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Earth Observing Missions and Sensors: Development, Implementation, and Characterization II

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The benefit of Space derived Geo-spatial information for Sustainable Development

Yasushi Horikawa
Japan Aerospace Exploration Agency (Japan)

As Chairman of the UN COPUOS I deal with many problems related to collaboration amongst UN Member States who are attempting to reach consensus on the use of space data technology and applications for the purpose of solving regional or global problems which affect all of humanity and to help sustainable development at a global level.

At this time, space science and exploration, Earth observations, climate change research, the sharing of environmental data, disaster mitigation and relief, space surveillance for near earth objects for debris monitoring and awareness are the most demanding fields for international collaboration. I consider the UN COPUOS to be the highest international platform for political, scientific, technical and legal debates connected with space, a platform for negotiations, elaboration and promotion of important international treaties, agreements, UN resolutions and guide-lines for all member states.

The UN COPUOS is at the same time both a reflection and an integration of most global and regional forums of cooperation in the space field. In an era where space is becoming increasingly crowded with new players the need to share a commitment to act responsibly to help prevent mishaps, misperceptions and mistrust has become a must.

In 2011, the United Nations celebrated the fiftieth anniversary of the Committee on the Peaceful Uses of Outer Space and recalled its outstanding achievements in ensuring that outer space was used for peaceful purposes. The declaration of the 50th anniversary expressed deep concerns about the fragility of the space environment, that is, the continuing threat of the impact of space debris. *Long term sustainability of space activities* is now one of the most challenging topics under discussion at the UN COPUOS and a topic that needs real global cooperation and understanding.

As you know, the primary objective of COPUOS is to maximize the benefits of space science, technology, their applications and to increase coherence, synergy, and international cooperation in space activities at various levels including national, regional, and global instrumental support efforts with special consideration for the needs of developing countries. Aiding this effort, the United States launched the first civilian Earth observation satellite, Landsat-1, on July 23, 1972, an achievement whose 40th year anniversary was celebrated this June at UNCOPUOS.

As you know, Earth observation from space has become a significant tool to benefit human life by helping illuminate dangers to our societies like global climate change due to global warming and the consequent problems of food security and global health, all of which are interlinked with disasters and poverty.

As such, we need a holistic approach to these problems and concerns in order to make sound long-term decisions for humanity's future. The 1992 Earth summit held in Rio de Janeiro neither recognized nor mentioned the use of such space tools to meet human needs on Earth. In the first draft of the Rio+20 Conference document the word "space" was not mentioned once even though today over 75% of the world is space-knowledgeable and consumes a large amount of space products and services daily. A timely and adapted integration of remote sensing, satellite telecommunication, and global navigation satellite systems to multi-source geospatial datasets will provide some key factors needed to resolve these difficulties.

With increasing awareness of, and concern for, the environmental impacts on Earth caused by global warming and related climate changes we should recognize the critical importance of monitoring these changes and devise climate change mitigation and adaptation measures. Joint development of interoperable systems to address such issues is an important area for international cooperation. The above circumstances notwithstanding, the collection, analysis and use of available information, including the space-acquired ones, to properly manage our life-support systems has been confirmed in many parts of the world as a necessary starting point on the path towards sustainable development and must be rigorously pursued.

Although the issues relating to Earth observation satellite systems and their information accessibility and data policy are being discussed at the meetings of the Group on Earth Observations (GEO) and the Committee on Earth Observation Satellites (CEOS), due to the global nature of its work COPUOS should also address these data utilization issues and further promote the relevance of research in data analysis and utilization in order to strengthen international cooperation among its member States.

Disasters continuously affect our societies in all parts of the World and demonstrate repeatedly how vulnerable we are against the forces of nature and how important it is to strengthen our ability to mitigate the devastating effects of natural disasters.

Loss of life and property could be diminished if better information were available through improved risk assessment, early warning, and monitoring of disasters. In this regard, the integrated and coordinated use of space technologies and their applications can play a crucial role in supporting disaster management by providing accurate and timely information and communication support.

After the Earthquake on 11 March 2011, JAXA, the Japanese space agency has been observing and analyzing of the disaster area with the Advanced Land Observing Satellite "Daichi" and other satellites of foreign space agencies. Japan once again thanks you for the kind support and help which came generously from all over the world. We have come to realize the importance of using satellite data for natural disaster preparation and response and we would like to share and reconfirm the importance of constant, regular images taken when disasters occur to compare the affected areas for crisis management and response.

The work currently being carried out by the Scientific and Technical Subcommittee through its Working Group on the Long-term Sustainability of Outer Space Activities is critically important. Its goal is to ensure the safe and sustainable use of outer space over many years by future generations.

