POSSIBILITY OF GCOM-C1 / SGLI FOR CLIMATE CHANGE IMPACTS ANALYZING

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ABSTRACT:

The Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) concluded that many collectiveobservations gave a aspect of a global warming and other changes in the climate system. It is very important to understand thisprocess accurately, and to construct the model by whom an environmental change is accurately forecast. Future earthobservation using satellite data should monitor global climate change, and should contribute to social benefits. Especially, human activities has given the big impacts to earth environment. This is a very complex affair, and nature itself also impacts the clouds,namely the seasonal variations. JAXA (former NASDA) has the plan of the Global Change Observation Mission (GCOM) formonitoring of global environmental change. SGLI (Second Generation GLI) onboard GCOM-C 1 (Climate) satellite, which is one of this mission, is an optical sensor from Near-UV to TIR. SGLI can provide the various high accuracy products of aerosol, cloud information, various biophysical parameters (Biomass, Land Cover, Albedo, NPP, Water Stressed Vegetation, LST, etc.), coastal information (CDOM, SS, PAR, CHL, SST, etc.), and cryospheric information (Albedo, Snow/Ice Cover, NDII, Sea ice type, Snow Grain Size, NDSI, Snow Surface Temperature, etc.). This paper shows the introduction of the unique aspects and characteristics of the next generation satellite sensor, SGLI/GCOM-C, and shows the preliminary research for this sensor.

1. INTRODUCTION

For the environment analysis, continuous global observation is necessary. Satellite remote sensing is very useful for this purpose and can provide the spatial and temporal monitoring of global environment. JAXA has made a new plan of Global Change Observation Mission (GCOM) for monitoring of global environmental change and understanding the mechanism of global environmental change, including global warming. Data obtained from GCOM are necessary for the monitoring of global climate change and the improvement of climate model, and it should bring useful contribution to social benefits.

GCOM is a follow-on satellite observation mission incorporating the technology and results of GLI (Global Imager) and AMSR (Advanced Microwave Scanning Radiometer) on ADEOS-II. The GCOM mission will consist of two series of medium-sized satellites: GCOM-C (Climate) and GCOM-W (Water). GCOM-C satellite will carry the instrument of SGLI (Second Generation GLI), which is the advanced version of GLI. On the other hand, GCOM-W satellite will carry the AMSR follow-on instrument such as scatterometer like SeaWinds onboard ADEOS-II. Three consecutive generations of satellite with one year overlap will be operated in over 13 years observing period. GCOM is designed to establish a long-term observation for monitoring global environment changes, improving knowledge of climate system, developing climate forecast models, and distributing the environmental data.

1.1 GCOM-C/SGLI

SGLI, optical sensors observe the reflected solar radiation and/or the infrared radiation from the surface of the earth including land, ocean, and cloud using multiple channels for measuring the biological contents (chlorophyll, photosynthetically active radiation, and vegetation index), temperature, snow, and ice cover, and cloud distribution. These data are useful for understanding the global circulation of carbon, estimating radiation budget, monitoring environmental changes, and also our comprehension of primary marine production.

SGLI has 19 spectral channels from near ultraviolet to thermal infrared. In particular, SGLI has some unique channels, which have been used rarely in previous: 380 nm channel for aerosol detection over land, 763 nm for oxygen absorption, and 1,380 nm for cirrus cloud detection. 11 channels from Near-UV to SWIR have a resolution of 250 m at the nadir and 2 channels in the MTIR have a resolution of 500 m, which cover a large portion of the earth's surface with various spatial scales. Various geophysical parameters consisting of atmospheric, oceanic, land, and cryospheric parameters, are retrieved from radiance data from SGLI. These parameters are used for evaluating ocean and land biomass and primary production on a global scale, for generating global fields of clouds, water vapor, and aerosol parameters, and for monitoring snow/ice properties around bi-polar regions, and so on (Refer to Table1).

2. SIMULATION RESULTS OF SGLI LAND PRODUCT FROM EXISTING DATA

In this chapter, some original SGLI Land products are discussed. These products are estimated by using new and unique channels of GCOM-C/SGLI sensor, and are expected as useful SGLI Land products for understanding and improvement of climate change.

2.1 Change detection of vegetation biomass

SGLI can observe surfaces of the earth on slant in RED-NIR region. This function improves the detection efficiency of vegetation biomass. Conventional biomass estimation method using existing vegetation couldn't reflect the 3D (three-dimensional) structure of vegetation canopy. Fig. 2 demonstrates the advantage of multi-angle observation applied to the detection of biomass change for NOAA/AVHRR data. Fig. 2 shows the change of vegetation biomass obtained from multi-angle observation of RED and NIR during 1995 to 1999 in China. In Fig. 1, enclosed regions by white circle show large differences between 1995 and 1999. In these regions, vegetation cover changes strongly.

