Satellite remote sensing for disaster management support: A holistic and staged approach based on case studies in Sentinel Asia

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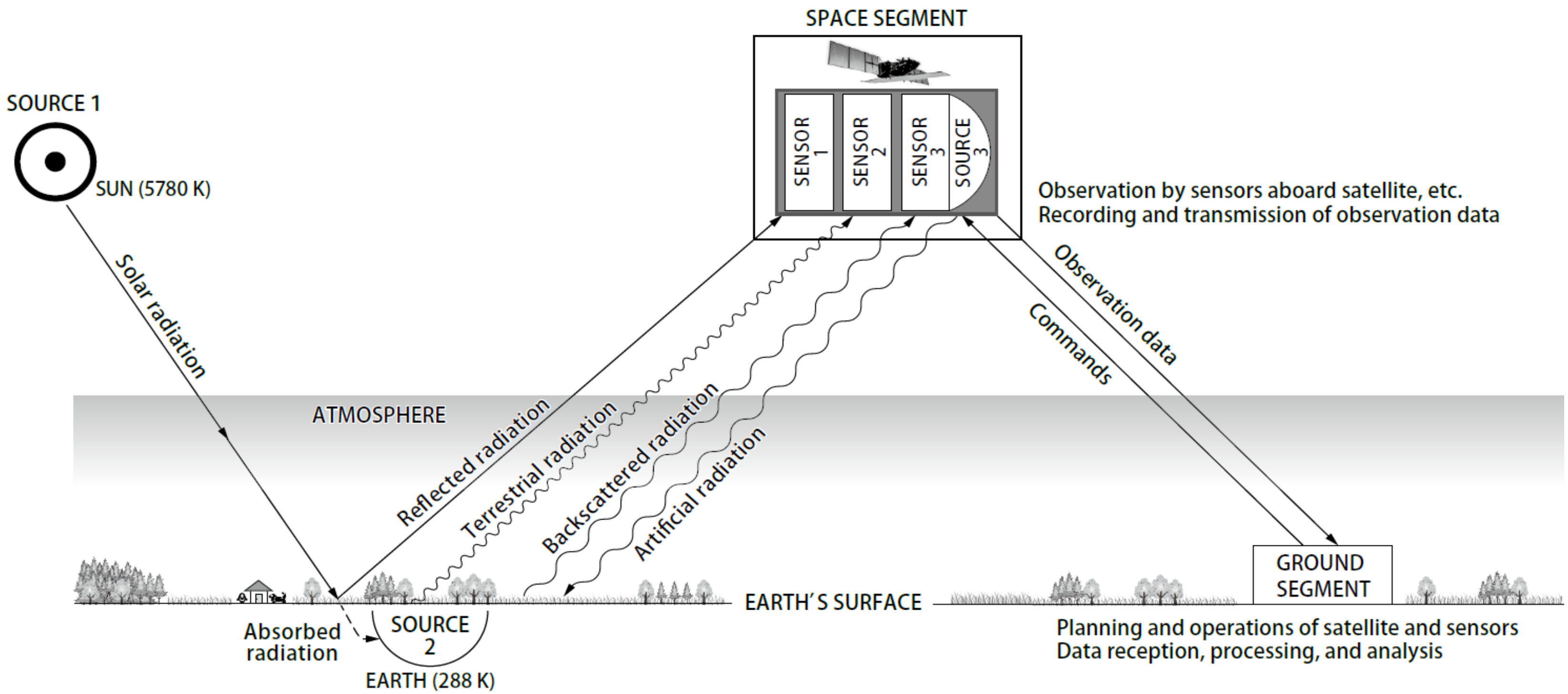
“Dr Kaku’s work “Satellite Remote Sensing for Disaster Management Support: A Holistic and Staged Approach Based on Case Studies in Sentinel Asia” is distinctive for this research domain. This research may indeed prove to be significant to fellow researchers and scientists working in the same discipline.”

Dr Stephen E. Haggerty

Editor, Global Journal of Human-Social Science (GJHSS)

A satellite remote sensing system

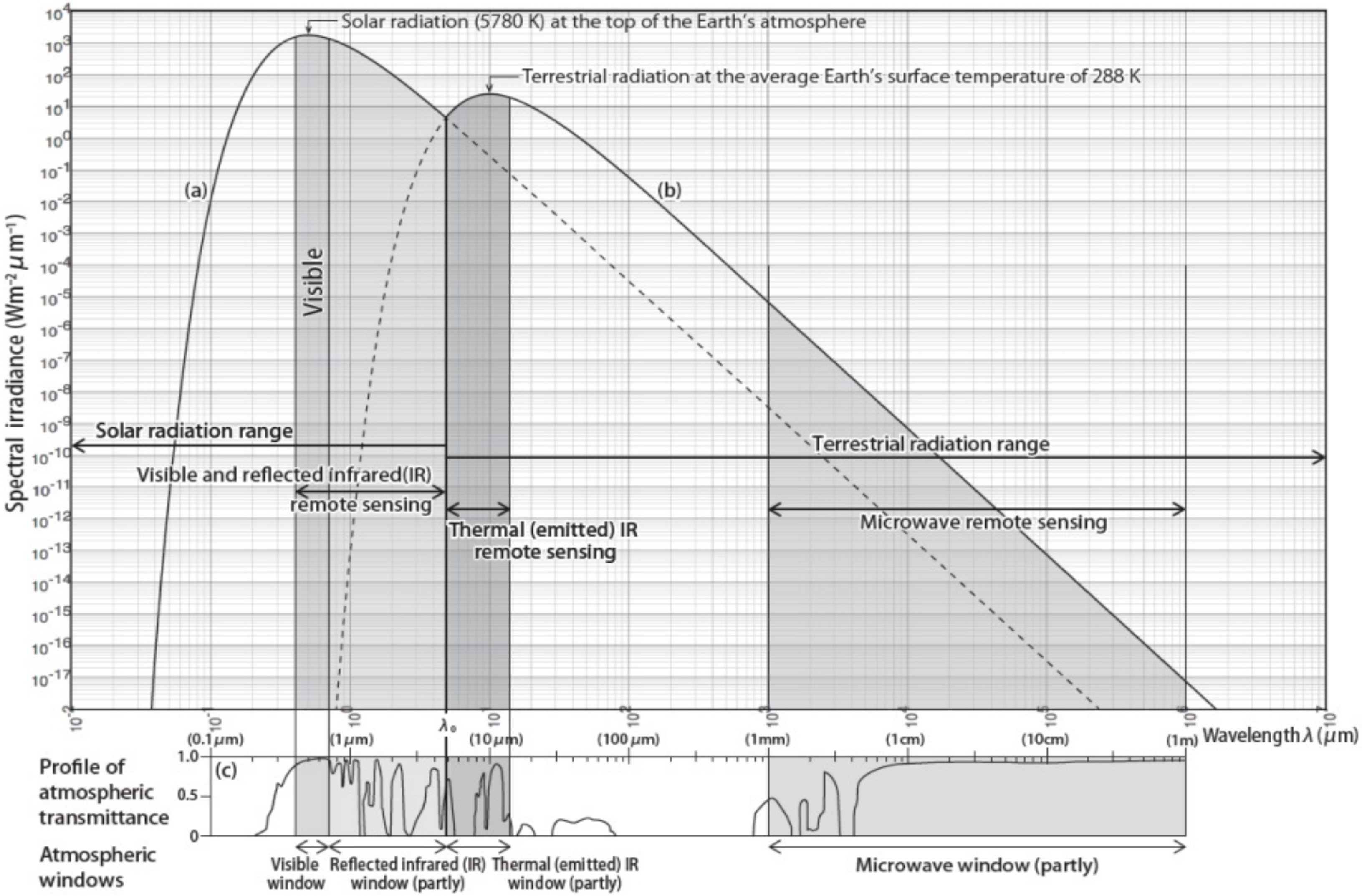


(1) sources of radiation (the Sun, the Earth, and an artificial radiation source)
(2) interaction with the atmosphere
(3) interaction with the Earth's surface
(4) space segment (sensors and satellites)
(5) ground segment.

Source: Kaku, 2019, An Introduction to Applying Satellite Remote Sensing to Disaster Management
Curran, 1985; with modifications

Overview of passive satellite remote sensing with respect to (c) atmospheric windows and segregation of (a) solar radiation and (b) terrestrial radiation

Source: Kaku, 2019, An Introduction to Applying Satellite Remote Sensing to Disaster Management



Source of atmospheric transmittance: NASA Earth Observatory. (a), (b): with MAC/Graper v2.

Three types of satellite remote sensing and typical sensors

Types of remote sensing (RS)		Visible and reflected infrared RS		Thermal infrared RS	Microwave RS
Atmospheric windows		Visible 0.4–0.7 μm	Reflected infrared 0.7–3 μm (partly)	Thermal (emitted) infrared 3–14 μm (partly)	Microwave 1 mm–1 m (partly)
Source of electro-magnetic radiation	Passive	Solar radiation		Terrestrial radiation	Terrestrial radiation
	Active	Artificial radiation		not applicable (NA)	Artificial radiation
Typical sensors	Passive	*Optical sensors*		*Infrared sensors*	*Microwave radiometers*
	Active	LiDAR (Light Detection and Ranging)		NA	Radar (Radio Detection and Ranging) - *Synthetic Aperture Radar (SAR)* - Precipitation Radar (PR) - Radar Scatterometer - Radar Altimeter

Source: Kaku, 2019, An Introduction to Applying Satellite Remote Sensing to Disaster Management