To implement a set of practical and prudent measures for enhancing the long-term sustainability of space activities, the Working Group was established to address sustainable space utilization and the support of sustainable development on Earth, space debris, space weather, space operations, tools to support collaborative space situational awareness, regulatory regimes, and guidance for actors in the space arena. This is a remarkable undertaking with the objective to identify and examine a wide range of issues and concerns for the long term sustainability of space activities and to prepare a consolidated set of practices and operating procedures and guidelines.

The space environment is quite different from conditions on the ground and air because the position of a space vehicle cannot be easily changed since its movement or orbital behaviour is strictly constrained to the orbit onto which it has been launched. Given how congested the space environment is with satellites, the condition is being exacerbated further by a large amount of space debris. Space utilization for nations involved could become unnecessarily constrained unless the operations of all space vehicles and other space objects are well managed.

The role of international organizations and other entities in the space field continues to be of major importance to our common goal of promoting space activities at the national, regional, interregional and global level. I would like to underline the particular role of regional mechanisms in providing platforms for enhanced coordination and cooperation between space faring nations and emerging space nations and in establishing partnerships between users and providers of space-based services. In this regard I am pleased to note the activities, programs, projects and strategies being performed and developed through the African Leadership Conference on Space Science and Technology for Sustainable Development (ALC); the Asia-Pacific Regional Space Agency Forum (APRSAF); the Asia-Pacific Space Cooperation Organization (APSCO); and the Space Conference of the Americas.

There is a need to strengthen international collaboration and support for data sharing and access to geospatial information which is expected to be useful in addressing the climate change associated with global warming, carbon cycles, water cycles, as well as human health, food security relating to agriculture and fisheries, and natural disasters.

More specifically, actions undertaken by the regional centers for space science and technology education affiliated with the United Nations could further advance the promotion of data utilization and relevant scientific research. The regional centers have firmly established infrastructures for advanced training in the field of space science and technology, and their long-standing education programmes have been highly successful. Likewise, the network of UN-SPIDER Regional Support Offices around the world caters to the regional coordination of efforts in the area of disaster risk reduction.

Today, various kinds of applications such as those for scientific observation missions, Earth resources observation, as well as educational and capacity building activities are being planned and carried out by an increasing number of governmental and non-governmental entities.

The operation of satellites, for example, gives rise to matters that could be further explored and discussed such as responsibility and liability under the legal regime on outer space. The application of the concept of the launching State in national regulatory frameworks, registration and notification measures, and the continuing development of national regulatory frameworks, as well as guidance to space actors should be understood. Even satellites launched for educational or training purposes should follow international regimes for registration, frequency coordination and liability for damages. In this regard, satellite should be designed for a certain level of reliability. To comply with this, it should be recommended that all satellite programs be reviewed by experts who have substantial experiences in this field.

Space technology provides a wide range of essential tools for making informed decisions in support of development at local, national, regional and global levels in both public and private domains. Information generated from space-derived geospatial data is indispensable in areas such as agriculture, climate change, forestry, public health, disasters, food security, land management, and urban growth. A continuous monitoring and observation system that feeds into decision support systems and ensures an informed decision-making process is crucial. There is a need to ensure a clear view of the planet's status at near real-time and at any given moment. The practical benefits of space technology applications today touch virtually every human endeavor extending across communication, navigation, meteorology, education, health, agriculture, resource management, environmental protection and disaster management. To adapt to emerging and future challenges to the global community, the United Nations system, in close coordination with its Member States, needs to find effective solutions to current and emerging global problems.

The United Nations System Task Team on the Post-2015 UN Development Agenda has presented its report to the Secretary-General of the United Nations entitled "Realizing the Future We Want for All". This is a comprehensive assessment of the overall involvement of the UN system and the report will be part of the process leading up to 2015. There are many areas covered in the report where space-based technologies and data are of crucial importance. In direct relation to space tools, I would like to bring to your attention to the scientific understanding of space environments, as well the importance of improved access to geographical information and geospatial data for more accurate environmental and social impact assessments and more informed decision-making at all levels.

The formulation and implementation of sustainable development policies can succeed only with accurate information concerning the Earth system which today's highly accurate satellites can provide. To be able to gauge and manage societal impacts on our planet, the global community will continue to require consistent and accurate information that can be used to measure such impacts. As an enabler of informed decision-making at all levels of society, space acquired data can produce a shared vision and understanding which in turn can produce joint action. The millennium development goals (MDG) belong to this category of actions which, if attained, can foster global yearning for sustainable development.