In the case of Fig. 1, NOAA/AVHRR data obtained from different path were used. For the SGLI, different angle observation is available with along track. It means that SGLI can observe different angle reflectance in almost same atmospheric condition.
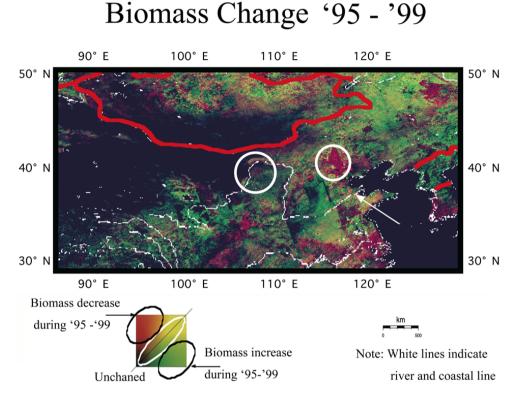

Fig 1. Biomass change detection using multi-angle observation data.

2.2 Shadow Index (SI)

The influence of shadow is inevitable to satellite data. In vegetation areas, the ratio of visible shadow space varies widely with tree type, plant growth, season, and so on, because the structure and roughness of vegetation are different each other. Then, taking into account the influence of shadow effect, new vegetation index is developed. This index is named shadow index (SI). The results are shown in Fig. 2. As seen from Fig. 2, SI expresses the difference of vegetation coverage and type, such as closed and open, or evergreen and deciduous broadleaf. Thus, it is expected that SI is useful for vegetation analysis of land-cover classification, vegetation-type classification, and vegetation biomass estimation, and so on.
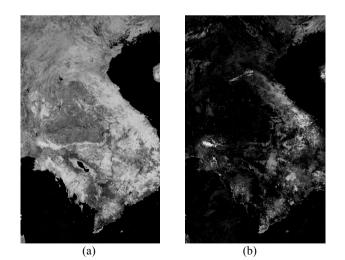

(a)   (b)

Fig 2. The images of ADEOS-II/GLI 250 m data around Indochina Peninsula on 2003/4/7-2003/4/22. The data shown are (a) NDVI image and (b) shadow index (SI) image in gray scale. Shadow index is estimated by utilizing the normalization method.

2.3 Water Stress Trend (WST)

Water is indispensable for animals and plants. The shortage of water is serious for many forms of life, but waterless area is spreading out by the impact of global warming. By monitoring plant growth, it is possible to grasp the water stress state of land, Recently, the drought damage of Australia becomes serious problem. Fig. 3 shows the WST results in two periods. Water stress was little in 2005, but big in 2006. As seen from Fig. 3, though WST in 2005 (Fig. 4 (a)) is small in the whole area, many big areas of WST are there in 2006 ((Fig. 3 (b)).

and we developed a new vegetation index, named Water Stress Trend (WST). Water is hard both to warm up and to cool down. This means that temperature variation of vegetation depends on the quantity of water stress. Based on this water characteristic, WST is estimated using the quantity of temperature change.

Therefore, WST which estimated from the accumulation of difference in radiant temperature is useful to detect waterless area.
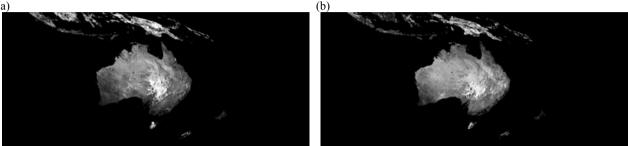
(a)

(b)

Fig. 3. The images are accumulation of difference of radiant temperature for area around Australia. Accumulation of difference of radiant temperature was calculated using day and night data. Data are (a) 2005/8/12-2005/8/20 and (b) 2006/8/12-2006/8/20as observed By Terra/MODIS.

