Guidance notes
Session 2: Obtaining spatial data for risk assessment

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Objectives

After this session you should be able to:

- Understand that a vast range of spatial data exist that may be useful for risk assessment
- Understand that different hazard types call for data with different spatial, spectral and temporal characteristics, and what we have to consider when trying to decide what to use
- Evaluate the different spatial, spectral and temporal characteristics of different data types
- Evaluate additional constraints that may influence which data set(s) we use in our risk assessment
- Know where to search for and obtain some key thematic and image data types
- Understand the basic concepts of 3-D vision
- List the most used remote sensing systems to create 3-D for hazard studies
- Create a 3-D vision yourself using the ILWIS software

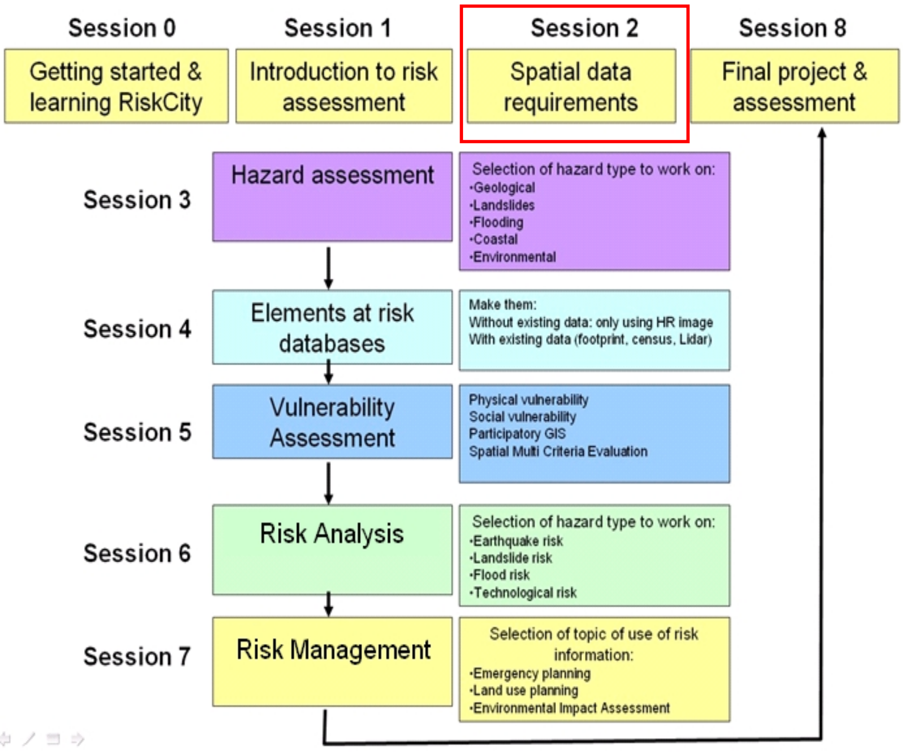
You will do this by using the following materials:

- These guidance notes, which contain the theory, tasks and exercises, specifically:
  - o Theory with main aspects related to this topic.
  - o A background box summarizing the main aspects of remote sensing theory, as well as main components of image processing and visualization, and a box with background information on digital elevation models (DEMs).
  - o A variety of short tasks. The overall purpose of the exercises is for you to practice how to decide on which data are suitable for a risk assessment, here focusing mostly on the hazards aspect.
  - o A comprehensive overview of the most important sources for thematic and image data.
  - o Background information with relevant literature.

Section	Topic	Task	Time required		
2.A.3	Which data are useful for risk assessment?	2. 1 Identify a hazard of interest		0.1 h	0.4 h
		2.2 Identify spatial types you already know		0.15 h	
		2. 3 Inventorise already available data for the chosen hazard type		0.15 h	
2.A.4	How to decide which data are suitable?	2. 4 Identification of suitable data		0.25 h	0.25 h
2.A.5	Spatial data for risk assessment	2. 5 Finding population data for your country		0.5 h	3.5 h
		2. 6 Use Google Earth to check the available data situation for your country		0.5 h	
		2.7 Explore two of the spatial data sources introduced		0.75 h	
		2. 8 Preparation of a summary for the given tasks		0.75 h	
2.B.1	Introduction	2.9 Have stereo vision yourself with the provided anaglyph glasses		0.15 h	0.15 h
2.B.3	Lidar	2.10 Study the text on the Actual Height Model of the Netherlands and look at Lidar animations		0.75 h	0.75 h
2.B.4	SRTM	2.11 Download of SRTM data from WWW		1.5 h	1.5 h
2.B.5	Optical systems for 3-D generation	2.12 Explore internet sites with examples of Aster and SPOT		0.5 h	0.5 h
2.B.8	Summary and Final Assignment	2.13Risk City Exercise 2		2.5 h	2.5 h
				Total	**9.55 h**

2.1 Spatial data requirements for risk assessment & sources of spatial data

2.1.1. Introduction



This is a course on geoinformatic-based risk assessment, and in Session 1 it was already explained that spatial data are uniquely suited to study and assess multi-hazard risk. All aspects of risk that we need to consider – the different natural or manmade hazards, the areas they might affect, the elements exposed during such events and their vulnerability – are spatial in nature. By that we mean that they have a certain location and extent, thus can be put in relation with one another, and can be associated with attributes that are linked to a geographic place or area (Figure 2.A.5). The course explains how the different aspects of risk can be analyzed and mapped with a variety of spatial data. In session 2 we want to look at what spatial data types exist, how they can be used in risk assessment, and how we decide which data set(s) to use, and where to get them.

2.1.2 Types of spatial data

In geoinformatics, also called geoinformation science, we can consider any data type that can be linked to a geographic place, which is easiest achieved through coordinates. The classic data type is a map, a more modern one could be a satellite image (for an introduction on remote sensing see box). However, we need to consider that our work is largely done digitally on a computer, and that we might want to use data that are actually quite variable in nature. When we think about disasters or risk, we may want to include (i) tabular data or statistics (e.g. on the number of hazard or disaster events of a certain type and in a given time period), (ii) thematic data (e.g. a road or river network, soil types, or digital elevation models [DEMs]), (iii) topographic maps, (iv) model results (e.g. for flood hazard or slope instability), or (v) images (e.g. aerial photos or satellite images). Even within those major data types there are large variations.

Remote Sensing

Remote sensing (RS) can be described as the process of making measurements or observations without direct contact with the object being measured or observed. Thus, while in the geoinformatics context satellites often come to mind, even amateur photography is a form of RS. It usually results in images, but also includes other measurements, such as of temperatures or gravity.

- ***Sensors and platforms.*** For remote sensing we normally require a **sensor** (i.e. a camera or scanner), but also something that carries the device. Such **platforms** can be airplanes or satellites, but also other instruments that allow us to place the sensor so that the area or object of interest is exposed, such as balloons or kites. The choice of platform directly affects what we can observe and how. Airplanes and helicopters are flexible in their operation, and by flying relatively low provide good spatial detail. However, such surveys can be expensive and regular imaging of the same area thus costly. Satellites fly on a fixed **orbit**, and are thus less flexible, but can provide data at regular intervals (think of trains on a track). We distinguish between so-called **polar orbiters**, whereby the satellites continuously circle the Earth at an altitude of some 500-900km, passing over or near the poles. Normally only a relatively narrow strip of Earth underneath the sensor is observed. Modern satellites can also point the sensor sideways for greater flexibility. The other class of satellites is positioned in **geostationary orbit**. This means that the satellite is always directly above a designated place on the equator, moving with the rotating Earth at an altitude of 36,000 km. At that height the sensor can usually observe an entire hemisphere (the side of the Earth facing it), and provide data at any desired frequency. Many weather and communication satellites fall in this category, while most Earth observation satellites are polar orbiters.
- ***Collecting information.*** The data we obtain depend primarily on the sensor type, just like you might take color or black/white photos with your camera. The secret to taking such different photos lies in the **electromagnetic energy**, which is what our sensors can detect. The most common source of energy is reflected sunlight, which, as you probably know, contains visible light, but also ultraviolet (UV), infrared (IR), thermal and other energy (Figure 2.1). Which part of this continuous energy band we capture depends on the sensor. Your camera might only capture visible light, while others can "see" UV, IR or thermal energy.

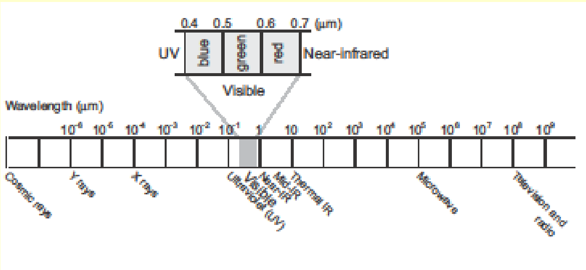


Figure 2.1: The electromagnetic (EM) spectrum

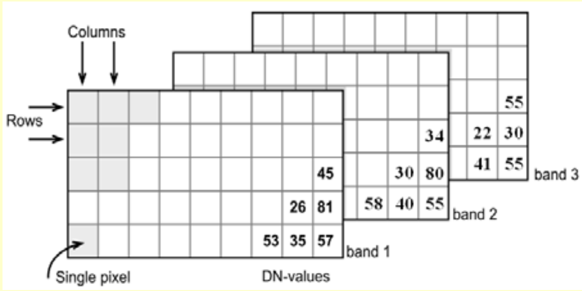


Figure 2.2: Grid structure of a multi-band image

- ***The data.*** The data our sensors record typically have the form of a grid, or raster (Figure 2.3). Rows and columns in that grid are populated by cells. These cells contain the information recorded by the sensor. A sensor can also have several **bands**, meaning that different sections of the electromagnetic spectrum are observed. Thus for the area observed we will have an image that contains several bands, and the cell corresponding to a small part on the ground will have one data value for each band. The most important point to understand here is that different materials on the ground reflect energy in a characteristic spectral pattern. For example, vegetation is characterized by high energy in the near infrared (NIR), while for water the energy is very low. In figure 2.2 this would result in high values (digital numbers [DN]) for vegetation and low values for water in the band corresponding to the NIR.
- ***Other factors influencing our data.*** RS data come in many forms, often described by **sensor type**, as well as **spatial**, **temporal** and **spectral resolution**. Sensors recording reflected sunlight or energy emitted by the earth are called **passive sensors**. However, we also have

sensors that emit their own energy, which is reflected by the earth, just like you use a flash on your camera. These are **active sensors**, well-known examples being radar (see Figure 2.10) or laser scanning. The **spatial** resolution describes the size of the ground area represented in a single pixel. This largely depends on the distance between the sensor and the object. While aerial photos may have a resolution of a few cm, data from polar orbiters range between about 50 cm and 1 km per cell. Sensors on geostationary satellites, being very far away, record data at resolutions of a few km. The **temporal** resolution describes the possible frequency of repeat observations. For aerial surveys this can be years. Depending on the type of polar orbiter and sensor, their temporal resolution varies between approx. 1 and 44 days, while geostationary sensors record data up to every 15 minutes. The **spectral** resolution describes how narrow a slice of the EM spectrum a sensor band records.

In the following part we also provide a short background on some basic image display and enhancement methods that you will encounter in this course

- **Displaying an image.** Once we have our data we can either display them directly on our monitor (if they are already digital), or first scan them. A monitor works with 3 different color channels (blue, green, red), and is able to generate any color (including black and white) with a combination of those 3 colors. Thus we can take an image with only 1 or with several bands and display 1 band at a time, thus as a **pan-chromatic** image (Figure 2.3 A). We can also use 3 bands and display them as a so-called **true-color composite** (B), which looks like the scene would look to us from space. However, we can essentially assign any of the image bands to one of the 3 colors. A typical combination, called a **false-color composite**, is shown in C, where the information from the NIR band is displayed in red. Recall that vegetation leads to high DN values in the NIR, hence the high vegetation signal leads to a dominant red color wherever there is vigorous vegetation. Image D shows another form for false-color composite.

