

**Toward the development of a comprehensive and integrated climate
change observation system:**

Observations for the monitoring of clouds, aerosol and atmospheric radiation,
and for the assessment of the impacts of climate change

Summary

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Scientific Advisory Board
of the Japanese Alliance for Climate Change Observation(JACCO)

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Foreword

Climate change due to global warming is a pressing concern. In order to overcome this problem, it is essential to develop models that can predict future climate change, and to use observation data in monitoring such climate change and validating the model results. Recently, the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) has addressed the importance of observation data. To enhance cooperation among ministries, agencies, and organizations related to Earth observation, which is addressed in the “Earth Observation Promotion Strategy” formulated in 2004 by the Council for Science and Technology Policy, the Japanese Alliance for Climate Change Observation (JACCO) and the Office for Coordination of Climate Change Observation (OCCCCO) have been established.

The Scientific Working Group (WG), which was established under OCCCCO to enhance cooperation, has investigated the requirements for observations related to climate change and published two reports.

The reports of the Working Group address the present status, issues, and future prospects of matters indispensable for the establishment of a comprehensive, coordinated, and sustained observational system based on the present situation and future direction of climate change observation in Japan, and propose a climate change observation system that should be established.

The reports have been submitted to the Earth Observation Promotion Commission of the Ministry of Education, Culture, Sports, Science and Technology (MEXT) as reference documents. OCCCCO has also already begun work on building some of the various inter-agency and/or interdisciplinary alliances (among fields and institutes) mentioned in the reports.

The Second WG Report, published in September 2010, describes detailed investigations into the observation of clouds, aerosols, atmospheric radiation, and tropospheric ozone, which would be at the core of the climate change observation system; observations needed to assess the impacts of climate change (observations of the water cycle, which has a major impact on society, as well as ecosystems and the cryosphere, which are vulnerable to climate change); and the gathering of socio-economic data to be used for detecting and predicting the impacts of climate change.

Because the Second WG Report is extensive, the Scientific Advisory Board of JACCO proposed that this summary be issued for convenience in planning future policies, as in the case of the First WG Report. This document was compiled as a summary of the complete report by the Scientific Advisory Board. Please refer to the complete report for details.

I would like to express my gratitude to the members of the Scientific Advisory Board who have contributed to this summary, and to the members of the Scientific Working Group (Chair: Akio Kito) who have helped in preparing the Second WG Report.

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Isao Koike
Chair, Scientific Advisory Board of JACCO

Note: The Japanese version of this summary was issued in September 2010. This English version was issued in March 2012, in response to requests by interested parties.

Chapter 1 Introduction

The government of Japan is pressed to take urgent actions and measures against the increasingly serious problem of climate change due to global warming, for which comprehensive, coordinated, and sustained observations of the Earth are indispensable. Monitoring of the effects of actions for mitigation of or adaptation to climate change should also be promoted, in addition to climate change observation, particularly in order to fulfill Japan's commitments as stipulated in the Kyoto Protocol.

To promote a close alliance among ministries, agencies, and organizations related to climate change observation, the Scientific Working Group (WG) of the Office for Coordination of Climate Change Observation (OCCCO) has investigated the requirements for climate change observation and issued two reports (hereinafter referred to as the "WG Reports"). These reports have been prepared to clarify the present status, issues, and future prospects of matters indispensable for the establishment of a comprehensive, coordinated, and sustained climate change observation system, and to contribute to future policies by the Earth Observation Promotion Commission of the Ministry of Education, Culture, Sports, Science and Technology (MEXT) and relevant ministries, agencies, organizations, and institutes, on actions for mitigating or adapting to climate change.

The Second WG Report describes detailed investigations into the observation of clouds, aerosols, atmospheric radiation, and tropospheric ozone, which would be at the core of the climate change observation system; observations needed for assessing the impacts of climate change (observations of the water cycle, which has a major impact on society, as well as ecosystems and the cryosphere, which are vulnerable to global warming); and the gathering of socioeconomic data to be used for detecting and predicting the impacts of climate change. A number of actions are ongoing in many fields, despite the limited availability of human and monetary resources, and the report describes these actions in detail and cites a host of opinions regarding observations to be continued and new observations to be commenced.

