Proc. International Conference on Space Optical Systems and Applications (ICSOS) 2014, P-12, Kobe, Japan, May 7-9 (2014)

Environmental Data Gathering System for Satellite-to-Ground Station Optical Communications

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***Abstract*— In the optical space communication between satellite-ground stations, if site diversity is constructed among two or more ground stations connected with the terrestrial network, it will be thought that the link can be established with certainty in one of ground stations. But by storing the data based on weather survey data quantitatively and statistically, and carrying out analysis processing needs to show the validity. Therefore, in this paper show the environmental-data collection system that collects data from sensors installed at approximately 10 appropriate locations throughout Japan.**

Keywords—Optical Communications; Site Diversity; Environmental-data

I. INTRODUCTION

As the resolution of earth observation satellite sensors increases, the quantity of data they produce also increases. In the optical satellite communication system of an earth observation satellite for example, even though an earth observation satellite communicates with a geostationary data relay satellite at from 1.5 Gbps to 2.5 Gbps, the narrow feeder downlink from the geostationary data relay satellite to a ground station means that the acquired data cannot be downloaded in real time. Study is needed for a broadband satellite communication system that uses light or millimeter waves for the feeder link from the geostationary data relay satellite to the ground station or for a direct downlink from the earth observation satellite to a ground station. However, light and millimeter waves are both susceptible to attenuation by rain or clouds, which can interfere with communication. Research on weather relevant to optical satellite communication, such as the extent of regions of clear skies, includes analysis of digital weather instrument data from the weather satellite “Himawari”, AMeDAS, and other such sources of the Japan Meteorological Agency [1][2]. However, there has been no verification of the site diversity effect taking actual satellite orbits into account by long-term acquisition, storage, and analysis of data such as the statistical distribution of clear sky regions, cloud age, and cloud height. We therefore took as our objective verification of the effectiveness of the site diversity effect by analysis of environmental data accumulated over a long period of time. For collection of environmental data, which is also necessary for practical free-space optical communication, we took advantage of the affiliate facilities of the National Institute of Information and Communications Technology (NICT) at ten geographically widespread locations at different longitudes and latitudes across the Japanese archipelago.

II. ENVIRONMENTAL DATA COLLECTION SYSTEM

The system configuration diagram shown in Fig. 1 includes environmental data collection systems installed at 10 observation stations located across the country and an environmental data collection, analysis and display server installed at a center station. The collected data is transmitted to the center station via a terrestrial network at specified time intervals. Assuming times when the terrestrial network cannot be used, such as during disasters, a satellite network can be used for the data transmission (Fig. 2). The observation stations are controlled entirely from the center station, making completely unmanned operation possible. The observation stations are installed at ten locations at NICT facilities throughout Japan (Fig. 3).