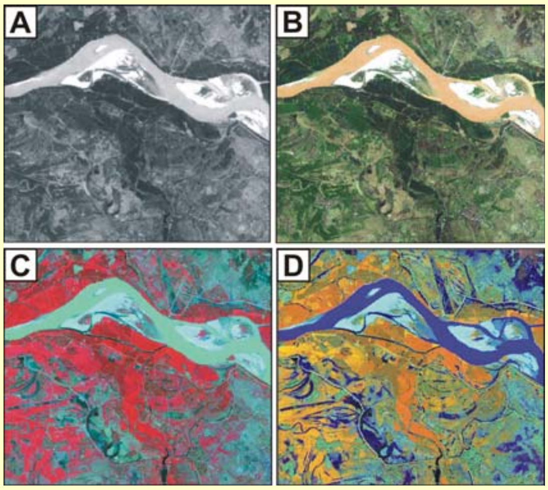


Figure 2.3: A – panchromatic, B- true-color, C and D – false color composites

- **Enhancing an image.** Sometime, for information to be made more visible, we have to enhance the image. One typical form is **stretching**. Our displays are typically able to display 256 brightness levels for each color, corresponding to 8bit. However, very often the image data only have a limited range, say with DNs between 50 and 150, where are not very bright or very dark features on the ground. To achieve a display with a richer contrast we can stretch the data over the entire available range (0-255). The same concept applies to other data types you will work with, for example elevation. The elevation file for our test area ranges between approximately 900 and 1350m. By default they will be stretched over the available display range. However, we can also stretch a small value range, say 950-1000, to highlight more details. Another common enhancing method is **filtering** (Figure 2.4). This is a so-called neighborhood analysis, often used to smoothen an image or to highlight edges. In the example the average of all cells shown in grey in the input image is calculated and written to a new file, before the filter template moves to the next pixel (hatched box). Many filter types have been developed, which you will also use in the ILWIS exercises (for example shadow and smoothing filters).

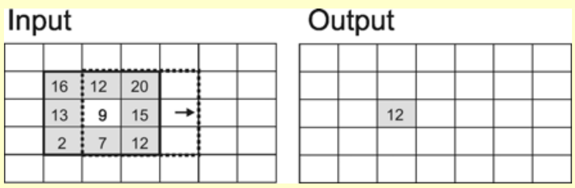


Figure 2.4: Principle of filtering

For example, you might find statistics presented in a table with either coordinates or grouped per administrative area, or illustrated as a chart or graphic. It can also happen that field photographs are available. Associating those with the other data, and integrating the information you think is useful in those photos with the rest of the analysis, can be challenging. Also consider that many maps or aerial photographs are available only as paper hardcopies. To use them in our work we first have to convert them to a digital format. This can be done by digitizing relevant information, or by scanning and subsequently georeferencing the maps or images.

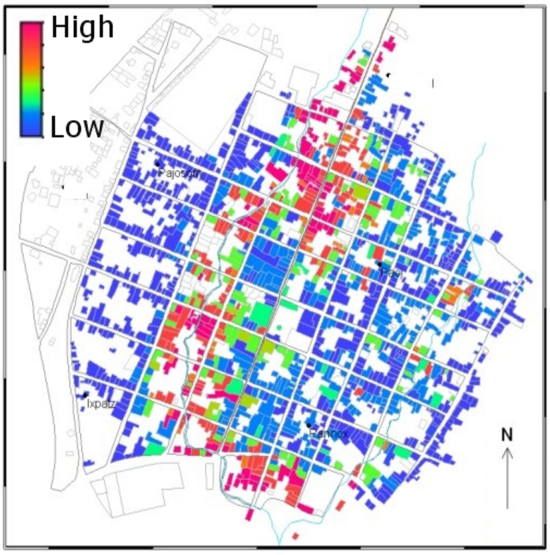


Figure 2.5: Example of a risk map for an urban area subjected to flooding (Source: Peters Guarin, ITC)

2.1.3 Which data are useful for risk assessment?

To determine which data are actually of use requires a detailed understanding of hazard and risk theory, which is an integral part of this course. In this session we want to focus on the practical considerations that are necessary to make the decision, and where those data are actually available. When you think about different hazard types you quickly realize why we have to adjust the data types we can use in the risk assessment. Consider Figure 2.6: as is illustrated, different hazard types, such as earthquakes or hurricanes, have different (i) **spatial**, (ii) **spectral** and (iii) **temporal** characteristics (see Remote Sensing box). (i) A hazard can be very local and spatially confined (e.g. an unstable slope), it can be very extensive (e.g. flooding or drought), or there can be a large distance between the actual source of the hazard and the area in question. Examples of that can be earthquakes, where the responsible fault may be a long distance away from areas that may still experience strong shaking during an event, or the breaking of a dam that may lead to flooding far downstream. We also have to consider the dimensions of the hazard: a dam or a hill slope are quite small in extent, while an area possibly exposed to a hurricane or a tsunami may be vast. The data we choose in the analysis need to reflect those dimensions and the details we need to see. Recall that it is largely the **platform** type that determines how large an area can be observed.

(ii) Remote sensing is very sensitive to the surface characteristics of the object or area under investigation, resulting from the different spectral characteristics of different materials, and different sensors have been built that are especially suitable for specific surface materials. For example, a near infrared band, common to most **passive** satellite sensors, is well suited to map vegetation health or water. It is thus suitable, at times in combination with other spectral bands, to track vegetation health (e.g. to monitor drought hazard), or to map flood or other surface water. In areas or situations where clouds, smoke, or night-time conditions prevent a clear view on the surface, we can resort to **active** sensors, such as radar. However, here it is particularly important to understand that radar data more strongly reflect the surface physics (structure/roughness, moisture, topography) than surface chemistry (mineral type, chlorophyll in leaves, etc.). Hence using radar is only of use if it not only penetrates difficult observing conditions, but still provides the information we require (compare Figures 2.9 and 2.10).

(iii) Hazard events can be sudden and of short duration (e.g. earthquakes or landslides), sudden but of long duration (e.g. a dam break leading to prolonged flooding), but can also show precursory signs (e.g. volcanic activity or hurricanes). Some events, such as earthquakes, may also show a repetitive pattern, where violent aftershocks may affect areas already destabilized by the primary event. Some effects may also be delayed, such as disease outbreak after a flood or earthquake. This is also a good example of one hazard type event leading to secondary effects. Other examples of that phenomenon are slope or dam instability caused by earthquakes.

Task 2.1: Question (duration 5 minutes)
Identify the hazard type you are most interested in, and write down for yourself how it can be characterized in terms of its spatial and temporal properties, as well as possibly its spectral characteristics.

Thus we see that we need to have a good understanding of the spatial, spectral and temporal characteristics of the hazard(s) under consideration, before deciding on a specific analysis type and data requirements. Figure 2.6 further illustrates that also our spatial data sources have spatial and temporal characteristics, in case of image data also in the spectral domain. Those need to be matched with the hazard characteristics, but, for risk assessment, also with those of the elements at risk. For example, while we may use a satellite image that shows a large area, such as the catchment from which a flood might originate, we may need very detailed imagery to map buildings and other structural elements that may be affected by a flood. This is difficult, as there is a largely inverse relationship between coverage and detail; very similar to a zoom lens on a camera we can either see a large area (wide angle) or detail (when zooming in; see Figure 2.7). Hence we may have to combine different data sets to cover both requirements.

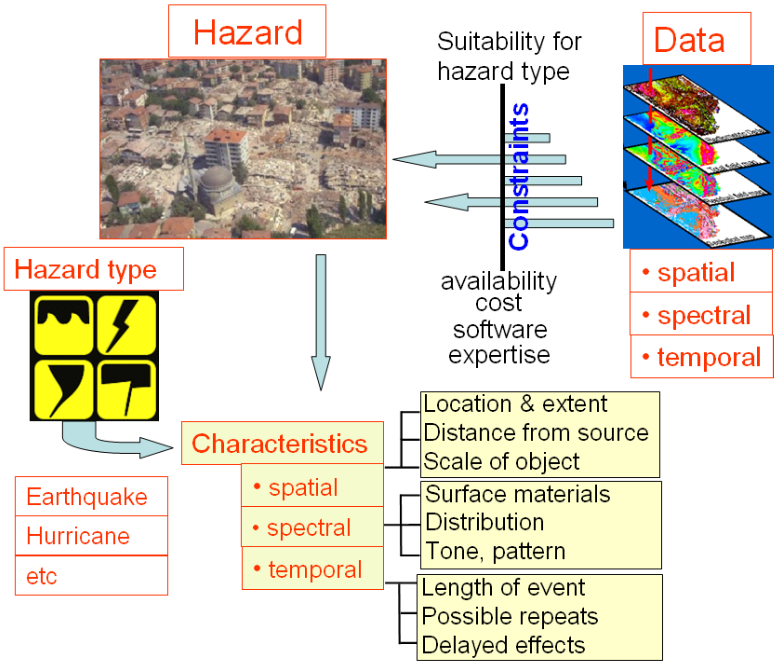


Figure 2.6: The hazard type dependency of spatial data suitability

Task 2.2: Question (duration 10 minutes)
Which spatial data types that you know already (both images and thematic data) do you think are useful to observe the hazard you selected in task 2.1? What relevant information can they provide?

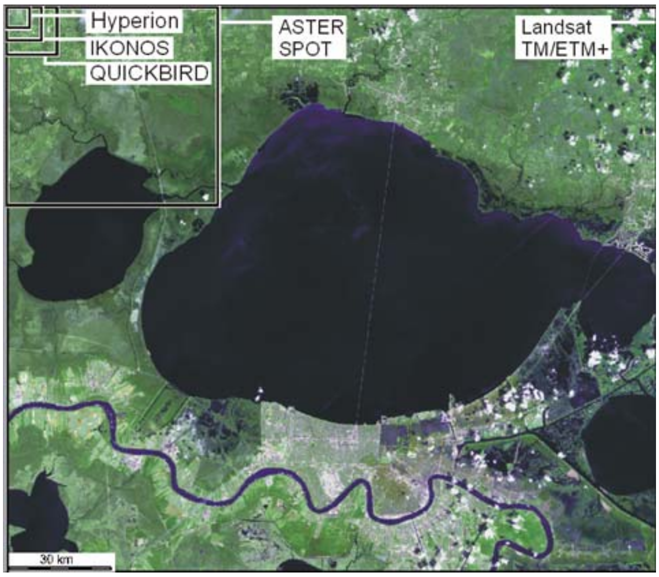


Figure 2.7: Ground coverage of different common satellite sensors

Once we have clarified the suitability of a given data type, or combination of types, there are a few other important considerations that typically act as constraints: **availability**, **cost**, **software**, **expertise**. There can be a large difference between suitable and actually **available data**. For example, we may want to use statistics on hazard events or census data for a certain area, only to find that no current data have been compiled. Some datasets may also be proprietary, meaning that they are not available outside a company or organization. Some countries, such as India, may even prohibit the sale or export of imagery of their territory for security reasons, while others degrade data quality on purpose, such as the US did for the global SRTM DEM (see below). Yet other data, such as census data, may only be available in aggregated form, which may limit their utility. For satellite images we further have to consider the difference between geostationary satellites and polar orbiters. The former are always positioned on the same spot above the Earth surface, thus being able to observe the same area with high frequency, as is the case for weather satellites. The highest current temporal resolution is achieved by Meteosat Second Generation (MSG), which provides data every 15 minutes. However, the satellite has to be placed in geostationary orbit, at about 36,000 km above the Earth, resulting in data between 1 and 3 km in resolution. An alternative are polar orbiters, circling at some 500-900 km above the surface. This means that the image detail the latter provide can be much higher (at the moment up to 50cm from GeoEye-1), but their revisit time ranges between 1 day and more than 1 month. Hence, if we need data very quickly, such as after a sudden disaster, no suitable images may exist. Also recall the tradeoff between coverage and detail (Figure 2.7); while MSG can see almost all of Africa, Europe and parts of the Middle East every 15 minutes, GeoEye can only image an area some 15 km across, and only every 3 days.

Satellite images also have a reputation for being **expensive**. That is still partly true, in particular for imagery from commercial satellite companies such as GeoEye or DigitalGlobe, but also for data from some governmental operations, such as from ENVISAT (operated by the European Space Agency), ALOS (Japanese Space Agency) or RADARSAT (Canadian Space Agency). However, there have been very interesting developments that work in our favour. First, geodata are now very commonly used in many aspects of science, industry or even recreation. Think of GPS as an example – cheap devises are now being used by hikers, and we take it for granted. Similarly, many people use Google Earth on a routine basis, and free of charge. While those images may be of limited utility for rigorous quantitative risk assessment, this wide use of spatial data has served as a catalyst. The more such products are being used, the better the chance that continuous development will take place, assuring that we will still have such data in the future, but it also tends to lead to lower prices. Later in this session we will look specifically at sources of free and low cost data, but also list some commercial providers.