In this summary, we have summarized the issues and future prospects for observations described in detail in each chapter of the Second WG Report. Chapter 10 of this summary restates the actual activities to be performed for achieving the preferential goals summarized in the Second WG Report. To achieve these goals, there is a need for measures to ameliorate the limitations on human and monetary resources, promote education and training of the next generation, and establish a cooperation system among related ministries, agencies, and organizations, so as to realize comprehensive, coordinated, and sustained observations of the Earth. Moreover, the Earth Observation Promotion Strategy (hereafter referred to as the "Promotion Strategy") emphasizes the importance of collaboration among relevant ministries, agencies, and organizations, in order to implement long-term and continuous observation, and this should be investigated without delay by the Earth Observation Promotion Commission and other commissions or groups.

Chapter 2 Observation of clouds, aerosols, and atmospheric radiation

Understanding the mechanisms of climate change and improving the accuracy of prediction are urgent issues in climate change studies. Aerosols and clouds are closely related to the atmospheric radiation balance and water cycle, and are key factors in the climate system, but uncertainties exist. Therefore, the following actions should be promoted.

(1) Systems should be developed for monitoring the radiation balance because quantitative

measurement of short-wave and long-wave radiation at the ground surface is insufficient. In particular, a system needs to be urgently developed for calibrating infrared radiometers, for which there is no internationally established standard method. It is also essential to maintain the sunphotometer standard (a standard based on the global standard of the World Radiation Center (WRC)). The possibility of using the standard lamp system should be investigated as well. Data on the radiation balance collected by various institutes should be integrated, cooperation with international programs and institutes such as the Baseline Surface Radiation Network (BSRN) should be enhanced, and an archive of long-term observation data should be promoted.

- (2) There are systems for monitoring aerosols, including SKYNET, which is a surface observation network in Asia equipped with a sky-radiometer and other instruments for monitoring aerosols and atmospheric radiation. These observation networks are of global importance, and Japan needs to establish a permanent and sustainable system for operating such networks. Japan is one of the few countries possessing a lidar observation network. Action should be taken to develop a multi-wavelength lidar with high spectral resolution, which can monitor extinction coefficient profiles with high sensitivity, day and night, as well as to improve the accuracy of monitored lidar data and make effective use of the data, such as for the estimation of extinction coefficients by type of aerosol. Furthermore, it is necessary to establish an observation system that uses aircraft equipped with instruments for monitoring clouds, aerosols, and atmospheric radiation.
- (3) Two programs should be proposed for satellite observation of clouds and aerosols: one for long-term monitoring and the other for process studies. The ongoing Japan-EU joint project entitled “Earth Clouds, Aerosols and Radiation Explorer (Earth CARE)”, and the satellite Aerosol, Cloud, Ecosystem (ACE) observation system of the National Aeronautics and Space Administration (NASA), which consists of passive and active sensors, are candidates as future cores in the area of long-term monitoring.
- (4) Data collected from various platforms, such as the surface and satellites, have been compared with values calculated using numerical models, and this has contributed to improvement of the models. Such data have also been used to estimate the sources of aerosols and their precursors by the inversion method. Recently, various methods have been developed for assimilating aerosol and cloud data. The assimilation of data into accurate numerical models must reflect an appropriate level of quality, and quality control of the observation data should be performed.

Chapter 3 Observation of tropospheric ozone

Tropospheric ozone, one of the greenhouse gases, and the cause of trans-boundary atmospheric pollution, has been gaining increasing attention as a key target of global observation. The concentration of tropospheric ozone has risen at various rates depending on the region, and the increase has been particularly fast in rapidly developing East Asia. Accurate, high-density, and long-term observations are therefore indispensable for estimating the long-term trend on a global scale. The entire troposphere, from the surface to the upper atmosphere, should also be thoroughly monitored to collect scientific knowledge on intercontinental long-distance transport. The following actions should therefore be promoted.

- (1) To standardize the scales of ozone concentration observations in Japan, the reference photometer (SRP) No. 35, maintained by the National Institute for Environmental Studies (NIES), should be utilized, along with the UV scale based on the international system. The availability of

observation data from relevant observation platforms should be improved by coordinating the timing of calibration, and by comparing the data. The intercomparison, therefore, should be conducted on a continuous basis.

