JAXA'S EARTH OBSERVING PROGRAM

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ABSTRACT ... Four programs, i.e. TRMM, ADEOS2, ASTER, and ALOS are going on in Japanese Earth Observation programs. TRMM and ASTER are operating well, and TRMM operation will be continued to 2009. ADEOS2 was failed, but AMSR-E on Aqua is operating. ALOS (Advanced Land Observing Satellite) was successfully launched on 24th Jan. 2006. ALOS carries three instruments, i.e., PRISM (Panchromatic Remote Sensing Instrument for Stereo Mapping), AVNIR-2 (Advanced Visible and Near Infrared Radiometer), and PALSAR (Phased Array L band Synthetic Aperture Radar). PRISM is a 3 line panchromatic push broom scanner with 2.5m IFOV. AVNIR-2 is a 4 channel multi spectral scanner with 10m IFOV. PALSAR is a full polarimetric active phased array SAR. PALSAR has many observation modes including full polarimetric mode and scan SAR mode. After the unfortunate accident of ADEOS2, JAXA still have plans of Earth observation programs. Next generation satellites will be launched in 2008-2012 timeframe. They are GOSAT (Greenhouse Gas Observation Satellite), GCOM-W and GCOM-C (ADEOS-2 follow on), and GPM (Global Precipitation Mission) core satellite. GOSAT will carry 2 instruments, i.e. a green house gas sensor and a cloud/aerosol imager. The main sensor is a Fourier transform spectrometer (FTS) and covers 0.76 to 15 μm region with 0.2 to 0.5 cm^{-1} resolution. GPM is a joint project with NASA and will carry two instruments. JAXA will develop DPR (Dual frequency Precipitation Radar) which is a follow on of PR on TRMM. Another project is EarthCare. It is a joint project with ESA and JAXA is going to provide CPR (Cloud Profiling Radar). Discussions on future Earth Observation programs have been started including discussions on ALOS F/O.

KEY WORDS: GCOM, GOSAT, GCOM-W, GCOM-C, GPM, ADEOS, ADEOS2, TRMM, ALOS

1. PAST SATELLITES AND SENSORS

Japan has started its satellite based Earth Observation programs from MOS-1 launched in 1987. MOS-1 carried 3 sensors, i.e. MESSR (Multi-spectral Electronic Self Scanning Radiometer), VTIR (Visible and Thermal Infrared Radiometer) and MSR (microwave Scanning Radiometer). MOS-1 and its 3 sensors were developed by JAXA (Japan Aerospace Exploration Agency). After the launch of almost the same satellite MOS-1b in 1990, JERS-1 (Earth Resources Satellite) was launched in 1992. JERS-1 carried 2 sensors, i.e., OPS (Optical Sensor) and SAR (Synthetic Aperture Radar). For JERS-1, the spacecraft was developed by JAXA and sensors were developed by METI (Ministry of Economics, Trade and Industry). In 1996, ADEOS (Advanced Earth Observing Satellite) was launched. ADEOS carried 8 sensors on board, i.e. OCTS, AVNIR, NSCAT, TOMS, POLDER, ILAS, RIS and IMG. ADEOS spacecraft, OCTS and AVNIR was developed by JAXA, IMG was developed by METI, ILAS and RIS were developed by MOE (Ministry of Environment). TOMS and NSCATO were provided by NASA and POLDER was provides by CNES. After the ADEOS, ADEOS-2 was launched in 2002. ADEOS-2 carried 5 sensors. GLI (OCTS F/O), AMSR, ILAS-2 (ILAS F/O), SeaWinds (NSCAT F/O) and POLDER. Unfortunately, ADEOS and ADEOS-2 stopped their operation 10 months after their launches. In addition to the satellites developed in Japan, several sensors were developed and launched on NASA satellites. The first one is PR (Precipitation Radar) on TRMM and launched in 1997. PR was jointly developed by JAXA and NICT (National Institute of Information and Communication Technologies). ASTER (Advanced Spaceborne Thermal Emission and Reflection radiometer) was launched on EOS-Terra in 2000. ASTER was developed by METI. AMSR-E, which is a very similar sensor to AMSR was launched on EOS-Aqua in 2003. Those 3 sensors are still operating.

