8. Satellite Earth observation and disaster management – lessons and needs after the Indian Ocean tsunami and the Haiti earthquake

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8.1. Introduction

The Indian Ocean tsunami in 2004 and the earthquake in Haiti in 2010 were two of the largest and most significant natural disasters to occur on Earth. The Indian Ocean tsunami of 26 December 2004 was created from an earthquake west of the Indonesian island of Sumatra that registered a magnitude on the Richter scale of between 9.1 and 9.3, the second largest earthquake ever recorded on Earth. The tsunami resulted in the loss of over 200,000 lives. The Haiti earthquake of 12 January 2010 was of a lower magnitude, 7.0 on the Richter scale, but also resulted in the loss of over 200,000 lives because the earthquake epicentre was very close to the population of the Haiti capital Port au Prince. The January 2010 earthquake was the worst earthquake to hit Haiti in 200 years.

The use of satellite remote sensing data after both of these disasters was put in place rapidly and extensively, and satellite images of the disaster areas were provided to relief teams and others within two days of the events. The purpose of this paper is to examine the lessons learned from the use of satellite Earth observation data of the two disasters and to identify future needs based on the experiences gained. The orientation of the paper is to make the examinations in the light of space policy rather than space technology or space science.

There was extensive publication of remote sensing science papers after the Indian Ocean tsunami. Special issues of two of the main scientific journals in remote sensing were published in 2007: both the *International Journal of Remote Sensing* and the *IEEE Transactions on Geoscience and Remote Sensing* published a special issue devoted to the tsunami itself in the case of the former and to disaster monitoring, assessment and prediction more generally in the case of the latter. However, although there has been extensive coverage of the Indian Ocean tsunami and the Haiti earthquake in science publications, there have been few papers that examine the policy dimensions of the use of satellite remote sensing

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data to help with these two major events and with natural disasters more generally, which is perhaps surprising as it is the policy dimensions of the use of space data in natural disasters that will assist most with preparing for future disasters.

One international policy that is relevant is the set of 15 principles that make up the UN Principles on Remote Sensing. This paper examines the context provided by the UN Principles and then goes on to discuss one of the main vehicles for the use of satellite remote sensing data in the two natural disasters, the International Charter on Space and Major Disasters. The paper then examines the wider question of data from space for science and concludes by identifying, from a space policy perspective, lessons learned and future needs to improve the role of satellite remote sensing in responding to major disasters.

The paper concentrates on the use of Earth observation data from space. Other space technologies that are particularly useful when responding to disasters are satellite communications and satellite navigation. Satellite telephones have allowed users on the ground to communicate with their home base via a geostationary satellite. Very Small Aperture Terminals (VSATs) require an antenna on the ground of about 1 m diameter and can provide internet access, while the Broadband Global Area Network (BGAN) also provides internet access normally via a laptop used in line of sight to an Inmarsat satellite. Satellite navigation is now common place by using the US Global Positioning System (GPS), a capability that will be enhanced in the future when Europe launches its Galileo satellite navigation system.

8.2. UN principles on remote sensing

After approximately 15 years of discussion and negotiation, in December 1986 the members of the United Nations reached agreement on the *Principles relating to remote sensing of the Earth from space*.[789] The Principles have a wide scope, but two principles in particular are concerned with space and disaster management, namely Principle X and Principle XI. To take Principle X first:

Remote sensing shall promote the protection of the Earth's natural environment. To this end, States participating in remote sensing activities that have identified information in their possession that can be used to avert any phenomenon harmful to the Earth's natural environment shall disclose such information to States concerned.

Principle X appeared in draft form in the UN Principles discussion as early as 1974 and by 1977 the text was in its more or less finished form, suggesting that reaching agreement on the value of remote sensing data for environmental protection did not prove difficult.

The core concept in Principle X is that of the good neighbour. A State that has acquired remote sensing data that shows potential harm to another State should provide the third State with that information, for example France should provide SPOT data to Haiti if processing of the SPOT data shows information that can be used to avert any natural environment phenomenon harmful to Haiti. The responsibilities in Principle X are among States, not least because the 15 UN Principles are agreements among UN member States. As such it is the responsibility of States to provide the information to affected States, although of course in practice this State responsibility is typically carried out by designated agencies.

Principle XI is similar to Principle X but has a focus of protecting mankind from natural disasters:

Remote sensing shall promote the protection of mankind from natural disasters. To this end, States participating in remote sensing activities that have identified processed data and analysed information in their possession that may be useful to States affected by natural disasters, or likely to be affected by impending natural disasters, shall transmit such data and information to States concerned as promptly as possible.

