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# Satellite imagery: the range and value

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High quality, medium resolution satellite imagery has been available worldwide since the mid-1980s, and in the late 1990s high and very high resolution imagery became available. We now have a wide choice of data captured by satellites to help satisfy requirements in terms of scale, area of coverage, application and budget. Due to the broad range of sensors onboard current and recent satellites, most parts of the world have been covered by usable imagery and that imagery is available for download or purchase. This paper provides a brief description of the range of satellite imagery currently available, some of the applications of this imagery, and also a summary of what satellites are expected to be launched in the near future.

**Keywords:** Satellite imagery, spatial resolution, spectral resolution, archive, fresh capture

## Introduction

Satellite imagery can be broadly categorised in three ways: by spatial resolution, by spectral resolution, and whether the data exists in archive only or is programmable for capture.

Medium resolution sensors including Landsat, ASTER and SPOT 1-4 have a pixel resolution of larger than 5 m; high resolution sensors including SPOT 5 and ALOS have a pixel resolution of 2.5 to 5 m; and very high resolution sensors including WorldView-1 and -2, GeoEye-1, QuickBird, IKONOS and Pléiades have a pixel resolution of less than 2.5 m and are usually sub-metre.

Once acquired, either by regular capture, for example in the cases of Landsat and ASTER, or by background or programmed tasking, for example in the cases of SPOT5 and GeoEye-1, the data is ‘archived’ and available for download or purchase. Web-based search engines allow perusal of the archives to facilitate choosing the imagery that best satisfies requirements.

As indicated in Table 1, some sensors can capture in stereo mode, allowing the generation of digital elevation models (DEMs). In general DEMs produced from satellite imagery are at twice the spatial resolution of the source imagery and the accuracy is dependent on the accuracy of the sensor itself. For example, DEMs produced from the GeoEye-1 or either of the WorldView sensors have a spatial resolution of 1 m and an accuracy of 0.5 to 0.7 m, whereas DEMs produced from ALOS PRISM imagery have a spatial resolution of 5 m and an accuracy of 2 to 4 m.

## Medium resolution imagery

Within this category there are the optical sensors: Landsat (Figure 1), ASTER and SPOT1-4, the radar sensors Radarsat-1, JERS, PALSAR (Figure 2), ERS and Envisat and DEMs generated from ASTER and SPOT HRS. Apart from Radarsat-1, imagery from all of these sensors is available as archived data only.

## High resolution imagery

High resolution optical imagery includes SPOT5 Pan, SPOT5 pan-sharpened colour (Figure 3), ALOS PRISM, ALOS PRISM pan-sharpened colour and SPOTMaps. Radarsat-2, TanDEM-X and TerraSAR-X radar imagery and DEMs from ALOS PRISM (Figure 4) also fall within this category.

## Very high resolution (VHR) imagery

Launched in 1999, IKONOS was the first commercial satellite to acquire very high resolution imagery. Since then QuickBird, WorldView-1, GeoEye-1 (Figure 5), WorldView-2 (Figure 6), Kompsat, Pléiades and the very recently launched SPOT6 have increased the options for delivery of VHR imagery over Australia and the rest of the world.

The choice of spatial resolution is determined by the size of the area to be covered, the working scale and budget. The medium and high resolution datasets are especially useful for regional coverage (Figure 7); however, large area coverage of VHR imagery is also made possible by a digital mosaic of the same or different data types.

The availability of imagery is also a factor in choosing the most appropriate sensor. In tropical areas, it is often difficult to find low-cloud optical imagery whether held in archive or programmed for fresh capture. Radar imagery is useful for structural analysis in these areas as radar is an active sensor and can penetrate cloud and/or be acquired at night (Figure 8).

## Spectral resolution

Knowledge of the spectral resolution of the different types of satellite imagery helps to understand which sensors provide the most suitable responses to ground cover for an application.

All optical sensors respond to light in the visible to near infrared wavelengths of the electromagnetic spectrum. In addition, some optical sensors capture in the short wave and thermal infrared and the coastal band and radar satellites capture in the microwave wavelengths (Figures 9 and 10).