2. ALOS

2.1 ALOS Status

ALOS was launched on 24th Jan. 2006 from Tanegashima Space Center by H2-A launcher. Satellite is operating well and all 3 sensors on-board are also operating well. Commissioning phase ended at the beginning of May and the satellite is under calibration and validation phase. ALOS will be full operational from the middle of October.

2.2 ALOS Mission

The mission of ALOS is to provide sufficient data, which enable to generate 1 to 25,000 scale base maps all over the world. ALOS will carry 3 sensors. One is a L band synthetic aperture radar called PALSAR (Phased Array L band Synthetic Aperture Radar). PALSAR has an active phased array antenna, and has many capabilities, like variable incidence angle, variable resolution, scan SAR capability and multi polarization capability.

ALOS has two optical sensors, i.e., AVNIR-2 and PRISM. AVNIR-2 (Advanced Visible and Near Infrared Radiometer) is a follow on of AVNIR on ADEOS and has 4 bands with 10 m resolution. PRISM is a panchromatic sensor with 3 telescopes, which will enable PRISM to take 3 direction (nadir, fore and aft) stereo pairs simultaneously. The resolution of PRISM is very high (2.5m) with rather narrow swath (35km).

In addition to the stereo capability which will provide global DEM data, PALSAR will be also useful for the evaluation of global tree stand biomass.

The largest characteristics of ALOS are its capability to store and transmit quite a few data volume. It can acquire and transmit all the data of global land area. ALOS was launched on 24th Jan. 2006, and for the study of hydrology, it is expected that the multi polarization characteristics of PALSAR can provide useful information of soil moisture.

Main products which can be generated from ALOS are shown below.

1) PRISM
    *DEM
    *ortho-photo map
    *base map (1/25,000)
2) AVNIR 2
    *land cover map (1/100,000)
    *land cover change
3) PALSAR
    *forest area
    *forest biomass (above ground)
    *agricultural land change
    *ice and snow area
    *soil moisture

3. GOSAT

3.1 GOSAT Mission

The mission of GOSAT is to clarify sources and sinks of CO_2 in sub-continental scales. In order to achieve this mission, sensors which can measure atmospheric CO_2 with more than 1% accuracy is necessary. After many discussions, FTS (Fourier transform spectrometer) which covers short wave infrared and thermal infrared was chosen. These sensors will provide measurements of not only CO_2, but also CH_4, temperature, water vapor and several other constituents.

3.2 GOSAT satellite

GOSAT will have a sun-synchronous orbit and will carry two instruments which will measure greenhouse gases. The tentative specifications of the satellite are as follows.

orbit : altitude : 666km
mass : 1.65 ton
ascending node time : 13:00

3.3 Greenhouse Observing Sensor

Type : Fourier transform spectrometer
Spectral bands :
    Band 1 : O_2-Aband (0.75-0.78μm)
    Band 2 : CO_2 band (1.56-1.72μm)
    Band 3 : CO_2 and CH_4 band (1.92-2.08μm)
    Band 4 : Thermal band (5.5-14.3μm)
Spectral resolution
    Band 1 : 0.5 cm^{-1}
    Band 2, 3,4 : 0.2cm^{-1}
IFOV : less than 10.5km
Pointing capability : ±45°

3.4 Cloud and Aerosol Sensor

Other than the main instrument, there will be another sensor for clouds and aerosol. The specifications of this instrument are as follows.

Spectral Channels :
    Band 1 : 0.380μm
    Band 2 : 0.678μm
    Band 3 : 0.870μm
    Band 4 : 1.62μm
IFOV :
    Band 1-3 : 500m
    Band 4 : 1500m
FOV : 900km

4. GCOM

4.1 Subjects of GCOM

After the accident of ADEOS II, JAXA is now planning to launch small satellites rather than large ones. According to this strategy, ADEOS II follow on is now divided into two missions, i.e., GCOM-W and GCOM-C. The continuous observation required to GCOM mission poses these two missions to be composed of series of satellites, i.e., 3 satellites for each mission, hence provides at least 13 years of continuous data.

