How about using rain data?

Case studies demonstrated by TRMM / GPM / GSMaP

JAXA
Explore to Realize

Introduction

The twenty-first century is often called "the century of water." Water is an essential element of the Earth's environment and is indispensable for our life and economic activities. Many places in the world now face water problems, such as water shortages and floods, which can cause food shortages, epidemics, and so on. In addition to these problems, global warming and climate change affect the global water cycle and result in abnormal weather, such as frequent heavy rains and droughts. Phenomena range from short-term, local events like heavy torrential rains to long-term, large-scale events like El Niño.

To solve these problems, we urgently need to determine rainfall distribution accurately, which is the input to water resources, and to improve the techniques of predicting and preparing for abnormal weather. For this purpose, it is imperative to monitor rainfall changes in every corner of the Earth and to recognize that we have to share the limited water resources. A comprehensive international satellite observation plan for understanding and predicting water distribution in real time is one way to address these problems.

Based on this idea, JAXA has conducted a 19-year long precipitation observation from space using the TRMM and GPM missions. Data of rainfall observations from space are currently used in various fields, such as weather forecasting and flood prediction. If you are interested in satellite rainfall data and would like to use them, many examples of use are presented in this book. If you would like further advice and information, please consider contacting us at the address below.

Contact information

Japan Aerospace Explore Agency

Inquiries for "TRMM / GPM / GSMaP Collection of Utilization Cases"

E-mail **Z-trmm_real@ml.jaxa.jp**

References

- http://www.eorc.jaxa.jp/TRMM/index_e.htm
- http://www.eorc.jaxa.jp/GPM/index_e.htm
- http://sharaku.eorc.jaxa.jp/GSMaP/index_e.htm

See also "Data Utilization Method and References" at the back of the book

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Tropical Rainfall Measuring Mission (TRMM)

The Tropical Rainfall Measuring Mission (TRMM) was proposed as a joint project between the US, National Aeronautics and Space Administration (NASA), and Japan, National Space Development Agency of Japan (NASDA) and Communication Research Laboratory (CRL). Japan developed the world's first spaceborne precipitation radar, and provided an H-Ⅱ rocket to launch the TRMM satellite. The US provided the observatory, four other sensors, and the satellite operation systems.

TRMM was launched on November 1997 from Tanegashima Space Center in Japan. The products of TRMM/PR have been used for research related to rainfall structure and phenomenon in typhoon and severe rainfall/snowfall and have thus contributed to the promotion of studies.

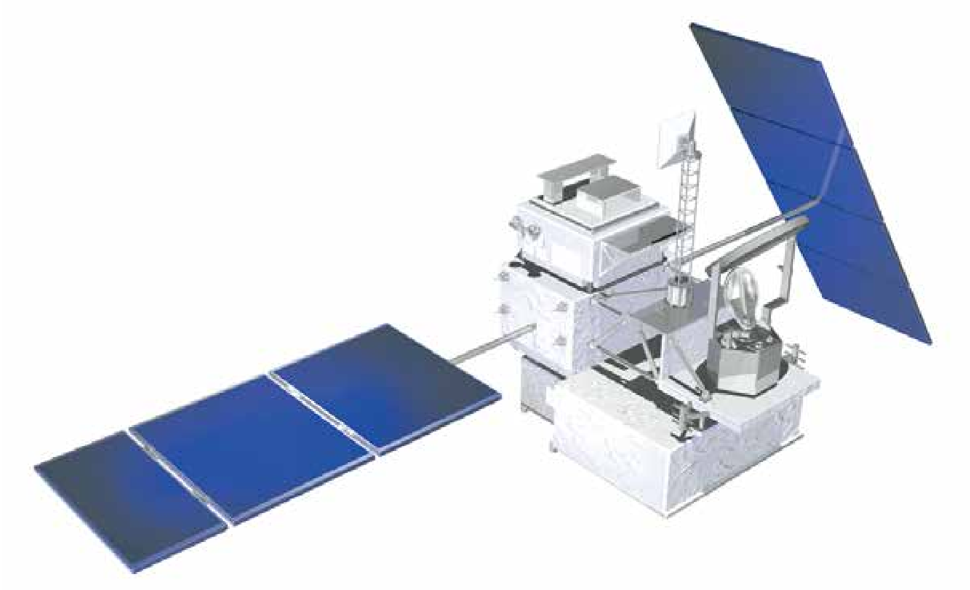
In April 2015, TRMM ended its observations after a period of 17 years. However, the Global Precipitation Measurement (GPM) Core Satellite was launched on February 2014. This takes over the observations of TRMM and continuously observes precipitation.

TRMM web site **http://www.eorc.jaxa.jp/TRMM/index_e.htm**

Major Specification of TRMM satellite	
Launch date	28th November 1997
Orbit Altitude	Approximately 350km (Approximately 400km in 2001-2014)
Orbit Inclination	Approximately 35°

Major Specifications of Precipitation Radar		
Observation Frequency		13.8GHz
Swath Width		Approximately 220km
Resolution	vertical	250m
	horizontal	approximately 4.3km

Global Precipitation Measurement (GPM) Mission



As the accuracy of satellite precipitation estimates improves and observation frequency increases, the data is expected to be applied to areas that benefit society, such as weather forecasts and flood predictions, in addition to research of precipitation climatology to analyze precipitation systems. There are, however, limitations on single satellite observation in coverage and frequency.

The international Global Precipitation Measurement (GPM) mission was thus advanced to fulfill various user requirements that cannot be achieved by the single TRMM satellite.

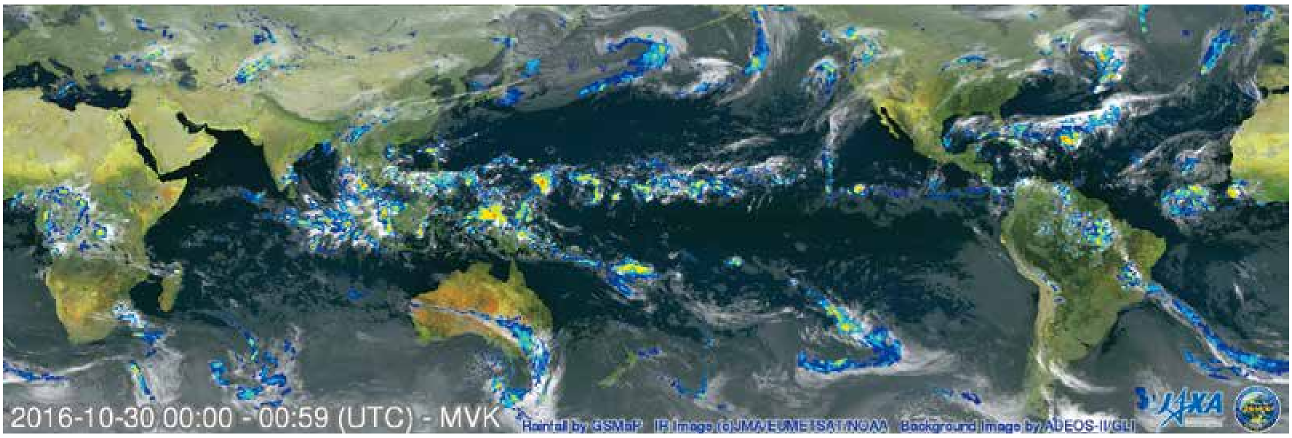
One major characteristic of the GPM mission as follow-on and expansion of the TRMM satellite is operation of the GPM core satellite, which will carry an active precipitation radar and a passive microwave radiometer, with a non-sun-synchronous orbit as a "calibrator" to other satellites. The other is its collaboration with a constellation of several other satellites developed by each international partner (space agency), each of which will carry passive microwave radiometers and/or microwave sounders, to increase observation frequency. Although the TRMM satellite focused on observation of the tropics, the GPM mission covers broader areas including high latitudes.

GPM web site **http://www.eorc.jaxa.jp/GPM/index_e.htm**

Major specifications of GPM core satellite	
Launch date	28th February, 2014
Orbit Altitude	Approximately 400km
Orbit Inclination	Approximately 65°

Major specifications of Dual-frequency Precipitation Radar		
Observation Frequency	Ku-band precipitation radar (KuPR)	13.6GHz
	Ka-band precipitation radar (KaPR)	35.5GHz
Swath Width	Ku-band precipitation radar (KuPR)	Approximately 245km
	Ka-band precipitation radar (KaPR)	Approximately 125km
Resolution	vertical	250m
	horizontal	Approximately 5km

Global Satellite Mapping of Precipitation (GSMaP)



Global Satellite Mapping of Precipitation (GSMaP) provides a highly accurate global rainfall map with a high resolution. Values are estimated using multi microwave radiometer data and a rain rate retrieval algorithm based on a reliable rainfall physical model. Data are also comprehensively provided using precipitation radar and infrared radiometers on geostationary satellites.

The spatial resolution is 0.1 degree (latitude and longitude) and the temporal resolution is 1-hr.

We can provide various types of GSMaP products to match user requirements, and these can be distributed in several data formats. To view the global rainfall map, please visit the website.

GSMaP web site	http://sharaku.eorc.jaxa.jp/GSMaP/index_e.htm

Utilization Cases of Rainfall Observation from Space

Disaster Management / Disaster Monitoring

- Utilization in Global Flood Alert System (GFAS-II)
- Effective Application to the Flood Forecasting and Warning System (Integrated Flood Analysis System: IFAS)
- Utilization of the GSMaP in the Flood Prediction/ Warning System in Developing Countries in Asia

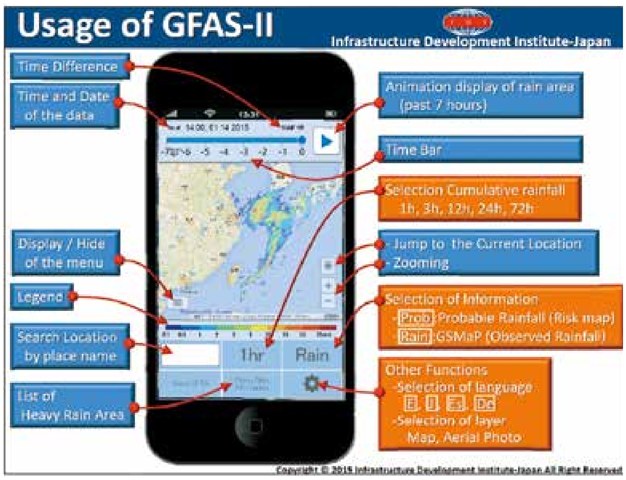
Utilization in Global Flood Alert System (GFAS-II)

Infrastructure Development Institute
http://www.idi.or.jp/english/00index.htm

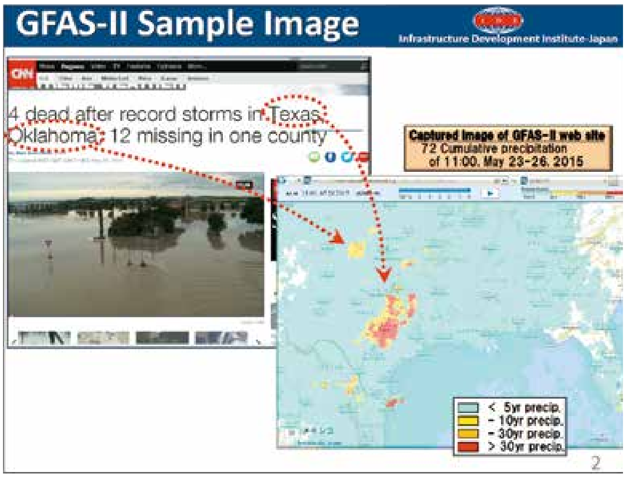
Description

The GFAS-II (Global Flood Alert System ver.2) is the system that obtains near-real-time (NRT) rainfall data from the FTP site, color-codes the probability levels of the rainfall, and displays the ranks of flood risk level of rainfall (resolution of about 10km grid and data update hourly). The flood risk level display of rainfall in real time (NOW) will be launched.
Rainfall probability is displayed using its return period from once in 5 years to once in 30 years per grid area, and strong rainfall area and movement speed are displayed visually in a way that is easy to understand to provide risk information.
The GFAS-II can be accessed not only PCs but also smartphones, which can be used even in an evacuation center at the time of disaster and has been common in developing countries. With the smartphone app system, an animated image displays information. Languages available, in addition to English, are Japanese, Spanish, German and Vietnamese (five common world languages).
GFAS was released in 2006, and GFAS-II is the latest version. GFAS evaluated the probability of rainfall observed using the TRMM satellite and displayed the strength of rainfall in areas on the map. However, GFAS is not operating at present with the observation end of the TRMM satellite.

Satellite / Sensor or products used in this case	TRMM GSMaP
Effect(s) to be expected	The current conditions strongly suggest that water disasters will become more catastrophic and occur frequently due to climate change, etc. in the near future. There is an urgent need to plan for damage reduction and enhancement of disaster prevention ability. In particular, community disaster prevention in developing countries is expected to benefit from the application of this system.
User / Purpose	Actually utilized (World Disaster Prevention Community Leader, for General Citizens)
Utilization Period (Phase)	GFAS-II: From June 2015 (Ongoing) GFAS: From 2006 to June 2015 (Completed)
Referenses	GFAS-II (For PC) http://gfas.internationalfloodnetwork.org/n-gfas-web/pc/frmMain.aspx GFAS-II((For smartphone) http://gfas.internationalfloodnetwork.org/n-gfas-web/sp/frmMain.aspx



General Operation Instructions for GFAS-II
*Resolution: about 10km grid (10km^2), Data Update: Hourly



Flood Damage Status and Probable Rainfall Distribution Application Example (Southern United States; May 2015)

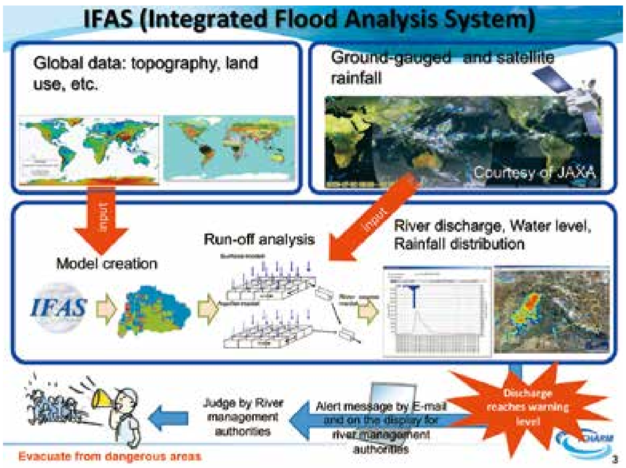
Effective Application to the Flood Forecasting and Warning System (Integrated Flood Analysis System: IFAS)

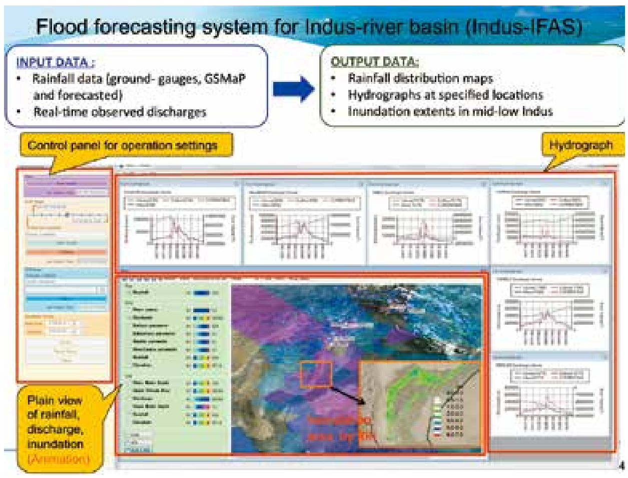
Public Works Research Institute, International Centre of Excellence for Water Hazard and Risk
http://www.icharm.pwri.go.jp/index.html

Description

International Centre for Water Hazard and Risk Management (ICHARM) of The Public Works Research Institute developed Integrated Flood Analysis System (IFAS) that can utilize satellite-based rainfall information as input data so that flood forecasting and warning can be conducted even in river-basin where ground-based rainfall information are not sufficiently observed. IFAS has model creation function using the GIS data globally available. The system can be downloaded from its web site free of charge.
Now, an effective flood forecasting and warning system using IFAS has been introduced on the basin of the Solo River in Indonesia, the Indus River in Pakistan, and the Cagayan River in the Philippines.

