger Smith, a member of the Institute's aeronomy group and associate professor of physics at UAF.

Aeronomers are generally interested in the region beginning at the higher limits of the tropospheric weather system (about 32 kilometers or 20 miles altitude) and extending through the stratosphere, mesosphere, and thermosphere to the top of the near-space environment. Successful application of technology for remote sensing, telecommunications, defense, and space travel all requires knowledge of this region.

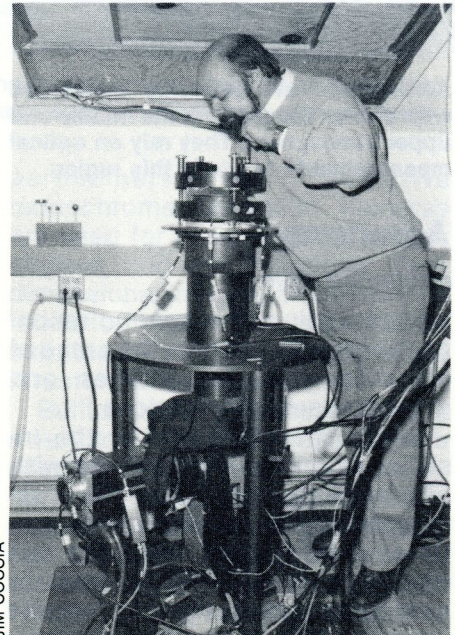
At the Institute, where aeronomy

is one of five major research areas, aeronomers specialize in high-latitude research, although their work is not exclusive to the polar regions. "Much of the stirring up of the atmosphere at the altitudes we're concerned with occurs in the polar regions," said Smith. "At middle and low latitudes, the upper atmosphere is fairly stable, with relatively small variations."

For disturbances originating in space, the most well-known response of the upper atmosphere is the aurora, which occurs in the ionosphere. "Auroral displays indicate that our protective atmosphere and the ionosphere are being energized by electric power generated in the magnetosphere. We study this response by observing the dynamics of auroral forms."

The ionosphere is a thin and partly ionized (electrically charged) layer of the earth's upper atmosphere that conducts electricity and reflects radio waves. It extends from about 70 or 80 kilometers (50 miles) altitude to an indefinite height (roughly 965 kilometers or 600 miles).

The solar wind is a completely ionized gas (plasma), with nearly equal numbers of protons and electrons. These positively and negatively charged particles stream at supersonic speeds from the solar atmosphere into interplanetary space. The earth's magnetic field prevents the solar wind from penetrating our atmosphere. Instead, the solar particles stream around the earth, encasing it and its



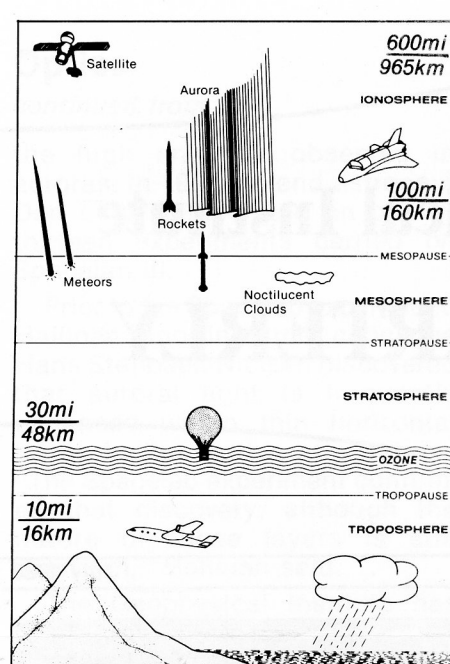
Aeronomer Roger Smith adjusts an interferometer at Poker Flat.

magnetic field within a comet-shaped cavity, the magnetosphere.

The aurora is the visible manifestation of what happens when the solar wind encounters the earth's magnetic field. Interaction between the solar wind and the magnetosphere can be viewed as a collision between a magnetized ionized gas (the solar wind) and a magnetized celestial body (the earth) surrounded by an ionized gas (the upper atmosphere).