## Archived versus tasking requests

As indicated in Table 1, some of the satellites can be programmed for fresh capture. This is useful if the data held in

Table 1. Comparison of the spatial and spectral resolutions of commercially available medium to very high resolution satellite imagery currently available, as well as sensors which may be programmed for fresh capture

| Satellite/ Sensor | Panchromatic resolution | Multispectral resolution | Pan-sharpened resolution | Bands available | Swath width | Programmable | Stereo available | Notes |
|---|---|---|---|---|---|---|---|---|
| Medium Resolution Imagery | | | | | | | | |
| ASTER | N/A | 15 m VNIR, 30 m SWIR, 90 m TIR | N/A | 15 bands | 60 km | No | Yes, as Level 1A NIR | |
| Landsat 7 ETM+ | 15 m | 30 m TM | 15 m | 8 bands | 180 km | No | No | SLC off since June 2003 |
| Landsat 5 TM | N/A | 30 m | N/A | 7 bands | 180 km | No | No | Non-operational |
| SPOT 1,2,3 | 10 m | 20 m | 10 m | 3 bands | 60 km | No | No | Non-operational |
| SPOT4 | 10 m | 20 m | 10 m | 4 bands | 60 km | No | No | Non-operational |
| Resourcesat | N/A | 23.5 to 56 m | N/A | 4 bands | 141 to 740 km | No | No | |
| Radarsat-1 | 10 to 100 m | N/A | N/A | C band | 50 to 500 km | Yes | No | |
| JERS | 18 m | N/A | N/A | L band | 75 km | No | No | Non-operational |
| ERS | 30 m | N/A | N/A | C band | 100 km | No | No | Non-operational |
| Envisat | 30 to 1 km | N/A | N/A | C band | 100 to 400 km | No | No | Non-operational |
| PALSAR | 6.25 to 100 m | N/A | N/A | L band | 70 to 350 km | No | No | Non-operational |
| SPOT HRS | 20 m | N/A | N/A | DSM | N/A | No | N/A | |
| ASTER GDEM | 30 m | N/A | N/A | DSM | N/A | No | N/A | Mosaic of DEMs from NIR |
| High resolution imagery | | | | | | | | |
| SPOT5 | 2.5 to 5 m | 10 m | 2.5 m to 5 m | 4 bands | 60 km | Yes | Yes | |
| ALOS | 2.5 m | 10 m | 2.5 m | 4 bands | 70 km | No | No | Non-operational |
| RapidEye | N/A | 5 m | N/A | 5 bands | 77 km | Yes | No | |
| Radarsat-2 | 1.6 to 160 m | N/A | N/A | C band | 18 to 500 km | Yes | Yes | |
| Tandem-X | 1.1 to 18.5 m | N/A | N/A | X band | 7 to 150 km | Yes | No | |
| TerraSAR-X | 1.1 to 18.5 m | N/A | N/A | X band | 7 to 150 km | Yes | No | |
| ALOS PRISM DEMs | 5 m | N/A | N/A | DSM | 35 km | No | Yes | Non-operational |
| Very high resolution imagery | | | | | | | | |
| WorldView-2 | 0.5 m | 2 m | 0.5 m | 8 bands | 16.4 km at nadir | Yes | Yes | |
| WorldView-1 | 0.5 m | N/A | N/A | 1 band | 17.6 km at nadir | Yes | Yes | |
| GeoEye-1 | 0.5 m | 2 m | 0.5 m | 4 bands | 15.2 km at nadir | Yes | Yes | |
| Pléiades | 0.5 m | 2 m | 0.5 m re-sampled | 4 bands | 20 km at nadir | Yes | Yes | |
| QuickBird | 0.65 m | 2.6 m | 0.6 m re-sampled | 4 bands | 16.5 km at nadir | Yes | No | |
| IKONOS | 0.8 m | 3.2 m | 0.8 m | 4 bands | 11 km at nadir | Yes | Yes | |
| Kompsat | 1 m | 4 m | 1 m | 4 bands | 15 km at nadir | No | No | |

