

An Introduction to Applying Satellite Remote Sensing to Disaster Management

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By

Kazuya Kaku

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Management

By Kazuya Kaku

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To all collaborators in Sentinel Asia and JAXA,
and my wife

TABLE OF CONTENTS

List of Figures	xi
List of Tables	xvi
Preface	xvii
Acknowledgements	xviii
Chapter 1	1
Introduction	
1.1 Background	
1.2 JAXA's approach	
1.3 Scope of this book	
Part I: Overview of Satellite Remote Sensing for Disaster Management	
Chapter 2	8
Basic Principles of Satellite Remote Sensing	
2.1 Satellite remote sensing system	
2.2 Sources of radiation	
2.3 Interaction with the atmosphere	
2.4 Types of satellite remote sensing	
Chapter 3	13
Space Segment: Typical Sensors for Disaster Management	
3.1 Introduction	
3.2 Optical sensors	
3.3 Synthetic aperture radar (SAR)	
3.4 Infrared sensors	
3.5 Microwave radiometers	

Chapter 4	50
Space Segment: Earth Observation Satellites	
4.1 Introduction	
4.2 Orbit and temporal resolution	
4.3 Observation time	
4.4 Examples of Earth observation satellites for disaster management: ALOS series of JAXA	
Chapter 5	61
Ground Segment	
5.1 Introduction	
5.2 Operations	
5.3 Definition of disaster management	
5.4 Areas of disaster management to which satellite remote sensing is applicable	
5.5 How to apply satellite remote sensing to disaster management	
 Part II: Case Studies on Areas of Disaster Management to which Satellite Remote Sensing is Applicable	
Chapter 6	74
Sentinel Asia	
6.1 Introduction	
6.2 Characteristics of Sentinel Asia	
6.3 SA's framework	
6.4 Implementation approach	
6.5 Activities: Disaster prevention/mitigation/preparedness phase	
6.6 Activities: Disaster response phase	
6.7 Activities: Disaster recovery phase	
6.8 Data and information sharing/dissemination	
Chapter 7	103
Case Studies in Sentinel Asia and JAXA	
7.1 Introduction	
7.2 Site survey after disaster response support	
7.3 SA success story in the Philippines	
7.4 Risk mapping in Sri Lanka	
7.5 Wildfire early detection and control in Indonesia	
7.6 Glacial lake outburst flood (GLOF) early warning in Bhutan	
7.7 SA mini-projects in Sri Lanka, the Philippines, Bangladesh,	

Myanmar, and others

Chapter 8	132
Response to the 2011 Great East Japan Earthquake	
8.1 Abstract	
8.2 Outline of the Great East Japan Earthquake	
8.3 JAXA's response to the Great East Japan Earthquake	
8.4 Approaches to examine JAXA's response	
8.5 Results and discussion	
8.6 Lessons learned and discussion for the future	
8.7 Conclusion	
Chapter 9	186
Responses to Disasters within Japan	
9.1 Abstract	
9.2 Volcano monitoring and response to eruption	
9.3 Response to flood/landslide	
9.4 Earthquake response	

**Part III: Holistic Study on how to Apply Satellite Remote Sensing
to Disaster Management**

Chapter 10	206
Holistic Study based on Case Studies	
10.1 Introduction	
10.2 Progression level of case studies	
10.3 Progress of technology	
10.4 User requirements	
10.5 Enhancement of support system	
10.6 How to better approach end-users and become a community-operated system	
10.7 Human factors	
Chapter 11	226
How to Apply Satellite Remote Sensing to Disaster Management	
11.1 Framework	
11.2 Activities	
11.3 Users and human factors	
11.4 Data providers (space agency, data analysis institutes, and others)	
11.5 Sharing/providing system for disaster information/data	

11.6 International collaboration	
11.7 Feedback from users	
Chapter 12	236
Future Studies	
12.1 Observation capability improvements	
12.2 Case- and holistic-study approach beyond Sentinel Asia	
Epilogue	240
Appendix A.....	241
Solar Radiation and Terrestrial Radiation	
A.1 Blackbody radiation	
A.2 Wien’s displacement law	
A.3 Solar radiation and terrestrial radiation	
Appendix B.....	246
Pulse Compression	
B.1 Range compression	
B.2 Azimuth compression	
Appendix C.....	250
Wildfire Detection by Satellite (MODIS): Algorithms and Evaluation	
C.1 Abstract	
C.2 Active wildfire detection by satellites	
C.3 Hotspot detection algorithms for MODIS	
C.4 Other approaches to improvement of wildfire detection	
C.5 Evaluation method for hotspot detection algorithms using Web-GIS	
C.6 Results of evaluation at study site in Thailand	
C.7 Conclusion	
References	275
Index.....	280

LIST OF FIGURES

Note: Figures in italics (3-8, 3-12 to -19, 6-13, 7-8, 8-4, 8-7, 9-7, and 12-1) can also be found in the color centerfold.

