

Table 2. AGO sites. (Boldface indicates future sites.)

Site	Year	Geographic latitude	Geographic longitude	Magnetic latitude	Magnetic longitude
P2	1992	85.67°S	46.38°W	70.00°S	18.60°E
P1	1994	83.86°S	129.61°E	80.00°S	18.60°E
P4	1994	82.01°S	96.76°E	80.00°S	43.10°E
P3	1995	82.50°S	30.00°E	72.50°S	40.10°E
P5	1996	75.70°S	89.20°E	80.00°S	80.00°E
P6	1995	74.10°S	128.80°E	90.00°S	0.00
SP	1956	90.0°S	0.00	74.20°S	18.60°E
B1	1992	77.50°S	23.40°W	63.69°S	28.99°E
B2	1995	80.75°S	20.40°W	66.53°S	28.53°E
B3	1996	81.50°S	3.00°E	68.88°S	35.81°E
B4	1997	78.00°S	3.00°E	66.57°S	40.25°E
J1	1991	~70.0°S	~39.5°E	~68.0°S	~74.0°E

of the airplane. Alternate sites at lower elevations are being considered for P5.

Data have been returned from the first year of AGO operations at site P2. Observations were obtained by all instruments until 1 June 1993 when a fault in an optical disk drive led to a shutdown of the station. The following series of papers describe some of the initial results obtained from P2 during the interval 23–31 May 1993 selected for preliminary review. In some instances, the data are compared with simultaneous observations from South Pole Station. The 1993 data from AGO site P2 represent the first opportunity to make comparisons between observations made at South Pole Station and an adjacent location, allowing the temporal and spatial continuity or dissimilarity of polar cap phenomena to be studied. The preliminary evaluation of this first week of AGO data clearly shows the promise of a rich prospect for the coordinated investigations to follow, first through the examination

of the rest of the 1993 data, then in further comparisons as the PENGUIN network is fully established.

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Coordinated auroral observations at South Pole Station and AGO-P2

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Antarctica offers some distinct advantages for conducting auroral research when compared to the high latitudes in the Northern Hemisphere. The larger offset between the magnetic and geographic poles (approximately 16° in the Southern Hemisphere vs. approximately 10° in the Northern Hemisphere) results in the winter polar darkness extending over a larger region of high magnetic latitude. This allows the aurora to be monitored around the clock for diurnal motions and for responses to activity in the geomagnetic and interplanetary magnetic fields.

Amundsen–Scott South Pole Station is located at a magnetic latitude of about 74.2°, a location that places it inside the polar cap during magnetic nighttime (that is, when the Sun is located in the direction of the magnetic pole) where field lines map to the magnetospheric tail. During magnetic midday, South Pole Station is situated under the magnetospheric cusp where the field lines are believed to open to the interplanetary magnetic field.

Rairden and Mende (1989) summarized the behavior of the cusp aurora based on 630.0-nanometer (nm) O(¹D₂)

observations. Since the austral winter of 1989, we have been using a novel dual channel all-sky camera that permits simultaneous observations of both 630.0-nm $O(^1D_2)$ and 427.8-nm N_2^+ auroral emissions to separate the hard and soft precipitation. The system records the local space, time, and energy morphology of auroral precipitation.

We have investigated the optical signature of impulsive magnetic events that were interpreted as the ground-based signature of "flux transfer events." Our observations have shown that these impulsive events take place on the inner side of the polar cusp (Mende et al. 1990), and therefore, if they are to be interpreted as the flux transfer events, then they must be the signature of the initial phase of the event and not the convective phase as it had been interpreted earlier.

A new phenomenon recently identified in the all-sky images (Doolittle and Mende in preparation) is an apparent suppression of background emissions at 427.8 nm occurring in correspondence to the simultaneous enhancement of 630.0 nm associated with plasma patches drifting across the polar cap. The drifting patches are believed to be formed on the dayside through photoionization or auroral precipitation. The drift motion is antisunward as they pass over the South Pole. The 427.8-nm background is presumed to be caused by polar cap rain of soft electrons. The mechanism for suppression in 427.8-nm intensity correlated with the passage of the plasma patches is not well understood and is a subject for the ongoing investigations.