The GCOM aims at continuing and improving the observation conducted by the ADEOS and ADEOS II with a view to accumulating the scientific knowledge necessary to elucidate global environmental problems.

In regard to global warming, the GCOM intends the measurement of most factors involved in the energy and water cycle and material cycle, which are the main mechanisms determining climate change, and also analysis of the relevant processes.

Within the material cycle, measurement of the carbon cycle is a key subject. In this particular field, the GCOM aims at estimating the primary production as well as carbon flux based on measurement data on land vegetation and oceanic phytoplankton.

In regard to changes of the land environment, the measuring subjects are tropical forests and the global distribution of vegetation and its changes. In regard to the cryosphere, the sea ice concentration and snow coverage are measured and their interaction with the climate is analyzed.

4.2 Expected achievements of GCOM

As a succeeding satellite in the ADEOS series beginning with the launch of the first ADEOS in 1996, the GCOM is expected to make the following achievements by the end of its mission (around 2023).

1) Global Warming

- Understanding of the global warming by global and long-term measurement data on various parameters.
- Separation between natural variability and trends using the data set covering the 27 year period from the launch of the ADEOS or the 21 year period from the launch of the ADEOS2.

2) Change of Land Environment

- Understanding of global forest dynamics
- Understanding of snow and ice changes

3) Clarification of sink and source of greenhouse gases.

4.5 GCOM- W satellites

After the ADEOS accident, JAXA has decided to use small or medium scale satellites rather than large satellites. The first generation satellites after ADEOS 2 will be composed of four satellites in order to meet this strategy. They are tentatively called GOSAT, GPM core satellite, GCOM-W and GCOM-C.

GCOM-W will have sun-synchronous orbit, but its local time at ascending node will be around 13:30 in order to continue the AMSR-E observation, and will focus on energy cycle. The tentative specifications of the satellite are as follows.

orbit : altitude : 700km
mass : 1.8 – 2.5 ton
launch : 2010

4.6 GCOM-W sensor

GCOM-W will carry one instruments, i.e., AMSR F/O.

1) AMSR F/O (Advanced Microwave Scanning Radiometer follow on)

The AMSR F/O will be the follow on of the AMSR on board the ADEOS2 and will aim at achieving the measurement of the same geophysical parameters. Tentative specifications of AMSR F/O are shown in Table 1.

a	b	c	d	e
6.9	50	350	0.3	12
10.65	50	100	0.6	12
18.7	25	200	0.6	12
23.8	25	400	0.5	12
36.5	15	1000	0.5	12
89.0	5	3000	1.0	12
50.3	10	200	1.7	12
52.8	10	400	1.3	12

Table 1 Tentative specifications of AMSR F/O.

a : central frequency (GHz)
b : ground resolution (km)
c : bandwidth (MHz)
d : NEdT
e : quantization bits

Type : parabolic antenna, conical scanning
Antenna Aperture : 2 m (TBR)
Swath Width : 1,400 km (at 700km orbit)
Incidence Angle : 55°

4.7 GCOM-C satellites

GCOM-C will have sun-synchronous orbit similar to ADEOS-2. The tentative specifications of the satellite are as follows.

orbit : altitude : 800km
mass : 2.0 – 2.5 ton
launch : 2011

4.8 Details of GCOM-C sensor

GCOM-C will carry only one instrument, i.e. SGLI (Second Generation Global Imager). The SGLI sensor will be a multi-purpose visual infrared imager and an advanced version of the GLI. It will be capable of measuring ocean color, land use and vegetation, snow and ice, clouds, aerosols and water vapor, etc. The different characteristics with GLI are as follows.

a) The largest target of SGLI is to retrieve global aerosol distributions. In order to achieve this target, SGLI will have 2 polarization channels with 3 directions.

b) SGLI is mainly focused to land and coastal areas. There are 11 250m IFOV channels compared to 6 250 channels in GLI.

c) VNIR component of SGLI is a push broom scanner.

The components of the SGLI are as follows.