Principle XI has three refinements or developments compared to Principle X: the principle is more explicit on the data-owning State having either processed data or analysed information in its possession rather than just the general term of information; the principle is explicit on the future with its reference to impending natural disasters, emphasising environmental prediction; and some element of time is provided although it is a rather weak “as promptly as possible”.

The 15 UN Principles have embedded within them other concepts that are relevant to space and disaster management, especially the use of remote sensing to benefit all countries specifically including the Less Economically Developed Countries (Principles II and IV), and the promotion and intensification of international cooperation on remote sensing (Principles V, VI, VIII and XIII).

8.3. International Charter

8.3.1. The Charter

At the UNISPACE III Conference held in Vienna in 1999 the International Charter *Space and Major Disasters* was announced by the European Space Agency

(ESA) and the French Space Agency (CNES), followed by the joining of the Canadian Space Agency (CSA) in 2000 shortly before the Charter became fully operational on 1 November 2000. Since then there has been an increase in the number of members, and Table 2 gives the Charter membership position in May 2010.

Tab. 2: *The members of the International Charter Space and Major Disasters, October 2010. Source: http://www.disasterscharter.org/web/charter/home.*

Member	Participant(s)	Satellite resources
CNES France	Centre national d'etudes spatiales Spotimage NSPO (Taiwan)	SPOT Formosat
CNSA China	China National Space Administration	FY, SJ, ZY satellite series
CONAE Argentina	Comision Nacional de Actividades Espaciales	SAC-C
CSA Canada	Canadian Space Agency	Radarsat
DLR	Deutsches Zentrum für Luft und Raumfahrt	TerraSAR-X TanDEM-X
DMCii Disaster Management Constellation	CNTS Algeria NSRD Nigeria Tubitak-BILTEN BNSC/SSTL BNSC/Qinetiq	ALSAT-1 NigeriaSat BILSAT-1 UK-DMC TopSat
ESA Europe	European Space Agency	ERS, Envisat
ISRO India	Indian Space Research Organisation	IRS
JAXA Japan	Japan Aerospace Exploration Agency	ALOS
NOAA USA	National Oceanic and Atmospheric Administration	POES, GOES
USGS USA	United States Geological Survey DigitalGlobe GeoEye	Landsat Quickbird GeoEye-1

There are two primary objectives of the International Charter.[790]

- Supply during periods of crisis, to States or communities whose population, activities or property are exposed to an imminent risk, or are already victims, of natural or technological disasters, data providing a basis for critical information for the anticipation and management of potential crises.
- Participation, by means of this data and of the information and services resulting from the exploitation of space facilities, in the organisation of emergency assistance or reconstruction and subsequent operations.

Under the aim of the Charter only authorised users are allowed to request and then initially receive Earth observation data. These authorised users are typically the civil protection, rescue, civil defence and security bodies of the participating country that has entered into the formal Charter agreement. The Earth observation data used under the International Charter are not openly distributed to any organisation that might happen to be interested, such as a research group in a university for example.

When a disaster occurs an authorised user calls a single point of contact with a data acquisition request.[791] The desk officer who receives the call works with an emergency on-call officer (or technical team) to identify the potential satellite resources available for the location in question, to plan satellite data acquisition and to task the satellite(s). The participating agencies task their satellite(s) and resolve any conflicts with their own, planned acquisitions. The images are acquired by the satellite(s), interpreted by one or more specialist teams and then the images and derived maps are delivered to the authorised user. One key data policy feature of the International Charter is that the authorised users are provided with the Earth observation data by the participating space data suppliers free of charge, no matter what the charging policy for the same data normally is.[792]

The number of activations of the Charter is approximately 40 per year.[793] In 2008 and 2009 there were 40 activations each year, and in 2010 there were 24 activations by the end of June. The largest category of activations has been in response to floods. For example, in 2009 there were 21 activations in response to flooding events, such as floods in Vietnam in July 2009 and floods in Georgia, USA in September 2009.