The network of six automatic geophysical observatories (AGOs) being installed on the antarctic plateau will provide much greater spatial coverage of the high-latitude aurora. Neighboring observing sites in the network have adjoining fields of view of the ionosphere at auroral heights [100–250 kilometers (km)]. The installation in December 1992 of AGO-P2 (85°40'S 46°23'W) at a magnetic latitude of about 70° is providing the first opportunities to make auroral observations in coordination with those being made at the South Pole. A low-power version of the South Pole all-sky camera has been developed for use in the AGOs.

The value of coordinated simultaneous all-sky imaging from adjacent sites can be seen by examining data obtained at AGO-P2 and South Pole Station. Figure 1 shows simultaneous all-sky images taken at 04:00 universal time (UT) near local magnetic midnight on 27 May 1993 at South Pole Station and at AGO-P2. Conditions were disturbed following a magnetic storm, and both sites were deep within the polar cap. A 630.0-nm double arc is seen equatorward of

South Pole Station and poleward of AGO-P2 with no apparent signature in the 427.8-nm channel. Concurrent observations of auroral absorption to the 38.2-megahertz cosmic background in radio noise were also made at the two sites by an imaging riometer (see Rosenberg and Detrick, *Antarctic Journal*, in this issue).

A convenient way of surveying all-sky camera data is to form a keogram in which meridional scans are shown as a function of time of day. Separate keograms can be made for each wavelength and for their intensity ratios. Figure 2 shows 24-hour 630.0-nm keograms for South Pole Station and AGO-P2 for 27 May 1993. The latitude scales on the left of each keogram show that magnetic poleward is toward the top and equatorward is toward the bottom. Assuming an emission altitude of 220 km, the all-sky camera can see more than 8° in latitude on either side of the station. For South Pole Station and AGO-P2, which are separated by only 4.3° in latitude, sig-