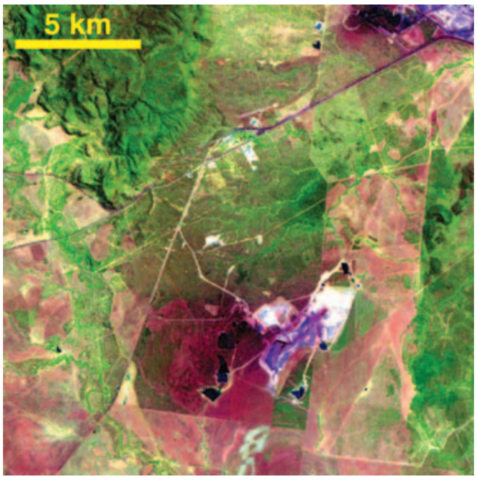


**Fig. 1.** *Landsat 5 TM bands 147 in BGR, 30-m resolution, Queensland.*

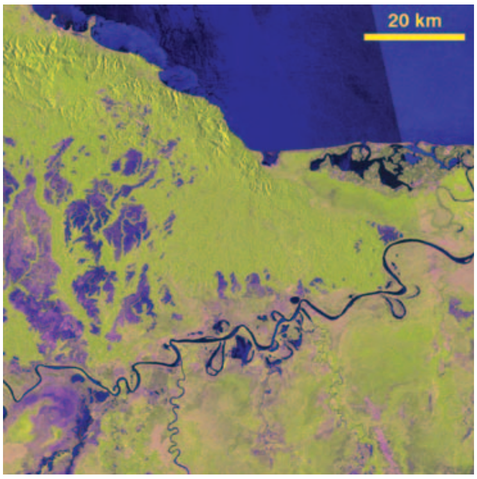


**Fig. 2.** *ALOS PALSAR Fine Beam dual-polarisation, 50-m resolution, Papua New Guinea.*


**Fig. 3.** *SPOT5 pan-sharpened colour, 2.5-m resolution imagery, New South Wales.*

archive is cloud affected, is too old or is incomplete over the area of interest, etc. In this case, a programmed task is requested over the area of interest until the capture is successful or the nominated time constraints are exceeded.

