Japan's efforts of using satellite remote sensing for the prediction of infectious diseases

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Tamotsu IGARASHI¹⁾, Shinichi SOBUE²⁾, Aya YAMAMOTO¹⁾ Kazuhide YAMAMOTO³⁾, Kei OYOSHI³⁾ and Toru FUKUDA³⁾

- 1) Research and Development Department, RESTEC
 - 2) Planning Department, RESTEC
 - 3) Earth Observation Research Center, JAXA

Japan's Efforts

- JAXA's Space Programs
- Prediction of infectious diseases
 - JAXA-Nagasaki University: Malaria and Cholera in Kenya
 - JAXA-Shibaura Institute of Technology: Remote sensing applied for a study geographical pathology for the relationships between malaria epidemic
 - JAXA Mini-Project: Risk Map of Japanese Encephalitis (JE) in Mid and Far Western Region of Nepal
- MEXT Green Network of Excellence (GRENE) (FY2011-2015)

Long-Term Plan of Earth Observation Projects of JAXA



Earth Observation Projects

- GCOM-W1 "SHIZUKU" is in operation after one year since the launch on May 18 2012.
- Forthcoming satellites/Sensors dedicated to monitor the Earth globally:
 - ALOS-2 will be launched in JFY 2013.
 - GPM/DPR will be launched in JFY2014.
 - GCOM-C1 will be launched in JFY2015.
 - EarthCARE/CPR will be launched in JFY2015.
 - ALOS-3 will be launched in JFY 2016.

Global Change Observation Mission

- GCOM is to construct and verify EO system enabling global earth observations producing effective parameters elucidating climate change, water cycle.
- GCOM is consisted with 2 satellite series (GCOM-W and C), 3 generations to perform consistent and sustained global observations for 13 years.

	GCOM-W1 "SHIZUKU"	GCOM-C1
Orbit	Type : Sun-synchronous, sub-recurrent Altitude : 699.6 km Inclination : 98.19 degrees Local time of ascending node : 13:30	Type : Sun-synchronous, sub-recurrent Altitude : 798 km Inclination : 98.6 degrees Local time of ascending node : 10:30
Satellite overview		
Mission life	5 ye	ears
Launch vehicle	H2A launo	ch vehicle
Mass	1940kg (AMSR2 404 kg)	2020 kg (SGLI 480 kg included)
Instrument	AMSR 2 (improved AMSR-E)	Second Generation Global Imager (SGLI, improved GLI)
Launch	In operation since one year after the launch on May 18 2012	JFY2015 (target)





GCOM-C products and SGLI design

GCOM-C products and SGLI channels



Specifications of SGLI, such as center wavelengths, band width, SNR, and dynamic range, are **designed in consideration of retrieval algorithms of the observation targets**.

Examples of expected GCOM-C product VNR 250m land and coastal observation

250m Ocean color chlorophyll-a and NDVI simulated using GLI 250m channels





100

30

0.3

(a) GLI 1km Osaka Bay (1 Oct. 2003, CHL by LCI)

(b) GLI 250m Osaka Bay (1 Oct. 2003, CHL by LCI)

SGLI 250m resolution will enable to detect more fine structure in the coastal area such as river outflow, regional blooms, and small current.

Hiroshi Murakami, Mitsuhiro Toratani and Hajime Fukushima, Satellite ocean color observation with 250 m spatial resolution using ADEOS-II GLI, Remote Sensing of the Marine Environment, Proceedings of SPIE, Volume 6406-05, Nov. 28, 2006

Examples of expected GCOM-C product *Thermal infrared 500m land and coastal observation*



- The 500m and 1000m spatial resolution thermal infrared images are simulated using ASTER data (original resolution is 90m) (Tokyo Bay in the night on August 4, 2003).
- SGLI 500m-resolution thermal infrared channels will enable detection of fine structures such as land and coastal surface temperature influenced by the city and the river flows.



Greenhouse Gases Observing Satellite (GOSAT), Ibuki

GOSAT enables global (with 56,000 points) and frequent (at every 3 days) monitoring CO_2 and CH_4 column density. (Launched in Jan 2009)



Current Ground-based Observation Points (320pts) *Provided by WMO WDCGG*



Increase of Observation Points using GOSAT (56,000pts)