JAXA Earth Observation Program Update

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ABSTRACT

To contribute to solving earth and environmental issues, particularly climate change mitigation and adaptation, Japan Aerospace Exploration Agency (JAXA) has developed and operated several types of earth observation remote sensing satellites starting with the Marine Observation Satellite-1 (MOS-1) in 1987. At the 2002 World Summit on Sustainable Development, the GEO (Group on Earth Observation) was proposed and established by the G8 (Group of Eight) leading industrialized countries. The GEO is constructing a Global Earth Observation System of Systems (GEOSS) on the basis of a 10-Year Implementation Plan for the period of 2005 to 2015. The Plan defines a vision statement for GEOSS, its purpose, scope, expected benefits, and the nine "Societal Benefit Areas" of disasters, health, energy, climate, water, weather, ecosystems, agriculture, and biodiversity. JAXA's earth observation satellite program is expected to develop GEOSS, particularly the areas of climate, water, and disaster. This paper describes the outline of JAXA's earth observation program including operating satellites [Greenhouse gas Observing SATellite (GOSAT), Tropical Rainfall Measurement Mission (TRMM), and Global Change Observation Mission-Water 1 (GCOM-W1)] as well as new generation satellites [Advanced Land Observing Satellite (ALOS)- 2/3, GCOM-C, Global Precipitation Measurement (GPM), Earth Cloud, Aerosol, and Radiation Explorer (EarthCARE) and GOSAT-2].

Keywords: GCOM, ALOS, GPM, TRMM, GOSAT, EarthCARE

1. INTRODUCTION

At the 2002 World Summit on Sustainable Development, the GEO (Group on Earth Observation) was proposed and established by the G8 (Group of Eight) leading industrialized countries. The GEO is constructing a Global Earth Observation System of Systems (GEOSS) on the basis of a 10-Year Implementation Plan for the period of 2005 to 2015. The Plan defines a vision statement for GEOSS, its purpose, scope, expected benefits, and the nine "Societal Benefit Areas" of disasters, health, energy, climate, water, weather, ecosystems, agriculture, and biodiversity. Japan Aerospace Exploration Agency's (JAXA) earth observation satellite program is mainly expected to develop GEOSS, especially for climate, water, and disaster, starting from the Marine Observation Satellite-1 (MOS-1) in 1987. This paper describes the outline of JAXA's earth observation program including operating satellites [Greenhouse gas Observing SATellite (GOSAT), Tropical Rainfall Measurement Mission (TRMM), and Global Change Observation Mission-Water 1 (GCOM-W1)] as well as new generation satellites [Advanced Land Observing Satellite (ALOS)- 2/3, GCOM-C, Global Precipitation Measurement (GPM), Earth Cloud, Aerosol, and Radiation Explorer (EarthCARE), and GOSAT-2)].

2. ON-GOING SATELLITES

2.1 TRMM

Water is an essential element of the Earth's environment and is indispensable for our life. Many places in the world now face water problems, such as water shortage and floods. In addition, global warming and climate change are predicted to affect the global water cycle and result in abnormal weather, such as frequent heavy rain and droughts. Since its launch on November 28th, 1997, Tropical Rainfall Measuring Mission (TRMM) has provided critical precipitation measurements in the tropical and subtropical regions of our planet. The Precipitation Radar (PR) developed by JAXA and the National Institute of Information and Communications Technology (NICT) can see through the precipitation column, providing new insights into severe storm structures and intensification. The TRMM Microwave Imager (TMI) measures microwave energy emitted by the Earth and its atmosphere to quantify water vapor, cloud water, and rainfall intensity in the atmosphere. TRMM precipitation measurements have made and continue to provide critical inputs to tropical cyclone forecasting, numerical weather prediction, and precipitation climatologies, among many other topics, as well as a wide array of societal applications.

Using TRMM observation with several microwave radiometers on the satellites, GSMaP (Global Satellite Mapping of Precipitation) was promoted for the study “Production of a high-precision, high-resolution global precipitation map using satellite data,” sponsored by Core Research for Evolutional Science and Technology (CREST) of the Japan Science and Technology Agency (JST) during 2002–2007. Since 2007, GSMaP project activities are promoted by the JAXA Earth Observation Research Center (JAXA/EORC). JAXA/EORC offers hourly global rainfall maps 4 h after observation with a 0.1° grid in near real time (http://sharaku.eorc.jaxa.jp/GSMaP/). Figure 1 shows an example of a global rainfall map with the typhoon MORAKOT near Chinese Taipei. Maps such as this GSMaP are useful for water related disaster management and integrated water resource management.