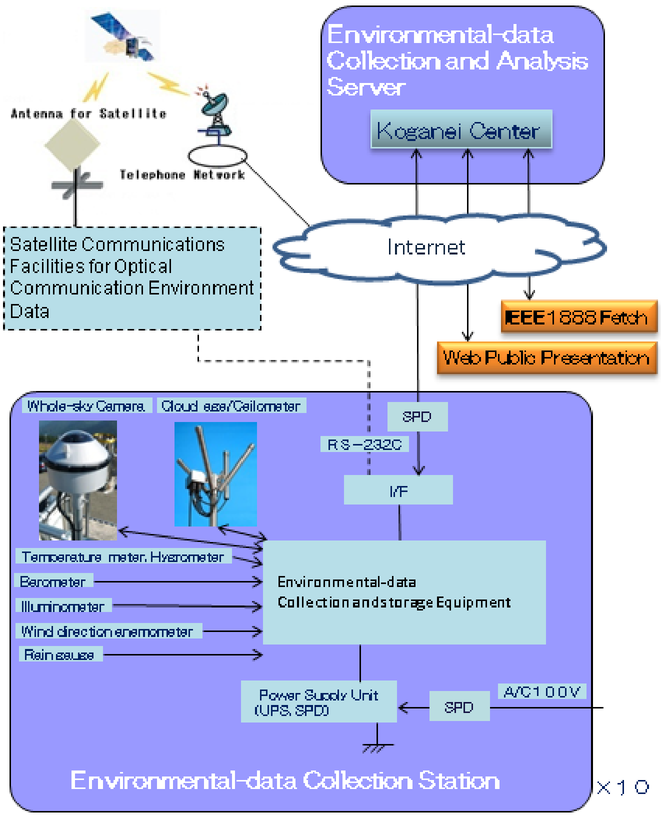

Figure 1. Configuration of an environmental data collection system

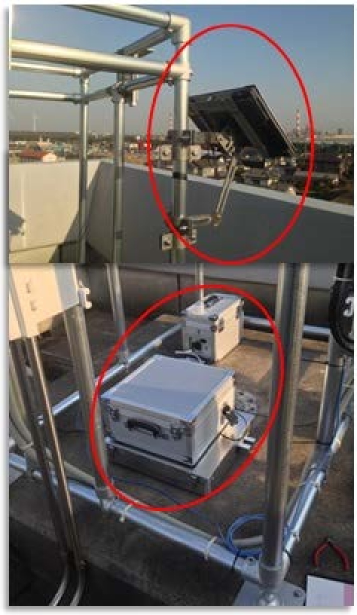

Figure 2. Satellite communication facilities

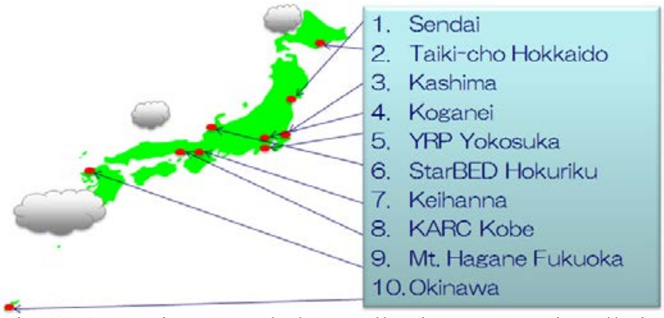

Figure 3. Environmental data collection system installation locations

The locations have a line-of-sight elevation angle of 15 degrees or more to ensure as wide a field of view as possible for the whole-sky camera. When the station is installed on a rooftop, it is placed as far as possible from outdoor units of air conditioning systems to prevent effects on the cloud age and ceilometer sensors.

III. ENVIRONMENTAL DATA COLLECTION STATION

The environmental data collection station is equipped with the sensors listed in Table 1. The data from the whole-sky camera for identifying clear sky regions (about 200 Kbytes per image), the cloud age and ceilometer instruments, and the various weather instruments is collected (263 bytes per measurement). The weather instruments used (3 to 5 in Table 1) were of the same grade as certified by the Meteorological Agency to ensure data reliability. A block diagram of the environmental data collection system is shown in Fig. 4. To protect the equipment that is installed out in the open and to prevent effects on upstream equipment, a discharge and insulated type SPD are used to protect the network system against lightning strikes and a discharge-type SPD, breaker and UPS are used to protect the power supply. An example of a field installation of an environmental data collection system is shown in Fig. 5. It is designed to withstand wind speeds of 50 m/sec at the installation location with no part of the equipment blown away (maximum instantaneous wind speed; the design for the Okinawa installation is for 90 m/sec).

Table 1. Specification of the sensor for measurement

Sensor	Specification
1) Whole-sky camera	VGA image with the color CCD fisheye lens(175deg of viewing angle)
2) Cloud age /Ceilometer	Angle of field 60 degrees infrared radiometer. 5 directions of the zenith and the north, south, east and west direction Amount of Cloud :0～100%±6%, Ceilometer: 0m～8000m±200m
3) Temperature	-60℃～60℃ (±0.2℃@20℃)
4) Humidity	0%～100%RH, ±1%RH(0～90%), ±1.7%RH(90～100%)
5) Pressure	500～1100hPa±0.15hPa,(Resolution: 0.01hPa)
6) Illumination/insolation	0～2000W/m^2
7) Anemoscope/anemometer	50m/sec Max(Survival wind speed100m/sec)
8) Rain gauge	Tipping bucket type with heater: ±0.5mm(～20mm), ±3%(20mm～)