(a) Visible and Near-Infrared (VNIR): 11 channel visible and near infrared push broom scanner.
(b) Polarization : 2 visible channel 3 direction push broom scanner
(c) Shortwave and Thermal Infrared (SWI & TMI): 5 channel shortwave and infrared optical mechanical scanner
(d) Visible and Near-Infrared (VNR): 29 channel visible and near infrared push broom scanner.
(e) Shortwave and Thermal Infrared (STI): 5 channel shortwave and visible infrared optical mechanical scanner

The details of tentative radiometric specifications of VNIR are shown in Table 2(a).

Ch.	a	b	c	d	e	S/N
VN1	380	250	10	60	210	250
VN2	412	250	10	75	250	400
VN3	443	250	10	64	400	300
VN4	490	250	10	53	120	400
VN5	530	250	20	41	350	250
VN6	565	250	20	33	90	400
VN7	670	250	10	23	62	400
VN8	670	250	20	25	210	250
VN9	865	250	20	8	30	400
VN10	763	1000	40	350	350	400
VN11	865	250	20	30	300	200

Table 2 (a) specifications of VNR

L_λ : standard radiance

L_{max}. : maximum radiance

a : central wavelength [nm]
b : IFOV [m]
c : $\Delta\lambda$ [nm]
d : L_λ [W/m^2/str/μm]
e : L_{max} [W/m^2/str/μm]

The details of tentative radiometric specifications of polarization channels are shown in Table 2(b).

Ch.	a	b	c	d	e	S/N
678-P1	678	1000	20	25	250	250
678-P2	678	1000	20	25	250	250
678-P3	678	1000	20	25	250	250
865-P1	865	1000	20	30	300	250
865-P2	865	1000	20	30	300	250
865-P3	865	1000	20	30	300	250

Table 2(b) specifications of polarization channels

The details of tentative specifications of SWI and TMI are shown in Table 2(c)

Ch.	a	b	g	d/h	e/i	S/Ne
SW1	1.05	1000	0.02	57	248	500
SW2	1.38	1000	0.02	8	103	150
SW3	1.64	250	0.2	3	50	57
SW4	2.21	1000	0.05	1.9	20	211
T1	10.8	500	0.7	300	340	0.2
T2	12.0	500	0.7	300	340	0.2

Table 2(c) specifications of SWI and TMI

Tstd : standard temperature
Tmax : maximum temperature

f : central wavelength [μm]
g : $\Delta\lambda$ [μm]
h : T_{std} [K]
i : T_{max} [K]
e : NEdT@300K[K]

5. GPM

5.1 Core sensors required for GPM core satellite

GPM is a mission composed of 1 core satellite and 8 constellation satellites. Constellation satellite will carry microwave radiometer to measure global precipitation with 3 hour interval. However, the accuracy of precipitation measurements by microwave radiometer over land is not sufficient. In order to validate the precipitation measurements by microwave radiometer, GPM core satellite should carry precipitation radar in addition to microwave radiometer.

5.2 Details of GPM core satellite sensors

GPM core satellite is actually the follow on of TRMM, and will have an oblique orbit and will carry two sensors which will measure mainly precipitation. The tentative specifications of the satellite is as follows.

orbit : altitude : 400km, inclination angle : 70°
mass : 3.0 – 3.5 ton

1) DPR (DUAL FREQUENCY PRECIPITATION RADAR)

DPR is a follow on of PR on TRMM. PR has only one frequency in Ku band. DPR will have two frequencies, i.e. one is the same with PR and another is around 35GHz. By this addition, DPR can retrieve both the precipitation rate as well as size distributions. Further, DPR can measure very weak rain, and can discriminate rain and snow.

2) MICROWAVE RADIOMETER

TRMM carries a microwave radiometer called TMI. The microwave radiometer on GPM core satellite will be very similar to TMI and called as GMI.

7. EarthCare

JAXA is also developing Cloud Profiling Radar (CPR) for ESA EartCare program. EarthCare is intended to measure cloud vertical structure and its radiative forcing. EarthCare will carry 4 sensors, i.e. CPR, Mie lidar, imager and radiation budget sensor.

8. ALOS F/O

JAXA is now planning ALOS follow on. It will be composed of 4 satellites, i.e. 2 SAR satellites and 2 optical sensor satellites. The main mission is disaster mitigation.