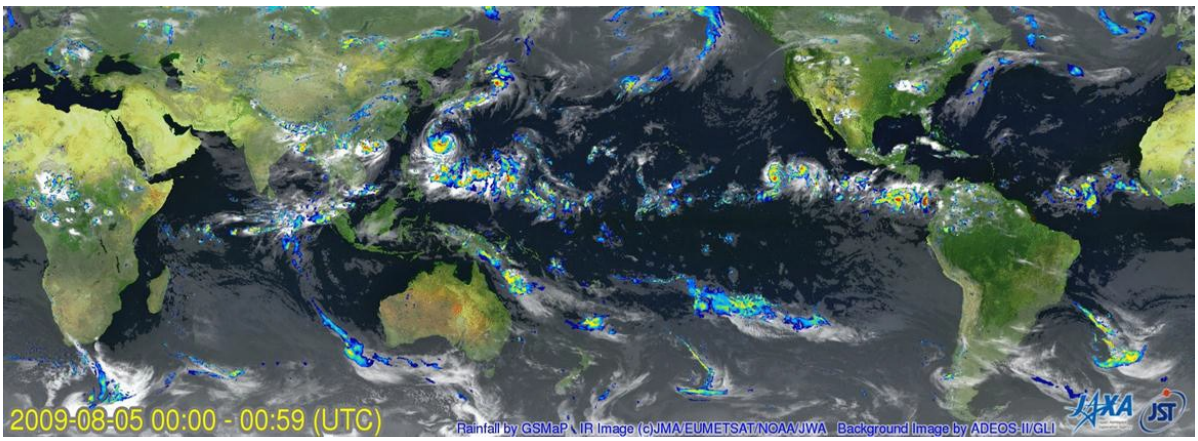

Figure 1. GSMaP product for typhoon MORAKOT (09W): Aug. 5–10, 2009 (large impact in Chinese Taipei)

2.2 GOSAT

Greenhouse gases Observing SATellite (GOSAT) is a Japanese mission that observes greenhouse gases, CO_2 and CH_4, from space with a Fourier transform spectrometer and a push broom imager. The GOSAT was launched on January 23rd, 2009. The GOSAT has been operating normally, and acquired the observation data over 3.5 years. The results of evaluation of the calibration data are reflected regularly to improve the Level 1 algorithm, for providing the calibrated Level 1 products. The Level 1 products have been released to the public from October 2009, and the Level 2 from February 2010.

Global distributions of XCO_2 and XCH_4—the FTS SWIR Level 3 data products—are available to general users through the GOSAT User Interface Gateway since November 30, 2010. The FTS SWIR Level 3 data products are derived from the FTS SWIR Level 2 data products. They include the estimated results of areas where no observational data were available (http://www.gosat.nies.go.jp/). Global distributions of XCO_2 are shown in Figure 2.

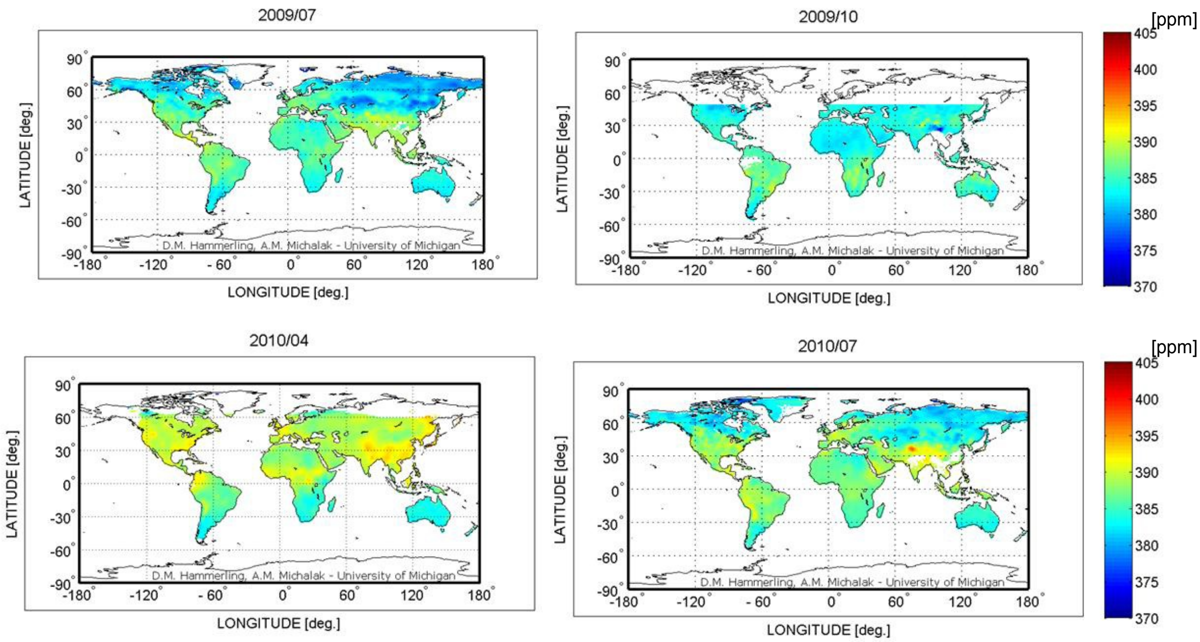

Figure 2. CO_2 column averaged dry air mole fraction processed by the ACOS team

2.3 GCOM-W1

The “Global Change Observation Mission” (GCOM) aims to construct, use, and verify systems that enable continuous global-scale observations of effective geophysical parameters for elucidating global climate change and water circulation mechanisms. GCOM will consist of two satellite series (GCOM-W and C) spanning three generations with one-year overlap in orbit, enabling over 13 years of observation in total.

