This chapter will describe the different types of remote sensing data available and locations on the Internet where remotely sensed data sets can be found. The satellite instruments and missions that collect the data are often referred to by their acronyms, such as Moderate Resolution Imaging Spectroradiometer (MODIS) or Medium Resolution Imaging Spectrometer (MERIS), and this chapter will give the abbreviated notations when introducing each data set.

### 3.1 Optical Data

#### 3.1.1 Passive: Visible and Infrared

Passive optical data sets are probably the easiest to understand as these data include visible wavebands, and therefore the imagery can be similar to how the human eye sees the world. However, they also use wavebands beyond human vision to detect signatures related to the temperature of the Earth.

Optical instruments use a variety of spectral wavebands, but the basic distinction tends to be based around spatial resolution, particularly between medium and high-/very high resolution imagery. Examples of medium spatial resolution instruments include the following:

- Landsat series, launched from 1972 onward, with a spatial resolution of between 30 and 83 m for up to 11 spectral bands depending on the mission; a detailed breakdown can be seen in Table 6.1.
- MERIS, launched in 2002 and ceased operating in 2012, with a spatial resolution of between 300 and 1200 m for 15 spectral bands.
- MODIS, launched on separate satellites in 1999 and 2002, with a spatial resolution of between 250 and 1000 m for 36 spectral bands.
• Visible Infrared Imaging Radiometer Suite (VIIRS), launched in 2011, with a spatial resolution range of between 375 and 750 m for 22 spectral bands.

The following are examples of high- to very high resolution instruments:

• Satellites Pour l’Observation de la Terre (SPOT or Earth-observing satellites) series, began in 1986 with the launch of SPOT-1. At the point of writing, SPOT-5 is scheduled to be decommissioned from commercial service during 2015, having been in operation since 2002. It has been replaced by SPOT-6 and SPOT-7, launched in September 2012 and June 2014, respectively, which operate in tandem with 6-m pixels for four spectral bands and panchromatic data at 1.5 m for a 60 km × 60 km swath.
• WorldView-2, launched in October 2009, collects data for eight wavebands with 1.8-m pixels.
• Pleiades 1A, launched in December 2011, followed by 1B, launched in December 2012, have 0.5-m pixels across four spectral bands primarily aimed at the commercial marketplace.
• WorldView-3, launched in August 2014, offering 0.31-m pixels for its panchromatic band and 1.24 m for its 16 spectral wavebands and 3.70 m for its shortwave infrared wavebands. It also included the Clouds, Aerosols, Water Vapor, Ice and Snow (CAVIS) instrument that aids with atmospheric correction.

As highlighted in Chapter 2, the spectral and spatial resolution vary between, and within, satellite instruments. Therefore, as shown for the listed missions, not all spectral bands will have the highest available spatial resolution.

3.1.2 Active: Lidar

Lidar, which stands for Light Detection and Ranging, is an active remote sensing technique that uses a laser scanner to map the Earth’s topography by emitting a laser pulse and then receiving the backscattered signal. There are two main types of Lidar: topographic and bathymetric; topographic Lidar uses a near-infrared (NIR) laser to map land, while bathymetric Lidar uses water-penetrating green light to measure the depth of the seafloor.

Airborne laser scanning is most common because of the power requirements placed on a satellite mission by an active system. However, there have been satellite Lidars such as the Ice, Cloud, and Land Elevation Satellite-Geoscience Laser Altimeter System (ICESat-GLAS).
3.2 Microwave Data

A second type of remote sensing data is from the microwave part of the EM spectrum and has an advantage over optical data in that the signal can penetrate clouds and smoke, and sometimes precipitation, hence is not so strongly affected by weather conditions. There are a number of different types of microwave instruments that use the time of travel to measure heights and determine different surfaces from their roughness or dielectric constant, which is the extent to which a material concentrates an electric flux.

3.2.1 Passive: Radiometer

Passive microwave sensors, often called microwave radiometers, detect the natural microwave radiation emitted from the Earth. The spatial resolution is relatively coarse, often tens of kilometers, and this is a weak signal prone to interference from external noise sources such as microwave transmitters. Radiometers are used to measure soil moisture, ocean salinity, sea ice concentrations, and the land and ocean surface temperature.