Satellite / Sensor or products used in this case	GSMaP(GSMaP NRT, GSMaP MVK)
Effect(s) to be expected	Flood forecasting becomes available in areas where ground hydrological information (rainfall) is insufficient, and early evacuation warnings will be able to reduce the loss of human life and property damage caused by such floods.
User / Purpose	Actually applied (Person in charge of River Disaster Prevention in each country)
Utilization Period (Phase)	From April 2011 (Ongoing)
Referenses	http://www.icharm.pwri.go.jp/research/ifas/





Utilization of the GSMaP in the Flood Prediction/ Warning System in Developing Countries in Asia

Asian Development Bank (ADB).. https://www.adb.org/

Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA)......... http://www.pagasa.dost.gov.ph/

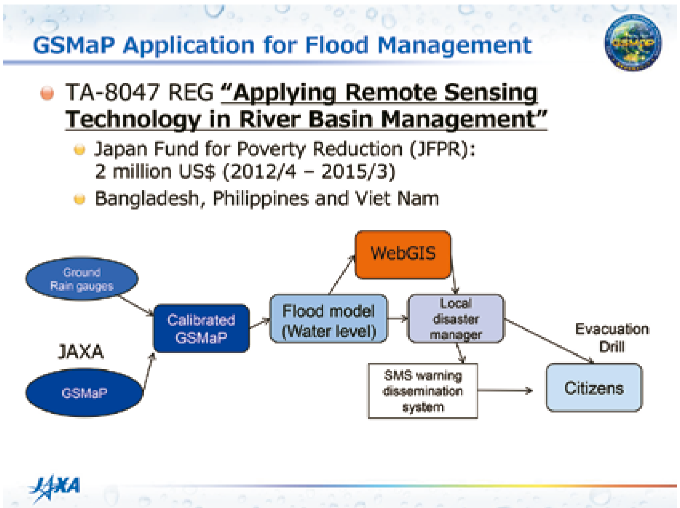
National Hydro-Meteorological Service (NHMS)....... http://www.nchmf.gov.vn/web/en-US/43/Default.aspx

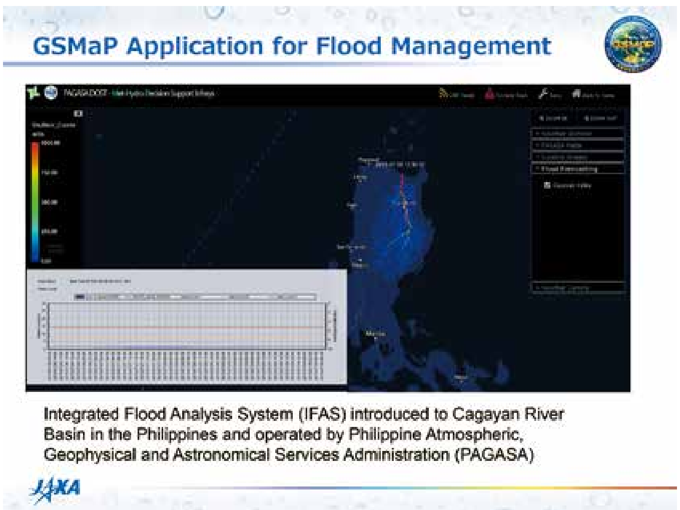
Bangladesh Water Development Board (BWDB) .... http://www.bwdb.gov.bd/

Description

For further effective flood prediction, GSMaPis used effectively as input data to the Integrated Flood Analysis System (IFAS) developed by ICHARM in the Cagayan River basin in the Philippines and to the flood model based on MIKE11 in the Red-Thai river basin in Vietnam. In the developing countries that do not have many ground rain gauges, GSMaP is expected to play an important role in wide-area rainfall information gathering, and can be used free of charge.

Satellite / Sensor or products used in this case	GSMaP (NRT)
Effect(s) to be expected	A reduction of flood damage can be expected with the introduction of the flood model with higher reliability and a longer lead-time.
User / Purpose	Actually utilized
Utilization Period (Phase)	From April 2012 to March 2015 (Completed)





Utilization Cases of Rainfall Observation from Space

Agriculture

- Utilization in the Food Security Package
- Drought monitoring system for the regional cooperation for food security on the Mekong River basin
- Development of Weather-based Index Insurance using GSMaP

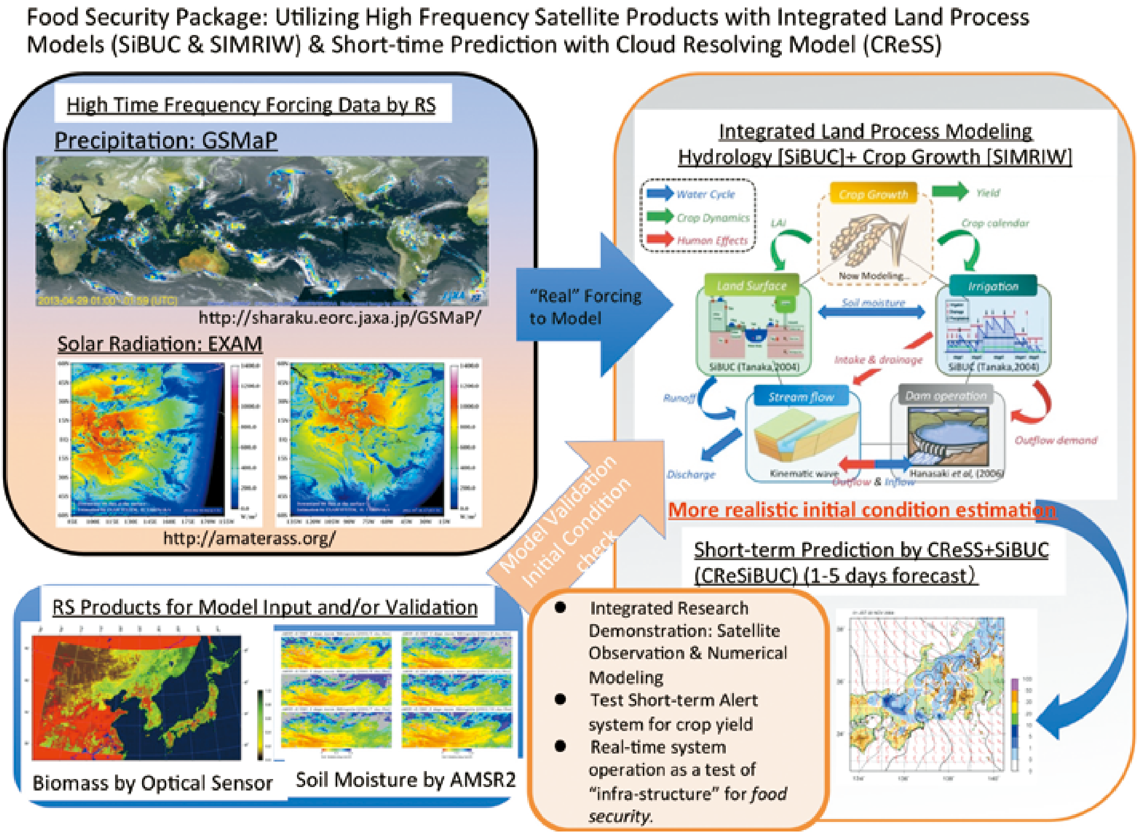
Utilization in the Food Security Package

Chiba University .... http://www.chiba-u.ac.jp/e/index.html
Kyoto University .... http://www.kyoto-u.ac.jp/en
Nagoya University .... http://en.nagoya-u.ac.jp/
JAXA Earth Observation Research Center.... http://www.eorc.jaxa.jp/en/index.html
University of Yamanashi .... http://www.yamanashi.ac.jp/en/
Institute of Physical and Chemical Research.................. http://www.riken.jp/en/

Description

The parameters for the items of solar radiation and precipitation are input, where estimations for wide areas are difficult with other means than satellite observation. Wide area crop is estimated based on the combination of the integrated land surface process model and crop growth model. Based on the cloud analysis model and the integrated land surface process + crop growth model, crop growth estimations to within one to five days later are performed, and are put to use in deciding on measures for crop and water management. The method to optimize the parameters in the integrated land surface/crop growth model is developed by comparison and validation of each element from model calculations with soil moisture content, model initial value (frequency is low), and products important for verification. This would be the first step for playing a role partly as semi-public property infrastructure contributing to Japan or world food security.

Satellite / Sensor or products used in this case	GSMaP(NOW, NRT, Gauge)
Effect(s) to be expected	The final use is for yield. However, because heat balance and water balance are also analyzed in the integrated land surface process model, it is available in the water resource related fields (high versatility for output).
User / Purpose	Utilization for Research
Utilization Period (Phase)	from 2013 (Ongoing)



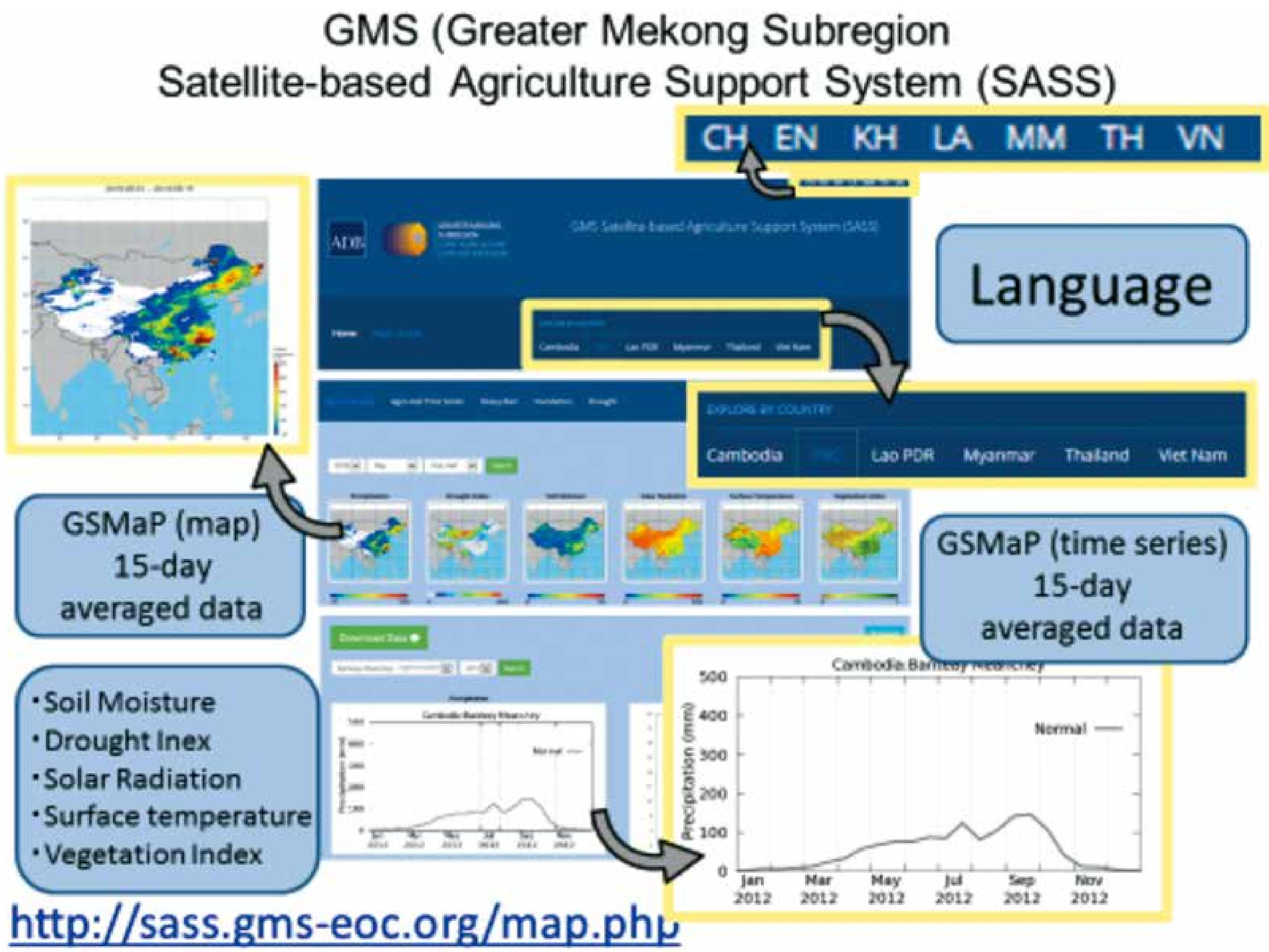
Drought monitoring system for the regional cooperation for food security on the Mekong River basin

Asian Development Bank (ADB)
https://www.adb.org/

Description

The Mekong River basin (Greater Mekong Subregion: GMS) is an area where a regional-cooperation type development initiative is being taken. The goal is to enhance economic development and reduce poverty, in cooperation with the member nations of Cambodia, China (Yunnan Province and Kwangsi Chuang Autonomous Region), Laos, Myanmar, Thailand and Vietnam. ADB introduced the drought monitoring system for GMS. Using this system, the draught index can be checked daily free of charge, for every 10km2 area in each member country of GMS. With this system, the GSMaP data is used effectively. The draught index map and graph for all points are automatically prepared every day.