2.4 Fire Detection Index (FDI)

SGLI does not have 4 μm channel which plays a significant role to the forest fire detection for MODIS and upcoming VIIRS data processing, however, SGLI will has finer spatial resolution channels such as 250 m for 1,600 nm and 500 m for 10.8 μm. To detect the forest fire from SGLI data, the thresholding technique will be available for 10.8 μm, 2,200 nm,

1,600 nm channels. Fig. 4 shows the simulated images of forest fire for ASTER band 4 (1,600 nm) and 13 (10.8 μm) by averaging into 250 m, 500 m and 1,000 m of spatial resolution over San Bernardino, CA on 26 Oct. 2003. This result shows that spatial resolution improvement makes the SGLI forest fire detection ability comparable with that of MODIS and VIIRS.
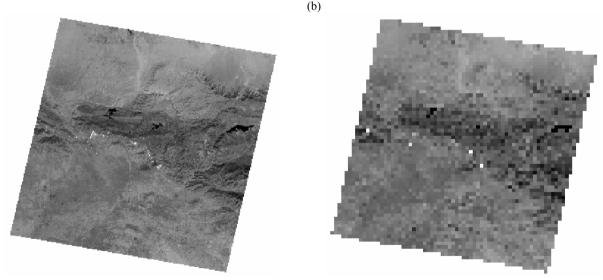
(a)

(b)

Fig. 4. (a) ASTER band 4 (resolution 250m), (b) ASTER band 4 (resolution 1000m).

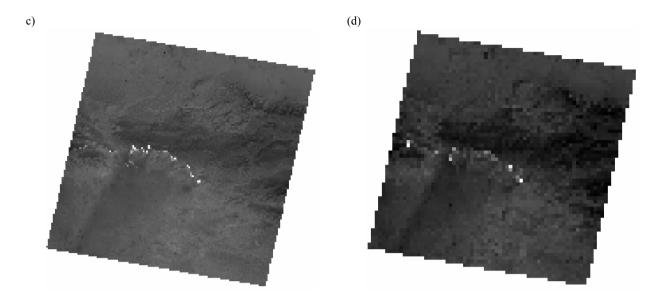c)   (d)

Fig. 4 (c) ASTER band 13 (resolution 500m), (d) ASTER band 13 (resolution 1000m).

3. SUMMARY

The Japan Aerospace Exploration Agency (JAXA; former NASDA) is making up the plan of the Global Change Observation Mission (GCOM) for monitoring of global environmental change. The launch plan is in 2014. SGLI (Second Generation GLI) onboard GCOM-C satellite is one of this mission, and provides optical sensors from Near-UV to MTIR. Characteristic specifications of SGLI are as follows:

1) Ultra Violet (380 nm),

2) Three direction polarization observation (red and NIR),

3) 250 m resolution (from Near-UV to SWIR),

4) 500 m resolution (MTIR).

From these new and unique characteristics, SGLI Land products are generate land surface reflectance which are corrected the atmospheric effect enough, and their qualities are high. Therefore, GCOM-C/SGLI data brings useful information on many fields of human benefit.

On 16 Feb., 2005, Kyoto Protocol entered into force, and Third Earth Observation Summit had agreed on 10-Year Implementation Plan for GEOSS. The social benefits on GEOSS mainly focus 9 items, which are disasters, health, energy, climate, water, weather, ecosystem, agriculture, and biodiversity. GCOM seeks to establish a long-term observation system for monitoring global environment changes, improving knowledge of climate system, developing climate forecast models. GCOM-C/SGLI is useful satellite to grasp the absorption quantity of carbon dioxide (CO_2) for land ecosystem, and to monitor forest area. Therefore, SGLI can contribute effectively to IPCC, Kyoto Protocol, and GEOSS.