Abstract

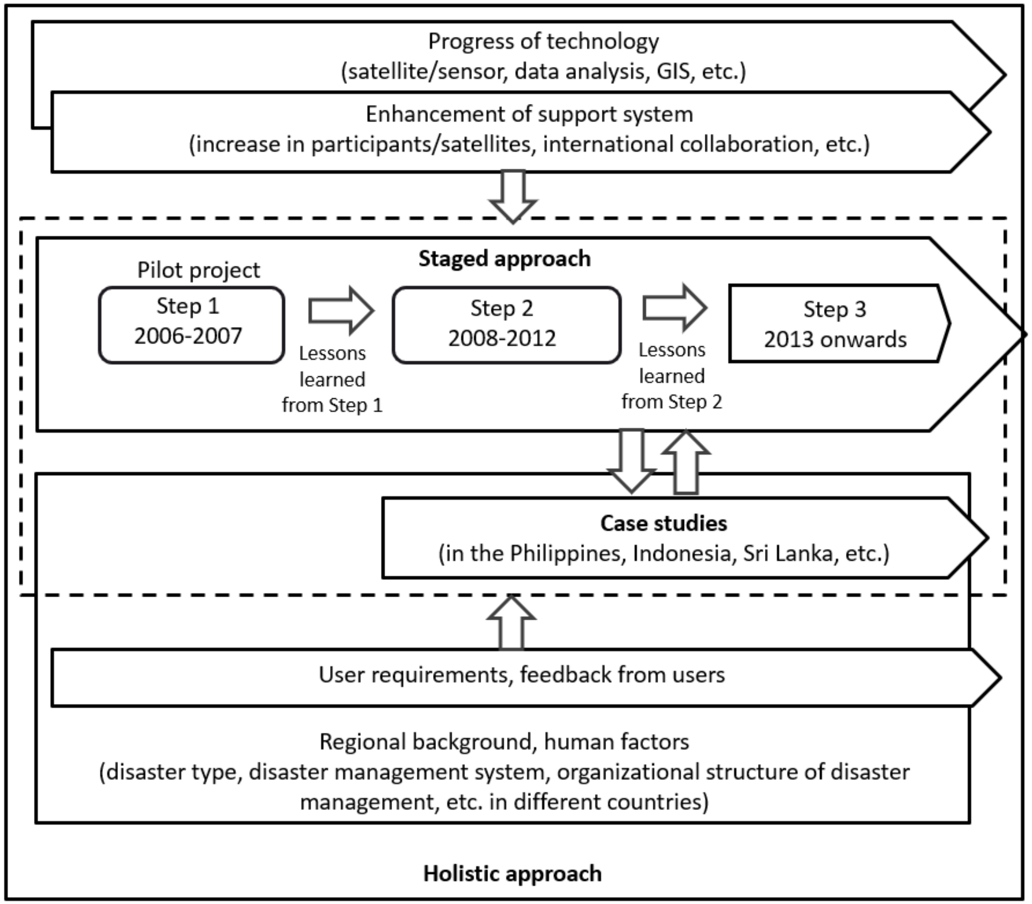
- The Sentinel Asia (SA) initiative was established in 2006 as a collaboration between regional space agencies and disaster management agencies, applying space technology (including representative satellite remote sensing) and Web-GIS technology to assist in disaster management of the Asia–Pacific region.

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
		STEP 1		STEP 2					STEP 3			
Major milestone	▲Oct. Implementation of "Sentinel Asia (SA)" decided (APRSAF-12)											
		▲Feb. Joint Project Team (JPT) organized							▲Dec. SA evolution decided (APRSAF-20)			
		▲ Oct. Operation started, website opened										

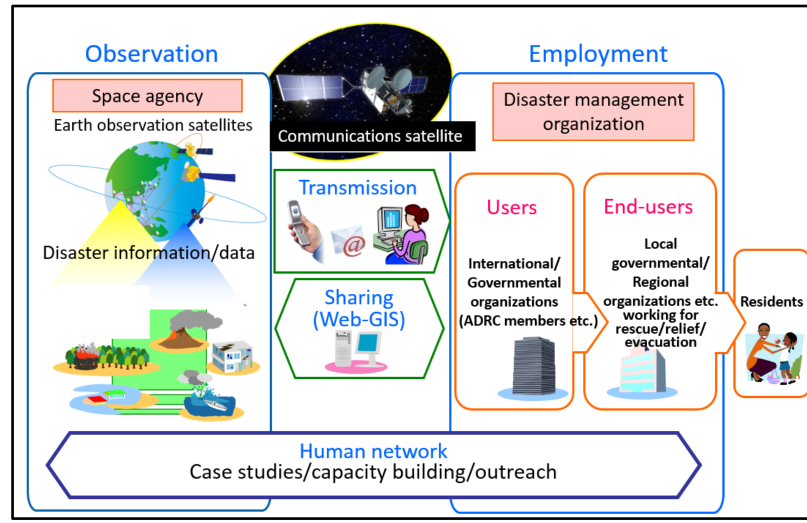
- SA can be regarded as an empirical research project to study how satellite remote sensing can support disaster management, in collaboration with users.
- This paper derives requirements for applying satellite remote sensing to disaster management support via a holistic (including human factors) and staged approach based on case studies in SA.

Schematic of subject

Approach



Objective



Employment of satellite-based disaster information/data by users and end-users who are working for disaster management including rescue/relief/evacuation

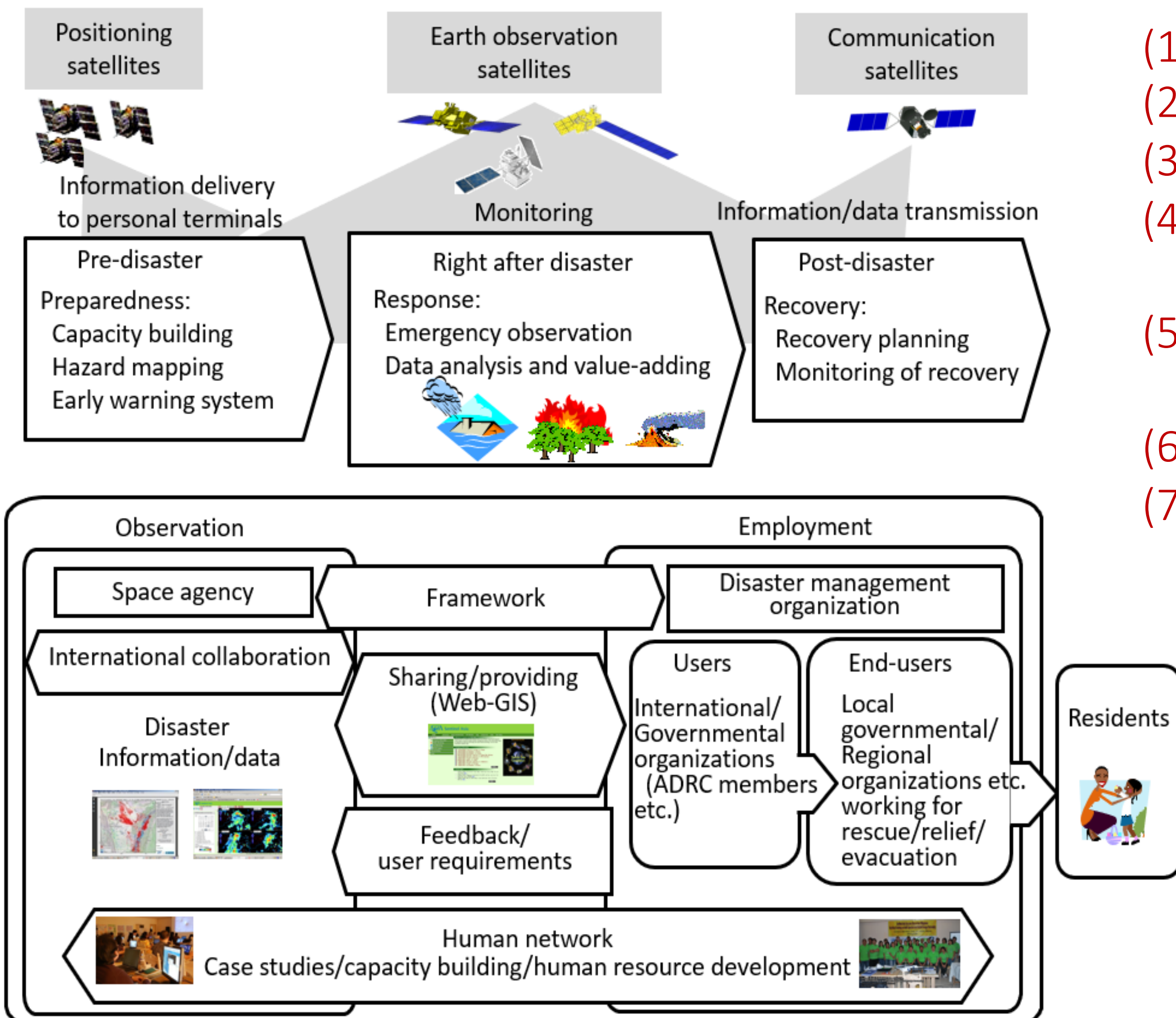
To derive requirements for realizing this objective, that is, applying satellite remote sensing to disaster management support

Methodology: Case- and holistic-study approach

- “Application of satellite remote sensing to disaster management” in this paper refers to the employment of satellite-based disaster information/data by users working for disaster management, including rescue/relief/evacuation; not just disclosing them on the Internet.
- In such applied science research areas, where practical implications are often required for their research results, case studies are methodologically useful. Furthermore, each individual case study of a particular complex social event is considered to be an entity that constitutes one "whole", allowing a holistic approach to the event.
  Reference: Ishizaka, Y. 2005. The Case Study as a Valuable Research Strategy (in Japanese). Journal of Kyushu Kyoritsu University Faculty of Economics (101), 1-17.