GOSAT CO₂ global distributions in spring and summer

2009/04/20 - 2009/04/28





Tropical Rainfall Measuring Mission

- TRMM is ;
 - Japan-U.S. joint mission, flying since Nov. 1997
 - World's first and only space-borne precipitation radar (PR) on-board with microwave radiometer and visible-infrared sensor
 - Still operational, and continues to provide the data
- Results of the TRMM
 - Accurate and highly stable rain measurement in the tropical and sub-tropical region, over the land as well as the ocean
 - More than 10 years rain observation data archive
 - Proved that the radar (PR) and microwave radiometer (TMI) is a very good combination for rainfall measurement
 - PR greatly contribute to the improvement of the rainfall retrieval error by microwave radiometer
 - Precipitation system three dimensional structure, diurnal cycle, seasonal change, long term variation such as El-Nino and La-Nina observation
 - New products development such as latent heating, soil moisture, and sea surface temperature
 - Demonstrated that TRMM data is valuable for the operational use, such as flood prediction, numerical weather forecast, typhoon prediction



Launch	28 Nov. 1997 (JST)
Altitude	About 350km (since 2001, boosted to 402km to extend mission operation)
Inc. angle	About 35 degree, non-sun- synchronous orbit
Design life	3-year and 2month (still operating)
Instruments	Precipitation Radar (PR) TRMM Microwave Imager (TMI) Visible Infrared Scanner (VIRS) Lightning Imaging Sensor (LIS) CERES (not in operation)

Production of GSMaP from Multi-satellite Data

GSMaP: Global Satellite Mapping of Precipitation



JAXA/EORC Global Rainfall Watch

1-8 August 2011 (6-hourly) - Typhoon No.9 in 2011 "MUIFA" can be seen near Okinawa, Japan.



Rain 0.1 0.5 1.0 2.0 3.0 5.0 10.0 15.0 20.0 25.0 30.0 [mm/hr]

<u>0.1-deg</u> and <u>hourly</u> global rainfall product available <u>4-hour after observation</u> via internet.

http://sharaku.eorc.jaxa.jp/GSMaP/

Global Precipitation Measurement (GPM)

 The Global Precipitation Measurement (GPM) is a follow-on and expanded mission of the Tropical Rainfall Measuring Mission (TRMM)

> Core Satellite (JAXA, NASA) Dual-frequency precipitation radar (DPR) GPM Microwave Imager (GMI)

- Precipitation with high precision
- Discrimination between rain and snow
- Adjustment of data from constellation satellites

(launch in JFY2014)



Improve the accuracy of both long-term and short-term weather forecasts

Improve water resource management in river control and irrigation systems for agriculture

EarthCARE/CPR

Climate monitoring of earth radiation, cloud and aerosol Cooperation between ESA and Japan (JAXA/NICT)

Mission

- Vertical profile of clouds, aerosol
- Interaction between clouds and aerosol
- Cloud stability and precipitation
- Orbit
 - Sun synchronous
 - Equator crossing time 13:45
 - Altitude 400km
- Instrument
 - CPR (Cloud Profile Radar)
 - ATLID (Atmospheric LIDAR)
 - MSI (Multi-Spectral Imager)
 - BBR (Broad Band Radiometer)

Task sharing

- JAXA/NICT (CPR)
- ESA (LIDAR, MSI, BBR, Spacecraft)

Launch target

– In 2015





Earth CARE/Cloud Profiling Radar

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- Launch target
 - JFY2015

Global / 3D distributions of clouds and aerosols with EarthCARE and numerical models. <u>Cloud Retrieval with CPR-only and Synergy</u> Example of Reff derived from CloudSAT and CALIPSO



Aerosols Retrieval with ATLID and MSI

- Optical / Microphysical / Radiative properties (Extinction, Size distribution, Single scattering albedo, Optical thicknees, Ångström Exponent)
- Type (Soil Dust, Carbonaceous, Sulfate, Sea Salt)
- Component (Dust, Sea-salt, black carbon, etc)

ALOS to ALOS-2 and ALOS-3



ALOS-2

HE LL	PALSAR-2 Observation Mode	Stripmap: 3 to 10m res., 50 to 70 km swath ScanSAR: 100m res., 350km swath Spotlight: 1×3m res., 25km swath
	Orbit	Sun-synchronous orbit Altitude: 628km Local sun time: 12:00 +/-15min Revisit: 14 days Orbit control: \leq +/-500m
	Life Time	5 years (target: 7 years)
	Launch	JFY2013, H-IIA launch vehicle
Left: PALSAR-2 simulated image (Pi-SAR-L:HV)	Downlink	X-band: 800Mbps (16QAM) 400/200Mbps (QPSK) Ka-band:278Mbps (QPSK)
Right: Google Earth image, Harumi, Tokyo		

ALOS-3

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Left: ALOS-3 PAN simulated image Right: ALOS PRISM image

