4 Ground-based Measurement Technologies

4-1 CRL Alaska Project
— International Collaborations for observing Arctic atmosphere environment in Alaska —

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In this paper we briefly overview the CRL Alaska Project, which is to develop advanced radio/optical remote-sensing technologies and to construct a comprehensive observation system of Arctic middle atmosphere, in cooperation with US and Japanese institutions including the most major partner of Geophysical Institute of University of Alaska. The observation system is to demonstrate the technologies and also to study Arctic atmosphere changes and variations in relation to Global Change and solar activity effects. Eight instruments out of nine, which are components of the observation system, have started experiments in Alaska in recent years. A data network system named SALMON (system for Alaska middle atmosphere observation data network) is also being developed to automatically transfer and process the observed data employing broadband international network experiments APAN and TransPAC, from Alaska through Japan for WEB displays open to the world.

Keywords
Alaska, Global environment, Middle atmosphere, Arctic region, Ground-based observation

1 Introduction

The middle atmosphere, an atmospheric layer in the altitude range of 10-100 km, has been stressed to be important in the context of global environmental issues. It is widely accepted that the middle atmosphere is closely connected to the global environment, and in particular it is considered to be sensitive to changes in variations and changes in the lower atmosphere and climate, although many processes to change the atmospheric state therein strongly need to be more fully understood. Besides that, there has been a controversy on hypothesis for some decades that the solar activity can affect the Earth's atmosphere, and there have been a number of theoretical and experimental evidences both to support and to reject the story. The atmospheric variations and changes caused by such various internal and external processes (solar, natural, volcanic, anthropogenic, etc.) tend to relatively intensively appear in polar regions. In particular, the Arctic region is located near the populated and industrialized Eurasian and North American regions, and the connection of anthropogenic factors to global changes could be relatively easily found there.

In order to fully understand the atmospheric variations/changes, and to have the technical and scientific findings and knowledge contributing to the solution of future environmental/global change problems, it will be essential to construct a comprehensive environmental/atmospheric observation system able to measure various aspects of the atmosphere. For example, the mechanism of the ozone hole involves numerous factors, such as the strong wind flow around the pole (the polar vortex), the low temperatures inside the vortex, aerosols in the vortex forming heterogeneous chemical reactions, and the presence of chlorine and bromine compounds therein, all of which directly destroy ozone. Therefore, it is clear that a comprehensive, multi-component, simultaneous observation system is necessary even when studying a single element of the polar atmospheric environment.

In this project, advanced technologies for radio/optical observations are applied to attempt the development and construction of a comprehensive observation system to enable remote sensing in various aspects of the middle atmosphere and the layers above and below that region. An observation system installed in Alaska will be used to make comprehensive observations and to conduct research on aspects of the polar atmosphere, such as dynamics, chemistry, and electrodynamical processes (aurora, etc.), which are believed to be closely related to the atmospheric variation, including the effects of solar activity, in a collaborative effort between Communications Research Laboratory (CRL) and the Geophysical Institute of the University of Alaska Fairbanks (GI/UAF). The development of the instruments forming the core components of the observation system has been progressing successfully, and eight of the nine instruments planned have already been installed in Alaska. In particular, the interior Alaska where the UAF is located, is often in the outside or edge region of the polar vortex which dominates the Arctic stratosphere in winter, and provides a useful setting for studies of detailed behaviors related to the polar vortex, such as mass transport/exchanges between the inside and outside of the vortex. Alaska is also one of the places with the largest probability of aurora displays, and features suitable conditions for studying the effects of the aurora and other types of solar activity to the atmosphere. In this paper, we will briefly introduce the research and development of the Alaska Project since its launch in 1993 and will also discuss some of the results obtained thus far. This R&D effort has produced nine types of observation instruments; detailed descriptions and the results of measurements made by some of those instruments will be presented in other papers within this special issue.