Conclusions

Holistic study on how to apply satellite remote sensing to disaster management: Requirements for applying satellite remote sensing to disaster management support



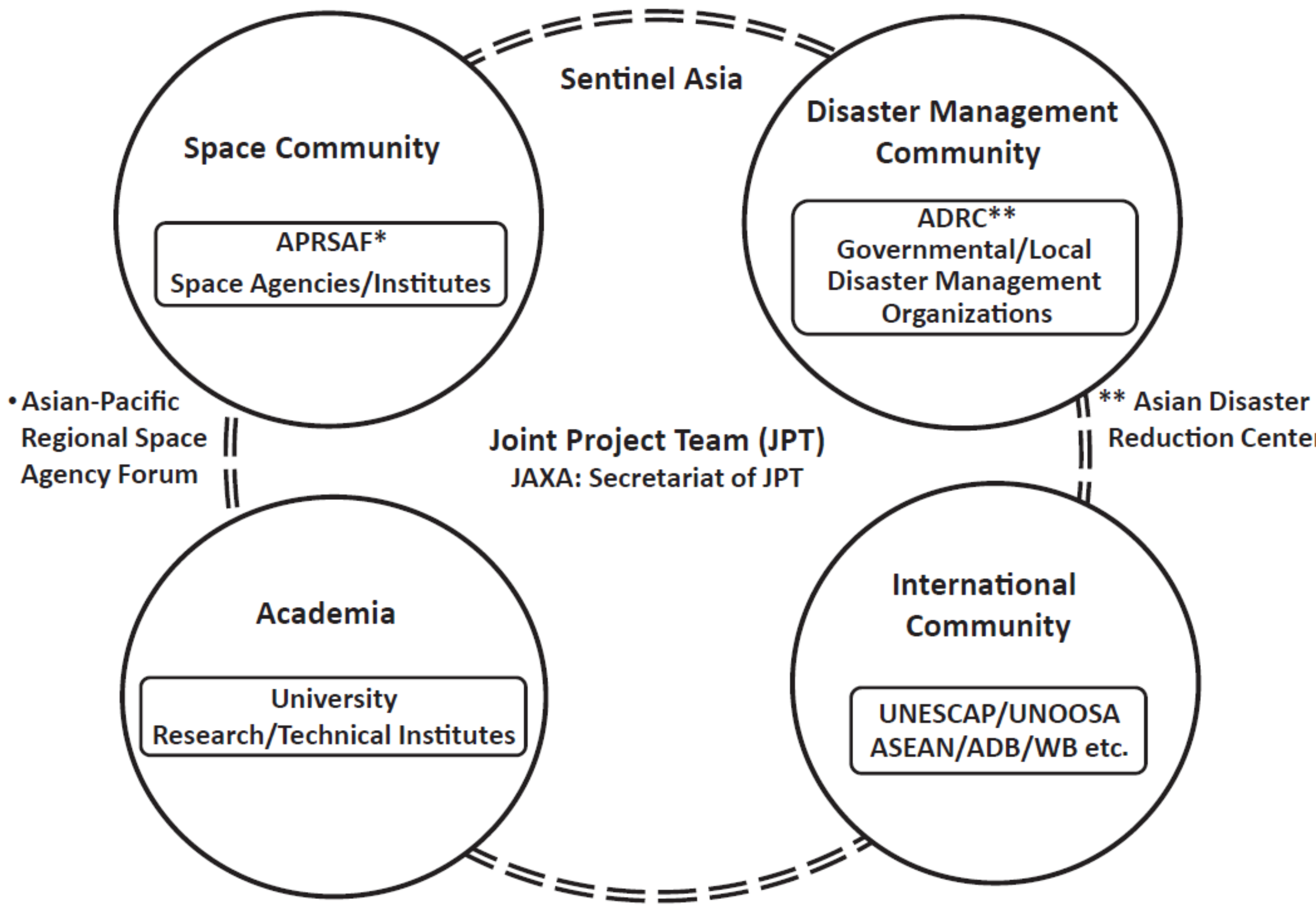
(1) Framework
(2) Activities
(3) Users and human factors
(4) Data providers
(space agency and others)
(5) Sharing/providing system of disaster information/data
(6) International collaboration
(7) Feedback from users

Requirements for applying satellite remote sensing to disaster management support

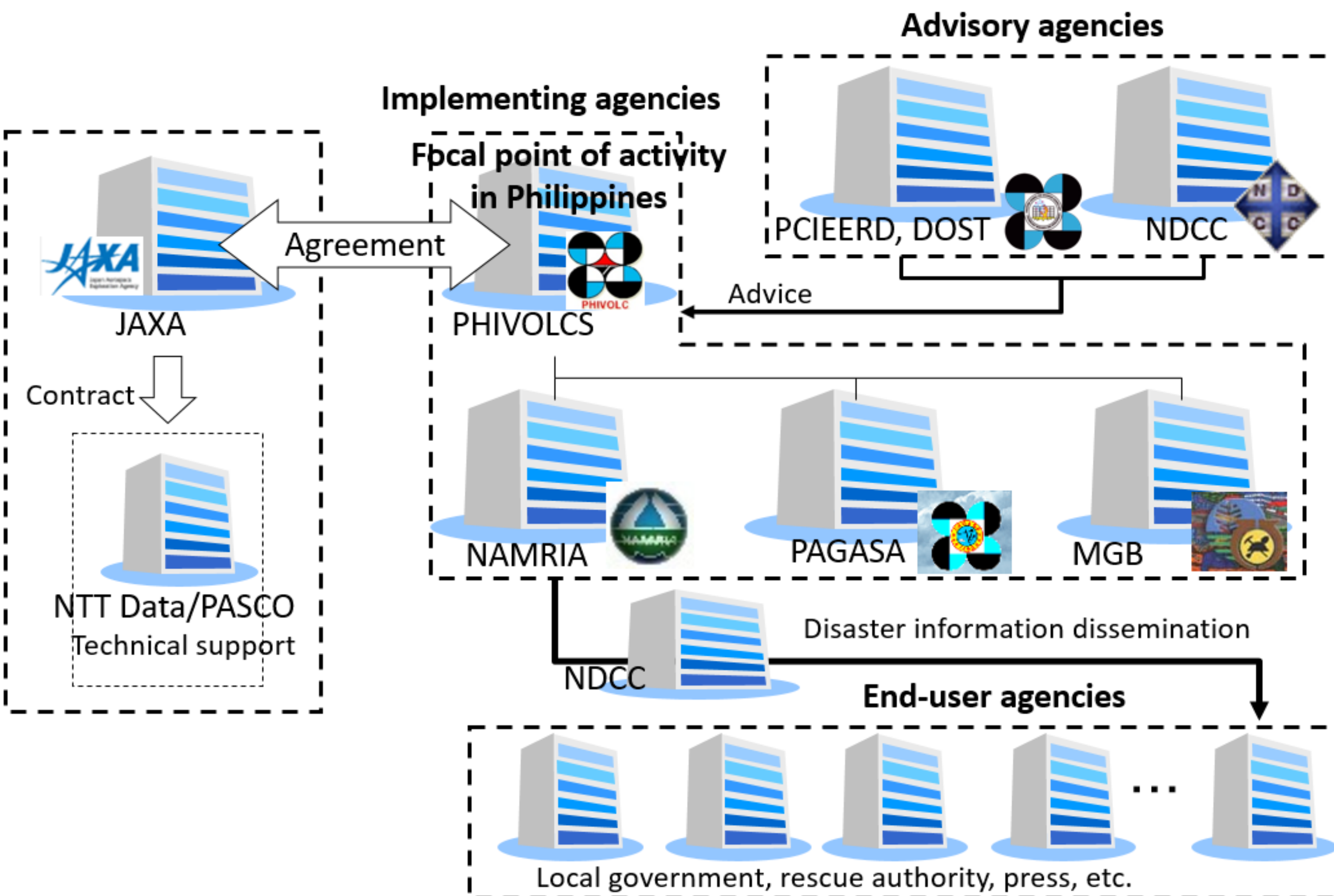
(1) Framework

- The opinion survey shows that numerous users request the establishment of a framework to supply satellite images free of charge and quickly in an emergency.
- A framework including data providers (space agencies), data analysts (universities, research institutes, etc.) and users (disaster management organizations) is necessary.
- In the case of SA, it was established as a voluntary and best-effort basis initiative under the APRSAF and collaboration among the space community (space agencies), the disaster management community (ADRC and its member organizations, the international community, and academia (university, research and technical institutes).

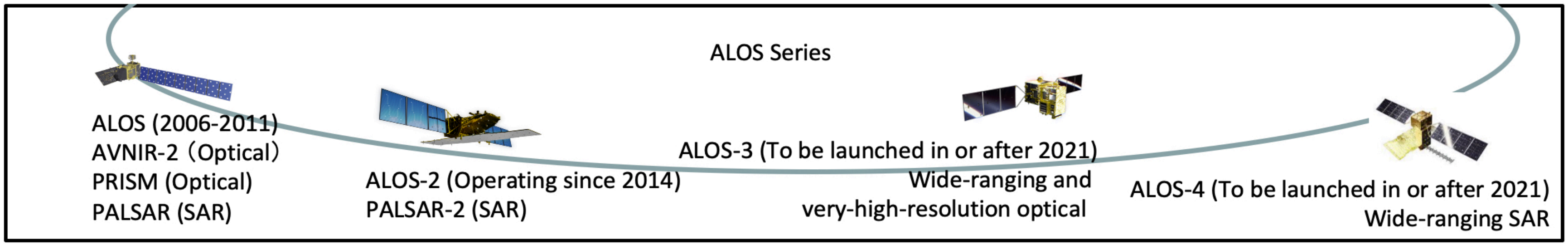
Framework of Sentinel Asia



Framework of SA Success Story in the Philippines, including end-users



JAXA’s approach to disaster management support



International contribution

Application demonstration

Emergency observation support

International collaboration → **Disaster response within Japan**

International collaboration

Bilateral cooperation

ASI (Italy)

International charter

ESA
CNES (France)
CSA (Canada)
NOAA (USA)
ISRO (India)
CONAE (Brazil)
USGS (USA)
JAXA (Japan)
BNSC/DMCii (England)
CNSA (China)
DLR (Germany)
KARI (Korea)
INPE (Argentina)
EUMETSAT
ROSCOSMOS (Russia)
ABAE (Venezuela)
UAESA (UAE)

Sentinel Asia

JAXA (Japan)
ISRO (India)
GISTDA (Thailand)
KARI (Korea)
NARLabs (Taiwan)
CRISP (Singapore)
VAST (Vietnam)
MBRSC (UAE)

Disaster response within Japan

Local governments etc.