1-1 Impacts of natural disasters by region, 1987–2016.....	2
1-2 JAXA’s approach to disaster management support.....	4
2-1 Satellite remote sensing system with five components: sources of radiation, interaction with the atmosphere, interaction with the Earth’s surface, space segment, and ground segment.....	10
2-2 Overview of passive satellite remote sensing with respect to atmospheric windows and segregation of solar radiation and terrestrial radiation.....	11
3-1 A classification of optical Earth observation satellites, with respect to spatial resolution and swath width, which supported the response to the Great East Japan Earthquake in 2011.....	16
3-2 Spectral signatures of soil, vegetation, and water, with spectral bands of the OLI aboard Landsat-8/LDCM.....	17
3-3 Schematic view of SAR observation.....	18
3-4 Schematic illustration of SAR observation and imaging for a point target.....	20
3-5 Schematic illustration of SAR observation timeline.....	21
3-6 Properties of the electric field of an electromagnetic wave.....	23
3-7a Scattering characteristics of microwaves with respect to the Earth’s surface. Basic type of scattering.....	25
3-7b Scattering characteristics of microwaves with respect to the Earth’s surface (continued). In terms of wavelength.....	26
3-8 <i>Optical and SAR images of a large-scale flood due to a dike burst in Nepal, August 2008</i>	28
3-9 Schematic illustration of SAR slant-range distortion.....	29
3-10 Comparison of the two ALOS-2 intensity images acquired before (on August 20, 2018) and after (on December 24, 2018) the eruption of the Anakh Krakatau volcano in Indonesia.....	30
3-11 Example of the scattering characteristics of L-band SAR. (Flooding in New Brunswick, Canada, 2008).....	31
3-12 <i>Principle of pre- and post-disaster SAR color composite images</i>	34
3-13 <i>Color composite image using ALOS/PALSAR of a flood in Vietnam on November 5, 2008 and pre-disaster image observed on August 5, 2008</i>	36

3-14 Images of areas A-D in Fig. 3-13 before and after the disaster, as well as the color composite images.....	37
3-15 Interpretation of interferogram (DInSAR)	39
3-16 ALOS/PALSAR DInSAR analysis of the 2008 Iwate Miyagi inland earthquake and its interpretation.....	41
3-17 Coherence obtained in the interferometric analysis of the eruption of Mt. Agung in Bali Island, Indonesia, November 2017, using ALOS-2 (PALSAR-2) data.....	42
3-18 Color composite image using ALOS-2 data with different polarized waves for a landslide in Sri Lanka on May 24, 2017	44
3-19 Typhoon Ketsana in Vietnam and wildfires in Indonesia on September 28, 2009	45
3-20 Wildfire in Queensland, Australia, November 2018, with the highest alert level (catastrophic) ever recorded in Australia.....	47
3-21 JAXA global satellite mapping of precipitation (GSMaP).....	49
4-1 Sun-synchronous orbit	51
4-2 Sub-recurrence with a recurrence interval of n days.....	52
4-3 Observation time of Earth observation satellites	53
4-4 ALOS-2 in-orbit configuration	54
4-5 PALSAR-2 aboard ALOS-2 observation mode	56
4-6 ALOS-2 observation attitude	58
4-7 ALOS-2 observation coverage.....	58
5-1 Disaster management cycle and applicable items for satellite remote sensing	64
6-1 SA's objective and approaches.....	77
6-2 SA's framework under the APRSAF in terms of coordination hierarchy.....	78
6-3 Framework of SA	79
6-4 SA constellation of Data Provider Node (DPN)	80
6-5 Concept of SA Step 3.....	83
6-6 SA activities for prevention/mitigation/preparedness phase	84
6-7 SA system operation training.....	85
6-8 Framework of SA success story in the Philippines, including end-users.....	86
6-9 SA success story in the Philippines. Activities related to volcano monitoring and response to volcanic eruption	87
6-10 Wildfires in the world and wildfire management cycle	89
6-11 Operational goal of SA wildfire control initiative.....	92
6-12 Concept of SA flood monitoring.....	94
6-13 Precipitation in September 2007, 2008, and 2009 in Kalimantan, Indonesia, by GFAS.....	95
6-14 Concept of SA mini-project	98
6-15 Emergency observation flow of SA	100
6-16 SA Step-2 system and data/information flow via the system.....	102
7-1 SA activities for collaboration with users	104