Satellite / Sensor or products used in this case	GSMaP (NRT)
Effect(s) to be expected	The local draught condition data is shared by related institutions including agricultural statistics organizations in six member countries, for regional food security on GMS, which is reflected in the policies of each country.
User / Purpose	Actually utilized
Utilization Period (Phase)	From May 2013 to December 2015 (Completed)



Development of Weather-based Index Insurance using GSMaP

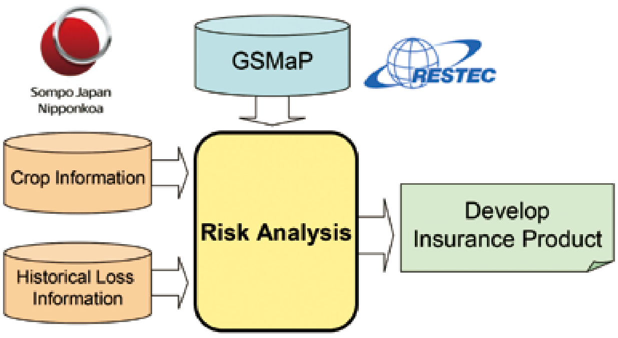
Sompo Japan Nipponkoa....................................http://www.sjnk.co.jp/english/
Sompo Risk Management & Health Care Inc..................https://sompo-rc.co.jp/
Remote Sensing Technology Center of Japan ....https://www.restec.or.jp/en/

Description

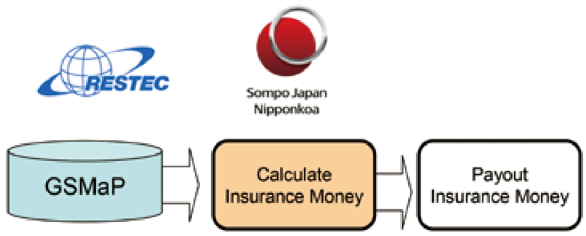
We jointly developed "Weather Index Insurance" utilizing GSMaP for small farmers in Myanmar, which is the Japan's first case.
The possibility of developing "Weather Index Insurance" spread even in other developing countries where the ground infrastructure related to weather observations is not well developed.

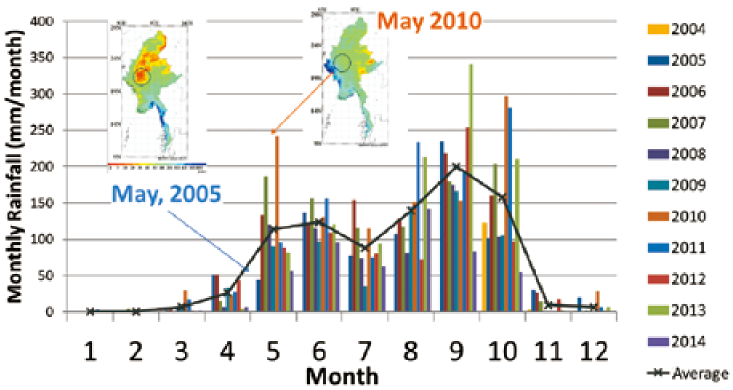
Satellite / Sensor or products used in this case	GSMaP (NRT)
Effect(s) to be expected	We can widely provide this insurance which is attracting attention as an adaptation measure to climate change for small farmars.
User / Purpose	Actually utilized
Utilization Period (Phase)	Developing phase: from 2014 (Ongoing) Operating phase: undecided (We are currently in negotiations with the government for sales.)

Developing phase



Operating phase





Utilization Cases of Rainfall Observation from Space

Energy / Resources

- Applications to Renewable Energy

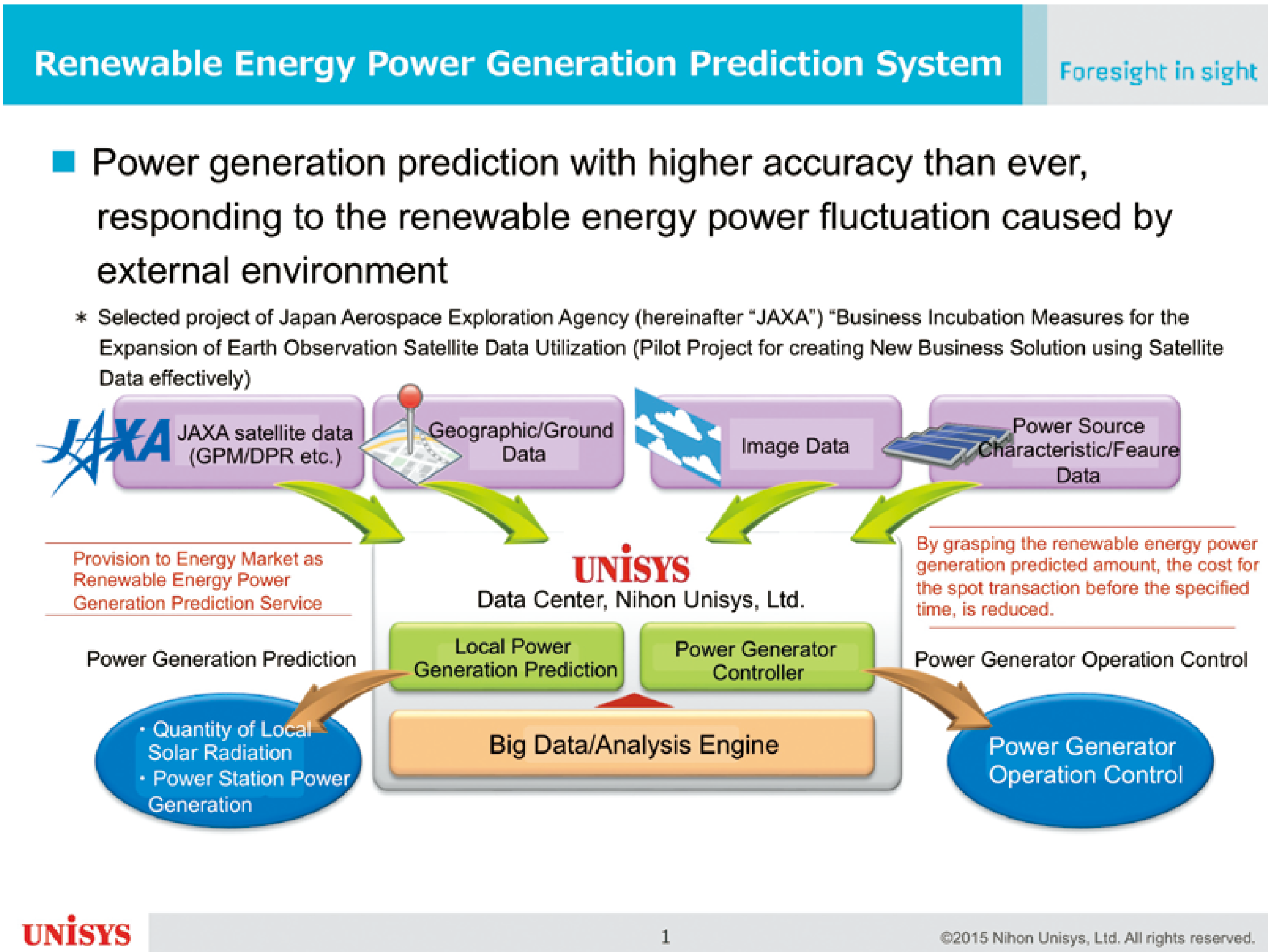
Applications to Renewable Energy

Nihon Unisys, Ltd.
https://www.unisys.co.jp/e/index.html

Description

Based on the big data obtained from the satellites and ground-based sensors, the prediction of renewable energy power generation amount is performed using the FEM numerical analysis and statistical methods. GPM/GSMaP are used to obtain the tendency before rainfall, and prediction accuracy enhancement is available. For satellite data, because it requires some man-hours before use (data preprocessing), and sometimes resolution is low depending on the application field (observation frequency and grid width), estimation technology development is required. However, using satellite data, better wide range observation data is attainable compared to ground-based sensors.

Satellite / Sensor or products used in this case	GPM GSMaP Others
Effect(s) to be expected	With careful planning to balance supply and demand, appropriate to fluctuations in electric power supply and demand, and adjustments combined with other power generators, a stable power supply and an increase of interconnection capacity can be expected.
User / Purpose	Actually applied (electric power company, electric power retailer, electric power device maker, etc.)
Utilization Period (Phase)	From May 2014 (Ongoing)
Referenses	https://www.unisys.co.jp/e/solutions_services.html



Utilization Cases of Rainfall Observation from Space

Climate / Water Resource Management

- Utilization of Rainfall Data for enhancing the Accuracy of Tropical Monsoon Forest Survey
- Calibration of Ground Precipitation Observation Data with GSMaP in the Central Area of Vietnam

Utilization of Rainfall Data for enhancing the Accuracy of Tropical Monsoon Forest Survey

Asia Air Survey Co., Ltd.
http://www.ajiko.co.jp/en/

Description

REDD+ (Reducing Emissions from Deforestation and forest Degradation in developing countries plus) is one of the global warming countermeasures. It has the forest inventory map required for monitoring the reduction or degradation of forests all over the country and for forest management, created and based on satellite image analysis, etc. The problem with creating a map of tropical monsoon forests in steep mountainous areas in Southeast Asia, is that the zoning accuracy of both evergreen forest and deciduous forest, is low using analyzed data from satellite images obtained from LANDSAT. The possibility of enhancing the accuracy of forest survey investigations of evergreen forest, deciduous forest and mixed forest, was examined using TRMM rainfall distribution data as auxiliary data, which is because the amount of leaves that fall in the dry season basically depends on the soil moisture content.At first, the mean annual rainfall map created based on ground-based rainfall data (1988 to 2007) in the existing 19 locations, was compared with the estimated mean annual rainfall map (1998 to 2009) by TRMM. As the result, in the locations around the ground observation points, consistency is found. However, in the mountain areas or areas without any ground observation point, there are large differences in the rainfall distribution between these two maps (Refer to Fig.1).This result shows that the TRMM data is effective for complementing the overall rainfall data in areas with just a few or no ground observation points. However, for the absolute value of rainfall, the final result was that the estimated value obtained from TRMM was larger. This shows that depending on the utilization purpose, calibration using ground observation data would be required.

In addition, when the existing forest map, the forest map obtained from the analysis of the satellite images of the subject area and site investigation etc., and the annual rainfall distribution map are compared, a correlation to a certain degree was found between evergreen forest distribution and rainfall distribution. However, in the border area of monsoon forest, there is an evergreen forest distribution even though the rainfall is relatively low. In this area, it was observed in the site investigation that wettability is high even in the dry season. In the analysis of vegetation types, it was suggested that the analysis of land conditions considering the requirements related to soil moisture such as the nature of the soil and inclination, as well as rainfall, and influence of land use including slash-and-burn farming, would be required.

Satellite / Sensor or products used in this case	TRMM (2B31 processed data)
Effect(s) to be expected	It seems that the relationship between the land conditions and vegetation type in the tropical region, has not been analyzed in detail yet. We believe that regarding rainfall as an important land condition, rainfall observation data using remote sensing from a satellite, would have great potential to be useful information in fields including related forest investigation and biodiversity conservation.
User / Purpose	Utilization for Research
Utilization Period (Phase)	From August 2014 (Ongoing)

Fig.1 Estimated Annual Mean Rainfall Map (Bookhagen, B.'s analysis data was edited to create) based on TRMM Data (1998 to 2009) and Comparison with Existing Forest Map

Data: FIPD, Edited Lao PDR

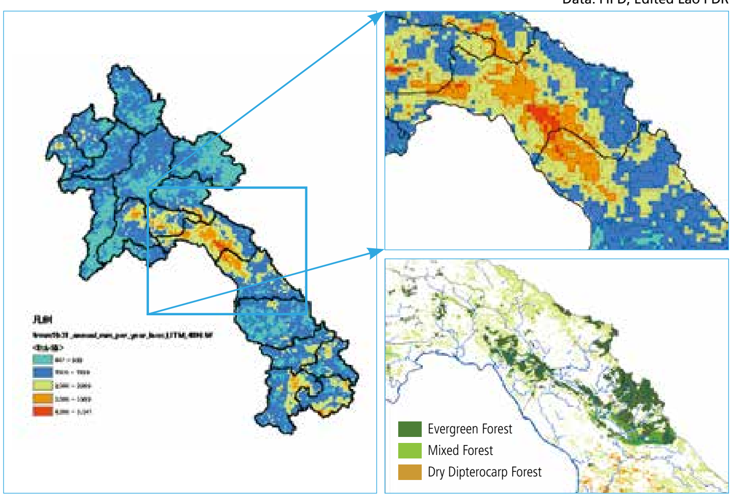


Fig.2 Site Investigation Photographs (in the dry season)

Mixed Forest

Evergreen Forest

Calibration of Ground Precipitation Observation Data with GSMaP in the Central Area of Vietnam

Tokyo Metropolitan University, Hachioji
http://www.tmu.ac.jp/english/index.html

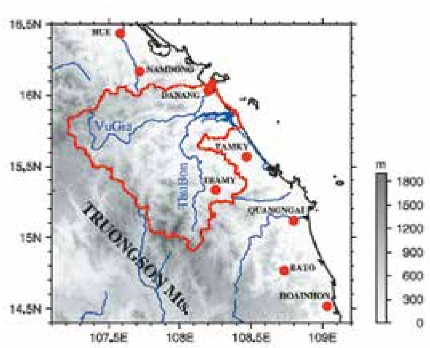
Description

The accuracy of the GSMaP_MVK v5.222.1 monthly precipitation data in the central area of Vietnam was examined using the ground rain gauge observation data and APHRODITE (Asian Precipitation - Highly-Resolved Observational Data Integration Towards Evaluation) data (*). Then, it was pointed out that the accuracy of the data, in particular, in the coastal region was low. In order to improve the accuracy, we have developed a new method where the correction is performed through neural networks using the past data. In central Vietnam where mountains are close to the seacoast, the GSMaP_MVK v5.222.1 data used at that time had a disadvantage. This is because the accuracy was quite low, in particular, in the seacoast area, and the original data was not appropriate for actual use.