- (2) Methods for collecting and providing observation data should be further improved, including providing data in near-real time and establishing an integrated database of monitoring data from all the institutes in Japan. Moreover, data utilization should be advanced by promoting data exchanges via the World Data Center for Greenhouse Gases (WDCGG), established under the Global Atmosphere Watch Program of the World Meteorological Organization (WMO/GAW), and operated by the Japan Meteorological Agency.
- (3) Activities for analyzing phenomena, and verifying and assimilating data, should be promoted by observing tropospheric ozone not only from the ground surface but also from aircraft and vessels, observing the vertical distribution of ozone by using ozone lidars and ozonesondes, collecting data from satellites, forming a data collection network for the whole of Japan, integrating various observation data, and obtaining precise and dense three-dimensional data in terms of both time and space. Continuous and long-term observation of tropospheric ozone from ground stations in polar regions is also needed.
- (4) As a basis for understanding the actual status and processes of, as well as changes in, regional atmospheric pollution in the northern hemisphere and East Asia, ozone and its precursors should be monitored near their sources, and international cooperation should be promoted to enhance observation in the Asian continent.

Chapter 4 Water cycle

A large part of the impact of climate change on human society and ecosystems appears in forms related to changes in the water cycle. Continuous monitoring of the water cycle, and development of advanced monitoring systems, are not only required for scientific purposes, but requisites for meeting the demands of society. Water cycle observation is essential, and some issues exist.

The temporal and spatial distribution and resolution of available data are insufficient. Some data are stored but unused at institutes of various countries, causing a reduction of data availability. In addition, data in a standard user-friendly format are limited. To resolve these issues, the following measures can be adopted.

- (1) The importance of establishing systems for long-term and continuous observation from the ground should be recognized, and technical assistance should be provided to those such as developing countries.
- (2) To improve the temporal and spatial distribution and resolution of ground observation data, assimilated data should be produced by comprehensively integrating ground observation data, numerical models, and satellite data. To achieve this goal, it is indispensable to assist developing countries in performing observations, and to rescue, archive and digitize data monitored in the past in developing countries.
- (3) A system should be established in which data are easy to access and obtain, by promoting the distribution of ground and satellite observation data in a unified format throughout various countries.
- (4) An organization should be established for integrating, managing, and stably providing water cycle observation data, in order to avoid undue reliance on limited-term projects.

Satellite observation is a key method for monitoring the water cycle in a large area over the long term, and will help to solve these problems. Japan is planning two satellite observation projects related to the water cycle. It is important to steadily implement the Global Change Observation Mission (GCOM) and Global Precipitation Measurement (GPM) with international cooperation. Japan should also expand activities which, through satellite observation, generate new scientific knowledge or create products that will lead to further improvement in social welfare. Once established, the organization mentioned above will play a central role in the development of satellite observation and the promotion of the utilization of collected data.

Chapter 5 Cryosphere

The Earth's cryosphere is expected to be rapidly altered by climate change, and this alteration is predicted to further accelerate global warming. Examples of apparent ongoing phenomena include shrinkage in the coverage of the sea ice in the Arctic Ocean, retreating glaciers, and reduction in permafrost, snow cover, and ice sheets. The cryosphere is characterized by time constants of several tens to several thousand years, as well as short time constants. It is therefore a matter of urgency to monitor such changes and clarify the response mechanisms, by establishing monitoring systems.

The cryosphere affects the global climate via the albedo feedback mechanism, the water cycle, sea-level rise, the release of greenhouse gases, and impact on human activities. In order to understand the processes involved, assess their impact, and develop and implement measures for long-term observation and data archive, the following actions should be taken with respect to the cryosphere.

- (1) The network for monitoring changes in the cryosphere should be strengthened, and a sustainable monitoring system should be established.

Global and regional monitoring systems and regional process studies, with international and nationwide cooperation, are required. An efficient and sustainable system should be established for collecting data, by improving ongoing regional monitoring activities and promoting collaborative utilization of observation facilities. Observation methods and elements, such as supersites, distribution-type observation networks, and traverse observations on land, as well as observation by vessels and automatic observation in the marine environment, should be enhanced, and related equipment should be developed.

- (2) An integrated analysis system should be established by collecting and maintaining the quality of satellite and ground observation data.

Cryospheric data are often collected through individual process studies, and there is no organization in charge of such data archives. Therefore, there are few datasets available to researchers and related institutes. Satellite and ground observation data products should be archived, managed, and provided, by unifying the metadata and format of the datasets possessed by observation institutes. The management system also requires enhancement of product quality by improving the method of acquiring data from satellites, as well as development of the methods for integrated analysis.

- (3) A core organization for assessing and predicting the impacts of climate change should be established by promoting continuous monitoring of the cryosphere and utilization of the resulting data.

Few observational elements concerning the cryosphere have been collected and used, and continuous observation is difficult. To understand the changes caused by climate change, and their potential impact, a core organization which takes charge of efficient, systematic, and comprehensive management of cryospheric data, and promotes interdisciplinary cooperation, should be established.