Working with digital data requires a **software** environment to process them. While a simple PC with basic software is enough perhaps to browse the internet and view images, processing spatial data tends to be more complicated. As we said before, we are dealing with data that use a reference framework (coordinates) and projections, meaning that usually some type of geographic information system (GIS) or image analysis software is used. Just like with the data, there are expensive software types, but also free or open source packages, such as the ILWIS software we use in this course. A rule of thumb is that software developed for very specific data types (e.g. radar or laser scanning data), or incorporating sophisticated model, tends to be expensive. Conversely, for more basic GIS and image analysis functions there are many free or low cost packages available.

Lastly, to process spatial data requires a certain amount of **expertise**. While the skills required for some basic or routine steps are quite easily obtained, doing more advanced data processing or integrating, as well as modeling, may require expertise that is not always available.

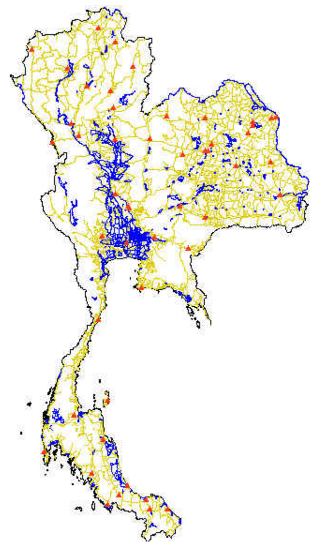


Figure 2.8. Thematic data of Thailand (points, lines, polygons), from the Digital Chart of the World.

The above means for us that, even if we understand the characteristics of a hazard or risk situation, not all suitable data may be available and we may not always have the software tools or expertise needed. Therefore, geoinformatics-based risk assessment requires much flexibility, as we have to strive for data interchangeability or workarounds when we hit an obstacle.

Task 2.3: Question (duration 10 minutes)
Continuing with the hazard type you considered in the previous questions, inventorize the data you currently have ready access to, but also which computing requirements (hardware and software) are available in your office, and what expertise can be made use of.

2.1.4 How to decide which data are suitable?

The preceding text should make it clear that there are different ways to do risk assessment with geodata, and that our requirements or chosen methodology can shift quickly, depending on the specific hazard situation, types of elements at risk, or secondary hazards. The following checklist can help you decide what data you need.

(i) Identify data type(s) needed (e.g. thematic layers [Figure 2.8], images [Figure 2.9], maps)

As explained above, understanding the risk components, and how we can assess and map hazards, elements at risk and their vulnerabilities, is a prerequisite. Once we understand the system we are dealing with, we can decide on the data needed for the job.

(ii) Date of (image data) acquisition (archived, current, future)

Most risk assessment work requires different data, often including historic data (e.g. statistics on a given hazard phenomenon), recent and older imagery (to detect changes of time), and we might also need data that have not yet been acquired. Also remember that the natural environment looks different throughout the year. If you want to map vegetation changes, looking at a winter image may be of little use. Thus we need to determine the types of data and their dates.

(iii) Number of datasets/images needed

How many datasets and images do we need? To assess changes we need at least two, to cover a larger areas also several images may be required. Some relevant statistics or thematic data may also be housed in several different databases or datasets.

(iv) Identify possible cost, check budget

While some data may be free of charge, others are very expensive. Once we have our list of needed data, check how much they cost and if the available budget supports the choice. If not, some data may have to be replaced with lower-cost alternatives.

(v) Identify relevant source and search for appropriate data

Once you have settled on a final data list, identify the sources for the different data types, and search for the data you need. Pay particular attention to the suitability of data that you find, for example with respect to coverage and extent, but also cloud cover.

(vi) Order data, or download directly

Figure 2.9. SPOT satellite optical image of a volcanic mudflow in Nicaragua (20m resolution).

Task 2.4: Exercise (duration 15 minutes)
Without yet having learnt in detail how to assess risk with geodata, try to fill in the checklist for steps (i)-(iii).
Hazard type chosen:
(i)

(ii)

(iii)

In the past most data, in particular image data, had to be ordered and were shipped on tape or CD. Increasingly the data can now be downloaded directly. However, if your internet bandwidth is insufficient, you typically can still order data on a CD or DVD. There are also increasing numbers of repositories for other relevant data, such as on populations, thematic data, or disaster statistics. Those are introduced further below.

The steps outlined above are not always easy, for a number of reasons:

- Databases housing suitable information are often fragmented, e.g. every organisation or data provider organizes their own distribution method. It is still quite rare that a single portal provides access to a range of datasets.
- Obtaining data for routine observations is quite straightforward. For more specific questions or small, specific areas, this is harder. For example, getting weather data for all of Africa is easy (from MSG), but getting a good soil or transport network map for a specific municipality in countries such as Kenya or Indonesia may not be successful.

- Also remember that there are many organisations collecting data, and many sensors taking images on a routine basis, all generating a massive amount of data. For example, ENVISAT alone produces >500GB of data, every day! Finding the needed data is often not easy.

Even within the cost-step there are many aspects to consider, all influencing the overall data cost:

- Data type and extent of study area
- Number of datasets (e.g. need for repeat datasets)
- Need for raw or processed (value-added) data
- Availability of reference data (e.g. existing GIS databases)
- Need for commercial image data (Landsat, Ikonos, Quickbird, etc.)
- Need for rapid custom image acquisition
- Need for ground crews for collection of additional information
- Need for outside special resources (experts, databases, etc.)

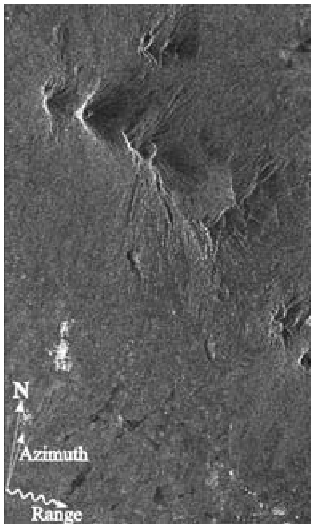


Figure 2.10. ERS-2 radar image of the same volcanic site as in figure 2.9. Note that the landslide is not visible.

Similarly, identifying relevant data sources may not always be easy, with many issues affecting both data availability and cost, and the need for specific software or expertise:

- We can distinguish between raw image data vs. thematic data (e.g. vegetation indices), which tend to be housed in separate catalogues
- There are global vs. regional vs. local data – the more local, the harder to find
- Image data can be obtained by different sensor types, e.g. satellite vs. airborne vs. ground-based; in principle the more global the easier the data are to get
- Do we need vector data or raster (image) data? (compare Figures 2.8 and 2.9)
- Do we need specific data types, such as laser scanning data or digital elevation models (DEMs)?

We can thus conclude that there are indeed many spatial datasets available, be it in form of tables, charts, statistics, or as maps, photos, model outputs or raster images. Where, then, do we find what we need? In the next section we introduce the main data repositories of interest for disaster risk management.

2.1.5 Spatial data for risk assessment

As there is a large range of spatial data that may be of use for risk assessment, below we only introduce the ones that are most widely used. Remember that it gets increasingly difficult to find data the more local your study area is, or the more specific your data needs are. Many other data sets can easily be found be searching the internet. Note that one very important data type – statistical disaster data – was already introduced in session 1 and is not repeated here.

Statistical data

If you require **population data**, organized on a per country or grid basis, try sources such as the global population database at Columbia University (http://sedac.ciesin.columbia.edu). Also census datasets are available, though they are usually provided by the governments of the respective countries, so you would have to search there.

For many specific hazards (not disasters), detailed databases also exist, which can be used to find out the approximate frequency of events for a given area and time frame. For example, for geophysical hazards check out NOAA's National Geophysical Data Center (http://www.ngdc.noaa.gov/hazard/), or specifically for seismic events, the USGS's Earthquake Hazard Program (http://neic.usgs.gov/neis/sopar/).

Task 2.5: Exercise (duration 30 minutes)
Go to the website of Columbia University listed above, and try to find population data for your country. Which data exist, and how detailed are they? Can you find more detailed data elsewhere, such as from your national census bureau? And which of the data you found are readily usable digitally and in a mapping framework (i.e. have a spatial reference system)?

Free or low cost thematic data

In this section we review commonly used thematic data that cover the world or large regions. As you will see below, there are more sources for image data than thematic databases with global or regional coverage.

(i) Digital Chart of the World (DCW)

An example of this dataset was already shown in Figure 2.8. The DCW is a global basemap of coastlines, international boundaries, cities, airports, elevations, roads, railroads, water features, cultural landmarks, etc. It was originally developed in 1991/1992, and national boundaries reflect political reality as of that time, thus in parts it is outdated. However, it still forms a widely used dataset that is free and easily obtained. On http://www.maproom.psu.edu/dcw/ you can search by country, and decide which data layers you need. The data are prepared for you immediately and can be downloaded. As it is originally an ESRI dataset, the data come in ArcInterchange format that can be read by most geoinformatics programs.

(ii) FAO/Geonetwork

The Food and Agricultural Organisation (FAO) of the UN has prepared a number of useful geo-tools, including the Geonetwork (http://www.fao.org/geonetwork/srv/en/main.home). Here you can search globally or by region, use existing maps or create your own. The available data comprise base layers (e.g. boundaries, roads, rivers), thematic layers (e.g. protected areas), or a backdrop image (e.g. World Forest 2000). Also try AgroMetShell, a specific software tool box for crop yield forecasting, or Dynamic Atlas (http://www.fao.org/gtos/atlas.html), designed for the integration of spatial (map), tabular (spreadsheet), and unstructured (document) data and metadata. Using dynamic Web Map Server technology it allows data from various sources to be integrated and customised online maps to be produced.

(iii) Geocommunity

Another useful source is Geocommunity (http://data.geocomm.com/). It is another source for DCW data, but also some DEMs, geology polygons, and some satellite imagery).

(iv) Mountain Environment and Natural Resources' Information Systems (MENRIS)

If you have an interest in the Himalayan countries (Figure 2.11), check out the Mountain Environment and Natural Resources' Information Systems (http://arcsde.icimod.org.np:8080/geonetwork/srv/en/main.home).

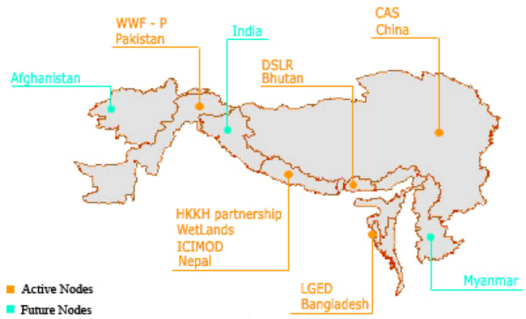


Figure 2.11: Countries covered by the MENRIS database.

Free or low cost image data

There are many sources for image data. As was pointed out before, it is much easier to find data from sensors that have global coverage (including those polar orbiters that only image a small part of the Earth at a time, but in time visit nearly the whole globe), than data from dedicated campaigns, for example for aerial photography. We also need to distinguish between the actual image data, and a picture. Many satellite images comprise several spectral bands that contain valuable information, such as the near infrared band for vegetation mapping that was already mentioned. If we convert such an image to a picture, such as a *.jpg or *.tif, the individual bands get merged, and the actual quantitative information lost. We can still use those pictures, but must be aware of the reduced information content. Note that there will be a separate exercise on finding and downloading of satellite data, thus this is not done here.

(i) Google Earth

The best example for the satellite imagery that has been converted to pictures is Google Earth. What you see there are typically the highest resolution and most recently available satellite images, but only shown as raster pictures. We cannot change bands, or enhance or otherwise manipulate the imagery. However, we can put many other available data layers on top, create our own or load those we get from other sources as *.klm files, and we also have an underlying DEM for 3D viewing. With Google Earth Pro (license cost of some 400 Euro) it is possible to save the high resolution pictures. We can then integrate them with other spatial data in a GIS. This can be very valuable when performing detailed elements at risk mapping, or for change detection when we have another, for example older image, available.

Task 2.6: Exercise (duration 30 minutes)

Open Google Earth (or install it if you don't have it yet). Review carefully the data coverage for your country, keeping in mind the hazards that are present, in particular the one you selected earlier. Evaluate how useful those data can be (also considering the 3D data) to study the hazards or elements at risk. What are the limitations?

(ii) Global DEMs

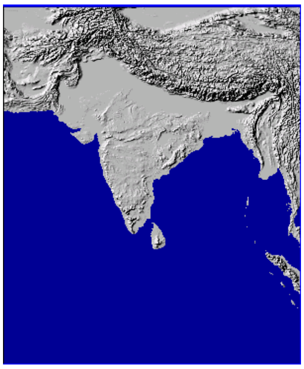


Figure 2.12: One of the tiles of the GTOP30 DEM.