8.3.2. Indian Ocean tsunami

As noted in the introduction, the Indian Ocean tsunami of 26 December 2004 resulted in the loss of over 200,000 lives, mostly in Indonesia, Sri Lanka and

India. The coastal regions of India, Sri Lanka, Thailand, Indonesia, Maldives, Malaysia and Myanmar were all severely affected, while Bangladesh, the Seychelles, Somalia, Kenya, and Tanzania also suffered damage and loss of life. The Charter was activated by a request from the Indian Space Research Organisation (ISRO) on 26 December 2004, and the data was project managed by ISRO, the National Remote Sensing Agency of India (NRSA), the UN Office for Outer Space Affairs (UNOOSA) and the French space agency (CNES).

Under the Charter there were three categories of map information produced. First, there were regional maps that showed the extent of the potential damage over the whole Indian Ocean coastal area. By 28 December 2004 (i.e. two days after the event) a regional map of the tsunami-affected areas had been produced by NASA and the USGS for UNOSAT. The map shows land lying below 20 m, and therefore susceptible to damage by the tsunami, as derived from the SRTM30/ETOPO2 data set, plus land cover information derived from the Modis instrument on the US Terra satellite. SRTM30 data are land surface altitude data from the Shuttle Radar Topography Mission (SRTM) re-mapped at a spatial resolution of 30 arc-seconds (approximately 1 km).

Second, there were image maps that showed the effects of the tsunami on specific regions. These were commonly shown as before and after images. Images captured by the Indian IRS-P6 AWiFS instrument of Trinkat Island in the Nicobar Islands group show what was a single island on 21 December 2004 had become three separate islands on 26 December 2004 because of flooding during the tsunami.[794] Images in the visible and near infrared parts of the electromagnetic spectrum are affected by cloud, which was commonly the case on and shortly after 26 December 2004. Radar has the ability to penetrate cloud and image the surface, so several of the before and after image maps use radar data from ESA's Envisat ASAR operating at C-band (around 5 cm wavelength) and with a spatial resolution of 30 m. The Envisat ASAR images taken after the tsunami show clearly many coastal areas submerged by the sea. Radar has the extra advantage for flooding in that the radar backscatter responds to surface roughness. Flooding is typically characterised by a change from a rough land surface of vegetation or buildings to a smooth surface of water, which means that flooding is relatively easy to see on radar images.

Third, there were images that showed the detail of the impact of the tsunami on individual buildings, fields and forest areas. Figure 10 shows two Ikonos images[795] of a region of Aceh, Sumatra, Indonesia, each covering a surface area of 2.59×2.59 km with a pixel size of approximately 2 m. The image on the left was acquired on 13 January 2003, i.e. before the tsunami event, and the image on the right was acquired on 29 December 2004, i.e. 5 days after the tsunami. At this spatial

Fig. 10: *Ikonos images of part of Aceh, Sumatra, Indonesia with a pixel size of approximately 2 m (source: CRISP, http://www.crisp.nus.edu.sg/tsunami/tsunami.html, accessed 22 July 2010).*

resolution it is possible to see in detail the flooding of large areas of agriculture, roads and buildings down to the level of individual fields, buildings and parts of roads.

8.3.3. Haiti earthquake

On 12 January 2010 a major earthquake of magnitude 7.0 on the Richter scale struck 16 km south of Port au Prince, Haiti on the Enriquillo fault line, followed by several aftershocks of magnitude over 5.0. The deaths, casualties and damage affected about 5.4 million people; the number was so large mainly because of the poor state of economic and social development of Haiti. On 13 January 2010 the Charter was activated by a group of organisations: the French Civil Protection Agency, UNOOSA on behalf of the UN Peacekeeping Mission in Haiti, Public Safety of Canada and the US Geological Survey (USGS).

In the case of the Indian Ocean tsunami of 2004 the main effects concerned flooding of low lying coastal areas. Earth observation data that showed the spatial extent of flooding were the preferred data. In the case of the Haiti earthquake the main effects were in direct connection with the earthquake and so the most useful Earth observation data were those that could show the physical effects of the earthquake itself. There were two broad categories of Earth observation data used after the Haiti earthquake: (1) optical wavelength data often with a very high spatial resolution of the order of 1 m and (2) radar data.[796] The optical wavelength data included image data from GeoEye-1 (USA, 0.41 m pixels), QuickBird (USA, 0.6 m pixels), Kompsat-2 (Korea, 1 m pixels), SPOT-5 (France, 2.5 m pixels), ALOS AVNIR (Japan, 10 m pixels) and Huanjing-1 A/B (China, 30 m pixels). Visual and machine-aided image interpretation of these optical data enabled the rapid production of maps of the affected areas such as the following.

