A study on possibility of land vegetation observation with Mid-resolution sensor

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ABSTRACT

The Fourth Assessment Report of IPCC predicted that global warming is already happening and it should be caused from the increase of greenhouse gases by the extension of human activities. These global changes will give a serious influence for human society. Global environment can be monitored by the earth observation using satellite. For the observation of global climate change and resolving the global warming process, satellite should be useful equipment and its detecting data contribute to social benefits effectively. JAXA (former NASDA) has made a new plan of the Global Change Observation Mission (GCOM) for monitoring of global environmental change. SGLI (Second Generation GLI) onboard GCOM-C (Climate) satellite, which is one of this mission, provides an optical sensor from Near-UV to TIR. Characteristic specifications of SGLI are as follows; 1) 250 m resolutions over land and area along the shore, 2) Three directional polarization observation (red and NIR), and 3) 500 m resolutions temperature over land and area along shore. These characteristics are useful in many fields of social benefits. For example, multi-angular observation and 250 m high frequency observation give new knowledge in monitoring of land vegetation. It is expected that land products with land aerosol information by polarization observation are improved remarkably. We are studying these possibilities by ground data and satellite data.

KEY WORDS: SGLI, GCOM-C, Global change, Vegetation Index, Biomass

1. INTRODUCTION

The continued release of greenhouse gases, especially carbon dioxide (CO_2), to the atmosphere is increasing the temperature of the earth, and is advancing the global warming. Recent fourth assessment report of the Intergovernmental Panel on Climate Change (IPCC) accumulated new knowledge obtained after the third assessment, and rewrote the past one. This fourth report concluded that global warming becomes reality by now, and should be caused mainly from the increase of greenhouse gases by the extension of human activities. The report also predicted that the average temperature of the earth may rise 7.4 degrees after 100 years in the worst case. These global changes will exert a serious influence on human society. It is in urgent need to resolve the process of global warming and other changes in the climate system, therefore, it is very important to construct a model which gives fairly accurate forecast of the environmental change.

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. The Japan Aerospace Exploration Agency (JAXA; former NASDA) 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.

1.1 Concept of GCOM

GCOM is a follow-on satellite observation mission incorporating the technology and results of GLI (Global Imager) and AMSER (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.

1.2 GCOM-C/SGLI

SGLI (Second Generation GLI) is an onboard GCOM-C satellite, and provides GLI follow-on sensors. 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.

2. SPECIFICATION OF GCOM-C/SGLI

Two tree-areas having different growth stages were selected in the area of Nakashibetsu-gun, Hokkaido, Japan (Figure 1.) and measurements were conducted on these trees composed of larch species (Figure 2.) closed canopy from September 11 to 13, 2007. The measured features were the radius of the tree crown (north, south, east, and west directions) and the radius between two adjacent trees crowns, and the height between the ground and the crown base (north, south, east, and west directions), tree height, diameter at breast height (DBH), and tree distance between adjacent trees (Figure 3.).

3. SIMULATION RESULTS OF SGLI LAND PRODUCT FROM EXISTING DATA

3.1 250 m composite mosaic data

The Fourth IPCC Assessment Report also indicated that anthropogenic contribution to aerosols (primarily sulphate, organic carbon, black carbon, nitrate and dust) produce a cooling effect, with a total direct radiative forcing of -0.5 Wm^{-2} and an indirect cloud albedo forcing of -0.7 Wm^{-2}. These forcings are better understood now than at the time of the third IPCC report due to improved satellite and ground-based measurements and more comprehensive modeling, but remain the dominant uncertainty in radiative forcing. Therefore, decreasing these uncertain parts is very important problem.

A high-precision physical quantity of ocean aerosol was demanded for the first time in the world by ADEOS/OCTS and ADEOS-II/GLI. However, enough results were not provided. First reason is that the high-precision physical quantity of land aerosol was not provided. ADEOS/POLDER can provide land aerosol, but it does not have enough resolution for land cover analysis. Similarly, though ADEOS/TOMS provide aerosol index, it does not express the physical quantity. In the conventional observation method, the identification of aerosol type or the estimation of high-precise physical quantity of land area aerosol is very difficult.

SGLI sensor will provide new and unique channels, such as multi angular, Ultra Violet (380 nm), and polarized light. From the result of GLI, it was found that aerosol parameters over land are able to determine by using 380 nm channel. It was difficult for previous sensors to determine aerosol parameters over land because of the high reflectance of land surfaces. However, the reflectance of land in the near ultraviolet band is very low. As a result, weak signals from aerosols can be detected over the dark background by the channel. Aerosol absorption can be determined using attenuation of the Rayleigh scattering ray. Therefore, it is expected that SGLI Land product, Atmospherically Corrected Land surface Reflectance (ACLR) is possible to correct the influence of aerosol as well as Rayleigh scattering and Ozone absorption, too. Furthermore, SGLI data contribute to grasp the radiative forcing.