*APHRODITE Data: Continental-scale and long-term data product provided daily based on the observation data in Asian region

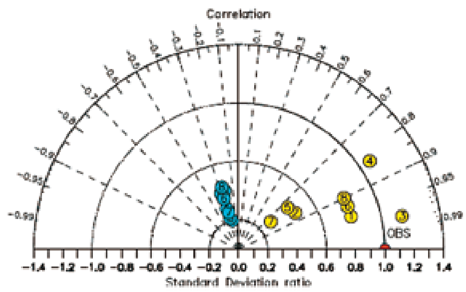
Satellite / Sensor or products used in this case	GSMaP (MVK ver. 5.222.1)
Effect(s) to be expected	By evaluatingaccurate precipitation in mountainous regions along the coastline, and examining the data in a shorter time scale, an application for actual use is expected.
User / Purpose	Utilization for Research
Utilization Period (Phase)	From August 2012 to October 2013 (Completed)
Referenses	Ngo-Duc, T., Matsumoto, J., Kamimera, H. and Bui, H.H. 2013: Monthly adjustment of Global Satellite Mapping of Precipitation (GSMaP) data over the VuGiaof Global Satellite Mapping of Precipitation using an artificial neural network. Hydrological Research Letters 7: 85–90, doi: 10.3178/hrl.7.85 http://www.hrljournal.org/archives/1540

Fig.1



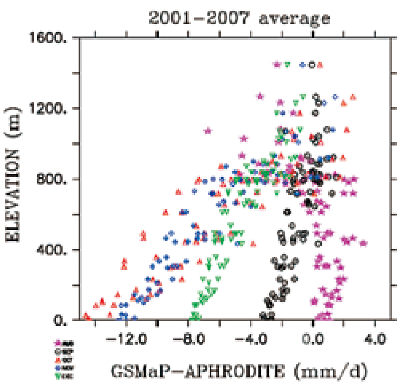
The Central Part of Vietnam VuGia-ThuVon River Basin is to be selected as a subject for research
(Ngo-Duc et al., 2013)

Fig.2



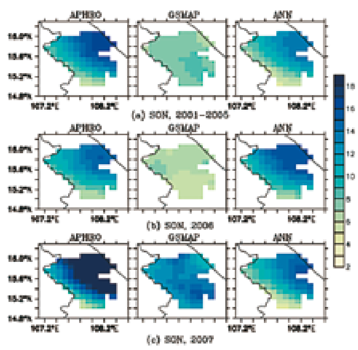
Tailored Diagram for the monthly precipitation based on ground observation in 8 locations within the research subject area in Fig.1 (red circles), and GSMaP (blue circles), and APHRODITE (yellow circles)
(Ngo-Duc et al., 2013)

Fig.3



Difference in Monthly Precipitation between the GSMaP data for each set altitude and APHRODITE data in the VuGia-ThuBon River between August and December, which is the rainy season in central Vietnam
(Ngo-Duc et al., 2013)

Fig.4



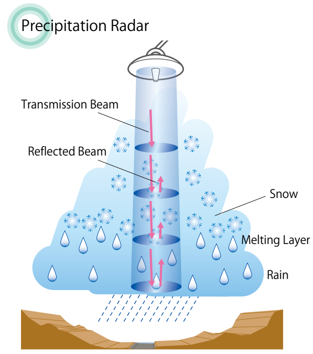
Precipitation in the VuGia-ThuBon River basin between September and November based on the APHRODITE (left), and GSMaP data before correction (center) and data after correction through neural networks. The right upper stage shows the mean values between 2001 to 2005, based on presumptions with teaching. The center and lower stages show the mean values in 2006 and 2007 without teaching.
(Ngo-Duc et al., 2013)

Rainfall Observation from Space

Rainfall observation by precipitation radar

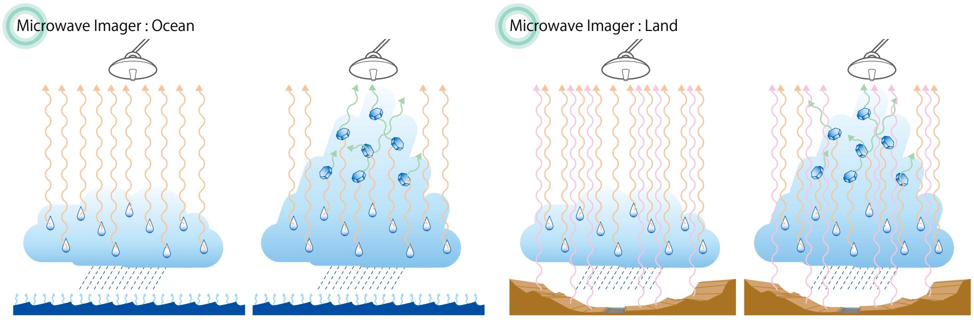
Precipitation radar is an active microwave instrument, which emits a pulse of electromagnetic waves and receives the echoes from raindrops and/or snow particles, and the rainfall and/or snowfall rate is estimated from the intensity of the echo. The distance (height) from the radar to the rain corresponds to the time difference between the transmission of the pulse and the reception of the echo. By combining this distance with the direction of the antenna beam, the location of the rain that causes the echo can be determined in a three-dimensional space.

Since the signal source is the known electromagnetic waves radiated by the radar itself, the quality of data is hardly affected by the background, i.e., whether it is land or ocean. Even though the swath width is rather narrow, PR and DPR have the advantage of high spatial resolutions: about 5 km in horizontal and about 250 m at nadir in vertical.



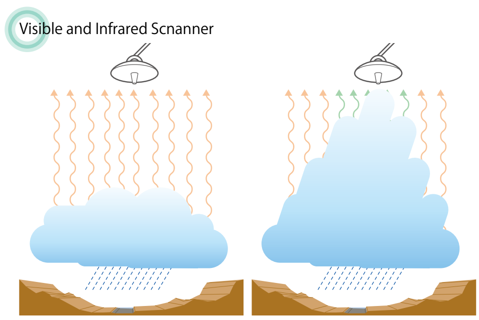
Rainfall observation by microwave radiometers

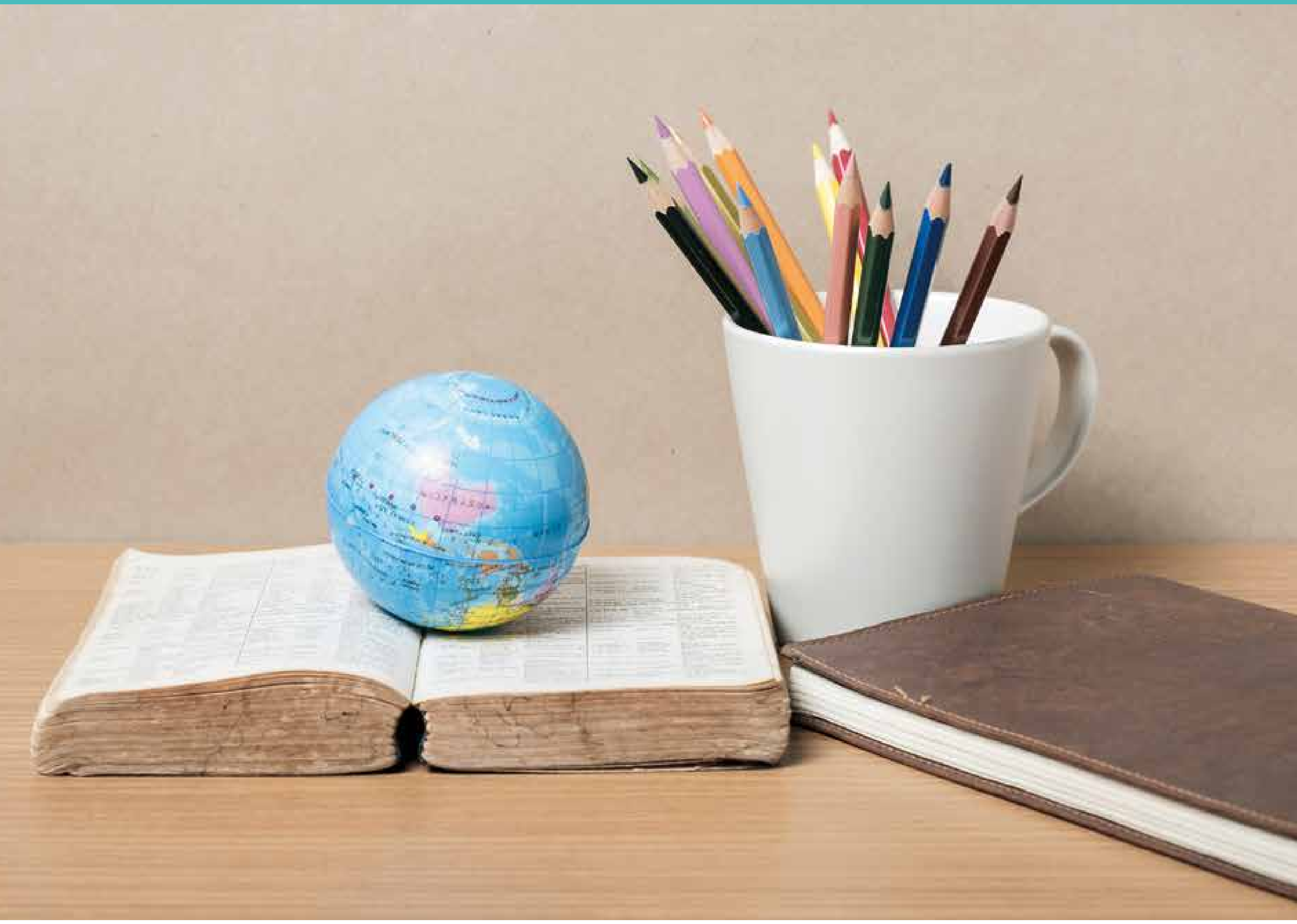
Microwave radiometers, including microwave imagers (such as TMI) and sounders (such as AMSU), can estimate rain rate by measuring the intensities of microwaves radiated or scattered by raindrops. If rainfall becomes heavy, raindrops at higher altitudes could absorb microwaves radiated by raindrops at lower altitudes and information of lower rainfall is difficult to obtain by the microwave intensity observed from space. As the observation frequency increases, the effect of microwave scattering by ice particles at higher altitudes increases. We can estimate rainfall type, its height, and rain rate by using those differences between effects of absorption and scattering in different frequencies, if we measure microwave radiation at multi-frequency channels.



Rainfall observation by visible and infrared imagers

Visible and infrared imagers, such as VIRS, can measure the intensities of electromagnetic waves at visible and infrared wavelengths. Intensity of infrared light corresponds to the cloud-top temperature when it is measured from space regardless of whether it is day or night. Since the relationship between the atmospheric temperature and the altitude is approximately known, the height of the cloud can be estimated from the cloud-top temperature. Through rain rate, it is inferred that there is heavy rain with high probability under clouds that have developed to high altitudes. Such inferences are not accurate in individual cases. For example, anvil clouds appear in association with cumulonimbus at a high altitude, but the rain rate under it is not heavy.





Utilization Cases of Rainfall Observation from Space

Education / Design

- Utilization of Satellite Data
  in the Digital Terrestrial Globe "Tangible Earth"

Utilization of Satellite Data in the Digital Terrestrial Globe "Tangible Earth"

Earth Literacy Program
http://www.elp.or.jp/en/

Description

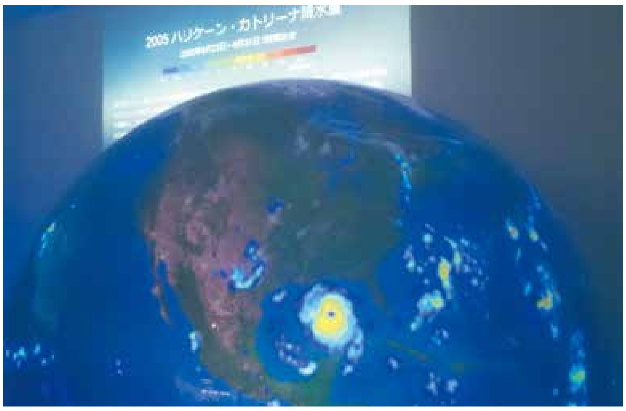
The "Tangible Earth" is a digital terrestrial globe model, where various global phenomena, including daily weather, global warming simulation, earthquake occurrence, tsunami generation, movement of migratory birds, urban population increases, etc., are projected and overlapped on a hemispherical display with a diameter of 80cm, to enhance new-generation literacy about earth processes. This has been employed in schools, science museums, natural history museums and company museums, etc.

Various remote sensing dataset such as cloud images are updated hourly. Vegetation data and ice & snow data obtained using the MODIS sensors have been also installed in it. Rainfall data obtained using TRMM/GSMaP is one of them.

The attached image shows Hurricane Katrina just before landing on the U.S. mainland, projected on the "Tangible Earth" display. The animation updated every three hours, has been created with this image as the contents, which can be overlapped with cloud images and the trajectory data of the hurricane. The hurricanes developing condition and movement with increased rainfall can be shown realistically. Also, when the replay time is extended, the hurricanes that hit one after another in summer and autumn in 2005 can be seen. Also, when the terrestrial globe is turned to show the area around Japan, we can understand that typhoons hit Japan also in the same period. Such understanding of global scale, local, short-term and long-term phenomena has been enabled with the effective use of "Tangible Earth" and remote sensing data.

Also, in the past, the distribution of near real-time rainfall was performed with some digital terrestrial globes using "JAXA Global Rainfall Watch" (GSMaP_NRT). We are going to update this system using "JAXA Realtime Rainfall Watch" (GSMaP_NOW) and distribution will be beginning within this year.