7-2 Images of a large-scale flood due to a dike burst in Sunsari district in southeastern Nepal on August 18, 2008.....	107
7-3 Large-scale flood in Nepal, August 2008.....	108
7-4 Deluge in Thailand, October 2010.....	109
7-5 Site survey for tsunami in Mentawai islands, Indonesia, December 2010.....	111
7-6 Comparison of the satellite image and local situation. (Tsunami in Mentawai islands, Indonesia, October 2010).....	112
7-7 Site survey for heavy rain in Vietnam, October 2008.....	114
7-8 <i>Four areas of the field survey in Hanoi. (Heavy rain in Vietnam, October 2008)</i>	116
7-9 Hazard mapping for lahars at Mayon volcano in the Philippines and application to response.....	119
7-10 Landslide early warning prototype system in the framework of the SA success story in the Philippines.....	121
7-11 Land subsidence near Manila using ALOS DInSAR (for 3 years, 2007–2010).....	122
7-12 Process to develop flood risk map.....	124
7-13 Developed flood hazard map and flood risk map for the lower Kalu-Ganga river basin in Sri Lanka.....	125
7-14 Fire detection and control system of the JST/JICA project on wildfire and carbon management in a peat forest in Indonesia.....	128
7-15 GLOF early warning system in Bhutan based on community collaboration in Mo River basin, Bhutan by ADRC and Ministry of Home and Cultural Affairs.....	129
7-16 SA mini-project to make disaster response support by emergency observation useful for end-users in each country.....	131
8-1 JAXA's approach to disaster management support.....	133
8-2 JAXA's approach to disaster management support within Japan in collaboration with collaborative users. Framework of organizations and their functions at the time of the Great East Japan Earthquake.....	134
8-3 Areas damaged by the tsunami along the Tohoku-Kanto Pacific coast.....	135
8-4 <i>FORMOSAT-2 image (observed on March 12) analysis by NARLabsi</i>	148
8-5 Optical images around Natori. (ALOS, THEOS, and FORMOSAT-2).....	149
8-6 CARTOSAT-2 image observed on March 14, 2011, over Sendai area. Sendai east road worked as a dike.....	150
8-7 <i>SAR color composite images of Sendai coast area. (RADARSAT-2 and TerraSAR-X)</i>	155
8-8 A WorldView-2 image recorded on March 12, covering the Oshika Peninsula in Miyagi Prefecture.....	158
8-9 ALOS/AVNIR-2 pre- and post-disaster images from Sendai to Soma.....	159
8-10 A proposed classification system of optical Earth observation satellites with respect to spatial resolution and swath width.....	179