Water cycle variations have been observed by the Advanced Microwave Scanning Radiometer-2 (AMSR2) onboard the GCOM-W1 (Water) satellite, launched on May 18th, 2012. GCOM-W1 observes precipitation, water, sea surface wind speed, sea surface temperature, soil moisture, and snow depth, among others (Table 1). Its orbit is sun-synchronous with 699.6 km altitude (over the equator), 98.186° inclination, and 13:30 local time of descending node. GCOM-W1 joined into the afternoon “A-Train” satellite constellation, which crosses the equator within a few minutes of each another at around 1:30 p.m. local time. The proposed location of GCOM-W1 in the A-Train is 259.5 s ahead of Aqua. Figure 3 shows yearly minimum arctic sea ice extensions in 2007 and 2012. Arctic sea ice in 2012 became the smallest in satellite observation history.

Table 1. GCOM-W1 Standard Products

Product	Range	Comments
Brightness temperatures		
Brightness temperatures	2.7–340 K	Global, 6 frequency with dual polarizations
Geophysical parameters		
Integrated water vapor	0–70 kg/m^2	Over global ocean*, columnar integrated value
Integrated cloud liquid water	0–1.0 kg/m^2	Over global ocean*, columnar integrated value
Precipitation	0–20 mm/h	Global (except over ice and snow), surface rain rate
Sea surface temperature	-2–35°C	Global ocean*
Sea surface wind speed	0–30 m/s	Global ocean*
Sea ice concentration	0–100%	High latitude ocean areas
Snow depth	0–100 cm	Land surface (except dense forest regions)
Soil moisture	0–40%	Land surface (except ice sheet and dense forest regions)

* *Except sea ice and precipitating areas*

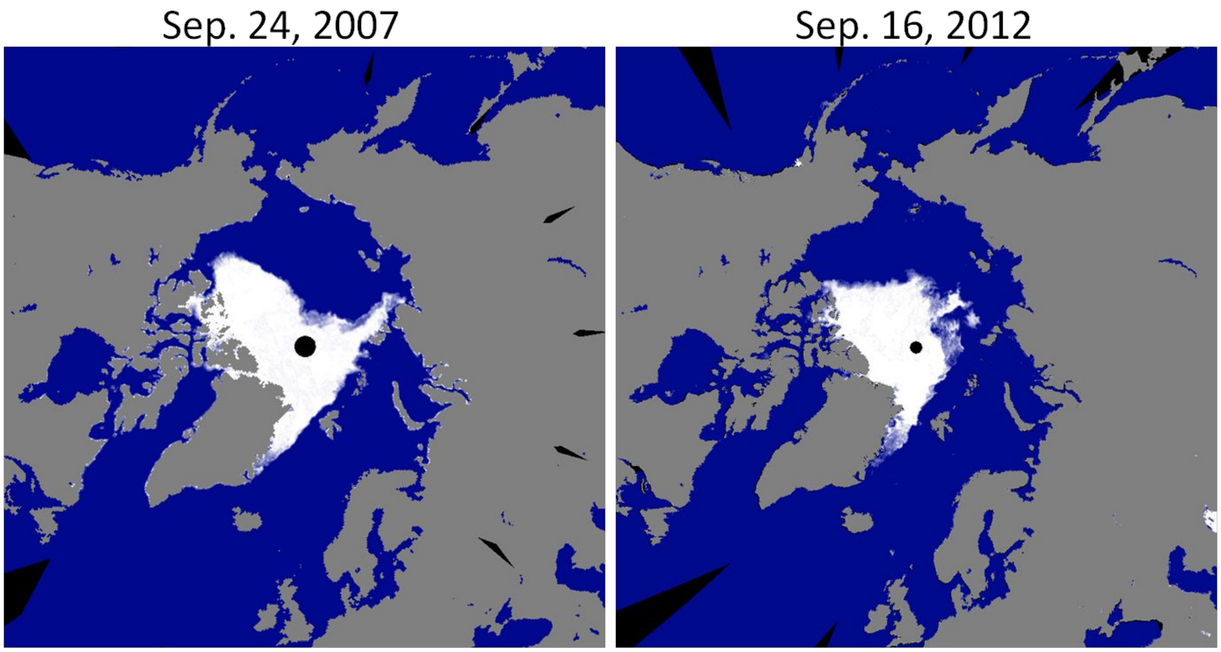

Figure 3. Arctic sea ice extension in 2007 (left) and 2012 (right) by AMSR-E and GCOM-W1
(2007 was minimum record of sea ice extension in September)