Chapter 6 Ecosystems

Many factors influence the state of and changes in an ecosystem, therefore studies should be conducted continuously over the long term by establishing various research targets and collecting information. Issues to be investigated urgently, in order to understand the long-term changes in ecosystems, and the mechanisms involved, are listed below.

- (1) There are still large spatial gaps in ground observation, satellite observation, and large-scale models of ecosystems. It is therefore important to reduce these gaps and identify consistencies. An advanced monitoring system including large-scale field experiments should be established and maintained over the long term for supersites. The supersites here are regarded as observation sites, on land or in coastal zones, covered by multiple ecological networks such as the Japan Long Term Ecological Research Network (JaLTER), JapanFlux, or Monitoring Sites 1000, to name a few. In order to enlarge the monitoring areas and reduce spatial gaps in observations, field observation bases in alpine and warm-temperate zones, in Japan and in the Asian and Eurasian regions, should be established and maintained over the long term.
- (2) Observation of ecosystems is directly related to biodiversity in many respects, and only a few items can be monitored using present sensing technologies. In many cases, ecosystems are difficult to observe automatically, causing delays in automatic data processing and data assimilation. Technological development and capacity enhancement are strongly required.
- (3) In order to scale up information monitored at surface observation stations, ultra-high resolution satellite sensors should be developed, and satellite observation systems should be established, targeting the Asian and Eurasian regions around Japan, in concert with geostationary satellites. Tight integration with relevant ecosystem observation should also be promoted.
- (4) To promote modeling using ground and satellite observation data on ecosystems, a database system with an open data policy and well-documented metadata, as well as a center for integrating and analyzing various observation data, should be established. It is also important to establish a comprehensive system for the observation of ecosystems and biodiversity, in order to promote large-scale remote sensing observations, verify the results of model output using observation data, and improve the accuracy of model calculation.
- (5) Most ecosystem observation networks have no long-term financial support from the government. Researchers themselves should apply for short-term competitive funds for managing and maintaining observation systems and administering databases. Immediate action should be considered.

Chapter 7 Socioeconomic data

The impacts of climate change on the human living environment generally involve various mechanisms and social conditions closely related to regional characteristics. To appropriately assess

these impacts and develop and implement measures, detailed information of regional climate change observation, along with prediction information, must be available, and social and economic data that reflect the characteristics of each region should be accumulated, managed, and disseminated. However, such information is certainly insufficient today. The majority of socioeconomic data has not been managed for use in research related to climate change, and data sharing and information availability details are also insufficient. Information should be exchanged, classified, and shared among ministries and agencies, as part of an effective and efficient communication system. Urgent issues are summarized below.

(1) Collection and preparation of socioeconomic data covering large areas, along with related geographical information

To analyze the impacts of climate change on human society, comprehensive analyses should be conducted, and the results should be used to identify particularly vulnerable regions and sectors. For this purpose, socioeconomic data covering large areas should be collected and provided, along with related geographical information, as has typically been the case for data on population. The socioeconomic data should not be limited to statistical information on observation data in the past, but should also include information related to future scenarios, in order to meet the needs of users (researchers on the impacts of climate change and administrators involved in adaptation measures).

(2) Collection and provision of regional data

To precisely analyze the impacts of climate change on human society, and investigate adaptation measures, information on regional characteristics is required, as well as spatial socioeconomic data covering large areas, such as population data. Regional information includes not only quantitative data that can be readily compared with data of other regions, but also qualitative information such as disasters experienced by residents in the past, and traditionally practiced control and mitigation measures. Documents of regional disaster prevention meetings and local administrative plans may also be useful for investigating adaptation measures. Local information and experience should be digitized, shared among regions, and used for risk assessment and management.

(3) Collection and provision of information on future scenarios

Appropriate socioeconomic scenarios that are consistent with assumed scenarios of climate change should be formulated for predicting the impacts on human society. Appropriate rules should be determined for describing metadata, and a system for sharing datasets, including information on uncertainties, should be established to promote studies on the impacts of climate change.