2 History of the Alaska Project

The governmental framework of this international collaboration was formed in 1992 through collaborative research between CRL and GI/UAF based on the Japan-US Science Technology Cooperation Agreement.

As shown in Section 1, various aspects of the atmosphere such as physical quantities and chemical gas distributions must be clarified in order to study the global and atmospheric environments. In this project, based in Alaska, a comprehensive observation system for the atmospheric environment is under development. So far, nine instruments have been developed individually by the Communications Research Laboratory (CRL) and through collaboration with other institutions, both in Japan and foreign countries, and technical developments are currently underway to integrate these instruments into a comprehensive observation system in Alaska. At present, experiments have already started using eight of the nine instruments in Alaska.

In this collaborative project, CRL will play

Table 1 *Instruments developed by CRL for the Alaska Project*

Instrument	Observed Item	Altitude	Mode
Millimeter-wave radiometer	Trace gas concentration	Stratosphere, lower mesosphere (20-70 km)	Vertical distribution; continuous day and night
FTIR spectrometer	Trace gas concentration	Troposphere, lower stratosphere (10 - 30 km)	Vertical distribution; day
Multi-wavelength lidar	Aerosols	Upper troposphere, lower stratosphere (5 - 40 km)	Vertical distribution; night
Rayleigh-Doppler lidar	Wind direction, wind speed, temperature	Stratosphere, lower mesosphere (30 - 80 km)	Vertical distribution; night
Partial reflection MF radar	Wind direction, wind speed	Upper mesosphere, lower thermosphere (60 - 100 km)	Vertical distribution; day and night
Fabry-Perot interferometers	Horizontal and vertical wind speed at airglow layer heights, neutral temperature	Upper mesosphere, lower thermosphere (85, 95, 250 km when quiet; 85, 120, 250 km when aurorally active)	Horizontal distribution; night (during new moon phase)
Imaging riometer	Cosmic noise absorption (CNA) in lower ionosphere	Mesopause region (about 80 - 90 km)	Horizontal distribution; day and night
Super DARN HF radar	Wind direction, wind speed	Lower thermosphere (80 - 110km)	Vertical distribution; day and night
	Plasma motions, electric fields	Middle thermosphere (up to 250 km)	Horizontal distribution; day and night
All sky imager	Luminosity of airglow layer, atmospheric wave images	Upper mesosphere, lower thermosphere (85, 95, 250 km when quiet; 85, 120, 250 km when aurorally active)	Horizontal distribution; night (during new moon phase)

the most major roles in Japan in developing a comprehensive observation system for the atmospheric environment. In the US, installation and extension of facilities are underway at the Poker Flat Research Range (PFRR) of UAF. These activities include expansion of the observation-rocket launching facility; construction of new observation buildings, the “T. Nail Davis Science Operations Center,” and the international LIDAR building, which will hold the instruments and control computers of CRL; and expansion and installation of power, communications, and other infrastructural elements within the research range and in the Alaskan region.

Fig.1 shows the observation system developed by CRL and the facilities being installed on the US side. As shown in Table 1, the nine types of atmospheric observation instruments are being developed in this project as components of the observation system. The main components are those for middle-atmosphere observations, but instruments are also being developed for observation of the thermosphere and the troposphere just above and below the middle atmosphere, respectively, which are considered to be closely coupled with the middle atmosphere.

3 Observation Results

As stated in the previous sections, CRL has been developing a comprehensive observation system of the polar middle atmosphere, and, therefore, integrated experiments should be the essential activity for the project. Each of the component instruments of the system offers unique technical and scientific chal-