3. SATELLITES IN DEVELOPMENT PHASE

3.1 ALOS-2

The Advanced Land Observing Satellite-2 (ALOS-2) is a post-ALOS mission. JAXA has been operating the Advanced Land Observing Satellite (ALOS) "Daichi" from January 2006 until May 2011. The PALSAR onboard ALOS is the L-band Synthetic Aperture Radar (SAR) to observe large areas by electronic beam steering with active phased array antenna (APAA) technology, and has full-polar metric measurement capability. The L-band microwave can penetrate leaves and grasses to measure the ground directly. With this unique characteristic, PALSAR has been used for monitoring the world forests, polar ice, crustal movements, and so on. In particular, PALSAR has contributed to domestic and international disaster management activities by its interferometry capability (INSAR) with high coherence.

Figure 4. ALOS-2 satellite

Table 2. ALOS-2 specifications

Observation mode	Stripmap: 3 to 10 m res., 50 to 70 km swath ScanSAR: 100 m res., 350 km swath Spotlight: 1 × 3 m res., 25 km swath
Orbit	Sun-synchronous orbit Altitude: 628 km Local sun time: 12:00 ±15 min Revisit: 14 days Orbit control: ≦±500 m
Life time	5 years (target: 7 years)
Launch	JFY2013, H-IIA launch vehicle

"ALOS-2" is the satellite carrying an L-band SAR, meant to succeed PALSAR. ALOS-2 is a satellite with L-band SAR based on APAA technology. The APAA of ALOS-2 allows not only conventional stripmap and ScanSAR but also Spotlight mode with electric beam steering to the direction of an azimuth. To cover wide areas, ALOS-2 has the capability of wide incidence angles from 8° to 70°, with electric beam steering and left- or right-looking by satellite maneuverability in about 2 min from the nominal look direction. ALOS-2 shall be continuously controlled to an orbit tube of 500 m to a reference orbit for high coherence repeat pass SAR interferometry, both between stripmap modes and ScanSAR modes. ALOS-2 specifications are shown in Figure 4 and Table 2, and will be launched in the Japanese Fiscal Year (JFY) 2013.

The features of each observation mode are as follows; all modes use a dual receive antenna system without Fine mode.

Spotlight mode: The azimuth resolution is 1 m for detailed observations of disaster areas with APAA technique, which is electronic beam steering ±3.5° in the direction of the azimuth away from nadir to increase the illumination time, i.e., the size of the synthetic aperture.

Ultra-Fine mode: In nominal, Ultra-Fine mode collects base-maps for interferometry (InSAR) in Japan with high resolution and wide swath. Within the range of incidence angles, the swath is satisfied to 50 km. Ultra-Fine mode is the basic mode to observe the disaster in Japan.

High-sensitive mode: High-sensitive mode is designed for only disaster use. This mode has better noise equivalent sigma zero (NESZ) for observation of water areas where the back scattering coefficient is small; the resolution is lower than Ultra-Fine mode though higher than PALSAR.

Fine mode: Fine mode is the conventional mode that succeeds PALSAR. The resolution and swath are almost equal to PALSAR.

ScanSAR mode: ScanSAR mode is a conventional mode also. The resolution and swath are almost equal to PALSAR with 5 scans.

3.2 GPM/DPR

GPM is a satellite program used to measure the global distribution of precipitation accurately in sufficient frequency so that the information provided by the program can drastically improve weather predictions, climate modeling, and understanding of water cycles. Its feasibility has been studied at the Goddard Space Flight Center of National Aeronautics and Space Administration (NASA) and JAXA as a successor of TRMM. The accurate measurement of precipitation will be achieved by the Dual-frequency Precipitation Radar (DPR) installed on the GPM core satellite. The DPR for the GPM Core satellite is being developed by JAXA and NICT. The GPM Core Satellite carrying DPR (KuPR and KaPR) and the GPM Microwave Imager (GMI) is scheduled to be launched in early 2014. Its orbit will be non-sun-synchronous, at 407 km altitude and 65° inclination. The GPM Core satellite is shown in Figure 5 and the specifications of DPR are shown in Table 3.

To meet the GPM objectives, retrieval algorithms will require global applicability, robustness, and long-term stability. Algorithms that can be extended and applied for similar instruments (e.g., PR and microwave radiometers onboard the other satellites) and historical data records are preferable for integrated retrieval. Computationally efficient, fast-processing algorithms are important for the operational applications of the products. The Level 2 Dual-frequency Precipitation product and the DPR/GMI combined product, and the Level 3 Global Precipitation Map product are also required for near-real-time processing. Each near-real-time algorithm will be developed based on the standard algorithm. All near-real-time products have to be produced and distributed within 60 min after acquisition of observation data. In addition, GSMaP product will be updated and improved using GPM satellites.