"The basic process in this collision is called magnetic reconnection," said Syun Akasofu, director of the Geophysical Institute and professor of geophysics. "The Institute's space physics and aeronomy groups are making significant contributions to the

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Aeronomers are primarily concerned with events occurring in the middle and upper atmosphere. They rely on optical measurements to study this region.

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understanding of magnetic reconnection, particularly in the areas of computer-simulated studies and ground-based observations."

While space physics at the Institute is primarily concerned with phenomena outside the atmosphere, the penetration of particles and fields into the atmosphere is of great interest in aeronomy research. "In recent years we have learned that the atmosphere, ionosphere, and magnetosphere are closely interdependent and should be treated as a coupled system driven by solar wind and responding to solar variability," Smith said.

"We know that atmosphere-ionosphere-magnetosphere coupling occurs, but we also want to be able to predict how it will produce changes in composition, wind, and temperature fields in the upper atmosphere.

"Atmospheric models under development require comprehensive data for their evaluation. Presently, much of our activity is directed toward obtaining such data sets working through the National Science Foundation CEDAR program." CEDAR (Coupling, Energetics, and Dynamics of Atmospheric Regions) aims to promote the understanding of processes occurring at different

altitude regions of the atmosphere and relationships among them.

This knowledge will be applied in areas such as the disruption of telecommunications at high latitudes and the stability of satellite orbits. "During high solar activity, orbits degrade faster than during low solar activity," said Smith. "This is related to increased density and temperature. We need to understand these global effects in order to make better use of this region as a satellite environment."

Institute aeronomers are also interested in the energy budget of the upper mesosphere (80-100 kilometers or 50 to 60 miles altitude). This region is somewhat chaotic because it is buffeted by wave disturbances from below, most of which originate in weather systems in the troposphere, and disruptions in air flow caused by mountains. "The energy income in this region depends a great deal on waves originating near the earth in the troposphere," Smith said. "Much of the wave energy propagating upwards is absorbed in the upper mesosphere, creating turbulence and thermal energy. Optical observations of waves and turbulence in this region enable us to estimate the rate of heating."

Optical studies in the mesosphere involve measurements of wind, temperature, and brightness of airglow, or night-sky luminescence. "Night airglow is a very weak glow in the upper atmosphere caused by the release of energy deposited by sunlight," said professor Chuck Deehr. Airglow is caused by the quasi-steady radiant emission from the upper atmosphere over middle and low latitudes, as distinguished from the sporadic emissions of auroras over high latitudes.

"Optical instruments are able to measure airglow intensity, temperature, and wind direction and magnitude," Deehr said. "Variations in these quantities constitute the weather at 60 miles altitude; they indicate forces acting on the atmosphere there. The magnitude and direction of these forces tells us the source of energy acting on the atmosphere at that level."

Rodney Viereck, who recently completed his doctorate at the Institute, has carried out optical measurements of the temperature and intensity of the airglow in the polar cap for several years.

"His observations from the Svalbard station demonstrated how

waves and turbulence from the lower atmosphere travel upward and modify the airglow layer," Deehr said. "These modifications of the upper atmosphere by major energy sources from the lower atmosphere, such as large storms and mountain ranges, may be the key to how solar activity affects the weather; the modified airglow layer may absorb solar energy in a different way and amplify small differences in the transport of solar energy to the earth."

Engineering applications of such knowledge include the navigation of space vehicles through the mesosphere, where the turbulent air disrupts the flight path of re-entering space vehicles such as the Space Shuttle.

Aeronomy research crosses international boundaries, encompassing the entire polar cap or even larger regions. Worldwide observations are required to determine differences between auroral spectra on the night side of the auroral oval and on the day side. This information is needed to understand the character of energetic particle precipitation in the two regions and relate this to interaction between the solar wind and the magnetosphere.