There are two main sources for global DEMs: the older GTOPO30, or the more recent SRTM-based DEM. The GTOPO30 (http://edcdaac.usgs.gov/gtopo30/ gtopo30.html) is a coarse, global DEM, with grid cells of 1km across. The global dataset has been tiled, and individual tiles (Figure 2.12) can be downloaded from the site given above. The data are georeferenced, providing a good backdrop for large areas where fine detail is not necessary.

A more detailed source for DEMs is the dataset collected in 2000 during the Shuttle Radar Topography Mission (SRTM). A radar pair mounted on a space shuttle mapped nearly the entire globe at 30m resolution (http://www.jpl.nasa.gov/srtm/). Note though that the data outside the US are degraded to 90m. However, the data are free, and still a substantial improvement over the GTOPO30. The link gets you to the Seamless Data Distribution Centre, where you can specify the area needed. Be aware that, due to the high resolution, the files to be downloaded can be quite large.

(iii) Advanced Very High Resolution Radiometer (AVHRR)

The AVHRR is an older satellite mission, having already flown, with continuously replaced instruments, for over 20 years. It provides better than daily coverage, at a resolution of 1.1km per cell at nadir, meaning that because of the wide swath the coverage towards the edge of the image is closer to 4km. It is an excellent tool for frequent mapping at regional scale (Figure 2.13). The data can be downloaded at http://www.class.noaa.gov/ (see Figure 2.14). Because of the frequent observations a very large archive exists.

(iv) Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER)

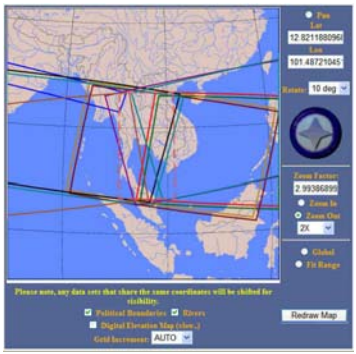


Figure 2.13: Example of AVHRR coverage for Thailand.

ASTER has become a very widely used satellite image source. Launched in 1999, the sensor carries a spectacular 15 channels, with 4 bands at 15 m resolution, 6 at 60m, and 5 at 90m. The spatial and spectral details are thus excellent, and, in addition, the data can be used to create DEMs. The best way to search for ASTER data is via the Earth Observing System Data Gateway (http://edcimswww.cr.usgs.gov/pub/imswelcome/), where also other data from NASA or NOAA-operated satellites can be found. You can register (for free), or search as a guest. Be aware that there are many different data products (Figure 2.14). It is advisable to read up on how these products were generated and what they are useful for (see http://asterweb.jpl.nasa.gov/). An even quicker way to check for available data is via the USGS'S Global Visualization Viewer (GLOVIS)'s (http://glovis.usgs.gov/), which gives a nice graphical overview. Aster data used to be free of charge for the first few years. Now they cost a nominal modest fee of 80US$ per scene. However, educational organizations such as universities can apply for free data (see http://lpdaac.usgs.gov/aster/afd/index.php).

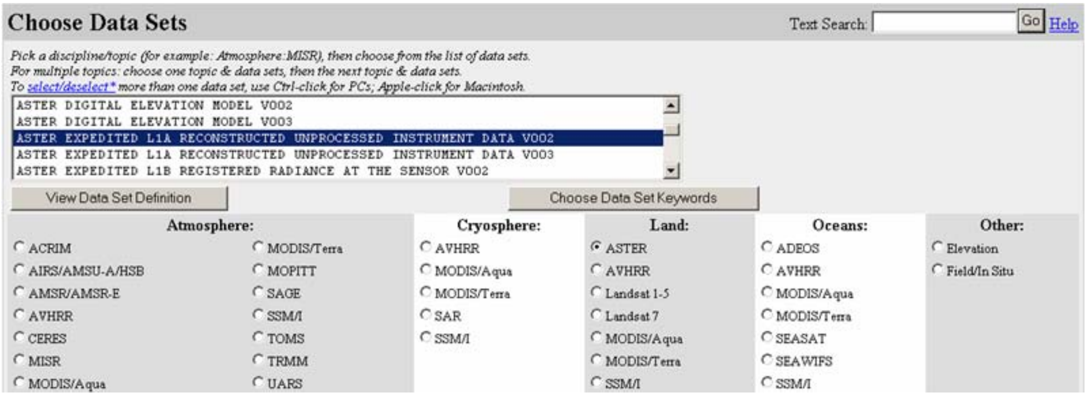


Figure 2.14: Screen capture of the data selection at NASA's Earth Observing System Data Gateway.

(v) Moderate Resolution Imaging Spectroradiometer (MODIS)

MODIS data are often considered together with ASTER, as the sensor is also NASA operated and compliments ASTER. There are actually MODIS sensors on two different satellites, acquiring data at moderate resolution in a remarkable 36 channels. Like ASTER, the resolution is variable, with some bands at 250m, some at 500, and some at 1,000m. The coverage of MODIS is 2,230km, thus very large regions can be monitored daily. The data are particularly suited for vegetation studies, see http://modis-land.gsfc.nasa.gov (select the Products category), http://edcdaac.usgs.gov/modis/dataproducts.asp. The data are free, but as with ASTER it is important to be careful in the product selection. As MODIS also contains bands that record information in the infrared and thermal parts of the spectrum, it is very sensitive to strong thermal emission, such as originating from wild fires or magmatic activity at volcanoes. At the University of Hawaii an automatic system was set up that uses MODIS data to map volcanic hotspots, see http://modis.higp.hawaii.edu/.

(vi) Landsat MSS/TM data

One of the oldest and best known satellites missions is Landsat, which has been providing Earth surface data since 1972. Initially the data had a resolution of 60 m, which was later improved to 30m (lower in the thermal bands). Despite its pioneering qualities, there have also been setbacks, with Landsat 6 failing to reach orbit in 1993, and the most current one, Landsat 7, suffering from some image quality problems. However, the latter also includes a 15m panchromatic band, and a thermal band that provides 60m data. For many years the data were also commercially sold, and at several thousand dollars per scene very expensive. Only recently the US government decided to make all Landsat data, including the entire archive, available free of charge. Data can be searched and downloaded using the GLOVIS tool already mentioned. There is also a source for free orthorectified Landsat data: http://www.landsat.org/ortho/index.htm. Good places to search are also the Global Landcover Facility (http://glcf.umiacs.umd.edu/index.shtml), or http://earthexplorer.usgs.gov. Be aware that Landsat datasets, even when compressed, can easily reach several hundred MB in size, which can make their download difficult (Figure 2.15). As with the other datasets mentioned above though, the files have geographic reference information and can easily be imported into a GIS or similar program.

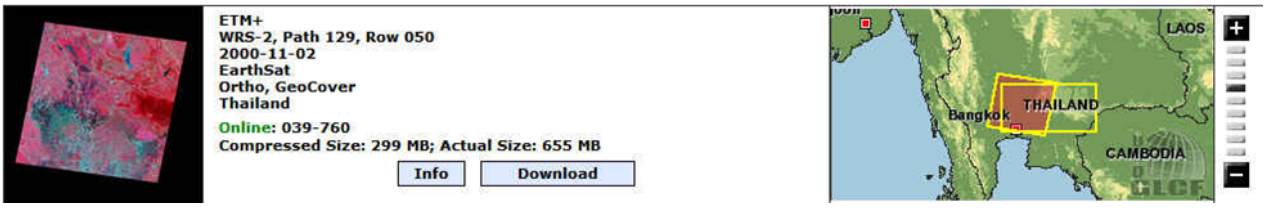


Figure 2.15: Landsat data ready for download at the Global Landcover Facility.

(vii) SPOT Vegetation

The SPOT satellites were initiated by the French Space Agency, but are now operated by Spot Imaging, a commercial company. The regular images are expensive, but the latest Spot satellite includes a vegetation mapper which collects data that are available for free if they are older than 3 months. They are distributed by VITO in Belgium (http://free.vgt.vito.be/). The resolution of the vegetation data is comparable to AVHRR at about 1.1 km (see Figure 2.16).

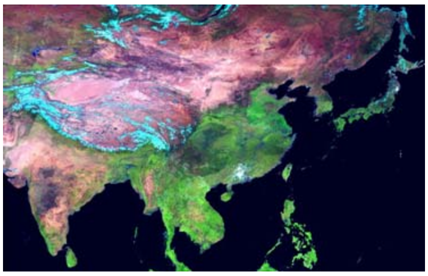


Figure 2.16: Example of Spot Vegetation data.

Task 2.7: Exercise (duration 45 minutes)
Select 2 of the above data sources, and go to the internet pages provided. Familiarise yourself with the interface. In case of the NASA portal you can register or use it as a guest. Select a dataset that you know, and have a try to seeing what data for your area and a given time period exist. How easy is it to find data? Are those many data types confusing? There will be a full exercise later that focuses on data funding and downloading, so you will have more time for that later.

Other commercial data sources

Commercial satellite data quickly reach costs in the thousands of dollars. Hence the well known commercial data types, such as Ikonos or Quickbird, are often not affordable, and are only briefly mentioned here. However, a few points must be noted. The mentioned commercial satellite operators have managed to increase the spatial resolution by a very impressive margin, for the first time reaching 50cm with GeoEye. These data are of a resolution comparable with many aerial photographs, but are already digital and usually include several spectral bands as well (the multispectral channels are of a lower resolution, usually at 4 times the resolution of the pan-chromatic band). There are also many more countries with their own space technology now. In addition to the traditional space powers – the US, Canada, Europe, Russia, and Japan – we now find many countries building and operating their own satellites instruments. Often these are small and relatively inexpensive satellites, such as micro- or even nanosatellites (less than 100 and 10 kg, respectively), thus we see a very active Earth observation arena, making it easier to get data. Countries that deserve special mention are India, which is operating one of the largest fleet of earth observation satellites, and has very ambitious plans, which are matched by China, which has also been collaborating with Brazil on a satellite program. Also in Africa there have been interesting developments, with Egypt, South Africa, Nigeria, and Algeria having operated Earth observation satellites, and plans exist for an African Resource Management Satellite.

For those who require high resolution commercial data, good search engines exist, such as http://ImageSearch.geoeye.com for GeoEye, Ikonos and OrbView data, or Eurimage for Quickbird data (www.eurimage.com/products/quickbird.html).

Task 2.8: Exercise (duration 45 minutes)
Submit to the discussion board a short overview of the hazard you have chosen, and a summary of the results you obtained in the various tasks. Check the submissions of your class mates, to learn about other hazard types, but also to see what data may exist for your hazard type in other countries.

2.2 Generation of digital stereo imagery

2.2.1 Introduction

We can see three-dimensionally – or "stereo" - because we have two eyes, which enable us to see a scene simultaneously from two viewpoints. The brain fuses the *stereo*scopic views into a three-dimensional impression (together with sensing what appears taller and what smaller, what is partially obscured, etc). We need therefore always two images taken from different positions for the creation of analog or digital stereo viewing (*Figure 2.20*). For applications in the field of hazard and disaster studies experts prefer images taken "from above", which can give an excellent overview of the terrain and the elements at risk.

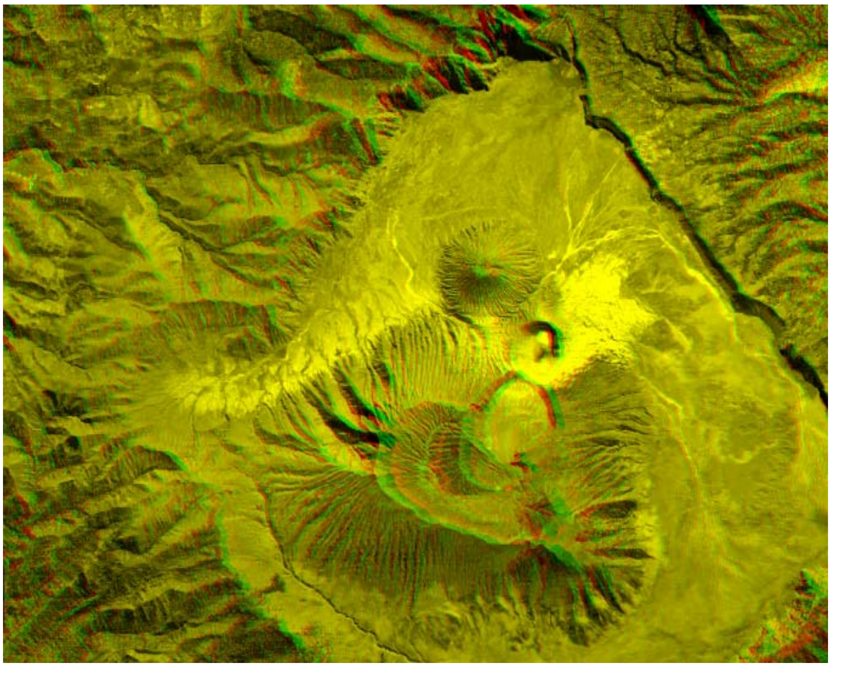


Figure 2.17: Anaglyph image - Bromo volcano, Indonesia (Damen, ITC)

One of the most widely used tools to see stereo is the *stereoscope***.** This device allows the observer to see images in three dimensions. Depending on the scale and image resolution of the (near) vertical images one can see in three dimensions for instance terrain morphology, building heights and other surface objects.