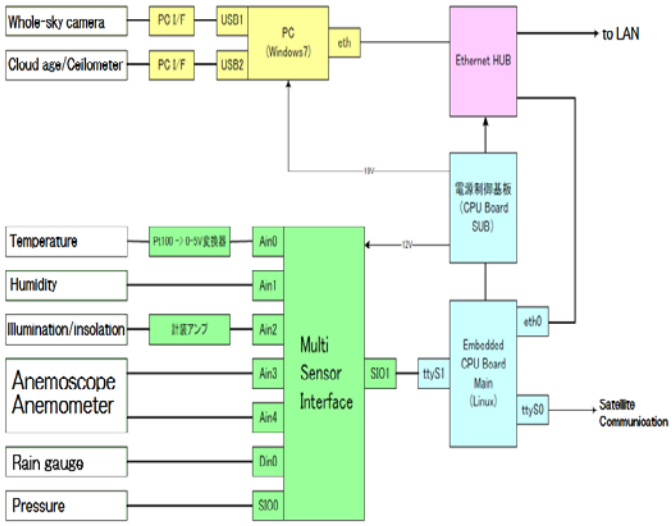

Figure 4. Block diagram of the environmental data collection system

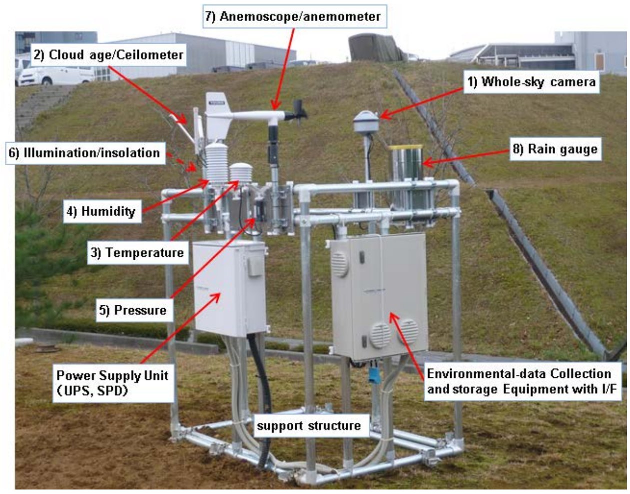

Figure 5. Example of environmental data collection station installation

A. Whole-sky camera

A photograph of the whole-sky camera is shown in Fig. 6. A highly-sensitive color CCD with a fish-eye lens captures VGA images of the entire sky. The images are output in JPEG compression format. Fogging inside the dome by a heater and air circulation fan that operate according to the outdoor air temperature and dome temperature. Other sensors include proprietary atmospheric pressure sensors and an infra-red thermometer oriented toward the azimuth. The day and night whole-sky camera images acquired at NICT Koganei (Fig. 7 and Fig. 8) show that regions of clear sky and clouds are clearly distinguished.

Figure 6. The Whole-sky camera

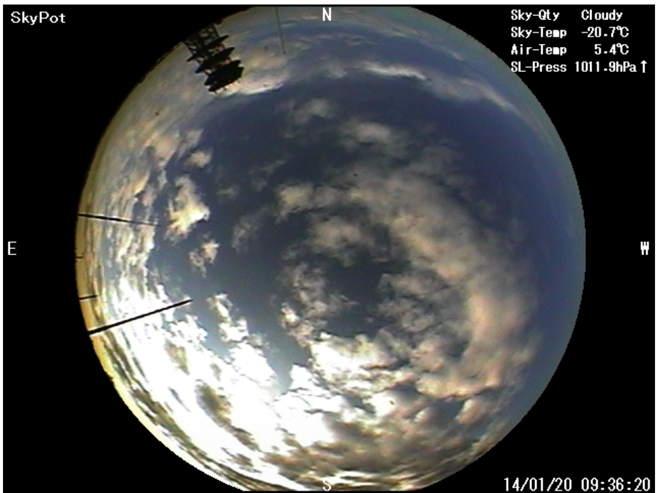

Figure 7. Whole-sky camera image(daytime)

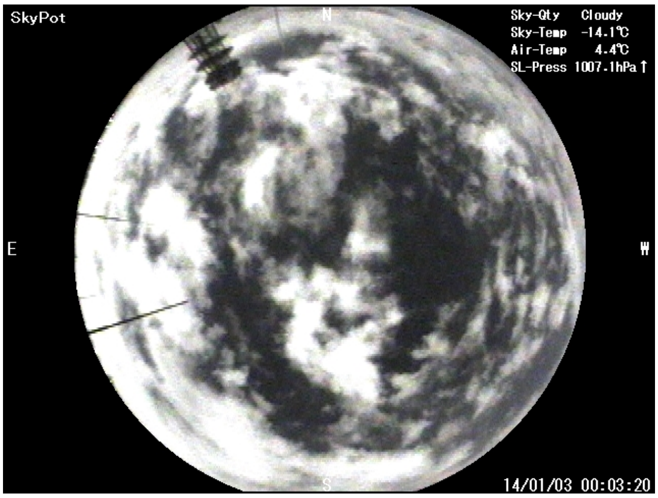

Figure 8. Whole -sky camera image (night)