Satellite / Sensor or products used in this case	TRMM GSMaP
Effect(s) to be expected	Accessing weather information, in particular rainfall predictions, is common for us, such as in weather forecasts. However, when short-term weather predictions and global-scale long-term weather data are combined, we are sure that such data can be useful in an educational context. For example, where and when are typhoons generated exactly? How do they trace their course? How much has the number of occurrences changed? The combined terrestrial global and local weather data show these answers clearly and correctly. This system was introduced into the "Super Science High Schools" in 2015, and actual use in classrooms has begun. The use of this system is increasing in museums and libraries.
User / Purpose	We distribute the data content with specific themes from the Earth Literacy Program to schools, science museums, natural history museums and company museums, etc., that have purchased the "Tangible Earth".
Utilization Period (Phase)	From 2013 (Ongoing)
Referenses	http://earth-museum.jp/en-2/



Utilization Cases of Rainfall Observation from Space

Public Hygiene

- Utilization in Risk Assessment for Malaria or Cholera Outbreak around Lake Victoria in Kenya

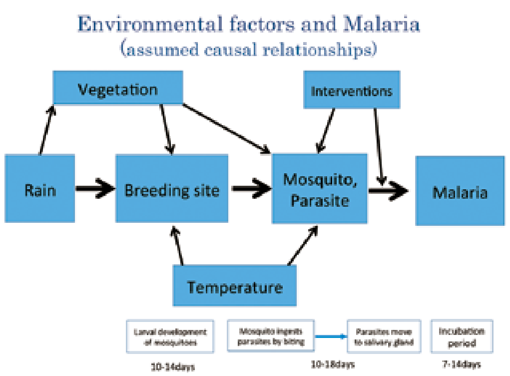
Utilization in Risk Assessment for Malaria or Cholera Outbreak around Lake Victoria in Kenya

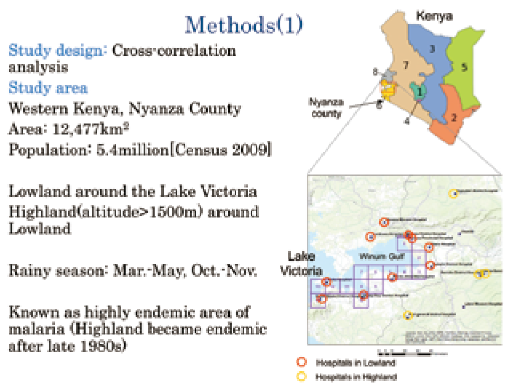
Institute of Tropical Medicine,
Nagasaki University, etc. .... http://www.tm.nagasaki-u.ac.jp/nekken/english/index.html
JAXA Earth Observation Research Center ....http://www.eorc.jaxa.jp/en/index.html
Remote Sensing Technology Center of Japan .... https://www.restec.or.jp/en/

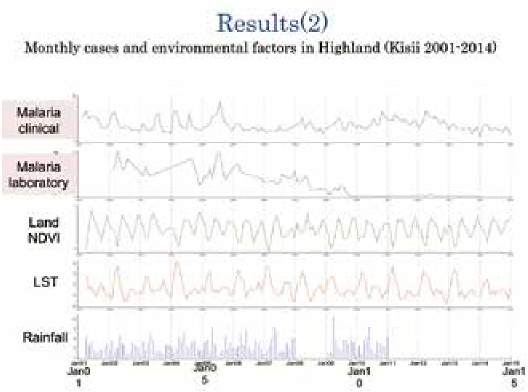
Description

"The association between environmental factors and malaria, diarrhea around the Lake Victoria in Kenya": The resulting report of the Lake Victoria Project conducted by the Institute of Tropical Medicine Nagasaki University, JAXA, and RESTEC, was presented at the International Society for Environmental Epidemiology Asia Chapter Conference on June 28, 2016. The main theme was environment, health and sustainable society. The data relating to diarrhea and malaria outbreak, and daily environmental data (MODIS ground temperature, lake-surface temperature, normalized vegetation index, GSMaP grid daily rainfall) in the highland and the lowland, was converted into weekly and monthly data. Next, auto correlation analysis was conducted for the past 0 to 10 months and related estimations and process examinations were performed. As a result, a positive correlation between rainfall and malaria which had occurred two or three months after incidents of rainfall was found in the highland, and a negative correlation of malaria occurrence immediately after, and up to five weeks after rainfall was found. For the correlation between ground-surface temperature and lake-surface temperature and malaria, a positive correlation was found in the lowland, where it occurred five weeks later. As a result, it was found that malaria had a significant correlation with environmental factors. Therefore, there is a solid base of science and data established to explore the development of a system for predicting these phenomena. In the future, we will conduct a time-series analysis, considering the influence of confounding factors and make efforts to develop a prediction model.

Satellite / Sensor or products used in this case	GSMaP Rainfall, JASMES (MODIS) ground-surface temperature, lake-surface temperature, normalized vegetation index, etc.
Effect(s) to be expected	Effective use of satellite remote sensing data for public hygiene
User / Purpose	Medical Institutes, Reduction of Infectious Diseases in and out of Japan
Utilization Period (Phase)	From April 2013 to March 2017 (Completed)







Utilization Cases of Rainfall Observation from Space

Meteorology / Weather Forecast

- Utilization of GSMaP for obtaining the Rainfall Present State in Ogasawara Village
- Tropical Cyclone Intensity Forecast Guidance by using GSMaP

Disaster Management / Disaster Monitoring
Agriculture
Energy / Resources
Climate / Water Resource Management
Education / Design
Public Hygiene
Meteorology / Weather Forecast
Utilization in Asia Pacific region

Utilization of GSMaP for obtaining the Rainfall Present State in Ogasawara Village

Ogasawara Village Office
http://en.vill.ogasawara.tokyo.jp/

Description

For the "Rainfall in Ogasawara viewing from Space", a link to the real time Global Satellite Mapping of Precipitation (GSMaP_NOW Ogasawara Islands Version) has been added to the web site of the Ogasawara Village Office.
The Ogasawara Islands are out of range of the ground precipitation radar of the Japan Meteorological Agency and Chichijima and Hahajima have only one ground rain gauge each. Therefore, it was difficult to grasp the horizontal distribution of rainfall with only ground observations. However, accessing this site, the real time rainfall around the Ogasawara Islands can be obtained, which can be useful when typhoons approach from the sea.

Satellite / Sensor or products used in this case	GSMaP NOW
Effect(s) to be expected	The rainfall observation information can be obtained in real time in Ogasawara Islands even though it is out of the observation range of the ground rainfall radar of Japan Meteorological Agency.
User / Purpose	Actually utilized
Utilization Period (Phase)	From April 2016 (Ongoing)
Referenses	http://sharaku.eorc.jaxa.jp/GSMaP_NOW/ogasawara_e.htm

Utilization in Ogasawara Village

The Ogasawara Islands are out of range of the ground precipitation radar of the Japan Meteorological Agency. Chichijima and Hahajima have only one ground rain gauge each.

Difficult to grasp the horizontal distribution of rainfall with only ground observations

Using "GSMaP Ogasawara Islands version"

Tropical Cyclone Intensity Forecast Guidance by using GSMaP

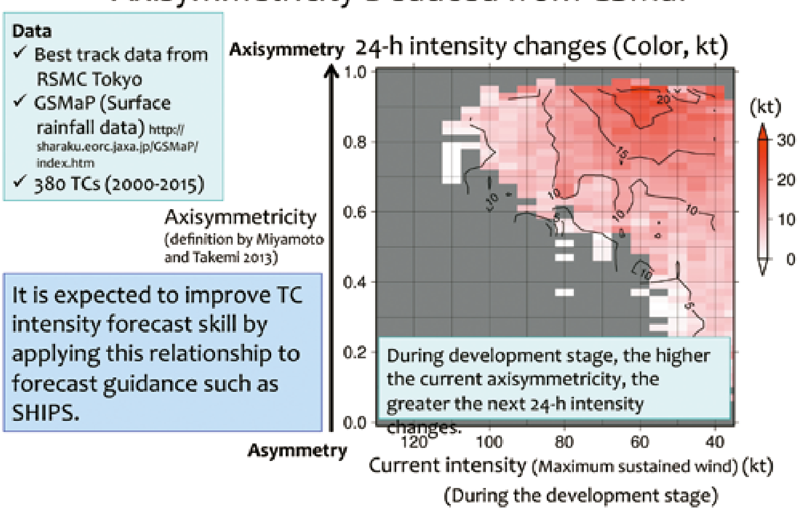
Meteorological Research Institute
http://www.mri-jma.go.jp/index_en.html

Description

Statistical Hurricane Intensity Prediction Scheme (SHIPS), which is a statistical multiple linear regression equation, is one of the tropical cyclone intensity forecast guidance used at operational centers in the world, and is one of the best intensity forecast models. As explanatory variables, SHIPS uses environmental conditions around a tropical cyclone, which are derived from a numerical weather model. However, SHIPS is not good at forecasting rapid intensification of tropical cyclones because of limitations in a multiple linear regression method based on past tropical cyclones' statistical data. According to current knowledge, the intensification of a tropical cyclone is not dependent only on environmental conditions, but controlled by processes associated with the inner-core dynamics of a tropical cyclone. Thus, by means of incorporating appropriate explanatory variables representing the inner-core processes into SHIPS's equation, the accuracy of forecast can be improved. In order to capture these inner-core processes, use of satellite data is appropriate.
As preliminary research for this, axisymmetricity of tropical cyclones was calculated based on GSMaP data, and the relationship between it and tropical cyclone intensity change was examined. The samples used were a total of 380 tropical cyclones that occurred in the western North Pacific basin between the years 2000 to 2015. Figure in the Separate Sheet shows intensity changes in the next 24 h (colors) relative to current intensity (maximum sustained wind speed) and axisymmetricity. It was found that intensity changes in tropical cyclones tended to become much larger when the axisymmetricity is larger. In contrast, rainfall distribution from hourly GSMaP data is changeable, depending on satellite data used in the GSMaP data. Also, the accuracy of real time analysis version of the GSMaP is not good enough. How to address these issues is a challenge regarding the application of the GSMaP data to SHIPS.
Currently, we are investigating whether there are other effective variables. Also, we are making a significant effort to improve the accuracy of SHIPS by incorporating the variable found here into SHIPS.

Satellite / Sensor or products used in this case	GSMaP
Effect(s) to be expected	Forecasting accuracy improvement is anticipated by incorporating variables calculated from GSMaP into SHIPS, which would further contribute to the improvement in tropical cyclone intensity forecast in JMA.
User / Purpose	Utilization for Research
Utilization Period (Phase)	From August 2015 (Ongoing)
Referenses	Shimada, U., K. Aonashi, and Y. Miyamoto, 2017: Tropical Cyclone Intensity Change and Axisymmetricity Deduced from GSMaP. Monthly Weather Review, 145, 1003-1017, doi:10.1175/MWR-D-16-0244.1.

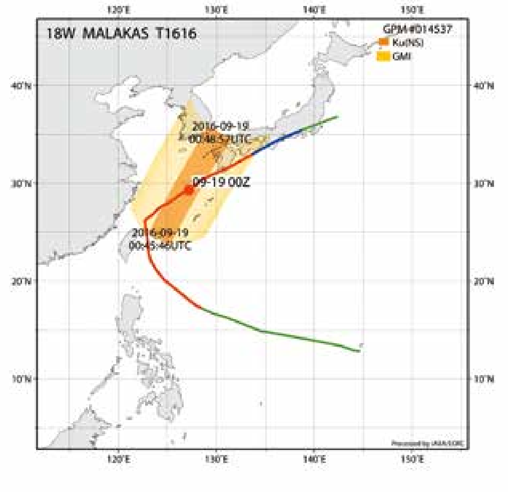
TC Intensity Change and Axisymmetricity Deduced from GSMaP



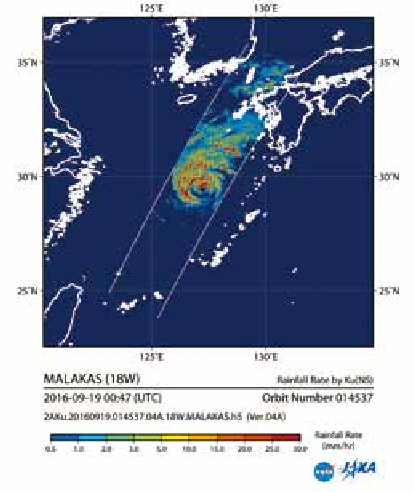
column2

Typhoon MALAKAS in 2016 observed by GPM

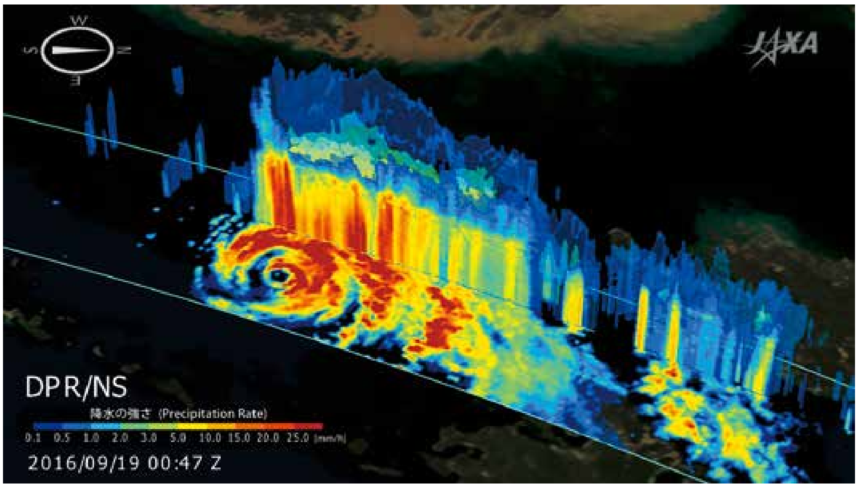
Track of Typhoon MALAKAS and DPR observation area