SGLI has characteristic of 250 m resolution, too. The influence of human activities extends to wide area. However, individual human impact is not so wide. Many small impacts of human activities make a tiny change of land cover (for example, deforestation by personal farmer, etc.). High resolution (250 m) is suitable to grasp these changes, precisely. Therefore, SGLI data is useful to clarify influence of human activities.

As mentioned above, it is expected that high-quality 250m composite mosaic data may be generated from enough atmospherically corrected land surface reflectance (ACLR) and high resolution (250 m).

3.2 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 is estimated from vegetation indexes obtained from the radiation to the vertical satellite, but it 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. The upper image in Fig. 2 shows the change of new vegetation index VRI (Vegetation Roughness Index) obtained from multi-angle observation of RED and NIR during 1995 to 1999 in China. Here, VRI is calculated from the following equation,

$$VRI = \frac{NIR_o - RED_o}{NIR_n - RED_n} \qquad (1)$$

where NIR and RED are reflectance in the NIR and RED regions, and subscripts n and o are defined nadir and off-nadir observation, respectively. In Fig. 2, enclosed regions by white circle show large differences between 1995 and 1999. In these regions, vegetation cover changes strongly.

In the case of Fig. 2, NOAA/AVHRR data obtained from different path were used. For the SGLI, different angle observation is available along track.