Gifu
Wakayama
Niigata
Kochi
Tokushima
Mie
Yamaguchi/Yamaguchi University

Governmental organizations

Cabinet Office (Disaster management)
  Large Scale Disaster Satellite Image Analysis Support Team
Cabinet Secretariat
MOD
MLIT
  Sediment disaster Working Group (WG)
  Flood WG
GSI
  Earthquake WG
JMA
  Volcano WG
Others

JAXA's approach to disaster response support within Japan

JAXA provides:
- ■ Satellite images observing disasters
  - Emergency observation immediately after disaster
  - Change extraction from images before and after disaster
  - Images at disaster prevention drill
- ■ Satellite topographic map
- ■ Image analysis knowledge

National government ministries/agencies and local governments:
- ■ Utilization of satellite image
  - Report on image utilization results
  - Issues, advice, and suggestions
- ■ Study of image utilization on GIS etc.
  - Sharing disaster related data
- ■ Sharing user needs

Data/information sharing via Daichi Bousai Web Portal

Local governments

Agreement with 7 local governments

Gifu	Wakayama	Niigata
Kochi	Tokushima	Mie
Yamaguchi Yamaguchi University		

Agreement with Cabinet Office

Observation request

Data provision

Agreement with MLIT

National government ministries and agencies

- Cabinet Office (Disaster Management)
  - Satellite image analysis support team for large-scale disaster (a)

(a) Co-organized by JAXA

- Cabinet Secretariat
- Ministry of Defense
- Ministry of Land, Infrastructure, Transport and Tourism (MLIT)
  - Sediment WG (a)
  - Flood WG (a)
- Geospatial Information Authority of Japan (GSI)
  - Earthquake WG
- Japan Meteorological Agency (JMA)
  - Volcano WG
- Others

Requirements for applying satellite remote sensing to disaster management support

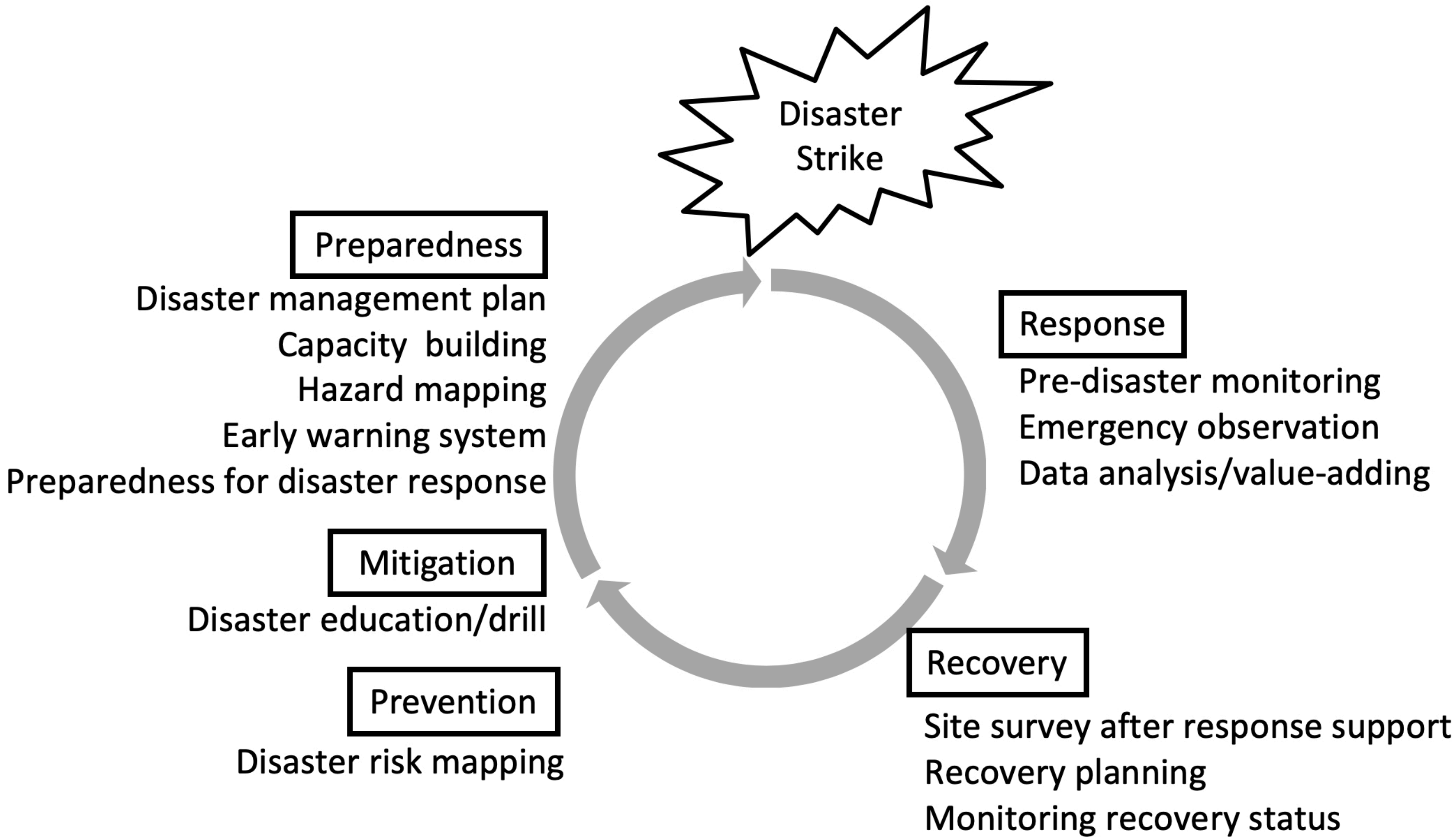
(2) Activities

- Users request to cover the entire disaster management cycle (preparedness, response, and recovery).
- In the case of SA, for preparedness support, capacity building, hazard mapping, and an early warning system have been implemented. It should be noted that the capacity building and early warning system align with the Sendai framework for disaster risk reduction (DRR) 2015–2030.
- Disaster response support is the most suitable field for satellite remote sensing, and is greatly expected from users, because satellite observation covers wide-ranging areas and operates continually, during all hours and in all types of weather.
- In future, it should be clarified how pre-disaster monitoring for impending disasters (which is a strong requirement from users) can be supported, considering the data policy of each space agency.

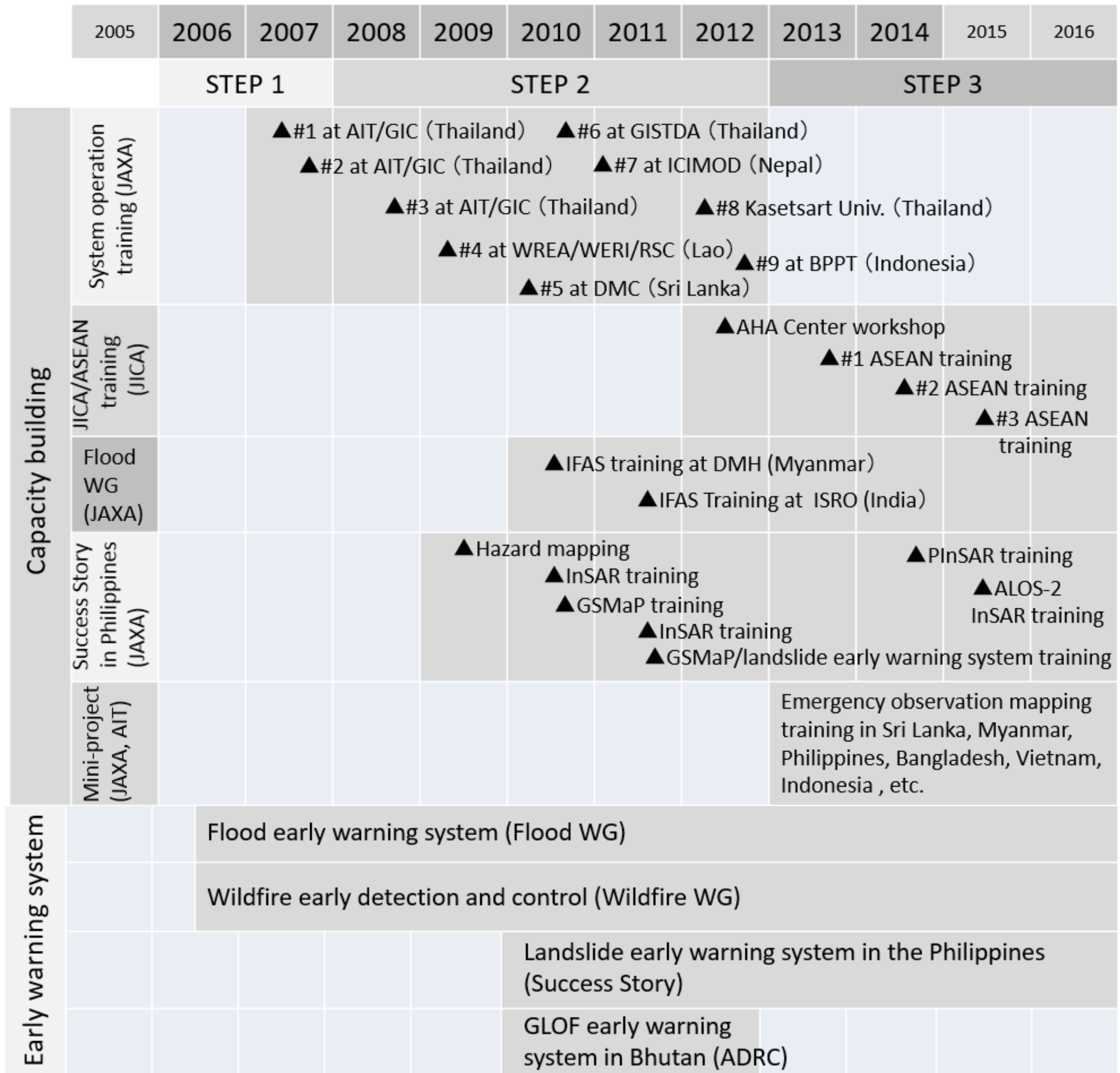
Requirements for applying satellite remote sensing to disaster management support

- As for recovery support, products produced by emergency observation can be utilized in the recovery phase as well, and to prepare for recurring disasters. In future, it should be clarified how this phase can be supported, considering the data policy of each space agency and making use of open and free satellite data such as MODIS and Himawari.
- Case studies and human networking through collaboration with users (including end-users), considering a regional background such as disaster type, disaster management systems, and organizational structure of disaster management in different countries are inevitable activities.
- It is also important to implement the theme of activities that meet the needs of users.

Disaster management cycle and applicable items of satellite remote sensing



Sentinel Asia activities for preparedness



Requirements for applying satellite remote sensing to disaster management support

(3) Users and human factors

- SA is characterized by collaboration with users who are working for disaster management and response. Users are neither existing nor given ones; they must be developed and maintained as a part of project activities, by sustained efforts of the human resource development and human network development, starting with awareness, education, training, and so on.
- In collaboration with users, a human network is an important underlying element.
- It is also important to collaborate with the appropriate organization/section/person in each country according to the theme, but this is not easy because it depends on the organizational structure of disaster management in each country. After all, collaboration is done by people; in this sense, the most important thing is the human network.