As an example, the European Space Agency (ESA) Soil Moisture and Ocean Salinity mission, launched in November 2009, carries a radiometer, and as its name suggests, it’s a soil moisture– and salinity-focused mission although it has also been used for a number of other applications, as happens for many instruments.

3.2.2 Active: Scatterometer

Scatterometers send out pulses of microwaves in several directions and record the magnitude of the signals scattered back to the sensor. They’re commonly used to measure wind speed and direction, which is primarily used for operational meteorology. As an example, the SeaWinds instrument onboard Quick Scatterometer (QuikSCAT) measured winds over the ice-free ocean on a daily basis from July 1999 to November 2009.

3.2.3 Active: Altimeter

This is an active sensor used to calculate heights on the Earth by sending out short bursts, or pulses, of microwave energy in the direction of interest with the strength and origins of the received back echoes or reflections measured. The signal is corrected for a number of potential error sources, for example, the speed of travel through the atmosphere and small changes in the orbit of the satellite. Applications include calculating the height of the land, ocean, and inland water bodies. An example is the
Jason-2 Ocean Surface Topography Mission, launched in 2008, that carries the Poseidon-3 Radar altimeter, Advanced Microwave Radiometer (which allows the altimeter to be corrected for water vapor in the atmosphere), and instruments to allow the satellite’s position in space to be determined very accurately.

### 3.2.4 Active: Synthetic Aperture Radar

Synthetic Aperture Radar (SAR) is an active sensor where the pixel brightness is related to the strength of the return signal, with a rougher surface producing a stronger radar return and the resulting pixels appearing brighter in the imagery. It’s called SAR as it uses a small physical antenna to imitate a large antenna, because detecting long microwave frequencies in space would require a physical antenna thousands of meters in length; however, the same result can be achieved with a synthetic antenna of approximately 10 m in length. This is possible because as the satellite moves, all the recorded reflections for a particular area are processed together, as if they were collected by a single large physical antenna.

The orientation of microwave signals is known as polarization. Signals emitted and received in horizontal polarization are known as HH signals, and those emitted and received in vertical polarization are known as VV signals. Cross-polarized signals, such as HV or VH, are also possible.

SAR data are influenced by the azimuth, direction the sensor is looking, and orientation of the object of interest. Smooth surfaces have a mirror-like reflection, where the sensor only measures a return signal when it is directly above the target, and these surfaces appear dark in SAR imagery as the sensors are normally measuring at an angle. However, large flat rectangular surfaces, such as building facades that extend upward, are oriented perpendicular to the signal and thus can act like corner reflectors enhancing the like-polarized return, meaning that a horizontally polarized signal sent out will have an enhanced horizontally polarized return signal. Therefore, the same area can appear different on different SAR images depending on the choice of polarization and look-angle.

A specially modified SAR system with C and X bands was flown onboard the space shuttle *Endeavor*, during an 11-day mission in February 2000. This produced the Shuttle Radar Topography Mission (SRTM) Digital Elevation Model (DEM) global data set (http://www2.jpl.nasa.gov/srtm/) that, as of 2014, began to be made available globally at 30 m resolution. This is of particular interest to remote sensors as it allows topographical features to be understood; for example, we’ll use these data to add contour lines to imagery in Chapter 10.
3.3 Distinction between Freely Available Data and Commercial Data

Another distinction that can be made is between the data that are freely available to the general public and the commercial data that need to be paid for. Historically, space agencies have launched global missions and have produced large data sets with medium to low spatial resolutions, and the majority of these data sets are made freely available in a variety of formats.

Probably the most well-known space agency is the National Aeronautics and Space Administration (NASA), and they’ve had a long program of launching satellites to observe the Earth. Other space agency examples include ESA, the China National Space Administration (CNSA), the Indian Space Research Organization (ISRO), and the Japan Aerospace Exploration Agency (JAXA); the full list is available from Committee on Earth Observation Satellites (CEOS, http://ceos.org/about-ceos/agencies/).

In addition, there are also national and international organizations that work with space agencies to deliver operational services; for example, the National Oceanic and Atmospheric Administration (NOAA) provides weather forecasting and weather warnings in the United States. Again, the data from these organizations are often freely available. In Europe, this has been taken one step further with the European Commission running the Copernicus program of Sentinel missions. ESA is responsible for the coordination of the data products and services provided by Copernicus, which are all freely available to any user.