Chapter 8 Issues related to integration of ground and satellite observation data

The Earth's environment is constituted by a broad range of scientific and social factors that interact with each other in a complex manner. It is therefore essential to intensively monitor certain targets using various methods such as ground observation and remote sensing via satellites, and to comprehensively understand and interpret the Earth's environment based on the acquired datasets. Issues to be resolved concerning today's research system in Japan, in order to implement integrated Earth observation by means of various ground and satellite observations are:

- (1) a lack of sustainable, enduring human and monetary resources for Earth observation;
- (2) problems related to the accuracy of observation data and mutual utilization; and
- (3) insufficient technologies for the use of integrated data compiled by interdisciplinary cooperation, and insufficient human resources for the development of such technologies.

The following actions in particular are needed to cope with these issues. For comprehensive, coordinated, and sustained observations of the Earth, efficient use must be made of the limited human and monetary resources of individual observation stations and groups. It is strongly recommended to appropriately overlap observation sites, and maintain them over the long term, by constructing and jointly operating monitoring sites and areas (supersites) so that observation networks, such as for the carbon cycle, water cycle, cryosphere, or atmospheric chemicals, and verification sites for satellite observation, overlap as much as possible.

To improve data accuracy and encourage data sharing, satellite sensors should be continuously operated over two or more generations to support long-term Earth observation, and inter-generational calibration should be performed to maintain the accuracy of observation. The accuracy of radiation monitoring should be improved and controlled over the long term by immediately establishing a system for calibrating the radiation for each wavelength monitored at ground stations and by satellites. Actions should also be taken to improve the technologies for observing common and indispensable parameters in various fields, such as land cover, biomass, precipitation, and snow depth.

Actions to be taken with respect to human resources are described in Chapter 9.

Chapter 9 Human resources development

In all areas investigated and summarized in this report, the necessity for human resources development has been emphasized, addressing the need to train people who can take charge of implementing observations related to climate change, and of managing and analyzing the data. Human resources development in science and technology faces a number of serious problems, however, such as a decrease in the number of elementary and middle school students who are interested in science, fewer graduate students going on to doctoral studies, and fewer employment opportunities for postdoctoral fellows. General issues in the field of Earth observation are listed below.

(1) Human resources development from a long-term point of view

Developing trained personnel is the most critical factor for long-term operation of observation systems. Because research projects are generally revised every five years, the human resources are limited. Insufficient numbers of experts in charge of maintaining observation instruments and facilities over the long term creates difficulties in addressing contingencies (such as power supply failures). The number of people, particularly young people, engaged in observation at overseas observation stations has decreased. Therefore, national and/or international systems should be established for training experts who can perform observations at such stations and/or at remote locations, and use the data obtained. Schemes should also be investigated that allow non-experts to participate in observations.

(2) Human resources development for improving observation and analytical technologies via research exchange

Human resources possessing broad knowledge and deep perception of the global environment are

indispensable for appropriate utilization and understanding of more complex numerical models, and for further improvement in these models through comparisons with long-term observation data. The requisite abilities depend on competence in basic sciences such as mathematics and physics, and therefore reliable education in the basic sciences should be provided at universities (both general and special courses), in order to cope with today's needs for the study of complex systems such as the global environment. To improve the skills of researchers in performing observations and analyzing data, substantial and consistent education should be provided. Furthermore, opportunities for training young researchers, exchanging information, and making proposals for future research plans, should be increased by holding workshops and training seminars.

(3) Human resources development to improve comprehensive skills in data utilization

Knowledge in various fields should be integrated to effectively utilize data collected by ground and satellite observations, monitor changes in climate and the global environment, and predict future changes. To integrate knowledge more effectively, researchers are expected to improve their capabilities in data utilization, such as the ability to understand the characteristics of various datasets (meanings and errors of observation data, space- and time-coverage, data formats, etc.), to process and analyze large amounts of data, to interpret data from a comprehensive point of view, and to apply knowledge and information to numerical models. Observation data will be able to be used in an integrated and effective manner by integrating remote sensing data from satellites and *in situ* observation data. Sustainable capability-enhancing activities are strongly required, in order to train individuals who will be in charge of developing integrated technical skills, not only at educational institutes such as universities, but also via observation and research activities at inter-field supersites.

(4) Human resources development for climate change observation, and promotion of impact assessment and formulation of adaptation measures

To monitor local and global climate change, assess its impacts, and investigate adaptation measures, human resources should be developed so that developing countries can acquire the techniques for implementing such activities by themselves. Japan has been playing an important role in promoting human resource development in Asia, by providing large numbers of human resources to working groups and advisory boards in various fields in Asia, and imparting advanced knowledge, technical skills, and experience to developing countries. On the other hand, the number of people in Japan who can fulfill such roles is still insufficient. There is no systematic scheme in Japan to cope with recent global issues such as climate change, and an excessive burden is imposed on a small number of experts. Human resources development within and outside Japan should be further promoted by improving graduate school courses and establishing institutes for comprehensive analysis of observation data.