Sensors	Pan: 0.8m res., 50km swath Stereo: TBD res., TBD swath Mu: 5m res., 90km swath (METI) Hyper: 30m res., 30km swath, 185chs, 0.4~2.5um (METI)
Orbit	Sun-synchronous orbit Altitude: 618km Inclination: 97.9deg Local sun time : 10:30 +/-15min Revisit: 60days Orbit control: \leq +/-500m
Life Time	5 years (target: 7 years)
Launch	JFY2015, H-IIA launch vehicle
Downlink	X-band: 800Mbps (16QAM) 400/200Mbps (QPSK) Ka-band: 800Mbps (QPSK)

JAXA-Nagasaki University cooperative research on Malaria and Cholera in Kenya

- Cooperative research
 - Health is one of Societal Benefit Areas (SBAs) of Group on Earth Observations (GEO)
 - JAXA-Nagasaki University cooperative research to predict epidemic diseases based on data analysis using satellite remote sensing and Health and Demographic Surveillance System (HDSS)
- Recent studies have been reviewed
 - Epidemic of malaria in Kenya, cholera in Bangladesh and regional environmental change
- Satellite data have been explored
 - High resolution optical and SAR data of land surface and aqua plants
 - Global environmental data of land surface , inland water, moisture, rain
- Next step, research focus

JAXA Mini-Project in Nepal

- Bhogendra Mishra, Bhoj Raj Ghimire, Diwakar Baral, Yogendra Mishra, Masahiko Nagai (CCAM Group, Nepal, Department of Irrigation, Government of Nepal GeoInformatics Center, Asian Institute of Technology, Bangkok, Thailand), Japanese Encephalitis Risk Zone Mapping Using Remote Sensing Data: A Case Study of Mid and Far-Western Part of Nepal, Journal of Remote Sensing & GIS, Vol. 4, Issue 2, ISSN: 2230-7990.
- JAXA, A Selection of Min-Projects utilizing JAXA'S Satellite Data in the Asia-Pacific Region, Vol. 1, FY2011.
 - Fostering local expertise through cooperation in capacity building related to the application of satellite technology
 - <u>http://web-tutorials.tksc.jaxa.jp/pdf/10_01_leaflet.pdf</u>

Risk Map of JE in Mid and Far Western Region of Nepal-July and August







Bheri Zonal Hospital, Nepalgunj Report of Encephalitis Cones

S.N.	Year	Discharge	Expired	Total	Fatality
1	2049	116	27	143	18.88
2	2050	54	17	71	23.94
3	2051	351	107	458	23.36
4	2052	232	72	304	23.68
5	2053	294	76	370	20.54
6	2054	700	123	823	14.95
7	2055	311	63	374	16.84
8	2056	619	140	768	19.40
9	2057	397	72	469	15.35
10	2058	509	91	600	15.17
11	2059	223	66	289	22.84
12	2050	190	49	239	20.50
13	2061	263	55	318	17.30
To	otal	4259	967	6226	18.50

- Study of relationship of Japanese Encephalitis (JE) with climatic/Environmental variables.
- Using statistical model and GIS in mid and far western part of Nepal.

ALOS-2 Cooperative Research for 2nd Research Announcement in 2013

- Theme: Remote sensing applied for a study geographical pathology for the relationships between malaria epidemic and Malaria as Anthropo-Ecosystem consisting various subsystems.
- PI: Sumiko Anno (Shibaura Institute of Technology)
- Cls: Takeo Tadono (JAXA), Tamotsu Igarashi, Aya Yamamoto (RESTEC), etc.

Green Network of Excellence (GRENE) MEXT (FY2011-2015)

- Establishment of Research Platform for Developing Models to Predict Future Health Risks Posed by Changes in Climate, Land Use and Population (Ecohealth)
- Prof. Chiho Watanabe, School of International Health Graduate School of Medicine The University of Tokyo
- Themes: Development and verification of
 - Models to predict risks of diseases
 - Transmission model of vector-borne diseases using HDSS
 - Predict water-borne diseases
- http://www.tr.yamagatau.ac.jp/~water/ecohealth/main.html

Research Area of Lake Victoria



Sediments and water hyacinths in Winam Gulf, Lake Victoria







ALOS AVNIR-2 images

- Floating aqua plants : possible vector of cholera
- Accumulated aqua plants : possible habitat of mosquito
 - larvae Top Left: 12 Nov. 2008 Top Right: 31 Dec. 2009 Bottom Left: 3 Jan. 2011

PALSAR Images (Left: HH, Right: HV-pol.)