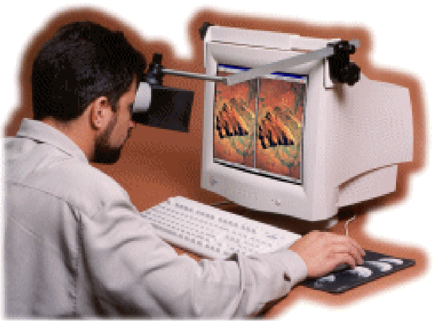


Figure 2.18: Use of screen-scope

Stereoscopes come in all shapes and sizes. The *mirror stereoscope* for instance uses mirrors to bring the two images to the two eyes of the photo-interpreter. The main advantage of using this type is that the *stereo pair* can be completely separated, thus permitting the analyst to see more of the image at once. In the ILWIS software it is possible to resample the left and right images to such a position relative to each other, that stereo vision is possible on the computer screen using a *screen-scope* (Figure 2.18)**;** but *anaglyph* vision is also possible in ILWIS. To make this possible, the overlapping part of the left and right images are combined in *two color layers*, to create a depth effect. For the viewing one need two color anaglyph glasses, with each lens a chromatically opposite color, usually red and green or red and blue (Figure 2.19).

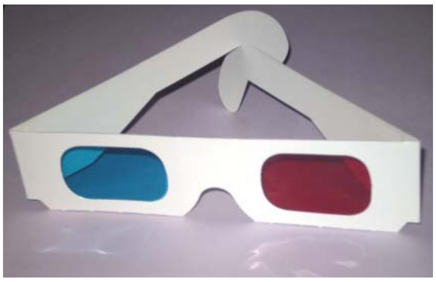


Figure 2.19: Anaglyph glasses

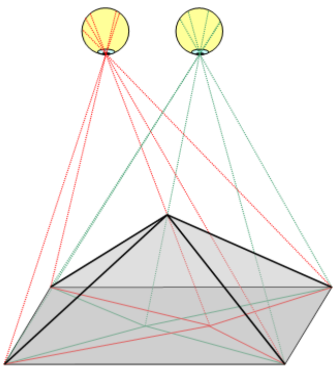


Figure 2.20: Stereoscopy: seeing of objects in three dimensions (RS Core Book, ITC, 2008)

Instead of using two overlapping images, one can create in ILWIS also a 3-D visualization by combining an image with a digital elevation model of the same area. Stereo images that do not have geographical co-ordinates, such as for instance a pair of scanned aerial photographs, can be geo-referenced in ILWIS using for instance a topographical map.

Nowadays more and more data are becoming available – some even free of costs– for the creation of 3-D visualization. Below an overview is given of the most widely used systems, starting with more traditional types such as aerial photographs, followed by laser scanning data together with various space borne systems.

With oblique viewing “as a birds eye” it also possible to receive kind of 3-D visualization. This option is given for instance in Google-Earth, in which the image is “draped over a DEM.

Task 2.9 : Exercise (duration 15 minutes + Optional task)
Have stereo vision yourself with the provided anaglyph glasses.

For the creation of the anaglyph image of Bromo volcano (Figure 2.17), first a digital elevation model (DEM) is made from the overlapping vertical (nadir) and backward looking Infra Red image bands of the Aster satellite sensor. (Remark: Special photogrammetric software is used for this processing; unfortunately this can not be done in ILWIS).
The horizontal spatial resolution of the DEM is 30 m.; the relative vertical accuracy is approximately 1 m. (the relative accuracy however is much higher, and can be 15 m. or more).
To create the anaglyph in ILWIS a"screenshot" of the high resolution image in Google Earth of the area has been "draped"over the DEM. This image has first given the same coordinate system as the DEM by image-to-image rectification.

- *Look at the anaglyph image of Bromo volcano, East Java, Indonesia (Figure 2.17). Keep the red glass to the right. Try to recognize the different geomorphological features, such as the volcanic craters and cones of different phases of eruption. Volcanic ash of one of the most recent eruptions is shown with a light tone.*

Optional task: Open Google Earth and browse to the area yourself (70 57'/ 1120 58').
Interesting websites:
Bromo volcano, ESA: http://www.esa.int/esaEO/SEMUAU0DU8E_index_0.html
ASTER satellite sensor: http://asterweb.jpl.nasa.gov/
You can comment on your findings on the discussion forum in Blackboard.

2.2.2 Aerial photography

Aerial photographs has been used since the early 20th century. The aerial camera using a lens to record data on photographic film is by far the oldest remote sensing method. Depending on the type of film this can be black and white, color infra-red or natural color. Also other options are available. Nowadays it is also possible to make digital aerial photographs

Aerial photos are an extreme useful source of information for specialists in the field of hazard and disaster studies. Not only do they provide detailed spatial data of the terrain, but also of the infrastructure and other elements at risk. By comparing older photos with more recent images, changes can be analyzed of for instance hill slopes, to be used to assess stability, or of the horizontal shifts of the river bed for flood hazard studies. However, many more examples can be given.

Figure 2.21: Sequential aerial photography in one run

The science and technique of making measurements from photos, including terrain models is called *photogrammetry*. Almost all topo-graphic maps are based on aerial photographs, which are replaced nowadays by modern digital aerial images. Also the topographic contour lines are created by photogrammetric measurements.

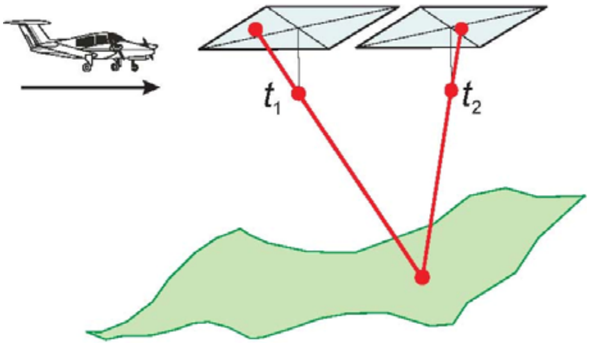


Figure 2.22: Image position at two aerial photos (t1 –t2) of the same terrain feature (RS Core Book, ITC, 2008)

Aerial photographs are mostly taken by a plane in parallel strips or *runs* (Figure 2.21). To create a good stereo vision, all the photos need overlap of about 60 % in the direction of the flight-line; the sideways overlap should be 30 % (Figure 2.24). In overlapping aerial photographs the same feature in the terrain will have a different position in the left and right image (Figure 2.22). By knowing the *internal* and *external* orientation of the camera, a digital or analog stereo model can be created. The *internal* orientation gives the position of the projection center of the camera lens with respect to *the image;* it is also called the *"principal point"* of the aerial photograph. In photo film cameras so

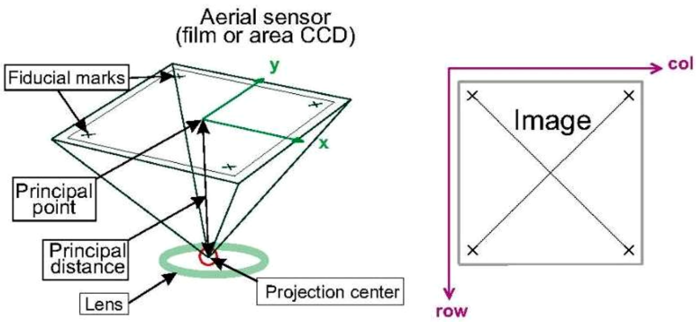


Figure 2.23: Inner geometry of a camera and associated aerial photograph (RS Core Book, ITC, 2008)

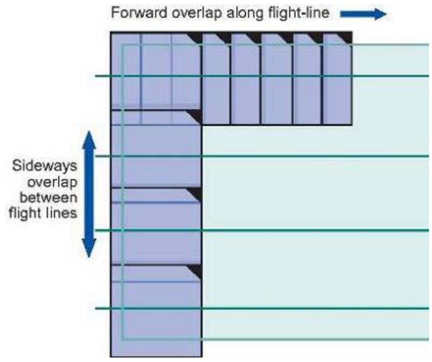


Figure 2.24: Overlap of aerial photographs (RS Core Book, ITC, 2008)

Figure 2.25: Damage mapping using small format aerial photography Aceh tsunami disaster (Photos: B. Widartono, UGM, Indonesia)

called *"fiducial marks"* are printed at the corners and edges of the photo to measure this principal point (Figure 2.23). *External* orientation gives the position and tilt of the camera in respect to the terrain co-ordinate system. As the calibration report of the aerial camera listing all the technical details on the internal and external orientation is not always available, it is in ILWIS also possible to create a stereo image without knowing all the details. A pair of scanned aerial photos with at east three fiducial marks is sufficient. However, one has to accept that the image has no real world co-ordinates.

In cases were stereo images are not quickly available – for instance for damage assessment immediately after a disaster – also monoscopic images - even in oblique mode - can be extremely useful (Figure 2.25). For the image acquisition one can think of "alternative" platforms, such as a microlight, helicopter or even a kite.

2.2.3 Lidar

Another air-borne system widely used to create 3-D is ***LI**ght **D**etection **A**nd **R**anging (**LIDAR**)*. A laser scanner mounted in an aircraft emits laser beams with a high frequency to record the reflections together with the time difference between the emission and reflection (Figure 2.26). With detailed information about the internal and external orientation using GPS and other devices, the elevation of the 'scanned' area can be measured in centimetre accuracy (Figure 2.28). LiDAR differs from RADAR mainly in its ability to resolve very small targets and penetrate vegetation.

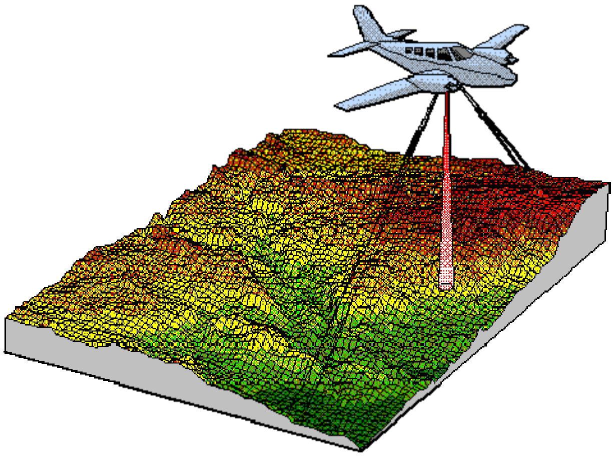


Figure 2.26: Lidar scanning (GEODAN, NL)

The reflection strength depends on the wave length and the terrain type. All terrain features are scanned, not only the terrain itself but also trees, buildings, cars on the street, etc... To create a 3-D *terrain* model all this data has to be filtered out from this original *surface* 3-D model. The multiple reflections from the same surface feature, such as a tree (see Figure 2.27) can also be used for, for instance 3-D vegetation mapping and biomass estimation.

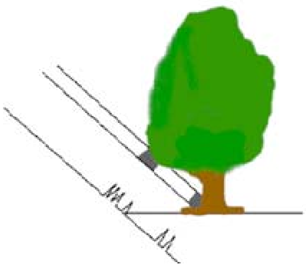


Figure 2.27: Multiple reflections of Lidar beam (Vosselman, ITC)

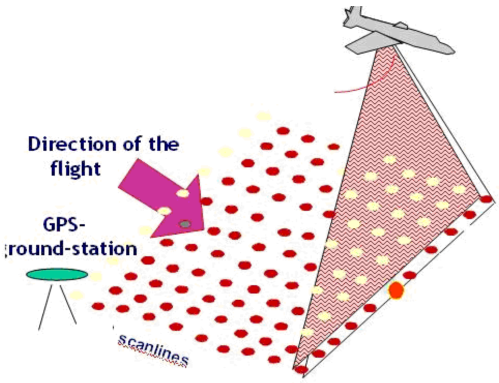
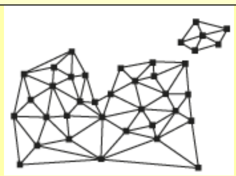
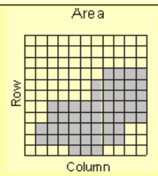


Figure 2.28: Lidar scanning (GEODAN, NL)

An excellent terrain representation can be created if a very high resolution optical image, such as IKONOS or Quickbird is "draped" over the Lidar surface or terrain model. One can use also downloaded high resolution "Google Earth images" for this purpose, after geo-referencing.