SA activities supported by human network
A good human network is the foundation of the project

APRSAF

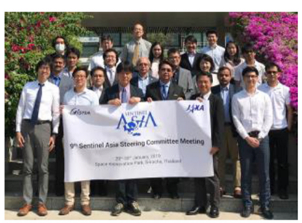
JPTM

Opinion survey

Capacity building

Field survey

Education, drill



Steering Committee

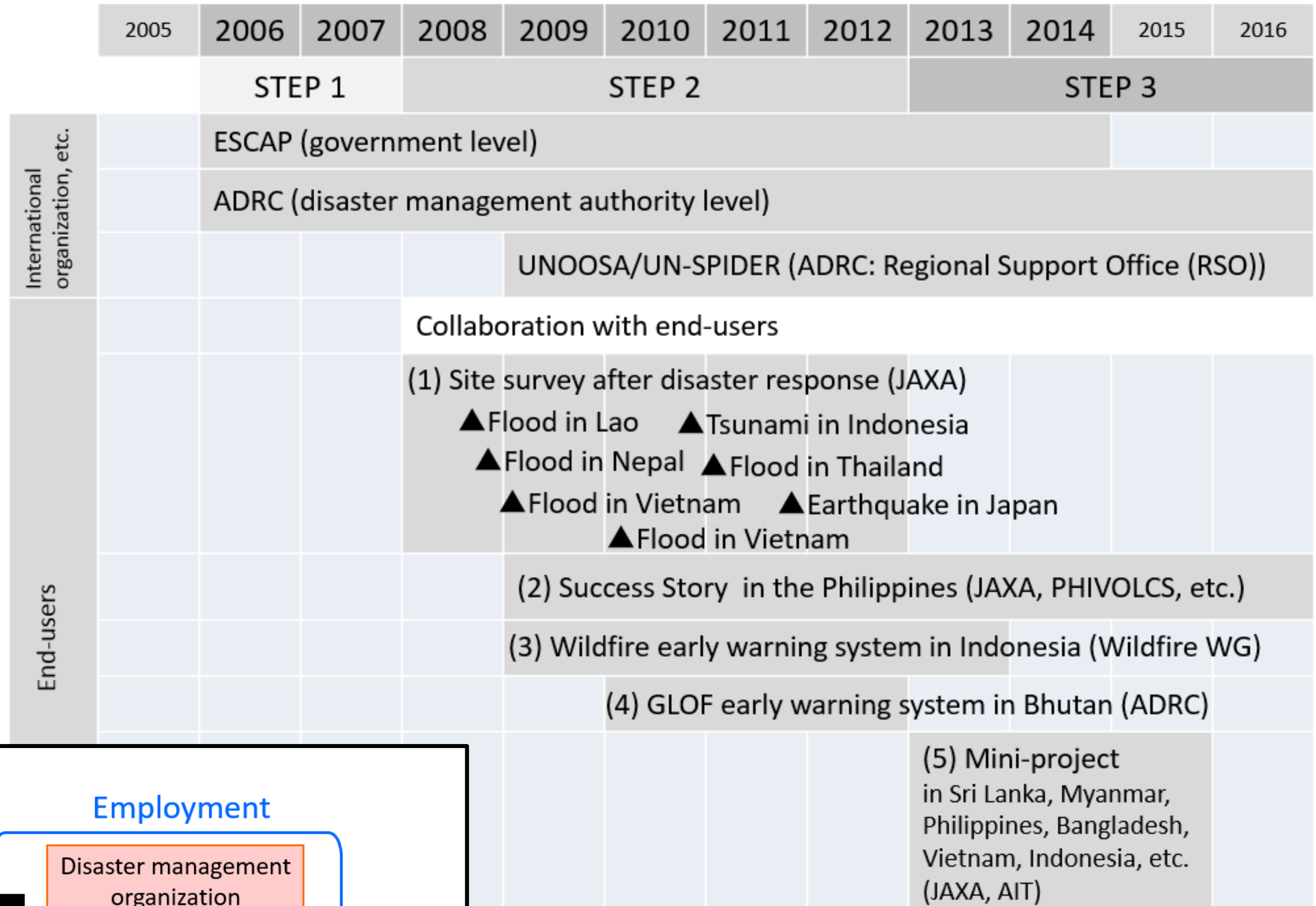
Working group

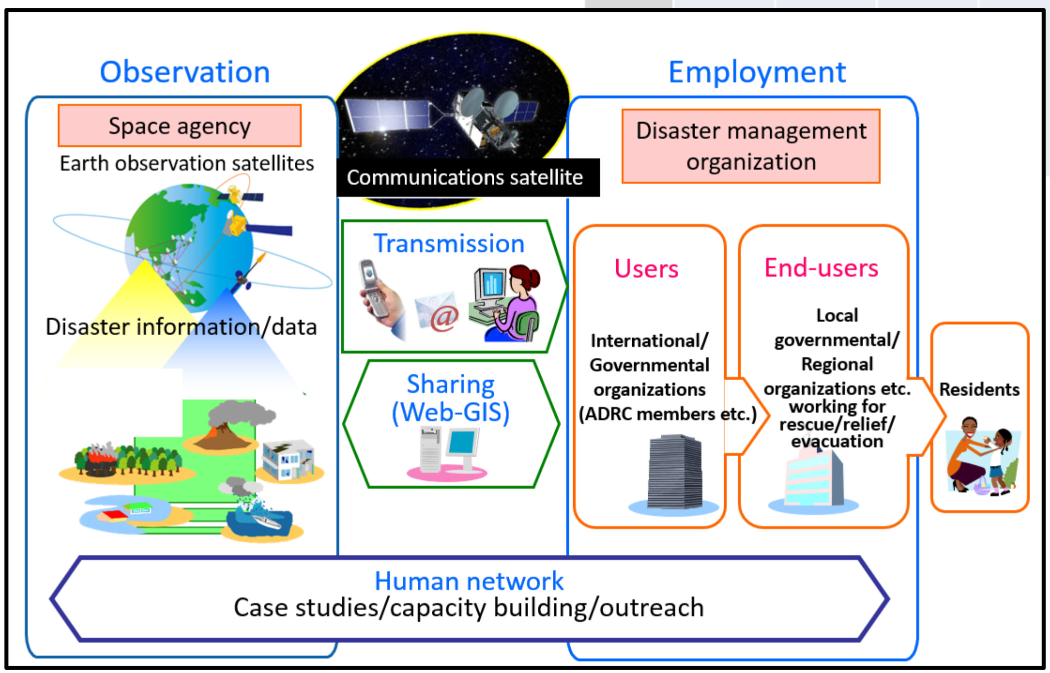
SA mini-project

Success story

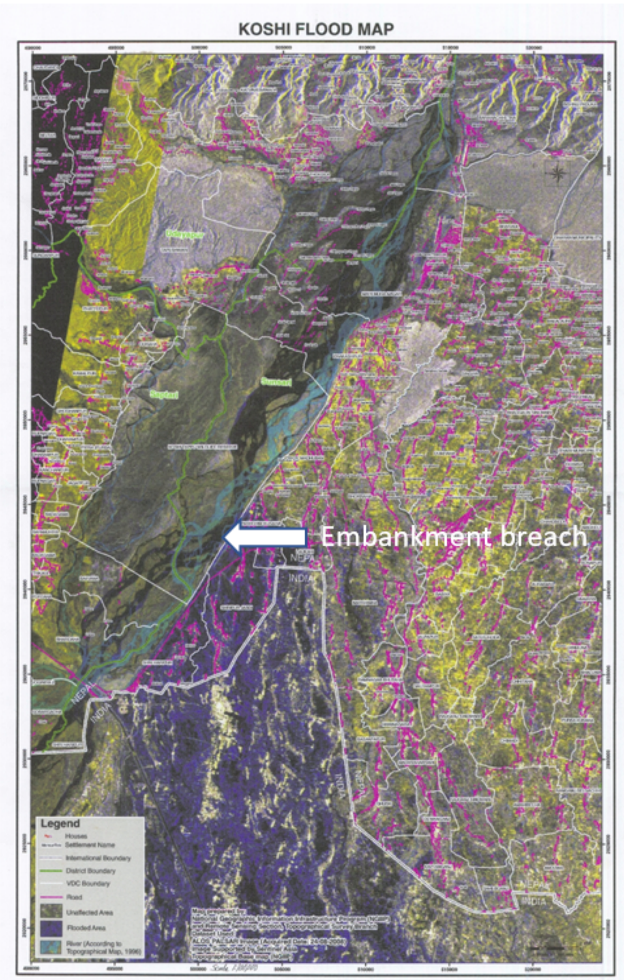
Program level **Project level** **For end-users**

Collaboration with users





Site survey after disaster response support: Large-scale flood in Nepal in August 2008



(a) Flood map

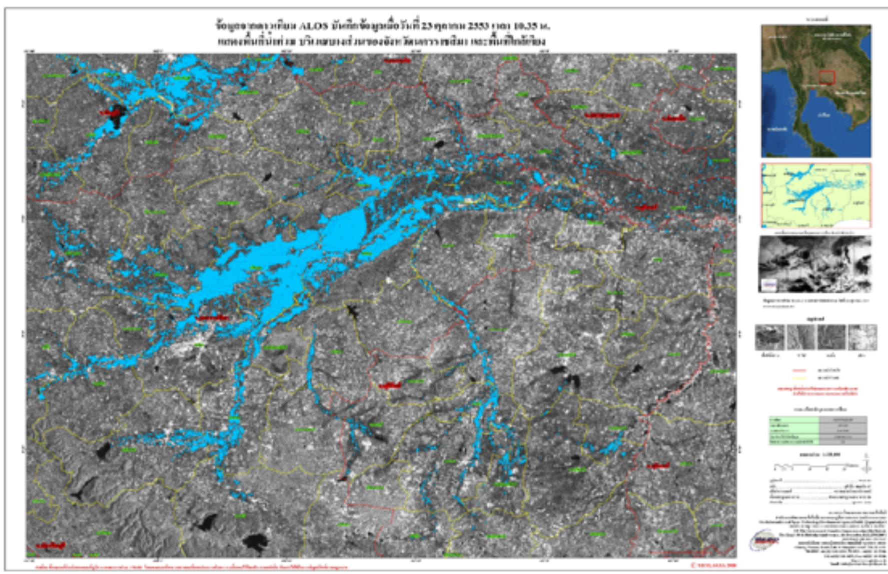
(b) Site survey in Dec. 2008

JAXA/ADRC conducted a site survey in December 2008

(a) Map of the damaged area overlaid with census data, made by the Survey Department of Nepal using ALOS emergency observation imagery. This map is provided courtesy of the Survey Department of Nepal.
(b) Photos were taken by ADRC in December 2008.