- Gathering areas for the population
- Location of public buildings affected by the earthquake
- Damage assessment for major buildings and infrastructures
- Obstacles on bridges and roads

Some of these maps were produced as early as 14 January 2010, that is 48 hours after the earthquake itself and 24 hours after the Earth observation data were acquired. An important characteristic of the image maps was that they were geo-rectified and were accompanied by a scale and a key: this is vital for users in the field who need information in a form that is easy to use and fits with other map data they possess.

The radar data were contributed from Radarsat (Canada), ERS-2 and Envisat (Europe), TerraSAR-X (Germany), Cosmo-SkyMed (Italy) and ALOS PALSAR (Japan). One interesting use of the radar data was the application of the technique of SAR interferometry to create maps of vertical surface deformation and horizontal surface movement that resulted from the earthquake. SAR interferometry (InSAR) uses the phase differences in the radar wave in the range direction from the radar antenna to the target from two different positions of the SAR antenna and was the basis, for example, of the Shuttle Radar Topography Mission. The vertical resolution of InSAR is of the order of half the wavelength of the radar system, which means that for C-band systems such as Envisat and Radarsat that have a wavelength of around 5 cm the maximum vertical resolution of InSAR is of the order of 2.5 cm, although in practice the vertical resolution is typically not as good as this. The use of SAR interferometry allowed the production of maps of surface height and surface height changes with contours of 12 cm. Maps showing horizontal displacement of up to 2 m were also produced.

8.3.4. Access and accuracy

The amount of Earth observation data made available after the Haiti earthquake was clearly very large. But the images produced from these data raise two policy questions, namely concerns over access and accuracy. First, there is the question of access. As noted earlier, the Earth observation data made available under the Charter are only for the use of the requesting organisation and the members of the team carrying out the related work. This restriction has extended more widely and the GEO Haiti Event Supersite Website illustrates such an exclusion.[797] Regarding the ALOS data from Japan there are four restrictions noted on the GEO site:

1. The [ALOS] data sets are to be utilized only for the requested purposes of the GEO task.
2. The data shall not be re-distributed to another party.
3. All copyright of [ALOS] PALSAR data belongs to JAXA and METI;[798] thus, copyright should be indicated as © METI, JAXA.
4. GEO Secretariat to report to JAXA the name (or affiliation) of each user and how the data was used.

The use of the ALOS data is therefore restricted to a relatively small number of individuals or organisations, those who are carrying out work on a recognised GEO task.

The International Charter was initially designed on a best-efforts basis to use the then existing Earth observation data resources for a specific humanitarian role. The Charter can be regarded as an operational system for those who are authorised users, but not an operational system for all users. Operational remote sensing has been a declared goal for many decades, but even the Charter with a defined humanitarian objective is only operational within narrow limits.

Second, there is the question of accuracy. There are many differences between the image maps produced showing damage in the Port au Prince region, even those image maps purporting to show the same type of information such as building damage. InSAR images are useful and interesting in a scientific context but they are still experimental outputs. They are hard for the layman to understand, not usually presented as image maps and different InSAR images of the same area show different surface deformation effects. They are not normally in a form that non-experts can use in the field.

8.3.5. Other disaster information systems

The International Charter is one of several information systems that use Earth observation data to provide information at times of disasters or emergencies. Table 3 gives examples of some of the other major disaster information systems

Tab. 3: *A summary of selected disaster management information systems that provide Earth observation data.*

Name	Characteristics	Web site
Center for Satellite Based Crisis Information	Rapid provision of Earth observation data products for humanitarian relief activities and for civil security	www.zki.dlr.de
Disaster Management Constellation	A proof of concept constellation, capable of multispectral imaging of any part of the world every day because of the large number of satellites in the constellation. Low cost satellites owned by Algeria, China, Nigeria, Spain, Turkey and the UK	www.dmcii.com
RESPOND	Part of GMES, works with the humanitarian community to improve access to maps, satellite imagery and geographic information	www.respond-int.org
SAFER	A pre-operational version of the GMES Emergency Response Service, 2009–2011	www.emergencyresponse.eu
Thomson Reuters AlertNet	Rapid alert of humanitarian organisations to disasters mainly through the mechanism of journalism	www.alertnet.org
UN-SPIDER	UN gateway to space information for disaster management support	www.oosa.unvienna.org/oosa/unspider/index.html

and a note on their characteristics. The list in Table 3 is not exhaustive, yet it shows the variety of systems already in existence to respond to disasters. These range from the Disaster Management Constellation which is a set of similar, low-cost satellites that provide rapid optical image data with a spatial resolution of around 30 m (see also the paper by Sandau in this volume), through to the AlertNet system of Thomson Reuters that has its foundation in the provision of up to date information about disasters through news channels.