Digital Elevation Models (DEMs) consist of a listing of elevations above a defined geographic datum, over some area of the earth.

Digital Elevation Models can either be stored in vector or in raster format. DEMs in vector format are often in the form of Triangulated Irregular Networks (TIN), which can be seen as a set of polygons in the form of triangles where the 3 corners of each triangle have known height values. Programs like ArcGIS use both the vector and raster format to store and manipulate DEMs; in ILWIS DEMs can only be stored in a raster format. In ILWIS it is possible to create a raster DEM by point and contour line interpolation. Good visualizations of terrain can be generated with this (Figure 2.29).

	TIN 	**RASTER** 
Advantages	o ability to describe the surface at different level of resolution o efficiency in storing data	o easy to store and manipulate o easy integration with raster databases o smoother, more natural appearance of derived terrain features
Disadvantages	o require often visual inspection and manual control of the network	o Inability to use various grid sizes to reflect areas of different complexity of relief.

Digital Elevation Models form one of most frequently used spatial data sources in GIS projects. The most important application areas of DEMs are:

- ***Slope steepness maps***, showing the steepness of slopes in degrees or percentages for each location (pixel).
- ***Slope direction maps*** (also called slope aspect maps), showing the orientation or compass direction of slopes (between 0°-360°).
- ***Slope convexity/concavity maps***, showing the change of slope angles within a short distance. From these maps you can see if slopes are straight, concave or convex in form.
- ***Hill shading maps*** (or shadow maps), showing the terrain under an artificial illumination, with bright sides and shadows. Hill shading shows relief difference and terrain morphology in hilly and mountainous areas
- ***Three dimensional views*** showing a bird's eye view of the terrain from a user defined position above the terrain.
- ***Cross-sections*** indicating the altitude of the terrain along a line and represented in a graph (distance against altitude).
- ***Volume maps*** (or cut-and-fill maps), generated by overlaying two DEMs from different periods. This allows you to quantify the changes in elevation that took place as a result of slope flattening, road construction, landslides etc.

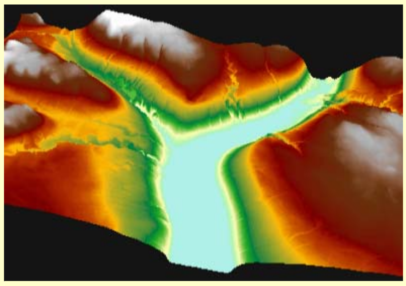


Figure 2.29: 3-D visualization of terrain with elevation in colors – See also DEMO

Digital Elevation Models are made via the following techniques:

- ***Photogrammetrical techniques.*** These methods use stereoscopic aerial photographs or satellite images, to sample a large number of ground points, with X, Y and Z elevation values, by means of special developed software. After this, the points are interpolated into a regular grid (raster). It is nowadays possible to buy ready-made DEM products on medium scale created from ASTER, SPOT, and other satellite systems. Large scale DEMs with high accuracy can be derived from Laser scanning or Stereo IKONOS imagery.
- ***Point interpolation techniques***. First elevation point data have to be collected from an area, for instance by ground surveying, using high accuracy differential Global Positioning Systems (GPS). The DEM is generated by point interpolation, in which values of the intermediate elevation points are being estimated;
- ***Interpolation of contour lines*** digitized from topographical maps.

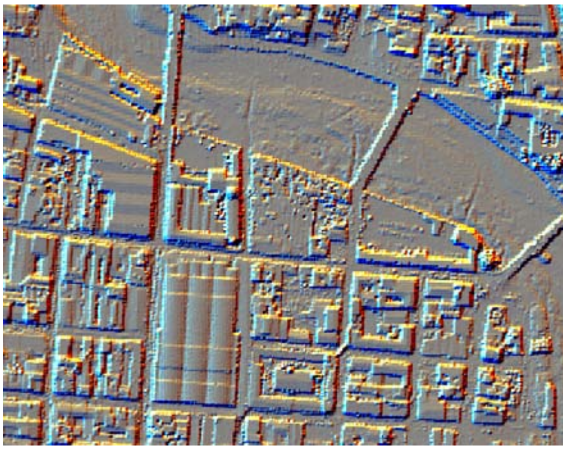


Figure 2.30: Terrain model of Risk City from Lidar – Hillshaded in color

Examples of the use of Lidar are corridor mapping for roads and rail roads, 3-D city modelling (see Figure 2.30), telecommunication planning, archaeological sub-surface site investigation, vegetation mapping and the quantification of erosion and sedimentation volumes. Also a good surface expression can be generated with a hill shade model (Figure 2.30)

Task 2.10 : Exercise (duration : 45 minutes)

1. *Read the text about the Actual Elevation Model of the Netherlands on: http://www.ahn.nl/english.php*
2. *Study also the lidar animations on: http://www.ahn.nl/demoanimaties.php*
3. *Animation of lidar acquisition of infrastructure with helicopter: http://nl.youtube.com/watch?v=f1P42oQHN_M*

2.2.4 Shuttle Radar Topography Mission (SRTM)

Other ways to create 3D terrain models are the use of radar. An example of this is data from the **Shuttle Radar Topography Mission** (SRTM) of February 2002, covering large parts of the globe, which can be downloaded for free from the internet (see the task).
The radar signal is recorded with antennas at two slightly different positions: one in the centre of the Space shuttle itself and another at the end of a 60 m long mast (Figure 2.31).

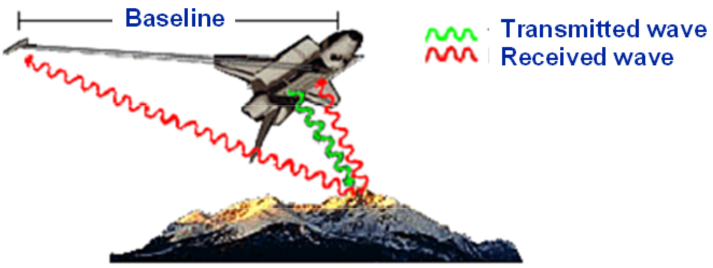


Figure 2.31: SRTM data collection(www2.jpl.nasa.gov/srtm)

Using the information about the distance between the two antennas and the differences in the reflected radar wave signals, elevation data of the Earth's surface can be generated at a relative accuracy. The pixel (*X* –*Y*) resolution of the data is 91 m; the vertical (*Z*) resolution 1 m. with an absolute accuracy of approximately 10 – 15 m.

This means that SRTM is not suitable for the measurement of accurate elevations. However, for medium of low terrain studies of large areas it can be very good. It the field of hazard and disaster studies it is extensively used for among others for tsunami impact studies along the coasts of Sumatra and Sri Lanka. Other applications include the impact of enhanced sea level rise. The map in Figure 2.32 shows low and high areas vulnerable to future sea intrusion along the West coast of Sri Lanka. SRTM data is also used for 3-D viewing in Google Earth.

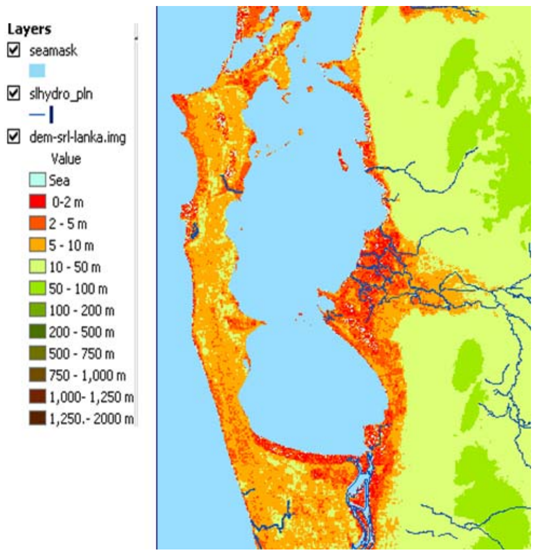


Figure 2.32: Medium scale elevation using SRTM data – West coast Sri Lanka (Damen, ITC)

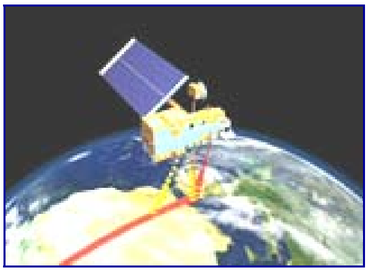
Task 2.11: Exercise (duration 1.5 hours)

Download of SRTM data from the www – Import and display in ILWIS
Read first the background information on SRTM on NASA website: http://www2.jpl.nasa.gov/srtm/
To download SRTM data from the CGIAR website: http://srtm.csi.cgiar.org/ follow the instructions given in ***RiskCity Exercise 2 Download SRTM & Import in ILWIS***
You can comment on your findings on the discussion forum in Blackboard

2.2.5 Optical satellite systems for 3-D model generation

Various modern satellite sensors have nowadays capabilities to generate 3-D models from the earth surface with sensors using the visible spectrum. Two systems widely used are the Advanced Space borne Thermal Emission and Reflection Radiometer (ASTER) and the French SPOT satellite.

The **ASTER satellite** has been launched in December 1999. The orbit has an altitude of 705 km altitude, and is sun-synchronous, so that at any given latitude it crosses directly overhead at the same time each day. Every 16 days (or 233 orbits) the pattern of orbits repeats itself.



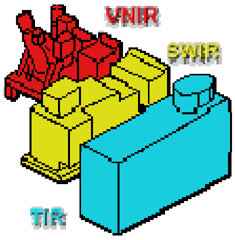


Figure 2.33: ASTER satellite and sensors http://asterweb.jpl.nasa.gov)

Aster has three sensors with together 14 image bands in the Visible & Near Infra Red (VNIR), Short Wave Infra Red (SWIR) and Thermal IR (TIR) (see Figure 2.33). The VNIR sensor has in total four bands, of which one is "back-ward" looking. By combining the vertical or "nadir' looking band with the backward looking band a three dimensional terrain model can be generated with a pixel resolution of 30 m (See example in Figure 2.34). The data can be bought relatively cheap from the US Geological Survey (USGS).

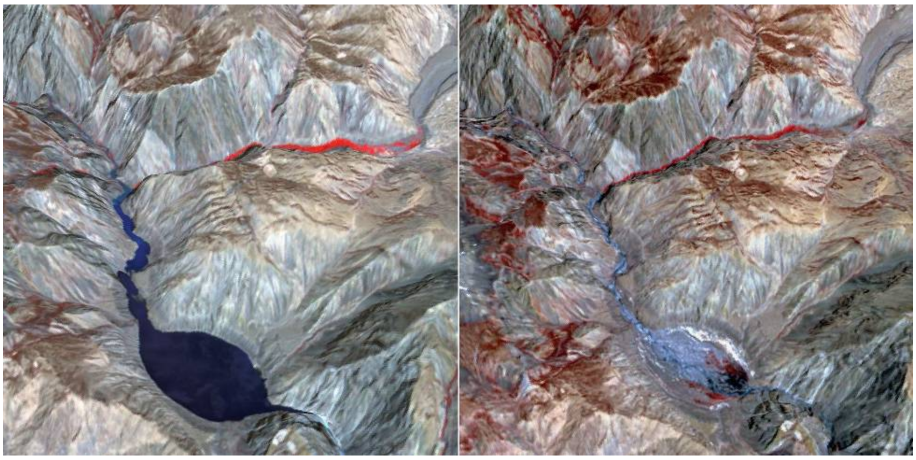


Figure 2.34: Water levels in the Pareechu River in Tibet continue to build behind a natural dam, created by a landslide. On September 1, 2004, ASTER captured the left image of the new lake. The right image was acquired May 24, 2000, before the landslide.
The water has filled the basin and poses a threat to communities downstream in northern India, which will be affected if the landslide-dam bursts. Both perspective views were created by draping a false color ASTER image over ASTER DEM data. (http://asterweb.jpl.nasa.gov)

The **SPOT satellite** has a different system compared to ASTER to generate 3-D data; it has a very good global coverage (Figure 2.35). The sensor has a steerable mirror by which it can detect terrain across track to the "right" or to the "left" of the satellite overpass (Figure 2.36). By combining this images– which are taken under an angle - from different overpasses, a three dimensional model can be generated.