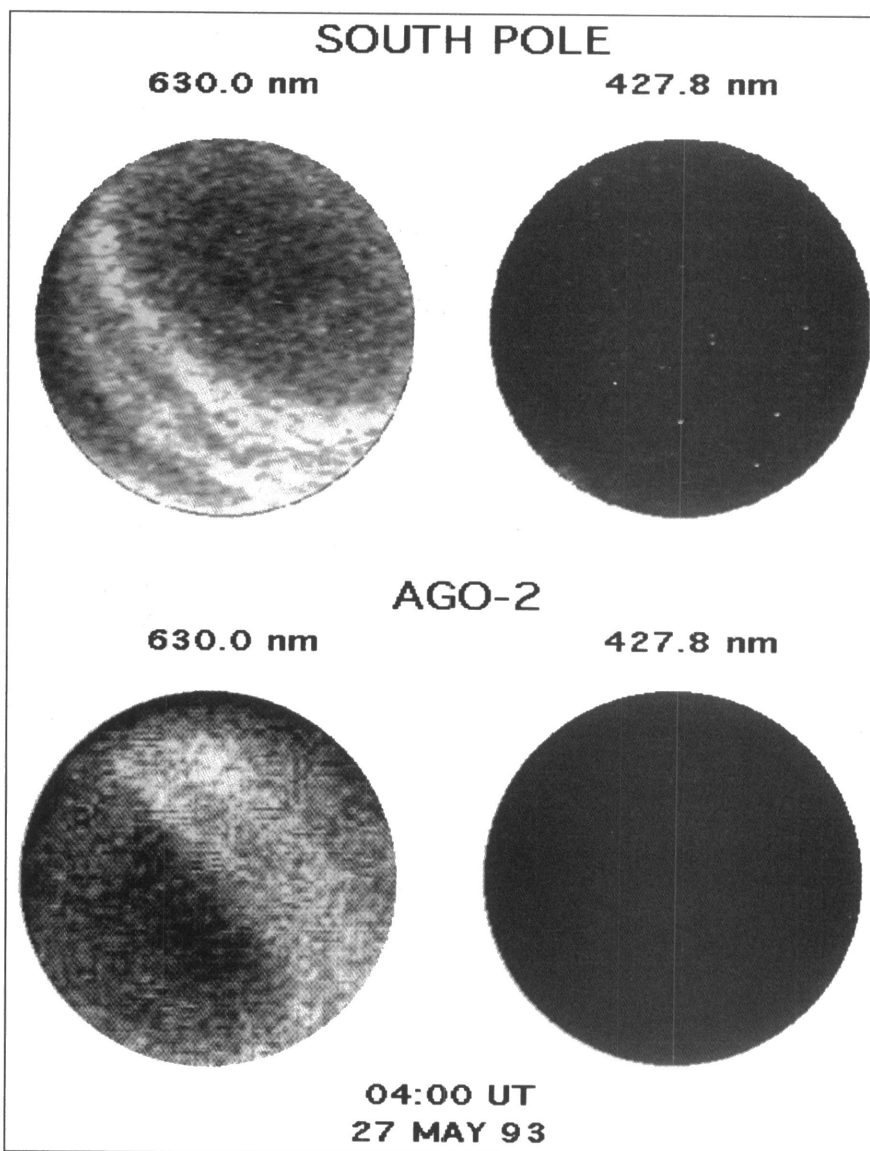


Figure 1. All-sky images looking up from South Pole (top) and AGO-P2 (bottom) at 04:00 UT on 27 May 1993 with 630.0 nm on the left and 427.8 nm on the right. A night-side 630.0-nm double arc is shown in the polar cap between South Pole Station and AGO-P2.