Chapter 10 Future outlook (Priority issues)

To address the problem of climate change, it is indispensable to continuously promote comprehensive, coordinated, and sustained observations of the Earth. Issues to be given priority were selected by means of a careful survey of the contents of the report, from the viewpoint of (1) promotion of data standardization, (2) promotion of data sharing, (3) promotion of collaborative utilization of observation facilities, and (4) minimization of temporal and spatial gaps in observation, and enrichment of observation elements—all of which are expected to be advanced by the establishment of

cooperation bases; as well as (5) development of observation technologies, and (6) human resources development, which are the basis for achieving goals (1) to (4). The titles and contents of the topics are given below (topics 10.1 to 10.6 are those specified in Chapter 9 of the Second WG Report).

In view of the fact that the “Promotion Strategy” emphasizes the importance of collaboration among relevant ministries, agencies, and organizations, in order to implement long-term and continuous observation; and calls for measures to overcome the limitations on human and monetary resources, to promote education and training of the next generation, and to establish a cooperation program among related ministries, agencies, and organizations to realize comprehensive and integrated observation; detailed concrete measures should be investigated without delay by the Earth Observation Promotion Commission of the Ministry of Education, Culture, Sports, Science and Technology, and other commissions or groups.

10.1 Promotion of data standardization

- Establishment of a high accuracy atmospheric radiation observation system and data archives
Although the amount of atmospheric radiation on the ground surface is the key element in the climate system, it has not been observed and evaluated accurately. In particular, calibration methods should be established for ground and satellite observations of long-wave radiation and spectral radiation, and a system needs to be established that can be maintained over the long term. Permanent observation systems should also be established, through cooperation with international programs and organizations such as the Baseline Surface Radiation Network (BSRN), the Global Atmosphere Watch (GAW) Program, and the World Radiation Center (WRC). Japan should also lead the world in promoting the long-term data archive.
- Unifying the scale of ozone concentration, and performing periodical comparison of observed data among institutes
The availability of observation data should be improved by unifying the ozone observation standards in Japan, such as the reference photometer (SRP) No. 35, maintained by the National Institute for Environmental Studies (NIES), and using the UV scale based on the international system. Intercomparison among institutes should also be conducted on a continuous basis.
- Establishment of an integrated analysis system by collecting and controlling the quality of satellite and ground observation data
Cryospheric data are not available for various studies, due to the lack of a system for integrating and analyzing the data. A system needs to be established for integrating and analyzing ground and satellite data, by managing the data and controlling their quality. It should be noted that this problem also exists in fields other than cryospheric study.

10.2 Promotion of data sharing

- Improvement of the data collection and dissemination scheme, and promotion of the exchange of ozone observation data
Methods for collecting and providing observation data, including near-real time data, should be further improved. Moreover, data utilization should be advanced by promoting data exchange via the World Data Center for Greenhouse Gases (WDCGG), established under the Global Atmosphere Watch Program of the World Meteorological Organization (WMO/GAW), and operated by the Japan Meteorological Agency.
- Enhancement of ozone observation in the Asian continent, and promotion of the exchange and use of observation data

As a basis for understanding the state of, processes involving, and changes in tropospheric ozone in the northern hemisphere and East Asia, ozone and its precursors should be monitored near their sources, and international cooperation should be promoted to enhance observation in the Asian continent.

➤ Establishment of an organization for integrating, managing, and providing water cycle observation data

A system is required that facilitates access to water cycle data, including ground observation data, satellite observation data, rescued data, and processed data, all provided in a unified format. To maintain sustainable services, an organization for integrating, managing, and providing water cycle observation data should be established.

➤ Establishment of a core organization for assessing and predicting the impacts of climate change on the cryosphere

To assess and predict the impacts of climate change on the cryosphere, it is essential to establish a core organization in charge of promoting continuous monitoring, data utilization, and integrated analysis.

➤ Establishment of a center for integrating and analyzing data on ecosystems

To promote modeling using ground and satellite observation data on ecosystems, a database system with an open data policy and well-documented metadata, as well as a center for integrating and analyzing various observation data, should be established.