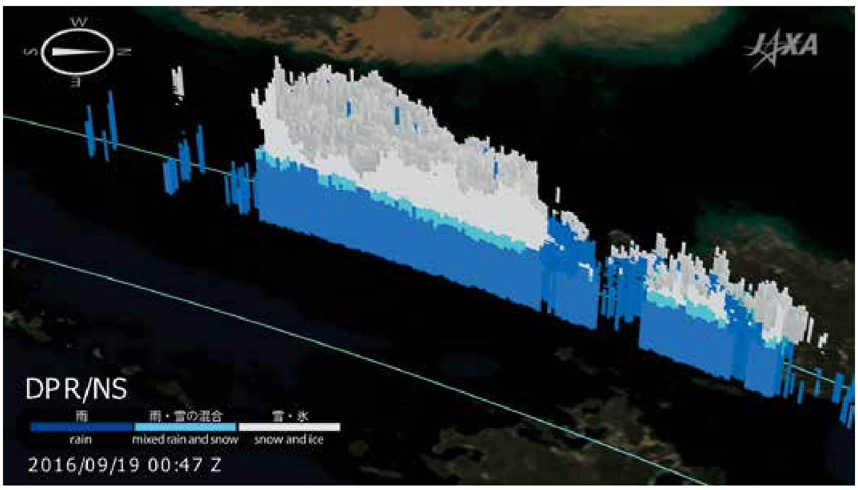


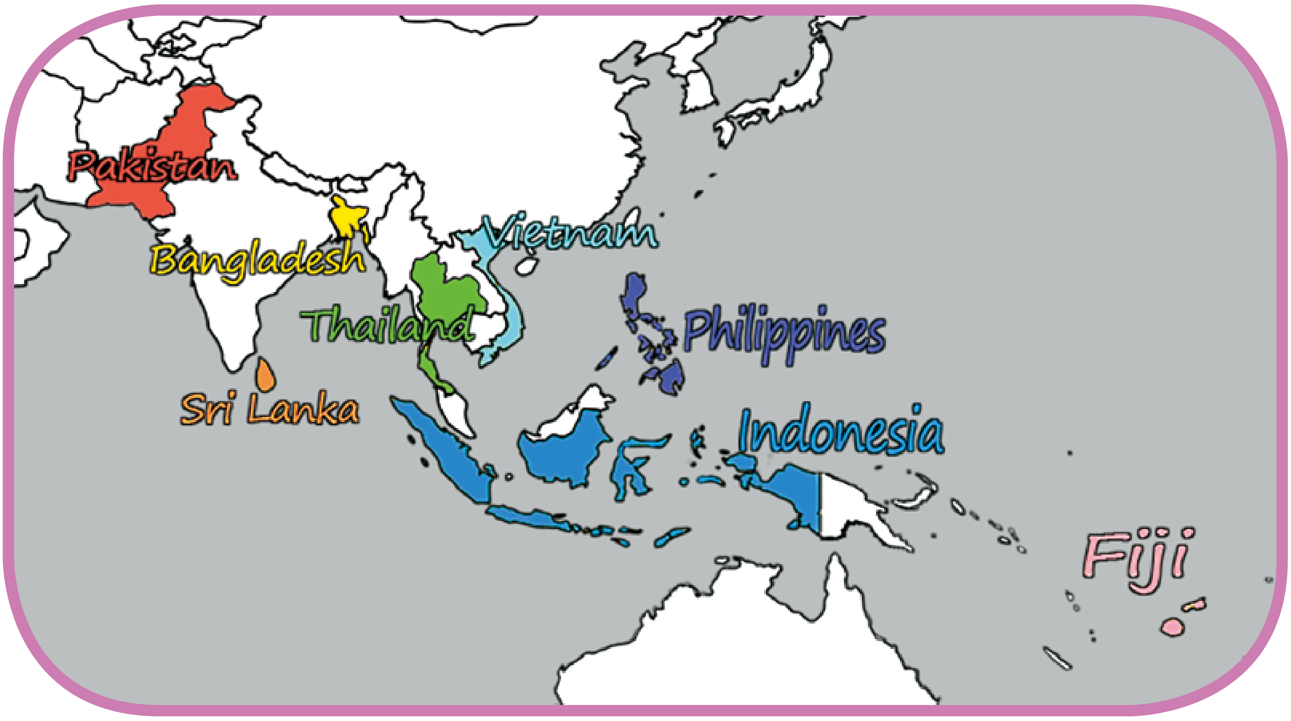
DPR surface precipitation (00:47UTC 19th September 2016)



DPR 3-demensional precipitation structure (precipitation intensity) and DPR 3-demensional precipitation distribution (rain/snow) in 00UTC 19th September, 2016







Utilization Cases of Rainfall Observation from Space

Utilization in Asia Pacific region

- Flood Prediction Systems and Rainfall Monitoring using GSMaP in Thailand
- Meteorological Utilization of GSMaP in Thailand
- Meteorological Utilization of GSMaP in Indonesia
- Hydrological Application using GSMaP in Vietnam
- Utilization of GSMaP in Philippines
- Flood Forecasting using GSMaP in Pakistan
- Flood Forecasting system using GSMaP in Sri Lanka
- Flood Forecasting System using GSMaP in Bangladesh
- Precipitation Monitoring using GSMaP in Fiji

Flood Prediction Systems and Rainfall Monitoring using GSMaP in Thailand

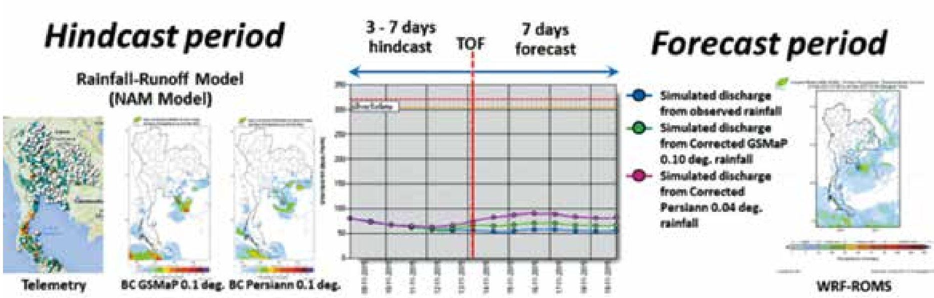
Hydro and Agro Informatics Institute
(HAII, Thailand)

Description

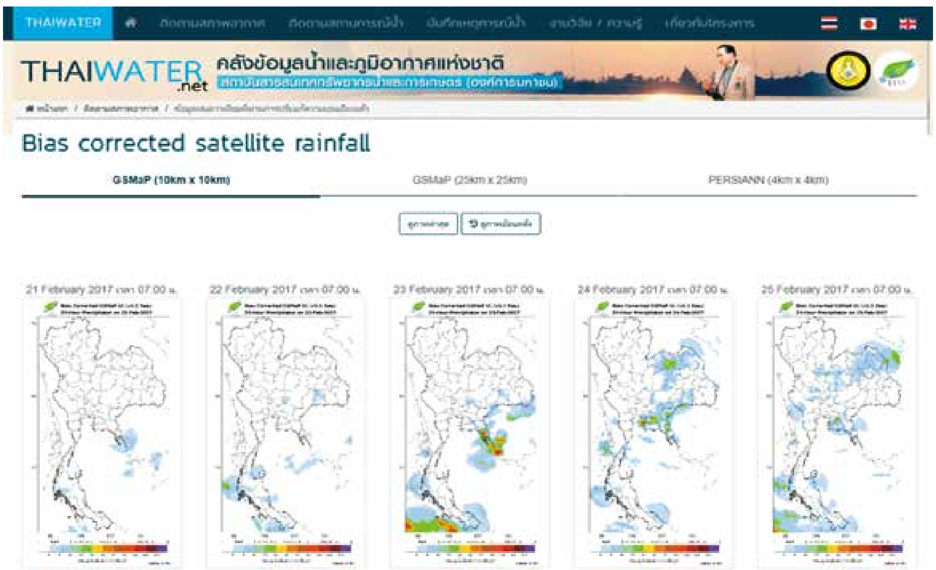
HAII used GSMaP in flood forecasting system and rainfall monitoring in Thailand. They developed a method to reduce the biases of GSMaP using Gamma-Gamma (GG) transformation. The bias corrected GSMaP precipitation is used as input variable for flood forecasting system to simulate more realistic runoff. The implementation and operation of the automated bias correction of the GSMaP in flood forecasting system have been carried on since October 2015 and the rainfall monitoring has been posted on their web site since January 2017.

Referenses	http://www.thaiwater.net/v3/gsmap/index

Satellite rainfall for operational flood forecasting



Source	Rainfall data	Domain	Spatial resolution	Temporal resolution	Delay	Time
HAII	Telemetry	Thailand	Point	Hourly	-	Hindcast Period
JAXA, HAII	Corrected GSMaP 0.1 deg.	Thailand (4.2°N-22.3°N, 96.5°E-108.7°E)	10km x 10km	Daily	~6 Hours	Hindcast Period
JAXA, HAII	Corrected Persiann 0.1 deg.	Thailand (5.6°N-20.4°N, 97.3°E-105.6°E)	4km x 4km	Daily	~4 Hours	Hindcast Period
HAII	WRF-ROMS	Regional (25°N-2°S, 86°E-120°E)	9km x 9km	Hourly	-	Forecast Period



Meteorological Utilization of GSMaP in Thailand

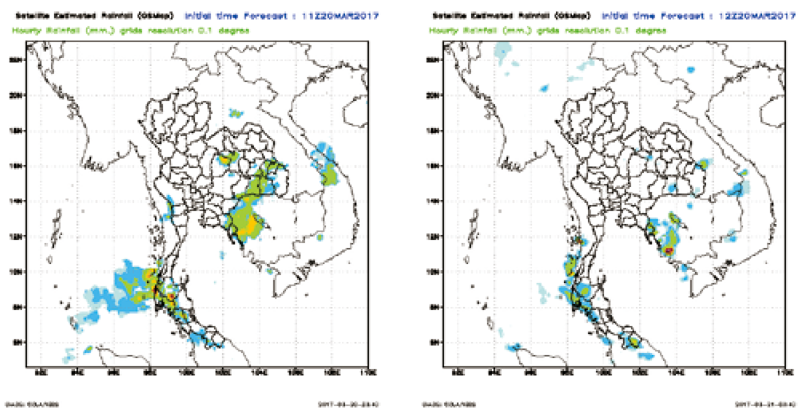
Thai Meteorological Department
(TMD, Thailand)

Description

Thai Meteorological Department (TMD) downloads the GSMaP data, converts to graphic in each hour and accumulate rain, converts to TEXT as same as Obs. Stations, and converts to lat./lon. for GIS, and also the TMD evaluates the GSMaP data using rain gauge data in Thailand. Steak holder in the Thailand need data such as EGAT (Electric Generate Authority of Thailand), RID (Royal Irrigation Department), Rice Department, NDWC (National Disaster Warning Center), DDPM (Department of Disaster Prevention Mitigation), NECTEC (National Electronics Computer Technology Center), get the data.

Referenses	http://www.satda.tmd.go.th/GSMaP/ http://www.satda.tmd.go.th/FY2E/Rain/ http://www.satda.tmd.go.th/all_gsmap_csv.php?date=20170107 http://www.satda.tmd.go.th/

Fig.1 GSMaP_NRT graphic in each hour cover Thailand, Cambodia, some part of PDR Lao, Vietnam and Myanmar.



GSMaPRain2017032011.gif GSMaPRain2017032012.gif

Fig.2 GSMaP_NRT accumulate rainfall

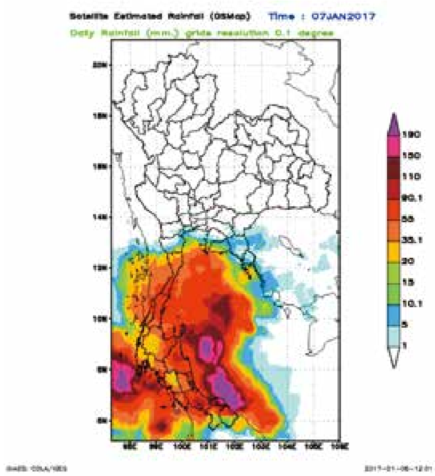


Fig.3 GSMaP_NRT (.csv format)

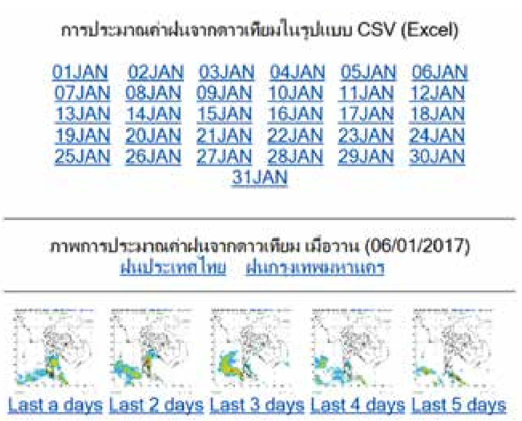
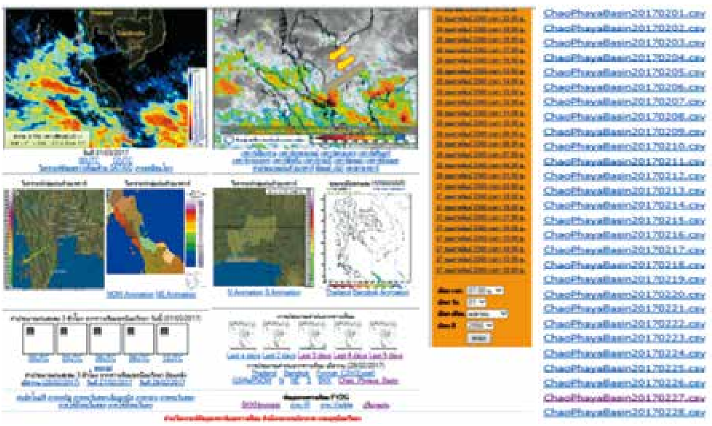


Fig.4 GSMaP_NRT (.csv format) in grid point. TMD's is generated .csv format support all users, need to use data in grid point: GIS, Surfer etc. program to integrate spatial rainfall in each basin.