Table 1 GCOM-C1 / SGLI Products

Area	Group	Product	Category	GLI heritage*1	Day/night	Production unit	Grid size	Release threshold*2	Standard accuracy*2	Target accuracy*2
common	Radiance	TOA radiance (including system geometric correction)	Standard	A(non-Pol) B(Pol)	TIR and land 2.2μm: both, Other VNR, SWI: daytime (+special operation)	Scene	VNR,SWI Land/coast: 250m, offshore: 1km, polarimetry:1km TIR Land/coast: 500m, offshore: 1km	Radiometric 5% (absolute)*3 Geometric<1 pixel	VNR,SWI: 5% (absolute), 1% (relative)*3 TIR: 0.5K (@300K) Geometric<0.5 pixel	VNR,SWI: 3% (absolute), 0.5% (relative)*3 TIR: 0.5K (@300K) Geometric<TBD pixel
Land	Surface reflectance	Precise geometric correction	Standard	A	Both	Scene, Global (mosaic 1, 16 days, month)	250m	<1pixel	<0.5pixel	<0.25pixel
		Atmospheric corrected reflectance (incl. cloud detection)	Standard	B	Daytime	Scene, Global (1, 16 days, month)	250m	0.3 (<=443nm), 0.2 (>443nm) (scene)*7	0.1 (<=443nm), 0.05 (>443nm) (scene)*7	0.05 (<=443nm), 0.025 (>443nm) (scene)*7
	Vegetation and carbon cycle	Vegetation index	Standard	A	Daytime	Scene, Global (1, 16 days, month)	250m	Grass: 25%, forest: 20% (scene)	Grass: 20%, forest: 15% (scene)	Grass: 10%, forest: 10% (scene)
		fAPAR	Standard	B				Grass: 50%, forest: 50%	Grass: 30%, forest:20%	Grass: 20%, forest: 10%
		Leaf area index	Standard	B				Grass: 50%, forest: 50%	Grass: 30%, forest:30%	Grass: 20%, forest: 20%
		Above-ground biomass	Standard	B	Daytime	Scene, Global (1, 16 days, month)	1km	Grass: 50%, forest: 100%	Grass: 30%, forest: 50%	Grass: 10%, forest: 20%
		Vegetation roughness index	Standard	B			1km	Grass and forest: 40% (scene)	Grass and forest: 20% (scene)	Grass and forest: 10% (scene)
		Shadow index	Standard	B			250m, 1km	Grass and forest: 30% (scene)	Grass and forest: 20% (scene)	Grass and forest: 10% (scene)
	Temperature	Surface temperature	Standard	B	Both	Scene, Global (1, 16 days, month)	500m	<3.0K (scene)	<2.5K (scene)	<1.5K (scene)
	Application	Land net primary production	Research	C	Daytime	Global (month, year)	1km	N/A	N/A	30% (yearly)
		Water stress trend	Research	C	N/A	Scene, Global (1, 16 days, month)	500m	N/A	N/A	10% *13 (error judgment rate)
		Fire detection index	Research	B	Both*12	Scene	500m	N/A	N/A	20% *14 (error judgment rate)
		Land cover type	Research	B	Daytime	Global (month, season)	250m	N/A	N/A	30% (error judgment rate)
		Land surface albedo	Research	B	N/A	Scene, Global (1, 16 days, month)	1km	N/A	N/A	10%
Atmosphere	Cloud	Cloud flag/Classification	Standard	A	Both	Scene, Global (1 day, month)	1km	10% (with whole-sky camera)	Incl. below cloud amount	Incl. below cloud amount
		Classified cloud fraction	Standard	A	Daytime	Global (1 day, month)	1km (scene), 0.1deg (global)	20% (on solar irradiance)*9	15% (on solar irradiance)*9	10% (on solar irradiance)*9
		Cloud top temp/height	Standard	A	Both	Scene, Global (1 day, month)		1K*4	3K/2km (top temp/height)*5	1.5K/1km (temp/height)*5
		Water cloud OT/effective radius	Standard	B	Daytime	Scene, Global (1 day, month)		10%/30% (Cloud OT/radius)*6	100% as CLW*7	50%*7 / 20%*8
		Ice cloud optical thickness	Standard	B	Daytime	Scene, Global (1 day, month)		30%*6	70%*8	20%*8
		Water cloud geometrical thickness	Research	C	Daytime	Scene, Global (1 day, month)		N/A	N/A	300m
	Aerosol	Aerosol over the ocean	Standard	A	Daytime	Scene, Global (1 day, month)		0.1 (Monthly $\tau a_{670,865}$)*10	0.1(scene $\tau a_{670,865}$)*10	0.05 (scene $\tau a_{670,865}$)
		Land aerosol by near UV	Standard	B	Daytime	Scene, Global (1 day, month)		0.15 (Monthly τa_{380})*10	0.15 (scene τa_{380})*10	0. 1(scene τa_{380})
		Aerosol by Polarization	Standard	B	Daytime	Scene, Global (1 day, month)		0.15 (Monthly $\tau a_{670,865}$)*10	0.15 (scene $\tau a_{670,865}$)*10	0.1 (scene $\tau a_{670,865}$)
	Radiation budget	Long-wave radiation flux	Research	C	Daytime	Scene, Global (1 day, month)		N/A	N/A	Downward 10W/m2, upward 15W/m2 (monthly)
		Short-wave radiation flux	Research	B	Daytime	Scene, Global (1 day, month)		N/A	N/A	Downward 13W/m2, upward 10W/m2