8-11 An SOS signal identified in very high-resolution satellite image. (WorldView-1).....	180
8-12 A WorldView-2 image covering Rikuchuyamada in Iwate Prefecture.....	181
8-13 Very high-resolution satellite images of Fukushima Dai-ichi nuclear power plant in Fukushima Prefecture. (WorldView-2 and GeoEye-1)	182
9-1 JAXA's approach to disaster response support within Japan	187
9-2 Observation images of lava dome by ALOS-2 (L-band SAR) and COSMO-SkyMed (X-band SAR) at Kirishimayama (Shinmoedake) and change in lava dome.....	189
9-3 ALOS-2 DInSAR image of Mount Hakone showing crustal deformation.....	192
9-4 Report at the 133rd Coordinating Committee for Prediction of Volcanic Eruptions (Mount Hakone) using ALOS-2 DInSAR	193
9-5 Estimated flooded area by ALOS-2 color composite image before (April 15, 2018) and after (July 8, 2018) the disaster in Takahashi river and Odagawa basin of Kurashiki city in heavy rain, July 2018.....	195
9-6 Estimated large-scale collapsed area in Kochi Prefecture by ALOS-2 color composite image for helicopter investigation in heavy rain, July 2018	196
9-7 <i>Estimated flooded area extraction image of Joso City. (Kanto/Tohoku torrential rains in September 2015). An analysis of the flooded area estimation from color composite images before and after the disaster</i>	198
9-8 Landslide dams indicated by the ALOS-2 image observed on September 6 with confirmation using an optical image observed by FORMOSAT-5 on September 6 in the framework of Sentinel Asia for the 2018 Hokkaido Eastern Iburi Earthquake	200
9-9 DInSAR image using ALOS-2 data, showing changes between February 10, 2015 and April 19, 2016, due to the 2016 Kumamoto earthquakes	202
9-10 The Aso-bridge landslide in Kumamoto Prefecture. ALOS-2 polarized wave color composite images near the Aso bridge.....	203
10-1 ALOS-2 rapid response.....	214
10-2 SA Step-2 system (Web-GIS) for data/information sharing/dissemination using WINDS.....	217
10-3 Improved accuracy of GSMaP data using GSMaP-IF under UNESCO project in Pakistan.....	218
10-4 An example of accuracy enhancement of GSMaP data using GSMaP-IF	219
11-1 Conceptual illustration of applying satellite remote sensing to disaster management.....	227
11-2 Framework of SA.....	228
11-3 Applicable items for satellite remote sensing in terms of disaster management cycle.....	230
11-4 SA activities supported by human network	231
11-5 SA Step-2 system (Web-GIS) for data/information sharing and Dissemination	233

<i>12-1 Observation of damaged area by predicted Nankai trough earthquake/tsunami in Japan</i>	237
A-1 The spectral irradiance of the solar radiation at the top of the atmosphere and the spectral irradiance emitted from the Earth's surface	245
B-1 Chirp pulse and compressed pulse, where $f_c = 0$	247
C-1 Definition of a pixel. The satellite detects integrated radiation and reflection over a pixel	251
C-2 Concept of error in hotspot detection using temperature threshold and incidental errors	255
C-3 Location of study site in Thailand observed by AVNIR-2 on board ALOS ...	261
C-4 Wildfires and firefighters in Thailand	262
C-5 The Web-GIS and procedure for evaluation	263
C-6 Evaluation of hotspot detection (overall imagery)	265
C-7 Evaluation of hotspot detection (enlarged imagery)	266
C-8 Geometrical configuration of detected hotspots, fires, and ground data	273

LIST OF TABLES

Note: Table in italics (7-1) can also be found in the color centerfold.

3-1 Three types of satellite remote sensing and typical sensors.....	14
4-1 Main specifications of ALOS-2	55
5-1 Areas of disaster management to which satellite remote sensing is applicable.....	65
<i>7-1 Field survey results in four areas in Fig. 7-8. (Flood in Vietnam, October 2008)</i>	117
8-1 List of satellites that supported relief efforts after the Great East Japan Earthquake	136
8-2 Observations conducted by ALOS, the International Charter, Sentinel Asia, and others (March 12–24, 2011)	139
8-3 Major analysis products provided by JAXA.....	142
8-4 Data needed by collaborative users and how they employed it	144
8-5 Timeline of initial response by JAXA	161
8-6a Summary of the opinion survey results.....	163
8-6b Summary of the opinion survey results (continued)	167
10-1 Achievements and progression level of case studies.....	207
C-1 Typical space-borne instruments used for hotspot detection.....	252
C-2 Studied algorithms	259
C-3a List of correctly detected fires.....	269
C-3b List of correctly detected fires (continued)	270
C-4 Number of false detections.....	271
C-5 Results of evaluation of algorithms.....	271

PREFACE

In Japan, the Japan Aerospace Exploration Agency (JAXA) has been engaged in disaster management support activities using the Advanced Land Observing Satellite (ALOS), launched in January 2006. I have been involved in this activity of JAXA from this time. At the beginning, I did not know what I should do to apply satellite remote sensing to disaster management. More than 10 years have passed since then; this book summarizes the knowledge and experience during this period and will be a response to my own question.