Site survey after disaster response support: Deluge in Thailand in October 2010

JAXA conducted a site survey in February 2011, and made an opinion survey of governmental agencies, GISTDA and the Royal Irrigation Department (RID), and residents, as well as a field survey for validation of satellite imagery



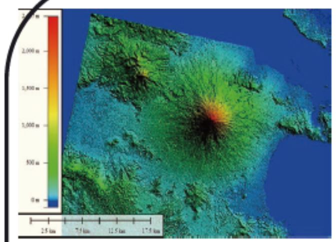
(a) Flood map

(b) Site survey in Feb. 2011

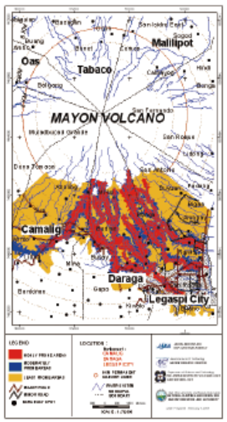
(a) A flood inundation map using ALOS/PALSAR imagery was made by GISTDA. The blue area shows the inundation area extracted from satellite imagery analysis. This map is provided courtesy of GISTDA.
(b) An opinion survey of GISTDA and RID, and residents, as well as a field survey for validation of satellite imagery.

Hazard mapping for lahars at Mayon volcano and application to response in the framework of the SA Success Story in the Philippines

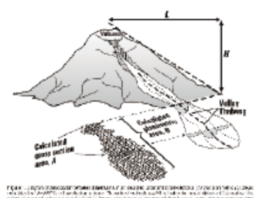
Preparedness



ALOS/PRISM DSM



Lahar hazard map

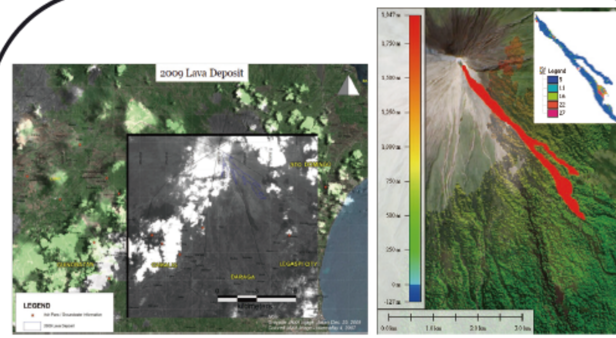


Modeling of lahar by LAHARZ (USGS OSS)

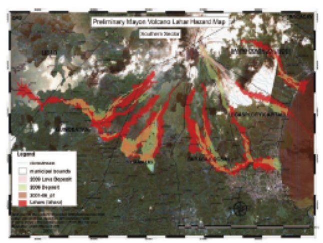
Technical training and workshops in 2009

Preparedness for frequent occurrences of lahars at Mayon volcano by hazard mapping using ALOS/PRISM digital surface model (DSM)

Response



PHIVOLCS detected lava deposit area from satellite emergency observation imagery (such as ALOS/AVNIR-2 observed on Dec. 25, 2009) and so on, and estimated the amount of lava deposited and possible damage in future. The lava deposit map was used in a briefing with the National Disaster Coordinating Council (NDCC) to understand the situation and make decisions.

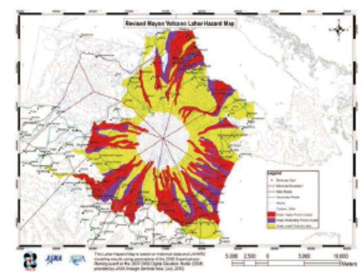


Lahar hazard map was preliminarily updated by PHIVOLCS using ALOS/AVNIR-2 imagery.

Response to eruption of Mayon volcano on Dec. 14, 2009

Preparedness

Fieldwork at Mayon to collect ground control points for DEM validation in Feb. 2010



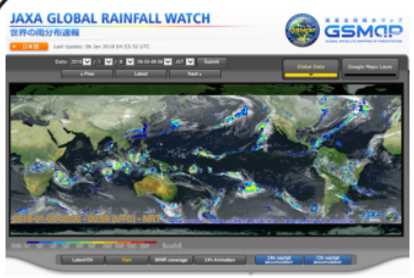
PHIVOLCS finally revised Mayon volcano lahar hazard map in July 2010.

Preparedness for expected lahar hazard

Source: Presentations by A. S. Daag and R. U. Solidum, Jr. of PHIVOLCS at JPT annual meetings and reply to feedback questionnaire of SA emergency observation.

Landslide early warning prototype system in the framework of the SA Success Story in the Philippines

Precipitation data

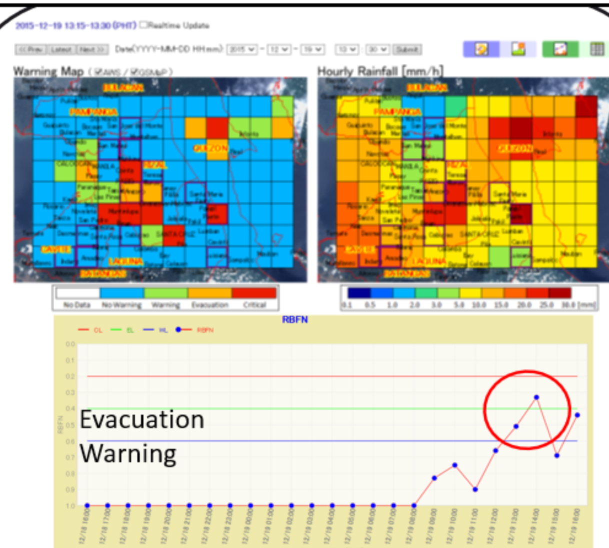


GSMaP_NOW

Automatic weather station (AWS)

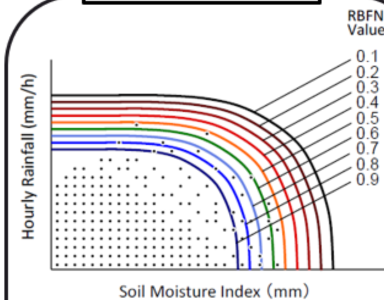
GSMaP_NOW data is corrected in real time using AWS data

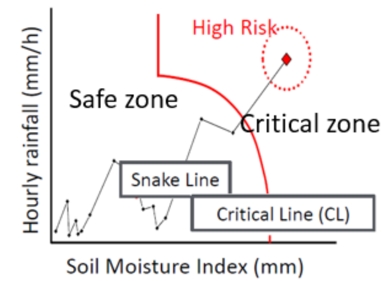
Landslide early warning prototype system



The system monitors rainfall in real time and determines the landslide warning level. The above shows a landslide at Barangay Tanauan, Quezon at 13:30 on 19 Dec. 2015

Methodology





Setting nonlinear CL using RBFN

Training and calibration




Local calibration and training in Antipolo City (Barrangay level) and Rizal Province (Municipal level)

Source: Presentation by A. S. Daag of PHIVOLCS at APRSAF-23 annual meeting.

Requirements for applying satellite remote sensing to disaster management support

(4) Data providers (space agency and others)

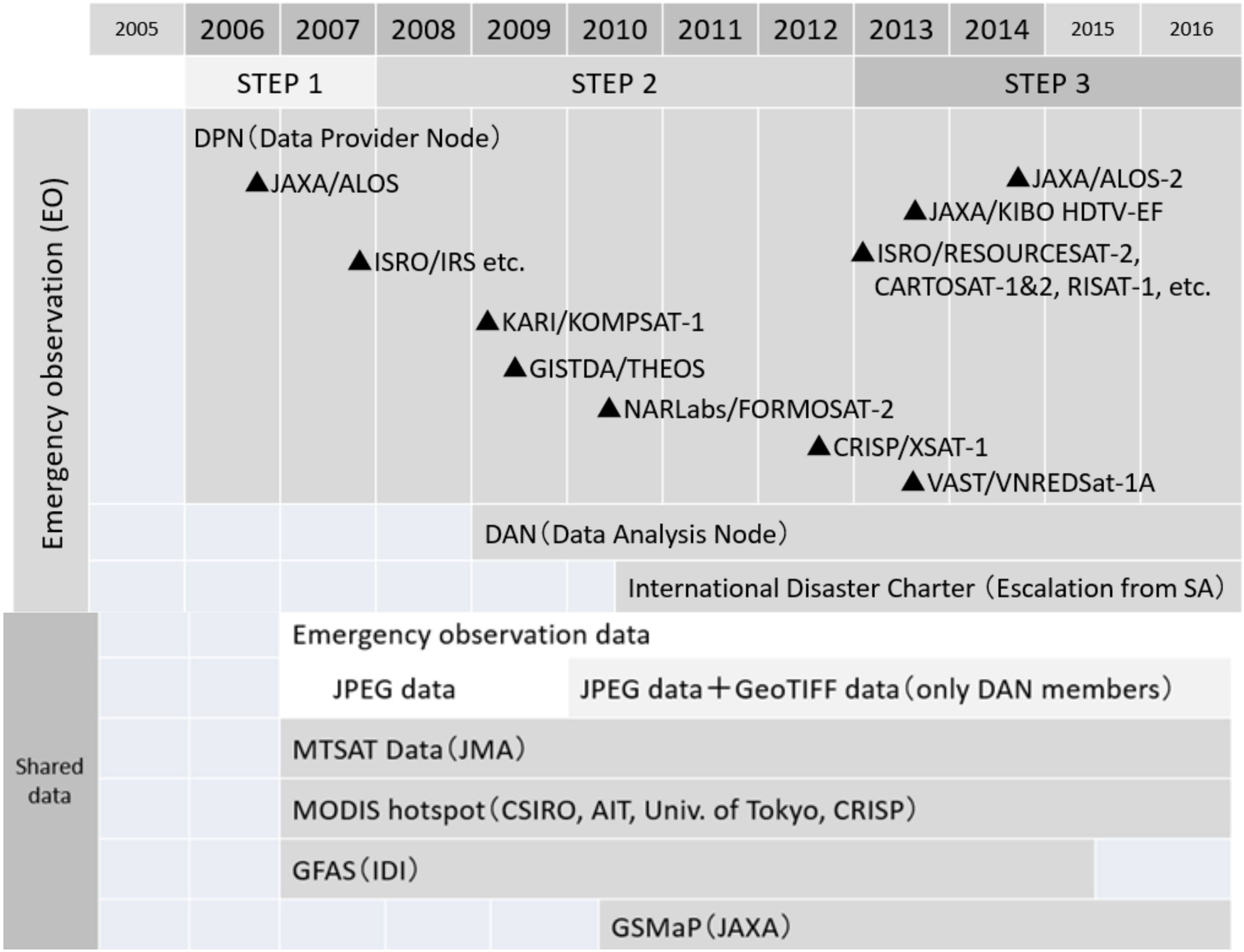
Space agencies have been requested continual efforts to realize following user requirements:

- The opinion survey shows requests concerning the timing of observation and providing data, including one hour after a disaster to assess the extent of the destruction, within two to three days to detect landslides, and one week later to estimate the quantity of debris. The goal would be much more than just the delivery of satellite Earth observation data, but rather to provide more specific "services" quickly on a 24-h, 7-day, 365 days basis.
- Data users are also deeply concerned about confirming the availability of roads and key facilities immediately after a mass calamity to ensure routes for evacuation, rescue, and support (availability monitoring), in addition to grasping the overall extent of the damage (overall monitoring).
- For overall monitoring, wide-ranging optical/SAR images are used. For availability monitoring, very-high-resolution optical images are necessary. Specifically, resolution of less than 1 m is required. In the case of the 2011 Great East Japan Earthquake, satellites with very high resolution from the International Charter were used for availability monitoring.