2009/09/13 (ALPSRP19382718) FBD

ALOS pan-sharpen true color image of Rusinga Island and Mbita district

Malaria Mosquito Larvae Habitats

- Left: Water hyacinth mat (Green) and Lagoon (Red)
- Right: Water hyacinth mat

Source of map: Minakawa N, Dida GO, Sonye GO, Futami K, Njenga SM (2012) Malaria Vectors in Lake Victoria and Adjacent Habitats in Western Kenya. PLoSONE 7(3): e32725.

Water surface height derived from Jason-2 (1992-2013, USDA)

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Solar radiation, temperature, wetness

GLI Image of Lake Victoria

http://www.eorc.jaxa.jp/imgdata/to pics/2013/tp130423.html

- Photo synthetically Available Radiation (PAR)
- Water Surface Temperature (ST)
- Water Stress Trend (WST)
- These MODIS geophysical parameters are considered as environmental factors to affects on the propagation of aquatic plants such as water hyacinth, Microcystis blue-green algae cyanobacteria

MODIS pseudo-color composite image

R: MODIS31(Thermal Infrared), G: MODIS2 (Near Infrared), B: MODIS1 (Red)

Top : Oct. 31, 2008, 08:05 UTC Bottom : Nov. 19, 2009, 11:15 UTC) Source: Moriyama Lab., Graduate School of Eng., Nagasaki University

- Turbid water, aquatic plants, vegetation on the ground, soil wetness and water flow into the lake.
- Land surface of Savanna in the beginning of short wet season on Oct. – Nov. are observed.
- Red: High temperature
- Green: Vegetation
- Blue: Red soil, turbid water, cloud cover
- Pink (Red+Blue): Mixed high
 temperature ground + red soil
- Orange Yellow (Red + Green): High temperature + vital vegetation after rainfall
- Blue: Turbid water flown in to the lake from rivers

Global rainfalls TRMM 3 monthly mean products

(Top: El Nino, Dec. 2002 - Feb. 2003, Bottom: La Nina, Dec. 2005 - Feb. 2006)

Altitude and Rainfall

- Fig. A: Height above mean sea level (m)
- Fig. B: Rainfall from model (mm) when atmospheric water vapor content on the east boundary reduced by 20%
- Fig. C: Rainfall from model (mm) when atmospheric water vapor content on the east boundary reduced by 50%
- Data collection points
 - Blue (Rain)
 - Green (Health)
 - Red (Health + Rain)
- Source: Anyah et al. AMS

Masahiro Hashizume, A.S.G. Faruque, Toru Terao, Md Yunus, Kim Streatfield, Taro Yamamoto, and Kazuhiko Moji, The Indian Ocean Dipole and Cholera Incidence in Bangladesh: A Time-Series Analysis, Environmental Health Perspectives, 2011 February, 119 (2):239-15 244.

Blue Algae along the lakeshore at Homa Bay, Lake Victoria

- Photo was taken by Prof. Gotoh, Nagasaki University around Homa Bay where the lake water is used for washing and drinking after filtration through cloth by local residents. However, rain water is more clear and good quality for drinking.
- In June 2013, there were many reports of Blue Algae in Winum Gulf, Lake Victoria.

Camera Image on Field Rooter in Mbita

 Green water was observed on July 10, 2013. Blue Algae was also observed in different places along the lakeshore.

Atmospheric Temperature(°C) and Humidity (%) on June 25

- Temperature: diurnal cycle within 20-27°C are observed
- Relative humidity: diurnal cycle within 50-90%are observed
- Humidity tends to low value after June 19.
- Water Stress Trend at low value was identified from MODIS data of former half month of June.¹⁸

Rainfall Rate (mm)

- On June 24, the rainfall rate 3 mm was observed, and on other days, almost 0 mm have been recorded.
- In the image of GSMaP on June 24, at 0-1h (UTC), rainfall area is extended to the eastern lakeshore of lake Victoria.

Solar Radiation on the Earth Surface

Monthly Mean on July 2009 (Aqua MODIS)

Time-series data of environment

- Objectives: Variation of Satellite Remote Sensing, models and correlation with health data
 - Inter-Validation of satellite remote sensing data with ground truth data
 - To identify vectors of malaria and cholera and to understand the relationship with environment data
- Regional Study Area (Kisumu, Mbita, Homa Bay)
 - Malaria: water hyacinth mats and lagoon water area
 - Cholera: monitoring of water hyacinths and Blue algae thought to carry bacteria to the human society
- Project period (annual average for several to decadal years)
 - Time-series data of satellite operational period, on the area of interest

Summery

- In the first year of JAXA-Nagasaki University cooperative research, relevant recent studies have been reviewed and satellite data have been explored.
- In the next step, research focus will be on the development of forecast model on incidence of infectious diseases in relation with environmental factors, using satellite remote sensing data including a time-series data product and GIS.