Satellite remote sensing is one of the primary support tools for disaster management, and the number of people involved in this field will increase in the future; however, it is not easy to approach for a beginner. It would be a great pleasure if this book would be useful for people with similar situations as the author in the year 2006, by providing a brief introduction and overall view of applying satellite remote sensing to disaster management, covering an overview of satellite remote sensing, case studies on areas of disaster management to which satellite remote sensing is applicable, and how to apply satellite remote sensing to disaster management.

It should be noted that “application of satellite remote sensing to disaster management” in this book refers to the employment of satellite-based disaster information/data by users and end-users working for disaster management, including rescue/relief/evacuation; not just disclosing them on the Internet.

Kazuya Kaku

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CHAPTER ONE

INTRODUCTION

1.1 Background

According to the Natural Disasters Data Book 2016 (ADRC, 2016), Asia has been seriously damaged by natural disasters over the last 30 years, as shown in Fig. 1-1. This is compounded by its high population density (more than half of the world's population). Disasters occurring in Asia comprise 39% of the worldwide total. The region suffers 61% of global fatalities and has 88% of the total victims associated with such disasters. In view of these circumstances, the Asia-Pacific Regional Space Agency Forum (APRSAF) proposed Sentinel Asia (SA) in November 2004, when it was realized that the rapid technological advances in the region could confer life-saving benefits, if satellite imagery and derived information could be delivered more quickly via the Internet to disaster management agencies in affected countries, in the form of easily interpreted disaster-related information. APRSAF itself was established in 1993 in response to a 1992 declaration adopted by the Asia-Pacific International Space Year Conference (APIC) to enhance the development of each country's space program and to exchange views toward future cooperation with respect to space activities in the Asia-Pacific region. It was originally designed to provide opportunities for regional space agencies and associated governmental bodies to exchange technical views, opinions, and information on national space programs and space resources.

The application of satellite remote sensing to disaster management under an international framework began around 2000, when satellite-based Earth observations for rapidly assessing disaster situations globally (namely, response support) were started by the International Charter Space and Major Disasters (hereinafter referred to as "the Charter" or "the International Charter" or "the International Disaster Charter") and the United Nations (UN) (Voigt et al., 2016).

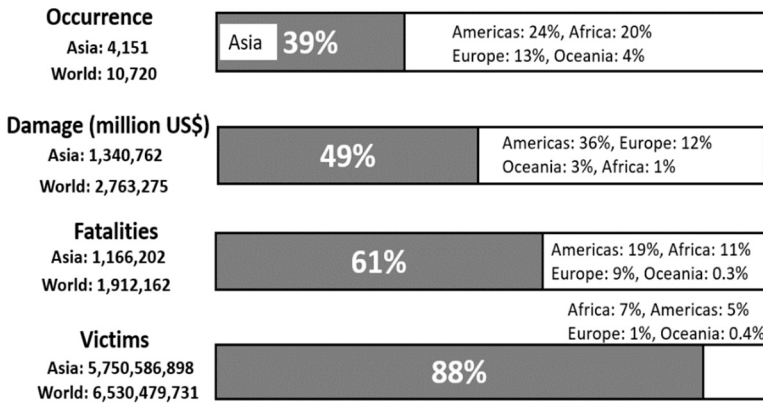


Fig. 1-1. Impacts of natural disasters by region, 1987–2016. Source: ADRC-Natural Disasters Data Book 2016.

The International Charter (Bessis et al., 2004) was initiated by the European Space Agency (ESA), the French Space Agency (CNES), and the Canadian Space Agency (CSA) in 2000 and has provided a mechanism for the rapid tasking of satellites for immediate response after sudden major disasters, such as floods, earthquakes, and tropical storms, under an international collaboration amongst space agencies and space operators. Between 2000 and 2017, 13 other space agencies, including the Japan Aerospace Exploration Agency (JAXA), joined. Free satellite-based information is provided to national disaster management authorities and humanitarian organizations to support the immediate response to major natural or man-made disasters (source: the 17th Annual Report of the International Charter).

JAXA has begun engaging in disaster management support activities using the Advanced Land Observing Satellite (ALOS), launched in January 2006. JAXA has been striving to highlight the role of Earth observation satellites in disaster management, within Japan and in the international activities of SA and the International Charter. JAXA worked to establish the SA framework and determine the implementation plan as an SA secretariat.