These investigations involve groups of optical instruments coordinated by scientists in the circumpolar regions of Scandinavia, the USSR, Canada, and the USA. Institute observations are primarily ground-based, although observations are also made from space vehicles.

In the ionosphere, the dayside interaction between the solar wind and the magnetosphere is visible as the midday aurora. Because the arctic midday aurora can only be seen between the east coast of Greenland and the Arctic Ocean off the Siberian coast in December and January, the Svalbard archipelago is a very useful location for related observations. Together with Norwegian researchers, Institute scientists play a leading role in conducting an international observation program centered around Svalbard.

Other work in progress requires observations in Alaska at Poker Flat near Fairbanks and at Fort Yukon. Other field sites are at Sondrestrom, Greenland, and Antarctica. Extensions of this network are planned for Mt. Haleakala, Hawaii, *continued on 4*

Optics technology opens window for aeronomy research

Trying to see what's going on in Times Square while standing in downtown Cincinnati—that's the rough equivalent of the problem aeronomers face trying to understand what's going on in the upper atmosphere. Whether probing 80 or 600 miles up, most aeronomy research relies heavily on optical observations and the information conveyed by light.

Light is electromagnetic radiation with wavelengths capable of causing the sensation of vision; the term is sometimes extended to include infrared and ultraviolet radiation. Aeronomers rely on optical observations to determine such factors as temperature, wind speed and direction, particle precipitation, and chemical activity in the atmosphere. These measurements supply the data necessary for developing a picture of processes in the upper atmosphere and ionosphere and the influences upon them, both from space and from the lower atmosphere.

Aeronomers depend on the resources of the Institute's optical projects laboratory, a well-equipped facility located in the Elvey Building on the University of Alaska Fairbanks campus. The space includes the calibration laboratory, where instruments are adjusted for making precise measurements. "The laboratory provides the means by which we obtain absolute measurements," said Roger Smith, a member of the aeronomy group. "For example, we can infer the number and energy of electrons coming into the atmosphere, creating an auroral display."

Now under construction at the lab is a high-resolution spectrometer (interferometer) Smith will need later this year. High-resolution interferometry is used to measure the subtle characteristics of auroral light to yield wind and temperature data. Smith will take the instrument to the South Pole station, Antarctica. He and a University of Washington colleague, Dr. Gonzalo Hernandez, will study wind speeds and temperatures at altitudes of 100-300 kilometers (75-180) miles. These observations will extend work done

JIM COCCIA



This computer controls a spectrometer in the optical projects laboratory. In the lab are (left to right) student interns Sarah Crane and Tom Godamski with graduate students Jim Conner and Ed Hoch.

in 1978 and 1981, when similar measurements were made at Halley Bay, Antarctica. The current three-year experiment is funded by a \$500,000 grant from the National Science Foundation (NSF).

Most of the instruments used by aeronomers are designed either to detect and capture light, no matter how faint (photometers), or to break up light into its spectral components (spectrometers). Spectrometers record the state of chemical and radiative excitation of the atmosphere. Photometers measure light or electromagnetic radiation in the visible range.

A spectrometer produces a spectrum calibrated for measuring wavelength and intensity of spectral lines and bands. Spectrophotometry is the best technique for studying the relationship among many auroral emissions lines, from the near ultraviolet to the near infrared. Several continuing programs in aeronomy and space physics depend on remote sensing of spectroscopic emissions to study physical and chemical processes in the atmosphere.

Now under development at the laboratory are new imaging instruments that use an imaging photon detector to record images photon-by-photon as they arrive. This technology will improve the aeronomers' current range of cameras, spectrometers, and interferometers.

Video equipment is another source of information for

aeronomers. Highly sensitive monochrome television cameras are used for observing the aurora, airglow, and ion injections. Two-dimensional imagery produced by a television system has proven to be suitable for studying details in the structure of auroral forms.