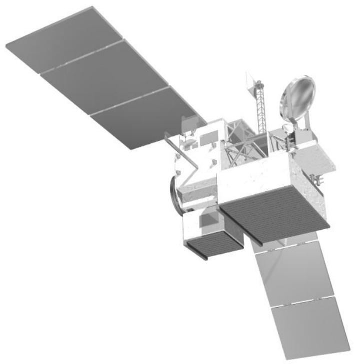

Figure 5. GPM core satellite

Table 3. Major characteristics of DPR

Name	**KuPR**	**KaPR**
radar type	active phased array radar	
antenna	slotted waveguide antenna	
frequency	Ku-band 13.60 GHz	Ka-band 35.55 GHz
peak transmit power	>1000 W	>140 W
swath	245 km	125 km
horizontal resolution	5 km	
range resolution	250 m	250 m/500 m
observation altitude	surface–19 km	
observation rain rate	~0.5 mm/h	~0.2 mm/h
size	2.4 m x 2.4 m x 0.6 m	1.44 m x 1.07 m x 0.7 m
	<470 kg	<336 kg

3.3 EarthCARE/CPR

EarthCARE is a joint European-Japanese mission addressing the need for a better understanding of the interactions between cloud, radiative, and aerosol processes that play a role in climate regulation. JAXA and NICT will provide Cloud Profiling Radar (CPR) to the spacecraft. CPR is a 94-GHz Doppler radar that has several characteristics. Firstly, the CPR requires high sensitivity. This is further divided into requiring large antenna size, low noise figure of the receiver, and high power of the transmitter. The second characteristic of the CPR is the Doppler capability. The EarthCARE satellite with CPR is shown in Figure 6, and its specifications are presented in Table 4. JAXA will produce not only CPR products, but also other products from each sensor and the synergetic use of other sensors.

Figure 6. EarthCARE satellite

Table 4. Major characteristics of CPR

Radar type	94-GHz Doppler Radar
Center frequency	94.05 GHz
Pulse width	3.3 μs (equivalent to 500 m vertical resolution)
Beam width	0.095°
Polarization	Circular
Transmit power	>1.5 kW (Klystron spec.)
Height range	-0.5 to 20 km
Resolution	500 m (100 m sample); Vertical, 500 m integration; Horizontal
Sensitivity*	-35 to21 dBZ
Radiometric accuracy*	< 2.7 dB
Doppler range*	-10 to 10 m/s
Doppler accuracy*	<1 m/s
Pulse repetition frequency	Variable; 6100–7500 Hz
Pointing accuracy	<0.015°

*; at 10 km integration and 387 km orbit height

3.4 GCOM-C1

Climate change observation will be performed by the Second-generation Global Imager (SGLI), a multi-wavelength optical radiometer, onboard the GCOM-C (Climate) satellite on clouds, aerosol, sea water color (marine organisms), vegetation, snow, and ice. SGLI onboard GCOM-C1 is a successor of ADEOS-II GLI. The first generation of GCOM-C (called GCOM-C1) is scheduled to be launched in or later than JFY2015. Its orbit will be sun-synchronous at 798 km altitude (over the equator), 98.6° inclination, and 10:30 local time of descending node. GCOM-C1 outlook and specifications are shown in Figure 7 and Table 5.

Since GCOM is a 13-year continuous satellite series, GCOM will provide climate change data to contribute to the study of environmental change, and for practical uses such as the GEOSS nine social benefit areas, especially for climate change, water, etc. For instance, food security assessment including crop yield monitoring and fishery management will be effectively implemented by the integration of GCOM-W and GCOM-C with other data sets. Figure 8 shows the soil moisture and solar radiation anomaly in the United States in May 2012.

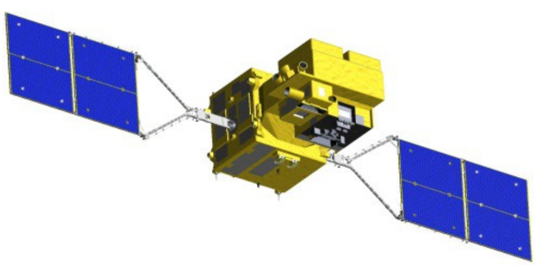

Figure 7. GCOM-C1 satellite

Table 5. SGLI Channel Specifications

	λ	$\Delta\lambda$	L_{std}	L_{max}	SNR at Lstd	IFOV
CH	VN, P, SW: nm T: µm		VN, P: $W/m^2/sr/\mu m$ T: Kelvin		VN, P, SW: - T: NEΔT	m
VN1	380	10	60	210	250	250
VN2	412	10	75	250	400	250
VN3	443	10	64	400	300	250
VN4	490	10	53	120	400	250
VN5	530	20	41	350	250	250
VN6	565	20	33	90	400	250
VN7	673.5	20	23	62	400	250
VN8	673.5	20	25	210	250	250
VN9	763	12	40	350	400	1000
VN10	868.5	20	8	30	400	250
VN11	868.5	20	30	300	200	250
P1	673.5	20	25	250	250	1000
P2	868.5	20	30	300	250	1000
SW1	1050	20	57	248	500	1000
SW2	1380	20	8	103	150	1000
SW3	1630	200	3	50	57	250
SW4	2210	50	1.9	20	211(TBD)	1000
T1	10.8	0.74	300	340	0.2	500
T2	12.0	0.74	300	340	0.2	500