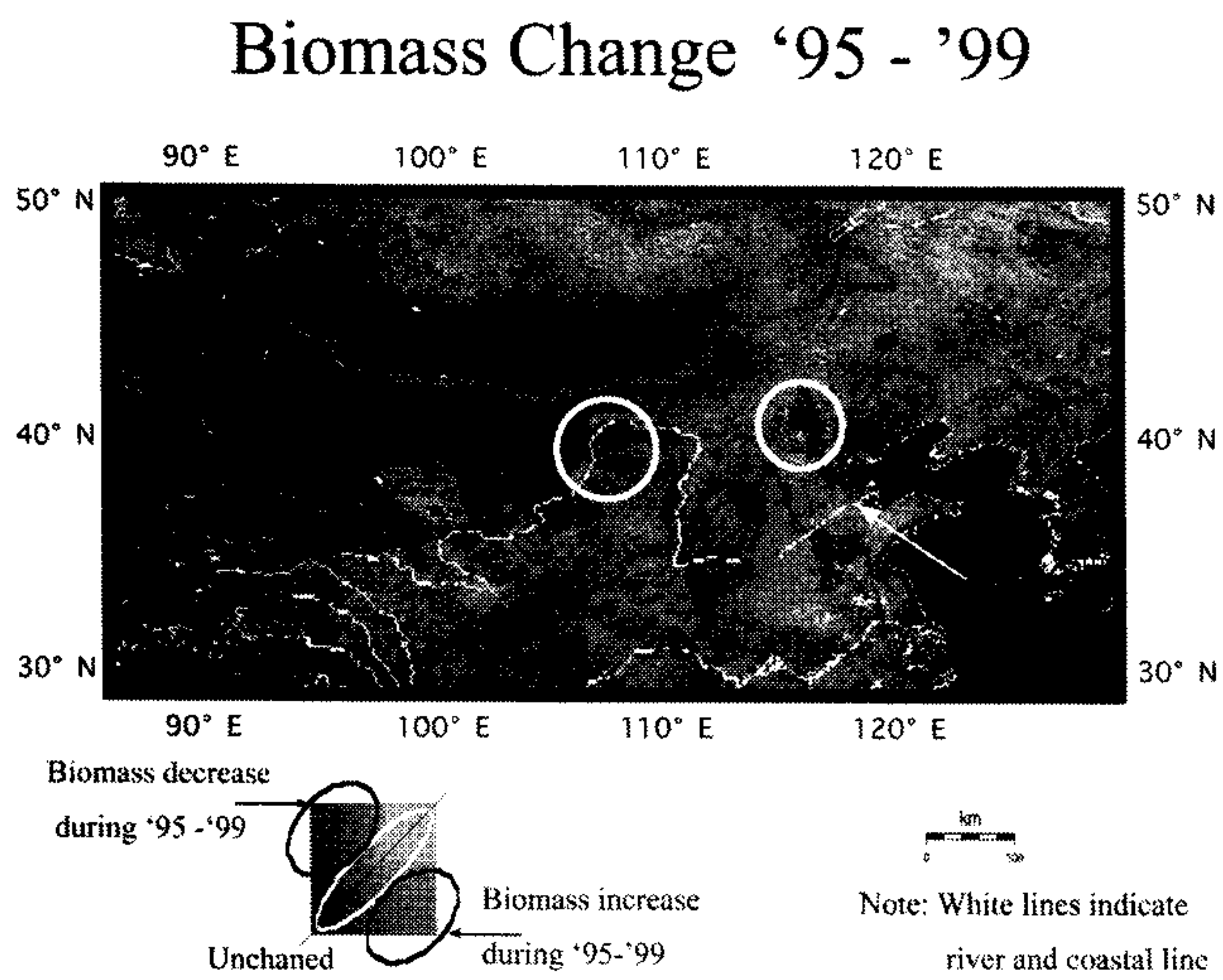
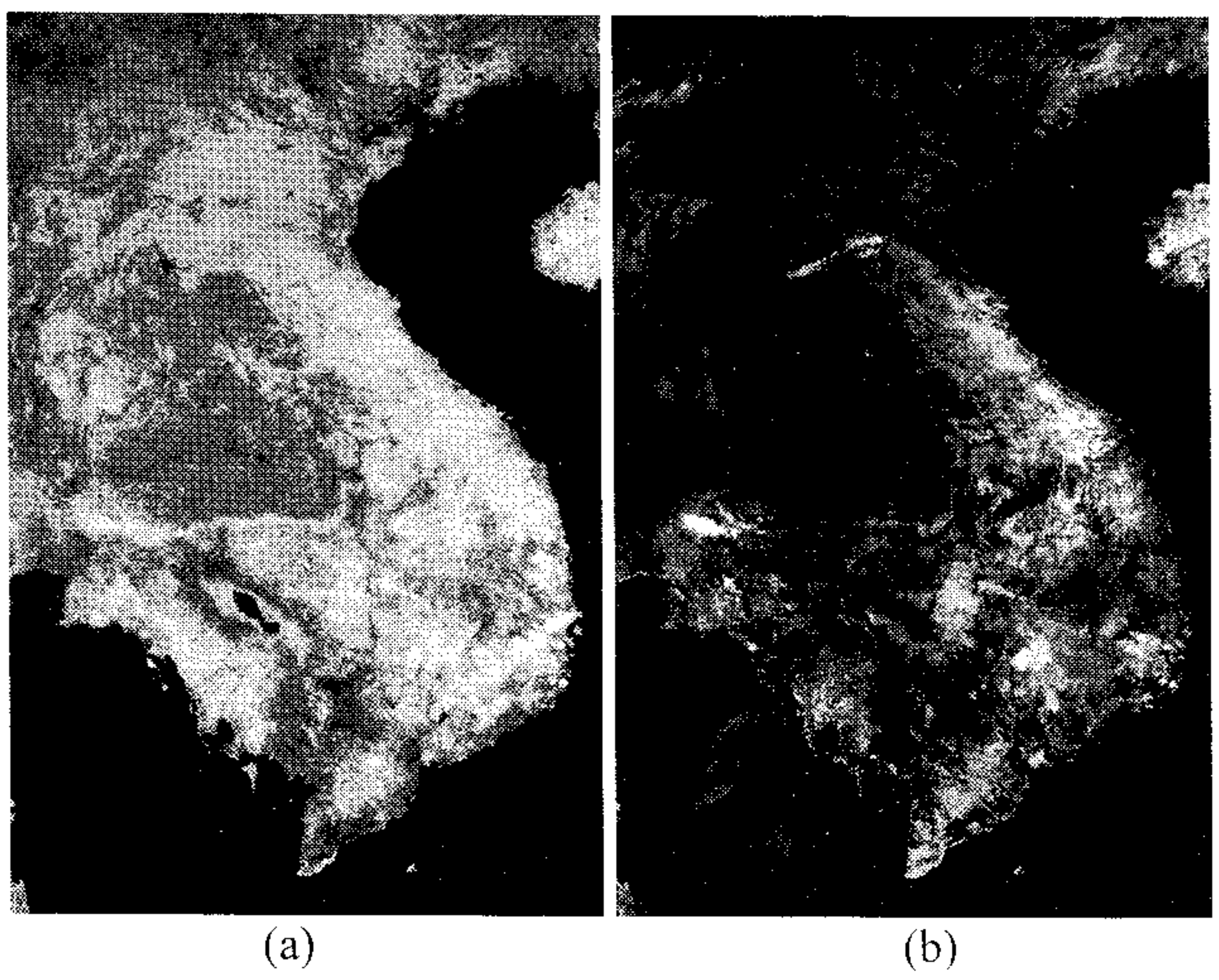


Fig 2. Biomass change detection using multi-angle observation data.