In web site of URL: http://www.satda.tmd.go.th/BASIN/ChaoPhayaBasin/

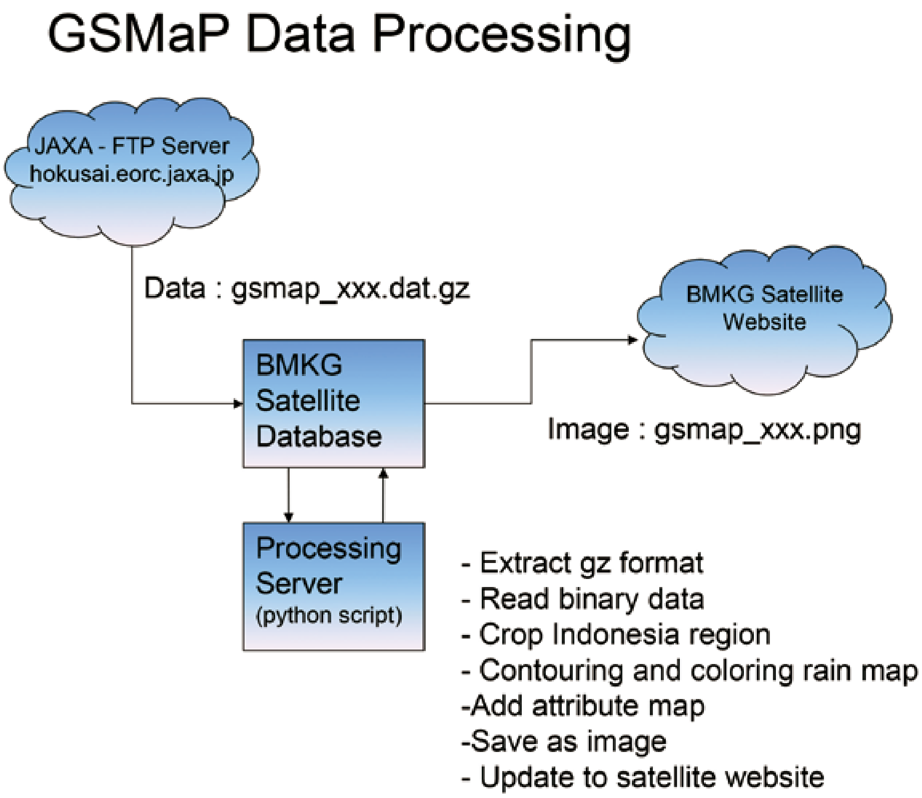


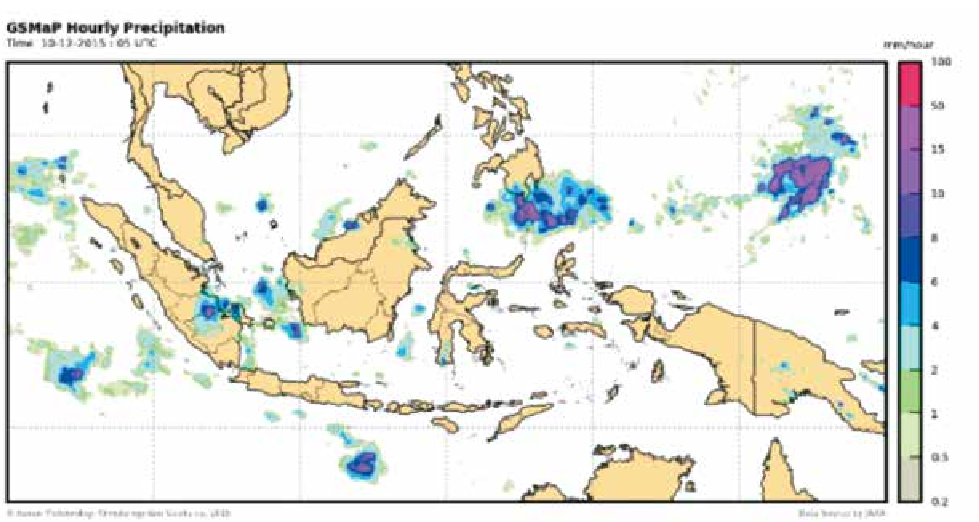
Meteorological Utilization of GSMaP in Indonesia

Meteorological, Climatological, and Geophysical Agency
(BMKG, Indonesia)

Description

BMKG obtains GSMaP data in binary files and displayed as an image for Indonesia region. GSMaP are used for analysis of hourly and daily rainfall accumulation to verify weather forecast. It has been also used for hydro-meteorological hazards analysis. To support operational weather forecasts and warnings, development of GSMaP derived products has been extended for other purposes such as MJO (Madden Julian Oscillation) onset and propagation, Drought and Forest Fire Potential Monitoring.





Hydrological Application using GSMaP in Vietnam

University of Science and Technology of Hanoi
(USTH, Vietnam)

Description

USTH first built new gridded rainfall datasets based on the daily-observed data from 481 rain gauges. The new datasets, called Vietnam Gridded Precipitation (VnGP) have the resolutions of 0.1° and 0.25° and cover the period 1980-2010 (Nguyen-Xuan et al., 2016). VnGP is currently available at the Data Integration and Analysis System (DIAS) managed by the University of Tokyo; and can be used as the reference to evaluate the performance of other datasets, including GSMaP.

Ngo-Duc et al. (2013) examined the performance of GSMaP over Vietnam for hydrological applications. Results showed that over the VuGia–ThuBon River basin and surrounding areas in central Vietnam (Fig 1), the GSMaP_MVK, version 5.222.1 has large negative rainfall biases for the winter monsoon period from October to December and the biases tend to increase as the elevation decreases. A correction method using an artificial neural network (ANN) was implemented and helped significantly improve the GSMaP quality in terms of spatial correlation, rainfall amplitude, and Nash–Sutcliffe efficiency coefficient for both the dependent period 2001–2005 and the independent period 2006–2007. The group is planning to continue the validation and application of the different products of GPM data recently reasleased, including GSMaP_NOW, GSMaP_NRT, GSMaP_MVK version 6.000, GSMaP_Gauge for hydrological forecasting in North Vietnam.

Referenses

Ngo-Duc T., J. Matsumoto, H. Kamimera, and H.-H. Bui, 2013: Monthly adjustment of Global Satellite Mapping of Precipitation (GS Ma P) data over the Vu Gia–Thu Bon River Basin in Central Vietnam using an artificial neural network. Hydrological Research Letters, 7(4), 85-90

Nguyen-Xuan, T., T. Ngo-Duc, H. Kamimera, L. Trinh-Tuan, J. Matsumoto, T. Inoue, T. Phan-Van, 2016: The Vietnam Gridded Precipitation (VnGP) dataset: Construction and validation. SOLA, 12, 291–296, doi:10.2151/sola.2016-057

Fig.1 Topography of the VuGia–ThuBon River basin (red boundary) and surrounding areas. Locations of eight meteorological stations used in the study are indicated by red circles
(Ngo-Duc et al., 2013)

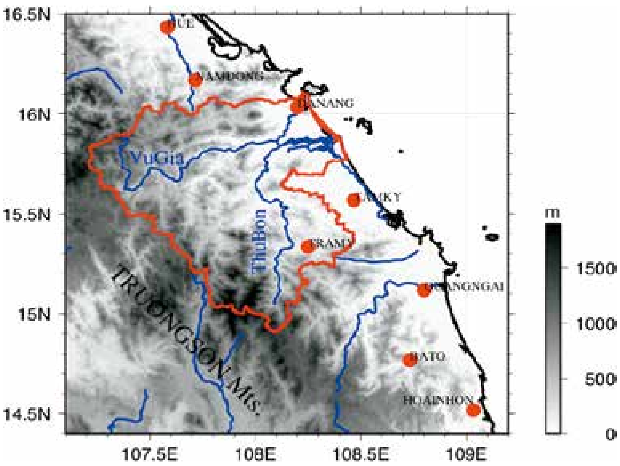
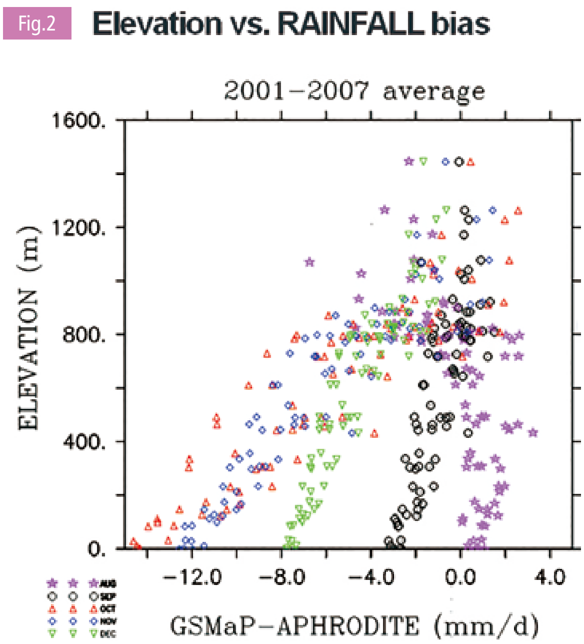


Fig.2

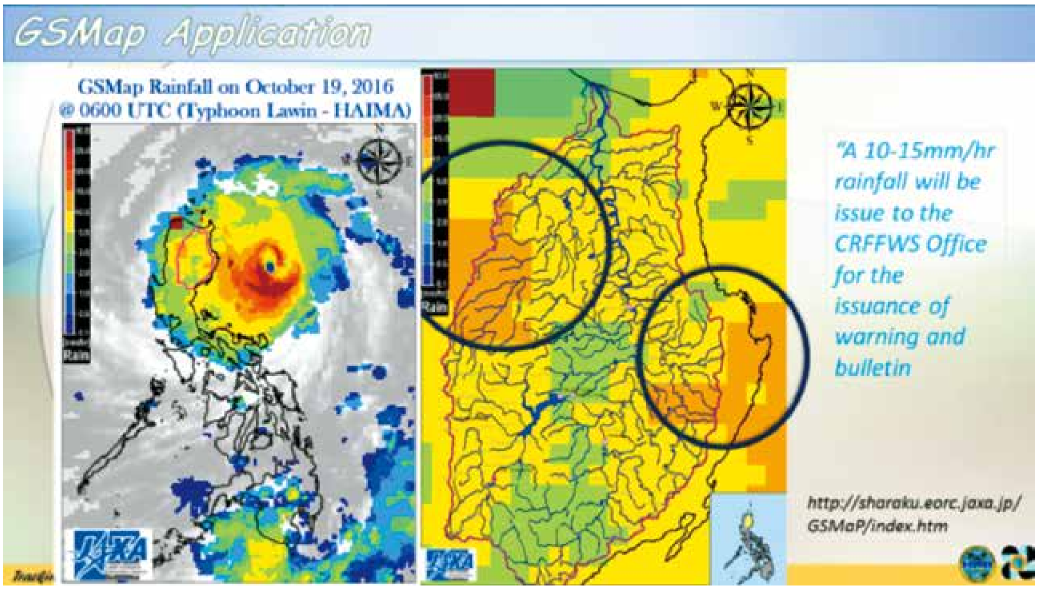


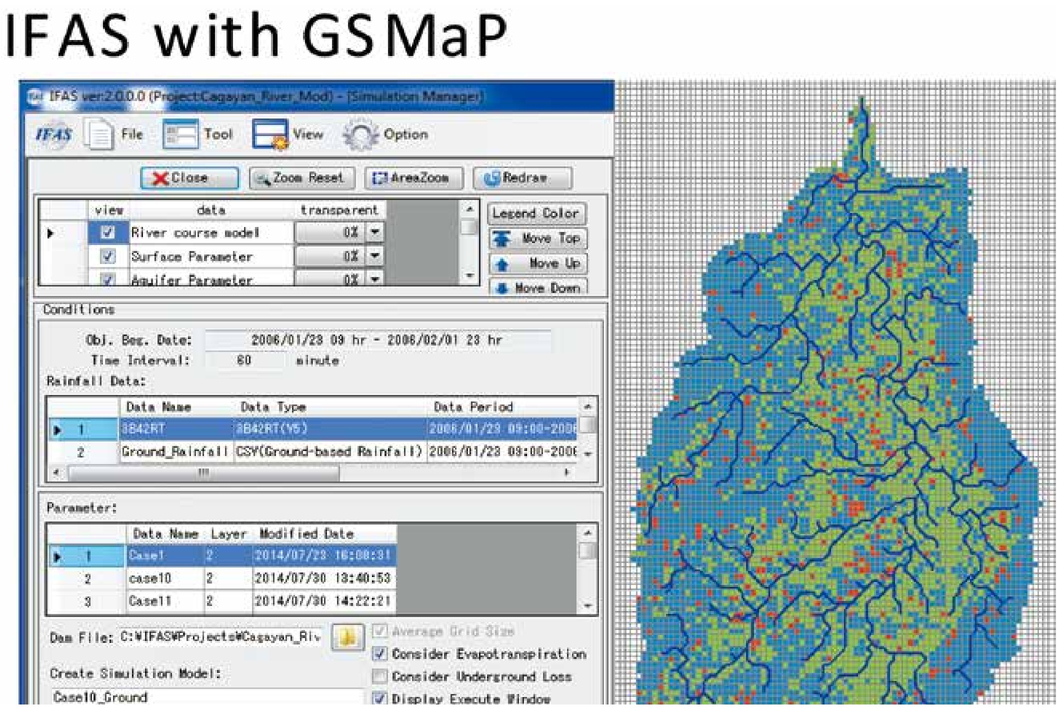
Utilization of GSMaP in Philippines

Philippine Atmospheric, Geophysical,
and Astronomical Services Administration (PAGASA, Philippines)

Description

Philippine Atmospheric, Geophysical, and Astronomical Services Administration (PAGASA) uses GSMaP in typhoon rainfall monitoring and flood forecasting. GSMaP was used for the rainfall spatial distribution during typhoon landfall (e.g. TY Sendong (Washi 2011), TY Pablo (Bopha 2012)). It also served as an additional tool for non-telemetered river basins for Flood Analysis in PAGASA such as identifying location of high rainfall occurrence. Moreover, it is used in River Basin Monitoring, at which GSMaP is integrated to IFAS (IFAS with GSMaP Technologies) to forecast and manage floods in Cagayan River Basin (ADB Project).



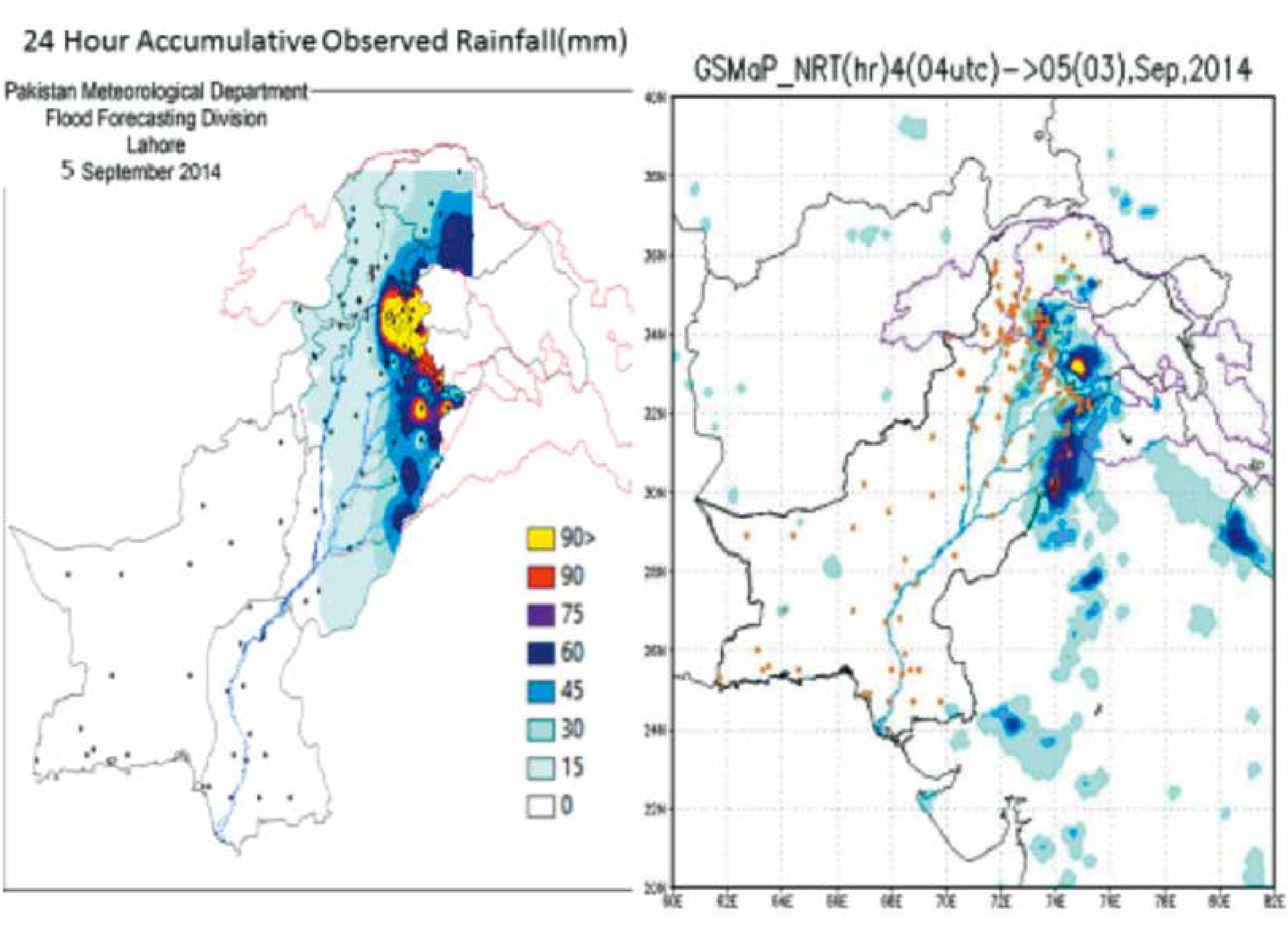


Flood Forecasting using GSMaP in Pakistan

Flood Forecasting Division,
Pakistan Meteorological Department (PMD, Pakistan)

Description

At Flood Forecasting Division (FFD), PMD, the GSMaP data is used by DFO (Duty Forecasting Officer) and as inputs of hydrological models such as IFAS (Integrated Flood Analysis System), and RRI(Rainfall Runoff Inundation).