Requirements for applying satellite remote sensing to disaster management support

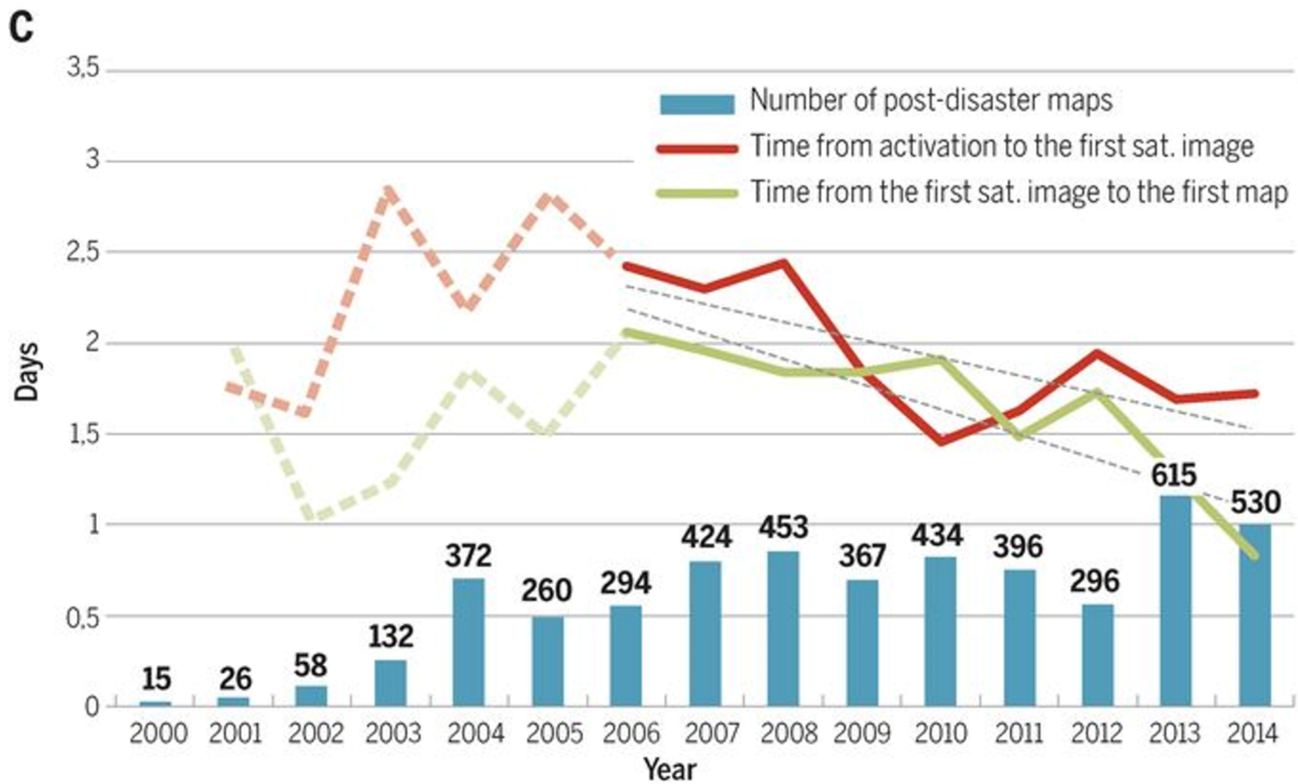
- Numerous interviewees (users) said they would find many types of information useful to assess damage after a mass disaster and would appreciate when satellite images and aerial photos are supplied quickly at no cost. Aerial photos provide very-high-resolution images of small areas and are complementary to satellite images.
- In future, data providers should continue to improve the emergency observation service to meet user needs, such as data type (optical or SAR, high resolution or wide range), response time, value adding, and reliability and validation of value-added products, under strong management and coordination over all the processes of emergency observation, including feedback from users.

Data providers to Sentinel Asia



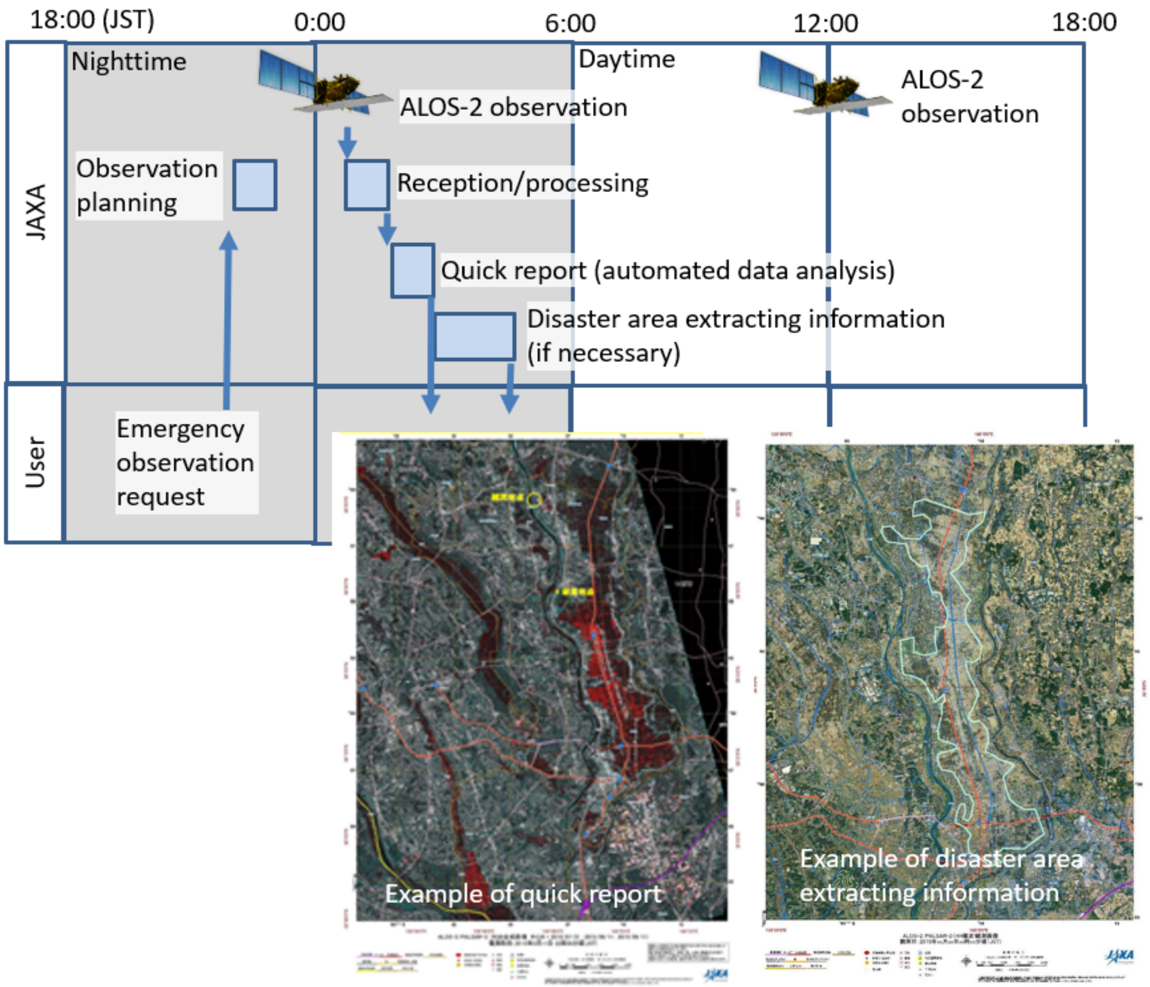
Holistic study on global trends in applying satellite remote sensing to disaster response support: Overall (Charter+SA+Copernicus+UN+NDRCC) map production volumes and response times