8.4. Data policy trends for science and research

As noted earlier, the International Charter provides data free of charge to the authorised users. This immediately raises the question of data policy. How extensive is the list of authorised users? For how long can the authorised users use the data? Can the authorised users give the data for free to their neighbouring organisations that have a legitimate interest in the data for disaster management? Why is it not possible for research scientists to have access to the disaster area data if they are carrying out research that assists those affected by the disaster?

There do appear to be some trends in data policy that may enable some answers to these questions to develop. The US federal government has for some time had a data policy that all federally produced data (including Earth observation data from space) should be made available to users for the cost of fulfilling a user request (COFUR). COFUR is also termed marginal cost by many. The science and technology ministers of the member countries of the Organisation for Economic Co-operation and Development (OECD) agreed in 2007 that for research data that are gathered using public funds for the purposes of producing publicly accessible knowledge then:[799]

. . . access [to the data] on equal terms for the international research community [should be available] at the lowest possible cost, preferably at no more than the marginal cost of dissemination.

The Programme Board for Earth Observation (PB-EO) of the European Space Agency (ESA) has approved a new data policy for ERS-2, Envisat, Earth Explorer and Sentinel missions. The new data policy ensures that any user has the right to access the data; that licences for the use of the data are free of charge; and that online access is provided with a user registration process whereby users accept a set of generic terms and conditions for use of the data.

In the UK the Ordnance Survey has changed its data policy to provide certain digital map data free of charge.[800] After an open consultation in 2009, government policy changed in 2010 to create a suite of digital products called OS OpenData that are free of charge to use and with no restrictions on re-use. The free data in the OS OpenData package are at map scales of around 1:25,000 plus digital point and boundary data.

The Group on Earth Observation (GEO) has, under the leadership of the Committee on Data for Science and Technology (CODATA), adopted a set of high level data sharing principles to guide the sharing of relevant Earth observation data contributed to GEOSS. The three data sharing principles are:[801]

- There will be full and open exchange of data, metadata and products shared within GEOSS, recognizing relevant international instruments and national policies and legislation;
- All shared data, metadata and products will be made available with minimum time delay and at minimum cost;
- All shared data, metadata and products being free of charge will be encouraged for research and education.

The International Council for Science is developing a World Data System (WDS) to draw together in a more coherent way the former data centres and geophysical services that it stimulated originally in the 1950s.[802] The World Data System Scientific Committee is discussing during 2010 the use of the three data sharing principles adopted by GEOSS for implementation for all the data in the World Data System.

The trend is clear. More and more organisations are producing data policies for all or part of their data to provide the data either free of all charges or at the marginal cost of reproduction and delivery, especially for research and education use. For disasters there is a moral dimension or pressure to provide data free of charge and very rapidly to respond to emergencies. This still leaves the ever-present question of who pays for the data. This is a matter of policy. In the USA the policy is to provide Earth observation data funded by the government and then achieve gearing by encouraging others to use the data and add value either in a commercial, or a science sense. In Europe and other parts of the world the policy is to fund Earth observation by government until it can become a sustainable sector, at which point government can exit and the sector can operate by itself. In the case of disasters, there would seem always the need for Earth observation data to be provided without a concern for paying a fee, which in turn suggests government support or charity support.

8.5. Lessons

In 2002 the UN organised a workshop on the use of space technology for disaster management in Addis Ababa. Bessis et al[803] explored the lessons learned after 20 months of operation of the International Charter. The authors identified nine points for improvement. The points on the need for better access to high resolution data, faster turnaround times, better use of space telecommunications, improved user feedback and the need to avoid conflicts with commercial coverage appear to have been resolved. With encouragement from the USGS and from the European Commission the commercial providers have provided more very high resolution data of disasters free of charge to the user community. For example, GeoEye stated on its web site[804] in 2010:

When a crisis on the scale of the Haitian earthquake occurs, we are all moved to help. GeoEye has done just that, by providing its satellite imagery of the devastation in Port-au-Prince for free to relief agencies, governments and the media.