Area	Group	Product	Category	GLI heritage*1	Day/night	Production unit	Grid size	Release threshold*2	Standard accuracy*2	Target accuracy*2
Ocean	Ocean color	Normalized water-leaving radiance (incl. cloud detection)	Standard	B	Daytime	Scene, Global (1, 8 days, month)	Coast: 250m Offshore: 1km Global: 4-9km	60% (443~565nm)	50% (<600nm) / 0.5W/m2/str/um (>600nm)	30% (<600nm) / 0.25W/m2/str/um (>600nm)
		Atmospheric correction parameter	Standard	A				80% (AOT@865nm)	50% (AOT@865nm)	30% (AOT@865nm)
		Photosynthetically available radiation	Standard	A	Daytime	Scene, Global (1, 8 days, month)		20% (10km/month)	15% (10km/month)	10% (10km/month)
		Euphotic zone depth	Research	B	Daytime	Scene, Global (1, 8 days, month)		N/A	N/A	30%
	In-water	Chlorophyll-a concentration	Standard	A	Daytime	Scene, Global (1, 8 days, month)		−60 to +150% (offshore)	−60 to +150%	−35 to +50% (offshore), −50 to +100% (coast)
		Suspended solid concentration	Standard	A				−60 to +150% (offshore)	−60 to +150%	−50 to +100%
		Colored dissolved organic matter	Standard	A				−60 to +150% (offshore)	−60 to +150%	−50 to +100%
		Inherent optical properties	Research	C	Daytime	Scene, Global (1, 8 days, month)		N/A	N/A	a (440): RMSE<0.25, bbp (550): RMSE<0.25
	Temperature	Sea-surface temperature	Standard	A	Both	Scene, Global (1, 8 days, month)	Coast: 500m Others: Same as above	0.8K (daytime)	0.8K (day & night time)	0.6K (day and night time)
	Application	Ocean net primary productivity	Research	C	Daytime	Scene, Global (1, 8 days, month)	Coast: 500m Others: Same as above	N/A	N/A	70% (monthly)
		Phytoplankton functional type	Research	C	Daytime	Scene, Global (1, 8 days, month)	Coast: 250m Others: Same as above	N/A	N/A	error judgment rate of large/small phytoplankton dominance<20%; or error judgment rate of the dominant phytoplankton functional group <40%
		Red tide	Research	B	Daytime	Scene, Global (1, 8 days, month)		N/A	N/A	error judgment rate <20%
		multi sensor merged ocean color	Research	B	Daytime	Area, Global (1, 8 days, month)	Coast: 250m Offshore: 1km	N/A	N/A	−35 to +50% (offshore), −50 to +100% (coast)
		multi sensor merged SST	Research	A	Both			N/A	N/A	0.8K (day & night time)
Cryosphere	Area/distribution	Snow and Ice covered area (incl. cloud detection)	Standard	A	Daytime	Scene, Global (1, 16 days, month)	250m (scene), 1km (global)	10% (vicarious val with other sat. data)	7%	5%
		Okhotsk sea-ice distribution	Standard	A	Daytime	Area (1day)	250m	10%	5%	3%
		Snow and ice classification	Research	B	Daytime	Global (16 days, month)	1km	N/A	N/A	10%
		Snow covered area in forests and mountains	Research	B	Daytime	Area (1, 8 days)	250m	N/A	N/A	30%
	Surface properties	Snow and ice surface Temperature	Standard	A	Daytime	Scene, Global (1, 16 days, month)	500m (scene), 1km (global)	5K (vicarious val with other sat. data and climatology)	2K	1K
		Snow grain size of shallow layer	Standard	B	Daytime	Scene, Global (1, 16 days, month)	250m (scene), 1km (global)	100% (vicarious val. with climatology between temp-size)	50%	30%
		Snow grain size of subsurface layer	Research	B	Daytime	Scene, Global (1, 16 days, month)	1km	N/A	N/A	50%
		Snow grain size of top layer	Research	C	Daytime	Scene, Global (1, 16 days, month)	250m (scene), 1km (global)	N/A	N/A	50%
		Snow and ice albedo	Research	B	Daytime	Global (1, 16 days, month)	1km	N/A	N/A	7%
Cryosphere	Surface properties	Snow impurity	Research	B	Daytime	Scene, Global (1, 16 days, month)	250m (scene), 1km (global)	N/A	N/A	50%
		Ice sheet surface roughness	Research	C	Daytime	Area (Season)	1km	N/A	N/A	0.05 *15
	Boundary	Ice sheet boundary monitoring	Research	B	Daytime	Area (Season)	250m	N/A	N/A	<500m

Common notes:

*1. Heritage levels from ADEOS-II/GLI study are shown by A-C; A: high heritage, B: Remaining issues, C: new or many issues remaining to be resolved

*2. The "release threshold" is minimum levels for the first data release at one year from launch. The "standard" and "research" accuracies correspond to full and extra success criteria of the mission. Accuracies are basically shown by RMSE.