Source: http://science.sciencemag.org/content/353/6296/247



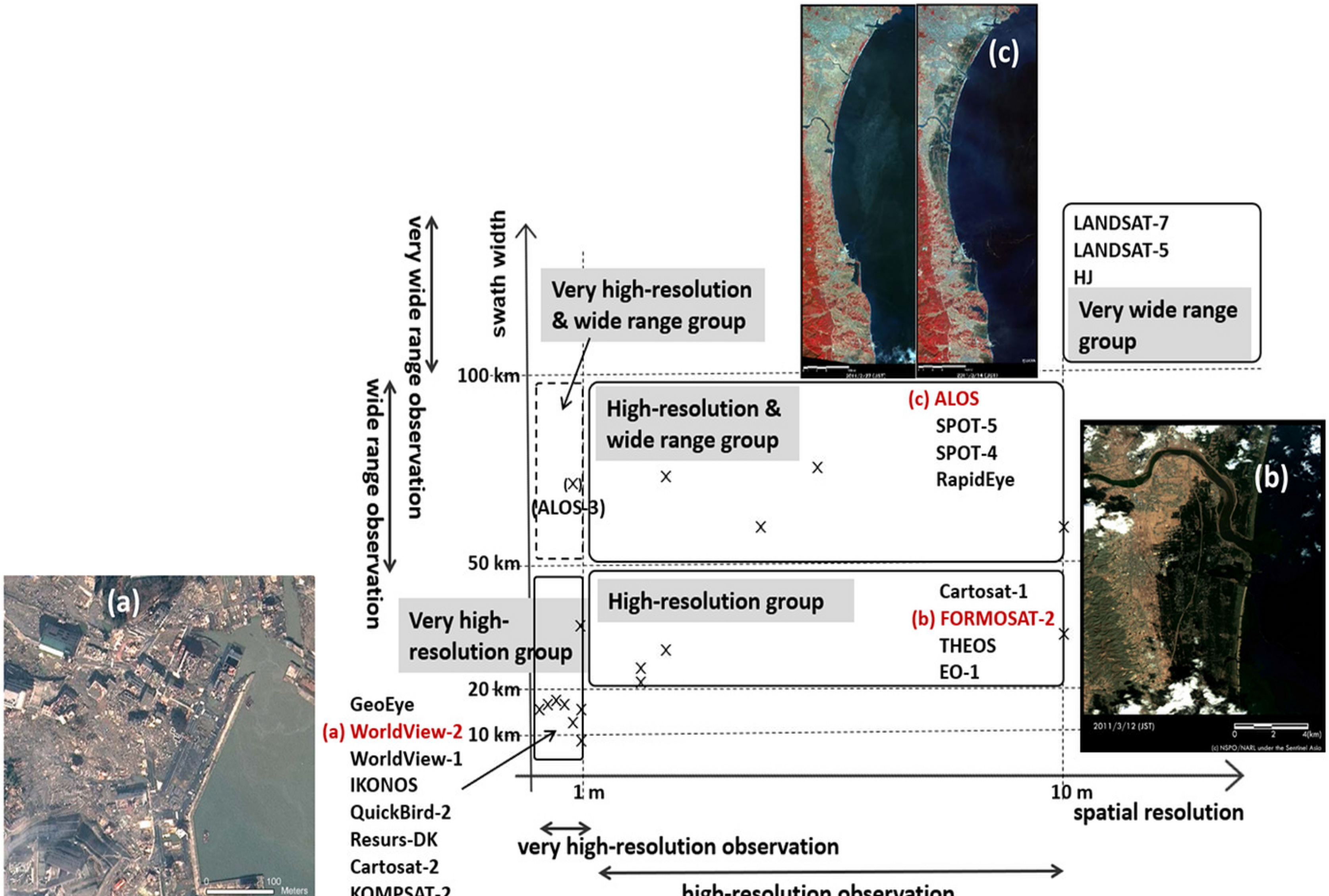
In 2006, the average overall response time from mobilization to first product was approximately 4.5 days; this was reduced to approximately 2.5 days on average by 2014.

ALOS-2 rapid response



An emergency observation request can be accepted up to 1 hour before the command uplink.
In addition, it is possible to provide a quick report via automated data analysis in about two hours, and disaster area extracting information in about 5 hours after observation.

A classification of optical earth observation satellites with respect to spatial resolution and swath width, which supported the response to the 2011 Great East Japan Earthquake

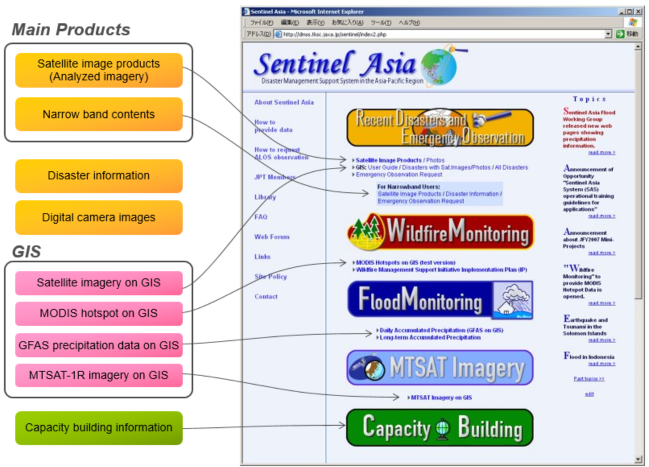


Requirements for applying satellite remote sensing to disaster management support

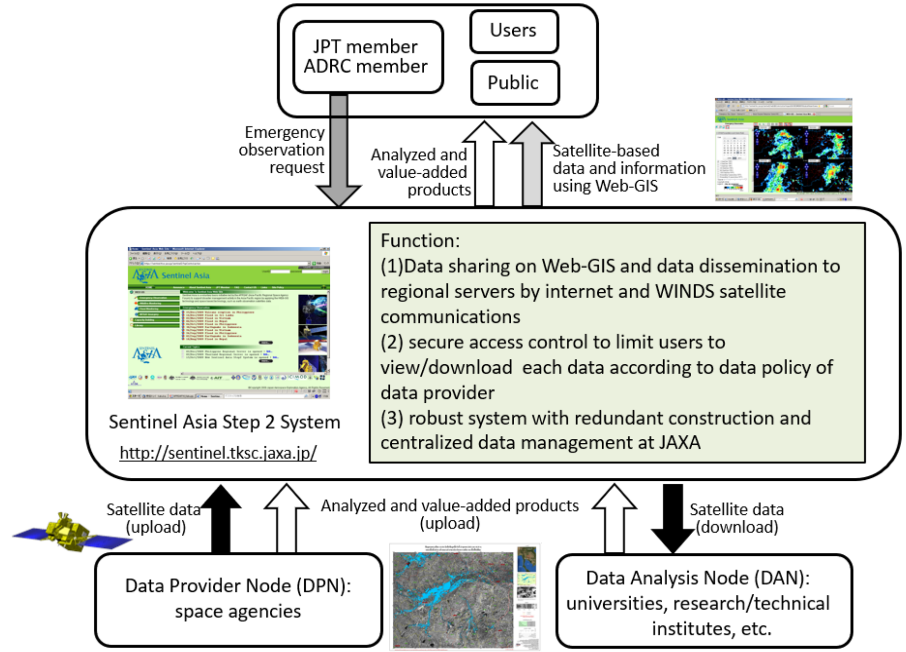
(5) Sharing/providing system of disaster information/data

- A sharing/providing system of data/information is essential for conducting disaster management support.
- It should function to share disaster information and data on Web-GIS, and to transmit data to authorized persons. It also has a secure-access control function to limit users from viewing and downloading data according to the data policies of the data providers. Communication satellites and positioning satellites are useful for satellite data transmission, evacuation warning message delivery, and others.

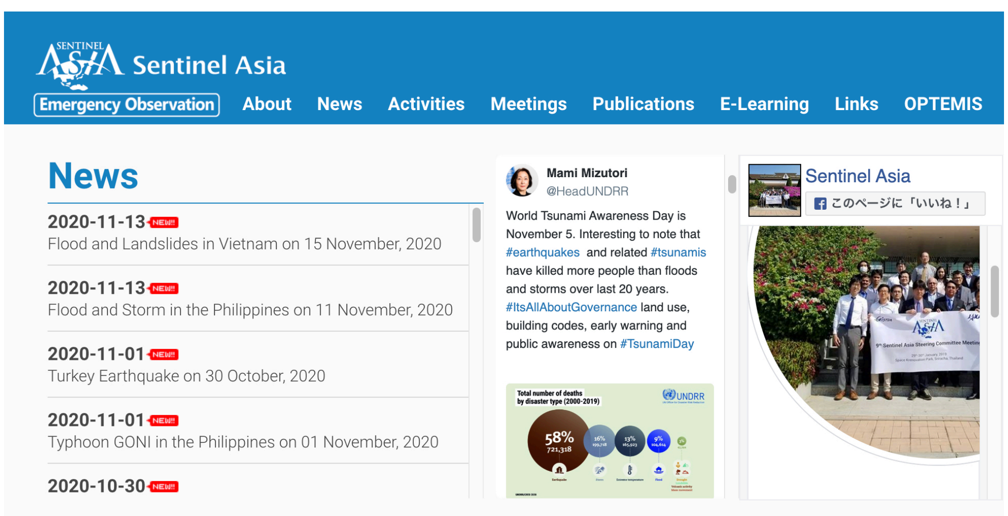
Sentinel Asia Web-GIS
for data/information sharing/dissemination



Step-1 system (using the Digital Asia Web-GIS of Keio University)



Step-2 system



Step-3 system (in operation)

https://sentinel-asia.org/index.html

Requirements for applying satellite remote sensing to disaster management support

(6) International collaboration

- International collaboration is essential for disaster management support, particularly in the case of catastrophic disasters such as the 2011 Great East Japan Earthquake.
- As many satellites as possible are expected to support disaster management, particularly response, to maximize results based on: (i) the frequency of observation; (ii) rapid response, that is, to provide satellite-based disaster information to users (disaster responders) as quickly as possible; (iii) wide area coverage; (iv) types of satellite data with respect to high-resolution or wide-ranging surveillance, as well as SAR (X- or C- or L-band) or optical sensors; and (v) the uncertainty of getting excellent imagery depending on weather conditions.
- Some international space-based initiatives are contributing to the field of disaster management: SA, the International Charter, the International Working Group on Satellite-based Emergency Mapping (IWG-SEM) by a voluntary group of organizations involved in satellite-based emergency mapping, the Committee on Earth-observation Satellites (CEOS), Copernicus (a European Union program), UN-SPIDER (a United Nations program), and the Global Earth-observation System of Systems (GEOSS) of GEO.

Requirements for applying satellite remote sensing to disaster management support

(7) Feedback from users

- Feedback from users on each disaster event is valuable to data providers, whether it goes well or not.
- If not successful, user feedback contains lessons learned for improvement of activities; if successful, it is a measure and evidence for the results of data providers.
- However, there are difficulties in collecting feedback from users. One solution is site surveys after disaster response support visiting users and end-users who worked for disaster response, to confirm in detail how satellite-based disaster data/information were employed and to discuss issues related to provided support.

Acknowledgements

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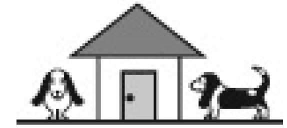
Finally,

users request continuity of activities; data providers (space agencies and others) need sustained efforts.

There is a saying, “Disasters befall us when we least expect them,” by Torahiko Terada (1878–1935), a Japanese scholar of disaster prevention as well as a physicist.

If you are interested, please see:



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