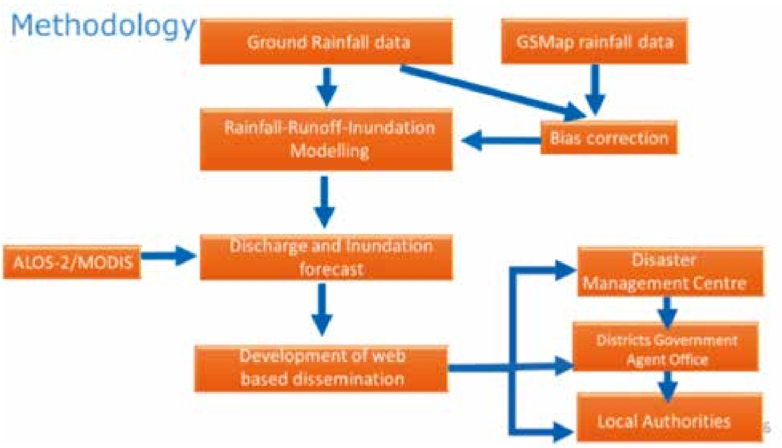


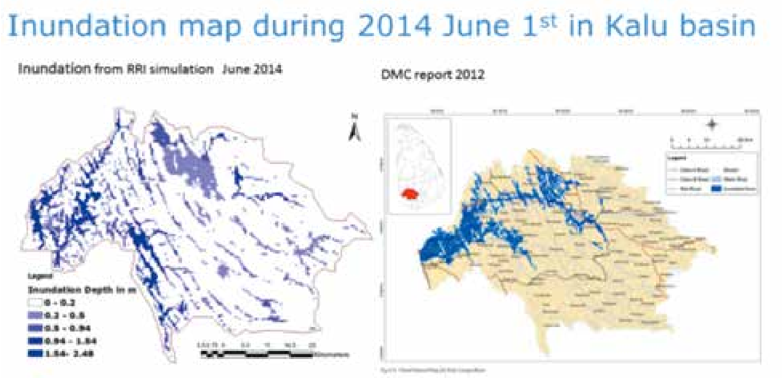
Flood Forecasting system using GSMaP in Sri Lanka

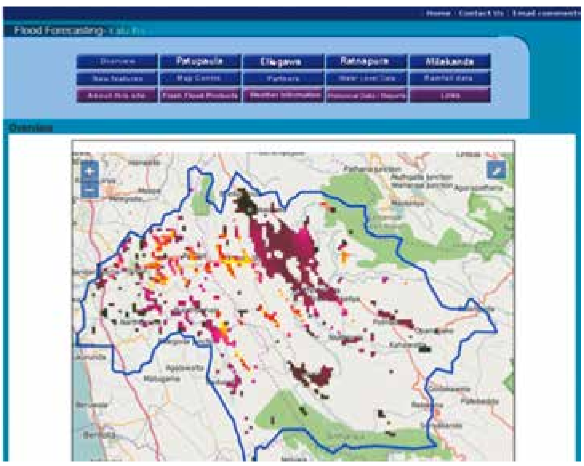
Irrigation Department
(Sri Lanka)

Description

Irrigation Department, Sri Lanka is developing flood forecasting system utilizing GSMaP for water related disaster management in SAFE prototyping project. This system adapts GSMaP, which is bias-corrected by real time ground rain gauge network and Rainfall Runoff Inundation (RRI) model. It is an automated system which can disseminate flood warning through internet based web page(which consists open layer based inundation map) to other stake holder agencies and public.





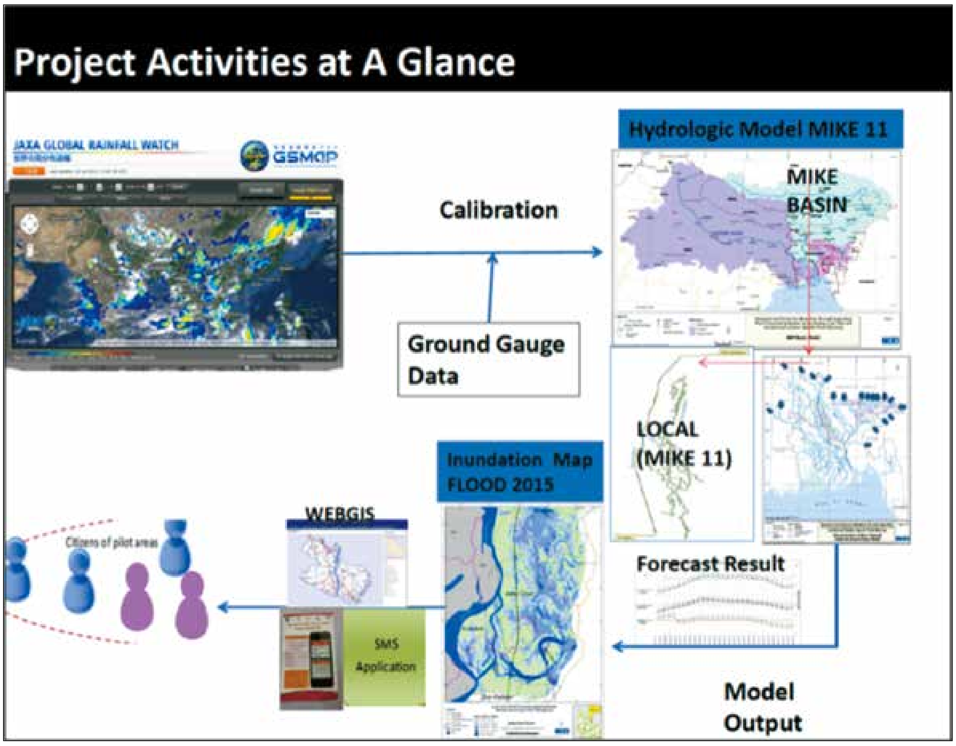


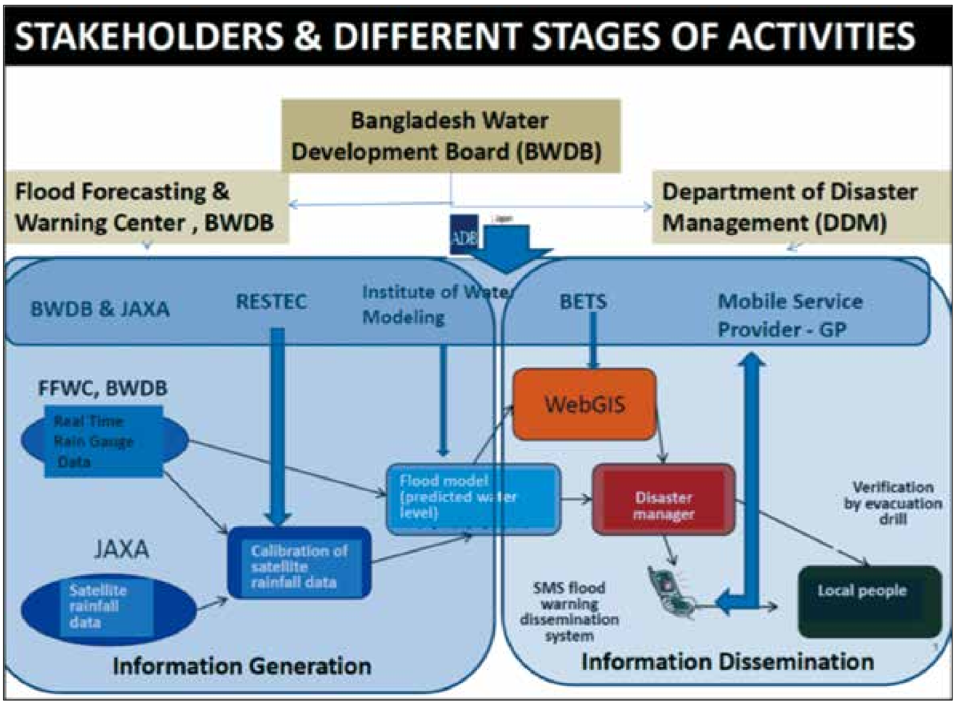
Flood Forecasting System using GSMaP in Bangladesh

Bangladesh Water Development Board
(BWDB, Bangladesh)

Description

BWDB uses GSMaP for flood forecasting. They input GSMaP, calibrated by rain gauges, to Hydrological Model, and output information is used for issuing warnings. (ADB project)



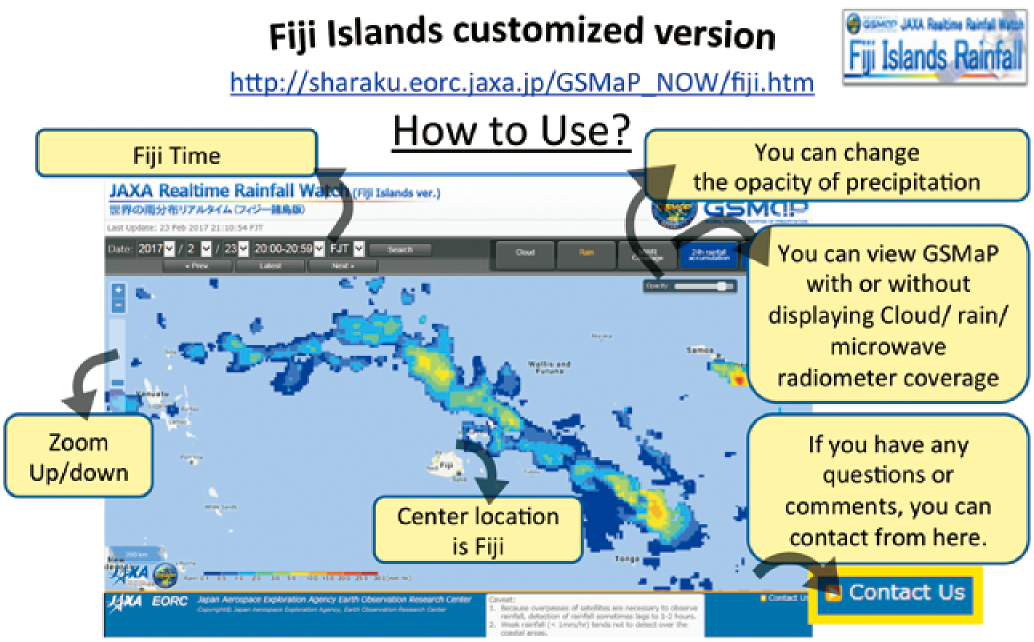


Precipitation Monitoring using GSMaP in Fiji

Fiji Meteorological Service
(FMS, Fiji)

Description

FMS uses GSMaP for rainfall precipitation monitoring. Forecasters in FMS check GSMaP to monitor the distribution of precipitation, especially severe convections around their islands. GSMaP can provide rainfall over ocean far from their islands. Combination of ground observations and GSMaP is effective.



Abbreviations

Abbreviations	Long Form
DPR	Dual-frequency Precipitation Radar
GFAS	Global Flood Alert System
GMI	GPM Microwave Imager
GPM	Global Precipitation Measurement
GSMaP	Global Satellite Mapping of Precipitation
GSMaP_GAUGE	GSMaP gauge-calibrated version
GSMaP_MVK	GSMaP standard version
GSMaP_NOW	GSMaP reltime version
GSMaP_NRT	GSMaP near realtime version
GSMaP_NRT_GAUGE	GSMaP Near realtime gauge-calibrated version
GSMaP_RNL	GSMaP reanalysis version
IFAS	Integrated Flood Analysis System
KaPR	Ka-band Precipitation Radar
KuPR	Ku-band Precipitation Radar
PR	Precipitation Radar
TRMM	Tropical Rainfall Measuring Mission

Data Utilization Method and References

GSMaP Data Utilization

JAXA Global Rainfall Watch (GSMaP_NRT)	http://sharaku.eorc.jaxa.jp/GSMaP/index_e.htm	
JAXA Realtime Rainfall Watch (GSMaP_NOW)	http://sharaku.eorc.jaxa.jp/GSMaP_NOW/index_e.htm	
EORC FTP server	User registration	http://sharaku.eorc.jaxa.jp/GSMaP/registration.html
	Users Guide	http://sharaku.eorc.jaxa.jp/GSMaP/guide.html
	Data format Description	http://sharaku.eorc.jaxa.jp/GSMaP/document/DataFormatDescription.pdf

GPM Data Utilization

GPM Reference room website	http://www.eorc.jaxa.jp/GPM/doc/index_e.htm	
GPM data utilization handbook	http://www.eorc.jaxa.jp/GPM/doc/data_utilization/GPM_data_util_handbook_E.pdf	
G-Portal (JAXA portal web site for search and deliver data of Earth observation satellite)	Search, download, and user registration via website	https://www.gportal.jaxa.jp/gp/top.html
	G-Portal User's manual	https://www.gportal.jaxa.jp/gportal_file/contents/help/UserManual_en.pdf

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