Therefore, with lots of medium- to low-resolution data freely available, commercial organizations have focused on providing high- and very high resolution imagery. These data have applications ranging from military intelligence to security and mapping, which was historically undertaken through airborne survey.

Very high resolution imagery will result in a large computer file (see Section 5.3), and there are constraints on the storage and transmission of files for satellites carrying these instruments, which means that commercial satellites often don’t routinely collect global data. Instead, when data are required, they are individually pointed toward the region of interest, a process known as tasking. This tasking generates a cost for the data collection, which is why commercial organizations charge extra for it. The cost can be lower if the data have already been requested by a previous user, that is, already sitting within an archive.

Costs vary between commercial operators, but generally microwave data are more expensive than optical data, and the higher the spatial resolution,
the higher the data purchase cost. Operators of commercial satellites include the following:

- DigitalGlobe with their GeoEye, IKONOS, QuickBird, and WorldView high- and very high resolution sensors, down to 0.3-m pixels.
- Urthecast Deimos Imaging with the DEIMOS missions that has 22-m pixels and operates in red, green, and NIR spectra.
- Surrey Satellite Technology Ltd operates the UK Disaster Monitoring Constellation (DMC) missions, which are a growing series of small satellites carrying three-waveband medium-resolution optical sensors with a wide swath of around 600 km and higher-resolution five-waveband sensors with a smaller swath, to provide daily global optical imaging of the Earth. They’re also developing NovaSAR-S (an S band Radar) that aims to deliver all-weather medium-resolution microwave data at a price similar to commercial optical missions.

There is also a series of joint ventures between space agencies and commercial organizations to design, build, and launch remote sensing satellites. The following are examples:

- Airbus DS designed and built both Cryosat-2 and SPOT 7, and was responsible for building the Sentinel-1 SAR instrument in addition to being the lead satellite contractor for the Copernicus Sentinel-2 mission. They also collaborated with the Deutsche Forschungsanstalt fur Luft und Raumfahrt (DLR) on the TerraSAR-X in June 2007 and then the TerraSAR-X add-on for Digital Elevation Measurement 2011 (Tandem-X) in June 2010.
- Boeing is building two small satellites, due to be launched in 2018, for the Australian company HySpecIQ that will carry the first commercial high-resolution hyperspectral instruments, focused on applications such as locating oil/gas or mineral-rich deposits and tracking agricultural yields.
- Raytheon designed and manufactured VIIRS.
- Thales Alenia Space designed and built, and are the lead for the Copernicus Sentinel-1A satellite and are playing the same role for the Copernicus Sentinel-3 missions with 3A due to launch in 2015. They also collaborated with the Agenzia Spaziale Italiana (ASI) on the COSMO-SkyMed constellation, which is a dual-use (civil and military) program with customers including public institutions, defense organizations, and the commercial sector.
There have been a number of companies such as Planet Labs, which raised $95 million through investor funding in 2014/2015 and then acquired BlackBridge’s geospatial business that included the five RapidEye satellites, and Skybox Imaging, which was purchased by Google for $500 million in 2014, that are launching constellations (or flocks) of small satellites to provide high spatial resolution and high revisit solutions.

3.4 Where to Find Data

There is currently no single location where all remote sensing data can be accessed from, but there is an increasing number of initiatives focused on creating data portals that provide either direct access or onward links to data from a range of sources for a particular application.

The historical route for obtaining the data, which still remains valid, is to go to the organization that was responsible for capturing and/or processing the data. A number of continually updated weblinks are provided via the online resource (see Chapter 4) alongside some of longer-term websites listed below:

- ESA (Landsat) ESA Online Dissemination, for Landsat data that have been received by ESA ground stations: https://landsat-ds.eo.esa.int/app/
- ESA Principle Investigator Community, a scientifically focused portal for accessing data held by ESA: https://earth.esa.int/web/guest/pi-community
- Global Earth Observation System of Systems (GEOSS) portal, which provides an interactive way to find out about how to access a large number of data sets: http://www.geoportal.org/
- Global Land Cover Facility (GLCF) from the University of Maryland, which focuses on land data from the local to global scales: http://glcf.umd.edu/
- NASA’s Geospatial Interactive Online Visualization ANd aNaLy-sis Infrastructure (Giovanni) Portal, an online tool that allows you to produce images and plots without downloading data: http://disc.sci.gsfc.nasa.gov/giovanni
- NASA OceanColor Web, which has ocean color, salinity, and sea surface temperature (SST) from a number of missions: http://oceancolor.gsfc.nasa.gov/
• NOAA Comprehensive Large Array-data Stewardship System (CLASS), for accessing all the data held by NOAA: http://www.nsof.class.noaa.gov/ with VIIRS data available at http://www.nsof.class.noaa.gov/saa/products/search?datatype_family=VIIRS
• UK Space Agency/Satellite Applications Catapult Data Discovery Hub, which is a growing portal for UK users to access a large number of data sets: http://data.satapps.org/
• USGS Landsat archive, the main route for accessing Landsat data: http://landsat.usgs.gov/

3.5 Picking the Right Type of Data for a Particular Application

The choice of which data source to use will be a combination of the following:

• Specification requirements for the application, such as whether it needs optical or microwave data, specific spectral wavebands/frequency bands, spatial resolution, and revisit time.
• Whether the data have to be freely available, or whether it can be purchased.
• Availability, in terms of which satellites cover the area required—not all satellites have global coverage, although there is a limited pointing capability for the high- to very high resolution missions.
• Lead time from the order, to the delivery of the data.

As we started discussing at the end of Chapter 2, the decision on which data to use involves making trade-offs:

• Revisit time: Landsat collects data with a revisit time of 16 days and provides regular, but not daily, coverage. Many applications require a revisit time of less than a week; hence, the Copernicus Sentinel-2 missions will use a pair of satellites to provide a revisit time of 5 days at the equator and 2 to 3 days at midlatitudes. Very high resolution satellites can be tasked to acquire data quickly and can often be pointed to acquire data from more than one possible orbit, but the faster the data are needed, the higher the cost is likely to be. Constellations, such as DMC and the small satellite operators, have several satellites so they can try to attain daily coverage.
• Spatial resolution: In addition to the influence of spatial resolution on what is visible within an image, as the resolution decreases, the ability to identify different components tends to decrease. Therefore, relatively small pixels are needed for characterizing highly variable areas, whereas larger pixels may suffice for characterizing larger scale variability.

• Required spectral wavebands/frequency bands: Depends on the spectral features and microwave signatures required. For different applications, different sections of the EM spectrum will be most optimum. These will be discussed, along with the approaches/algorithms used to derive quantitative results, in the applications chapters within the second part of the book.

• Cost: When considering cost, it’s necessary to think about both the cost of acquiring the data and the cost of the data analysis. Images that are more highly processed are likely to cost more, although cheaper raw data will take time, and knowledge, to process. The cost price is often also related to spatial resolution, with the higher the resolution, the higher the cost. However, recent developments of smaller and lower-cost satellites aim to reduce the cost of high-resolution imagery and are discussed further in Chapter 12.

### 3.6 Summary

Chapter 2 introduced you to how satellite remote sensing works, whereas in this chapter, we’ve focused on the data collected by those satellites. Understanding the different types of data available, and their different characteristics, forms the basis of remote sensing, and we’ve also given you some signposts on where to find these different types of data.

In the second half of the book, we’ll describe the most appropriate type, or types, of data to use for individual applications. The practical exercises will be mainly focused around visible and infrared data, as these are easier to access, although we’ll also be using some SAR data in the later chapters.

### 3.7 Key Terms

- Altimeters: Active sensors used to measure heights on Earth through measuring the return time of emitted pulses.
• DEM: Three-dimensional representation of the Earth’s surface in terms of the elevation.
• Dielectric constant: Number that indicates the extent to which a material concentrates electric flux.
• Polarization: Property of EM waves that can oscillate with more than one orientation.
• Radiometer: Passive sensor that measures the natural EM radiation emitted or reflected from the Earth.
• SAR: Uses a small physical antenna to imitate having a large physical antenna by taking advantage of the movement of the satellite to collate multiple recorded reflections that are processed together as if they were collected by a single large physical antenna.
• Scatterometer: Active sensor that sends multiple microwave pulses in several directions and uses the returned signals to determine parameters such as wind speed and direction.