(a) (b)

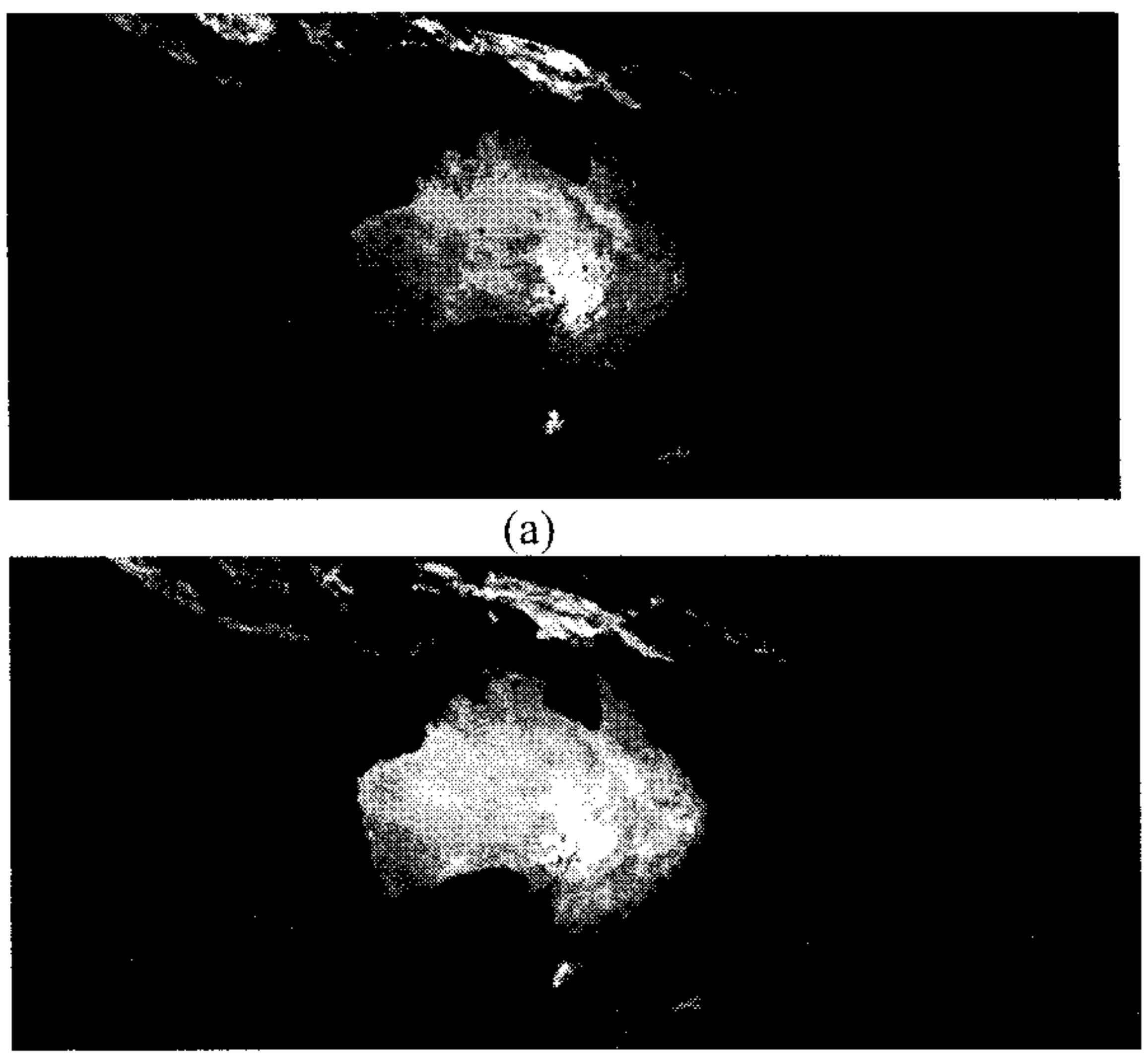
Fig 3. The images of ADEOS-II/GLI 250 m data around Indochina Peninsula on 2003/4/7-2003/4/22. The data shown are (a) NDVI image and (b) shadow index (SI) image in gray scale. Shadow index is estimated by utilizing the normalization method.

3.3 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). From the conventional analysis result, it is found that the normalization method with the arithmetic mean of bands can suppress the shadow effect as well as topographic and atmospheric effects, too. In other words, this technique can separate shady places and restrain a shadow effect. Then, we can estimate SI by using the difference of the observing radiance spectrum and its normalization value. The results are shown in Fig. 3. As seen from Fig. 3, 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.

3.4 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, 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



(a)

(b)

Fig. 4. 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) 2006/8/12-2006/8/20 as observed By Terra/MODIS.

temperature change.

Recently, the drought damage of Australia becomes serious problem. Fig. 4 shows the WST results in two periods. Water stress was little in 2005, but big in 2006. As seen from Fig. 4, though WST in 2005 (Fig. 4 (a)) is small in the whole area, many big areas of WST are there in 2006 ((Fig. 4 (b)). Therefore, WST which estimated from the accumulation of difference in radiant temperature is useful to detect waterless area.

4. 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 2013. 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.

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