1.2 JAXA's approach

Space technology is a new tool in the field of disaster management in Japan. JAXA began supporting disaster management efforts using ALOS series (refer to Section 4.3) beginning in 2006 (Kaku et al., 2018). Concerning disasters within Japan, under an agreement with the Cabinet Office (in charge of disaster prevention), when a disaster occurs, JAXA conducts emergency observations by ALOS-2 and others and provides observation images and disaster information to users of disaster-related ministries and agencies; for preparedness, JAXA provides the necessary satellite images for their Geographic Information System (GIS) and disaster prevention drills. Furthermore, to expand employment of satellite data and imagery for disaster management to end-users, JAXA also has agreements with specific municipal users and promotes demonstration incorporating satellite-based disaster information to regional disaster prevention. Working groups (WGs) for each type of disaster are organized in collaboration with disaster-related research institutions and universities and proceed with the goal of creating a mechanism whereby disaster-related organizations can employ satellite images. The volcano WG (secretariat: Japan Meteorological Agency (JMA)) and the earthquake WG (secretariat: Geospatial Information Authority of Japan (GSI)), organized as a working group on satellite image analysis under the umbrella of the Coordinating Committee for Prediction of Volcanic Eruptions and the Coordinating Committee for Earthquake Prediction, respectively, promote the employment of satellite data in monitoring active volcanoes, as well as grasping the situation after volcanic eruption and earthquake.

Disaster management support using the ALOS series is conducted not only within Japan but also for overseas disasters through the international collaboration framework of SA and the International Charter. The international collaboration framework makes it possible to receive support from overseas space agencies when domestic disasters occur.

In November 2016, JAXA concluded a bilateral agreement on disaster response collaboration with the Italian Space Agency (ASI), whereby ALOS-2 and COSMO-SkyMed (CSK) can be used for disaster response in both countries. JAXA's approach to disaster management support is summarized in Fig. 1-2.

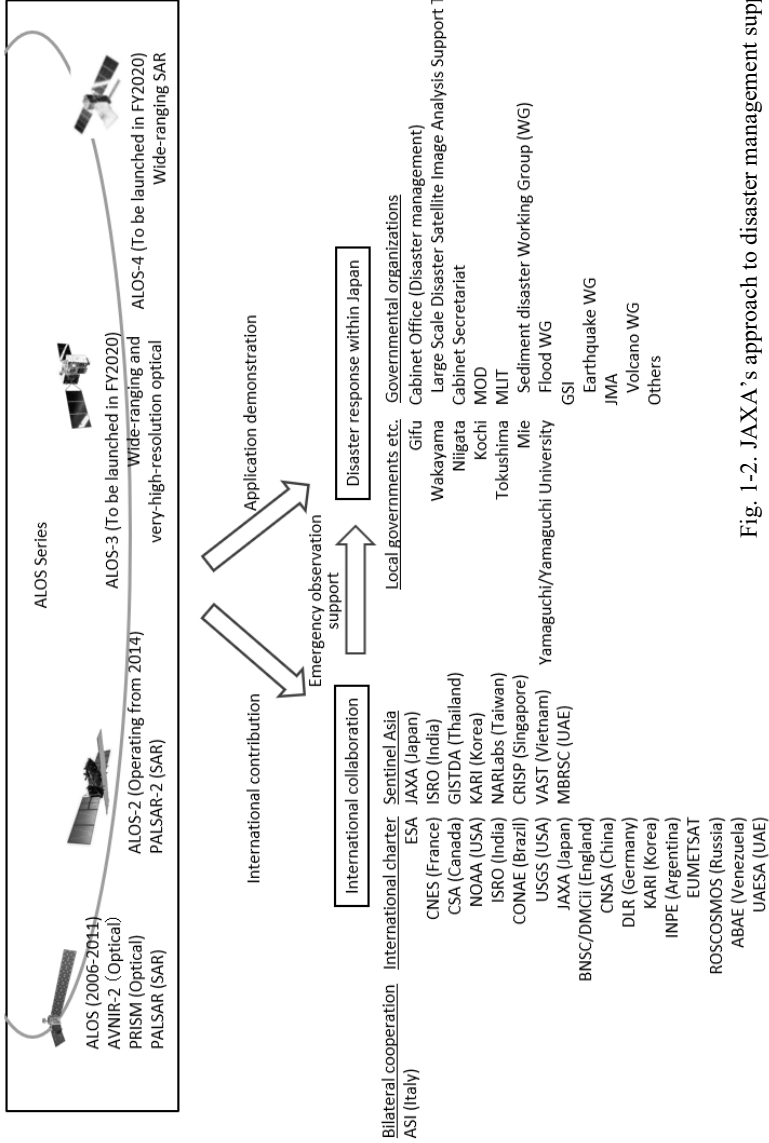


Fig. 1-2. JAXA's approach to disaster management support.