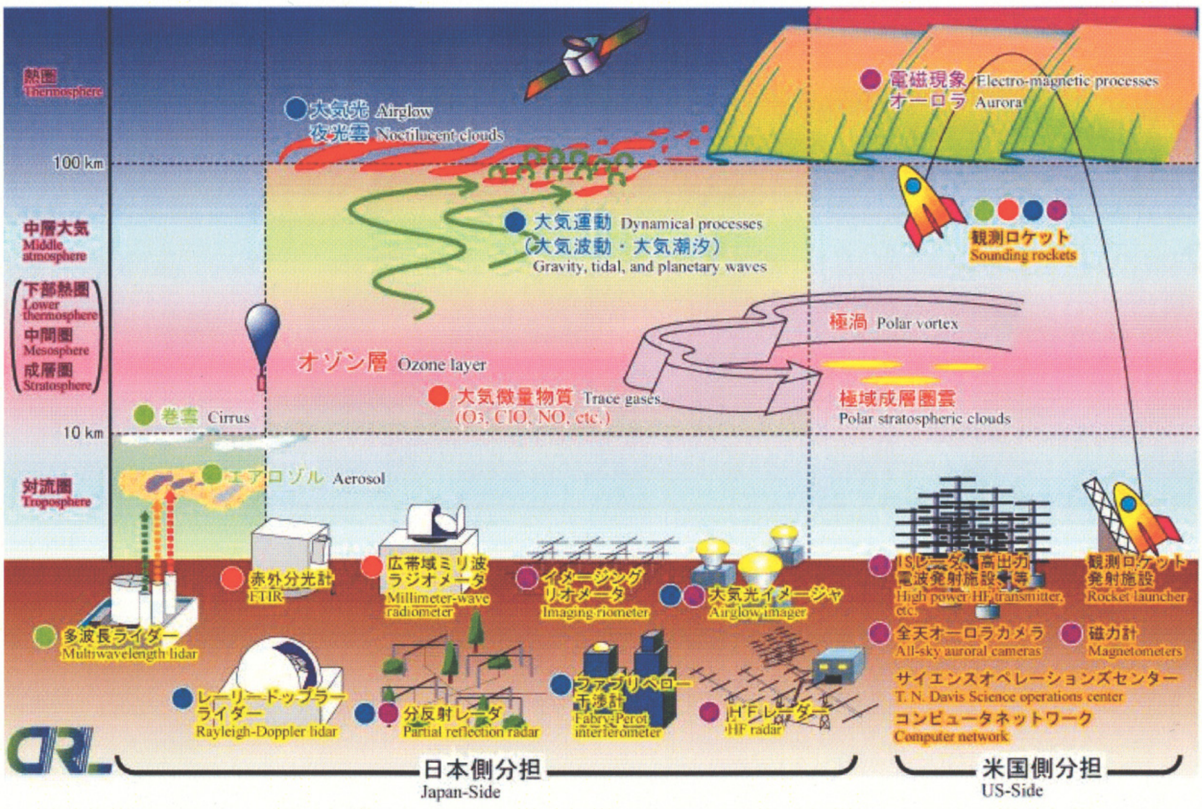

Fig. 1 *The overall scheme of the Alaska Project, showing the observation instruments being developed and implemented*

lenges; technical development and research to overcome these problems have thus far been carried out. At present, development is still underway to integrate the nine instruments into a single observation system, but some separate technical and scientific results have already been obtained, based on preliminary experiments. Results for two of the eight instruments will be presented in the following section. The two examples show observation results of stratospheric ozone distribution and aurora, respectively. Although these results appear to reflect two separate scientific fields, the integrated data are expected to contribute to new and important achievements when the instruments work as part of a comprehensive observation system.

3.1 Observation of Tropospheric and Stratospheric Trace Gas Distribution with an Infrared Spectrometer

As one of the components of the comprehensive observation system, the Poker Flat FTIR (Fourier Transform Infrared Spectrometer) was installed for observation of the tropospheric and stratospheric trace gas. The FTIR experiment started in July 1999, with the measurement of infrared absorption spectra from atmospheric trace gases using the sun as the light source. The advantage of FTIR observation is that various molecules (such as O_3, HNO_3, N_2O, NO_2, CH_4, CFC, HCl, H_2O, $ClONO_2$, and HF) can be measured simultaneously, since measurements are made over a wide range of wavelengths in a single run. Attempts are being made to perform nighttime observation of the radiation spectrum. Spectral observations of cloud radiation have been performed under cloudy conditions; this function, combined with infrared observations of cloud cover and the optical thickness of clouds, is expected to make significant contributions to cloud research.