A SPOT DEM is a digital elevation model produced by stereopairs acquired by SPOT-5. The resampled resolution is 20 m; vertical accuracy 7 m and horizontal accuracy 10m.

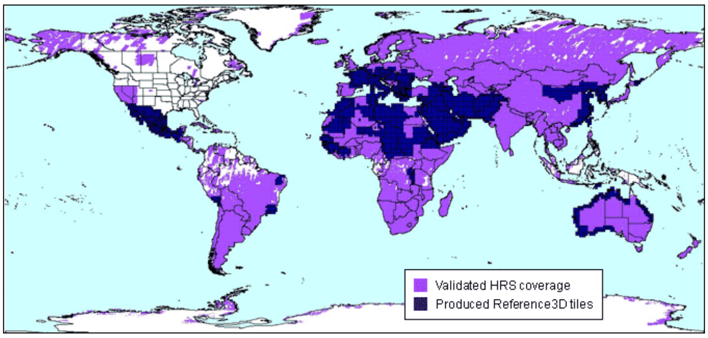


Figure 2.35: DEM Global coverage of SPOT satellite

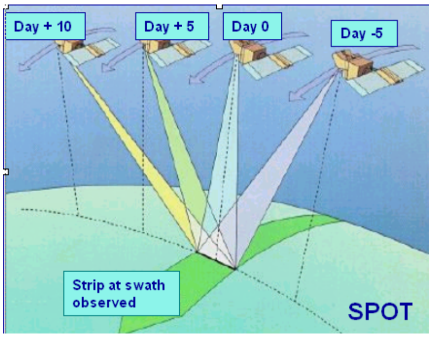


Figure 2.36: SPOT satellite system

Task 2.12: Internet assignment (duration 30 minutes)

Explore the internet pages of ASTER and SPOT:
http://asterweb.jpl.nasa.gov/data.asp & http://www.spotimage.fr/
Explore the pages of the mission
Find examples of images from natural hazards in the galleries
Try to find other sensors with stereo capabilities

2.2.6 Examples of the use of DEMs

Many derivate maps can be produced from DEMs using fairly simple GIS operations. An example of DEM derivatives obtained from an SRTM DEM for the watershed area in which RisKCity is located is shown in Figure 2.37. After obtaining the raw data, several processing steps had to be applied in order to correct for the missing data values and to remove so-called “sinks”, which are closed depression in the DEM due to artifacts.

The LiDAR DEM of the Riskcity area was obtained from the USGS. It was collected by the University of Texas using an ALTM 1225 in March 2000, at an altitude of 800-1200 resulting in a spacing of 2.6 m between scan lines. A TopScan vegetation removal filter was applied and the data was interpolated into a 1.5 m resolution DEM. The LiDAR DEM was used together with the SRTM DEM (90 m spatial resolution) and with two other DEMS from contour maps. The first contour maps had a scale of 1:2000, 2.5 meters contour lines and the resulting DEM was made at 1 m spatial resolution. The second contour map was at scale 1:50000 with 20 m contour lines interpolated in a DEM with 30 meter pixel size. The four DEMs were used to produce slope angle maps, using horizontal and vertical gradient filters. The resulting slope maps were classified into classes of 10 degrees, and overlain with a landslide inventory. Figure 2.39 shows the 4 slope class maps with the corresponding histograms. The slope class maps derived from SRTM and 1:50000 scale topomaps contain more flat areas as compared to the DEMs from 1:2000 topomaps and LiDAR. From the figure it can be concluded that the resolution and accuracy of the DEM has a very large influence on the slope classes.

Figure 2.37: Examples of different types of optical remote sensing images for El Berrinche landslide in RiskCity,. A: Section of an Aerial-photo, scale 1:14,000 from 16-March-1975, B: Section of an aerial-photo, scale 1:20,000 from 9-February-1990, C: Section of an aerial-photo, scale 1:25,000 from 1998, taken after hurricane Mitch, D: Section of an orthophoto, generated from 1:10,000 photos from May 2001, E: Section of a Aster image, with a spatial resolution of 15 meters from 2005; F: Section of a IRS P6 image, with a spatial resolution of 5.6 m from 14-April 2006; G: Section of a Digital Globe image from Google Earth, from 2007; H: Shaded relief image from a LiDAR DEM with 1.5 meter spatial resolution.

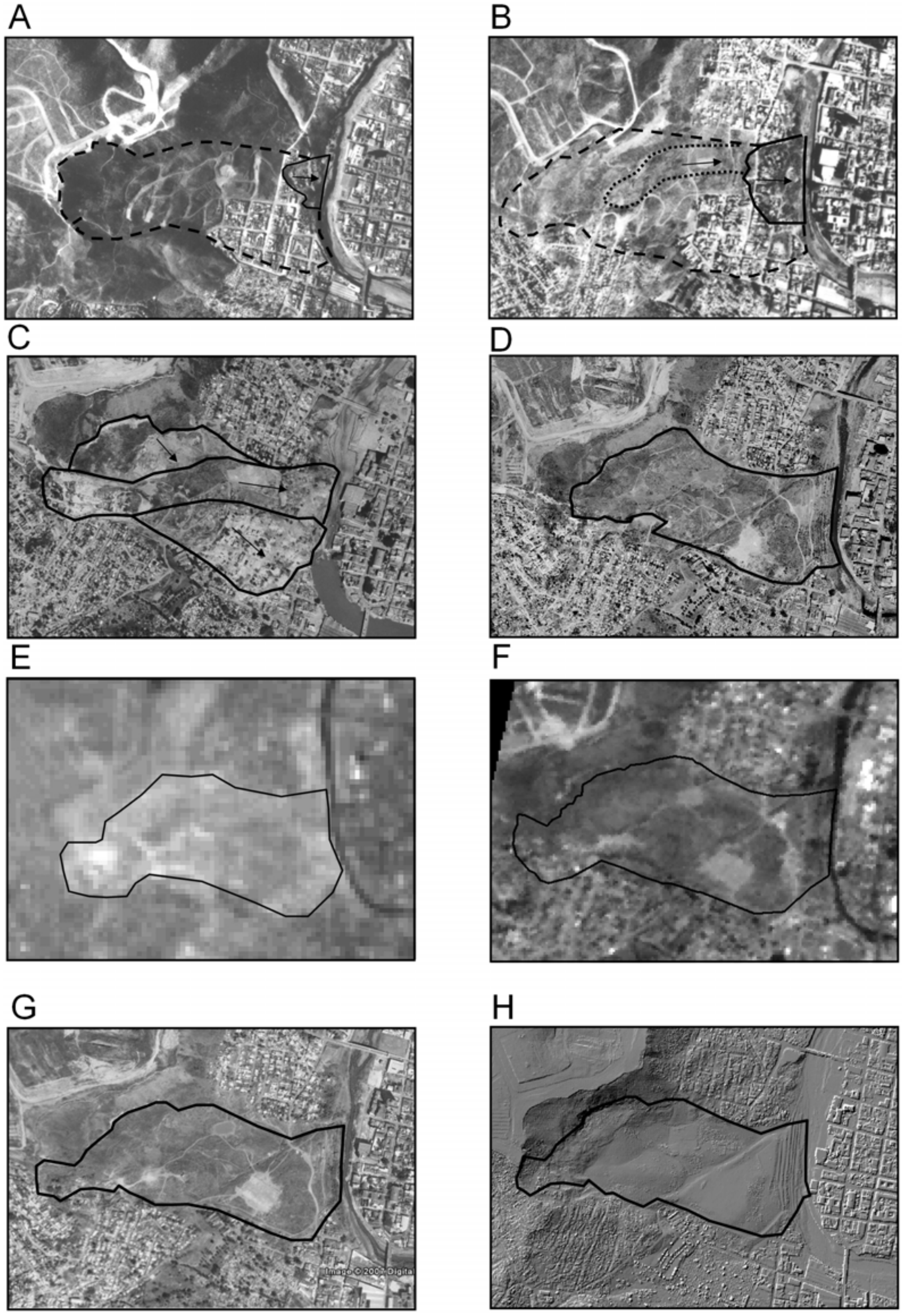


Figure 2.38: Examples of derivative maps from a SRTM DEM of the watershed of the Choluteca River, near Tegucigalpa. A: Altitude, B: Shaded relief image, C: Slope angle (in degrees), D: Slope direction (in degrees), E: Flow accumulation, F: Automatic drainage and catchment delineation, G: Drainage direction, H: Landsat TM image showing the location of Tegucigalpa, and the watershed boundary..