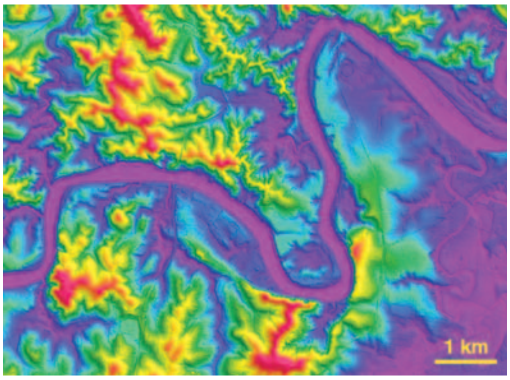


**Fig. 4.** *ALOS PRISM DEM, 5-m resolution, Queensland, shaded drape.*


**Fig. 5.** *GeoEye-1 pan-sharpened colour, 0.5-m resolution imagery, Northern Territory.*

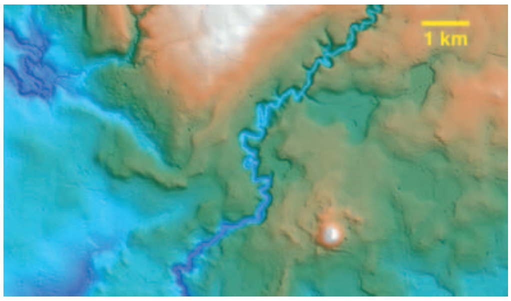


**Fig. 6.** *WorldView-2 DEM, 1-m resolution, Victoria, shaded drape.*

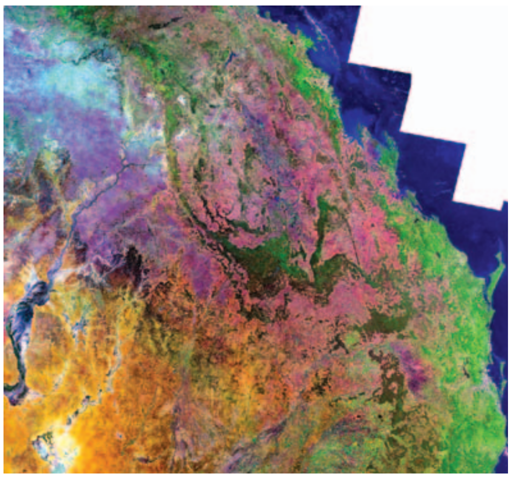

**Fig. 7.** *Landsat 5 TM digital mosaic of 47 scenes, 30-m resolution, Bowen Basin, Queensland.*

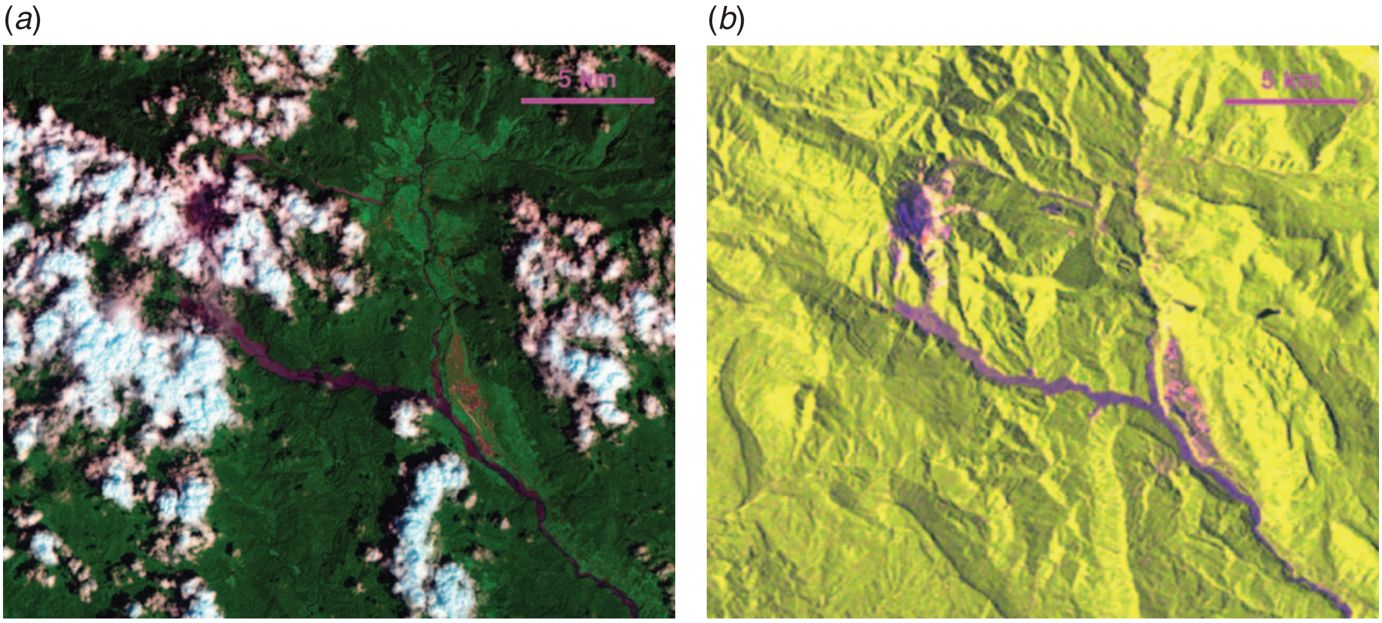


**Fig. 8.** *(a) Landsat 5 TM with ~50% of the area shown covered in cloud. (b) PALSAR over the same area, Papua New Guinea.*