While observations have mostly been aimed at determining the total column amount (the amount of gas existing inside the region above a unit surface area on the ground), SFIT2 software[1][2] developed by National

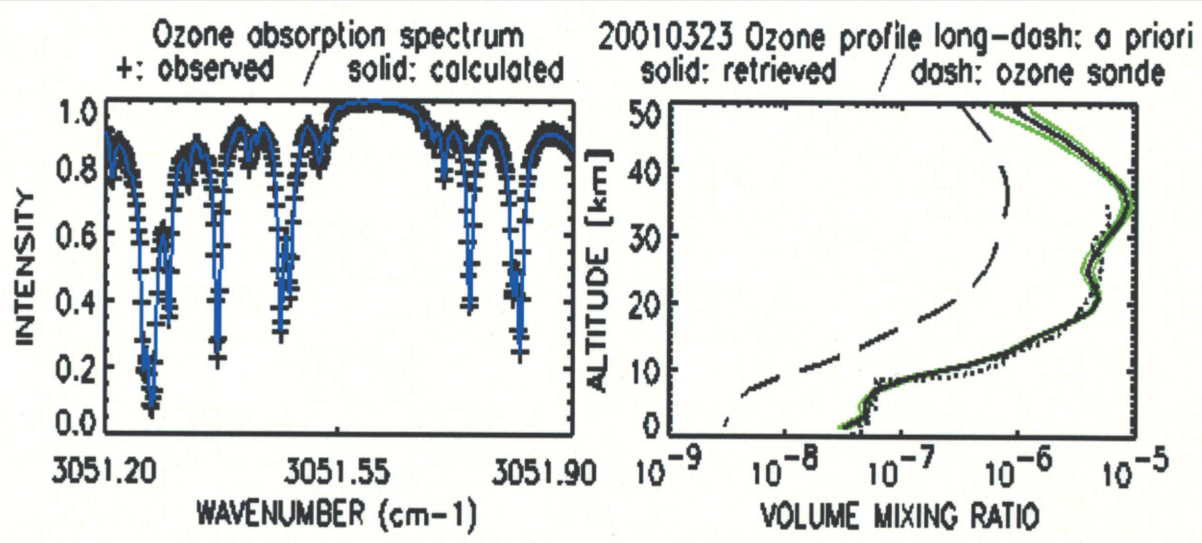

Fig.2 *(Left) The observed values (+) of the infrared absorption spectra for ozone observed with the Poker Flat FTIR on March 23, 2001 at UT 18:00 and the results of retrieval (solid line). Fittings were performed on multiple spectral lines. (Right) The vertical profile of the ozone mixing ratio calculated from the spectra. A priori information, observed values, and ozonesonde are represented by the line with long dashes, the solid line, and the normal dashed line, respectively*