➤ Improvement of the usability of socioeconomic data by integrating and digitizing data covering various fields

Socioeconomic data should be digitized and integrated with spatial and geographical information (a) to improve the usability of data for detecting and assessing the impacts of climate change, and considering adaptation measures, and (b) to promote the exchange of such data. Measures should be investigated not only with respect to statistical information on the monitoring targets but also future scenarios.

➤ Modifying the collection of information on data sources for socioeconomic data, for ministerial cooperation and addressing needs

The majority of the socioeconomic data required for detecting and assessing the impacts of climate change, and for investigating adaptation measures, has not been prepared for utilization related to climate change, and information on data sources has not been shared. Related ministries and agencies should cooperate in the comprehensive collection of information on socioeconomic data sources, and provide the information in ways that address the needs of users (researchers of climate change impacts and administrators involved in adaptation measures).

➤ Promotion of a satellite observation data archive

Satellite observation is indispensable for long-term Earth observation over a large area. Thus, an archive of observation data is essential.

10.3 Promotion of collaborative utilization of observation facilities

➤ Establishment of a long-term operation system for ground observation networks of aerosols, clouds, and atmospheric radiation

Ground observation networks such as SKYNET, equipped with sky radiometers, lidars, and other instruments for monitoring aerosols, clouds, and atmospheric radiation, have provided important data in East Asia. A permanent system for operating these globally essential networks needs to be established.

- Establishment of supersites related to ecosystems
Observation sites covered by multiple ecosystem observation networks such as the Japan Long Term Ecological Research Network (JaLTER), JapanFlux, and Monitoring Sites 1000, need to be regarded as supersites, and monitored over the long term by establishing an advanced observation system actively incorporating large-scale field experiments.
- Establishment of comprehensive, coordinated, and sustained observation stations in Japan, Asia, and Eurasia
To integrate and analyze various ground and satellite observation data by making optimal use of existing observation functions (such as facility and observation technologies, human resources, parameters, accuracy, and space and time coverage), a network should be formed among observation systems established in different fields, to share observation facilities and promote the open use of observation data collected by different networks.

10.4 Minimization of temporal and spatial gaps in observation, and enrichment of observation elements

- Continuous launching of satellites for monitoring of clouds, aerosols and atmospheric radiation
Satellite observation, which can cover the entire globe, is essential for the development of global climate models and atmospheric chemical transport models, and for the effective use of ground observation data. Japan should promote satellite observation, which has obtained excellent scientific results in recent years, with international cooperation, from the viewpoint of long-term monitoring and process studies.
- Expansion of continuous long-term observation of tropospheric ozone, and verification and assimilation of observation data by models
Long-term continuous observation of ozone in the entire troposphere, from the ground to the upper atmosphere, from ground stations including those in polar regions, should be continued. Three-dimensional data should be obtained by integrating various observation data collected on the ground, from aircraft and vessels, and by ozone lidars, ozonesondes, and satellites. These data should also be used for promoting activities related to analysis of phenomena, and verification and assimilation by models.
- Ensuring and strengthening the sustainability of ground observation systems for the water cycle and the rescue and archiving of past observation data
For appropriate monitoring of changes in the water cycle caused by climate change, and calibration and verification of satellite data and climate models, high-quality long-term ground data are indispensable. Necessary technical assistance should be given to developing countries to ensure and strengthen the quality and sustainability of ground data observation systems for the water cycle. Past data that are not being utilized should also be rescued (and digitized) and made available to experts and policy decision-makers, particularly in developing countries.
- Expansion of satellite observation of the water cycle in Japan, and utilization of data
Satellite observation is the key method for monitoring the water cycle over the long term, by bridging spatial gaps in ground observation. Japan should steadily implement the two satellite observation projects on the water cycle (namely, the Global Change Observation Mission (GCOM) and Global Precipitation Measurement (GPM)), with international cooperation. Japan should also obtain new scientific knowledge from satellite observation, and expand activities that generate products that will lead to further improvement in social welfare.
- Enhancement of the network for monitoring changes in the cryosphere, and establishment of a

sustainable monitoring system

It is indispensable to continuously monitor changing phenomena with high accuracy, and to understand the relevant response mechanisms, in order to assess the impacts on the global environment. A sustainable monitoring system should be established by strengthening the network for monitoring the cryosphere.

- Minimization of spatial gaps in observation, such as alpine and warm-temperate zones
Alpine zones, which have vulnerable ecosystems, and warm-temperate zones where flux observations are not conducted, are areas in which spatial observation gaps exist. Such gaps should be minimized by establishing observation bases, in order to collect data for the comparison of ecosystems over large areas, and to assess the impacts of climate change.