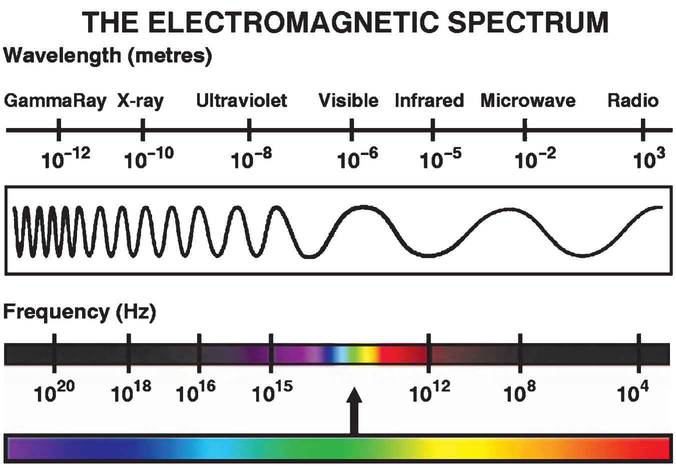


**Fig. 9.** *The electromagnetic spectrum from gamma ray to radio waves.*

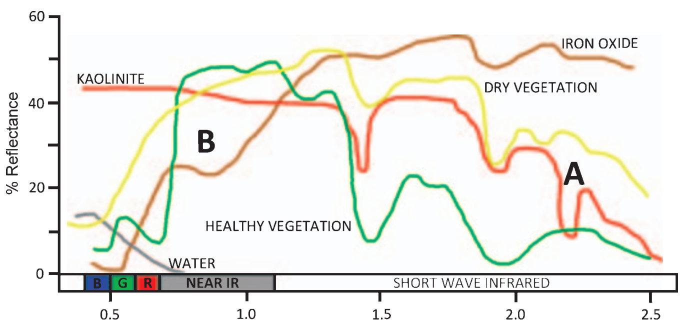


**Fig. 10.** *Part of the electromagnetic spectrum from Figure 9 showing examples of ground cover responses in the visible, near infrared and short wave infrared wavelengths.*

In Australia we are fortunate to have a large archive of low-. cloud imagery but even so fresh capture may be required. Because we have minimal conflict for tasking requests and along with our low-cloud conditions, programming requests usually

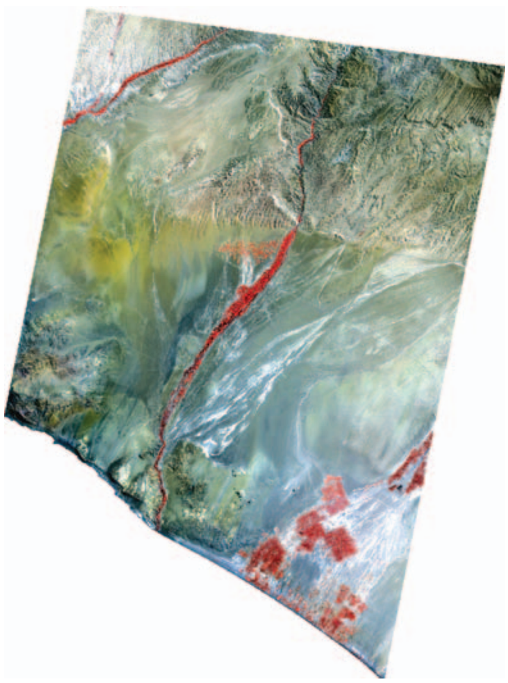

**Fig. 11.** *ASTER double scene, false colour (vegetation in red), Peru.*

result in successful capture. In other areas of the world archived data may be difficult to find or tasking delays may be lengthy because of weather conditions or programming conflicts; however, we have virtually unlimited access to satellite imagery of some form, even over regions that may be inaccessible for reasons of geography or political instability.

## Applications

The uses of satellite imagery are many and varied and applicable to most sciences and industries. Following are a few examples of these uses.

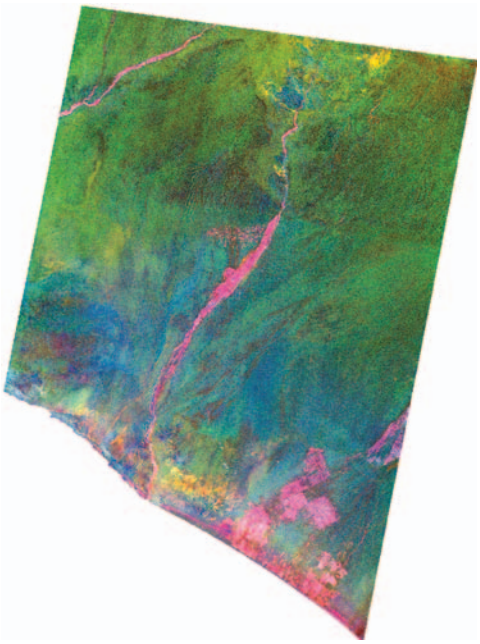

**Fig. 12.** *Larry Rowan's Relative Band Depth image of Figure 11 highlighting the kaolinite/alunite group in red, the illite group in green and the chlorite group in blue.*