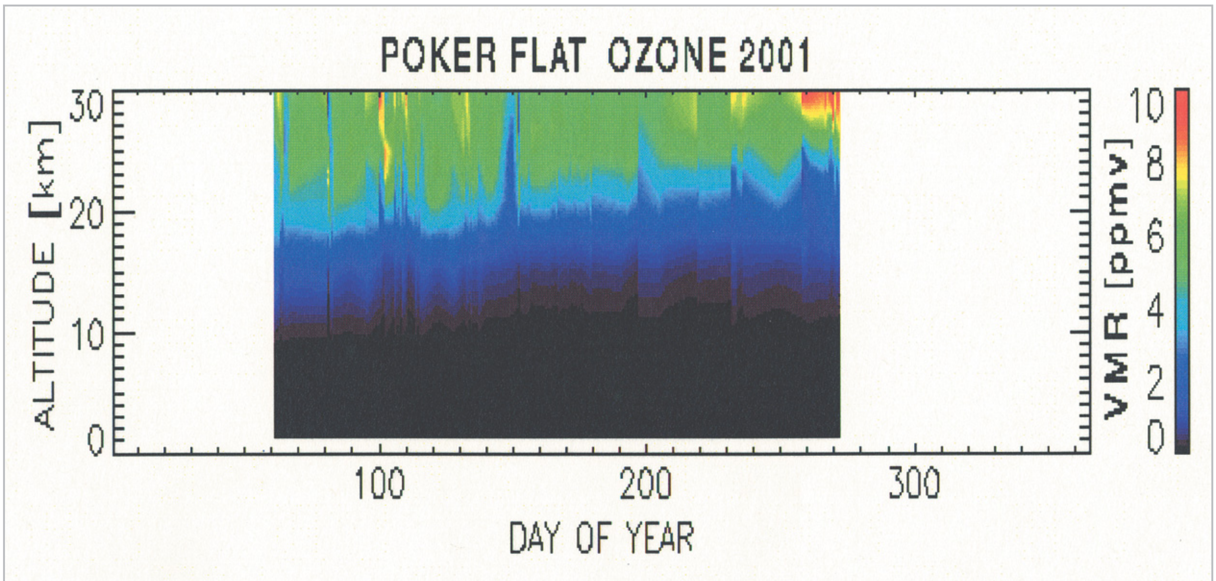

Fig.3 *(Right) Time-height cross-section of the quantity of ozone from Feb.-Sept. 2001. Ozone in the polar lower stratosphere displays a decreasing trend from spring to summer*

Institute of Water and Atmosphere (NIWA) in New Zealand and the National Aeronautics and Space Administration's Langley Research Center (NASA Langley) in the US was used in the retrieval procedure to determine the vertical profile of ozone from the troposphere to the stratosphere. We have succeeded in obtaining fits for multiple spectral lines. Fig.2 shows examples of the determined vertical ozone profiles for the infrared absorption spectra shown. Fig.3 shows the time-height cross-section of ozone abundance between February and September 2001 determined by this method, demonstrating that ozone displays a decreasing trend from spring to summer.

3.2 Dynamics and Effects of Aurora in the Thermosphere Observed with the Fabry-Perot Interferometers

The Fabry-Perot interferometer (FPI) is a device for estimating wind velocity and temperature in the mesosphere and thermosphere by high resolution spectroscopy of aurora and airglow. Observations with CRL's Fabry-Perot interferometers (hereafter referred to as the CRLFPI) started in October 1998 at Poker Flat and Eagle, Alaska. Simultaneous observations at the two wavelengths of 557.7 nm (emission height: approx. 110 km) and 630.0 nm (emission height: approx. 240 km) normally are made by two different interferometers. The temporal resolution of the CRLFPI is two minutes. This makes it a powerful tool in the observation of auroras that fluctuate on short time scales[3][4].

Energy transfer between the ionosphere and the thermosphere by auroral precipitating particles represents an energy transfer to the earth from the sun under a form different from that of solar radiation (ultraviolet, visible, and infrared light). Although the total energy supplied by the aurora is relatively small compared to that of the direct solar radiation, the former is concentrated in a small region at the poles, and so is considered to have a large effect on dynamics at these altitudes. Studies using the CRLFPIs mainly observe thermospheric neutral dynamics. Below is a list of the results of research conducted to date.

(1) Correlation between auroras and changes in the vertical wind velocity:Thermospheric vertical winds were believed to be negligible relative to horizontal winds. However, following a report of vertical winds exceeding 100 m/s[5], the importance of these winds is being re-evaluated. With the CRLFPI at Poker Flat, strong upward and downward winds were frequently observed on the north and south sides of an aurora arc[6]. Fig.4 shows an example of the observed results, which is consistent with those of previous studies[7]~[10].