The environmental trends indicated by the changes in data from the whole-sky camera, zenith-oriented infra-red thermometer, outdoor air temperature, and atmospheric pressure are presented in Fig. 9. The cloud age and cloud height can be estimated from changes in the ground temperature and upper air temperature, within the 60 degree field of view. When the temperature is low and clouds appear in a clear sky region, the temperature rises and it is judged that clouds are present.

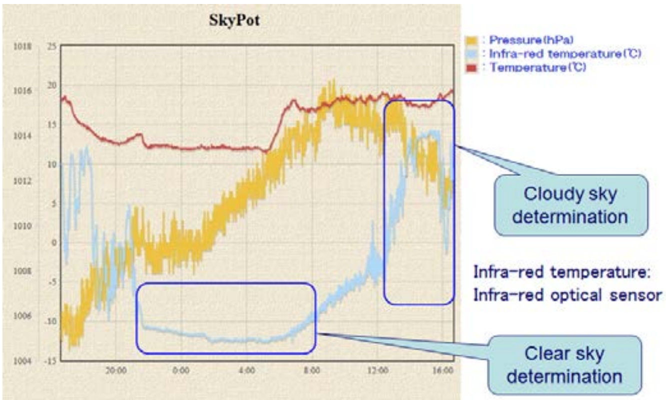

Figure 9. Environmental trends(Kashima)

B. Cloud age and ceilometer instruments

A photograph of the cloud age and ceilometer instruments is shown in Fig. 10. Five infra-red temperature sensors that have a 60 degree field of view are arranged with one oriented to the zenith and the other four oriented to the north, south, east and west at elevation angles of 55 degrees. The sensors have the same specifications for power supply and control communication based on RS485. The cloud age is obtained by calculating the relation of the ground surface temperature and infra-red temperature to the cloud age obtained from the ground surface temperature and infra-red temperature and the whole-sky camera image data that has been accumulated on the basis of the coefficients of the statistically calculated correlation function. Cloud height is obtained from the ground surface temperature and infra-red radiation temperature, with the reference value being -45°C at 8,000 m above sea level.

Figure 10. Cloud age and ceilometer instruments

IV. Environmental Data Collection, Analysis and Display Server

The environmental data collected by the system at each observation station is stored on a environmental data collection, analysis and display server of the center station located at NICT Koganei. The data is analyzed to determine the degree to which windows for free-space optical communication between satellites and ground stations can be ensured. The environmental data collection, analysis and display server has the functions described below.

A. Monitoring and control:

The environmental data collection, analysis and display server monitors the situation at the observation stations and sets the data acquisition intervals, etc.

B. Estimation of the proportion of time optical communication with ground stations is possible:

The periodically transmitted environmental data is used to estimate the total cloud cover and clear sky region ratio (determination of clear sky regions), and visibility, etc. at each observation station, and statistical data processing to determine daily averages, etc. is performed. The resulting data is entered into a database.

C. Data display function:

Trend graphs that include the most recent environmental data for all of the observation stations are displayed by a browser(Fig. 11). The IEEE 1888 FETCH protocol is also supported. Furthermore, a past data search and display function retrieves search results for the specified search conditions, which include the observation station, the time and day of the observation, and a range of weather instrument data such as cloud age and cloud height, and displays the results as a list or a graph, or the whole-sky camera images that correspond to the search results.

Figure 11. Real time environmental data by a browser

D. Estimation of communication windows for optical communication considering satellite orbit:

This function takes the TLE orbit elements of the assumed earth observation satellite as input and estimates the visibility at each observation station (clear sky regions). In addition to searching and displaying environmental data from the observation stations that are in the range of visibility of the satellite and the observation time, statistical processing of the proportion of times at which optical satellite communication is possible is performed.

V. Conclusion

We plan to verify the correlations between the laser wavelengths used in free-space optical communication and environmental data, collect, store and analyze environmental data that cover a period of at least two years, predict site diversity line of sight at the time the satellite is passing for establishing free-space optical communication between satellites and ground stations, and investigate algorithms for optimum ground station selection.

References

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