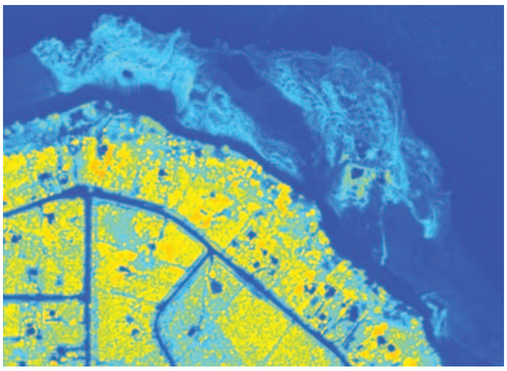

**Fig. 13.** *NDVI image of Figure 5, showing healthy vegetation in yellow-orange-red, water and impervious surfaces in blue, less healthy or sparse vegetation in cyan.*

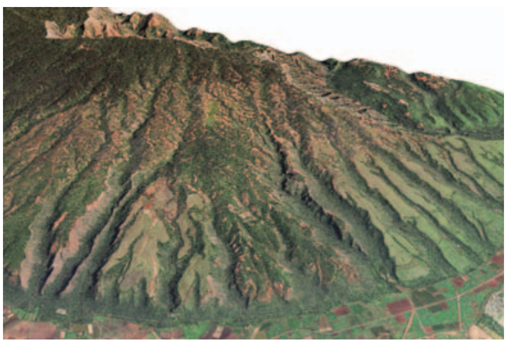

**Fig. 14.** *WorldView-2 natural colour draped over a regional DEM, Hawaii.*

### *For mineral exploration:*

The presence of clays at surface is indicated by a strong absorption in the short wave infrared (SWIR). This is shown by the trough (A) in the kaolinite (red) graph in Figure 10. Landsat 5 TM, Landsat 7 ETM+ and ASTER sense in SWIR at a wavelength suitable for clay detection. Landsat has one band in the SWIR however ASTER has six bands in this range and better defines groups of clays than does Landsat (Figures 11 and 12).

### *For mineral exploration:*

The presence of iron oxides is enhanced by the ratio of visible red on visible blue. This ratio exaggerates the sharp rise in the iron oxide (brown) graph in the visible bands shown in Figure 10. All optical sensors have at least two bands in the visible range.

### *For vegetation studies:*

The normalised difference vegetation index (NDVI) is a standard ratio that may be used to indicate vegetation health or to delineate impervious bodies, for example, bitumen surfaces (Figure 13). The ratio uses the sharp rise in the healthy vegetation (green) graph between the visible red and the NIR as shown in Figure 10.

### *For structural analysis:*

Digital elevation models are an integral part of any geospatial analysis. They can be used to map potential flood levels, provide line-of-sight information or can provide a topographic base over which other imagery is draped for 3D visual analysis (Figure 14).

## A look to the future

Later this year and into 2014, the following satellites are expected to be launched:

- Pléiades 2, which is identical to Pléiades 1, acquiring 0.5-m imagery re-sampled from 0.7 m
- The Landsat Data Continuity Mission (Landsat 8) providing medium resolution imagery
- ASNARO acquiring ~0.5-m pan-sharpened colour
- GeoEye-2 acquiring 0.25-m pan-sharpened colour
- ALOS-2 acquiring 3-m L-band radar
- WorldView-3 acquiring 0.31-m pan-sharpened colour in 16 spectral bands.

## Conclusion

Satellite-borne sensors have been acquiring high quality imagery over the Earth at medium resolution since the mid-1980s and at high to very high resolution since the late 1990s. As a result, we now have easy access to a large amount of useful data, either already acquired and held in archive or for which we can place programming requests.

The decision on which satellite imagery is best suited to requirements should be based on a consideration of:

- Which spatial resolution is best suited to the scale and size of the area to be covered?
- Is a monoscopic image only required as a backdrop or for spectral analysis or is a DEM also needed?
- Which spectral resolution is relevant to the application?
- What is the suitability of archived imagery or is fresh capture more appropriate?
- Is optical imagery likely to be cloud affected and if so would radar imagery be more useful?

## Acknowledgements and copyright statements

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