Built especially for the Institute is a very low-light-level video camera used for making real-time observations of the aurora. Tom Hallinan, associate professor of geophysics, has been instrumental in establishing an impressive capability for obtaining real-time images of low-light level sources using the cameras in various combinations, and with both narrow-field and all-sky lenses and a variety of filters. Hallinan has been interested primarily in the mechanisms responsible for the characteristic shapes of auroral forms.

"Distant electric and magnetic fields control the streams of energetic electrons that bombard the atmosphere and produce auroral light," said Hallinan. "By watching the changing patterns as the aurora dances overhead, it's possible to infer details about electric fields several thousand kilometers away."

Early observations made by Hallinan with the super-sensitive television cameras showed that the electric fields are many times as intense as had been thought. This led in part to a new understanding of how electrons are accelerated to

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the high energies observed in auroras. In 1985, he and astronaut Don Lind collaborated on one of thirteen experiments carried on Spacelab III.

Prior to the Spacelab experiment, Hallinan and institute colleague Hans Stenbaek-Nielsen discovered that auroral light is frequently enhanced within thin horizontal layers in the earth's atmosphere. "The Spacelab experiment confirmed that discovery, although the nature of these layers is still unknown," Hallinan said.

The Geophysical Institute has produced "Aurora Color Television Project," a videotape for the public. It shows rare, real-time images of the aurora selected from footage obtained during the first year of operation of the special low-light camera. The tape is marketed by the Institute and includes a booklet, *Understanding the Aurora*.

To fully understand the processes that produce optical auroral emissions, parameters are needed that can best be obtained by theoretical computations. Extensive modeling is required to relate observations to the microphysics and large-scale dynamics of the atmosphere. Models are developed to find relationships between remotely sensed and in-situ measurements. Although experimental projects in aeronomy are ground-based, theoretical and modeling efforts also make use of observations by rocket-

and satellite-borne instruments for in-situ measurements. Sounding rockets launched at the Institute's Poker Flat Research Range near Fairbanks carry optical and radio instruments to specific altitudes for some experiments.

The optical observatory at Poker Flat houses a wide range of ground-based equipment: magnetometers, riometers, all-sky auroral cameras, video cameras, interferometers, and scanning photometers. It is considered one of the key auroral stations for a major national program, CEDAR (Coupling, Energetics, and Dynamics of Atmospheric Regions). Along with the goal of coordinating atmospheric research, the NSF program calls for upgrading existing optical and radar facilities and developing new instruments.

The analytic capability for aeronomy research is supported by the Institute's VAX computer cluster and nationally available supercomputers. Several microcomputers control instruments in the field. Important tools for analysis of images are the dedicated image processing computers, including specially equipped COMPAQ 386 and DEC ECLIPSE S-250 systems.

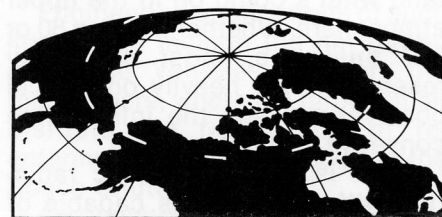
Although research quality depends first on the talents of individual scientists, increasingly complex technology means an expanded role for technical support staff, specialized instruments, well-equipped laboratories, and sophisticated computers. In aeronomy, as in other fields, the Geophysical Institute faces a continuing challenge to meet these needs.

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and Amundsen-Scott South Pole Station.

Annual funding for aeronomy research at the Institute is approximately one-half million dollars. Major sponsors of these studies are the National Science Foundation and the National Aeronautics and Space Administration.



Geophysical Institute Quarterly

The quarterly is published as a public service by the Geophysical Institute, University of Alaska Fairbanks.

Subscriptions are available free on request. Contact the Special Publications Project Office
Geophysical Institute
University of Alaska Fairbanks
Fairbanks, AK 99775-0800
Telephone (907) 474-7942

Contributors: special thanks for this issue to members of the Institute aeronomy group and to Dorothy Giggey.

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