1.3 Scope of this book

This book has three themes:

- (1) Overview of satellite remote sensing for disaster management (Part I): Satellite remote sensing is comprehensively outlined from the viewpoint of applications to disaster management in Chapters 2 to 5.
- (2) Case studies on areas of disaster management to which satellite remote sensing is applicable (Part II): Sections 5.3 and 5.4 for overview; Chapters 6 to 9.
- (3) Holistic study on how to apply satellite remote sensing to disaster management (Part III): Section 5.5 for overview; Chapters 10 to 12.

This book provides an overview of satellite remote sensing, detailing how it works and for what fields of disaster management it can be used. This book is unique in the sense that it is based on 13 years of empirical study through international collaboration projects and case studies conducted by JAXA since 2006, taking human factors (users) into account. This book will particularly appeal to practitioners (such as disaster responders, policy makers, and administrative officials) and researchers in the field of disaster management who are interested in applying satellite remote sensing to disaster management, as well as researchers in the satellite-remote-sensing field (such as space agencies, universities, and research institutes) who are interested in or working for applications of satellite remote sensing to disaster management. Of course, people (including students) from other fields who are interested in satellite remote sensing and disaster management are also readers.

I tried to write the text using illustrations and satellite images, without mathematical formulas; three appendices provide mathematical explanations on solar and terrestrial radiations, pulse compression, and wildfire detection algorithms.

PART I:

**OVERVIEW OF SATELLITE REMOTE
SENSING FOR DISASTER MANAGEMENT**

Part I (Chapters 2 to 5) provides an overview of satellite remote sensing from the viewpoint of its application to disaster management by describing an entire satellite remote sensing system.

CHAPTER TWO

BASIC PRINCIPLES OF SATELLITE REMOTE SENSING

2.1 Satellite remote sensing system

Remote sensing is a technology for remotely studying the properties of objects using electromagnetic radiation, without touching the objects directly. Satellite remote sensing covers wide-ranging areas, operates continually during all hours and in all types of weather, and is used to survey Earth's surface and atmosphere to study global environmental problems, monitor disasters, explore resources, and so on.

A satellite remote sensing system (Curran, 1985) consists of five components, as shown in Fig. 2-1: sources of radiation (the Sun, the Earth, and an artificial radiation source), interaction with the atmosphere, interaction with the Earth's surface, space segment (sensors and satellites), and ground segment. It should be noted that human factors (such as system operators and system users working in disaster management and response) in the ground segment as well as technical factors are important when applying satellite remote sensing to disaster management.

2.2 Sources of radiation

Everything that is hotter than 0 K emits electromagnetic radiation. The largest source of electromagnetic radiation is the Sun (solar radiation), and the Earth's surface reflects and absorbs the solar radiation, as shown in Fig. 2-1. Furthermore, absorbed solar radiation raises the Earth's temperature and is radiated back to space as thermal radiation according to its temperature (terrestrial radiation). This mechanism keeps absorbed solar radiation and emitted terrestrial radiation in balance macroscopically. Remote sensing measures the reflected solar radiation and emitted terrestrial radiation. In addition, remote sensing employs an artificial source of electromagnetic radiation; that is, the

satellite itself emits electromagnetic radiation and receives the returned electromagnetic radiation from the Earth's surface. The former (which uses natural radiation) is called passive remote sensing; the latter (an artificial radiation source) is known as active remote sensing.

The wavelengths at which solar radiation and terrestrial radiation are employed can be shown to be almost completely distinct for remote sensing, as shown in Fig. 2-2. Although there is much more solar radiation than terrestrial radiation, because the Earth is very far from the Sun, the segregation of the solar radiation and the terrestrial radiation results at the top of the Earth's atmosphere in satellite remote sensing. For wavelengths that are shorter than an intersection point at λ_0 (see Fig. 2-2), solar radiation is dominant, which is called the solar radiation (or "shortwave radiation") range. For wavelengths that are longer than the intersection point, terrestrial radiation is dominant, which is called the terrestrial radiation (or "longwave radiation") range. For derivation of Figs. 2-2(a) and (b), refer to Appendix A.