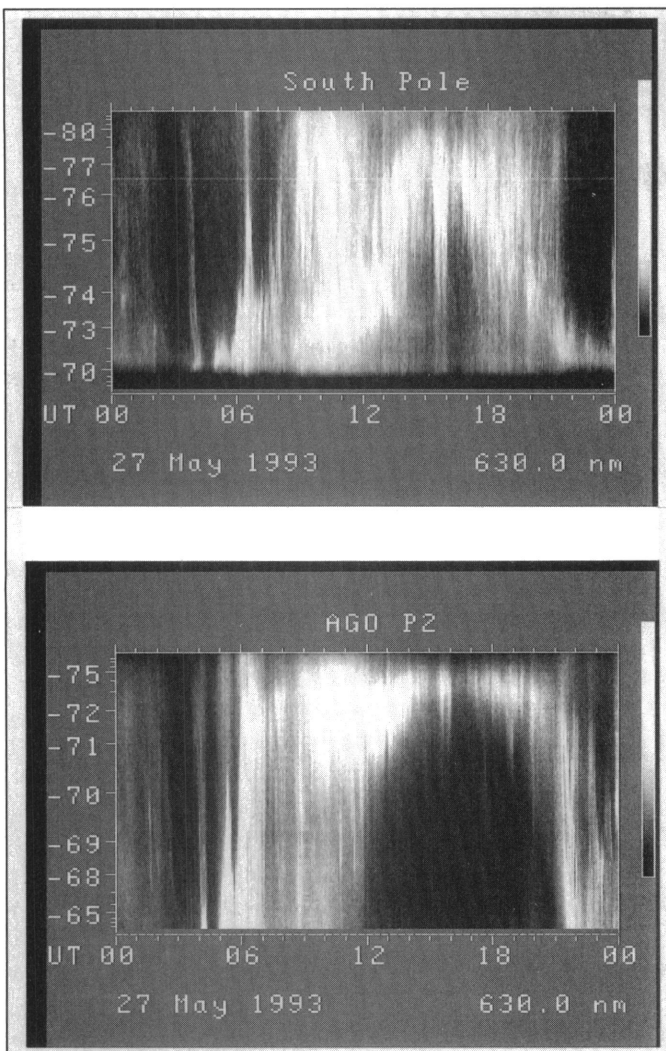


Figure 2. Keograms for South Pole Station (top) and AGO-P2 (bottom) for 27 May 1993. These meridian scans show the 630.0-nm auroral emissions over the latitudinal extent of the images as a function of time. On the magnetic meridian shared by South Pole Station and AGO-P2, local magnetic midnight is at about 03:30 UT and local magnetic midday is at about 15:30 UT. The keogram shows that the auroral oval is located well equatorward of AGO-P2 on the nightside and slightly poleward of South Pole Station on the dayside. Keograms provide for easy identification of events such as a substorm expansion seen at about 15:30 and plasma patches or arc features drifting across the polar cap such as seen at about 04:00.

nificant overlap exists between the two meridional fields of view.

The keograms in figure 2 show a typical diurnal positioning of the auroral oval under disturbed magnetic conditions. The oval is equatorward of AGO-P2 at local magnetic midnight (03:30 UT), whereas at midday (15:30 UT) the oval (and cusp) is slightly poleward of South Pole Station. Keograms provide for easy identification of events such as a substorm expansion seen at about 15:30 UT and plasma patches or arc features drifting across the polar cap such as seen at about 04:00 UT. As a survey tool, the keogram allows quick assessment of the optical data before examining the all-sky images to discern the spatial morphology of the auroral features.

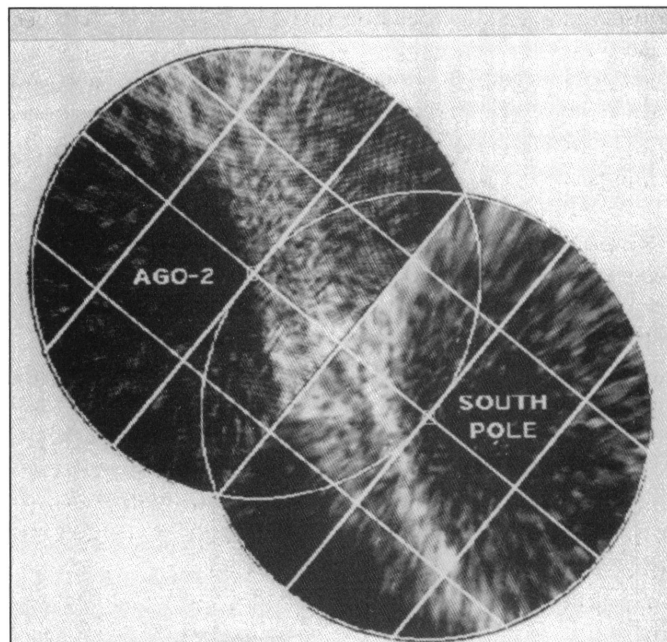


Figure 3. Geographic projections of the 04:00 UT 27 May 1993 630.0-nm all-sky images from South Pole and AGO-P2 onto a plane at 220-km altitude. A 250-km rectilinear grid is superimposed on the images. The projections give a down-looking (spacecraft) perspective of the aurora suitable for display as a mosaic on a map of Antarctica showing the 500-km radius fields of view of all stations in the AGO network (see, for example, figure 2 of the companion paper by Rosenberg and Doolittle, *Antarctic Journal*, in this issue).

Another data analysis tool that can be used to interpret the auroral images is geographic projection. The all-sky images show inherently better spatial resolution near the zenith and less toward the horizon. To make comparisons of features seen from adjacent observing sites, the images can be mapped onto a plane at a representative altitude so that distances are shown in rectilinear coordinates. Figure 3 shows geographic projections to the 220-km altitude plane of the simultaneous 630.0-nm all-sky images from South Pole and AGO-P2 at 04:00 UT when the double arc of figure 1 lies between the two sites. The projections are reversed with respect to the up-looking perspective of the all-sky images to give a down-looking (spacecraft) perspective of the aurora. A 250-km grid is superimposed on the mapped images. The adjacent observations of figure 3 can be seen in the context of the mosaic of all-sky images to be provided by the full AGO network (including South Pole Station) by projecting the images onto a map of Antarctica where all-sky fields of view for each of the sites are shown (for example, figure 2 of the companion paper by Rosenberg and Doolittle, *Antarctic Journal*, in this issue). By January 1994, AGOs 1, 2, and 4 had been installed. The network is planned for completion with deployments of AGOs 3, 5, and 6 by 1996.