From experience with the Indian Ocean tsunami and the Haiti earthquake (amongst others) it is clear that there is a very rapid response time to produce image maps using Earth observation data. The image maps are typically produced within one day of the analysts receiving the data and the satellite data acquisition is typically within one day of the disaster event. The image maps produced within the International Charter were geo-rectified and in a form that can be readily used by the disaster relief users, although it must be noted that Earth observation imagery does not replace expert assessment in the field.

Where there is still room for further development from the list of lessons identified by Bessis et al is in the fit of sensors with disasters, the selectivity of data with respect to each disaster and importantly capacity building by end users to make better use of Earth observation data. There has been better working between Earth observation experts and disaster management experts since the start of the International Charter. There has been a growth of data from different types of sensor, but this may well confuse more than enlighten as end users have difficulty understanding InSAR products for example. The large number of different data types contributed by satellite owners to disaster management, combined with open web access to much of the data, has had the benefit of providing several independent perspectives on disasters. The question raised here is whether the end users can cope with the multiplicity of independent views when time to respond is at a premium. The list of different disaster management systems in Table 3 also raises the question of complexity and implicitly the question of international policy coordination.

The development of higher capacity satellite communications such as VSAT and BGAN has provided the opportunity to send image maps of disasters to users on the ground within days or hours of a disaster event. Sometimes these events have a single impact, such as the Chile earthquake in 2010, but on other occasions the disaster develops over a period of time, such as the forest fires in Russia or the flooding in Pakistan in 2010, and so the needs also develop over time.

8.6. Future needs

It is likely that the effects of natural disasters such as floods, droughts, landslides, fires and earthquakes will increase in the future because of the increasing urbanisation of the world's population, the exploitation of marginal land resources and the effects of climate change (see also the paper by Cheli in this volume). These factors may explain why already it is flooding that is the largest activation category in the International Charter.

The systems that respond to disasters listed in Table 3 (and others beside) are still best efforts and are not what can be regarded as operational. The International Charter could develop into a more binding instrument with (say) European Union involvement, or it could migrate to become part of GEO, although it would be wise to follow Roy Gibson's advice at the GEO symposium in November 2009 that GEO needs much stronger financial and political support to succeed.[805] Users expect Earth observation to provide operational support and the GEO structure could be a vehicle for this operational support. The SAFER project is still a pre-operational version of the GMES Emergency Response, so still funded as an evaluation rather than an operational system although with the expectation that the operational system will develop once SAFER concludes successfully.

The spatial resolution of civilian Earth observation systems has been edging towards those of defence systems since the 1960s. Now that we have optical systems and radar systems providing data with a spatial resolution of less than 1 m then perhaps a point of convergence for practical purposes has been reached, at least for responding to disasters? This then raises the question of whether better Earth observation systems can be provided by being explicit about such convergence, accepting that the dual use of civil and military assets can benefit both sectors.[806] In practical terms the acquisition of images from defence Earth observation satellites at times of disasters proves impossible or at best very difficult, yet these satellite resources could provide useful information to respond to disasters.

Geophysical data showing surface deformation resulting from earthquake damage will have greater value when it is presented in a way that can be easily used and integrated with other map data sets.[807] After the Shuttle Radar Topography Mission there have been TerraSAR-X and TanDEM-X. These X-band radar systems will allow the production of a digital elevation map of the globe with a vertical resolution of the order of 2 m and a spatial resolution of the order of 12 m, and their data will allow surface change maps to be created at times of earthquakes and landslides. These data will be at their most valuable when they are geo-registered and presented in a form that is compatible with other geographical data sets.

Government ministers are implicated in Earth observation data policy through their approval of (1) the OECD principles and guidelines for access to research data from public funding and (2) the GEO data sharing principles planned to be approved by ministers in November 2010. This may provide more weight for Earth observation data provided in the case of disasters to be made available free of charge to all users.

8.7. Conclusion

Satellite Earth observation has a unique role in disaster management in that the data can show the spatial extent of a disaster at a time when finding out the extent of the disaster on the ground is difficult or impossible because of the disaster itself. Earthquakes, landslides and floods all damage or destroy roads and bridges so that surface transport becomes impossible. Floods resulting from heavy rain can be characterised by periods of thick cloud that prevent aerial survey planes from flying and collecting images. From the experience of dealing with the Indian Ocean tsunami and the Haiti earthquake the value of geo-rectified satellite Earth observation images and derived information products delivered within a few days of the disaster has been clearly shown. As users gain more experience of Earth observation image maps and build their own capacity to use the maps then the role of space data is likely to increase.

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