10.5 Development of observation technologies

- Development of multi-wavelength lidar with high spectral resolution
Japan is one of the few countries that have lidar observation networks, and is leading the world in this field. A multi-wavelength lidar with high spectral resolution should be developed to monitor extinction coefficient profiles of aerosols, day and night, with high sensitivity.
- Improvement of observational aircraft equipped with instruments for observing clouds, aerosols, and atmospheric radiation
Japan conducted aircraft observation of clouds, aerosols, and atmospheric radiation particularly intensively in the 1980s and 1990s, and obtained excellent results from these research activities. Although understanding the three-dimensional structures of these phenomena is of growing importance, the development of a system for aircraft observation has not advanced since the 1990s. Improvement of the aircraft observation system should be promoted to achieve new breakthroughs in research.
- Archiving of assimilated data by integrated use of numerical models and ground and satellite observation data
Data should be collected over a large area and over the long term to investigate changes in the water cycle caused by climate change. There remain spatial and temporal gaps in past data, even if all past datasets in developing countries were to be rescued. Among the various measures to bridge these gaps involving the use and/or development of advanced technologies, it will be most appropriate to prepare assimilated data via the integrated use of numerical models and ground and satellite observation data. Therefore, the preparation of ‘reanalysis climate data’ should be continued, and further developed and upgraded.
- Development of ultra-high resolution satellite sensors and systemic integration, for ecosystem observation
To scale up information monitored at surface observation stations, ultra-high resolution satellite sensors should be developed, and satellite observation systems should be established targeting the Asian and Eurasian regions around Japan, in concert with geostationary satellites. Tight integration with ecosystem observation should also be promoted.
- Long-term operation of satellite sensors for two or more generations, and mutual calibration of sensors
For long-term Earth observation, satellite sensors must be used for a long period. Various means should be employed to ensure the continuity of observation by satellite sensors, which have a lifetime of three to seven years, and to maintain and control the accuracy of data over the long term, such as by inter-calibration of different generation sensors, and by comparing satellite data

with ground observation data.

10.6 Human resources development and capability enhancement

In all the reported fields, the need for human resources development has been emphasized, with the aim of training the next generation that will be in charge of carrying out observations and data management. Human resources development faces a number of serious problems, however, not only in the field of Earth observation but in the entire science and technology field in Japan, such as a decrease in the number of elementary and middle school students who are interested in science, fewer graduate students going on to doctoral studies, and fewer employment opportunities for postdoctoral fellows. In this section, specific problems common to the fields studied in the report are mentioned.

➤ Human resources development from the long-term point of view

Observation related to climate change involves continuous monitoring from remote locations, and effective utilization of the monitoring data. Human resources with the ability to conduct such observations and data analysis should be trained and engaged within and outside Japan.

➤ Human resources development to improve observational and analysis techniques, via research exchange

To improve the skills of researchers in analyzing data as well as performing observations, steady education from a broad perspective, informed by basic science, should be enhanced, and opportunities for exchanging information on research, proposing future plans, and training young researchers, should be increased by means of workshops and training seminars.

➤ Human resources development to improve comprehensive data utilization capabilities

Capabilities involved in the utilization of varied data should be developed, such as possessing a full understanding of the characteristics (meanings and errors of observation data, space- and time-coverage, data formats, etc.) of various datasets obtained by both ground and satellite observations, as well as the ability to process and analyze large amounts of data, interpret data from a comprehensive point of view, and gather knowledge on numerical models. Human resources development should also be promoted for the development of related technologies.

➤ Human resources development for climate change observation, and for application of the relevant data to impact assessments and the development of adaptation measures

An excessive burden has been imposed on a small number of experts, to cope with the emerging issue of climate change. Human resources development within and outside Japan should be further promoted, by improving graduate school courses and establishing institutes for the comprehensive analysis of observation data.

Appendix

Scientific Working Group for OCCCO Report No. 2

“Toward the development of a comprehensive and integrated climate change observation system:—Observations for the monitoring of clouds, aerosols, and atmospheric radiation, and for the assessment of impacts of climate change —”

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List of abbreviations

Technical terms

Members of the Scientific Advisory Board of JACCO

Members of the Scientific Working Group of OCCCO

Schedule of meetings

Members of the Scientific Advisory Board of the Japanese Alliance for Climate Change Observation(JACCO)

Isao Koike	Chair of the Scientific Advisory Board of JACCO Inspector General, University of the Ryukyus
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