(2) Ionospheric currents estimated from geomagnetic variations and correlation with vertical winds: Cases of positive correlations were found between the horizontal component of geomagnetic variations and vertical winds. This indicates that the vertical winds may be affected by Joule heating by ionospheric currents. Furthermore, comparison of the position of the current system (estimated from the geomagnetic observation chain) and the vertical winds suggested the possibility that the correlation in paragraph 1 above is dependent upon the direction of the horizontal current.

(3) Comparison of the ionospheric convection estimated by HF radar and neutral dynamics: The horizontal winds (estimated based on the all-sky CRLFPI in Eagle and on the ion drift estimated from HF radars in Kodiak and Prince George) were compared to estimate the energy transfer between the ionosphere and thermosphere. As a result, a case was found in which neutral wind was accelerated in the direction of the relatively strong plasma flow only after the flow had continued in excess of 500 m/s for approximately two hours.

4. Conclusions, Use of Data, and Future Plans

In this paper, we have introduced an outline and examples of the results of the Alaska Project, an international collaboration that was launched in 1993 between Communications Research Laboratory, Geophysical Institute of University of Alaska Fairbanks, and other partners. The implementation of the instruments in Alaska has been progressing successfully to construct a comprehensive observation system of the arctic atmospheric environment, which is to play the most major role in this project. This system includes nine types of CRL's observational instruments (components), and experiments for eight of the instruments have already started in Alaska. The research activity will work to integrate the individual components into a single comprehensive system, and the project is expected to thereafter increasingly contribute to scientific and environmental observations and understanding. Already preliminary experiments