Solar radiation, that reached the top of the Earth's atmosphere (see Fig. 2-2(a)), reaches the Earth's surface through the atmosphere and is reflected by the Earth's surface and finally reaches sensors at the space segment through the atmosphere. In this process, solar radiation is influenced by the atmosphere that has unique spectral features of transmittance (see Fig. 2-2(c) and Section 2.3). Similarly, terrestrial radiation that reaches sensors at the space segment through the atmosphere is influenced by the atmosphere.

The intersection point (λ_0), which is the boundary point between the solar and terrestrial radiation ranges, varies depending on the Earth's surface temperature. Given that the range of the Earth's surface temperature is 200–350 K (Kondo, 2000), the intersection point is rounded as a wavelength interval of $\sim 3\text{--}8\ \mu\text{m}$, where the dominance of solar or terrestrial radiation is not uniquely defined and special handling is required. It should be noted that only terrestrial radiation can be detected without the influence of solar radiation at night, regardless of wavelength. For example, an infrared wavelength of $\sim 4\ \mu\text{m}$, which is suitable for monitoring volcanoes and wildfires, belongs to the mixing range ($\sim 3\text{--}8\ \mu\text{m}$), for which only night-time data are employed.

In conclusion, the solar radiation range and the terrestrial radiation range are separated at the intersection point, although the intersection point is not fixed and is at a wavelength range of $\sim 3\text{--}8\ \mu\text{m}$.

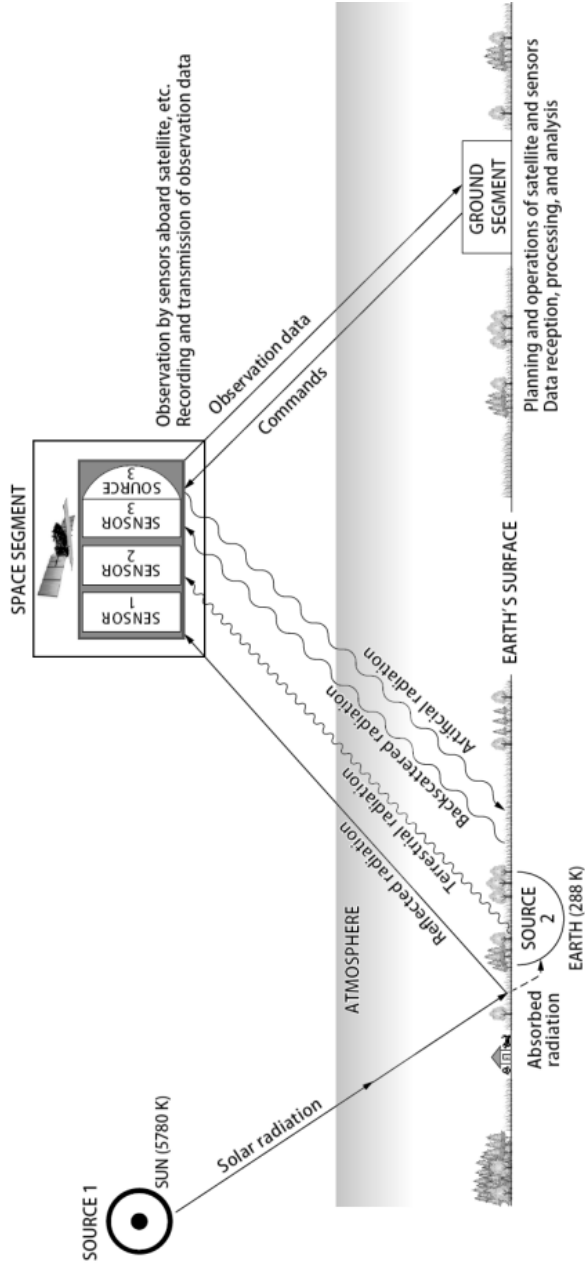


Fig. 2-1. Satellite remote sensing system with five components: sources of radiation, interaction with the atmosphere, interaction with the Earth's surface, space segment, and ground segment (Curran, 1985; with modifications).