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Coordinated auroral absorption observations at South Pole Station and AGO-P2

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As described in Rosenberg and Doolittle (*Antarctic Journal*, in this issue), the combination of automatic geophysical observatories (AGOs) and manned stations in Antarctica is intended to facilitate studies of the polar upper atmosphere. In particular, simultaneous observations with essentially similar instrumentation at all sites will enable the separation of spatial and temporal effects and will provide the means to follow the evolution, progression, and decay of geophysical phenomena over great distances. The first opportunity to carry out such investigations involves the use of data from AGO-P2 and South Pole Station.

Doolittle and Mende (*Antarctic Journal*, in this issue) presented simultaneous all-sky images of Sun-aligned polar cap arcs evident in the 630.0-nanometer (nm) emission of atomic oxygen. The absence of 427.8-nm emission from ionized molecular nitrogen indicates that this auroral feature is due to the precipitation of electrons with less than 1 kiloelectronvolt energy. South Pole Station and P2 were situated inside the polar cap near magnetic midnight at the time. A time sequence of all-sky images showed that the arcs were drifting anti-Sunward, moving equatorward across the fields of view of first the South Pole and then the AGO.

Concurrent observations made with an imaging riometer at each site show substantial localized absorption of the 38.2-megahertz (MHz) cosmic-noise background in association with the polar cap arcs. Absorption images presented in figure 1 for South Pole Station (left) show a coherent feature that enters the South Pole field of view at about 0358:20 universal time (UT) near the poleward edge and progresses equatorward, eventually leaving the field of view at the equatorward edge around 0403 UT, all the while remaining in the western sector. The absorption images for P2 (figure 1, right) show that a coherent feature, also confined to the western sector, enters the P2 field of view near its poleward edge at about 0403 UT and similarly progresses equatorward, eventually leaving the field of view at 0407 UT. Details of the time history of the absorption at South Pole Station (figure 2) and at P2

(figure 3) clearly show the equatorward-drifting features in the western sectors of the fields of view.

The overall fields of view of the imaging riometers at South Pole Station (49-beam system) and at P2 (16-beam system) are approximately the same, although the spatial resolutions differ [compare the P2 ionospheric projection pattern in Detrick and Lutz (*Antarctic Journal*, in this issue) with the South Pole pattern in Detrick and Rosenberg (1988, 1990)]. Using these projection patterns and assuming an effective height for the absorption layer, one can obtain the drift speeds of the arcs as they transit the respective fields of view. In the present instance, however, an average drift speed, independent of the altitude of the absorption, can be obtained because the feature has been tracked between South Pole Station and P2. Thus, from figures 2 and 3 and using the times of absorption peaks, we obtain a time of 330 seconds for the features to move between South Pole Station and P2, a distance of 480 kilometers (km). This is equivalent to a drift speed of about 1.5 kilometers per second (km sec^{-1}).

We can now estimate the height of the absorbing layer at South Pole Station and at P2, assuming that this speed also applies to the drift of the feature across the South Pole Station and P2 fields of view. We will skip the details of the calculations and simply note that we obtained a height of 205 km for the absorbing layer near South Pole Station and 130 km for the height of the absorbing layer near P2. A plausible explanation for the decrease of the layer height is that the precipitation associated with the Sun-aligned arc hardens with decreasing latitude as the features drift across the polar cap toward the auroral oval.

The heights obtained for the absorbing layers are in the F region and upper-E region, in both cases well above the altitude typically associated with auroral absorption (90 km, in the D region). Previous work (Stauning 1984; Rosenberg et al. 1993; Wang et al. 1994) has established that F- and E-region absorption can predominate under suitable circumstances. It is interesting to note that the absence of any appreciable