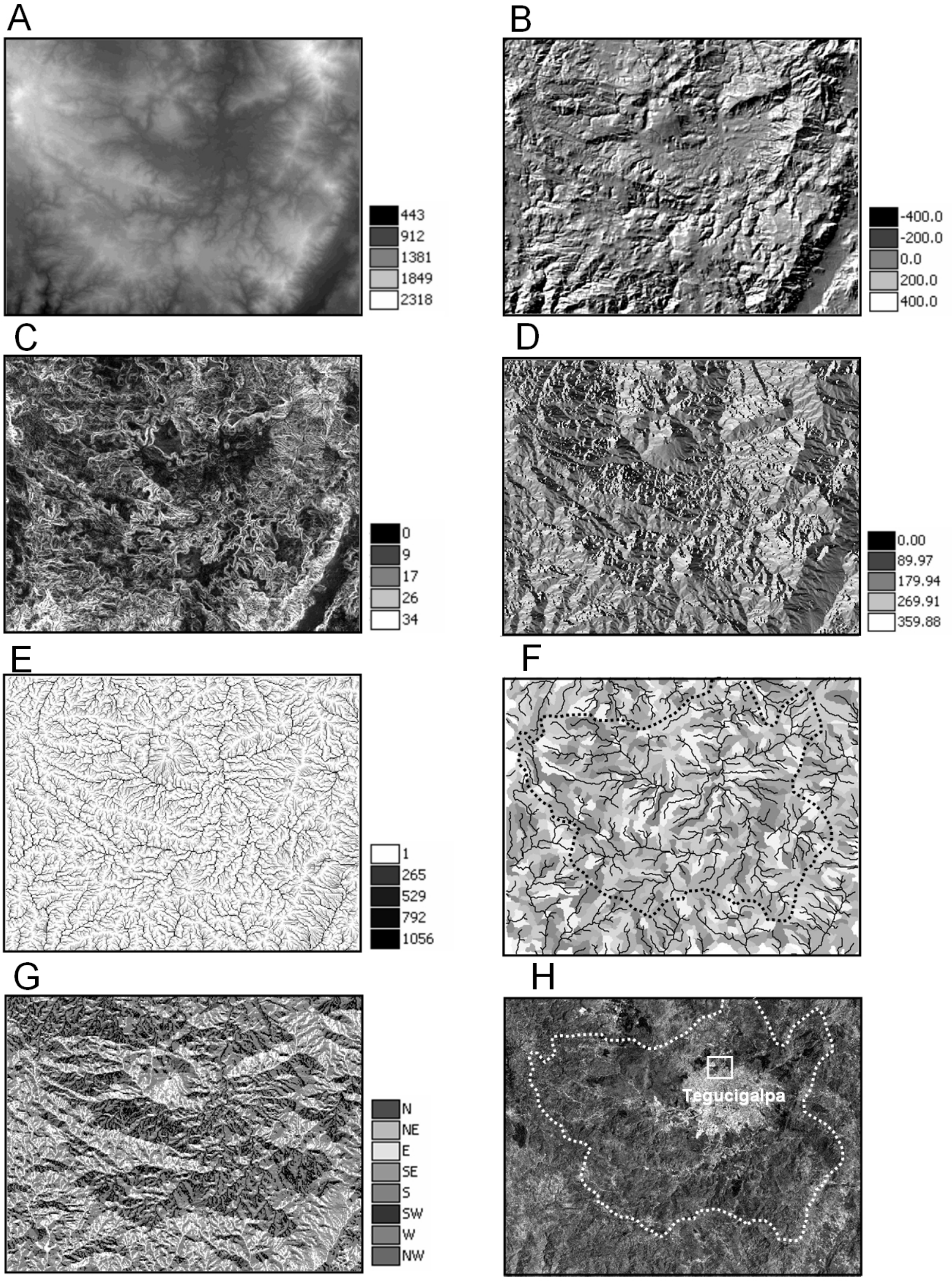
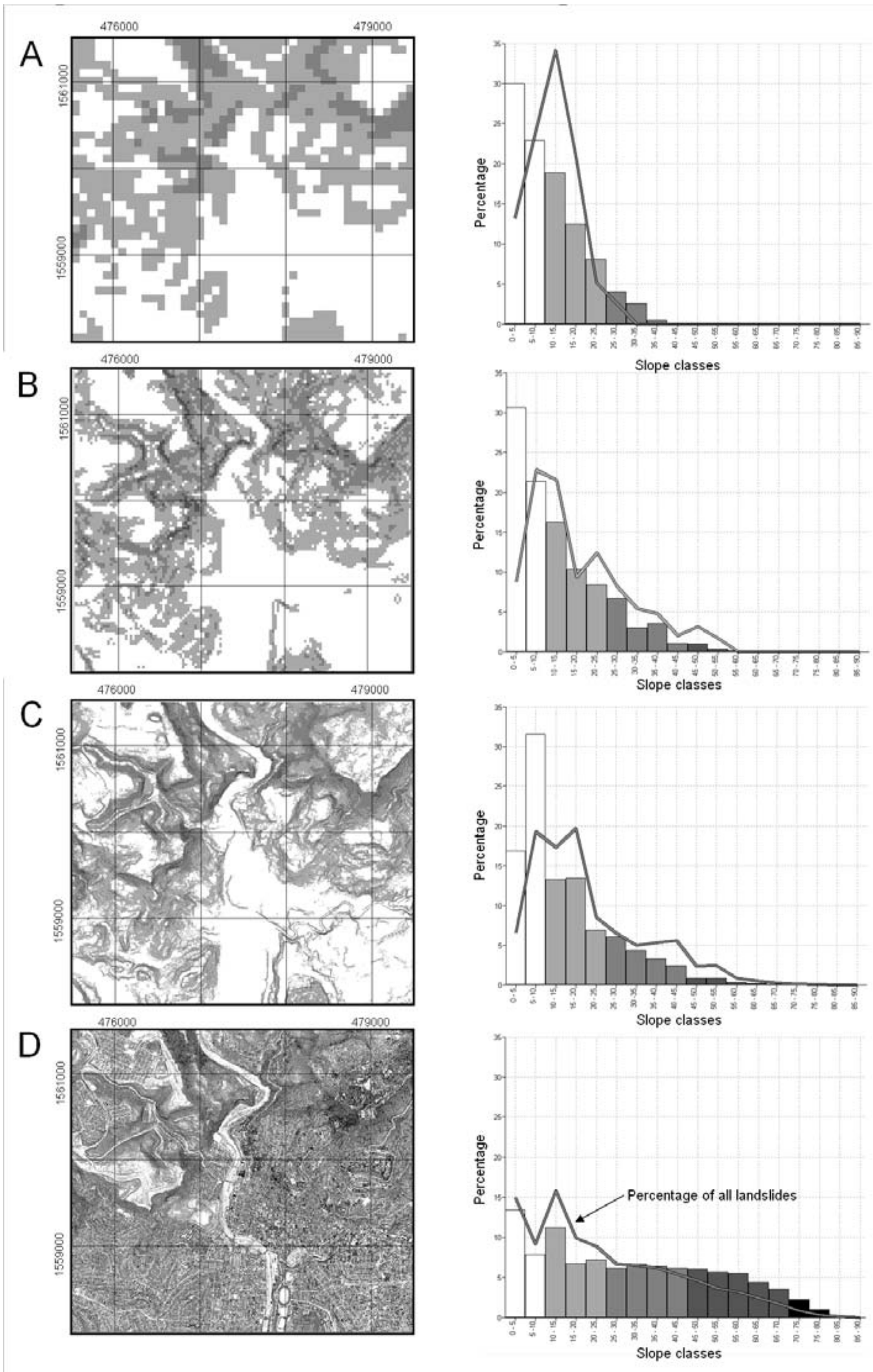


Figure 2.39 : Effect of the use of different DEMs on the generation of slope maps and the relation with landslide distribution. The left side of the figure shows the slope angle maps (in degrees) generated from: A. SRTM data; with 90 m spatial resolution, B. 1:50,000 topomaps with 20 m contour interval, resulting in a DEM with 30 m horizontal resolution, C. 1:2,000 topomaps with 2.5 m contour interval, resulting in a DEM with 1 m spatial resolution, D. a LiDAR image, from which the vegetation has been removed, with 1.5 m spatial resolution. The right side of the figure shows the percentage of area per slope class (bar charts), and the percentage of all landslides per slope class (thick lines).



2.2.7 Overview of different types of RS systems for disaster management

As has been explained before in this Session 2 of the Guidance Notes, optical and active (radar) RS systems as well as digital elevation models can have different characteristics in respect to the number of image bands, temporal coverage and pixel size. Aerial photographs for instance have in most cases a much higher spatial resolution compared to satellite images but a low temporal coverage (may be every 5 or 10 years only). And the relative high resolution IKONOS satellite with its 1 meter panchromatic band has a higher spatial resolution than for instance the 15 m panchromatic band of Landsat Enhanced Thematic Mapper. Digital elevation models derived from Lidar have much smaller pixels (up to 1 m or less) compared to SRTM (pixel size approx. 90 m). Many more examples can be given of this; it will be clear all the available systems have their own specific advantages and disadvantages in respect to disaster risk management.

Table 1 provides an overview of the requirements for different types of information for the various phases of disaster risk management, and the utility of remote sensing and other spatial data types and methods. Note that this is a generalized schematic that does not reflect sub-hazards, the assessment of which may require different data and/or different spatial and temporal characteristics.

Task 2.13: RiskCity Exercise 2 : Creating and interpreting multi-temporal digital stereo images (duration 2.5 hour)

The exercise shows you how you can generate stereo images from digital aerial photographs and Digital elevation Models. The stereo images can be displayed using the anaglyph method and are used to interpret the landslide activity in RiskCity from different periods (1977, 1998, 2001 and 2006).

If you also will do the GIS exercise (Task 1.11) you may also decide to skip this exercise now.

	Phase	Data type	Spat (m)	Temp	Other tools	Satellite sensors				
						VIS/IR	TH	SAR	INSAR	Other sensors
Flood	Hazard mapping/ Prevention	Land use / landcover	10 - 1000	Months	API + field survey	X		X		
		Historical events	10 - 1000	Days	Historical records, media	X		X		
		Geomorphology	10 - 30	Years	API + field survey	Stereo				
		Topography, roughness	1 - 10 *	Years	Topomaps	Stereo		X	X	Laser altimetry
	Preparedness	Rainfall	1000	Hours	Rainfall stations	X	X			Weather satellites/ Passive Microwave/ ground radar
		Detailed topography	0.1 - 1 *	Months	GPS, field measurements				X	Laser altimetry
	Relief	Flood mapping	10 - 1000	Days	Airborne + field survey	X		X		
		Damage mapping	1 - 10	Days	Airborne + field survey	X				
Earthquake	Hazard mapping/ Prevention	Land use / landcover	1 - 10	Years	API + field survey	X				
		Geomorphology	1 - 10	Decade	API + field survey	Stereo				
		Lithology	30 - 100	Decade	API + field survey	X				Hyperspectral
		Faults	5 - 10	Decade	API + field survey	Stereo		X		
		Soil mapping	10 - 30	Decade	API + drilling + lab. testing	X				
	Preparedness	Strain accumulation	0.01 *	Month	GPS, SLR, VLBI				X	
	Relief	Damage assessment	1 - 5	Days	Airborne + field survey	X		X		
		Associated features	10 - 30	Days	Airborne + field survey	X		X		
Volcano**	Hazard mapping/ Prevention	Topography	10 *	Years	Topomaps	Stereo			X	Laser altimetry
		Lithology	10 - 30	Decade	API + field survey	X		X		Hyperspectral
		Geomorphology	5 - 10	Years	API + field survey	Stereo				
		Landcover/snow	10 - 30	Months	API + field survey	X				
	Preparedness	Thermal anomalies	10 - 120	Weeks	Field measurements		X			
		Topography/deformation	0.01 *	Weeks	GPS, tilt meters				X	Laser altimetry
		Gas (composition, amount)	50 - 100	Weeks	IR spectrometer (COSPEC, FTIR)	X				Weather satellites
		Instability	10-30	Months	Field spectrometer					Hyperspectral
	Relief	Mapping ash cover	10 - 30	Days	Airborne + field surveys	X				
		Mapping flows	10 - 30	Days	Airborne + field surveys	X	X	X		
		Ash cloud monitoring	1000	Hours	Field surveys, webcams	X				Hyperspectral / weather satellites
Landslide	Hazard mapping/ Prevention	Landslide distribution	1 - 5	Year	Multi-temporal API, field survey, historic records	Stereo				
		Geomorphology	1- 10	Decade	API + field survey	Stereo				
		Geology	10 - 30	Decade	API + field survey	X				Hyperspectral
		Faults	5 - 10	Decade	API + field survey	Stereo				
		Topography	10 *	Decade	Topomaps	Stereo			X	Laser altimetry
		Landuse	10 - 30	Year	API + field survey	X				
	Preparedness	Slope movement	0.01 *	Days	GPS, field instrumentation				X	Laser altimetry
		Rainfall	100 - 1000	Hours	Rainfall stations	X	X			Weather satellites/ Passive Microwave/ ground radar
	Relief	Damage mapping	1-10	Days	API + field survey	X		X		

*Table 1: Requirements for the application of remote sensing and other spatial data in the various phases of disaster risk management. For each data type an indication is given of the optimal spatial resolution (spat), the minimum time for which successive data should be available (temp), and the sensor types that could be used (API – aerial photos, VIS =.visible, IR =infrared, TH = thermal, SAR = Synthetic Aperture Radar, INSAR = interferometric SAR,), VLBI = Very Long Baseline Interferometry, SLR = Satellite Laser Ranging, FTIR = Fourier Transform Infrared Spectroscopy, * = In this case the minimum resolution of the resulting DEM values are given, ** = this refers to eruptive activity. See Session 03 on more detailed information on volcanic hazards. Depending on the subhazard the data types have to be adapted.*

Self Test

Self test
In order to evaluate whether you have understood the concepts that were presented in this session. Please make the following test, and check the answers in Blackboard.

Note: several answers might be correct

Question 1: Why are spatial data so well suited for disaster risk assessment?

A) Spatial data are 3-dimensional
B) Spatial data have color information
C) All risk aspects are spatial, i.e. have a spatial location and extent
D) Spatial data can be referenced to geographic coordinates and displayed together in a GIS.

Question 2: Why is not every image type suitable for every hazard?

A) Images can have different spatial resolutions that may not always fit a given hazard
B) The observation frequency (temporal resolution) may be too low to pick up fast-changing hazards
C) I lack the right software to process the data
D) Images have variable spectral characteristics that need to match individual hazard types

Question 3: To map and observe a wildfire the following data type(s) or sensors would be useful.

A) Stereo aerial photos
B) Meteorological satellites
C) Laser data
D) Airborne infrared scanners

Question 4: When should I use Google Earth data for hazard assessment?

A) To map volcanic activity or wild fires
B) For landcover change detection
C) For broad visual assessment of hazards with clear surface expression
D) To study the area in preparation for a field campaign

Question 5: Why is it often useful to integrate auxiliary vector data in image analysis?

A) It helps my orientation
B) Many features can only be unambiguously identified in relation to other geographic features
C) It lowers the cost of analysis
D) Many features (e.g. political boundaries) cannot be seen in images, but knowing where they are can make the analysis easier.

Further reading:

Lillesand, T.M., Kiefer, R.W., and Chipman, J.W., 2004, Remote sensing and image interpretation: New York, John Wiley & Sons, 763 p.

Metternicht, G., Hurni, L., and Gogu, R., 2005, Remote sensing of landslides: An analysis of the potential contribution to geo-spatial systems for hazard assessment in mountainous environments: Remote Sensing of Environment, v. 98, p. 284-303.

Showalter, P.S., 2001, Remote sensing's use in disaster research: a review: Disaster Prevention and Management, v. 10, p. 21-29.

Tralli, D.M., Blom, R.G., Zlotnicki, V., Donnellan, A., and Evans, D.L., 2005, Satellite remote sensing of earthquake, volcano, flood, landslide and coastal inundation hazards: Isprs Journal of Photogrammetry and Remote Sensing, v. 59, p. 185-198.

Zlatanova, S. and Li, J., 2008, Geospatial information technology for emergency response, Springer.