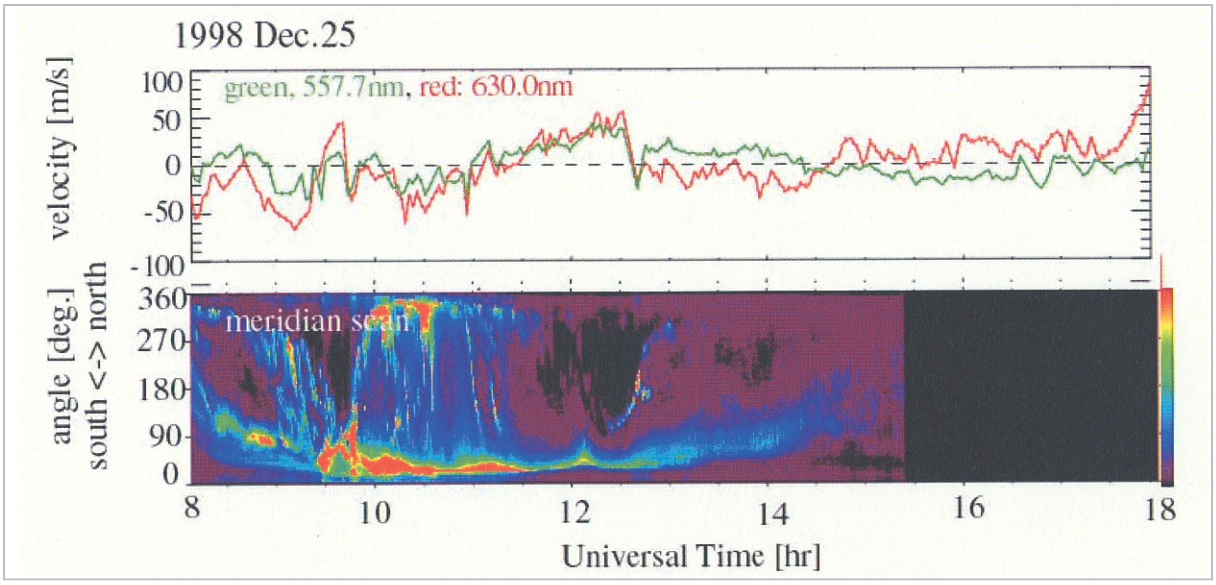

Fig.4 *A comparison of the temporal variations of thermospheric vertical wind observed with the CRL Fabry-Perot interferometer in Alaska (top) and aurora observed (at atomic-oxygen green and red emissions with wavelengths of 557.7 nm and 630.0 nm, respectively) with the meridional scanning photometer of the University of Alaska Fairbanks (bottom). The vertical axis in the bottom figure represents the meridional scan angle, with the zenith at 180°. The vertical wind is highly sensitive to the aurora arc passing through the sky over Poker Flat, and upward and downward winds (maximum velocities of 50 m/s) are also noted*

and test operations of the instruments in Japan, Europe and the US, have been achieving scientific publications.

Space-borne missions for global environment and atmospheric observation have been both proposed and realized by Japan, the US, Europe, and Canada (such as ILAS-II (Improved Limb Atmospheric Spectrometer-II)/ADEOES-II, ACE (Atmospheric Chemistry Experiment)/SCISAT-1, TIMED (Thermosphere-Ionosphere-Mesosphere-Energetics and Dynamics) mission, and so on. There have been requests for joint experiments with the Alaska Project for ground-based validation experiments for the satellite observations. To fulfill our responsibilities to the international research community, we expect to use our instrumentation and observed data sets for the cooperative activities.

The observation data obtained from this system will be publicized or provided for research purposes to other institutions on a collaborative basis in principle. We have been developing and operating the “SALMON” (System for the Alaska Middle atmosphere Observation data Network) system as part of the collaborative efforts between CRL, GI/UAF, and ARSC (Arctic Region Supercomputing Center)/UAF. Current and upcoming computer-controlled instruments tend to provide huge datasets easily, and importance should be stressed to establish techniques of accessing, and processing data effectively for scientists and for more general purposes. SALMON enables automatic data transfer, processing, and display, connecting users, database servers, remote sites of scientific experiments such as in Alaska, through international “next-generation Internet” collaboration.

The network application experiment employed in the SALMON system has been achieved as part of an international collaboration of network research “APAN” (The Asia Pacific Advanced Network). In Japan, APAN’s secretariat is KDDI and participants are KDDI, Keio Univ., Electrotechnical Laboratory (presently the National Institute of Advanced Industrial Science and Technology), the Science and Technology Agency (presently the Ministry of Education, Culture, Sports, Science and Technology), the Ministry of Agriculture, Forestry and Fisheries, CRL, and others. On the US side, the system is linked through next-generation Internet experiments (involving various research and experimental networks such as TransPAC/vBNS and Abiline, for example). Therefore, the SALMON system can also be used as a research application in the long-distance and high-speed transfer of data connecting various types of network experiments. The effective use of data of our polar environmental observation will be promoted in help with this network system, and in the next stage, online data distribution will enable rapid access to the project's data by collaborators and potential data users in future.

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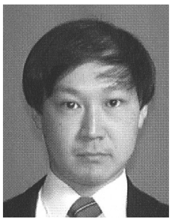
Observational Study of Middle Atmosphere



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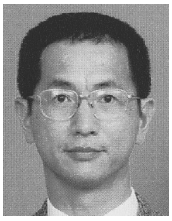

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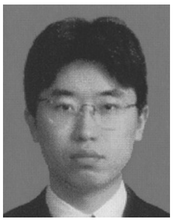

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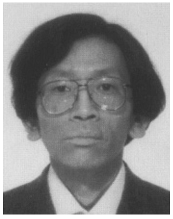

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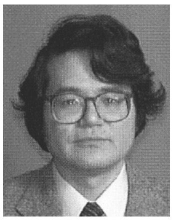

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Aurora, Magnetosphere, and Arctic Environment Changes