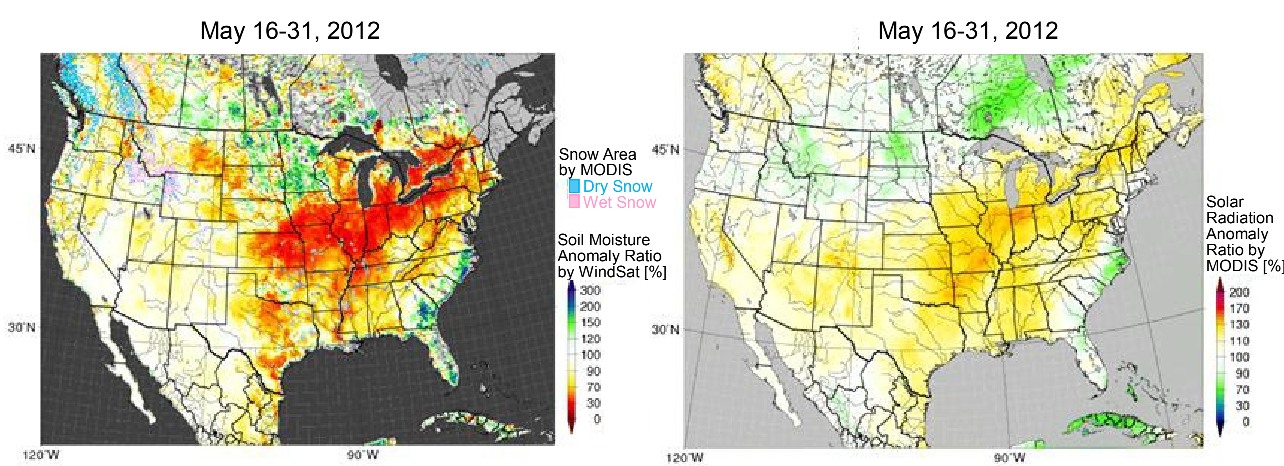

Figure 8. Agro-meteorological anomaly in the US, May 2012 (left is soil moisture and right is solar radiation (PAR)).

3.5 CIRC

The Compact InfraRed Camera (CIRC) is also being developed to monitor forest fires, and will be onboard ALOS-2 and KIBO on the International Space Station (ISS).

4. SATELLITES AND SENSORS IN THE FUTURE

4.1 ALOS-3

ALOS-3 carries an optical imager with more enhanced capabilities than those of the Panchromatic Remote-sensing Instrument for Stereo Mapping (PRISM) aboard ALOS with other optical instruments. ALOS-3 will produce a precise basic map with its systematic observation to be used in the Geographical Information System (GIS) with 0.8 m GSD and a targeted 50 km width swath. ALOS-3 will also promptly provide precise post-disaster images to detect damaged areas through emergency observations when disasters occur.

4.2 GOSAT-2

With ALOS series, GCOM series, GOSAT, TRMM/GPM, and EarthCARE, JAXA also studies GOSAT-2 in cooperation with the ministry of environment and NIES to observe CO_2 at higher spatial resolution and higher accuracy than GOSAT.

4.3 Future sensor studies

To contribute to the study of earth and environmental change and provide social benefits of using earth observation from space, it is very important to enhance the capability of new advanced sensors with ongoing earth observation satellite series such as GCOM, ALOS, TRMM/GPM, GOSAT, and EarthCARE. Using ISS KIBO for earth observation, JAXA studies vegetation lidar and atmospheric chemical observations in cooperation with universities and related institutes. JAXA also uses altimeters to observe ocean height and oceanic currents. In addition, JAXA has a steering committee to investigate new possible sensors for land-atmosphere-ocean study.

5. CONCLUSION

Remote sensing information services are powerful tools to assist with development of adaptation and mitigation strategies for environmental change, disaster mitigation and prevention, and economic and social development. It is very important for observation and communication systems under international cooperation, such as GEOSS, to develop and operate integrated systems using satellites and ground systems. JAXA wishes to play a key role in international initiatives, such as UNFCCC COP and ISCCP, and to contribute to strategy development and operation of climate change adaptation and mitigation using earth observation satellites including the GCOM series, ALOS series, TRMM/GPM, EarthCARE, GOSAT-1/2, and other sensors.